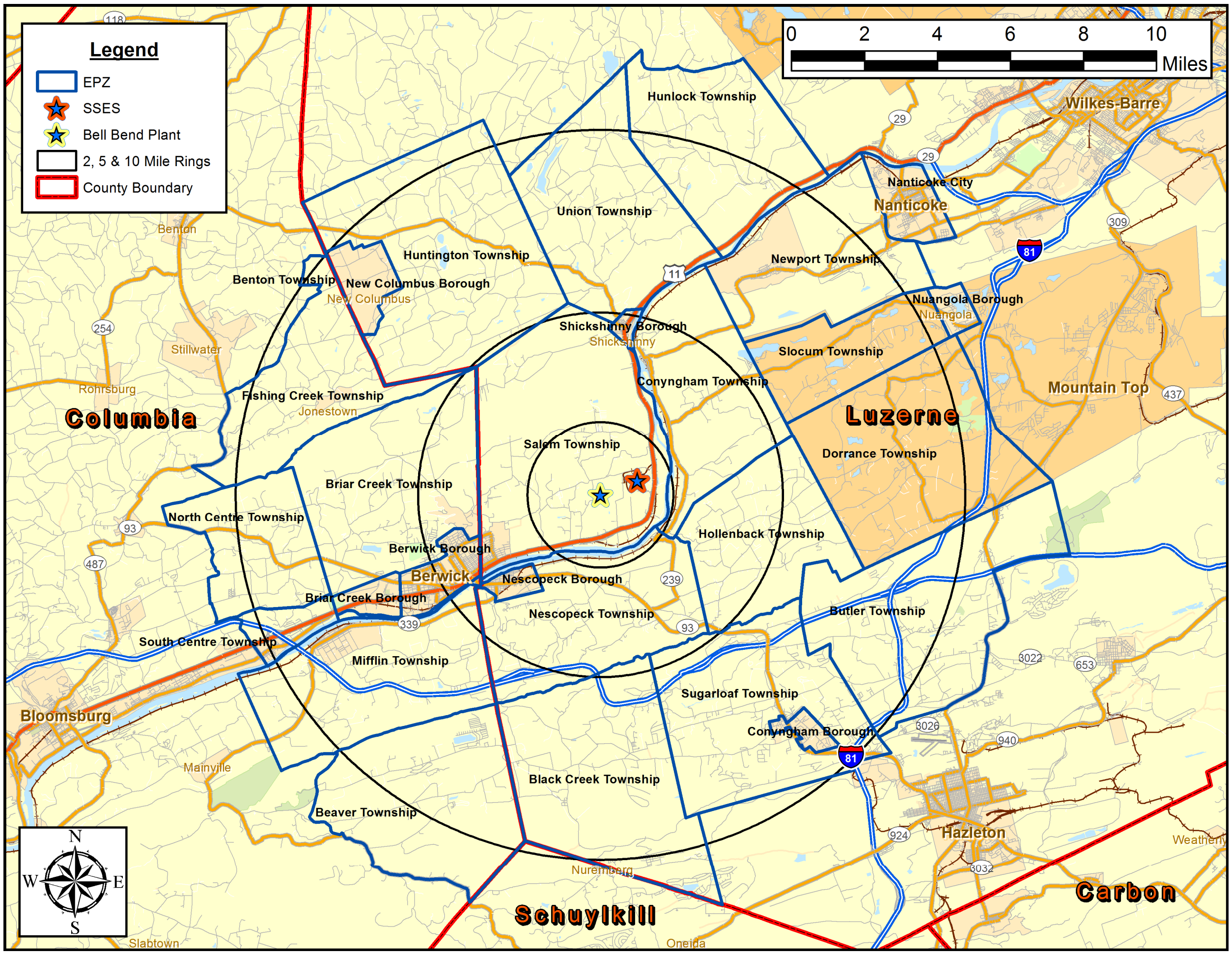
Susquehanna Steam Electric Station (SSES)/Bell Bend
Development of Evacuation Time Estimates



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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 Susquehanna Steam Electric Station (SSES) and the proposed Bell Bend Nuclear Power Plant located in Luzerne County, Pennsylvania. ETE are part of the required planning basis and provide SSES/Bell Bend and State and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available prior documentation published by Federal Government agencies and relevant to ETE was reviewed. Most important of these are:

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

Overview of Project Activities

This project began in May, 2008 and extended over a period of 5 months. The major activities performed are briefly described in chronological sequence:

- Attended "kick-off" meetings with PPL, UniStar, and emergency management personnel representing state and local governments.
- Reviewed prior ETE reports prepared for the SSES/Bell Bend.
- Reviewed the existing county and municipal emergency plans.
- Accessed U.S. Census Bureau data files for the year 2000. Studied Geographical Information Systems (GIS) maps of the area in the vicinity of SSES/Bell Bend 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 beyond the EPZ extending to 15 miles from the plant.
- Designed and sponsored a telephone survey of residents within the EPZ to gather focused data needed for this ETE study not contained within the census database. The survey instrument was reviewed and modified by Unistar, PPL and county personnel prior to the survey.
- A data collection survey was conducted to obtain data pertaining to employment,

transients, and special facilities within the EPZ.

- 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 27 emergency response planning areas (ERPA) using existing municipal boundaries. These ERPA are then grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 22 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 was considered: construction at the Bell Bend site during refueling of SSES in the Year 2015.
- The Planning Basis for the calculation of ETE is:
  - A rapidly escalating accident at SSES/Bell Bend that quickly assumes the status of General Emergency such that the advisory to evacuate is virtually coincident with the siren alert.
  - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the advisory to evacuate until the last vehicle exits the impacted region, that represent "upper bound" estimates. This conservative Planning Basis is applicable for all initiating events.
- If the emergency occurs while schools are in session, the ETE study assumes that the children will be evacuated by bus directly to specified host schools and reception centers located outside the EPZ. Parents, relatives, and neighbors are advised to not pick up their children at school prior to the arrival of the buses dispatched for that purpose. The ETE for school children are calculated separately.
- Evacuees who do not have access to a private vehicle will either ride-share with relatives, friends or neighbors, or be evacuated by buses provided as specified in the county evacuation plans. Those in special facilities will likewise be evacuated with public transit, as needed: bus, van, or ambulance, as required. Separate ETE are calculated for the transit-dependent evacuees and for those evacuated from special facilities.
- This revision of the report is the result of the following:
  - Incorporated changes identified in the responses to RAI Letter No. 47 and RAI Letter No. 92.
  - Shifted centerline of the proposed plant to 76°09'57.34" N, 41°05'21.19" E.

Computation of ETE

A total of 286 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 22 Evacuation Regions to completely evacuate from that Region, under the circumstances defined for one of the 13 Evacuation Scenarios (22 x 13 = 286). Separate ETE are calculated for transit-dependent evacuees, including school children for applicable scenarios.

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

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

The computational procedure is outlined as follows:

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

Traffic Management

This study includes the development of a comprehensive traffic management plan designed to expedite the evacuation of people from within an impacted region.

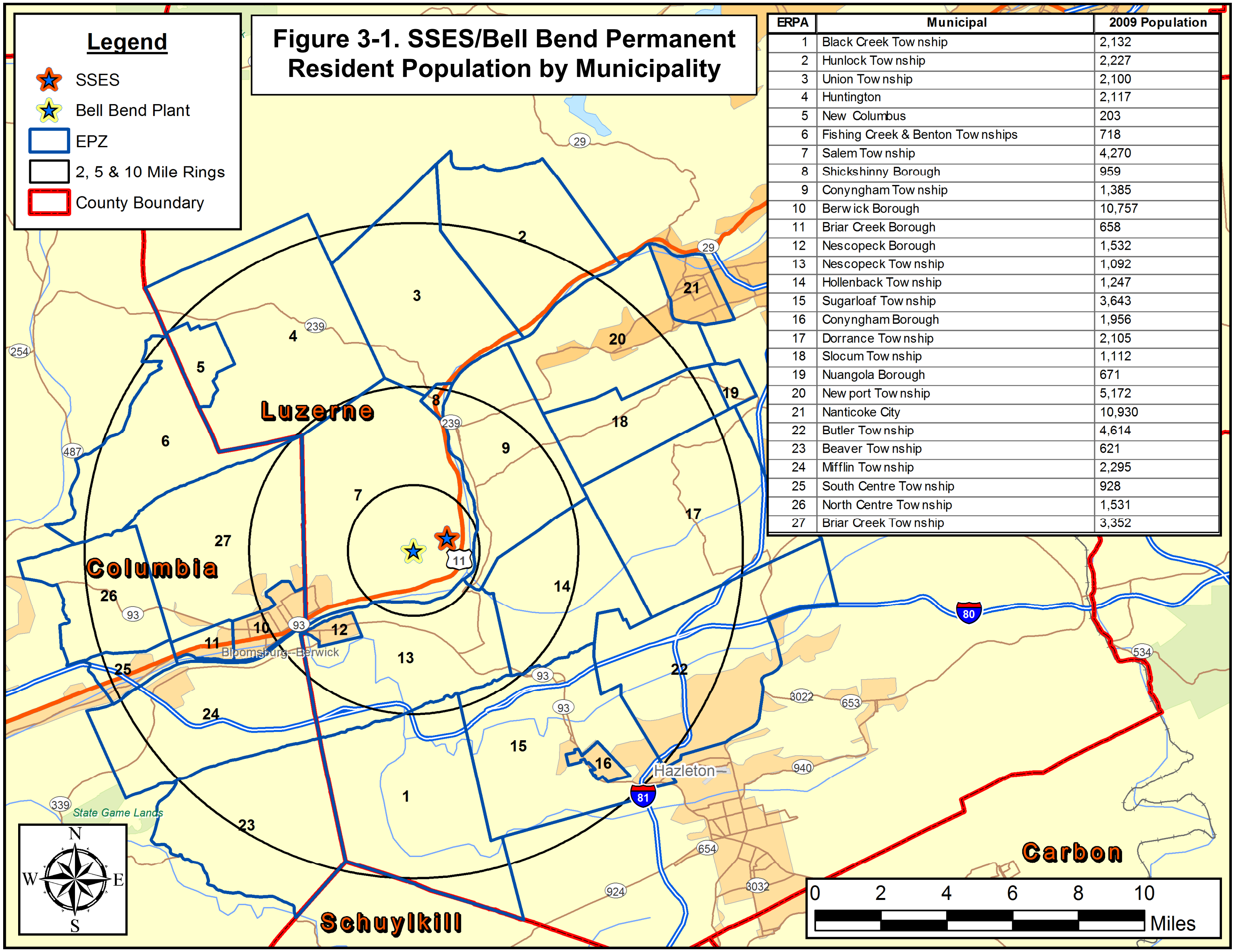
The plan is documented in the form of detailed schematics specifying: (1) the directions of evacuation travel to be facilitated, and other traffic movements to be discouraged; (2) the traffic control personnel and equipment needed (cones, barricades) and their deployment; (3) the locations of these "Traffic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

Selected Results

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

- Figure 3-1 displays a map of the SSES/Bell Bend site showing the layout of the 27 ERPAs that comprise, in aggregate, the Emergency Planning Zone (EPZ). The 2009 estimates of permanent resident population within each municipality are also provided.
- Table 3-2 presents the estimates of permanent resident population in each ERPA based on the 2000 Census data. Extrapolation to the year 2009 reflects population growth rates in each county obtained from the census.
- Table 6-1 defines each of the 22 Evacuation Regions in terms of their respective groups of ERPAs.
- Table 6-2 lists the 13 Evacuation Scenarios.
- Tables 7-1C and 7-1D are compilations of ETE. These data are the times needed to *clear the indicated regions* of 95 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated voluntary evacuations from other regions within the EPZ and from the shadow region.
- Table 8-5A presents ETE for the schoolchildren in good weather.
- Table 8-7A presents ETE for the transit-dependent population in good weather.

Figure 3-1. SSES/Bell Bend Permanent Resident Population by Municipality



ERPA	Municipal	2009 Population
1	Black Creek Township	2,132
2	Hunlock Township	2,227
3	Union Township	2,100
4	Huntington	2,117
5	New Columbus	203
6	Fishing Creek & Benton Townships	718
7	Salem Township	4,270
8	Shickshinny Borough	959
9	Conyngham Township	1,385
10	Berwick Borough	10,757
11	Briar Creek Borough	658
12	Nescopeck Borough	1,532
13	Nescopeck Township	1,092
14	Hollenback Township	1,247
15	Sugarloaf Township	3,643
16	Conyngham Borough	1,956
17	Dorrance Township	2,105
18	Slocum Township	1,112
19	Nuangola Borough	671
20	Newport Township	5,172
21	Nanticoke City	10,930
22	Butler Township	4,614
23	Beaver Township	621
24	Mifflin Township	2,295
25	South Centre Township	928
26	North Centre Township	1,531
27	Briar Creek Township	3,352

Table 3-2. EPZ Permanent Resident Population

Municipality	2000 Population	2009 Population
1	2,132	2,132
2	2,227	2,227
3	2,100	2,100
4	2,117	2,117
5	203	203
6	703	718
7	4,270	4,270
8	959	959
9	1,385	1,385
10	10,552	10,757
11	645	658
12	1,532	1,532
13	1,092	1,092
14	1,247	1,247
15	3,613	3,643
16	1,956	1,956
17	2,105	2,105
18	1,112	1,112
19	671	671
20	5,021	5,172
21	10,930	10,930
22	4,614	4,614
23	609	621
24	2,251	2,295
25	910	928
26	1,501	1,531
27	3,288	3,352
TOTAL	**69,745**	**70,327**
Population Growth:		**0.57%**

Table 6-1. Description of Evacuation Regions

Region	Description	ERPA 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R01	2 mile ring							x		x																		
R02	5-mile ring							x	x	x			x	x	x													
R03	Full EPZ	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2-MileRing and 5-Mile Downwind																												
Region	**Description**	**ERPA 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
R04	N,NNE,NNW							x	x	x																		
-	NE,W,WNW,NW	Refer to Region R01																										
R05	ENE,E,ESE							x		x					x													
R06	SE, SSE							x		x			x	x	x													
R07	S, SSW,SW,WSW							x		x			x	x														
5-Mile Ring and Downwind to EPZ Boundary																												
Region	**Description**	**ERPA 1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
R08	N		x	x	x	x		x	x	x			x	x	x						x							
R09	NNE		x	x				x	x	x			x	x	x				x		x	x						
R10	NE		x					x	x	x			x	x	x			x	x	x	x	x						
R11	ENE							x	x	x			x	x	x			x	x	x	x	x	x					
R12	E							x	x	x			x	x	x			x	x	x			x					
R13	ESE, SE							x	x	x			x	x	x	x	x	x					x					
R14	SSE	x						x	x	x			x	x	x	x	x						x					
R15	S	x						x	x	x			x	x	x	x	x							x				
R16	SSW	x						x	x	x			x	x	x									x	x			
R17	SW	x						x	x	x	x	x	x	x	x									x	x	x	x	x
R18	WSW						x	x	x	x	x	x	x	x	x									x	x	x	x	x
R19	W				x	x	x	x	x	x	x	x	x	x	x										x	x	x	x
R20	WNW				x	x	x	x	x	x			x	x	x												x	x
R21	NW			x	x	x	x	x	x	x			x	x	x													x
R22	NNW		x	x	x	x		x	x	x			x	x	x													

Table 6-2. Evacuation Scenario Definitions					
Scenarios	**Season**	**Day of Week**	**Time of Day**	**Weather**	**Special**
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	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	Midweek	Midday	Good	Bell Bend Construction and SSES Refueling

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

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	3:10	3:10	2:45	2:45	2:45	R01 2-Mile Region	3:05	3:05	4:15	2:45	2:50	3:50	2:45	R01 2-Mile Region	3:15
R02 5-Mile Region	2:50	2:50	2:05	2:05	2:25	R02 5-Mile Region	2:50	2:50	3:45	2:05	2:05	3:00	2:25	R02 5-Mile Region	3:05
R03 Entire EPZ	3:25	3:40	3:15	3:25	3:15	R03 Entire EPZ	3:30	3:40	4:25	3:15	3:25	4:10	3:15	R03 Entire EPZ	3:55
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	3:10	3:10	2:45	2:45	2:45	R04 N,NNE,NNW	3:10	3:10	4:15	2:45	2:45	3:50	2:45	R04 N,NNE,NNW	3:15
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	3:10	3:10	2:50	2:50	2:50	R05 ENE,E,ESE	3:05	3:05	4:20	2:50	2:50	3:55	2:50	R05 ENE,E,ESE	3:15
R06 SE,SSE	2:45	2:45	2:00	2:05	2:25	R06 SE,SSE	2:45	2:45	3:40	2:00	2:05	3:00	2:25	R06 SE,SSE	3:05
R07 S, SSW,SW,WSW	2:45	2:45	2:00	2:00	2:25	R07 S, SSW,SW,WSW	2:45	2:45	3:35	2:00	2:00	2:55	2:25	R07 S, SSW,SW,WSW	3:05
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	3:10	3:15	2:45	2:45	2:55	R08 N	3:10	3:20	4:05	2:45	2:45	3:35	2:55	R08 N	3:35
R09 NNE	3:15	3:25	2:55	3:10	3:00	R09 NNE	3:20	3:30	4:15	2:55	3:10	4:00	3:00	R09 NNE	3:30
R10 NE	3:05	3:15	2:50	3:00	2:55	R10 NE	3:15	3:20	4:05	2:50	3:00	3:50	2:55	R10 NE	3:20
R11 ENE	3:00	3:10	2:40	2:50	2:55	R11 ENE	3:05	3:15	4:00	2:40	2:50	3:40	2:55	R11 ENE	3:05
R12 E	2:40	2:45	2:05	2:10	2:25	R12 E	2:40	2:45	3:30	2:05	2:10	2:55	2:25	R12 E	2:55
R13 ESE, SE	2:50	2:50	2:15	2:20	2:35	R13 ESE, SE	2:50	2:50	3:45	2:15	2:20	3:05	2:35	R13 ESE, SE	3:00
R14 SSE	2:50	2:50	2:15	2:20	2:35	R14 SSE	2:50	2:50	3:45	2:15	2:20	3:05	2:35	R14 SSE	3:00
R15 S	2:45	2:45	2:05	2:10	2:25	R15 S	2:45	2:45	3:40	2:05	2:10	3:00	2:25	R15 S	3:00
R16 SSW	3:15	3:15	3:00	3:00	2:55	R16 SSW	3:15	3:20	3:55	3:00	3:05	3:35	2:55	R16 SSW	3:20
R17 SW	3:30	3:45	3:20	3:30	3:20	R17 SW	3:35	3:45	4:30	3:20	3:30	4:10	3:20	R17 SW	4:00
R18 WSW	3:30	3:45	3:20	3:30	3:20	R18 WSW	3:35	3:45	4:30	3:20	3:30	4:15	3:20	R18 WSW	4:00
R19 W	3:30	3:45	3:20	3:30	3:20	R19 W	3:30	3:45	4:30	3:20	3:30	4:15	3:20	R19 W	4:00
R20 WNW	3:00	3:00	2:30	2:35	2:40	R20 WNW	3:00	3:00	4:00	2:30	2:35	3:25	2:40	R20 WNW	3:10
R21 NW	3:00	3:00	2:30	2:35	2:35	R21 NW	3:00	3:00	4:00	2:30	2:35	3:25	2:35	R21 NW	3:10
R22 NNW	3:10	3:10	2:45	2:45	2:55	R22 NNW	3:10	3:15	4:00	2:45	2:45	3:35	2:55	R22 NNW	3:30

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	5:30	5:30	5:00	5:00	5:00	R01 2-Mile Region	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R01 2-Mile Region	5:30
R02 5-Mile Region	5:30	5:30	5:00	5:00	5:00	R02 5-Mile Region	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R02 5-Mile Region	5:30
R03 Entire EPZ	5:40	5:40	5:10	5:20	5:10	R03 Entire EPZ	5:40	5:40	6:40	5:10	5:20	6:20	5:10	R03 Entire EPZ	5:40
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	5:30	5:30	5:00	5:00	5:00	R04 N,NNE,NNW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R04 N,NNE,NNW	5:30
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	5:30	5:30	5:00	5:00	5:00	R05 ENE,E,ESE	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R05 ENE,E,ESE	5:30
R06 SE,SSE	5:30	5:30	5:00	5:00	5:00	R06 SE,SSE	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R06 SE,SSE	5:30
R07 S, SSW,SW,WSW	5:30	5:30	5:00	5:00	5:00	R07 S, SSW,SW,WSW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R07 S, SSW,SW,WSW	5:30
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	5:30	5:30	5:00	5:00	5:10	R08 N	5:30	5:30	6:30	5:00	5:00	6:10	5:00	R08 N	5:30
R09 NNE	5:30	5:30	5:00	5:00	5:00	R09 NNE	5:30	5:30	6:30	5:00	5:10	6:10	5:00	R09 NNE	5:30
R10 NE	5:30	5:30	5:00	5:10	5:10	R10 NE	5:30	5:30	6:40	5:00	5:10	6:10	5:00	R10 NE	5:30
R11 ENE	5:30	5:30	5:10	5:10	5:10	R11 ENE	5:30	5:30	6:30	5:10	5:10	6:10	5:10	R11 ENE	5:30
R12 E	5:30	5:30	5:10	5:10	5:10	R12 E	5:30	5:30	6:30	5:10	5:10	6:00	5:10	R12 E	5:30
R13 ESE, SE	5:30	5:30	5:10	5:10	5:10	R13 ESE, SE	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R13 ESE, SE	5:30
R14 SSE	5:30	5:30	5:10	5:10	5:10	R14 SSE	5:30	5:30	6:40	5:10	5:10	6:00	5:10	R14 SSE	5:30
R15 S	5:30	5:30	5:00	5:00	5:00	R15 S	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R15 S	5:30
R16 SSW	5:30	5:40	5:10	5:10	5:10	R16 SSW	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R16 SSW	5:30
R17 SW	5:40	5:40	5:10	5:20	5:10	R17 SW	5:40	5:40	6:40	5:10	5:20	6:10	5:10	R17 SW	5:40
R18 WSW	5:40	5:40	5:10	5:10	5:10	R18 WSW	5:40	5:40	6:40	5:10	5:10	6:10	5:10	R18 WSW	5:40
R19 W	5:40	5:40	5:10	5:10	5:10	R19 W	5:40	5:40	6:40	5:10	5:10	6:20	5:10	R19 W	5:40
R20 WNW	5:30	5:30	5:10	5:10	5:10	R20 WNW	5:40	5:40	6:40	5:10	5:10	6:10	5:10	R20 WNW	5:30
R21 NW	5:30	5:30	5:10	5:10	5:10	R21 NW	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R21 NW	5:30
R22 NNW	5:30	5:30	5:00	5:00	5:00	R22 NNW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R22 NNW	5:30

Table 8-5A. School Evacuation Time Estimates - Good Weather								
School	Driver Mobilization Time(min)	Loading Time (min)	Dist. to EPZ Boundary (mi.)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bndry to H.S. (mi.)	Travel Time EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Columbia County								
Beaver Main Elementary School	90	5	0.3	1	**1:40**	15.0	27	**2:05**
Berwick Area Middle School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Berwick Senior High School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Fourteenth Street Elementary School	90	5	6.5	12	**1:50**	18.0	32	**2:20**
Heritage Christian Academy	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Holy Family Consolidated School	90	5	6.2	11	**1:50**	18.0	32	**2:20**
Mulberry Street Elementary School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Nescopeck Elementary School	90	5	7.3	13	**1:50**	14.0	25	**2:15**
Orange Street Elementary School	90	5	5.8	10	**1:45**	14.0	25	**2:10**
Luzerne County								
Drums Elementary School	90	5	2.0	4	**1:40**	8.2	15	**1:55**
Garrison Memorial Elementary School	90	5	7.2	13	**1:50**	17.0	30	**2:20**
GNA Elementary Center	90	5	0.6	1	**1:40**	4.0	7	**1:45**
GNA Educational Center	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Greater Nanticoke High School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Hunlock Creek Elementary School	90	5	5.0	9	**1:45**	17.0	30	**2:15**
Huntington Mills Elementary School	90	5	8.4	15	**1:50**	17.0	30	**2:20**
J F Kennedy Elementary School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
K M Smith Elementary School	90	5	1.7	3	**1:40**	4.0	7	**1:45**
Keystone Job Corp High School	90	5	3.5	6	**1:45**	8.2	15	**2:00**
Mulhenberg Christian Academy	90	5	5.0	9	**1:45**	17.0	30	**2:15**
Northwest Area High School	90	5	5.2	9	**1:45**	17.0	30	**2:15**
Pope John Paul II School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Rice Elementary School	90	5	0.6	1	**1:40**	5.5	10	**1:50**
Salem Elementary School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
The Learning Station School	90	5	1.7	3	**1:40**	4.0	7	**1:45**
Valley Elementary School	90	5	3.0	5	**1:40**	8.2	15	**1:55**
				Maximum for EPZ:	**1:50**		**Maximum:**	**2:20**
						Average:	**20**	**2:05**

Table 8-6. Transit Dependent Evacuation Time Estimate											
Good Weather											
Single Wave					Second Wave						
Mobilization	Route Travel Time	Pickup Time	ETE	Mobilization	Unload Time	Driver Rest Time	Return Time	Pickup Time	Route travel Time	ETE	
90	9	30	2:10	125	5	10	20	30	15	3:25	
Rain											
Single Wave					Second Wave						
Mobilization	Route Travel Time	Pickup Time	ETE	Mobilization	Unload Time	Driver Rest Time	Return Time	Pickup Time	Route travel Time	ETE	
95	13	40	2:30	145	5	10	28	40	17	4:05	

1. INTRODUCTION

This report describes the analyses undertaken and the results obtained in preparing the Evacuation Time Estimates (ETE) for the Susquehanna Steam Electric Station (SSES) and the proposed Bell Bend Nuclear Power Plant (Bell Bend), located in Luzerne County, Pennsylvania. ETE are part of the required planning basis and provide state and local governments with site-specific information needed for Protective Action decision-making.

In the performance of this effort, all available documentation published by Federal Government agencies and relevant to ETE was reviewed. Most important of these are:

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

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

1.1 Overview of the ETE Determination Process

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

1. Information Gathering:
   - Defined the scope of work in discussions with representatives of UniStar and PPL.
   - Attended meetings with emergency planners from the two EPZ counties and from the state to identify issues to be addressed.
   - Conducted a detailed field survey of the EPZ highway system and of area traffic conditions.
   - Obtained demographic data from the census and from state and county agencies.
   - Conducted a random sample telephone survey of EPZ residents.

- Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important sources of information.

2. Estimated distributions of trip generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample telephone survey.

3. Defined evacuation scenarios. These scenarios reflect the variation in demand, trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.

4. Defined evacuation areas or regions. The EPZ is partitioned into emergency response planning areas (ERPA) using existing municipal boundaries which serve as a basis for the ETE analysis presented herein. Evacuation "regions" are comprised of contiguous ERPAs for which ETE are calculated. The configuration of these regions reflects the fact that the wind can take any direction and that the radial extent of the impacted area depends on accident-related circumstances. Each region, other than those that approximate circular areas, approximates a "key-hole" configuration within the EPZ as required by NUREG/CR-6863.

5. Estimated demand for transit services for persons at "special facilities" and for transit-dependent persons at home.

6. Defined a traffic management strategy. Traffic control is applied at specified Traffic Control Points (TCP) located both within and outside the Emergency Planning Zone (EPZ).

7. Prepared the input streams for the IDYNEV system.
   - Estimated the traffic demand, based on the available information derived from census data, from data provided by local and state agencies and from the telephone survey.
   - Applied the procedures specified in the 2000 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 within the EPZ and the Shadow Region.
   - Developed the link-node representation of the evacuation network, which is used as the basis for the computer analysis that calculates the ETE.

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

- Calculated the evacuating traffic demands for each evacuation region and for each evacuation scenario. Considered the effects on demand of “voluntary evacuation” and of the “shadow effect”.
- Represented the traffic management strategy if special treatments are to be implemented.
- Specified the candidate destinations of evacuation travel consistent with outbound movement relative to the location of the SSES.
- Prepared the input stream for the IDYNEV System.
- Executed the IDYNEV models to provide the estimates of evacuation routing and ETE.

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

Steps 6, 7 and 8 are iterated.

1.2 Location of the SSES and Bell Bend Nuclear Power Plants

SSES and the proposed Bell Bend Nuclear Power Plant are located within Salem Township in Luzerne County approximately one-half mile from the northern shore of the Susquehanna River. The site is approximately 22 miles southeast of the Scranton Wilkes-Barre region. The Emergency Planning Zone (EPZ) consists of parts of two counties: Luzerne County and Columbia County. Figure 1-1 displays the area surrounding SSES/Bell Bend. Using GIS data a total of 27 municipalities were identified within the EPZ, some of which are completely within the EPZ that contribute to the resident population within the EPZ.

The proposed Bell Bend site is located approximately 1 mile west of the existing site at SSES. The EPZ boundary was updated to include an extension of the EPZ to the west within Columbia County to account for the distance between the proposed Bell Bend site and the existing SSES site. This expanded EPZ is presented in Figure 1-1.

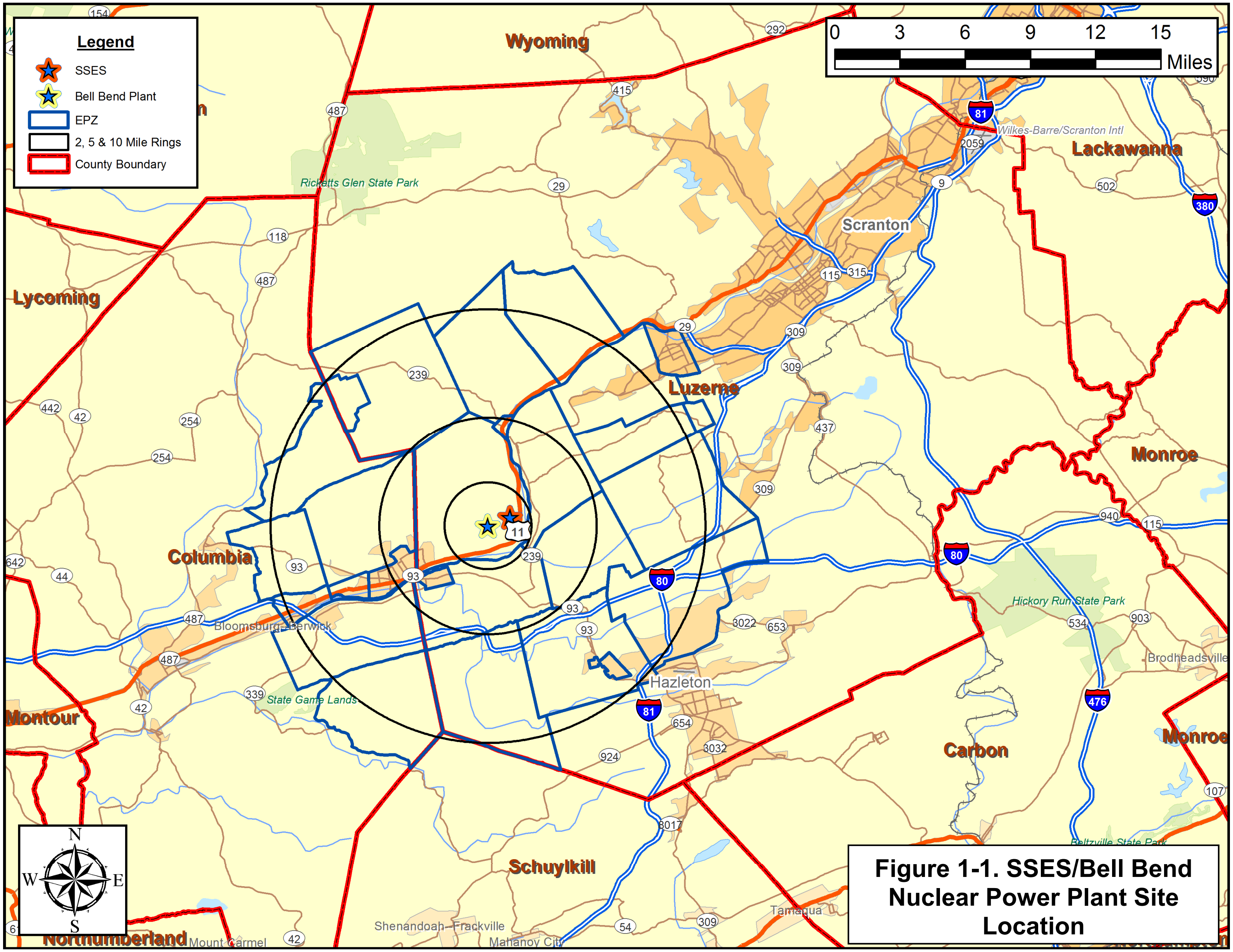


Figure 1-1. SSES/Bell Bend Nuclear Power Plant Site Location
Legend
SSES
Bell Bend Plant
EPZ
2, 5 & 10 Mile Rings
County Boundary
0 3 6 9 12 15 Miles
N
S
E
W
Wyoming
Lackawanna
Lycoming
Columbia
Luzerne
Monroe
Carbon
Schuylkill
Montour
Northumberland
Scranton
Hazleton
Bloomsburg-Berwick
Wilkes-Barre/Scranton Intl
Ricketts Glen State Park
Hickory Run State Park
State Game Lands
Brodheadsville
Tamaqua
Shenandoah-Frackville
Mahanoy City
Mount Carmel

1.3 Preliminary Activities

KLD performed preliminary review activities as described below.

Literature Review

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

Field Surveys of the Highway Network

KLD personnel drove the entire highway system within the EPZ and for some distance outside. A tablet personal computer equipped with Global Positioning Satellite (GPS) and Geographical Information Systems (GIS) technologies was used during the road survey to acquire and record data. The characteristics of each section of highway were recorded. These characteristics include:

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

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 20-5 in the Highway Capacity Manual (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 12-15 in the HCM shows no sensitivity for the estimates of Service Volumes at Level of Service (LOS) E (near capacity), with respect to FFS. The topography of the highway (Level, Rolling, and Mountainous) is a far more important factor than lane and shoulder width when estimating capacity.

The data from the audio and video recordings were used to create detailed 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 IDYNEV System.

As documented on page 20-3 of the HCM2000, the capacity of a two-lane highway is 1700 passenger cars per hour for each direction of travel. For freeway sections, a value of 2250 vehicles per hour per lane is assigned. The road survey has identified several segments which are characterized by adverse geometrics which are reflected in reduced values for both capacity and speed. These estimates reflect the service volumes for LOS E presented in HCM Exhibit 12-15. These links may be identified by reviewing Appendix K. Link capacity is an input to IDYNEV which calculates the ETE. The locations of these sections may be identified by reference to the maps in Appendix K which are discussed below.

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

Developing the Evacuation Time Estimates

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

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

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 for clarity. The detailed figures K-2 through K-19, 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.

For the reader interested in more details of the model than are provided in Appendices B,

C and D, and in Highway Research Record No. 772 (discussed in Section 4 of this report), 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

Analytical Tools

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

IDYNEV consists of three submodels:

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

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

Still another software product developed by KLD, named UNITES (UNIfied Transportation Engineering System) was used to expedite data entry. Finally, software to display animations of the evacuating traffic environment, named EVAN (EVacuation ANimation), was used to assist the analysts during the iterative procedure described above, and to prepare some of the displays in this report.

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

For the reader interested in more details of the model than are provided in Appendices B, C and D, and in Highway Research Record No. 772, 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

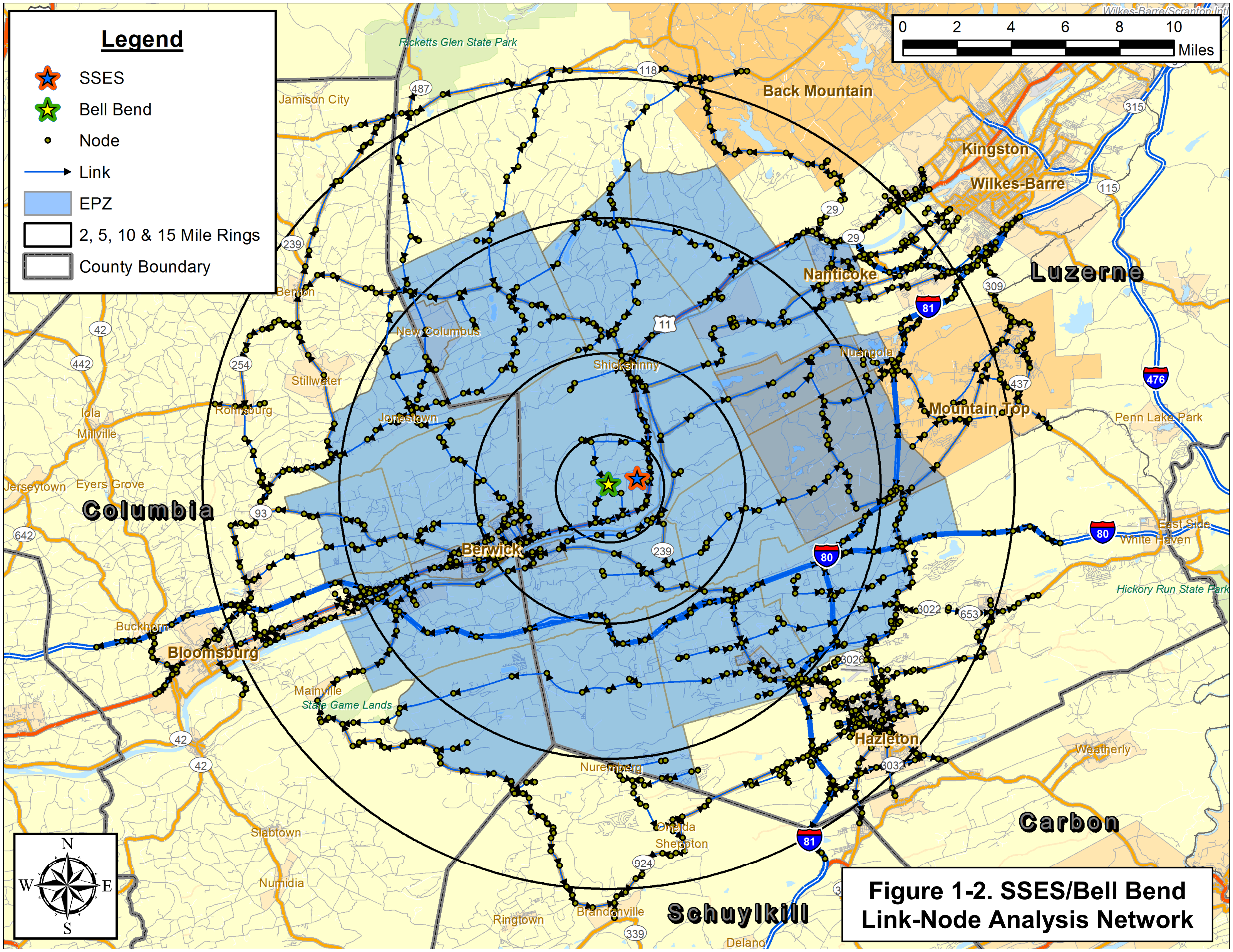


Figure 1-2. SSES/Bell Bend Link-Node Analysis Network

The evacuation analysis procedures are based upon the need to:

- Route traffic along paths that will expedite their travel from their respective points of origin to points outside the EPZ
- Restrict movement toward SSES/Bell Bend 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 SSES/Bell Bend.

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

The simulation model is then executed to provide a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to consider the development of countermeasures designed to expedite the movement of vehicles. These are discussed in subsequent sections. The outputs of this model are the volume of traffic, expressed as vehicles/hour, that exit the evacuation region along the various highways (links) that cross the region boundaries. These outputs are exported into a spreadsheet which documents the ETE. Intermediate, detailed results are also produced, at specified time intervals, for each network link. Section 7 presents a further description of this process along with the ETE Tables.

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

1.4 Comparison with Prior ETE Study

Table 1-1 presents a comparison of the present ETE study with the earlier ETE study conducted in 1981 by HMM Associates. 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:

- A slight decrease in permanent resident population.
- Vehicle occupancy and trip-generation rates are based on the results of a telephone survey of EPZ residents.
- Voluntary and shadow evacuations are considered.
- The highway representation is far more detailed. The link-node analysis network extends out to 15 miles from the plant.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Resident Population Basis	ArcGIS Software using 1980 US Census blocks; area ratio method used. Population = 71,511	ArcGIS Software using 2000 US Census blocks; block centroid method used; population extrapolated to 2009 using the 2006 census estimates. Population = 70,327
Resident Population Vehicle Occupancy	3.0 persons per evacuating household based on discussions with emergency management officials.	1.94 persons per evacuating vehicle based on telephone survey results. (1.30 evac. veh./evacuating household; 2.52 persons/household)
Employee Population	Employees treated as separate population group. Employee estimates based on information provided by the counties and direct phone calls to major employers. All employees were counted as part of the evacuating population. 1 employee/vehicle.	Employees treated as separate population group. Employee estimates based on information provided by the counties, by Internet searches, and by direct phone calls to major employers. Using the Journey to Work census data, estimated the percentage of employees residing outside the EPZ. 1.02 employees/vehicle based on phone survey results.
Voluntary evacuation from within EPZ in areas outside region to be evacuated	Not considered	50 percent of population within the outer extent of the region; 35 percent of population in annular ring between the outer extent and the EPZ boundary. (See Figure 2-1)
Shadow Evacuation	Not considered.	30% of people outside of the EPZ within the shadow area. (See Figure 7-2)

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Network Size	75 Nodes; 135 Links.	1517 Links; 1046 Nodes.
Roadway Geometric Data	Field surveys conducted. Date not provided.	Field surveys conducted in 2008. Major intersections were video archived. GIS shape-files of signal locations and roadway characteristics created during road survey. Road capacities based on 2000 HCM.
School Evacuation	Direct evacuation to designated Reception Center/Host School.	Direct evacuation to designated Host School.
Transit Dependent Population	Transit dependent population estimated using 1970 census data on HH with 0 vehicles	Defined as households with 0 vehicles + households with 1 vehicle with commuters who do not return home + households with 2 vehicles with commuters who do not return home. Telephone survey results used to estimate transit dependent population. Verified with the information provided in the county and municipal emergency plans.
Ridesharing	Conservatively assumed no ride sharing.	50 percent of transit dependent persons will ride with a neighbor or friend.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Trip Generation for Evacuation	Based on discussions with emergency management officials: Residents and Transients leave between 30 minutes, and 2 hours and 30 minutes, with 95% mobilized in 2 hours. Employees leave between 30 minutes and 90 minutes with 90% mobilized within the first 30 minutes. All times measured from the Advisory to Evacuate.	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning, leave between 45 minutes and 5 hours and 30 minutes. Residents without commuters returning leave between 15 minutes and 5 hours. Employees and transients leave between 15 minutes and 2 hours. All times measured from the Advisory to Evacuate.
Traffic and Access Control	Not discussed.	Traffic control used in all scenarios to facilitate the flow of traffic outbound relative to the plant. Detailed schematics provided for each identified traffic control point. These were cross referenced with the detailed traffic control defined in the county and municipal emergency plans.
Modeling	NETVAC3	IDYNEV System: TRAD and PC-DYNEV.
Evacuation Cases	10 Regions, 3 Base Scenarios and 3 Adverse Weather Scenarios. A total of 48 unique cases.	22 Regions (key-hole:central sector in wind direction with adjacent sectors) and 13 Scenarios producing 286 unique cases
Evacuation Time Estimates Reporting	ETE reported 100th percentile population. Results presented by Region and Scenario	ETE reported for 50th, 90th, 95th, and 100th percentile population. Results presented by Region and Scenario.

Table 1-1. ETE Study Comparisons		
Topic	**Treatment**	
	Previous ETE Study	**Current ETE Study**
Evacuation Time Estimates for the entire EPZ: 100th percentile of general population	Full EPZ – Summer Weekday: Good weather = 6:05 Full EPZ – Summer Weekend: Good weather = 6:00	Full EPZ – Summer Weekday Good weather = 5:40 Full EPZ – Summer Weekend: Good weather = 5:10

2. STUDY ESTIMATES AND ASSUMPTIONS

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

2.1 Data Estimates

1. Population estimates are based upon census 2000 data, projected to year 2009. County-specific projections are based upon growth rates obtained from the census website. Estimates of employees who commute into the EPZ to work are based upon employment data obtained from county economic development websites and from census journey to work files.
2. Population estimates at special facilities are based on available data from county emergency management offices and from direct phone calls to the facilities.
3. Roadway capacity estimates are based on field surveys and the application of Highway Capacity Manual 2000 guidance.
4. Population mobilization times are based on a statistical analysis of data acquired from the telephone survey.
5. The relationship between resident population and evacuating vehicles is developed from the telephone survey. The average values of 2.52 persons per household and 1.30 evacuating vehicles per household are used.
6. The relationship between persons and vehicles for transients is as follows:
    a. Transients: 2 to 4 persons per vehicle, depending on the facility being visited.
    b. Employees: 1.02 employees per vehicle (telephone survey results)
7. The ETE are presented for the evacuation of the 50th, 90th, 95th and 100th percentiles of population, for each evacuation region and for each scenario. These ETE are presented in tabular and graphical formats. An evacuation region is defined as a group of contiguous emergency response planning areas (ERPA) or municipalities that is issued an advisory to evacuate.
8. The number of transit-dependent persons at home and in special facilities is estimated using the results of telephone survey and from the estimates provided in the radiological emergency plans for each of the municipalities within the EPZ. The number of vehicle-trips required is based upon these estimates and their physical condition (ambulatory, special needs).

2.2 Study Methodological Assumptions

1. The ETE is defined as the elapsed time from the advisory to evacuate issued to persons within a specific evacuation region of the EPZ, to the time that Region is clear of the indicated percentile of people.
2. The ETE are computed and presented in a format compliant with the guidance in the cited NUREG documentation. The ETE for each evacuation area ("region" comprised of included Municipalities) is presented in both statistical and graphical formats.
3. Evacuation movements (paths of travel) are generally outbound relative to the power plant to the extent permitted by the highway network, as computed by the computer models. All available evacuation routes are used in the analysis.
4. Evacuation regions are defined by the underlying "keyhole" or circular configurations as specified in NUREG/CR-6863. These regions, as defined, display irregular boundaries reflecting the geography of the Municipalities included within these underlying configurations. Besides the 3 circular regions (2-Mile, 5-Mile and Full EPZ) there are two "keyhole configurations" that form most evacuation regions: (1) a central circular area of 2-mile radius and a sector with a central angle of 67.5 degrees that extends to a distance of about 5 miles; and (2) a central circular area of 5-mile radius and a sector extending to a distance of 10 miles (actually, to the EPZ boundary).

   Voluntary evacuation is anticipated for all types of regions as indicated in Figure 2-1. For the circular regions (R01 and R02), it is assumed that in the area that is within the EPZ but outside the evacuation region (shown in blue), 35 percent of the population will elect to voluntarily evacuate. For the keyhole configuration regions R04 through R07 (evacuate 2-Mile ring and sector downwind to 5-Miles), shown in the bottom left of Figure 2-1, the area shown in red is external to the evacuation region but within 5 miles of the power station. It is assumed that 50 percent of the population within this area will elect to voluntarily evacuate. In the surrounding blue area (which extends from 5 miles to the EPZ boundary) within the EPZ, it is assumed that 35 percent of that population will elect to voluntarily evacuate. For the other keyhole configurations, regions R08 through R22 (evacuate 5-Mile ring and sector downwind to EPZ boundary) shown in the bottom right of Figure 2-1, it is assumed that 50 percent of the population within the red area which is within the EPZ, but outside the evacuation region, will elect to voluntarily evacuate.

   In the area between the EPZ boundary and a 15-mile-radius circle centered at the plant shown in yellow (the "Shadow Region") in all configurations, it is assumed that 30 percent of the permanent resident people will evacuate voluntarily. Sensitivity studies explored the effect on

ETE, of increasing this percentage of voluntary evacuees in the Shadow Region; see Appendix I for the results of this study.

5. A total of 13 "Scenarios" representing different seasons, time of day, day of week and weather are considered. One special event scenario is studied; the peak construction period of the Bell Bend plant during refueling at the SSES site. These scenarios are detailed in Table 2-1.

6. The models of the IDYNEV System were recognized as state of the art by Atomic Safety & Licensing Boards (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik[1]). The models have been independently validated by a consultant retained by the NRC and have continuously been refined and extended since those hearings.

Table 2-1. Evacuation Scenario Definitions

Scenarios	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	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	Midweek	Midday	Good	Bell Bend Construction and SSES Refueling

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

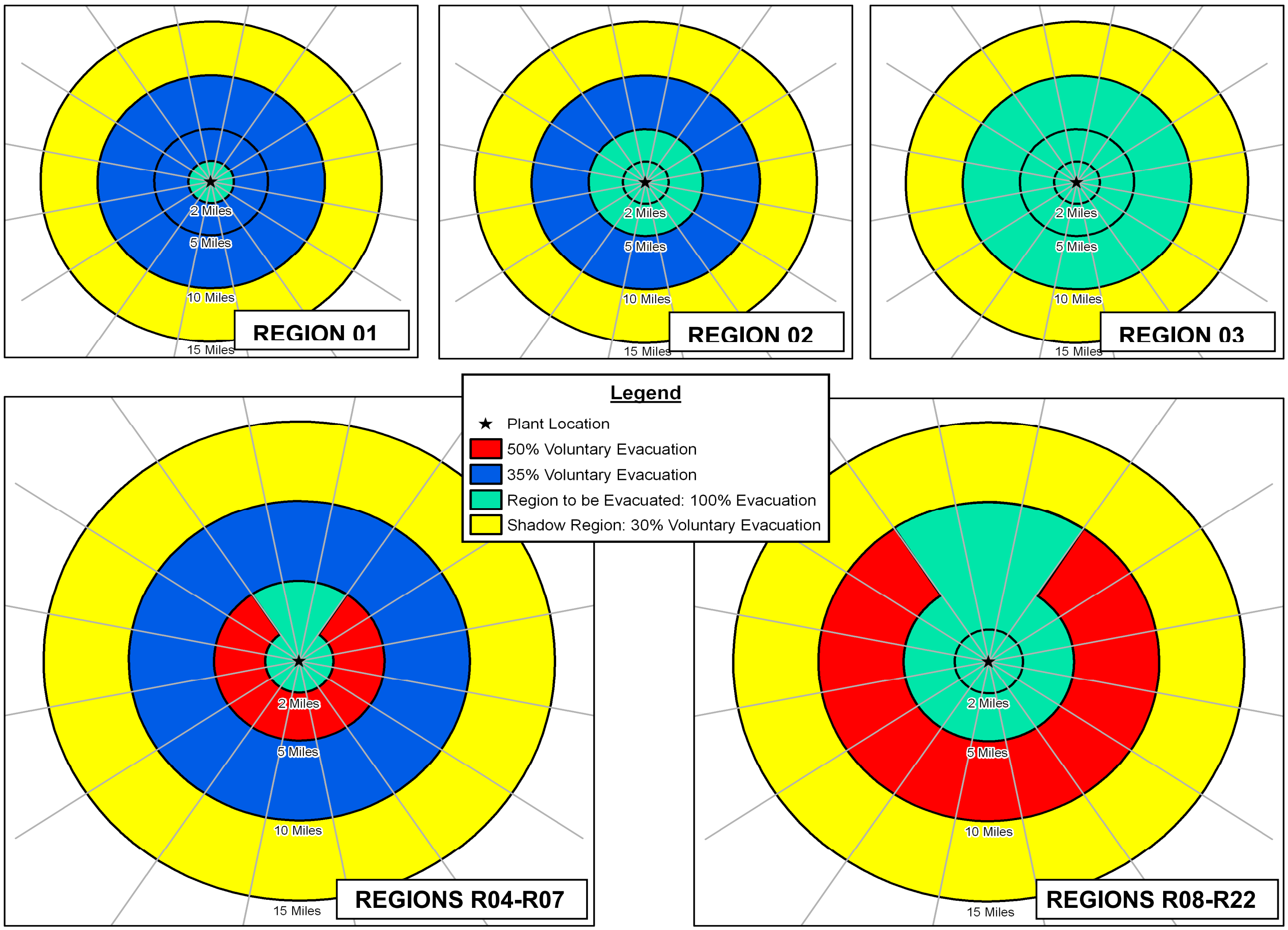


Figure 2-1. Assumed Evacuation Response

2.3 Study Assumptions

1. The Planning Basis assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following:
   a. Advisory to evacuate is announced coincident with the siren notification.
   b. Mobilization of the general population will commence within 10 minutes of the advisory to evacuate.
   c. ETE are measured relative to the advisory to evacuate.
2. It is assumed that everyone within the group of ERPA (municipalities) forming a region that is issued an advisory to evacuate will, in fact, respond in general accord with the planned routes.
3. It is further assumed that:
   a. Buses will evacuate the schools first (if in session at the time of the accident) before those who are transit-dependent.
   b. 52 percent of households in the EPZ have at least one commuter.
   c. The telephone survey results suggest that 60 percent of those households will await the return of a commuter before beginning their evacuation trip. However, the ETE was computed based on the conservative assumption that all (100 percent) of the households with commuters will await the return of the commuter before beginning their evacuation trip.
4. The ETE calculations 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.

   The effect of heavy truck traffic on traffic operations during evacuation was determined to be immaterial; therefore, the presence of truck traffic is not expressly considered in calculating ETE. However, the buses used to evacuate transit dependent persons from within the EPZ are represented within the modeling process as being equivalent to two passenger car units in calculating the ETE.

5. Access Control Points (ACP) will be staffed within approximately 90 minutes of the siren notifications, to divert through traffic attempting to enter the EPZ. Earlier activation of ACP locations could delay returning commuters. It is assumed that no through vehicles will enter the EPZ after this 90 minute mobilization 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 toward the power station.
c. Provide assurance and guidance to all travelers. This guidance is provided by the deployment of traffic cones and by the user of hand signals by the traffic guides.
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 drivers will act rationally, travel in directions identified in the plan, and obey all control devices and traffic guides. These TCP serve many useful functions, but are not considered in specifying the inputs to the DYNEV model used to calculate ETE. Consequently, the results presented in Section 7 and in Appendix J are conservative in that they do not reflect an incremental enhancement in traffic performance due to the presence of these TCP. The time needed to mobilize personnel or equipment to staff the TCP will not influence ETE results.

The goal of the ETE modeling activity is to realistically represent the traffic environment during emergency evacuation conditions. Consistent with this objective of representing realistic driver behavior, it is assumed that all drivers will respond safely to traffic control regardless of whether that control is implemented by a traffic signal, a stop sign or by traffic control personnel at a TCP. The signal splits input to the model are adjusted to represent realistic human behavior during emergency evacuation based on traffic conditions but are not treated optimally as though there is expert traffic control personnel controlling the signal at all times. The outcome of this approach to developing ETE is to produce realistic estimates of evacuation time.

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 assigned host schools.
   b. Schoolchildren, if school is in session, are given priority in assigning transit vehicles.
   c. Bus mobilization time is considered in ETE calculations.
   d. Analysis of the number of required “waves” of transit vehicles used for evacuation is presented.
8. It is reasonable to assume that 50 percent of transit-dependent people will ride-share with family, neighbors, and friends, thus reducing the demand

for buses. This assumption is based upon reported experience for other emergencies[2]. The remaining transit-dependent portion of the general population will be evacuated to reception centers by bus.

9. Two types of adverse weather scenarios are considered. Rain may occur in winter or summer. It is assumed that the rain begins at about the same time the evacuation advisory is issued. Therefore, no weather-related reduction in the number of transients who may be present in the EPZ is assumed.

   Snow may occur in winter scenarios. Transient population reductions are not assumed for snow scenarios. Further, it is assumed that roads are passable and that the appropriate agencies are plowing the roads as they would normally.

   Adverse weather scenarios affect roadway capacity, free flow highway speeds and possibly the time required to mobilize the general population. The factors assumed for the ETE study are:

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time
Rain[3]	90%	90%	No Effect
Snow[3]	80%	80%	Clear driveway before leaving home (Source: Telephone Survey)
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.			

10. School buses used to transport students are assumed to have the capacity to transport 70 children per bus for elementary schools, and 50 children per bus for middle and high schools. Transit buses used to transport the transit-dependent general population are assumed to transport an average of 30 people per bus, taking into account that they will be carrying luggage and allowing for some reserve capacity.

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

[3] 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.

3. DEMAND ESTIMATION

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

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

2. An estimate, for each population group, of mean occupancy per evacuating vehicle. This estimate is used to determine the number of evacuating vehicles. In developing this estimate, it is necessary to distinguish between those who have access to privately owned vehicles (POV) and those who would require transit vehicles. The latter group includes home-based persons and those in "special facilities."

3. An estimate of potential double counting of vehicles.

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

Throughout the year, vacationers and tourists enter the EPZ. These non-residents may dwell within the EPZ for a short period (a few days, or one or two weeks), or may enter and leave within one day. Estimates of the size of this population component 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 within the EPZ could be counted as a resident, and again as an employee.
- 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.

As outlined above, the population of the SSES/Bell Bend EPZ is comprised of three distinct groups:

- Permanent residents - people who are year-round residents of the EPZ.
- Transients - people who reside outside of the EPZ, who enter the area for a specific purpose (e.g., hunting, fishing) and then leave the area.
- Commuter-employees - people who reside outside the EPZ and commute to businesses within the EPZ on a daily basis.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each municipality and by polar coordinate representation (population rose). The SSES/Bell Bend EPZ has been subdivided into 27 Municipalities as shown in Figure 3-1.

<u>Permanent Residents</u>

The primary source for estimating permanent population is the latest U.S. Census data. The average household size (2.52 persons/household) and the average number of evacuating vehicles per household (1.30 vehicles/household) were obtained from the telephone survey results.

The annual rate of population change for each county in the study area was estimated from Census data. These growth rates were applied to Year 2000 Census block point data using Geographical Information Systems (GIS) software to project population within the EPZ and within the shadow region to the Year 2009. Table 3-1 summarizes the annual rate of population change used for each county. The county wide averages suggest that Columbia and Carbon counties are growing at a nominal rate while the population within Luzerne and Schuylkill counties is declining.

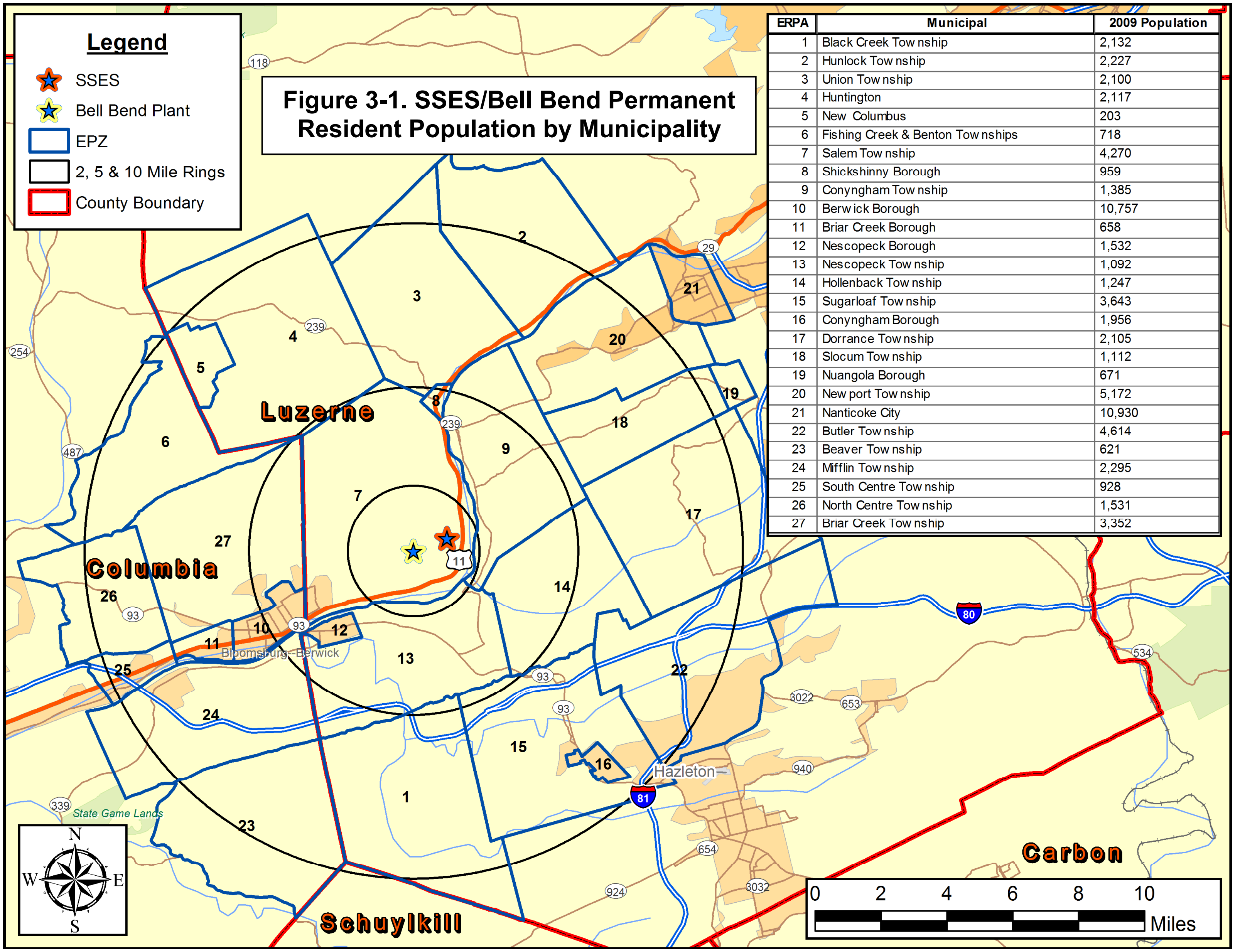
Permanent resident population estimates for 2000 and 2009 are presented in Table 3-2 and vehicle estimates for 2009 are presented in Table 3-3. Figures 3-2 and 3-3 present the permanent resident population and permanent resident vehicle estimates by sector and distance from the existing SSES site. This "rose" was constructed using GIS software.

Table 3-1 Population Estimates by County

County	2000 Census	2006 Census Estimate	Annual Growth Rate %
Columbia	64,151	65,014	0.21
Luzerne	319,250	313,020	-0.32*
Carbon	58,802	62,567	0.99
Schuylkill	150,336	147,405	-0.32*

* Conservatively maintained the 2000 population for Year 2009 for these counties.

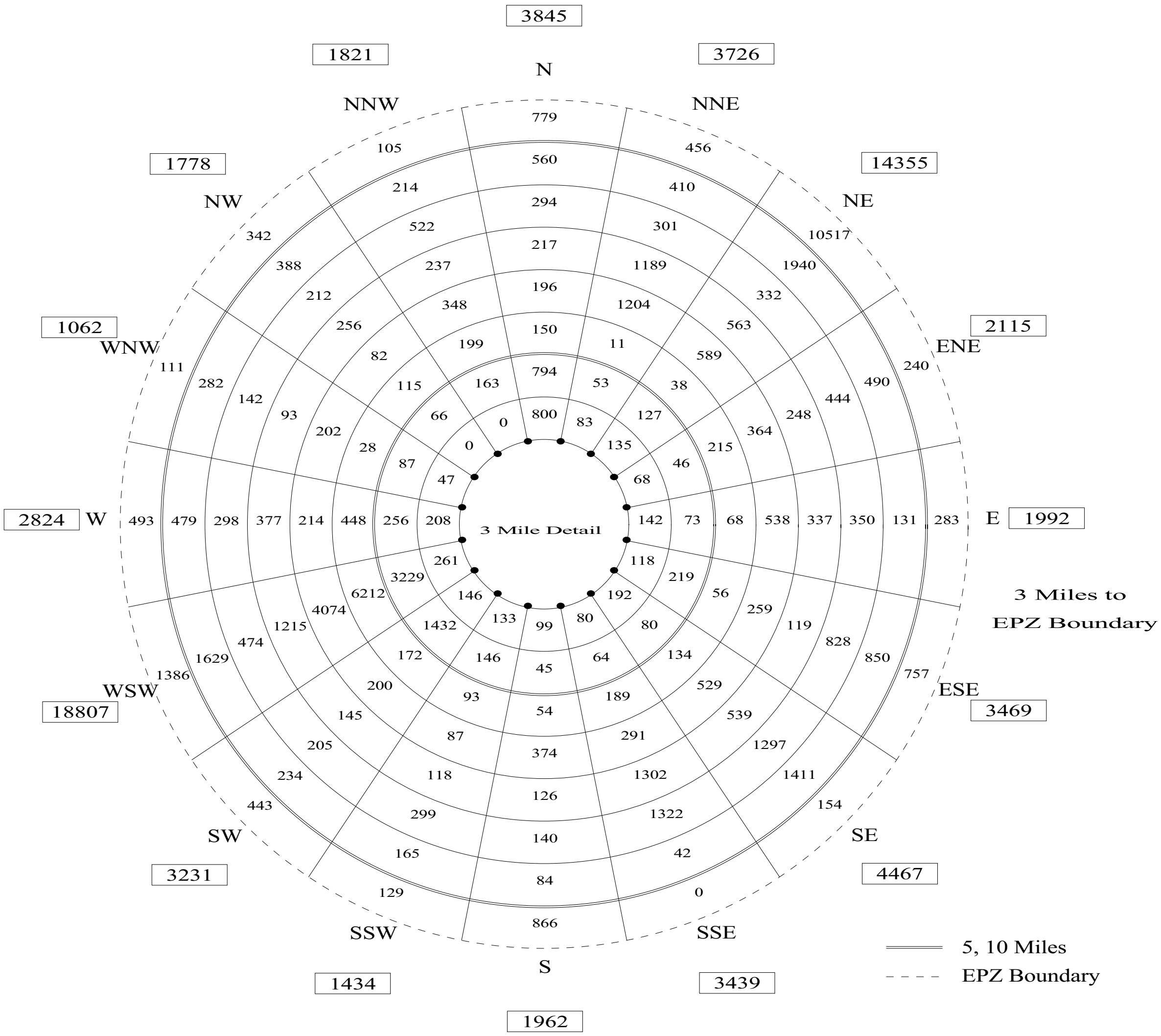
Figure 3-1. SSES/Bell Bend Permanent Resident Population by Municipality



ERPA	Municipal	2009 Population
1	Black Creek Township	2,132
2	Hunlock Township	2,227
3	Union Township	2,100
4	Huntington	2,117
5	New Columbus	203
6	Fishing Creek & Benton Townships	718
7	Salem Township	4,270
8	Shickshinny Borough	959
9	Conyngham Township	1,385
10	Berwick Borough	10,757
11	Briar Creek Borough	658
12	Nescopeck Borough	1,532
13	Nescopeck Township	1,092
14	Hollenback Township	1,247
15	Sugarloaf Township	3,643
16	Conyngham Borough	1,956
17	Dorrance Township	2,105
18	Slocum Township	1,112
19	Nuangola Borough	671
20	Newport Township	5,172
21	Nanticoke City	10,930
22	Butler Township	4,614
23	Beaver Township	621
24	Mifflin Township	2,295
25	South Centre Township	928
26	North Centre Township	1,531
27	Briar Creek Township	3,352

Table 3-2. EPZ Permanent Resident Population		
Municipality	2000 Population	2009 Population
1	2,132	2,132
2	2,227	2,227
3	2,100	2,100
4	2,117	2,117
5	203	203
6	703	718
7	4,270	4,270
8	959	959
9	1,385	1,385
10	10,552	10,757
11	645	658
12	1,532	1,532
13	1,092	1,092
14	1,247	1,247
15	3,613	3,643
16	1,956	1,956
17	2,105	2,105
18	1,112	1,112
19	671	671
20	5,021	5,172
21	10,930	10,930
22	4,614	4,614
23	609	621
24	2,251	2,295
25	910	928
26	1,501	1,531
27	3,288	3,352
TOTAL	**69,745**	**70,327**
Population Growth:		**0.57%**

Table 3-3. Permanent Resident Population and Vehicles by Municipality		
Municipality	2009 Population	2009 Vehicles
1	2,132	1,100
2	2,227	1,149
3	2,100	1,084
4	2,117	1,093
5	203	105
6	718	371
7	4,270	2,203
8	959	495
9	1,385	715
10	10,757	5,550
11	658	340
12	1,532	791
13	1,092	564
14	1,247	644
15	3,643	2,110
16	1,956	1,010
17	2,105	1,086
18	1,112	574
19	671	347
20	5,172	2,229
21	10,930	5,639
22	4,614	2,381
23	621	321
24	2,295	1,184
25	928	479
26	1,531	790
27	3,352	1,730
TOTAL	**70,327**	**36,084**



Resident Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	173	0-1	173
1-2	894	0-2	1067
2-3	1224	0-3	2291
3-4	2512	0-4	4803
4-5	6880	0-5	11683
5-6	8182	0-6	19865
6-7	9551	0-7	29416
7-8	7081	0-8	36497
8-9	7460	0-9	43957
9-10	9309	0-10	53266
10-EPZ	17061	0-EPZ	70327

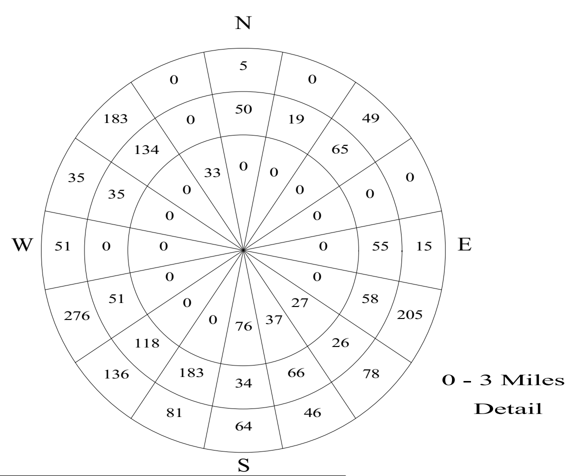
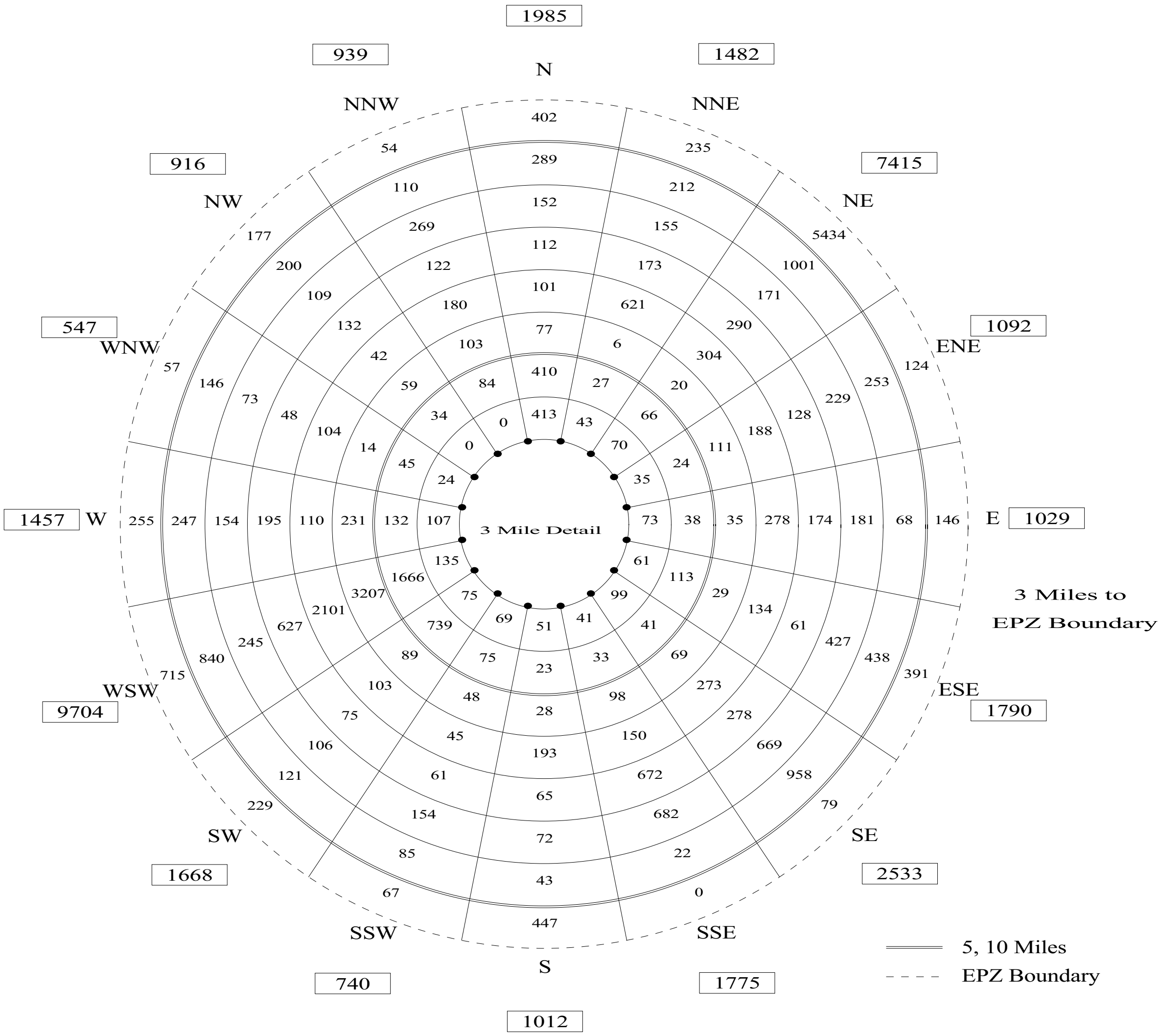


Figure 3-2. Permanent Residents by Sector



Resident Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	89	0-1	89
1-2	461	0-2	550
2-3	631	0-3	1181
3-4	1296	0-4	2477
4-5	3550	0-5	6027
5-6	4224	0-6	10251
6-7	4927	0-7	15178
7-8	3213	0-8	18391
8-9	3848	0-9	22239
9-10	5033	0-10	27272
10-EPZ	8812	0-EPZ	36084

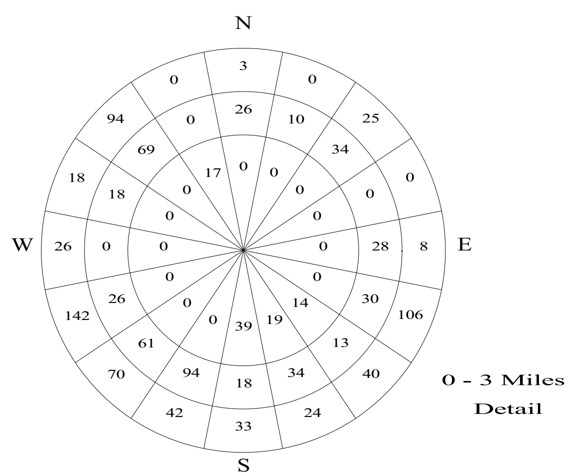


Figure 3-3. Permanent Resident Vehicles by Sector

Transient Population

Transients are defined as those people who are not permanent residents and who enter the EPZ for a specific purpose (hunting, fishing). Transients may spend less than one day or stay overnight or longer at camping facilities, hotels and motels. There are several locations within the SSES/Bell Bend EPZ that attract transients.

1. Fishing

Fishing is popular along the Susquehanna River and at lakes within the EPZ. Using the Pennsylvania State Fishing website, three locations within the EPZ were identified: one site along the Susquehanna River, one site at Lake Lily and another at Briar Creek Lake. The Pennsylvania Game Commission (PGC) was contacted and they did not have data on fishing within the EPZ. The capacity of the parking lot at each facility was estimated using aerial imagery; the average occupancy of 76% and the average percent transients of 53% obtained for campgrounds in the EPZ (see item 5 below) were applied to estimate the number of parking spaces used by transients. An average of 2 persons per vehicle was assumed to estimate the number of transients based on data obtained from calls to golf courses (see item 3 below) as both activities are recreational sports.

2. Hunting

The Pennsylvania State Game Lands 55, 58, 187, 224 and 260 (identification numbers provided by the state) are within the EPZ. These were identified using geospatial data obtained from the Pennsylvania Geospatial Data Clearinghouse. Based on a telephone conversation with the Information Officer (IO) for the PGC, there are 900,000 licensed hunters in the state. There are a total of 1.46 million acres of game land within the state (8,158 acres of which are within the EPZ) based on a GIS analysis of the aforementioned geospatial data.

Based on information provided by the IO, the peak hunting season is during the months of November and December – a total of 61 days. It is assumed that each hunter hunts for 7 days of the season, on average, and that these 7 days are uniformly distributed throughout the season. Multiplying the 900,000 licensed hunters by 7 days of hunting per season and dividing by a 61 day season results in about 103,300 hunters per day, on average. Dividing the 103,000 hunters per day by the 1.46 million acres of state game land results in 0.071 hunters per acre per day. Multiplying this result by the 8,158 acres of state game land within the EPZ results in 577 hunters in the EPZ. As there are many game lands throughout the state, it is unlikely that people would travel outside of their local area to hunt at a different state game land; therefore, most people hunting in the EPZ are most likely EPZ residents. However, a conservative transient percentage of 53% obtained from the campground data is applied (see item 5 below). Thus, there are 306 transient hunters in the EPZ. These 306 transient hunters are apportioned amongst the 5 state game lands within the EPZ by acreage. It is assumed there are 2 hunters per vehicle based on data obtained from calls to

golf courses (see item below) as both activities are recreational sports.

3. Golf Courses

Four major golf courses were identified within the EPZ. Based on telephone conversations with representatives from the golf courses, the peak population at these facilities ranges from 75 to 175 persons and the percent transients ranges from 5% to 70%. All facilities indicated 2 people per vehicle.

4. Parks

The Nescopeck State Park is located along the eastern boundary of the EPZ; hiking and fishing are prevalent in the park. Approximately 9% of the park, by area, is within the EPZ. Using aerial imagery of the parking lots within the EPZ, 125 vehicle spaces were estimated. Based on telephone conversations with management of the park, detailed data on peak occupancy and percent transients was not available. The average occupancy of 76% and percent transients of 53% obtained for campgrounds (see item 5 below) are applied to the 125 parking spaces within the EPZ to estimate the number of transient vehicles. It is assumed that people will travel to the park as a family in a single vehicle; the average household size of 2.52 persons (see Figure F-1) is used to estimate the number of transients based on the number of transient vehicles.

The Susquehanna Riverlands Recreational Area is approximately 400 acres and offers picnicking, hiking, ball fields, playgrounds, fishing along the north branch of the Susquehanna River, and hunting. Based on data provided by management of the facility, the peak season for the facility is from April to June with approximately 300 people per day visiting on the weekends. The percentage of these people which are transients was unknown. The average transient percentage of 53% obtained for campgrounds (see item 5 below) is applied to this facility to estimate the number of transients. It is assumed that people will travel to the facility as a family in a single vehicle; the number of transients is divided by the average household size of 2.52 persons (see Figure F-1) to estimate the number of evacuating vehicles.

5. Campgrounds

Four camping facilities and one children's camp were identified within the EPZ. The children's camp is dependent on transportation assistance for evacuation. As such, the children at this camp are not considered as transients, but rather as transit-dependent population; see Section 8 for discussion of the evacuation of this facility. Based on telephone conversations with management of three of these facilities, the following data, on average, were provided: 1 vehicle and 4 persons per occupied site; 53% of these people are transients; and peak occupancy is 76%.

6. Hotels/Motels

A total of 11 lodging facilities were identified within the EPZ. Detailed data for 7 of these facilities were provided during telephone conversations with management of these facilities. Based on the data provided, the average occupancy for lodging facilities is 89%. Those people staying at lodging facilities are by definition transients. On average, there are 2 people and 1 vehicle per occupied room.

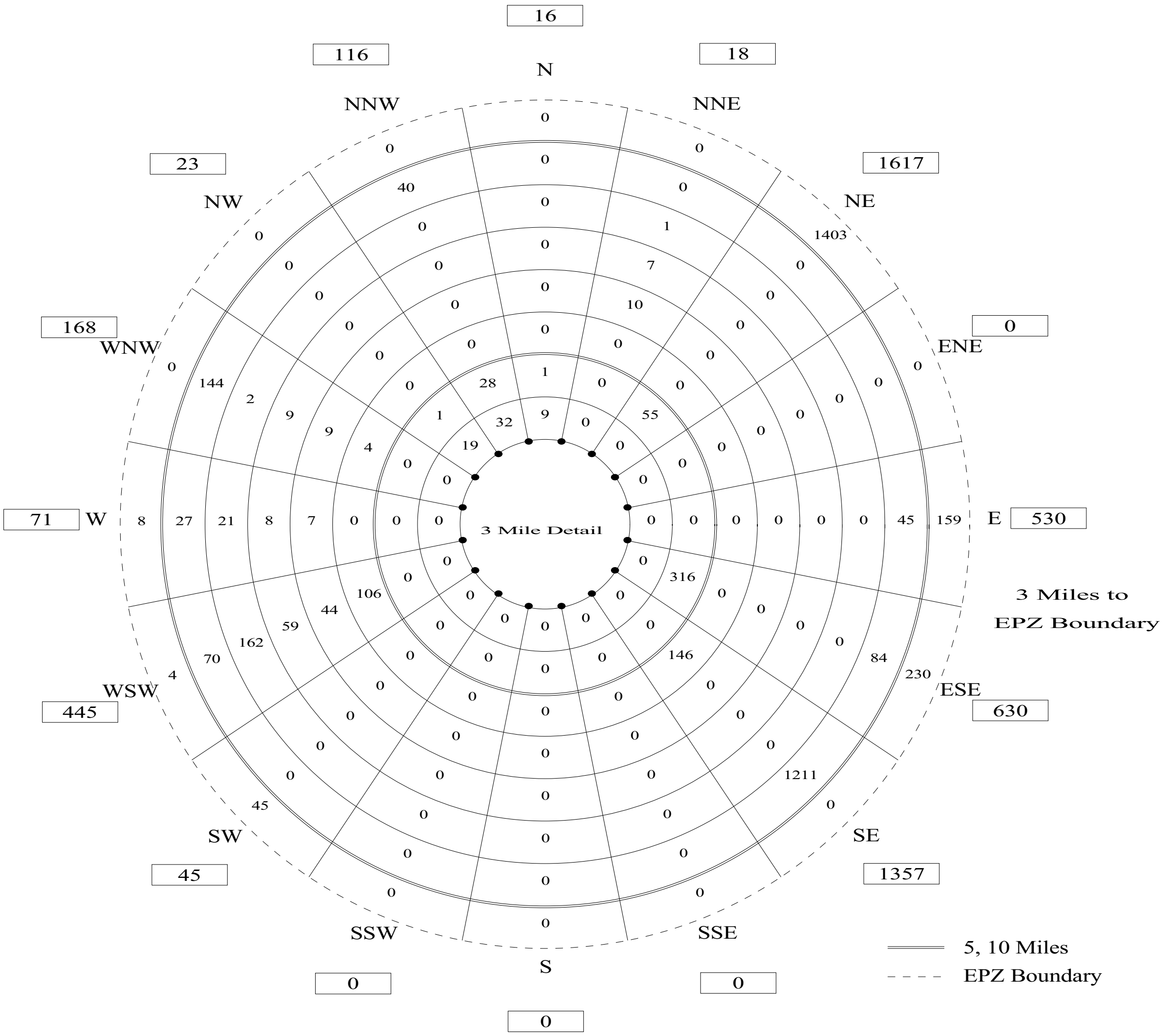
7. Penn State University and Luzerne Community College

The Penn State Hazelton campus enrollment consists of 475 resident students and 757 commuting students. These commuting students are considered transients as their departure patterns are similar to other transients. Similarly, 1403 and 100 students, at the Luzerne Community College campuses at Nanticoke and Berwick, respectively, are considered as transients. An average vehicle occupancy of 1.0 is assumed for these transients.

There are a total of 5,036 transients in 3,415 vehicles within the SSES/Bell Bend EPZ during peak times. Appendix E presents the supporting data for these estimates, as well as maps of the major transient destinations within the EPZ.

Table 3-4 summarizes the transient population and vehicles by Municipality. Figures 3-4 and 3-5 present transient population and transient vehicle data by sector.

Table 3-4. Transient Population and Vehicles by Municipality		
Municipality	Transients	Transient Vehicles
1	0	0
2	10	5
3	48	14
4	0	0
5	0	0
6	170	49
7	276	122
8	0	0
9	326	82
10	133	117
11	52	26
12	0	0
13	0	0
14	316	79
15	1,357	1,057
16	0	0
17	44	22
18	55	28
19	0	0
20	0	0
21	1,403	1,403
22	474	224
23	16	8
24	143	72
25	70	35
26	7	4
27	136	68
TOTAL	**5,036**	**3,415**



Transient Population			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	159	0-1	159
1-2	327	0-2	486
2-3	24	0-3	510
3-4	60	0-4	570
4-5	401	0-5	971
5-6	256	0-6	1227
6-7	70	0-7	1297
7-8	83	0-8	1380
8-9	186	0-9	1566
9-10	1621	0-10	3187
10-EPZ	1849	0-EPZ	5036

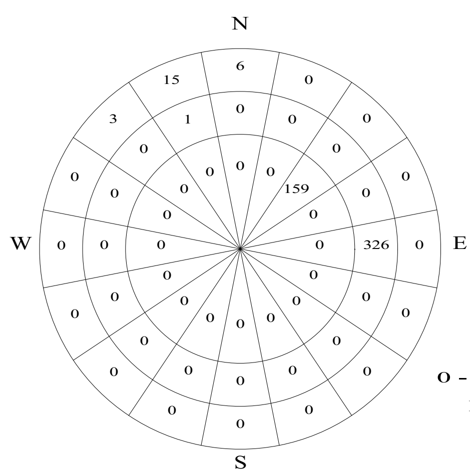
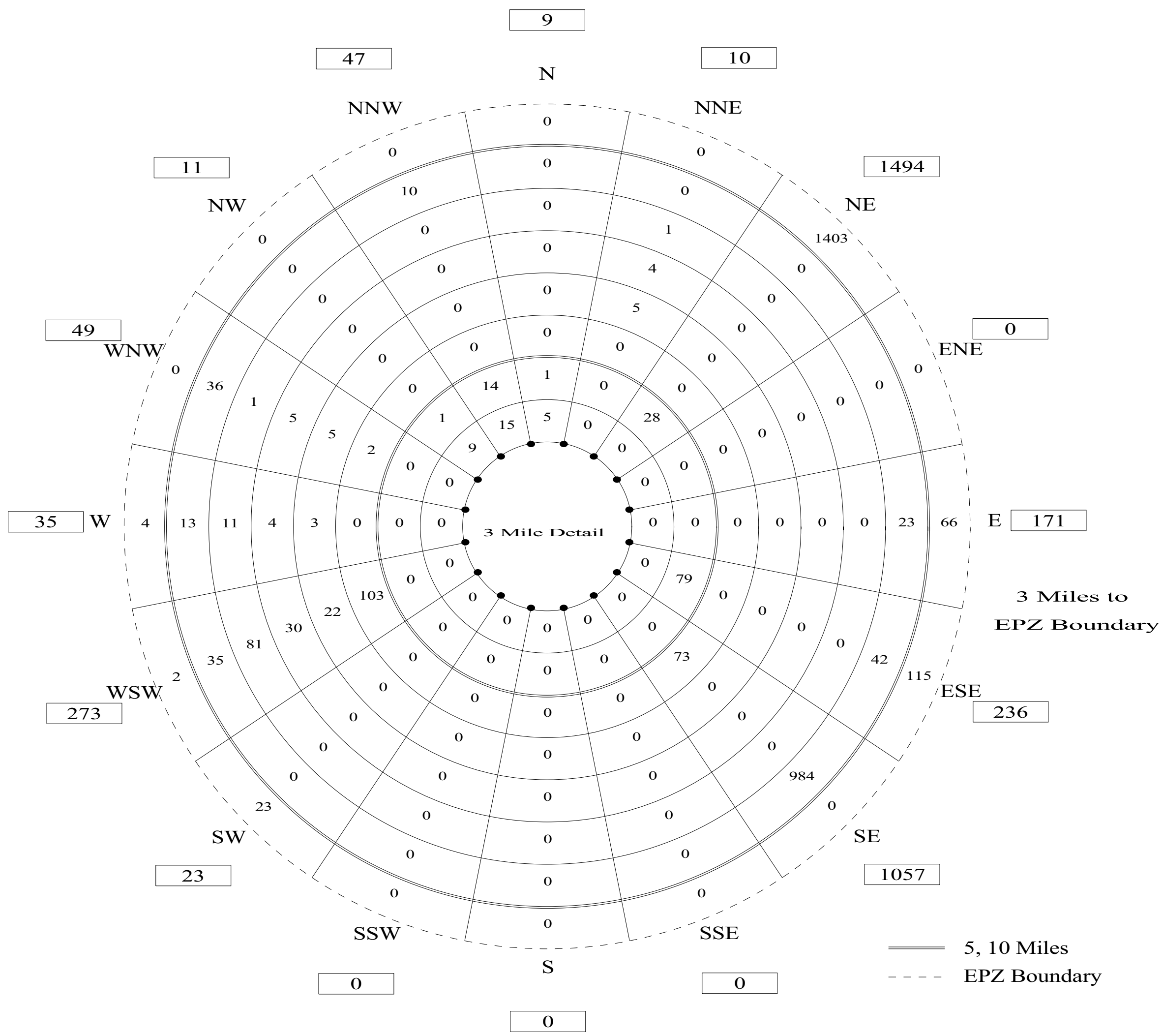


Figure 3-4. Transient Population by Sector



Transient Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	63	0-1	63
1-2	83	0-2	146
2-3	11	0-3	157
3-4	29	0-4	186
4-5	123	0-5	309
5-6	178	0-6	487
6-7	35	0-7	522
7-8	43	0-8	565
8-9	94	0-9	659
9-10	1143	0-10	1802
10-EPZ	1613	0-EPZ	3415

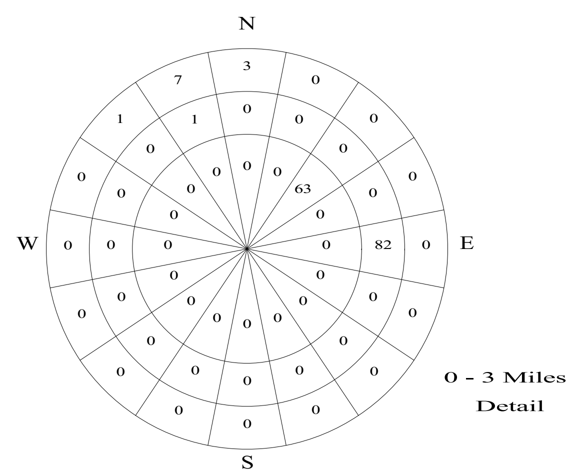


Figure 3-5. Transient Vehicles by Sector

Employees

Employees who work within the EPZ fall into two categories:

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

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

Data for major employers in the EPZ were obtained from a variety of sources including internet searches and direct phone calls to major employers. The locations of these facilities were mapped using GIS software. The GIS map was overlaid with the evacuation analysis network and employees were loaded onto appropriate links.

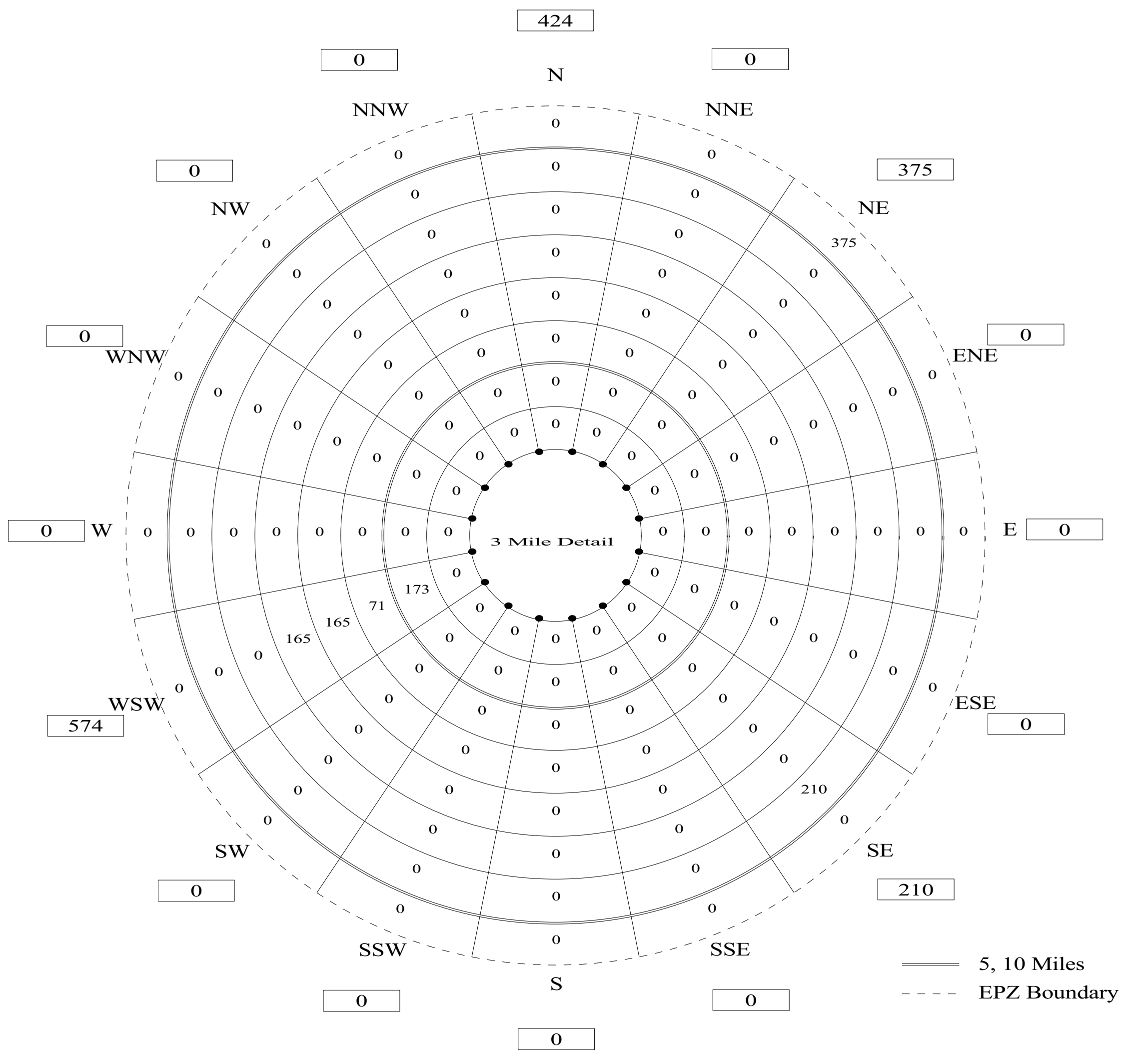
Appendix E provides the data obtained for major employers within the EPZ as well as a map of the major employers.

There are likely several smaller employment centers within the EPZ, but it is assumed that employees at these facilities are EPZ residents.

Detailed data were provided by PPL for the current site employment at SSES, including an accurate estimate of the number of employees who live outside the EPZ. For the other major employers, Census Journey to Work data were used to identify the travel and work patterns within Luzerne and Columbia County. An occupancy of 1.02 persons per employee-vehicle (some carpooling) obtained from the telephone survey, was used to determine the number of evacuating employee vehicles.

There are a total of 1,583 employees commuting into the EPZ on a daily basis. These employees use 1,555 vehicles. Table 3-5 summarizes the employees commuting into the EPZ by municipality. Figures 3-6 and 3-7 present non-EPZ resident employee data by sector.

Table 3-5. Employees and Vehicles Commuting into the EPZ by Municipality		
Municipality	**Employees**	**Employee Vehicles**
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	424	416
8	0	0
9	0	0
10	409	403
11	165	162
12	0	0
13	0	0
14	0	0
15	210	206
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	375	368
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
TOTAL	**1,583**	**1,555**



Employees			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	424	0-1	424
1-2	0	0-2	424
2-3	0	0-3	424
3-4	0	0-4	424
4-5	173	0-5	597
5-6	71	0-6	668
6-7	165	0-7	833
7-8	165	0-8	998
8-9	0	0-9	998
9-10	210	0-10	1208
10-EPZ	375	0-EPZ	1583

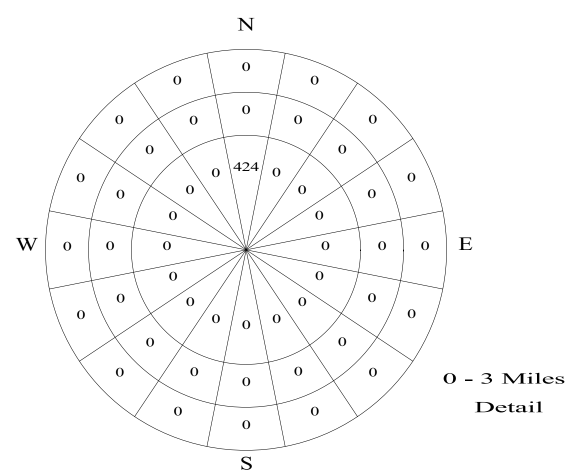
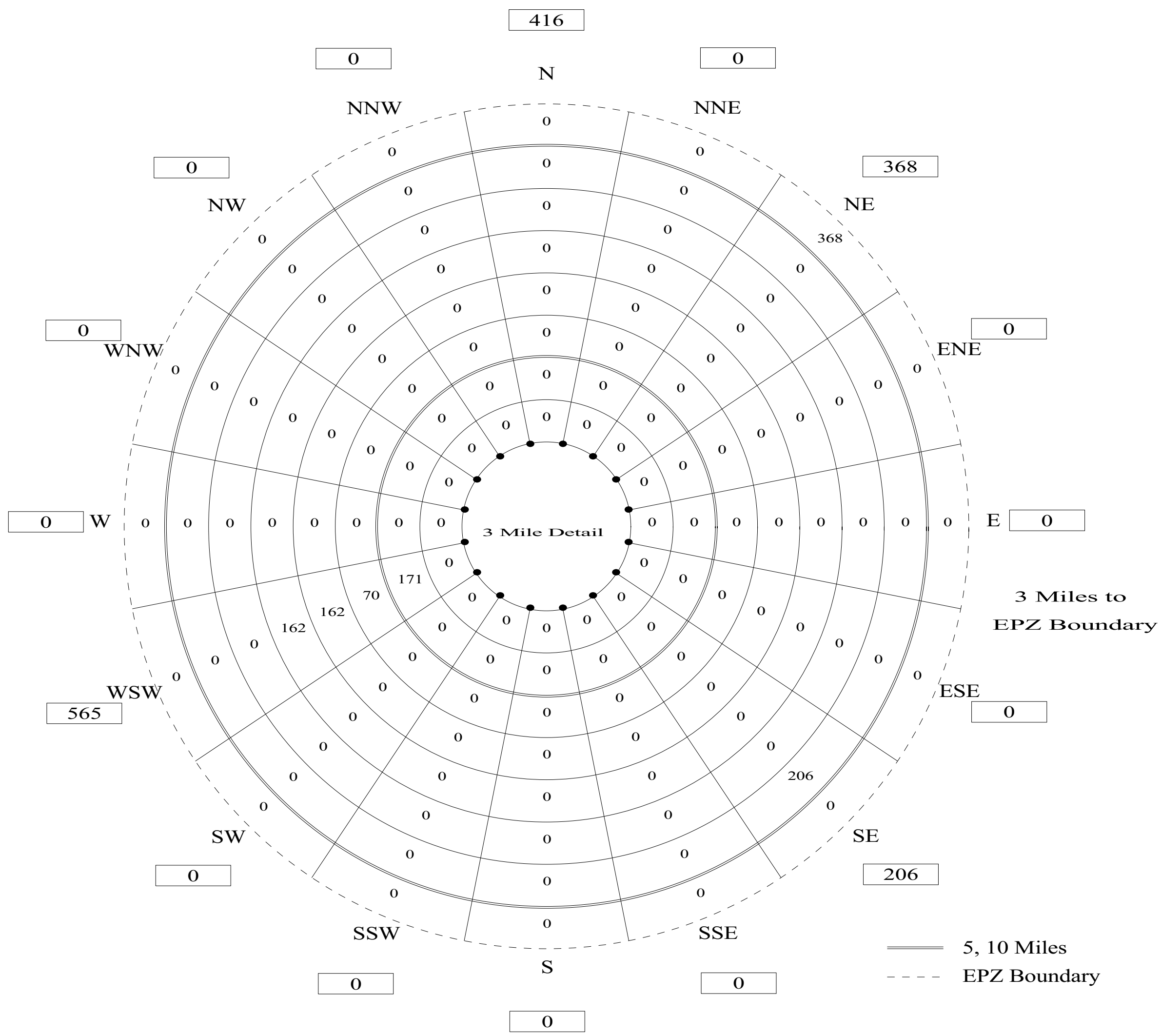


Figure 3-6. Employee Population by Sector



Employee Vehicles			
Miles	Ring Subtotal	Total Miles	Cumulative Total
0-1	416	0-1	416
1-2	0	0-2	416
2-3	0	0-3	416
3-4	0	0-4	416
4-5	171	0-5	587
5-6	70	0-6	657
6-7	162	0-7	819
7-8	162	0-8	981
8-9	0	0-9	981
9-10	206	0-10	1187
10-EPZ	368	0-EPZ	1555

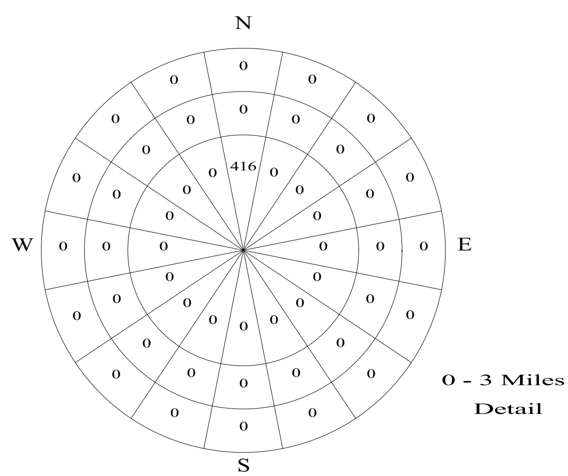


Figure 3-7. Employee Vehicles by Sector

Special Events

Construction

A special event scenario (Scenario 13) represents a typical summer, midweek, midday with construction workers at the proposed Bell Bend site, constructing the new unit when an accident occurs at the existing SSES site. Based on discussions with UniStar, the peak construction will be in the Year 2015, with a workforce of 3,940 construction workers per day. The work force will be assigned to three shifts (day, swing, and night) according to the following percentages: 60%, 35%, and 5%. The average occupancy of the construction worker vehicles is expected to be 1.3, yielding 1,819 construction vehicles for the day shift.

It is also assumed that refueling at SSES will occur for this scenario. The 1,400 additional workers needed for refueling will be split between two shifts. Traffic count data collected at the SSES entrance indicates that 70% of this work force (980 additional workers) is present during the day shift. Based on the construction schedule, 363 workers related to the operations at the new unit will also be on site. The average vehicle occupancy of 1 worker per vehicle is used to estimate the additional vehicle demand for these workers.
A new access road from the Bell Bend site to US Route 11 is considered in this study, based on the information provided. It is assumed that a traffic signal is present at this intersection during the construction years. Those workers present for construction of the new unit will use this new site access road, while the refueling workers and the SSES employees will use the present SSES site access road.

Thus, there are an additional 3,053 vehicles (1,819+0.7x363+980) expected on site during the construction/refueling conditions specified for Scenario 13. Permanent resident population and shadow population are extrapolated to 2015 for this scenario.

Medical Facilities

There are several medical facilities in the EPZ. Chapter 8 details the evacuation time estimate for the patients residing in these facilities. The number and type of evacuating vehicles that need to be provided depends on the state of health of the patients. Buses can transport up to 40 people; vans, up to 12 people; ambulances, up to 2 people (patients).

Pass-Through Demand

Vehicles will be traveling through the EPZ (external-external trips) at the time of an accident. After the advisory to evacuate (ATE) is announced, these through travelers will also evacuate. These through vehicles are assumed to travel on the major pass-through routes in the EPZ (Interstate 80, Interstate 81 and US Route 11). It is assumed that this traffic will continue to enter the EPZ during the first 90 minutes following the ATE. Using traffic count data from the Pennsylvania Department of Transportation website, it is estimated that 8,321 vehicles per hour will enter the EPZ as pass-through demand for the

first 90 minutes (1.5 hours) following the ATE. Thus, the total pass-through demand is 12,482 vehicles (8,321 veh/hr x 1.5 hr). The following table summarizes the inputs to the DYNEV model:

Highway	**Flow (vehicles/hour)**	**Total Demand (vehicles)**
Interstate-80 West	1,584	2,376
Interstate-80 East	1,890	2,835
Interstate-81 North	1,566	2,349
Interstate-81 South	2,106	3,159
US Route 11 North	383	575
US Route 11 South	792	1,188
Total	8,321	12,482

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 2000 Highway Capacity Manual (HCM).

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 12-15 of the HCM. As indicated there, the SV varies with Free Flow Speed (FFS), Terrain and LOS. However, the SV at LOS E (which approximates capacity) varies only with Terrain. This Exhibit was referenced when estimating capacity for two-lane rural highways within the EPZ and Shadow Region; such highways are predominant within the analysis network.

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

- Lane width
- Shoulder width
- Pavement Condition
- Percent Truck Traffic
- 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 free flow speed (FFS) according to Exhibit 20-5 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. The estimated FFS were measured using the survey vehicle’s speedometer and observing local traffic.

As discussed in Section 2.3, it is necessary to adjust capacity estimates 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.

Given the high population density in the borough of Berwick and in the City of Nanticoke, and the limited roadways servicing traffic, congestion arising from evacuation is significant in these areas. As such, estimates of roadway capacity must be determined with great care.

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, 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 IDYNEV system.

Capacity Estimation 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 traffic directions may supersede traffic control devices. The Traffic Management Plan identifies these locations (Traffic Control Points, TCP) and the management procedures applied.

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

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

where:

$Q_{cap,m}$	=	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 to IDYNEV 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,

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

where:

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

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

$$h_m \geq h_{sat}$$

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

The above discussion is necessarily brief given the scope of this ETE report and the complexity of the subject of intersection capacity. In fact, the two longest chapters in the HCM (16 and 17), each well over 100 pages, address this topic. The factors, F_1, F_2, …, influencing saturation flow rate are indentified in equation (16-4) and Exhibit 16-7 of the HCM; Exhibit 10-12 identifies the required data and Exhibit 10-7 presents representative values of Service Volume.

Capacity Estimation Along Freeway Sections

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

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

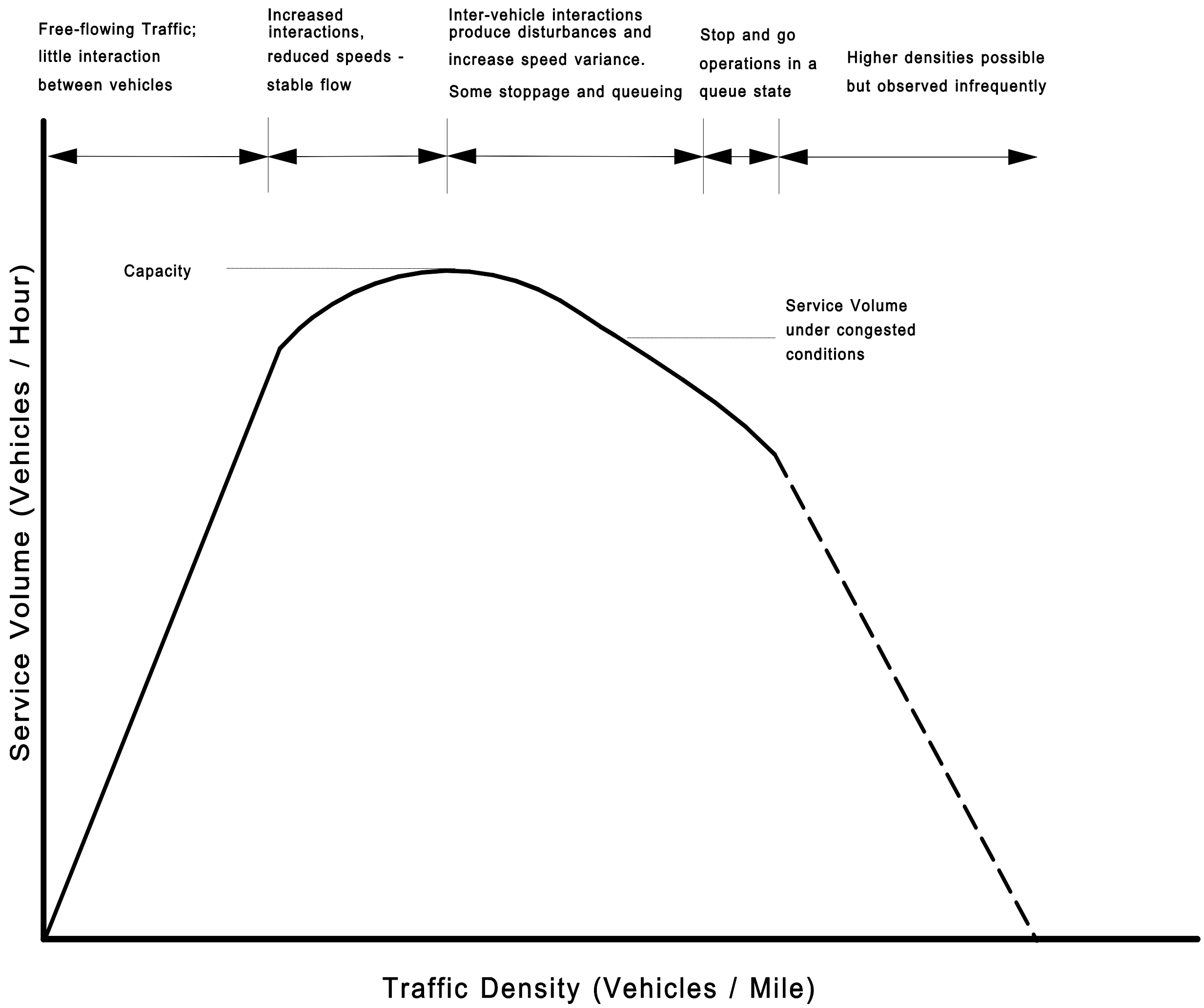


Figure 4-1. Fundamental Relationship Between Volume and Density

As indicated, there are two flow regimes: (1) Free Flow (left side of curve); and (2) Forced Flow (right side). In the free flow regime, the traffic demand is fully serviced; 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. Therefore, in order to realistically represent traffic performance during congested conditions (when demand exceeds capacity), it is necessary to estimate the service volume, V_F, under congested (LOS F) conditions.

The value of V_F can be expressed as:

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

where R = Reduction factor which is less than unity.

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

The advisability of such a capacity 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[2] 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. The data collected in the cited reference indicates that the variation of QDF at a location is generally in the range of +/- 5% about the average QDF. That is, the lower tail of this distribution would be equivalent to a capacity reduction factor of 0.90 - 0.05 = 0.85 which is the figure adopted.

2 Lei Zhang and David Levinson, “Some Properties of Flows at Freeway Bottlenecks,” Transportation Research Record 1883, 2004.

It is seen that a conservative view is taken in estimating the capacity at bottlenecks when congestion develops (this capacity, of course, is the QDF rate discussed above). One could argue that a more representative value for this capacity reduction factor could be 0.90 as discussed above. Given the emergency conditions, a conservative stance is justified. Therefore, a factor of 0.85 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. The breakdowns on rural roads which are experienced on this network occur at intersections where other model logic applies. Therefore, the application of a factor of 0.85 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. Table 12-15 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.

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

<u>Application to the SSES/Bell Bend Nuclear Power Plant EPZ</u>

As part of the development of the SSES/Bell Bend EPZ traffic network, an estimate of roadway capacity is required. The source material for the capacity estimates presented herein is contained in:

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

The highway system in the SSES/Bell Bend EPZ consists primarily of three categories of roads and, of course, intersections:

- Two-lane roads: Local, State
- Multi-lane Highways (at-grade)
- Freeways (Interstate-81, Interstate-84)

Each of these classifications will be discussed.

Two-Lane Roads

Ref: HCM Chapters 12 and 20

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

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

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

Multi-Lane Highway

Ref: HCM Chapters 12 and 21

Exhibit 21-23 (in the HCM) presents a set of curves that indicates a per-lane capacity of approximately 2100 pc/h, for free-speeds of 55-60 mph. Based on observation, the multi-lane highways outside of urban areas within the EPZ service traffic with free-flow 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.

Chapter 12 presents the basic concepts underlying the procedures in Chapters 20 and 21.

Freeways

Ref: HCM Chapters 13, 22-25

Chapter 22 of the HCM describes a procedure for integrating the results obtained in Chapters 23, 24 and 25, which compute capacity and LOS for freeway components. The discussion also references Chapter 31, which presents a discussion on simulation models. The simulation model, PC-DYNEV, automatically performs this integration process.

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

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

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

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

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

Chapter 13 presents basic concepts underlying the procedures in the later chapters.

Intersections

Ref: HCM Chapters 10, 16, 17

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapters 16 (signalized intersections) and 17 (unsignalized intersections). As previously mentioned, these are the two longest chapters in the HCM 2000, reflecting the complexity of these procedures. The simulation logic is likewise complex, but different; as stated on page 31-21 of the HCM2000:

> *"Assumptions and complex theories are used in the simulation model to represent the real-world dynamic traffic environment."*

Simulation and Capacity Estimation

Chapter 31 of the HCM is entitled, "Simulation and other Models." The lead sentence on the subject of Traffic Simulation Models is:

> Traffic simulation models use numerical techniques on a digital computer to create a description of how traffic behaves over extended periods of time for a given transportation facility or system…by stepping through time and across space, tracking events as the system state unfolds. Traffic simulation models focus on the dynamic of traffic flow.

In general terms, this description applies to the PC-DYNEV model, which 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.

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, as described earlier. These parameters are listed in Appendix K, for each network link.

5. ESTIMATION OF TRIP GENERATION TIME

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

Background

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

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

At each level, the Federal guidelines specify a set of actions to be undertaken by the licensee, and by state and local offsite authorities. The planning basis adopts a conservative posture, in accord with Federal Regulations, that a rapidly escalating accident will be considered in calculating the trip generation time. We will assume:

a. The Advisory to Evacuate will be announced coincident with the emergency notification.
b. Mobilization of the general population will commence up to 10 minutes after the alert notification.
c. Evacuation Time Estimates (ETEs) are measured relative to the Advisory to Evacuate.

The adoption of this planning basis is not a representation that these events will occur at the SSES/Bell Bend Nuclear Power Plant within the indicated time frame. Rather, these assumptions are necessary in order to:

- Establish a temporal framework for estimating the trip generation distribution as recommended in Appendix 4 of NUREG 0654.
- Identify temporal points of reference that uniquely define "clear time" and ETE.

It is likely that a longer time will elapse between the various classes of an emergency at SSES/Bell Bend and that the advisory to evacuate is announced somewhat later than the siren alert.

For example, suppose one hour elapses from the declaration of a general emergency (and the siren alert) to the 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 Emergency Planning Zone (EPZ) will be lower when the advisory to evacuate is announced, than at the time of the general emergency. Under these circumstances, the time needed to evacuate the EPZ, after the advisory to evacuate will be less than the estimates presented in this report.

The notification process consists of two events:

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

The peak population within the EPZ approximates 74,250 people[1] who are deployed over an area of approximately 367 square miles and engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident.

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

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

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

[1] This estimate is for a winter midweek scenario and includes 100% of permanent residents, 100% of employees commuting into the EPZ to work, and 65% of transients.

Fundamental Considerations

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

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

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

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

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

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

These relationships are shown graphically in Figure 5-1.

An employee who lives outside the EPZ will follow sequence (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. Note that event 5, "Leave to evacuate the area," is conditional either on event 2 or on event 4. For this study, we adopt the conservative posture that all activities will occur in sequence.

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, the estimate of the time distribution of event 5 depends on the estimates of the time distributions of all preceding events.

Estimated Time Distributions of Activities Preceding Event 5

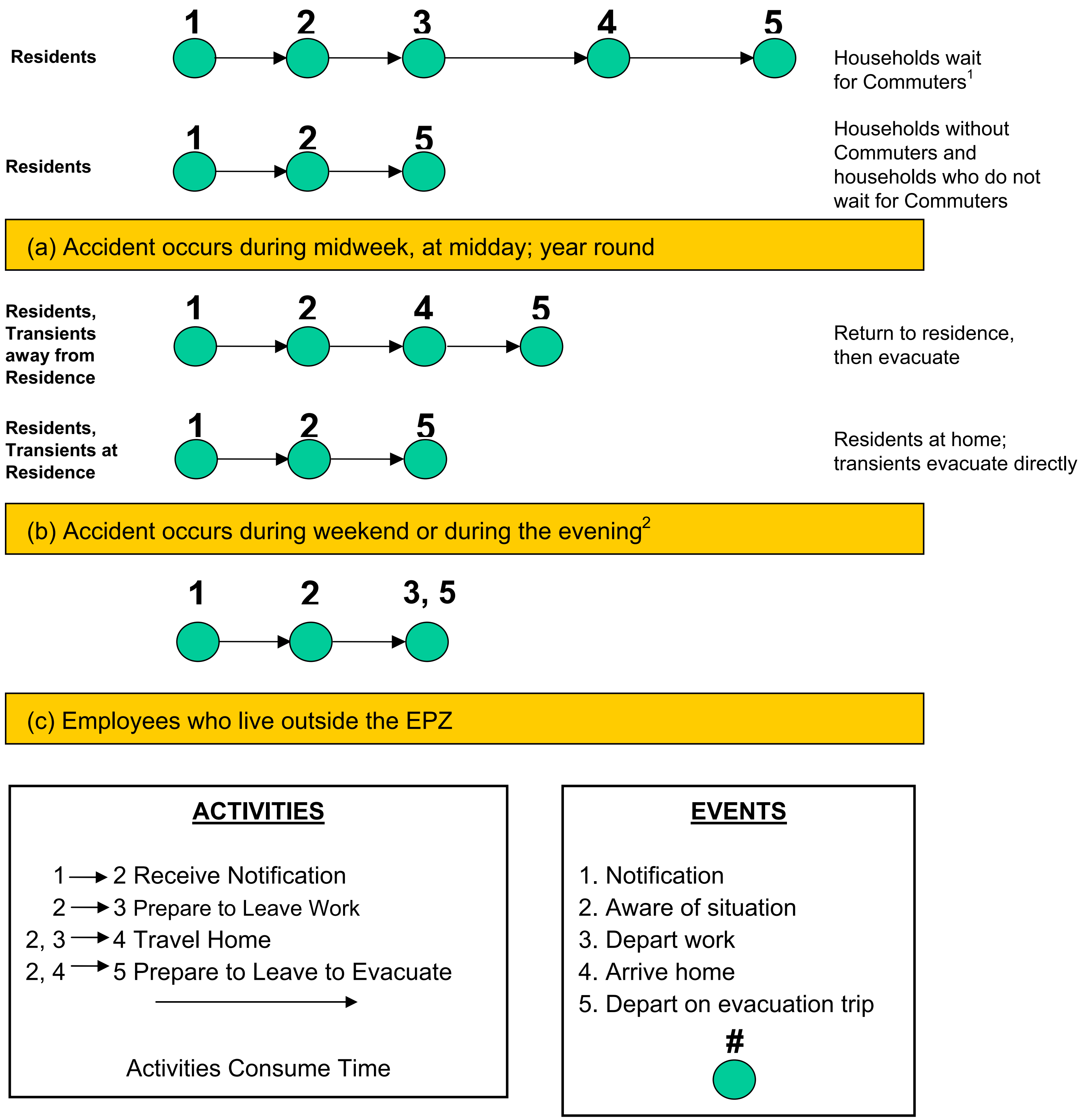
The time distribution of an event is obtained by "summing" the time distributions of all prior contributing activities. (This "summing" process is quite different than an algebraic sum).

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

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

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

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



[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

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

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

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0.0%
5	45.6%
10	60.0%
15	67.2%
20	71.4%
25	72.3%
30	83.8%
35	86.9%
40	87.8%
45	91.0%
50	91.5%
55	91.5%
60	97.2%
65	97.6%
70	98.0%
75	98.5%
80	98.7%
85	98.9%
90	99.1%
95	99.4%
100	99.7%
105	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 returns which included responses 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 the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0.0%
5	14.3%
10	30.8%
15	45.3%
20	61.4%
25	70.2%
30	82.9%
35	86.7%
40	90.2%
45	94.5%
50	95.1%
55	95.3%
60	98.2%
65	98.2%
70	98.2%
75	98.2%
80	98.3%
85	98.4%
90	98.4%
95	98.5%
100	98.6%
105	98.6%
110	99.0%
115	99.3%
120	99.6%
125	99.7%
130	99.7%
135	99.8%
140	99.9%
145	99.9%
150	100.0%

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 the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
0	0.0%
5	8.5%
10	17.1%
15	25.6%
20	37.0%
25	48.4%
30	59.9%
35	63.2%
40	66.6%
45	70.0%
50	75.4%
55	80.8%
60	86.2%
65	88.4%
70	90.6%
75	92.8%
80	93.2%
85	93.5%
90	93.8%
95	93.8%
100	93.8%
105	93.8%
110	94.8%
115	95.9%
120	96.9%
125	97.1%
130	97.3%
135	97.5%
140	97.5%
145	97.5%
150	97.5%
155	97.5%
160	97.5%
165	97.5%
170	97.7%
175	97.9%
180	98.1%
185	98.3%
190	98.4%
195	98.6%
200	98.6%
205	98.6%
210	98.6%
215	98.6%
220	98.6%
225	98.6%
230	98.7%
235	98.8%
240	98.8%
245	98.8%
250	98.8%
255	98.8%
260	98.9%
265	99.0%
270	99.0%
275	99.0%
280	99.0%
285	99.0%
290	99.2%
295	99.3%
300	99.4%
305	99.5%
310	99.5%
315	99.6%
320	99.6%
325	99.6%
330	99.6%
335	99.6%
340	99.6%
345	99.6%
350	99.7%
355	99.9%
360	100.0%

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 their 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 the telephone survey. This distribution is plotted in Figure 5-2 and listed below.

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
0	0.0%
5	13.2%
10	26.4%
15	39.7%
20	50.4%
25	61.1%
30	71.8%
35	74.6%
40	77.5%
45	80.4%
50	83.0%
55	85.7%
60	88.4%
65	89.6%
70	90.8%
75	92.0%
80	92.6%
85	93.2%
90	93.8%
95	94.3%
100	94.8%

Elapsed Time (Minutes)	Cumulative Pct. Ready to Evacuate
105	95.3%
110	96.0%
115	96.8%
120	97.6%
125	97.8%
130	97.9%
135	98.1%
140	98.1%
145	98.2%
150	98.3%
155	98.3%
160	98.3%
165	98.3%
170	98.6%
175	98.9%
180	99.1%
185	99.4%
190	99.7%
195	100.0%

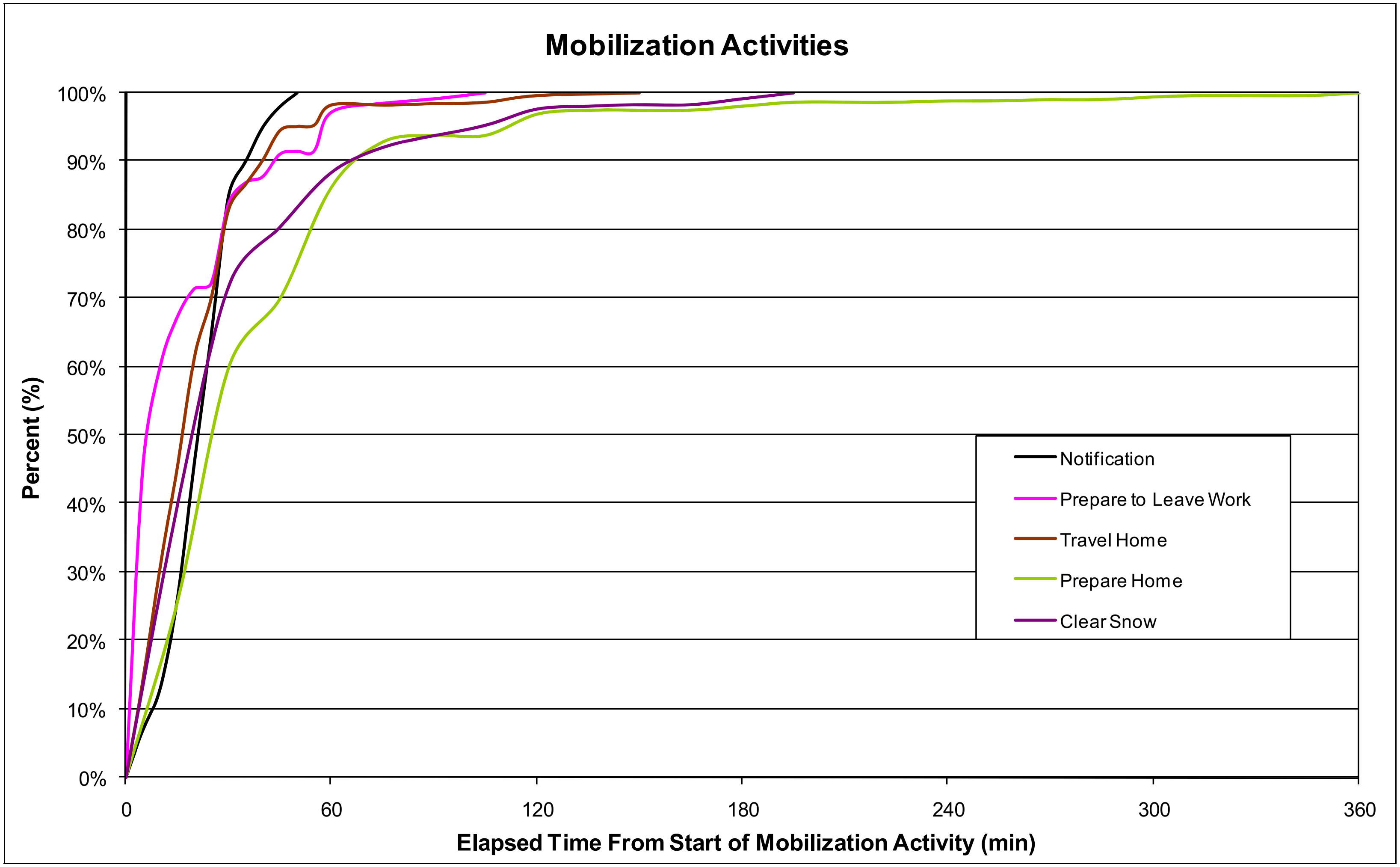


Figure 5-2. Evacuation Mobilization Activities

Calculation of Trip Generation Time Distribution

The time distributions for each of the mobilization activities presented herein must be combined to form the appropriate Trip Generation Distributions. It is assumed 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; "letter" designations are assigned to these intermediate distributions to describe the procedure.

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 A and 4	Distribution D	Event 5
Distributions C and 5	Distribution E	Event 5
Distributions D and 5	Distribution F	Event 5

Distributions A through F are described below.

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ but live outside the EPZ, and to Transients within the EPZ.
B	Time distribution of commuters arriving home.
C	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip.
D	Time distribution of residents with no commuters returning home to begin the evacuation trip.
E	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip after snow clearance activities.
F	Time distribution of residents with no commuters returning home, leaving to begin the evacuation trip after snow clearance activities.

As shown in Figure 5-2, the mobilization activity distributions have long tails. Combining multiple distributions with long tails results in an even longer tail. Thus, the 100th percentile of the combined distribution is indistinct and difficult to quantify. Given these characteristics, a statistical analysis on the mobilization distributions was performed to quantify a "confidence band" about the distribution. This band serves as the basis for establishing the point in time where the long tail should be "truncated".

The ETE for the vast majority of evacuees should not be distorted for those few stragglers (typically less than 2 percent of households) who take considerably longer to prepare to evacuate. As such, the combined distributions are "truncated" to avoid biasing the ETE. In "truncating" these distributions, the mobilization of the stragglers is advanced. Therefore, the stragglers are not eliminated from the ETE.

Figure 5-3 presents the combined trip generation distributions designated A, C, D, E and F. These distributions are presented on the same time scale. Comparison of Figures 5-2 and 5-3 indicates that the combined distributions in Figure 5-3 are somewhat shorter (5 hours and 30 minutes) than the individual distributions in Figure 5-2 (up to 6 hours). This is a result of the aforementioned "truncation".

The PC-DYNEV simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These

histograms, which represent Distributions A, C, D, E, and F, properly displaced with respect to one another, are tabulated in Table 5-1 (Distribution B, Arrive Home, omitted for clarity).

The final time period (13) 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.

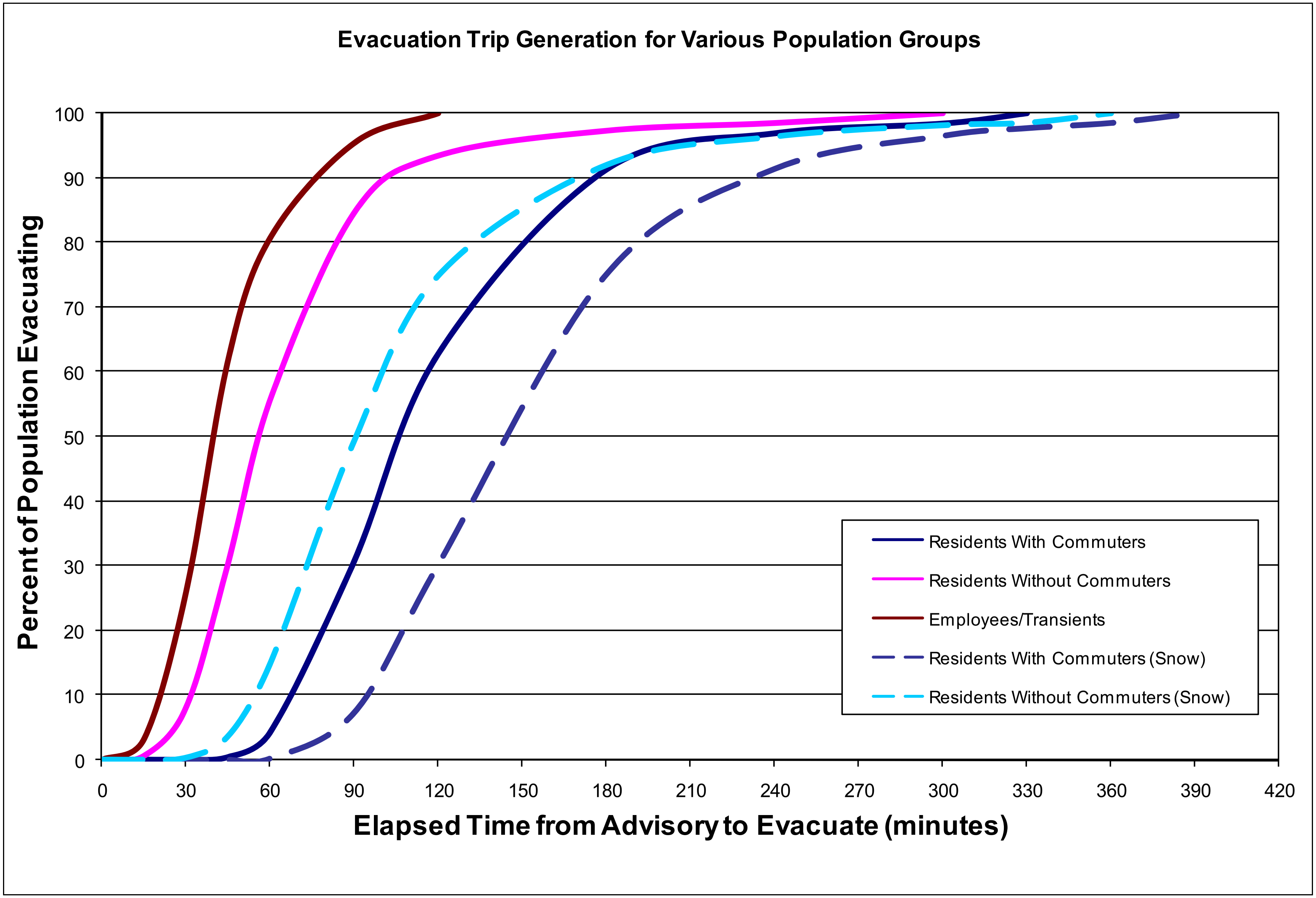


Figure 5-3. Comparison of Trip Generation Distributions

Table 5-1. Trip Generation Time Histograms for the EPZ Population

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period					
		Employees (Distribution A)	Transients (Distribution B)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	3	3	0	1	0	0
2	15	23	23	0	7	0	0
3	15	36	36	0	22	0	3
4	15	19	19	4	25	0	11
5	30	15	15	27	29	7	35
6	30	4	4	32	9	23	26
7	60	0	0	29	4	45	17
8	60	0	0	6	1	16	4
9	60	0	0	1	2	5	2
10	30	0	0	1	0	1	1
11	30	0	0	0	0	1	1
12	30	0	0	0	0	2	0
13	600	0	0	0	0	0	0

6. DEMAND ESTIMATION FOR EVACUATION SCENARIOS

An evacuation “case” defines a combination of evacuation region and evacuation scenario. The definitions of “region” and “scenario” are as follows:

Region — A grouping of contiguous emergency response planning areas (ERPA) or municipalities 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 and highway operations (calibration).

A total of 22 regions were defined which encompass all the groupings of ERPA considered. These regions are defined in Table 6-1. The ERPA configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a circular area centered at the SSES site, and three adjoining sectors, each with a central angle of 22.5 degrees. These sectors extend to a distance of 5 miles from SSES, or to the EPZ boundary.

A total of 13 scenarios were evaluated for all regions. Thus, there are 13 x 22 = 286 evacuation cases. Table 6-2 is a description of all Scenarios.

Each combination of region and scenario defines a “case” that implies a specific population to be evacuated. Table 6-3 presents the percent of population groups that evacuate for each scenario, which applies throughout the EPZ. The number of voluntary evacuees varies by evacuation region – not by scenario. Therefore, voluntary evacuees are not included in Table 6-3. Similarly, Table 6-4 presents vehicle estimates for region R03 (the entire EPZ) for all scenarios. These estimates do not include voluntary evacuees for the same reason given above.

Table 6-1 identifies those combinations of ERPA that define each of 22 evacuation regions. For a given region, an empty cell along a row in this table represents an ERPA which is not included within the region, but which contributes voluntary evacuees to the evacuating traffic environment. The number of voluntary evacuees depends on the population within the ERPA and upon the region that is being evacuated.

For example, consider ERPA 6. This ERPA, shown in Figure 6-1, lies between the 5-mile ring and the EPZ boundary to the west. If region R06 were evacuated, then ERPA 6 which is external to R06 (see row for R06 in Table 6-1), would contribute 35% of its population as voluntary evacuees according to Figure 2-1.

Now, if region R06 is advised to evacuate under the conditions of Scenario 1, then the percentages for that scenario that appear in Table 6-3[1] will also apply to the population within ERPA 6. The trip generation distributions (Section 5) for the voluntary evacuees that originate their trips within ERPA 6 are the same as though the ERPA were advised to evacuate; the number of evacuees from that ERPA, however, would be 35% of the total, as explained above.

To summarize, the number of voluntary evacuees in any given evacuation "case" is taken into proper account for each "empty" cell in Table 6-1. The necessary computations to calculate the number of generated trips within each Area are performed by the UNITES software (see page 1-7). The output of UNITES, for each case, is the input stream to the IDYNEV system.

[1] Refer to the columns in Table 6-3 labeled "Residents with Commuters in Household", "Residents with No Commuters in Household", "Employees", and "Transients".

Table 6-1. Description of Evacuation Regions

Region	Description	ERPA 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R01	2 mile ring							x		x																		
R02	5-mile ring							x	x	x			x	x	x													
R03	Full EPZ	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2-MileRing and 5-Mile Downwind																												
Region	Description	ERPA 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R04	N,NNE,NNW							x	x	x																		
-	NE,W,WNW,NW	Refer to Region R01																										
R05	ENE,E,ESE							x		x					x													
R06	SE, SSE							x		x			x	x	x													
R07	S, SSW,SW,WSW							x		x			x	x														
5-Mile Ring and Downwind to EPZ Boundary																												
Region	Description	ERPA 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R08	N		x	x	x	x		x	x	x			x	x	x						x							
R09	NNE		x	x				x	x	x			x	x	x				x		x	x						
R10	NE		x					x	x	x			x	x	x			x	x	x	x	x						
R11	ENE							x	x	x			x	x	x			x	x	x	x	x	x					
R12	E							x	x	x			x	x	x			x	x	x			x					
R13	ESE, SE							x	x	x			x	x	x	x	x	x					x					
R14	SSE	x						x	x	x			x	x	x	x	x						x					
R15	S	x						x	x	x			x	x	x	x	x							x				
R16	SSW	x						x	x	x			x	x	x									x	x			
R17	SW	x						x	x	x	x	x	x	x	x									x	x	x	x	x
R18	WSW						x	x	x	x	x	x	x	x	x									x	x	x	x	x
R19	W				x	x	x	x	x	x	x	x	x	x	x										x	x	x	x
R20	WNW				x	x	x	x	x	x			x	x	x												x	x
R21	NW			x	x	x	x	x	x	x			x	x	x													x
R22	NNW		x	x	x	x		x	x	x			x	x	x													

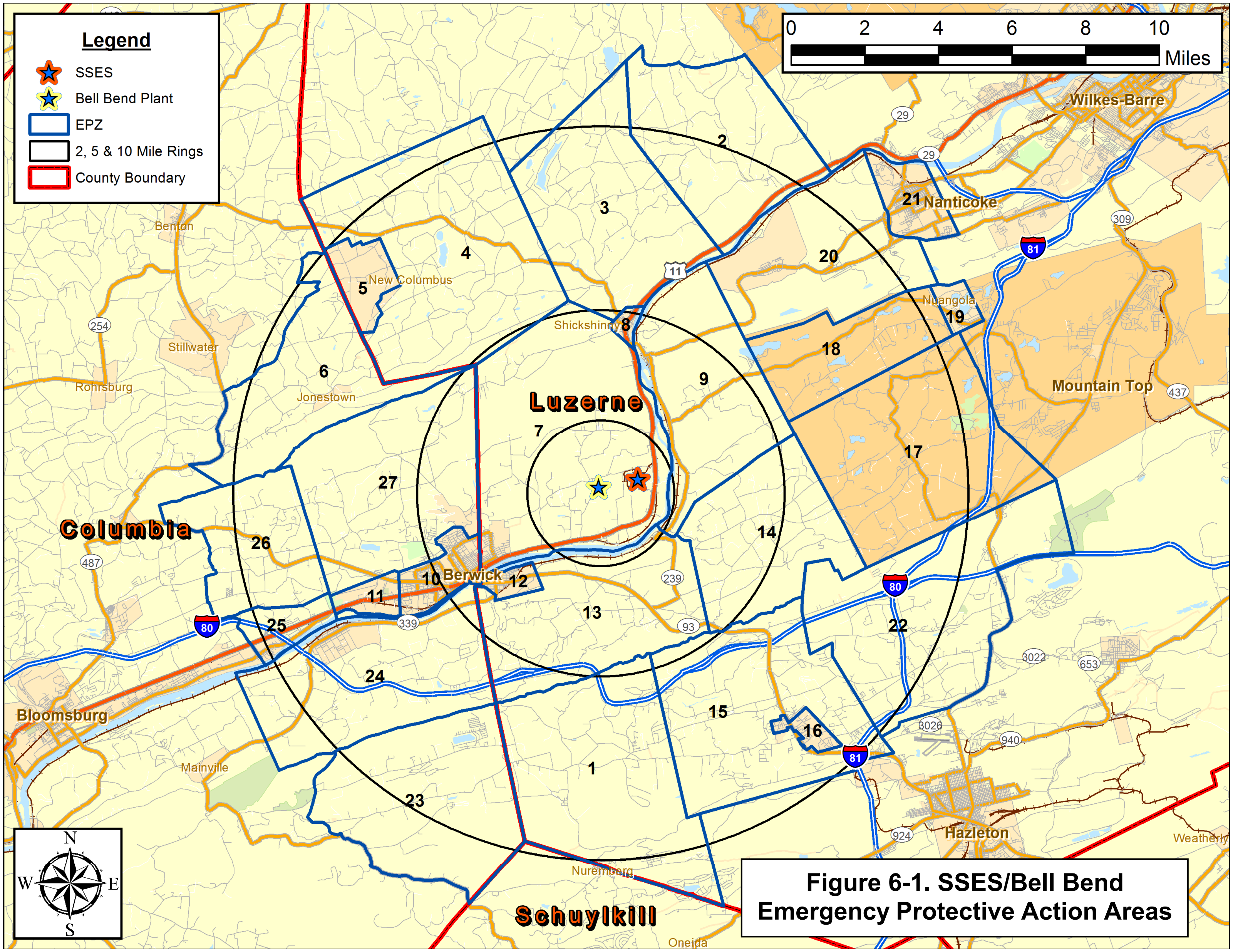


Figure 6-1. SSES/Bell Bend Emergency Protective Action Areas

Table 6-2. Evacuation Scenario Definitions					
Scenarios	**Season**	**Day of Week**	**Time of Day**	**Weather**	**Special**
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	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	Midweek	Midday	Good	Bell Bend Construction and SSES Refueling

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

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

Scenarios	Residents With Commuters in Household	Residents With No Commuters in Household	Employees	Transients	Shadow	Special Event	School Buses	Transit Buses	External Through Traffic
1	52%	48%	96%	11%	31%	0%	10%	100%	100%
2	52%	48%	96%	11%	31%	0%	10%	100%	100%
3	5%	95%	10%	12%	30%	0%	0%	100%	100%
4	5%	95%	10%	12%	30%	0%	0%	100%	100%
5	5%	95%	10%	16%	30%	0%	0%	100%	40%
6	52%	48%	100%	68%	31%	0%	100%	100%	100%
7	52%	48%	100%	68%	31%	0%	100%	100%	100%
8	52%	48%	100%	68%	31%	0%	100%	100%	100%
9	5%	95%	10%	9%	30%	0%	0%	100%	100%
10	5%	95%	10%	9%	30%	0%	0%	100%	100%
11	5%	95%	10%	9%	30%	0%	0%	100%	100%
12	5%	95%	10%	17%	30%	0%	0%	100%	40%
13	52%	48%	96%	11%	31%	100%	10%	100%	100%

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

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

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

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

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

Special Event .... Additional vehicles present at the Bell Bend site during the construction of the new unit and additional vehicles present at the SSES site for refueling in the Year 2015.

School and Transit Buses .... Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus is equivalent to 2 passenger vehicles), respectively. School buses for Scenarios 1, 2 and 13 are used to transport those students attending summer school.

External Through Traffic .... Traffic on local highways and major arterial roads at the start of the evacuation. It is assumed that this traffic is stopped by access control approximately 90 minutes after the evacuation begins.

Table 6-4. Vehicle Estimates by Scenario[2]

Scenarios	Residents with Commuters	Residents without Commuters	Employees	Transients	Shadow	Special Event	School Buses*	Transit Buses*	External Traffic	Total Scenario Vehicles
1	18,856	17,228	1,493	376	14,381	-	38	260	12,482	65,114
2	18,856	17,228	1,493	376	14,381	-	38	260	12,482	65,114
3	1,886	34,198	156	410	13,869	-	0	260	12,482	63,261
4	1,886	34,198	156	410	13,869	-	0	260	12,482	63,261
5	1,886	34,198	156	546	13,869	-	0	260	4,993	55,908
6	18,856	17,228	1,555	2,322	14,404	-	370	260	12,482	67,477
7	18,856	17,228	1,555	2,322	14,404	-	370	260	12,482	67,477
8	18,856	17,228	1,555	2,322	14,404	-	370	260	12,482	67,477
9	1,886	34,198	156	307	13,869	-	0	260	12,482	63,158
10	1,886	34,198	156	307	13,869	-	0	260	12,482	63,158
11	1,886	34,198	156	307	13,869	-	0	260	12,482	63,158
12	1,886	34,198	156	581	13,869	-	0	260	4,993	55,943
13	18,950**	17,322**	1,493	376	14,378**	3,053	38	260	12,482	68,352**

NOTE:
* School Buses and Transit Buses are expressed in vehicle equivalents (1 bus = 2 vehicles). Therefore actual number of buses are 1/2 the value shown.
**Permanent Resident population and Shadow population have been extrapolated (using county specific growth rates – See Table 3-1) to the Year 2015 when construction of the Bell Bend unit will be at its peak.

[2] The vehicle estimates presented are for an evacuation of the entire EPZ (Region R03).

7. GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the current results of the computer analyses using the IDYNEV System described in Appendices B, C and D. These results cover the 22 Regions within the SSES/Bell Bend Nuclear Power Plant EPZ and the 13 evacuation scenarios discussed in Section 6.

The ETE for the general population (permanent residents, transients, and employees commuting into the EPZ to work) for all evacuation cases are presented in Tables 7-1A through 7-1D. **These tables present the estimated times to clear the indicated population percentages from the evacuation regions for all evacuation scenarios.** The tabulated values of ETE are obtained from the PC-DYNEV simulation model outputs of vehicles exiting the specified evacuation regions. These outputs are generated at 10-minute intervals, and then interpolated to the nearest 5 minutes.

7.1 Voluntary Evacuation and Shadow Evacuation

"Voluntary evacuees" are people who are within the EPZ, in municipalities located outside the evacuation region, for whom an advisory to evacuate *has not* been issued, yet who nevertheless elect to evacuate. The "shadow evacuation" is the movement of people from areas *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 SSES/Bell Bend address the issue of voluntary evacuees as discussed in Section 2.2 and displayed in Figure 7-1 (same as Figure 2-1). Figure 7-2 presents the area identified as the Shadow Region. This region extends radially from the boundary of the EPZ to a distance of 15 miles from SSES/Bell Bend.

The population within the shadow region was estimated using the same methodology that was used for the permanent resident population, which is detailed on page 3-2. The growth rates presented in Table 3-1 were used to extrapolate the year 2000 population estimates in the shadow region to year 2009. Based on the analysis, there are 89,340 people within the shadow region, evacuating in 46,088 vehicles.

Traffic generated within this shadow region, traveling away from the plant, has the potential for impeding evacuating vehicles from within the evacuation region. It is assumed that traffic volumes emitted within the shadow region correspond to 30 percent of the residents there plus a proportionate number of employees in that region (see "Shadow" footnote to Table 6-3 on page 6-6). **All ETE calculations include this shadow traffic movement.**

7.2 Patterns of Traffic Congestion During Evacuation

Figures 7-3 through 7-6 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 (2000 HCM):

> Level of Service F is used to define forced or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount that can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go waves, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, and then be required to stop in a cyclic fashion. Level of Service F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge flow, which causes the queue to form, and Level of Service F is an appropriate designation for such points.

This definition is general and conceptual in nature, and applies primarily to uninterrupted flow. Levels of Service for interrupted flow facilities vary widely in terms of both the user's perception of service quality and the operational variables used to describe them.

All highway "links" which experience LOS F at the indicated times are delineated in these figures by a heavy red line; all others are lightly indicated. Congestion develops in areas with high population density and at traffic bottlenecks. Figures 7-3 through 7-6 present traffic congestion patterns at 1 hour intervals after the advisory to evacuate. Traffic congestion is observed only within the cities of Berwick and Nanticoke. The congestion dissipates within 4 hours from the advisory to evacuate. US Route 11 and State Route 93 within the city of Berwick, State Route 29 approaches to Interstate 81, and Kirmar Avenue through the city of Nanticoke are the major congested routes. The average delays (min/veh) experienced along these roadway sections are presented in Section 7.5.

7.3 Evacuation Rates

Another format for displaying the dynamics of evacuation is depicted in Figure 7-7. This plot indicates the rate at which traffic flows out of the indicated areas for the case of an evacuation of the entire EPZ (Region R03) under Scenario 1 conditions. Appendix J presents these plots for all evacuation scenarios for region R03.

As indicated in Figure 7-7, there is typically a long "tail" to these distributions. Vehicles evacuate an area slowly at the beginning, as people respond to the advisory to evacuate 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 the real world, this ideal is generally unattainable reflecting the variation in population density and in highway capacity within the EPZ.

7.4 Guidance on Using ETE Tables

Tables 7-1A through 7-1D present the ETE values for all 22 Evacuation Regions and all 13 Evacuation Scenarios. They are organized as follows:

Table	Contents
7-1A	ETE represents the elapsed time required for 50 percent of the population within a Region, to evacuate from that Region.
7-1B	ETE represents the elapsed time required for 90 percent of the population within a Region, to evacuate from that Region.
7-1C	ETE represents the elapsed time required for 95 percent of the population within a Region, to evacuate from that Region.
7-1D	ETE represents the elapsed time required for 100 percent of the population within a Region, to evacuate from that Region.

The user first determines the percentile of population for which the ETE is sought. The applicable value of ETE within the chosen Table may then be identified using the following procedure:

1. Identify the applicable **Scenario**:
    - The Season
        - Summer (schools not in session)
        - Winter (also Autumn and Spring)
    - The Day of Week
        - Midweek (work-day)
        - Weekend, Holiday
    - The Time of Day
        - Midday (work and commuting hours)
        - Evening
    - Weather Condition
        - Good Weather
        - Rain
        - Snow
    - Special Event (if any)
        - Construction at Bell Bend site and refueling at SSES site

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 Tables 7-1A through 7-1D. For these

conditions, scenario (4) applies.

- The conditions of a winter evening (either midweek or weekend) and rain are not explicitly identified in Tables 7-1A through 7-1D. For these conditions, scenario (10) applies. For snow, scenario (11) applies.
- The seasons are defined as follows:
  - Summer implies that public schools are *not* in session.
  - Winter (also Autumn and Spring) imply that public schools *are* in session.
- Time of Day: Midday implies the time over which most commuters are at work.

2. With the scenario (and column in the Table) 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: *toward* N, NNE, NE…
   - Determine the distance that the evacuation region will extend from the nuclear power plant. The applicable distances and their associated regions are given below:
     - 2 Miles (Region R01)
     - 5 Miles (Regions R02, R04 through R07)
     - to EPZ boundary (Regions R03, R08 through R22)
   - Enter Table 7-2 and identify the applicable group of candidate regions based on the wind direction and on the distance that the selected region extends from SSES/Bell Bend. Select the evacuation region identifier in that row from the first column of the Table.

3. Determine the **ETE for the scenario** identified in Step 1 and the **region** identified in Step 2, as follows:
   - The columns of Tables 7-1 are labeled with the scenario numbers. Identify the proper column in the selected Table using the scenario number determined 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 *toward* the southwest (SW).
- Wind speed is such that the distance to be evacuated is judged to be 10 miles (to EPZ boundary).
- The desired ETE is that value needed to evacuate 95 percent of the population from within the impacted region.

Table 7-1C is applicable because the 95th-percentile population is desired. Proceed as follows:

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1C, 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 7-2 and locate the group entitled “5-Mile Ring and Downwind to EPZ Boundary”. Scan down the second column of that group (with the heading, “Description”), to identify the row with “SW” (southwest azimuth) and read Region “R17” in the first column of that row.

3. Enter Table 7-1C to locate the data cell containing the value of ETE for Scenario 4 and Region R17. This data cell is in the fifth column with the heading for Scenario (4) and in the row for Region R17 SW; it contains the ETE value of **3:30**.

7.5 Discussion of ETE Results

The ETE for the 95% percentile (Table 7-1C) suggests that the 5-Mile ring (R02) has a shorter evacuation time compared to the 2-Mile (R01) and the 10-Mile EPZ (R03). This is attributed to the following:

- Trip mobilization, and
- Congestion within Berwick and Nanticoke.

The smaller population within the 2-mile ring relative to that within the 5-mile ring, and the long tail of the trip mobilization (See Section 5), combine to produce a longer time to evacuate 95% of the population within the 2-mile ring, than the time to evacuate 95% of the population within the 5-mile ring. Note, however, that this phenomenon does not persist for the 100th percentile ETE (Table 7-1D)

The average delays (in minutes per vehicle) experienced by evacuees on representative congested links in the network (see Figure 7-3 for locations), at various times during the evacuation, are presented below. These delays are experienced by traffic on the indicated links during the 10 minute period preceding the specified times. For, example, vehicles that travel on link, (748,249) between 1:50 (hr:min) and 2:00 after the advisory to evacuate, experience an average delay of 8.9 minutes. Since this delay approaches the 10 minute sampling period, it indicates that the traffic on this link at this time is experiencing pronounced congestion. One hour later, the average delay per vehicle for traffic traversing this link has declined to 2.3 minutes, indicating that congestion is far less intense. Over the following hour, congestion eases and traffic is free-flowing, with zero delay.

Location	From Node	To Node	Average Delay (min/veh) at Indicated Elapsed Time (hr:min) from Advisory to Evacuate			
			1:00	2:00	3:00	4:00
RT 11 in Berwick	199	738	4.6	4.6	4.5	0.0
RT 11 in Berwick	961	962	6.5	7.4	2.8	0.0
RT 339 through Mifflin township	748	249	0.0	8.9	2.3	0.0
Main Street in Nanticoke City	284	504	3.4	5.1	4.3	0.0
Kirmar Avenue in Nanticoke City	286	285	0.0	9.3	0.0	0.0
RT 11/RT 29 near Nanticoke City	210	406	0.3	2.6	2.6	0.0
RT 93 in Berwick	237	1052	1.5	7.0	5.9	0.0

Comparison of the ETE for the 95th and 100th percentiles indicates that between 2 and 3 additional hours are needed to evacuate the remaining 5% of the EPZ population. As indicated in Figure 7-6, congestion has dissipated within the EPZ by 4 hours after the advisory to evacuate – well before the trip generation time of 5½ hours. Therefore, the 100th percentile ETE is dictated by the mobilization activities of the evacuating populace. The ETE should not be distorted for those relatively few stragglers who take significantly longer to begin their evacuation trips.

The 100th percentile ETE for an evacuation of the entire EPZ (Region R03) is not affected by the increased traffic related to construction and refueling activities at the Bell Bend/SSES sites (compare the ETE for scenarios 1 and 13 in Table 7-1D). The 90th and 95th percentile ETE for Region R03, however, increase by 20 minutes and 30 minutes, respectively, for Scenario 13 relative to Scenario 1. The additional traffic from the construction site does prolong congestion within the city of Berwick; however, the congestion there dissipates within 4 hours. As a result, the 90th and 95th percentile ETE are impacted; however, the 100th percentile ETE is not because mobilization time dictates ETE at the 100th percentile.

Table 7-1A. Time To Clear The Indicated Area of 50 Percent of the Affected Population

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	1:20	1:20	1:05	1:05	1:05	R01 2-Mile Region	1:20	1:20	1:50	1:05	1:05	1:35	1:05	R01 2-Mile Region	1:30
R02 5-Mile Region	1:10	1:10	1:00	1:00	1:05	R02 5-Mile Region	1:10	1:10	1:25	1:00	1:00	1:20	1:05	R02 5-Mile Region	1:15
R03 Entire EPZ	1:30	1:35	1:20	1:25	1:25	R03 Entire EPZ	1:30	1:35	1:55	1:20	1:25	1:45	1:25	R03 Entire EPZ	1:35
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	1:20	1:20	1:05	1:05	1:05	R04 N,NNE,NNW	1:20	1:20	1:50	1:05	1:05	1:35	1:05	R04 N,NNE,NNW	1:35
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	1:20	1:20	1:05	1:05	1:05	R05 ENE,E,ESE	1:20	1:20	1:50	1:05	1:05	1:35	1:05	R05 ENE,E,ESE	1:30
R06 SE,SSE	1:10	1:10	1:00	1:00	1:05	R06 SE,SSE	1:10	1:10	1:25	1:00	1:00	1:20	1:05	R06 SE,SSE	1:15
R07 S, SSW,SW,WSW	1:10	1:10	1:00	1:00	1:05	R07 S, SSW,SW,WSW	1:10	1:10	1:25	1:00	1:00	1:20	1:05	R07 S, SSW,SW,WSW	1:15
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	1:20	1:20	1:10	1:10	1:10	R08 N	1:20	1:20	1:40	1:10	1:10	1:30	1:10	R08 N	1:25
R09 NNE	1:25	1:25	1:15	1:15	1:20	R09 NNE	1:25	1:30	1:45	1:15	1:15	1:40	1:20	R09 NNE	1:30
R10 NE	1:15	1:20	1:10	1:10	1:15	R10 NE	1:20	1:20	1:35	1:10	1:10	1:25	1:15	R10 NE	1:20
R11 ENE	1:15	1:15	1:10	1:10	1:15	R11 ENE	1:15	1:15	1:30	1:10	1:10	1:25	1:15	R11 ENE	1:15
R12 E	1:10	1:10	1:05	1:05	1:05	R12 E	1:10	1:10	1:20	1:05	1:05	1:20	1:05	R12 E	1:10
R13 ESE, SE	1:15	1:15	1:05	1:05	1:05	R13 ESE, SE	1:15	1:15	1:30	1:05	1:05	1:25	1:05	R13 ESE, SE	1:15
R14 SSE	1:15	1:15	1:05	1:05	1:05	R14 SSE	1:10	1:15	1:30	1:05	1:05	1:25	1:05	R14 SSE	1:15
R15 S	1:10	1:10	1:00	1:05	1:05	R15 S	1:10	1:10	1:25	1:00	1:05	1:20	1:05	R15 S	1:15
R16 SSW	1:20	1:25	1:10	1:10	1:10	R16 SSW	1:20	1:20	1:40	1:10	1:10	1:30	1:10	R16 SSW	1:25
R17 SW	1:35	1:35	1:20	1:25	1:25	R17 SW	1:35	1:35	2:00	1:20	1:25	1:50	1:25	R17 SW	1:40
R18 WSW	1:35	1:40	1:25	1:30	1:30	R18 WSW	1:35	1:40	2:00	1:25	1:30	1:50	1:30	R18 WSW	1:40
R19 W	1:35	1:40	1:25	1:25	1:30	R19 W	1:35	1:40	2:00	1:25	1:25	1:50	1:30	R19 W	1:40
R20 WNW	1:20	1:20	1:10	1:10	1:10	R20 WNW	1:20	1:20	1:40	1:10	1:10	1:30	1:10	R20 WNW	1:25
R21 NW	1:20	1:20	1:10	1:10	1:10	R21 NW	1:20	1:20	1:40	1:10	1:10	1:30	1:10	R21 NW	1:25
R22 NNW	1:15	1:20	1:05	1:05	1:10	R22 NNW	1:15	1:20	1:35	1:05	1:05	1:25	1:10	R22 NNW	1:25

Table 7-1B. Time To Clear The Indicated Area of 90 Percent of the Affected Population

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	2:45	2:45	2:00	2:00	2:00	R01 2-Mile Region	2:40	2:40	3:30	2:00	2:00	3:00	2:00	R01 2-Mile Region	3:00
R02 5-Mile Region	2:10	2:10	1:45	1:50	1:55	R02 5-Mile Region	2:10	2:15	2:55	1:45	1:50	2:30	1:55	R02 5-Mile Region	2:45
R03 Entire EPZ	3:05	3:15	2:50	3:00	2:55	R03 Entire EPZ	3:05	3:20	3:55	2:50	3:00	3:40	2:55	R03 Entire EPZ	3:25
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	2:45	2:45	2:00	2:00	2:00	R04 N,NNE,NNW	2:45	2:45	3:35	2:00	2:00	3:00	2:00	R04 N,NNE,NNW	2:55
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	2:45	2:45	2:00	2:00	2:00	R05 ENE,E,ESE	2:40	2:40	3:35	2:00	2:00	3:00	2:00	R05 ENE,E,ESE	2:55
R06 SE,SSE	2:10	2:10	1:45	1:50	1:55	R06 SE,SSE	2:10	2:10	2:55	1:45	1:50	2:25	1:55	R06 SE,SSE	2:45
R07 S, SSW,SW,WSW	2:05	2:05	1:45	1:50	1:55	R07 S, SSW,SW,WSW	2:05	2:05	2:55	1:45	1:50	2:25	1:55	R07 S, SSW,SW,WSW	2:45
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	2:40	2:45	2:10	2:20	2:20	R08 N	2:45	2:50	3:30	2:10	2:20	3:05	2:20	R08 N	3:05
R09 NNE	2:55	3:00	2:35	2:45	2:40	R09 NNE	3:00	3:10	3:45	2:35	2:45	3:25	2:40	R09 NNE	3:05
R10 NE	2:40	2:50	2:20	2:30	2:35	R10 NE	2:50	2:55	3:30	2:20	2:30	3:10	2:35	R10 NE	2:55
R11 ENE	2:30	2:40	2:10	2:15	2:25	R11 ENE	2:40	2:45	3:20	2:10	2:15	2:55	2:25	R11 ENE	2:40
R12 E	2:05	2:05	1:50	1:50	2:00	R12 E	2:05	2:10	2:50	1:50	1:50	2:25	2:00	R12 E	2:25
R13 ESE, SE	2:15	2:20	1:55	2:00	2:00	R13 ESE, SE	2:15	2:20	3:00	1:50	2:00	2:35	2:00	R13 ESE, SE	2:35
R14 SSE	2:20	2:20	1:55	1:55	2:00	R14 SSE	2:15	2:20	3:00	1:50	1:55	2:35	2:00	R14 SSE	2:35
R15 S	2:10	2:10	1:50	1:50	1:55	R15 S	2:10	2:10	2:55	1:45	1:50	2:25	1:55	R15 S	2:35
R16 SSW	2:50	2:55	2:35	2:35	2:30	R16 SSW	2:50	2:55	3:25	2:35	2:40	3:05	2:30	R16 SSW	3:00
R17 SW	3:10	3:25	3:05	3:15	3:00	R17 SW	3:15	3:25	4:05	3:05	3:15	3:50	3:00	R17 SW	3:35
R18 WSW	3:15	3:25	3:05	3:15	3:00	R18 WSW	3:15	3:25	4:05	3:05	3:15	3:50	3:00	R18 WSW	3:35
R19 W	3:10	3:20	3:00	3:10	3:00	R19 W	3:15	3:25	4:05	3:00	3:10	3:50	3:00	R19 W	3:35
R20 WNW	2:30	2:35	2:10	2:15	2:15	R20 WNW	2:30	2:35	3:15	2:10	2:15	2:55	2:15	R20 WNW	2:45
R21 NW	2:30	2:30	2:05	2:10	2:10	R21 NW	2:30	2:30	3:15	2:05	2:10	2:55	2:10	R21 NW	2:45
R22 NNW	2:40	2:45	2:05	2:15	2:20	R22 NNW	2:40	2:50	3:30	2:05	2:15	3:00	2:20	R22 NNW	3:05

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	3:10	3:10	2:45	2:45	2:45	R01 2-Mile Region	3:05	3:05	4:15	2:45	2:50	3:50	2:45	R01 2-Mile Region	3:15
R02 5-Mile Region	2:50	2:50	2:05	2:05	2:25	R02 5-Mile Region	2:50	2:50	3:45	2:05	2:05	3:00	2:25	R02 5-Mile Region	3:05
R03 Entire EPZ	3:25	3:40	3:15	3:25	3:15	R03 Entire EPZ	3:30	3:40	4:25	3:15	3:25	4:10	3:15	R03 Entire EPZ	3:55
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	3:10	3:10	2:45	2:45	2:45	R04 N,NNE,NNW	3:10	3:10	4:15	2:45	2:45	3:50	2:45	R04 N,NNE,NNW	3:15
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	3:10	3:10	2:50	2:50	2:50	R05 ENE,E,ESE	3:05	3:05	4:20	2:50	2:50	3:55	2:50	R05 ENE,E,ESE	3:15
R06 SE,SSE	2:45	2:45	2:00	2:05	2:25	R06 SE,SSE	2:45	2:45	3:40	2:00	2:05	3:00	2:25	R06 SE,SSE	3:05
R07 S, SSW,SW,WSW	2:45	2:45	2:00	2:00	2:25	R07 S, SSW,SW,WSW	2:45	2:45	3:35	2:00	2:00	2:55	2:25	R07 S, SSW,SW,WSW	3:05
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	3:10	3:15	2:45	2:45	2:55	R08 N	3:10	3:20	4:05	2:45	2:45	3:35	2:55	R08 N	3:35
R09 NNE	3:15	3:25	2:55	3:10	3:00	R09 NNE	3:20	3:30	4:15	2:55	3:10	4:00	3:00	R09 NNE	3:30
R10 NE	3:05	3:15	2:50	3:00	2:55	R10 NE	3:15	3:20	4:05	2:50	3:00	3:50	2:55	R10 NE	3:20
R11 ENE	3:00	3:10	2:40	2:50	2:55	R11 ENE	3:05	3:15	4:00	2:40	2:50	3:40	2:55	R11 ENE	3:05
R12 E	2:40	2:45	2:05	2:10	2:25	R12 E	2:40	2:45	3:30	2:05	2:10	2:55	2:25	R12 E	2:55
R13 ESE, SE	2:50	2:50	2:15	2:20	2:35	R13 ESE, SE	2:50	2:50	3:45	2:15	2:20	3:05	2:35	R13 ESE, SE	3:00
R14 SSE	2:50	2:50	2:15	2:20	2:35	R14 SSE	2:50	2:50	3:45	2:15	2:20	3:05	2:35	R14 SSE	3:00
R15 S	2:45	2:45	2:05	2:10	2:25	R15 S	2:45	2:45	3:40	2:05	2:10	3:00	2:25	R15 S	3:00
R16 SSW	3:15	3:15	3:00	3:00	2:55	R16 SSW	3:15	3:20	3:55	3:00	3:05	3:35	2:55	R16 SSW	3:20
R17 SW	3:30	3:45	3:20	3:30	3:20	R17 SW	3:35	3:45	4:30	3:20	3:30	4:10	3:20	R17 SW	4:00
R18 WSW	3:30	3:45	3:20	3:30	3:20	R18 WSW	3:35	3:45	4:30	3:20	3:30	4:15	3:20	R18 WSW	4:00
R19 W	3:30	3:45	3:20	3:30	3:20	R19 W	3:30	3:45	4:30	3:20	3:30	4:15	3:20	R19 W	4:00
R20 WNW	3:00	3:00	2:30	2:35	2:40	R20 WNW	3:00	3:00	4:00	2:30	2:35	3:25	2:40	R20 WNW	3:10
R21 NW	3:00	3:00	2:30	2:35	2:35	R21 NW	3:00	3:00	4:00	2:30	2:35	3:25	2:35	R21 NW	3:10
R22 NNW	3:10	3:10	2:45	2:45	2:55	R22 NNW	3:10	3:15	4:00	2:45	2:45	3:35	2:55	R22 NNW	3:30

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

	Summer		Summer		Summer		Winter			Winter			Winter		Summer
	Midweek		Weekend		Midweek Weekend		Midweek			Weekend			Midweek Weekend		Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	Scenario:	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Scenario:	(13)
	Midday		Midday		Evening		Midday			Midday			Evening		Midday
Region Wind Toward:	Good Weather	Rain	Good Weather	Rain	Good Weather	Region Wind Toward:	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Region Wind Toward:	Bell Bend Construction and SSES Refueling
Entire 2-Mile Region, 5-Mile Region, and EPZ															
R01 2-Mile Region	5:30	5:30	5:00	5:00	5:00	R01 2-Mile Region	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R01 2-Mile Region	5:30
R02 5-Mile Region	5:30	5:30	5:00	5:00	5:00	R02 5-Mile Region	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R02 5-Mile Region	5:30
R03 Entire EPZ	5:40	5:40	5:10	5:20	5:10	R03 Entire EPZ	5:40	5:40	6:40	5:10	5:20	6:20	5:10	R03 Entire EPZ	5:40
2-Mile Ring and Downwind to 5 Miles															
R04 N,NNE,NNW	5:30	5:30	5:00	5:00	5:00	R04 N,NNE,NNW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R04 N,NNE,NNW	5:30
R01 NE,W,WNW,NW	See Region R01					R01 NE,W,WNW,NW	See Region R01							R01 NE,W,WNW,NW	See Region R01
R05 ENE,E,ESE	5:30	5:30	5:00	5:00	5:00	R05 ENE,E,ESE	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R05 ENE,E,ESE	5:30
R06 SE,SSE	5:30	5:30	5:00	5:00	5:00	R06 SE,SSE	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R06 SE,SSE	5:30
R07 S, SSW,SW,WSW	5:30	5:30	5:00	5:00	5:00	R07 S, SSW,SW,WSW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R07 S, SSW,SW,WSW	5:30
5-Mile Ring and Downwind to EPZ Boundary															
R08 N	5:30	5:30	5:00	5:00	5:10	R08 N	5:30	5:30	6:30	5:00	5:00	6:10	5:00	R08 N	5:30
R09 NNE	5:30	5:30	5:00	5:00	5:00	R09 NNE	5:30	5:30	6:30	5:00	5:10	6:10	5:00	R09 NNE	5:30
R10 NE	5:30	5:30	5:00	5:10	5:10	R10 NE	5:30	5:30	6:40	5:00	5:10	6:10	5:00	R10 NE	5:30
R11 ENE	5:30	5:30	5:10	5:10	5:10	R11 ENE	5:30	5:30	6:30	5:10	5:10	6:10	5:10	R11 ENE	5:30
R12 E	5:30	5:30	5:10	5:10	5:10	R12 E	5:30	5:30	6:30	5:10	5:10	6:00	5:10	R12 E	5:30
R13 ESE, SE	5:30	5:30	5:10	5:10	5:10	R13 ESE, SE	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R13 ESE, SE	5:30
R14 SSE	5:30	5:30	5:10	5:10	5:10	R14 SSE	5:30	5:30	6:40	5:10	5:10	6:00	5:10	R14 SSE	5:30
R15 S	5:30	5:30	5:00	5:00	5:00	R15 S	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R15 S	5:30
R16 SSW	5:30	5:40	5:10	5:10	5:10	R16 SSW	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R16 SSW	5:30
R17 SW	5:40	5:40	5:10	5:20	5:10	R17 SW	5:40	5:40	6:40	5:10	5:20	6:10	5:10	R17 SW	5:40
R18 WSW	5:40	5:40	5:10	5:10	5:10	R18 WSW	5:40	5:40	6:40	5:10	5:10	6:10	5:10	R18 WSW	5:40
R19 W	5:40	5:40	5:10	5:10	5:10	R19 W	5:40	5:40	6:40	5:10	5:10	6:20	5:10	R19 W	5:40
R20 WNW	5:30	5:30	5:10	5:10	5:10	R20 WNW	5:40	5:40	6:40	5:10	5:10	6:10	5:10	R20 WNW	5:30
R21 NW	5:30	5:30	5:10	5:10	5:10	R21 NW	5:30	5:30	6:40	5:10	5:10	6:10	5:10	R21 NW	5:30
R22 NNW	5:30	5:30	5:00	5:00	5:00	R22 NNW	5:30	5:30	6:30	5:00	5:00	6:00	5:00	R22 NNW	5:30

Table 7-2. Description of Evacuation Regions

Region	Description	ERPA																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R01	2 mile ring							x		x																		
R02	5-mile ring							x	x	x			x	x	x													
R03	Full EPZ	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2-MileRing and 5-Mile Downwind																												
Region	Description	ERPA																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R04	N,NNE,NNW							x	x	x																		
-	NE,W,WNW,NW	Refer to Region R01																										
R05	ENE,E,ESE							x		x					x													
R06	SE, SSE							x		x			x	x	x													
R07	S, SSW,SW,WSW							x		x			x	x														
5-Mile Ring and Downwind to EPZ Boundary																												
Region	Description	ERPA																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
R08	N		x	x	x	x		x	x	x			x	x	x						x							
R09	NNE		x	x				x	x	x			x	x	x				x		x	x						
R10	NE		x					x	x	x			x	x	x			x	x	x	x	x						
R11	ENE							x	x	x			x	x	x			x	x	x	x	x	x					
R12	E							x	x	x			x	x	x			x	x	x			x					
R13	ESE, SE							x	x	x			x	x	x	x	x	x					x					
R14	SSE	x						x	x	x			x	x	x	x	x						x					
R15	S	x						x	x	x			x	x	x	x	x							x				
R16	SSW	x						x	x	x			x	x	x									x	x			
R17	SW	x						x	x	x	x	x	x	x	x									x	x	x	x	x
R18	WSW						x	x	x	x	x	x	x	x	x									x	x	x	x	x
R19	W				x	x	x	x	x	x	x	x	x	x	x										x	x	x	x
R20	WNW				x	x	x	x	x	x			x	x	x												x	x
R21	NW			x	x	x	x	x	x	x			x	x	x													x
R22	NNW		x	x	x	x		x	x	x			x	x	x													

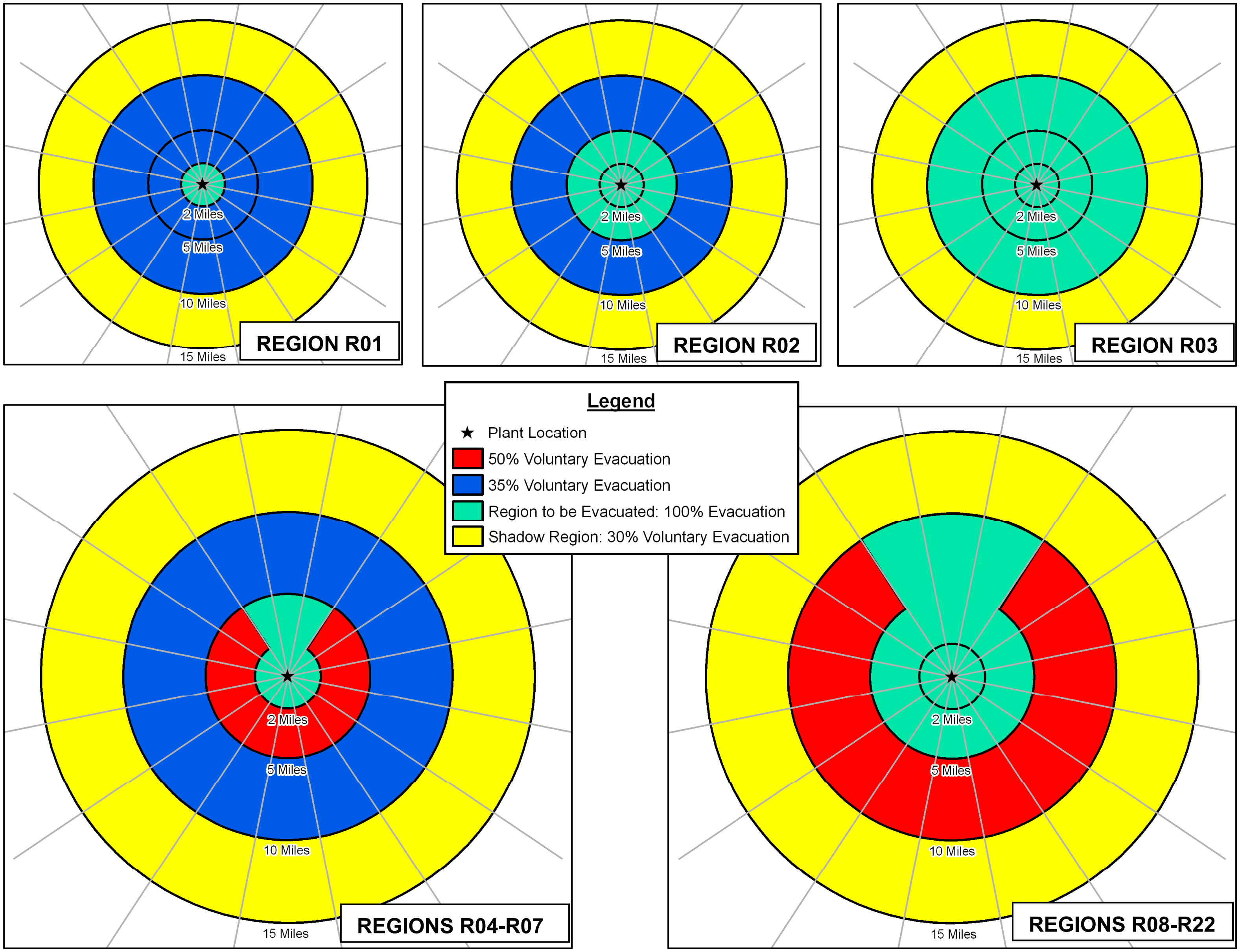


Figure 7-1. Assumed Evacuation Response

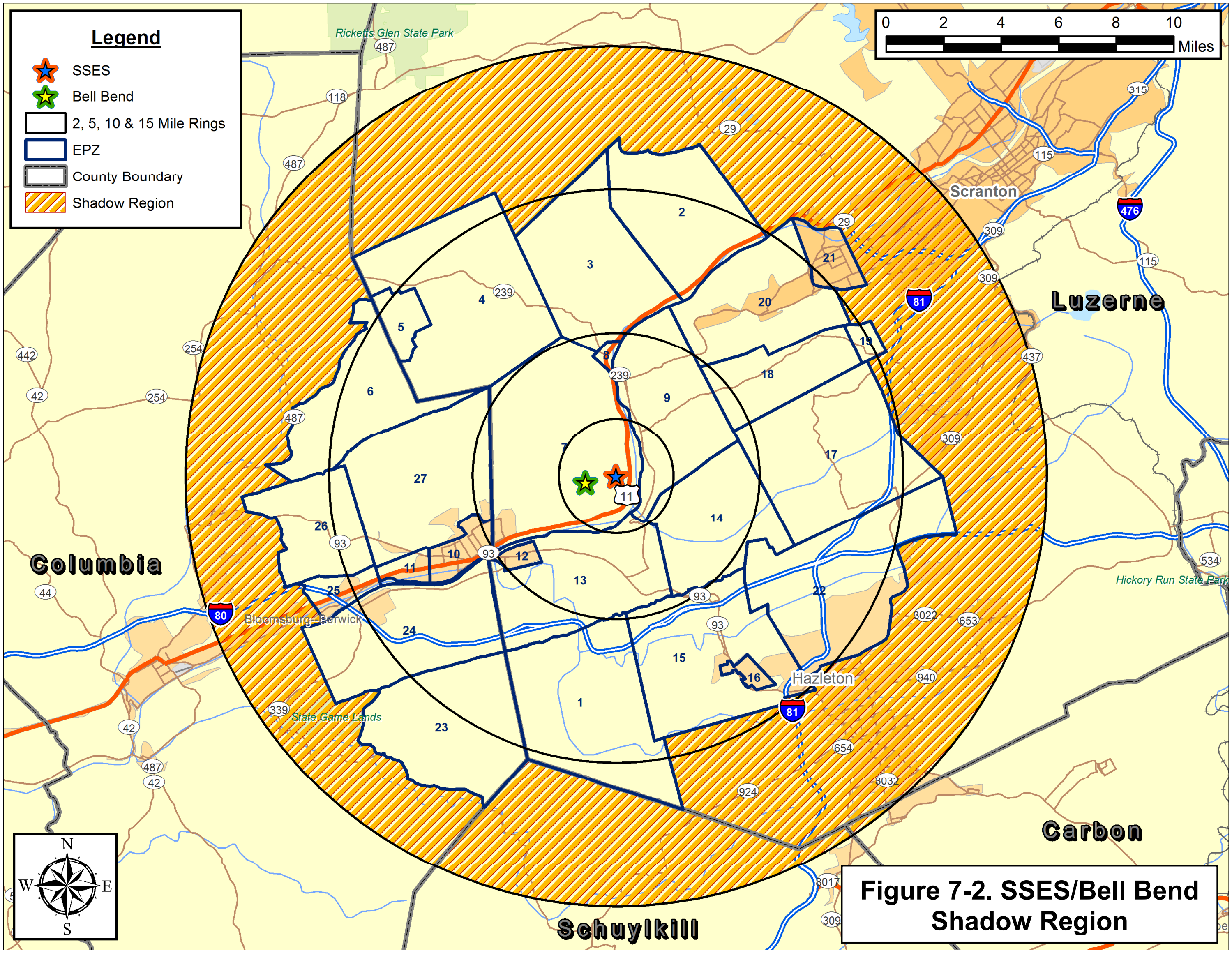


Figure 7-2. SSES/Bell Bend Shadow Region

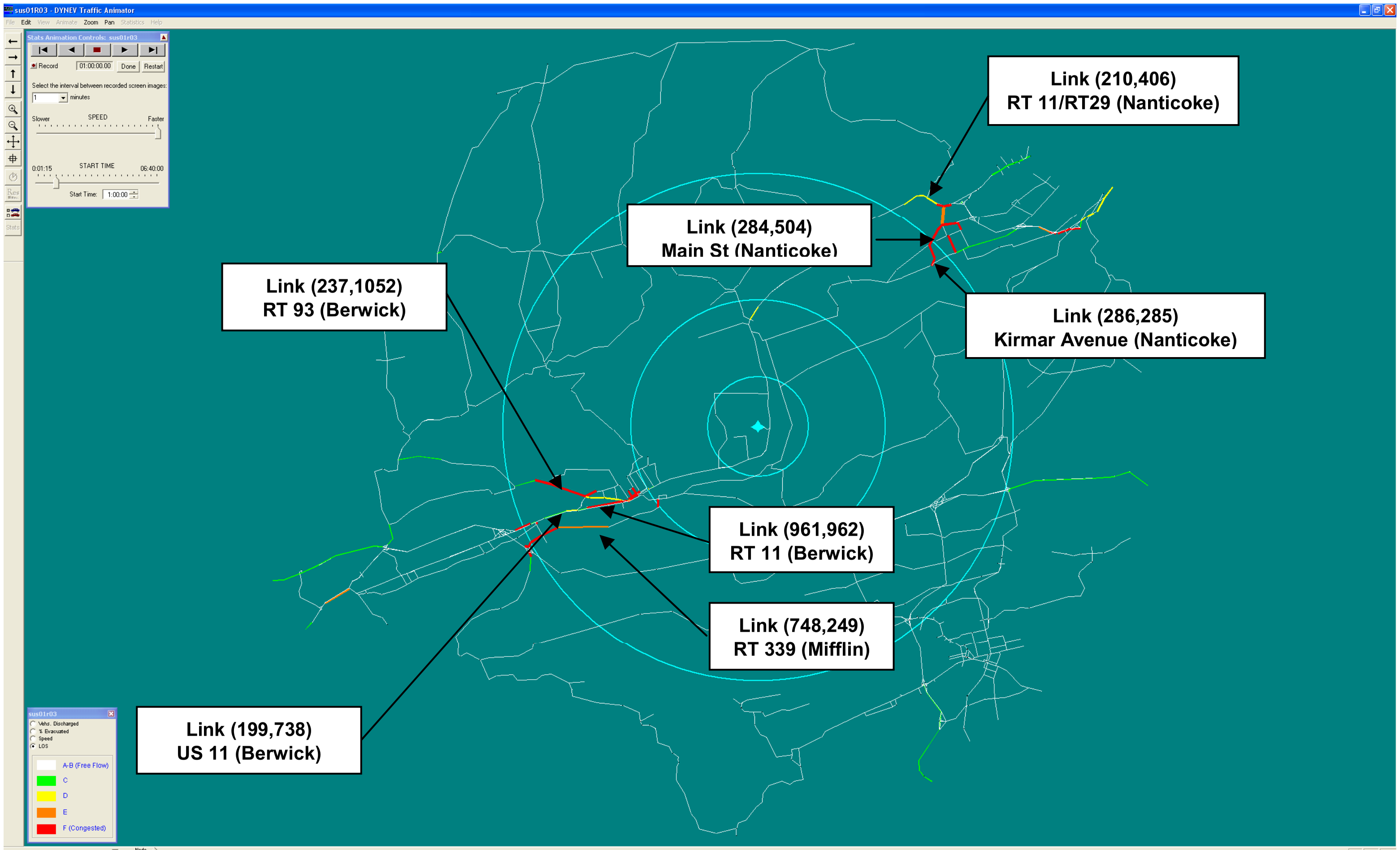


Figure 7-3. Congestion Patterns at 1 Hour after the Advisory to Evacuate (Scenario 1, Region R03)

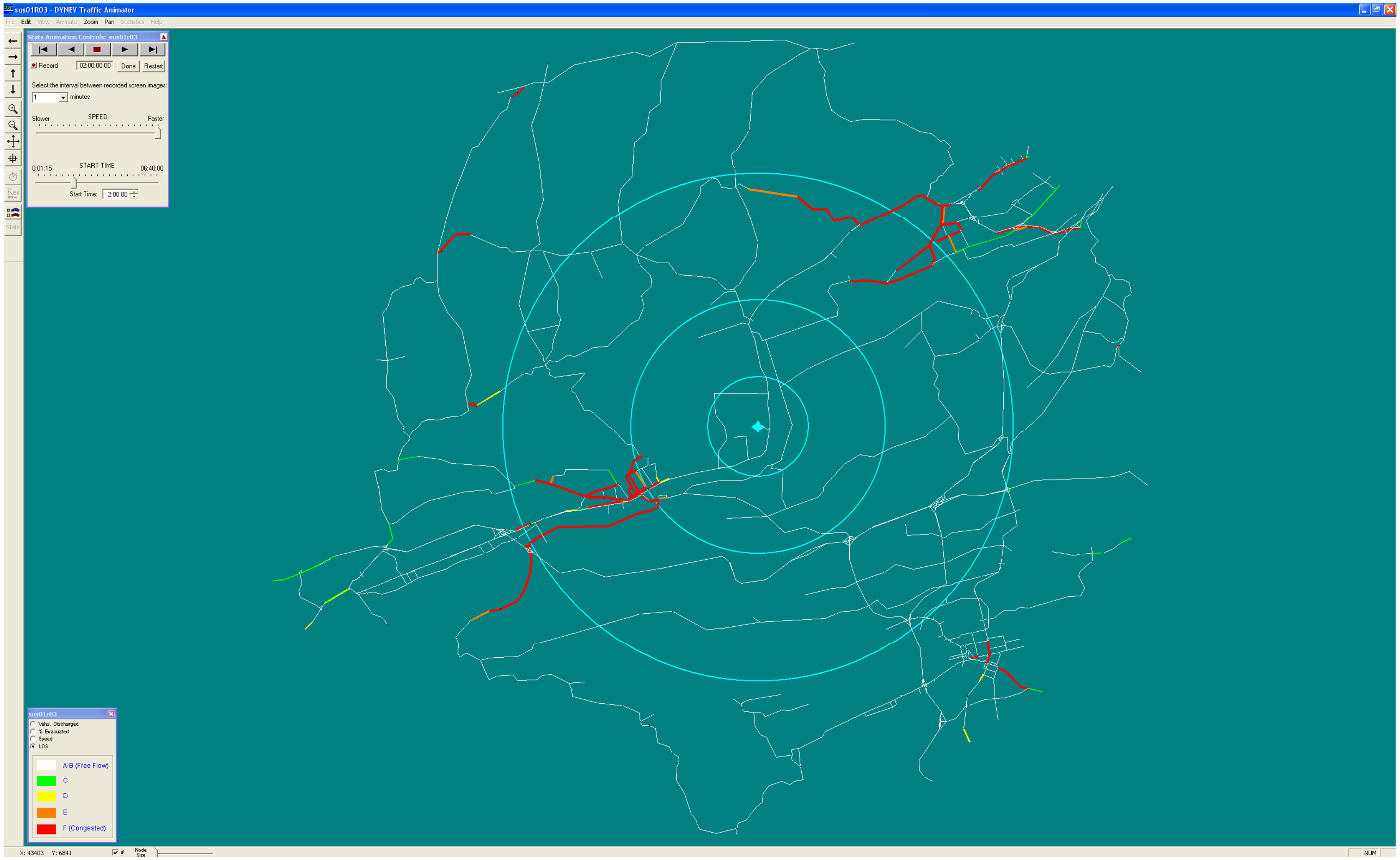


Figure 7-4. Congestion Patterns at 2 Hours after the Advisory to Evacuate (Scenario 1, Region R03)

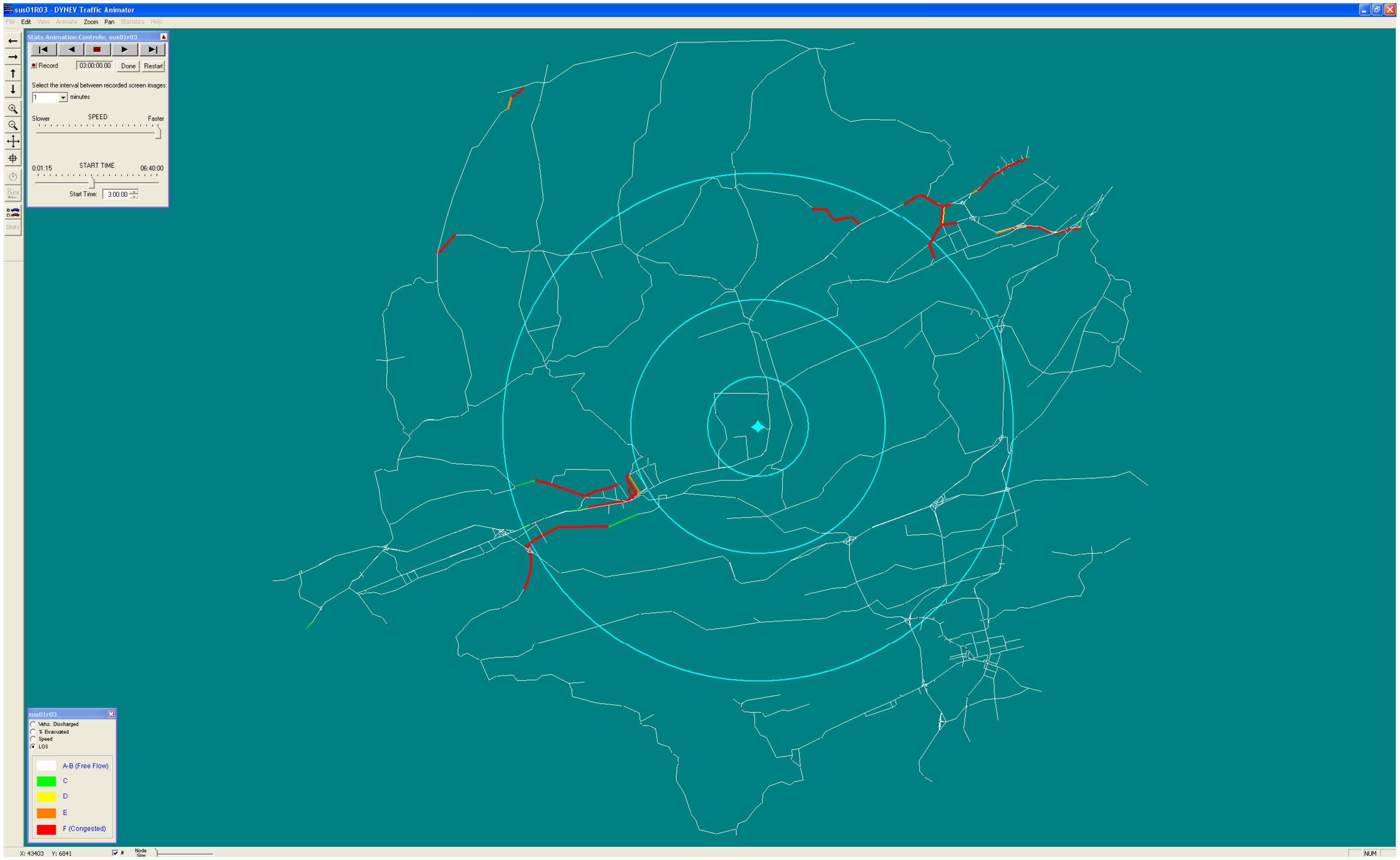


Figure 7-5. Congestion Patterns at 3 Hours after the Advisory to Evacuate (Scenario 1, Region R03)

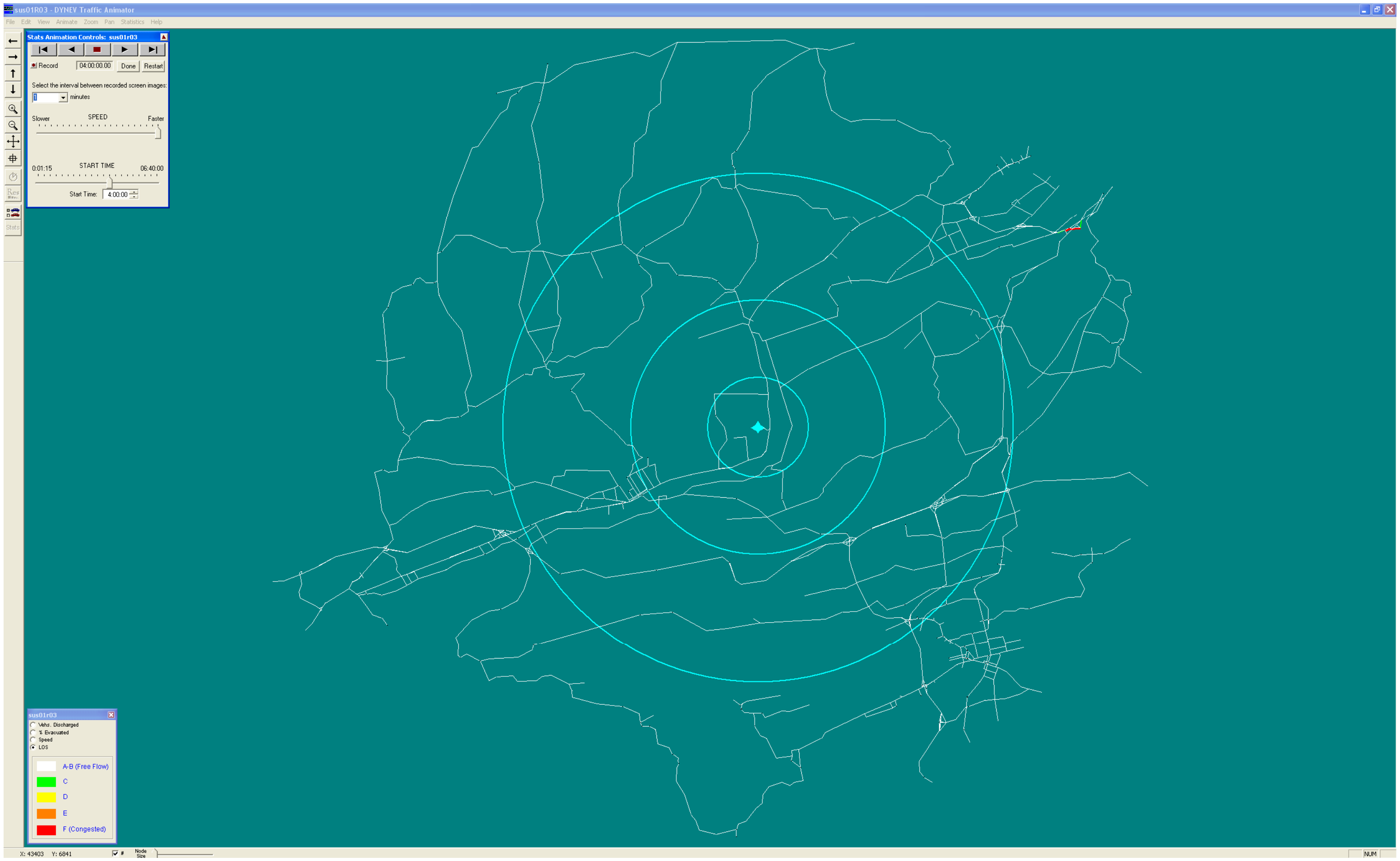


Figure 7-6. Congestion Patterns at 4 Hours after the Advisory to Evacuate (Scenario 1, Region R03)

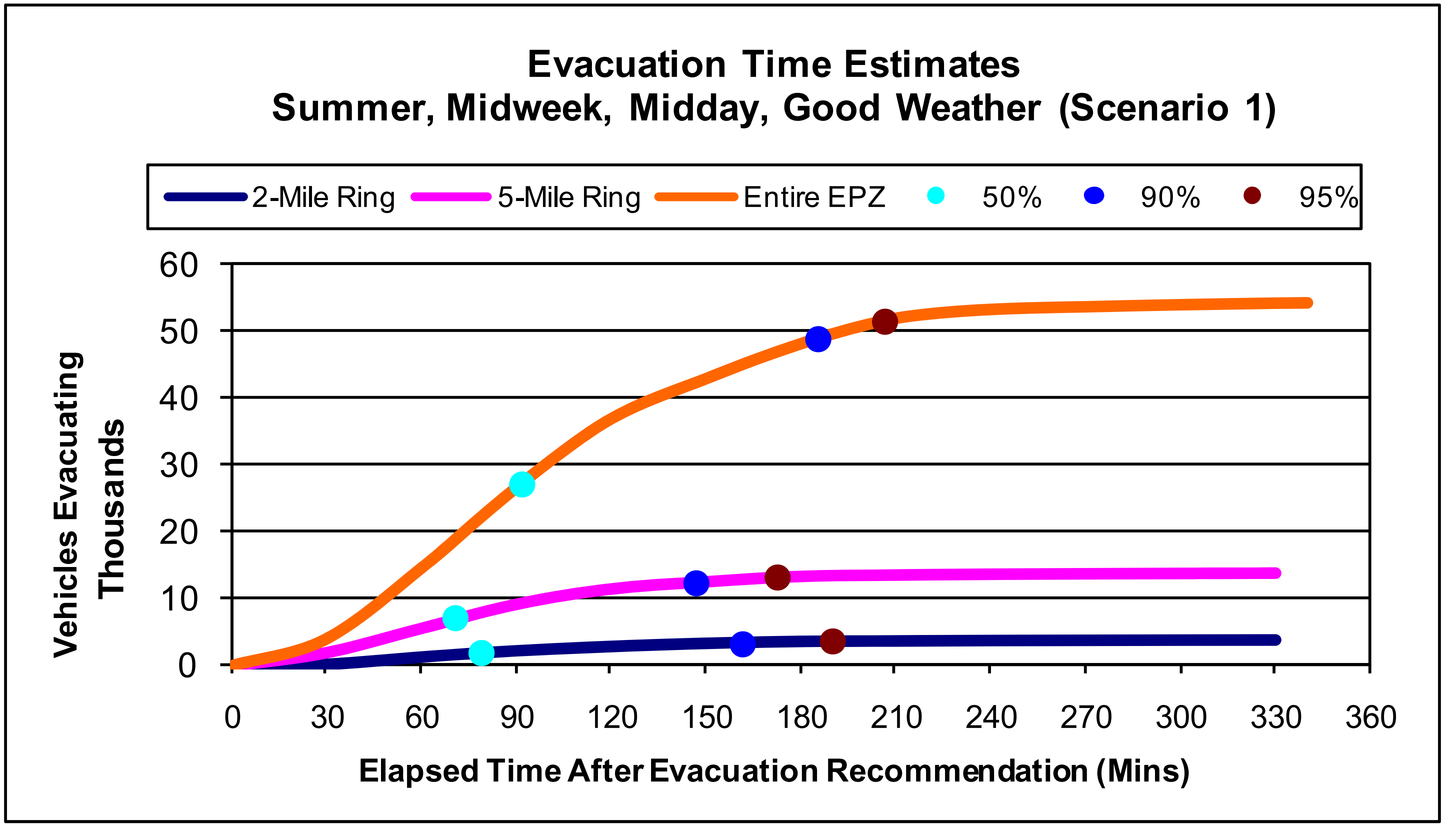


Figure 7-7. Evacuation Time Estimates for SSES/Bell Bend Summer, Midweek, Midday, Good Weather (Scenario 1) Evacuation of Region R03 (Entire EPZ)

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 (buses). The demand for transit service reflects the needs of two population groups: (1) residents with no vehicles available; and (2) residents of special facilities such as schools and medical facilities.

These transit vehicles merge into and become a part of the general evacuation traffic environment 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 larger 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
- They must travel from the depot to the assigned route or facility

These activities consume time. Based on studies at similar sites, it is estimated that bus mobilization time will be approximately 90 minutes extending from the advisory to evacuate, to the time when buses arrive at their respective assignments for Luzerne and Columbia counties.

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 family members is universally prevalent during emergencies and should be anticipated in the planning process. Many emergency plans, however, call for parents to pick up children at host schools to speed the evacuation of the school children in the event that buses need to return to the EPZ to evacuate other transit dependent persons. These ETE for transit-based evacuation are developed under the assumption that no children will be picked up at school by their parents; this assumption yields an upper bound estimate of the transit vehicles needed.

The procedure is:

- Estimate demand for transit service
- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the host schools

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 ordered.

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 school children. For those evacuation scenarios where children are at school when an evacuation is ordered, separate transportation is provided for the school children. The actual need for transit vehicles by residents under these circumstances is thereby less than the given estimates.
- 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.**

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 (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.

Table 8-1 indicates that transportation must be provided for 2,040 people. Therefore, a total of 68 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 SSES/Bell Bend EPZ:

$$P = 27{,}825 \times (0.054 \times 1.68 + 0.293 \times (1.75 - 1) \times 0.52 \times 0.40 + 0.436 \times (2.54 - 2) \times (0.52 \times 0.40)^2)$$

$$P = 27{,}825 * (0.1466) = 4{,}080$$

$$B = (0.5 \times P) \div 30 = 68$$

These calculations are explained as follows:

- All members (1.68) of households (HH) with no vehicles (5.4%) will evacuate by public transit or ride-share. The term 27,825 (total households) x 0.054 x 1.68, accounts for these people.
- The members of HH with 1 vehicle away (29.3%), who are at home, equal (1.75-1). The number of HH where the commuter will not return home is equal to (27,825 x 0.293 x 0.52 x 0.40), given that 52% of the households in the EPZ have at least one commuter, 40% (see page F-8) of which will not wait for the commuter to return before evacuating. 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 (43.6%), who are at home, equal (2.54 – 2). The number of HH where neither commuter will return home is equal to 27,825 x 0.436 x $(0.52 \times 0.40)^2$. 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.

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. The column in Table 8-2 entitled “Bus Runs 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.
- 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 that is in the neighborhood of 3 percent, daily.

The counties may contact schools prior to the dispatch of buses from the depot, 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. Some parents will likely pick up their children at school, although they are asked to pick children up at the host schools. Those buses originally allocated to evacuate school children 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 host schools for the various schools in the EPZ. Those students not picked up by their parents prior to the arrival of the buses, will be transported to these schools where they will be subsequently retrieved by their respective families.

The estimates of the bus requirements are comparable with the estimates provided in the county emergency management plans.

It is assumed that those children at day care facilities within the EPZ are picked up by their parents or designee. Children are typically dropped off at day care in the morning and picked up in the evening, on a daily basis. The telephone survey asks questions about the daily routines of EPZ residents. Thus, the time needed to perform this activity is accounted for in the travel home from work distribution (See Figure F-11). Based on these assumptions buses are not needed to evacuate day care children and their ETE is accounted for in the general population ETE.

8.3 Special Facility Demand

Table 8-4 presents the census of special facilities in the EPZ as of April 2010. 836 people have been identified as residents of these facilities. This census also indicates the number of vans, buses and ambulances required to evacuate those residing at the facilities. Table 8-4A summarizes the ambulance needs for those homebound people within the EPZ who require transportation assistance.

8.4 Evacuation Time Estimates for Transit-Dependent People

Based on the county emergency management plans, the available bus resources are sufficient in each county to service the school evacuation demand in a "single-wave", assuming drivers are available for all vehicles. The county emergency plans indicate that there are a total of 194 buses available and this is greater than the estimated 185 buses in Tables 8-2A and 8-2B. In general, the buses will transport the evacuees to the appropriate host school and be available to return to the EPZ for a second trip to service transit dependent people and other special facilities, if needed.

For each county, transit resources will be assigned to schools as a first priority. When these 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 along the pick-up routes. The local plans identify a number of centrally located bus pick-up points within each municipality. It is assumed that these pick-up points are dispersed such that residents live within a half-mile of a pick-up point. It is further assumed that the transit-dependent people walk to the bus pick-up points. As discussed in the local plans, those transit-dependent people who are not within walking distance of a pick-up point or not able to walk to a pick-up point should coordinate with the local emergency management agency for transportation out of the EPZ.

ETE 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 have arrived at the facility to be evacuated. Based on studies at other sites, a mobilization time of 90 minutes is assumed. Also, an additional 5 minutes is required under adverse weather conditions to account for slower travel times.

Activity: Board Passengers (C→D)

Studies have shown that passengers can board a bus at headways of 2-4 seconds (Ref. HCM Page 27-10). Therefore, for a bus with a maximum capacity of 70 passengers, the total dwell time to service boarding passengers at a single stop (e.g., at a school) is about 5 minutes). A loading time of 10 minutes will be used for rain scenarios. For multiple stops along a pick-up route, an allowance must be made for the additional delay associated with stopping and starting at each pick-up point. This additional delay to service passengers expands this estimate of boarding time to 30 minutes in good weather, and 40 minutes in rain.

Activity: Travel to EPZ Boundary (D→E)

School Evacuation

The distance from a school to the EPZ boundary is measured using Geographical Information Systems (GIS) software along the most likely route out of the EPZ toward the designated host school. The travel times to the EPZ boundary are based on evacuation speeds computed by the model (PC-DYNEV). The average speed for an evacuation of the full EPZ (Region 3) under Scenario 6 (winter [school in session], midweek, midday, good weather) conditions, at 95 minutes (mobilization time plus loading time) after the advisory to evacuate, is 33.5 mph, while the average speed for an evacuation of the full EPZ under Scenario 7 conditions (Rain) at 105 minutes (mobilization time plus loading time) is 23.9 mph. The travel times to the Host Schools were computed using these average speeds. Based on information provided by county emergency management, there are an adequate number of buses to evacuate the school children in a single wave; therefore, no estimate of two wave ETE is provided for school children.

Tables 8-5A (good weather) and 8-5B (rain) 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 host school . The evacuation time out of the EPZ can be computed as the sum of travel times associated with Activities A→B→C, C→D, and D→E (For example: 90 + 5 + 13 minutes = 1:50 for Berwick Area Middle School, with good weather). The evacuation time to the host school 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 indicated in Section 5, about 86 percent of the evacuees (residents without commuters) will complete their mobilization when the first buses will begin their routes, 90 minutes after the advisory to evacuate.

Those buses servicing the transit-dependent evacuees will travel along their routes picking up those passengers who need transportation, then proceed out of the EPZ.

The county emergency plans have identified the bus staging areas throughout Luzerne County at the municipal buildings or key locations within each municipality and at the Bloomsburg Fairgrounds within Columbia County with detailed pick up points located within each municipality's plans. Assuming an internal travel distance of 5 miles within the EPZ, the ETE is calculated as shown in Table 8-6. The average speed output by the PC-DYNEV model at the mobilization time (90 minutes for good weather, 95 minutes for rain) is used to estimate the route travel time – 33.5 mph with good weather; 23.9 mph, with rain. The average distance to the reception centers from the EPZ boundary for both counties is approximately 30 miles.

The use of bus headways would provide a more robust service by servicing those transit-dependent persons that may need more time to mobilize.

Activity: Travel to Host Schools (E→F)

The distances from the EPZ boundary to the host school are also measured using Geographical Information Systems (GIS) software along the most likely route from the EPZ to the host school. 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 public. EPZ schools were routed to the appropriate host school as indicated in Table 8-3.

Activity: Passengers Leave Bus (F→G)

Passengers can deboard within 5 minutes (HCM Exhibit 27-9). The bus 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 buses that evacuated the schools. Thus, the mobilization time for the second wave is the average time that buses arrive at the host schools (See Table 8-5). The travel time back to the EPZ is the average of the travel time to the host school from Table 8-5 - 20 minutes for good weather and 28 minutes for rain. The bus then travels its route and picks up transit-dependent evacuees along the route. The average speed output by PC-DYNEV (20.1 mph at 2 hours and 40 minutes after advisory to evacuate for good weather and 17.4 mph at 3 hours and 10 minutes for rain) at the time the buses begin the second wave is used to compute the route travel time. Other buses arriving at the host schools may need to return for a second wave evacuation of special facilities as detailed in the following section.

The second wave ETE is computed as follows for good weather:

- Bus arrives at host school at 2:05 in good weather (average of "ETE to H.S (hr:min)" column in Table 8-5A).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ: 20 minutes (average of "Travel Time EPZ Bdry to H.S. (min)" column in Table 8-5A).
- Bus completes pick-ups along route and departs EPZ: 30 minutes + (5 miles @ 20.1 mph) = approximately 45 minutes.
- Bus exits EPZ at time 2:05+ 0:15 + 0:20+ 0:45 = 3:25 after the Advisory to Evacuate.

The ETE for the transit-dependent population do not exceed the ETE for the general population.

Evacuation of Ambulatory Persons from Special Facilities

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

- Buses are assigned on the basis of 40 passengers to allow for some staff to accompany the patients and to allow room for walkers, canes, etc.
- 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 and for slow boarding rates.

Based on studies at other facilities, a mobilization time for these buses of 90 minutes is applied. In the event there is a shortfall of transit vehicles for a single wave evacuation, the buses used to evacuate schools will have to return to participate in a second-wave evacuation of the special facilities.

Appendix E indicates that the medical facilities are 8.0 miles from the plant, on average. Thus, buses evacuating these facilities will have to travel approximately 2.0 miles to leave the EPZ; conservatively estimate the travel distance out of the EPZ as 5 miles. The average travel speed at 130 minutes (90 minutes mobilization plus 40 minutes loading

time, at most) after the advisory to evacuate is 19.9 mph; thus the travel time out of the EPZ for buses evacuating special facilities is 15 minutes. Inspection of Table 8-4 indicates that the census ranges from 12 to 268 patients. It is assumed that those facilities with more than 40 patients, would board multiple buses in parallel. Therefore, the maximum loading time for any facility is 40 minutes. The ETE for Bonham Nursing Center, with 34 ambulatory patients, is provided as an example:

90 min (mobilization) + 34 min (patient loading) + 15 min (transit out of EPZ) = 139 min. or 2:20 (hr:min) rounded to nearest 5 minutes.

The second wave ETE is computed as follows for good weather:

- Bus arrives at host school at 2:05 in good weather (average of "ETE to H.S (hr:min)" column in Table 8-5A).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ: 20 minutes (average of "Travel Time EPZ Bdry to H.S. (min)" column in Table 8-5A).
- Load at most 40 passengers on to the bus: 40 minutes
- Bus departs EPZ: 12 minutes (5 miles @ 23.5 mph – average speed output by model at 3 hours and 20 minutes(total time needed to complete the previous 4 steps))

Bus exits EPZ at time 2:05+ 0:15 + 0:20+ 0:40 + 0:12 = 3:35 (rounded up to the nearest 5 minutes) after the Advisory to Evacuate.

Thus, the ETE for the ambulatory patients at special facilities for one wave and two wave evacuations do not exceed the general population ETE.

<u>Emergency Medical Services (EMS) Vehicles</u>

The previous discussion focused on transit operations for ambulatory persons residing at medical facilities within the Evacuation Region. It is also necessary to provide transit services to non-ambulatory persons who do not – or cannot – have access to private vehicles. Based on the data provided in Table 8-4, 85 ambulances are needed for special facilities within the EPZ (81 ambulances for Luzerne County and 4 ambulances for Columbia County). Based on the data provided in the county emergency plans (see Table 8-4A), the estimated requirement for ambulances for homebound special needs are 20 and 37 in Columbia and Luzerne Counties, respectively.

Table 8-7 summarizes the ambulances available within the EPZ and neighboring counties. Columbia County has 12 ambulances available and needs 24 ambulances to support evacuation in a single wave. Columbia County will rely on Lycoming, Montour, Northumberland and Union Counties, through established mutual aid agreements (see Appendix 21 of the county plan), for the additional 12 ambulances needed. Luzerne County has 107 ambulances available and needs 118 ambulances to support evacuation in a single wave. Luzerne County will rely on Lackawanna and Wyoming Counties, through established mutual aid agreements (see Appendix 21 of the county plan), for the

additional 11 ambulances needed. Thus, ambulance evacuation can be completed in a single wave.

Figure 8-2 maps the EPZ and neighboring counties and provides the estimated travel distances (based on straight line distances from the center point of each county) and estimated travel times for ambulances to arrive from neighboring counties based on an assumed inbound travel speed of 40 mph. It is estimated that at most 60 minutes (see Figure 8-2) will be needed to mobilize ambulances and travel to the medical facilities. Loading time is at most 40 minutes. As with the buses transporting ambulatory patients, ambulances travel 5 miles, on average, to leave the EPZ. The average speed output by the model at 100 minutes (60 minute mobilization plus 40 minute loading time) for Region 3, Scenario 6 is 33.5 mph; thus, travel time out of the EPZ is 9 minutes.

The ETE for ambulances is: 60 + 40 + 9 = 1:50 (rounded to nearest 5 minutes).

Thus, the ETE for EMS/ambulance vehicles do not exceed the general population ETE.

ETE for Homebound Special Needs Population

Ambulances

As shown in Table 8-4A, it is estimated that 142 ambulance runs will be needed to evacuate the homebound bed-ridden population within the EPZ. The table also indicates that there are 119 ambulances available.

Under county and state concept of operations, unmet needs are passed to the state which coordinates needed support resources. In this case, the State Department of Health would obtain needed ambulance resources from surrounding jurisdictions (as discussed on page 8-8). In addition, local ambulances used in the first wave could also be re-assigned to a second transport mission, if necessary.

As stated on page 8-9, mobilization time and loading time are assumed to be 100 minutes each per ambulance. Each ambulance servicing the homebound bed-ridden population will make 2 stops with an estimated distance of 2 miles between stops and an estimated distance of 5 miles to the EPZ boundary after the final stop. It is conservatively assumed that ambulances will travel at 30 mph within the EPZ. Mobilization time is 10 minutes longer, loading time is 5 minutes longer and travel speed is 10% less in rain – 27 mph. All ETE are rounded to nearest 5 minutes.

The first wave ETE are computed as follows:

a. Ambulance arrives at first household: 60 minutes
b. Loading time at first household: 20 minutes
c. Ambulance travels to second household: 2 miles @ 30 mph = 5 minutes
d. Loading time at second household: 20 minutes
e. Travel time to EPZ boundary: 5 miles @ 30 mph = 10 minutes

ETE: 60 + 20 + 5 + 20 + 10 = 1:55

Rain ETE: 70 + 25 + 5 + 25 + 11 = 2:15 (rounded to nearest 5 minutes)

The second wave ETE, if needed, are computed as follows:

a. Ambulance departs EPZ at 1:55
b. Travel time from EPZ boundary to host facility: 5 miles @ 30 mph = 10 minutes
c. Ambulance unloads (20 minutes) and driver takes a 10-minute rest: 30 minutes
d. Ambulance returns to EPZ and arrives at first house: 10 miles @ 30 mph = 20 minutes
e. Loading time at first household: 20 minutes
f. Ambulance travels to second household: 2 miles @ 30 mph = 5 minutes
g. Loading time at second household: 20 minutes
h. Travel time to EPZ boundary: 5 miles @ 30 mph = 10 minutes

ETE: 115 + 10 + 30 + 20 + 20 + 5 + 20 +10 = 3:50

Rain ETE: 135 + 11 + 35 + 22 + 25 + 5 + 25 + 11 = 4:30

Evacuation of Camp Louise

There is one children's camp – Camp Louise – within the EPZ. Camp Louise is an overnight Girl Scout camp for girls from ages 6 to 17. Based on e-mails received from the management of this facility, the peak population at the camp is 176 children and 25 staff. The peak season for the camp is from mid-June to early August. The camp has an agreement with Bowers Bus in Berwick to supply buses in the event of an emergency evacuation. The buses would arrive at the camp within 30 minutes of being contacted. As with the schoolchildren, it is estimated that bus loading time is 5 minutes. The most likely route from Camp Louise out of the EPZ is south on Shickshinny Valley Rd, west on Knob Mountain Rd, south on Yost Hollow Rd and then west on State Route 93 out of the EPZ, a 12.4 mile long route. The average speed output by DYNEV at approximately 35 minutes (30 minute mobilization time for the buses plus 5 minute loading time) after the Advisory to Evacuate (ATE) for an evacuation of Region 3 (Entire EPZ) under Scenario 1 conditions (Summer, Midweek, Midday) is 56.8 mph. Based on this speed, it will take approximately 13 minutes to travel the 12.4 mile route necessary to exit the EPZ. ETE = 0:30 (mobilization) + 0:05 (loading) + 0:13 (travel time) = 0:50 (rounded to nearest 5 minutes)

8.5 Evacuation Time Estimates for Inmates at SCI Retreat

The State Correctional Institute (SCI) Retreat is located in Hunlock Creek Township (Luzerne County) 7.4 miles north-northeast of the Susquehanna Steam Electric Station and 8.1 miles north-northeast of the Bell Bend Nuclear Plant (see Figure E-8).

The Pennsylvania Department of Corrections (PDOC) and Luzerne County Emergency Management Agency (EMA) were contacted; it was indicated that the detailed evacuation

plan for SCI Retreat is confidential. However, the following information needed to compute ETE for the facility was provided:

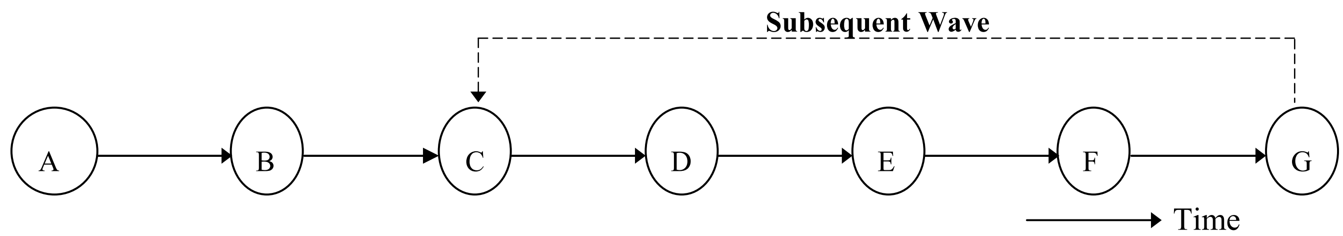
- Based on the current and maximum census at SCI Retreat, the PDOC and Luzerne County have buses available to evacuate the entire population in a single wave.
- The buses evacuating inmates and guards from SCI Retreat will travel northbound on US Route 11 out of the EPZ, a 3.3 mile route. After exiting the EPZ, the buses will continue to their planned destinations (confidential) and will not need to return to the EPZ.
- Buses will arrive at SCI Retreat between 2 hours (early buses) and 4 hours (late buses) after the evacuation order.

The following additional data are needed to compute ETE for the SCI Retreat:

- Typical capacities for buses are 40 adults, as discussed on page 8-2. It is assumed that approximately 40 passengers (inmates and guards) will be loaded onto each bus. Exhibit 27-9 (page 27-10) of the 2000 Highway Capacity Manual (HCM2000) shows that passengers can board a bus at headways of 2 to 3 seconds per passenger. Thus, a single bus can be loaded to capacity in approximately 2 minutes. It is assumed that several buses will be loaded in parallel and that all inmates and guards will be loaded on to buses within 30 minutes of the arrival of the buses.
- For Scenario 6 (winter), Region 3 (entire EPZ), the average speed output by DYNEV at approximately 2:30 (2:00 mobilization time for those buses which arrive first, plus 30 minute loading time) after the ATE is 19.5 mph. Based on this speed, it will take approximately 10 minutes to travel the 3.3 mile route out of the EPZ.
- For Scenario 6 (winter), Region 3 (entire EPZ), the average speed output by DYNEV at approximately 4:30 (4:00 mobilization time for those buses which arrive last, plus 30 minute loading time) after the ATE is 47.5 mph. Based on this speed, it will take approximately 5 minutes to travel the 3.3 mile route out of the EPZ.

The ETE for SCI Retreat is bounded by:

Mobilize the buses:	2:00	Mobilize the buses:	4:00
Board the Inmates:	0:30	Board the Inmates:	0:30
Travel out of EPZ:	0:10	Travel out of EPZ:	0:05
ETE (early buses)	**2:40**	**ETE (late buses)**	**4:35**



Event

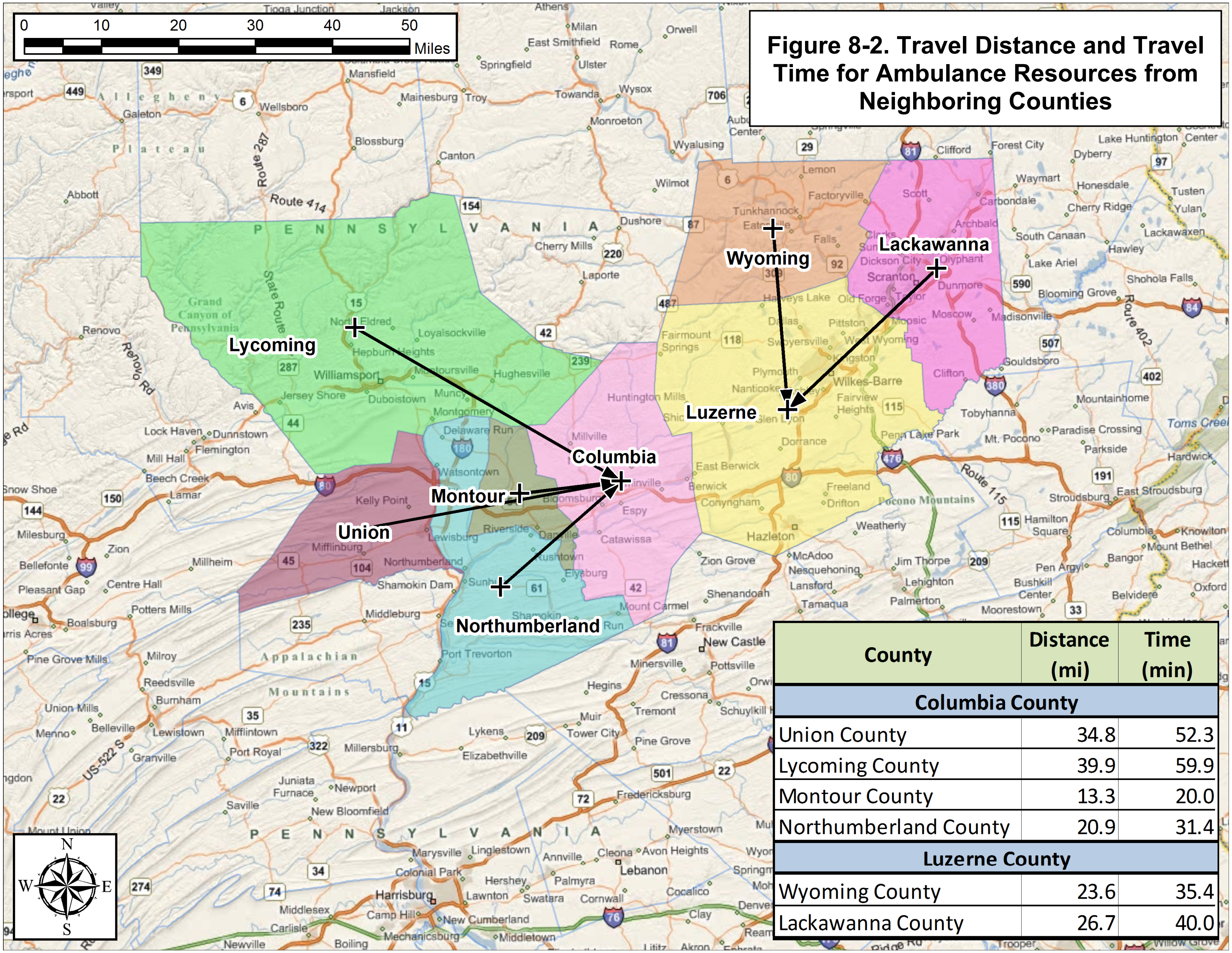
A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Host School
E	Bus Exits Region
F	Bus Arrives at Host School
G	Bus Available for “Second Wave” Evacuation Service

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 Host School Outside the EPZ.
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

Figure 8-2. Travel Distance and Travel Time for Ambulance Resources from Neighboring Counties



County	Distance (mi)	Time (min)
Columbia County		
Union County	34.8	52.3
Lycoming County	39.9	59.9
Montour County	13.3	20.0
Northumberland County	20.9	31.4
Luzerne County		
Wyoming County	23.6	35.4
Lackawanna County	26.7	40.0

Table 8-1. Transit Dependent Population Estimates

Facility Name	2009 EPZ Population	Survey Average Household Size With Indicated No. of Vehicles			Estimated Number of Households	Survey Percent Households With Indicated No. of Vehicles			Survey Percent Households With Commuters	Survey Percent Households With Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent of Population Requiring Public Transit
		0	1	2		0	1	2						
SSES/Bell Bend Nuclear Power Plant	70,327	1.68	1.75	2.54	27,825	5.4%	29.3%	43.6%	52%	40%	4,080	50%	2,040	2.9%

Table 8-2A. Luzerne County Schools		
School Name	**Enrollment**	**Bus Runs Required**
Drums Elementary/Middle School	731	11
Garrison Memorial Elementary School	160	3
GNA Educational Center	324	5
GNA Elementary School	443	7
Greater Nanticoke High School	953	20
Hunlock Creek Elementary School	284	5
Huntington Mills Elementary School	308	5
JFK Elementary School	132	2
K M Smith Elementary School	322	5
Keystone Job Corp High School	600	12
Muhlenburg Christian Academy	75	2
Northwest Area High School	668	14
Pope John Paul II Catholic School	320	5
Rice Elementary School	790	12
Salem Elementary School	462	7
The Learning Station School	42	1
Valley Elementary/Middle School	1109	16
Total:	**7723**	132

Table 8-2B. Columbia County Schools		
School Name	**Enrollment**	**Bus Runs Required**
Beaver Main Elementary School	104	2
Berwick Area Middle School	897	13
Berwick Senior High School	992	20
Fourteenth Street Elementary School	214	4
Heritage Christian Academy	24	1
Holy Family Consolidated School	67	1
Mulberry Street Elementary School	88	2
Nescopeck Elementary School	276	4
Orange Street Elementary School	386	6
Total:	**3048**	53

Table 8-3. Schools and Host Schools	
School	**Host School**
LUZERNE COUNTY	
Drums Elementary/Middle School	McAdoo-Kelayres Elementary School Kelayres, PA
Garrison Memorial Elementary School	Dallas Junior High School Dallas, PA
GNA Educational Center	Hanover Area Senior High School Wilkes Barre, PA
GNA Elementary School	Hanover Area Senior High School Wilkes Barre, PA
Greater Nanticoke High School	Hanover Area Senior High School Wilkes Barre, PA
Hunlock Creek Elementary School	Dallas Junior High School Dallas, PA
Huntington Mills Elementary School	Dallas Junior High School Dallas, PA
JFK Elementary School	Hanover Area Senior High School Wilkes Barre, PA
K M Smith Elementary School	Hanover Area Senior High School Wilkes Barre, PA
Keystone Job Corp High School*	McAdoo-Kelayres Elementary School Kelayres, PA
Muhlenburg Christian Academy*	Dallas Junior High School Dallas, PA
Northwest Area High School	Dallas Junior High School Dallas, PA
Pope John Paul II Catholic School	Hanover Area Senior High School Wilkes Barre, PA
Rice Elementary School	Schools attended until 5 p.m., then to Crestwood Jr.-Sr. High School
Salem Elementary School	Mahoning-Cooper Elementary
The Learning Station School*	Hanover Area Senior High School Wilkes Barre, PA
Valley Elementary School	McAdoo-Kelayres Elementary School Kelayres, PA
COLUMBIA COUNTY	
Beaver Main Elementary School	Bloomsburg High School
Berwick Middle School	Danville Middle School
Berwick Senior High School	Danville Senior High School
Fourteenth Street Elementary School	Liberty Valley Elementary
Heritage Christian Academy	Mahoning-Cooper Elementary
Holy Family Consolidated School	Liberty Valley Elementary
Mulberry Street Elementary School	Danville Elementary
Nescopeck Elementary School	Liberty Valley Elementary
Orange St Elementary School	Danville Middle School

Note: Students and staff at Penn State Hazelton and the Luzerne Community Colleges at Berwick and Nanticoke will evacuate in their private vehicles.

* Not listed in County emergency plans and are directed to the same host school assigned to nearby schools.

Table 8-4: Special Facility Transit Demand

Facility Name	Street Address	Town/City	Capacity	Census	Ambulances Needed	Buses Needed	Vans Needed
LUZERNE COUNTY							
Johnson Personal Care Home	897 Hobbie Rd	Wapwallopen	18	18	0	0	2
Guardian Elder Care Center	147 Old Newport St	Nanticoke	110	100	11	0	7
Fritzingertown Senior Living Community	1162 South Old Turnpike Rd	Drums	168	148	20	2	3
Mercy Special Care Hospital	128 W Washington St	Nanticoke	32	24	12*	0	1
Bonham Nursing Center	477 Bonnieville Rd	Stillwater	77	70	18	1	0
Northeast Counseling	West Washington St	Nanticoke	17	12	0	0	1
Butler Valley Manor Home	463 N. Hunter Hwy	Drums	37	36	10	0	2
Birchwood Nursing Home	395 East Middle Rd	Nanticoke	120	110	10	1	5
Villa Personal Care	50 N. Walnut St	Nanticoke	76	50	0	1	1
		Luzerne County Total	**655**	**568**	**81**	**5**	**22**
COLUMBIA COUNTY							
Berwick Hospital Center and Retirement Village	701 E 16th St	Berwick	268	268	4	5	5
Elmcroft Of Berwick	2050 West Front St	Berwick	Day Care Only. No Transportation Needed				
		Columbia County Total	**268**	**268**	**4**	**5**	**5**
		EPZ Total	**923**	**836**	**85**	**10**	**27**

* A high percentage of the patients at this facility are special needs; therefore, an ambulance capacity of 1 patient is used for this facility

TABLE 8-4A RISK MUNICIPALITY MEDICAL TRANSPORTATION REQUIREMENTS			
Municipality	**People Requiring Ambulance**	**Total Ambulance Requirement**	**Available Ambulance Resources Countywide[1]**
COLUMBIA COUNTY			
Berwick Borough	28	14	12
Beaver Township	2	1	
Briar Creek Borough	2	1	
Briar Creek Township	2	1	
Fishing Creek Township	0	0	
Mifflin Township	2	1	
North Centre Township	0	1	
South Centre Township	0	1	
Special Facilities (see Table 8-4)	8	4	
TOTAL	44	24	12
LUZERNE COUNTY			
Black Creek Township	1	1	107
Butler Township	2	1	
Conyngham Borough	4	2	
Conyngham Township	8	4	
Dorrance Township	6	3	
Hollenback Township	4	2	
Hunlock Township	2	1	
Huntington Township/New Columbus Borough	0	1	
Nanticoke City	10	5	
Nescopeck Borough	4	2	
Nescopeck Township	4	2	
Newport Township	12	6	
Nuangola Borough	0	1	
Salem Township	4	2	
Shickshinny Borough	4	2	
Slocum Township	2	1	
Sugarloaf Township	0	0	
Union Township	2	1	
Special Facilities (see Table 8-4)	150	81	
TOTAL	219	118	107
EPZ TOTAL	263	142	119

1 Additional ambulances are available from neighboring counties. See the Emergency Medical Services (EMS) Vehicles section above and Table 8-7 for additional information.

Table 8-5A. School Evacuation Time Estimates - Good Weather								
School	Driver Mobilization Time(min)	Loading Time (min)	Dist. to EPZ Boundary (mi.)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bndry to H.S. (mi.)	Travel Time EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Columbia County								
Beaver Main Elementary School	90	5	0.3	1	**1:40**	15.0	27	**2:05**
Berwick Area Middle School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Berwick Senior High School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Fourteenth Street Elementary School	90	5	6.5	12	**1:50**	18.0	32	**2:20**
Heritage Christian Academy	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Holy Family Consolidated School	90	5	6.2	11	**1:50**	18.0	32	**2:20**
Mulberry Street Elementary School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
Nescopeck Elementary School	90	5	7.3	13	**1:50**	14.0	25	**2:15**
Orange Street Elementary School	90	5	5.8	10	**1:45**	14.0	25	**2:10**
Luzerne County								
Drums Elementary School	90	5	2.0	4	**1:40**	8.2	15	**1:55**
Garrison Memorial Elementary School	90	5	7.2	13	**1:50**	17.0	30	**2:20**
GNA Elementary Center	90	5	0.6	1	**1:40**	4.0	7	**1:45**
GNA Educational Center	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Greater Nanticoke High School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Hunlock Creek Elementary School	90	5	5.0	9	**1:45**	17.0	30	**2:15**
Huntington Mills Elementary School	90	5	8.4	15	**1:50**	17.0	30	**2:20**
J F Kennedy Elementary School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
K M Smith Elementary School	90	5	1.7	3	**1:40**	4.0	7	**1:45**
Keystone Job Corp High School	90	5	3.5	6	**1:45**	8.2	15	**2:00**
Mulhenberg Christian Academy	90	5	5.0	9	**1:45**	17.0	30	**2:15**
Northwest Area High School	90	5	5.2	9	**1:45**	17.0	30	**2:15**
Pope John Paul II School	90	5	0.6	1	**1:40**	4.0	7	**1:45**
Rice Elementary School	90	5	0.6	1	**1:40**	5.5	10	**1:50**
Salem Elementary School	90	5	7.0	13	**1:50**	14.0	25	**2:15**
The Learning Station School	90	5	1.7	3	**1:40**	4.0	7	**1:45**
Valley Elementary School	90	5	3.0	5	**1:40**	8.2	15	**1:55**
				Maximum for EPZ:	**1:50**		**Maximum:**	**2:20**
						Average:	**20**	**2:05**

Table 8-5B. School Evacuation Time Estimates - Rain								
School	Driver Mobilization Time(min)	Loading Time (min)	Dist. to EPZ Boundary (mi.)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bndry to H.S. (mi.)	Travel Time EPZ Bdry to H.S. (min)	ETE to H.S. (hr:min)
Columbia County								
Beaver Main Elementary School	95	10	0.3	1	**1:50**	15.0	38	**2:25**
Berwick Area Middle School	95	10	7.0	18	**2:05**	14.0	35	**2:40**
Berwick Senior High School	95	10	7.0	18	**2:05**	14.0	35	**2:40**
Fourteenth Street Elementary School	95	10	6.5	16	**2:05**	18.0	45	**2:50**
Heritage Christian Academy	95	10	7.0	18	**2:05**	14.0	35	**2:40**
Holy Family Consolidated School	95	10	6.2	16	**2:05**	18.0	45	**2:50**
Mulberry Street Elementary School	95	10	7.0	18	**2:05**	14.0	35	**2:40**
Nescopeck Elementary School	95	10	7.3	18	**2:05**	14.0	35	**2:40**
Orange Street Elementary School	95	10	5.8	15	**2:00**	14.0	35	**2:35**
Luzerne County								
Drums Elementary School	95	10	2.0	5	**1:50**	8.2	21	**2:15**
Garrison Memorial Elementary School	95	10	7.2	18	**2:05**	17.0	43	**2:50**
GNA Elementary Center	95	10	0.6	2	**1:50**	4.0	10	**2:00**
GNA Educational Center	95	10	0.6	2	**1:50**	4.0	10	**2:00**
Greater Nanticoke High School	95	10	0.6	2	**1:50**	4.0	10	**2:00**
Hunlock Creek Elementary School	95	10	5.0	13	**2:00**	17.0	43	**2:45**
Huntington Mills Elementary School	95	10	8.4	21	**2:10**	17.0	43	**2:50**
J F Kennedy Elementary School	95	10	0.6	2	**1:50**	4.0	10	**2:00**
K M Smith Elementary School	95	10	1.7	4	**1:50**	4.0	10	**2:00**
Keystone Job Corp High School	95	10	3.5	9	**1:55**	8.2	21	**2:15**
Mulhenberg Christian Academy	95	10	5.0	13	**2:00**	17.0	43	**2:45**
Northwest Area High School	95	10	5.2	13	**2:00**	17.0	43	**2:45**
Pope John Paul II School	95	10	0.6	2	**1:50**	4.0	10	**2:00**
Rice Elementary School	95	10	0.6	2	**1:50**	5.5	14	**2:05**
Salem Elementary School	95	10	7.0	18	**2:05**	14.0	35	**2:40**
The Learning Station School	95	10	1.7	4	**1:50**	4.0	10	**2:00**
Valley Elementary School	95	10	3.0	8	**1:55**	8.2	21	**2:15**
				Maximum for EPZ:	**2:10**		**Maximum:**	**2:50**
						Average:	**28**	**2:25**

Table 8-6. Transit Dependent Evacuation Time Estimates										
Good Weather										
Single Wave					Second Wave					
Mobilization	Route Travel Time	Pickup Time	ETE	Mobilization	Unload Time	Driver Rest Time	Return Time	Pickup Time	Route travel Time	ETE
90	9	30	2:10	125	5	10	20	30	15	3:25
Rain										
Single Wave					Second Wave					
Mobilization	Route Travel Time	Pickup Time	ETE	Mobilization	Unload Time	Driver Rest Time	Return Time	Pickup Time	Route travel Time	ETE
95	13	40	2:30	145	5	10	28	40	17	4:05

Table 8-7. Ambulances Available by County	
County	**Ambulances**
Columbia County	12
Lackawanna County	55
Luzerne County	107
Lycoming County	36
Montour County	6
Northumberland County	21
Union County	10
Wyoming County	11
TOTAL	**258**

9. TRAFFIC MANAGEMENT STRATEGY

This section presents the current traffic control and management strategy that is designed to expedite the movement of evacuating traffic. The resources required to implement this strategy include:

- Personnel with the capabilities of performing the planned control functions of traffic guides (preferably, not necessarily, law enforcement officers).
- Traffic Control Devices to assist these personnel in the performance of their tasks. These devices should comply with the guidance of the Manual of Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) of the U.S.D.O.T. All state and most county transportation agencies have access to the MUTCD (also available online). Applicable devices include, with reference to the MUTCD:
    - Traffic Barriers: Chapter 6F, section 6F.61, 62 and Figure 6F-4.
    - Traffic Cones: Chapter 3F and section 6F.56.
    - Signs: Chapter 2I
- A plan that defines all necessary details and is documented in a format that is readily understood by those assigned to perform traffic control.

The functions to be performed in the field are:

1. Facilitate evacuating traffic movements that serve to expedite travel out of the EPZ along routes that the analysis has found to be most effective.
2. Discourage traffic movements that permit evacuating vehicles to travel in a direction which takes them significantly closer to the power plant, or which interferes with the efficient flow of other evacuees.

The terms "facilitate" and "discourage" are used rather than "enforce" and "prohibit" to indicate the need for flexibility in performing the traffic control function. There are always legitimate reasons for a driver to prefer a direction other than that indicated. For example:

- A driver may be traveling home from work or from another location, to join other family members preliminary to evacuating.
- An evacuating driver may be taking a detour from the evacuation route in order to pick up a relative, or other evacuees.
- The driver may be an emergency worker en route to perform an important activity.

The implementation of a plan must also be flexible enough for the application of sound judgment by the traffic guide.

The traffic management strategy is the outcome of the following process:

1. A field survey of these critical locations.
   The schematics describing traffic control, which are presented in Appendix G, are based on data collected during field surveys, upon large-scale maps, and on overhead photos.
2. Computer analysis of the evacuation traffic flow environment.
   This analysis identifies the best routing and those locations that experience pronounced congestion.
3. Consultation with emergency management and law enforcement personnel.
   Trained personnel who are experienced in controlling traffic and are aware of the likely evacuation traffic patterns should review these control tactics.

The control tactics at the TCPs are presented in schematics that appear in Appendix G.

The use of Intelligent Transportation Systems (ITS) technologies, if available, could reduce manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) could be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and reception center information. DMS can also be placed outside of the EPZ to warn other motorists to avoid using routes that may conflict with the flow of evacuees away from the nuclear power plant. Highway Advisory Radio (HAR) could broadcast information to evacuees en route through their vehicle stereo systems. Automated Traveler Information Systems (ATIS) could also provide evacuees with information. Internet websites could provide traffic and evacuation route information before the evacuee begins the trip, while on board navigation systems (GPS units) could provide information en route. These are only several examples of how ITS technologies that are in the process of being deployed could benefit evacuees, if available.

Chapter 2I of the MUTCD presents guidance on emergency management signing. Specifically, the evacuation route sign, EM-1 on page 2I-3, with the word “Hurricane” removed could be installed selectively within the EPZ, if considered advisable by local and state authorities. Similar comments apply to sign EM-3 which identifies TCP locations.

As discussed in Section 2.3, these TCP are not credited in calculating the ETE results. Access control points (ACP) are deployed near the periphery of the EPZ to divert “through” trips. The ETE calculations reflect the assumption that all “external-external” trips are interdicted after 90 minutes have elapsed after the advisory to evacuate (ATE).

All transit trips and other responders entering the EPZ to support the evacuation are assumed to be unhindered by personnel manning TCP.

Study Assumptions 5 and 6 in Section 2.3 discuss ACP and TCP staffing schedules and operations.

10. EVACUATION ROUTES

Evacuation routes are composed of two distinct components:

- Routing from an emergency response planning area (ERPA) or municipality being evacuated to the boundary of the evacuation region and thence out of the emergency planning zone (EPZ).

- Routing of evacuees from the EPZ boundary to the reception centers.

Evacuees should be routed within the EPZ in such a way as to *minimize their exposure to risk*. This primary requirement is met by routing traffic to move away from the location of the SSES and Bell Bend sites, to the extent practicable, and by delineating evacuation routes that expedite the movement of evacuating vehicles. This latter objective is addressed by developing evacuation routes to achieve a balancing of traffic demand relative to the available highway capacity to the extent possible, subject to satisfying the primary requirement noted above. This is achieved by carefully specifying candidate destinations for all origin centroids where evacuation trips are generated, and applying the TRAD model effectively. See Appendices A-D for further discussion.

The routing of evacuees from the EPZ boundary to the reception centers should be responsive to several considerations:

- Minimize the amount of travel outside the EPZ, from the points where these routes cross the EPZ boundary, to the reception centers.

- Relate the anticipated volume of traffic destined to the reception center, to the capacity of the reception center facility.

Table 10-1 lists the details for the designated reception centers. Table 10-2 identifies the reception center for each ERPA. Figure 10-1 maps each of the reception centers. An overview of the major evacuation routes for the EPZ is presented in Figure 10-2, while Figures 10-3 and 10-4 show the evacuation routes for Berwick and Nanticoke, respectively. The ETE analysis network is not limited to the primary evacuation routes. All highways other than local streets are represented in the following figures. Some local roads used by traffic to access the primary evacuation routes are included in the analysis network, as shown in Figure 1-2.

Table 10-1. Reception Center Details

Reception Center	EPZ County Serviced	Street Address	City	State	ZIP	County
Big Lots	Luzerne	1010 O'Neill Hwy #1	Dunmore	PA	18512	Lackawanna
Lycoming Mall	Columbia	300 Lycoming Mall Circle #3021	Muncy	PA	17756	Lycoming
Marian High School	Columbia & Luzerne	166 Marian Ave	Tamaqua	PA	18252	Schuylkill
Shikellamy High School	Columbia	Sixth and Walnut Street	Sunbury	PA	17801	Northumberland
Montandon Elementary School	Columbia & Luzerne	2733 State Route 45	Montandon	PA	17850	Northumberland
Tunkhannock High School	Luzerne	120 W Tioga St	Tunkhannock	PA	18657	Wyoming

Table 10-2. Reception Center Assignments

ERPA	Municipality	County	Reception Center
1	Black Creek Township	Luzerne	Marian High School
2	Hunlock Township	Luzerne	Tunkhannock High School
3	Union Township	Luzerne	Tunkhannock High School
4	Huntington Township	Luzerne	Tunkhannock High School
5	New Columbus Borough	Luzerne	Tunkhannock High School
6	Fishing Creek Township	Columbia	Lycoming Mall
7	Salem Township	Luzerne	Montandon Elementary School
8	Shickshinny Borough	Luzerne	Tunkhannock High School
9	Conyngham Township	Luzerne	Big Lots
10	Berwick Borough	Columbia	Lycoming Mall
11	Briar Creek Borough	Columbia	Lycoming Mall
12	Nescopeck Borough	Luzerne	Montandon Elementary School
13	Nescopeck Township	Luzerne	Montandon Elementary School
14	Hollenback Township	Luzerne	Montandon Elementary School
15	Sugarloaf Township	Luzerne	Marian High School
16	Conyngham Borough	Luzerne	Marian High School
17	Dorrance Township	Luzerne	Big Lots
18	Slocum Township	Luzerne	Big Lots
19	Nuangola Borough	Luzerne	Big Lots
20	Newport Township	Luzerne	Big Lots
21	Nanticoke City	Luzerne	Big Lots
22	Butler Township	Luzerne	Marian High School
23	Beaver Township	Columbia	Marian High School
24	Mifflin Township	Columbia	Montandon Elementary School
25	South Centre Township	Columbia	Montandon Elementary School
26	North Centre Township	Columbia	Shikellamy High School
27	Briar Creek Township	Columbia	Shikellamy High School

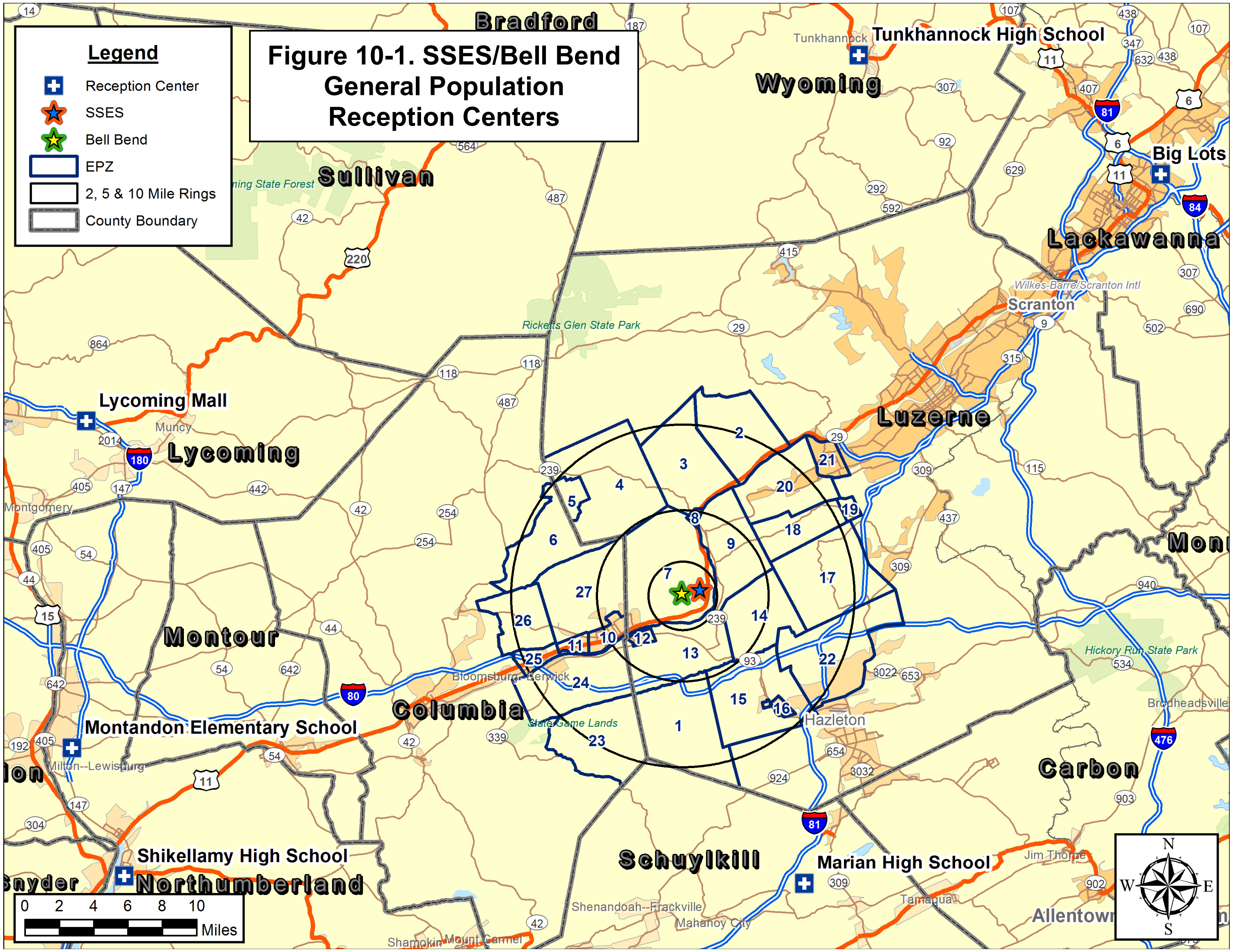


Figure 10-1. SSES/Bell Bend General Population Reception Centers
Legend
Reception Center
SSES
Bell Bend
EPZ
2, 5 & 10 Mile Rings
County Boundary
Bradford
Wyoming
Sullivan
Lackawanna
Luzerne
Lycoming
Montour
Columbia
Schuylkill
Carbon
Northumberland
Snyder
Tunkhannock High School
Big Lots
Lycoming Mall
Montandon Elementary School
Shikellamy High School
Marian High School
Scranton
Hazleton
Bloomsburg-Berwick
Ricketts Glen State Park
Hickory Run State Park
State Game Lands
Allentown
0 2 4 6 8 10
Miles

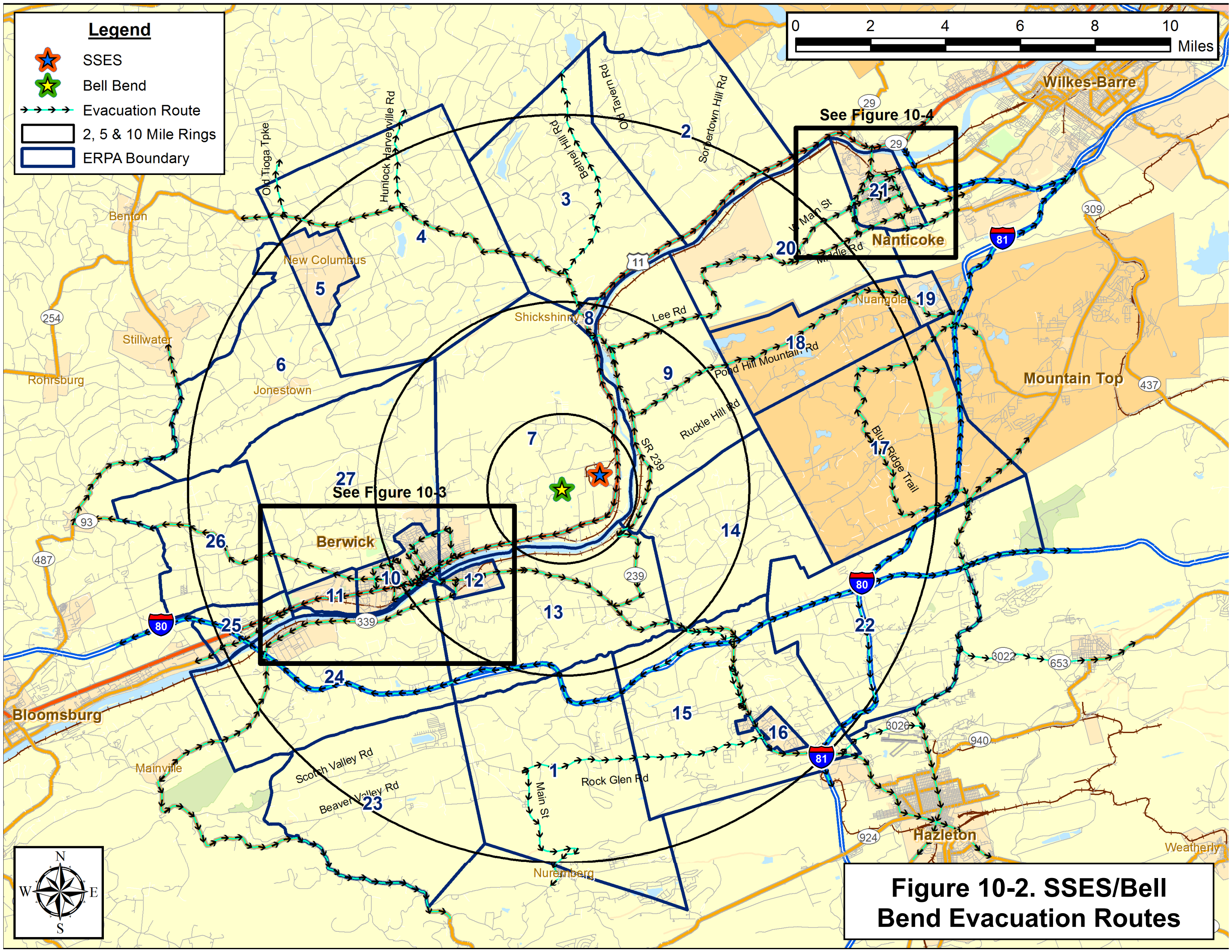


Figure 10-2. SSES/Bell Bend Evacuation Routes

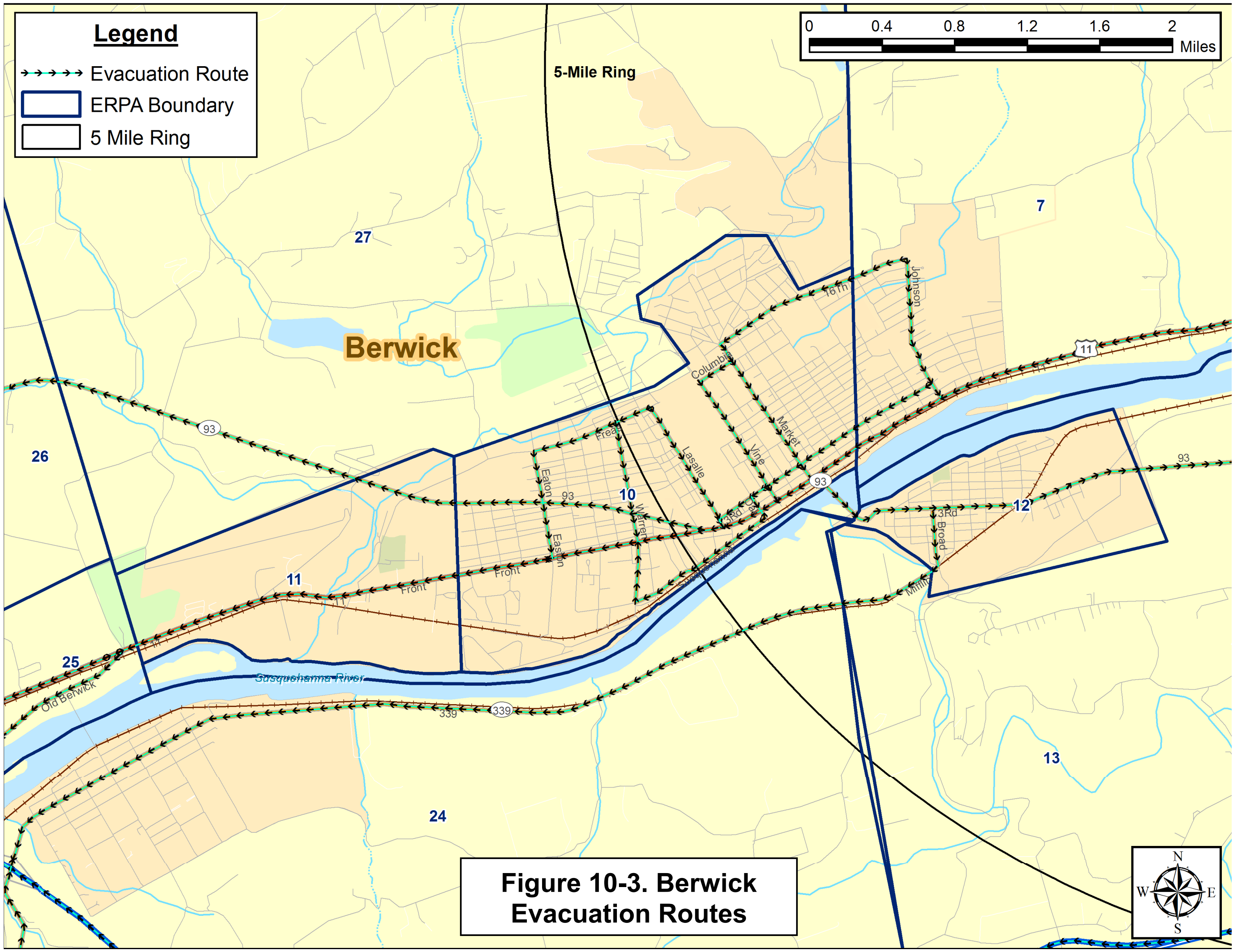
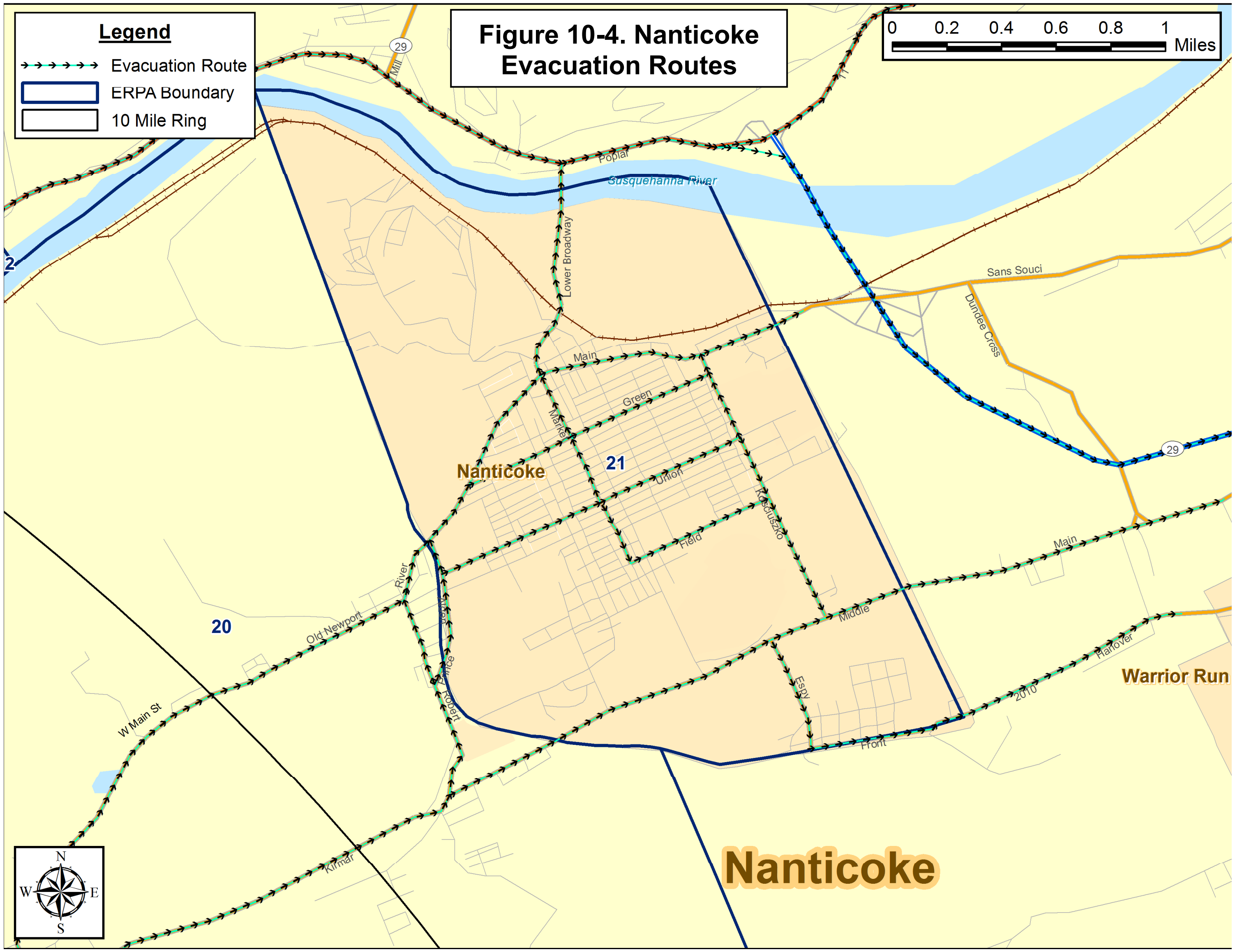


Figure 10-3. Berwick Evacuation Routes



Legend
Evacuation Route
ERPA Boundary
10 Mile Ring
Figure 10-4. Nanticoke
Evacuation Routes
0
0.2
0.4
0.6
0.8
1
Miles
Susquehanna River
Poplar
Lower Broadway
Mill
29
11
Sans Souci
Dundee Cross
Main
Green
Market
Union
Kosciuszko
Field
River
Old Newport
W Main St
Kirmar
Robert
Middle
Espy
Front
Hanover
2010
Nanticoke
21
20
2
Warrior Run
N
S
E
W

11. SURVEILLANCE OF EVACUATION OPERATIONS

There is a need for surveillance of traffic operations during the evacuation. There is also a need to clear any blockage of roadways arising from accidents or vehicle disablement. Surveillance can take several forms.

1. Traffic control personnel, located at traffic control and access control points, provide fixed point surveillance.
2. Ground patrols may be undertaken along well-defined paths to ensure coverage of those highways that serve as major evacuation routes.
3. Aerial surveillance of evacuation operations may also be conducted using helicopter or fixed-wing aircraft.
4. Cellular phone calls (if cellular coverage exists) from motorists may also provide direct field reports of road blockages.

These concurrent surveillance procedures are designed to provide coverage of the entire EPZ as well as the area around its periphery. It is the responsibility of the counties to support an emergency response system that can receive messages from the field and be in a position to respond to any reported problems in a timely manner. This coverage should quickly identify, and expedite the response to any blockage caused by a disabled vehicle.

Tow Vehicles

In a low-speed traffic environment, any vehicle disablement is likely to arise due to a low-speed collision, mechanical failure or the exhaustion of its fuel supply. In any case, the disabled vehicle can be pushed onto the shoulder, thereby restoring traffic flow. Past experience in other emergencies indicates that evacuees who are leaving an area often perform activities such as pushing a disabled vehicle to the side of the road without prompting.

While the need for tow vehicles is expected to be low under the circumstances described above, it is still prudent to be prepared for such a need. Tow trucks with a supply of gasoline may be deployed at strategic locations within, or just outside, the EPZ. These locations should be selected so that:

- They permit access to key, heavily loaded, evacuation routes.
- Responding tow trucks would most likely travel counter-flow relative to evacuating traffic.

12. CONFIRMATION TIME

Guidance in Appendix 4 of NUREG-0654 requires that the time required for confirmation of evacuation be estimated. Although the counties in the EPZ may use their own procedures for confirmation, we suggest an alternative or complementary approach which does not depend on visual observation from a vantage point outside of residences.

The procedure we suggest employs a stratified random sample and a telephone survey. The size of the sample is dependent on the expected number of households that do not comply with the advisory to evacuate. It is reasonable to assume, for the purpose of estimating sample size that at least 80 percent of the population within the EPZ will comply with the advisory to evacuate. On this basis, an analysis could be undertaken (see Table 12-1) to yield an estimated sample size of approximately 300.

If this methodology is used, the confirmation process would start at about 3 hours after the advisory to evacuate, which is when 90 percent of evacuees have completed their mobilization activities. At this time, virtually all evacuees will have departed on their respective trips and the local telephone system will be largely free of traffic.

As indicated in Table 12-1, approximately 7½ person hours are needed to complete the telephone survey. If six people are assigned to this task, each dialing a different set of telephone exchanges (e.g., each person can be assigned a different set of Municipalities), then the confirmation process will extend over a time frame of about 75 minutes. Assigning 3 people would require 2½ hours. In either case, the confirmation should be completed before the evacuated area is cleared. Of course, fewer people would be needed for this survey if the evacuation region were only a portion of the EPZ. Use of modern automated computer controlled dialing equipment can significantly reduce the manpower requirements and the time required to undertake this type of confirmation survey.

Should the number of telephone responses (i.e., people still at home) exceed 20 percent, then the telephone survey should be repeated after an hour's interval until the confirmation process is completed.

If this methodology is used, a list of resident and business telephone numbers – including cell phone and land lines – could be compiled in advance and archived by local response agencies for this purpose. Such lists can be purchased from vendors at modest cost. For ease of access, this list could be broken down by evacuation region. This approach could be supplemented with other confirmation techniques:

- Patrol cars equipped with loud speakers (route alerting)
- Helicopters or fixed-wing aircraft (if available) equipped with loud speakers

TABLE 12-1
ESTIMATED NUMBER OF TELEPHONE CALLS REQUIRED
FOR CONFIRMATION OF EVACUATION

Problem Definition

Estimate number of phone calls, n, needed to ascertain the proportion, F of households that have not evacuated.

Reference: Burstein, H., Attribute Sampling, McGraw Hill, 1971

Given:

No. of households plus other facilities, N, within the EPZ (est.) = 27,825
Est. proportion, F, of households that have not evacuated = 0.20
Allowable error margin, e: 0.05
Confidence level, α: 0.95 (implies A = 1.96)

Applying Table 10 of cited reference,

$$p = F + e = 0.25; \; q = 1 - p = 0.75$$

$$n = \frac{A^2 pq + e}{e^2} = 308$$

Finite population correction:

$$n_F = \frac{nN}{n + N - 1} = 305$$

Thus, some 300 telephone calls will confirm that approximately 20 percent of the population has not evacuated. If only 10 percent of the population does not comply with the Advisory to Evacuate, then the required sample size, n_F = 214.

Est. Person Hours to complete 300 telephone calls

Assume: Time to dial using touch-tone (random selection of listed numbers): 30 seconds
Time for 6 rings (no answer): 36 seconds
Time for 4 rings plus short conversation: 60 sec.
Interval between calls: 20 sec.

Person Hours: 300[30+20+0.8(36)+0.2(60)]/3600 = 7.6

APPENDIX A

Glossary of Traffic Engineering Terms

APPENDIX A: GLOSSARY OF TRAFFIC ENGINEERING TERMS

Term	Definition
Link	A network link represents a specific, one-directional section of roadway. A link has both physical (length, number of lanes, topology, etc.) and operational (turn movement percentages, service rate, free-flow speed) characteristics.
Measures of Effectiveness	Statistics describing traffic operations on a roadway network
Node	A network node generally represents an intersection of network links. A node has control characteristics, i.e., the allocation of service time to each approach link.
Origin	A location connected to a network link, within the EPZ or shadow area, where trips are generated at a specified rate in vehicles per hour (vph). These trips enter the roadway system to travel to their respective destinations.
Network	A graphical representation of the geometric topology of a physical roadway system, which is comprised of directional links and nodes.
Prevailing roadway and traffic conditions	Relates to the physical features of the roadway, the nature (e.g., composition) of traffic on the roadway and the ambient conditions (weather, visibility, pavement conditions, etc.)
Service Rate	Maximum rate at which vehicles, executing a specific turn maneuver, can be discharged from a section of roadway at the prevailing conditions, expressed in vehicles per second (vps) or vehicles per hour (vph).
Service Volume	Maximum number of vehicles which can pass over a section of roadway in one direction during a specified time period with operating conditions at a specified Level of Service (The Service Volume at the upper bound of Level of Service E equals Capacity). Service Volume is usually expressed as vehicles per hour (vph).
Signal Cycle Length	The total elapsed time to display all signal indications, in sequence. The cycle length is expressed in seconds.
Signal Interval	A single combination of signal indications. The interval duration is expressed in seconds. A signal phase is comprised of a sequence of signal intervals.
Signal Phase	A set of signal indications (and intervals) which services a particular combination of traffic movements on selected approaches to the intersection. The phase duration is expressed in seconds.

Term	Definition
Traffic (Trip) Assignment	A process of assigning traffic to paths of travel in such a way as to satisfy all trip objectives (i.e., the desire of each vehicle to travel from a specified origin in the network to a specified destination) and to optimize some stated objective or combination of objectives. In general, the objective is stated in terms of minimizing a generalized "cost". For example, "cost" may be expressed in terms of travel time.
Traffic Density	The number of vehicles that occupy one lane of a roadway section of specified length at a point in time, expressed as vehicles per mile (vpm).
Traffic (Trip) Distribution	A process for determining the destinations of all traffic generated at the origins. The result often takes the form of a Trip Table, which is a matrix of origin-destination traffic volumes.
Traffic Simulation	A computer model designed to replicate the real-world operation of vehicles on a roadway network, so as to provide statistics describing traffic performance. These statistics are called Measures of Effectiveness.
Traffic Volume	The number of vehicles that pass over a section of roadway in one direction, expressed in vehicles per hour (vph). Where applicable, traffic volume may be stratified by turn movement.
Travel Mode	Distinguishes between private auto, bus, rail, pedestrian and air travel modes.
Trip Table or Origin-Destination Matrix	A rectangular matrix or table, whose entries contain the number of trips generated at each specified origin, during a specified time period, that are attracted to (and travel toward) each of its specified destinations. These values are expressed in vehicles per hour (vph) or in vehicles.
Turning Capacity	The capacity associated with that component of the traffic stream which executes a specified turn maneuver from an approach at an intersection.

APPENDIX B

Traffic Assignment Model

APPENDIX B: TRAFFIC ASSIGNMENT MODEL

This section describes the integrated trip assignment and distribution model named TRAD that is expressly designed for use in analyzing evacuation scenarios. This model employs equilibrium traffic assignment principles and is one of the models of the IDYNEV System.

To apply TRAD, the analyst must specify the highway network, link capacity information, the volume of traffic generated at all origin centroids, a set of accessible candidate destination nodes on the periphery of the EPZ for each origin, and the capacity (i.e., “attraction”) of each destination node. TRAD calculates the optimal trip distribution and the optimal trip assignment (i.e., routing) of the traffic generated at each origin node, traveling to the associated set of candidate destination nodes, so as to minimize evacuee travel times.

Overview of Integrated Distribution and Assignment Model

The underlying premise is that the selection of destinations and routes is intrinsically coupled in an evacuation scenario. That is, people in vehicles seek to travel out of an area of potential risk as rapidly as possible by selecting their “best” route. The model is designed to identify these “best” routes in a manner that distributes vehicles from origins to destinations and routes them over the highway network, in a consistent and optimal manner.

The approach we adopt is to extend the basic user-equilibrium assignment methodology to embrace the distribution process, as well. Specifically, the analyst assigns a set of candidate destination nodes to each origin node which reflects the general outward-bound direction of travel relative to the location of the power station. The selection of specific destination nodes by travelers from each origin node, and the selection of the connecting paths of travel, are both determined by the integrated model. This determination is subject to specified highway capacity constraints, so as to satisfy the stated objective function. This objective function is the statement of the User Optimization Principle by Wardrop[1].

To accomplish this integration, we leave the equilibrium assignment model intact, changing the form of the objective function. The model creates a "fictional" augmentation of the “real” highway network. This augmentation consists of Pseudo-Links and Pseudo-Nodes, so configured as to permit the extended network to embed an equilibrium Distribution Model within the fabric of the Assignment Model. Additional discussion may be found in NUREG/CR-4873 (“Benchmark Study of the I-DYNEV Evacuation Time

[1] Wardrop, J.G., 1952. Some Theoretical Aspects of Road Traffic Research, *Proceedings, Institute of Civil Engineers*, Part II, Vol. 1, pp. 325-378.

Estimate Computer Code") and 4874 ("The Sensitivity of Evacuation Time Estimates to Changes in Input Parameters for the I-DYNEV Computer Code").

Specification of TRAD Model Inputs

The analyst must specify, for each origin node, the average hourly traffic volume generated, as well as a set of candidate accessible destinations. A destination is "accessible" to traffic originating at an origin node if there is at least one path connecting the origin to the destination node. There must be at least one destination node specified for each origin centroid. The number of trips generated at the origin node, which are distributed to each specified, accessible destination node within this set, is determined by the model in a way that satisfies the network-wide objective function (Wardrop's Principle).

The analyst must also specify the total number of trips which can be accommodated by each destination node. This value reflects the capacities of the road(s) immediately servicing the destination node. We call this number of trips, the "attraction" of the destination node, consistent with conventional practice. Clearly, we require that the total number of trips traveling to a destination, j, from all origin nodes, i, cannot exceed the attraction of destination node, j. By summing over all destination nodes, this constraint also states that the total trips generated at all origin nodes must not exceed the total capacity to accommodate these trips at all of the specified destinations.

In summary, the analyst must specify the total trips generated at each of the origin nodes, the maximum number of trips that can be accommodated by each of the specified destination nodes and the highway network attributes which include the traffic control tactics. The TRAD model includes a function which expresses travel time on each network link in terms of traffic volume and link capacity. This function drives the underlying trip distribution and trip assignment decision-making process. Thus, the TRAD model satisfies the objectives of evacuees to select destination nodes and travel paths to minimize evacuation travel time. As such, this integrated model is classified as a behavioral model.

At the outset, it may appear that we have an intractable problem:

- If TRAD retains the basic assignment algorithm, it must be provided a Trip Table (a matrix defining origin-destination traffic volumes) as input.
- On the other hand, if the distribution model is embedded within the assignment model, rather than preceding it, a Trip Table is not available as input.

The resolution of this problem is as follows:

1. The model constructs an "augmentation" network that allows the user to specify only the volume for each origin node. The allocation of trips from the origin node to each candidate destination node is not specified and will be determined internally by the model.
2. We construct pseudo-links which enforce the specified values of attraction, A_j, for all destination nodes, j, by suitably calibrating the relationship of the travel time vs. volume and capacity.

This augmented network is comprised of three sub-networks:

1. The “real” highway sub-network, which consists of "Class I" Links and Nodes.
2. A sub-network of "Class II" Pseudo-Links which acts as an interface between the highway sub-network and the network augmentation.
3. The sub-network of "Class III" Pseudo-Links and Nodes which comprises the network augmentation described above.

The need for these Class II links will become clear later. The classifications are described below:

Class I Links and Nodes

These links and nodes represent the physical highway network: sections of highway and intersections. Trips generated at each Origin [Centroid] Node are assigned to a specified Class I link via a "connector" link. These connector links are transparent to the user and offer no impedance to the traveler; they represent the aggregation of local streets which service the centroidal generated trips and feed them onto the highway network. The real-world destination nodes are part of this network. The immediate approaches to these destination nodes are Class I links.

Class II Links

These pseudo-links are constructed so as to connect each specified destination node with its Class III Pseudo-Node (P-N) counterpart on a one-to-one basis. The capacities of these Class II links are set equal to the capacities at their respective destination nodes.

Class III Links and Nodes

Class III links and nodes form the augmentation to the basic network. These Pseudo-Links provide paths from the Class II links servicing traffic traveling from the specified set of [real] candidate destination nodes, to the Super-Nodes which collect the

traffic travelling through the specified set of destination nodes associated with each origin node.

Each Class of links provides a different function:

- Class I links represent the physical highway network. As such, each link has a finite capacity, a finite length and an estimated travel time for free-flowing vehicles. The nodes generally represent intersections, interchanges and, possibly, changes in link geometry. The topology of the Class I network represents that of the physical highway system.
- The Class II links represent the interface between the real highway sub-network and the augmentation sub-network. These pseudo-links are needed to represent the specified "attractions" of each destination node, i.e., the maximum number of vehicles that can be accommodated by each destination node. Instead of explicitly assigning a capacity limitation to the destination <u>nodes</u>, we assign this capacity limitation of the Class II Pseudo-Links. This approach is much more suitable, computationally.
- The topology of the network augmentation (i.e., Class III Links and Nodes) is designed so that all traffic from an origin node can only travel to the single “Super-Node” by flowing through its specified set of real destination nodes, thence along the links of the augmented network.

The Class II Pseudo-Links and the network augmentation of Class III Pseudo-Nodes and Links represent logical constructs of fictitious links created internally by the model, which allows the user to specify the <u>identity</u> of all destination nodes in each origin-based set, <u>without</u> specifying the distribution of traffic volumes from the origin to each destination node in that set.

<u>Calculation of Capacities and Impedances</u>

Each class of links exhibits different properties. Specifically, the relationship between travel impedance (which is expressed in terms of travel time) and both volume and capacity will differ:

- For Class I links, the capacity represents the physical limitation of the highway sections. Travel impedance is functionally expressed by relating travel time with respect to the traffic volume-link capacity relationship.
- For Class II links, link capacity represents the maximum number of vehicles that can be accommodated at the [real] destination nodes that form the upstream nodes of each Class II link. Since Class II links are Pseudo-Links, there should be virtually no <u>difference</u> in impedance to traffic along Class II links when the assigned traffic volume on these links is below their respective capacities. That is, the assignment of traffic should not be

influenced by differences in travel impedance on those Class II links where the assigned volumes do not exceed their respective capacities.

- For Class III links, both capacity and impedance have no meaning. Since the Class II links limit the number of vehicles entering the Class III subnetwork at all entry points (i.e., at the Class II Pseudo-Nodes) and since all these links are Pseudo-Links, it follows that the Class III network is, by definition, an uncapacitated network.

Specification of the Objective Function

It is computationally convenient to be able to specify a single impedance (or "cost") function relating the travel time on a link, to its capacity and assigned traffic volume, for all classes of links. To achieve this, we will adopt the following form based on the original "BPR Formula[2]":

$$T = T_o\{\alpha[1 + a_1(\frac{v}{c})^{b_1}] + \beta[1 + a_2(\frac{v}{c})^{b_2}]\} + I$$

Where, as for the present traffic assignment model in TRAD,

T	=	Link travel time, sec.
T_o	=	Unimpeded link travel time, sec.
V	=	Traffic volume on the link, veh/hr
C	=	Link capacity, veh/hr
a_i, b_i	=	Calibration parameters
α, ß	=	Coefficients defined below
I	=	Impedance term, expressed in seconds, which could represent turning penalties or any other factor which is justified in the user's opinion

The assignment of coefficients varies according to the Class in which a link belongs:

Class	α	ß	T_o
I	1	0	L/U_f
II	0	1	W
III	0	0	1

Here, L is a highway link length and U_f is the free-flow speed of traffic on a highway link. The values of a_1 and b_1, which are applicable only for Class I links, are based on experimental data:

$a_1 = 0.8$ $b_1 = 5.0$

[2] Bureau of Public Roads (1964). Traffic Assignment Manual. U.S. Dept. of Commerce, Urban Planning Division, Washington D.C.

The values of a_2 and b_2, which are applicable for each Class II link, are based upon the absolute requirement that the upstream destination node can service no more traffic than the user-specified value of the maximum "attraction". In addition, these parameters must be chosen so that these Pseudo-Links all offer the same impedance to traffic when their assigned volumes are less than their respective specified maximum attractions.

The weighting factor, W, is computed internally by the software.

Of course, it is still possible for the assignment algorithm within TRAD to distribute more traffic to a destination node than that node can accommodate. (Note that there is no upper-bound constraint in the BPR formula. Of course, when v/c > 1, the exponential terms grow very rapidly, degrading operational performance and discouraging trips from accessing those links.) For emergency planning purposes, this is a desirable model feature. Such a result will be flagged by the model to alert the user to the fact that some factor is strongly motivating travelers to move to that destination node, despite its capacity limitations. This factor can take many forms: inadequate highway capacity to other destinations, improper specification of candidate destinations for some of the origins, or some other design inadequacy. The planner can respond by modifying the control tactics, changing the origin-destination distribution pattern, providing more capacity at the overloaded destinations, etc.

APPENDIX C

Traffic Simulation Model: PC-DYNEV

APPENDIX C: TRAFFIC SIMULATION MODEL: PC-DYNEV

A model, named PC-DYNEV, is an adaptation of the TRAFLO Level II simulation model[1], developed by KLD for the Federal Highway Administration (FHWA). Extensions in scope were introduced to expand the model's domain of application to include all types of highway facilities, to represent the evacuation traffic environment and to increase its computational efficiency. This model produces the extensive set of output Measures of Effectiveness (MOE) shown in Table C-1.

The traffic stream is described internally in the form of statistical flow profiles. These profiles, expressed internally as statistical histograms, describe the platoon structure of the traffic stream on each network link. The simulation logic identifies five types of histograms:

- The ENTRY histogram which describes the platoon flow at the upstream end of the subject link. This histogram is simply an aggregation of the appropriate OUTPUT turn-movement-specific histograms of all feeder links.
- The INPUT histograms which describe the platoon flow pattern arriving at the stop line. These are obtained by first disaggregating the ENTRY histogram into turn-movement-specific component ENTRY histograms. Each such component is modified to account for the platoon dispersion which results as traffic traverses the link. The resulting INPUT histograms reflect the specified turn percentages for the subject link.
- The SERVICE histogram which describes the service rates for each turn movement. These service rates reflect the type of control device servicing traffic on this approach; if it is a signal, then this histogram reflects the specified movement-specific signal phasing. A separate model estimates service rates for each turn movement, given that the control is GO.

These data are provided for each network link:

- The QUEUE histograms that describe the time-varying ebb and growth of the queue formation at the stop line. These histograms are derived from the interaction of the respective IN histograms with the SERVICE histograms.
- The OUT histograms that describe the pattern of traffic discharging from the subject link. Each of the IN histograms is transformed into an OUT histogram by the control applied to the subject link. Each of these OUT histograms is added into the (aggregate) ENTRY histogram of its receiving link. This approach provides the model with the ability to identify the characteristics of each turn-movement-specific component of the traffic stream. Each component is serviced at a different saturation flow rate as is

[1] Lieberman, E. et al. 1980. Macroscopic Simulation for Urban Traffic Management: The TRAFLO Model, Volume 3: Analytical Developments for TRAFLO. Federal Highway Administration Report No. FHWA-RD-80-113.

the case in the real world. The logic recognizes when one component of the traffic flow encounters saturation conditions even if the others do not.

Algorithms provide estimates of delay and stops reflecting the interaction of the IN histograms with the SERVICE histograms. The logic also provides for properly treating spillback conditions reflecting queues extending from its host link, into its upstream feeder links.

A valuable feature is the ability to internally generate functions that relate mean speed to density on each link, given user-specified estimates of free-flow speed and saturation service rates for each link. Such relationships are essential in order to simulate traffic operations on freeways and rural roads, where signal control does not exist or where its effect is not the dominant factor in impeding traffic flow.

All traffic simulation models are data-intensive. Table C-2 outlines the input data elements. This input describes:

- Topology of the roadway system
- Geometrics of each roadway component
- Channelization of traffic on each roadway component
- Motorist behavior that, in aggregate, determines the operational performance of vehicles in the system
- Specification of the traffic control devices and their operational characteristics
- Traffic volumes entering and leaving the roadway system
- Traffic composition.

To provide an efficient framework for defining these specifications, the physical environment is represented as a network. The unidirectional links of the network generally represent roadway components: either urban streets or freeway segments. The nodes of the network generally represent urban intersections or points along the freeway where a geometric property changes (e.g. a lane drop, change in grade or ramp).

Figure C-1 is an example of a small network representation. The freeway is defined by the sequence of links (20, 21), (21, 22), and (22, 23). Links (8001, 19) and (3, 8011) are Entry and Exit links, respectively. An arterial extends from node 3 to node 19 and is partially subsumed within a grid network. Note that links (21, 22) and (17, 19) are grade-separated.

Table C-1. Measures of Effectiveness Output by PC-DYNEV	
Measure	**Units**
Travel	Vehicle-Miles and Vehicle-Trips
Moving Time	Vehicle-Minutes
Delay Time	Vehicle-Minutes
Total Travel Time	Vehicle-Minutes
Efficiency: Moving Time/Total Travel Time	Percent
Mean Travel Time per Vehicle	Seconds
Mean Delay per Vehicle	Seconds
Mean Delay per Vehicle-Mile	Seconds/Mile
Mean Speed	Miles/Hour
Mean Occupancy	Vehicles
Mean Saturation	Percent
Vehicle Stops	Percent

Table C-2. Input Requirements for the PC-DYNEV Model

GEOMETRICS

- Links defined by upstream and downstream node numbers
- Link lengths
- Number of lanes (up to 6)
- Turn pockets
- Grade
- Network topology defined in terms of target nodes for each receiving link

TRAFFIC VOLUMES

- On all entry links and sink/source nodes stratified by vehicle type: auto, car pool, bus, truck
- Link-specific turn movements

TRAFFIC CONTROL SPECIFICATIONS

- Traffic signals: link-specific, turn movement specific
- Signal control treated as fixed time
- Stop and Yield signs
- Right-turn-on-red (RTOR)
- Route diversion specifications
- Turn restrictions
- Lane control (e.g. lane closure, movement-specific)

DRIVER'S AND OPERATIONAL CHARACTERISTICS

- Drivers (vehicle-specific) response mechanisms: free-flow speed, aggressiveness, discharge headway
- Link-specific mean speed for free-flowing (unimpeded) traffic
- Vehicle-type operational characteristics: acceleration, deceleration
- Such factors as bus route designation, bus station location, dwell time, headway, etc.

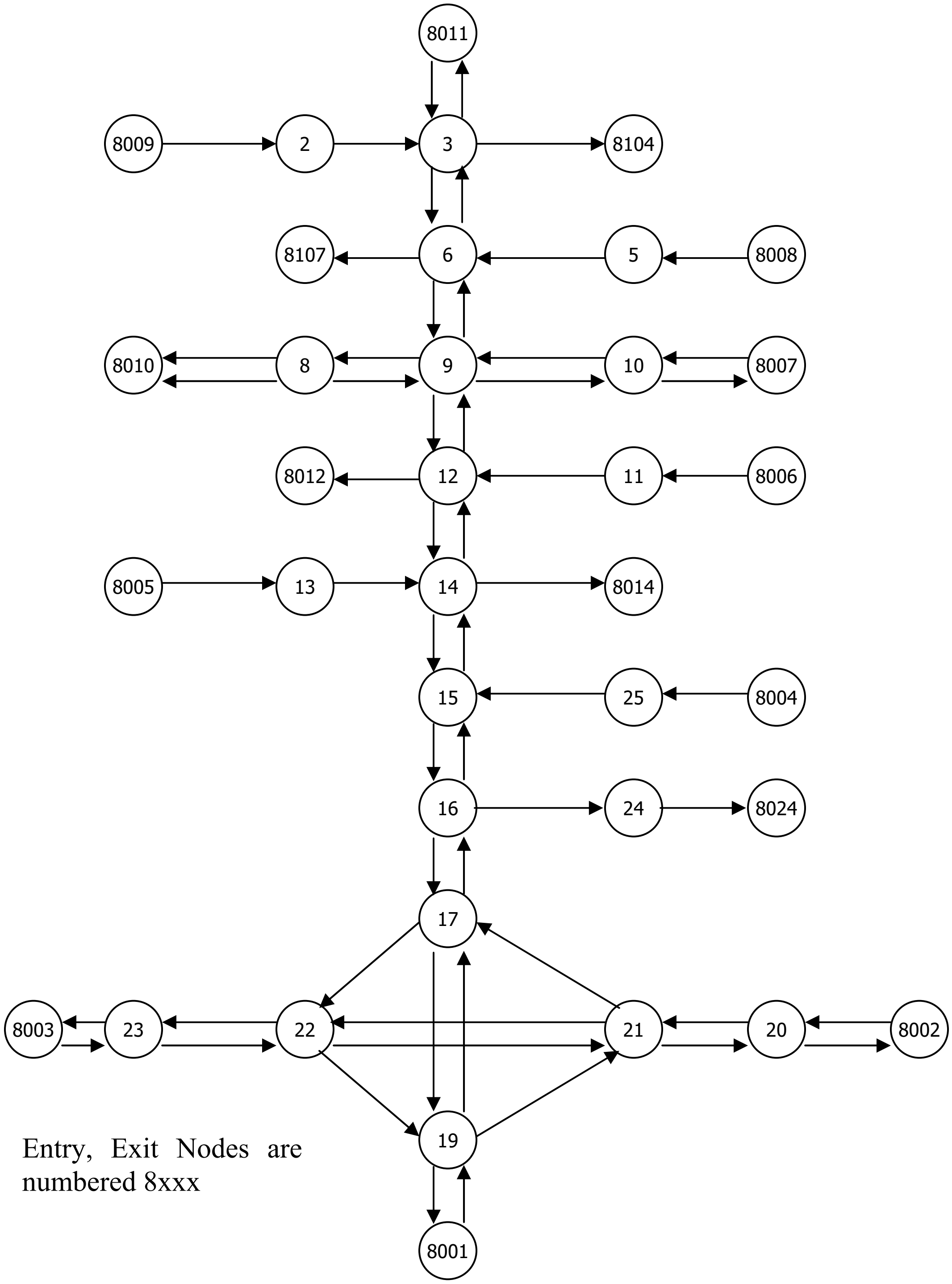


Figure C-1: Representative Analysis Network

APPENDIX D

Detailed Description of Study Procedure

APPENDIX D: DETAILED DESCRIPTION OF STUDY PROCEDURE

This appendix describes the activities that were performed to compute accurate Evacuation Time Estimates (ETE). The individual steps of this effort are represented as a flow diagram in Figure D-1. Each numbered step in the description that follows corresponds to the numbered element in this flow diagram.

Step 1.
The first activity is to obtain data defining the spatial distribution and demographic characteristics of the population within the Emergency Planning Zone (EPZ). These data were obtained from U.S. Census files and from the results of a telephone survey conducted within the EPZ. Data related to recreational areas, major employers and special facilities were obtained from a variety of sources including existing county and municipality emergency plans, internet searches, and telephone conversations with the facilities.

Step 2.
The next activity is to examine large-scale maps of the EPZ in both hard-copy form and using Geographical Information System (GIS) software. These maps were used to identify the analysis highway network and the access roads from each residential and employment development to the adjoining elements of this network. This information is used to plan a field survey of the highway system and later, to assign generated evacuation trips to the correct destinations at the periphery of the EPZ.

Step 3.
The next step is to conduct a physical survey of the roadway system. The purpose of this survey is to determine the geometric properties of the highway elements, the channelization of lanes on each section of roadway, whether there are any turn restrictions or special treatment of traffic at intersections, the type and functioning of traffic control devices and to make the necessary observations needed to estimate realistic values of roadway capacity. A tablet computer equipped with Global Positioning Satellites (GPS) technology together with video and audio recording equipment are used during the road survey to accurately record the position of traffic control devices and record other roadway data.

Step 4.
With this information, develop the evacuation network representation of the physical roadway system.

Step 5.
With the network created, proceed to estimate the capacities of each link and to locate the origin centroids where trips would be generated during the evacuation process.

Step 6.
With this information at hand, the data were entered into the computer to create the input stream for the TRaffic Assignment and Distribution (TRAD) model. This model was designed to be compatible with the PC-DYNEV traffic simulation model used later in the project; the input stream required for one model is entirely compatible with the input stream required by the other. Using a software system developed by KLD named UNITES, the data entry activity is performed interactively directly on the computer.

Step 7.
The TRAD model contains software that performs diagnostic testing of the input stream. These assist the user in identifying and correcting errors in the input stream.

Step 8.
After creating the input stream, execute the TRAD model to compute evacuating traffic routing patterns consistent with the guidelines of NUREG 0654, Appendix 4. The TRAD model also provides estimates of traffic loading on each highway link as well as rough estimates of operational performance.

Step 9.
Critically examine the statistics produced by the TRAD model. This is a labor-intensive activity, requiring the direct participation of skilled engineers who possess the necessary practical experience to interpret the results and to determine the causes of any problems reflected in the results.

Essentially, the approach is to identify those "hot spots" in the network that represent locations where congested conditions are pronounced and to identify the cause of this congestion. This cause can take many forms: excess demand; improper routing; a shortfall of capacity; a quantitative error in the way the physical system was represented in the input stream. This examination leads to one of two conclusions:

- The results are as satisfactory as could be expected at this stage of the analysis process; or
- The input stream must be modified accordingly.

This decision requires, of course, the application of the analyst's judgment based upon the results obtained in previous applications of the TRAD model and a comparison of the results of this last case with the previous ones. If the results are satisfactory in the opinion of the analyst, then the process continues with Step 12. Otherwise, proceed to Step 10.

Step 10.
There are many "treatments" available to the user in resolving such problems. These treatments range from decisions to reroute the traffic by imposing turn restrictions where they can produce significant improvements in capacity, changing the control treatment at critical intersections so as to provide improved service for one or more movements, or in prescribing specific treatments for channelizing the flow so as to expedite the movement of traffic along major roadway systems or changing the trip table. Such "treatments" take the form of modifications to the original input stream.

Step 11.
As noted above, the changes to the input stream must be implemented to reflect the modifications undertaken in Step 10. At the completion of this activity, the process returns to Step 8 where the TRAD model is again executed.

Step 12.
The output of the TRAD model includes the computed turn movements for each link. These data are required and accessed by the PC-DYNEV simulation model. This step completes the specification of the PC-DYNEV input stream.

Step 13.
After the PC-DYNEV input stream has been debugged, the simulation model is executed to provide detailed estimates, expressed as statistical Measures of Effectiveness (MOE), which describe the detailed performance of traffic operations on each link of the network.

Step 14.
In this step, the detailed output of the simulation model is examined to identify whether problems exist on the network. The results of the simulation model are extremely detailed and far more accurately describe traffic operations than those provided by the TRAD model. Thus, it is possible to identify the cause of any problems by carefully studying the output.

Again, one can implement corrective treatments designed to expedite the flow of traffic on the network in the event that the results are considered to be less efficient than is possible to achieve. If input changes are needed, the analysis process proceeds to Step 15. On the other hand, if the results are satisfactory, then one can decide whether to return to Step 8 to again execute the TRAD model and repeat the whole process, or to accept the simulation results. If there were no changes indicated by the activities of Step 14, because the results were satisfactory, we can then proceed to document them in Step 17. Otherwise, return to Step 8 to determine the effects of the changes implemented in Step 14 on the optimal routing patterns over the network. This determination can be ascertained by executing the TRAD model.