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August 23, 2007

Mrs. Teresa Gildersleeve
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Ref: Harris ETE Report

Dear Teresa:

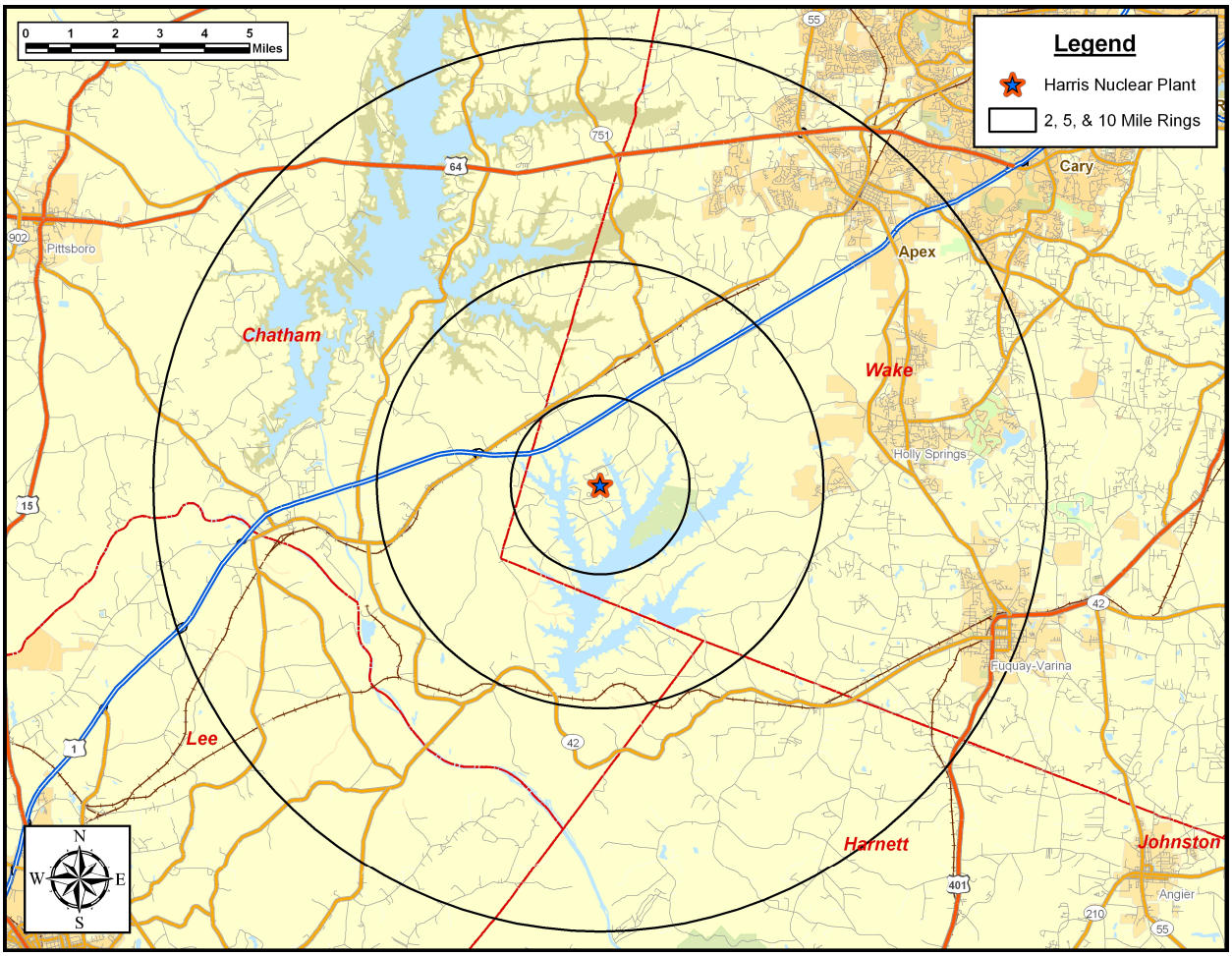
Enclosed is a PDF file containing the final version of the Harris ETE Report. We have addressed the comments provided by Progress Energy and the counties over the past several months. We will be mailing you a hard copy version of the report along with CDs containing the electronic version of the report.

Sincerely yours,

Kevin Weinisch, P.E.
Senior Traffic Engineer

Harris Nuclear Plant

Development of Evacuation Time Estimates



Prepared for:

Progress Energy

by:

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August, 2007 **Final Report** **KLD TR – 409v2**

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EXECUTIVE SUMMARY

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Harris Nuclear Plant (HNP) located in New Hill, North Carolina. Evacuation time estimates are part of the required planning basis and provide HNP and State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available prior documentation relevant to Evacuation Time Estimates was reviewed. Other guidance is provided by documents published by Federal Government agencies. Most important of these are:

- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA-REP-1, Rev. 1, November 1980.
- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR-1745, November 1980.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

Overview of Project Activities

This project began in December, 2006 and extended over a period of 6 months. The major activities performed are briefly described in chronological sequence:

- Attended “kick-off” meetings with Progress Energy personnel and emergency management personnel representing state and local governments.
- Reviewed prior ETE reports prepared for HNP and accessed U.S. Census Bureau data files for the year 2000. Studied Geographical Information Systems (GIS) maps of the area in the vicinity of HNP, then conducted a detailed field survey of the highway network.
- Synthesized this information to create an analysis network representing the highway system topology and capacities within the Emergency Planning Zone (EPZ), plus a “Shadow” area extending 15 miles radially from the plant.
- Designed and sponsored a telephone survey of residents within the EPZ to gather focused data needed for this ETE study that were not contained within the census database. The survey instrument was reviewed and modified by State and county personnel prior to the survey.
- Received GIS files from the Wake County Office of Emergency Management providing data on employment, traffic control points, and the locations of special facilities. Data collection forms (provided to the counties at the kickoff meeting) were returned with data pertaining to employment, transients, and special facilities in each county.

- The traffic demand and trip-generation rates of evacuating vehicles were estimated from the gathered data. The trip generation rates reflected the estimated mobilization time (i.e., the time required by evacuees to prepare for the evacuation trip) computed using the results of the telephone survey of EPZ residents.
- Following Federal guidelines, the EPZ is subdivided into 14 sub-zones. These sub-zones are then grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 25 Evacuation Regions.
- The time-varying external circumstances are represented as Evacuation Scenarios, each described in terms of the following factors: (1) Season (Summer, Winter); (2) Day of Week (Midweek, Weekend); (3) Time of Day (Midday, Evening); and (4) Weather (Good, Rain, Ice). One special scenario involving construction of a new unit at the HNP site was considered.
- The Planning Basis for the calculation of ETE is:
  - A rapidly escalating accident at HNP that quickly assumes the status of General Emergency such that the Advisory to Evacuate is virtually coincident with the siren alert.
  - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the Advisory to Evacuate until the last vehicle exits the impacted Region, that represent "upper bound" estimates. This conservative Planning Basis is applicable for all initiating events.
- If the emergency occurs while schools are in session, the ETE study assumes that the children will be evacuated by bus directly to specified host schools located outside the EPZ. Parents, relatives, and neighbors are advised to not pick up their children at school prior to the arrival of the buses dispatched for that purpose. The ETE for school children are calculated separately.
- Evacuees who do not have access to a private vehicle will either ride-share with relatives, friends or neighbors, or be evacuated by buses provided as specified in the county evacuation plans. Those in special facilities will likewise be evacuated with public transit, as needed: bus, van, or ambulance, as required. Separate ETE are calculated for the transit-dependent evacuees and for those evacuated from special facilities.

<u>Computation of ETE</u>

A total of 300 ETE were computed for the evacuation of the general public. Each ETE quantifies the aggregate evacuation time estimated for the population within one of the 25 Evacuation Regions to completely evacuate from that Region, under the circumstances defined for one of the 12 Evacuation Scenarios (25 x 12 = 300). Separate ETE are calculated for transit-dependent evacuees, including school children for applicable scenarios.

Except for Region R03, which is the evacuation of the entire EPZ, only a portion of the people within the EPZ would be advised to evacuate. That is, the Advisory to Evacuate applies only to those people occupying the specified impacted region. It is assumed that 100 percent of the people within the impacted region will evacuate in response to this Advisory. The people occupying the remainder of the EPZ outside the impacted region may be advised to take shelter.

The computation of ETE assumes that a portion of the population within the EPZ but outside the impacted region, will elect to "voluntarily" evacuate. In addition, a portion of the population in the "Shadow" region beyond the EPZ that extends a distance of 15 miles from HNP, will also elect to evacuate. These voluntary evacuees could impede those who are evacuating from within the impacted region. The impedance that could be caused by voluntary evacuees is considered in the computation of ETE for the impacted region.

The computational procedure is outlined as follows:

- A link-node representation of the highway network is coded. Each link represents a unidirectional length of highway; each node usually represents an intersection or merge point. The capacity of each link is estimated based on the field survey observations and on established procedures.
- The evacuation trips are generated at locations called "zonal centroids" located within the EPZ. The trip generation rates vary over time reflecting the mobilization process, and from one location (centroid) to another depending on population density and on whether a centroid is within, or outside, the impacted area.
- The computer models compute the routing patterns for evacuating vehicles that are compliant with federal guidelines (outbound relative to the location of HNP), then simulate the traffic flow movements over space and time. This simulation process estimates the rate that traffic flow exits the impacted region.
- The ETE statistics provide the elapsed times for 50 percent, 90 percent, 95 percent and 100 percent, respectively, of the population within the impacted region, to evacuate from within the impacted region. These statistics are presented in tabular and graphical formats.

Traffic Management

This study includes the development of a comprehensive traffic management plan designed to expedite the evacuation of people from within an impacted region. This plan, which was reviewed with State and local law enforcement personnel, is also designed to control access into the EPZ after returning commuters have rejoined their families.

The plan is documented in the form of detailed schematics specifying: (1) the directions of evacuation travel to be facilitated, and other traffic movements to be discouraged; (2) the traffic control personnel and equipment needed (cones, barricades) and their deployment; (3) the locations of these "Traffic Control Points" (TCP); (4) the priority assigned to each traffic control point indicating its relative importance and how soon it should be manned relative to others; and (5) the number of traffic control personnel required.

Selected Results

A compilation of selected information is presented on the following pages in the form of Figures and Tables extracted from the body of the report; these are described below.

- Figure 3-1 displays a map of the HNP site showing the layout of the 14 sub-zones that comprise, in aggregate, the Emergency Planning Zone (EPZ).
- Table 3-1 presents the estimates of permanent resident population in each sub-zone based on the 2000 Census data. Extrapolation to the year 2007 reflects population growth rates in each county derived from census data.
- Table 6-1 defines each of the 25 Evacuation Regions in terms of their respective groups of sub-zones.
- Table 6-2 lists the 12 Evacuation Scenarios.
- Tables 7-1C and 7-1D are compilations of Evacuation Time Estimates (ETE). These data are the times needed to *clear the indicated regions* of 95 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated voluntary evacuations from other regions within the EPZ and from the shadow region.
- Table 8-5A presents ETE for the schoolchildren in good weather.
- Table 8-7A presents ETE for the transit-dependent population in good weather.

Conclusion

This report presents the methodological details supporting the results obtained and recommendations for consideration by local emergency responders.

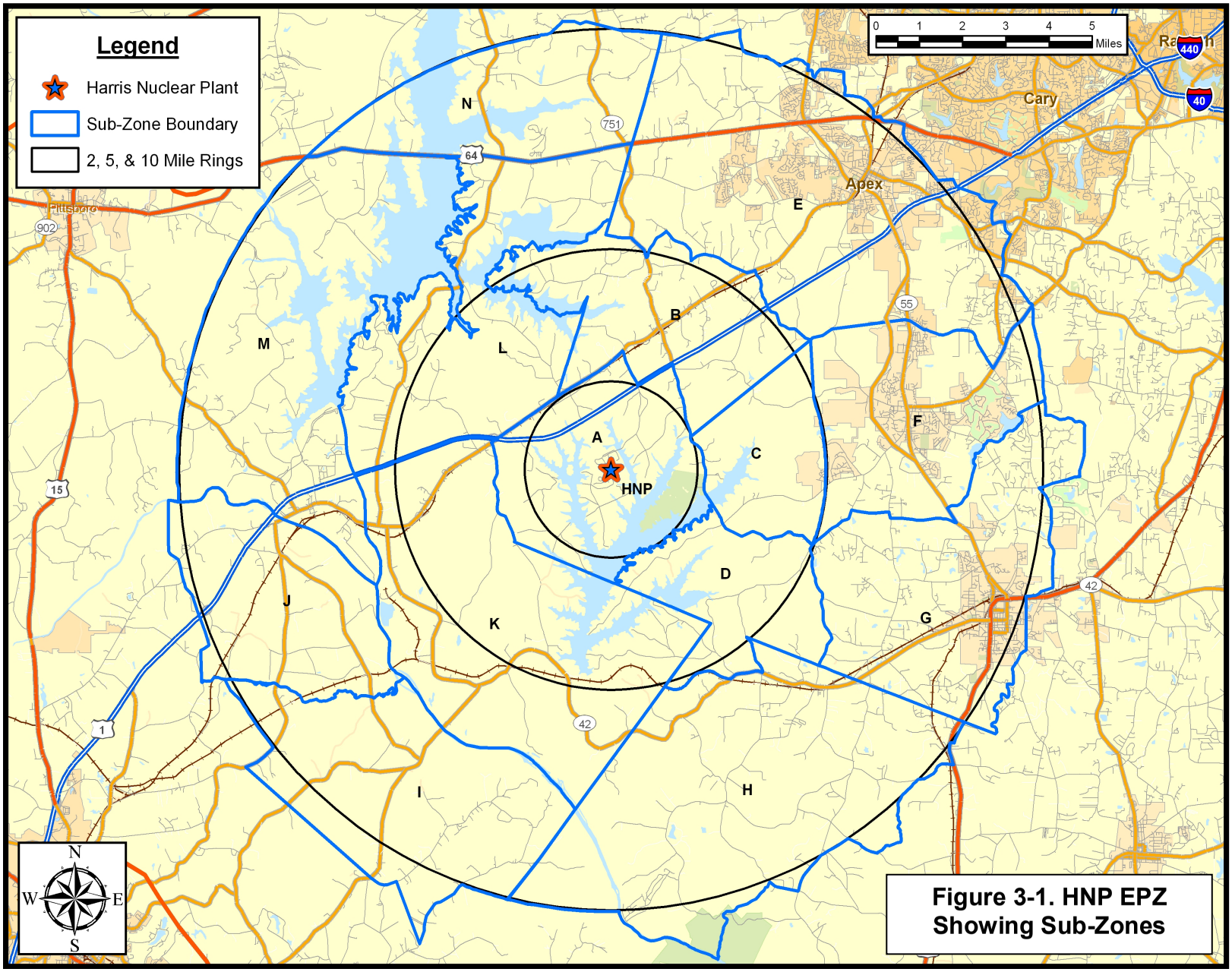

Figure 3-1. HNP EPZ Showing Sub-Zones

Table 3-1. EPZ Permanent Resident Population		
Sub-Zone	**2000 Population**	**2007 Population**
A	143	180
B	1,113	1,397
C	331	416
D	258	319
E	26,146	32,879
F	10,764	13,534
G	12,324	15,497
H	2,906	3,444
I	804	947
J	1,145	1,348
K	619	763
L	708	874
M	1,440	1,778
N	584	721
TOTAL	**59,285**	**74,097**
	Population Growth:	**25.0%**

Table 6-1. Description of Evacuation Regions															
		Sub-Zone													
Region	**Description**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R01	2 mile ring	■													
R02	5-mile ring	■	■	■	■							■	■		
R03	Full EPZ	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Evacuate 2-mile ring and 5 miles downwind															
		Sub-Zone													
Region	**Wind Direction**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R04	N,NW,NNW	■	■										■		
R05	NNE	■	■												
R06	NE,ENE	■	■	■											
R07	E	■	■	■	■										
R08	ESE	■		■	■										
R09	SE	■		■	■							■			
R10	SSE,S	■			■							■			
R11	SSW, SW	■										■			
R12	WSW,W,WNW	■										■	■		
Evacuate 5-mile ring and downwind to EPZ boundary															
		Sub-Zone													
Region	**Wind Direction**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
R13	N,NNE	■	■	■	■	■						■	■		■
R14	NE	■	■	■	■	■	■					■	■		
R15	ENE, E	■	■	■	■	■	■	■				■	■		
R16	ESE	■	■	■	■		■	■	■			■	■		
R17	SE	■	■	■	■			■	■			■	■		
R18	SSE	■	■	■	■			■	■	■		■	■		
R19	S	■	■	■	■				■	■		■	■		
R20	SSW	■	■	■	■				■	■	■	■	■		
R21	SW	■	■	■	■					■	■	■	■		
R22	WSW	■	■	■	■					■	■	■	■	■	
R23	W,WNW	■	■	■	■						■	■	■	■	
R24	NW	■	■	■	■							■	■	■	■
R25	NNW	■	■	■	■	■						■	■	■	■

Table 6-2. Evacuation Scenario Definitions					
Scenario	**Season**	**Day of Week**	**Time of Day**	**Weather**	**Special**
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

Table 7-1C. Time to Clear the Indicated Area of 95 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
Region Wind Toward:	Midday		Midday		Evening	Region Wind Toward:	Midday			Midday		Evening	Region Wind Toward:	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather		Good Weather	Rain	Ice	Good Weather	Rain	Good Weather		New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	2:10	2:20	1:50	1:50	2:10	R01 2-mile ring	2:10	2:10	2:10	1:50	1:50	2:20	R01 2-mile ring	2:35
R02 5-mile ring	2:20	2:20	2:40	2:50	2:10	R02 5-mile ring	2:30	2:30	2:30	2:00	2:00	2:10	R02 5-mile ring	3:30
R03 Entire EPZ	2:55	3:00	2:40	2:50	2:30	R03 Entire EPZ	3:00	3:05	3:20	2:30	2:40	2:30	R03 Entire EPZ	4:00
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	2:20	2:20	2:40	2:50	2:10	R04 N, NW, NNW	2:30	2:30	2:30	1:50	1:50	2:10	R04 N, NW, NNW	3:40
R05 NNE	2:20	2:20	1:50	1:50	2:10	R05 NNE	2:20	2:20	2:20	1:50	1:50	2:10	R05 NNE	3:10
R06 NE, ENE	2:20	2:20	2:00	2:00	2:10	R06 NE, ENE	2:20	2:20	2:30	2:00	2:00	2:10	R06 NE, ENE	3:10
R07 E	2:30	2:30	2:00	2:00	2:10	R07 E	2:30	2:30	2:30	2:00	2:00	2:10	R07 E	3:10
R08 ESE	2:30	2:30	2:00	2:00	2:10	R08 ESE	2:30	2:30	2:30	2:00	2:00	2:10	R08 ESE	2:40
R09 SE	2:30	2:30	2:10	2:10	2:20	R09 SE	2:40	2:40	2:40	2:10	2:10	2:20	R09 SE	2:40
R10 SSE, S	2:30	2:30	2:00	2:00	2:20	R10 SSE, S	2:30	2:30	2:30	2:00	2:00	2:20	R10 SSE, S	2:35
R11 SSW, SW	2:20	2:20	2:00	2:00	2:20	R11 SSW, SW	2:20	2:20	2:20	2:00	2:00	2:20	R11 SSW, SW	2:30
R12 WSW, W, WNW	2:20	2:20	2:40	2:50	2:20	R12 WSW, W, WNW	2:30	2:30	2:30	2:00	2:00	2:20	R12 WSW, W, WNW	3:10
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	2:50	2:50	2:30	2:40	2:30	R13 N, NNE	2:50	2:50	3:05	2:30	2:30	2:30	R13 N, NNE	3:40
R14 NE	2:55	3:00	2:30	2:45	2:30	R14 NE	2:55	3:05	3:20	2:30	2:40	2:30	R14 NE	4:00
R15 ENE, E	2:55	3:00	2:30	2:45	2:30	R15 ENE, E	2:55	3:05	3:20	2:30	2:40	2:30	R15 ENE, E	4:00
R16 ESE	2:50	2:55	2:40	2:40	2:30	R16 ESE	2:50	3:00	3:10	2:30	2:30	2:30	R16 ESE	3:50
R17 SE	2:50	2:50	2:40	2:40	2:30	R17 SE	2:50	3:00	3:10	2:20	2:30	2:30	R17 SE	3:45
R18 SSE	2:50	2:50	2:40	2:40	2:30	R18 SSE	2:50	3:00	3:10	2:20	2:30	2:30	R18 SSE	3:45
R19 S	2:40	2:40	2:40	2:40	2:20	R19 S	2:50	2:50	2:50	2:10	2:10	2:20	R19 S	3:20
R20 SSW	2:50	2:50	2:40	2:50	2:20	R20 SSW	2:50	2:50	2:50	2:20	2:20	2:20	R20 SSW	3:30
R21 SW	2:40	2:40	2:40	2:50	2:20	R21 SW	2:40	2:40	2:40	2:10	2:10	2:20	R21 SW	3:30
R22 WSW	2:40	2:40	2:40	2:50	2:20	R22 WSW	2:40	2:40	2:40	2:10	2:10	2:20	R22 WSW	3:30
R23 W, WNW	2:30	2:30	2:40	2:50	2:20	R23 W, WNW	2:40	2:40	2:40	2:00	2:00	2:20	R23 W, WNW	3:30
R24 NW	2:30	2:30	2:40	2:40	2:20	R24 NW	2:40	2:40	2:40	2:00	2:00	2:20	R24 NW	3:30
R25 NNW	2:50	2:50	2:40	2:40	2:30	R25 NNW	2:50	2:50	3:05	2:30	2:30	2:30	R25 NNW	3:40

Table 7-1D. Time to Clear the Indicated Area of 100 Percent of The Affected Population

	Summer		Summer		Summer		Winter			Winter		Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend		Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	Scenario:	(12)
Region Wind Toward:	Midday		Midday		Evening	Region Wind Toward:	Midday			Midday		Evening	Region Wind Toward:	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather		Good Weather	Rain	Ice	Good Weather	Rain	Good Weather		New Plant Construction
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01 2-mile ring	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00	4:00	4:00	3:00	3:00	3:00	R01 2-mile ring	4:00
R02 5-mile ring	4:05	4:05	3:10	3:20	3:10	R02 5-mile ring	4:05	4:05	4:05	3:05	3:10	3:10	R02 5-mile ring	4:10
R03 Entire EPZ	4:10	4:10	4:00	4:00	4:00	R03 Entire EPZ	4:10	4:10	4:10	4:00	4:00	4:00	R03 Entire EPZ	4:40
2-Mile Ring and Downwind to 5 Miles														
R04 N, NW, NNW	4:00	4:05	3:10	3:20	3:10	R04 N, NW, NNW	4:05	4:05	4:05	3:00	3:10	3:10	R04 N, NW, NNW	4:10
R05 NNE	4:00	4:00	3:00	3:00	3:00	R05 NNE	4:00	4:00	4:00	3:00	3:00	3:00	R05 NNE	4:00
R06 NE, ENE	4:00	4:00	3:00	3:00	3:00	R06 NE, ENE	4:00	4:00	4:00	3:00	3:00	3:00	R06 NE, ENE	4:00
R07 E	4:00	4:00	3:00	3:00	3:00	R07 E	4:00	4:00	4:00	3:00	3:00	3:00	R07 E	4:00
R08 ESE	4:00	4:00	3:00	3:00	3:00	R08 ESE	4:00	4:00	4:00	3:00	3:00	3:00	R08 ESE	4:00
R09 SE	4:00	4:00	3:00	3:00	3:00	R09 SE	4:00	4:00	4:00	3:00	3:00	3:00	R09 SE	4:00
R10 SSE, S	4:00	4:00	3:00	3:00	3:00	R10 SSE, S	4:00	4:00	4:00	3:00	3:00	3:00	R10 SSE, S	4:00
R11 SSW, SW	4:00	4:00	3:00	3:00	3:00	R11 SSW, SW	4:00	4:00	4:00	3:00	3:00	3:00	R11 SSW, SW	4:00
R12 WSW, W, WNW	4:00	4:00	3:10	3:20	3:10	R12 WSW, W, WNW	4:05	4:00	4:05	3:00	3:10	3:00	R12 WSW, W, WNW	4:00
5-Mile Ring and Downwind to EPZ Boundary														
R13 N, NNE	4:05	4:10	4:00	4:00	4:00	R13 N, NNE	4:05	4:05	4:10	4:00	4:00	4:00	R13 N, NNE	4:30
R14 NE	4:05	4:05	3:50	4:00	4:00	R14 NE	4:05	4:05	4:10	3:50	4:00	4:00	R14 NE	4:40
R15 ENE, E	4:05	4:05	4:00	4:00	4:00	R15 ENE, E	4:05	4:10	4:10	4:00	4:00	4:00	R15 ENE, E	4:40
R16 ESE	4:10	4:10	4:00	4:00	4:00	R16 ESE	4:05	4:10	4:10	4:00	4:00	4:00	R16 ESE	4:20
R17 SE	4:10	4:10	4:00	4:00	4:00	R17 SE	4:05	4:10	4:10	4:00	4:00	4:00	R17 SE	4:20
R18 SSE	4:10	4:10	4:00	4:00	4:00	R18 SSE	4:05	4:10	4:10	4:00	4:00	4:00	R18 SSE	4:20
R19 S	4:10	4:10	3:50	3:50	3:50	R19 S	4:05	4:10	4:10	3:50	3:50	3:50	R19 S	4:10
R20 SSW	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:05	4:10	4:10	3:50	3:50	3:50	R20 SSW	4:10
R21 SW	4:05	4:05	3:15	3:25	3:15	R21 SW	4:05	4:05	4:10	3:05	3:10	3:10	R21 SW	4:10
R22 WSW	4:05	4:10	3:40	3:40	3:15	R22 WSW	4:05	4:10	4:10	3:40	3:40	3:10	R22 WSW	4:20
R23 W, WNW	4:05	4:10	3:40	3:40	3:15	R23 W, WNW	4:05	4:10	4:10	3:40	3:40	3:10	R23 W, WNW	4:20
R24 NW	4:05	4:05	3:50	3:50	3:40	R24 NW	4:05	4:10	4:10	3:40	3:50	3:40	R24 NW	4:20
R25 NNW	4:05	4:05	3:50	3:50	4:00	R25 NNW	4:05	4:10	4:10	3:50	3:50	4:00	R25 NNW	4:30

Table 8-5A. School Evacuation Time Estimates - Good Weather								
School	**Driver Mobilization Time(min)**	**Loading Time (min)**	**Dist. to EPZ Boundary (mi.)**	**Travel Time to EPZ Bdry (min)**	**ETE (hr:min)**	**Dist. EPZ Bndry to R.C. (mi.)**	**Travel Time EPZ Bdry to RC (min)**	**ETE to R.C. (hr:min)**
Wake County Schools								
Apex Elementary School	90	5	3.2	9	**1:45**	15.1	23	**2:10**
Apex High School	90	5	0.2	1	**1:40**	16.4	25	**2:05**
Apex Middle School	90	5	3	8	**1:45**	18.3	28	**2:15**
Baucom Elementary School	90	5	2.2	6	**1:45**	19.6	30	**2:15**
Community Partners Charter High School	90	5	4.4	12	**1:50**	13.7	21	**2:10**
Fuquay-Varina High School	90	5	1	3	**1:40**	5.9	9	**1:50**
Fuquay-Varina Middle School	90	5	0.9	3	**1:40**	28.6	43	**2:25**
Holly Grove Elementary School	90	5	7.2	19	**1:55**	25.1	38	**2:35**
Holly Ridge Elementary School	90	5	3.2	9	**1:45**	25.1	38	**2:25**
Holly Ridge Middle School	90	5	3.2	9	**1:45**	25.1	38	**2:25**
Holly Springs Elementary School	90	5	3.8	10	**1:45**	25.1	38	**2:25**
Holly Springs High School	90	5	7.2	19	**1:55**	25.1	38	**2:35**
Hope Montessori	90	5	1.3	4	**1:40**	16.4	25	**2:05**
Lincoln Heights Elementary School	90	5	2	6	**1:45**	28.6	43	**2:25**
Lufkin Rd Middle School	90	5	1.2	4	**1:40**	18.3	28	**2:10**
Olive Chapel Elementary School	90	5	4.3	12	**1:50**	19.6	30	**2:20**
Salem Elementary School	90	5	1.3	4	**1:40**	19.6	30	**2:10**
Salem Middle School	90	5	1.4	4	**1:40**	19.6	30	**2:10**
Southern Wake Montessori School	90	5	5	14	**1:50**	25.1	38	**2:30**
St. Mary Magdalene Catholic School	90	5	4.4	12	**1:50**	10.6	16	**2:05**
The New School Montessori Center	90	5	2.8	8	**1:45**	13.7	21	**2:05**
Chatham County Schools								
Moncure Elementary School	90	5	4.3	12	**1:50**	14.3	22	**2:10**
				Average for EPZ:	**1:45**		**Average:**	**2:15**

Table 8-7A. Transit Dependent Evacuation Time Estimates - Good Weather												
		Single Wave				Second Wave						
Route Number	Bus Number	Mobilization	Route Travel Time	Pickup Time	ETE	Travel Time to Rec. Ctr	Unload	Driver Rest	Retun time to EPZ	Route Travel Time	Pickup Time	ETE
1	1	90	45	10	2:25	**Second Wave is Not Needed**						
	2	100	45	10	2:35							
	3	115	45	10	2:50							
	4	135	45	10	3:10							
	5	165	45	10	3:40							
2 and 3	1	90	30	10	2:10	**Second Wave is Not Needed**						
	2	100	30	10	2:20							
	3	115	30	10	2:35							
	4	130	30	10	2:50							
	5	150	30	10	3:10							
	6	170	30	10	3:30							
4	1	90	30	10	2:10	25	5	10	20	30	10	3:50
	2	95	30	10	2:15	25	5	10	20	30	10	3:55
	3	100	30	10	2:20	25	5	10	20	30	10	4:00
	4	105	30	10	2:25	25	5	10	20	30	10	4:05
	5	110	30	10	2:30	25	5	10	20	30	10	4:10
	6	115	30	10	2:35	25	5	10	20	30	10	4:15
	7	120	30	10	2:40	25	5	10	20	30	10	4:20
	8	125	30	10	2:45	25	5	10	20	30	10	4:25
5	1	90	30	10	2:10	30	5	10	25	30	10	4:00
	2	95	30	10	2:15	30	5	10	25	30	10	4:05
	3	100	30	10	2:20	30	5	10	25	30	10	4:10
	4	105	30	10	2:25	30	5	10	25	30	10	4:15
	5	110	30	10	2:30	30	5	10	25	30	10	4:20
6	1	90	30	10	2:10	25	5	10	20	30	10	3:50
	2	95	30	10	2:15	25	5	10	20	30	10	3:55
	3	100	30	10	2:20	25	5	10	20	30	10	4:00
	4	105	30	10	2:25	25	5	10	20	30	10	4:05
	5	110	30	10	2:30	25	5	10	20	30	10	4:10
	6	115	30	10	2:35	25	5	10	20	30	10	4:15

1. INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to update the existing Evacuation Time Estimates (ETE) for the Harris Nuclear Plant (HNP), located in Wake County, North Carolina. Evacuation time estimates are part of the required planning basis and provide State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available prior documentation relevant to Evacuation Time Estimates was reviewed.

Other guidance is provided by documents published by Federal Government agencies. Most important of these are:

- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA-REP-1, Rev. 1, November 1980.
- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR-1745, November 1980.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

We wish to express our appreciation to all the directors and staff members of the Chatham County, Harnett County, Lee County and Wake County emergency management agencies and local and state law enforcement and planning agencies, who provided valued guidance and contributed information contained in this report.

1.1 Overview of the ETE Update Process

The following outline presents a brief description of the work effort in chronological sequence:

1. Information Gathering:
    - Defined the scope of work in discussion with representatives of Progress Energy.
    - Reviewed existing reports describing past evacuation studies.
    - Attended meetings with emergency planners from the four EPZ Counties to identify issues to be addressed.

- Conducted a detailed field survey of the EPZ highway system and of area traffic conditions.
- Obtained demographic data from census and state agencies.
- Conducted a random sample telephone survey of EPZ residents.
- Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important sources of information.

2. Estimated distributions of Trip Generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample telephone survey.
3. Defined Evacuation Scenarios. These scenarios reflect the variation in demand, trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Defined a traffic management strategy. Traffic control is applied at specified Traffic Control Points (TCP) located within the Emergency Planning Zone (EPZ), and at Security Road Blocks (SRB) located outside the EPZ. Local and state police personnel should review all traffic control plans.
5. Defined Evacuation Areas or Regions. The EPZ is partitioned into sub-zones which serve as a basis for the ETE analysis presented herein. Evacuation "Regions" are comprised of contiguous sub-zones for which ETE are calculated. The configuration of these Regions reflects the fact that the wind can take any direction and that the radial extent of the impacted area depends on accident-related circumstances. Each Region, other than those that approximate circular areas, approximates a "key-hole" configuration within the EPZ as required by NUREG/CR-6863.
6. Estimated demand for transit services for persons at "Special Facilities" and for transit-dependent persons at home.
7. Prepared the input streams for the IDYNEV system.
   - Estimated the traffic demand, based on the available information derived from Census data, from prior studies, from data provided by local and state agencies and from the telephone survey.
   - Applied the procedures specified in the 2000 Highway Capacity Manual (HCM) to the data acquired during the field survey, to

estimate the capacity of all highway segments comprising the evacuation routes.

- Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the Evacuation Time Estimates (ETE).
- Calculated the evacuating traffic demands for each Region and for each Evacuation Scenario. Considered the effects on demand of "voluntary evacuation" and of the "shadow effect".
- Represented the traffic management strategy.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of the HNP.
- Prepared the input stream for the IDYNEV System.
- Executed the IDYNEV models to provide the estimates of evacuation routing and Evacuation Time Estimates (ETE).

8. Generated a complete set of ETE for all specified Evacuation Regions and Scenarios.
9. Documented ETE in formats responsive to the cited NUREG reports.
10. Calculated the ETE for all transit activities including those for special facilities (schools, health-related facilities, etc.) and for the transit-dependent.

Steps 4, 7 and 8 are iterated as described in Appendix D.

1.2 The Harris Nuclear Plant Site Location

The Harris Nuclear Plant is located approximately 20 miles southwest of Raleigh, North Carolina. The Emergency Planning Zone (EPZ) consists of parts of four counties: Chatham County, Harnett County, Lee County, and Wake County. Figure 1-1 displays the area surrounding the Harris Nuclear Plant. This map identifies the communities in the area and the major roads.

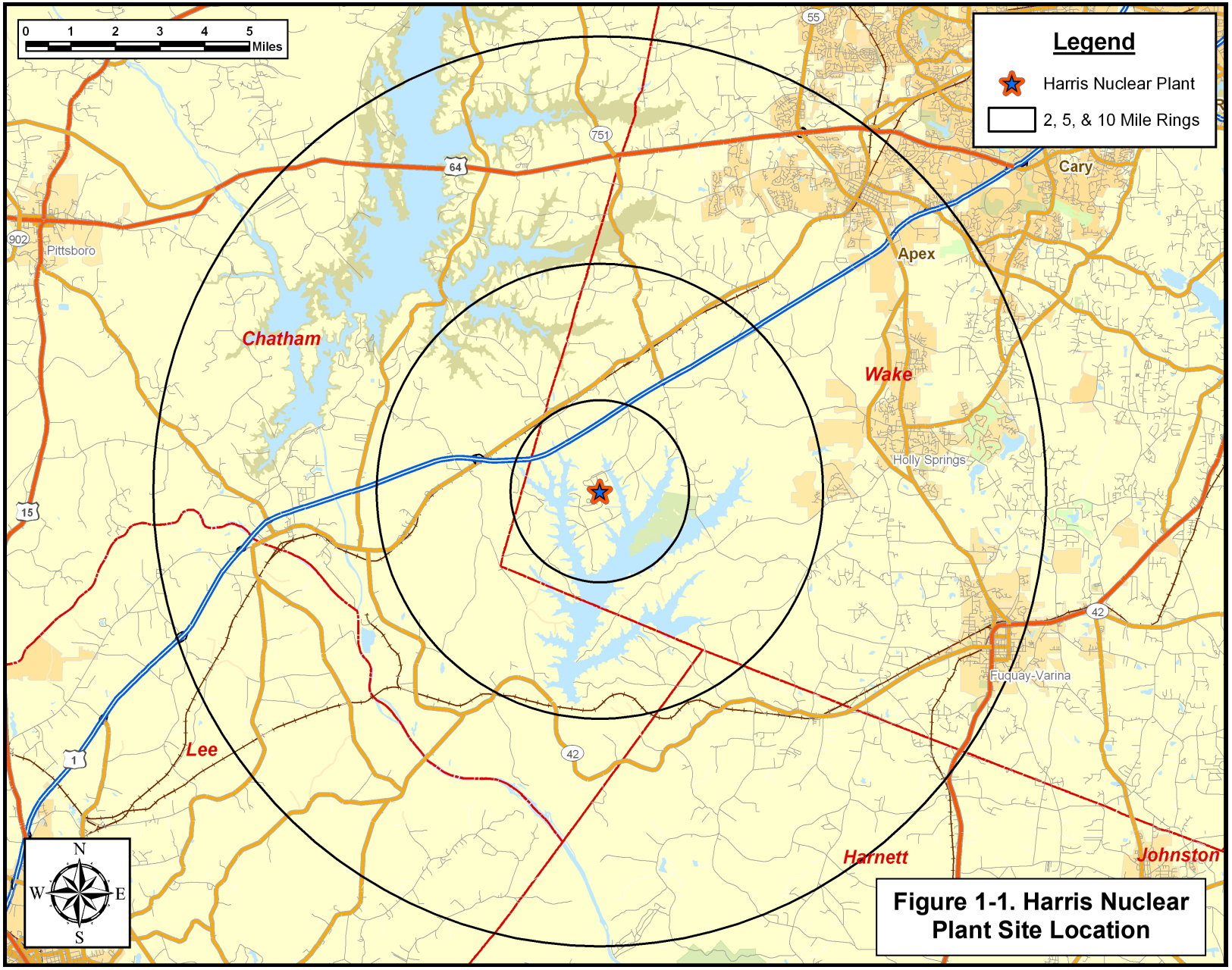

Figure 1-1. Harris Nuclear Plant Site Location

1.3 Preliminary Activities

Since this plan constitutes an update of an existing document, it was necessary to review the prior process and findings. These activities are described below.

Literature Review

KLD Associates was provided with copies of documents describing past studies and analyses leading to the development of emergency plans and of the ETE. We also obtained supporting documents from a variety of sources, which contained information needed to form the database used for conducting evacuation analyses.

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and for some distance outside. The characteristics of each section of highway were recorded. These characteristics include:

• Number of lanes	• Posted speed
• Pavement Width	• Actual free speed
• Shoulder type & width	• Abutting land use
• Intersection configuration	• Control devices
• Lane channelization	• Interchange geometries
• Geometrics: Curves, grades	• Street parking
• Unusual characteristics: Narrow bridges, sharp curves, poor pavement, flood warning signs, inadequate delineations, etc.	

The data were then transcribed; this information was referenced while preparing the input stream for the IDYNEV System. Key highway locations were video archived.

Telephone Survey

A telephone survey was undertaken to gather information needed for the evacuation study. Appendix F presents the survey instrument, the procedures used and tabulations of data compiled from the survey returns.

These data were utilized to develop estimates of vehicle occupancy during an evacuation and to estimate elements of the mobilization process. This database was also referenced to estimate the number of transit-dependent residents.

Developing the Evacuation Time Estimates

The overall study procedure is outlined in Appendix D. Demographic data were obtained from several sources, as detailed later in this report. These data were analyzed and converted into vehicle demand data.

Highway capacity was estimated for each highway segment based on the field surveys and on the principles specified in the 2000 Highway Capacity Manual (HCM[1]). The link-node representation of the physical highway network was developed using Geographic Information System (GIS) mapping software and the observations obtained from the field survey. This network representation of "links" and "nodes" is shown in Figure 1-2.

Analytical Tools

The IDYNEV System that was employed for this study is comprised of several integrated computer models. One of these is the PC-DYNEV (DYnamic Network EVacuation) macroscopic simulation model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA).

I-DYNEV consists of three submodels:

- A macroscopic traffic simulation model (for details, see Appendix C).
- An intersection capacity model (for details, see Highway Research Record No. 772, Transportation Research Board, 1980, papers by Lieberman and McShane & Lieberman).
- A dynamic, node-centric routing model that adjusts the "base" routing in the event of an imbalance in the levels of congestion on the outbound links.

Another model of the IDYNEV System is the TRAD (Traffic Assignment and Distribution) model. This model integrates an equilibrium assignment model with a trip distribution algorithm to compute origin-destination volumes and paths of travel designed to minimize travel time. For details, see Appendix B.

Still another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry.

The procedure for applying the IDYNEV System within the framework of developing an update to an ETE is outlined in Appendix D. Appendix A is a glossary of terms.

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[1] Highway Capacity Manual (HCM2000), Transportation Research Board, National Research Council, 2000.

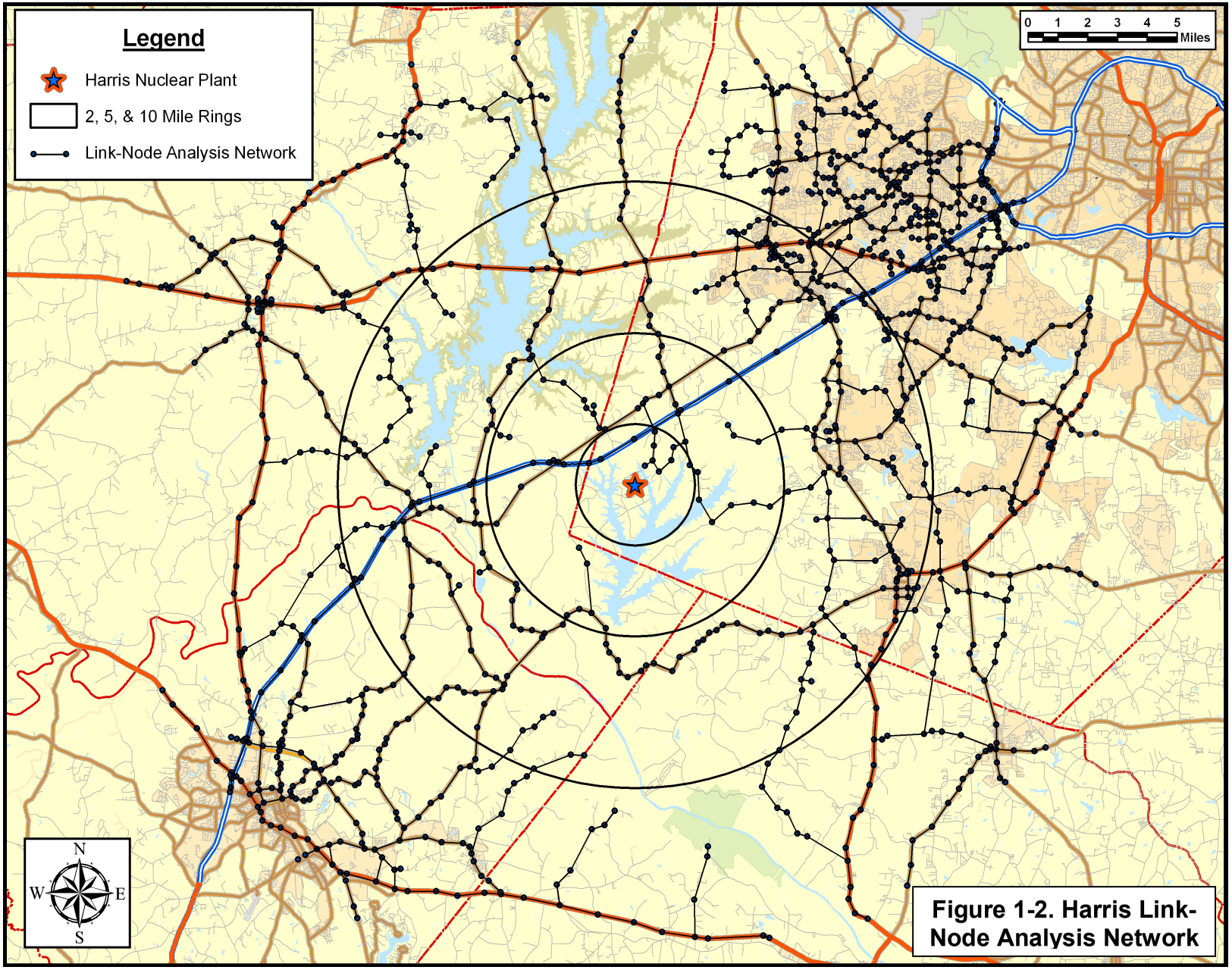


Figure 1-2. Harris Link-Node Analysis Network

The evacuation analysis procedures are based upon the need to:

- Route traffic along paths of travel that will expedite their travel from their respective points of origin to points outside the EPZ
- Restrict movement toward HNP to the extent practicable, and disperse traffic demand so as to avoid focusing demand on a limited number of highways
- Move traffic in directions that are generally outbound, relative to the location of HNP.

A set of candidate destination nodes on the periphery of the EPZ is specified for each traffic origin (or centroid) within the EPZ. The TRAD model produces output that identifies the "best" traffic routing, subject to the design conditions outlined above. In addition to this information, rough estimates of travel time are provided, together with turn-movement data required by the PC-DYNEV simulation model.

The simulation model is then executed to provide a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to develop countermeasures that are designed to expedite the movement of vehicles. The outputs of this model are the volume of traffic, expressed as vehicles/hour, that exit the Evacuation Region along the various highways (links) that cross the Region boundaries. These outputs are exported into a spreadsheet, which contain the ETE. Section 7 presents a further description of this process along with the ETE Tables.

As outlined in Appendix D, this procedure consists of an iterative design-analysis-redesign sequence of activities. If properly done, this procedure converges to yield an evacuation plan which best services the evacuating public.

1.4 Comparison with Prior ETE Study

Table 1-1 presents a comparison of the present ETE study with the 2002 study. The major factors contributing to the differences between the ETE values obtained in this study and those of the previous study can be summarized as follows:

- An increase in permanent resident population.
- Vehicle occupancy and Trip-generation rates are based on the results of a telephone survey of EPZ residents.
- Voluntary and shadow evacuations are considered.
- The highway representation is far more detailed.
- Many more evacuation cases considered, responsive to NUREG/CR-6863.
- Traffic management plan included.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Resident Population Basis	ArcGIS Software using 2000 US Census blocks; area ratio method used. Population = 61,845	ArcGIS Software using 2000 US Census blocks; block centroid method used; population extrapolated to 2007. Population = 74,097
Resident Population Vehicle Occupancy	Average household size varies by County. 2.5 persons/vehicle.	3.12 persons/household, 1.39 evacuating vehicles/household yielding: 2.24 persons/vehicle
Employee Population	Employees grouped with transient population. Employee estimates based on information provided about major employers in EPZ. 2.5 employees/vehicle.	Employees treated as separate population group. Employee estimates based on information provided about major employers in EPZ, supplemented by observations of commercial property in EPZ from aerial photography. 1.02 employees/vehicle based on phone survey results.
Voluntary evacuation from within EPZ in areas outside region to be evacuated	Not considered	50 percent of population within the circular portion of the region; 35 percent, in annular ring between the circle and the EPZ boundary. (See Figure 2-1)
Shadow Evacuation	Not considered.	30% of people outside of the EPZ within the shadow area. (See Figure 7-2)
Network Size	349 links; Number of nodes not provided.	1,720 Links; 1,234 Nodes.

Table 1-1. ETE Study Comparisons (cont.)		
Roadway Geometric Data	Field surveys conducted in 2002.	Field surveys conducted in 2006. Major intersections were video archived. GIS shape-files of signal locations and roadway characteristics created during road survey. Road capacities based on 2000 HCM.
School Evacuation	Direct evacuation to designated Reception Center/Host School.	Direct evacuation to designated Reception Center/Host School.
Transit Dependent Population	Not considered.	Defined as households with 0 vehicles + households with 1 vehicle with commuters who do not return home + households with 2 vehicles with commuters who do not return home. Telephone surveys results used to estimate transit dependent population.
Ridesharing	Not considered.	50 percent of transit dependent persons will ride out with a neighbor of friend.
Trip Generation for Evacuation	Trip Generation curves adapted from chemical stockpile evacuation studies. Same distribution used for all population groups; all population is mobilized within 50 minutes	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 and 180 minutes. Residents without commuters returning leave between 15 and 120 minutes. Employees and transients leave between 15 and 120 minutes. All times measured from the Advisory to Evacuate.

Table 1-1. ETE Study Comparisons (cont.)		
Traffic and Access Control	Not considered.	Traffic and Access Control used in all scenarios to facilitate the flow of traffic outbound relative to HNP.
Weather	Adverse. The capacity of each link in the network is reduced by 25% for adverse weather.	Normal, Rain, or Ice. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain and 15% for ice.
Modeling	Evacuation Simulation Model (ESIM) – part of Oak Ridge Evacuation Modeling System (OREMS)	IDYNEV System: TRAD and PC-DYNEV.
Special Events	None considered.	One considered – new plant construction.
Evacuation Cases	35 Regions (single sector wind direction used) and 4 Scenarios producing 108 unique cases	25 Regions (central sector wind direction and each adjacent sector technique used) and 12 Scenarios producing 300 unique cases
Evacuation Time Estimates Reporting	ETE reported for 90 and 100th percentile population. Results presented by Region and Scenario	ETE reported for 50, 90, 95, and 100th percentile population. Results presented by Region and Scenario.
Evacuation Time Estimates for the entire EPZ, 100th percentile.	Full EPZ – Summer Weekday: Good weather = 4:13 Full EPZ – Summer Weekend: Good weather = 5:46	Summer Weekday Midday Good weather = 4:10 Summer Weekend Midday Good weather = 4:00

2. STUDY ESTIMATES AND ASSUMPTIONS

This section presents the estimates and assumptions utilized in the development of the evacuation time estimates.

2.1 Data Estimates

1. Population estimates are based upon Census 2000 data, projected to year 2007. County-specific projections are based upon growth rates estimated by comparing the 2000 census data and 2005 census estimates. Estimates of employees who commute into the EPZ to work are based upon employment data obtained from county emergency management officials.
2. Population estimates at special facilities are based on available data from county emergency management offices.
3. Roadway capacity estimates are based on field surveys and the application of Highway Capacity Manual 2000[1].
4. Population mobilization times are based on a statistical analysis of data acquired from the telephone survey.
5. The relationship between resident population and evacuating vehicles is developed from the telephone survey. The average values of 3.12 persons per household and 1.39 evacuating vehicles per household are used.
6. The relationship between persons and vehicles for special facilities is as follows:
   a. Parks/Recreational: 1 vehicle per family
   b. Boat Ramps: 2 vehicles (vehicle plus trailer) per family
   c. Employees: 1.02 employees per vehicle (telephone survey results)
7. Evacuation Time Estimates (ETE) are presented for the evacuation of the 100th percentile of population for each Region and for each Scenario, and for the 2-mile, 5-mile and 10-mile distances. ETEs are presented in tabular format and graphically, showing the values of ETE associated with the 50th, 90th and 95th percentiles of population. An Evacuation Region is defined as a group of sub-zones that is issued the Advisory to Evacuate.

2.2 Study Methodological Assumptions

1. The Evacuation Time is defined as the elapsed time from the Advisory to Evacuate issued to persons within a specific Region of the EPZ, and the time that Region is clear of the indicated percentile of people.
2. The ETEs are computed and presented in a format compliant with the

[1] Highway Capacity Manual (HCM2000), Transportation Research Board, National Research Council, 2000.

guidance in the cited NUREG documentation. The ETE for each evacuation area ("Region" comprised of included sub-zones) is presented in both statistical and graphical formats.

3. Evacuation movements (paths of travel) are generally outbound relative to the power plant to the extent permitted by the highway network, as computed by the computer models. All available evacuation routes are used in the analysis.
4. Regions are defined by the underlying "keyhole" or circular configurations as specified in NUREG/CR-6863. These Regions, as defined, display irregular boundaries reflecting the geography of the sub-zones included within these underlying configurations.
5. Voluntary evacuation is considered as indicated in the accompanying Figure 2-1. Within the circle defined by the distance to be evacuated but outside the Evacuation Region, 50 percent of the people not advised to evacuate are assumed to evacuate within the same time-frame. In the annular area between the circle defined by the central "key-hole" of the Evacuation Region and the EPZ boundary, it is assumed that 35 percent of people will voluntarily evacuate. In the area between the EPZ boundary and a 15-mile annular area centered at the plant (the "shadow region"), it will be assumed that 30 percent of the people will evacuate voluntarily. Sensitivity studies explored the effect on ETE, of increasing the percentage of voluntary evacuees in this area. (Appendix I)
6. A total of 12 "Scenarios" representing different seasons, time of day, day of week and weather are considered. One special event scenario is studied: the construction period of a new nuclear plant. These Scenarios are tabulated below:

Scenario	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

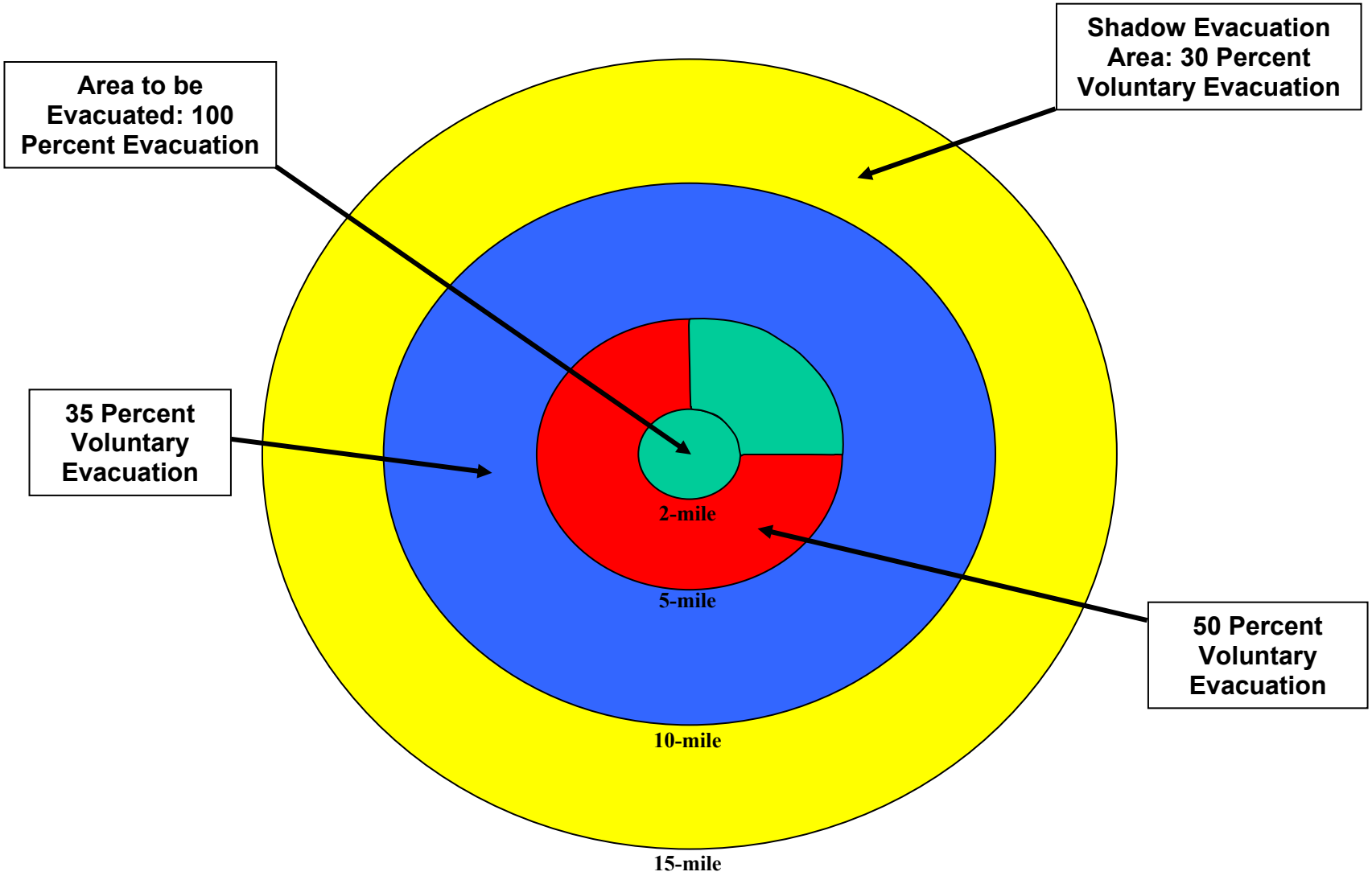


Figure 2-1. Voluntary Evacuation Methodology

7. The models of the IDYNEV System represent the state of the art, and have been recognized as such by the Atomic Safety and Licensing Board (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik[2]).

2.3 Study Assumptions

1. The Planning Basis Assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following:
   a. Advisory to Evacuate is announced coincident with the siren notification.
   b. Mobilization of the general population will commence within 10 minutes after Advisory to Evacuate.
   c. ETE are measured relative to Advisory to Evacuate.
2. It is assumed that everyone within the group of sub-zones forming a Region that is issued an Advisory to Evacuate will, in fact, respond in general accord with the planned routes.
3. It is further assumed that:
   a. Schools may be evacuated prior to notification of the general public.
   b. 26 percent of households in the EPZ will await the return of a commuter before beginning their evacuation trip, based on the telephone survey results.
4. A portion of the population outside the evacuated Region will elect to evacuate even though not advised to do so ("voluntary evacuation"). See Figure 2-1.
5. The ETE will also include consideration of "through" (External-External) trips during the time that such traffic is permitted to enter the evacuated Region. "Normal" traffic flow is assumed to be present within the EPZ at the start of the emergency.
6. Security Road Blocks (SRB) will be staffed within approximately 1 - 2 hours following the siren notifications, to divert traffic attempting to enter the EPZ. Earlier activation of SRB locations could delay returning commuters. It is assumed that no vehicles will enter the EPZ after this 1 – 2 hour mobilization time period.
7. Traffic Control Points (TCP) within the EPZ will be staffed over time, beginning at the Advisory to Evacuate. Their number and location will depend on the Region to be evacuated and personnel resources available. It is assumed that drivers will act rationally, travel in the directions identified in the plan (as documented in the public information material), and obey all control devices and traffic guides.

[2] Urbanik, T., et. al. Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code, NUREG/CR-4873, Nuclear Regulatory Commission, June, 1988

8. Traffic Control Points (TCP) outside the EPZ should be established to facilitate evacuation flow to the Reception Centers.
9. Buses will be used to transport those without access to private vehicles:
   a. If schools are in session, transport (buses) will evacuate students directly to the assigned Reception Centers.
   b. School children, if school is in session, are given priority in assigning transit vehicles.
   c. Bus mobilization time is considered in ETE calculations.
   d. Analysis of the number of required "waves" of transit vehicles used for evacuation is presented.
10. It is reasonable to assume that some of transit-dependent people will ride-share with family, neighbors, and friends, thus reducing the demand for buses. We assume that the percentage of people who rideshare is 50 percent. This assumption is based upon reported experience for other emergencies,[3] which cites previous evacuation experience. The remaining transit-dependent portion of the general population will be evacuated to reception centers by bus.
11. Two types of adverse weather scenario are considered. Rain may occur for either winter or summer scenarios. In the case of rain, it is assumed that the rain begins prior to, or at about the same time as the evacuation advisory is issued. Ice occurs as a winter scenario, only. No weather-related reduction in the number of transients who may be present in the EPZ is assumed. Adverse weather scenarios affect roadway capacity, free flow highway speeds and the time required to mobilize the general population. The factors assumed for the ETE study are:

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time
Rain	90%	90%	No Effect
Ice	85%	85%	No Effect
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.			

12. School buses used to transport students are assumed to have the capacity to transport 70 children per bus for elementary schools, and 50 children per bus for middle and high schools. Transit buses used to transport the transit-dependent general population are assumed to transport an average of 30 people per bus.
13. Officials in boats will use sirens, colored smoke and flares to alert people on Jordan and Harris Lakes.

[3] Institute for Environmental Studies, University of Toronto, THE MISSISSAUGA EVACUATION FINAL REPORT, June 1981. The report indicates that 6,600 people of a transit-dependent population of 8,600 people shared rides with other residents; a ride share rate of 76% (Page 5-10).

3. DEMAND ESTIMATION

The estimates of demand, expressed in terms of people and vehicles, constitute a critical element in developing an evacuation plan. These estimates consist of three components:

1. An estimate of population within the Emergency Planning Zone (EPZ), stratified into groups (resident, employee, transient).

2. An estimate, for each population group, of mean occupancy per evacuating vehicle. This estimate is used to determine the number of evacuating vehicles.

3. An estimate of potential double-counting of vehicles.

Appendix E presents much of the source material for the population estimates. Our primary source of population data, the 2000 Census, however, is not adequate for directly estimating some transient groups.

Throughout the year, vacationers and tourists enter the EPZ. These non-residents may dwell within the EPZ for a short period (e.g. a few days or one or two weeks), or may enter and leave within one day. Estimates of the size of these population components must be obtained, so that the associated number of evacuating vehicles can be ascertained.

The potential for double-counting people and vehicles must be addressed. For example:

- A resident who works and shops within the EPZ could be counted as a resident, again as an employee and once again as a shopper.
- A visitor who stays at a hotel and spends time at a park, then goes shopping could be counted three times.

Furthermore, the number of vehicles at a location depends on time of day. For example, motel parking lots may be full at dawn and empty at noon. Similarly, parking lots at area parks, which are full at noon, may be almost empty at dawn. It is clearly wrong to estimate counts of vehicles by simply adding up the capacities of different types of parking facilities, without considering such factors.

Analysis of the population characteristics of the Harris Nuclear Plant (HNP) EPZ indicates the need to identify three distinct groups:

- Permanent residents - people who are year-round residents of the EPZ.
- Transients - people who reside outside of the EPZ, who enter the area for a specific purpose (e.g., boating, camping) and then leave the area.

- Commuter-Employees - people who reside outside the EPZ and commute to businesses within the EPZ on a daily basis.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each sub-zone and by polar coordinate representation (population rose). The HNP EPZ has been subdivided into 14 Sub-Zones as shown in Figure 3-1.

Permanent Residents

The primary source for estimating permanent population is the latest U.S. Census data. The average household size (3.12 persons/household) and the number of evacuating vehicles per household (1.39 vehicles/household) were adapted from the telephone survey results.

Comparing census estimates available for the year 2005, with that for 2000, it is possible to estimate the rate of population change over time and to project the year 2000 resident population to a 2007 base year. The rate of population change was found for each County in the EPZ and applied to project population growth to 2007. The data in Table 3-1 show that the EPZ population has increased by 25 percent over the last 7 years.

Permanent resident population and vehicle estimates for 2007 are presented in Table 3-2. Figures 3-2 and 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from the HNP. This “rose” was constructed using GIS software.

Construction

A “special event” scenario (Scenario 12) which represents a typical summer, mid-week, midday with construction workers on-site at the time of the emergency, was considered. The peak construction period – based on discussions with Progress Energy – would be in the year 2016, with workforce estimates of 3,500 workers. An average vehicle occupancy of 1.02 workers per vehicle (adapted from telephone survey results) was used to convert workers to vehicles – 3,432 total vehicles. The existing roadway system was used for the construction scenario; no roadway improvements were considered. Permanent resident population and shadow population were extrapolated to 2016 for this scenario.

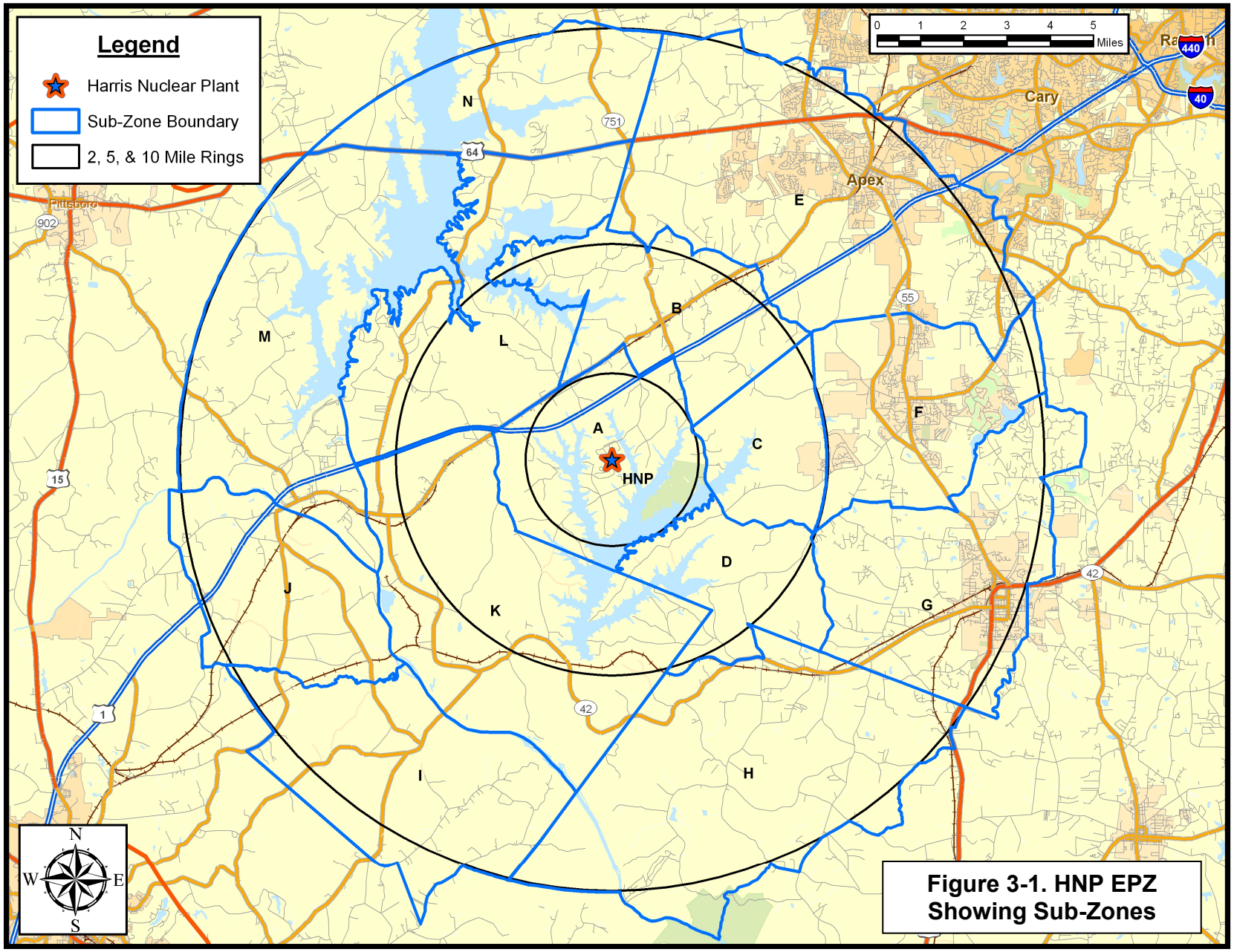
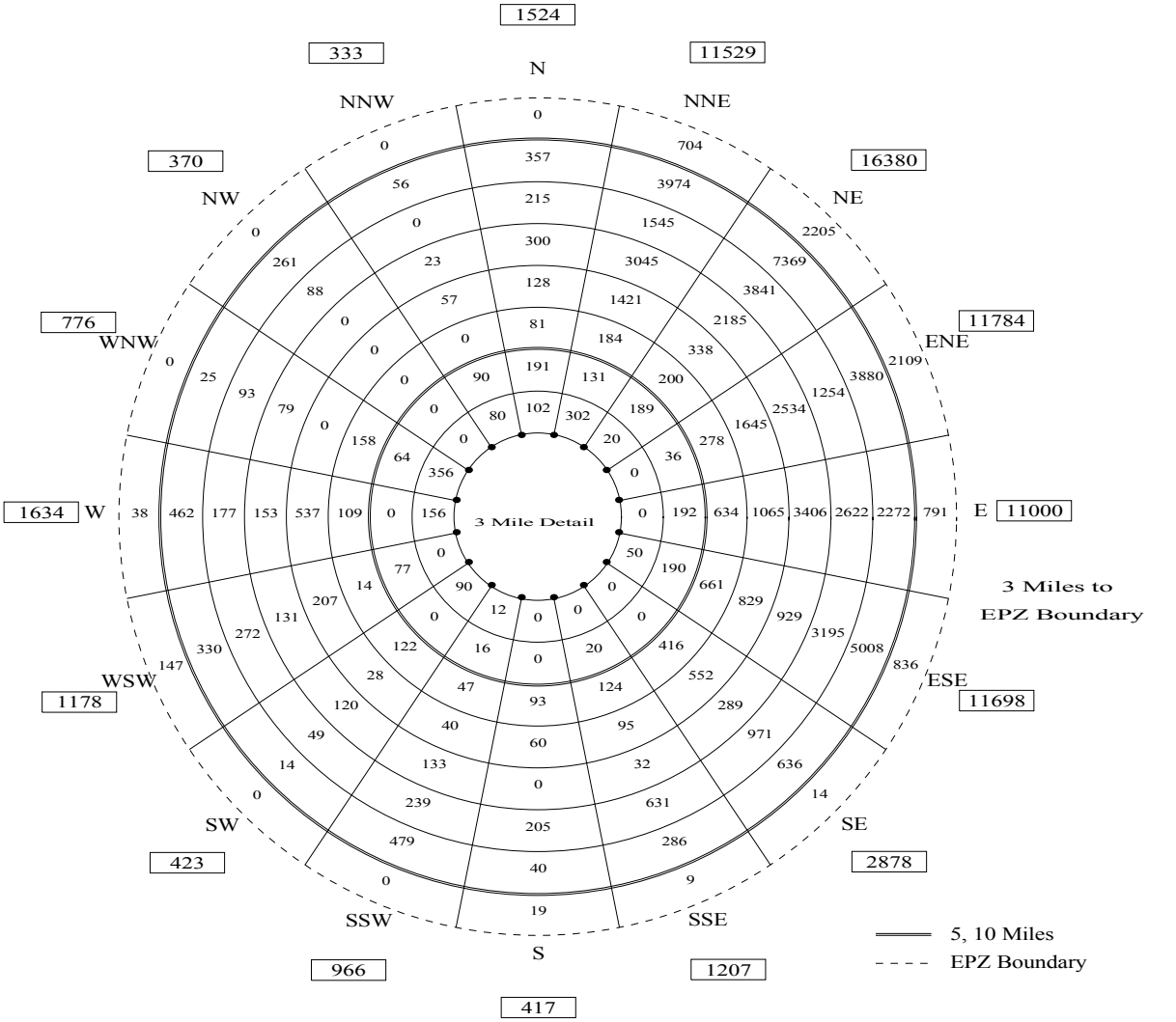


Figure 3-1. HNP EPZ Showing Sub-Zones

Table 3-1. EPZ Permanent Resident Population		
Sub-Zone	**2000 Population**	**2007 Population**
A	143	180
B	1,113	1,397
C	331	416
D	258	319
E	26,146	32,879
F	10,764	13,534
G	12,324	15,497
H	2,906	3,444
I	804	947
J	1,145	1,348
K	619	763
L	708	874
M	1,440	1,778
N	584	721
TOTAL	**59,285**	**74,097**
	Population Growth:	**25.0%**

Table 3-2. Permanent Resident Population and Vehicles by Sub-Zone		
Sub-Zone	**2007 Population**	**2007 Vehicles**
A	180	80
B	1,397	623
C	416	185
D	319	143
E	32,879	14,649
F	13,534	6,027
G	15,497	6,910
H	3,444	1,536
I	947	422
J	1,348	597
K	763	342
L	874	391
M	1,778	793
N	721	321
TOTAL	**74,097**	**33,019**



Resident Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	87	0-2	87
2-3	446	0-3	533
3-4	1168	0-4	1701
4-5	1196	0-5	2897
5-6	3121	0-6	6018
6-7	7002	0-7	13020
7-8	13359	0-8	26379
8-9	15397	0-9	41776
9-10	25449	0-10	67225
10-EPZ	6872	0-EPZ	74097

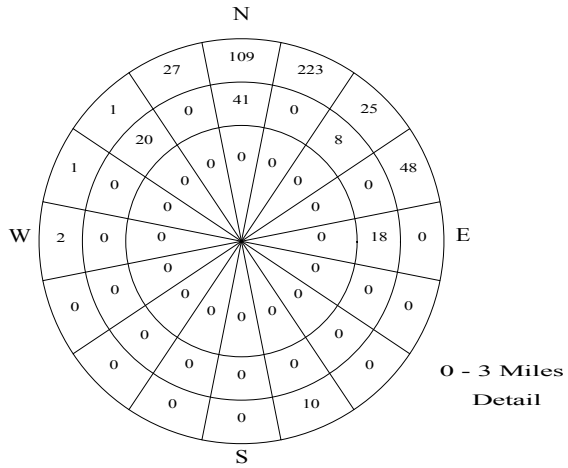
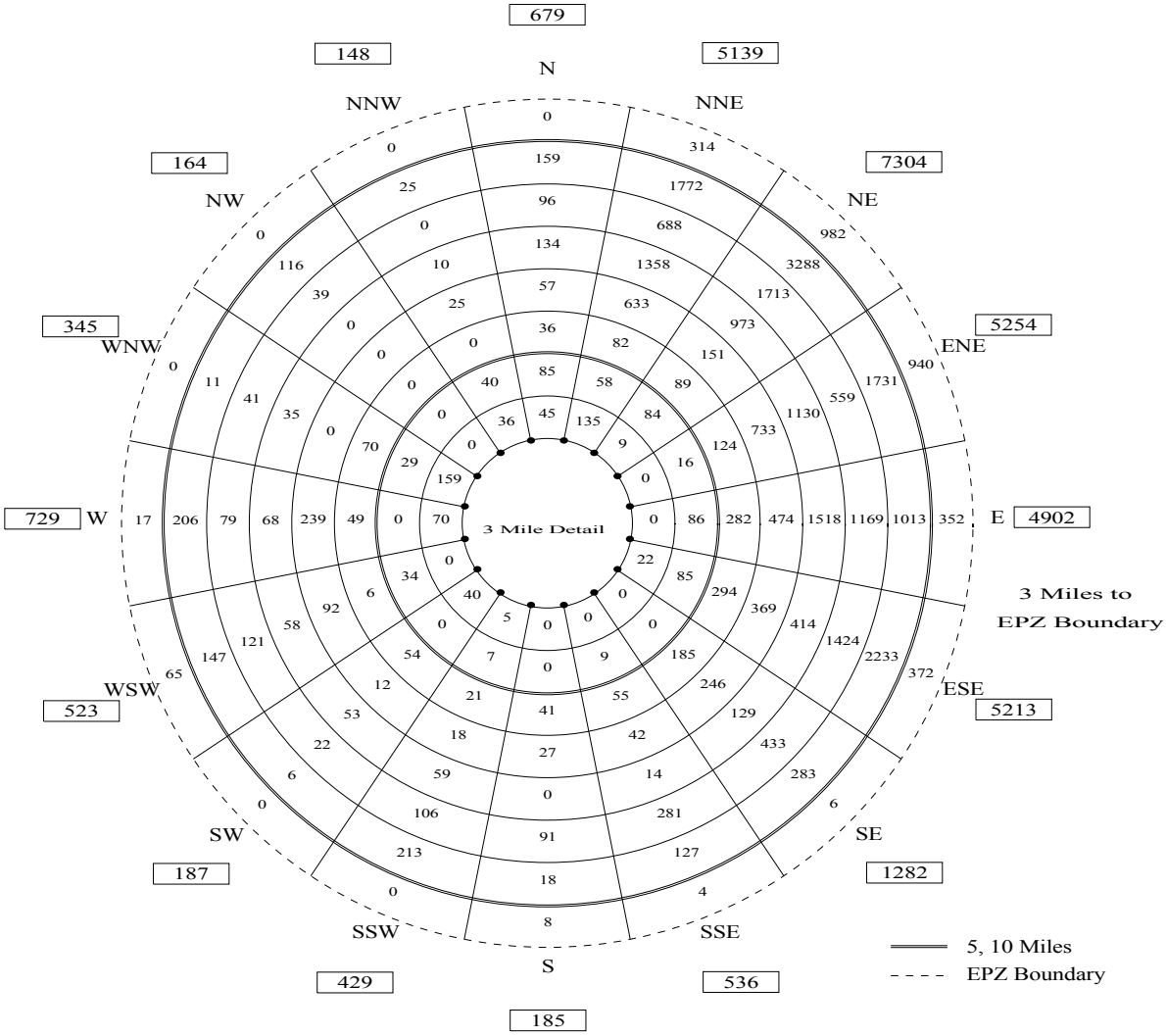


Figure 3-2. Permanent Residents by Sector



Resident Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	39	0-2	39
2-3	197	0-3	236
3-4	521	0-4	757
4-5	533	0-5	1290
5-6	1388	0-6	2678
6-7	3118	0-7	5796
7-8	5953	0-8	11749
8-9	6862	0-9	18611
9-10	11348	0-10	29959
10-EPZ	3060	0-EPZ	33019

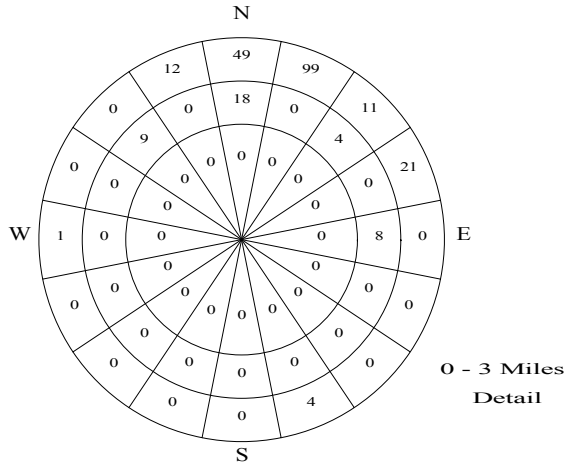


Figure 3-3. Permanent Resident Vehicles by Sector

Transient Population

Transient population groups are defined as those people who are not permanent residents and who enter the EPZ for a specific purpose (shopping, recreation). Transients may spend less than one day or stay overnight or longer at rented apartments, camping facilities, hotels and motels. The Harris EPZ has a number of areas that attract transients, including:

- Jordan Lake State Recreation Area
- Harris Lake

Estimates of the peak attendance at these transient facilities were provided by County emergency management offices. Internet searches were also used to obtain more detailed information about these facilities and supplement the data provided. The average household size of 3.12 persons per household was applied to the transient facilities to estimate the number of visiting persons; one evacuating vehicle per transient family was assumed. The following are estimates of transient population of each of these facilities:

Jordan Lake State Recreation Area

Jordan Lake is a 46,768 acre lake located in the northwestern portion of the EPZ, occupying parts of sub-zones L, M, and N. The Jordan Lake State Recreation Area consists of 12 separate facilities (11 of which are in the EPZ) that offer camping, fishing, swimming, and boating:

1. New Hope Overlook: Offers 2 boat ramps to public, primitive camping at 24 campsites, fishing and trails. The campsites can only be accessed by hiking the trails. Overhead imagery indicates parking for 200 vehicles with trailers which is modeled as 400 passenger car equivalents (PCEs) in Dynev.

2. Ebenezer Church: Offers a boat ramp with 24 hour access, fishing, picnic areas, a swimming area, and trails. Overhead imagery indicates parking for 275 vehicles at the swimming and picnic areas and parking for 150 vehicles with trailers (300 PCEs).

3. Poplar Point: Offers primitive camping, recreational vehicle (RV) camping, boat ramps for campers only, fishing, swimming, and trails. There are a total of 579 campsites with 6 people and 2 vehicles per campsite on a peak day. Overhead imagery shows parking for 80 additional vehicles at the swimming area and 70 cars with trailers at the boat launch (140 PCEs).

4. Crosswinds Campground: Offers primitive camping, RV camping, boat ramps for campers only, fishing, swimming and trails. A total of 160 campsites with 6 people and 2 vehicles per campsite on a peak day.

5. Robeson Creek: Offers 24 hour boat ramp and fishing to the public. Overhead imagery indicates parking for 70 vehicles with trailers (140 PCEs).

6. Seaforth: Offers 2 public boat ramp, fishing, picnic areas, a swimming area, and trails. Overhead imagery indicates parking for 175 vehicles with trailers (350 PCEs) and an additional 350 parking spaces for the picnic and swimming area.

7. Parker's Creek: Offers group camping, primitive camping, and RV camping, fishing, picnic areas, a swimming area, and boat ramps for campers only. There are a total of 250 campsites with 6 people and 2 vehicles per campsite on a peak day.

8. Vista Point: Offers group camping, RV camping, fishing, picnic areas, a swimming area for campers only, and trails. There are a total of 330 campsites with 6 people and 2 vehicles per campsite on a peak day. Overhead imagery indicates parking for 100 vehicles with trailers (200 PCEs)

9. White Oak: Offers 2 boat ramps to the public, fishing, picnic areas, and a swimming area. Overhead imagery indicates parking for 90 vehicles with trailers (180 PCEs) and an additional 40 parking spaces for the swimming and picnic areas.

10. Crosswinds Marina: Overhead imagery indicates approximately 275 slips available for boats and a parking lot capacity of approximately 200 vehicles.

11. Poe's Ridge: Offers 2 public boat ramps with 24 hour access. Overhead imagery indicates parking for 82 vehicles with trailers (164 PCEs)

Appendix E includes a map of these recreation areas. It is assumed that 1 vehicle per family is used at these facilities. The average family size for the EPZ (3.12 persons/household) is multiplied by the number of vehicles at each facility to estimate the number of transients present. The peak transient population for Jordan Lake is estimated as 13,006 people evacuating in 5,317 vehicles.

Harris Lake

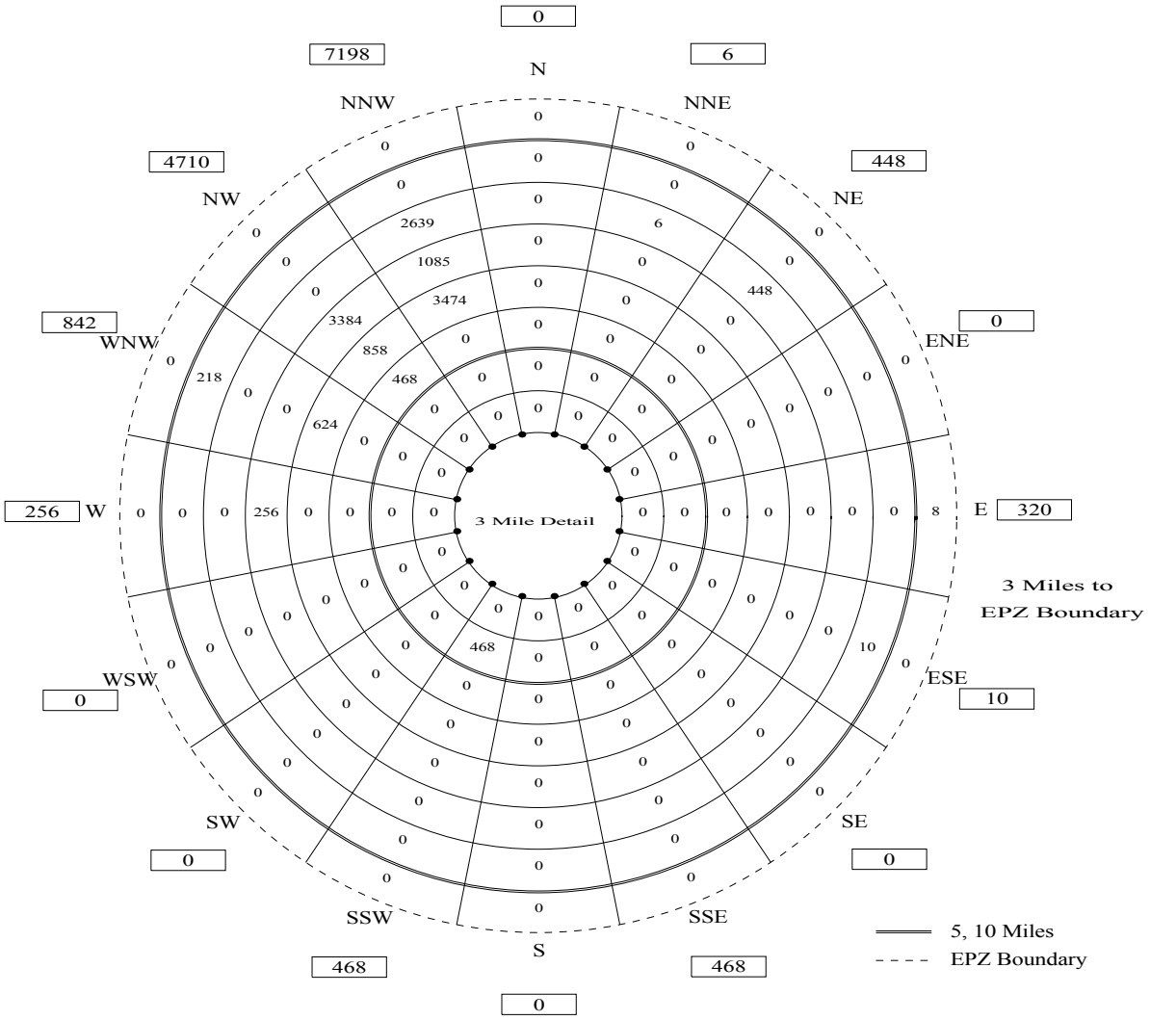
The Harris Nuclear Plant is located on Harris Lake which occupies parts of sub-zones A, C, D and K. Attractions at the site include the Harris Lake County Park, 2 boat ramps, and a fishing pier. The Harris Lake County Park spans 680 acres, including the Buckhorn Disc Golf Course (golf played by throwing Frisbees) and several mountain bike and hiking trails. The number of parking spaces at the boat ramps and for the County Park was estimated using overhead imagery. The peak attendance is estimated as 1,248 persons evacuating in 700 vehicles.

Hotels and Motels

There are 3 major hotels (50 or more rooms) and three bed and breakfast lodgings in the EPZ. Appendix E details the hotel data provided by county emergency management offices. The peak attendance at the hotels and motels is estimated as 472 people evacuating in 236 vehicles.

Table 3-3. Summary of Transients by Sub-Zone

Sub-Zone	Transients	Transient Vehicles
A	312	100
B	**No Transients**	
C		
D	468	300
E	454	227
F	**No Transients**	
G	18	9
H	**No Transients**	
I		
J		
K	468	300
L	5424	2213
M	4404	1864
N	3178	1240
TOTAL	**14,726**	**6,253**



Transient Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	312	0-2	312
2-3	468	0-3	780
3-4	0	0-4	780
4-5	468	0-5	1248
5-6	468	0-6	1716
6-7	4956	0-7	6672
7-8	4725	0-8	11397
8-9	3093	0-9	14490
9-10	228	0-10	14718
10-EPZ	8	0-EPZ	14726

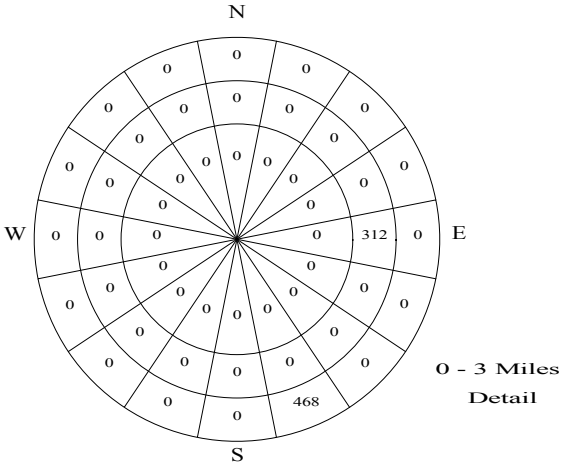
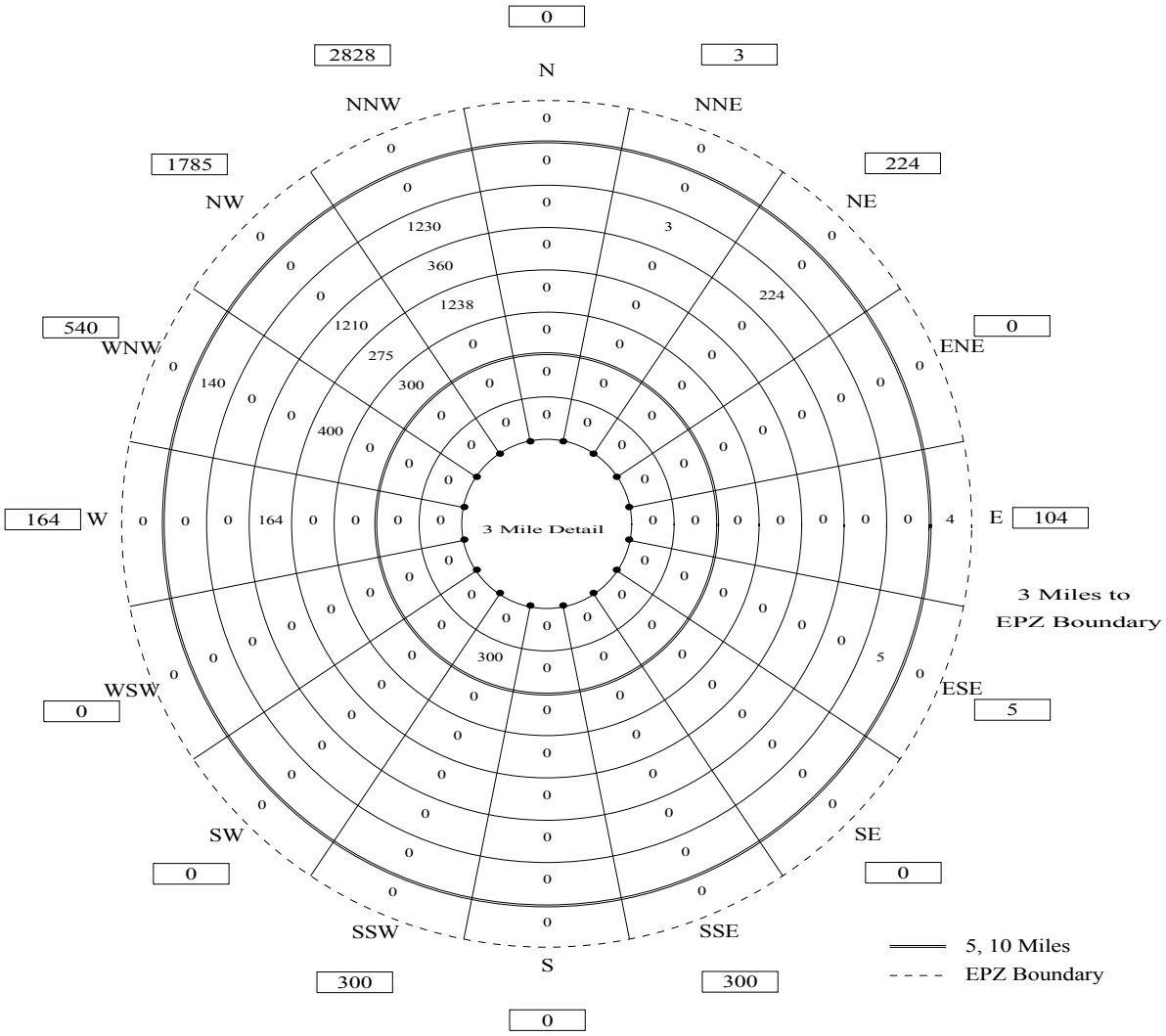


Figure 3-4. Transient Population by Sector



Transient Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	0	0-1	0
1-2	100	0-2	100
2-3	300	0-3	400
3-4	0	0-4	400
4-5	300	0-5	700
5-6	300	0-6	1000
6-7	1913	0-7	2913
7-8	1734	0-8	4647
8-9	1457	0-9	6104
9-10	145	0-10	6249
10-EPZ	4	0-EPZ	6253

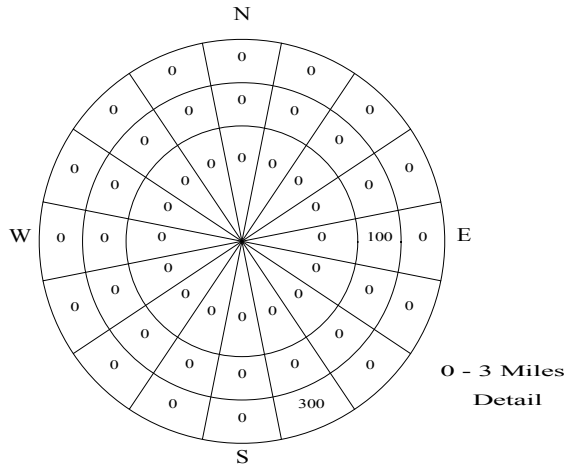


Figure 3-5. Transient Vehicles by Sector

Employees

Employees who work within the EPZ fall into two categories:

- Those who live and work in the EPZ
- Those who live outside of the EPZ and commute to jobs within the EPZ.

Those of the first category are already counted as part of the permanent resident population. To avoid double counting, we focus on those commuting employees who will evacuate along with the permanent resident population.

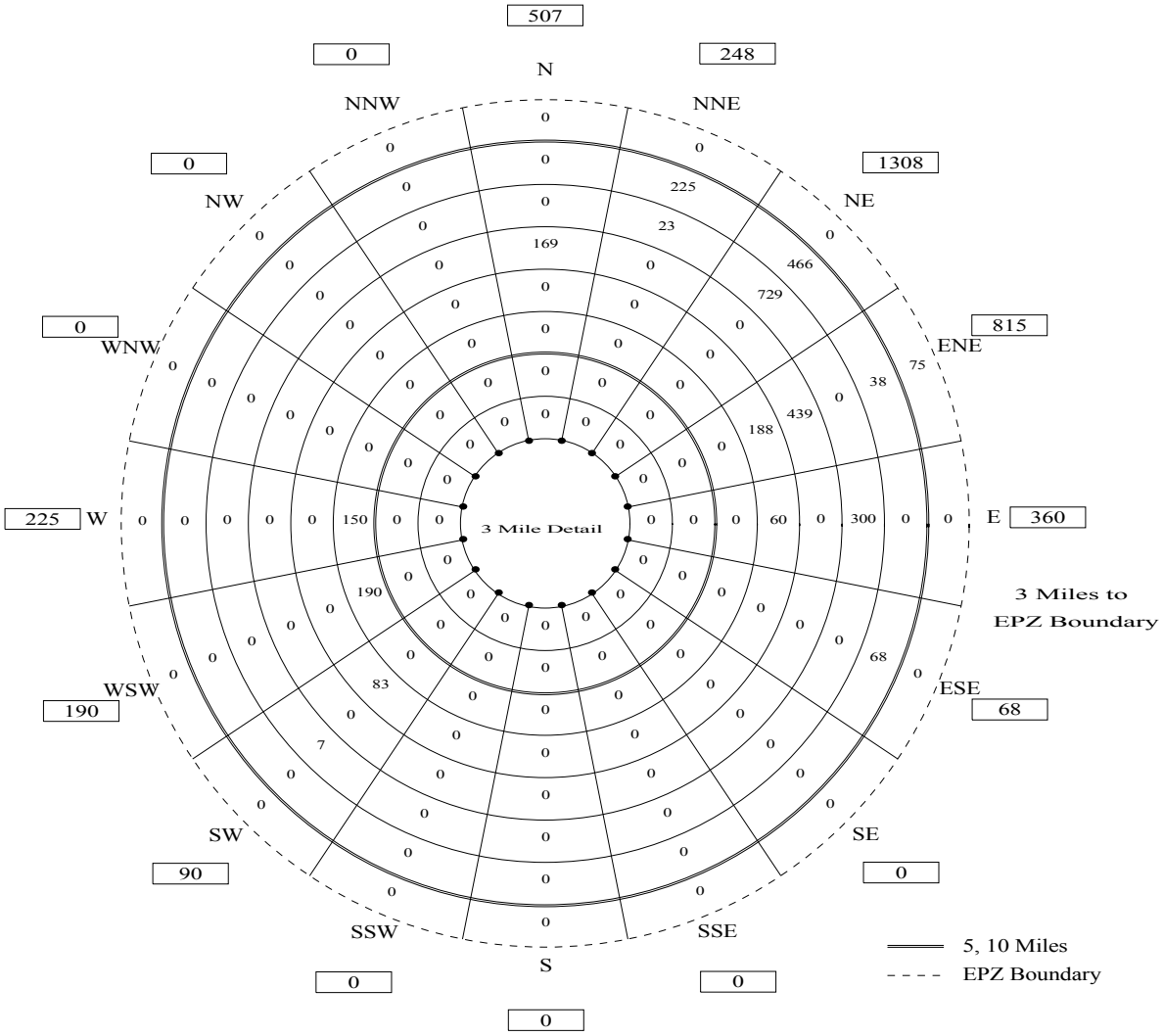
Data for major employers (more than 50 total employees) in the EPZ was provided by the county offices of emergency management. The locations of these facilities were mapped using GIS software. Additional commercial properties were located using overhead imagery and mapped in GIS; estimates of parking lot capacity were also made using the imagery. The GIS map was overlaid with the evacuation analysis network and employees were loaded onto appropriate links. The map of major employers and commercial properties in the EPZ can be seen in Appendix E.

Data provided by the county offices of emergency management indicate that, on average, 60% of the employees in the EPZ travel to work from outside the EPZ. This percentage was applied to the data provided by the counties to estimate the total number of people commuting into the EPZ to work.

An occupancy of 1.02 persons per employee-vehicle obtained from the telephone survey, was used to determine the number of evacuating employee vehicles.

Table 3-4 presents non-EPZ Resident employee and vehicle estimates by sub-zone. Figures 3-6 and 3-7 present these data by sector.

Table 3-4. Summary of Non-EPZ Employees by Sub-Zone		
Sub-Zone	**Total Non-EPZ Employees**	**Employee Vehicles**
A	526	516
B	**No employment**	
C		
D		
E	1,995	1,961
F	248	244
G	368	361
H	**No employment**	
I	7	7
J	**No employment**	
K	498	489
L	169	166
M	**No employment**	
N		
TOTAL	**3,811**	**3,744**



Employees			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	338	0-1	338
1-2	75	0-2	413
2-3	188	0-3	601
3-4	0	0-4	601
4-5	0	0-5	601
5-6	340	0-6	941
6-7	331	0-7	1272
7-8	608	0-8	1880
8-9	1059	0-9	2939
9-10	797	0-10	3736
10-EPZ	75	0-EPZ	3811

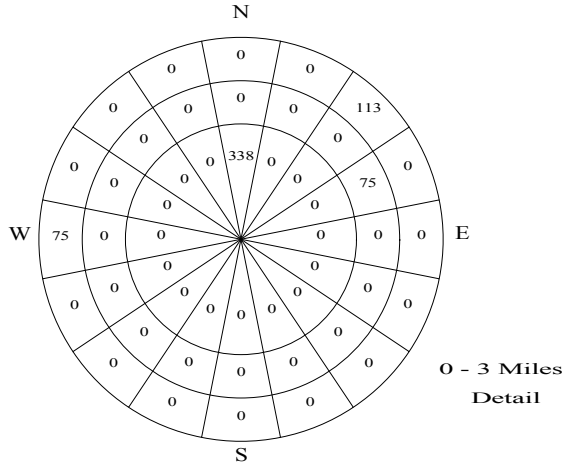
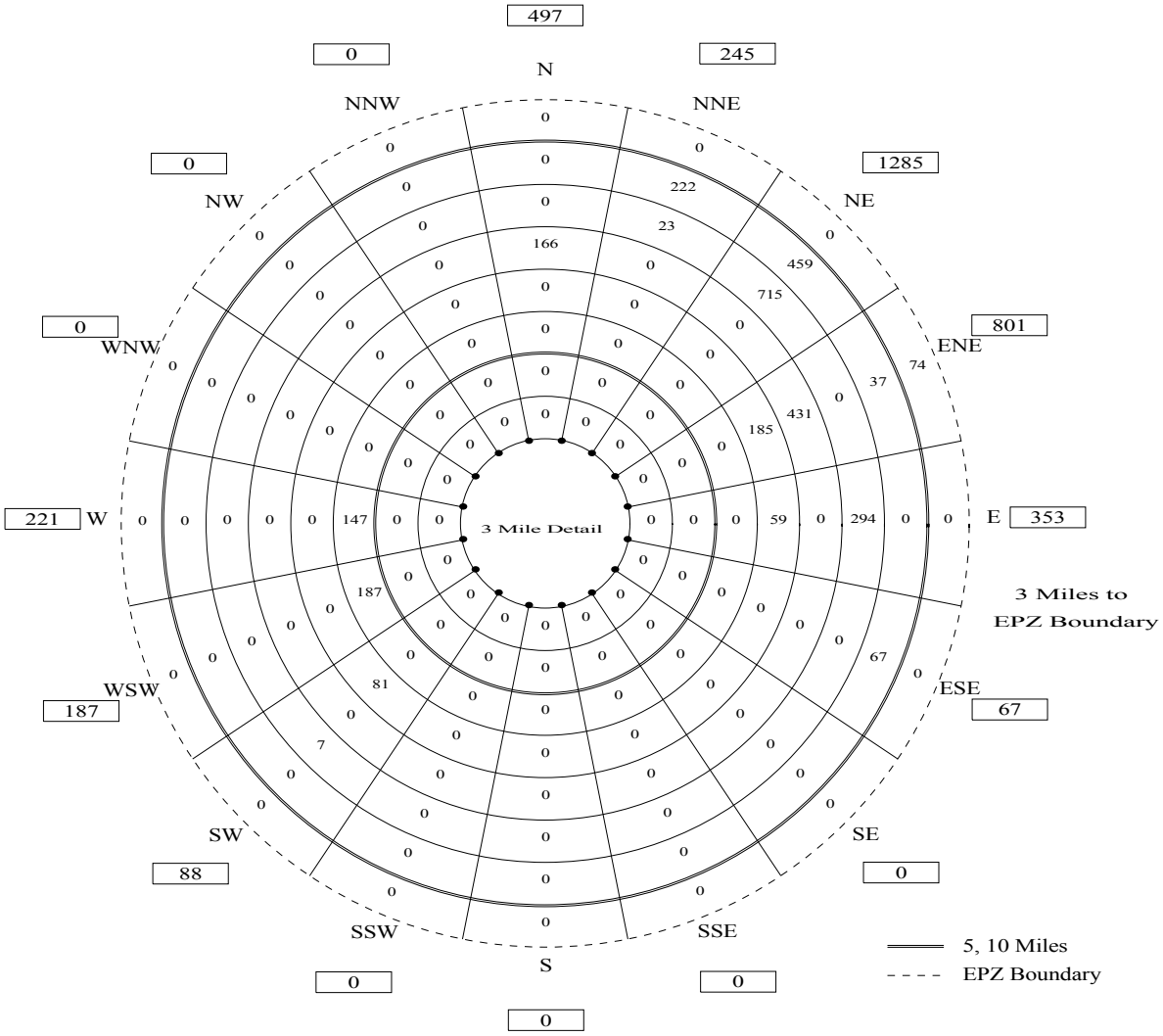


Figure 3-6. Employee Population by Sector



Employee Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	331	0-1	331
1-2	74	0-2	405
2-3	185	0-3	590
3-4	0	0-4	590
4-5	0	0-5	590
5-6	334	0-6	924
6-7	325	0-7	1249
7-8	597	0-8	1846
8-9	1039	0-9	2885
9-10	785	0-10	3670
10-EPZ	74	0-EPZ	3744

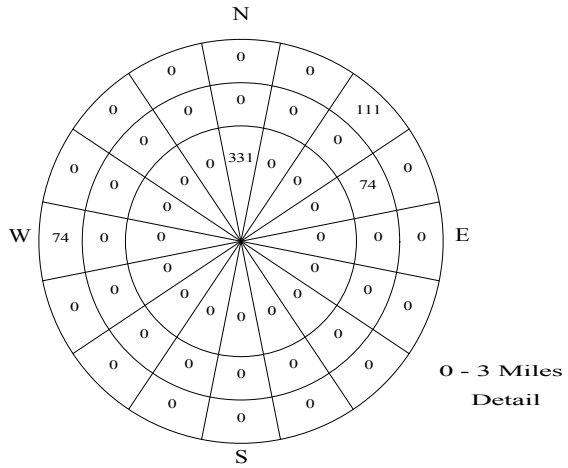


Figure 3-7. Employee Vehicles by Sector

Medical Facilities

Data request forms were completed for each of the medical facilities within the HNP EPZ. Chapter 8 details the evacuation of medical facilities and their patients. The number and type of evacuating vehicles that need to be provided depends on the patients' states of health. Buses can transport up to 40 people; vans, up to 12 people; ambulances, up to 2 people (patients).

Pass-Through Demand

Vehicles will be traveling through the EPZ (external-external trips) at the time of an accident. After the Advisory to Evacuate is announced, these through travelers will also evacuate. These through vehicles are assumed to travel on the major routes through the EPZ (e.g. US Hwy 1 and US Hwy 64). It is assumed that this traffic will continue to enter the EPZ during the first 60 minutes following the Advisory to Evacuate. We estimate approximately 8,100 vehicles enter the EPZ as external-external trips during this period.

4. ESTIMATION OF HIGHWAY CAPACITY

The ability of the road network to service vehicle demand is a major factor in determining how rapidly an evacuation can be completed. The capacity of a road is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane of roadway during a given time period under prevailing roadway, traffic and control conditions. (From the 2000 Highway Capacity Manual)

In discussing capacity, different operating conditions have been assigned alphabetical designations, A through F, to reflect the range of traffic operational characteristics. These designations have been termed "Levels of Service" (LOS). For example, LOS A connotes free-flow and high-speed operating conditions; LOS F represents a forced flow condition. LOS E describes traffic operating at or near capacity.

Because of the effect of weather on the capacity of a roadway, it is necessary to adjust capacity figures to represent the prevailing conditions during inclement weather. Based on limited empirical data, weather conditions such as heavy rain reduce the values of free speed and of highway capacity by approximately 10 percent. Over the last decade new studies have been made on the effects of rain on traffic capacity. These studies indicate a range of effects between 5 and 20 percent depending on wind speed and precipitation rates.

Given the suburban character of the EPZ, its population, and the availability of well-maintained highways, congestion arising from evacuation is likely to exist, especially in the northeastern portion of the EPZ near Raleigh. Estimates of roadway capacity must be determined with great care. Because of its importance, a brief discussion of the major factors that influence highway capacity is presented in this section.

Capacity Estimations on Approaches to Intersections

At-grade intersections are apt to become the first bottleneck locations under local heavy traffic volume conditions. This characteristic reflects the need to allocate access time to the respective competing traffic streams by exerting some form of control. During evacuation, control at critical intersections will often be provided by traffic control personnel assigned for that purpose, whose directions may supersede traffic control devices. The Traffic Management Plan identifies these locations (called Traffic Control Points, TCP) and the management procedures applied.

The per-lane capacity of an approach to a signalized intersection can be expressed (simplistically) in the following form:

$$Q_{cap,m} = \left(\frac{3600}{h_m}\right) \bullet \left[\frac{G-L}{C}\right]_m = \left(\frac{3600}{h_m}\right) \bullet P_m$$

where:

$Qcap,m$	=	Capacity of a single lane of traffic on an approach, which executes movement, *m*, upon entering the intersection; vehicles per hour (vph)
h_m	=	Mean queue discharge headway of vehicles on this lane that are executing movement, *m*; seconds per vehicle
G_m	=	The mean duration of GREEN time servicing vehicles that are executing movement, *m*, for each signal cycle; seconds
L	=	The mean "lost time" for each signal phase servicing movement, m; seconds
C	=	The duration of each signal cycle; seconds
P_m	=	The proportion of GREEN time allocated for vehicles executing movement, *m*, from this lane. This value is specified as part of the control treatment.
m	=	The movement executed by vehicles after they enter the intersection: through, left-turn, right-turn, diagonal.

The turn-movement-specific mean discharge headway h_m, depends in a complex way upon many factors: roadway geometrics, turn percentages, the extent of conflicting traffic streams, the control treatment, and others. A primary factor is the value of "saturation queue discharge headway", h_{sat}, which applies to through vehicles that are not impeded by other conflicting traffic streams. This value, itself, depends upon many factors including motorist behavior. Formally, we can write,

$$h_m = f_m\,(h_{sat}, F_1, F_2, ...)$$

where:

h_{sat}	=	Saturation discharge headway for through vehicles; seconds per vehicle
F_1, F_2	=	The various known factors influencing h_m
$f_m\,(\cdot)$	=	Complex function relating h_m to the known (or estimated) values of $h_{sat}, F_1, F_2, \ldots$

The estimation of h_m for specified values of $h_{sat}, F_1, F_2, ...$ is undertaken within the PC-DYNEV simulation model and within the TRAD model by a mathematical model[1]. The resulting values for h_m always satisfy the condition:

$$h_m \geq h_{sat}$$

That is, the turn-movement-specific discharge headways are always greater than, or equal to the saturation discharge headway for through vehicles. These headways (or its inverse equivalent, “saturation flow rate”), may be determined by observation or using the

1 Lieberman, E., "Determining Lateral Deployment of Traffic on an Approach to an Intersection", McShane, W. & Lieberman, E., "Service Rates of Mixed Traffic on the far Left Lane of an Approach". Both papers appear in Transportation Research Record 772, 1980.

procedures of the Highway Capacity Manual.

Capacity Estimation Along Sections of Highway

The capacity of highway sections -- as distinct from approaches to intersections -- is a function of roadway geometrics, traffic composition (e.g. percent heavy trucks and buses in the traffic stream) and, of course, motorist behavior. There is a fundamental relationship which relates service volume (i.e. the number of vehicles serviced within a uniform highway section in a given time period) to traffic density. Figure 4-1 describes this relationship.

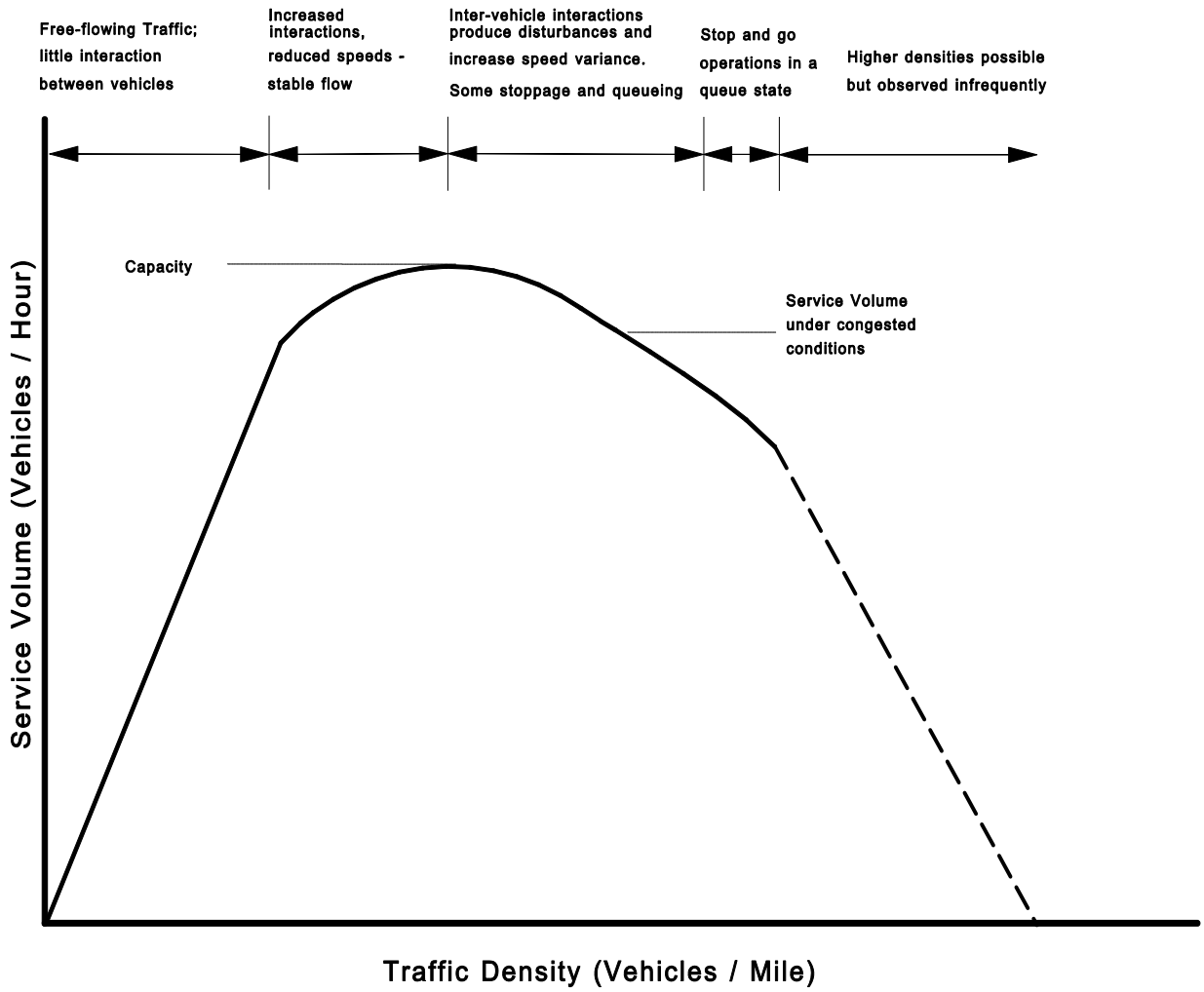


Figure 4-1. Fundamental Relationship Between Volume and Density

As indicated, there are two flow regimes: (1) Free Flow (left side of curve); and (2) Forced Flow (right side). In the Free Flow regime, the traffic demand is fully serviced; this service volume increases as demand volume and density increase, until the service volume attains its maximum value, which is the capacity of the highway section. As traffic demand and the resulting highway density increase beyond this "critical" value, the rate at which traffic can be serviced (i.e. the service volume) can actually decline below capacity. Therefore, in order to realistically represent traffic performance during congested conditions (i.e. when demand exceeds capacity), it is necessary to estimate the service volume, V_F, under congested conditions.

The value of V_F can be expressed as:

$$V_F = R \times \text{Capacity}$$

where R = Reduction factor which is less than unity.

Based on empirical data collected on freeways, we have employed a value of R=0.85. It is important to mention that some investigators, on analyzing data collected on freeways, conclude that little reduction in capacity occurs even when traffic is operating at Level of Service, *F*. While there is conflicting evidence on this subject, we adopt a conservative approach and use a value of capacity, V_F, that is applied during LOS F conditions; V_F, is lower than the specified capacity.

The estimated value of capacity is based primarily upon the type of facility and on roadway geometrics. Sections of roadway with adverse geometrics are characterized by lower free-flow speeds and lane capacity.

The procedure used here was to estimate "section" capacity, V_E, based on observations made traveling over each section of the evacuation network, by the posted speed limits and travel behavior of other motorists and by reference to the 2000 Highway Capacity Manual. It was then determined for each highway section, represented as a network link, whether its capacity would be limited by the "section-specific" service volume, V_E , or by the intersection-specific capacity. For each link, the model selects the lower value of capacity.

Application to the Harris Nuclear Plant EPZ

As part of the development of the Harris Nuclear Plant (HNP) EPZ traffic network, an estimate of roadway capacity is required. The source material for the capacity estimates presented herein is contained in:

2000 Highway Capacity Manual (HCM)
Transportation Research Board
National Research Council
Washington, D.C.

The highway system in the HNP EPZ consists primarily of three categories of roads and, of course, intersections:

- Two-lane roads: Local, State
- Multi-lane Highways (at-grade)
- Freeways (e.g., US Hwy 1 and US Hwy 64)

Each of these classifications will be discussed.

Two-Lane Roads

Ref: HCM Chapter 20

Two lane roads comprise the majority of highways within the EPZ. The per-lane capacity of a two-lane highway is estimated at 1700 passenger cars per hour (pc/h). This estimate is essentially independent of the directional distribution of traffic volume except that, for extended distances, the two-way capacity will not exceed 3200 pc/h. The HCM procedures then estimate Level of Service (LOS) and Average Travel Speed. The evacuation simulation model accepts the specified value of capacity as input and computes average speed based on the time-varying demand: capacity relations.

Based on the field survey and on expected traffic operations associated with evacuation scenarios:

- Most sections of two-lane roads within the EPZ are classified as “Class I”, with "level terrain"; some are “rolling terrain”.
- “Class II” highways are mostly those within city limits.

Multi-Lane Highway

Ref: HCM Chapter 21

Exhibit 21-23 (in the HCM) presents a set of curves that indicates a per-lane capacity of approximately 2100 pc/h, for free-speeds of 55-60 mph. Based on observation, the multi-lane highways outside of urban areas within the EPZ, service traffic with free-speeds in this range. The actual time-varying speeds computed by the simulation model reflect the demand:capacity relationship and the impact of control at intersections.

Freeways

Ref: HCM Chapters 22-25

Chapter 22 of the HCM describes a procedure for integrating the results obtained in Chapters 23, 24 and 25, which compute capacity and LOS for freeway components. The

discussion also references Chapter 31, which presents a discussion on simulation models. The simulation model, PC-DYNEV, automatically performs this integration process.

Chapter 23 of the HCM presents procedures for estimating capacity and LOS for “Basic Freeway Segments". Exhibit 23-3 of the HCM2000 presents capacity vs. free speed estimates.

Free Speed:	55	60	65	70+
Per-Lane Capacity (pc/h):	2250	2300	2350	2400

The inputs to the simulation model are highway geometrics, and free-speeds and capacity based on field observations. The simulation logic calculates actual time-varying speeds based on demand: capacity relationships.

Chapter 24 of the HCM presents procedures for estimating capacity, speed, density and LOS. The simulation model contains logic that relates speed to demand volume: capacity ratio. The value of capacity that is obtained from Exhibit 24-8 (of the HCM2000) depends on the "Type" and geometrics of the weaving segment and on the "Volume Ratio" (ratio of weaving volume to total volume).

Chapter 25 of the HCM presents procedures for estimating capacities of ramps and of "merge" areas. The capacity of a merge area "is determined primarily by the capacity of the downstream freeway segment". Values of this merge area capacity are presented in Exhibit 25-7 of the HCM2000, and depend on the number of freeway lanes and on the freeway free speed. The KLD simulation model logic simulates the merging operations of the ramp and freeway traffic. If congestion results from an excess of demand relative to capacity, then the model allocates service appropriately to the two entering traffic streams and produces LOS F conditions. (The HCM does not address LOS F explicitly).

Intersections

Ref: HCM Chapters 16, 17

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapters 16 (signalized intersections) and 17 (un-signalized intersections). These are the two longest chapters in the HCM 2000, reflecting the complexity of these procedures. The simulation logic is likewise complex, but different; as stated on page 31-21 of the HCM2000: “Assumptions and complex theories are used in the simulation model to represent the real-world dynamic traffic environment.”

5. ESTIMATION OF TRIP GENERATION TIME

Federal Government guidelines (see NUREG 0654, Appendix 4) specify that the planner estimate the distributions of elapsed times associated with mobilization activities undertaken by the public to prepare for the evacuation trip. The elapsed time associated with each activity is represented as a statistical distribution reflecting differences between members of the public. The quantification of these activity-based distributions relies largely on the results of the telephone survey (Appendix F). We define the sum of these distributions of elapsed times as the Trip Generation Time Distribution.

Background

In general, an accident at a nuclear power station is characterized by the following Emergency Action Classification Levels (see Appendix 1 of NUREG 0654 for details):

1. Unusual Event
2. Alert
3. Site Area Emergency
4. General Emergency

At each level, the Federal guidelines specify a set of Actions to be undertaken by the Licensee, and by State and Local offsite authorities. As a Planning Basis, we will adopt a conservative posture, in accord with Federal Regulations, that a rapidly escalating accident will be considered in calculating the Trip Generation Time. We will assume:

a. The Order to Evacuate will be announced coincident with the emergency notification.
b. Mobilization of the general population will commence up to 10 minutes after the alert notification.
c. Evacuation Time Estimates (ETEs) are measured relative to the Order to Evacuate.
d. Schools will be evacuated prior to the Order to Evacuate; if circumstances permit.

We emphasize that the adoption of this planning basis is not a representation that these events will occur at the Harris Nuclear Plant (HNP) within the indicated time frame. Rather, these assumptions are necessary in order to:

- Establish a temporal framework for estimating the Trip Generation distribution as recommended in Appendix 4 of NUREG 0654.
- Identify temporal points of reference that uniquely define "Clear Time" and Evacuation Time Estimates (ETE).

It is more likely that a longer time will elapse between the various classes of an emergency at HNP and that the Order to Evacuate is announced somewhat later than the siren alert.

For example, suppose one hour elapses from the declaration of a General Emergency (and the siren alert) to the Order to Evacuate. In this case, it is reasonable to expect some degree of spontaneous evacuation by the public during this one-hour period. As a result, the population within the Emergency Planning Zone (EPZ) will be lower when the Order to Evacuate is announced, than at the time of the General Emergency. Thus, the time needed to evacuate the EPZ, after the Order to Evacuate will be less than the estimates presented in this report.

The notification process consists of two events:

- Transmitting information (e.g. using sirens, tone alerts, EAS broadcasts, loud speakers).
- Receiving and correctly interpreting the information that is transmitted.

The peak permanent resident population within the EPZ approximates 75,000 persons who are deployed over an area of approximately 314 square miles and engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident.

The amount of elapsed time will vary from one individual to the next depending where that person is, what that person is doing, and related factors. Furthermore, some persons who will be directly involved with the evacuation process may be outside the EPZ at the time that the emergency is declared. These people may be commuters, shoppers and other travelers who reside within the EPZ and who will return to join the other household members upon receiving notification of an emergency.

As indicated in NUREG 0654, the estimated elapsed times for the receipt of notification can be expressed as a distribution reflecting the different notification times for different people within, and outside, the EPZ. By using time distributions, it is also possible to distinguish between different population groups and different day-of-week and time-of-day scenarios, so that accurate ETEs may be obtained.

For example, people at home or at work within the EPZ will be notified by siren, and/or tone alert and/or radio. Those well outside the EPZ will be notified by telephone, radio, TV and word-of-mouth, with potentially longer time lags. Furthermore, the spatial distribution of the EPZ population will differ with time of day - families will be united in the evenings, but dispersed during the day. In this respect, weekends will also differ from weekdays.

Fundamental Considerations

The environment leading up to the time that people begin their evacuation trips consists of a sequence of events and activities. Each event (other than the first) occurs at an instant in time and is the outcome of an activity.

Activities are undertaken over a period of time. Activities may be in "series" (i.e. to undertake an activity implies the completion of all preceding activities) or may be in parallel (two or more activities may take place over the same period of time). Activities conducted in series are functionally dependent on the completion of prior activities; activities conducted in parallel are functionally independent of one-another. The relevant events associated with the public's preparation for evacuation are:

Event Number	Event Description
1	Notification-accident condition
2	Awareness of accident situation
3	Depart place of work or elsewhere, to return home
4	Arrive (or be at) home
5	Begin evacuation trip to leave the area

Associated with each sequence of events are one or more activities, as outlined below:

Event Sequence	Activity	Distribution
1 → 2	Public receives notification information	1
2 → 3	Prepare to leave work	2
2,3 → 4	Travel home*	3
2,4 → 5	Prepare to leave for evacuation trip	4

*If already at home, this is a null (no-time-consumed) activity.

These relationships are shown graphically in Figure 5-1.

An employee who lives outside the EPZ will follow sequence (d) of Figure 5-1; a resident of the EPZ who is at work, and will return home before beginning the evacuation trip will follow sequence (a) of Figure 5-1. Note that event 5, "Leave to evacuate the area," is conditional either on event 2 or on event 4. That is, activity 2 → 5 by a resident at home can be undertaken in parallel with activities 2 → 3, 3 → 4 and 4 → 5 by a commuter returning to that home, as shown in Figure 5-1 (a). Specifically, one adult member of a

household can prepare to leave home (i.e. secure the home, pack clothing, etc.), while others are traveling home from work. In this instance, the household members would be able to evacuate sooner than if such trip preparation were deferred until all household members had returned home. For this study, we adopt the conservative posture that all activities will occur in sequence.

It is seen from Figure 5-1, that the Trip Generation time (i.e. the total elapsed time from Event 1 to Event 5) depends on the scenario and will vary from one household to the next. Furthermore, Event 5 depends, in a complicated way, on the time distributions of all activities preceding that event. That is, to estimate the time distribution of Event 5, we must obtain estimates of the time distributions of all preceding events.

Estimated Time Distributions of Activities Preceding Event 5

The time distribution of an event is obtained by "summing" the time distributions of all prior contributing activities. (This "summing" process is quite different than an algebraic sum since we are operating on distributions – not scalar numbers).

Time Distribution No. 1, Notification Process: Activity 1 $\rightarrow$ 2

It is reasonable to expect that 85 percent of those within the EPZ will be aware of the accident within 30 minutes with the remainder notified within the following 20 minutes. The notification distribution is given below:

Distribution No. 1, Notification Time: Activity 1 $\rightarrow$ 2

Elapsed Time (Minutes)	**Percent of Population Notified**
0	0
5	7
10	13
15	26
20	46
25	65
30	85
35	90
40	95
45	98
50	100

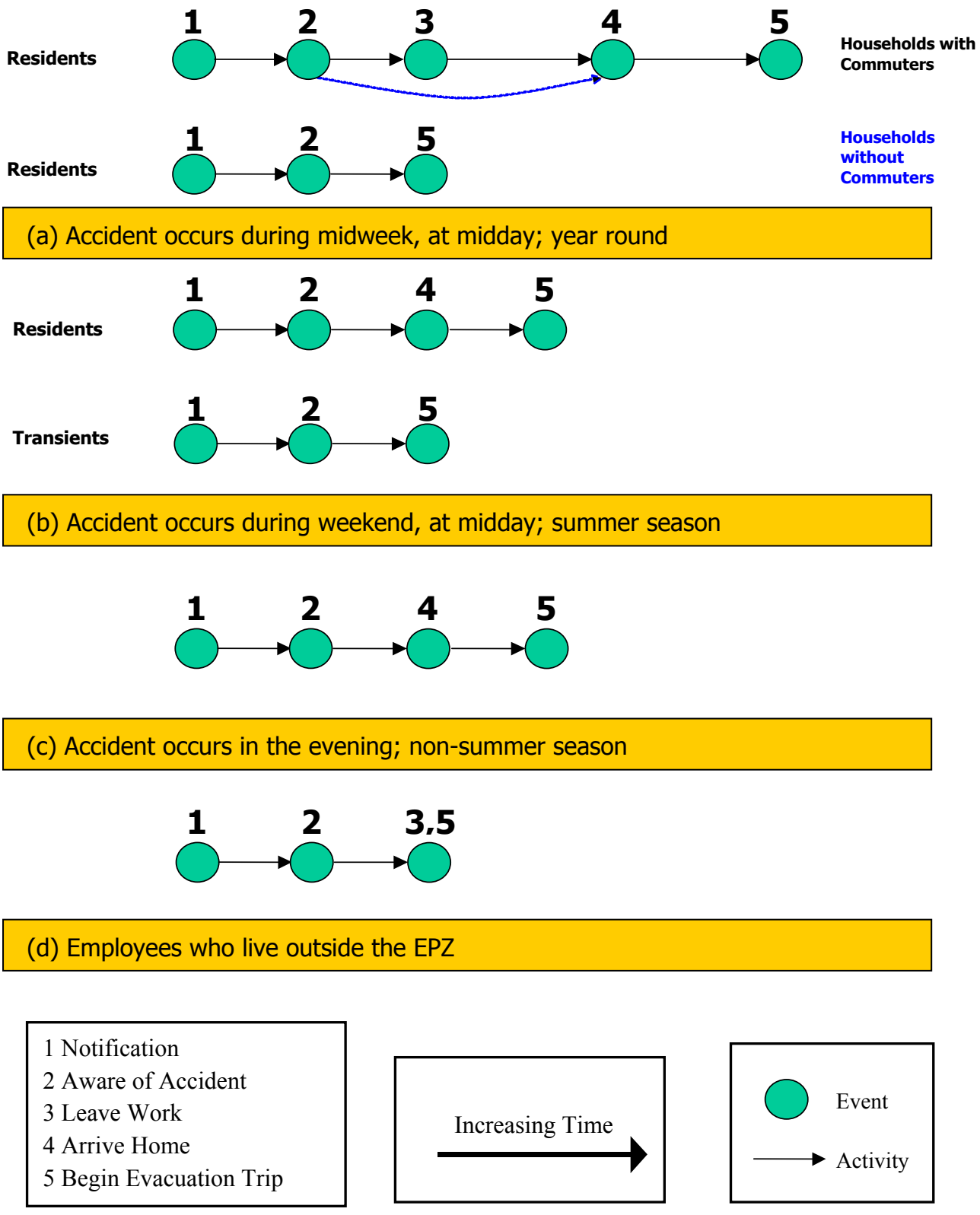


Figure 5-1. Events and Activities Preceding the Evacuation Trip

Distribution No. 2, Prepare to Leave Work: Activity 2 → 3

It is reasonable to expect that the vast majority of business enterprises within the EPZ will elect to shut down following notification and most employees would leave work quickly. Commuters, who work outside the EPZ could, in all probability, also leave quickly since facilities outside the EPZ would remain open and other personnel would remain. Personnel or farmers responsible for equipment or livestock would require additional time to secure their facility. The distribution of Activity 2 → 3 reflects data obtained by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0
5	29
10	43
15	56
20	63
25	67
30	83
35	86
40	88
45	92
50	93
55	93
60	98
65	98
70	98
75	99
80	99
85	99
90	99
95	99
100	99
105	99
110	99
115	99
120	100

NOTE: The survey data was normalized to distribute the "Don't know" response

Distribution No. 3, Travel Home: Activity 3 → 4

These data are provided directly by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0
5	8
10	19
15	33
20	50
25	59
30	76
35	82
40	85
45	94
50	96
55	96
60	98
65	98
70	99
75	99
80	99
85	99
90	99
95	99
100	100

NOTE: The survey data was normalized to distribute the "Don't know" response

Distribution No. 4, Prepare to Leave Home: Activity 2, 4 $\rightarrow$ 5

These data are provided directly by the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
0	0
5	10
10	20
15	30
20	42
25	53
30	64
35	67
40	69
45	71
50	76
55	82
60	82
65	88
70	89
75	90
80	90
85	90
90	91
95	91
100	91
105	92
110	93
115	94
120	95
125	95
130	95
135	96
140	96
145	96
150	96
155	96
160	97
165	97
170	97
175	97
180	98
185	99
190	99
195	100

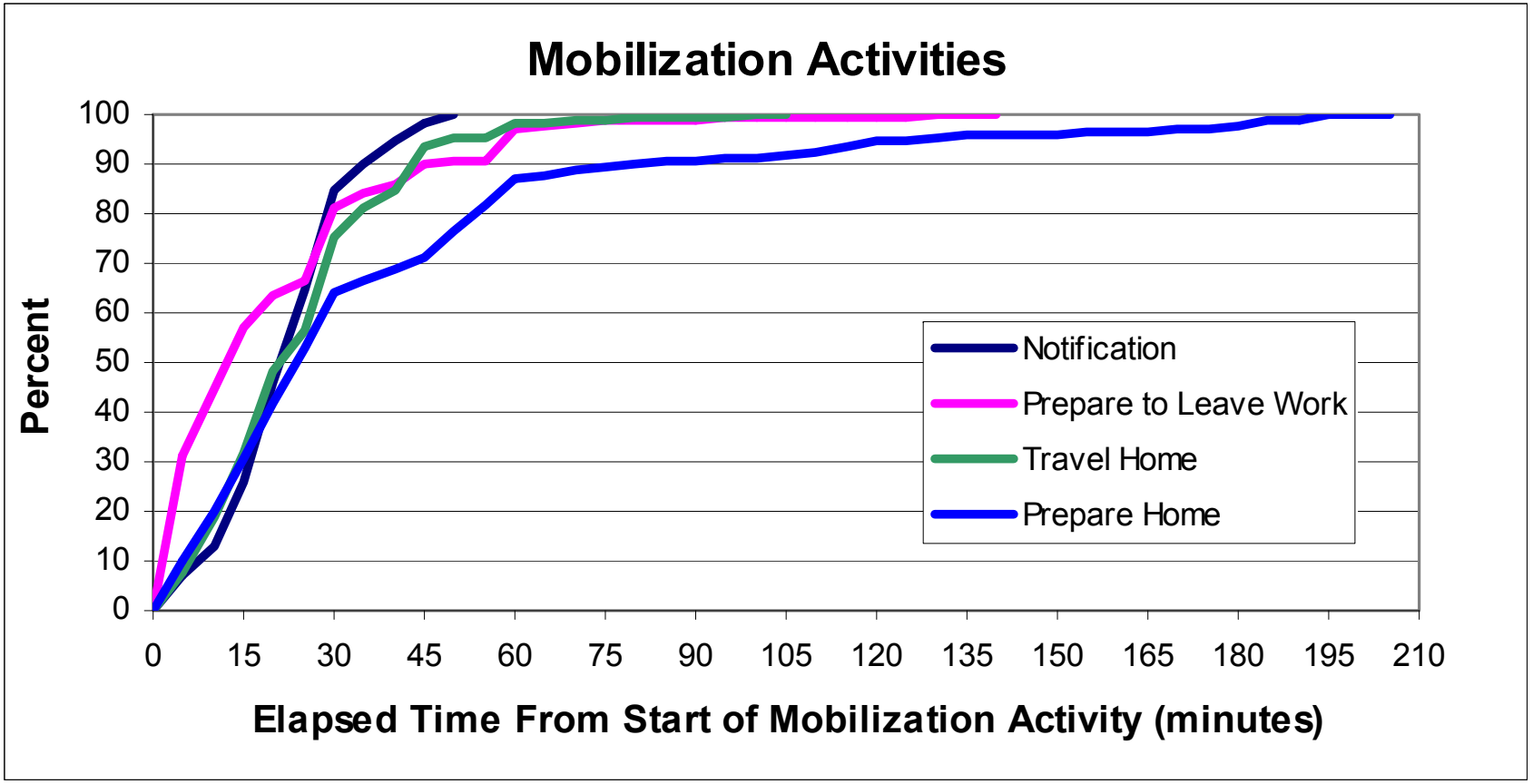


Figure 5-2. Evacuation Mobilization Activities

Calculation of Trip Generation Time Distribution

The time distributions for each of the mobilization activities presented herein must be combined to form the appropriate Trip Generation Distributions. We assume that the stated events take place in sequence such that all preceding events must be completed before the current event can occur. For example, if a household awaits the return of a commuter, the work-to-home trip (Activity 3 $\rightarrow$ 4) must precede Activity 4 $\rightarrow$ 5.

To calculate the time distribution of an event that is dependent on two sequential activities, it is necessary to "sum" the distributions associated with these prior activities. The distribution summing algorithm is applied repeatedly as shown to form the required distribution. As an outcome of this procedure, new time distributions are formed; we assign "letter" designations to these intermediate distributions to describe the procedure.

Apply "Summing" Algorithm To:	**Distribution Obtained**	**Event Defined**
Distributions 1 and 2	To Obtain Distribution A	That defines Event 3
Distributions A and 3	To Obtain Distribution B	That defines Event 4
Distributions B and 4	To Obtain Distribution C	That defines Event 5
Distributions 1 and 4	To Obtain Distribution D	That defines Event 5

Distributions A through D are described below; distributions A, C, and D are shown in Figure 5-3:

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ who live outside, and to Transients within the EPZ.
B	Time distribution of commuters arriving home.
C	Time distribution of residents with commuters leaving home to begin the evacuation trip.
D	Time distribution of residents without commuters returning home to begin the evacuation trip.

Figure 5-3 presents the combined trip generation distributions designated A, C, and D. These distributions are presented on the same time scale. The PC-DYNEV simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These histograms, which represent Distributions A, C, and D, properly displaced with respect to one another, are tabulated in Table 5-1. (Distribution B, Arrive Home, omitted for clarity).

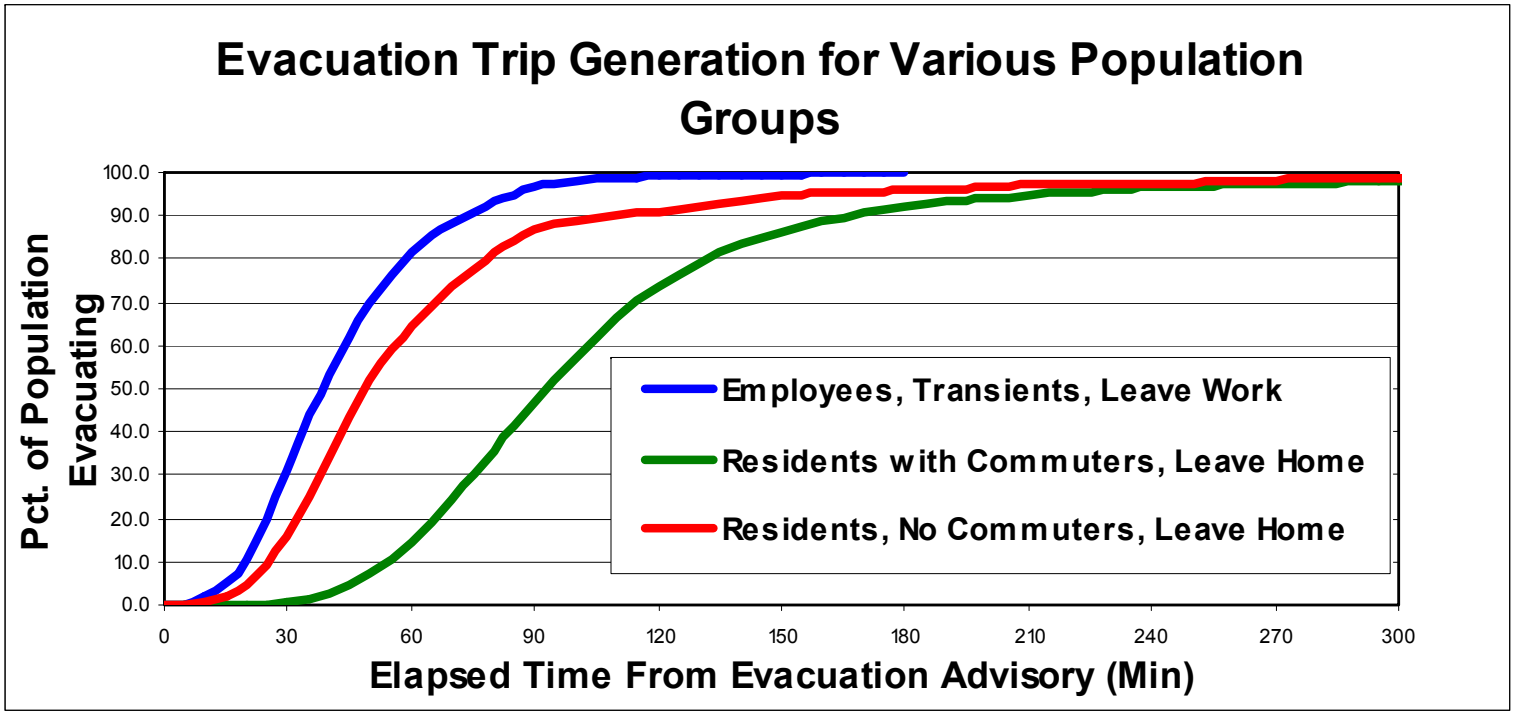


Figure 5-3. Comparison of Trip Generation Distributions

Table 5-1. Trip Generation Time Histograms for the EPZ Population					
Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period			
		Residents With Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Employees (Distribution A)	Transients (Distribution A)
1	15	0	2	5	5
2	15	1	13	23	23
3	15	4	26	33	33
4	15	10	23	22	22
5	30	32	23	14	14
6	30	30	6	2	2
7	30	15	3	1	1
8	30	6	4	0	0
9	60	2	0	0	0
10	900	0	0	0	0

6. DEMAND ESTIMATION FOR EVACUATION SCENARIOS

An evacuation "case" defines a combination of Evacuation Region and Evacuation Scenario. The definitions of "Region" and "Scenario" are as follows:

Region — A grouping of contiguous evacuation sub-zones, that forms either a "keyhole" sector-based area, or a circular area within the EPZ, that must be evacuated in response to a radiological emergency.

Scenario — A combination of circumstances, including time of day, day of week, season, and weather conditions. Scenarios define the number of people in each of the affected population groups and their respective mobilization time distributions.

A total of 25 Regions were defined which encompass all the groupings of sub-zones considered. These Regions are defined in Table 6-1. The sub-zone configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a circular area centered at the Harris Nuclear Plant (HNP), and three adjoining sectors, each with a central angle of 22.5 degrees. These sectors extend to a distance of 5 miles from HNP (Regions R4 to R12), or to the EPZ boundary (Regions R13 to R25). The azimuth of the center sector defines the orientation of these Regions.

A total of 12 Scenarios were evaluated for all Regions. Thus, there are a total of 12x25=300 evacuation cases. Table 6-2 is a description of all Scenarios.

Each combination of region and scenario implies a specific population to be evacuated. Table 6-3 presents the percentage of each population group assumed to evacuate for each scenario. Table 6-4 presents the vehicle counts for each scenario.

Table 6-1. Description of Evacuation Regions															
		Sub-Zone													
Region	Description	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R01	2 mile ring	■													
R02	5-mile ring	■	■	■	■							■	■		
R03	Full EPZ	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Evacuate 2-mile ring and 5 miles downwind															
		Sub-Zone													
Region	Wind Direction	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R04	N,NW,NNW	■	■										■		
R05	NNE	■	■												
R06	NE,ENE	■	■	■											
R07	E	■	■	■	■										
R08	ESE	■		■	■										
R09	SE	■		■	■							■			
R10	SSE,S	■			■							■			
R11	SSW, SW	■										■			
R12	WSW,W,WNW	■										■	■		
Evacuate 5-mile ring and downwind to EPZ boundary															
		Sub-Zone													
Region	Wind Direction	A	B	C	D	E	F	G	H	I	J	K	L	M	N
R13	N,NNE	■	■	■	■	■						■	■		■
R14	NE	■	■	■	■	■	■					■	■		
R15	ENE, E	■	■	■	■	■	■	■				■	■		
R16	ESE	■	■	■	■		■	■	■			■	■		
R17	SE	■	■	■	■			■	■			■	■		
R18	SSE	■	■	■	■			■	■	■		■	■		
R19	S	■	■	■	■				■	■		■	■		
R20	SSW	■	■	■	■				■	■	■	■	■		
R21	SW	■	■	■	■					■	■	■	■		
R22	WSW	■	■	■	■					■	■	■	■	■	
R23	W,WNW	■	■	■	■						■	■	■	■	
R24	NW	■	■	■	■							■	■	■	■
R25	NNW	■	■	■	■	■						■	■	■	■

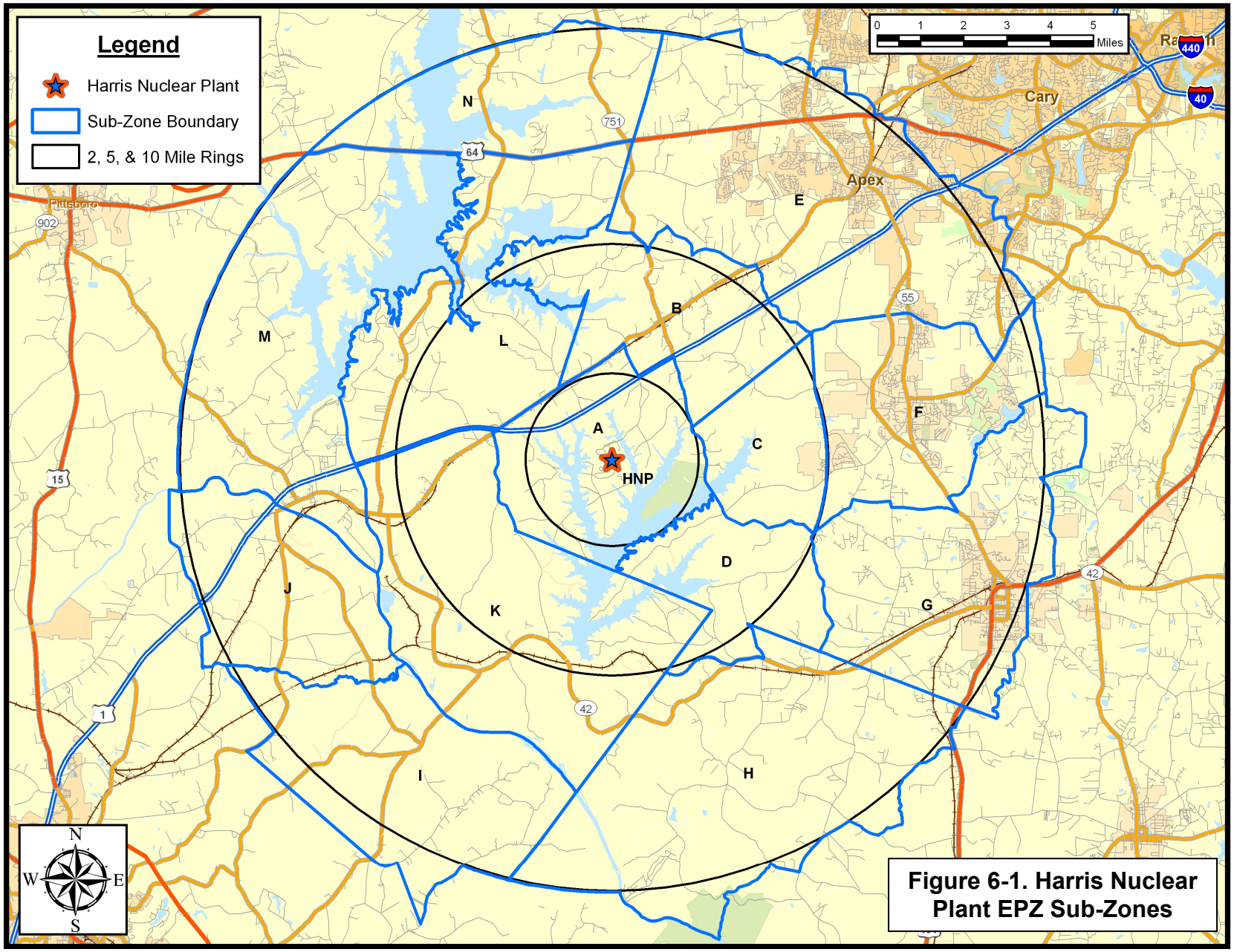


Figure 6-1. Harris Nuclear Plant EPZ Sub-Zones

Table 6-2. Evacuation Scenario Definitions					
Scenario	**Season**	**Day of Week**	**Time of Day**	**Weather**	**Special**
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Ice	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Midweek, Weekend	Evening	Good	None
12	Summer	Midweek	Midday	Good	New Plant Construction

Note: Schools are assumed to be in session for the Winter season (midweek, midday).

Table 6-3. Percent of Population Groups for Various Scenarios									
Scenarios	Residents With Commuters in Household	Residents With No Commuters in Household	Employees	Transients	Shadow	Special Events	School Buses	Transit Buses	External Through Traffic
1	75%	25%	96%	50%	33%	0%	10%	100%	100%
2	75%	25%	96%	50%	33%	0%	10%	100%	100%
3	10%	90%	47%	100%	32%	0%	0%	100%	100%
4	10%	90%	47%	100%	32%	0%	0%	100%	100%
5	10%	90%	10%	25%	30%	0%	0%	100%	60%
6	75%	25%	100%	25%	33%	0%	100%	100%	100%
7	75%	25%	100%	25%	33%	0%	100%	100%	100%
8	75%	25%	100%	25%	33%	0%	100%	100%	100%
9	10%	90%	47%	40%	32%	0%	0%	100%	100%
10	10%	90%	47%	40%	32%	0%	0%	100%	100%
11	10%	90%	10%	15%	30%	0%	0%	100%	60%
12	75%	25%	96%	50%	33%	100%	10%	100%	100%

Resident Households With Commuters ..... Households of EPZ residents who await the return of commuters prior to beginning the evacuation trip.

Resident Households With No Commuters .... Households of EPZ residents who do not have commuters or will not await the return of commuters prior to beginning the evacuation trip.

Employees ..... EPZ employees who live outside of the EPZ.

Transients ..... People who are in the EPZ at the time of an accident for recreational or other (non-employment) purposes.

Shadow ..... Residents and employees in the shadow region (outside of the EPZ) who will spontaneously decide to relocate during the evacuation. The basis for the values shown is a 30% relocation of shadow residents along with a proportional percentage of shadow employees. The percentage of shadow employees is computed using the scenario-specific ratio of EPZ employees to residents.

Special Events ..... Additional vehicles in the Harris Nuclear Plant area during the construction phase of the new unit.

School and Transit Buses ..... Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus is equivalent to 2 passenger vehicles), respectively.

External Through Traffic ..... Traffic on local highways and major arterial roads at the start of the evacuation. This traffic is stopped by access control approximately 1-2 hours after the evacuation begins.

Table 6-4. Vehicle Estimates By Scenario										
Scenarios	**Residents with Commuters**	**Residents without Commuters**	**Employees**	**Transients**	**Shadow**	**Special Events**	**School Buses**	**Transit Buses**	**External Traffic**	**Total Scenario Vehicles**
1	24,607	8,412	3,594	3,127	25,381	-	62	110	8,100	73,393
2	24,607	8,412	3,594	3,127	25,381	-	62	110	8,100	73,393
3	2,461	30,558	1,760	6,253	24,110	-	-	110	8,100	73,352
4	2,461	30,558	1,760	6,253	24,110	-	-	110	8,100	73,352
5	2,461	30,558	374	1,563	23,149	-	-	110	4,860	63,075
6	24,607	8,412	3,744	1,563	25,485	-	618	110	8,100	72,639
7	24,607	8,412	3,744	1,563	25,485	-	618	110	8,100	72,639
8	24,607	8,412	3,744	1,563	25,485	-	618	110	8,100	72,639
9	2,461	30,558	1,760	2,501	24,110	-	-	110	8,100	69,600
10	2,461	30,558	1,760	2,501	24,110	-	-	110	8,100	69,600
11	2,461	30,558	374	938	23,149	-	-	110	4,860	62,450
12	43,144*	14,822*	3,594	3,127	39,297*	3,432	62	110	8,100	115,688

***Permanent Resident population and Shadow population have been extrapolated to the Year 2016, which is when construction workforce will be at its peak.**