Attachment

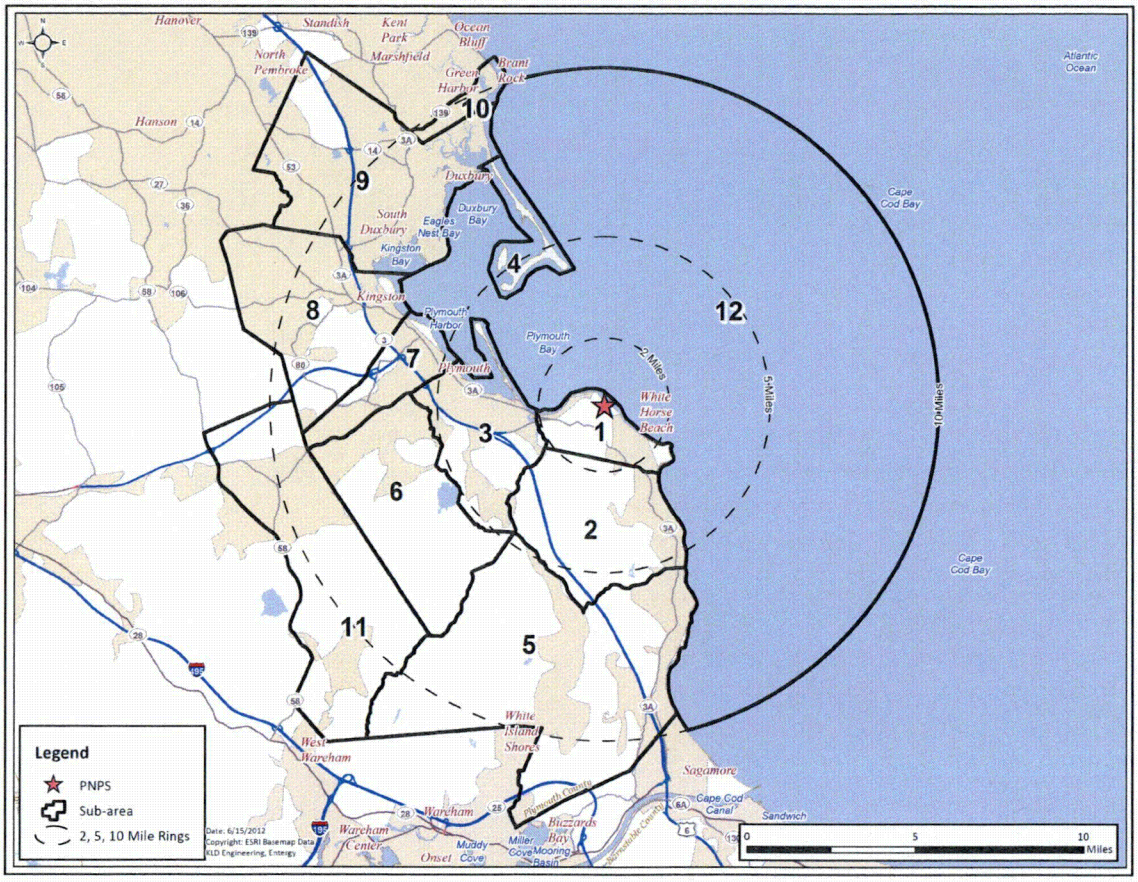
Letter Number 2.16.007

TR510, Evacuation Time Estimates, Revision 2 and
associated 10 CFR 50.54(q) Review

KLD ENGINEERING, P.C.

Pilgrim Nuclear Power Station

Development of Evacuation Time Estimates



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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 Pilgrim Nuclear Power Station (PNPS) located in Plymouth, MA. ETE are part of the required planning basis and provide Entergy and State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, guidance is provided by documents published by Federal Governmental agencies. Most important of these are:

- Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, November 2011.
- 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.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.
- 10CFR50, Appendix E – "Emergency Planning and Preparedness for Production and Utilization Facilities"

Overview of Project Activities

This project began in December, 2011 and extended over a period of 12 months. The major activities performed are briefly described in chronological sequence:

- Attended "kick-off" meetings with Entergy personnel and emergency management personnel representing state and county governments.
- Accessed U.S. Census Bureau data files for the year 2010. Studied Geographical Information Systems (GIS) maps of the area in the vicinity of the PNPS, 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 Region covering the region between the EPZ boundary and approximately 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 the licensee and offsite response organization (ORO) personnel prior to the survey.
- Data collection forms (provided to the OROs at the kickoff meeting) were returned with data pertaining to employment, transients, and special facilities in each town. Telephone calls to specific facilities supplemented the data provided.

- 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 12 sub-areas. These sub-areas are then grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 27 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, Snow). One special event scenario involving a 4th of July firework show in Plymouth Harbor was considered. One roadway impact scenario was considered wherein a single lane was closed on Route 3 northbound for the duration of the evacuation.
- Staged evacuation was considered for those regions wherein the 2 mile radius and sectors downwind to 5 miles were evacuated.
- As per NUREG/CR-7002, the Planning Basis for the calculation of ETE is:
  - A rapidly escalating accident at the PNPS that quickly assumes the status of General Emergency such that the Advisory to Evacuate is virtually coincident with the siren alert, and no early protective actions have been implemented.
  - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the Advisory to Evacuate until the stated percentage of the population 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 reception centers or 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 schoolchildren 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, for homebound special needs population, and for those evacuated from special facilities.

Computation of ETE

A total of 378 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 27 Evacuation Regions to evacuate from that Region, under the circumstances defined for one of the 14

Evacuation Scenarios (27 x 14 = 378). Separate ETE are calculated for transit-dependent evacuees, including schoolchildren 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 20% of the population within the EPZ but outside the impacted region, will elect to "voluntarily" evacuate. In addition, 20% of the population in the Shadow Region 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.

Staged evacuation is considered wherein those people within the 2-mile region evacuate immediately, while those beyond 2 miles, but within the EPZ, shelter-in-place. Once 90% of the 2-mile region is evacuated, those people beyond 2 miles begin to evacuate. As per federal guidance, 20% of people beyond 2 miles will evacuate (non-compliance) even though they are advised to shelter-in-place.

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 traffic engineering procedures.
- The evacuation trips are generated at locations called "zonal centroids" located within the EPZ and Shadow Region. 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 evacuation model computes the routing patterns for evacuating vehicles that are compliant with federal guidelines (outbound relative to the location of the plant), 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 90 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. The 90^{th} percentile ETE have been identified as the values that should be considered when making protective action decisions because the 100^{th} percentile ETE are prolonged by those relatively few people who take longer to mobilize. This is referred to as the "evacuation tail" in Section 4.0 of NUREG/CR-7002.

The use of a public outreach (information) program to emphasize the need for evacuees to minimize the time needed to prepare to evacuate (secure the home, assemble needed clothes,

medicines, etc.) should also be considered.

Traffic Management

This study references the comprehensive traffic management plans provided by the Entergy and state, and identifies critical intersections.

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 6-1 displays a map of the PNPS EPZ showing the layout of the 12 sub-areas that comprise, in aggregate, the EPZ.
- Table 3-1 presents the estimates of permanent resident population in each sub-area based on the 2010 Census data.
- Table 6-1 defines each of the 27 Evacuation Regions in terms of their respective groups of sub-area.
- Table 6-2 lists the Evacuation Scenarios.
- Tables 7-1 and 7-2 are compilations of ETE. These data are the times needed to clear the indicated regions of 90 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.
- Tables 7-3 and 7-4 present ETE for the 2-mile region for un-staged and staged evacuations for the 90th and 100th percentiles, respectively.
- Table 8-7 presents ETE for the schoolchildren in good weather.
- Table 8-11 presents ETE for the transit-dependent population in good weather.
- Figure H-8 presents an example of an Evacuation Region (Region R08) to be evacuated under the circumstances defined in Table 6-1. Maps of all regions are provided in Appendix H.

Conclusions

- General population ETE were computed for 378 unique cases – a combination of 27 unique Evacuation Regions and 14 unique Evacuation Scenarios. Table 7-1 and Table 7-2 document these ETE for the 90th and 100th percentiles. These ETE range from 1:45 (hr:min) to 3:30 at the 90th percentile.
- Inspection of Table 7-1 and Table 7-2 indicates that the ETE for the 100th percentile are significantly longer than those for the 90th percentile. This is the result of the congestion within the EPZ. When the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand. See Figures 7-10 through 7-23.
- Inspection of Table 7-3 and Table 7-4 indicates that a staged evacuation provides no

benefits to evacuees from within the 2 mile region and unnecessarily delays the evacuation of those beyond 2 miles (compare Regions R02 and R04 through R08 with Regions R22 through R27, respectively, in Tables 7-1 and 7-2). See Section 7.6 for additional discussion.

- Comparison of Scenarios 5 (summer, midweek/weekend, evening) and 13 (summer, weekend, evening) in Table 7-2 indicates that the special event has a material impact on the ETE at the 90th percentile for several evacuation regions, with increases up to 25 minutes. See Section 7.5 for additional discussion.
- Comparison of Scenarios 1 and 14 in Table 7-1 indicates that the roadway closure – one lane northbound on Route 3 from the interchange with Clark Road (Exit 3) to the end of the analysis-network after the interchange with Church Street (Exit 12) – has a material impact on the 90th and 100th percentile ETE, with increases up to 40 minutes and 15 minutes respectively. See Section 7.5 for additional discussion.
- The last location in the EPZ to exhibit traffic congestion is along Tihonet Rd where the town of Wareham causes queuing which extends into the EPZ. All congestion within the EPZ clears by 4 hours and 10 minutes after the Advisory to Evacuate. See Section 7.3 and Figures 7-3 through 7-9.
- Separate ETE were computed for schools, medical facilities, transit-dependent persons, homebound special needs persons and correctional facilities. The average single-wave ETE for schools and special facilities are within a similar range as the general population ETE at the 90th percentile, higher for transit-dependent population. See Section 8.
- Table 8-5 indicates that there are not enough buses, wheelchair buses or ambulances available to evacuate the transit-dependent population within the EPZ in a single wave. The second-wave ETE do exceed the general population ETE at the 90th percentile. See Sections 8.4 and 8.5.
- The general population ETE at the 90th percentile is insensitive to reductions in the base trip generation time of 4½ hours due to the traffic congestion within the EPZ. See Table M-1.
- The general population ETE is relatively insensitive to the voluntary evacuation of vehicles in the Shadow Region (tripling the shadow evacuation percentage only increases 90th and 100th percentile ETE by 10 and 25 minutes, respectively). See Table M-2.
- Population changes of ±30% or more result in ETE changes which meet the criteria for updating ETE between decennial Censuses. See Section M.3.

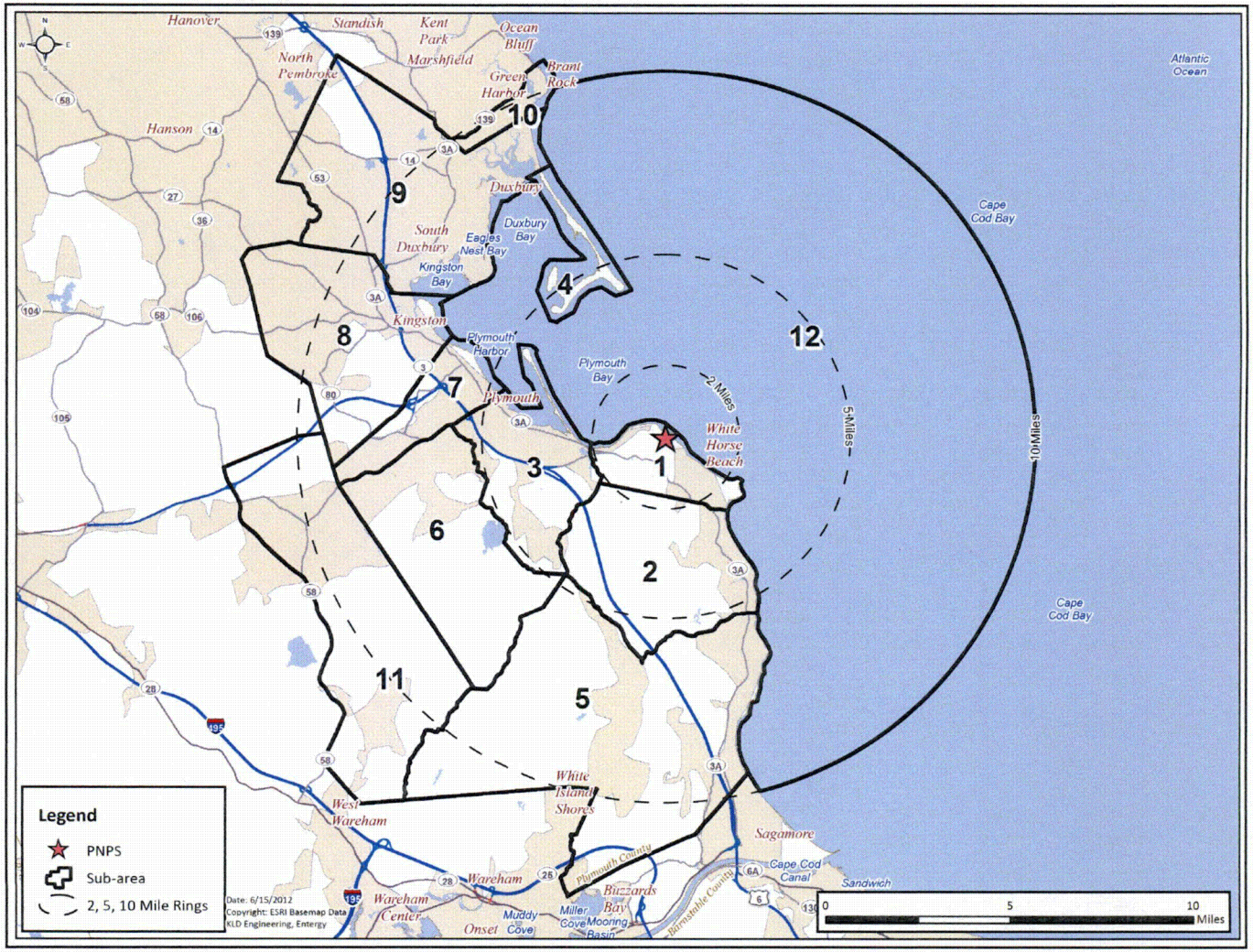


Figure 6-1. PNPS EPZ Sub-areas

Table 3-1. EPZ Permanent Resident Population

Sub-area	2000 Population	2010 Population
1	2,484	3,710
2	6,975	8,985
3	10,194	10,946
4	15	17
5	14,317	15,546
6	9,896	8,305
7	7,820	8,959
8	11,780	12,629
9	14,248	15,059
10	1,388	2,329
11	8,010	7,479
12	0	0
TOTAL	**87,127**	**93,964**
EPZ Population Growth:		**7.85%**

Table 6-1. Description of Evacuation Regions

Basic Regions													
			Sub-area										
Region	Description	Site PAR Description	1	2	3	4	5	6	7	8	9	10	11	12
R01	2-Mile Radius	2-Mile Ring	x											x
R02	5-Mile Radius	5-Mile Ring	x	x	x	x								x
R03	Full EPZ	10-Mile Ring	x	x	x	x	x	x	x	x	x	x	x	x
Evacuate 2-Mile Radius and Downwind to 5 Miles														
			Sub-area											
Region	Wind Direction From:	Site PAR Description	1	2	3	4	5	6	7	8	9	10	11	12
R04	NW, NNW, N	306° - 019°	x	x										x
R05	NNE, NE, ENE	020° - 069°	x	x	x									x
R06	E	070° - 122°	x		x									x
R07	ESE, SE	123° - 140°	x		x	x								x
R08	SSE, S	141° - 183°	x			x								x
N/A	SSW, SW, WSW, W, WNW	184° - 305°	Refer to Region R01											
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary														
			Sub-area											
Region	Wind Direction From:	Site PAR Description	1	2	3	4	5	6	7	8	9	10	11	12
R09	NW, NNW, N	319° - 019°	x	x	x	x	x							x
R10	-	020° - 021°	x	x	x	x	x	x						x
R11	NNE, NE	022° - 056°	x	x	x	x	x	x					x	x
R12	-	057° - 066°	x	x	x	x		x					x	x
R13	-	067° - 069°	x	x	x	x		x	x				x	x
R14	ENE	070° - 103°	x	x	x	x		x	x	x			x	x
R15	E, ESE	104° - 109°	x	x	x	x		x	x	x	x		x	x
R16	-	110° - 115°	x	x	x	x		x	x	x	x			x
R17	-	116° - 129°	x	x	x	x			x	x	x			x
R18	SE	130° - 132°	x	x	x	x			x	x	x	x		x
R19	-	133° - 140°	x	x	x	x				x	x	x		x
R20	SSE, S	141° - 175°	x	x	x	x					x	x		x
R21	-	176° - 179°	x	x	x	x						x		x
N/A	SSW, SW, WSW, W, WNW	180° - 318°	Refer to Region R02											
Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles														
			Sub-area											
Region	Wind Direction From:	Site PAR Description	1	2	3	4	5	6	7	8	9	10	11	12
R22	None	5-Mile Ring	x	x	x	x								x
R23	NW, NNW, N	020° - 069°	x	x										x
R24	NNE, NE, ENE	070° - 122°	x	x	x									x
R25	E	123° - 140°	x		x									x
R26	ESE, SE	141° - 183°	x		x	x								x
R27	SSE, S	184° - 305°	x			x								x
N/A	SSW, SW, WSW, W, WNW	2-Mile Ring	Refer to Region R01											
Key														
Shelter-in-Place until 90% ETE for R01, then Evacuate			Sub-area(s) Shelter-in-					Sub-area(s) Evacuate						

Table 6-2. Evacuation Scenario Definitions

Scenario	Season[1]	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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Weekend	Evening	Good	Plymouth 4th of July Fireworks
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on Rt. 3 NB

[1] Winter assumes that school is in session (also applies to spring and autumn). Summer assumes that school is not in session.

Table 7-1. Time to Clear the Indicated Area of *90* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R02	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:35	2:10	2:10	2:30	2:10	2:20	2:45
R03	2:55	3:05	2:55	3:05	2:40	2:45	3:00	3:30	2:40	2:55	3:20	2:40	3:00	3:20
2-Mile Region and Keyhole to 5 Miles														
R04	2:10	2:15	2:10	2:10	2:15	2:10	2:15	2:30	2:10	2:10	2:25	2:15	2:15	2:30
R05	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:35	2:10	2:10	2:30	2:10	2:20	2:45
R06	2:05	2:05	2:00	2:00	2:00	2:05	2:10	2:20	2:00	2:05	2:15	2:00	2:20	2:45
R07	2:05	2:05	2:00	2:00	2:00	2:05	2:10	2:20	2:00	2:05	2:15	2:00	2:20	2:45
R08	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
5-Mile Region and Keyhole to EPZ Boundary														
R09	2:45	2:50	2:40	2:50	2:45	2:40	2:50	3:20	2:35	2:50	3:15	2:45	2:45	3:10
R10	2:40	2:50	2:30	2:50	2:40	2:40	2:45	3:20	2:30	2:40	3:15	2:35	2:45	3:10
R11	2:40	2:55	2:40	2:55	2:40	2:40	2:50	3:15	2:35	2:45	3:10	2:35	2:50	3:10
R12	2:25	2:30	2:15	2:25	2:15	2:20	2:25	2:55	2:10	2:20	2:45	2:15	2:35	2:50
R13	2:35	2:40	2:30	2:40	2:20	2:30	2:40	3:10	2:20	2:30	3:00	2:20	2:45	2:40
R14	2:30	2:45	2:25	2:35	2:20	2:30	2:40	3:15	2:20	2:30	2:55	2:20	2:45	2:55
R15	2:40	2:50	2:35	2:45	2:25	2:35	2:45	3:20	2:25	2:35	3:05	2:25	2:50	3:10
R16	2:25	2:35	2:25	2:35	2:20	2:25	2:35	3:05	2:20	2:30	2:55	2:20	2:35	3:00
R17	2:25	2:40	2:30	2:35	2:20	2:25	2:35	3:05	2:20	2:30	2:55	2:20	2:35	3:05
R18	2:30	2:35	2:25	2:35	2:20	2:25	2:35	3:05	2:25	2:30	2:55	2:20	2:35	3:00
R19	2:20	2:25	2:20	2:25	2:15	2:25	2:25	3:00	2:15	2:25	2:50	2:15	2:25	3:00
R20	2:15	2:20	2:10	2:15	2:15	2:15	2:20	2:45	2:10	2:15	2:35	2:15	2:15	2:45
R21	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:40	2:10	2:10	2:30	2:10	2:20	2:45
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	2:45	2:50	2:40	2:45	2:50	2:45	2:50	3:50	2:45	2:45	3:50	2:50	2:45	3:10
R23	2:40	2:45	2:40	2:45	2:55	2:45	2:50	3:50	2:40	2:45	3:45	2:55	2:55	3:00
R24	2:45	2:50	2:40	2:45	2:50	2:45	2:50	3:50	2:45	2:45	3:50	2:50	2:45	3:10
R25	2:25	2:30	2:25	2:25	2:30	2:30	2:30	3:25	2:25	2:25	3:25	2:30	2:30	3:00
R26	2:25	2:30	2:25	2:25	2:30	2:30	2:30	3:25	2:25	2:25	3:25	2:30	2:30	3:00
R27	2:15	2:15	1:55	1:55	2:00	2:15	2:15	3:05	2:00	2:00	2:55	2:00	1:55	2:15

Table 7-2. Time to Clear the Indicated Area of *100* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R02	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R03	4:40	4:40	4:40	4:45	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:50
2-Mile Region and Keyhole to 5 Miles														
R04	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R05	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R06	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R07	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R08	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
5-Mile Region and Keyhole to EPZ Boundary														
R09	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R10	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R11	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R12	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R13	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R14	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R15	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:50
R16	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R17	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R18	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R19	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R20	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R21	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R23	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R24	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R25	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R26	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R27	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35

Table 7-3. Time to Clear 90 Percent of the 2-Mile Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R02	2:05	2:05	1:50	2:00	1:50	2:10	2:10	2:55	1:50	2:05	2:40	1:55	2:05	2:05
2-Mile Region and Keyhole to 5 Miles														
R04	2:10	2:10	1:55	2:10	1:55	2:10	2:10	2:55	2:00	2:00	2:45	1:55	1:55	2:10
R05	2:05	2:05	1:50	2:00	1:55	2:10	2:10	2:55	1:50	2:00	2:40	1:55	2:05	2:05
R06	2:00	2:05	1:40	1:40	1:45	2:10	2:10	2:55	1:50	1:50	2:40	1:50	2:05	2:00
R07	2:00	2:05	1:40	1:40	1:45	2:10	2:10	2:55	1:50	1:50	2:40	1:50	2:05	2:00
R08	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R23	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R24	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R25	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R26	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R27	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10

Table 7-4. Time to Clear 100 Percent of the 2-Mile Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R02	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
2-Mile Region and Keyhole to 5 Miles														
R04	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R05	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R06	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R07	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R08	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R23	4:30	4:35	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R24	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R25	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R26	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R27	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30

Table 8-7. School Evacuation Time Estimates – Good Weather

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
After School Club Alden	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Alden School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Bay Farm Montessori Academy	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Berrybrook School	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Blue River Montesorri School	90	15	0.7	27.0	2	1:50	20.7	32	2:20
Breakfast Club Chandler	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Bright Ideas Preschool	90	15	12.5	19.5	39	2:25	28.7	44	3:10
Capt Pal Pre School	90	15	2.1	4.2	30	2:15	16.2	25	2:40
Carver Elementary School	90	15	3.2	5.1	38	2:25	16.2	25	2:50
Carver High School	90	15	4.8	7.3	40	2:25	16.2	25	2:50
Carver Middle School	90	15	4.8	7.3	40	2:25	16.2	25	2:50
Cedarhill Retreat Conference Center Daycare	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Chandler Elementary School	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Children's Creative Learning Center	90	15	8.6	9.8	53	2:40	16.2	25	3:05
Cold Spring Elementary School	90	15	8.8	10.0	53	2:40	16.2	25	3:05
Cranberry Crossing Day Care	90	15	2.1	4.2	30	2:15	16.2	25	2:40
Crayon College At Plymouth	90	15	7.2	8.2	53	2:40	16.2	25	3:05
Crayon College Inc.	90	15	5.3	40.0	8	1:55	10.6	16	2:10
Discovery Corner Daycare	90	15	3.6	12.0	19	2:05	19.3	29	2:35
Duxbury Bay Maritime School	90	15	6.6	4.8	83	3:10	17.7	27	3:35
Duxbury High School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Duxbury Middle School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Elements Montessori School	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Erwin K. Washburn Primary School	90	15	3.2	5.1	38	2:25	16.2	25	2:50
Federal Furnace School	90	15	5.9	12.3	29	2:15	22.1	34	2:50
Garden of Knowledge	90	15	12.7	13.1	59	2:45	18.5	28	3:15
Good Shepherd Christian Academy	90	15	7.2	40.0	11	2:00	17.7	27	2:25
Governor Edward Winslow School	90	15	0.2	40.0	1	1:50	4.3	7	1:55

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Growth Unlimited Preschool	90	15	3.4	40.0	6	**1:55**	10.6	16	**2:10**
Hedge Elementary School	90	15	7.5	8.9	51	**2:40**	16.2	25	**3:05**
Hop, Skip & Jump Preschool	90	15	8.5	10.0	52	**2:40**	17.2	26	**3:05**
Indian Brook Elementary School	90	15	15.9	16.4	59	**2:45**	28.6	43	**3:30**
Junior Club Chandler	90	15	5.7	17.1	21	**2:10**	17.7	27	**2:35**
Kids Count Day School	90	15	0.6	2.2	18	**2:05**	16.2	25	**2:30**
Kidstop Early Childhood Center	90	15	2.1	4.2	30	**2:15**	16.2	25	**2:40**
Kinder Kollege	90	15	19.6	40.0	30	**2:15**	30.6	46	**3:05**
KinderCare - Pilgrim Hill	90	15	6.7	9.8	41	**2:30**	16.2	25	**2:55**
KinderCare - Richard's Road	90	15	7.0	8.2	52	**2:40**	16.2	25	**3:05**
Kindergarten Ext Chandler	90	15	17.1	23.6	44	**2:30**	17.7	27	**3:00**
Kingston Elementary School	90	15	4.4	40.0	7	**1:55**	10.6	16	**2:10**
Kingston Intermediate School	90	15	4.4	40.0	7	**1:55**	10.6	16	**2:10**
Leaping Frogs Preschool	90	15	19.5	40.0	30	**2:15**	30.6	46	**3:05**
Learning Safari Day Care & Preschool	90	15	34.6	19.2	108	**3:35**	50.6	76	**4:50**
Little Peoples Country Day	90	15	34.2	40.0	52	**2:40**	10.6	16	**2:55**
Magic Dragon Childrens Center	90	15	17.1	23.6	44	**2:30**	17.7	27	**3:00**
Manomet Elementary School	90	15	18.2	12.9	85	**3:10**	31.5	48	**4:00**
Methodist Nursery School	90	15	6.7	9.8	42	**2:30**	16.2	25	**2:55**
Miss Jo Anne's Bright Begnnngs	90	15	6.8	9.8	42	**2:30**	16.2	25	**2:55**
Mount Pleasant School	90	15	11.4	11.7	59	**2:45**	16.2	25	**3:10**
Nathaniel Morton Elementary School	90	15	6.8	9.2	45	**2:30**	14.2	22	**2:55**
New Testament Christian School	90	15	10.4	34.4	19	**2:05**	30.6	46	**2:50**
Old Colony YMCA	90	15	3.2	5.1	38	**2:25**	16.2	25	**2:50**
Pied Piper Preschool	90	15	3.6	16.0	14	**2:00**	19.3	29	**2:30**
Pilgrim Academy	90	15	4.1	8.7	29	**2:15**	22.4	34	**2:50**
Pilgrim Area Collab. (Alden)	90	15	5.6	4.2	81	**3:10**	17.7	27	**3:35**
Pilgrim Area Collab. (Chandler)	90	15	17.1	23.6	44	**2:30**	17.7	27	**3:00**
Pilgrim Area Collab. (High School)	90	15	5.6	4.2	81	**3:10**	17.7	27	**3:35**

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Pilgrim Area Collab. (Middle)	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Pilgrim Area Collaborative	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Pilgrim Child Care & Preschool	90	15	6.6	4.8	83	3:10	17.7	27	3:35
Plymouth Community Intermediate School	90	15	10.9	11.4	58	2:45	14.8	23	3:10
Plymouth North High School	90	15	10.6	11.5	56	2:45	16.2	25	3:10
Plymouth South High School	90	15	11.3	30.9	22	2:10	19.9	30	2:40
Plymouth South Middle School	90	15	11.3	30.9	22	2:10	19.9	30	2:40
Ponds Chlidcare Center	90	15	11.3	17.8	39	2:25	19.9	30	2:55
Rising Tide Charter Public School	90	15	7.0	8.2	52	2:40	16.2	25	3:05
Room 2 Grow Nursery School	90	15	9.1	10.3	53	2:40	16.2	25	3:05
Sacred Heart Early Childhood	90	15	4.8	36.5	8	1:55	14.6	22	2:15
Sacred Heart Elementary School	90	15	4.8	36.5	8	1:55	14.6	22	2:15
Sacred Heart High School	90	15	4.8	36.5	8	1:55	14.6	22	2:15
Silver Lake Regional High School	90	15	1.1	35.0	2	1:50	13.0	20	2:10
Silver Lake Regional Middle School	90	15	1.1	35.0	2	1:50	13.0	20	2:10
South Elementary School	90	15	3.0	36.4	5	1:50	28.1	43	2:35
South Shore Cons Preschool	90	15	5.6	4.2	81	3:10	17.7	27	3:35
South Shore Early Education	90	15	3.5	40.0	6	1:55	10.6	16	2:10
Small Scholars Preschool	90	15	1.4	9.0	10	1:55	3.5	6	2:05
Tiny Town Inc.	90	15	15.7	16.4	58	2:45	30.6	46	3:30
West Elementary School	90	15	5.3	8.5	38	2:25	16.2	25	2:50
Wooded Acres Child Care	90	15	4.4	40.0	7	1:55	10.6	16	2:10
Woodside School and Community Resource Center	90	15	5.9	12.3	29	2:15	22.1	34	2:50
					Maximum for EPZ:	**3:35**		**Maximum:**	**4:50**
					Average for EPZ:	**2:25**		**Average:**	**2:55**

Table 8-11. Transit-Dependent Evacuation Time Estimates – Good Weather

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	90	25.6	37.2	41	30	2:45	27.3	41	5	10	79	30	5:30
	2, 3	110	25.6	40.0	38	30	3:00	27.3	41	5	10	79	30	5:45
2	1, 2	90	25.3	13.4	113	30	3:55	27.3	41	5	10	79	30	6:40
	3, 4	100	25.3	14.5	105	30	3:55	27.3	41	5	10	79	30	6:40
	5, 6, 7	110	25.3	15.7	97	30	4:00	27.3	41	5	10	79	30	6:45
3	1, 2, 3	90	22.0	16.8	79	30	3:20	20.1	30	5	10	63	30	5:40
	4, 5, 6	100	22.0	18.0	73	30	3:25	20.1	30	5	10	63	30	5:45
	7, 8, 9	110	22.0	19.1	69	30	3:30	20.1	30	5	10	63	30	5:50
4	1	90	7.1	4.9	87	30	3:30	17.7	27	5	10	37	30	5:20
5	1, 2, 3	90	25.2	15.1	100	30	3:40	29.7	45	5	10	82	30	6:35
	4, 5, 6	95	25.2	15.5	98	30	3:45	29.7	45	5	10	82	30	6:35
	7, 8, 9	100	25.2	15.9	95	30	3:50	29.7	45	5	10	82	30	6:40
	10, 11, 12	110	25.2	17.8	85	30	3:45	29.7	45	5	10	82	30	6:40
6	1, 2, 3	90	21.5	13.6	95	30	3:35	14.8	22	5	10	54	30	5:40
	4, 5, 6	110	21.5	15.6	83	30	3:45	14.8	22	5	10	54	30	5:45
7	1, 2	90	8.9	9.3	57	30	3:00	14.4	22	5	10	35	30	4:40
	3, 4	100	8.9	9.2	58	30	3:10	14.4	22	5	10	35	30	4:50
	5, 6, 7	110	8.9	9.8	54	30	3:15	14.4	22	5	10	35	30	5:00
8	1, 2	90	22.3	40.0	33	30	2:35	13.7	21	5	10	54	30	4:35
	3, 4	95	22.3	40.0	33	30	2:40	13.7	21	5	10	54	30	4:40
	5, 6, 7	100	22.3	40.0	33	30	2:45	13.7	21	5	10	54	30	4:45
	8, 9, 10	110	22.3	40.0	33	30	2:55	13.7	21	5	10	54	30	4:55
9	1, 2, 3	90	44.3	39.4	67	30	3:10	17.7	27	5	10	93	30	5:55
	4, 5, 6	95	44.3	39.4	67	30	3:15	17.7	27	5	10	93	30	6:00

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
	7, 8, 9	100	44.3	39.4	67	30	**3:20**	17.7	27	5	10	93	30	**6:05**
	10, 11, 12	110	44.3	39.4	67	30	**3:30**	17.7	27	5	10	93	30	**6:15**
10	1	90	7.1	35.9	12	30	**2:15**	23.8	36	5	10	47	30	**4:20**
	2	110	7.1	36.6	12	30	**2:35**	23.8	36	5	10	47	30	**4:40**
11	1, 2	90	35.5	16.8	127	30	**4:10**	14.4	22	5	10	75	30	**6:30**
	3, 4	110	35.5	19.3	111	30	**4:15**	14.4	22	5	10	75	30	**6:35**
						Maximum ETE:	**4:15**						**Maximum ETE:**	**6:45**
						Average ETE:	**3:25**						**Average ETE:**	**5:45**

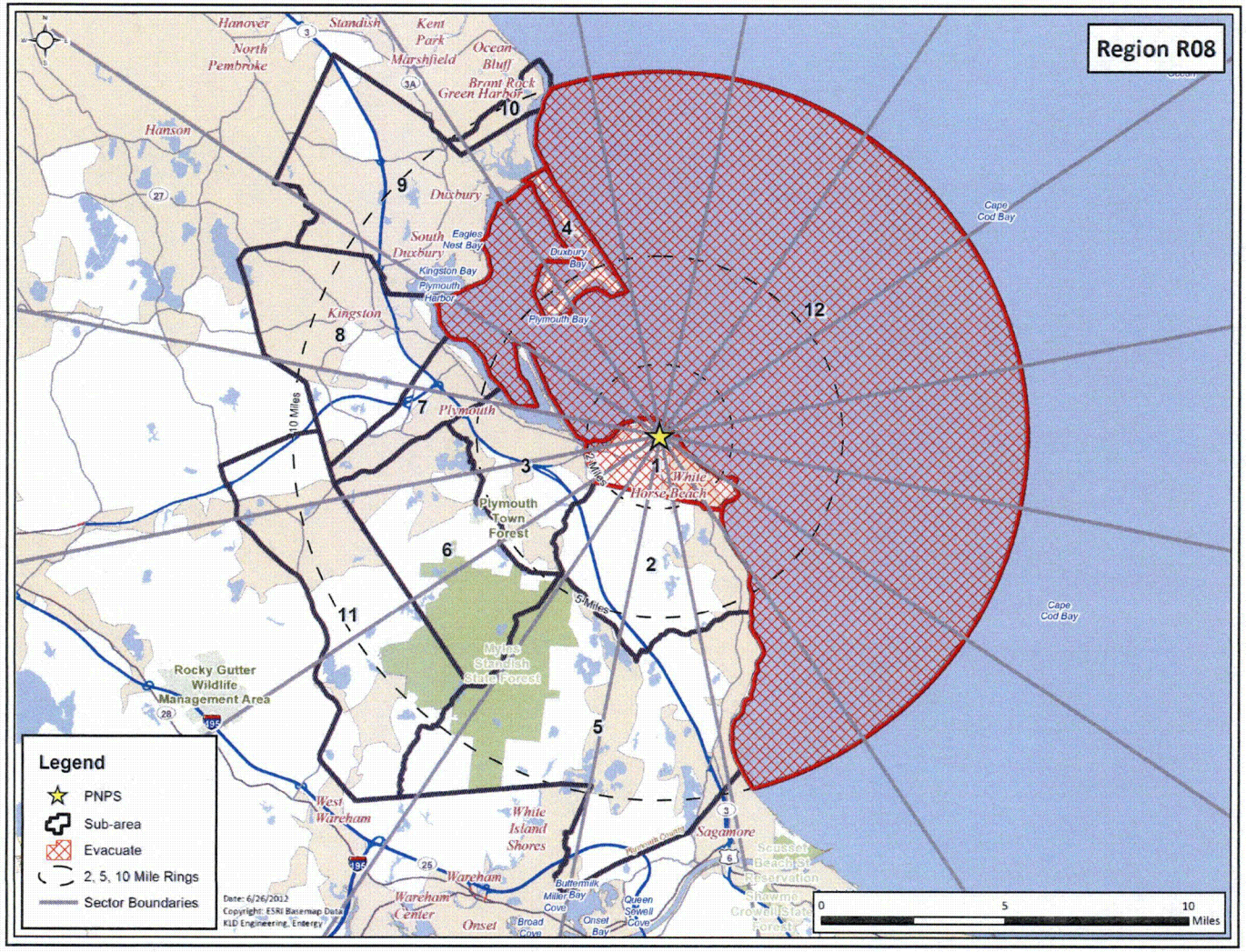


Figure H-8. Region R08

1 INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Pilgrim Nuclear Power Station (PNPS), located in Plymouth, MA. ETE provide State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, guidance is provided by documents published by Federal Governmental agencies. Most important of these are:

- Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, November 2011.
- 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.

The work effort reported herein was supported and guided by local stakeholders who contributed suggestions, critiques, and the local knowledge base required. Table 1-1 presents a summary of stakeholders and interactions.

Table 1-1. Stakeholder Interaction

Stakeholder	Nature of Stakeholder Interaction
Entergy	Meetings to define data requirements and set up contacts with local government agencies
Town Emergency Management Offices	Obtain emergency plans and special facility data
State Emergency Management Office	Obtain emergency and traffic management plans

1.1 Overview of the ETE Process

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

1. Information Gathering:
    a. Defined the scope of work in discussions with representatives from Entergy.
    b. Attended meetings with emergency planners from town emergency management agencies and police departments and Entergy to identify issues to be addressed and resources available.
    c. Conducted a detailed field survey of the highway system and of area traffic

conditions within the Emergency Planning Zone (EPZ) and Shadow Region.

d. Obtained demographic data from the 2010 census, Carver EMA, Duxbury EMD, Kingston EM, Marshfield EMA, and Plymouth EMA.

e. Conducted a random sample telephone survey of EPZ residents.

f. Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important 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, in trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.

4. Reviewed the existing traffic management plan to be implemented by local and state police in the event of an incident at the plant. Traffic control is applied at specified Traffic Control Points (TCP) located within the EPZ.

5. Used existing sub-areas to define Evacuation Regions. The EPZ is partitioned into 12 sub-areas along jurisdictional and geographic boundaries. "Regions" are groups of contiguous sub-areas for which ETE are calculated. The configurations of these Regions reflect wind direction and the radial extent of the impacted area. Each Region, other than those that approximate circular areas, approximates a "key-hole section" within the EPZ as recommended by NUREG/CR-7002.

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 DYNEV II system.

   a. Estimated the evacuation traffic demand, based on the available information derived from Census data, and from data provided by local and state agencies, Entergy and from the telephone survey.

   b. Applied the procedures specified in the 2010 Highway Capacity Manual (HCM[1]) to the data acquired during the field survey, to estimate the capacity of all highway segments comprising the evacuation routes.

   c. Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the ETE.

   d. Calculated the evacuating traffic demand for each Region and for each Scenario.

[1] Highway Capacity Manual (HCM 2010), Transportation Research Board, National Research Council, 2010.

e. Specified selected candidate destinations for each "origin" (location of each "source" where evacuation trips are generated over the mobilization time) to support evacuation travel consistent with outbound movement relative to the location of the Pilgrim Nuclear Power Station.

8. Executed the DYNEV II model to determine optimal evacuation routing and compute ETE for all residents, transients and employees ("general population") with access to private vehicles. Generated a complete set of ETE for all specified Regions and Scenarios.
9. Documented ETE in formats in accordance with NUREG/CR-7002.
10. Calculated the ETE for all transit activities including those for special facilities (schools, medical facilities, etc.), for the transit-dependent population and for homebound special needs population.

1.2 The Pilgrim Nuclear Power Station

The PNPS is located along the shores of the Atlantic Ocean in Pilgrim, MA. The site is approximately 40 miles southeast of Boston, MA and 45 mile east of Providence, RI. The Emergency Planning Zone (EPZ) consists of parts of Carver, Duxbury, Kingston, Marshfield and Plymouth townships in Massachusetts. Figure 1-1 displays the area surrounding the PNPS. This map identifies the communities in the area and the major roads.

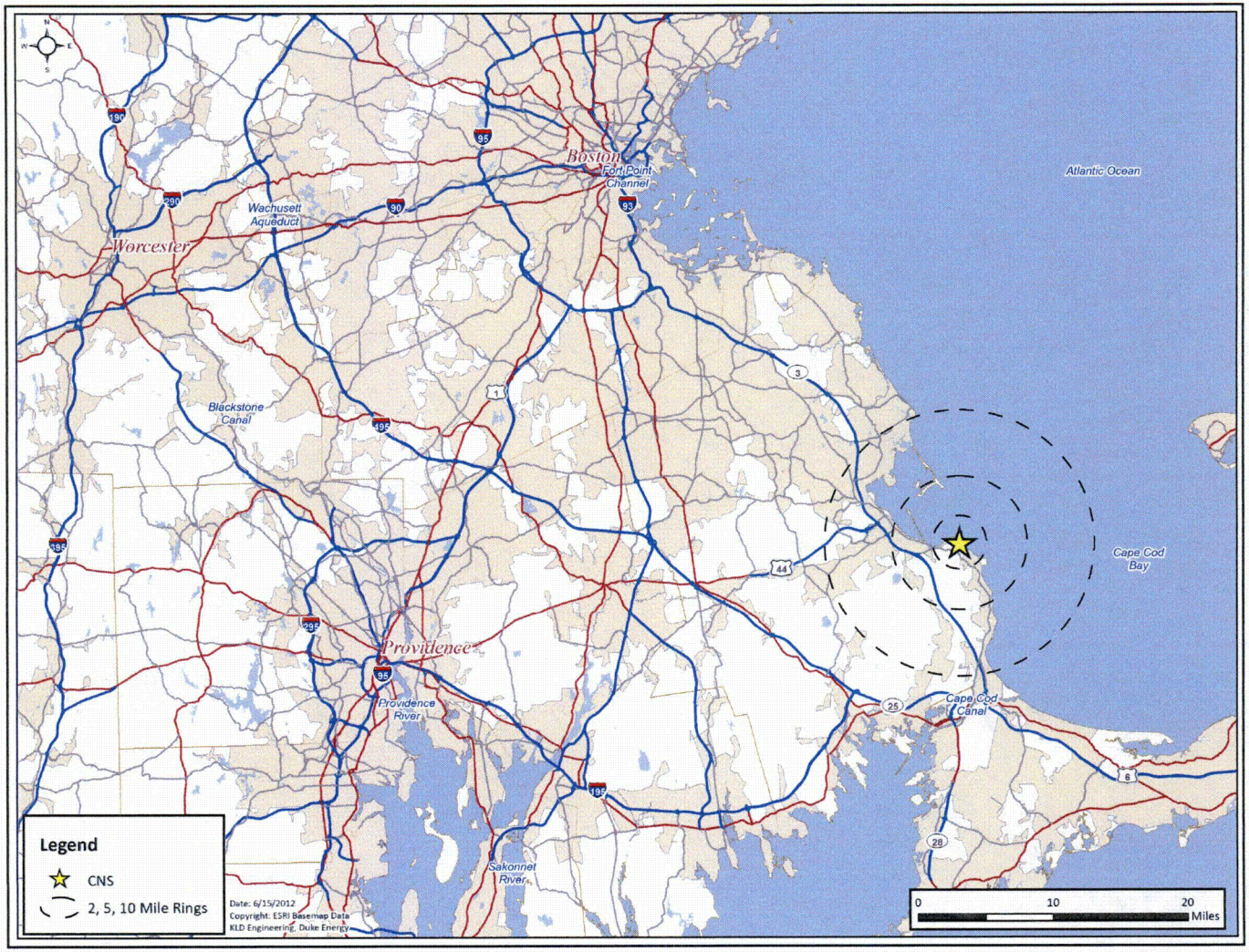


Figure 1-1. PNPS Location

1.3 Preliminary Activities

These activities are described below.

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and the Shadow Region which consists of the area between the EPZ boundary and approximately 15 miles radially from the plant. The characteristics of each section of highway were recorded. These characteristics are shown in Table 1-2:

Table 1-2. Highway Characteristics

- Number of lanes
- Lane width
- Shoulder type & width
- Interchange geometries
- Lane channelization & queuing capacity (including turn bays/lanes)
- Geometrics: curves, grades (>4%)
- Posted speed
- Actual free speed
- Abutting land use
- Control devices
- Intersection configuration (including roundabouts where applicable)
- Traffic signal type
- Unusual characteristics: Narrow bridges, sharp curves, poor pavement, flood warning signs, inadequate delineations, toll booths, etc.

Video and audio recording equipment were used to capture a permanent record of the highway infrastructure. No attempt was made to meticulously measure such attributes as lane width and shoulder width; estimates of these measures based on visual observation and recorded images were considered appropriate for the purpose of estimating the capacity of highway sections. For example, Exhibit 15-7 in the HCM indicates that a reduction in lane width from 12 feet (the "base" value) to 10 feet can reduce free flow speed (FFS) by 1.1 mph – not a material difference – for two-lane highways. Exhibit 15-30 in the HCM shows little sensitivity for the estimates of Service Volumes at Level of Service (LOS) E (near capacity), with respect to FFS, for two-lane highways.

The data from the audio and video recordings were used to create detailed geographical information systems (GIS) shapefiles and databases of the roadway characteristics and of the traffic control devices observed during the road survey; this information was referenced while preparing the input stream for the DYNEV II System.

As documented on page 15-5 of the HCM 2010, the capacity of a two-lane highway is 1700 passenger cars per hour in one direction. For freeway sections, a value of 2250 vehicles per hour per lane is assigned, as per Exhibit 11-17 of the HCM 2010. The road survey has identified several segments which are characterized by adverse geometrics on two-lane highways which are reflected in reduced values for both capacity and speed. These estimates are consistent with the service volumes for LOS E presented in HCM Exhibit 15-30. These links may be

identified by reviewing Appendix K. Link capacity is an input to DYNEV II which computes the ETE. Further discussion of roadway capacity is provided in Section 4 of this report.

Traffic signals are either pre-timed (signal timings are fixed over time and do not change with the traffic volume on competing approaches), or are actuated (signal timings vary over time based on the changing traffic volumes on competing approaches). Actuated signals require detectors to provide the traffic data used by the signal controller to adjust the signal timings. These detectors are typically magnetic loops in the roadway, or video cameras mounted on the signal masts and pointed toward the intersection approaches. If detectors were observed on the approaches to a signalized intersection during the road survey, detailed signal timings were not collected as the timings vary with traffic volume. TCPs at locations which have control devices are represented as actuated signals in the DYNEV II system.

If no detectors were observed, the signal control at the intersection was considered pre-timed, and detailed signal timings were gathered for several signal cycles. These signal timings were input to the DYNEV II system used to compute ETE, as per NUREG/CR-7002 guidance.

Figure 1-2 presents the link-node analysis network that was constructed to model the evacuation roadway network in the EPZ and Shadow Region. The directional arrows on the links and the node numbers have been removed from Figure 1-2 to clarify the figure. The detailed figures provided in Appendix K depict the analysis network with directional arrows shown and node numbers provided. The observations made during the field survey were used to calibrate the analysis network.

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 to estimate the number of evacuating vehicles during an evacuation and to estimate elements of the mobilization process. This database was also referenced to estimate the number of transit-dependent residents.

Computing 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. The vehicle demand was loaded onto appropriate "source" links of the analysis network using GIS mapping software. The DYNEV II system was then used to compute ETE for all Regions and Scenarios.

Analytical Tools

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

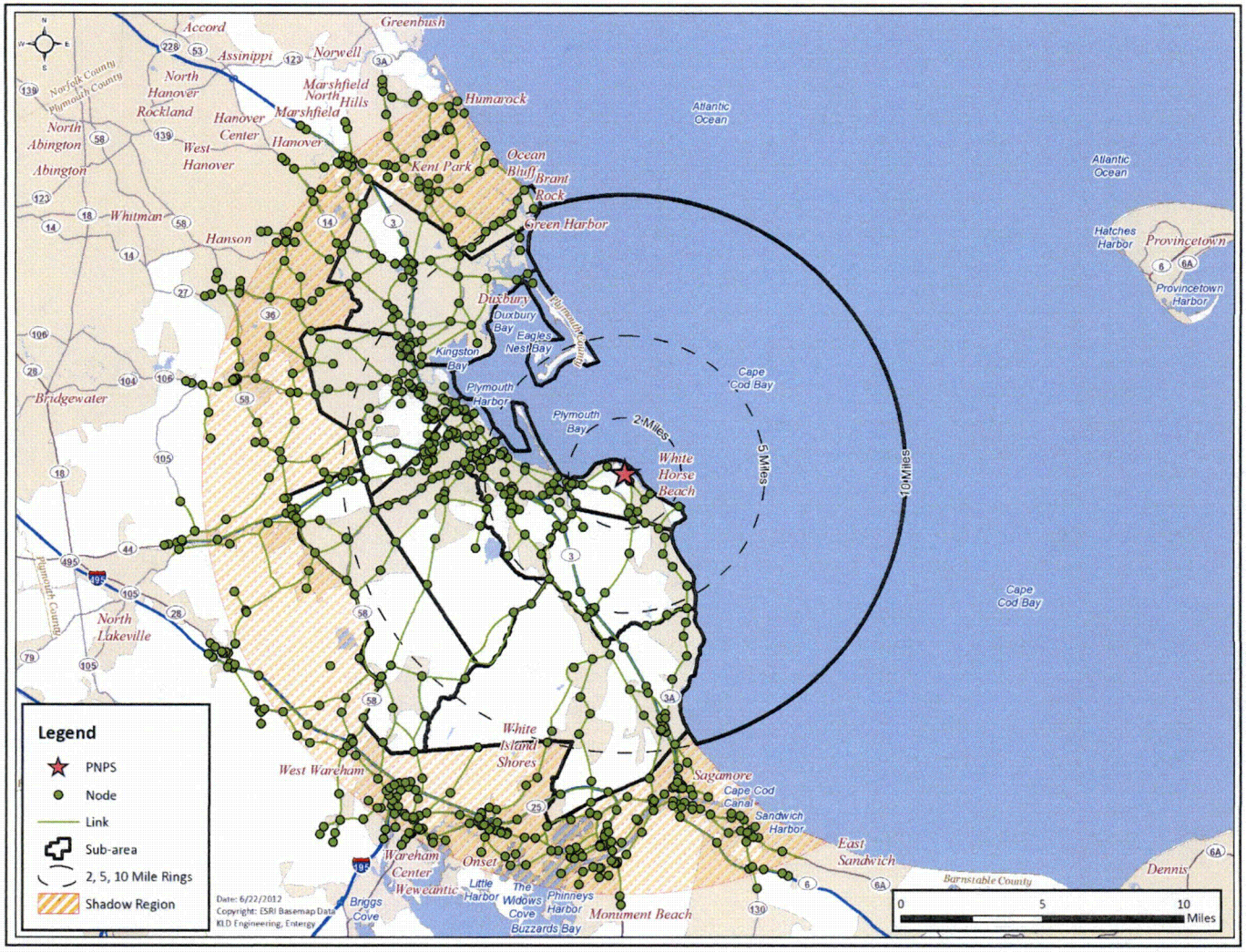


Figure 1-2. PNPS Link-Node Analysis Network

DYNEV II consists of four sub-models:

- A macroscopic traffic simulation model (for details, see Appendix C).
- A Trip Distribution (TD), model that assigns a set of candidate destination (D) nodes for each "origin" (O) located within the analysis network, where evacuation trips are "generated" over time. This establishes a set of O-D tables.
- A Dynamic Traffic Assignment (DTA), model which assigns trips to paths of travel (routes) which satisfy the O-D tables, over time. The TD and DTA models are integrated to form the DTRAD (Dynamic Traffic Assignment and Distribution) model, as described in Appendix B.
- A Myopic Traffic Diversion model which diverts traffic to avoid intense, local congestion, if possible.

Another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry and to automate the production of output tables.

The dynamics of traffic flow over the network are graphically animated using the software product, EVAN (EVacuation ANimator), developed by KLD. EVAN is GIS based, and displays statistics such as LOS, vehicles discharged, average speed, and percent of vehicles evacuated, output by the DYNEV II System. The use of a GIS framework enables the user to zoom in on areas of congestion and query road name, town name and other geographical information.

The procedure for applying the DYNEV II System within the framework of developing ETE is outlined in Appendix D. Appendix A is a glossary of terms.

For the reader interested in an evaluation of the original model, I-DYNEV, the following references are suggested:

- NUREG/CR-4873 – Benchmark Study of the I-DYNEV Evacuation Time Estimate Computer Code
- NUREG/CR-4874 – The Sensitivity of Evacuation Time Estimates to Changes in Input Parameters for the I-DYNEV Computer Code

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 the plant 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 the PNPS.

DYNEV II provides 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 represent the behavioral responses of evacuees. The effects of these

countermeasures may then be tested with the model.

1.4 Comparison with Prior ETE Study

Table 1-3 presents a comparison of the present ETE study with the 2004 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:

- Vehicle occupancy and trip-generation rates have changed
- Voluntary and shadow evacuations are considered at different percentages.
- The highway representation is far more detailed.
- A greater effort was taken to ensure no double-counting of vehicles
- The simulation model includes actuated signal, traffic control points and more realistic dynamic routing

Table 1-3. ETE Study Comparisons

Topic	Previous ETE Study	Current ETE Study
Resident Population Basis	2000 US Census Data estimated for 2005; Population = 92,617	ArcGIS Software using 2010 US Census blocks; area ratio method used. Population = 93,946
Resident Population Vehicle Occupancy	1.27 evacuating vehicles per household	1.37 evacuating vehicles/household based on new telephone survey 1.89 persons per vehicle
Employee Population	Growth in state employment between 1990 and 2000 used to extrapolate employment for 2005. Employment journey to work data (State 2001 data files) identified the proportion of employees who commute into the EPZ relative to the total number of employees. These proportions were applied on a town-by-town basis to total employment for 2005. In addition, data surveys were sent to major employers. Employees = 11,299 Vehicle occupancy = 1.11	Employee estimates based on information provided about major employers in EPZ, supplemented by observations of commercial property in EPZ from aerial photography. 1.05 employees per vehicle based on telephone survey results. Employees = 2,235 Vehicle occupancy = 1.05

Topic	Previous ETE Study	Current ETE Study
Transit-Dependent Population	Census data used to provide an estimate of the number of people without access to personal transportation, 2,478 total transit-dependents.	Estimates based upon U.S. Census data and the results of the telephone survey. A total of 2,167 people who do not have access to a vehicle, requiring 73 buses to evacuate. An additional 296 homebound special needs persons needed special transportation to evacuate (228 required a bus, 59 required a wheelchair-accessible vehicle, and 9 required an ambulance).
Transient Population	Beach overhead photos taken as well as beach data surveys, hotels, motels, camps, campsites and marinas contacted, day trippers estimated by town. Transients = 42,215	Transient data provided by local agencies. Transients = 26,606
Special Facilities Population	Special facility population based on information provided by each county within the EPZ. Number not provided.	Special facility population based on information provided by each town within the EPZ. Medical Facility census = 2,018 Buses Required = 43 Wheelchair Bus Required = 42 Ambulances Required = 141 Correctional Facility Census = 1,820 Buses Required = 37
School Population	School population based on information provided by each county within the EPZ. School enrollment = 19,297 Vehicles originating at schools = 420 buses	School population based on information provided by each town within the EPZ. School enrollment = 21,608 Vehicles originating at schools = 410 buses, 35 vans
Voluntary evacuation from within EPZ in areas outside region to be evacuated	50 percent of population within the circular portion of the region; 35 percent, in annular ring between the circle and the EPZ boundary.	20 percent of the population within the EPZ, but not within the Evacuation Region (see Figure 2-1)

Topic	Previous ETE Study	Current ETE Study
Shadow Evacuation	Movement of traffic from Cape Cod during an emergency at PNPS is explicitly considered. Traffic control is designed to route traffic leaving Cape Cod from the Sagamore Bridge to the Bourne Bridge. This eliminates any shadow evacuation effect.	20% of people outside of the EPZ within the Shadow Region (see Figure 7-2)
Network Size	593 links; 375 nodes	1,120 links; 746 nodes
Roadway Geometric Data	Additional field surveys carried out in areas where roadway system has changed since previous revision. Road capacities based on 2000 HCM.	Field surveys conducted in December 2011. Roads and intersections were video archived. Road capacities based on 2010 HCM.
School Evacuation	Direct evacuation to designated Reception Center/Host School.	Direct evacuation to designated Reception Center/Host School.
Ridesharing	50 percent of transit-dependent persons will evacuate with a neighbor or friend.	50 percent of transit-dependent persons will evacuate with a neighbor or friend.
Trip Generation for Evacuation	Based on residential telephone survey of specific pre-trip mobilization activities. Distributions obtained for: notification time, time to travel from home to work, time to prepare home and snow clearance time.	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 and 270 minutes. Residents without commuters returning leave between 15 and 210 minutes. Employees and transients leave between 15 and 120 minutes. All times measured from the Advisory to Evacuate.
Weather	Normal, Rain, or Snow. The capacity and free flow speed of all links in the network are reduced by 20% in the event of rain and 30% for snow.	Normal, Rain, or Snow. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain and 20% for snow.
Modeling	IDYNEV System	DYNEV II System – Version 4.0.5.0
Special Events	None considered	Plymouth 4th of July Fireworks Special Event Population = 10,417 additional transients
Evacuation Cases	35 Regions and 12 Scenarios producing 420 unique cases.	27 Regions (central sector wind direction and each adjacent sector technique used) and 14 Scenarios producing 378 unique cases.

Topic	Previous ETE Study	Current ETE Study
Evacuation Time Estimates Reporting	Reported for 50, 90, 95, and 100 percentile population. Results presented by Region.	ETE reported for 90th and 100th percentile population. Results presented by Region and Scenario.
Evacuation Time Estimates for the entire EPZ, 90th percentile	Winter Weekday Midday, Good Weather: 3:55 Summer Weekend, Midday, Good Weather: 4:30	Winter Weekday Midday, Good Weather: 2:45 Summer Weekend, Midday, Good Weather: 2:55

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 2010 data.
2. Estimates of employees who reside outside the EPZ and commute to work within the EPZ are based upon data provided by local agencies.
3. Population estimates at special facilities are based on available data from town emergency management agencies and from phone calls to specific facilities.
4. Roadway capacity estimates are based on field surveys and the application of the Highway Capacity Manual 2010.
5. Population mobilization times are based on a statistical analysis of data acquired from a random sample telephone survey of EPZ residents (see Section 5 and Appendix F).
6. The relationship between resident population and evacuating vehicles is developed from the telephone survey. Average values of 2.56 persons per household and 1.37 evacuating vehicles per household are used. The relationship between persons and vehicles for transients and employees is as follows:
    a. Employees: 1.05 employees per vehicle (telephone survey results) for all major employers.
    b. Parks: Vehicle occupancy varies based upon data gathered from local transient facilities.
    c. Special Events: Assumed transients attending the Plymouth 4th of July Fireworks travel as families/households in a single vehicle, and used the average household size of 2.56 persons to estimate the number of vehicles.

2.2 Study Methodological Assumptions

1. ETE are presented for the evacuation of the 90th and 100th percentiles of population for each Region and for each Scenario. The percentile ETE is defined as the elapsed time from the Advisory to Evacuate issued to a specific Region of the EPZ, to the time that Region is clear of the indicated percentile of evacuees. A Region is defined as a group of sub-areas that is issued an Advisory to Evacuate. A scenario is a combination of circumstances, including time of day, day of week, season, and weather conditions.
2. The ETE are computed and presented in tabular format and graphically, in a format compliant with NUREG/CR-7002.
3. Evacuation movements (paths of travel) are generally outbound relative to the plant to the extent permitted by the highway network. All major evacuation routes are used in the analysis.
4. Regions are defined by the underlying "keyhole" or circular configurations as specified in Section 1.4 of NUREG/CR-7002. These Regions, as defined, display irregular boundaries reflecting the geography of the sub-areas included within these underlying configurations.
5. As indicated in Figure 2-2 of NUREG/CR-7002, 100% of people within the impacted "keyhole" evacuate. 20% of those people within the EPZ, not within the impacted keyhole, will voluntarily evacuate. 20% of those people within the Shadow Region will voluntarily evacuate. See Figure 2-1 for a graphical representation of these evacuation percentages. Sensitivity studies explore the effect on ETE of increasing the percentage of voluntary evacuees in the Shadow Region (see Appendix M).
6. A total of 14 "Scenarios" representing different temporal variations (season, time of day, day of week) and weather conditions are considered. These Scenarios are outlined in Table 2-1.
7. Scenario 14 considers the closure of a single lane northbound on Route 3 from the interchange with Clark Road (Exit 3) to the end of the analysis-network after the interchange with Church Street (Exit 12).
8. The models of the I-DYNEV System were recognized as state of the art by the Atomic Safety & Licensing Board (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik[1]). The models have continuously been refined and extended since those hearings and were independently validated by a consultant retained by the NRC. The new DYNEV II model incorporates the latest technology in traffic simulation and in dynamic traffic assignment. The DYNEV II System is used to compute ETE in this study.

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

Table 2-1. Evacuation Scenario Definitions

Scenario	Season[2]	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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Weekend	Evening	Good	Plymouth 4th of July Fireworks
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on Rt. 3 NB

[2] Winter assumes that school is in session (also applies to spring and autumn). Summer assumes that school is not in session.

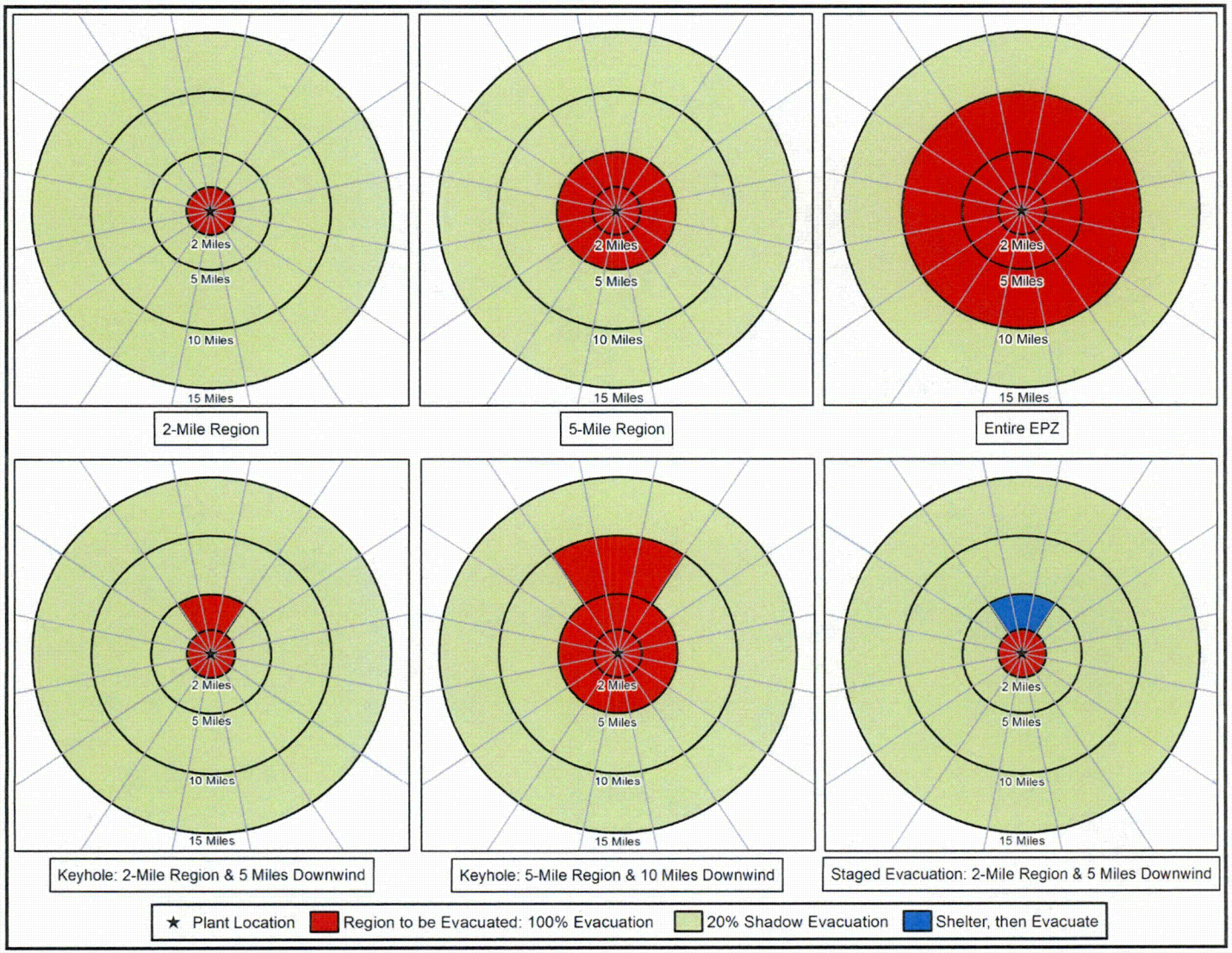


Figure 2-1. Voluntary Evacuation Methodology

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 15 minutes after siren notification.
    c. ETE are measured relative to the Advisory to Evacuate.
2. It is assumed that everyone within the group of sub-areas forming a Region that is issued an Advisory to Evacuate will, in fact, respond and evacuate in general accord with the planned routes.
3. 65% percent of the households in the EPZ have at least 1 commuter; 38% percent of those households with commuters will await the return of a commuter before beginning their evacuation trip, based on the telephone survey results. Therefore 25 percent (65% x 38% = 25%) of EPZ households will await the return of a commuter, prior to beginning their evacuation trip.
4. 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.
5. Access Control Points (ACP) will be staffed within approximately 120 minutes following the siren notifications, to divert traffic attempting to enter the EPZ. Earlier activation of ACP locations could delay returning commuters. It is assumed that no through traffic will enter the EPZ after this 120 minute time period.
6. 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 resources available. The objectives of these TCP are:
    a. Facilitate the movements of all (mostly evacuating) vehicles at the location.
    b. Discourage inadvertent vehicle movements towards the plant.
    c. Provide assurance and guidance to any traveler who is unsure of the appropriate actions or routing.
    d. Act as local surveillance and communications center.
    e. Provide information to the emergency operations center (EOC) as needed, based on direct observation or on information provided by travelers.

    In calculating ETE, it is assumed that evacuees will drive safely, travel in directions identified in the plan, and obey all control devices and traffic guides.

7. 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 designated host facility.
    b. It is assumed parents will pick up children at day care centers prior to evacuation.
    c. Buses, wheelchair vans and ambulances will evacuate patients at medical facilities and at any senior facilities within the EPZ, as needed.
    d. Transit-dependent general population will be evacuated to Reception Centers.
    e. Schoolchildren, if school is in session, are given priority in assigning transit vehicles.
    f. Bus mobilization time is considered in ETE calculations.
    g. Analysis of the number of required round-trips ("waves") of evacuating transit vehicles is presented.
    h. Transport of transit-dependent evacuees from reception centers to congregate care centers is not considered in this study.
8. Provisions are made for evacuating the transit-dependent portion of the general population to reception centers by bus, based on the assumption that some of these 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], and on guidance in Section 2.2 of NUREG/CR-7002.
9. Two types of adverse weather scenarios are considered. Rain may occur for either winter or summer scenarios; snow occurs in winter scenarios only. It is assumed that the rain or snow begins earlier or at about the same time the evacuation advisory is issued. No weather-related reduction in the number of transients who may be present in the EPZ is assumed. It is assumed that roads are passable and that the appropriate agencies are plowing the roads as they would normally when snowing.

    Adverse weather scenarios affect roadway capacity and the free flow highway speeds. The factors applied for the ETE study are based on recent research on the effects of weather on roadway operations[4]; the factors are shown in Table 2-2.

[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).

[4] Agarwal, M. et. Al. Impacts of Weather on Urban Freeway Traffic Flow Characteristics and Facility Capacity, Proceedings of the 2005 Mid-Continent Transportation Research Symposium, August, 2005. The results of this paper are included as Exhibit 10-15 in the HCM 2010.

10. School buses used to transport students are assumed to transport 70 students per bus for elementary schools and 50 students per bus for middle and high schools, based on discussions with town emergency management agencies. Transit buses used to transport the transit-dependent general population are assumed to transport 30 people per bus.

Table 2-2. Model Adjustment for Adverse Weather

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time for General Population
Rain	90%	90%	No Effect
Snow	80%	80%	Clear driveway before leaving home (See Figure F-14)
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.			

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 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 2010 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. Estimating counts of vehicles by simply adding up the capacities of different types of parking facilities will tend to overestimate the number of transients and can lead to ETE that are too conservative.

Analysis of the population characteristics of the PNPS 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 (shopping, recreation) and then leave the area.
- Employees - people who reside outside of 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-area and by polar coordinate representation (population rose). The PNPS EPZ is subdivided into 12 sub-areas. The EPZ is shown in Figure 3-1.

3.1 Permanent Residents

The primary source for estimating permanent population is the latest U.S. Census data. The average household size (2.56 persons/household – See Figure F-1) and the number of evacuating vehicles per household (1.37 vehicles/household – See Figure F-8) were adapted from the telephone survey results.

Population estimates are based upon Census 2010 data. The estimates are created by cutting the census block polygons by the sub-area and EPZ boundaries. A ratio of the original area of each census block and the updated area (after cutting) is multiplied by the total block population to estimate what the population is within the EPZ. This methodology assumes that the population is evenly distributed across a census block. Table 3-1 provides the permanent resident population within the EPZ, by sub-area based on this methodology.

The year 2010 permanent resident population is divided by the average household size and then multiplied by the average number of evacuating vehicles per household in order to estimate number of vehicles. Permanent resident population and vehicle estimates are presented in Table 3-2. Figure 3-2 and Figure 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from the plant. This "rose" was constructed using GIS software.

It can be argued that this estimate of permanent residents overstates, somewhat, the number of evacuating vehicles, especially during the summer. It is certainly reasonable to assert that some portion of the population would be on vacation during the summer and would travel elsewhere. A rough estimate of this reduction can be obtained as follows:

- Assume 50 percent of all households vacation for a two-week period over the summer.
- Assume these vacations, in aggregate, are uniformly dispersed over 10 weeks, i.e. 10 percent of the population is on vacation during each two-week interval.
- Assume half of these vacationers leave the area.

On this basis, the permanent resident population would be reduced by 5 percent in the summer and by a lesser amount in the off-season. Given the uncertainty in this estimate, we elected to apply no reductions in permanent resident population for the summer scenarios to account for residents who may be out of the area.

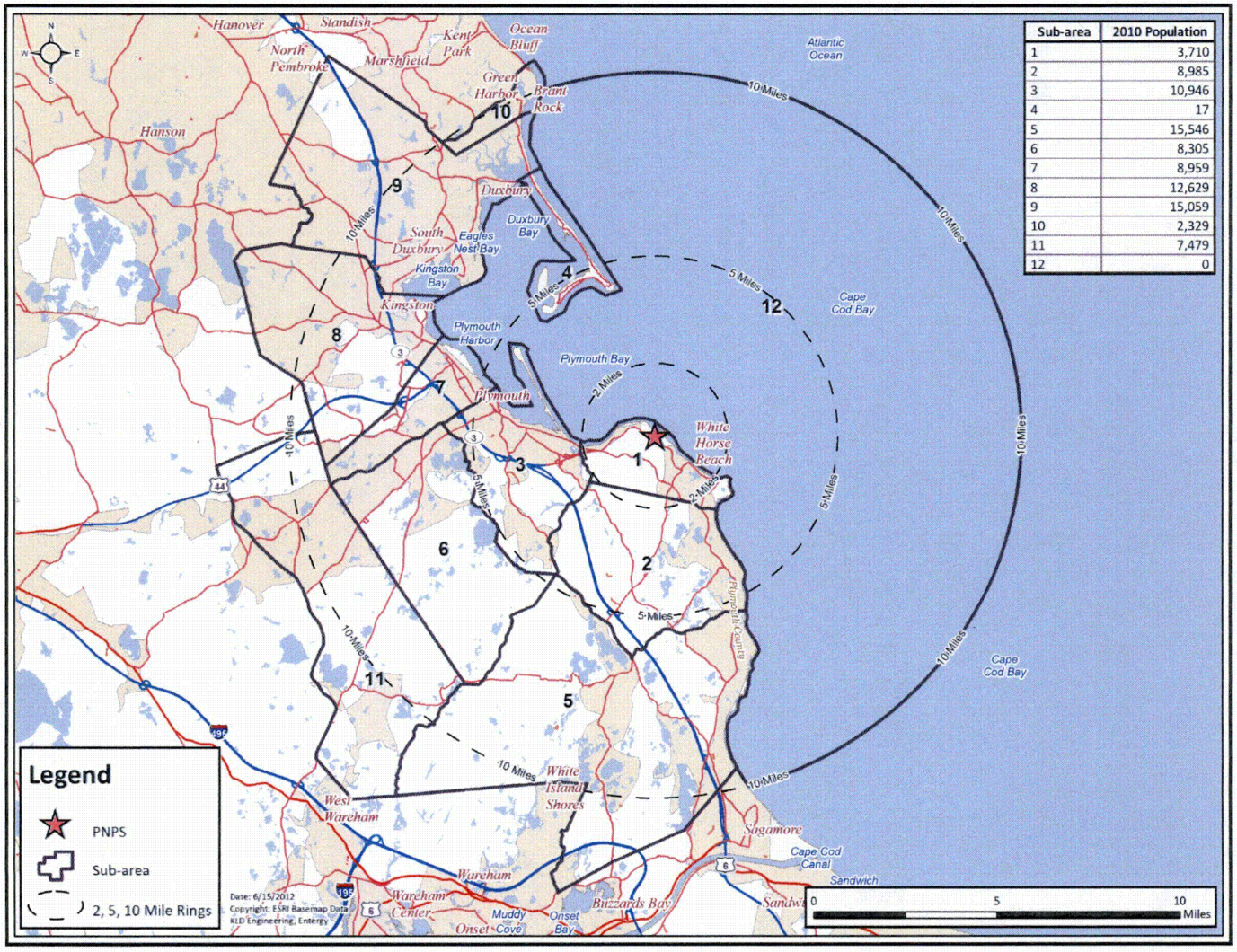


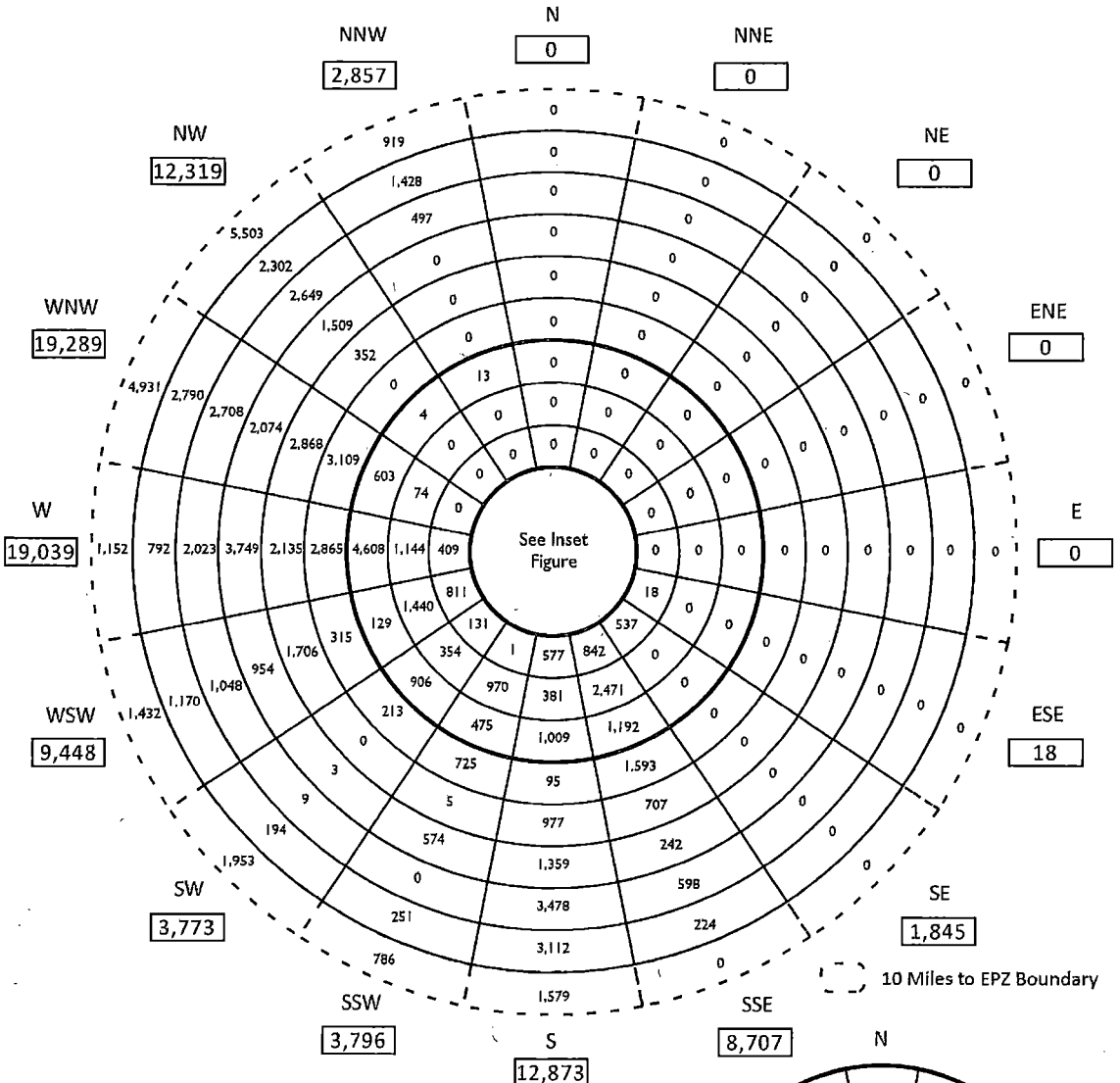
Figure 3-1. PNPS EPZ

Table 3-1. EPZ Permanent Resident Population

Sub-area	2000 Population	2010 Population
1	2,484	3,710
2	6,975	8,985
3	10,194	10,946
4	15	17
5	14,317	15,546
6	9,896	8,305
7	7,820	8,959
8	11,780	12,629
9	14,248	15,059
10	1,388	2,329
11	8,010	7,479
12	0	0
TOTAL	87,127	93,964
EPZ Population Growth:		7.85%

Table 3-2. Permanent Resident Population and Vehicles by Sub-area

Sub-area	2010 Population	2010 Resident Vehicles
1	3,710	1,985
2	8,985	4,761
3	10,946	5,077
4	17	10
5	15,546	8,207
6	8,305	4,442
7	8,959	4,798
8	12,629	6,758
9	15,059	7,990
10	2,329	1,248
11	7,479	4,009
12	0	0
TOTAL	93,964	49,285



Resident Population

Miles	Subtotal by Ring	Cumulative Total
0 - 1	708	708
1 - 2	2,500	3,208
2 - 3	3,326	6,534
3 - 4	6,834	13,368
4 - 5	8,939	22,307
5 - 6	8,915	31,222
6 - 7	8,750	39,972
7 - 8	10,464	50,436
8 - 9	13,010	63,446
9 - 10	12,263	75,709
10 - EPZ	18,255	93,964
	Total:	93,964

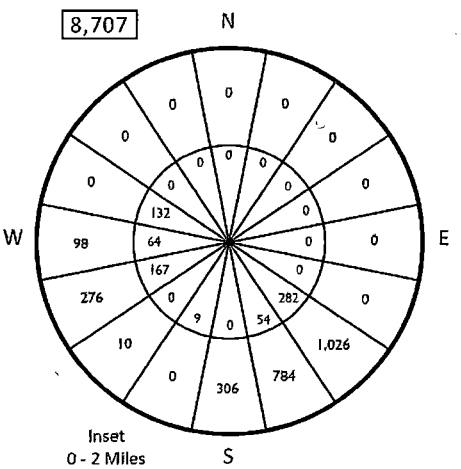
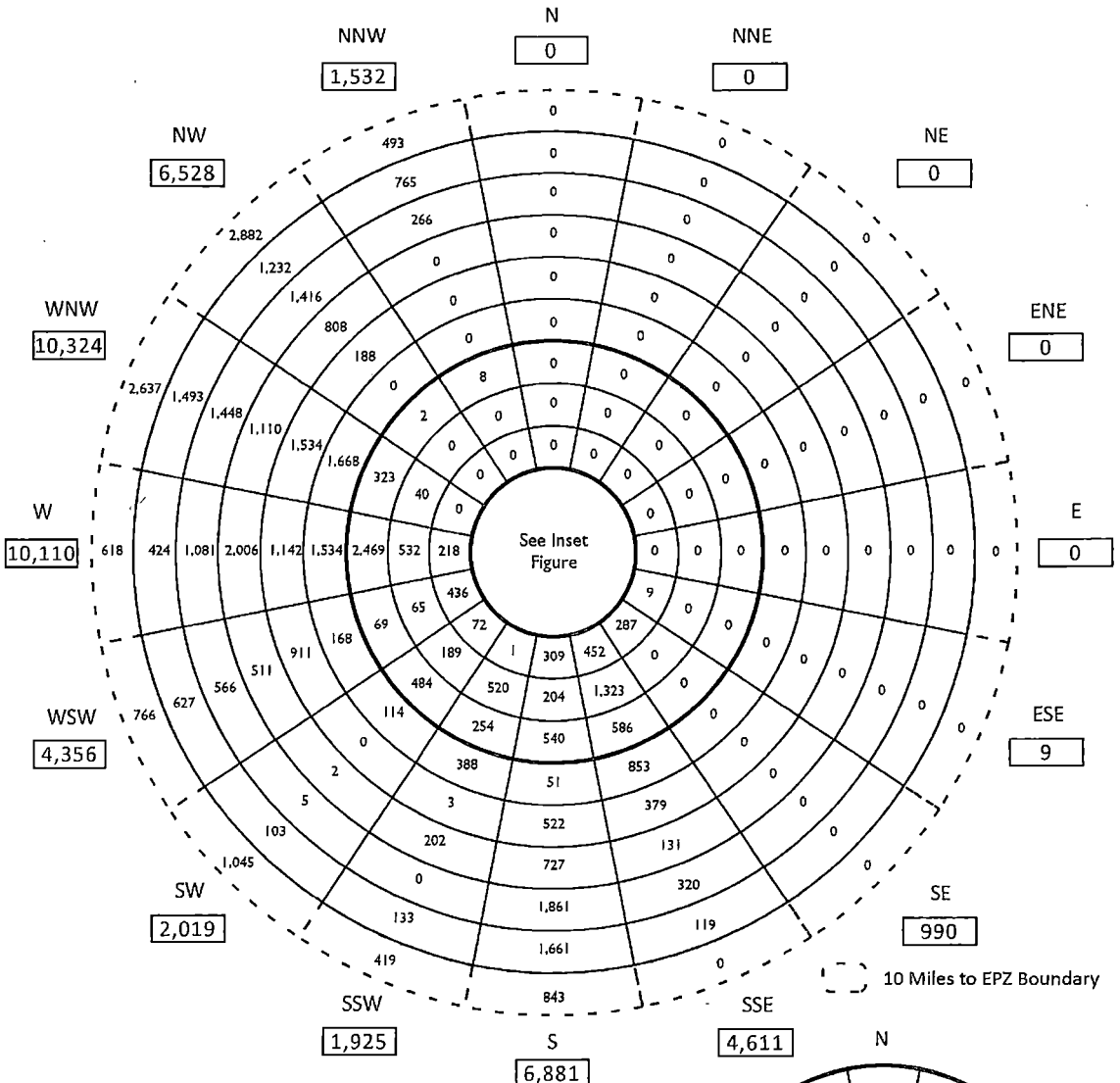
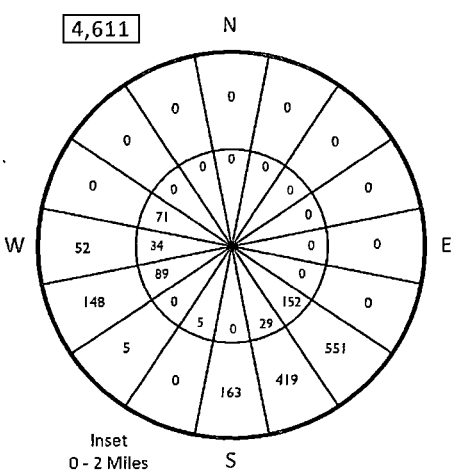


Figure 3-2. Permanent Resident Population by Sector





Resident Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	380	380
1 - 2	1,338	1,718
2 - 3	1,784	3,502
3 - 4	2,873	6,375
4 - 5	4,735	11,110
5 - 6	4,776	15,886
6 - 7	4,679	20,565
7 - 8	5,497	26,062
8 - 9	6,963	33,025
9 - 10	6,557	39,582
10 - EPZ	9,703	49,285
	Total:	49,285

Figure 3-3. Permanent Resident Vehicles by Sector

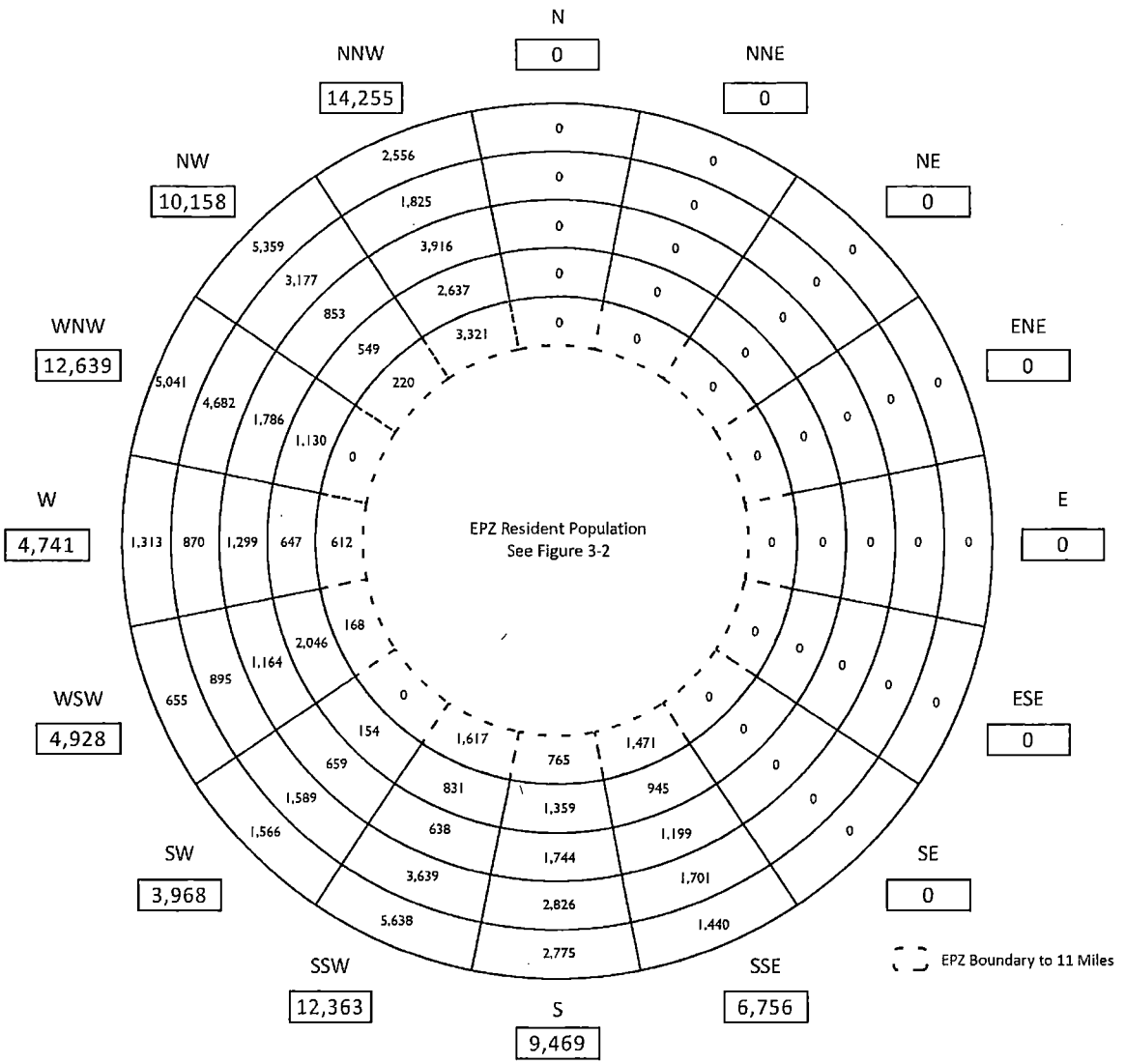
3.2 Shadow Population

A portion of the population living outside the evacuation area extending to 15 miles radially from the PNPS (in the Shadow Region) may elect to evacuate without having been instructed to do so. Based upon NUREG/CR-7002 guidance, it is assumed that 20 percent of the permanent resident population, based on U.S. Census Bureau data, in this Shadow Region will elect to evacuate.

Shadow population characteristics (household size, evacuating vehicles per household, mobilization time) are assumed to be the same as that for the EPZ permanent resident population. Table 3-3, Figure 3-4, and Figure 3-5 present estimates of the shadow population and vehicles, by sector.

Table 3-3. Shadow Population and Vehicles by Sector

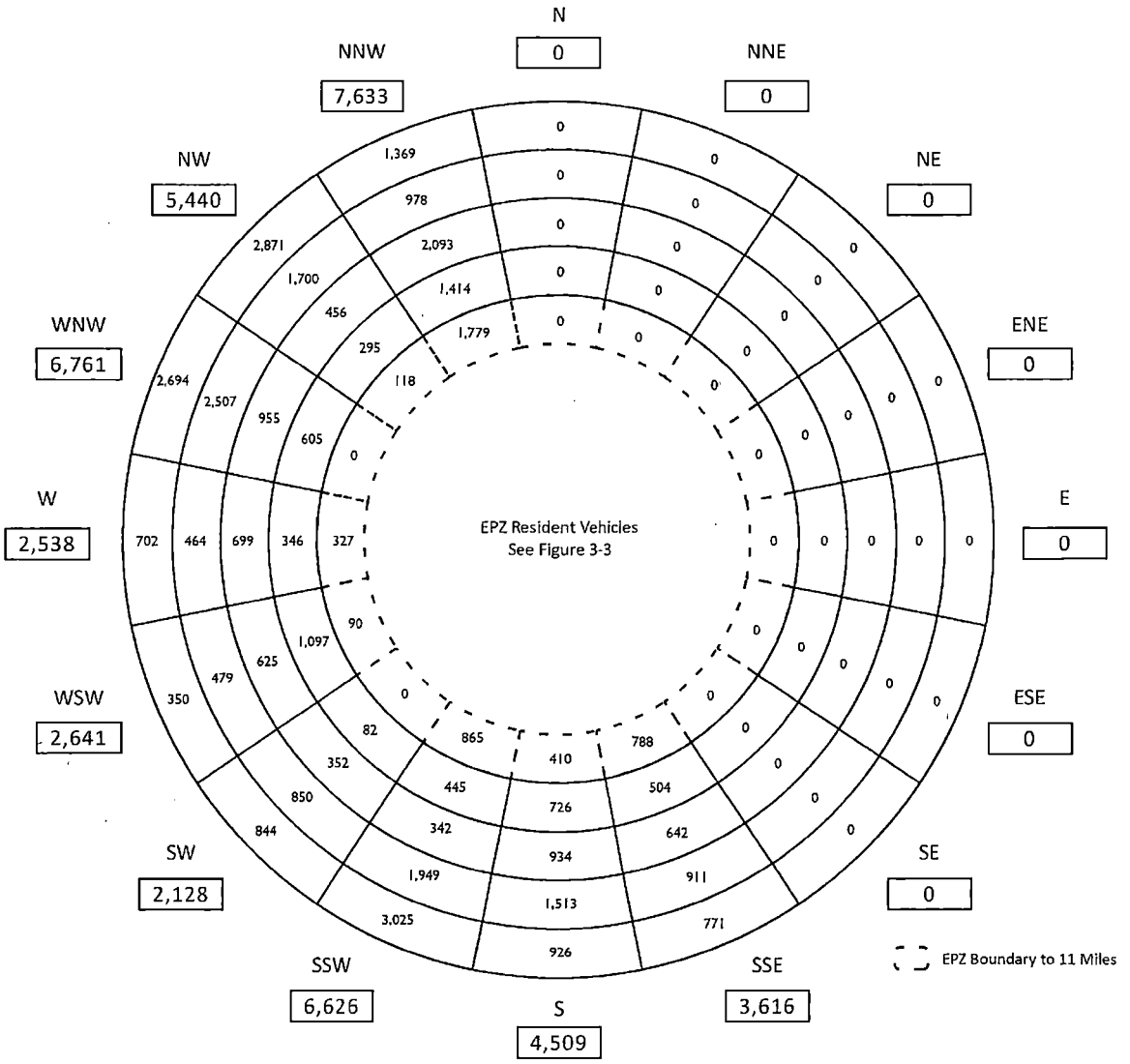
Sector	Population	Evacuating Vehicles
N	0	0
NNE	0	0
NE	0	0
ENE	0	0
E	0	0
ESE	0	0
SE	0	0
SSE	6,756	3,616
S	9,469	4,509
SSW	12,363	6,626
SW	3,968	2,128
WSW	4,928	2,641
W	4,741	2,538
WNW	12,639	6,761
NW	10,158	5,440
NNW	14,255	7,633
TOTAL	79,277	41,892



Shadow Population

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	8,174	8,174
11 - 12	10,298	18,472
12 - 13	13,258	31,730
13 - 14	21,204	52,934
14 - 15	26,343	79,277
	Total:	79,277

Figure 3-4. Shadow Population by Sector



Shadow Vehicles

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	4,377	4,377
11 - 12	5,514	9,891
12 - 13	7,098	16,989
13 - 14	11,351	28,340
14 - 15	13,552	41,892
	Total:	41,892

Figure 3-5. Shadow Vehicles by Sector

3.3 Transient Population

Transient population groups are defined as those people (who are not permanent residents, nor commuting employees) who enter the EPZ for a specific purpose (shopping, recreation). Transients may spend less than one day or stay overnight at camping facilities, hotels and motels. Data for these facilities was provided by local agencies. The PNPS EPZ has a number of areas and facilities that attract transients, including:

- Beaches – 5,840 transients and 2,281 vehicles
- Campgrounds – 6,288 transients and 2,356 vehicles
- Day Camps – 799 transients in 32 vehicles (1 bus = 2 vehicles)
- Golf Courses – 1,761 transients and 689 vehicles
- Historic Sites – 1,643 transients and 639 vehicles
- Lodging Facilities – 1,234 transients and 780 vehicles
- Marinas – 1,292 transients and 505 vehicles
- Parks – 1,607 transients and 629 vehicles
- Retail – 281 transients and 281 transient vehicles

Appendix E summarizes the transient data that was estimated for the EPZ. Table E-5 presents the number of transients visiting recreational areas, while Table E-6 presents the number of transients at lodging facilities within the EPZ.

Table 3-4 presents transient population and transient vehicle estimates by sub-area. Figure 3-6 and Figure 3-7 present these data by sector and distance from the plant.

3.3.1 Seasonal Transient Population

The secondary category of transient population is seasonal residents. These people will enter the area during the summer months and may stay considerably longer (several weeks or the entire season) than the average transient staying at a lodging facility. The seasonal population use other lodging facilities such as condos, beach houses and summer rentals that otherwise would not be captured with the year-round typical lodging population.

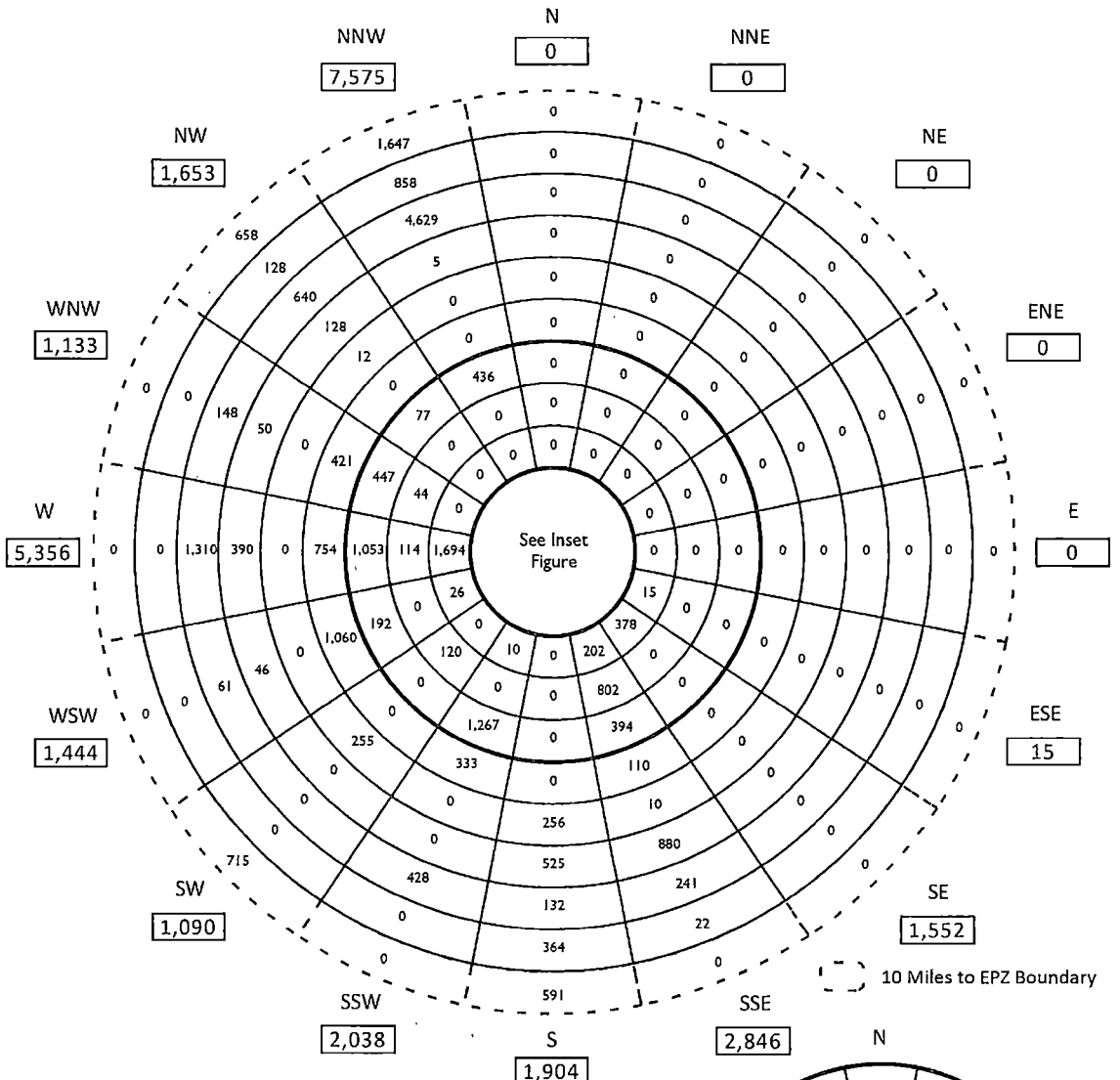
The methodology behind calculating the seasonal population involves using 2010 Census Block data. Each Census block includes information regarding the number of vacant and occupied households. Using the Census data, an average vacant household percentage of 24% was calculated for the entire PNPP EPZ.

It is assumed that seasonal residents will be renting homes near the shoreline. Using only those Census blocks that are within half a mile of these waterways, the number of seasonal homes was calculated by determining the percentage of vacant households and subtracting out the average vacant household percentages (24%) within the EPZ. An average household size of 2.56 persons per household is used to determine the seasonal transient population, and 1.37 evacuating vehicles per seasonal household is used to determine the number of seasonal transient vehicles. These numbers are adapted from the telephone survey results (see Appendix F).

Based on this analysis, it is estimated that there is an additional seasonal population of 5,861 transients and 3,108 transient vehicles within the PNPP EPZ. These numbers are included with the transient population in Table 3-4 as well as in Figure 3-6 and Figure 3-7.

Table 3-4. Summary of Transients and Transient Vehicles

Subarea	Transients	Transient Vehicles	Seasonal Residents	Seasonal Resident Vehicles	Total Transients	Total Transient Vehicles
1	108	50	1,840	983	1,948	1,033
2	1,531	617	1,305	689	2,836	1,306
3	3,311	1,400	145	75	3,456	1,475
4	0	0	518	277	518	277
5	3,079	1,126	753	393	3,832	1,519
6	2,737	1,070	0	0	2,737	1,070
7	1,572	839	0	0	1,572	839
8	292	103	0	0	292	103
9	6,102	2,224	306	162	6,408	2,386
10	1,298	507	994	529	2,292	1,036
11	715	256	0	0	715	256
12	0	0	0	0	0	0
TOTAL	**20,745**	**8,192**	**5,861**	**3,108**	**26,606**	**11,300**



Transients

Miles	Subtotal by Ring	Cumulative Total
0 - 1	359	359
1 - 2	1,169	1,528
2 - 3	2,325	3,853
3 - 4	1,080	4,933
4 - 5	3,866	8,799
5 - 6	2,678	11,477
6 - 7	533	12,010
7 - 8	2,024	14,034
8 - 9	7,589	21,623
9 - 10	1,372	22,995
10 - EPZ	3,611	26,606
	Total:	26,606

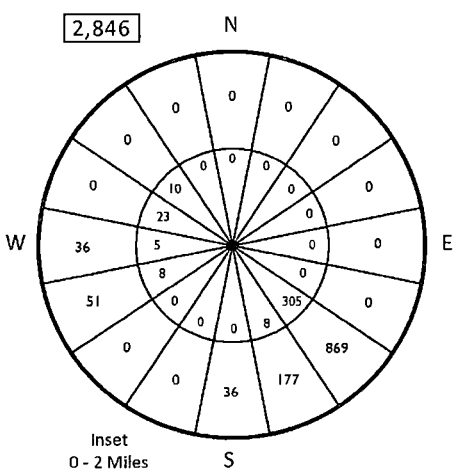
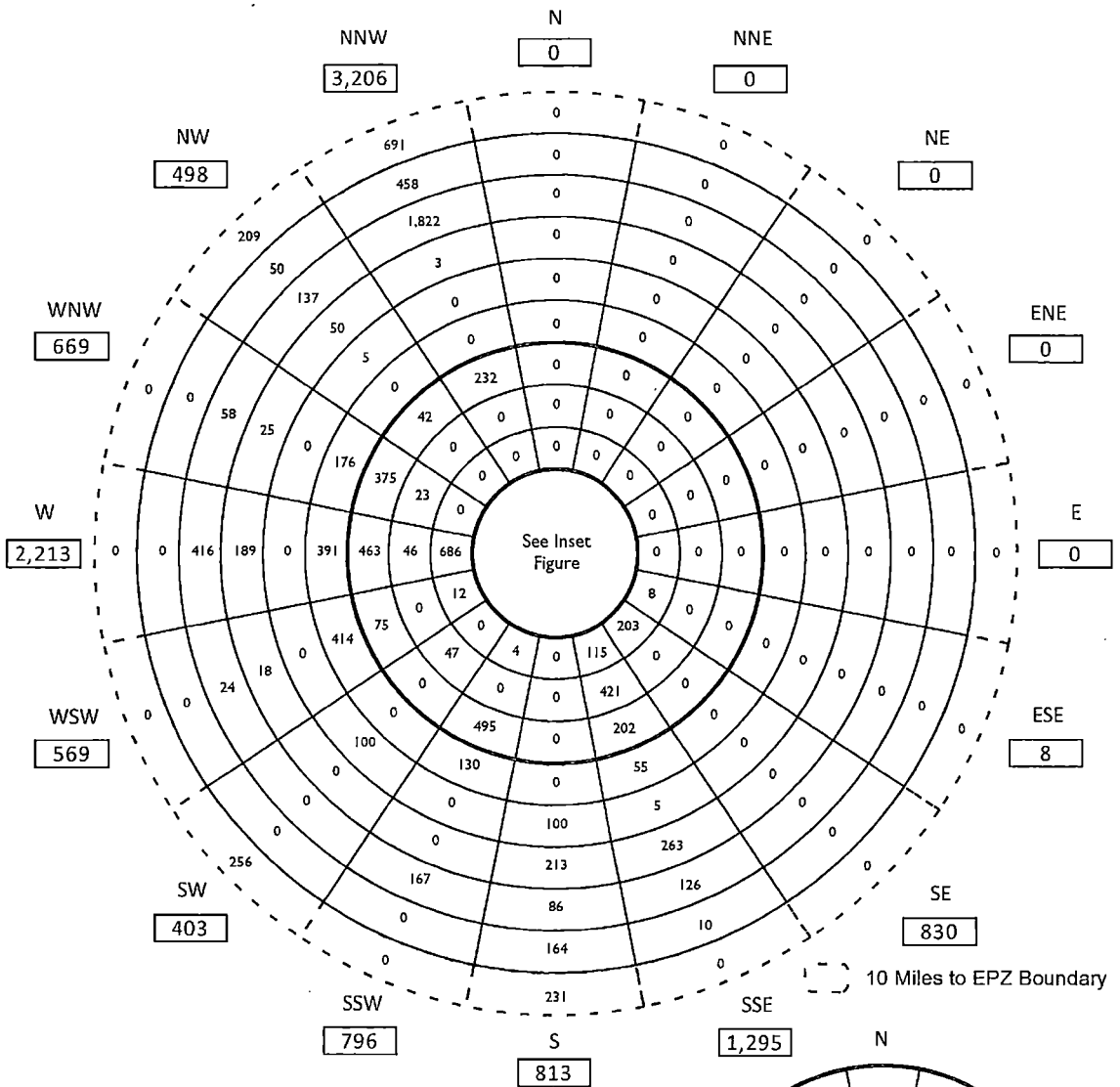


Figure 3-6. Transient Population by Sector



Transient Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	193	193
1 - 2	616	809
2 - 3	1,028	1,837
3 - 4	537	2,374
4 - 5	1,884	4,258
5 - 6	1,166	5,424
6 - 7	210	5,634
7 - 8	761	6,395
8 - 9	2,836	9,231
9 - 10	682	9,913
10 - EPZ	1,387	11,300
	Total:	11,300

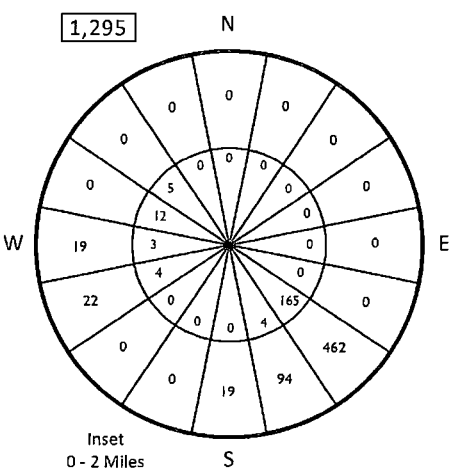


Figure 3-7. Transient Vehicles by Sector

3.4 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 only on those employees commuting from outside the EPZ who will evacuate along with the permanent resident population.

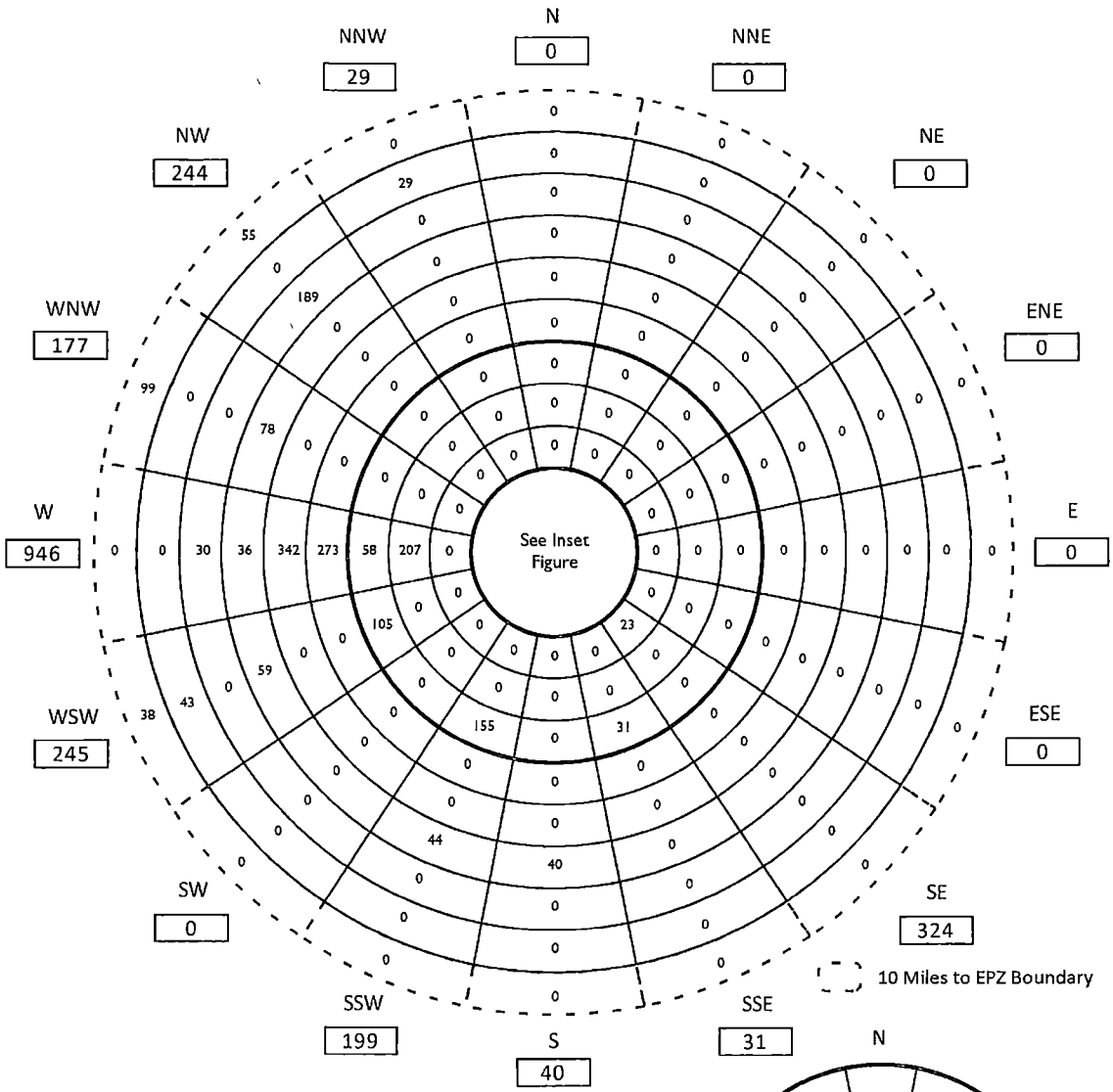
Data provided by the towns were used to estimate the number of employees commuting into the EPZ for those employers who did not provide data.

In Table E-3, the Employees (Max Shift) is multiplied by the percent Non-EPZ factor to determine the number of employees who are not residents of the EPZ. A vehicle occupancy of 1.05 employees per vehicle obtained from the telephone survey (See Figure F-7) was used to determine the number of evacuating employee vehicles for all major employers.

Table 3-5 presents non-EPZ resident employee and vehicle estimates by sub-area. In addition to the facilities listed in Table E-3, employers from schools (listed in Table E-1) are also included. Figure 3-8 and Figure 3-9 present these data by sector.

Table 3-5. Summary of Non-EPZ Resident Employees and Employee Vehicles

Sub-area	Employees	Employee Vehicles
1	324	309
2	186	178
3	370	352
4	0	0
5	84	80
6	59	56
7	651	620
8	207	198
9	244	232
10	29	28
11	81	77
12	0	0
TOTAL	**2,235**	**2,130**



Employees

Miles	Subtotal by Ring	Cumulative Total
0 - 1	301	301
1 - 2	0	301
2 - 3	23	324
3 - 4	207	531
4 - 5	349	880
5 - 6	273	1,153
6 - 7	342	1,495
7 - 8	257	1,752
8 - 9	219	1,971
9 - 10	72	2,043
10 - EPZ	192	2,235
	Total:	2,235

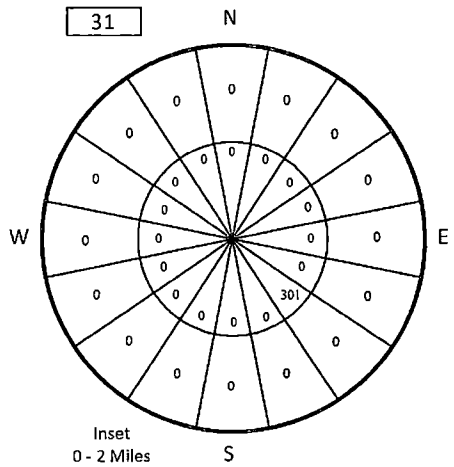
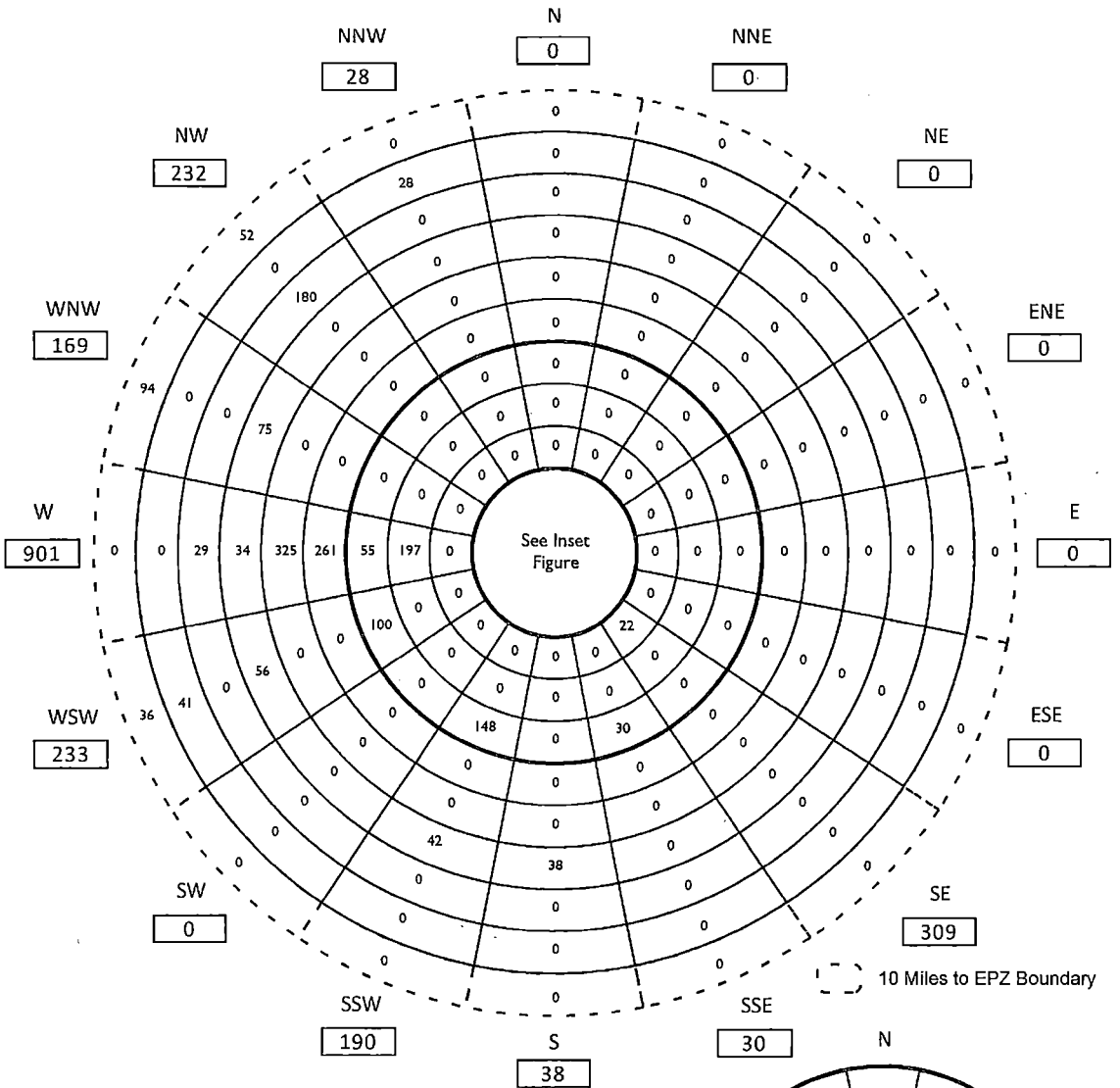


Figure 3-8. Employee Population by Sector



Employee Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	287	287
1 - 2	0	287
2 - 3	22	309
3 - 4	197	506
4 - 5	333	839
5 - 6	261	1,100
6 - 7	325	1,425
7 - 8	245	1,670
8 - 9	209	1,879
9 - 10	69	1,948
10 - EPZ	182	2,130
	Total:	2,130

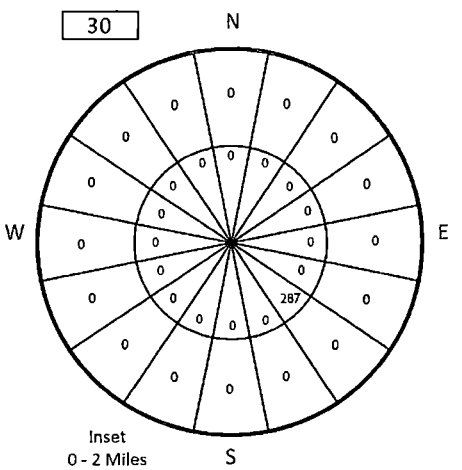


Figure 3-9. Employee Vehicles by Sector

3.5 Medical Facilities

Data were provided by the towns for each of the medical facilities within the EPZ. Table E-2 in Appendix E summarizes the data gathered. Section 8 details the evacuation of medical facilities and their patients. The number and type of evacuating vehicles that need to be provided depend on the patients' state of health. It is estimated that buses can transport up to 30 people; wheelchair vans, up to 4 people; wheelchair buses up to 15 people; and ambulances, up to 2 people.

3.6 Total Demand in Addition to Permanent Population

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 traversing the EPZ – Route 3, Route 25 and I-195. It is assumed that this traffic will continue to enter the EPZ during the first 120 minutes following the Advisory to Evacuate.

Average Annual Daily Traffic (AADT) data was obtained from Federal Highway Administration to estimate the number of vehicles per hour on the aforementioned routes. The AADT was multiplied by the K-Factor, which is the proportion of the AADT on a roadway segment or link during the design hour, resulting in the design hour volume (DHV). The design hour is usually the 30^{th} highest hourly traffic volume of the year, measured in vehicles per hour (vph). The DHV is then multiplied by the D-Factor, which is the proportion of the DHV occurring in the peak direction of travel (also known as the directional split). The resulting values are the directional design hourly volumes (DDHV), and are presented in Table 3-6, for each of the routes considered. The DDHV is then multiplied by 2 hours (access control points – ACP – are assumed to be activated at 120 minutes after the advisory to evacuate) to estimate the total number of external vehicles loaded on the analysis network. As indicated, there are 22,260 vehicles entering the EPZ as external-external trips prior to the activation of the ACP and the diversion of this traffic. This number is reduced by 60% for evening scenarios (Scenarios 5 and 12) as discussed in Section 6.

3.7 Special Event

The special event (Scenario 13) considered for the ETE study occurs at night on Fourth of July weekend in Plymouth. There is an upper-bound estimate of 80,000 spectators attending, where 33% are considered transients, resulting in 26,666 transients. It is assumed that families travel to the event as a household unit in a single vehicle; therefore, the average household size of 2.56 is used as the vehicle occupancy resulting in an additional 10,417 vehicles. The special event vehicle trips are generated utilizing the same mobilization distributions for transients.

Table 3-6. PNPS EPZ External Traffic

Upstream Node	Downstream Node	Road Name	Direction	HPMS[1] AADT	K-Factor[2]	D-Factor[2]	Hourly Volume	External Traffic
8001	425	Route 3	NB	49,000	0.107	0.5	2,622	5,244
8046	46	Route 3	SB	66,939	0.091	0.5	3,046	6,092
8062	62	Route 25	NB	36,400	0.107	0.5	1,947	3,894
8081	81	Route 25	SB	36,400	0.107	0.5	1,947	3,894
8089	89	I-195	NB	29,300	0.107	0.5	1,568	3,136
8001	425	Route 3	NB	49,000	0.107	0.5	2,622	5,244
							TOTAL:	**22,260**

[1]Highway Performance Monitoring System (HPMS), Federal Highway Administration (FHWA), Washington, D.C., 2011
[2]HCM 2010

3.8 Summary of Demand

A summary of population and vehicle demand is provided in Table 3-7 and Table 3-8, respectively. This summary includes all population groups described in this section. Additional population groups – transit-dependent, special facility and school population – are described in greater detail in Section 8. A total of 166,273 people and 94,739 vehicles are considered in this study.

Table 3-7. Summary of Population Demand

Subarea	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Schools	Shadow Population	External Traffic	Total
1	3,710	86	1,948	324	0	469	0	0	6,537
2	8,985	207	2,836	186	210	3,096	0	0	15,520
3	10,946	252	3,456	370	2,745	3,395	0	0	21,140
4	17	0	518	0	0	0	0	0	535
5	15,546	359	3,832	84	241	985	0	0	21,047
6	8,305	192	2,737	59	0	563	0	0	11,856
7	8,959	207	1,572	651	206	1,434	0	0	13,029
8	12,629	291	292	207	241	4,546	0	0	18,206
9	15,059	347	6,408	244	195	4,538	0	0	26,791
10	2,329	54	2,292	29	0	450	0	0	5,154
11	7,479	172	715	81	0	2,132	0	0	10,601
12	0	0	0	0	0	0	0	0	0
Shadow	0	0	0	0	0	0	15,855	0	15,855
Total	**93,964**	**2,167**	**26,606**	**2,235**	**3,838**	**21,608**	**15,855**	**0**	**166,271**

NOTE: Shadow Population has been reduced to 20%. Refer to Figure 2-1 for additional information.
NOTE: Special Facilities include both medical facilities and correctional facilities.

Table 3-8. Summary of Vehicle Demand

Subarea	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Schools	Shadow Population	External Traffic	Total
1	1,985	6	1,033	309	0	20	0	0	3,353
2	4,761	14	1,306	178	32	116	0	0	6,407
3	5,077	18	1,475	352	207	137	0	0	7,266
4	10	2	277	0	0	0	0	0	289
5	8,207	24	1,519	80	16	32	0	0	9,878
6	4,442	12	1,070	56	0	28	0	0	5,608
7	4,798	14	839	620	43	54	0	0	6,368
8	6,758	20	103	198	46	180	0	0	7,305
9	7,990	24	2,386	232	41	188	0	0	10,861
10	1,248	4	1,036	28	0	18	0	0	2,334
11	4,009	8	256	77	0	82	0	0	4,434
12	0	0	0	0	0	0	0	0	0
Shadow	0	0	0	0	0	0	8,378	22,260	30,638
Total	**49,285**	**146**	**11,300**	**2,130**	**385**	**855**	**8,378**	**22,260**	**94,739**

NOTE: Buses represented as two passenger vehicles. Refer to Section 8 for additional information.

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, as stated in the 2010 Highway Capacity Manual (HCM 2010).

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.

Another concept, closely associated with capacity, is "Service Volume" (SV). Service volume is defined as "The maximum hourly rate at which vehicles, bicycles or persons reasonably can be expected to traverse a point or uniform section of a roadway during an hour under specific assumed conditions while maintaining a designated level of service." This definition is similar to that for capacity. The major distinction is that values of SV vary from one LOS to another, while capacity is the service volume at the upper bound of LOS E, only.

This distinction is illustrated in Exhibit 11-17 of the HCM 2010. As indicated there, the SV varies with Free Flow Speed (FFS), and LOS. The SV is calculated by the DYNEV II simulation model, based on the specified link attributes, FFS, capacity, control device and traffic demand.

Other factors also influence capacity. These include, but are not limited to:

- Lane width
- Shoulder width
- Pavement condition
- Horizontal and vertical alignment (curvature and grade)
- Percent truck traffic
- Control device (and timing, if it is a signal)
- Weather conditions (rain, snow, fog, wind speed, ice)

These factors are considered during the road survey and in the capacity estimation process; some factors have greater influence on capacity than others. For example, lane and shoulder width have only a limited influence on Base Free Flow Speed (BFFS[1]) according to Exhibit 15-7 of the HCM. Consequently, lane and shoulder widths at the narrowest points were observed during the road survey and these observations were recorded, but no detailed measurements of lane or shoulder width were taken. Horizontal and vertical alignment can influence both FFS and capacity. The estimated FFS were measured using the survey vehicle's speedometer and observing local traffic, under free flow conditions. Capacity is estimated from the procedures of

[1] A very rough estimate of BFFS might be taken as the posted speed limit plus 10 mph (HCM 2010 Page 15-15)

the 2010 HCM. For example, HCM Exhibit 7-1(b) shows the sensitivity of Service Volume at the upper bound of LOS D to grade (capacity is the Service Volume at the upper bound of LOS E).

As discussed in Section 2.3, it is necessary to adjust capacity figures to represent the prevailing conditions during inclement weather. Based on limited empirical data, weather conditions such as 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. As indicated in Section 2.3, we employ a reduction in free speed and in highway capacity of 10 percent and 20 percent for rain and snow, respectively.

Since congestion arising from evacuation may be significant, 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.

Rural highways generally consist of: (1) one or more uniform sections with limited access (driveways, parking areas) characterized by "uninterrupted" flow; and (2) approaches to at-grade intersections where flow can be "interrupted" by a control device or by turning or crossing traffic at the intersection. Due to these differences, separate estimates of capacity must be made for each section. Often, the approach to the intersection is widened by the addition of one or more lanes (turn pockets or turn bays), to compensate for the lower capacity of the approach due to the factors there that can interrupt the flow of traffic. These additional lanes are recorded during the field survey and later entered as input to the DYNEV II system.

4.1 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 existing traffic management plans documented in the town emergency plans are extensive and were adopted without change.

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

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

where:

$Q_{cap,m}$ = 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 = Mean duration of GREEN time servicing vehicles that are executing movement, m, for each signal cycle; seconds

L = Mean "lost time" for each signal phase servicing movement, m; seconds

C = Duration of each signal cycle; seconds

P_m = 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, and 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,

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

where:

h_{sat} = Saturation discharge headway for through vehicles; seconds per vehicle

F_1, F_2 = The various known factors influencing h_m

$f_m( )$ = Complex function relating h_m to the known (or estimated) values of h_{sat}, F_1, F_2, ...

The estimation of h_m for specified values of h_{sat}, F_1, F_2, ... is undertaken within the DYNEV II simulation model by a mathematical model[2]. The resulting values for h_m always satisfy the condition:

$$h_m \geq h_{sat}$$

[2]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. Lieberman, E., Xin, W., "Macroscopic Traffic Modeling For Large-Scale Evacuation Planning", presented at the TRB 2012 Annual Meeting, January 22-26, 2012

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 procedures of the HCM 2010.

The above discussion is necessarily brief given the scope of this ETE report and the complexity of the subject of intersection capacity. In fact, Chapters 18, 19 and 20 in the HCM 2010 address this topic. The factors, F_1, F_2,..., influencing saturation flow rate are identified in equation (18-5) of the HCM 2010.

The traffic signals within the EPZ and Shadow Region are modeled using representative phasing plans and phase durations obtained as part of the field data collection. Traffic responsive signal installations allow the proportion of green time allocated (P_m) for each approach to each intersection to be determined by the expected traffic volumes on each approach during evacuation circumstances. The amount of green time (G) allocated is subject to maximum and minimum phase duration constraints; 2 seconds of yellow time are indicated for each signal phase and 1 second of all-red time is assigned between signal phases, typically. If a signal is pre-timed, the yellow and all-red times observed during the road survey are used. A lost time (L) of 2.0 seconds is used for each signal phase in the analysis.

4.2 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. The top curve in Figure 4-1 illustrates this relationship.

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; the 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 ("capacity drop"). 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:

$$V_F = R \times Capacity$$

where:

R = Reduction factor which is less than unity

We have employed a value of R=0.90. The advisability of such a capacity reduction factor is based upon empirical studies that identified a fall-off in the service flow rate when congestion occurs at "bottlenecks" or "choke points" on a freeway system. Zhang and Levinson[3] describe a research program that collected data from a computer-based surveillance system (loop detectors) installed on the Interstate Highway System, at 27 active bottlenecks in the twin cities metro area in Minnesota over a 7-week period. When flow breakdown occurs, queues are formed which discharge at lower flow rates than the maximum capacity prior to observed breakdown. These queue discharge flow (QDF) rates vary from one location to the next and also vary by day of week and time of day based upon local circumstances. The cited reference presents a mean QDF of 2,016 passenger cars per hour per lane (pcphpl). This figure compares with the nominal capacity estimate of 2,250 pcphpl estimated for the ETE and indicated in Appendix K for freeway links. The ratio of these two numbers is 0.896 which translates into a capacity reduction factor of 0.90.

Since the principal objective of evacuation time estimate analyses is to develop a "realistic" estimate of evacuation times, use of the representative value for this capacity reduction factor (R=0.90) is justified. This factor is applied only when flow breaks down, as determined by the simulation model.

Rural roads, like freeways, are classified as "uninterrupted flow" facilities. (This is in contrast with urban street systems which have closely spaced signalized intersections and are classified as "interrupted flow" facilities.) As such, traffic flow along rural roads is subject to the same effects as freeways in the event traffic demand exceeds the nominal capacity, resulting in queuing and lower QDF rates. As a practical matter, rural roads rarely break down at locations away from intersections. Any breakdowns on rural roads are generally experienced at intersections where other model logic applies, or at lane drops which reduce capacity there. Therefore, the application of a factor of 0.90 is appropriate on rural roads, but rarely, if ever, activated.

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. Exhibit 15-30 in the Highway Capacity Manual was referenced to estimate saturation flow rates. The impact of narrow lanes and shoulders on free-flow speed and on capacity is not material, particularly when flow is predominantly in one direction as is the case during an evacuation.

The procedure used here was to estimate "section" capacity, V_E, based on observations made traveling over each section of the evacuation network, based on the posted speed limits and travel behavior of other motorists and by reference to the 2010 HCM. The DYNEV II simulation model determines 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.

[3]Lei Zhang and David Levinson, "Some Properties of Flows at Freeway Bottlenecks," Transportation Research Record 1883, 2004.

4.3 Application to the PNPS Study Area

As part of the development of the link-node analysis network for the study area, an estimate of roadway capacity is required. The source material for the capacity estimates presented herein is contained in:

2010 Highway Capacity Manual (HCM)
Transportation Research Board
National Research Council
Washington, D.C.

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

- Two-Lane roads: Local, State
- Multi-Lane Highways (at-grade)
- Freeways

Each of these classifications will be discussed.

4.3.1 Two-Lane Roads

Ref: HCM Chapter 15

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 DYNEV II 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 urban and suburban centers.

4.3.2 Multi-Lane Highway

Ref: HCM Chapter 14

Exhibit 14-2 of the HCM 2010 presents a set of curves that indicate a per-lane capacity ranging from approximately 1900 to 2200 pc/h, for free-speeds of 45 to 60 mph, respectively. 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. A

conservative estimate of per-lane capacity of 1900 pc/h is adopted for this study for multi-lane highways outside of urban areas, as shown in Appendix K.

4.3.3 Freeways

Ref: HCM Chapters 10, 11, 12, 13

Chapter 10 of the HCM 2010 describes a procedure for integrating the results obtained in Chapters 11, 12 and 13, which compute capacity and LOS for freeway components. Chapter 10 also presents a discussion of simulation models. The DYNEV II simulation model automatically performs this integration process.

Chapter 11 of the HCM 2010 presents procedures for estimating capacity and LOS for "Basic Freeway Segments". Exhibit 11-17 of the HCM 2010 presents capacity vs. free speed estimates, which are provided below.

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

The inputs to the simulation model are highway geometrics, free-speeds and capacity based on field observations. The simulation logic calculates actual time-varying speeds based on demand: capacity relationships. A conservative estimate of per-lane capacity of 2250 pc/h is adopted for this study for freeways, as shown in Appendix K.

Chapter 12 of the HCM 2010 presents procedures for estimating capacity, speed, density and LOS for freeway weaving sections. The simulation model contains logic that relates speed to demand volume: capacity ratio. The value of capacity obtained from the computational procedures detailed in Chapter 12 depends on the "Type" and geometrics of the weaving segment and on the "Volume Ratio" (ratio of weaving volume to total volume).

Chapter 13 of the HCM 2010 presents procedures for estimating capacities of ramps and of "merge" areas. There are three significant factors to the determination of capacity of a ramp-freeway junction: The capacity of the freeway immediately downstream of an on-ramp or immediately upstream of an off-ramp; the capacity of the ramp roadway; and the maximum flow rate entering the ramp influence area. In most cases, the freeway capacity is the controlling factor. Values of this merge area capacity are presented in Exhibit 13-8 of the HCM 2010, and depend on the number of freeway lanes and on the freeway free speed. Ramp capacity is presented in Exhibit 13-10 and is a function of the ramp free flow speed. The DYNEV II simulation model logic simulates the merging operations of the ramp and freeway traffic in accord with the procedures in Chapter 13 of the HCM 2010. 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).

4.3.4 Intersections

Ref: HCM Chapters 18, 19, 20, 21

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapter 18 (signalized intersections), Chapters 19, 20 (un-signalized intersections) and Chapter 21 (roundabouts). The complexity of these computations is indicated by the aggregate length of these chapters. The DYNEV II simulation logic is likewise complex.

The simulation model explicitly models intersections: Stop/yield controlled intersections (both 2-way and all-way) and traffic signal controlled intersections. Where intersections are controlled by fixed time controllers, traffic signal timings are set to reflect average (non-evacuation) traffic conditions. Actuated traffic signal settings respond to the time-varying demands of evacuation traffic to adjust the relative capacities of the competing intersection approaches.

The model is also capable of modeling the presence of manned traffic control. At specific locations where it is advisable or where existing plans call for overriding existing traffic control to implement manned control, the model will use actuated signal timings that reflect the presence of traffic guides. At locations where a special traffic control strategy (continuous left-turns, contra-flow lanes) is used, the strategy is modeled explicitly. Where applicable, the location and type of traffic control for nodes in the evacuation network are noted in Appendix K. The characteristics of the ten highest volume signalized intersections are detailed in Appendix J.

4.4 Simulation and Capacity Estimation

Chapter 6 of the HCM is entitled, "HCM and Alternative Analysis Tools." The chapter discusses the use of alternative tools such as simulation modeling to evaluate the operational performance of highway networks. Among the reasons cited in Chapter 6 to consider using simulation as an alternative analysis tool is:

> *"The system under study involves a group of different facilities or travel modes with mutual interactions invoking several procedural chapters of the HCM. Alternative tools are able to analyze these facilities as a single system."*

This statement succinctly describes the analyses required to determine traffic operations across an area encompassing an EPZ operating under evacuation conditions. The model utilized for this study, DYNEV II, is further described in Appendix C. It is essential to recognize that simulation models do not replicate the methodology and procedures of the HCM – they *replace* these procedures by describing the complex interactions of traffic flow and computing Measures of Effectiveness (MOE) detailing the operational performance of traffic over time and by location. The DYNEV II simulation model includes some HCM 2010 procedures only for the purpose of estimating capacity.

All simulation models must be calibrated properly with field observations that quantify the performance parameters applicable to the analysis network. Two of the most important of

these are: (1) Free flow speed (FFS); and (2) saturation headway, h_{sat}. The first of these is estimated by direct observation during the road survey; the second is estimated using the concepts of the HCM 2010, as described earlier. These parameters are listed in Appendix K, for each network link.

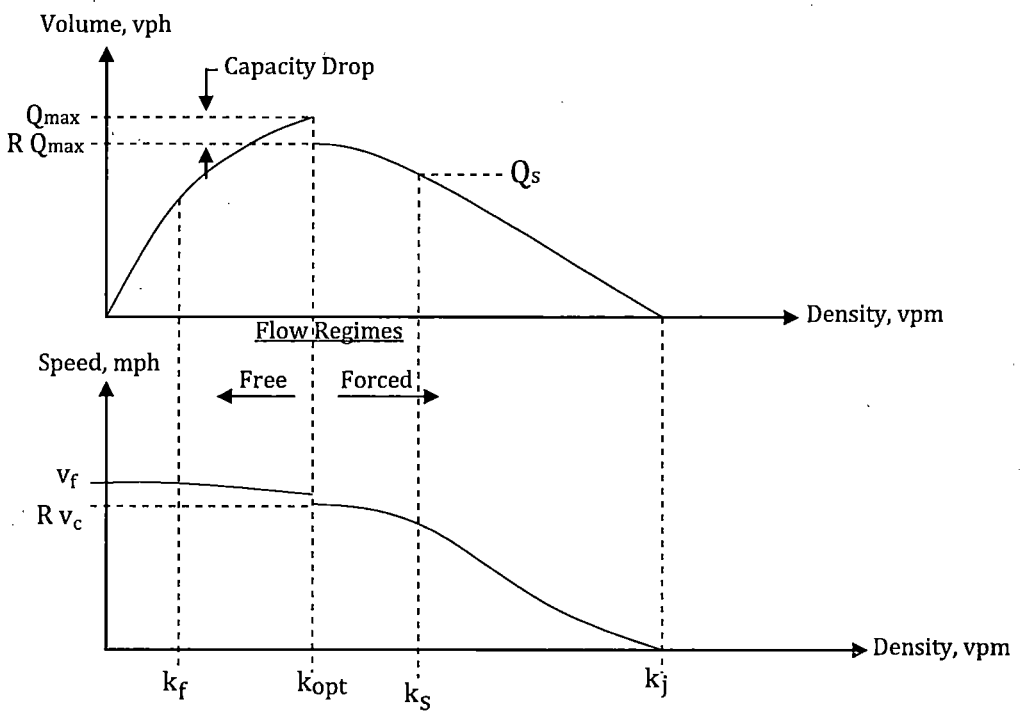


Figure 4-1. Fundamental Diagrams

5 ESTIMATION OF TRIP GENERATION TIME

Federal Government guidelines (see NUREG CR-7002) 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. We define the sum of these distributions of elapsed times as the Trip Generation Time Distribution.

5.1 Background

In general, an accident at a nuclear power plant is characterized by the following Emergency 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 accordance with Section 1.2 of NUREG/CR-7002, that a rapidly escalating accident will be considered in calculating the Trip Generation Time. We will assume:

1. The Advisory to Evacuate will be announced coincident with the siren notification.
2. Mobilization of the general population will commence within 15 minutes after the siren notification.
3. ETE are measured relative to the Advisory to Evacuate.

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

1. Establish a temporal framework for estimating the Trip Generation distribution in the format recommended in Section 2.13 of NUREG/CR-6863.
2. Identify temporal points of reference that uniquely define "Clear Time" and ETE.

It is likely that a longer time will elapse between the various classes of an emergency.

For example, suppose one hour elapses from the siren alert to the Advisory 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 EPZ will be lower when the Advisory to Evacuate is announced, than at the time of the siren alert. In addition, many will engage in preparation activities to evacuate, in anticipation that an Advisory will be broadcast. Thus, the time needed to complete the mobilization activities and the number of people remaining to evacuate the EPZ after the Advisory to Evacuate, will both be somewhat less than

the estimates presented in this report. Consequently, the ETE presented in this report are higher than the actual evacuation time, if this hypothetical situation were to take place.

The notification process consists of two events:

1. Transmitting information using the alert notification systems available within the EPZ (e.g. sirens, tone alerts, EAS broadcasts, loud speakers).
2. Receiving and correctly interpreting the information that is transmitted.

The population within the EPZ is dispersed over an area of approximately 185 square miles and is 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 on 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 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 Section 2.13 of NUREG/CR-6863, 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 ETE may be computed.

For example, people at home or at work within the EPZ will be notified by siren, and/or tone alert and/or radio (if available). 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 differ from weekdays.

As indicated in Section 4.1 of NUREG/CR-7002, the information required to compute trip generation times is typically obtained from a telephone survey of EPZ residents. Such a survey was conducted in support of this ETE study. Appendix F presents the survey sampling plan, survey instrument, and raw survey results. It is important to note that the shape and duration of the evacuation trip mobilization distribution is important at sites where traffic congestion is not expected to cause the evacuation time estimate to extend in time well beyond the trip generation period. The remaining discussion will focus on the application of the trip generation data obtained from the telephone survey to the development of the ETE documented in this report.

5.2 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 events) 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
2	Awareness of Situation
3	Depart Work
4	Arrive Home
5	Depart on Evacuation Trip

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

Table 5-1. Event Sequence for Evacuation Activities

Event Sequence	Activity	Distribution
1 → 2	Receive Notification	1
2 → 3	Prepare to Leave Work	2
2,3 → 4	Travel Home	3
2,4 → 5	Prepare to Leave to Evacuate	4
N/A	Snow Clearance	5

These relationships are shown graphically in Figure 5-1.

- An Event is a 'state' that exists at a point in time (e.g., depart work, arrive home)
- An Activity is a 'process' that takes place over some elapsed time (e.g., prepare to leave work, travel home)

As such, a completed Activity changes the 'state' of an individual (e.g. the activity, 'travel home' changes the state from 'depart work' to 'arrive home'). Therefore, an Activity can be described as an 'Event Sequence'; the elapsed times to perform an event sequence vary from one person to the next and are described as statistical distributions on the following pages.

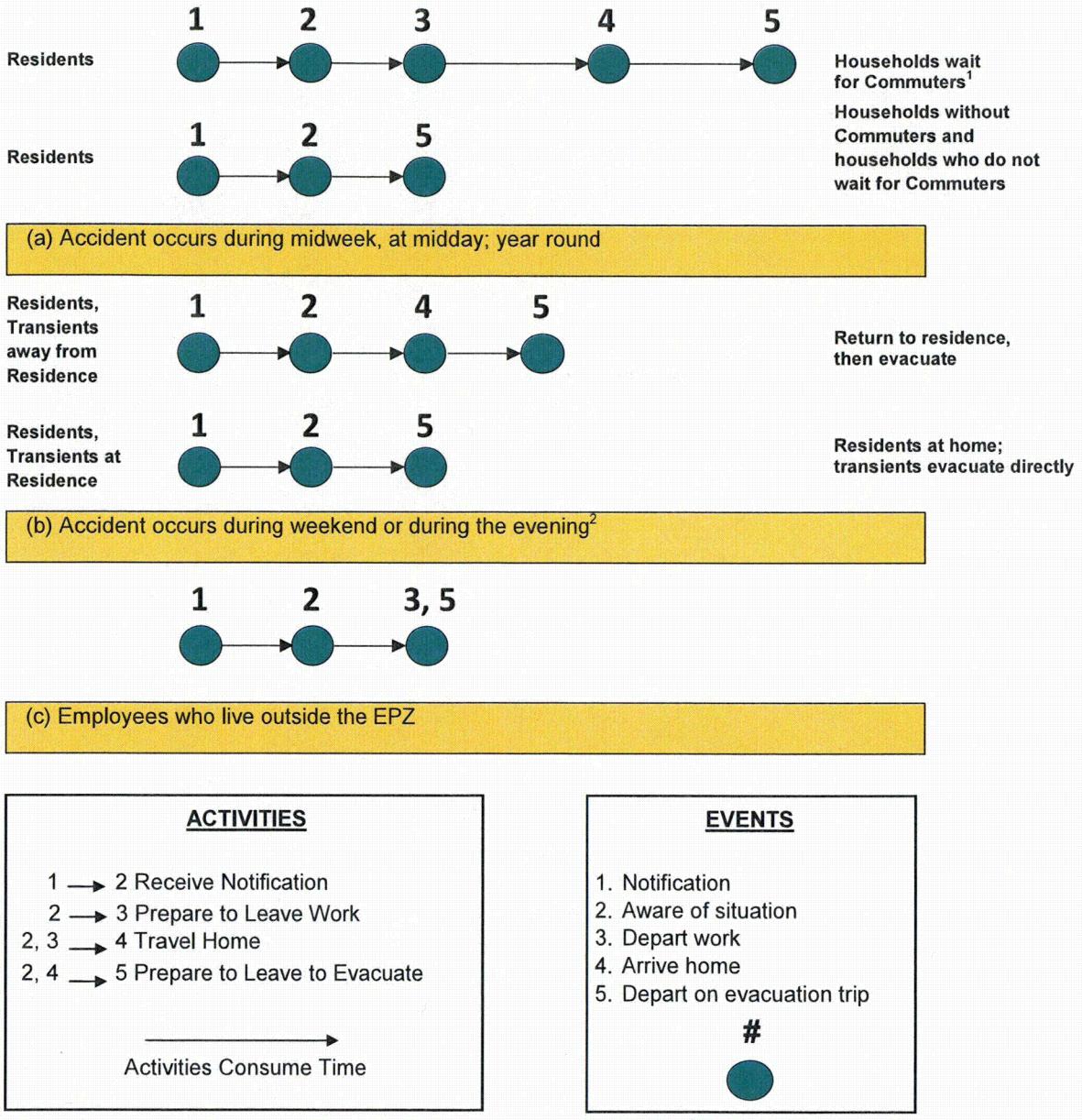
An employee who lives outside the EPZ will follow sequence (c) of Figure 5-1. A household

within the EPZ that has one or more commuters at work, and will await their return before beginning the evacuation trip will follow the first sequence of Figure 5-1(a). A household within the EPZ that has no commuters at work, or that will not await the return of any commuters, will follow the second sequence of Figure 5-1(a), regardless of day of week or time of day.

Households with no commuters on weekends or in the evening/night-time, will follow the applicable sequence in Figure 5-1(b). Transients will always follow one of the sequences of Figure 5-1(b). Some transients away from their residence could elect to evacuate immediately without returning to the residence, as indicated in the second 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. For this study, we adopt the conservative posture that all activities will occur in sequence.

In some cases, assuming certain events occur strictly sequential (for instance, commuter returning home before beginning preparation to leave, or removing snow only after the preparation to leave) can result in rather *conservative* (that is, longer) estimates of mobilization times. It is reasonable to expect that at least some parts of these events will overlap for many households, but that assumption is not made in this study.



[1] Applies for evening and weekends also if commuters are at work.
[2] Applies throughout the year for transients.

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

5.3 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 it is performed on distributions – not scalar numbers).

Time Distribution No. 1, Notification Process: Activity 1 → 2

In accordance with the 2012 Federal Emergency Management Agency (FEMA) Radiological Emergency Preparedness Program Manual, 100% of the population is notified within 45 minutes. It is assumed (based on the presence of sirens within the EPZ) that 87 percent of those within the EPZ will be aware of the accident within 30 minutes with the remainder notified within the following 15 minutes. The notification distribution is given below:

Table 5-2. Time Distribution for Notifying the Public

Elapsed Time (Minutes)	Percent of Population Notified
0	0.0%
5	7.1%
10	13.3%
15	26.5%
20	46.9%
25	66.3%
30	86.7%
35	91.8%
40	96.9%
45	100.0%

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/livestock would require additional time to secure their facility. The distribution of Activity 2 → 3 shown in Table 5-3 reflects data obtained by the telephone survey. This distribution is plotted in Figure 5-2.

Table 5-3. Time Distribution for Employees to Prepare to Leave Work

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work	Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0.0%	35	91.7%
5	44.0%	40	91.9%
10	62.6%	45	93.0%
15	75.4%	50	93.2%
20	78.7%	55	93.2%
25	79.3%	60	99.2%
30	91.5%	75	100.0%

NOTE: The survey data was normalized to distribute the "Don't know" response. That is, the sample was reduced in size to include only those households who responded to this question. The underlying assumption is that the distribution of this activity for the "Don't know" responders, if the event takes place, would be the same as those responders who provided estimates.

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

These data are provided directly by those households which responded to the telephone survey. This distribution is plotted in Figure 5-2 and listed in Table 5-4.

Table 5-4. Time Distribution for Commuters to Travel Home

Elapsed Time (Minutes)	Cumulative Percent Returning Home	Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0.0%	45	78.4%
5	10.6%	50	79.9%
10	23.7%	55	80.2%
15	35.8%	60	91.9%
20	47.7%	75	94.8%
25	51.1%	90	97.8%
30	63.5%	105	98.4%
35	65.5%	120	100.0%
40	69.4%		

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

Distribution No. 4, Prepare to Leave Home: Activity 2, 4 → 5

These data are provided directly by those households which responded to the telephone survey. This distribution is plotted in Figure 5-2 and listed in Table 5-5.

Table 5-5. Time Distribution for Population to Prepare to Evacuate

Elapsed Time (Minutes)	Cumulative Percent Ready to Evacuate
0	0.0%
15	12.9%
30	58.0%
45	63.9%
60	86.2%
75	91.0%
90	91.9%
105	92.1%
120	96.8%
135	98.0%
150	98.0%
165	98.0%
180	100.0%

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

Distribution No. 5, Snow Clearance Time Distribution

Inclement weather scenarios involving snowfall must address the time lags associated with snow clearance. It is assumed that snow equipment is mobilized and deployed during the snowfall to maintain passable roads. The general consensus is that the snow-plowing efforts are generally successful for all but the most extreme blizzards when the rate of snow accumulation exceeds that of snow clearance over a period of many hours.

Consequently, it is reasonable to assume that the highway system will remain passable – albeit at a lower capacity – under the vast majority of snow conditions. Nevertheless, for the vehicles to gain access to the highway system, it may be necessary for driveways and employee parking lots to be cleared to the extent needed to permit vehicles to gain access to the roadways. These clearance activities take time; this time must be incorporated into the trip generation time distributions. These data are provided by those households which responded to the telephone survey. This distribution is plotted in Figure 5-2 and listed in Table 5-6.

Note that those respondents (43%) who answered that they would not take time to clear their driveway were assumed to be ready immediately at the start of this activity. Essentially they would drive through the snow on the driveway to access the roadway and begin their evacuation trip.

Table 5-6. Time Distribution for Population to Clear 6"-8" of Snow

Elapsed Time (Minutes)	Cumulative Percent Completing Snow Removal
0	43.0%
15	49.3%
30	71.6%
45	76.8%
60	88.0%
75	90.1%
90	92.0%
105	92.2%
120	96.0%
135	98.3%
150	98.7%
165	98.7%
180	100.0%

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

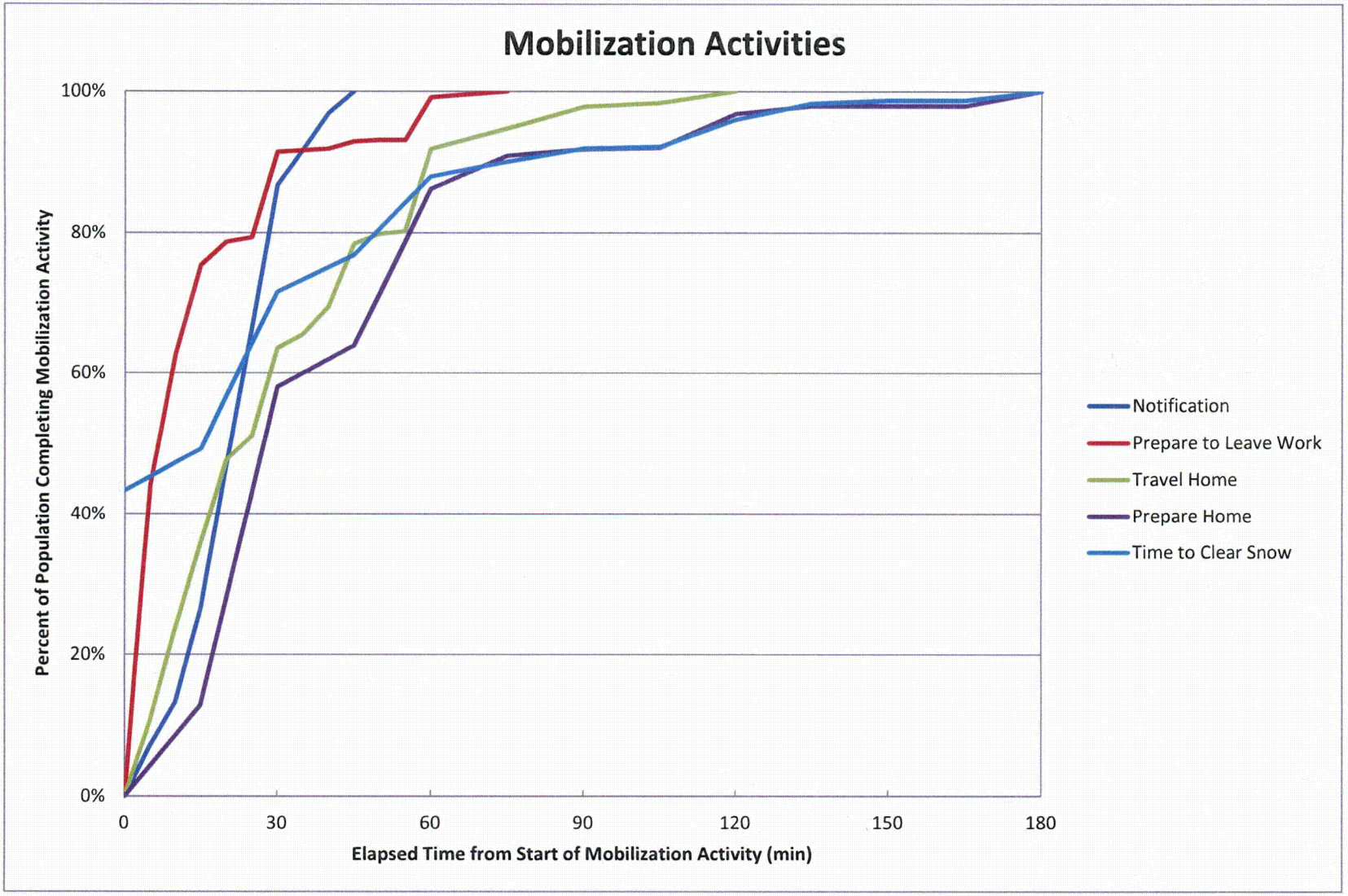


Figure 5-2. Evacuation Mobilization Activities

5.4 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. As discussed above, this study assumes 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 → 4) must precede Activity 4 → 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. Table 5-7 presents the summing procedure to arrive at each designated distribution.

Table 5-7. Mapping Distributions to Events

Apply "Summing" Algorithm To:	Distribution Obtained	Event Defined
Distributions 1 and 2	Distribution A	Event 3
Distributions A and 3	Distribution B	Event 4
Distributions B and 4	Distribution C	Event 5
Distributions 1 and 4	Distribution D	Event 5
Distributions C and 5	Distribution E	Event 5
Distributions D and 5	Distribution F	Event 5

Table 5-8 presents a description of each of the final trip generation distributions achieved after the summing process is completed.

Table 5-8. Description of the Distributions

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 (Event 4).
C	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip (Event 5).
D	Time distribution of residents without commuters returning home, leaving home to begin the evacuation trip (Event 5).
E	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip, after snow clearance activities (Event 5).
F	Time distribution of residents with no commuters returning home, leaving to begin the evacuation trip, after snow clearance activities (Event 5).

5.4.1 Statistical Outliers

As already mentioned, some portion of the survey respondents answer "don't know" to some questions or choose to not respond to a question. The mobilization activity distributions are based upon actual responses. But, it is the nature of surveys that a few numeric responses are inconsistent with the overall pattern of results. An example would be a case in which for 500 responses, almost all of them estimate less than two hours for a given answer, but 3 say "four hours" and 4 say "six or more hours".

These "outliers" must be considered: are they valid responses, or so atypical that they should be dropped from the sample?

In assessing outliers, there are three alternates to consider:

1) Some responses with very long times may be valid, but reflect the reality that the respondent really needs to be classified in a different population subgroup, based upon special needs;

2) Other responses may be unrealistic (6 hours to return home from commuting distance, or 2 days to prepare the home for departure);

3) Some high values are representative and plausible, and one must not cut them as part of the consideration of outliers.

The issue of course is how to make the decision that a given response or set of responses are to be considered "outliers" for the component mobilization activities, using a method that objectively quantifies the process.

There is considerable statistical literature on the identification and treatment of outliers singly or in groups, much of which assumes the data is normally distributed and some of which uses non-

parametric methods to avoid that assumption. The literature cites that limited work has been done directly on outliers in sample survey responses.

In establishing the overall mobilization time/trip generation distributions, the following principles are used:

1) It is recognized that the overall trip generation distributions are conservative estimates, because they assume a household will do the mobilization activities sequentially, with no overlap of activities;

2) The individual mobilization activities (prepare to leave work, travel home, prepare home, clear snow) are reviewed for outliers, and then the overall trip generation distributions are created (see Figure 5-1, Table 5-7, Table 5-8);

3) Outliers can be eliminated either because the response reflects a special population (e.g. special needs, transit dependent) or lack of realism, because the purpose is to estimate trip generation patterns for personal vehicles;

4) To eliminate outliers,
    a) the mean and standard deviation of the specific activity are estimated from the responses,
    b) the median of the same data is estimated, with its position relative to the mean noted,
    c) the histogram of the data is inspected, and
    d) all values greater than 3.5 standard deviations are flagged for attention, taking special note of whether there are gaps (categories with zero entries) in the histogram display.

    In general, only flagged values more than 4 standard deviations from the mean are allowed to be considered outliers, with gaps in the histogram expected.

    When flagged values are classified as outliers and dropped, steps "a" to "d" are repeated.

5) As a practical matter, even with outliers eliminated by the above, the resultant histogram, viewed as a cumulative distribution, is not a normal distribution. A typical situation that results is shown below in Figure 5-3.

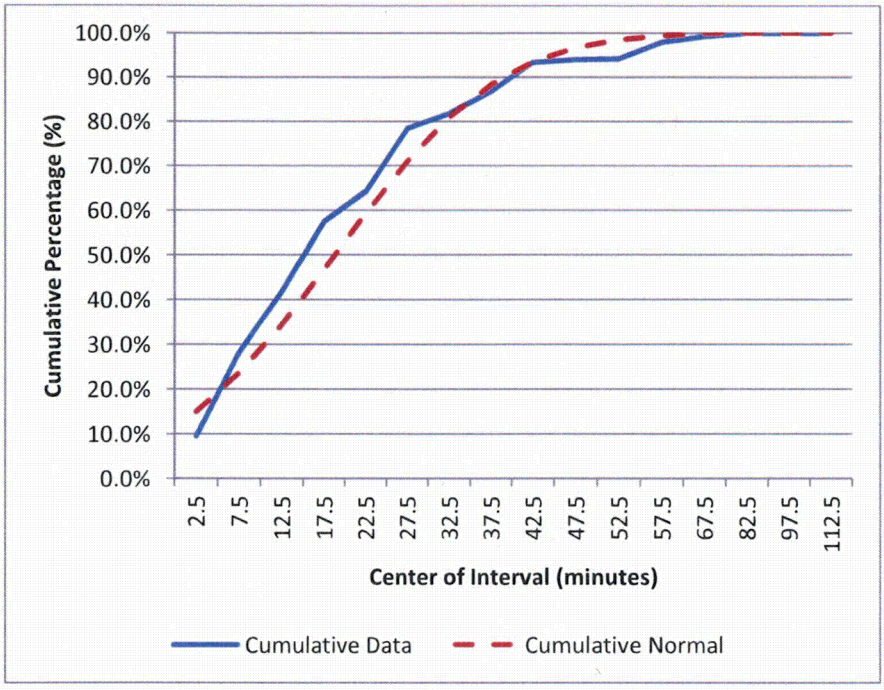


Figure 5-3. Comparison of Data Distribution and Normal Distribution

6) In particular, the cumulative distribution differs from the normal distribution in two key aspects, both very important in loading a network to estimate evacuation times:

- Most of the real data is to the left of the "normal" curve above, indicating that the network loads faster for the first 80-85% of the vehicles, potentially causing more (and earlier) congestion than otherwise modeled;
- The last 10-15% of the real data "tails off" slower than the comparable "normal" curve, indicating that there is significant traffic still loading at later times.

Because these two features are important to preserve, it is the histogram of the data that is used to describe the mobilization activities, not a "normal" curve fit to the data. One could consider other distributions, but using the shape of the *actual* data curve is unambiguous and preserves these important features;

7) With the mobilization activities each modeled according to Steps 1-6, including preserving the features cited in Step 6, the overall (or total) mobilization times are constructed.

This is done by using the data sets and distributions under different scenarios (e.g. commuter returning, no commuter returning, no snow or snow in each). In general, these are additive, using

weighting based upon the probability distributions of each element; Figure 5-4 presents the combined trip generation distributions designated A, C, D, E and F. These distributions are presented on the same time scale. (As discussed earlier, the use of strictly additive activities is a conservative approach, because it makes all activities sequential – preparation for departure follows the return of the commuter; snow clearance follows the preparation for departure, and so forth. In practice, it is reasonable that some of these activities are done in parallel, at least to some extent – for instance, preparation to depart begins by a household member at home while the commuter is still on the road.)

The mobilization distributions that result are used in their tabular/graphical form as direct inputs to later computations that lead to the ETE.

The DYNEV II 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, D, E and F, properly displaced with respect to one another, are tabulated in Table 5-9 (Distribution B, Arrive Home, omitted for clarity).

The final time period (15) is 600 minutes long. This time period is added to allow the analysis network to clear, in the event congestion persists beyond the trip generation period. Note that there are no trips generated during this final time period.

5.4.2 Staged Evacuation Trip Generation

As defined in NUREG/CR-7002, staged evacuation consists of the following:

1. Sub-areas comprising the 2 mile region are advised to evacuate immediately
2. Sub-areas comprising regions extending from 2 to 5 miles downwind are advised to shelter in-place while the 2 mile region is cleared
3. As vehicles evacuate the 2 mile region, sheltered people from 2 to 5 miles downwind continue preparation for evacuation
4. The population sheltering in the 2 to 5 mile region are advised to begin evacuating when approximately 90% of those originally within the 2 mile region evacuate across the 2 mile region boundary
5. Non-compliance with the shelter recommendation is the same as the shadow evacuation percentage of 20%

Assumptions

1. The EPZ population in sub-areas beyond 5 miles will react as does the population in the 2 to 5 mile region; that is they will first shelter, then evacuate after the 90^{th} percentile ETE for the 2 mile region
2. The population in the shadow region beyond the EPZ boundary, extending to approximately 15 miles radially from the plant, will react as they do for all non-staged evacuation scenarios. That is 20% of these households will elect to evacuate with no shelter delay.
3. The transient population will not be expected to stage their evacuation because of the limited sheltering options available to people who may be at parks, on a beach, or at other venues. Also, notifying the transient population of a staged evacuation would prove difficult.
4. Employees will also be assumed to evacuate without first sheltering.

Procedure

1. Trip generation for population groups in the 2 mile region will be as computed based upon the results of the telephone survey and analysis.
2. Trip generation for the population subject to staged evacuation will be formulated as follows:
    a. Identify the 90^{th} percentile evacuation time for the sub-areas comprising the two mile region. This value, T_{Scen}^{*}, obtained from simulation results is scenario-specific. It will become the time at which the region being sheltered will be told to evacuate for each scenario.
    b. The resultant trip generation curves for staging are then formed as follows:
        i. The non-shelter trip generation curve is followed until a maximum of 20% of the total trips are generated (to account for shelter non-compliance).

ii. No additional trips are generated until time T_{Scen}^*
iii. Following time T_{Scen}^*, the balance of trips are generated:
1. by stepping up and then following the non-shelter trip generation curve (if T_{Scen}^* is $\leq$ max trip generation time) or
2. by stepping up to 100% (if T_{Scen}^* is > max trip generation time)

c. Note: This procedure implies that there may be different staged trip generation distributions for different scenarios. NUREG/CR-7002 uses the statement "approximately 90th percentile" as the time to end staging and begin evacuating. The value of T_{Scen}^* is 2:10 for non-snow scenarios and 3:00 for snow scenarios.

3. Staged trip generation distributions are created for the following population groups:
a. Residents with returning commuters
b. Residents without returning commuters
c. Residents with returning commuters and snow conditions
d. Residents without returning commuters and snow conditions

Figure 5-5 presents the staged trip generation distributions for both residents with and without returning commuters; the 90th percentile two-mile evacuation time is 130 minutes for good weather and 140 minutes for snow scenarios. At the 90th percentile evacuation time, 20% of the population (who normally would have completed their mobilization activities for an un-staged evacuation) advised to shelter has nevertheless departed the area. These people do not comply with the shelter advisory. Also included on the plot are the trip generation distributions for these groups as applied to the regions advised to evacuate immediately.

Since the 90th percentile evacuation time occurs before the end of the trip generation period, after the sheltered region is advised to evacuate, the shelter trip generation distribution rises to meet the balance of the non-staged trip generation distribution. Following time T_{Scen}^*, the balance of staged evacuation trips that are ready to depart are released within 15 minutes. After T_{Scen}^*+15, the remainder of evacuation trips are generated in accordance with the unstaged trip generation distribution.

Table 5-10 provides the trip generation (histograms) for staged evacuation.

5.4.3 Trip Generation for Waterways and Recreational Areas

In the Town of Plymouth Radiological Emergency Response Plant for Pilgrim Nuclear Power Station, Section E item 6 c states that:

> The public and commercial boating population and marinas will receive notification from the Harbor Master and U.S. Coast Guard boats equipped with public address systems. Additional notification is also conducted via marine and citizen band (CB) radios to those boats that are radio-equipped.

There is no time estimate given for these activities. It is assumed boaters will return to marinas within the mobilization time of transients within the EPZ.

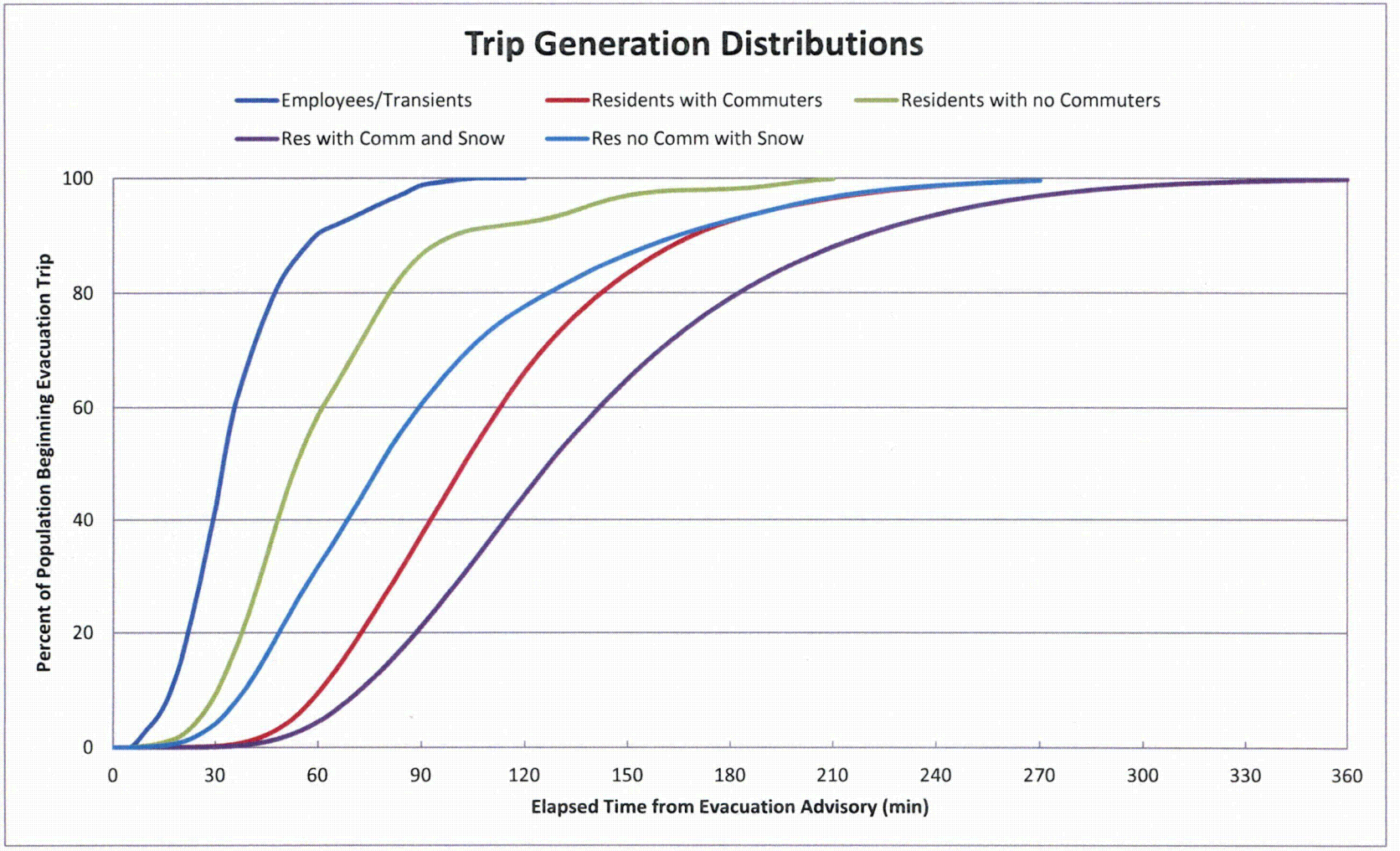


Figure 5-4. Comparison of Trip Generation Distributions

Table 5-9. Trip Generation Histograms for the EPZ Population for Unstaged Evacuation

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period					
		Employees (Distribution A)	Transients (Distribution A)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	7%	7%	0%	1%	0%	0%
2	15	35%	35%	0%	8%	0%	4%
3	15	35%	35%	2%	24%	1%	12%
4	15	13%	13%	7%	26%	3%	16%
5	30	9%	9%	28%	28%	17%	29%
6	30	1%	1%	29%	5%	24%	17%
7	30	0%	0%	17%	5%	20%	9%
8	15	0%	0%	6%	1%	8%	3%
9	15	0%	0%	4%	0%	6%	3%
10	15	0%	0%	2%	1%	5%	2%
11	15	0%	0%	2%	1%	4%	2%
12	30	0%	0%	2%	0%	6%	2%
13	30	0%	0%	1%	0%	3%	1%
14	90	0%	0%	0%	0%	3%	0%
15	600	0%	0%	0%	0%	0%	0%

NOTE:

- Shadow vehicles are loaded onto the analysis network (Figure 1-2) using Distributions C and E for good weather and snow, respectively.
- Special event vehicles are loaded using Distribution A.

Table 5-10. Trip Generation Histograms for the EPZ Population for Staged Evacuation

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period*			
		Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	0%	0%	0%	0%
2	15	0%	2%	0%	1%
3	15	0%	5%	0%	2%
4	15	2%	5%	1%	3%
5	30	5%	5%	3%	6%
6	30	6%	1%	5%	4%
7	30	70%	79%	4%	1%
8	15	6%	1%	2%	1%
9	15	4%	0%	1%	1%
10	15	2%	1%	68%	76%
11	15	2%	1%	4%	2%
12	30	2%	0%	6%	2%
13	30	1%	0%	3%	1%
14	90	0%	0%	3%	0%
15	600	0%	0%	0%	0%

*Trip Generation for Employees and Transients (see Table 5-9) is the same for Unstaged and Staged Evacuation.

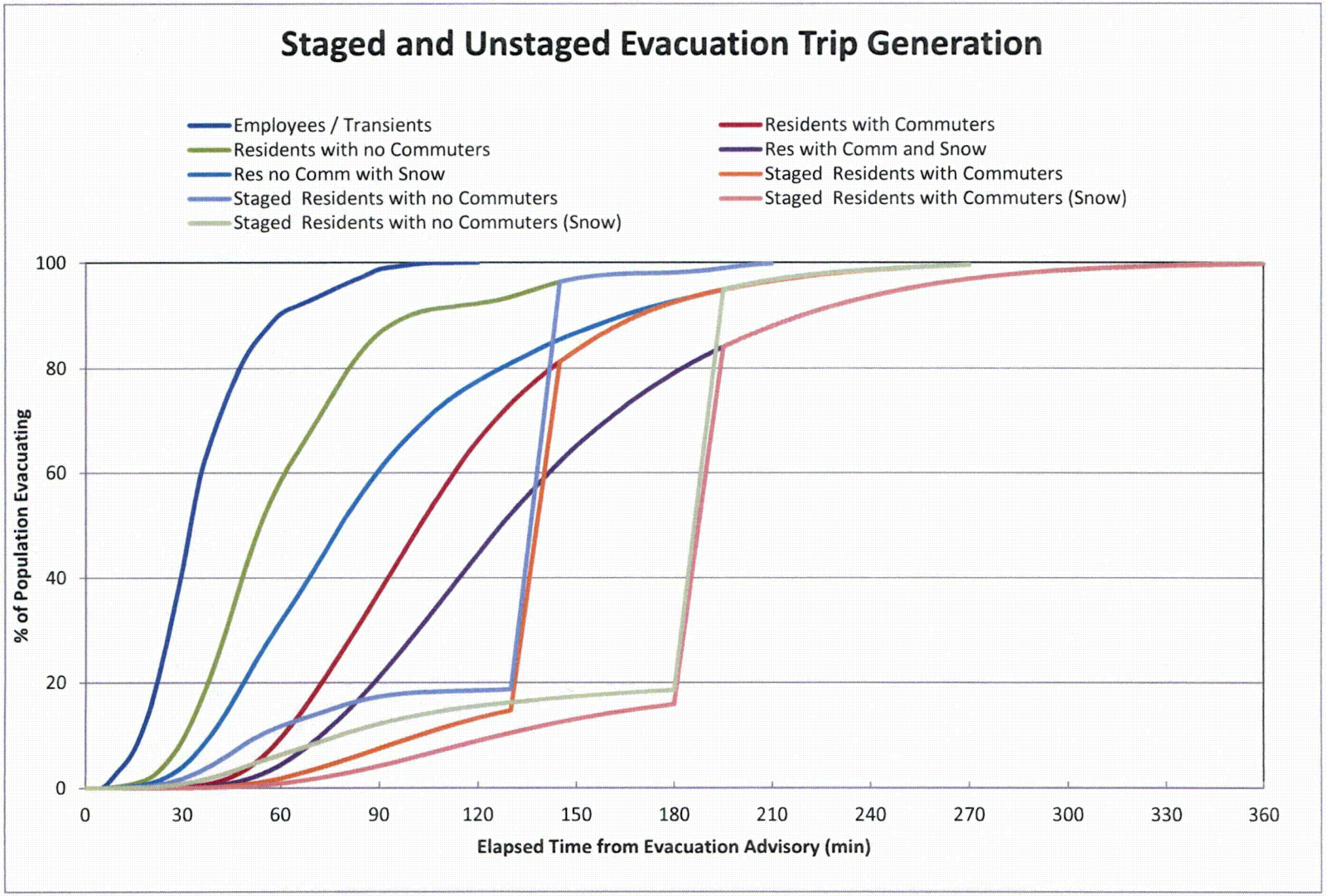


Figure 5-5. Comparison of Staged and Unstaged Trip Generation Distributions in the 2 to 5 Mile Region

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 evacuating sub-areas 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 27 Regions were defined which encompass all the groupings of sub-areas considered. These Regions are defined in Table 6-1. The sub-area configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a central circle centered at the power plant, and three adjoining sectors, each with a central angle of 22.5 degrees, as per NUREG/CR-7002 guidance. The central sector coincides with the wind direction. These sectors extend to 5 miles from the plant (Regions R04 through R08) or to the EPZ boundary (Regions R09 through R21). Regions R01, R02 and R03 represent evacuations of circular areas with radii of 2, 5 and 10 miles, respectively. Regions R22 through R27 are identical to Regions R02 and R04 through R08, respectively; however, those sub-areas between 2 miles and 5 miles are staged until 90% of the 2-mile region (Region R01) has evacuated.

A total of 14 Scenarios were evaluated for all Regions. Thus, there are a total of 27x14=378 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 estimated to evacuate for each scenario. Table 6-4 presents the vehicle counts for each scenario for an evacuation of Region R03 – the entire EPZ.

The vehicle estimates presented in Section 3 are peak values. These peak values are adjusted depending on the scenario and region being considered, using scenario and region specific percentages, such that the average population is considered for each evacuation case. The scenario percentages are presented in Table 6-3, while the regional percentages are provided in Table H-1. The percentages presented in Table 6-3 were determined as follows:

The number of residents with commuters during the week (when workforce is at its peak) is equal to the product of 65% (the number of households with at least one commuter) and 38% (the number of households with a commuter that would await the return of the commuter prior to evacuating). See assumption 3 in Section 2.3. It is estimated for weekend and evening scenarios that 10% of households with returning commuters will have a commuter at work during those times.

Employment is assumed to be at its peak during the winter, midweek, midday scenarios.

Employment is reduced slightly (96%) for summer, midweek, midday scenarios. This is based on the estimation that 50% of the employees commuting into the EPZ will be on vacation for a week during the approximate 12 weeks of summer. It is further estimated that those taking vacation will be uniformly dispersed throughout the summer with approximately 4% of employees vacationing each week. It is further estimated that only 10% of the employees are working in the evenings and during the weekends.

Transient activity is estimated to be at its peak during summer weekends and less (80%) during the week. As shown in Appendix E, there is a significant amount of lodging and campgrounds offering overnight accommodations in the EPZ; thus, transient activity is estimated to be high during evening hours – 40% for summer and 15% for winter. Transient activity on winter weekends is estimated to be 35%.

As noted in the shadow footnote to Table 6-3, the shadow percentages are computed using a base of 20% (see assumption 5 in Section 2.2); to include the employees within the shadow region who may choose to evacuate, the voluntary evacuation is multiplied by a scenario-specific proportion of employees to permanent residents in the shadow region. For example, using the values provided in Table 6-4 for Scenario 1, the shadow percentage is computed as follows:

$$20\% \times \left(1 + \frac{1{,}048}{12{,}175 + 37{,}110}\right) = 20\%$$

One special event – Plymouth 4th of July Fireworks – was considered as Scenario 13. Thus, the special event traffic is 100% evacuated for Scenario 13, and 0% for all other scenarios.

It is estimated that summer school enrollment is approximately 10% of enrollment during the regular school year for summer, midweek, midday scenarios. School is not in session during weekends and evenings, thus no buses for school children are needed under those circumstances. As discussed in Section 7, schools are in session during the winter season, midweek, midday and 100% of buses will be needed under those circumstances. Transit buses for the transit-dependent population are set to 100% for all scenarios as it is assumed that the transit-dependent population is present in the EPZ for all scenarios.

External traffic is estimated to be reduced by 60% during evening scenarios and is 100% for all other scenarios.

Table 6-1. Description of Evacuation Regions

Basic Regions													
Region	Description	Site PAR Description	Sub-area										
			1	2	3	4	5	6	7	8	9	10	11	12
R01	2-Mile Radius	2-Mile Ring	x											x
R02	5-Mile Radius	5-Mile Ring	x	x	x	x								x
R03	Full EPZ	10-Mile Ring	x	x	x	x	x	x	x	x	x	x	x	x
Evacuate 2-Mile Radius and Downwind to 5 Miles														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R04	NW, NNW, N	306° - 019°	x	x										x
R05	NNE, NE, ENE	020° - 069°	x	x	x									x
R06	E	070° - 122°	x		x									x
R07	ESE, SE	123° - 140°	x		x	x								x
R08	SSE, S	141° - 183°	x			x								x
N/A	SSW, SW, WSW, W, WNW	184° - 305°	Refer to Region R01											
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R09	NW, NNW, N	319° - 019°	x	x	x	x	x							x
R10	-	020° - 021°	x	x	x	x	x	x						x
R11	NNE, NE	022° - 056°	x	x	x	x	x	x					x	x
R12	-	057° - 066°	x	x	x	x		x					x	x
R13	-	067° - 069°	x	x	x	x		x	x				x	x
R14	ENE	070° - 103°	x	x	x	x		x	x	x			x	x
R15	E, ESE	104° - 109°	x	x	x	x		x	x	x	x		x	x
R16	-	110° - 115°	x	x	x	x		x	x	x	x			x
R17	-	116° - 129°	x	x	x	x			x	x	x			x
R18	SE	130° - 132°	x	x	x	x			x	x	x	x		x
R19	-	133° - 140°	x	x	x	x				x	x	x		x
R20	SSE, S	141° - 175°	x	x	x	x					x	x		x
R21	-	176° - 179°	x	x	x	x						x		x
N/A	SSW, SW, WSW, W, WNW	180° - 318°	Refer to Region R02											
Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R22	None	5-Mile Ring	x	x	x	x								x
R23	NW, NNW, N	020° - 069°	x	x										x
R24	NNE, NE, ENE	070° - 122°	x	x	x									x
R25	E	123° - 140°	x		x									x
R26	ESE, SE	141° - 183°	x		x	x								x
R27	SSE, S	184° - 305°	x			x								x
N/A	SSW, SW, WSW, W, WNW	2-Mile Ring	Refer to Region R01											
Key														
Shelter-in-Place until 90% ETE for R01, then Evacuate			Sub-area(s) Shelter-in-Place											Sub-area(s) Evacuate

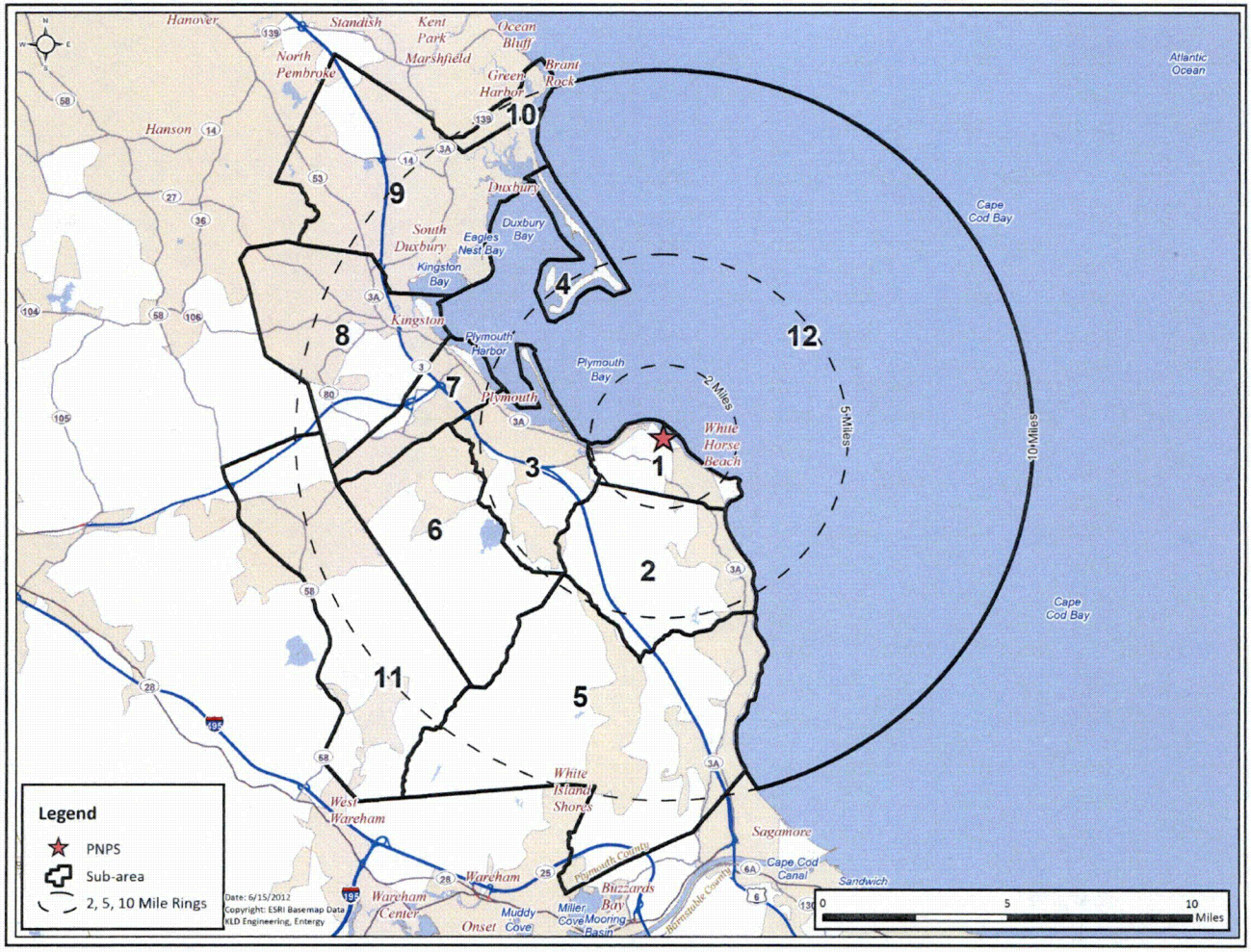


Figure 6-1. PNPs EPZ Sub-areas

Table 6-2. Evacuation Scenario Definitions

Scenario	Season[1]	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	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Weekend	Evening	Good	Plymouth 4th of July Fireworks
14	Summer	Midweek	Midday	Good	Roadway Impact – Lane Closure on Rt. 3 NB

[1] Winter means that school is in session (also applies to spring and autumn). Summer means that school is not in session.

Table 6-3. Percent of Population Groups Evacuating for Various Scenarios

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Events	School Buses	Transit Buses	External Through Traffic
1	25%	75%	96%	80%	20%	0%	10%	100%	100%
2	25%	75%	96%	80%	20%	0%	10%	100%	100%
3	10%	90%	10%	100%	21%	0%	0%	100%	100%
4	10%	90%	10%	100%	21%	0%	0%	100%	100%
5	10%	90%	10%	40%	21%	0%	0%	100%	40%
6	25%	75%	100%	25%	20%	0%	100%	100%	100%
7	25%	75%	100%	25%	20%	0%	100%	100%	100%
8	25%	75%	100%	25%	20%	0%	100%	100%	100%
9	10%	90%	10%	35%	21%	0%	0%	100%	100%
10	10%	90%	10%	35%	21%	0%	0%	100%	100%
11	10%	90%	10%	35%	21%	0%	0%	100%	100%
12	10%	90%	10%	15%	21%	0%	0%	100%	40%
13	10%	90%	10%	40%	21%	100%	0%	100%	40%
14	25%	75%	96%	80%	20%	0%	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 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 20% relocation of shadow residents along with a proportional percentage of shadow employees.
Special Events .....Additional vehicles in the EPZ due to the identified special event.
School and Transit Buses .....Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people and correctional facility population (1 bus is equivalent to 2 passenger vehicles).
External Through Traffic .....Traffic on interstates/freeways and major arterial roads at the start of the evacuation. This traffic is stopped by access control approximately 2 hours after the evacuation begins.

Table 6-4. Vehicle Estimates by Scenario

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Events	School Buses	Transit Buses[1]	External Through Traffic	Total Scenario Vehicles
1	12,175	37,110	2,045	9,040	8,557	-	86	220	22,260	91,493
2	12,175	37,110	2,045	9,040	8,557	-	86	220	22,260	91,493
3	1,218	48,067	213	11,300	8,397	-	-	220	22,260	91,675
4	1,218	48,067	213	11,300	8,397	-	-	220	22,260	91,675
5	1,218	48,067	213	3,277	8,397	-	-	220	8,904	70,296
6	12,175	37,110	2,130	2,825	8,564	-	855	220	22,260	86,139
7	12,175	37,110	2,130	2,825	8,564	-	855	220	22,260	86,139
8	12,175	37,110	2,130	2,825	8,564	-	855	220	22,260	86,139
9	1,218	48,067	213	3,955	8,397	-	-	220	22,260	84,330
10	1,218	48,067	213	3,955	8,397	-	-	220	22,260	84,330
11	1,218	48,067	213	3,955	8,397	-	-	220	22,260	84,330
12	1,218	48,067	213	1,695	8,397	-	-	220	8,904	68,714
13	1,218	48,067	213	3,277	8,397	10,417	-	220	8,904	80,713
14	12,175	37,110	2,045	9,040	8,557	-	86	220	22,260	91,493

[1]Transit buses include buses used to evacuate the transit-dependent permanent resident population and those buses used to evacuate the correctional facilities within the EPZ.

Note: Vehicle estimates are for an evacuation of the entire EPZ (Region R03)

7 GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the ETE results of the computer analyses using the DYNEV II System described in Appendices B, C and D. These results cover 27 regions within the PNPS EPZ and the 14 Evacuation Scenarios discussed in Section 6.

The ETE for all Evacuation Cases are presented in Table 7-1 and Table 7-2. These tables present the estimated times to clear the indicated population percentages from the Evacuation Regions for all Evacuation Scenarios. The ETE of the 2-mile region in both staged and un-staged regions are presented in Table 7-3 and Table 7-4. Table 7-5 defines the Evacuation Regions considered. The tabulated values of ETE are obtained from the DYNEV II System outputs which are generated at 5-minute intervals.

7.1 Voluntary Evacuation and Shadow Evacuation

"Voluntary evacuees" are people within the EPZ in sub-areas for which an Advisory to Evacuate has not been issued, yet who elect to evacuate. "Shadow evacuation" is the voluntary outward movement of some people from the Shadow Region (outside the EPZ) for whom no protective action recommendation has been issued. Both voluntary and shadow evacuations are assumed to take place over the same time frame as the evacuation from within the impacted Evacuation Region.

The ETE for the PNPS EPZ addresses the issue of voluntary evacuees in the manner shown in Figure 7-1. Within the EPZ, 20 percent of people located in sub-areas outside of the evacuation region who are not advised to evacuate, are assumed to elect to evacuate. Similarly, it is assumed that 20 percent of those people in the Shadow Region will choose to leave the area.

Figure 7-2 presents the area identified as the Shadow Region. This region extends radially from the plant to cover a region between the EPZ boundary and approximately 15 miles. The population and number of evacuating vehicles in the Shadow Region were estimated using the same methodology that was used for permanent residents within the EPZ (see Section 3.1). As discussed in Section 3.2, it is estimated that a total of 79,277 people reside in the Shadow Region; 20 percent of them would evacuate. See Table 6-4 for the number of evacuating vehicles from the Shadow Region.

Traffic generated within this Shadow Region, traveling away from the PNPS location, has the potential for impeding evacuating vehicles from within the Evacuation Region. All ETE calculations include this shadow traffic movement.

7.2 Staged Evacuation

As defined in NUREG/CR-7002, staged evacuation consists of the following:

1. Sub-areas comprising the 2 mile region are advised to evacuate immediately.
2. Sub-areas comprising regions extending from 2 to 5 miles downwind are advised to shelter in-place while the two mile region is cleared.

3. As vehicles evacuate the 2 mile region, people from 2 to 5 miles downwind continue preparation for evacuation while they shelter.
4. The population sheltering in the 2 to 5 mile region is advised to evacuate when approximately 90% of the 2 mile region evacuating traffic crosses the 2 mile region boundary.
5. Non-compliance with the shelter recommendation is the same as the shadow evacuation percentage of 20%.

See Section 5.4.2 for additional information on staged evacuation.

7.3 Patterns of Traffic Congestion during Evacuation

Figure 7-3 through Figure 7-9 illustrate the patterns of traffic congestion that arise for the case when the entire EPZ (Region R03) is advised to evacuate during the summer, midweek, midday period under good weather conditions (Scenario 1).

Traffic congestion, as the term is used here, is defined as Level of Service (LOS) F. LOS F is defined as follows (HCM 2010, page 5-5):

> The HCM uses LOS F to define operations that have either broken down (i.e., demand exceeds capacity) or have exceeded a specified service measure value, or combination of service measure values, that most users would consider unsatisfactory. However, particularly for planning applications where different alternatives may be compared, analysts may be interested in knowing just how bad the LOS F condition is. Several measures are available to describe individually, or in combination, the severity of a LOS F condition:
>
> • *Demand-to-capacity ratios* describe the extent to which capacity is exceeded during the analysis period (e.g., by 1%, 15%, etc.);
>
> • *Duration of LOS F* describes how long the condition persists (e.g., 15 min, 1 h, 3 h); and
>
> • *Spatial extent measures* describe the areas affected by LOS F conditions. These include measures such as the back of queue, and the identification of the specific intersection approaches or system elements experiencing LOS F conditions.

All highway "links" which experience LOS F are delineated in these figures by a thick red line; all others are lightly indicated. Congestion develops rapidly around concentrations of population and traffic bottlenecks. Figure 7-3 displays the developing congestion within the EPZ, just 30 minutes after the Advisory to Evacuate (ATE). Note that US-44, which serves as one of the main evacuation routes out of the EPZ, displays fully developed congestion (LOS F) just outside the EPZ where the highway narrows to a single lane. Route 3, which is servicing the external-external trips, is displaying moderate traffic demand (LOS C and D) on those sections exiting the EPZ (southbound to the south; northbound to the north).

At one hour after the ATE, Figure 7-4 displays an EPZ that is fully congested, particularly the

population centers of Plymouth and Duxbury. To the south, there are a limited number of routes exiting the EPZ; as such, evacuating vehicles are queued along Route 3A and Long Pond Rd well into the 5-mile region. There are few access points to Route 25 and I-195 south of the EPZ, which causes congestion in the towns of Buzzards Bay and Wareham. Traffic congestion along Route 3 is now fully developed in the town of Plymouth and to the north of the EPZ in the town Marshfield. State Route 58 is experiencing significant congestion towards US-44 which is prohibiting the rate of evacuees exiting Sub-areas 6 and 11. Congestion along Beaver Dam Rd, which is used to access Route 3, in Sub-area 2 is fully developed which has created moderate congestion within the 2-mile ring and in Sub-Area 1.

At 2 hours, as shown in Figure 7-5, traffic congestion persists along US-44 westbound, Route 3 in the town of Plymouth, and Route 3A Southbound and Long Pond Rd. Traffic congestion in Sub-areas 6 and 11 and in the towns of Plymouth and Duxbury begins to dissipate. The 2-mile region is now clear of congestion. Heavy congestion still exists to the south of the EPZ in Buzzards Bay and Wareham, and to the north in Pembroke. The congestion in the shadow is impeding the flow of evacuating traffic out of the EPZ.

At 2 hours, 45 minutes, as shown in Figure 7-6, the town of Plymouth is now clear of congestion. Congested conditions remain on US-44 westbound, Route 3 northbound in Marshfield, along Long Pond Rd and Route 3A to the south, and in the shadow region around the towns of Buzzards Bay and Wareham. The 5-mile region is essentially clear of congestion with the exception of Route 3A.

At 3 hours, 30 minutes, the 5-mile area is cleared of congestion as shown in Figure 7-7. The portion of US-44 within the EPZ is also free of congestion. The town of Duxbury is essentially clear of congestion. Long Pond Rd has been cleared of congestion, but LOS F still remains along Route 3A. Congestion in the shadow still persists in the towns of Buzzards Bay and Wareham to the south. Congestion in Pembroke has begun to dissipate and no longer extends into the EPZ. Congestion on Route 3 clears within the EPZ at 2 hours, 50 minutes.

At 4 hours, Figure 7-8 displays an EPZ that is essentially clear of congestion. Congestion to the south in the town of Wareham causes some queuing into the EPZ in Sub-area 11 along Tihonet Rd. Traffic congestion within the EPZ clears at 4:10 after the ATE, which is before the completion of trip-generation (mobilization) time.

Finally, at 4 hours, 30 minutes after the ATE, the lone remnant of congestion is in the shadow region to the south, in the town of Wareham, as shown in Figure 7-9. This traffic clears at 4:45 after the ATE.

7.4 Evacuation Rates

Evacuation is a continuous process, as implied by Figure 7-10 through Figure 7-23. These Figures indicate the rate at which traffic flows out of the indicated areas for the case of an evacuation of the full EPZ (Region R03) under the indicated conditions. One figure is presented for each scenario considered.

As indicated in Figure 7-10, there is typically a long "tail" to these distributions. Vehicles begin

to evacuate an area slowly at first, as people respond to the ATE at different rates. Then traffic demand builds rapidly (slopes of curves increase). When the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand.

This decline in aggregate flow rate, towards the end of the process, is characterized by these curves flattening and gradually becoming horizontal. Ideally, it would be desirable to fully saturate all evacuation routes equally so that all will service traffic near capacity levels and all will clear at the same time. For this ideal situation, all curves would retain the same slope until the end – thus minimizing evacuation time. In reality, this ideal is generally unattainable reflecting the spatial variation in population density, mobilization rates and in highway capacity over the EPZ.

7.5 Evacuation Time Estimate (ETE) Results

Table 7-1 through Table 7-2 present the ETE values for all 27 Evacuation Regions and all 14 Evacuation Scenarios. Table 7-3 through Table 7-4 present the ETE values for the 2-Mile region for both staged and un-staged keyhole regions downwind to 5 miles. They are organized as follows:

Table	Contents
7-1	ETE represents the elapsed time required for 90 percent of the population within a Region, to evacuate from that Region. All Scenarios are considered, as well as Staged Evacuation scenarios.
7-2	ETE represents the elapsed time required for 100 percent of the population within a Region, to evacuate from that Region. All Scenarios are considered, as well as Staged Evacuation scenarios.
7-3	ETE represents the elapsed time required for 90 percent of the population within the 2-mile Region, to evacuate from that Region with both Concurrent and Staged Evacuations.
7-4	ETE represents the elapsed time required for 100 percent of the population within the 2-mile Region, to evacuate from that Region with both Concurrent and Staged Evacuations.

The animation snapshots described above reflect the ETE statistics for the concurrent (un-staged) evacuation scenarios and regions, which are displayed in Figure 7-3 through Figure 7-9. Most of the congestion is located in the shadow, south of Sub-area 5; this is reflected in the ETE statistics:

- The 90th percentile ETE for Regions R01 and R02 (2- and 5-mile areas) are comparable and generally range between 1:50 (hr:min) and 2:15 (higher for snow).

- The 90th percentile ETE for Regions R03 (full EPZ) and R09 – R11 (which extend to the EPZ boundary to the south) are approximately an hour longer.

The 100th percentile ETE for all Regions and for all Scenarios are the same values as the mobilization times plus a short travel time. This fact implies that the congestion within the EPZ dissipates prior to the end of mobilization, as is displayed in Figure 7-9.

Comparison of Scenarios 5 and 13 in Table 7-1 indicates that the Special Event – 4th of July Fireworks in Plymouth – has a material impact on the ETE for the 90th percentile for Regions R03 (full EPZ) and Regions R13 – R18 (Regions which include Sub-area 7) with increases up to 25 minutes. As discussed in Section 6, the external traffic is reduced by 60% for these scenarios as they are evening scenarios. The additional 10,417 vehicles present for the special event increase congestion on the local roads in Plymouth and on the ramps to Route 3. However, much of the capacity along Route 3 is available because of the reduced external traffic. As a result, the 100th percentile ETE is unaffected by the special event.

Comparison of Scenarios 1 and 14 in Table 7-1 indicates that the roadway closure – one lane northbound on Route 3 from the interchange with Clark Road (Exit 3) to the end of the analysis-network after the interchange with Church Street (Exit 12) – has a material impact on the 90th and 100th percentile ETE, with increases up to 40 minutes and 15 minutes respectively. As discussed in Section 7.3, the congestion on Route 3 is localized around the population centers of Plymouth in the EPZ and in Marshfield in the Shadow. Plymouth is located within the 5-mile region, and therefore the 90th percentile ETE increases by up to 40 minutes for regions which extend downwind to 5 miles. Winds from the South and East (Regions R16 through R19) carry the plume over the population center of Plymouth which routes traffic onto Route 3. With a lane closed on Route 3 northbound, the capacity is reduced to half, increasing congestion and prolonging ETE.

The results of the roadway impact scenario indicate that events such as adverse weather or traffic accidents which close a lane on Route 3, could impact ETE. State and local police could consider traffic management tactics such as using the shoulder of the roadway as a travel lane or re-routing of traffic along other evacuation routes to avoid overwhelming Route 3. All efforts should be made to remove the blockage on Route 3, particularly within the first 3 hours of the evacuation.

7.6 Staged Evacuation Results

Table 7-3 and Table 7-4 present a comparison of the ETE compiled for the concurrent (un-staged) and staged evacuation studies. Note that Regions R22 through R27 are the same geographic areas as Regions R02 and R04 through R08, respectively.

To determine whether the staged evacuation strategy is worthy of consideration, one must show that the ETE for the 2 Mile region can be reduced without significantly affecting the region between 2 miles and 5 miles. In all cases, as shown in these tables, the ETE for the 2 mile region is unchanged when a staged evacuation is implemented. The reason for this is that the congestion within the 5-mile area does not extend upstream to the extent that it penetrates to

within 2 miles of the PNPS. Consequently, the impedance, due to this congestion within the 5-mile area, to evacuees from within the 2-mile area is not sufficient to materially influence the 90th percentile ETE for the 2-mile area. Therefore, staging the evacuation to sharply reduce congestion within the 5-mile area, provides no benefits to evacuees from within the 2 mile region and unnecessarily delays the evacuation of those beyond 2 miles.

While failing to provide assistance to evacuees from within 2 miles of the PNPS, staging produces a negative impact on the ETE for those evacuating from within the 5-mile area. A comparison of ETE between Regions, R22 and R02; R23 and R04; R24 and R05; R25 and R06; R26 and R07; and R27 and R08 reveals that staging retards the 90th percentile evacuation time for those in the 2 to 5-mile area by up to 40 minutes for non-snow scenarios and 1 hour and 20 minutes for snow scenarios (see Table 7-1). This extending of ETE is due to the delay in beginning the evacuation trip, experienced by those who shelter, plus the effect of the trip-generation "spike" (significant volume of traffic beginning the evacuation trip at the same time) that follows their eventual ATE, in creating congestion within the EPZ area beyond 2 miles.

In summary, the staged evacuation option provides no benefits and adversely impacts many evacuees located beyond 2 miles from the PNPS.

7.7 Guidance on Using ETE Tables

The user first determines the percentile of population for which the ETE is sought (The NRC guidance calls for the 90th percentile). The applicable value of ETE within the chosen Table may then be identified using the following procedure:

1. Identify the applicable **Scenario**:
   - Season
     - Summer
     - Winter (also Autumn and Spring)
   - Day of Week
     - Midweek
     - Weekend
   - Time of Day
     - Midday
     - Evening
   - Weather Condition
     - Good Weather
     - Rain
     - Snow
   - Special Event
     - Plymouth 4th of July Fireworks
     - Road Closure (One lane on Rt. 3 northbound is closed)
   - Evacuation Staging
     - No, Staged Evacuation is not considered
     - Yes, Staged Evacuation is considered

While these Scenarios are designed, in aggregate, to represent conditions throughout the year, some further clarification is warranted:

- The conditions of a summer evening (either midweek or weekend) and rain are not explicitly identified in the Tables. For these conditions, Scenarios (2) and (4) apply.
- The conditions of a winter evening (either midweek or weekend) and rain are not explicitly identified in the Tables. For these conditions, Scenarios (7) and (10) for rain apply.
- The conditions of a winter evening (either midweek or weekend) and snow are not explicitly identified in the Tables. For these conditions, Scenarios (8) and (11) for snow apply.
- The seasons are defined as follows:
  - Summer assumes that public schools are not in session.
  - Winter (includes Spring and Autumn) considers that public schools are in session.
- Time of Day: Midday implies the time over which most commuters are at work or are travelling to/from work.

2. With the desired percentile ETE and Scenario identified, now identify the **Evacuation Region**:
   - Determine the projected azimuth direction of the plume (coincident with the wind direction). This direction is expressed in terms of compass orientation: from N, NNE, NE, ...
   - Determine the distance that the Evacuation Region will extend from the nuclear power plant. The applicable distances and their associated candidate Regions are given below:
     - 2 Miles (Region R01)
     - To 5 Miles (Region R02, R04 through R08)
     - To EPZ Boundary (Regions R03, R09 through R21)
   - Enter Table 7-5 and identify the applicable group of candidate Regions based on the distance that the selected Region extends from PNPS. Select the Evacuation Region identifier in that row, based on the azimuth direction of the plume, from the first column of the Table.
3. Determine the **ETE Table based on the percentile selected. Then, for the Scenario** identified in Step 1 and the **Region** identified in Step 2, proceed as follows:
   - The columns of Table 7-1 are labeled with the Scenario numbers. Identify the proper column in the selected Table using the Scenario number defined in Step 1.
   - Identify the row in this table that provides ETE values for the Region identified in Step 2.
   - The unique data cell defined by the column and row so determined contains the desired value of ETE expressed in Hours:Minutes.

Example

It is desired to identify the ETE for the following conditions:

- Sunday, August 10th at 4:00 AM.
- It is raining.
- Wind direction is from the northeast (NE).
- Wind speed is such that the distance to be evacuated is judged to be a 5-mile radius and downwind to 10 miles (to EPZ boundary).
- The desired ETE is that value needed to evacuate 90 percent of the population from within the impacted Region.
- A staged evacuation is not desired.

Table 7-1 is applicable because the 90th percentile ETE is desired. Proceed as follows:

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to Scenario 4.
2. Enter Table 7-5 and locate the Region described as "Evacuate 5-Mile Radius and Downwind to the EPZ Boundary" for wind direction from the NE and read Region R11 in the first column of that row.
3. Enter Table 7-1 to locate the data cell containing the value of ETE for Scenario 4 and Region R11. This data cell is in column (4) and in the row for Region R11; it contains the ETE value of 2:55.

Table 7-1. Time to Clear the Indicated Area of *90* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R02	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:35	2:10	2:10	2:30	2:10	2:20	2:45
R03	2:55	3:05	2:55	3:05	2:40	2:45	3:00	3:30	2:40	2:55	3:20	2:40	3:00	3:20
2-Mile Region and Keyhole to 5 Miles														
R04	2:10	2:15	2:10	2:10	2:15	2:10	2:15	2:30	2:10	2:10	2:25	2:15	2:15	2:30
R05	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:35	2:10	2:10	2:30	2:10	2:20	2:45
R06	2:05	2:05	2:00	2:00	2:00	2:05	2:10	2:20	2:00	2:05	2:15	2:00	2:20	2:45
R07	2:05	2:05	2:00	2:00	2:00	2:05	2:10	2:20	2:00	2:05	2:15	2:00	2:20	2:45
R08	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
5-Mile Region and Keyhole to EPZ Boundary														
R09	2:45	2:50	2:40	2:50	2:45	2:40	2:50	3:20	2:35	2:50	3:15	2:45	2:45	3:10
R10	2:40	2:50	2:30	2:50	2:40	2:40	2:45	3:20	2:30	2:40	3:15	2:35	2:45	3:10
R11	2:40	2:55	2:40	2:55	2:40	2:40	2:50	3:15	2:35	2:45	3:10	2:35	2:50	3:10
R12	2:25	2:30	2:15	2:25	2:15	2:20	2:25	2:55	2:10	2:20	2:45	2:15	2:35	2:50
R13	2:35	2:40	2:30	2:40	2:20	2:30	2:40	3:10	2:20	2:30	3:00	2:20	2:45	2:40
R14	2:30	2:45	2:25	2:35	2:20	2:30	2:40	3:15	2:20	2:30	2:55	2:20	2:45	2:55
R15	2:40	2:50	2:35	2:45	2:25	2:35	2:45	3:20	2:25	2:35	3:05	2:25	2:50	3:10
R16	2:25	2:35	2:25	2:35	2:20	2:25	2:35	3:05	2:20	2:30	2:55	2:20	2:35	3:00
R17	2:25	2:40	2:30	2:35	2:20	2:25	2:35	3:05	2:20	2:30	2:55	2:20	2:35	3:05
R18	2:30	2:35	2:25	2:35	2:20	2:25	2:35	3:05	2:25	2:30	2:55	2:20	2:35	3:00
R19	2:20	2:25	2:20	2:25	2:15	2:25	2:25	3:00	2:15	2:25	2:50	2:15	2:25	3:00
R20	2:15	2:20	2:10	2:15	2:15	2:15	2:20	2:45	2:10	2:15	2:35	2:15	2:15	2:45
R21	2:10	2:15	2:10	2:10	2:10	2:15	2:15	2:40	2:10	2:10	2:30	2:10	2:20	2:45
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	2:45	2:50	2:40	2:45	2:50	2:45	2:50	3:50	2:45	2:45	3:50	2:50	2:45	3:10
R23	2:40	2:45	2:40	2:45	2:55	2:45	2:50	3:50	2:40	2:45	3:45	2:55	2:55	3:00
R24	2:45	2:50	2:40	2:45	2:50	2:45	2:50	3:50	2:45	2:45	3:50	2:50	2:45	3:10
R25	2:25	2:30	2:25	2:25	2:30	2:30	2:30	3:25	2:25	2:25	3:25	2:30	2:30	3:00
R26	2:25	2:30	2:25	2:25	2:30	2:30	2:30	3:25	2:25	2:25	3:25	2:30	2:30	3:00
R27	2:15	2:15	1:55	1:55	2:00	2:15	2:15	3:05	2:00	2:00	2:55	2:00	1:55	2:15

Table 7-2. Time to Clear the Indicated Area of *100* Percent of the Affected Population

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region, 5-Mile Region, and EPZ														
R01	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R02	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R03	4:40	4:40	4:40	4:45	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:50
2-Mile Region and Keyhole to 5 Miles														
R04	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R05	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R06	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R07	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R08	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
5-Mile Region and Keyhole to EPZ Boundary														
R09	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R10	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R11	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R12	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R13	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R14	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R15	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:50
R16	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R17	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R18	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:55
R19	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R20	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
R21	4:40	4:40	4:40	4:40	4:40	4:40	4:40	6:10	4:40	4:40	6:10	4:40	4:40	4:40
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R23	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R24	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R25	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R26	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35
R27	4:35	4:35	4:35	4:35	4:35	4:35	4:35	6:05	4:35	4:35	6:05	4:35	4:35	4:35

Table 7-3. Time to Clear *90* Percent of the 2-Mile Area within the Indicated Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R02	2:05	2:05	1:50	2:00	1:50	2:10	2:10	2:55	1:50	2:05	2:40	1:55	2:05	2:05
2-Mile Region and Keyhole to 5 Miles														
R04	2:10	2:10	1:55	2:10	1:55	2:10	2:10	2:55	2:00	2:00	2:45	1:55	1:55	2:10
R05	2:05	2:05	1:50	2:00	1:55	2:10	2:10	2:55	1:50	2:00	2:40	1:55	2:05	2:05
R06	2:00	2:05	1:40	1:40	1:45	2:10	2:10	2:55	1:50	1:50	2:40	1:50	2:05	2:00
R07	2:00	2:05	1:40	1:40	1:45	2:10	2:10	2:55	1:50	1:50	2:40	1:50	2:05	2:00
R08	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R23	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R24	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R25	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R26	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10
R27	2:10	2:10	1:50	1:50	1:50	2:10	2:10	2:55	1:50	1:50	2:45	1:50	1:45	2:10

Table 7-4. Time to Clear *100* Percent of the 2-Mile Area within the Indicated Region

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Evening	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Entire 2-Mile Region and 5-Mile Region														
R01	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R02	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
2-Mile Region and Keyhole to 5 Miles														
R04	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R05	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R06	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R07	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R08	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
Staged Evacuation - 2-Mile Region and Keyhole to 5 Miles														
R22	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R23	4:30	4:35	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R24	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R25	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R26	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30
R27	4:30	4:30	4:30	4:30	4:30	4:30	4:30	6:00	4:30	4:30	6:00	4:30	4:30	4:30

Table 7-5. Description of Evacuation Regions

Basic Regions													
Region	Description	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R01	2-Mile Radius	2-Mile Ring	x											x
R02	5-Mile Radius	5-Mile Ring	x	x	x	x								x
R03	Full EPZ	10-Mile Ring	x	x	x	x	x	x	x	x	x	x	x	x
Evacuate 2-Mile Radius and Downwind to 5 Miles														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R04	NW, NNW, N	306° - 019°	x	x										x
R05	NNE, NE, ENE	020° - 069°	x	x	x									x
R06	E	070° - 122°	x		x									x
R07	ESE, SE	123° - 140°	x		x	x								x
R08	SSE, S	141° - 183°	x			x								x
N/A	SSW, SW, WSW, W, WNW	184° - 305°	Refer to Region R01											
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R09	NW, NNW, N	319° - 019°	x	x	x	x	x							x
R10	-	020° - 021°	x	x	x	x	x	x						x
R11	NNE, NE	022° - 056°	x	x	x	x	x	x					x	x
R12	-	057° - 066°	x	x	x	x		x					x	x
R13	-	067° - 069°	x	x	x	x		x	x				x	x
R14	ENE	070° - 103°	x	x	x	x		x	x	x			x	x
R15	E, ESE	104° - 109°	x	x	x	x		x	x	x	x		x	x
R16	-	110° - 115°	x	x	x	x		x	x	x	x			x
R17	-	116° - 129°	x	x	x	x			x	x	x			x
R18	SE	130° - 132°	x	x	x	x			x	x	x	x		x
R19	-	133° - 140°	x	x	x	x				x	x	x		x
R20	SSE, S	141° - 175°	x	x	x	x					x	x		x
R21	-	176° - 179°	x	x	x	x						x		x
N/A	SSW, SW, WSW, W, WNW	180° - 318°	Refer to Region R02											
Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles														
Region	Wind Direction From:	Site PAR Description	Sub-area											
			1	2	3	4	5	6	7	8	9	10	11	12
R22	None	5-Mile Ring	x	x	x	x								x
R23	NW, NNW, N	020° - 069°	x	x										x
R24	NNE, NE, ENE	070° - 122°	x	x	x									x
R25	E	123° - 140°	x		x									x
R26	ESE, SE	141° - 183°	x		x	x								x
R27	SSE, S	184° - 305°	x			x								x
N/A	SSW, SW, WSW, W, WNW	2-Mile Ring	Refer to Region R01											
Key														
Shelter-in-Place until 90% ETE for R01, then Evacuate			Sub-area(s) Shelter-in-Place							Sub-area(s) Evacuate				

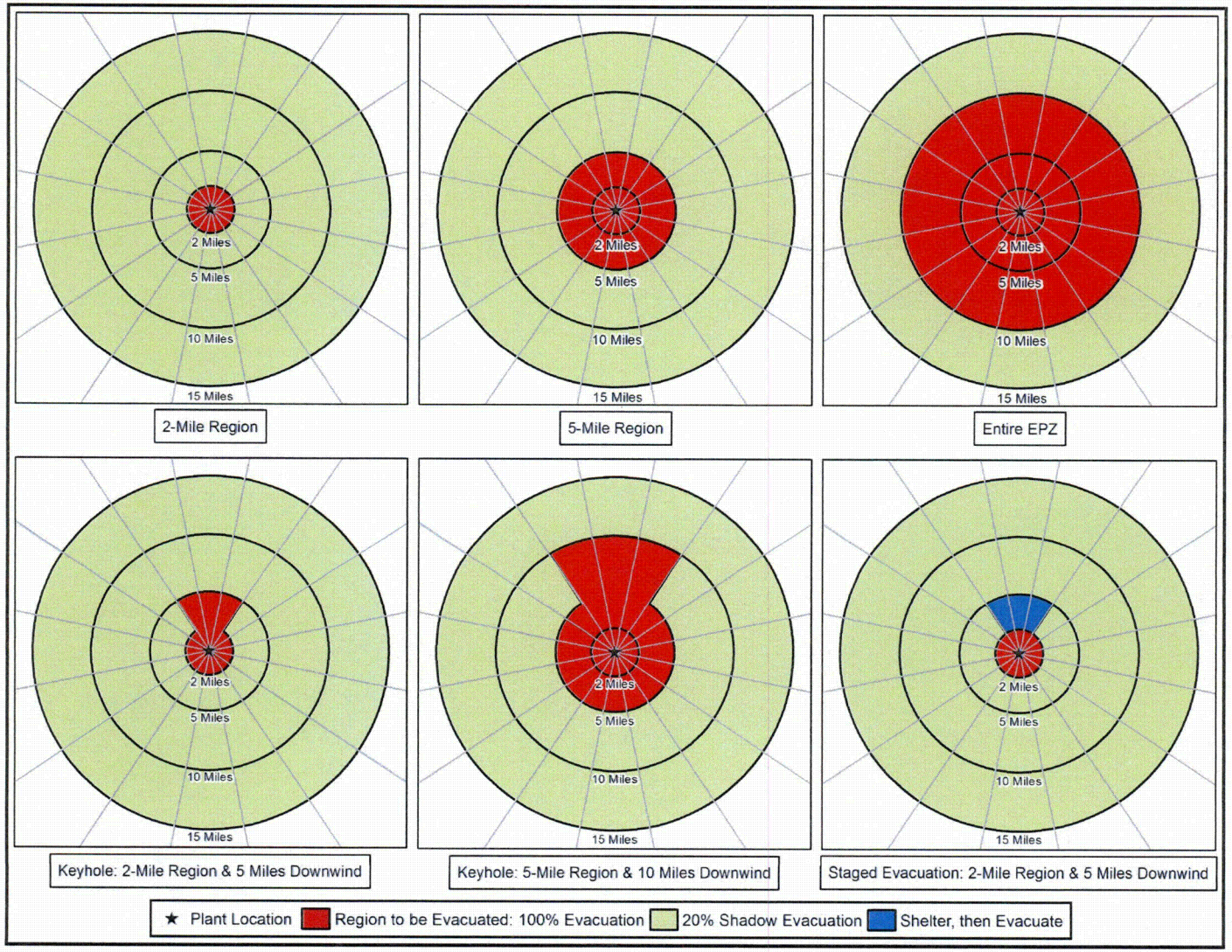


Figure 7-1. Voluntary Evacuation Methodology

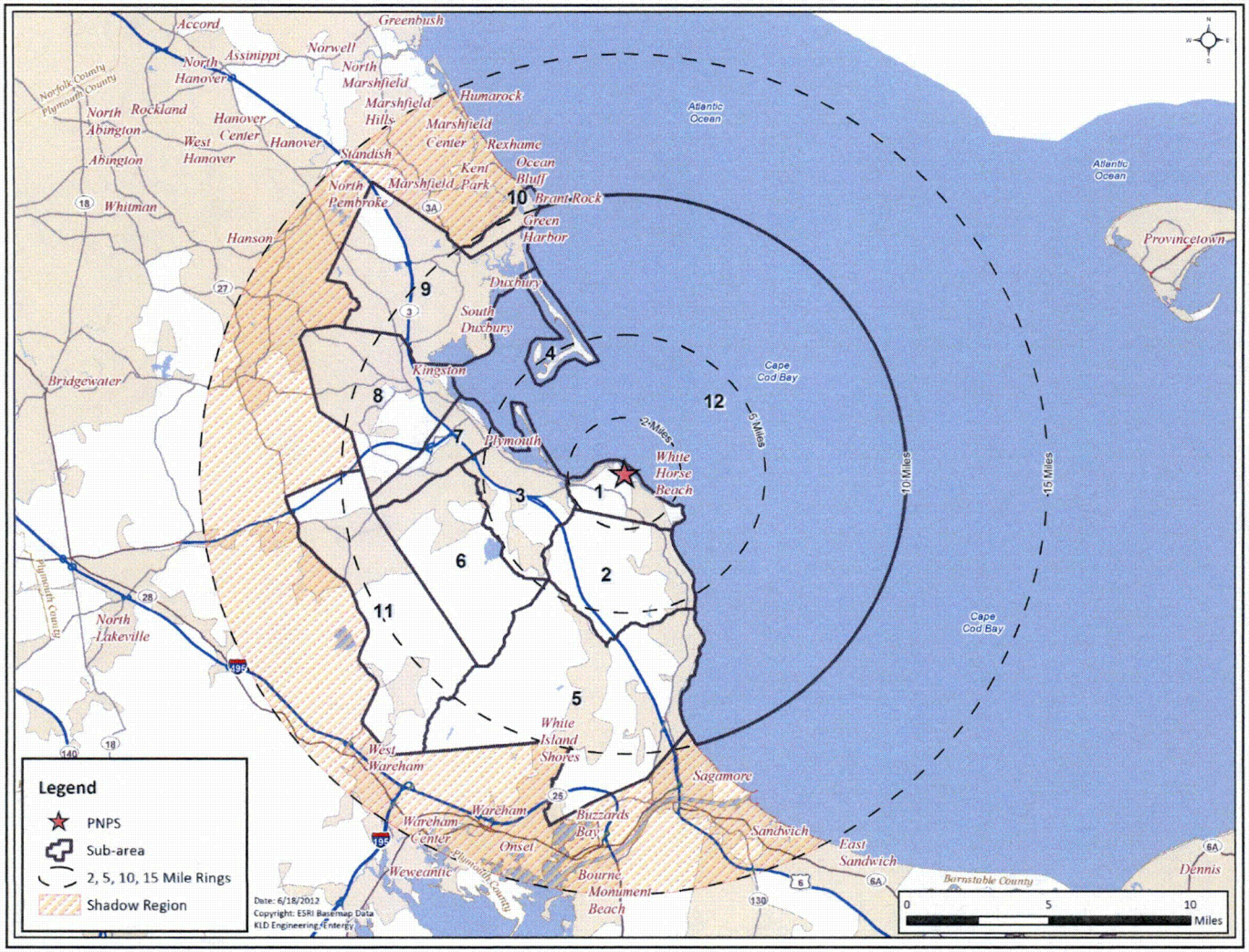


Figure 7-2. PNPS Shadow Region

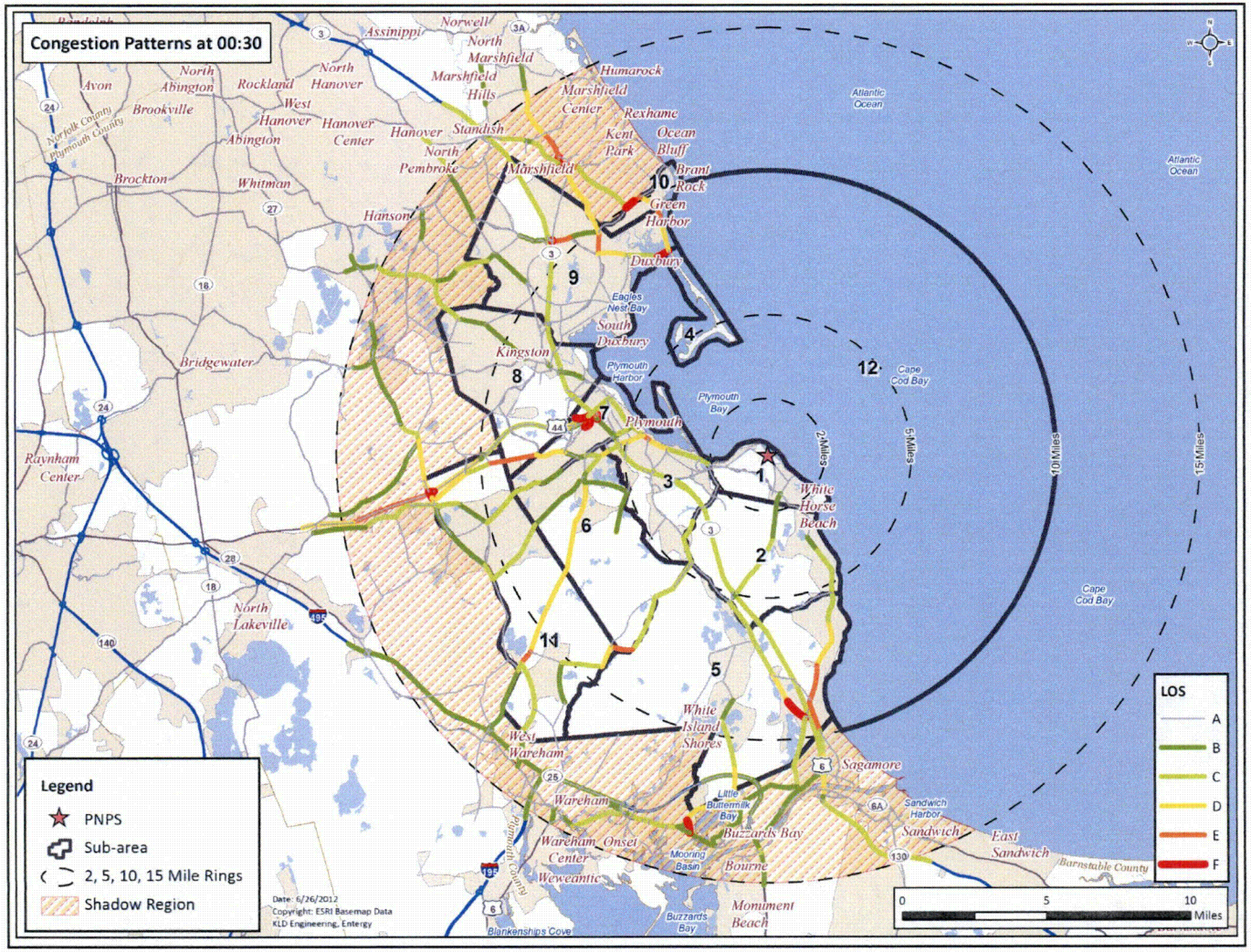


Figure 7-3. Congestion Patterns at 30 Minutes after the Advisory to Evacuate

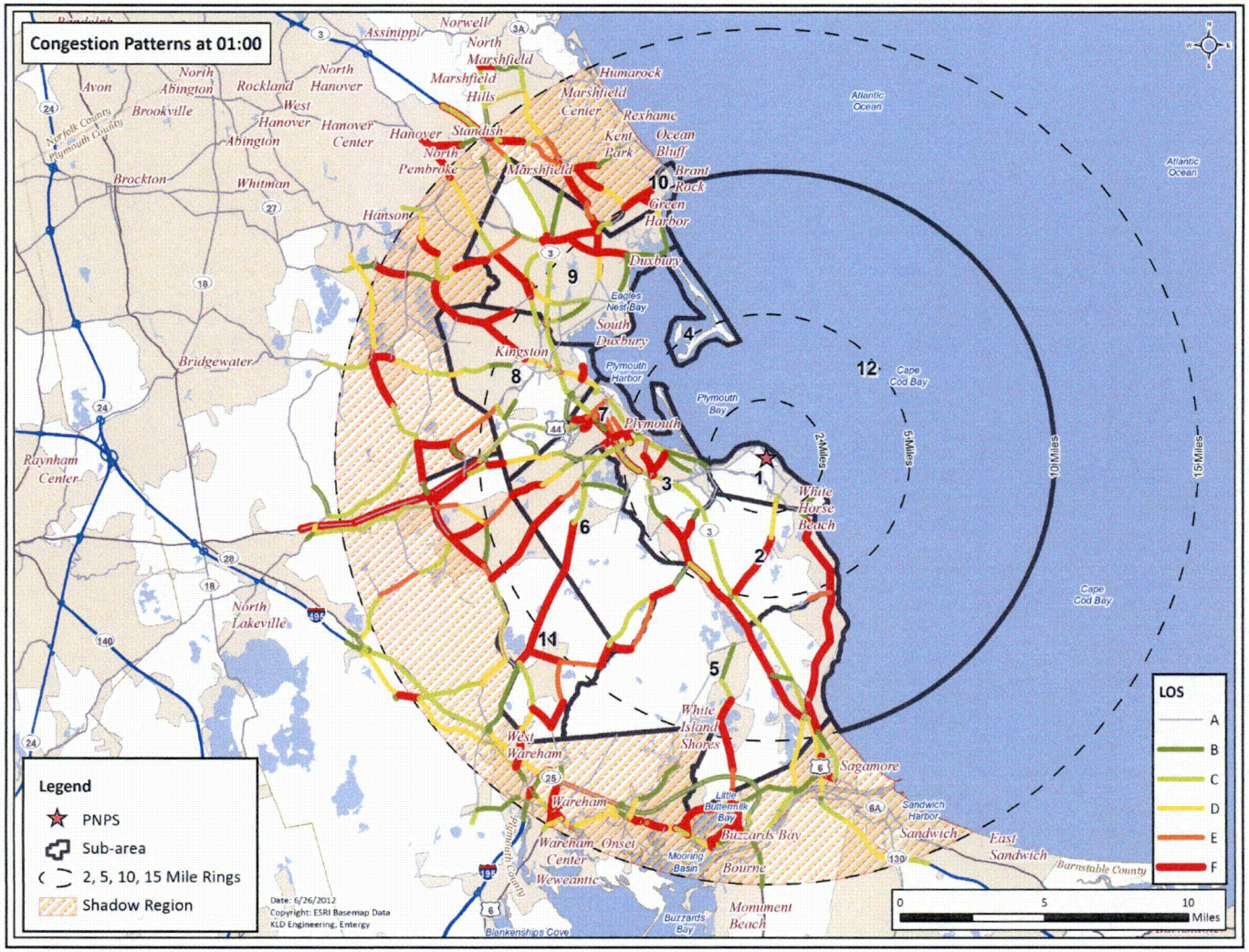


Figure 7-4. Congestion Patterns at 1 Hour after the Advisory to Evacuate

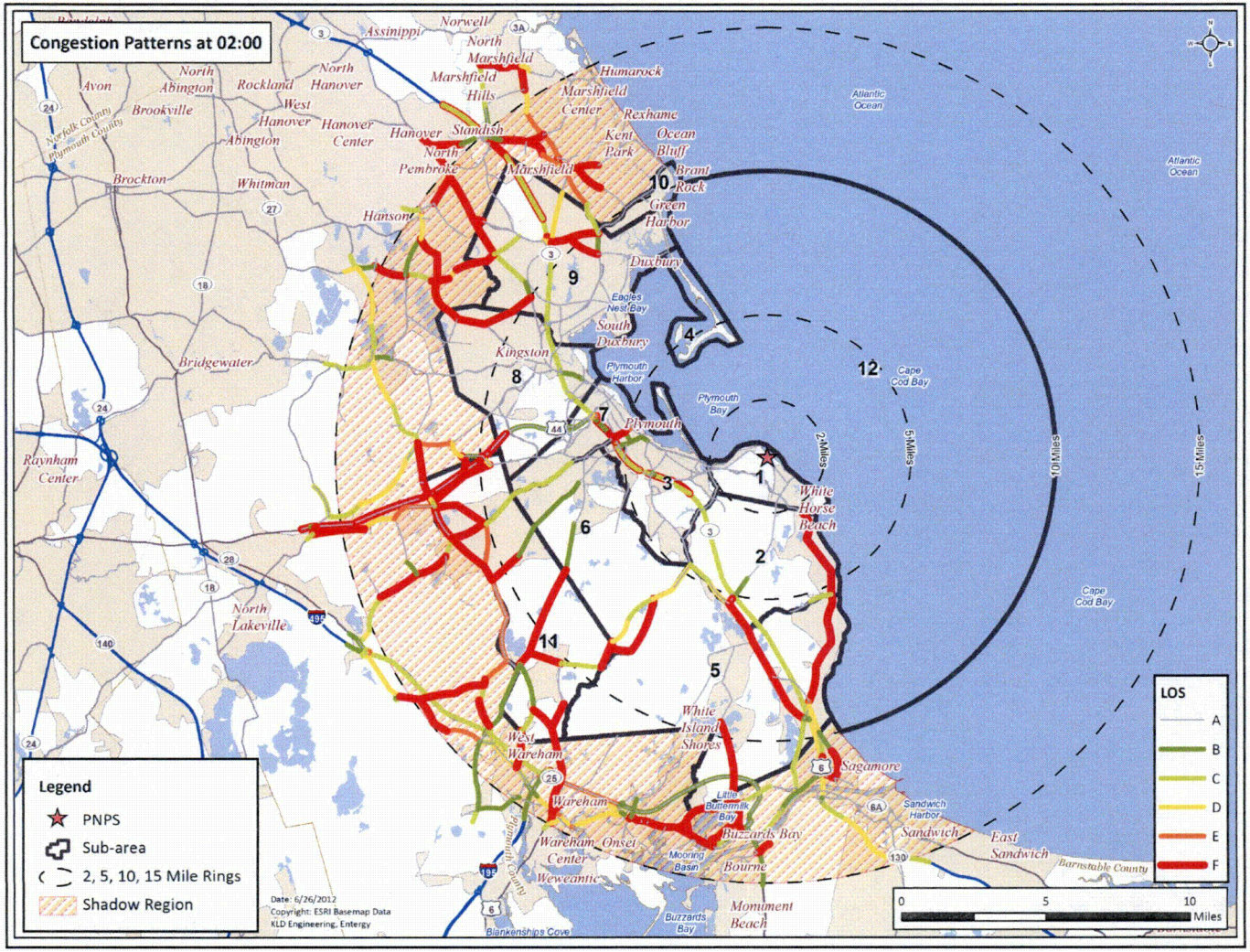


Figure 7-5. Congestion Patterns at 2 Hours after the Advisory to Evacuate

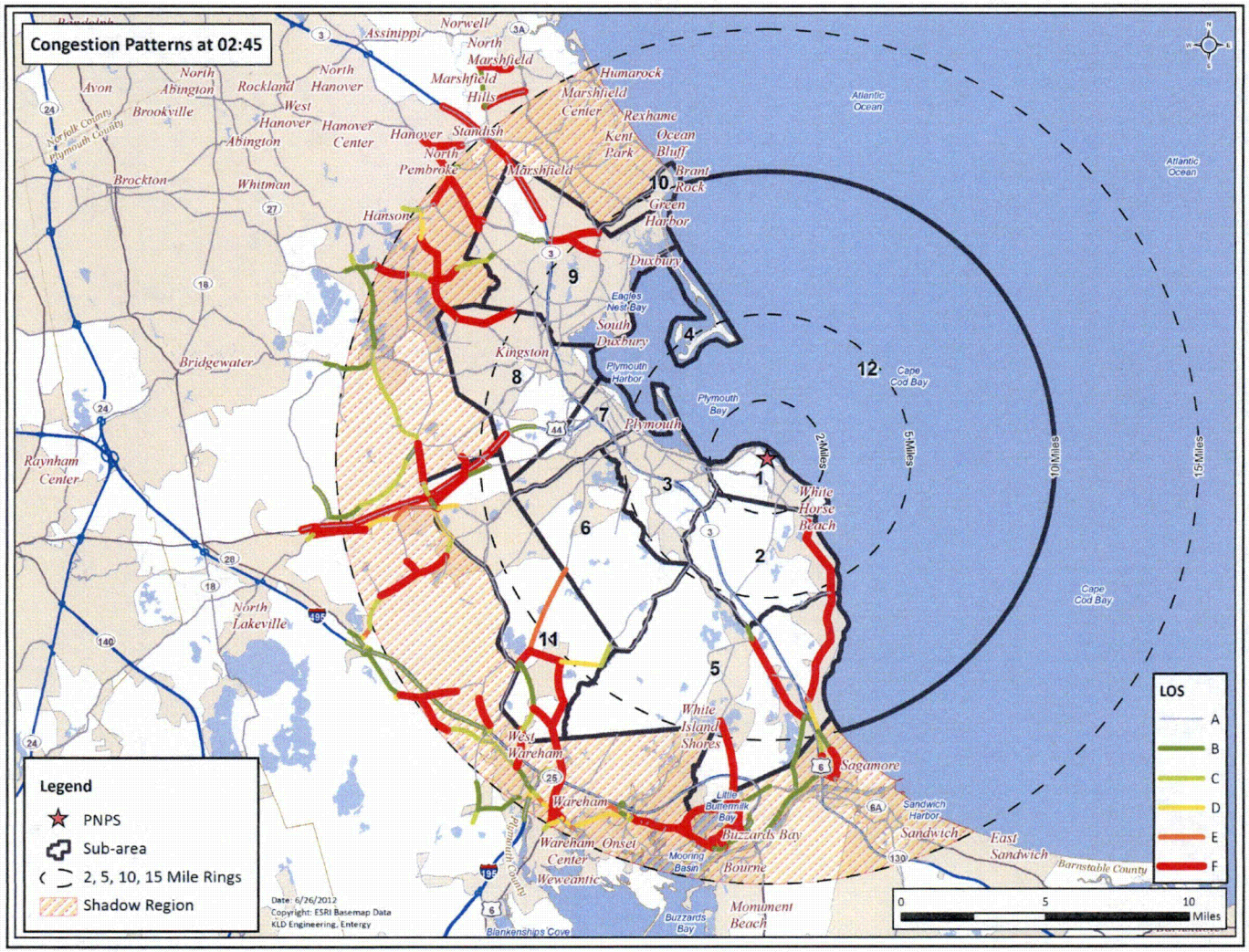


Figure 7-6. Congestion Patterns at 2 Hours and 45 minutes after the Advisory to Evacuate

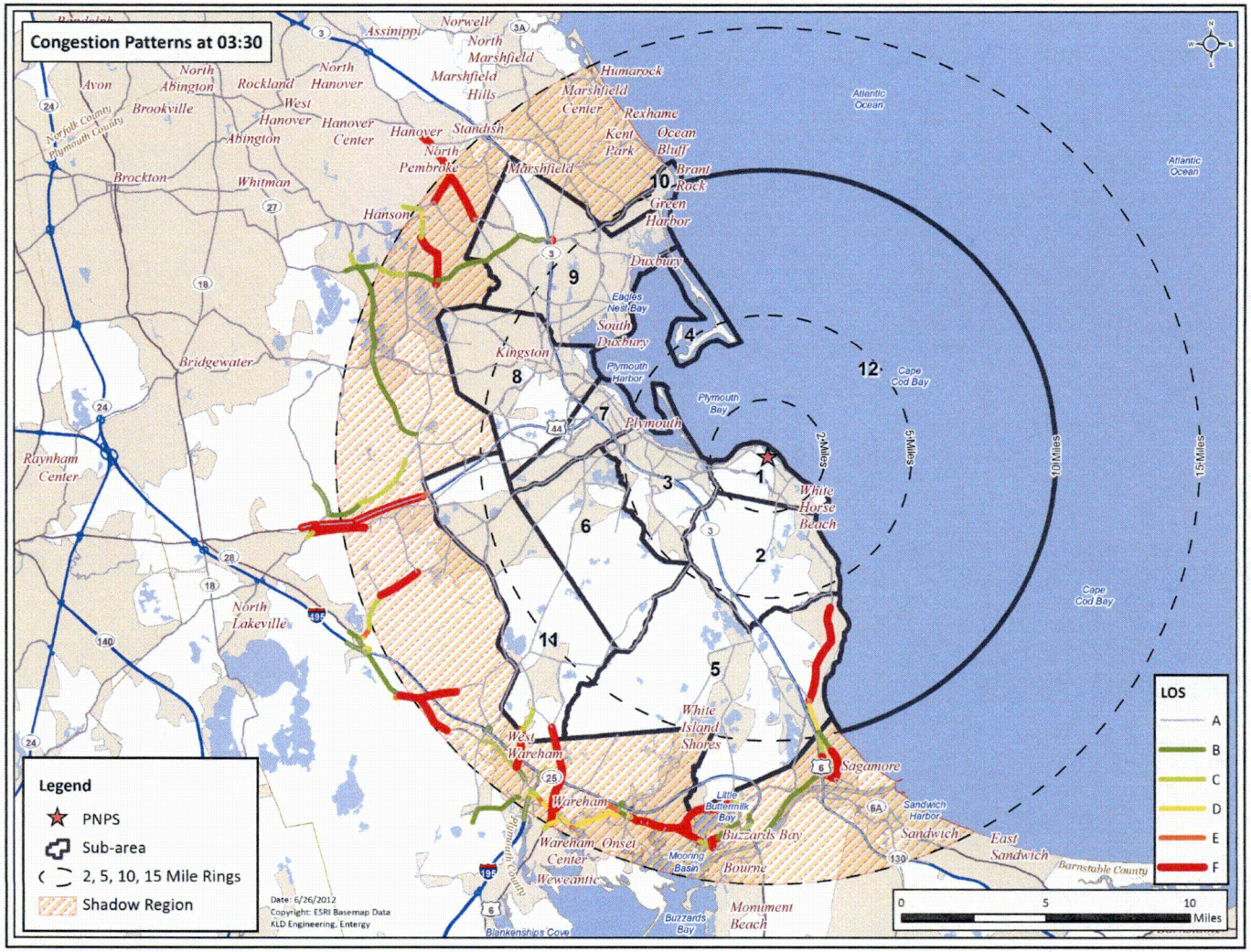


Figure 7-7. Congestion Patterns at 3 Hours, 30 Minutes after the Advisory to Evacuate

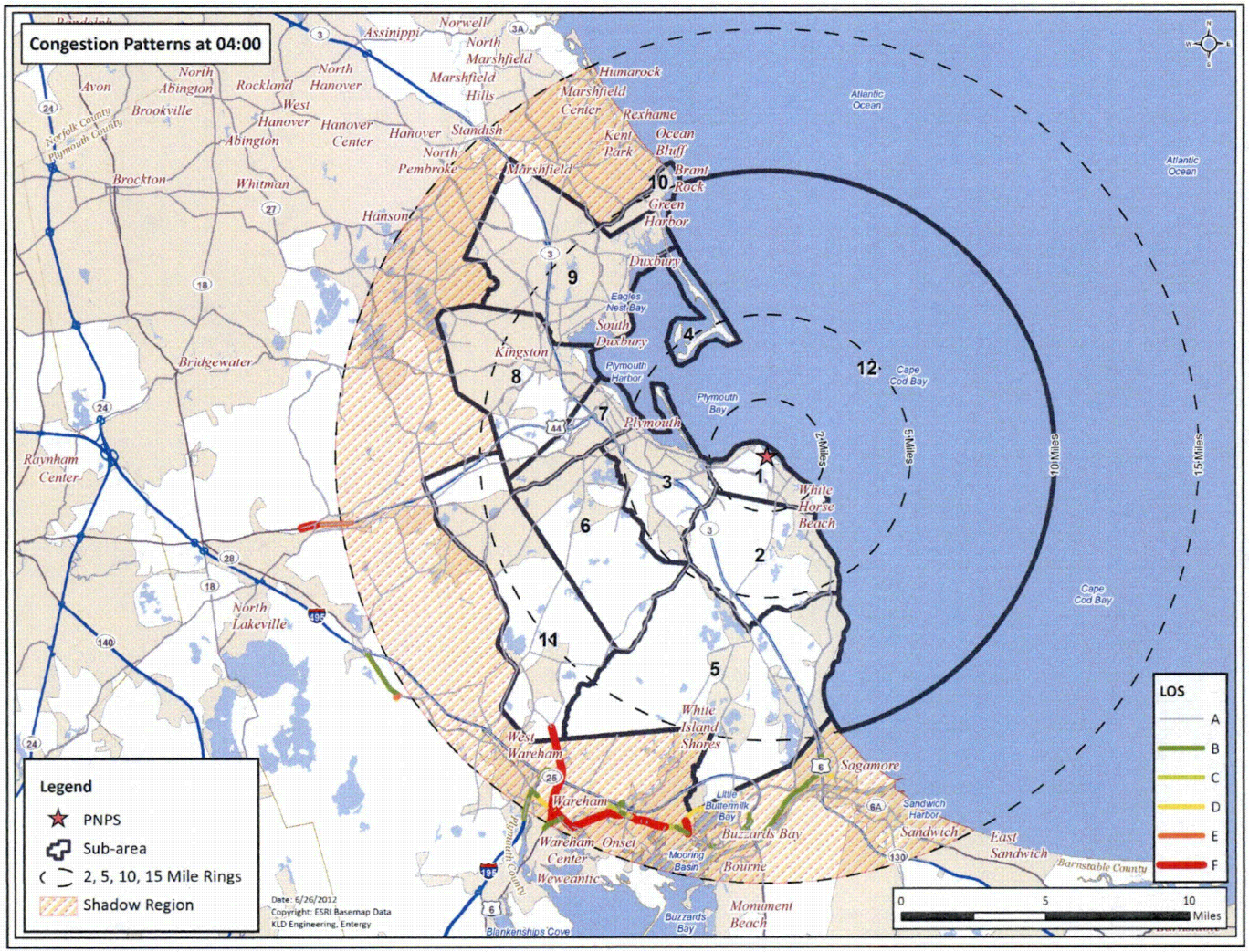


Figure 7-8. Congestion Patterns at 4 Hours after the Advisory to Evacuate

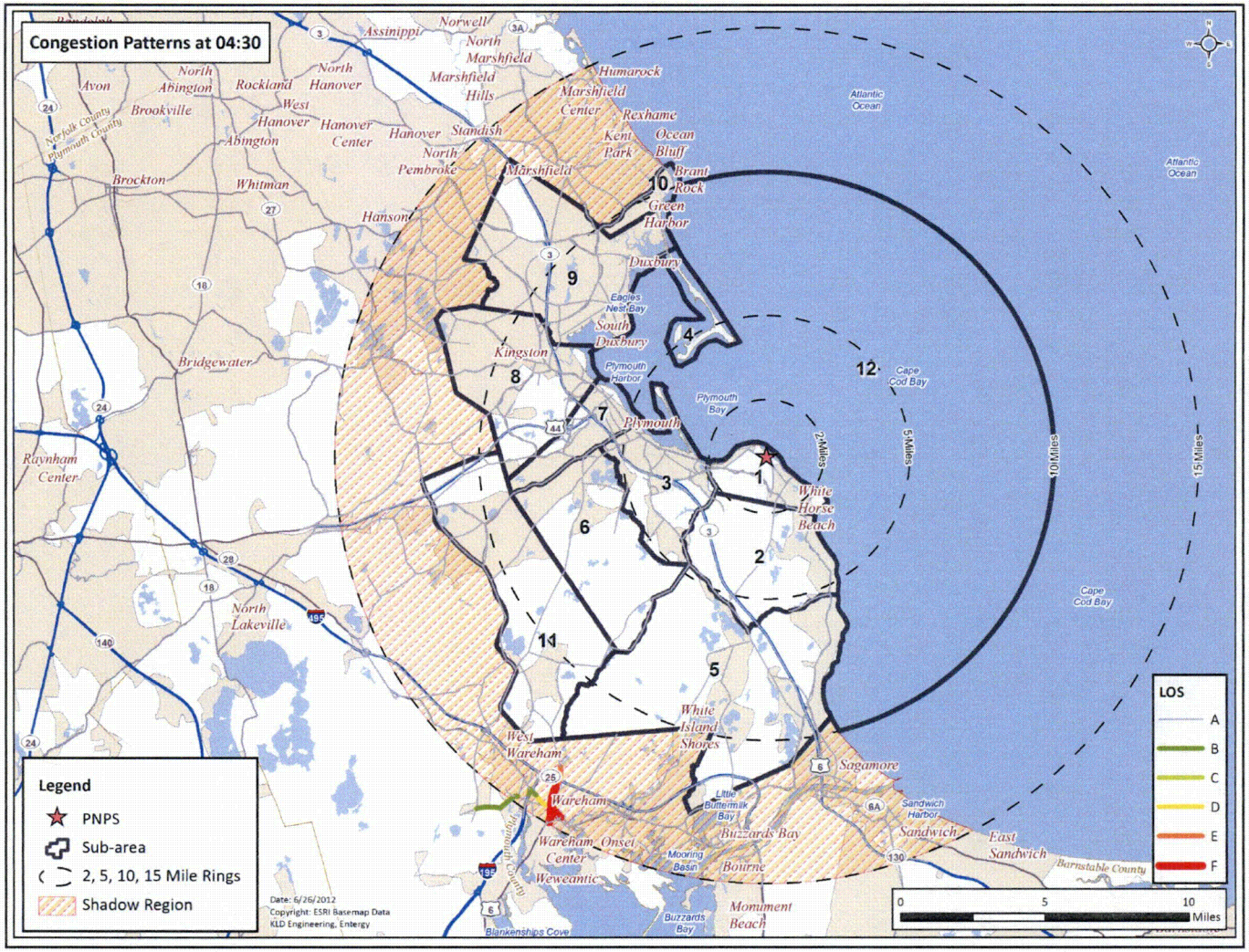


Figure 7-9. Congestion Patterns at 4 Hours and 30 minutes after the Advisory to Evacuate

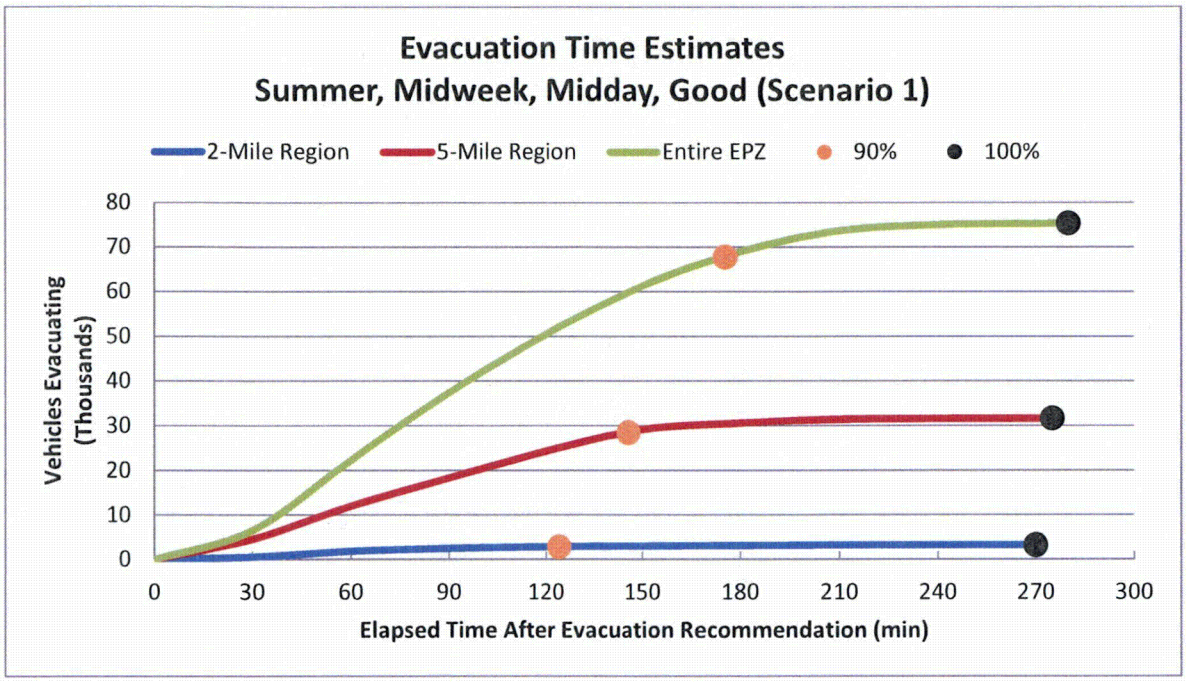


Figure 7-10. Evacuation Time Estimates - Scenario 1 for Region R03

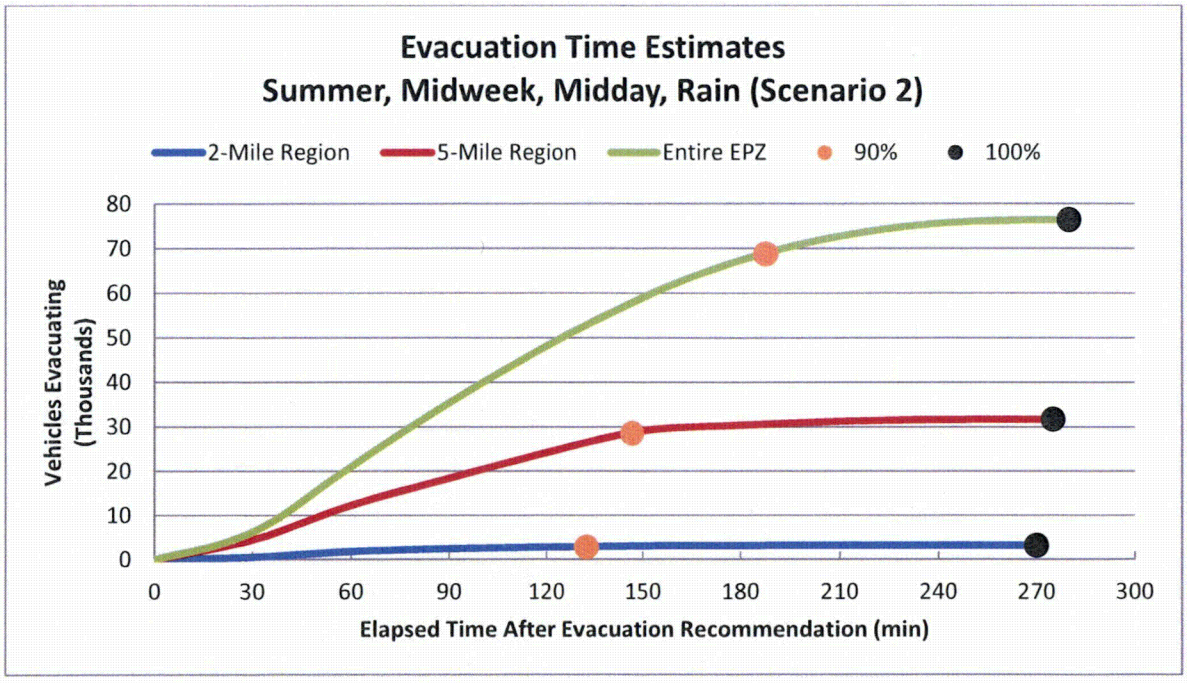


Figure 7-11. Evacuation Time Estimates - Scenario 2 for Region R03

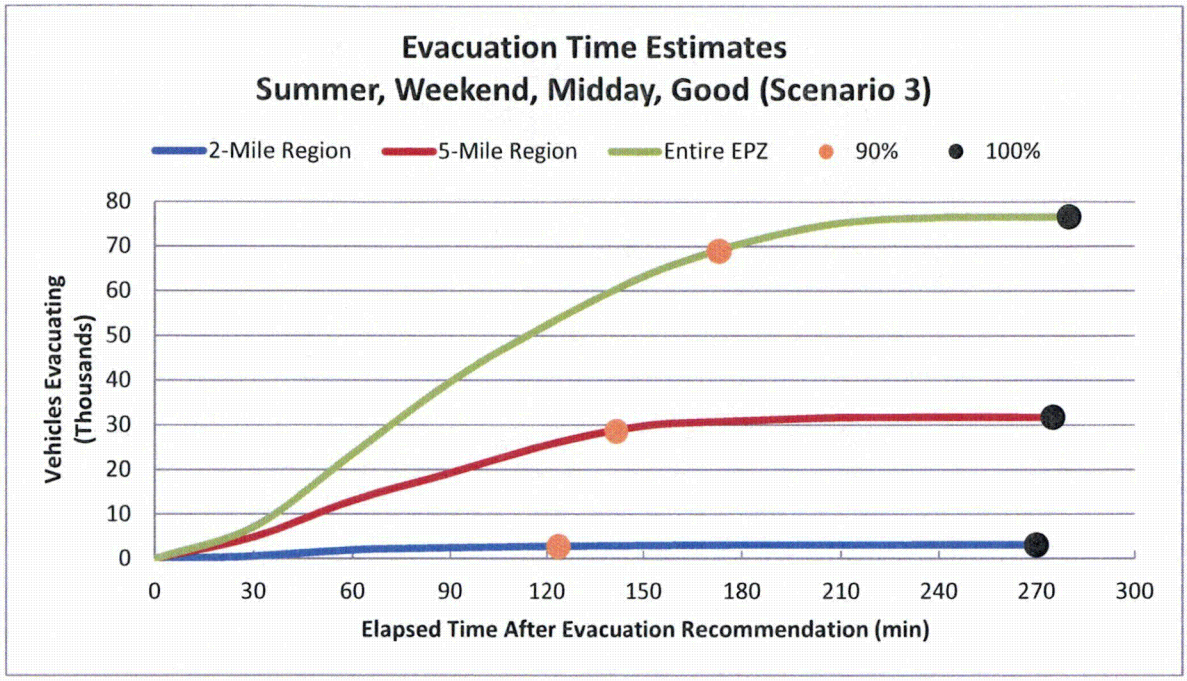


Figure 7-12. Evacuation Time Estimates - Scenario 3 for Region R03

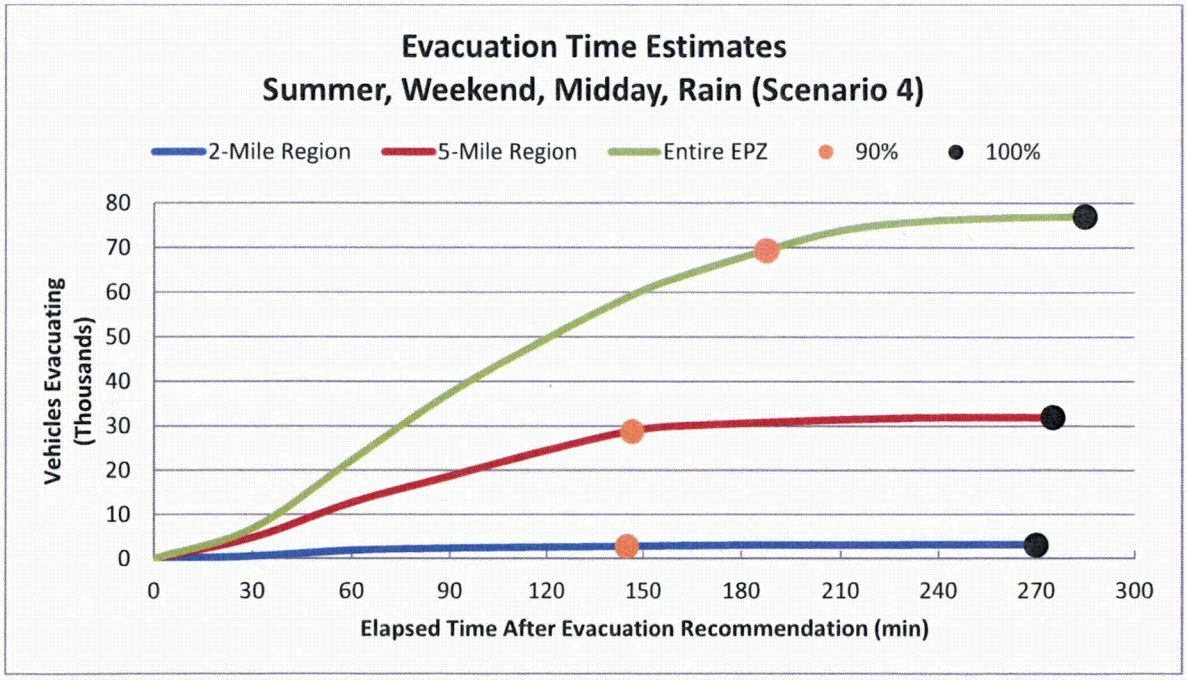


Figure 7-13. Evacuation Time Estimates - Scenario 4 for Region R03

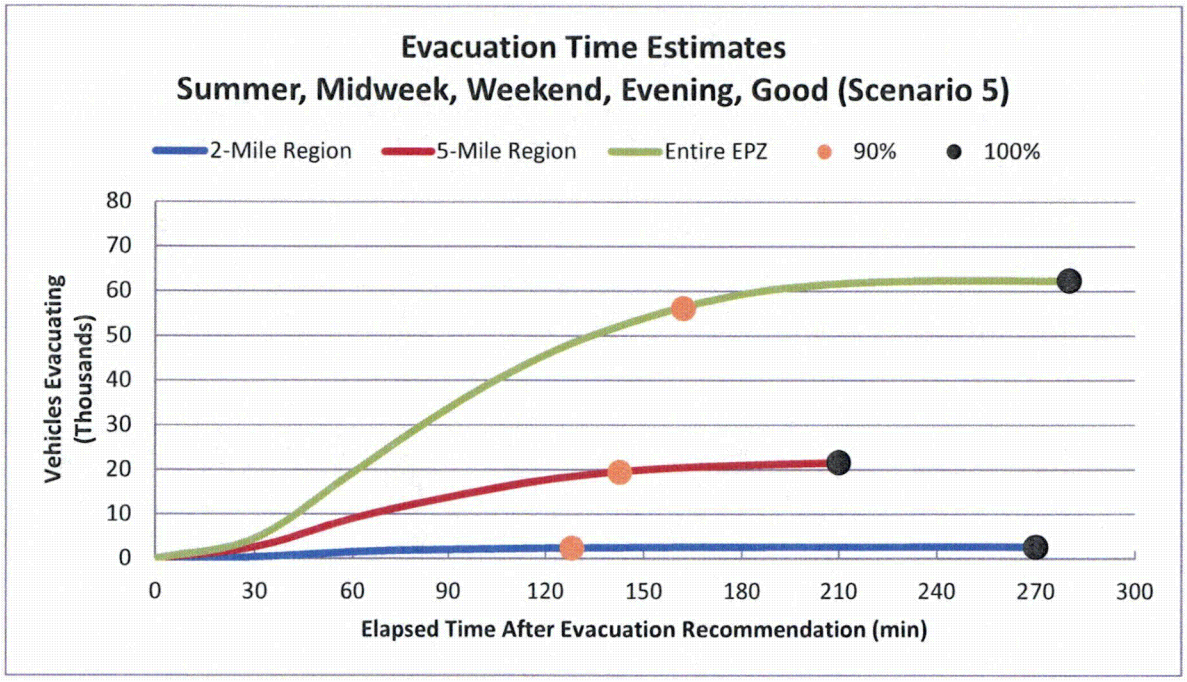


Figure 7-14. Evacuation Time Estimates - Scenario 5 for Region R03

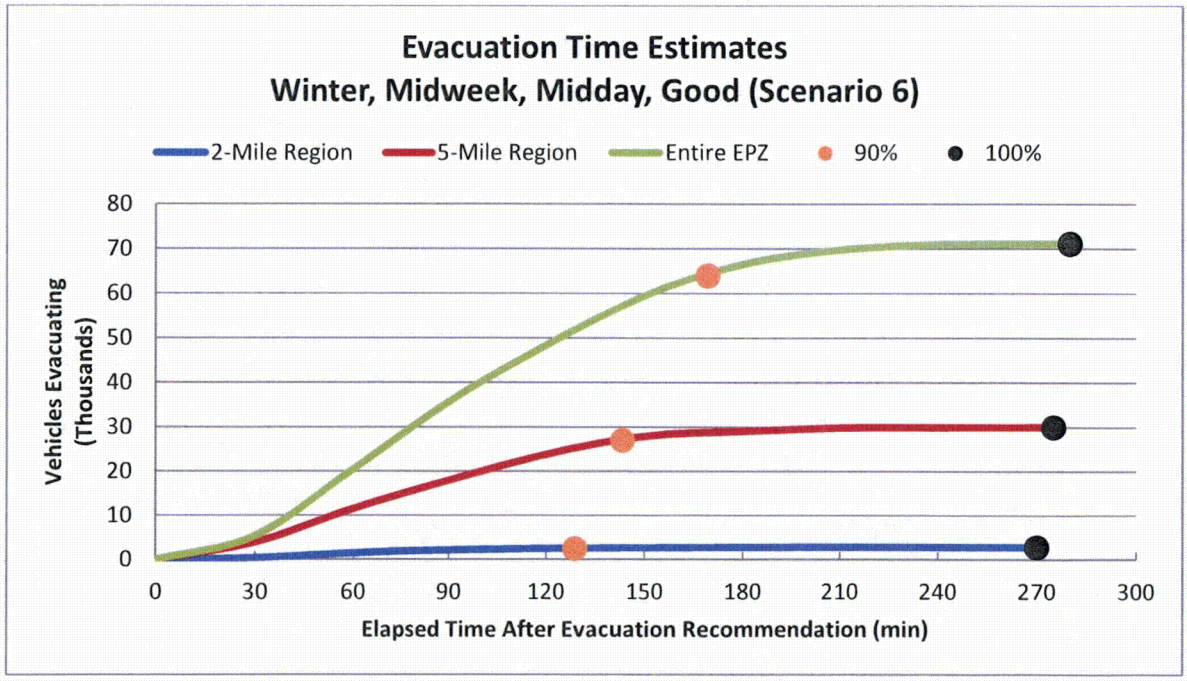


Figure 7-15. Evacuation Time Estimates - Scenario 6 for Region R03

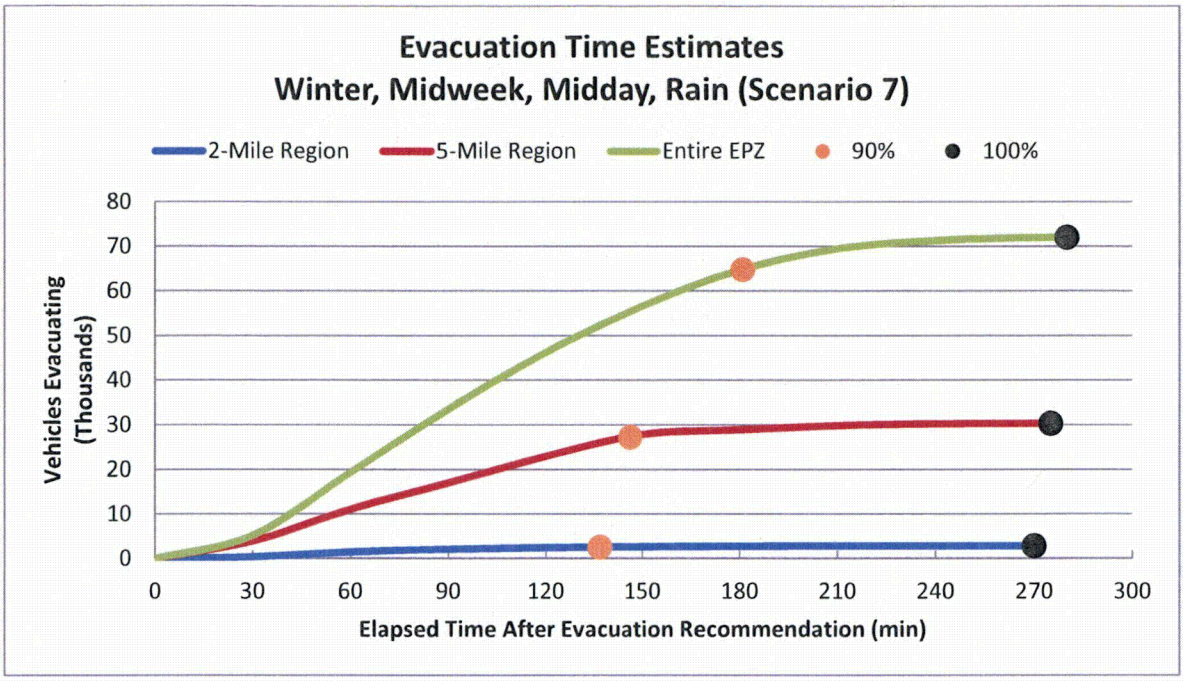


Figure 7-16. Evacuation Time Estimates - Scenario 7 for Region R03

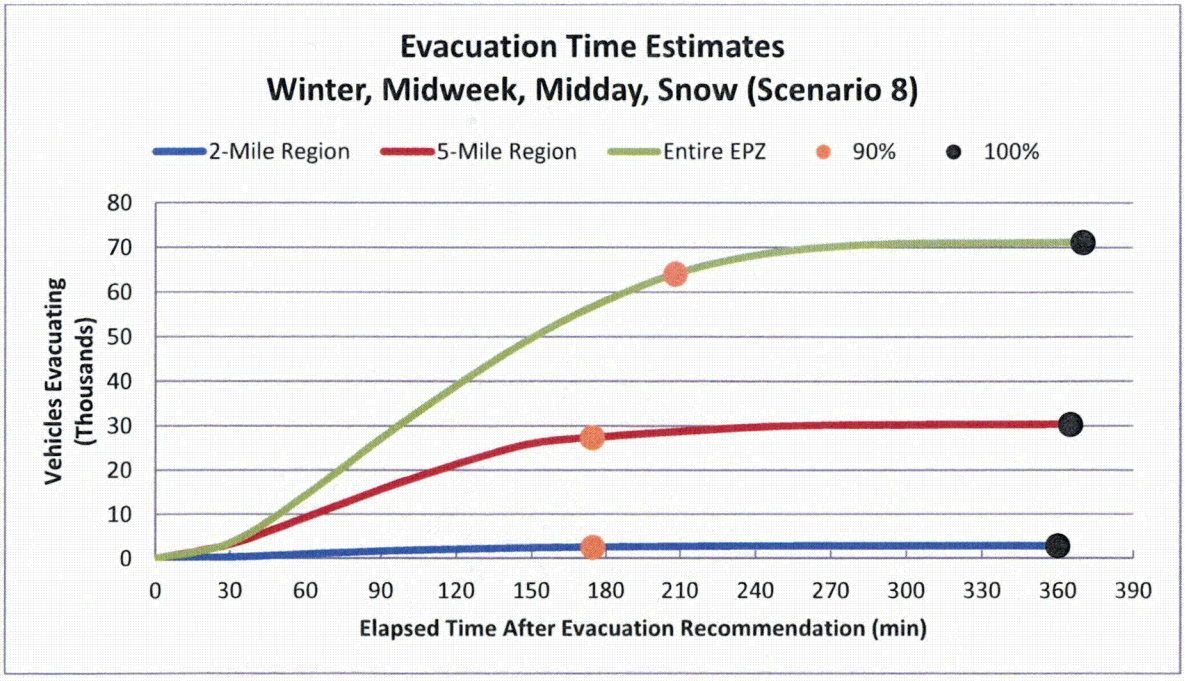


Figure 7-17. Evacuation Time Estimates - Scenario 8 for Region R03

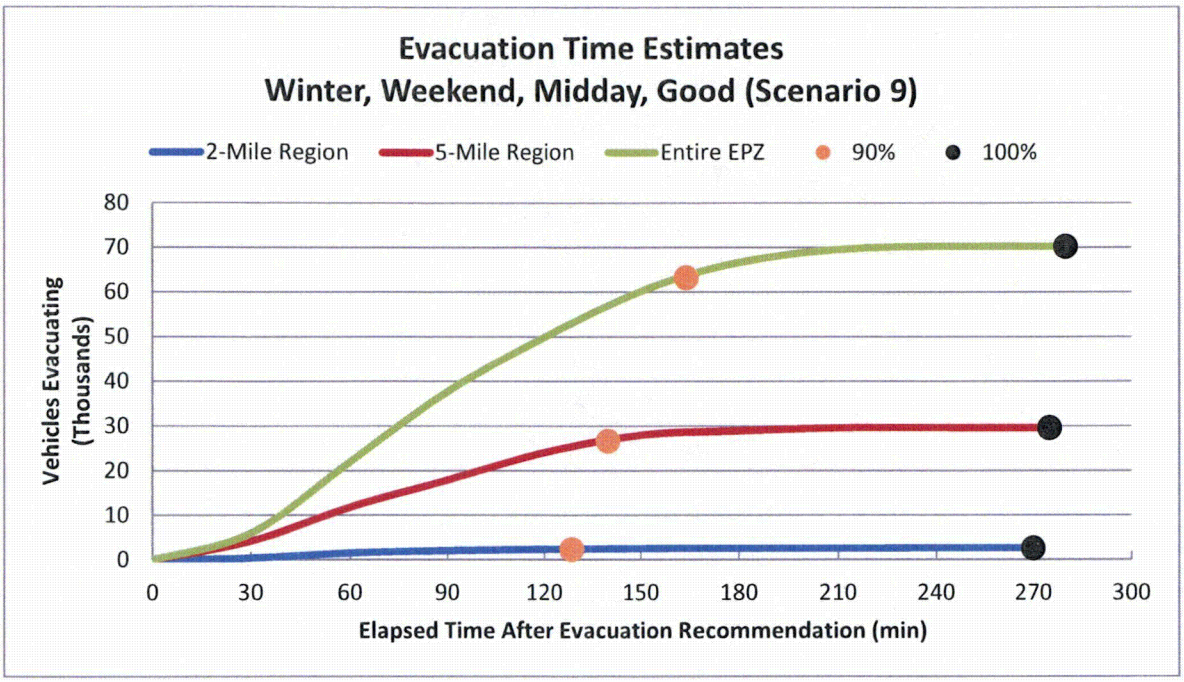


Figure 7-18. Evacuation Time Estimates - Scenario 9 for Region R03

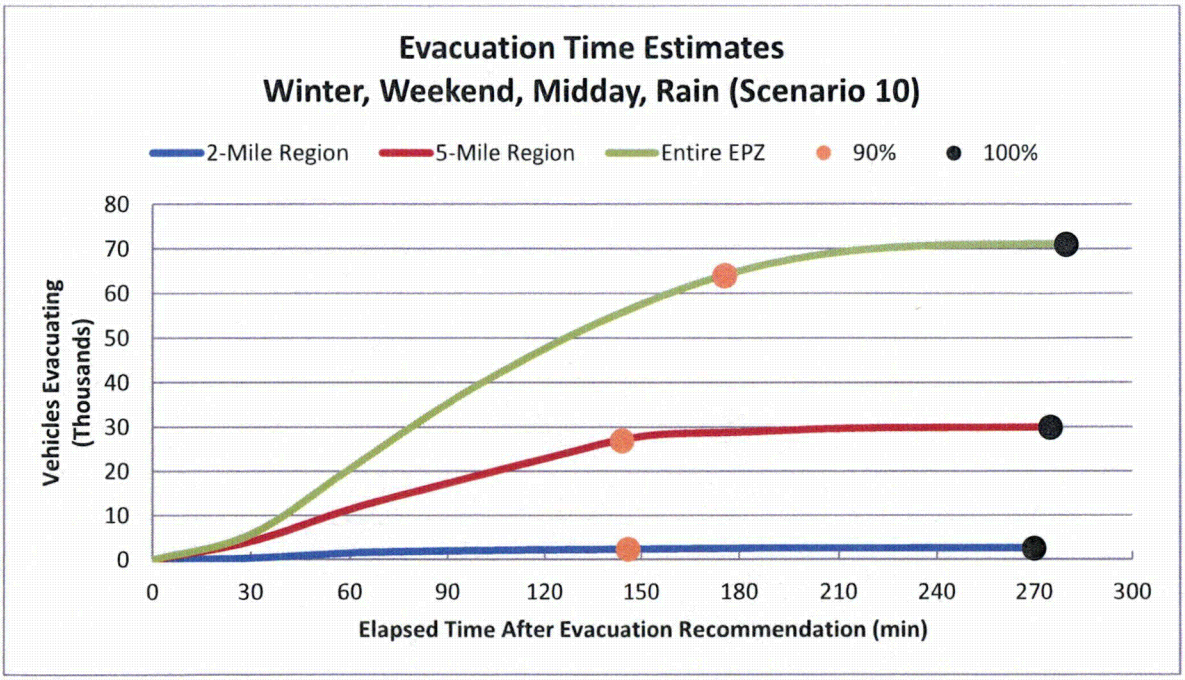


Figure 7-19. Evacuation Time Estimates - Scenario 10 for Region R03

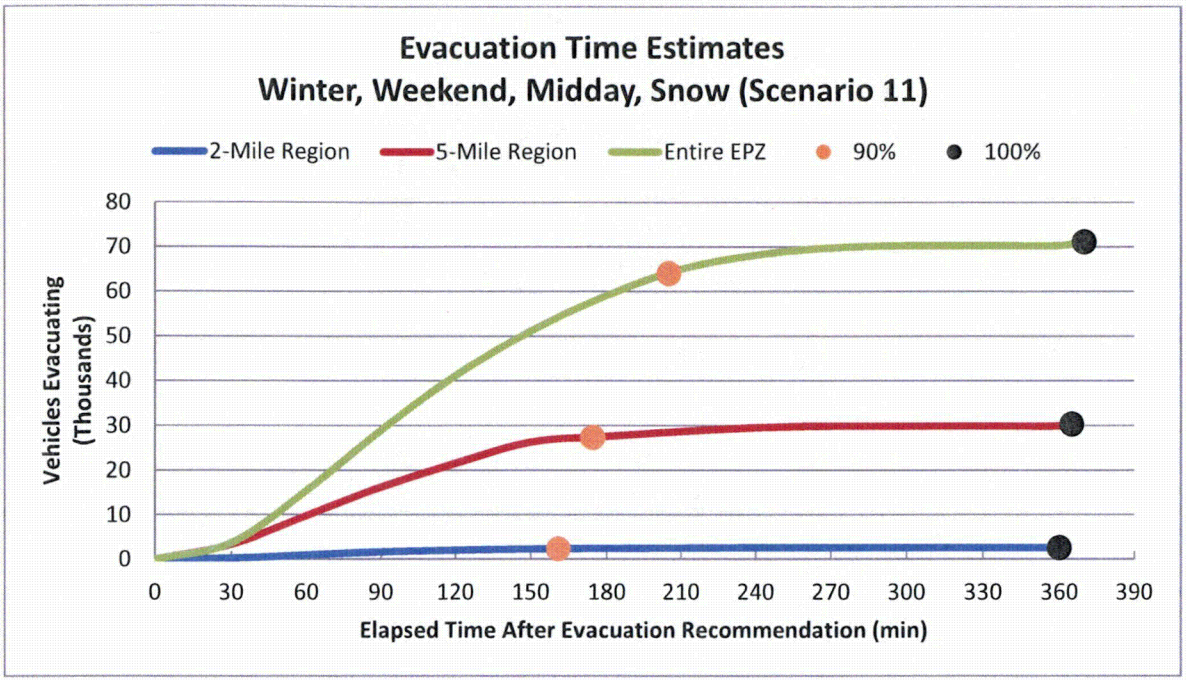


Figure 7-20. Evacuation Time Estimates - Scenario 11 for Region R03

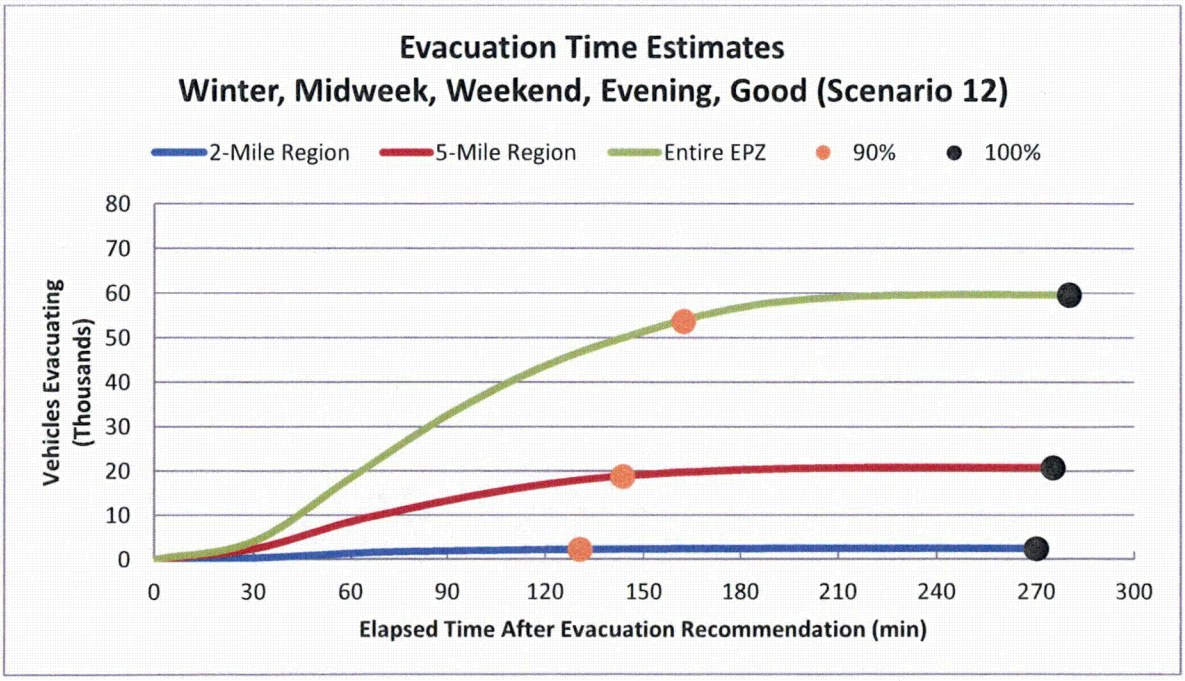


Figure 7-21. Evacuation Time Estimates - Scenario 12 for Region R03

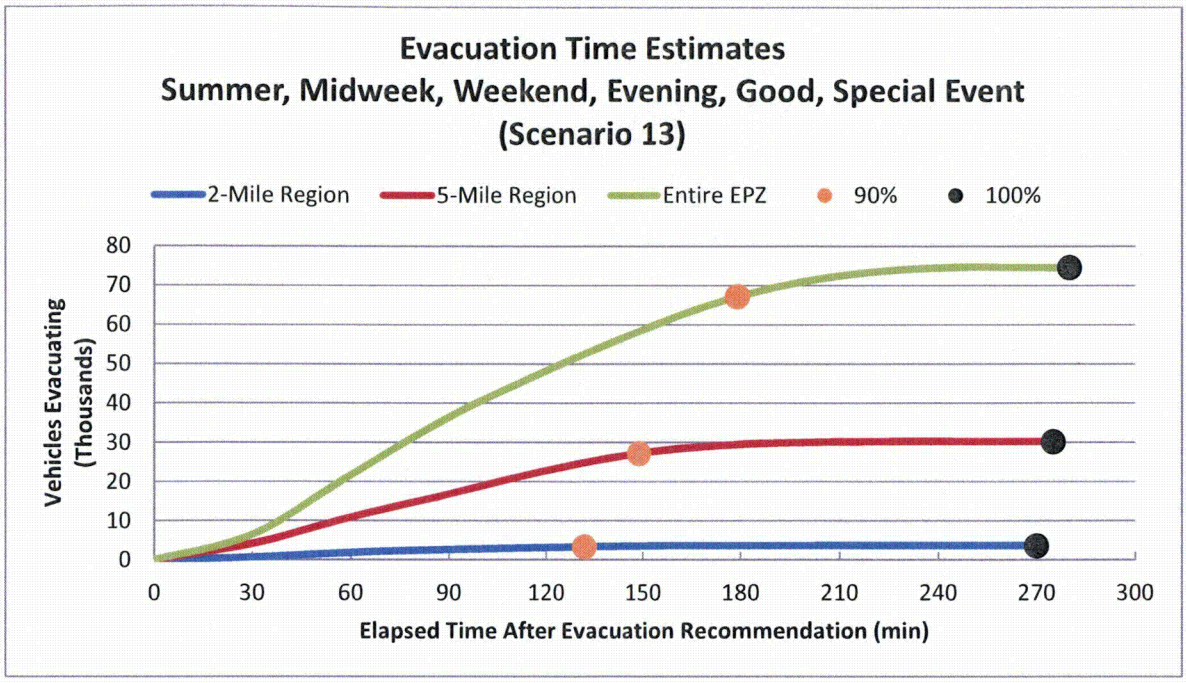


Figure 7-22. Evacuation Time Estimates - Scenario 13 for Region R03

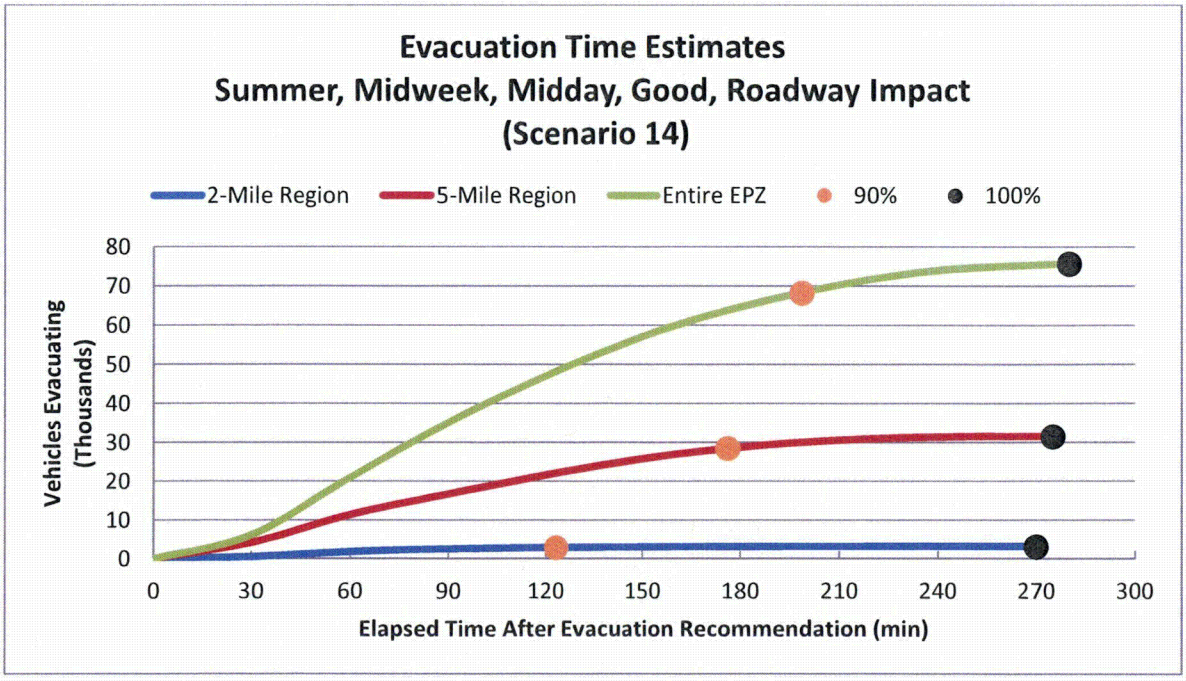


Figure 7-23. Evacuation Time Estimates - Scenario 14 for Region R03

8 TRANSIT-DEPENDENT AND SPECIAL FACILITY EVACUATION TIME ESTIMATES

This section details the analyses applied and the results obtained in the form of evacuation time estimates for transit vehicles. The demand for transit service reflects the needs of three population groups: (1) residents with no vehicles available; (2) residents of special facilities such as schools, medical facilities, and correctional facilities; and (3) homebound special needs population.

These transit vehicles mix with the general evacuation traffic that is comprised mostly of "passenger cars" (pc's). The presence of each transit vehicle in the evacuating traffic stream is represented within the modeling paradigm described in Appendix D as equivalent to two pc's. This equivalence factor represents the longer size and more sluggish operating characteristics of a transit vehicle, relative to those of a pc.

Transit vehicles must be mobilized in preparation for their respective evacuation missions. Specifically:

- Bus drivers must be alerted
- They must travel to the bus depot
- They must be briefed there and assigned to a route or facility

These activities consume time. Based on discussion with the offsite agencies, it is estimated that bus mobilization time will average approximately 90 minutes extending from the Advisory to Evacuate, to the time when buses first arrive at the facility to be evacuated.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this "bonding" process of uniting families is universally prevalent during emergencies and should be anticipated in the planning process. The current public information disseminated to residents of the PNPS EPZ indicates that if an evacuation is ordered, schoolchildren will be evacuated to Reception Centers, and that parents should pick schoolchildren up at these Reception Centers. As discussed in Section 2, this study assumes a fast breaking general emergency. Therefore, children are evacuated to Reception Centers. Picking up children at school could add to traffic congestion at the schools, delaying the departure of the buses evacuating schoolchildren, which may have to return in a subsequent "wave" to the EPZ to evacuate the transit-dependent population. This report provides estimates of buses under the assumption that no children will be picked up by their parents (in accordance with NUREG/CR-7002), to present an upper bound estimate of buses required. It is assumed that children at day-care centers are picked up by parents or guardians, unless the school is indicated in the local plans, and that the time to perform this activity is included in the trip generation times discussed in Section 5.

The procedure for computing transit-dependent ETE is to:

- Estimate demand for transit service

- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the host facilities

8.1 Transit Dependent People Demand Estimate

The telephone survey (see Appendix F) results were used to estimate the portion of the population requiring transit service:

- Those persons in households that do not have a vehicle available.
- Those persons in households that do have vehicle(s) that would not be available at the time the evacuation is advised.

In the latter group, the vehicle(s) may be used by a commuter(s) who does not return (or is not expected to return) home to evacuate the household.

Table 8-1 presents estimates of transit-dependent people. Note:

- Estimates of persons requiring transit vehicles include schoolchildren. For those evacuation scenarios where children are at school when an evacuation is ordered, separate transportation is provided for the schoolchildren. The actual need for transit vehicles by residents is thereby less than the given estimates. However, estimates of transit vehicles are not reduced when schools are in session.
- It is reasonable and appropriate to consider that many transit-dependent persons will evacuate by ride-sharing with neighbors, friends or family. For example, nearly 80 percent of those who evacuated from Mississauga, Ontario who did not use their own cars, shared a ride with neighbors or friends. Other documents report that approximately 70 percent of transit dependent persons were evacuated via ride sharing. **We will adopt a conservative estimate that 50 percent of transit dependent persons will ride share, in accordance with NUREG/CR-7002.**

The estimated number of bus trips needed to service transit-dependent persons is based on an estimate of average bus occupancy of 30 persons at the conclusion of the bus run. Transit vehicle seating capacities typically equal or exceed 60 children on average (roughly equivalent to 40 adults). If transit vehicle evacuees are two thirds adults and one third children, then the number of "adult seats" taken by 30 persons is 20 + (2/3 x10) = 27. On this basis, the average load factor anticipated is (27/40) x 100 = 68 percent. Thus, if the actual demand for service exceeds the estimates of Table 8-1 by 50 percent, the demand for service can still be accommodated by the available bus seating capacity.

$$\left[20 + \left(\frac{2}{3} \times 10\right)\right] \div 40 \times 1.5 = 1.00$$

Table 8-1 indicates that transportation must be provided for 2,167 people. Therefore, a total of **73 bus runs** are required to transport this population to reception centers.

To illustrate this estimation procedure, we calculate the number of persons, P, requiring public transit or ride-share, and the number of buses, B, required for the PNPS EPZ:

$$P = No.of\ HH\ \times \sum_{i=0}^{n} \{(\%\ HH\ with\ i\ vehicles) \times [(Average\ HH\ Size) - i]\} \times A^i C^i$$

Where,

A = Percent of households with commuters

C = Percent of households who will not await the return of a commuter

$$P = 36{,}705 \times [0.012 \times 1.50 + 0.231 \times (1.57 - 1) \times 0.65 \times 0.62 + 0.526 \times (2.55 - 2) \times (0.65 \times 0.62)^2] = 4{,}333$$

$$B = (0.5 \times P) \div 30 = 73$$

These calculations are explained as follows:

- All members (1.50 avg.) of households (HH) with no vehicles (1.2%) will evacuate by public transit or ride-share. The term 36,705 (number of households) x 0.012 x 1.50, accounts for these people.
- The members of HH with 1 vehicle away (23.1%), who are at home, equal (1.57-1). The number of HH where the commuter will not return home is equal to (36,705 x 0.231 x 0.65 x 0.62), as 65% of EPZ households have a commuter, 62% of which would not return home in the event of an emergency. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms.
- The members of HH with 2 vehicles that are away (52.6%), who are at home, equal (2.55 – 2). The number of HH where neither commuter will return home is equal to 36,705 x 0.526 x $(0.65 \times 0.62)^2$. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms (the last term is squared to represent the probability that neither commuter will return).
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.
- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that are away from home.

The estimate of transit-dependent population in Table 8-1 far exceeds the number of registered transit-dependent persons in the EPZ as provided by the towns (discussed below in Section 8.5). This is consistent with the findings of NUREG/CR-6953, Volume 2, in that a large majority of the transit-dependent population within the EPZs of U.S. nuclear plants does not register with their local emergency response agency.

8.2 School Population – Transit Demand

Table 8-2 presents the school population and transportation requirements for the direct evacuation of all schools within the EPZ for the 2010-2011 school year. This information was provided by the local town emergency management agencies. The column in Table 8-2 entitled "Buses Required" specifies the number of buses required for each school under the following set of assumptions and estimates:

- No students will be picked up by their parents prior to the arrival of the buses.
- While many high school students commute to school using private automobiles (as discussed in Section 2.4 of NUREG/CR-7002), the estimate of buses required for school evacuation do not consider the use of these private vehicles.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools.
- Those staff members who do not accompany the students will evacuate in their private vehicles.
- No allowance is made for student absenteeism, typically 3 percent daily.

It is recommended that the towns in the EPZ introduce procedures whereby the schools are contacted prior to the dispatch of buses from the depot (approximately one hour after the Advisory to Evacuate), to ascertain the current estimate of students to be evacuated. In this way, the number of buses dispatched to the schools will reflect the actual number needed. The need for buses would be reduced by any high school students who have evacuated using private automobiles (if permitted by school authorities). Those buses originally allocated to evacuate schoolchildren that are not needed due to children being picked up by their parents, can be gainfully assigned to service other facilities or those persons who do not have access to private vehicles or to ride-sharing. Table 8-3 presents a list of the school reception centers for each school in the EPZ. Students will be transported to these facilities where they will be subsequently retrieved by their respective families.

8.3 Medical Facility Demand

Table 8-4 presents the census of medical facilities in the EPZ. 2,018 people have been identified as living in, or being treated in, these facilities. The capacity and current census for each facility were provided by the town emergency management agencies. This data includes the number of ambulatory, wheel-chair bound and bedridden patients at each facility.

The transportation requirements for the special facility population are also presented in Table 8-4. The number of ambulance runs is determined by assuming that 2 patients can be accommodated per ambulance trip; the number of wheelchair bus runs assumes 15 wheelchairs per trip and the number of bus runs estimated assumes 30 ambulatory patients per trip.

8.4 Evacuation Time Estimates for Transit Dependent People

EPZ bus resources are assigned to evacuating schoolchildren (if school is in session at the time

of the ATE) as the first priority in the event of an emergency. In the event that the allocation of buses dispatched from the depots to the various facilities and to the bus routes is somewhat "inefficient", or if there is a shortfall of available drivers, then there may be a need for some buses to return to the EPZ from the reception center after completing their first evacuation trip, to complete a "second wave" of providing transport service to evacuees. For this reason, the ETE for the transit-dependent population will be calculated for both a one wave transit evacuation and for two waves. Of course, if the impacted Evacuation Region is other than R03 (the entire EPZ), then there will likely be ample transit resources relative to demand in the impacted Region and this discussion of a second wave would likely not apply.

When school evacuation needs are satisfied, subsequent assignments of buses to service the transit-dependent should be sensitive to their mobilization time. Clearly, the buses should be dispatched after people have completed their mobilization activities and are in a position to board the buses when they arrive at the pick-up points.

Evacuation Time Estimates for transit trips were developed using both good weather and adverse weather conditions. Figure 8-1 presents the chronology of events relevant to transit operations. The elapsed time for each activity will now be discussed with reference to Figure 8-1.

Activity: Mobilize Drivers (A→B→C)

Mobilization is the elapsed time from the Advisory to Evacuate until the time the buses arrive at the facility to be evacuated. It is assumed that for a rapidly escalating radiological emergency with no observable indication before the fact, drivers would likely require 90 minutes to be contacted, to travel to the depot, be briefed, and to travel to the transit-dependent facilities. Mobilization time is slightly longer in adverse weather – 100 minutes when raining, 110 minutes when snowing.

Activity: Board Passengers (C→D)

Based on discussions with offsite agencies, a loading time of 15 minutes (20 minutes for rain and 25 minutes for snow) for school buses is used.

For multiple stops along a pick-up route (transit-dependent bus routes) estimation of travel time must allow for the delay associated with stopping and starting at each pick-up point. The time, t, required for a bus to decelerate at a rate, "a", expressed in ft/sec/sec, from a speed, "v", expressed in ft/sec, to a stop, is t = v/a. Assuming the same acceleration rate and final speed following the stop yields a total time, T, to service boarding passengers:

$$T = t + B + t = B + 2t = B + \frac{2v}{a},$$

Where B = Dwell time to service passengers. The total distance, "s" in feet, travelled during the deceleration and acceleration activities is: $s = v^2/a$. If the bus had not stopped to service passengers, but had continued to travel at speed, v, then its travel time over the distance, s, would be: $s/v = v/a$. Then the total delay (i.e. pickup time, P) to service passengers is:

$$P = T - \frac{v}{a} = B + \frac{v}{a}$$

Assigning reasonable estimates:

- B = 50 seconds: a generous value for a single passenger, carrying personal items, to board per stop
- v = 25 mph = 37 ft/sec
- a = 4 ft/sec/sec, a moderate average rate

Then, P ≈ 1 minute per stop. Allowing 30 minutes pick-up time per bus run implies 30 stops per run, for good weather. It is assumed that bus acceleration and speed will be less in rain; total loading time is 40 minutes per bus in rain, 50 minutes in snow.

Activity: Travel to EPZ Boundary (D→E)

School Evacuation

Transportation resources available were provided by the EPZ town emergency management agencies and are summarized in Table 8-5. Also included in the table are the number of buses needed to evacuate schools, medical facilities, transit-dependent population, homebound special needs (discussed below in Section 8.5) and correctional facilities (discussed below in Section 0). These numbers indicate there are not enough buses to evacuate the transit-dependent population in one wave. For this reason, a two-wave evacuation is presented in Table 8-11, Table 8-12, and Table 8-13.

The buses servicing the schools are ready to begin their evacuation trips at 105 minutes after the advisory to evacuate – 90 minutes mobilization time plus 15 minutes loading time – in good weather. The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely path from a school being evacuated to the EPZ boundary, traveling toward the appropriate school reception center. This is done in UNITES by interactively selecting the series of nodes from the school to the EPZ boundary. Each bus route is given an identification number and is written to the DYNEV II input stream. DYNEV computes the route length and outputs the average speed for each 5 minute interval, for each bus route. The specified bus routes are documented in Table 8-6 (refer to the maps of the link-node analysis network in Appendix K for node locations). Data provided by DYNEV during the appropriate timeframe depending on the mobilization and loading times (i.e., 100 to 105 minutes after the advisory to evacuate for good weather) were used to compute the average speed for each route, as follows:

$$Average\ Speed\ \left(\frac{mi.}{hr}\right) = \left[\frac{\sum_{i-1}^{n} length\ of\ link\ i\ (mi)}{\sum_{i=1}^{n} Delay\ on\ link\ i\ (min.) + \frac{length\ of\ link\ i\ (mi.)}{current\ speed\ on\ link\ i\ \left(\frac{mi.}{hr.}\right)} \times \frac{60\ min.}{1\ hr.}}\right] \times \frac{60\ min.}{1\ hr.}$$

The average speed computed (using this methodology) for the buses servicing each of the schools in the EPZ is shown in Table 8-7 through Table 8-9 for school evacuation, in Table 8-11 through Table 8-13 for the transit vehicles evacuating transit-dependent persons (which are discussed later), and Table 8-14 through Table 8-16 for the people living at, or being treated in, special facilities. The travel time to the EPZ boundary was computed for each bus using the computed average speed and the distance to the EPZ boundary along the most likely route out of the EPZ. The travel time from the EPZ boundary to the Reception Center was computed assuming an average speed of 40 mph, 35 mph, and 30 mph for good weather, rain and snow, respectively. Speeds were reduced in Table 8-7 through Table 8-9, Table 8-11 through Table 8-13, and for buses only in Table 8-14 through Table 8-16 to 40 mph (36 mph for rain – 10% decrease – and 32 mph for snow – 20% decrease) for those calculated bus speeds which exceed 40 mph, as the school bus speed limit for state routes in Massachusetts is 40 mph.

Table 8-7 (good weather), Table 8-8 (rain) and Table 8-9 (snow) present the following evacuation time estimates (rounded up to the nearest 5 minutes) for schools in the EPZ: (1) The elapsed time from the Advisory to Evacuate until the bus exits the EPZ; and (2) The elapsed time until the bus reaches the School Reception Center. The evacuation time out of the EPZ can be computed as the sum of times associated with Activities A→B→C, C→D, and D→E (For example: 90 min. + 15 + 81 = 3:10 for After School Club Alden, with good weather). The evacuation time to the School Reception Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

Evacuation of Transit-Dependent Population

The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As shown in Figure 5-4 (Residents with no Commuters), 87 percent of the evacuees will complete their mobilization when the buses will begin their routes, approximately 90 minutes after the Advisory to Evacuate. Transit-dependent buses were distributed throughout the EPZ based on Sub-area population. Sub-areas 5 and 9 have the largest populations and require more buses than any other sub-areas. Routes which are serviced by multiple buses use 5, 10 or 20 minute headways depending on the number of buses, as shown in Table 8-11 through Table 8-13. The use of bus headways ensures that those people who take longer to mobilize will be picked up. Mobilization time is 10 minutes longer in rain and 20

minutes longer in snow, to account for slower travel speeds and reduced roadway capacity.

Those buses servicing the transit-dependent evacuees will first travel along their pick-up routes, then proceed out of the EPZ. The 11 bus routes shown graphically in Figure 8-2 and described in Table 8-10 are defined in the 2011 Emergency Public Information Calendar. It is assumed that residents will walk to and congregate at these pre-designated pick-up routes, and that they can arrive at the stops within the 90 minute bus mobilization time (good weather).

As previously discussed, a pickup time of 30 minutes (good weather) is estimated for 30 individual stops to pick up passengers, with an average of one minute of delay associated with each stop. Longer pickup times of 40 minutes and 50 minutes are used for rain and snow, respectively.

The travel distance along the respective pick-up routes within the EPZ is estimated using the UNITES software. Bus travel times within the EPZ are computed using average speeds computed by DYNEV, using the aforementioned methodology that was used for school evacuation.

Table 8-11 through Table 8-13 present the transit-dependent population evacuation time estimates for each bus route calculated using the above procedures for good weather, rain and snow, respectively.

For example, the ETE for the bus route servicing sub-area 1 is computed as 90 + 41 + 30 = 2:45 for good weather (rounded up to nearest 5 minutes). Here, 41 minutes is the time to travel 25.6 miles at 37.2 mph, the average speed output by the model for this route at 90 minutes. The ETE for a second wave (discussed below) is presented in the event there is a shortfall of available buses or bus drivers, as previously discussed.

Activity: Travel to Reception Centers (E→F)

The distances from the EPZ boundary to the reception centers are measured using GIS software along the most likely route from the EPZ exit point to the reception center. The reception centers are mapped in Figure 10-1. For a one-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. For a two-wave evacuation, the ETE for buses must be considered separately, since it could exceed the ETE for the general population. Assumed bus speeds of 40 mph, 35 mph, and 30 mph for good weather, rain, and snow, respectively, will be applied for this activity for buses servicing the transit-dependent population.

Activity: Passengers Leave Bus (F→G)

A bus can empty within 5 minutes. The driver takes a 10 minute break.

Activity: Bus Returns to Route for Second Wave Evacuation (G→C)

The buses assigned to return to the EPZ to perform a "second wave" evacuation of transit-dependent evacuees will be those that have already evacuated transit-dependent people who mobilized more quickly. The first wave of transit-dependent people depart the bus, and the bus then returns to the EPZ, travels to its route and proceeds to pick up more transit-dependent evacuees along the route. The travel time back to the EPZ is equal to the travel time

to the reception center.

The second-wave ETE for the bus route servicing sub-area 1 is computed as follows for good weather:

- Bus arrives at reception center at 3:26 in good weather (2:45 to exit EPZ + 41 minute travel time to reception center).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ and completes second route: 41 minutes (equal to travel time to reception center) + 38 minutes (25.6 miles @ 40 mph) = 79 minutes
- Bus completes pick-ups along route: 30 minutes.
- Bus exits EPZ at time 2:45 + 0:41 + 0:15 + 0:79 + 0:30 = 5:30 (rounded to nearest 5 minutes) after the Advisory to Evacuate.

The ETE for the completion of the second wave for all transit-dependent bus routes are provided in Table 8-11 through Table 8-13. The average ETE for a two-wave evacuation of transit-dependent people exceeds the ETE for the general population at the 90th percentile.

The relocation of transit-dependent evacuees from the reception centers to congregate care centers, if the towns decide to do so, is not considered in this study.

Evacuation of Medical Facilities

The bus operations for this group are similar to those for school evacuation except:

- Buses are assigned on the basis of 30 patients to allow for staff to accompany the patients.
- The passenger loading time will be longer at approximately one minute per patient to account for the time to move patients from inside the facility to the vehicles.

Table 8-4 indicates that 47 bus runs, 42 wheelchair bus runs and 141 ambulance runs are needed to service all of the medical facilities in the EPZ. According to Table 8-5, the towns can collectively provide 502 buses, 90 vans and 11 ambulances. Thus, there are not enough resources to evacuate people from the medical facilities in a single wave; a multi-wave evacuation is needed to evacuate these people.

As is done for the schools, it is estimated that mobilization time averages 90 minutes. Specially trained medical support staff (working their regular shift) will be on site to assist in the evacuation of patients. Additional staff (if needed) could be mobilized over this same 90 minute timeframe.

Table 8-14 through Table 8-16 summarize the ETE for medical facilities within the EPZ for good weather, rain, and snow. Average output speeds produced by the model for Scenario 6 (Scenario 7 for rain and Scenario 8 for snow) Region 3, capped at 40 mph (36 mph for rain and 32 mph for snow) for buses, are used to compute travel time to EPZ boundary. The travel time to the EPZ boundary is computed by distance to the EPZ boundary by the average travel speed. The ETE is the sum of the mobilization time, total passenger loading time, and travel time out of the EPZ. Concurrent loading on multiple buses, wheelchair buses/vans, and ambulances at

capacity is assumed such that the maximum loading times for buses, wheelchair buses and ambulances are 30, 75, and 30 minutes respectively. All ETE are rounded to the nearest 5 minutes. For example, the calculation of ETE for the Baird Center Group Home with 19 ambulatory residents during good weather is:

ETE: 90 + 19 x 1 + 9 = 118 min. or 2:00 rounded to the nearest 5 minutes.

It is assumed that special facility population is directly evacuated to appropriate host medical facilities. Relocation of this population to permanent facilities and/or passing through the reception center before arriving at the host facility are not considered in this analysis.

8.5 Special Needs Population

The local emergency management agencies have a registration for transit-dependent and homebound special needs persons. Based on data provided by the municipalities, there are an estimated 60 homebound special needs people within Carver, 51 people within Duxbury, 40 people within Kingston, 7 people within Marshfield, and 138 people within Plymouth who require transportation assistance to evacuate. Throughout the entire EPZ, there are 228 ambulatory persons, 59 wheelchair-bound persons and 9 bedridden persons.

ETE for Homebound Special Needs Persons

Table 8-17 summarizes the ETE for homebound special needs people. The table is categorized by type of vehicle required and then broken down by weather condition. The table takes into consideration the deployment of multiple vehicles to reduce the number of stops per vehicle. It is conservatively assumed that ambulatory and wheelchair bound special needs households are spaced 3 miles apart and bedridden households are spaced 5 miles apart. Van and bus speeds approximate 20 mph between households and ambulance speeds approximate 30 mph in good weather (10% slower in rain, 20% slower in snow). Mobilization times of 90 minutes were used (100 minutes for rain, and 110 minutes for snow). The last HH is assumed to be 5 miles from the EPZ boundary, and the network-wide average speed, capped at 40 mph (36 mph for rain and 32 mph for snow), after the last pickup is used to compute travel time. ETE is computed by summing mobilization time, loading time at first household, travel to subsequent households, loading time at subsequent households, and travel time to EPZ boundary. All ETE are rounded to the nearest 5 minutes.

For example, assuming no more than one special needs person per HH implies that 228 ambulatory households need to be serviced. While only 8 buses are needed from a capacity perspective, if 25 buses are deployed to service these special needs HH, then each would require about 10 stops. The following outlines the ETE calculations:

1. Assume 25 buses are deployed, each with about 10 stops, to service a total of 228 HH.
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 90 minutes
    b. Load HH members at first pickup: 5 minutes
    c. Travel to subsequent pickup locations: 9 @ 9 minutes = 81 minutes
    d. Load HH members at subsequent pickup locations: 8 @ 5 minutes = 45 minutes

e. Travel to EPZ boundary: 13 minutes (5 miles at 23.1 mph).

ETE: 90 + 5 + 81 + 45 + 13 = 3:55 rounded to the nearest 5 minutes

The following outlines the ETE calculations if a second wave is needed using school buses after the schools have been evacuated:

a. Bus arrives at school reception center: 2:45 (average time for ETE to R.C. from Table 8-7)
b. Unload students at Reception Center: 5 minutes.
c. Driver takes 10 minute rest: 10 minutes.
d. Travel time back to EPZ: 28 minutes (31 minutes – rain, 36 minutes – snow) (average time of "Travel Time from EPZ Bdry to H.S." from Table 8-7, 8-8 and 8-9)
e. Loading time at first household: 5 minutes
f. Bus travels to subsequent households: 9 stops @ 9 minutes = 81 minutes (90 minutes – rain, 99 minutes – snow)
g. Loading time at subsequent households: 9 stops @ 5 minutes = 45 minutes
h. Travel time to EPZ boundary at 5:30 (6:20 – rain; 6:45 – snow): 5 miles @ 23.0 mph = 13 minutes (19.4 mph, 16 minutes – rain; 19.0 mph, 16 minutes - snow)

ETE: 2:45 + 5 + 10 + 18 + 5 + 81 + 45 + 13 = 5:45

Rain ETE: 3:10 + 5 + 10 + 31 + 5 + 90 + 45 + 26 = 6:45

Snow ETE: 3:25 + 5 + 10 + 36 + 5 + 99 + 45 + 16 = 7:05

8.6 Correctional Facilities

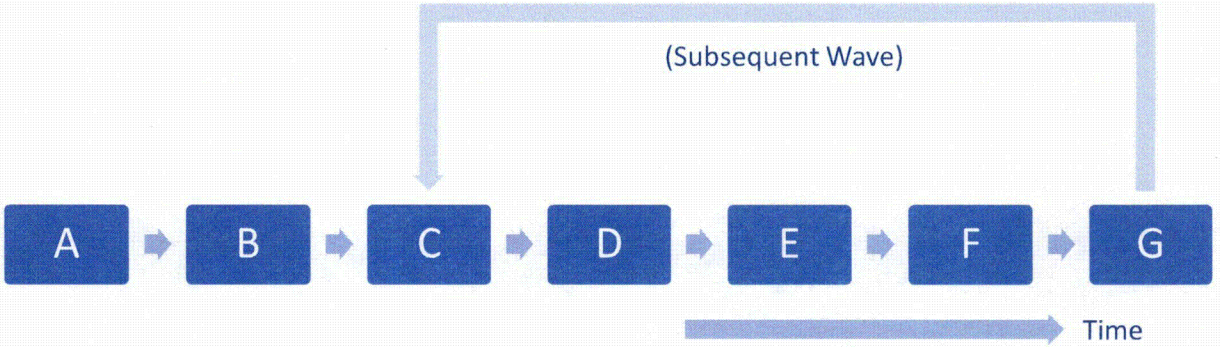
As detailed in Table E-6, there are two correctional facilities within the EPZ – Plymouth County Correctional Facility and MCI Plymouth. The total inmate population at these facilities is 1,820 persons. A total of 37 buses are needed to evacuate these two facilities, based on a capacity of 50 inmates per bus. Mobilization time is assumed to be 90 minutes (100 minutes in rain and 110 in snow). It is estimated that it takes 15 minutes to load the inmates onto a bus, and that 5 buses can be loaded in parallel. Thus, maximum loading time is estimated at approximately 1 hours and 40 minutes (Plymouth County Correctional). The detailed evacuation plans for these facilities are confidential. Using GIS software, the shortest distance from the facility to the EPZ boundary, traveling away from the plant, is about 7 miles and 5 miles for Plymouth County Correctional and MCI Plymouth, respectively. The travel time to traverse 7 miles, for Plymouth County Correction Facility, is 11 minutes (37 mph at 3:10 after the ATE) in good weather, 13 minutes (33.6 mph at 3:20) in rain and 15 minutes (28.7 mph at 3:30) in snow. Table 8-18 summarizes the ETE for the correctional facilities in the EPZ. All ETE are rounded to the nearest 5 minutes.

For example, for Plymouth County Correctional Facility the ETE is calculated as follows:

ETE: 90 + 96 + 11 = 3:20

Rain ETE: 100 + 96 + 13 = 3:30

Snow ETE: 110 + 96 + 15 = 3:45



Event	
A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Reception Center
E	Bus Exits Region
F	Bus Arrives at Reception Center/Host Facility
G	Bus Available for "Second Wave" Evacuation Service
Activity	
A→B	Driver Mobilization
B→C	Travel to Facility or to Pick-up Route
C→D	Passengers Board the Bus
D→E	Bus Travels Towards Region Boundary
E→F	Bus Travels Towards Reception Center Outside the EPZ
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

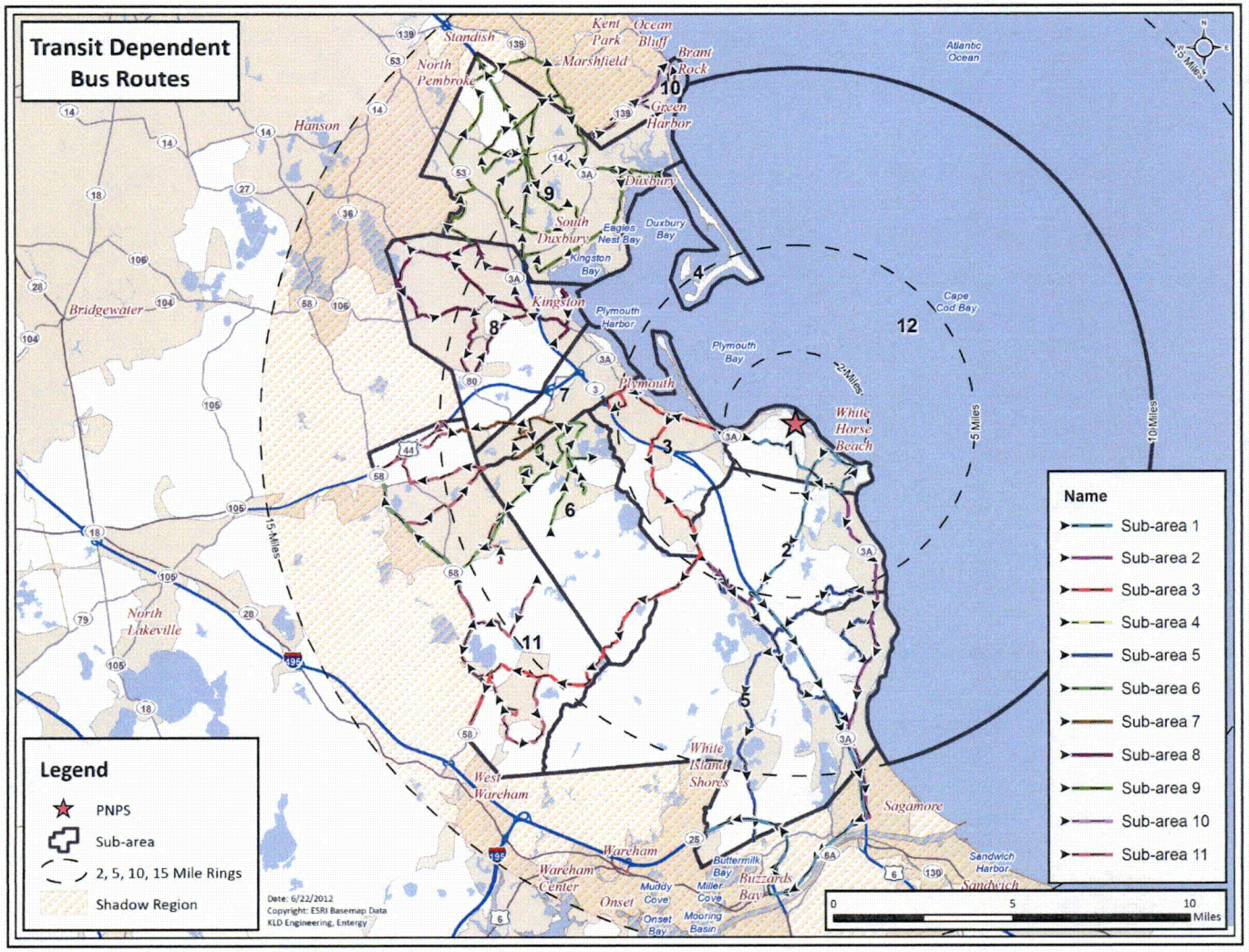


Figure 8-2. Transit-Dependent Bus Routes

Table 8-1. Transit-Dependent Population Estimates

2010 EPZ Population	Survey Average HH Size with Indicated No. of Vehicles			Estimated No. of Households	Survey Percent HH with Indicated No. of Vehicles			Survey Percent HH with Commuters	Survey Percent HH with Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent Population Requiring Public Transit
	0	1	2		0	1	2						
93,964	1.50	1.57	2.55	36,705	1.2%	23.1%	52.6%	65%	62%	4,333	50%	2,167	2.3%

Table 8-2. School Population Bus and Van Demand Estimates

Sub-area	School Name	Enrollment	Bus Runs	Van Runs
1	Garden of Knowledge	44	1	0
1	Kinder Kollege	30	0	3
1	Leaping Frogs Preschool	20	0	3
1	Manomet Elementary School	375	6	0
2	Indian Brook Elementary School	770	11	0
2	Plymouth South High School	1,531	31	0
2	Plymouth South Middle School	750	15	0
2	Tiny Town Inc.	45	1	0
3	Children's Creative Learning Center	20	0	3
3	Hop, Skip & Jump Preschool	20	1	0
3	KinderCare - Pilgrim Hill	71	1	0
3	Learning Safari Day Care & Preschool	44	1	0
3	Mount Pleasant School	142	3	0
3	Nathaniel Morton Elementary School	636	10	0
3	Plymouth Community Intermediate School	1,277	26	0
3	Plymouth North High School	1,116	23	0
3	Room 2 Grow Nursery School	31	1	0
3	Small Scholars Preschool	38	1	0
5	Bright Ideas Preschool	36	0	2
5	New Testament Christian School	111	2	0
5	Ponds Childcare Center	83	2	0
5	South Elementary School	755	11	0
6	Federal Furnace School	460	7	0
6	Methodist Nursery School	30	0	3
6	Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	25	0	3
6	Woodside School and Community Resource Center	48	4	0
7	Cold Spring Elementary School	258	4	0
7	Crayon College At Plymouth	39	3	0
7	Hedge Elementary School	226	4	0
7	KinderCare - Richard's Road	55	1	0
7	Pilgrim Academy	58	1	0
7	Rising Tide Charter Public School	320	7	0
7	West Elementary School	478	7	0
8	Crayon College Inc.	55	1	0
8	Growth Unlimited Preschool	30	1	0
8	Kingston Elementary School	675	10	0
8	Kingston Intermediate School	709	15	0
8	Little Peoples Country Day	9	0	2
8	Sacred Heart Early Childhood	100	2	0
8	Sacred Heart Elementary School	355	6	0
8	Sacred Heart High School	462	10	0

Sub-area	School Name	Enrollment	Bus Runs	Van Runs
8	Silver Lake Regional High School	1,251	26	0
8	Silver Lake Regional Middle School	610	13	0
8	South Shore Early Education	245	4	0
8	Wooded Acres Child Care	45	1	0
9	After School Club Alden	35	1	0
9	Alden School	822	12	0
9	Bay Farm Montessori Academy	188	3	0
9	Berrybrook School	54	1	0
9	Blue River ~~Montesorri~~Montessori School	10	0	2
9	Breakfast Club Chandler	30	1	0
9	Cedarhill Retreat Conference Center Daycare	10	0	1
9	Chandler Elementary School	642	10	0
9	Discovery Corner Daycare	10	1	0
9	Duxbury Bay Maritime School	250	5	0
9	Duxbury High School	1,017	21	0
9	Duxbury Middle School	810	17	0
9	Elements Montessori School	19	1	0
9	Good Shepherd Christian Academy	108	3	0
9	Junior Club Chandler	47	1	0
9	Kindergarten Ext Chandler	97	2	0
9	Magic Dragon Childrens Center	170	3	0
9	Pied Piper Preschool	49	1	0
9	Pilgrim Area Collab. (Alden)	8	0	3
9	Pilgrim Area Collab. (Chandler)	13	0	3
9	Pilgrim Area Collab. (High School)	17	0	3
9	Pilgrim Area Collab. (Middle)	5	0	1
9	Pilgrim Area Collaborative	17	0	3
9	Pilgrim Child Care & Preschool	76	2	0
9	South Shore Cons Preschool	34	1	0
10	Governor Edward Winslow School	450	9	0
11	Capt Pal Pre School	30	1	0
11	Carver Elementary School	448	7	0
11	Carver High School	526	11	0
11	Carver Middle School	452	10	0
11	Cranberry Crossing Day Care	58	1	0
11	Erwin K. Washburn Primary School	407	6	0
11	Kids Count Day School	39	1	0
11	Kidstop Early Childhood Center	92	2	0
11	Old Colony YMCA	80	2	0
	TOTAL:	**21,608**	**410**	**35**

Table 8-3. School Host Facilities

School	Host Facility
Capt Pal Pre School	Adrian Tinsley Center at Bridgewater State University
Cranberry Crossing Day Care	
Crayon College At Plymouth	
Growth Unlimited Preschool	
Kids Count Day School	
Kidstop Early Childhood Center	
Kingston Elementary School	
Kingston Intermediate School	
Little Peoples Country Day	
Wooded Acres Child Care	
Manomet Elementary School	Bennett School
After School Club Alden	Braintree High School
Alden School	
Bay Farm Montessori Academy	
Berrybrook School	
Blue River ~~Montesorri~~Montessori School	
Breakfast Club Chandler	
Cedarhill Retreat Conference Center Daycare	
Chandler Elementary School	
Discovery Corner Daycare	
Duxbury Bay Maritime School	
Duxbury High School	
Duxbury Middle School	
Elements Montessori School	
Good Shepherd Christian Academy	
Junior Club Chandler	
Kindergarten Ext Chandler	
Magic Dragon Children's Center	
Pied Piper Preschool	
Pilgrim Area Collab. (Alden)	
Pilgrim Area Collab. (Chandler)	
Pilgrim Area Collab. (High School)	
Pilgrim Area Collab. (Middle)	
Carver High School	Bridgewater/Raynham Regional High School
Carver Middle School	
Sacred Heart Early Childhood	
Sacred Heart Elementary School	

School	Host Facility
Sacred Heart High School	Bridgewater/Raynham Regional High School
Silver Lake Regional High School	
Silver Lake Regional Middle School	
Plymouth North High School	Bristol-Plymouth Regional Technical School
Cold Spring Elementary School	Coyle and Cassidy High School
Hedge Elementary School	Elizabeth Pole School
Mount Pleasant School	Friedman Middle School
Governor Edward Winslow School	Furnace Brook School
Crayon College Inc.	Hopewell School
Garden of Knowledge	
Kinder Kollege	
KinderCare - Richard's Road	
Leaping Frogs Preschool	
Methodist Nursery School	
Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	
New Testament Christian School	
Rising Tide Charter Public School	
Room 2 Grow Nursery School	
South Elementary School	
Tiny Town Inc.	
West Elementary School	
Woodside School and Community Resource Center	
Federal Furnace School	James L. Mulcahey School
KinderCare - Pilgrim Hill	KinderCare Taunton
Bright Ideas Preschool	Leddy School
Children's Creative Learning Center	
Ponds Childcare Center	
South Shore Cons Preschool	
South Shore Early Education	
Nathaniel Morton Elementary School	Martin Middle School
Indian Brook Elementary School	Our Lady of Lourdes Elementary School
Pilgrim Area Collaborative	Taunton High School
Pilgrim Child Care & Preschool	
Plymouth Community Intermediate School	
Plymouth South High School	
Plymouth South Middle School	
Carver Elementary School	Williams Middle School

School	Host Facility
Erwin K. Washburn Primary School	
Hop, Skip & Jump Preschool	Williams Middle School
Learning Safari Day Care & Preschool	
Old Colony YMCA	
Pilgrim Academy	
Small Scholars Preschool	

Table 8-4. Medical Facility Transit Demand

Sub-area	Facility Name	Municipality	Capacity	Current Census	Ambulatory	Wheelchair Bound	Bedridden	Bus Runs	Wheelchair Bus Runs	Ambulance
2	High Point Treatment Center	Plymouth	219	210	164	2	44	6	1	22
3	Chilton House Inc.	Plymouth	42	40	22	10	8	1	1	4
3	Emeritus	Plymouth	101	97	58	30	9	2	2	5
3	Golden Living Center-Plymouth[1]	Plymouth	135	130	50	22	58	2	2	0
3	Jordan Hospital	Plymouth	155	149	79	39	31	3	3	16
3	Life Care Center of Plymouth[1]	Plymouth	213	204	65	79	60	3	6	0
3	Newfield House[1]	Plymouth	95	91	57	31	3	2	3	0
3	Plymouth Crossings	Plymouth	95	91	68	4	19	3	1	10
3	Radius Health Care Nursing Home[1]	Plymouth	238	228	98	96	34	4	7	0
3	Stafford Hill Assisted Living	Plymouth	120	115	85	6	24	3	1	12
5	Team Works	Plymouth	22	21	12	5	4	1	1	2
7	Baird Center Group Home	Plymouth	36	35	19	9	7	1	1	4
7	Community Connections Inc.	Plymouth	48	46	31	5	10	2	1	5
7	Cozy Corner ADHC LLC	Plymouth	43	41	28	4	9	1	1	5
7	Habilitation Assistance Corporation	Plymouth	88	84	40	26	18	2	2	9
8	Wingate at Silver Lake	Kingston	252	241	127	63	51	5	5	26
9	Bay Path Rehabilitation & Nursing Center	Duxbury	120	115	61	30	24	3	2	12
9	Duxbury House	Duxbury	23	22	11	6	5	1	1	3
9	The Village At Duxbury	Duxbury	60	58	31	15	12	2	1	6
		TOTAL:	**2,105**	**2,018**	**1,106**	**482**	**430**	**47**	**42**	**141**

1. Bedridden patients shelter in place

Table 8-5. Summary of Transportation Resources

Transportation Resource	Buses	Vans	Wheelchair Buses	Ambulances
Resources Available				
Bloom	33	15	-	-
Carver Schools	19	2	-	-
Whit	41	-	-	-
Judco	-	7	-	-
Grata	-	12	-	-
Brockton	77	41	-	-
Duxbury Schools	48	-	-	-
Pembroke	77	-	-	-
Bill's Taxi	12	13	-	-
Totman	13	-	-	-
Plymouth Schools	109	-	-	-
F.S. Mid	33	-	-	-
Bridge	17	-	-	-
F.S. Free	19	-	-	-
E. Bridgewater	1	-	-	-
South Shore Headstart	3	-	-	-
Marshfield Fire Department	-	-	-	2
TOTAL:	**502**	**90**	**0**	**2**
Resources Needed				
Schools (Table 8-2):	410	35	-	-
Medical Facilities (Table 8-4):	47	-	42	141
Transit-Dependent Population (Table 8-10):	73	-	-	-
Homebound Special Needs (Section 8.5):	25	-	6	5
Correctional Facilities (Table 8-10):	37	-	-	-
TOTAL TRANSPORTATION NEEDS:	**592**	**35**	**48**	**146**

Table 8-6. Bus Route Descriptions

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
1	Alden School, Duxbury High School, Duxbury Middle School, Pilgrim Area Collaborative, South Shore Cons Preschool	146, 499, 500, 502, 501, 504, 42, 43, 44
2	Duxbury Bay Maritime School, Pilgrim Child Care & Preschool	145, 146, 499, 500, 502, 501, 504, 42, 43, 44
3	Chandler Elementary School, Elements Montessori School, Magic Dragon Childrens Center	672, 673, 671, 505, 504, 42, 43, 44
4	Berrybrook School, Discovery Corner Daycare	681, 165, 166, 675
5	Pied Piper Preschool	164, 681, 165, 166, 675
6	Bay Farm Montessori Academy, Good Shepherd Christian Academy, Cedar Hill Retreat Conference Center Daycare	496, 143, 142, 141, 522, 37, 38, 39, 40, 41, 42, 43, 44
7	Blue River ~~Montesorri~~Montessori School	536, 148, 149
8	Carver Elementary School, Erwin K. Washburn Primary School, Old Colony YMCA	230, 206, 229, 255, 228, 227, 57
9	Little Crusaders	234, 386, 383
10	Carver High School, Carver Middle School	423, 231, 230, 206, 229, 255, 228, 227, 57
11	Capt Pal Pre School, Cranberry Crossing Day Care, Kidstop Early Childhood Center	206, 229, 255, 228, 227, 57
12	Kids Count Day School	236, 235, 229, 255, 228, 227, 57
13	Kingston Elementary School, Kingston Intermediate School, Wooded Acres Child Care	289, 125, 126, 127, 128, 129, 130, 659, 661, 660, 658
14	Sacred Heart Early Childhood, Sacred Heart Elementary School, Sacred Heart High School	493, 252, 662
15	Silver Lake Regional High School, Silver Lake Regional Middle School	691, 560, 692
16	Crayon College Inc.	121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 659, 661, 660, 658
17	Growth Unlimited Preschool, South Shore Early Education, Little Peoples Country Day	129, 130, 659, 661, 660, 658
18	Governor Edward Winslow School	533, 528, 532
19	Plymouth South High School, Plymouth South Middle School	680, 328, 678, 592, 722, 721, 714

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
20	Plymouth Community Intermediate School, Learning Safari Day Care & Preschool	319, 326, 318, 317, 316, 321, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 5, 7
21	Indian Brook Elementary School	104, 105, 689, 106, 107, 108, 109, 110, 462, 464, 463, 469, 471, 172, 473, 472, 173, 174, 175, 176, 177, 17, 8, 478, 479, 67, 68, 69, 70, 71
22	Federal Furnace School, Woodside School and Community Resource Center	247, 248, 602, 234, 386, 383178, 478, 479, 67, 68, 69, 70, 71
23	Manomet Elementary School	98, 97, 102, 103, 688, 104, 105, 689, 106, 107, 108, 109, 110, 462, 464, 463, 469, 471, 172, 473, 472,173,174, 175, 176,177,178, 478, 479, 67, 68, 69, 70, 71
24	Plymouth North High School	312, 313, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
25	West Elementary School	251, 667, 252, 662, 253, 257, 55, 56, 57
26	Mount Pleasant School	114, 314, 313, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
27	Nathaniel Morton Elementary School, Small Scholars Preschool	114, 115, 116, 117, 250, 683, 629, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
28	South Elementary School, Ponds Childcare Center	713, 482, 481
29	Cold Spring Elementary School, Hop Skip & Jump Preschool	628, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
30	Hedge Elementary School	280, 278, 263, 262, 276, 51, 52, 53, 54, 55, 56, 57
31	Crayon College At Plymouth	278, 263, 262, 276, 51, 52, 53, 54, 55, 56, 57
32	Garden of Knowledge	94, 100, 296, 298, 299, 301, 300, 21, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55,56, 57
33	KinderCare Mulberry, KinderCare Super Kids, Rising Tide Charter Public School, Pilgrim Academy	269, 260, 261, 275, 262, 276, 51, 52, 53, 54, 55, 56, 57
34	Kinder Kollege, Leaping Frogs Preschool	96, 686, 99, 293, 290, 291, 17, 16, 15, 14, 13, 12, 11, 10, 9, 470, 172, 473, 472, 173, 174, 175, 176,177,178, 478, 479,67,68, 69, 70, 71
35	Methodist Nursery School	243, 201, 202, 251, 667, 252, 662, 253, 257, 55, 56, 57

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
36	New Testament Christian School	331, 332, 460, 10, 9, 470, 172, 473, 472, 173, 174, 175, 176, 177, 178, 478, 479, 67, 68, 69, 70, 71
37	Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	422, 663, 423, 231, 230, 206, 229, 255, 228, 227, 57
38	Room 2 Grow Nursery School	240, 241, 593, 595, 218, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
39	Tiny Town Inc.	104, 105, 689, 106, 107, 108, 109, 110, 462, 464, 463, 469, 471, 172, 473, 472, 173, 174, 175, 176, 177, 178,478,479,67,68,69, 70, 71
40	Bright Ideas Preschool	330, 331, 332, 460, 10, 9, 470, 172, 473, 472, 173, 174, 175, 176, 177, 178, 478, 479, 67, 68, 69, 70,71
41	Children's Creative Learning Center	596, 595, 218, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
42	High Point Treatment Center	104, 105, 689, 106, 107, 108, 109, 110, 462, 464, 463, 469, 471, 172, 473, 472, 173, 174, 175, 176, 177, 178,478,479,67,68,69, 70, 71
43	Jordan Hospital, Golden Living Center-Plymouth	312, 313, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
44	The Village At Duxbury, Bay Path Rehabilitation & Nursing Center, Duxbury House	672, 673, 671, 505, 504, 42, 43, 44
45	Baird Center Group Home, Habilitation Assistance Corporation	635, 669, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 659, 661, 660, 658
46	Chilton House Inc	116, 117, 250, 683, 629, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
47	Community Connections Inc	279, 269, 260, 261, 275, 262, 276, 51, 52, 53, 54, 55, 56, 57
48	Cozy Corner ADHC LLC	280, 119, 120, 635, 669, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 659, 661, 660, 658
49	Emeritus	112, 113, 114, 115, 116, 117, 250, 683, 629, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56,57
50	Life Care Center of Plymouth, Plymouth Crossings	313, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
51	Newfield House	241, 593, 595, 218, 197, 198, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57
52	Radius Health Care Nursing Home, Stafford Hill Assisted Living	314, 313, 315, 320, 22, 23, 24, 25, 26, 27, 28, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
53	Team Works	378, 379, 73
54	Wingate at Silver Lake	560, 692, 561
55	Transit Dependent Route - Sub-area 1	622, 95, 96, 686, 99, 293, 290, 291, 17, 16, 15, 14, 13, 12, 11, 10, 9, 470, 172, 473, 472, 173, 174,175,176, 177, 178, 478,479, 67, 68, 69, 70, 71
56	Transit Dependent Route - Sub-area 2	96, 687, 97, 102, 103, 688, 104, 105, 689, 106, 107, 108, 109, 110, 462, 464, 463, 469, 471, 172, 473,472,173, 174, 175,176,177, 178, 478, 479, 67, 68, 69, 70, 71
57	Transit Dependent Route - Sub-area 3	111, 112, 113, 312, 313, 315, 321, 316, 317, 318, 326, 319, 327, 322, 303, 328, 678, 592, 722, 721, 714, 694,249,248,602, 234, 386, 383
58	Transit Dependent Route - Sub-area 4	498, 497, 146, 499, 500, 502, 501, 504, 42, 43, 44
59	Transit Dependent Route - Sub-area 5	680, 292, 698, 329, 336, 337, 338, 339, 340, 664, 341
60	Transit Dependent Route - Sub-area 6	243, 201, 244, 245, 424, 422, 663, 423, 231, 230, 206, 229, 255, 228, 227, 57
61	Transit Dependent Route - Sub-area 7	202, 251, 667, 252, 662, 253, 257, 55, 56, 57
62	Transit Dependent Route - Sub-area 8	122, 123, 124, 125, 126, 127, 128, 129, 130, 659, 661, 660, 658
63	Transit Dependent Route - Sub-area 9	518, 496, 143, 142, 141, 522, 37, 38, 39, 40, 41, 42, 43, 44
64	Transit Dependent Route - Sub-area 10	535, 524, 525
65	Transit Dependent Route - Sub-area 11	234, 233, 232, 231, 230, 206, 229, 255, 228, 227, 57

Table 8-7. School Evacuation Time Estimates - Good Weather

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
After School Club Alden	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Alden School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Bay Farm Montessori Academy	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Berrybrook School	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Blue River ~~Montesorri~~Montessori School	90	15	0.7	27.0	2	1:50	20.7	32	2:20
Breakfast Club Chandler	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Bright Ideas Preschool	90	15	12.5	19.5	39	2:25	28.7	44	3:10
Capt Pal Pre School	90	15	2.1	4.2	30	2:15	16.2	25	2:40
Carver Elementary School	90	15	3.2	5.1	38	2:25	16.2	25	2:50
Carver High School	90	15	4.8	7.3	40	2:25	16.2	25	2:50
Carver Middle School	90	15	4.8	7.3	40	2:25	16.2	25	2:50
Cedarhill Retreat Conference Center Daycare	90	15	7.1	40.0	11	2:00	17.7	27	2:25
Chandler Elementary School	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Children's Creative Learning Center	90	15	8.6	9.8	53	2:40	16.2	25	3:05
Cold Spring Elementary School	90	15	8.8	10.0	53	2:40	16.2	25	3:05
Cranberry Crossing Day Care	90	15	2.1	4.2	30	2:15	16.2	25	2:40
Crayon College At Plymouth	90	15	7.2	8.2	53	2:40	16.2	25	3:05
Crayon College Inc.	90	15	5.3	40.0	8	1:55	10.6	16	2:10
Discovery Corner Daycare	90	15	3.6	12.0	19	2:05	19.3	29	2:35
Duxbury Bay Maritime School	90	15	6.6	4.8	83	3:10	17.7	27	3:35
Duxbury High School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Duxbury Middle School	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Elements Montessori School	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Erwin K. Washburn Primary School	90	15	3.2	5.1	38	2:25	16.2	25	2:50
Federal Furnace School	90	15	5.9	12.3	29	2:15	22.1	34	2:50
Garden of Knowledge	90	15	12.7	13.1	59	2:45	18.5	28	3:15
Good Shepherd Christian Academy	90	15	7.2	40.0	11	2:00	17.7	27	2:25
Governor Edward Winslow School	90	15	0.2	40.0	1	1:50	4.3	7	1:55

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Growth Unlimited Preschool	90	15	3.4	40.0	6	1:55	10.6	16	2:10
Hedge Elementary School	90	15	7.5	8.9	51	2:40	16.2	25	3:05
Hop, Skip & Jump Preschool	90	15	8.5	10.0	52	2:40	17.2	26	3:05
Indian Brook Elementary School	90	15	15.9	16.4	59	2:45	28.6	43	3:30
Junior Club Chandler	90	15	5.7	17.1	21	2:10	17.7	27	2:35
Kids Count Day School	90	15	0.6	2.2	18	2:05	16.2	25	2:30
Kidstop Early Childhood Center	90	15	2.1	4.2	30	2:15	16.2	25	2:40
Kinder Kollege	90	15	19.6	40.0	30	2:15	30.6	46	3:05
KinderCare - Pilgrim Hill	90	15	6.7	9.8	41	2:30	16.2	25	2:55
KinderCare - Richard's Road	90	15	7.0	8.2	52	2:40	16.2	25	3:05
Kindergarten Ext Chandler	90	15	17.1	23.6	44	2:30	17.7	27	3:00
Kingston Elementary School	90	15	4.4	40.0	7	1:55	10.6	16	2:10
Kingston Intermediate School	90	15	4.4	40.0	7	1:55	10.6	16	2:10
Leaping Frogs Preschool	90	15	19.5	40.0	30	2:15	30.6	46	3:05
Learning Safari Day Care & Preschool	90	15	34.6	19.2	108	3:35	50.6	76	4:50
Little Peoples Country Day	90	15	34.2	40.0	52	2:40	10.6	16	2:55
Magic Dragon Children's Center	90	15	17.1	23.6	44	2:30	17.7	27	3:00
Manomet Elementary School	90	15	18.2	12.9	85	3:10	31.5	48	4:00
Methodist Nursery School	90	15	6.7	9.8	42	2:30	16.2	25	2:55
Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	90	15	6.8	9.8	42	2:30	16.2	25	2:55
Mount Pleasant School	90	15	11.4	11.7	59	2:45	16.2	25	3:10
Nathaniel Morton Elementary School	90	15	6.8	9.2	45	2:30	14.2	22	2:55
New Testament Christian School	90	15	10.4	34.4	19	2:05	30.6	46	2:50
Old Colony YMCA	90	15	3.2	5.1	38	2:25	16.2	25	2:50
Pied Piper Preschool	90	15	3.6	16.0	14	2:00	19.3	29	2:30
Pilgrim Academy	90	15	4.1	8.7	29	2:15	22.4	34	2:50
Pilgrim Area Collab. (Alden)	90	15	5.6	4.2	81	3:10	17.7	27	3:35
Pilgrim Area Collab. (Chandler)	90	15	17.1	23.6	44	2:30	17.7	27	3:00
Pilgrim Area Collab. (High School)	90	15	5.6	4.2	81	3:10	17.7	27	3:35

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Pilgrim Area Collab. (Middle)	90	15	5.6	4.2	81	**3:10**	17.7	27	**3:35**
Pilgrim Area Collaborative	90	15	5.6	4.2	81	**3:10**	17.7	27	**3:35**
Pilgrim Child Care & Preschool	90	15	6.6	4.8	83	**3:10**	17.7	27	**3:35**
Plymouth Community Intermediate School	90	15	10.9	11.4	58	**2:45**	14.8	23	**3:10**
Plymouth North High School	90	15	10.6	11.5	56	**2:45**	16.2	25	**3:10**
Plymouth South High School	90	15	11.3	30.9	22	**2:10**	19.9	30	**2:40**
Plymouth South Middle School	90	15	11.3	30.9	22	**2:10**	19.9	30	**2:40**
Ponds Chlidcare Center	90	15	11.3	17.8	39	**2:25**	19.9	30	**2:55**
Rising Tide Charter Public School	90	15	7.0	8.2	52	**2:40**	16.2	25	**3:05**
Room 2 Grow Nursery School	90	15	9.1	10.3	53	**2:40**	16.2	25	**3:05**
Sacred Heart Early Childhood	90	15	4.8	36.5	8	**1:55**	14.6	22	**2:15**
Sacred Heart Elementary School	90	15	4.8	36.5	8	**1:55**	14.6	22	**2:15**
Sacred Heart High School	90	15	4.8	36.5	8	**1:55**	14.6	22	**2:15**
Silver Lake Regional High School	90	15	1.1	35.0	2	**1:50**	13.0	20	**2:10**
Silver Lake Regional Middle School	90	15	1.1	35.0	2	**1:50**	13.0	20	**2:10**
South Elementary School	90	15	3.0	36.4	5	**1:50**	28.1	43	**2:35**
South Shore Cons Preschool	90	15	5.6	4.2	81	**3:10**	17.7	27	**3:35**
South Shore Early Education	90	15	3.5	40.0	6	**1:55**	10.6	16	**2:10**
Small Scholars Preschool	90	15	1.4	9.0	10	**1:55**	3.5	6	**2:05**
Tiny Town Inc.	90	15	15.7	16.4	58	**2:45**	30.6	46	**3:30**
West Elementary School	90	15	5.3	8.5	38	**2:25**	16.2	25	**2:50**
Wooded Acres Child Care	90	15	4.4	40.0	7	**1:55**	10.6	16	**2:10**
Woodside School and Community Resource Center	90	15	5.9	12.3	29	**2:15**	22.1	34	**2:50**
					Maximum for EPZ:	**3:35**		**Maximum:**	**4:50**
					Average for EPZ:	**2:25**		**Average:**	**2:55**

Table 8-8. School Evacuation Time Estimates - Rain

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
After School Club Alden	100	20	5.6	4.5	75	3:15	17.7	31	3:50
Alden School	100	20	5.6	4.5	75	3:15	17.7	31	3:50
Bay Farm Montessori Academy	100	20	7.1	38.2	12	2:15	17.7	31	2:45
Berrybrook School	100	20	7.1	38.2	12	2:15	17.7	31	2:45
Blue River Montesorri School	100	20	0.7	26.9	2	2:05	20.7	36	2:40
Breakfast Club Chandler	100	20	5.7	25.2	14	2:15	17.7	31	2:45
Bright Ideas Preschool	100	20	12.5	19.6	39	2:40	28.7	50	3:30
Capt Pal Pre School	100	20	2.1	4.5	29	2:30	16.2	28	3:00
Carver Elementary School	100	20	3.2	5.9	32	2:35	16.2	28	3:00
Carver High School	100	20	4.8	8.3	35	2:35	16.2	28	3:05
Carver Middle School	100	20	4.8	8.3	35	2:35	16.2	28	3:05
Cedarhill Retreat Conference Center Daycare	100	20	7.1	38.2	12	2:15	17.7	31	2:45
Chandler Elementary School	100	20	5.7	25.2	14	2:15	17.7	31	2:45
Children's Creative Learning Center	100	20	8.6	10.5	50	2:50	16.2	28	3:20
Cold Spring Elementary School	100	20	8.8	10.7	50	2:50	16.2	28	3:20
Cranberry Crossing Day Care	100	20	2.1	4.5	29	2:30	16.2	28	3:00
Crayon College At Plymouth	100	20	7.2	8.8	50	2:50	16.2	28	3:20
Crayon College Inc.	100	20	5.3	40.0	8	2:10	10.6	19	2:30
Discovery Corner Daycare	100	20	3.6	5.1	43	2:45	19.3	34	3:20
Duxbury Bay Maritime School	100	20	6.6	5.5	73	3:15	17.7	31	3:45
Duxbury High School	100	20	5.6	4.5	75	3:15	17.7	31	3:50
Duxbury Middle School	100	20	5.6	4.5	75	3:15	17.7	31	3:50
Elements Montessori School	100	20	5.7	25.2	14	2:15	17.7	31	2:45
Erwin K. Washburn Primary School	100	20	3.2	5.9	32	2:35	16.2	28	3:00
Federal Furnace School	100	20	5.9	18.5	20	2:20	22.1	38	3:00
Garden of Knowledge	100	20	12.7	13.9	55	2:55	18.5	32	3:30
Good Shepherd Christian Academy	100	20	7.2	38.2	12	2:15	17.7	31	2:45
Governor Edward Winslow School	100	20	0.2	40.0	1	2:05	4.3	8	2:10

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Growth Unlimited Preschool	100	20	3.4	40.0	6	**2:10**	10.6	19	**2:25**
Hedge Elementary School	100	20	7.5	9.6	47	**2:50**	16.2	28	**3:15**
Hop, Skip & Jump Preschool	100	20	8.5	10.5	49	**2:50**	17.2	30	**3:20**
Indian Brook Elementary School	100	20	15.9	17.5	55	**2:55**	28.6	50	**3:45**
Junior Club Chandler	100	20	5.7	25.2	14	**2:15**	17.7	31	**2:45**
Kids Count Day School	100	20	0.6	2.9	14	**2:15**	16.2	28	**2:45**
Kidstop Early Childhood Center	100	20	2.1	4.5	29	**2:30**	16.2	28	**3:00**
Kinder Kollege	100	20	19.6	40.0	30	**2:30**	30.6	53	**3:25**
KinderCare - Pilgrim Hill	100	20	6.7	10.7	38	**2:40**	16.2	28	**3:10**
KinderCare - Richard's Road	100	20	7.0	8.9	48	**2:50**	16.2	28	**3:20**
Kindergarten Ext Chandler	100	20	17.1	29.5	35	**2:35**	17.7	31	**3:10**
Kingston Elementary School	100	20	4.4	40.0	7	**2:10**	10.6	19	**2:30**
Kingston Intermediate School	100	20	4.4	40.0	7	**2:10**	10.6	19	**2:30**
Leaping Frogs Preschool	100	20	19.5	40.0	30	**2:30**	30.6	53	**3:25**
Learning Safari Day Care & Preschool	100	20	34.6	21.6	97	**3:40**	50.6	87	**5:05**
Little Peoples Country Day	100	20	34.2	40.0	52	**2:55**	10.6	19	**3:15**
Magic Dragon Childrens Center	100	20	17.1	29.5	35	**2:35**	17.7	31	**3:10**
Manomet Elementary School	100	20	18.2	14.8	74	**3:15**	31.5	54	**4:10**
Methodist Nursery School	100	20	6.7	10.7	38	**2:40**	16.2	28	**3:10**
Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	100	20	6.8	11.6	36	**2:40**	16.2	28	**3:05**
Mount Pleasant School	100	20	11.4	12.6	55	**2:55**	16.2	28	**3:25**
Nathaniel Morton Elementary School	100	20	6.8	10.5	39	**2:40**	14.2	25	**3:05**
New Testament Christian School	100	20	10.4	34.0	19	**2:20**	30.6	53	**3:15**
Old Colony YMCA	100	20	3.2	5.9	32	**2:35**	16.2	28	**3:00**
Pied Piper Preschool	100	20	3.6	6.0	37	**2:40**	19.3	34	**3:15**
Pilgrim Academy	100	20	4.1	7.8	32	**2:35**	22.4	39	**3:15**
Pilgrim Area Collab. (Alden)	100	20	5.6	4.5	75	**3:15**	17.7	31	**3:50**
Pilgrim Area Collab. (Chandler)	100	20	17.1	29.5	35	**2:35**	17.7	31	**3:10**
Pilgrim Area Collab. (High School)	100	20	5.6	4.5	75	**3:15**	17.7	31	**3:50**

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Pilgrim Area Collab. (Middle)	100	20	5.6	4.5	75	**3:15**	17.7	31	**3:50**
Pilgrim Area Collaborative	100	20	5.6	4.5	75	**3:15**	17.7	31	**3:50**
Pilgrim Child Care & Preschool	100	20	6.6	5.5	73	**3:15**	17.7	31	**3:45**
Plymouth Community Intermediate School	100	20	10.9	12.3	54	**2:55**	14.8	26	**3:20**
Plymouth North High School	100	20	10.6	12.3	52	**2:55**	16.2	28	**3:20**
Plymouth South High School	100	20	11.3	29.7	23	**2:25**	19.9	35	**3:00**
Plymouth South Middle School	100	20	11.3	29.7	23	**2:25**	19.9	35	**3:00**
Ponds Chlidcare Center	100	20	11.3	25.1	28	**2:30**	19.9	35	**3:05**
Rising Tide Charter Public School	100	20	7.0	8.9	48	**2:50**	16.2	28	**3:20**
Room 2 Grow Nursery School	100	20	9.1	11.0	50	**2:50**	16.2	28	**3:20**
Sacred Heart Early Childhood	100	20	4.8	35.8	9	**2:10**	14.6	26	**2:35**
Sacred Heart Elementary School	100	20	4.8	35.8	9	**2:10**	14.6	26	**2:35**
Sacred Heart High School	100	20	4.8	35.8	9	**2:10**	14.6	26	**2:35**
Silver Lake Regional High School	100	20	1.1	35.0	2	**2:05**	13.0	23	**2:25**
Silver Lake Regional Middle School	100	20	1.1	35.0	2	**2:05**	13.0	23	**2:25**
South Elementary School	100	20	3.0	36.7	5	**2:05**	28.1	49	**2:55**
South Shore Cons Preschool	100	20	5.6	4.5	75	**3:15**	17.7	31	**3:50**
South Shore Early Education	100	20	3.5	40.0	6	**2:10**	10.6	19	**2:25**
Small Scholars Preschool	100	20	1.4	9.5	10	**2:10**	3.5	6	**2:20**
Tiny Town Inc.	100	20	15.7	17.2	55	**2:55**	30.6	53	**3:50**
West Elementary School	100	20	5.3	8.4	39	**2:40**	16.2	28	**3:10**
Wooded Acres Child Care	100	20	4.4	40.0	7	**2:10**	10.6	19	**2:30**
Woodside School and Community Resource Center	100	20	5.9	18.5	20	**2:20**	22.1	38	**3:00**
					Maximum for EPZ:	**3:40**		**Maximum:**	**5:05**
					Average for EPZ:	**2:40**		**Average:**	**3:10**

Table 8-9. School Evacuation Time Estimates - Snow

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
After School Club Alden	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Alden School	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Bay Farm Montessori Academy	110	25	7.1	38.7	12	**2:30**	17.7	36	**3:05**
Berrybrook School	110	25	7.1	38.7	12	**2:30**	17.7	36	**3:05**
Blue River ~~Montesorri~~Montessori School	110	25	0.7	28.6	2	**2:20**	20.7	42	**3:00**
Breakfast Club Chandler	110	25	5.7	30.1	12	**2:30**	17.7	36	**3:05**
Bright Ideas Preschool	110	25	12.5	19.7	39	**2:55**	28.7	58	**3:55**
Capt Pal Pre School	110	25	2.1	5.0	26	**2:45**	16.2	33	**3:15**
Carver Elementary School	110	25	3.2	7.5	26	**2:45**	16.2	33	**3:15**
Carver High School	110	25	4.8	10.2	29	**2:45**	16.2	33	**3:20**
Carver Middle School	110	25	4.8	10.2	29	**2:45**	16.2	33	**3:20**
Cedarhill Retreat Conference Center Daycare	110	25	7.1	38.7	11	**2:30**	17.7	36	**3:05**
Chandler Elementary School	110	25	5.7	30.1	12	**2:30**	17.7	36	**3:05**
Children's Creative Learning Center	110	25	8.6	11.5	45	**3:00**	16.2	33	**3:35**
Cold Spring Elementary School	110	25	8.8	11.7	45	**3:00**	16.2	33	**3:35**
Cranberry Crossing Day Care	110	25	2.1	5.0	26	**2:45**	16.2	33	**3:15**
Crayon College At Plymouth	110	25	7.2	10.0	44	**3:00**	16.2	33	**3:35**
Crayon College Inc.	110	25	5.3	40.0	8	**2:25**	10.6	22	**2:45**
Discovery Corner Daycare	110	25	3.6	9.7	23	**2:40**	19.3	39	**3:20**
Duxbury Bay Maritime School	110	25	6.6	5.9	67	**3:25**	17.7	36	**4:00**
Duxbury High School	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Duxbury Middle School	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Elements Montessori School	110	25	5.7	30.1	12	**2:30**	17.7	36	**3:05**
Erwin K. Washburn Primary School	110	25	3.2	7.5	26	**2:45**	16.2	33	**3:15**
Federal Furnace School	110	25	5.9	36.1	10	**2:25**	22.1	45	**3:10**
Garden of Knowledge	110	25	12.7	16.1	48	**3:05**	18.5	37	**3:40**
Good Shepherd Christian Academy	110	25	7.2	38.7	12	**2:30**	17.7	36	**3:05**
Governor Edward Winslow School	110	25	0.2	40.0	1	**2:20**	4.3	9	**2:25**

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Growth Unlimited Preschool	110	25	3.4	40.0	6	**2:25**	10.6	22	**2:45**
Hedge Elementary School	110	25	7.5	10.4	44	**3:00**	16.2	33	**3:35**
Hop, Skip & Jump Preschool	110	25	8.5	11.7	44	**3:00**	17.2	35	**3:35**
Indian Brook Elementary School	110	25	15.9	17.8	54	**3:10**	28.6	58	**4:10**
Junior Club Chandler	110	25	5.7	30.1	12	**2:30**	17.7	36	**3:05**
Kids Count Day School	110	25	0.6	3.3	12	**2:30**	16.2	33	**3:00**
Kidstop Early Childhood Center	110	25	2.1	5.0	26	**2:45**	16.2	33	**3:15**
Kinder Kollege	110	25	19.6	40.0	30	**2:45**	30.6	62	**3:50**
KinderCare - Pilgrim Hill	110	25	6.7	10.8	38	**2:55**	16.2	33	**3:30**
KinderCare - Richard's Road	110	25	7.0	9.6	44	**3:00**	16.2	33	**3:35**
Kindergarten Ext Chandler	110	25	17.1	34.3	30	**2:45**	17.7	36	**3:25**
Kingston Elementary School	110	25	4.4	40.0	7	**2:25**	10.6	22	**2:45**
Kingston Intermediate School	110	25	4.4	40.0	7	**2:25**	10.6	22	**2:45**
Leaping Frogs Preschool	110	25	19.5	40.0	30	**2:45**	30.6	62	**3:50**
Learning Safari Day Care & Preschool	110	25	34.6	24.5	85	**3:40**	50.6	102	**5:25**
Little Peoples Country Day	110	25	34.2	40.0	52	**3:10**	10.6	22	**3:30**
Magic Dragon Childrens Center	110	25	17.1	34.3	30	**2:45**	17.7	36	**3:25**
Manomet Elementary School	110	25	18.2	16.4	67	**3:25**	31.5	63	**4:25**
Methodist Nursery School	110	25	6.7	10.8	38	**2:55**	16.2	33	**3:30**
Miss Jo Anne's Bright ~~Begnnngs~~Beginnings	110	25	6.8	13.7	30	**2:45**	16.2	33	**3:20**
Mount Pleasant School	110	25	11.4	14.6	48	**3:05**	16.2	33	**3:40**
Nathaniel Morton Elementary School	110	25	6.8	11.5	36	**2:55**	14.2	29	**3:20**
New Testament Christian School	110	25	10.4	34.4	19	**2:35**	30.6	62	**3:40**
Old Colony YMCA	110	25	3.2	7.5	26	**2:45**	16.2	33	**3:15**
Pied Piper Preschool	110	25	3.6	10.9	21	**2:40**	19.3	39	**3:15**
Pilgrim Academy	110	25	4.1	8.9	28	**2:45**	22.4	45	**3:30**
Pilgrim Area Collab. (Alden)	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Pilgrim Area Collab. (Chandler)	110	25	17.1	34.3	30	**2:45**	17.7	36	**3:25**
Pilgrim Area Collab. (High School)	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time from EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Pilgrim Area Collab. (Middle)	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Pilgrim Area Collaborative	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
Pilgrim Child Care & Preschool	110	25	6.6	5.9	67	**3:25**	17.7	36	**4:00**
Plymouth Community Intermediate School	110	25	10.9	14.3	46	**3:05**	14.8	30	**3:35**
Plymouth North High School	110	25	10.6	14.3	45	**3:00**	16.2	33	**3:35**
Plymouth South High School	110	25	11.3	32.1	22	**2:40**	19.9	40	**3:20**
Plymouth South Middle School	110	25	11.3	32.1	22	**2:40**	19.9	40	**3:20**
Ponds Childcare Center	110	25	11.3	37.1	19	**2:35**	19.9	40	**3:15**
Rising Tide Charter Public School	110	25	7.0	9.6	44	**3:00**	16.2	33	**3:35**
Room 2 Grow Nursery School	110	25	9.1	12.6	44	**3:00**	16.2	33	**3:35**
Sacred Heart Early Childhood	110	25	4.8	36.6	8	**2:25**	14.6	30	**2:55**
Sacred Heart Elementary School	110	25	4.8	36.6	8	**2:25**	14.6	30	**2:55**
Sacred Heart High School	110	25	4.8	36.6	8	**2:25**	14.6	30	**2:55**
Silver Lake Regional High School	110	25	1.1	35.0	2	**2:20**	13.0	26	**2:45**
Silver Lake Regional Middle School	110	25	1.1	35.0	2	**2:20**	13.0	26	**2:45**
South Elementary School	110	25	3.0	36.6	5	**2:20**	28.1	57	**3:20**
South Shore Cons Preschool	110	25	5.6	5.2	65	**3:20**	17.7	36	**4:00**
South Shore Early Education	110	25	3.5	40.0	6	**2:25**	10.6	22	**2:45**
Small Scholars Preschool	110	25	1.4	8.9	10	**2:25**	3.5	7	**2:35**
Tiny Town Inc.	110	25	15.7	17.8	53	**3:10**	30.6	62	**4:10**
West Elementary School	110	25	5.3	9.6	34	**2:50**	16.2	33	**3:25**
Wooded Acres Child Care	110	25	4.4	40.0	7	**2:25**	10.6	22	**2:45**
Woodside School and Community Resource Center	110	25	5.9	36.1	10	**2:25**	22.1	45	**3:10**
					Maximum for EPZ:	**3:40**		**Maximum:**	**5:25**
					Average for EPZ:	**2:50**		**Average:**	**3:25**

Table 8-10. Summary of Transit-Dependent Bus Routes

Route	Route Description	Length (mi.)	No. of Buses
Transit Dependent Residents			
1	Sub-area 1 to Taunton High School Reception Center	25.6	3
2	Sub-area 2 to Taunton High School Reception Center	25.3	7
3	Sub-area 3 to Taunton High School Reception Center	22.0	9
4	Sub-area 4 to Braintree High School Reception Center	7.1	1
5	Sub-area 5 to Taunton High School Reception Center	25.2	12
6	Sub-area 6 to Taunton High School Reception Center	21.5	6
7	Sub-area 7 to Bridgewater State University Reception Center	8.9	7
8	Sub-area 8 to Bridgewater State University Reception Center	22.3	10
9	Sub-area 9 to Braintree High School Reception Center	44.3	12
10	Sub-area 10 to Braintree High School Reception Center	7.1	2
11	Sub-area 11 to Bridgewater State University Reception Center	35.5	4
	Transit Dependent Resident Subtotal:		***73***
Correctional Facilities			
N/A	Plymouth County Correctional Facility	10.7	32
N/A	MCI Plymouth	6.9	5
	Correctional Facility Subtotal:		***37***
	Total:		**110**

Table 8-11. Transit-Dependent Evacuation Time Estimates - Good Weather

		One-Wave						Two-Wave					
Route Number	Bus Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	90	25.6	37.2	41	30	2:45	27.3	41	5	10	79	30	5:30
	2, 3	110	25.6	40.0	38	30	3:00	27.3	41	5	10	79	30	5:45
2	1, 2	90	25.3	13.4	113	30	3:55	27.3	41	5	10	79	30	6:40
	3, 4	100	25.3	14.5	105	30	3:55	27.3	41	5	10	79	30	6:40
	5, 6, 7	110	25.3	15.7	97	30	4:00	27.3	41	5	10	79	30	6:45
3	1, 2, 3	90	22.0	16.8	79	30	3:20	20.1	30	5	10	63	30	5:40
	4, 5, 6	100	22.0	18.0	73	30	3:25	20.1	30	5	10	63	30	5:45
	7, 8, 9	110	22.0	19.1	69	30	3:30	20.1	30	5	10	63	30	5:50
4	1	90	7.1	4.9	87	30	3:30	17.7	27	5	10	37	30	5:20
5	1, 2, 3	90	25.2	15.1	100	30	3:40	29.7	45	5	10	82	30	6:35
	4, 5, 6	95	25.2	15.5	98	30	3:45	29.7	45	5	10	82	30	6:35
	7, 8, 9	100	25.2	15.9	95	30	3:50	29.7	45	5	10	82	30	6:40
	10, 11, 12	110	25.2	17.8	85	30	3:45	29.7	45	5	10	82	30	6:40
6	1, 2, 3	90	21.5	13.6	95	30	3:35	14.8	22	5	10	54	30	5:40
	4, 5, 6	110	21.5	15.6	83	30	3:45	14.8	22	5	10	54	30	5:45
7	1, 2	90	8.9	9.3	57	30	3:00	14.4	22	5	10	35	30	4:40
	3, 4	100	8.9	9.2	58	30	3:10	14.4	22	5	10	35	30	4:50
	5, 6, 7	110	8.9	9.8	54	30	3:15	14.4	22	5	10	35	30	5:00
8	1, 2	90	22.3	40.0	33	30	2:35	13.7	21	5	10	54	30	4:35
	3, 4	95	22.3	40.0	33	30	2:40	13.7	21	5	10	54	30	4:40
	5, 6, 7	100	22.3	40.0	33	30	2:45	13.7	21	5	10	54	30	4:45
	8, 9, 10	110	22.3	40.0	33	30	2:55	13.7	21	5	10	54	30	4:55
9	1, 2, 3	90	44.3	39.4	67	30	3:10	17.7	27	5	10	93	30	5:55
	4, 5, 6	95	44.3	39.4	67	30	3:15	17.7	27	5	10	93	30	6:00

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
	7, 8, 9	100	44.3	39.4	67	30	**3:20**	17.7	27	5	10	93	30	**6:05**
	10, 11, 12	110	44.3	39.4	67	30	**3:30**	17.7	27	5	10	93	30	**6:15**
10	1	90	7.1	35.9	12	30	**2:15**	23.8	36	5	10	47	30	**4:20**
	2	110	7.1	36.6	12	30	**2:35**	23.8	36	5	10	47	30	**4:40**
11	1, 2	90	35.5	16.8	127	30	**4:10**	14.4	22	5	10	75	30	**6:30**
	3, 4	110	35.5	19.3	111	30	**4:15**	14.4	22	5	10	75	30	**6:35**
						Maximum ETE:	**4:15**						**Maximum ETE:**	**6:45**
						Average ETE:	**3:25**						**Average ETE:**	**5:45**

Table 8-12. Transit-Dependent Evacuation Time Estimates - Rain

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	100	25.6	32.5	47	40	3:10	27.3	47	5	10	89	40	6:20
	2, 3	120	25.6	35.9	43	40	3:25	27.3	47	5	10	89	40	6:35
2	1, 2	100	25.3	12.1	125	40	4:25	27.3	47	5	10	89	40	7:40
	3, 4	110	25.3	13.2	115	40	4:25	27.3	47	5	10	89	40	7:40
	5, 6, 7	120	25.3	13.8	110	40	4:30	27.3	47	5	10	89	40	7:45
3	1, 2, 3	100	22.0	21.4	62	40	3:25	20.1	34	5	10	71	40	6:05
	4, 5, 6	110	22.0	21.2	62	40	3:35	20.1	34	5	10	71	40	6:15
	7, 8, 9	120	22.0	22.6	58	40	3:40	20.1	34	5	10	71	40	6:20
4	1	100	7.1	4.0	107	40	4:10	17.7	30	5	10	42	40	6:15
5	1, 2, 3	100	25.2	13.7	110	40	4:15	29.7	51	5	10	93	40	7:30
	4, 5, 6	105	25.2	14.0	108	40	4:15	29.7	51	5	10	93	40	7:35
	7, 8, 9	110	25.2	14.3	106	40	4:20	29.7	51	5	10	93	40	7:35
	10, 11, 12	120	25.2	15.4	98	40	4:20	29.7	51	5	10	93	40	7:40
4	1, 2, 3	100	21.5	13.1	99	40	4:00	14.8	25	5	10	61	40	6:25
	4, 5, 6	120	21.5	14.3	90	40	4:10	14.8	25	5	10	61	40	6:35
7	1, 2	100	8.9	8.5	63	40	3:25	14.4	25	5	10	40	40	5:25
	3, 4	110	8.9	9.0	60	40	3:30	14.4	25	5	10	40	40	5:30
	5, 6, 7	120	8.9	9.1	58	40	3:40	14.4	25	5	10	40	40	5:40
8	1, 2	100	22.3	36.0	37	40	3:00	13.7	23	5	10	61	40	5:20
	3, 4	105	22.3	36.0	37	40	3:05	13.7	23	5	10	61	40	5:25
	5, 6, 7	110	22.3	36.0	37	40	3:10	13.7	23	5	10	61	40	5:30
	8, 9, 10	120	22.3	36.0	37	40	3:20	13.7	23	5	10	61	40	5:40
9	1, 2, 3	100	44.3	33.9	78	40	3:40	17.7	30	5	10	104	40	6:50
	4, 5, 6	105	44.3	33.9	78	40	3:45	17.7	30	5	10	104	40	6:55

		One-Wave						Two-Wave						
Route Number	Bus Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
	7, 8, 9	110	44.3	33.9	78	40	3:50	17.7	30	5	10	104	40	7:00
	10, 11, 12	120	44.3	33.9	78	40	4:00	17.7	30	5	10	104	40	7:10
10	1	100	7.1	33.1	13	40	2:35	23.8	41	5	10	53	40	5:05
	2	120	7.1	32.4	13	40	2:55	23.8	41	5	10	53	40	5:25
11	1, 2	100	35.5	15.6	136	40	4:40	14.4	25	5	10	84	40	7:20
	3, 4	120	35.5	17.6	121	40	4:45	14.4	25	5	10	84	40	7:25
						Maximum ETE:	4:45						Maximum ETE:	7:45
						Average ETE:	3:50						Average ETE:	6:35

Table 8-13. Transit Dependent Evacuation Time Estimates - Snow

		One-Wave									Two-Wave			
Route Number	Bus Number	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	110	25.6	31.8	48	50	**3:30**	27.3	55	5	10	103	50	**7:15**
	2, 3	130	25.6	32.0	48	50	**3:50**	27.3	55	5	10	103	50	**7:35**
2	1, 2	110	25.3	13.2	115	50	**4:35**	27.3	55	5	10	102	50	**8:20**
	3, 4	120	25.3	13.8	110	50	**4:40**	27.3	55	5	10	102	50	**8:25**
	5, 6, 7	130	25.3	14.9	102	50	**4:45**	27.3	55	5	10	102	50	**8:25**
3	1, 2, 3	110	22.0	21.2	62	50	**3:45**	20.1	40	5	10	81	50	**6:50**
	4, 5, 6	120	22.0	22.6	58	50	**3:50**	20.1	40	5	10	81	50	**7:00**
	7, 8, 9	130	22.0	23.4	56	50	**4:00**	20.1	40	5	10	81	50	**7:05**
4	1	110	7.1	4.1	104	50	**4:25**	17.7	35	5	10	49	50	**6:55**
5	1, 2, 3	110	25.2	14.2	107	50	**4:30**	29.7	59	5	10	107	50	**8:20**
	4, 5, 6	115	25.2	15.1	100	50	**4:30**	29.7	59	5	10	107	50	**8:20**
	7, 8, 9	120	25.2	15.3	99	50	**4:30**	29.7	59	5	10	107	50	**8:20**
	10, 11, 12	130	25.2	16.5	92	50	**4:35**	29.7	59	5	10	107	50	**8:25**
4	1, 2, 3	110	21.5	13.8	93	50	**4:15**	14.8	30	5	10	70	50	**7:00**
	4, 5, 6	130	21.5	15.3	84	50	**4:25**	14.8	30	5	10	70	50	**7:10**
7	1, 2	110	8.9	9.0	60	50	**3:40**	14.4	29	5	10	45	50	**6:00**
	3, 4	120	8.9	9.1	58	50	**3:50**	14.4	29	5	10	45	50	**6:10**
	5, 6, 7	130	8.9	8.7	61	50	**4:05**	14.4	29	5	10	45	50	**6:25**
8	1, 2	110	22.3	32.0	42	50	**3:25**	13.7	27	5	10	69	50	**6:05**
	3, 4	115	22.3	32.0	42	50	**3:30**	13.7	27	5	10	69	50	**6:10**
	5, 6, 7	120	22.3	32.0	42	50	**3:35**	13.7	27	5	10	69	50	**6:15**
	8, 9, 10	130	22.3	32.0	42	50	**3:45**	13.7	27	5	10	69	50	**6:25**
9	1, 2, 3	110	44.3	31.9	83	50	**4:05**	17.7	35	5	10	118	50	**7:45**
	4, 5, 6	115	44.3	31.9	83	50	**4:10**	17.7	35	5	10	118	50	**7:50**

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to R. C. (miles)	Travel Time to R. C. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
	7, 8, 9	120	44.3	31.9	83	50	4:15	17.7	35	5	10	118	50	7:55
	10, 11, 12	130	44.3	31.9	83	50	4:25	17.7	35	5	10	118	50	8:05
10	1	110	7.1	32.0	13	50	2:55	23.8	48	5	10	61	50	5:50
	2	130	7.1	32.0	13	50	3:15	23.8	48	5	10	61	50	6:10
11	1, 2	110	35.5	16.2	131	50	4:55	14.4	29	5	10	95	50	8:05
	3, 4	130	35.5	18.3	116	50	5:00	14.4	29	5	10	95	50	8:10
						Maximum ETE:	5:00						Maximum ETE:	8:25
						Average ETE:	4:05						Average ETE:	7:20

Table 8-14. Medical Facility Evacuation Time Estimates - Good Weather

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Baird Center Group Home	Ambulatory	90	1	19	19	5.7	9	2:00
	Wheelchair bound	90	5	9	45	5.7	9	2:25
	Bedridden	90	15	7	30	5.7	8	2:10
Bay Path Rehabilitation & Nursing Center	Ambulatory	90	1	61	30	5.6	13	2:15
	Wheelchair bound	90	5	30	75	5.6	8	2:55
	Bedridden	90	15	24	30	5.6	13	2:15
Chilton House Inc	Ambulatory	90	1	22	22	8.8	51	2:45
	Wheelchair bound	90	5	10	50	8.8	42	3:05
	Bedridden	90	15	8	30	8.8	49	2:50
Community Connections Inc	Ambulatory	90	1	31	30	7.1	45	2:45
	Wheelchair bound	90	5	5	25	7.1	46	2:45
	Bedridden	90	15	10	30	7.1	45	2:45
Cozy Corner ADHC LLC	Ambulatory	90	1	28	28	7.0	11	2:10
	Wheelchair bound	90	5	4	20	7.0	11	2:05
	Bedridden	90	15	9	30	7.0	11	2:15
Duxbury House	Ambulatory	90	1	11	11	5.6	20	2:05
	Wheelchair bound	90	5	6	30	5.6	13	2:15
	Bedridden	90	15	5	30	5.6	13	2:15
Emeritus	Ambulatory	90	1	58	30	10.9	53	2:55
	Wheelchair bound	90	5	30	75	10.9	29	3:15
	Bedridden	90	15	9	30	10.9	53	2:55
Golden Living Center-Plymouth	Ambulatory	90	1	50	30	11.1	54	2:55
	Wheelchair bound	90	5	22	75	11.1	28	3:15
	Bedridden	90	15	58	30	11.1	54	2:55
Habilitation	Ambulatory	90	1	40	30	5.7	9	2:10

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Assistance Corporation	Wheelchair bound	90	5	26	75	5.7	9	**2:55**
	Bedridden	90	15	18	30	5.7	8	**2:10**
High Point Treatment Center	Ambulatory	90	1	164	30	18.3	62	**3:05**
	Wheelchair bound	90	5	2	10	18.3	68	**2:50**
	Bedridden	90	15	44	30	18.3	62	**3:05**
Jordan Hospital	Ambulatory	90	1	79	30	11.1	54	**2:55**
	Wheelchair bound	90	5	39	75	11.1	28	**3:15**
	Bedridden	90	15	31	30	11.1	54	**2:55**
Life Care Center of Plymouth	Ambulatory	90	1	65	30	10.2	52	**2:55**
	Wheelchair bound	90	5	79	75	10.2	29	**3:15**
	Bedridden	90	15	60	30	10.2	52	**2:55**
Newfield House	Ambulatory	90	1	57	30	9.0	50	**2:50**
	Wheelchair bound	90	5	31	75	9.0	28	**3:15**
	Bedridden	90	15	3	30	9.0	50	**2:50**
Plymouth Crossings	Ambulatory	90	1	68	30	10.2	52	**2:55**
	Wheelchair bound	90	5	4	20	10.2	54	**2:45**
	Bedridden	90	15	19	30	10.2	52	**2:55**
Radius Health Care Nursing Home	Ambulatory	90	1	98	30	10.5	52	**2:55**
	Wheelchair bound	90	5	96	75	10.5	29	**3:15**
	Bedridden	90	15	34	30	10.5	52	**2:55**
Stafford Hill Assisted Living	Ambulatory	90	1	85	30	10.5	52	**2:55**
	Wheelchair bound	90	5	6	30	10.5	52	**2:55**
	Bedridden	90	15	24	30	10.5	52	**2:55**
Team Works	Ambulatory	90	1	12	12	2.8	5	**1:50**
	Wheelchair bound	90	5	5	25	2.8	5	**2:00**
	Bedridden	90	15	4	30	2.8	5	**2:05**

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
The Village At Duxbury	Ambulatory	90	1	31	30	5.6	13	**2:15**
	Wheelchair bound	90	5	15	75	5.6	8	**2:55**
	Bedridden	90	15	12	30	5.6	13	**2:15**
Wingate at Silver Lake	Ambulatory	90	1	127	30	0.7	1	**2:05**
	Wheelchair bound	90	5	63	75	0.7	1	**2:50**
	Bedridden	90	15	51	30	0.7	1	**2:05**
							Maximum ETE:	**3:05**
							Average ETE:	**2:30**

Table 8-15. Medical Facility Evacuation Time Estimates - Rain

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Baird Center Group Home	Ambulatory	100	1	19	19	5.7	10	**2:10**
	Wheelchair bound	100	5	9	45	5.7	10	**2:35**
	Bedridden	100	15	7	30	5.7	8	**2:20**
Bay Path Rehabilitation & Nursing Center	Ambulatory	100	1	61	30	5.6	28	**2:40**
	Wheelchair bound	100	5	30	75	5.6	9	**3:05**
	Bedridden	100	15	24	30	5.6	28	**2:40**
Chilton House Inc	Ambulatory	100	1	22	22	8.8	59	**3:05**
	Wheelchair bound	100	5	10	50	8.8	49	**3:20**
	Bedridden	100	15	8	30	8.8	59	**3:10**
Community Connections Inc	Ambulatory	100	1	31	30	7.1	55	**3:05**
	Wheelchair bound	100	5	5	25	7.1	54	**3:00**
	Bedridden	100	15	10	30	7.1	55	**3:05**
Cozy Corner ADHC LLC	Ambulatory	100	1	28	28	7.0	12	**2:20**
	Wheelchair bound	100	5	4	20	7.0	12	**2:15**
	Bedridden	100	15	9	30	7.0	11	**2:25**
Duxbury House	Ambulatory	100	1	11	11	5.6	34	**2:25**
	Wheelchair bound	100	5	6	30	5.6	28	**2:40**
	Bedridden	100	15	5	30	5.6	28	**2:40**
Emeritus	Ambulatory	100	1	58	30	10.9	62	**3:15**
	Wheelchair bound	100	5	30	75	10.9	38	**3:35**
	Bedridden	100	15	9	30	10.9	62	**3:15**
Golden Living Center-Plymouth	Ambulatory	100	1	50	30	11.1	64	**3:15**
	Wheelchair bound	100	5	22	75	11.1	37	**3:35**
	Bedridden	100	15	58	30	11.1	64	**3:15**
Habilitation	Ambulatory	100	1	40	30	5.7	10	**2:20**

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Assistance Corporation	Wheelchair bound	100	5	26	75	5.7	10	3:05
	Bedridden	100	15	18	30	5.7	8	2:20
High Point Treatment Center	Ambulatory	100	1	164	30	18.3	70	3:20
	Wheelchair bound	100	5	2	10	18.3	72	3:05
	Bedridden	100	15	44	30	18.3	70	3:20
Jordan Hospital	Ambulatory	100	1	79	30	11.1	64	3:15
	Wheelchair bound	100	5	39	75	11.1	37	3:35
	Bedridden	100	15	31	30	11.1	64	3:15
Life Care Center of Plymouth	Ambulatory	100	1	65	30	10.2	61	3:15
	Wheelchair bound	100	5	79	75	10.2	38	3:35
	Bedridden	100	15	60	30	10.2	61	3:15
Newfield House	Ambulatory	100	1	57	30	9.0	60	3:10
	Wheelchair bound	100	5	31	75	9.0	38	3:35
	Bedridden	100	15	3	30	9.0	60	3:10
Plymouth Crossings	Ambulatory	100	1	68	30	10.2	61	3:15
	Wheelchair bound	100	5	4	20	10.2	65	3:05
	Bedridden	100	15	19	30	10.2	61	3:15
Radius Health Care Nursing Home	Ambulatory	100	1	98	30	10.5	61	3:15
	Wheelchair bound	100	5	96	75	10.5	38	3:35
	Bedridden	100	15	34	30	10.5	61	3:15
Stafford Hill Assisted Living	Ambulatory	100	1	85	30	10.5	61	3:15
	Wheelchair bound	100	5	6	30	10.5	61	3:15
	Bedridden	100	15	24	30	10.5	61	3:15
Team Works	Ambulatory	100	1	12	12	2.8	6	2:00
	Wheelchair bound	100	5	5	25	2.8	6	2:15
	Bedridden	100	15	4	30	2.8	6	2:20

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
The Village At Duxbury	Ambulatory	100	1	31	30	5.6	28	**2:40**
	Wheelchair bound	100	5	15	75	5.6	9	**3:05**
	Bedridden	100	15	12	30	5.6	28	**2:40**
Wingate at Silver Lake	Ambulatory	100	1	127	30	0.7	1	**2:15**
	Wheelchair bound	100	5	63	75	0.7	1	**3:00**
	Bedridden	100	15	51	30	0.7	1	**2:15**
							Maximum ETE:	**3:20**
							Average ETE:	**2:45**

Table 8-16. Medical Facility Evacuation Time Estimates - Snow

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Baird Center Group Home	Ambulatory	110	1	19	19	5.7	11	2:20
	Wheelchair bound	110	5	9	45	5.7	11	2:50
	Bedridden	110	15	7	30	5.7	8	2:35
Bay Path Rehabilitation & Nursing Center	Ambulatory	110	1	61	30	5.6	11	2:35
	Wheelchair bound	110	5	30	75	5.6	11	3:20
	Bedridden	110	15	24	30	5.6	11	2:35
Chilton House Inc	Ambulatory	110	1	22	22	8.8	45	3:00
	Wheelchair bound	110	5	10	50	8.8	28	3:10
	Bedridden	110	15	8	30	8.8	42	3:05
Community Connections Inc	Ambulatory	110	1	31	30	7.1	40	3:00
	Wheelchair bound	110	5	5	25	7.1	41	3:00
	Bedridden	110	15	10	30	7.1	40	3:00
Cozy Corner ADHC LLC	Ambulatory	110	1	28	28	7.0	13	2:35
	Wheelchair bound	110	5	4	20	7.0	13	2:25
	Bedridden	110	15	9	30	7.0	11	2:35
Duxbury House	Ambulatory	110	1	11	11	5.6	12	2:15
	Wheelchair bound	110	5	6	30	5.6	11	2:35
	Bedridden	110	15	5	30	5.6	11	2:35
Emeritus	Ambulatory	110	1	58	30	10.9	45	3:05
	Wheelchair bound	110	5	30	75	10.9	20	3:25
	Bedridden	110	15	9	30	10.9	45	3:05
Golden Living Center-Plymouth	Ambulatory	110	1	50	30	11.1	45	3:05
	Wheelchair bound	110	5	22	75	11.1	21	3:30
	Bedridden	110	15	58	30	11.1	45	3:05
Habilitation	Ambulatory	110	1	40	30	5.7	11	2:35

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Assistance Corporation	Wheelchair bound	110	5	26	75	5.7	11	3:20
	Bedridden	110	15	18	30	5.7	8	2:30
High Point Treatment Center	Ambulatory	110	1	164	30	18.3	59	3:20
	Wheelchair bound	110	5	2	10	18.3	62	3:05
	Bedridden	110	15	44	30	18.3	59	3:20
Jordan Hospital	Ambulatory	110	1	79	30	11.1	45	3:05
	Wheelchair bound	110	5	39	75	11.1	21	3:30
	Bedridden	110	15	31	30	11.1	45	3:05
Life Care Center of Plymouth	Ambulatory	110	1	65	30	10.2	43	3:05
	Wheelchair bound	110	5	79	75	10.2	19	3:25
	Bedridden	110	15	60	30	10.2	43	3:05
Newfield House	Ambulatory	110	1	57	30	9.0	43	3:05
	Wheelchair bound	110	5	31	75	9.0	17	3:25
	Bedridden	110	15	3	30	9.0	43	3:05
Plymouth Crossings	Ambulatory	110	1	68	30	10.2	43	3:05
	Wheelchair bound	110	5	4	20	10.2	48	3:00
	Bedridden	110	15	19	30	10.2	43	3:05
Radius Health Care Nursing Home	Ambulatory	110	1	98	30	10.5	43	3:05
	Wheelchair bound	110	5	96	75	10.5	20	3:25
	Bedridden	110	15	34	30	10.5	43	3:05
Stafford Hill Assisted Living	Ambulatory	110	1	85	30	10.5	43	3:05
	Wheelchair bound	110	5	6	30	10.5	43	3:05
	Bedridden	110	15	24	30	10.5	43	3:05
Team Works	Ambulatory	110	1	12	12	2.8	5	2:10
	Wheelchair bound	110	5	5	25	2.8	5	2:20
	Bedridden	110	15	4	30	2.8	5	2:25

Medical Facility	Patient	Mobilization (min)	Loading Rate (min per person)	People	Total Loading Time (min)	Dist. To EPZ Bdry (mi)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
The Village At Duxbury	Ambulatory	110	1	31	30	5.6	11	**2:35**
	Wheelchair bound	110	5	15	75	5.6	11	**3:20**
	Bedridden	110	15	12	30	5.6	11	**2:35**
Wingate at Silver Lake	Ambulatory	110	1	127	30	0.7	1	**2:25**
	Wheelchair bound	110	5	63	75	0.7	1	**3:10**
	Bedridden	110	15	51	30	0.7	1	**2:25**
							Maximum ETE:	**3:20**
							Average ETE:	**2:50**

Table 8-17. Homebound Special Needs Population Evacuation Time Estimates

Vehicle Type	People Requiring Vehicle	Vehicles deployed	Stops	Weather Conditions	Mobiliza-tion Time (min)	Loading Time at 1st Stop (min)	Travel to Subsequent Stops (min)	Total Loading Time at Subsequent Stops (min)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Buses	228	25	10	Normal	90	5	81	45	13	**3:55**
				Rain	100		90		15	**4:15**
				Snow	110		99		16	**4:35**
Wheelchair Buses	59	6	10	Normal	90	5	81	45	13	**3:55**
				Rain	100		90		15	**4:15**
				Snow	110		99		16	**4:35**
Ambulances	9	5	2	Normal	30	15	10	15	8	**1:20**
				Rain	40		11		10	**1:35**
				Snow	50		13		9	**1:45**
									Maximum ETE:	**4:35**
									Average ETE:	**3:35**

Table 8-18. Evacuation Time Estimates for Correctional Facilities

Facility	People Requiring Vehicle	Buses Needed	Weather Conditions	Driver Mobilization Time (min)	Loading Time per Bus (min)	Total Loading Time (min)	Dist. EPZ Bdry to R.C. (mi.)	Average Speed (mph)	Travel Time from EPZ Bdry to R.C. (min)	ETE (hr:min)
Plymouth County Correctional Facility	1,600	32	Normal	90	15	96	7	37.0	11	**3:20**
			Rain	100				33.6	13	**3:30**
			Snow	110				28.7	15	**3:45**
MCI Plymouth	220	5	Normal	90	15	15	5	8.4	36	**2:25**
			Rain	100				7.8	38	**2:35**
			Snow	110				7.8	38	**2:45**
									Maximum ETE:	**3:45**
									Average ETE:	**3:05**