7 GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the current ETE results of the computer analyses using the DYNEV II System described in Appendices B, C, and D. These results cover 30 regions within the VCSNS EPZ and the 14 Evacuation Scenarios discussed in Section 6.

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

7.1 Voluntary Evacuation and Shadow Evacuation

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

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

Figure 7-2 presents the area identified as the Shadow Region. This region extends radially from the plant to cover a region between the EPZ boundary and approximately 15 miles. The population and number of evacuating vehicles in the Shadow Region were estimated using the same methodology used for permanent residents within the EPZ (see Section 3.1). As discussed in Section 3.2, it is estimated that a total of 52,851 people reside in the Shadow Region; 20 percent (10,570 residents) of them would evacuate. See Table 6-4 for the number of evacuating vehicles from the Shadow Region.

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

7.2 Staged Evacuation

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

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

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

See Section 5.4.2 for additional information on staged evacuation.

7.3 Patterns of Traffic Congestion during Evacuation

Figure 7-3 and Figure 7-4 illustrate the patterns of traffic congestion (or absence of congestion) that arise for the case when the entire EPZ (Region R03) is advised to evacuate during the summer, midweek, midday period under good weather conditions (Scenario 1).

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

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

All highway "links" which experience LOS F are delineated in these figures by a red line; all others are lightly indicated. Little to no congestion exists within the EPZ during the evacuation.

As shown in Figure 7-3, at 1:15 after the Advisory to Evacuate (ATE), some congestion is evident on eastbound US Highway 76 in the vicinity of Columbia within the Shadow Region, about 15 miles from VCSNS. Within the EPZ, I-26 operates at LOS B except for a section exiting the west of the EPZ, which operates at LOS C. A two mile section of US 76 exiting the west of the EPZ operates at a LOS B at this time. State Highway 215 experiences some congestion within the Shadow Region southeast of the plant; it operates at LOS B. Most of the other highway sections operate at LOS A.

Figure 7-4, at 2:15 after the ATE, indicates that the highways within the Shadow Region north of Columbia operate at LOS B and C. The congestion in the study area clears by 2:50 after the ATE. The sections of I-26 exiting the EPZ on the east and west, respectively, operate at LOS B. All other highway sections operate at LOS A.

All highway sections at 4:45 after the ATE which marks the conclusion of the trip-generation activity (See Section 5) are effectively clear of traffic. Thus, the ETE for the 100th percentile evacuation is dictated by the trip generation time. The 90th percentile ETE should be considered when making protective action decisions, as specified in NUREG/CR-7002. A public outreach (information) program to emphasize the advisability for evacuees to minimize the time needed to prepare to evacuate (secure the home, assemble needed clothes, medicines, etc.) should be considered.

7.4 Evacuation Rates

Evacuation is a continuous process, as implied by Figure 7-5 through Figure 7-18. These figures indicate the rate at which traffic flows out of the indicated areas for the case of an evacuation of the full EPZ (Region R03) under the indicated conditions. One figure is presented for each scenario considered.

As indicated in Figure 7-5, there is typically a long "tail" to these distributions. Vehicles begin to evacuate an area slowly at first, as people respond to the ATE at different rates. Then traffic demand builds rapidly (slopes of curves increase). If the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand.

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

The VCSNS ETE under all conditions is dictated by the trip mobilization time. The traffic congestion shown in Figure 7-3 and in Figure 7-4 is not material. Generally trips are generated over a 4 hour 45 minute period (see Table 5-8). Consequently the 100th percentile evacuation time is reflective of this value. The entire EPZ (100th percentile) is evacuated in under 5 hours.

7.5 Evacuation Time Estimate (ETE) Results

Table 7-1 and Table 7-2 present the ETE values for all 30 Evacuation Regions and all 14 Evacuation Scenarios. Table 7-3 and Table 7-4 present the ETE values for the 2-Mile region for both staged and un-staged (i.e., concurrent evacuation) evacuation of the 2 to 5 mile regions.

They are organized as follows:

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

The VCSNS ETE under all conditions reflects the trip mobilization time. Traffic congestion occurs only within a small portion of the Shadow Region and it dissipates after a short interval, well before the end of the trip generation process. Generally, trips are generated within a 4 hour 45 minutes period after the ATE for all weather conditions (see Table 5-8). Consequently the 100th percentile evacuation time represents this value. The entire EPZ is evacuated in just under 5 hours under good weather, rain, and ice conditions.

Comparison of Scenarios 6 and 13 in Table 7-1 indicates that the Special Event – construction of Units 2 and 3 at VCSNS in 2014 – has a slightly shorter 90th percentile ETE for the entire EPZ. The 90th percentile ETE for the 2-mile region (Region R01) is slightly longer because of the additional 4,158 construction vehicles evacuating from the VCSNS Site. The additional VCSNS construction employee traffic in PAZ A-0 mobilizes more quickly than the resident population (see Figure 5-4). As a result, given this "front-loading" of construction employee evacuation trips and the absence of congestion within the EPZ even with this additional traffic, the 90th percentile ETE for the 5-mile ring (Region R02) and the entire EPZ (Region R03) is shorter for Scenario 13 than the ETE shown for Scenario 6. The 100th percentile ETE are unaffected by the special event.

Comparison of Scenarios 1 and 14 in Table 7-1 and in Table 7-2 indicates that the lane closure – one lane eastbound on I-26 in Lexington County – does not have a material impact on the 90th or 100th percentile ETE. While state and local police could consider traffic management tactics such as using the shoulder of the roadway as a travel lane or re-routing traffic along other evacuation routes, such tactics were not considered in Scenario 14, and likely would not be needed as ETE are not impacted by the lane closure.

7.6 Staged Evacuation Results

Table 7-3 and Table 7-4 present a summary of the staged evacuation results. Regions R22 through R30 are geographically identical to Regions R02 and Regions R04 through R11, respectively; however, those subareas between 2 miles and 5 miles are staged until 90% of the 2-mile region (Region R01) has evacuated. These tables present the ETE for the 2 mile Region, R01, when each of the indicated regions extending to 5 miles, are evacuated. For example, the results presented for Region R22 in Table 7-3 and Table 7-4, indicate the ETE for Region R01, given that a SHELTER Advisory, followed by an ATE (staged evacuation), is issued for those PAZs between 2 and 5 miles within Region 22 (geographically equivalent to Region 02).

To determine whether the staged evacuation strategy is worthy of consideration, one must show that the ETE (shown in Table 7-3 and Table 7-4) for the 2 Mile region (R01) can be materially reduced without significantly affecting the ETE for the regions wherein the 2–mile radius and 5 miles downwind are evacuated. In all cases, as shown in these tables, the ETE for this 2 mile region shows little material change when a staged evacuation is implemented. This result reflects the absence of congestion when the evacuation is concurrent (i.e., not staged). Thus, staging the evacuation provides no benefits to evacuees from within the 2 mile region.

However, a comparison of 90th percentile ETE listed in Table 7-1 between Regions R22 and R02, between Regions R23 and R04, ..., and between Regions R30 and R11 reveals that the time spent sheltering the population in the 2-5 mile regions, could increase their ETE by up to 20 minutes. Thus staging the evacuation could increase the 90th percentile ETE for those within the 2-5 mile regions by a modest amount. There are no differences in 100th percentile ETE due to staging, since these ETE reflect only mobilization time, which is unaffected by staging the evacuation.

In summary, the staged evacuation option provides little material benefit to those people within the 2-mile region, while adversely impacting evacuees located beyond 2 miles from the plant.

7.7 Guidance on Using ETE Tables

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

1. Identify the applicable **Scenario**:
   - Season
     - Summer
     - Winter (also Autumn and Spring)
   - Day of Week
     - Midweek
     - Weekend
   - Time of Day
     - Midday

    - Evening
- Weather Condition
    - Good Weather
    - Rain
    - Ice
- Special Event
    - VCSNS Construction of Units 2 and 3 and Outage at Unit 1
    - Road Impact (a lane on I-26 eastbound is closed)
- Evacuation Staging for a 5-mile evacuation
    - No, Staged Evacuation is not considered
    - Yes, Staged Evacuation is considered

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

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

2. With the desired percentile ETE and Scenario identified, now identify the **Evacuation Region**:

- Determine the projected azimuth direction of the plume (coincident with the wind direction). This direction is expressed in terms of compass orientation: from N, NNE, NE, ...
- Determine the distance that the Evacuation Region will extend from the nuclear power plant. The applicable distances and their associated candidate Regions are given below:
    - 2 Miles (Region R01)
    - 5 Miles (Regions R02, R04 through R11)
    - to EPZ Boundary (Regions R03, R12 through R21)
- Enter Table 7-5 and identify the applicable group of candidate Regions based on the distance that the selected Region extends from the VCSNS Site. Select the Evacuation Region identifier in that row, based on the azimuth direction of the plume, from the first column of the table.

3. Determine the ETE Table based on the percentile selected. Then, for the Scenario identified in Step 1 and the Region identified in Step 2, as follows:
   - The columns of Table 7-1 are labeled with the Scenario numbers. Identify the proper column in the selected table using the Scenario number 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

<u>Example</u>

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

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

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

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to **Scenario 4**.
2. Enter Table 7-5 and locate the group of regions described as "Evacuate 5-Mile Radius and Downwind to the EPZ boundary;" then locate the row for wind direction from the **NE** and read **Region R18** in the first column of that row.
3. Enter Table 7-1 to locate the data cell containing the value of ETE for **Scenario 4** and **Region R18.** This data cell is in column (4) and in the row for **Region R18**; it contains the ETE value of **2:10.**

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

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

Table 7-1. (Continued from above)

	Summer		Summer		Summer	Winter			Winter			Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Ice	Good Weather	Rain	Ice	Good Weather	Special Event	Roadway Impact
Staged Evacuation - 2-Mile Ring and Keyhole to 5 Miles														
R22	2:15	2:15	2:00	2:00	2:00	2:15	2:15	2:15	2:00	2:00	2:00	2:00	1:55	2:15
R23	2:05	2:05	1:55	1:55	2:00	2:05	2:05	2:05	1:55	1:55	1:55	2:00	1:45	2:05
R24	2:10	2:10	2:00	2:00	2:00	2:10	2:10	2:10	2:00	2:00	2:00	2:00	1:50	2:10
R25	2:05	2:05	1:55	1:55	2:00	2:05	2:05	2:05	1:55	1:55	1:55	2:00	1:50	2:05
R26	2:00	2:00	1:50	1:50	2:00	2:00	2:00	2:00	1:50	1:50	1:55	2:00	1:50	2:00
R27	2:05	2:05	1:55	1:55	2:00	2:05	2:05	2:05	1:55	1:55	2:00	2:00	1:55	2:05
R28	2:00	2:00	1:55	1:55	2:00	2:00	2:00	2:00	1:55	1:55	1:55	2:00	1:50	2:00
R29	2:05	2:05	1:55	1:55	2:00	2:05	2:05	2:05	1:55	1:55	1:55	2:00	1:50	2:05
R30	2:00	2:00	1:55	1:55	2:00	2:00	2:00	2:05	1:55	1:55	1:55	2:00	1:45	2:00

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

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

Table 7-2. (Continued from above)

	Summer		Summer		Summer	Winter			Winter			Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Ice	Good Weather	Rain	Ice	Good Weather	Special Event	Roadway Impact
Staged Evacuation - 2-Mile Ring and Keyhole to 5 Miles														
R22	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R23	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R24	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R25	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R26	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R27	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R28	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R29	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50
R30	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50	4:50

Table 7-3. Time to Clear _90_ Percent of the 2-Mile Area within the Indicated Region

	Summer		Summer		Summer	Winter			Winter			Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Ice	Good Weather	Rain	Ice	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R01	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R02	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R04	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R05	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R06	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R07	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R08	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R09	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R10	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R11	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
Staged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R22	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R23	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R24	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R25	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R26	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R27	1:40	1:40	1:30	1:30	1:40	1:40	1:40	1:40	1:30	1:30	1:30	1:40	1:40	1:40
R28	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R29	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35
R30	1:35	1:35	1:30	1:30	1:35	1:35	1:35	1:35	1:30	1:30	1:30	1:35	1:40	1:35

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

	Summer		Summer		Summer	Winter			Winter			Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Ice	Good Weather	Rain	Ice	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R01	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R02	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R04	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R05	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R06	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R07	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R08	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R09	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R10	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R11	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
Staged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R22	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R23	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R24	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R25	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R26	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R27	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R28	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R29	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45
R30	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45	4:45

Table 7-5. Description of Evacuation Regions

Region	Description	Protective Action Zone												
		A-0	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2
R01	2-Mile Ring	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
Evacuate 2-Mile Radius and Downwind to 5 Miles														
Region	Wind Direction From:	Protective Action Zone												
		A-0	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2
R04	S, SSW	X	X		X									
R05	SW, WSW	X	X		X		X							
R06	W	X			X		X							
R07	WNW, NW	X					X							
R08	NNW, N	X					X				X			
R09	NNE, NE	X									X			
R10	ENE, E	X									X		X	
R11	ESE, SE, SSE	X	X										X	
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary														
Region	Wind Direction From:	Protective Action Zone												
		A-0	A-1	A-2	B-1	B-2	C-1	C-2	D-1	D-2	E-1	E-2	F-1	F-2
R12	S	X	X	X	X		X				X		X	
R13	SSW, SW	X	X	X	X	X	X				X		X	
R14	WSW, W	X	X		X	X	X	X			X		X	
R15	WNW, NW	X	X		X		X	X	X		X		X	
R16	NNW	X	X		X		X	X	X	X	X		X	
R17	N, NNE	X	X		X		X		X	X	X	X	X	
R18	NE	X	X		X		X			X	X	X	X	X
R19	ENE, E	X	X		X		X				X	X	X	X
R20	ESE	X	X		X		X				X		X	X
R21	SE, SSE	X	X	X	X		X				X		X	X

Table 7-5. (Continued from above)

Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles														
	Wind Direction From:	**Protective Action Zone**												
Region		**A-0**	**A-1**	**A-2**	**B-1**	**B-2**	**C-1**	**C-2**	**D-1**	**D-2**	**E-1**	**E-2**	**F-1**	**F-2**
R22	5-Mile Ring	X	X		X		X				X		X	
R23	S, SSW	X	X		X									
R24	SW, WSW	X	X		X		X							
R25	W	X			X		X							
R26	WNW, NW	X					X							
R27	NNW, N	X					X				X			
R28	NNE, NE	X									X			
R29	ENE, E	X									X		X	
R30	ESE, SE, SSE	X	X										X	
Shelter-in-Place until 90% ETE for R01, then Evacuate				PAZ(s) Shelter-in-Place					PAZ(s) Evacuate					

Figure 7-1. Voluntary Evacuation Methodology

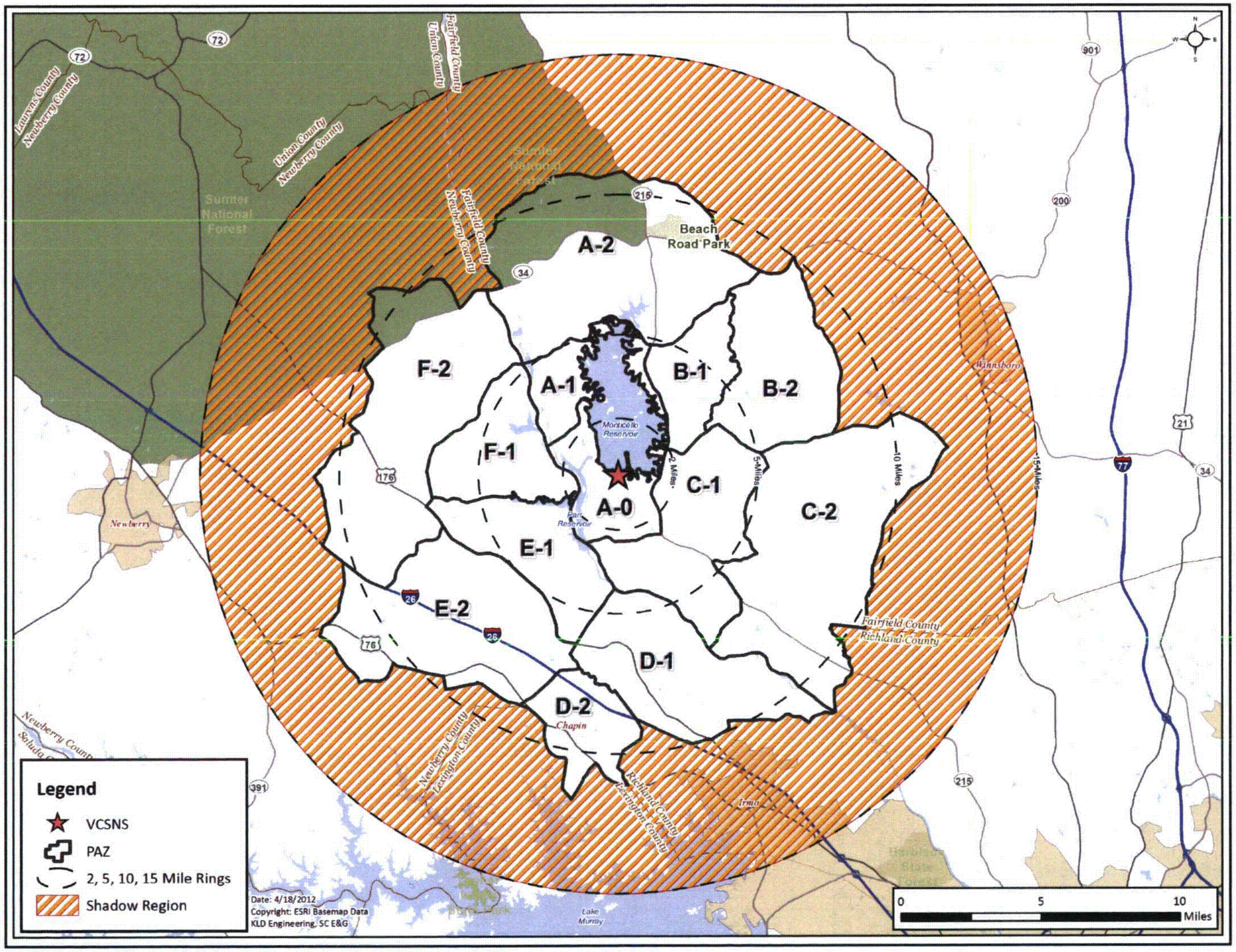


Figure 7-2.VCSNS Site Shadow Region

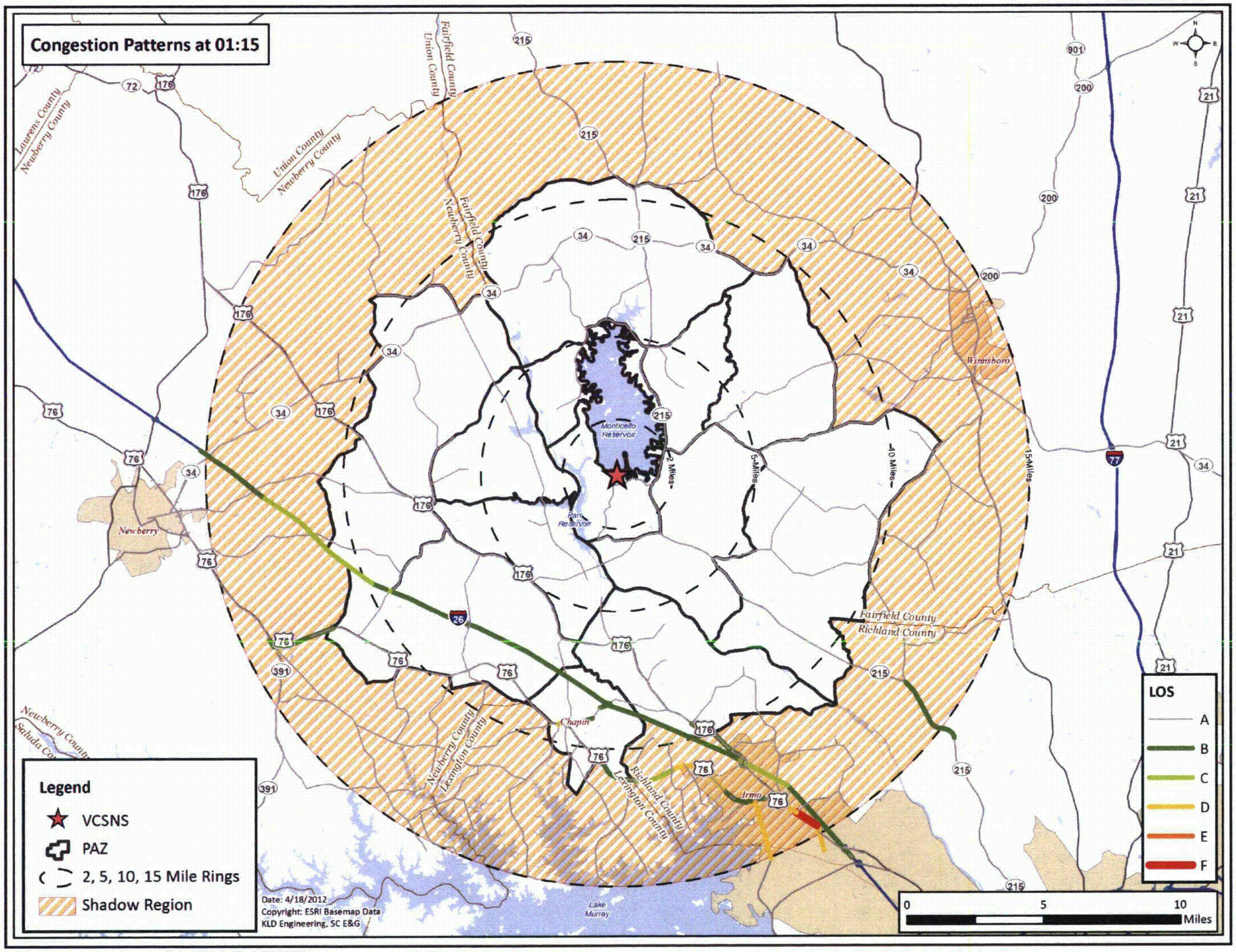


Figure 7-3. Congestion Patterns at 1:15 after the Advisory to Evacuate

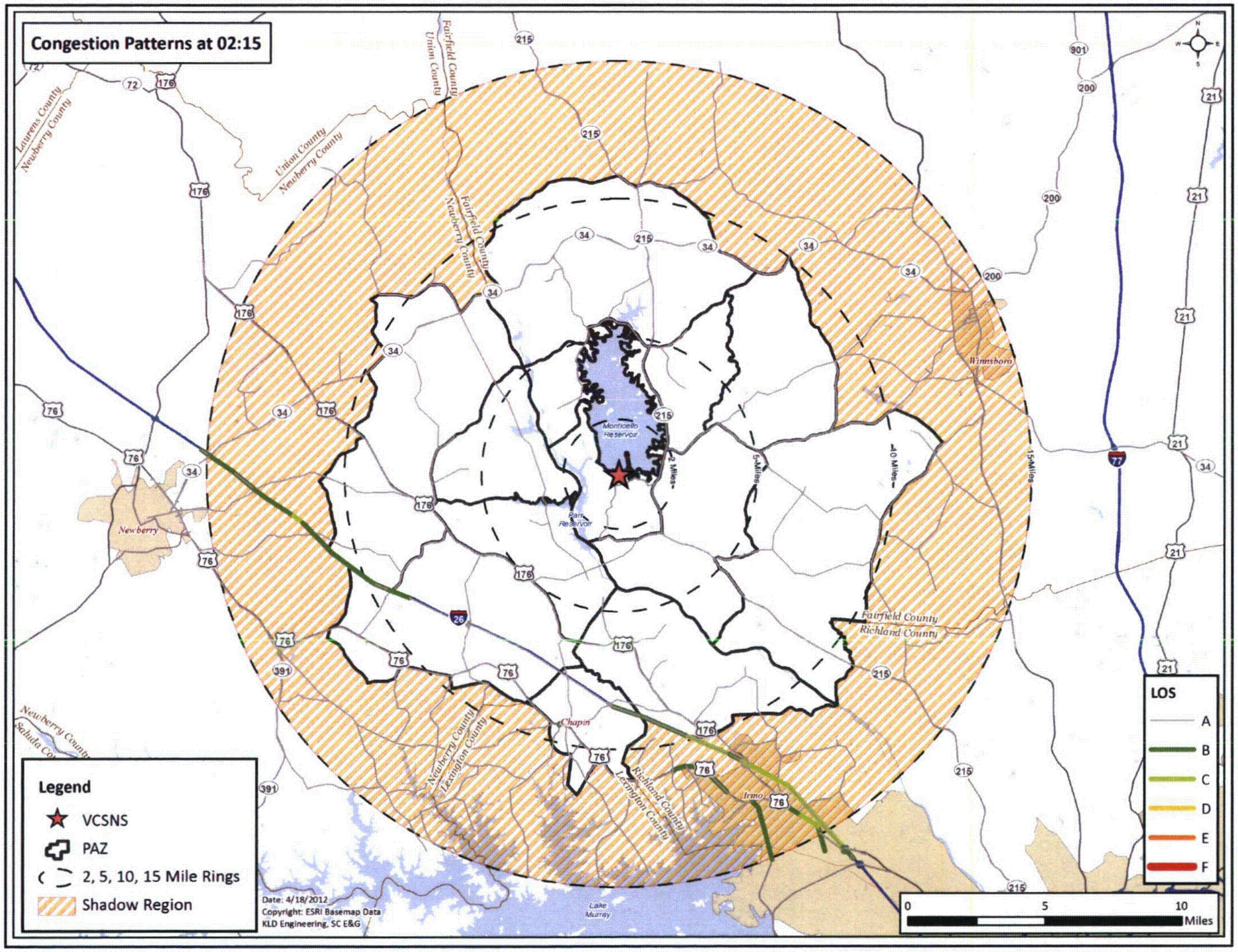


Figure 7-4. Congestion Patterns at 2:15 after the Advisory to Evacuate

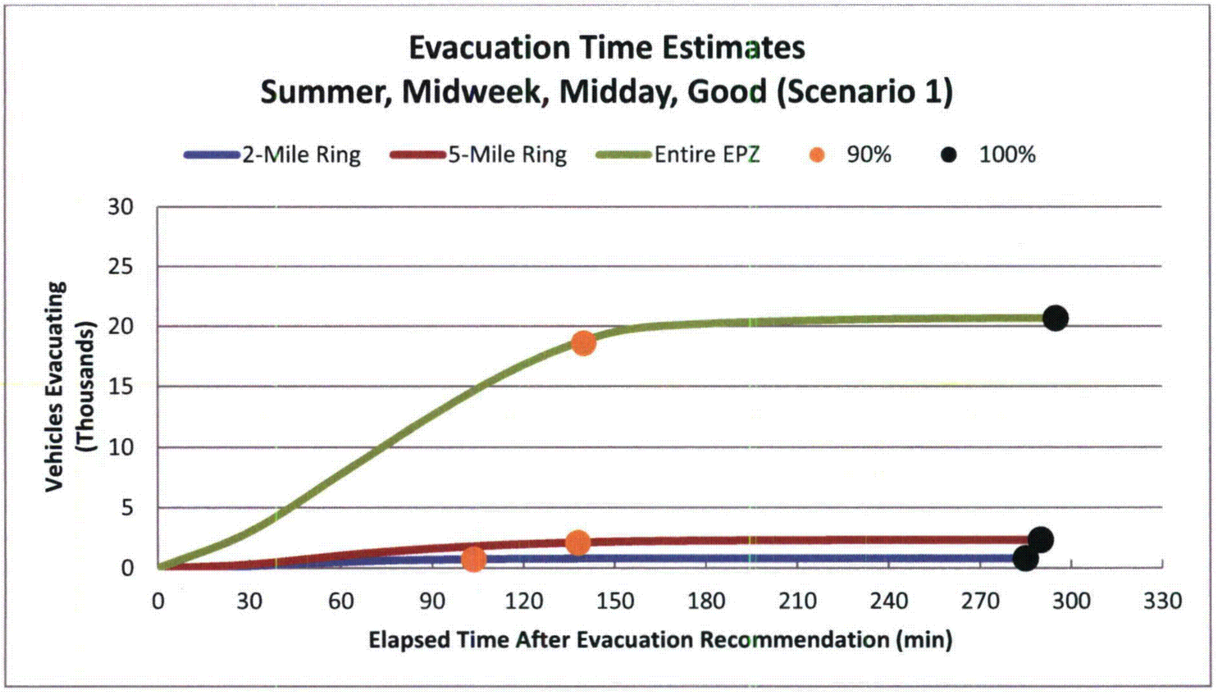


Figure 7-5. Evacuation Time Estimates - Scenario 1 for Region R03

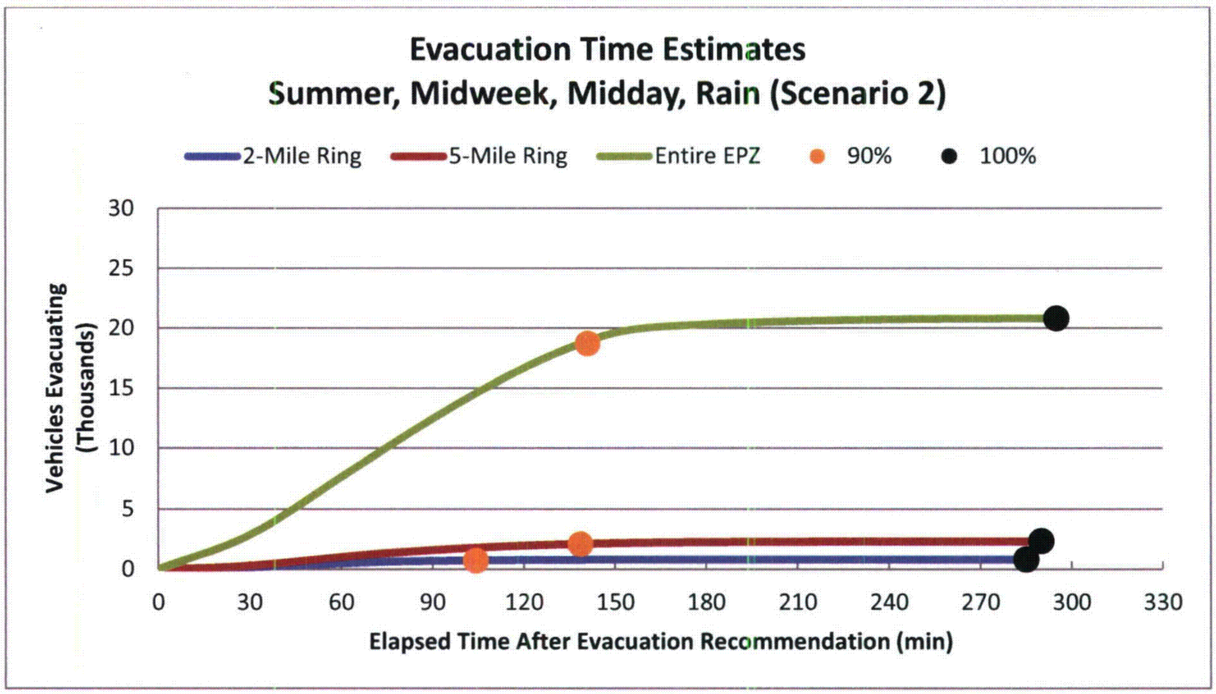


Figure 7-6.Evacuation Time Estimates - Scenario 2 for Region R03

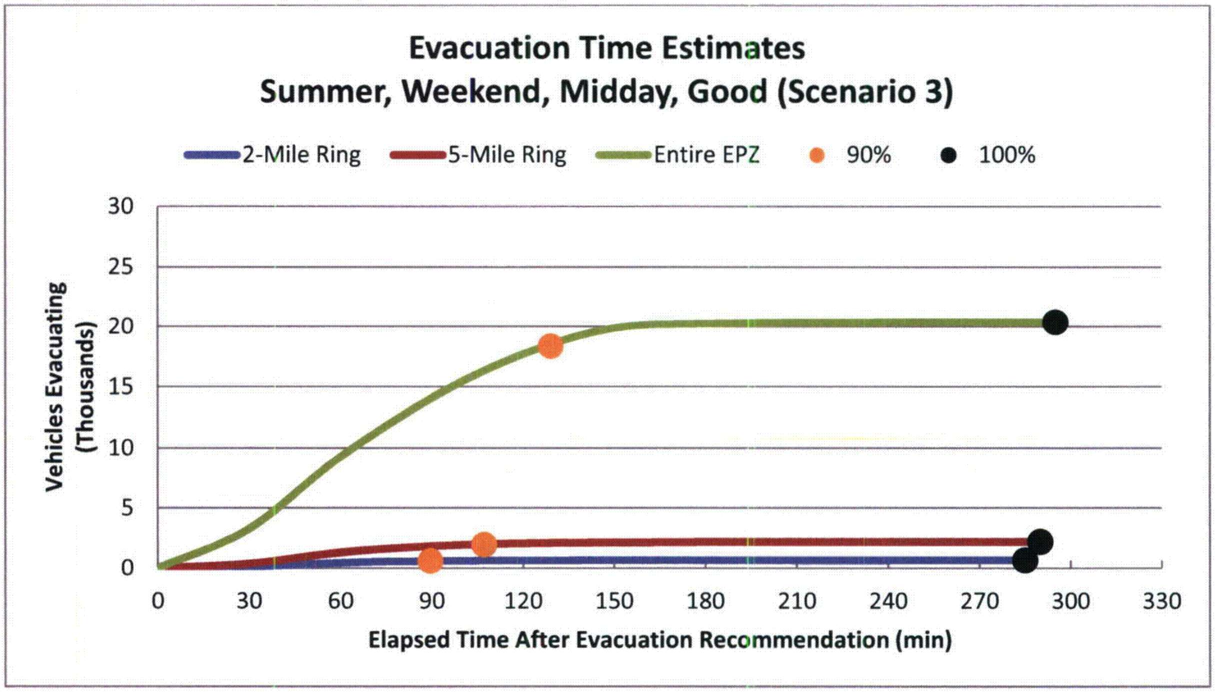


Figure 7-7.Evacuation Time Estimates - Scenario 3 for Region R03

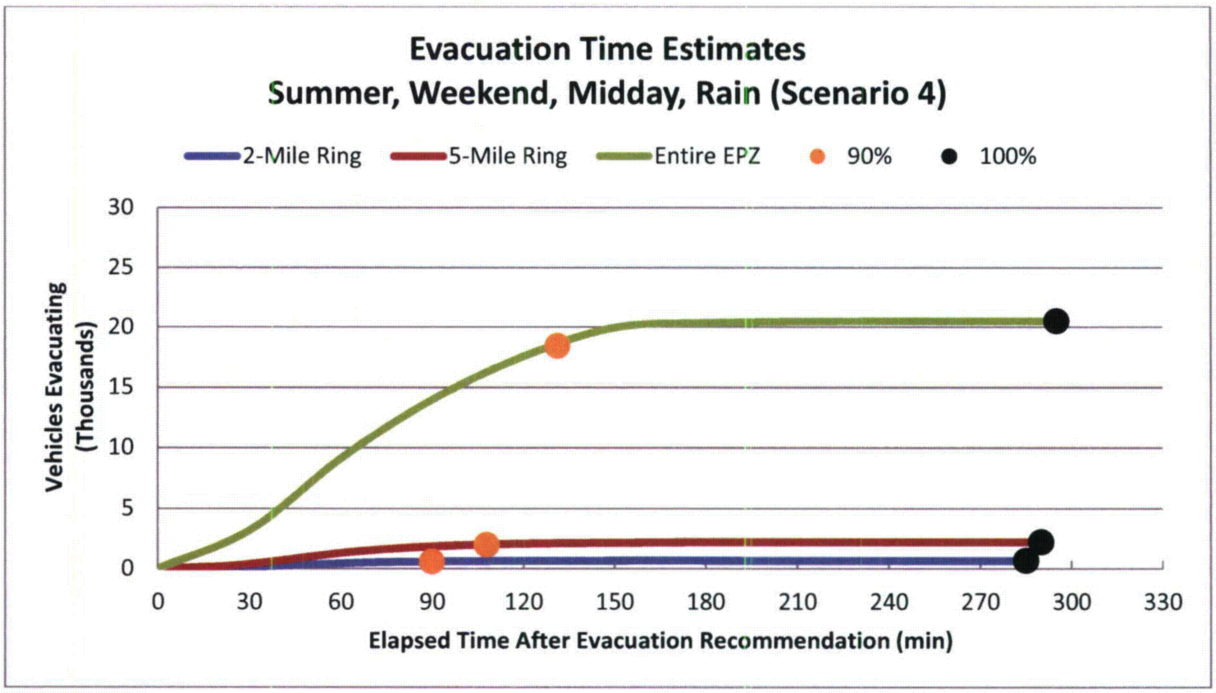


Figure 7-8.Evacuation Time Estimates - Scenario 4 for Region R03

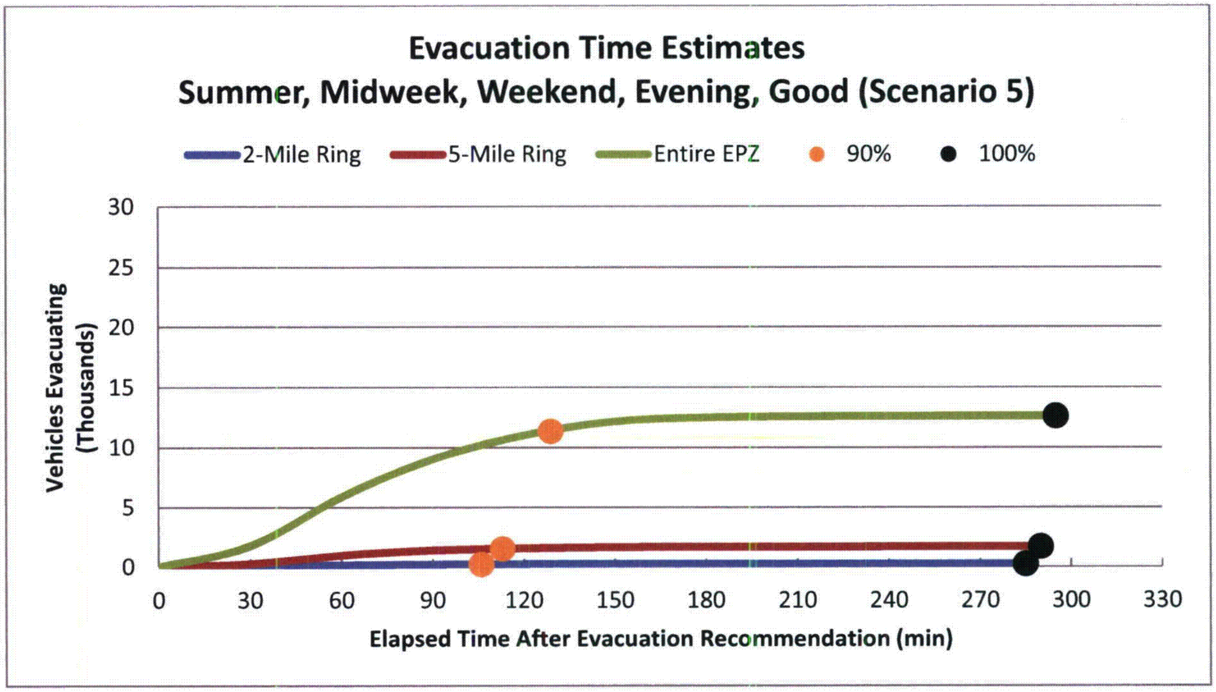


Figure 7-9. Evacuation Time Estimates - Scenario 5 for Region R03

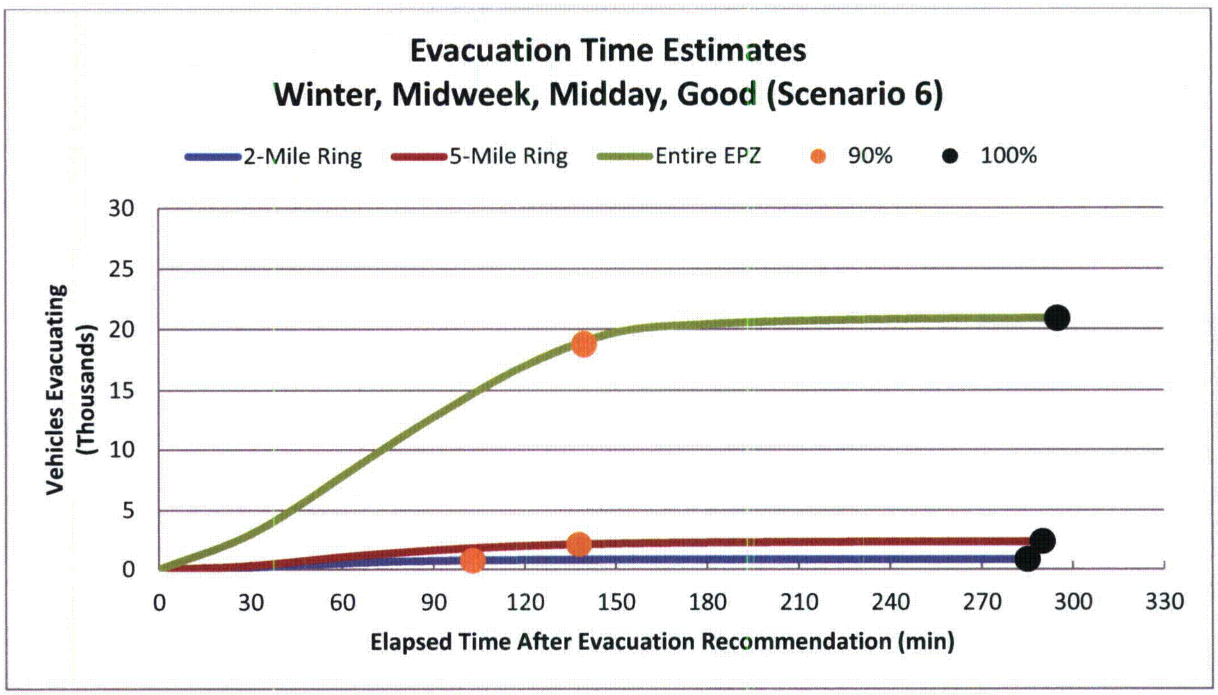


Figure 7-10. Evacuation Time Estimates - Scenario 6 for Region R03

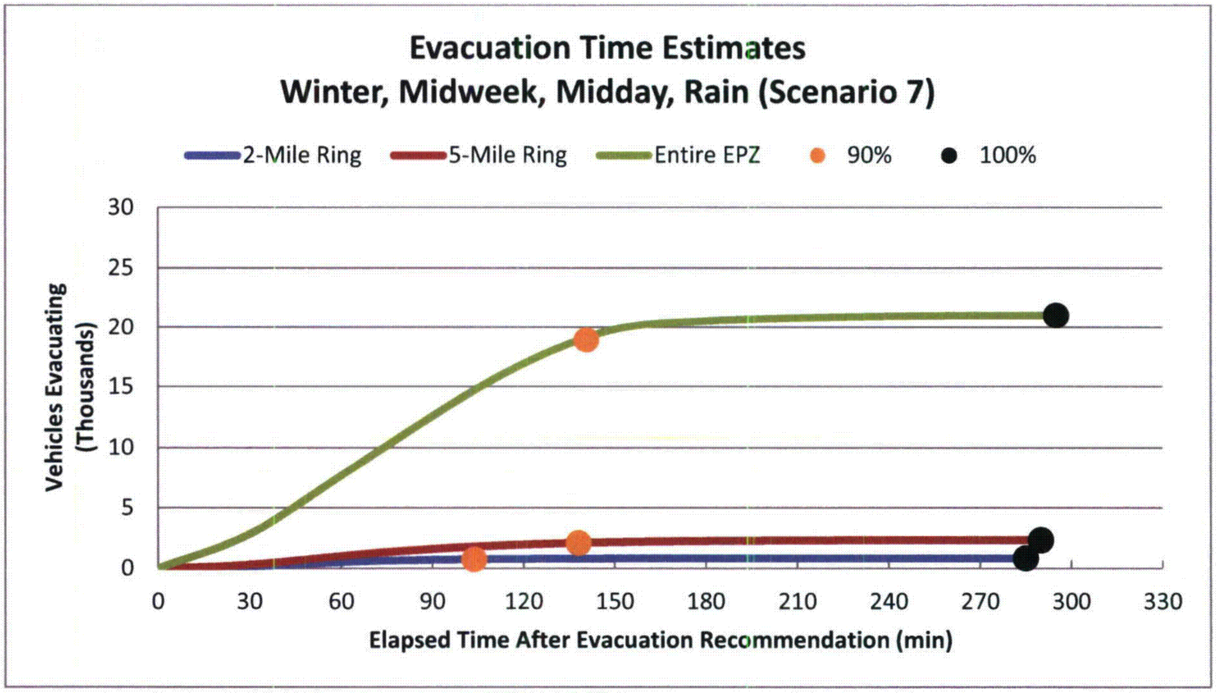


Figure 7-11. Evacuation Time Estimates - Scenario 7 for Region R03

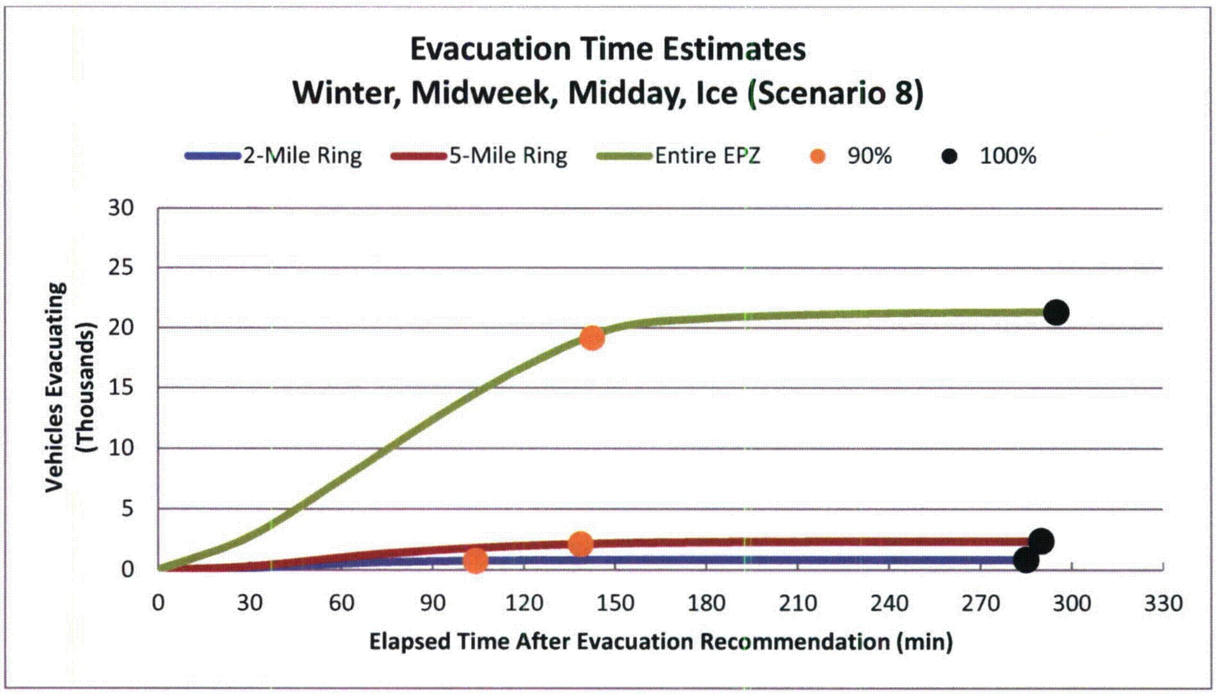


Figure 7-12. Evacuation Time Estimates - Scenario 8 for Region R03

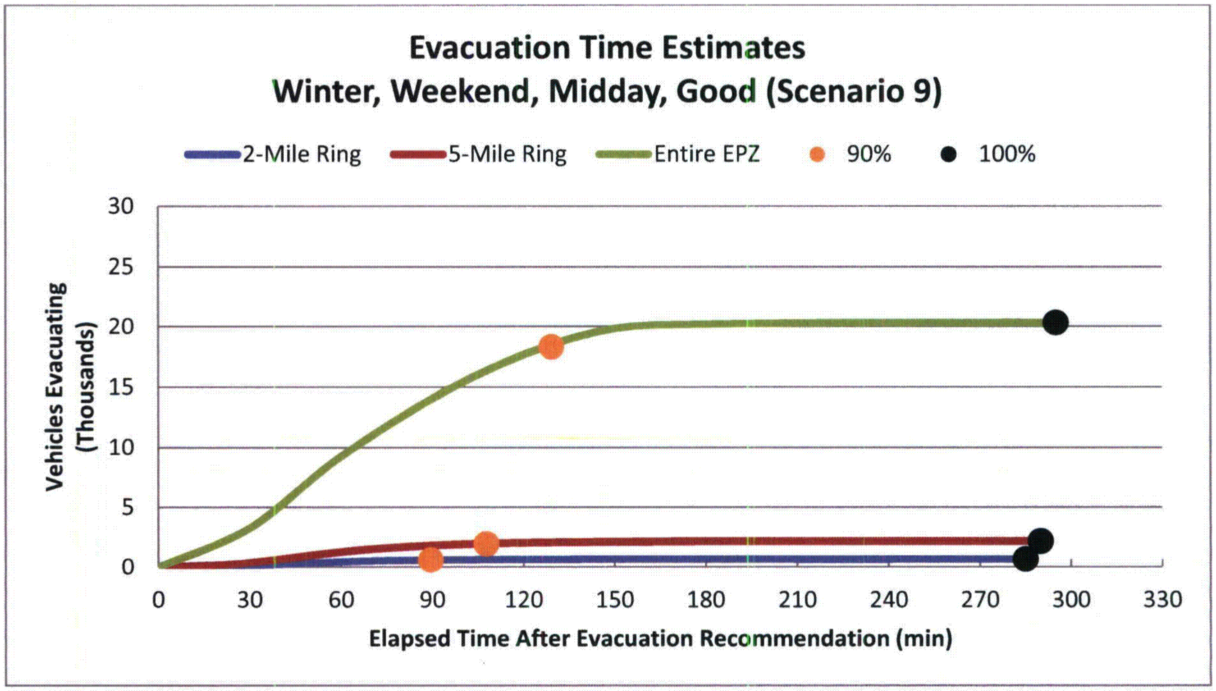


Figure 7-13. Evacuation Time Estimates - Scenario 9 for Region R03

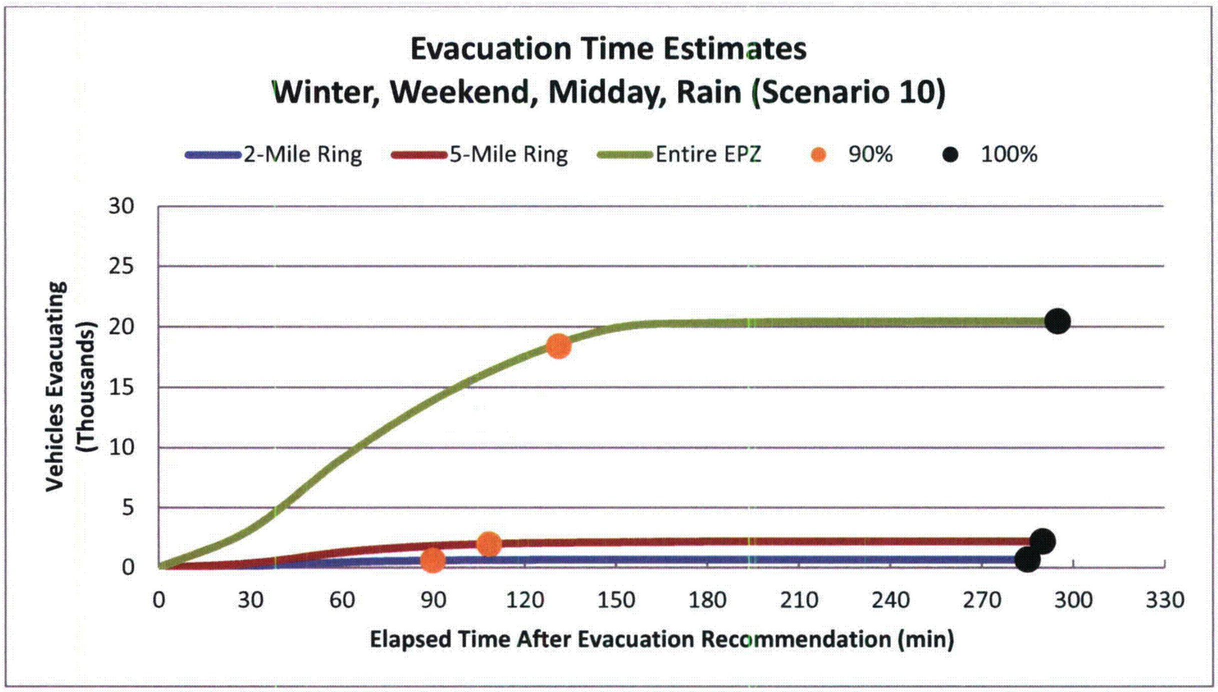


Figure 7-14. Evacuation Time Estimates - Scenario 10 for Region R03

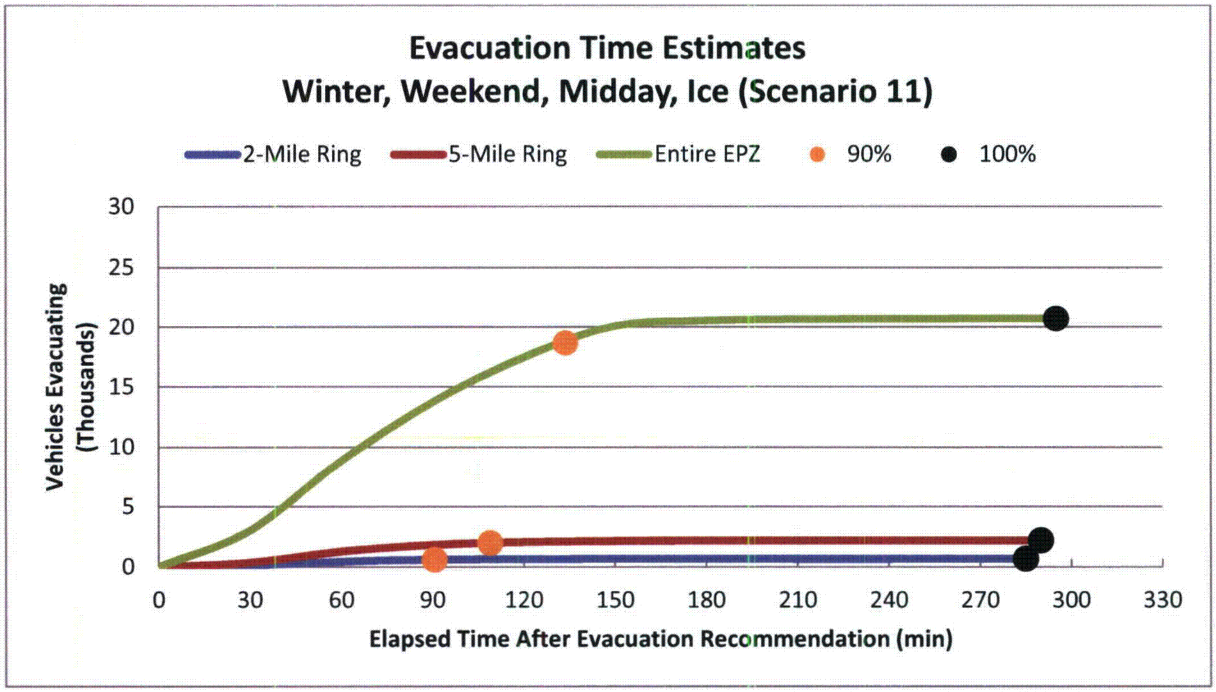


Figure 7-15. Evacuation Time Estimates - Scenario 11 for Region R03

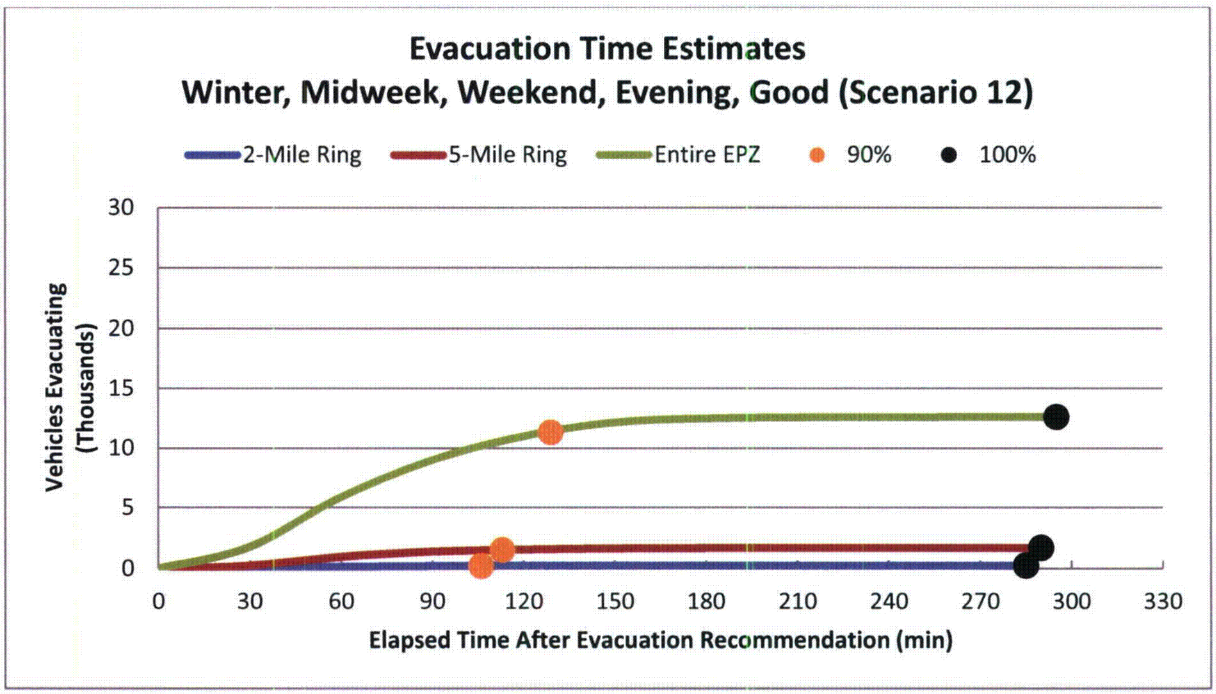


Figure 7-16. Evacuation Time Estimates - Scenario 12 for Region R03

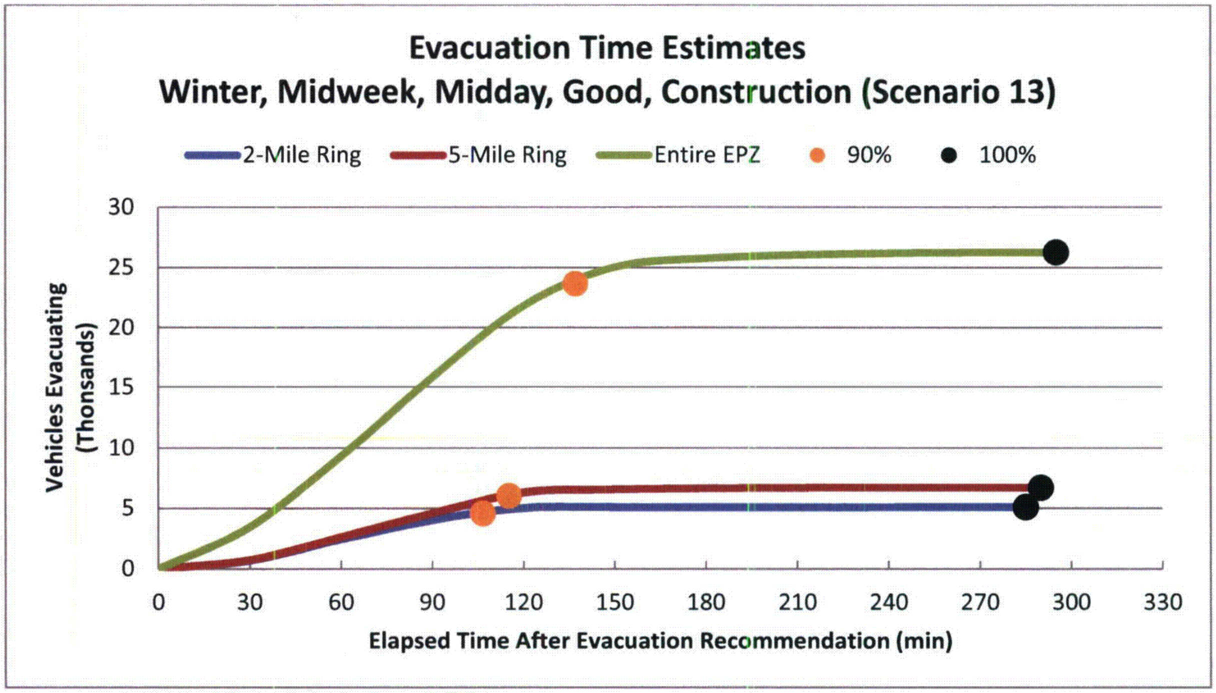


Figure 7-17. Evacuation Time Estimates - Scenario 13 for Region R03

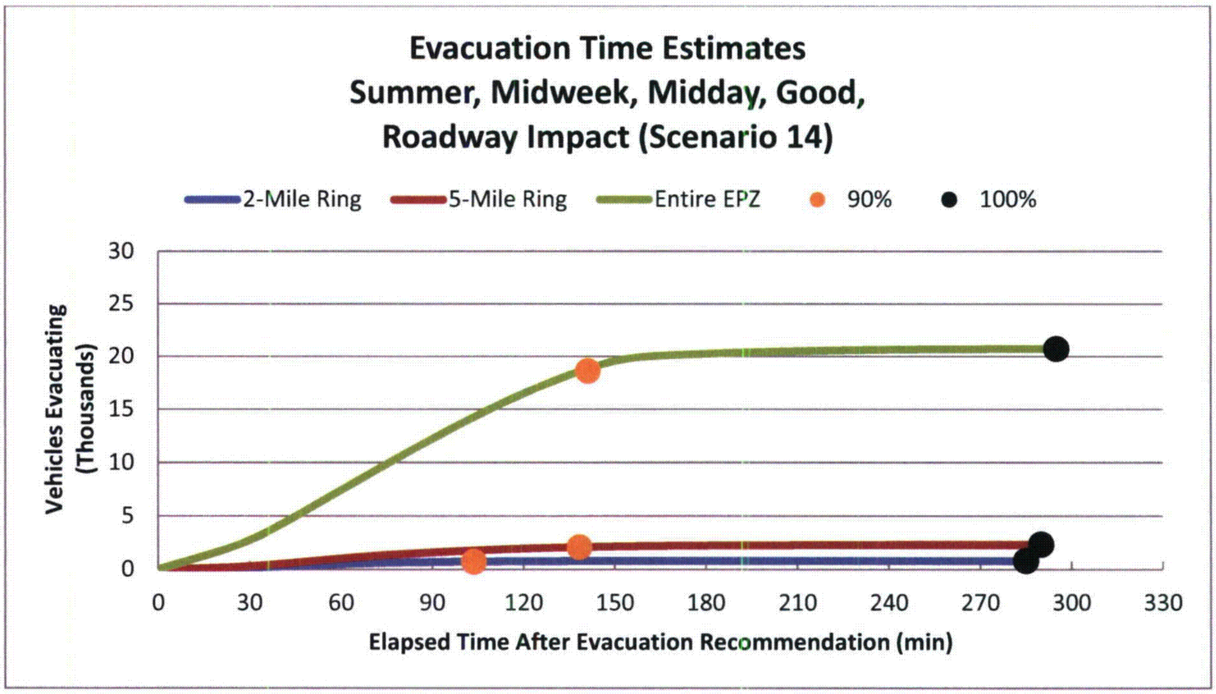


Figure 7-18. Evacuation Time Estimates - Scenario 14 for Region R03

8 TRANSIT-DEPENDENT AND SPECIAL FACILITY EVACUATION TIME ESTIMATES

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

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

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

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

These activities consume time. Discussions with the county emergency management agencies within the VCSNS EPZ indicate that buses for schoolchildren can be mobilized in 90 minutes, except for Lexington County who can mobilize their buses in 50 minutes. Buses used for transit dependents can be mobilized in 120 minutes except for Newberry County who can mobilize their transit buses in 60 minutes. Transit buses will be drawn from the Central Midlands Regional Transit Authority fleet based upon mutual aid agreements.

Bus mobilization time is measured from the Advisory to Evacuate (ATE) to the time when buses arrive at the facility to be evacuated.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives, and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this "bonding" process of uniting family units is universally prevalent during emergencies and should be anticipated in the planning process. The current emergency planning information disseminated to residents of the Virgil C. Summer Nuclear Station's EPZ indicates that parents should not pick up children at school; rather, they should pick up children at the appropriate reception center. Picking up children at school could add to traffic congestion at the schools, delaying the departure of the buses evacuating schoolchildren. The estimates of buses presented herein are developed under the assumption that no children will be picked up by their parents (in accordance with NUREG/CR-7002), to present an upper bound estimate of buses required. It is assumed that children at day-care centers are picked up by parents or guardians and that the time to perform this activity is captured in the trip generation times discussed in Section 5.

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 school reception centers

8.1 Transit Dependent People Demand Estimate

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

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

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

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

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

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

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

Table 8-1 indicates that transportation must be provided for 242 people. Therefore, a total of **9 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 VCSNS Site EPZ:

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

Where,

A = Percent of households with i vehicles, with commuters

C = Percent of households with i vehicles, who will not await the return of a commuter

$$P = 4{,}846 \times [0.048 \times 1.38 + 0.225 \times (1.8 - 1) \times 0.67 \times 0.22 + 0.385 \times (2.86 - 2) \times (0.67 \times 0.22)^2] = 484$$

$$B = (0.5 \times P) \div 30 = 9$$

These calculations are explained as follows:

- All members (1.38 avg.) of households (HH) with no vehicles (4.8%) will evacuate by public transit or ride-share. The term 4,846 (number of households) x 0.048 x 1.38, accounts for these people.
- The members of HH with 1 vehicle away (22.5%), who are at home, equal (1.8-1). The number of HH where the commuter will not return home is equal to (4,846 x 0.225 x 0.67 x 0.22), as 67% of EPZ households have a commuter, 22% of which would not return home in the event of an emergency. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms.
- The members of HH with 2 vehicles that are away (38.5%), who are at home, equal (2.86 – 2). The number of HH where neither commuter will return home is equal to 4,846 x 0.385 x $(0.67 \times 0.22)^2$. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms (the last term is squared to represent the probability that neither commuter will return).
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.
- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that are away from home.

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

8.2 School Population – Transit Demand

Table 8-2 presents the school population and transportation requirements for the direct evacuation of all schools within the EPZ for the 2010-2011 school year. This information was provided by local county emergency management agencies. 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
- All high school students except those in Chapin High School will use school buses to evacuate. Discussions with Chapin High School officials indicate they would permit students who drive to school to evacuate using their personal vehicles. This approach conforms to that cited in Section 2.4 of NUREG/CR-7002.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools
- Those staff members who do not accompany the students will evacuate in their private vehicles
- No allowance is made for student absenteeism, typically 3 percent daily

It is recommended that the counties in the EPZ introduce procedures whereby the schools are contacted prior to the dispatch of buses from the depot (approximately one hour after the Advisory to Evacuate for most schools), 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. Those buses originally allocated to evacuate schoolchildren that are not needed due to children being absent or 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 reception centers for each school in the EPZ. Students will be transported to these centers where they will be subsequently retrieved by their respective families.

8.3 Special Facility Demand

Table 8-4 presents the census of special facilities in the EPZ. Approximately 320 people have been identified as living in, or being treated in these facilities. The capacity and current census for each facility were provided by representatives from each facility. This census also indicates the number of ambulatory, wheelchair-bound, and bed-ridden people at each facility.

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

8.4 Evacuation Time Estimates for Transit Dependent People

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

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

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

Activity: Mobilize Drivers (A→B→C)

Driver mobilization is the elapsed time from the Advisory to Evacuate until the time the buses arrive at the facility to be evacuated. As discussed above, information provided by Fairfield and Richland Counties indicates that for a rapidly escalating radiological emergency with no observable indication before the fact, bus drivers would likely require 90 minutes to be contacted, to travel to the depot, be briefed, and to travel to the schools to be evacuated, and 120 minutes for the transit-dependent bus routes. Newberry County would also require 90 minutes for schools, but only 60 minutes for transit-dependent bus routes; Lexington County – 50 minutes for schools, 120 minutes for transit-dependent bus routes.

Activity: Board Passengers (C→D)

Based on discussions with offsite agencies, a loading time of 5 minutes (10 minutes for rain and 15 minutes for ice) for school buses is used.

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

$T = t + B + t = B + 2t = B + \frac{2v}{a}$, where B = Dwell time to service boarding passengers.

The total distance, "s" in feet, travelled during the deceleration and acceleration activities is:

$$s = v^2/a.$$

If the bus had not stopped to service passengers, but had continued to travel at speed, v, then its travel time over the distance, s, would be:

$$s/v, \text{ or } (v^2/a)/v = v/a.$$

Then the total delay (i.e. pickup time, P) to service passengers is:

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

Assigning reasonable estimates:

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

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

Activity: Travel to EPZ Boundary (D→E)

School Evacuation

Transportation resources available were provided by the EPZ county emergency management agencies and are summarized in Table 8-5. Also included in the table are the number of buses needed to evacuate medical facilities, transit-dependent population, and homebound special needs (discussed below in Section 8.5).

Comparison of the available bus resources in Table 8-5 with the number of buses needed shown in Table 8-2 indicates that Newberry County School District does not have sufficient resources to evacuate schoolchildren in a single wave. However, it was confirmed with Newberry County Officials that Mutual Aid Agreements (MAA) with schools outside of the EPZ exist to help evacuate the students in a single wave.

The buses servicing the schools in Fairfield, Newberry, and Richland Counties are ready to begin their evacuation trips at 95 minutes after the advisory to evacuate – 90 minutes mobilization time plus 5 minutes loading time. Lexington County has practiced bus mobilization and confirmed that buses will arrive at the school within 50 minutes, thus their route start time is 55 minutes. The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely path to the EPZ boundary from a school being evacuated, traveling toward the appropriate reception center. This is done in UNITES by interactively selecting the sequence of nodes from the school to the EPZ boundary. The bus route is given an identification number and is written to the DYNEV II input stream. DYNEV II computes the route length and outputs the average speed for each 5 minute interval over the duration of the evacuation, for each bus route. The bus routes input are documented in Table 8-6 (refer to the maps of the link-node analysis network in Appendix K for node locations). Data from 95 minutes (55 minutes for

Lexington County) after the advisory to evacuate were used. The average speed along the route using the data generated by DYNEV II was computed as follows:

$$Average\ Speed\ \left(\frac{mi.}{hr}\right) = \left[\frac{\sum_1^n length\ of\ link\ i\ (mi)}{\sum_1^n Service\ time\ on\ link\ i\ (min.) + \frac{length\ of\ link\ i\ (mi.)}{current\ speed\ on\ link\ i\ \left(\frac{mi.}{hr.}\right)} \times \frac{60\ min.}{1\ hr.}}\right] \times \frac{60\ min.}{1\ hr.}$$

The average speed computed (using this methodology) for the buses servicing each of the schools in the EPZ is shown in Table 8-7 through Table 8-9 (good weather, rain, ice), and in Table 8-11 through Table 8-13 (good weather, rain, ice) for the transit vehicles evacuating transit-dependent persons, which are discussed later. The travel time to the EPZ boundary was computed for each bus using the computed average speed and the distance to the EPZ boundary along the most likely route out of the EPZ. The travel time from the EPZ boundary to the Reception Center was computed assuming an average speed of 45 mph, 40 mph, and 35 mph for good weather, rain, and ice respectively. Speeds were reduced in Table 8-7 through Table 8-9 and in Table 8-11 through Table 8-13 to 45 mph, 40 mph, and 35 mph (good weather, rain and ice, respectively) for those calculated bus speeds which exceed 45 mph (40 – rain, 35 – ice), to conform to state school bus speed limits.

Table 8-7 (good weather), Table 8-8 (rain), and Table 8-9 (ice) present the following evacuation time estimates (rounded up to the nearest 5 minutes) for schools in the EPZ: (1) The elapsed time from the Advisory to Evacuate until the bus exits the EPZ; and (2) The elapsed time until the bus reaches the School Reception Center. The evacuation time out of the EPZ can be computed as the sum of travel times associated with Activities A→B→C, C→D, and D→E (For example: 90 min. + 5 + 3 = 1:40 for Kelly Miller Elementary School, with good weather, rounded up to the nearest 5 minutes). The evacuation time to the Reception Center is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

Evacuation of Transit-Dependent Population

The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As shown in Figure 5-4 (Residents without Commuters), approximately 90 percent of the evacuees will complete their mobilization when the buses will begin their routes, approximately 120 minutes for all counties except Newberry County after the Advisory to Evacuate. Note that only approximately 65 percent of evacuees have mobilized when buses begin routes in Newberry County, 60 minutes after the ATE. Those transit-dependents in Newberry County not serviced by the first wave of transit-dependent buses will be picked up by the second wave buses which arrive later.

Those buses servicing the transit-dependent evacuees will first travel along their pick-up routes, then proceed out of the EPZ. Buses will travel along the major routes in the EPZ as described in Table 8-10 and shown graphically in Figure 8-2.

The bus route for Richland County was provided to KLD by emergency management representatives. The bus routes for the remaining three counties were designed by KLD to service the major routes through each PAZ. Residents will walk to and congregate at these pre-designated evacuation routes, according to the county emergency plans. It is assumed that they can arrive at the stops within the 120 minute mobilization time (good weather) for buses, 60 minutes for Newberry County. There is one bus route each for Richland, Fairfield, and Lexington Counties; two routes are considered for Newberry County. Each route has two assigned buses except for Route 15 (See Table 8-10) which was assigned a single bus. Routes with two buses follow the same path with a headway of 20 minutes between buses for people who mobilize more slowly, as shown in Table 8-11.

As previously discussed, a pickup time of 30 minutes is estimated for 30 individual stops to pick up passengers, with an average delay of one minute associated with each stop. An increase is applied for rain and ice conditions.

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

Table 8-11, Table 8-12, and Table 8-13 present the transit-dependent population evacuation time estimates for each bus route calculated using the above procedures for good weather, rain, and ice respectively.

For example, the ETE for the Richland County Transit Dependent Bus Route is computed as 120 + 48 + 30 = 3:20 for good weather (rounded to nearest 5 minutes). Here, 48 minutes is the time to travel 36.2 miles at 45 mph, the average speed output by the model for this route at 120 minutes. The ETE for a second wave (discussed below) is presented in the event there is a shortfall of available buses or bus drivers and to service those people who mobilize in more than 120 minutes for Lexington, Richland, and Fairfield County or 60 minutes for Newberry County.

<u>Activity: Travel to Reception Centers (E→F)</u>

The distances from the EPZ boundary to the reception centers are measured using Geographical Information Systems (GIS) software along the most likely route from the EPZ to the reception center. The reception centers are mapped in Figure 10-1. For a one-wave evacuation, this travel time outside the EPZ does not contribute to the ETE. For a two-wave evacuation, travel time outside the EPZ does need to be considered. Assumed bus speeds of 45 mph, 40 mph, and 35 mph for good weather, rain, and ice, respectively, will be applied for this activity for buses servicing the transit-dependent population.

<u>Activity: Passengers Leave Bus (F→G)</u>

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

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

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

The second-wave ETE for the Richland County Transit Dependent bus route is computed as follows for good weather:

- Bus arrives at reception center at 3:35 (3:20 ETE to exit EPZ + 15 minute travel time to reception center) in good weather
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes
- Bus returns to EPZ and completes a second route: 15 minutes (Same time as Travel Time to Reception Center) + 48 minutes (36.2 miles @ 45 mph) = 63 minutes
- Bus completes pick-ups along route: 30 minutes
- Bus exits EPZ at time 3:20 + 0:15 + 0:15 + 0:15 + 0:48 + 0:30 = 5:25 (rounded to nearest 5 minutes) after the Advisory to Evacuate

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

Any subsequent relocation of transit-dependent evacuees from the reception centers to congregate care centers is not considered in this study.

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

Table 8-4 indicates that 9 bus runs, 3 wheelchair bus runs, and 7 ambulance runs are needed to service all of the special facilities in the EPZ. According to Table 8-5, the counties can collectively provide 136 buses, 3 vans, and 25 wheel-chair accessible buses. Thus, there are sufficient resources to evacuate the ambulatory and wheelchair bound persons from the special facilities in a single wave. There are not sufficient ambulances to transport the bedridden people; however, Lexington Medical Center confirmed Mutual Aid Agreements exist with Medshore Ambulance to supply 37 ambulances and 3 wheelchair vans, if needed. Lexington Medical Center also has MAAs with Lexington County to supply buses if needed.

It is assumed that mobilization time is 90 minutes for medical facilities. Specially trained medical support staff (working their regular shift) will be on site to assist in the evacuation of patients. These people are expected to evacuate in their personal vehicles. Additional staff (if needed) could be mobilized over this same 90 minute timeframe.

Based on the locations of the medical facilities in Figure E-2, it is estimated that buses will have to travel 3 miles, on average, to leave the EPZ. The average speed output by the model at 90 minutes for Region 3, Scenario 1 is 58.83 mph (capped at 45 mph for good weather; 40 mph for rain; 35 mph for ice) Thus, travel time out of the EPZ is approximately 4 minutes for good weather, 5 minutes for rain and ice.

The ETE for buses evacuating ambulatory patients at medical facilities is the sum of the mobilization time, total passenger loading time, and travel time out of the EPZ. For example, the calculation of ETE for Generations of Chapin with 30 ambulatory residents is (rounded up to the nearest 5 minutes):

ETE: 90 + 30 x 1 + 4 = 124 min. or 2:05

Rain ETE: 100 + 30 x 1 + 5 = 2:15

Ice ETE: 110 + 30 x 1 + 5 = 2:25

The ETE for buses evacuating wheelchair-bound patients at medical facilities assumes a loading time of 5 minutes per wheelchair bound person as staff will have to assist them in boarding the bus. For example, the ETE for the wheelchair bound at Generations of Chapin with 15 wheelchair-bound patients is (rounded to the nearest 5 minutes) (assuming concurrent loading on multiple buses with a capacity of 15 patients):

ETE: 90 + 15 x 5 + 4 = 2:50

Rain ETE: 100 + 15 x 5 + 5 = 3:00

Ice ETE: 110 + 15 x 5 + 5 = 3:10

The ETE for ambulances evacuating bedridden patients at medical facilities assumes 15 minutes loading time per bedridden person as staff will have to assist them in boarding an ambulance. For example, the ETE for the bedridden patients at Generations of Chapin with 3 bedridden patients is (rounded to the nearest 5 minutes) (assuming concurrent loading on multiple ambulances with a capacity of 2 patients):

ETE: 90 + 2 x 15 + 4 = 2:05

Rain ETE: 100 + 2 x 15 + 5 = 2:15

Ice ETE: 110 + 2 x 15 + 5 = 2:25

If a second wave is needed, the host facility is located near Columbia or in Newberry. The route to the host facility is 20 miles and requires 27 minutes of travel in good weather (30 – rain, 35 minutes - ice), 30 minutes to unload both passengers at host facility, 27 minutes (30 – rain, 35 - ice) to travel back to the original medical facility, a loading time of 15 minutes per bedridden person (2 per ambulance) and a travel time of 5 minutes to leave the EPZ on the second wave, yields:

Second Wave

ETE: 2:05 + 0:27 + 0:30 + 0:27 + 0:30 + 0:05 = 4:05 (rounded to the nearest 5 minutes)

Rain ETE: 2:15 + 0:30 + 0:30 + 0:30 + 0:30 + 0:05 = 4:20

Ice ETE: 2:25 + 0:35 + 0:30 + 0:35 + 0:30 + 0:05 = 4:40

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

8.5 Special Needs Population

Based on data provided by the county emergency management agencies, there are an estimated 185 homebound special needs people within the VCSNS EPZ. Of these people, 83 require special transportation to evacuate. A total of 17 people are bed-ridden and require an ambulance to evacuate, totaling 9 ambulances. There are 38 wheelchair bound homebound special needs people who require wheelchair vans to evacuate, totaling 3 wheelchair buses. Twenty eight of the homebound special needs people are ambulatory, requiring only 1 bus to accommodate these people (although additional buses will be used – see below).

ETE for Homebound Special Needs Persons

Wheelchair Vans

Section 8.3 identifies a wheelchair van capacity of 4 wheelchairs per trip; therefore 10 wheelchair vans are needed for these 38 people. However, as noted in Table 8-5, there are limited resources for wheelchair vans and a surplus of wheelchair buses. Thus, wheelchair buses will be used to evacuate these 38 people. It is assumed that 10 buses will each service 4 households (HH). It is further assumed that the households are spaced 3 miles apart, and that van speeds approximate 30 mph between households in good weather (10% slower in rain, 20% slower in ice). The last households is assumed to be 5 miles from the EPZ boundary, and speeds of 45, 40, and 35 mph are used for good weather, rain and ice, respectively. All ETE are rounded to the nearest 5 minutes.

a. Assumed mobilization time for wheelchair bus resources to arrive at first household: 90 minutes (100 minutes in rain; 110 minutes in ice)
b. Loading time at first household: 5 minutes (as discussed above in Section 8.4)
c. Travel time to subsequent households: 3 @ 6 minutes (3 miles @ 30 mph, 27 mph in rain; 24 mph in ice) = 18 minutes (20 minutes in rain; 22 minutes in ice)
d. Loading time at subsequent households: 3 @ 5 minutes = 15 minutes
e. Travel time to EPZ 5 miles @ 45 mph (10% slower, 41 mph in rain; 36 mph in ice) = 7 minutes (8 minutes in rain; 9 minutes in ice)

ETE: 90 + 5 + 18 + 15 + 7 = 2:15

Rain ETE: 100 + 5 + 20 + 15 + 8 = 2:30

Ice ETE: 110 + 5 + 22 + 15 + 9 = 2:40

From a capacity perspective (15 wheelchairs per bus), fewer buses could have been used. However, buses would have to make additional stops resulting in prolonged ETE.

Buses

Assuming no more than one special needs person per household implies that 28 households need to be serviced. While only 1 bus is needed from a capacity perspective, if 4 buses are deployed to service these special needs HH, then each would require about 7 stops. The following outlines the ETE calculations:

1. Assume 4 buses are deployed, each with about 7 stops, to service a total of 28 HH
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 90 minutes
    b. Load HH members at first pickup: 5 minutes
    c. Travel to subsequent pickup locations: 6 @ 6 minutes = 36 minutes
    d. Load HH members at subsequent pickup locations: 6 @ 5 minutes = 30 minutes
    e. Travel to EPZ boundary (assume 5 miles at 45 mph): 7 minutes.

ETE: 90 + 5 + 36 + 30 + 7 = 2:50

Rain ETE: 100 + 5 + 42 + 30 + 8 = 3:05

Ice ETE: 110 + 5 + 48 + 30 + 9 = 3:10

If planned properly, the pickup locations for each bus run should be clustered within the same general area; it is assumed that stops are 3 miles apart. The estimated travel time between pick-ups is 6 minutes (7 minutes in rain; 8 minutes in ice); to the EPZ boundary is based on a distance of 5 miles @ 45 mph = 7 minutes (8 minutes in rain; 9 minutes in ice). It is assumed that mobilization time to first pickup is 10 minutes longer in rain = 100 minutes (110 minutes in ice). All ETE are rounded to nearest 5 minutes.

Assuming all HH members (avg. HH size equals 2.68 persons) travel with the disabled person yields 7 x 2.68 = 19 persons per bus, well within bus capacity.

Ambulances

It is estimated that 9 ambulances will be needed to evacuate the 17 homebound bed-ridden persons within the EPZ.

Discussions with emergency management personnel for Newberry, Lexington, Fairfield, and Richland Counties indicated that there are sufficient ambulance resources available to evacuate the institutionalized and homebound bed-ridden populations in a single wave using Mutual Aid Agreements.

Mobilization time is assumed to be 60 minutes to the first home. Each ambulance servicing the homebound bed-ridden population will make 2 stops with an estimated separation distance of 5 miles and an estimated distance of 5 miles to the EPZ boundary after the second stop. Loading time per stop is estimated at 15 minutes. It is assumed that ambulances will travel at 40 mph between households, given the absence of congestion within the EPZ. Mobilization time is 5 minutes longer in rain and travel speed is 10% less in rain – 36 mph, an additional 5 minutes longer and 10% less in ice – 32 mph. All ETE are rounded to nearest 5 minutes.

The ETE are computed as follows:

a. Ambulance arrives at first household: 60 minutes (some ambulances are coming from neighboring counties through mutual aid; thus, they must drive a greater distance)
b. Loading time at first household: 15 minutes
c. Ambulance travels to second household: 5 miles @ 40 mph = 8 minutes
d. Loading time at second household: 15 minutes
e. Travel time to EPZ boundary: 5 miles @ 40 mph = 8 minutes

ETE: 60 + 15 + 8 + 15 + 8 = 1:45

Rain ETE: 65 + 15 + 9 + 15 + 9 = 1:55

Ice ETE: 70 + 15 + 10 + 15 + 10 = 2:00

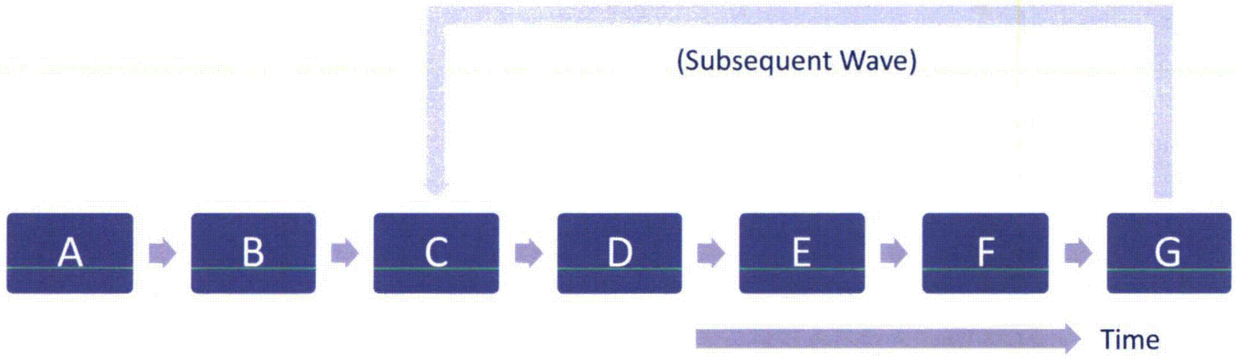
The following outlines the ETE calculations if a second wave is needed:

a. Travel to host facility from EPZ boundary: 20 miles @ 45 mph and requires 27 minutes of travel in good weather (30 minutes in rain; 35 - ice)
b. Unload passengers at host facility: 30 minutes
c. Travel time back to EPZ: 20 miles @ 45 mph and requires 27 minutes of travel in good weather (30 minutes in rain; 35 minutes in ice)
d. Loading time at first household: 15 minutes
e. Ambulance travels to second household: 5 miles @ 40 mph = 8 minutes (9 minutes in rain; 10 minutes in ice)
f. Loading time at second household: 15 minutes
g. Travel time to EPZ boundary: 5 miles @ 40.0 mph = 8 minutes (9 minutes in rain; 10 minutes in ice)

ETE: 1:45 + 0:27 + 0:30 + 0:27 + 0:15 + 0:08 + 0:15 + 0:08 = 3:55

Rain ETE: 1:55 + 0:30 + 0:30 + 0:30 + 0:15 + 0:09 + 0:15 + 0:09 = 4:15

Ice ETE: 2:00 + 0:35 + 0:30 + 0:35 + 0:15 + 0:10 + 0:15 + 0:10 = 4:30



Event	
A	Advisory to Evacuate
B	Bus Dispatched from Depot
C	Bus Arrives at Facility/Pick-up Route
D	Bus Departs for Reception Center
E	Bus Exits Region
F	Bus Arrives at Reception Center
G	Bus Available for "Second Wave" Evacuation Service

Activity	
A→B	Driver Mobilization
B→C	Travel to Facility or to Pick-up Route
C→D	Passengers Board the Bus
D→E	Bus Travels Towards Region Boundary
E→F	Bus Travels Towards Reception Center Outside the EPZ
F→G	Passengers Leave Bus; Driver Takes a Break

Figure 8-1. Chronology of Transit Evacuation Operations

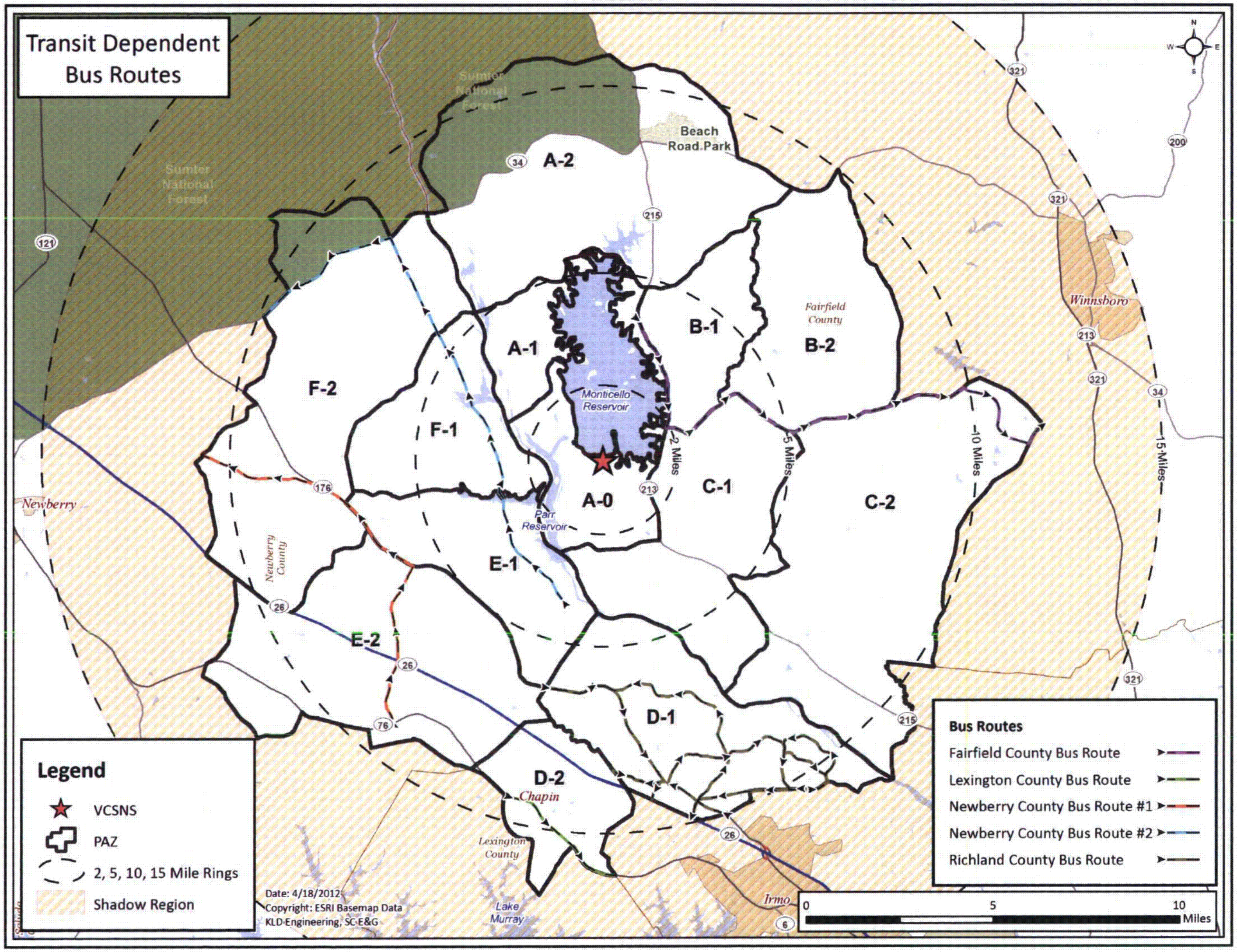


Figure 8-2. Transit-Dependent Bus Routes

Table 8-1. Transit-Dependent Population Estimates

2010 EPZ Population	Survey Average HH Size with Indicated No. of Vehicles			Estimated No. of Households	Survey Percent HH with Indicated No. of Vehicles			Survey Percent HH with Commuters	Survey Percent HH with Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent Population Requiring Public Transit
	0	1	2		0	1	2						
12,988	1.38	1.80	2.86	4,846	4.8%	22.5%	38.5%	67%	22%	484	50%	242	1.9%

Table 8-2. School Population Demand Estimates

PAZ	School Name	Municipality	Enrollment	Staff	Bus Runs Required
FAIRFIELD COUNTY SCHOOLS					
A-2	McCrorey-Liston Elementary School	Blair	219	37	4
C-2	Kelly Miller Elementary School	Winnsboro	270	50	4
		Fairfield County Total:	489	87	8
LEXINGTON COUNTY SCHOOLS					
D-2	Abner Montessori School	Chapin	116	20	2
D-2	Alternative Academy	Chapin	120	17	3
D-2	Chapin Elementary School	Chapin	845	105	13
D-2	Chapin High School[1]	Chapin	1,293	156	16
D-2	Chapin Middle School	Chapin	1,100	122	22
D-2	Crooked Creek Park After School Program[2]	Chapin	100	20	2
		Lexington County Total:	3,474	420	56
NEWBERRY COUNTY SCHOOLS					
E-2	Little Mountain Elementary	Little Mountain	373	40	6
E-2	Mid-Carolina High School	Prosperity	699	87	14
E-2	Mid-Carolina Middle School	Prosperity	600	75	12
F-2	Pomaria - Garmany Elementary School	Pomaria	392	50	6
		Newberry County Total:	2,064	252	38
	EPZ Total		**6,207**	**759**	**102**

Notes:

1 500 Students drive to Chapin High School. Discussion with high school officials indicate they would permit students to evacuate the school using their personal vehicles. Only 793 students require transportation (with one wheelchair bound student).

2 Students at this facility are previously counted at the neighboring schools; therefore, they have not been included in the county or EPZ totals. Also, Children are at this program only when all other schools are not in session; therefore, the buses needed for this facility have not been included in the county or EPZ totals.

Table 8-3. School Reception Centers

School	PAZ	Reception Center
McCrorey-Liston Elementary School	A-2	White Oak Conference Center
Kelly Miller Elementary School	C-2	
Abner Montessori School	D-2	Crossroads Middle School
Alternative Academy	D-2	
Chapin Elementary School	D-2	
Chapin High School	D-2	
Chapin Middle School	D-2	
Crooked Creek Park After School Program	D-2	
Little Mountain Elementary School	E-2	Newberry High School
Mid-Carolina High School	E-2	
Mid-Carolina Middle School	E-2	
Pomaria-Garmany Elementary	F-2	

Table 8-4. Special Facility Transit Demand

PAZ	Facility Name	Municipality	Cap-acity	Current Census	Ambu-latory	Wheel-chair Bound	Bed-ridden	Ambul-ance Runs	Wheel-chair Bus Runs	Wheel-chair Van Runs	Bus Runs
LEXINGTON COUNTY MEDICAL FACILITIES											
D-2	Generations of Chapin	Chapin	64	60	30	15	3	2	1	0	1
		Totals:	64	60	30	15	3	2	1	0	1

Table 8-5. Summary of Transportation Resources

Transportation Resource	Buses	Vans	Wheelchair Buses	Wheelchair Vans	Ambulances
Resources Available					
Lexington County School District	100	-	25	-	-
Newberry County School District	26	-	-	-	-
Kelly Miller Elementary School	6	-	-	-	-
McCrorey-Liston Elementary School	4	-	-	-	-
Generations of Chapin	-	3	-	-	-
Lexington Medical Center	-	-	-	-	-
Fairfield Memorial Hospital	-	-	-	-	9
Medshore Ambulance (through mutual aid)	-	-	-	3	37
TOTAL:	**136**	**3**	**25**	**3**	**46**
Resources Needed					
Schools (Table 8-2):	102	-	-	-	-
Medical Facilities (Table 8-4):	1	-	1	-	2
Transit-Dependent Population (Table 8-10):	9	-	-	-	-
Homebound Special Needs (Section 8.5):	1	-	3	-	9
TOTAL TRANSPORTATION NEEDS:	**113**	**-**	**4**	**-**	**11**

Table 8-6. Bus Route Descriptions

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
1	Chapin High School & Abner Montessori School Evacuation Route	278, 277, 276, 273, 274, 376, 377
2	Chapin Middle School Evacuation Route	702, 230, 229, 228, 686
3	Kelly Miller Elementary School Evacuation Route	896, 654, 652, 75, 74
4	McCrorey-Liston Elementary School Evacuation Route	95, 96, 97, 98, 99, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 2
5	Little Mountain Elementary School Evacuation Route	239, 284, 283, 876, 298, 877, 282, 301, 371, 370, 305, 304, 369, 368
6	Mid Carolina High & Middle School Evacuation Route	859, 858, 243, 311, 292, 291, 303, 302, 304, 369, 368
7	Pomaria-Garmany Elementary School Evacuation Route	307, 308, 309, 317, 332, 318, 333, 319, 320
8	Chapin Elementary School Evacuation Route	702, 230, 229, 228, 686
9	Crooked Creek Afterschool Program Evacuation Route	702, 230, 229, 228, 686
10	Alternative Academy Evacuation Route	931, 267, 278, 277, 276, 273, 274, 376, 377
11	Richland County Transit Dependent Bus Route	202, 203, 204, 205, 206, 207, 208, 209, 210, 605, 211, 212
12	Fairfield County Transit Dependent Bus Route	1, 3, 33, 34, 35, 803, 482, 483, 484, 485, 486, 487, 488, 489, 480, 491
13	Lexington County Transit Dependent Bus Route	234, 684, 233, 855, 232, 231, 230, 229, 228, 686
14	Newberry County Transit Dependent Bus Route #1	194, 195, 196, 307, 308, 309, 317, 332, 318, 333, 319, 320
15	Newberry County Transit Dependent Bus Route #2	190, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 159, 160, 161, 545, 162, 163

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

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Fairfield County, SC Schools									
McCrorey-Liston Elementary School	90	5	8.2	45.0	11	**1:50**	13.57	19	**2:05**
Kelly Miller Elementary School	90	5	1.4	41.0	3	**1:40**	13.62	19	**2:00**
Lexington County, SC Schools									
Abner Montessori School	50	5	4.4	45.0	6	**1:05**	9.75	13	**1:15**
Alternative Academy	50	5	5.1	45.0	7	**1:05**	9.75	13	**1:15**
Chapin Elementary School	50	5	3.4	42.9	5	**1:00**	10.40	14	**1:15**
Chapin High School	50	5	4.4	45.0	6	**1:05**	9.75	13	**1:15**
Chapin Middle School	50	5	2.6	42.9	4	**1:00**	10.40	14	**1:15**
Crooked Creek Park After School Program*	15	5	2.8	43.6	4	**0:25**	10.40	14	**0:40**
Newberry County, SC Schools									
Little Mountain Elementary School	90	5	8.1	45.0	11	**1:50**	5.80	8	**1:55**
Mid-Carolina High School	90	5	5.4	45.0	8	**1:45**	5.80	8	**1:55**
Mid-Carolina Middle School	90	5	5.4	45.0	8	**1:45**	5.80	8	**1:55**
Pomaria-Garmany Elementary School	90	5	4.6	45.0	7	**1:45**	4.97	7	**1:50**
					Maximum for EPZ:	**1:50**		**Maximum:**	**2:05**
					Average for EPZ:	**1:26**		**Average:**	**1:37**

*Buses remain at the facility while students are at the afterschool program; therefore, a shorter mobilization time is appropriate. ETE is not included in Average for EPZ as this facility is only in use when all other schools are not in session.

Table 8-8 School Evacuation Time Estimates – Rain

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Fairfield County, SC Schools									
McCrorey-Liston Elementary School	100	10	8.2	40.0	13	**2:05**	13.57	21	**2:25**
Kelly Miller Elementary School	100	10	1.4	37.9	3	**1:55**	13.62	21	**2:15**
Lexington County, SC Schools									
Abner Montessori School	60	10	4.4	40.0	7	**1:20**	9.75	15	**1:35**
Alternative Academy	60	10	5.1	40.0	8	**1:20**	9.75	15	**1:35**
Chapin Elementary School	60	10	3.4	38.5	6	**1:20**	10.40	16	**1:35**
Chapin High School	60	10	4.4	40.0	7	**1:20**	9.75	15	**1:35**
Chapin Middle School	60	10	2.6	38.5	4	**1:15**	10.40	16	**1:30**
Crooked Creek Park After School Program*	25	10	2.8	38.2	5	**0:40**	10.40	16	**1:00**
Newberry County, SC Schools									
Little Mountain Elementary School	100	10	8.1	40.0	13	**2:05**	5.80	9	**2:15**
Mid-Carolina High School	100	10	5.4	40.0	9	**2:00**	5.80	9	**2:10**
Mid-Carolina Middle School	100	10	5.4	40.0	9	**2:00**	5.80	9	**2:10**
Pomaria-Garmany Elementary School	100	10	4.6	40.0	7	**2:00**	4.97	8	**2:05**
					Maximum for EPZ:	2:05	**Maximum:**		2:25
					Average for EPZ:	1:41	**Average:**		1:55

*Buses remain at the facility while students are at the afterschool program; therefore, a shorter mobilization time is appropriate. ETE is not included in Average for EPZ as this facility is only in use when all other schools are not in session.

Table 8-9 School Evacuation Time Estimates – Ice

School	Driver Mobilization Time	Loading Time (min)	Dist. To EPZ Bdry (mi.)	Average Speed (mph)	Travel Time to EPZ Bdry (min.)	ETE (hr:min)	Dist. EPZ Bdry to R.C. (mi.)	Travel Time EPZ Bdry to R.C. (min)	ETE to R.C. (hr:min)
Fairfield County, SC Schools									
McCrorey-Liston Elementary School	110	15	8.2	35.0	15	**2:20**	13.57	24	**2:45**
Kelly Miller Elementary School	110	15	1.4	33.6	3	**2:10**	13.62	24	**2:35**
Lexington County, SC Schools									
Abner Montessori School	70	15	4.4	21.1	13	**1:40**	9.75	17	**1:55**
Alternative Academy	70	15	5.1	22.7	14	**1:40**	9.75	17	**2:00**
Chapin Elementary School	70	15	3.4	35.0	6	**1:35**	10.40	18	**1:50**
Chapin High School	70	15	4.4	21.1	13	**1:40**	9.75	17	**1:55**
Chapin Middle School	70	15	2.6	35.0	5	**1:30**	10.40	18	**1:50**
Crooked Creek Park After School Program*	35	15	2.8	34.1	5	**0:55**	10.40	18	**1:15**
Newberry County, SC Schools									
Little Mountain Elementary School	110	15	8.1	35.0	14	**2:20**	5.80	10	**2:30**
Mid-Carolina High School	110	15	5.4	35.0	10	**2:15**	5.80	10	**2:25**
Mid-Carolina Middle School	110	15	5.4	35.0	10	**2:15**	5.80	10	**2:25**
Pomaria-Garmany Elementary School	110	15	4.6	35.0	8	**2:15**	4.97	9	**2:25**
					Maximum for EPZ:	2:20		**Maximum:**	2:45
					Average for EPZ:	1:58		**Average:**	2:14

*Buses remain at the facility while students are at the afterschool program; therefore, a shorter mobilization time is appropriate. ETE is not included in Average for EPZ as this facility is only in use when all other schools are not in session.

Table 8-10 Summary of Transit-Dependent Bus Routes

Route Number	Route Name	No. of Buses	Route Description	Route Length within EPZ (mi.)
11	Richland County Bus Route	2	Richland County Transit Dependent Bus Route	36.2
12	Fairfield County Bus Route	2	Route 215 in Monticello SB to Route 213 EB to SR S-20-48 SB to Reservoir Rd EB to Rion Rd SB in Rion to Route 269 NB to US 321 to White Oak Conference Center	15.5
13	Lexington County Bus Route	2	US 76 EB in Chapin to N Woodrow St to Crossroads Middle School	3.7
14	Newberry County Bus Route - #1	2	Route 202 NB in Little Mountain to US 176 WB to Route 219 to Newberry High School	11.2
15	Newberry County Bus Route - #2	1	CR S-36-28 NB in Peak to Route 34 WB to I 26 EB to Route 219 SB to Newberry High School	15.5

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

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobilization	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time	ETE	Distance to Rec Ctr (miles)	Travel Time to Rec. Ctr	Unload	Driver Rest	Route Travel Time (min)	Pickup Time	ETE
11	1	120	36.2	45	48	30	**3:20**	11.3	15	5	10	63	30	**5:25**
	2	140	36.2	45	48	30	**3:40**	11.3	15	5	10	63	30	**5:45**
12	1	120	15.5	45	21	30	**2:55**	13.6	18	5	10	39	30	**4:35**
	2	140	15.5	45	21	30	**3:15**	13.6	18	5	10	39	30	**4:55**
13	1	120	3.7	45	5	30	**2:35**	10.8	14	5	10	19	30	**3:55**
	2	140	3.7	45	5	30	**2:55**	10.8	14	5	10	19	30	**4:15**
14	1	60	11.2	45	15	30	**1:45**	5.0	7	5	10	22	30	**3:00**
	2	80	11.2	45	15	30	**2:05**	5.0	7	5	10	22	30	**3:20**
15	1	60	15.5	45	21	30	**1:55**	10.9	15	5	10	35	30	**3:30**
						Maximum ETE:	**3:40**						**Maximum ETE:**	**5:45**
						Average ETE:	**2:42**						**Average ETE:**	**4:17**

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

		One-Wave							Two-Wave					
Route Number	Bus Number	Mobili-zation	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time	ETE	Distance to Rec Ctr (miles)	Travel Time to Rec. Ctr	Unload	Driver Rest	Route Travel Time (min)	Pickup Time	ETE
11	1	130	36.2	40	54	40	**3:45**	11.3	17	5	10	71	40	**6:10**
	2	150	36.2	40	54	40	**4:05**	11.3	17	5	10	71	40	**6:30**
12	1	130	15.5	40	23	40	**3:15**	13.6	20	5	10	44	40	**5:15**
	2	150	15.5	40	23	40	**3:35**	13.6	20	5	10	44	40	**5:35**
13	1	130	3.7	40	6	40	**3:00**	10.8	16	5	10	22	40	**4:30**
	2	150	3.7	40	6	40	**3:20**	10.8	16	5	10	22	40	**4:50**
14	1	70	11.2	40	17	40	**2:10**	5	8	5	10	24	40	**3:35**
	2	90	11.2	40	17	40	**2:30**	5	8	5	10	24	40	**3:55**
15	1	70	15.5	40	23	40	**2:15**	10.9	16	5	10	40	40	**4:05**
						Maximum ETE:	**4:05**						**Maximum ETE:**	**6:30**
						Average ETE:	**3:06**						**Average ETE:**	**4:56**

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

Route Number	Bus Number	One-Wave						Two-Wave						
		Mobili-zation	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time	ETE	Distance to Rec Ctr (miles)	Travel Time to Rec. Ctr	Unload	Driver Rest	Route Travel Time	Pickup Time	ETE
11	1	140	36.2	35	62	50	**4:15**	11.3	19	5	10	81	50	**7:00**
	2	160	36.2	35	62	50	**4:35**	11.3	19	5	10	81	50	**7:20**
12	1	140	15.5	35	27	50	**3:40**	13.6	23	5	10	50	50	**5:55**
	2	160	15.5	35	27	50	**4:00**	13.6	23	5	10	50	50	**6:15**
13	1	140	3.7	35	6	50	**3:20**	10.8	19	5	10	25	50	**5:05**
	2	160	3.7	35	6	50	**3:40**	10.8	19	5	10	25	50	**5:25**
14	1	80	11.2	35	19	50	**2:30**	5	9	5	10	28	50	**4:15**
	2	100	11.2	35	19	50	**2:50**	5	9	5	10	28	50	**4:35**
15	1	80	15.5	35	27	50	**2:40**	10.9	19	5	10	45	50	**4:50**
						Maximum ETE:	**4:35**						**Maximum ETE:**	**7:20**
						Average ETE:	**3:30**						**Average ETE:**	**5:37**

9 TRAFFIC MANAGEMENT STRATEGY

This section discusses the suggested 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, which is available on-line: http://mutcd.fhwa.dot.gov which provides access to the official PDF version
- A plan that defines all locations, provides 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 safely expedite travel out of the EPZ
2. Discourage traffic movements that move evacuating vehicles in a direction which takes them significantly closer to the power plant, or which interferes with the efficient flow of other evacuees

We employ the terms "facilitate" and "discourage" 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 prior to evacuating
- An evacuating driver may be travelling 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 plan is the outcome of the following process:

1. The existing TCPs and ACPs identified by the offsite agencies in their existing emergency plans serve as the basis of the traffic management plan, as per NUREG/CR-7002
2. Computer analysis of the evacuation traffic flow environment

   This analysis identifies the best routing and those critical intersections that experience pronounced congestion. Any critical intersections that are not identified in the existing offsite plans are suggested as additional TCPs and ACPs
3. A field survey of the highway network within 15 miles of the power plant
4. Consultation with emergency management and law enforcement personnel
5. Prioritization of TCPs and ACPs

   Application of traffic and access control at some TCPs and ACPs will have a more pronounced influence on expediting traffic movements than at other TCPs and ACPs. For example, TCPs controlling traffic originating from areas in close proximity to the power plant could have a more beneficial effect on minimizing potential exposure to radioactivity than those TCPs located far from the power plant.

The use of Intelligent Transportation Systems (ITS) technologies can reduce manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) can 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 motorists to avoid using routes that may conflict with the flow of evacuees away from the power plant. Highway Advisory Radio (HAR) can be used to broadcast information to evacuees en route through their vehicle stereo systems. Automated Traveler Information Systems (ATIS) can also be used to provide evacuees with information. Internet websites can provide traffic and evacuation route information before the evacuee begins his trip, while on board navigation systems (GPS units), cell phones, and pagers can be used to provide information en route. These are only several examples of how ITS technologies can benefit the evacuation process. Consideration should be given that ITS technologies be used to facilitate the evacuation process, and any additional signage placed should consider evacuation needs.

The ETE analysis treated all intersections that are existing TCP locations in the offsite agency plans as being controlled by actuated signals.

Chapters 2N and 5G, and Part 6 of the 2009 MUTCD are particularly relevant and should be reviewed during emergency response training.

The ETE calculations reflect the assumption that all "external-external" trips are interdicted and diverted after 2 hours have elapsed from the advisory to evacuate (ATE).

All transit vehicles and other responders entering the EPZ to support the evacuation are assumed to be unhindered by personnel manning ACPs and TCPs.

Study Assumptions 6 and 7 in Section 2.3 discuss ACP and TCP staffing schedules and operations.

10 EVACUATION ROUTES

Evacuation routes are comprised of two distinct components:

- Routing from a Protective Action Zone (PAZ) being evacuated to the boundary of the Evacuation Region and thence out of the Emergency Planning Zone (EPZ)
- Routing of transit-dependent evacuees from the EPZ boundary to reception centers

Evacuees will select routes within the EPZ in such a way as to minimize their exposure to risk. This expectation is met by the DYNEV II model routing traffic away from the location of the plant, to the extent practicable. The DTRAD model satisfies this behavior by routing traffic so as to balance traffic demand relative to the available highway capacity to the extent possible. See Appendices B through D for further discussion.

The routing of transit-dependent evacuees from the EPZ boundary to reception centers or host facilities is designed to minimize the amount of travel outside the EPZ, from the points where these routes cross the EPZ boundary.

Figure 10-1 presents a map showing the general population reception centers. The major evacuation routes for the four quadrants of the EPZ are presented in Figure 10-2.

It is assumed that all school evacuees will be taken to the appropriate host school/reception center and subsequently picked up by parents or guardians. Transit-dependent evacuees are transported to the nearest reception center for each county. This study does not consider the transport of evacuees from reception centers to congregate care centers, if the counties do make the decision to relocate evacuees.

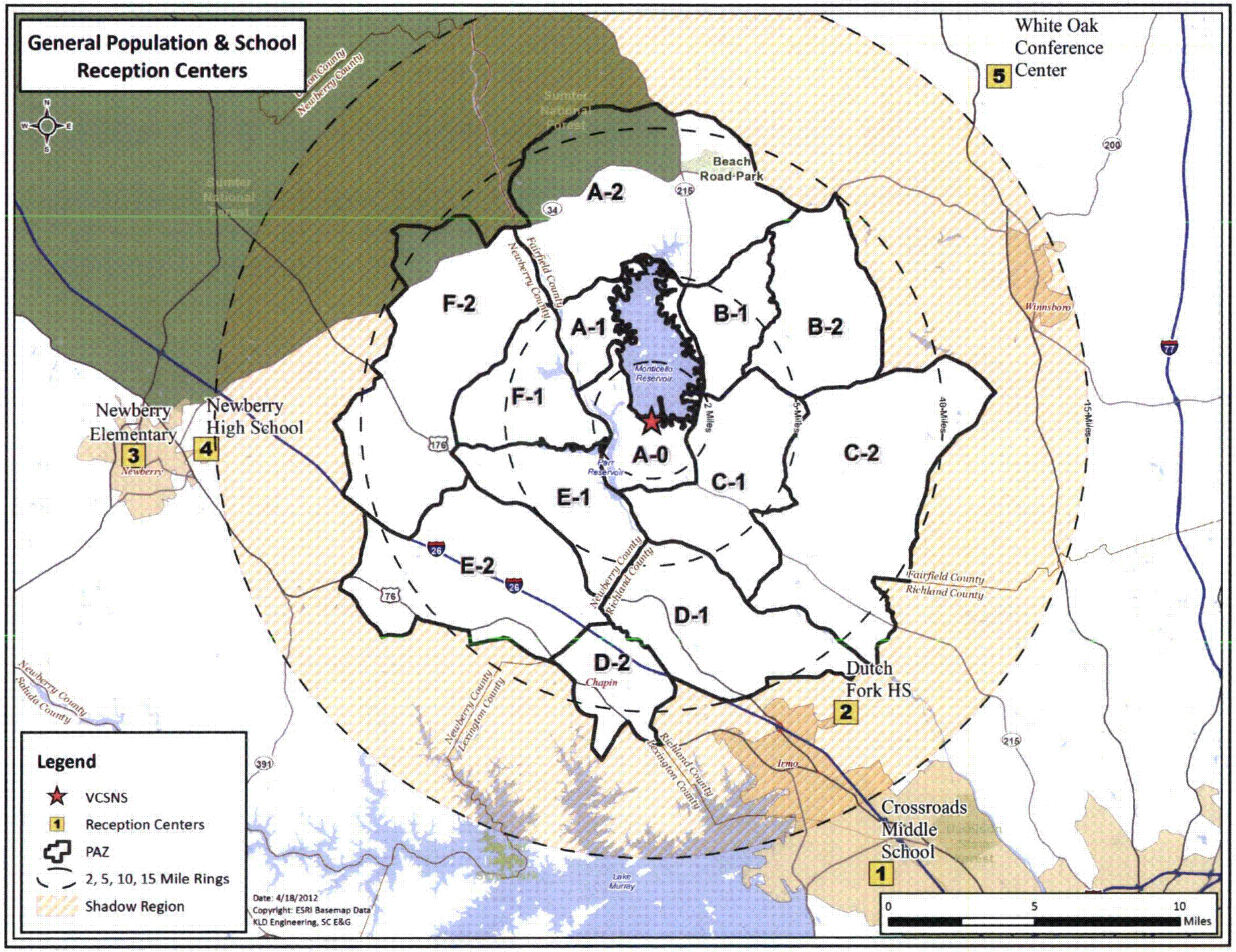


Figure 10-1. General Population Reception Centers

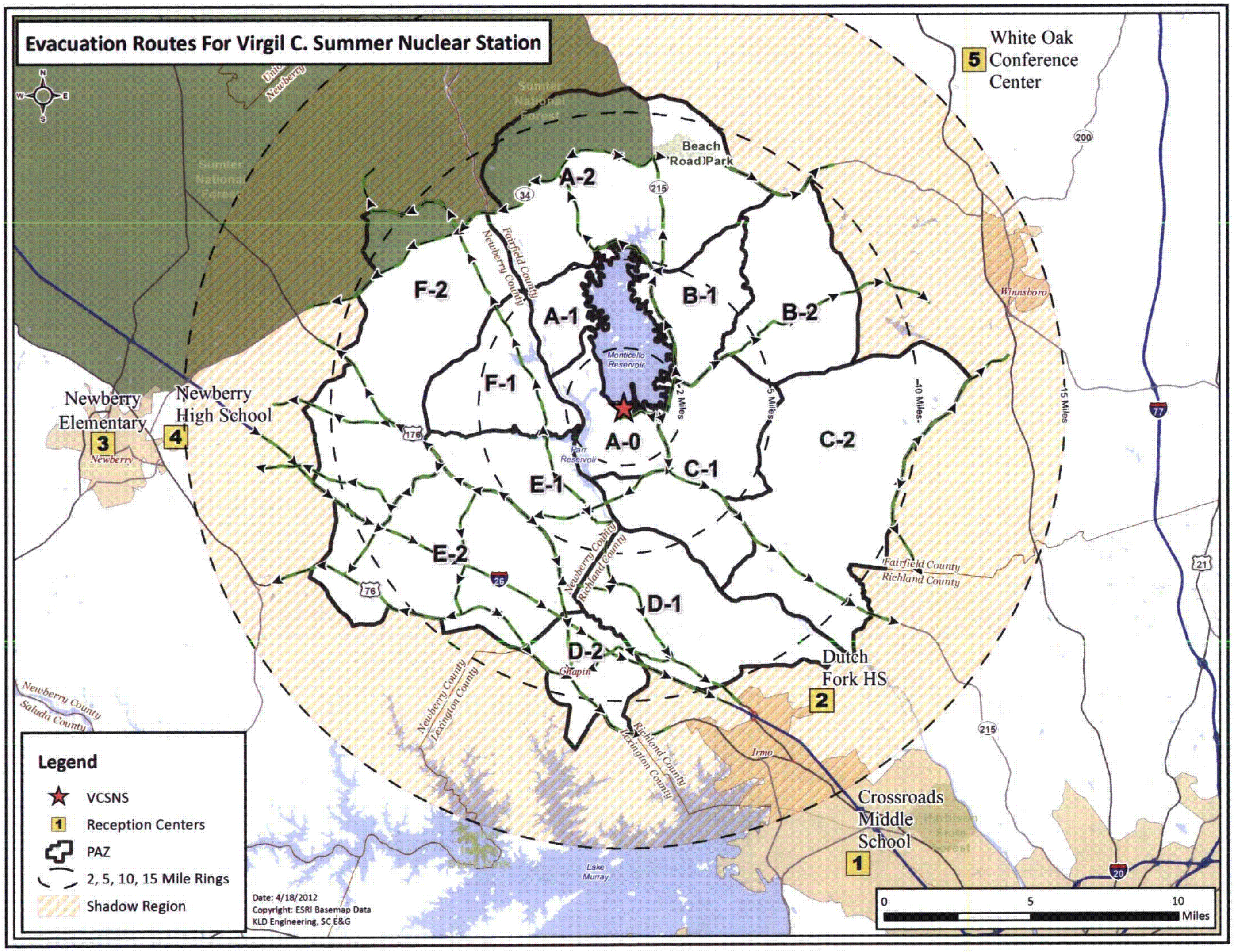


Figure 10-2. Evacuation Route Map

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, if available
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. Consideration should be given that tow trucks with a supply of gasoline 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

Consideration should also be given that the state and local emergency management agencies encourage gas stations to remain open during the evacuation.

12 CONFIRMATION TIME

It is necessary to confirm that the evacuation process is effective in the sense that the public is complying with the Advisory to Evacuate. Part 3 (page Part 3-5) of the South Carolina Operational Radiological Emergency Response Plan indicates that evacuation confirmation time is 4-5 hours; however, details on how the evacuation will be confirmed are not provided. Should procedures to confirm evacuation not already exist, we suggest an alternative or complementary approach.

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.

The confirmation process should start at about 2 hours and 30 minutes after the Advisory to Evacuate, which is when 90 percent of evacuees have completed their mobilization activities (see Figure 5-4). 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 PAZs), then the confirmation process will extend over a time frame of about 75 minutes. Thus, 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.

If this method is indeed used by the offsite agencies, consideration should be given to maintain a list of telephone numbers within the EPZ in the Emergency Operations Center (EOC) at all times. Such a list could be purchased from vendors and should be periodically updated. As indicated above, the confirmation process should not begin until 2 hours and 30 minutes after the Advisory to Evacuate. This 2½-hour timeframe will enable telephone operators to arrive at their workplace, obtain a call list and prepare to make the necessary phone calls.

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.

Other techniques should also be considered. After traffic volumes decline, the personnel manning TCPs can be redeployed to travel through residential areas to observe and to confirm evacuation activities.

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.) = 5,000
- Est. proportion, F, of households that will not evacuate = 0.20
- Allowable error margin, e: 0.05
- Confidence level, α: 0.95 (implies A = 1.96)

Applying Table 10 of cited reference,

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

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

Finite population correction:

$$n_F = \frac{nN}{n + N - 1} = 290$$

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, $n_F = 207$.

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:

$$\frac{300[30 + 0.8(36) + 0.2(60) + 20]}{3600} = 7.6$$

13 RECOMMENDATIONS

The following recommendations are offered:

1. Examination of the general population ETE in Section 7 shows that the ETE for 100 percent of the population is generally 2 to 2½ hours longer than for 90 percent of the population. Specifically, the additional time needed for the last 10 percent of the population to evacuate can be as much as double the time needed to evacuate 90 percent of the population. This non-linearity reflects the fact that these relatively few stragglers require significantly more time to mobilize (i.e. prepare for the evacuation trip) than their neighbors. This leads to two recommendations:
   a. The public outreach (information) program should emphasize the need for evacuees to minimize the time needed to prepare to evacuate (secure the home, assemble needed clothes, medicines, etc.)
   b. The decision makers should reference Table 7-1 which list the time needed to evacuate 90 percent of the population, when preparing recommended protective actions, as per NUREG/CR-7002 guidance
2. Staged evacuation has been shown to be ineffective in reducing evacuation time for the 2-mile region. There is no congestion within the EPZ; thus evacuees from the 2-mile region are not delayed when evacuating. Staged evacuation need not be considered in developing protective action recommendation and/or decision logic.
3. The roadway impact scenario considered, closing one lane eastbound on I-26 in Lexington County, did not materially affect ETE. Sufficient reserve highway capacity and the availability of alternative routes mitigate the impacts on ETE.
4. Counties should implement procedures whereby schools are contacted prior to dispatch of buses from the depots to get an accurate count of students needing transportation and the number of buses required (See Section 8).
5. Average school ETE (Tables 8-7 through 8-9) does not exceed the ETE for the general population at the 90th percentile for an evacuation of the entire EPZ (Region R03). The ETE for transit-dependent people (Tables 8-11 through 8-13) do exceed the ETE for the general population at the 90th percentile. Thus, Tables 8-11 through 8-13 should be considered when making Protective Action Decisions.
6. Intelligent Transportation Systems (ITS) such as Dynamic Message Signs (DMS), Highway Advisory Radio (HAR), Automated Traveler Information Systems (ATIS), etc. should be used to facilitate the evacuation process (See Section 9). The placement of additional signage should consider evacuation needs.
7. Counties should establish strategic locations to position tow trucks provided with gasoline containers in the event of a disabled vehicle during the evacuation process (see Section 11) and should encourage gas stations to remain open during the evacuation.
8. Counties should establish a system to confirm that the Advisory to Evacuate is being adhered to (see the approach suggested by KLD in Section 12). Should the approach recommended by KLD in Section 12 be used, a list of telephone numbers within the EPZ should be kept in the Emergency Operations Center (EOC). The use of Reverse 911 or automated dialing technologies may be considered, if available.

APPENDIX A

Glossary of Traffic Engineering Terms

A GLOSSARY OF TRAFFIC ENGINEERING TERMS

Table A-1. Glossary of Traffic Engineering Terms

Term	Definition
Analysis Network	A graphical representation of the geometric topology of a physical roadway system, which is comprised of directional links and nodes.
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 attached to a network link, within the EPZ or Shadow Region, 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.
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, usually green, yellow, red.

Term	Definition
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.
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

DTRAD: Dynamic Traffic Assignment and Distribution Model

B. DYNAMIC TRAFFIC ASSIGNMENT AND DISTRIBUTION MODEL

This section describes the integrated dynamic trip assignment and distribution model named DTRAD (Dynamic Traffic Assignment and Distribution) that is expressly designed for use in analyzing evacuation scenarios. DTRAD employs logit-based path-choice principles and is one of the models of the DYNEVII System.The DTRAD module implements path-based *Dynamic Traffic Assignment* (DTA) so that time dependent Origin-Destination (OD) trips are "assigned" to routes over the network based on prevailing traffic conditions.

To apply the DYNEV II System, the analyst must specify the highway network, link capacity information, the time-varying volume of traffic generated at all origin centroids and, optionally, a set of accessible candidate destination nodes on the periphery of the EPZ for selected origins. DTRAD calculates the optimal dynamic trip distribution (i.e., trip destinations) and the optimal dynamic trip assignment (i.e., trip routing) of the traffic generated at each origin node traveling to its set of candidate destination nodes, so as to minimize evacuee travel "cost".

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 the "best" routes. The model is designed to identify these "best" routes in a manner that realistically distributes vehicles from origins to destinations and routes them over the highway network, in a consistent and optimal manner, reflecting evacuee behavior.

For each origin, a set of "candidate destination nodes" is selected by the software logic and by the analyst to reflect the desire by evacuees to travel away from the power plant and to access major highways. The specific destination nodeswithin this set that are selected by travelers and the selection of the connecting paths of travel, are both determined by DTRAD. This determination is made by a logit-based path choice model in DTRAD, so as to minimize the trip "cost", as discussed later.

The traffic loading on the network and the consequent operational traffic environment of the network (density, speed, throughput on each link) vary over time as the evacuation takes place. The DTRAD model, which is interfaced with the DYNEV simulation model, executes a succession of "sessions" wherein it computes the optimal routing and selection of destination nodes for the conditions that exist at that time.

Interfacing the DYNEV Simulation Model with DTRAD

The DYNEV II system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. An algorithm was developed to support the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next. Another algorithm executes a "mapping" from the specified "geometric" network (link-node analysis network) that represents the physical highway system, to a "path" network that represents the vehicle [turn] movements. DTRAD computations are performed on the "path" network: DYNEV simulation model, on the "geometric" network.

DTRAD Description

DTRAD is the DTA module for the DYNEV II System.

When the road network under study is large, multiple routing options are usually available between trip origins and destinations. The problem of loading traffic demands and propagating them over the network links is called Network Loading and is addressed by DYNEVII using macroscopic traffic simulation modeling. Traffic assignment deals with computing the distribution of the traffic over the road network for given O-D demands and is a model of the route choice of the drivers. Travel demand changes significantly over time, and the road network may have time dependent characteristics, e.g., time-varying signal timing or reduced road capacity because of lane closure, or traffic congestion. To consider these time dependencies, DTA procedures are required.

The DTRAD DTA module represents the dynamic route choice behavior of drivers, using the *specification of dynamic origin-destination matrices as flow input. Drivers choose their routes* through the network based on the travel cost they experience (as determined by the simulation model). This allows traffic to be distributed over the network according to the time-dependent conditions. The modeling principles of D-TRAD include:

- It is assumed that drivers not only select the best route (i.e., lowest cost path) but some also select less attractive routes. The algorithm implemented by DTRAD archives several "efficient" routes for each O-D pair from which the drivers choose.
- The choice of one route out of a set of possible routes is an outcome of "discrete choice modeling". Given a set of routes and their generalized costs, the percentages of drivers *that choose each route is computed. The most prevalent model for discrete choice* modeling is the logit model. DTRAD uses a variant of Path-Size-Logit model (PSL). PSL overcomes the drawback of the traditional multinomial logit model by incorporating an additional deterministic path size correction term to address path overlapping in the random utility expression.
- DTRAD executes the TA algorithm on an abstract network representation called "the path network" which is built from the actual physical link-node analysis network. This execution continues until a stable situation is reached: the volumes and travel times on the edges of the path network do not change significantly from one iteration to the next. The criteria for this convergence are defined by the user.
- Travel "cost" plays a crucial role in route choice. In DTRAD, path cost is a linear summation of the generalized cost of each link that comprises the path. The generalized cost for a link, a, is expressed as

$$c_a = \alpha t_a + \beta l_a + \gamma s_a ,$$

where c_a is the generalized cost for link a, and α, β, and γ are cost coefficients for link travel time, distance, and supplemental cost, respectively. Distance and supplemental costs are defined as invariant properties of the network model, while travel time is a dynamic property dictated by prevailing traffic conditions. The DYNEV simulation model computes travel times on all edges in the network and DTRAD uses that information to constantly update the costs of paths. The route choice decision model in the next simulation iteration uses these updated values to adjust the route choice behavior. This way, traffic demands are dynamically re-assigned based on time dependent conditions. The interaction between the DTRAD traffic assignment and DYNEV II simulation models is depicted in Figure B-1. Each round of interaction is called a Traffic Assignment Session (TA session). A TA session is composed of multiple iterations, marked as loop B in the figure.

- The supplemental cost is based on the "survival distribution" (a variation of the exponential distribution). The Inverse Survival Function is a "cost" term in DTRAD to represent the potential risk of travel toward the plant:

  $s_a = - \beta \ln (p), 0 \leq p \leq l ; \beta > 0$

  $p = \frac{d_n}{d_0}$

  d_n = Distance of node, n, from the plant
  d_0 = Distance from the plant where there is zero risk
  β = Scaling factor

The value of d_o = 15 miles, the outer distance of the shadow region. Note that the supplemental cost, s_a, of link, a, is (high, low), if its downstream node, n, is (near, far from) the power plant.

Network Equilibrium

In 1952, John Wardrop wrote:

> *Under equilibrium conditions traffic arranges itself in congested networks in such a way that no individual trip-maker can reduce his path costs by switching routes.*

The above statement describes the "User Equilibrium" definition, also called the "Selfish Driver Equilibrium". It is a hypothesis that represents a [hopeful] condition that evolves over time as drivers search out alternative routes to identify those routes that minimize their respective "costs". It has been found that this "equilibrium" objective to minimize costs is largely realized by most drivers who routinely take the same trip over the same network at the same time (i.e., commuters). Effectively, such drivers "learn" which routes are best for them over time. Thus, the traffic environment "settles down" to a near-equilibrium state.

Clearly, since an emergency evacuation is a sudden, unique event, it does not constitute a long-term learning experience which can achieve an equilibrium state. Consequently, DTRAD was not designed as an equilibrium solution, but to represent drivers in a new and unfamiliar situation, who respond in a flexible manner to real-time information (either broadcast or observed) in such a way as to minimize their respective costs of travel.

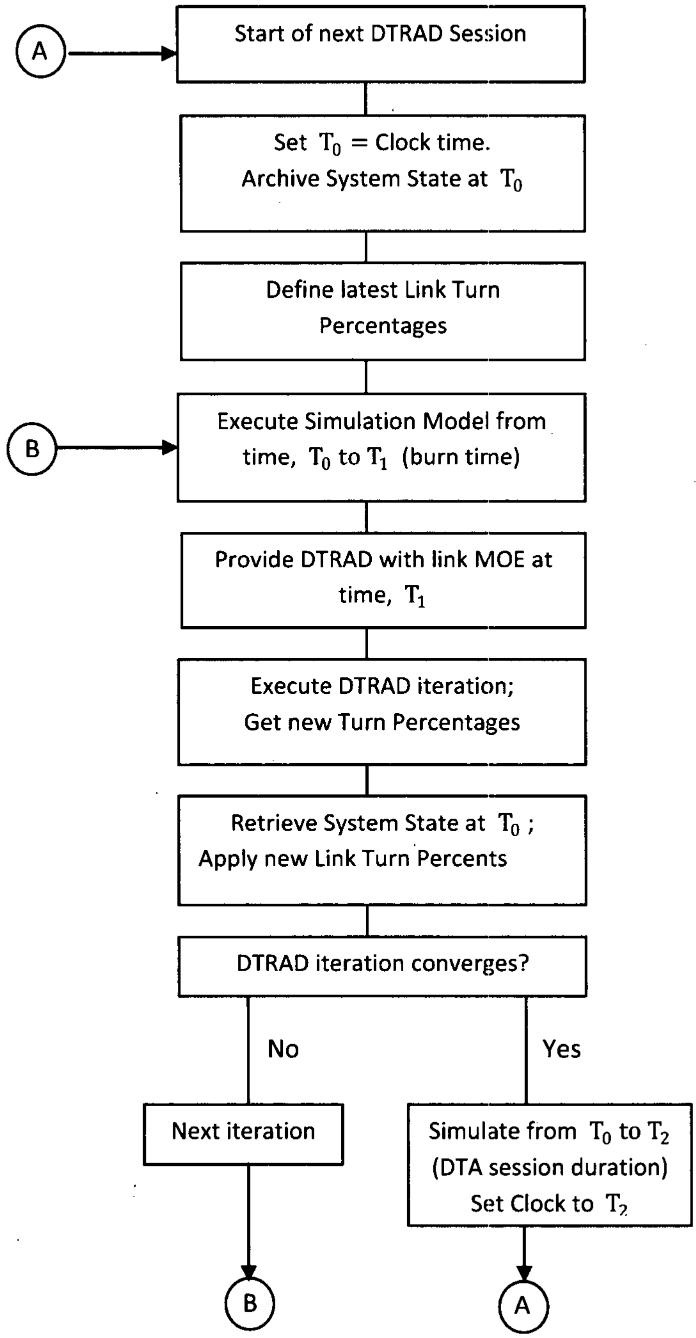


Figure B-1. Flow Diagram of Simulation-DTRAD Interface

APPENDIX C

DYNEV Traffic Simulation Model

C. DYNEV TRAFFIC SIMULATION MODEL

The DYNEV traffic simulation model is a *macroscopic* model that describes the operations of traffic flow in terms of aggregate variables: vehicles, flow rate, mean speed, volume, density, queue length, *on each link*, for each turn movement, during each Time Interval (simulation time step). The model simulates the movements of all vehicles on all network links over time until the network is empty. At intervals, the model outputs Measures of Effectiveness (MOE) such as those listed in Table C-1.

Model Features Include:

- Explicit consideration is taken of the variation in density over the time step; an iterative procedure is employed to calculate an average density over the simulation time step for the purpose of computing a mean speed for moving vehicles.
- Multiple turn movements can be serviced on one link; a separate algorithm is used to estimate the number of (fractional) lanes assigned to the vehicles performing each turn movement, based, in part, on the turn percentages provided by the DTRAD model.
- At any point in time, traffic flow on a link is subdivided into two classifications: queued and moving vehicles. The number of vehicles in each classification is computed. Vehicle spillback, stratified by turn movement for each network link, is explicitly considered and quantified. The propagation of stopping waves from link to link is computed within each time step of the simulation. There is no "vertical stacking" of queues on a link.
- Any link can accommodate "source flow" from zones via side streets and parking facilities that are not explicitly represented. This flow represents the evacuating trips that are generated at the source.
- The relation between the number of vehicles occupying the link and its storage capacity is monitored every time step for every link and for every turn movement. If the available storage capacity on a link is exceeded by the demand for service, then the simulator applies a "metering" rate to the entering traffic from both the upstream feeders and source node to ensure that the available storage capacity is not exceeded.
- A "path network" that represents the specified traffic movements from each network link is constructed by the model; this path network is utilized by the DTRAD model.
- A two-way interface with DTRAD: (1) provides link travel times; (2) receives data that translates into link turn percentages.
- Provides MOE to animation software, EVAN
- Calculates ETE statistics

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

To provide an efficient framework for defining these specifications, the physical highway environment is represented as a network. The unidirectional links of the network represent roadway sections: rural, multi-lane, urban streets, or freeways. The nodes of the network generally represent intersections or points along a section where a geometric property changes (e.g. a lane drop, change in grade, or free flow speed).

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. Selected Measures of Effectiveness Output by DYNEV II

Measure	Units	Applies To
Vehicles Discharged	Vehicles	Link, Network, Exit Link
Speed	Miles/Hours (mph)	Link, Network
Density	Vehicles/Mile/Lane	Link
Level of Service	LOS	Link
Content	Vehicles	Network
Travel Time	Vehicle-hours	Network
Evacuated Vehicles	Vehicles	Network, Exit Link
Trip Travel Time	Vehicle-minutes/trip	Network
Capacity Utilization	Percent	Exit Link
Attraction	Percent of total evacuating vehicles	Exit Link
Max Queue	Vehicles	Node, Approach
Time of Max Queue	Hours:minutes	Node, Approach
Route Statistics	Length (mi); Mean Speed (mph); Travel Time (min)	Route
Mean Travel Time	Minutes	Evacuation Trips, Network

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

HIGHWAY NETWORK

- Links defined by upstream and downstream node numbers
- Link lengths
- Number of lanes (up to 6) and channelization
- Turn bays (1 to 3 lanes)
- Destination (exit) nodes
- Network topology defined in terms of downstream nodes for each receiving link
- Node Coordinates (X,Y)
- NPP Coordinates (X,Y)

GENERATED TRAFFIC VOLUMES

- On all entry links and source nodes (origins), by Time Period

TRAFFIC CONTROL SPECIFICATIONS

- Traffic signals: link-specific, turn movement specific
- Signal control treated as fixed time or actuated
- Location of traffic control points (these are represented as actuated signals)
- 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

- Driver's (vehicle-specific) response mechanisms: free-flow speed, discharge headway
- Bus route designation

DYNAMIC TRAFFIC ASSIGNMENT

- Candidate destination nodes for each origin (optional)
- Duration of DTA sessions
- Duration of simulation "burn time"
- Desired number of destination nodes per origin

INCIDENTS

- Identify and Schedule of closed lanes
- Identify and Schedule of closed links

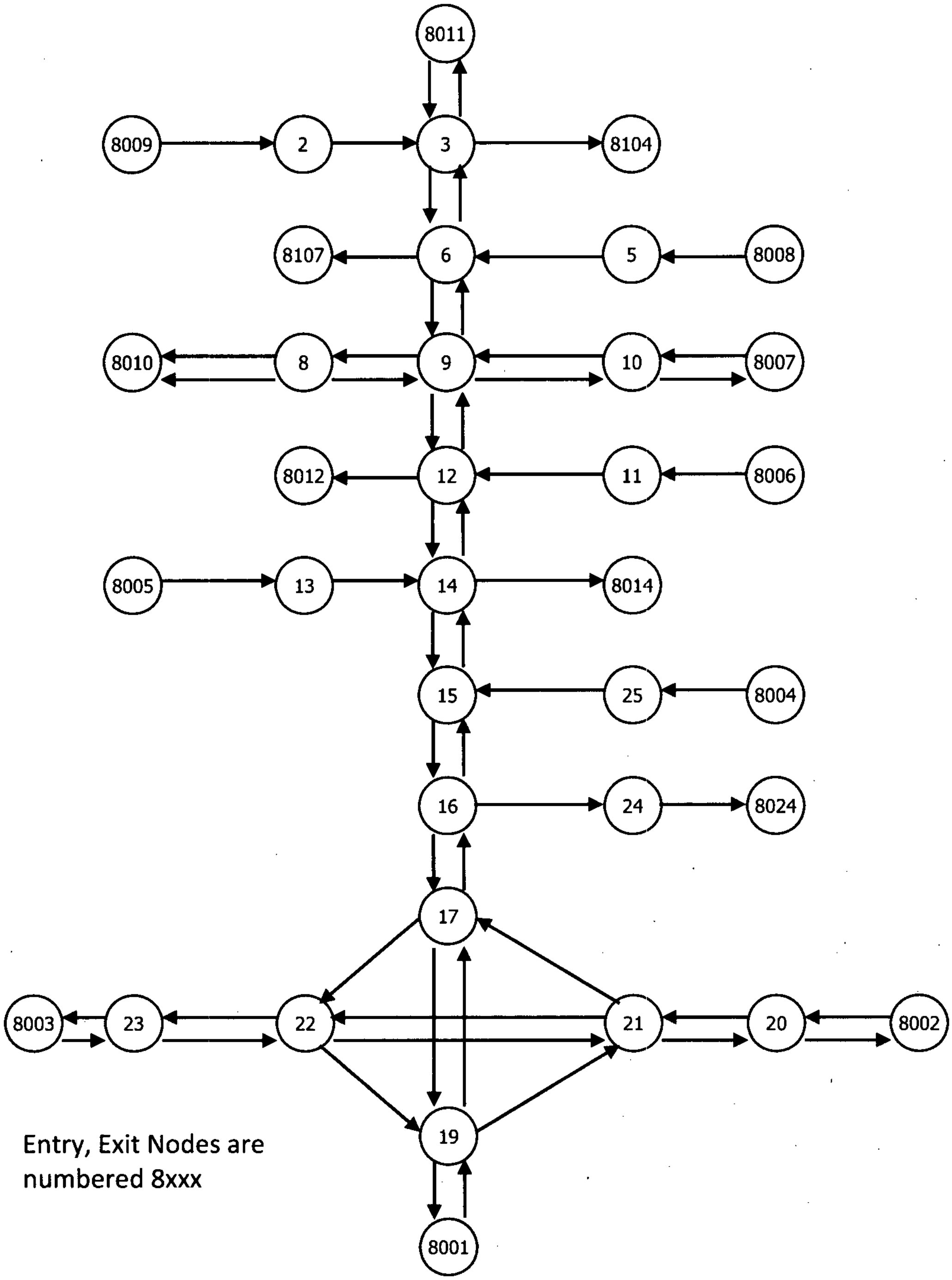


Figure C-1. Representative Analysis Network

METHODOLOGY

The Fundamental Diagram

It is necessary to define the fundamental diagram describing flow-density and speed-density relationships. Rather than "settling for" a triangular representation, a more realistic representation that includes a "capacity drop", $(I\text{-}R)Q_{max}$, at the critical density when flow conditions enter the forced flow regime, is developed and calibrated for each link. This representation, shown in Figure C-2, asserts a constant free speed up to a density, k_f, and then a linear reduction in speed in the range, $k_f \leq k \leq k_c = 45$ vpm, the density at capacity. In the flow-density plane, a quadratic relationship is prescribed in the range, $k_c < k \leq k_s = 95$ vpm which roughly represents the "stop-and-go" condition of severe congestion. The value of flow rate, Q_s, corresponding to k_s, is approximated at $0.7\,RQ_{max}$. A linear relationship between k_s and k_j completes the diagram shown in Figure C-2. Table C-3 is a glossary of terms.

The fundamental diagram is applied to moving traffic on every link. The specified calibration values for each link are: (1) Free speed, v_f; (2) Capacity, Q_{max}; (3) Critical density, $k_c = 45$ vpm ; (4) Capacity Drop Factor, R = 0.9 ; (5) Jam density, k_j . Then, $v_c = \frac{Q_{max}}{k_c}$, $k_f = k_c - \frac{(V_f - V_c)k_c^2}{Q_{max}}$. Setting $\bar{k} = k - k_c$, then $Q = RQ_{max} - \frac{RQ_{max}}{8333}\bar{k}^2$ for $0 \leq \bar{k} \leq \bar{k}_s = 50$. It can be shown that $Q = (0.98 - 0.0056\,\bar{k})\,RQ_{max}$ for $\bar{k}_s \leq \bar{k} \leq \bar{k}_j$, where $\bar{k}_s = 50$ and $\bar{k}_j = 175$.

The Simulation Model

The simulation model solves a sequence of "unit problems". Each unit problem computes the movement of traffic on a link, for each specified turn movement, over a specified time interval (TI) which serves as the simulation time step for all links. Figure C-3 is a representation of the unit problem in the time-distance plane. Table C-3 is a glossary of terms that are referenced in the following description of the unit problem procedure.

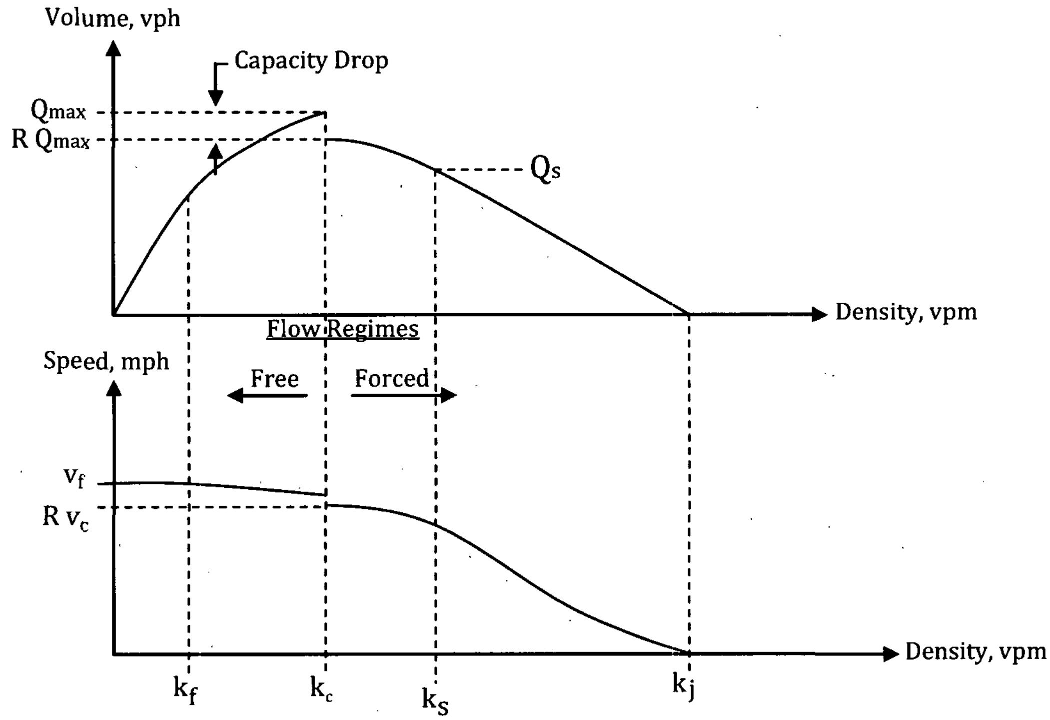


Figure C-2. Fundamental Diagrams

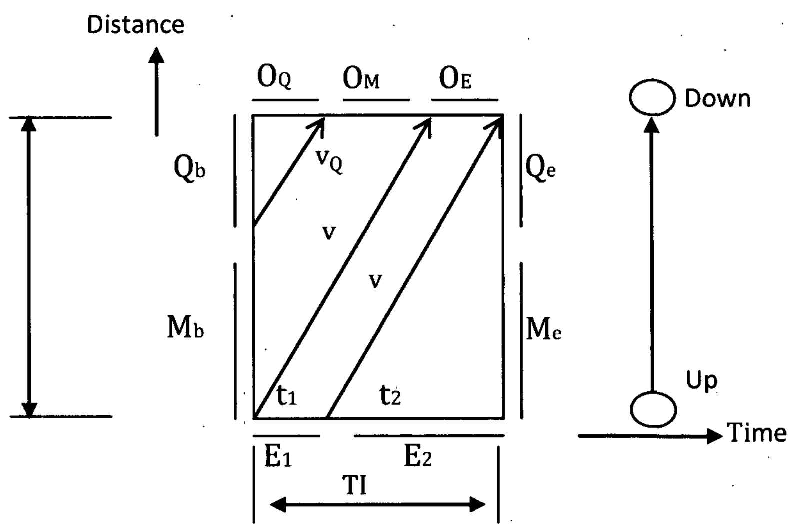


Figure C-3. A UNIT Problem Configuration with $t_1 > 0$

Table C-3. Glossary

Cap	The maximum number of vehicles, of a particular movement, that can discharge from a link within a time interval.
E	The number of vehicles, of a particular movement, that enter the link over the time interval. The portion, E_{TI}, can reach the step-bar within the TI.
G/C	The green time: cycle time ratio that services the vehicles of a particular turn movement on a link.
h	The mean queue discharge headway, seconds.
k	Density in vehicles per lane per mile.
$\bar{k}$	The average density of <u>moving</u> vehicles of a particular movement over a TI, on a link.
L	The length of the link in feet.
L_b , L_e	The queue length in feet of a particular movement, at the [beginning, end] of a time interval.
LN	The number of lanes, expressed as a floating point number, allocated to service a particular movement on a link.
L_v	The mean effective length of a queued vehicle including the vehicle spacing, feet.
M	Metering factor (Multiplier): 1.
M_b , M_e	The number of moving vehicles on the link, of a particular movement, that are moving at the [beginning, end] of the time interval. These vehicles are assumed to be of equal spacing, over the length of link upstream of the queue.
O	The total number of vehicles of a particular movement that are discharged from a link over a time interval.
O_Q , O_M , O_E	The components of the vehicles of a particular movement that are discharged from a link within a time interval: vehicles that were Queued at the beginning of the TI; vehicles that were Moving within the link at the beginning of the TI; vehicles that Entered the link during the TI.
P_x	The percentage, expressed as a fraction, of the total flow on the link that executes a particular turn movement, x.

Q_b , Q_e	The number of queued vehicles on the link, of a particular turn movement, at the [beginning, end] of the time interval.
Q_{max}	The maximum flow rate that can be serviced by a link for a particular movement in the absence of a control device. It is specified by the analyst as an estimate of link capacity, based upon a field survey, with reference to the HCM 2010.
R	The factor that is applied to the capacity of a link to represent the "capacity drop" when the flow condition moves into the forced flow regime. The lower capacity at that point is equal to RQ_{max} .
RCap	The remaining capacity available to service vehicles of a particular movement after that queue has been completely serviced, within a time interval, expressed as vehicles.
S_x	Service rate for movement x, vehicles per hour (vph).
t_1	Vehicles of a particular turn movement that enter a link over the first t_1 seconds of a time interval, can reach the stop-bar (in the absence of a queue down-stream) within the same time interval.
TI	The time interval, in seconds, which is used as the simulation time step.
v	The mean speed of travel, in feet per second (fps) or miles per hour (mph), of moving vehicles on the link.
v_Q	The mean speed of the last vehicle in a queue that discharges from the link within the TI. This speed differs from the mean speed of moving vehicles, v.
W	The width of the intersection in feet. This is the difference between the link length which extends from stop-bar to stop-bar and the block length.

The formulation and the associated logic presented below are designed to solve the unit problem for each sweep over the network (discussed below), for each turn movement serviced on each link that comprises the evacuation network, and for each TI over the duration of the evacuation.

Given $= Q_b, M_b, L, TI, E_0, LN, {}^G/_C, h, L_v, R_0, L_c, E, M$
Compute $= O, Q_e, M_e$
Define $O = O_Q + O_M + O_E$; $E = E_1 + E_2$

1. For the first sweep, s = 1, of this TI, get initial estimates of mean density, k_0, the R – factor, R_0 and entering traffic, E_0, using the values computed for the final sweep of the prior TI. For each subsequent sweep, $s > 1$, calculate $E = \sum_i P_i O_i + S$ where P_i, O_i are the relevant turn percentages from feeder link, i, and its total outflow (possibly metered) over this TI; S is the total source flow (possibly metered) during the current TI.
   Set iteration counter, n = 0, $k = k_0$, and $E = E_0$.

2. Calculate $v(k)$ such that $k \leq 130$ using the analytical representations of the fundamental diagram.
   Calculate $Cap = \frac{Q_{max}(TI)}{3600} ({}^G/_C)\, LN$, in vehicles, this value may be reduced due to metering
   Set $R = 1.0$ if ${}^G/_C < 1$ or if $k \leq k_c$; Set $R = 0.9$ only if ${}^G/_C = 1$ and $k > k_c$
   Calculate queue length, $L_b = Q_b \frac{L_v}{LN}$

3. Calculate $t_1 = TI - \frac{L}{V}$. If $t_1 < 0$, set $t_1 = E_1 = O_E = 0$; Else, $E_1 = E \frac{t_1}{TI}$.

4. Then $E_2 = E - E_1$; $t_2 = TI - t_1$

5. If $Q_b \geq Cap$, then
   $O_Q = Cap, O_M = O_E = 0$
   If $t_1 > 0$, then
   $Q_e' = Q_b + M_b + E_1 - Cap$
   Else
   $Q_e' = Q_b - Cap$
   End if
   Calculate Q_e and M_e using Algorithm A (below)

6. Else $(Q_b < Cap)$
   $O_Q = Q_b$, $RCap = Cap - O_Q$

7. If $M_b \leq RCap$, then

8. If $t_1 > 0$, $O_M = M_b, O_E = \min\left(RCap - M_b, \frac{t_1\,Cap}{TI}\right) \geq 0$

$Q'_e = E_1 - O_E$

If $Q'_e > 0$, then

Calculate Q_e, M_e with Algorithm A

Else

$Q_e = 0$, $M_e = E_2$

End if

Else $(t_1 = 0)$

$O_M = \left(\frac{v(TI) - L_b}{L - L_b}\right) M_b$ and $O_E = 0$

$M_e = M_b - O_M + E$; $Q_e = 0$

End if

9. Else $(M_b > RCap)$

$O_E = 0$

If $t_1 > 0$, then

$O_M = RCap$, $Q'_e = M_b - O_M + E_1$

Calculate Q_e and M_e using Algorithm A

10. Else $(t_1 = 0)$

$M_d = \left[\left(\frac{v(TI) - L_b}{L - L_b}\right) M_b\right]$

If $M_d > RCap$, *then*

$O_M = RCap$

$Q'_e = M_d - O_M$

Apply Algorithm A to calculate Q_e and M_e

Else

$O_M = M_d$

$M_e = M_b - O_M + E$ and $Q_e = 0$

End if

End if

End if

End if

11. Calculate a new estimate of average density, $\bar{k}_n = \frac{1}{4}[k_b + 2\,k_m + k_e]$,

where k_b= density at the beginning of the TI

k_e= density at the end of the TI

k_m= density at the mid-point of the TI

All values of density apply only to the <u>moving</u> vehicles.

If $|\bar{k}_n - \bar{k}_{n-1}| > \epsilon$ and $n < N$

where N = max number of iterations, and ϵ is a convergence criterion, then

12. set $n = n + 1$, and return to step 2 to perform iteration, n, using $k = \bar{k}_n$.
End if

Computation of unit problem is now complete. Check for excessive inflow causing spillback.

13. If $Q_e + M_e > \frac{(L-W)\, LN}{L_v}$, then

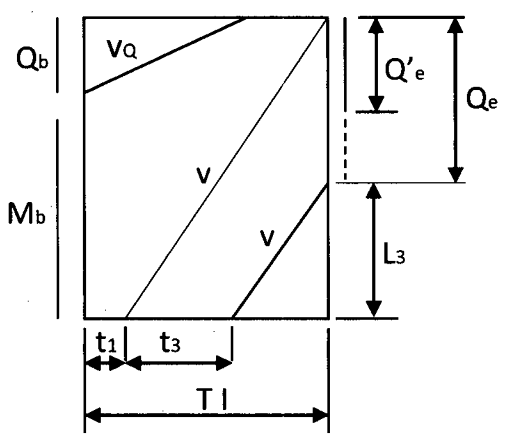
The number of excess vehicles that cause spillback is: $SB = Q_e + M_e - \frac{(L-W) \cdot LN}{L_v}$, where W is the width of the upstream intersection. To prevent spillback, meter the outflow from the feeder approaches and from the source flow, S, during this TI by the amount, SB. That is, set

$$M = 1 - \frac{SB}{(E + S)} \geq 0 \text{, where M is the metering factor (over all movements).}$$

This metering factor is assigned appropriately to all feeder links and to the source flow, to be applied during the next network sweep, discussed later.

Algorithm A

This analysis addresses the flow environment over a TI during which moving vehicles can join a standing or discharging queue. For the case shown, $Q_b \leq Cap$, with $t_1 > 0$ and a queue of length, Q'_e, formed by that portion of M_b and E that reaches the stop-bar within the TI, but could not discharge due to inadequate capacity. That is, $Q_b + M_b + E_1 > Cap$. This queue length, $Q'_e = Q_b + M_b + E_1 - Cap$ can be extended to Q_e by traffic entering the approach during the current TI, traveling at speed, v, and reaching the rear of the queue within the TI. A portion of the entering vehicles, $E_3 = E \frac{t_3}{TI}$, will likely join the queue. This analysis calculates t_3, Q_e, and M_e for the input values of L, TI, v, E, t, L_v, LN, Q'_e .



When $t_1 > 0$ and $Q_b \leq Cap$:

Define: $L'_e = Q'_e \frac{L_v}{LN}$. From the sketch, $L_3 = v(TI - t_1 - t_3) = L - (Q'_e + E_3) \frac{L_v}{LN}$.

Substituting $E_3 = \frac{t_3}{TI} E$ yields: $-vt_3 + \frac{t_3}{TI} E \frac{L_v}{LN} = L - v(TI - t_1) - L'_e$. Recognizing that the first two terms on the right hand side cancel, solve for t_3 to obtain:

$$t_3 = \frac{L'_e}{\left[v - \frac{E}{TI}\frac{L_v}{LN}\right]} \qquad \text{such that} \quad 0 \le t_3 \le TI - t_1$$

If the denominator, $\left[v - \frac{E}{TI}\frac{L_v}{LN}\right] \le 0$, set $t_3 = TI - t_1$.

$$\text{Then, } Q_e = Q'_e + E\,\frac{t_3}{TI} \quad , \qquad M_e = E\left(1 - \frac{t_1 + t_3}{TI}\right)$$

The complete Algorithm A considers all flow scenarios; space limitation precludes its inclusion, here.

Lane Assignment

The "unit problem" is solved for each turn movement on each link. Therefore it is necessary to calculate a value, LN_x, of allocated lanes for each movement, x. If in fact all lanes are specified by, say, arrows painted on the pavement, either as full lanes or as lanes within a turn bay, then the problem is fully defined. If however there remain unchannelized lanes on a link, then an analysis is undertaken to subdivide the number of these physical lanes into turn movement specific virtual lanes, LN_x.

IMPLEMENTATION

Computational Procedure

The computational procedure for this model is shown in the form of a flow diagram as Figure C-4. As discussed earlier, the simulation model processes traffic flow for each link independently over the TI that the analyst specifies; it is usually 60 seconds or longer. The first step is to execute an algorithm to define the sequence in which the network links are processed so that as many links as possible are processed after their feeder links are processed, within the same network sweep. Since a general network will have many closed loops, it is not possible to guarantee that every link processed will have all of its feeder links processed earlier.

The processing then continues as a succession of time steps of duration, TI, until the simulation is completed. Within each time step, the processing performs a series of "sweeps" over all network links; this is necessary to ensure that the traffic flow is synchronous over the entire network and that a spillback condition is properly resolved in the form of metering rates applied to the feeder links and to any source flow. Specifically, the sweep ensures continuity of flow among all the network links; in the context of this model, this means that the values of E, M, and S are all defined for each link, each time-step, TI, such that they represent the synchronous movement of traffic from each link to all of its outbound links. These sweeps also serve to compute the metering rates that control spillback and that are applied as initial conditions for the following TI.

Within each sweep, processing solves the "unit problem" for each turn movement on each link.

With the turn movement percentages for each link provided by the DTRAD model, an algorithm allocates the number of lanes to each movement serviced on each link. The timing at a signal, if any, applied at the downstream end of the link, is expressed as a G/C ratio; the signal timing needed to define this ratio is an input requirement for the model. The model also has the capability of representing, with macroscopic fidelity, the actions of actuated signals responding to the time-varying competing demands on the approaches to the intersection.

The solution of the unit problem yields the values of the number of vehicles, O, that discharge from the link over the time interval and the number of vehicles that remain on the link at the end of the time interval as stratified by queued and moving vehicles: Q_e and M_e. The procedure considers each movement separately (multi-piping). After all network links are processed for a given network sweep, the updated consistent values of entering flows, E; metering rates, M; and source flows, S are defined so as to satisfy the "no spillback" condition and satisfy the storage constraint on each link. The procedure then performs the unit problem solutions for all network links during the following sweep.

Experience has shown that the system converges (i.e. the values of E, M and S "settle down" for all network links) in just two sweeps if the network is entirely under-saturated, or in four sweeps in the presence of extensive congestion with link spillback. (The initial sweep over each link uses the final values of E and M, of the prior TI). At the completion of the final sweep for a TI, the procedure computes and stores all measures of effectiveness (MOE) for each link and turn movement for output purposes and for supporting the DTRAD model with operational metrics used in DTRAD's cost function. It then prepares for the following time interval by defining the values of Q_b and M_b for the start of the next TI as being those values of Q_e and M_e at the end of the prior TI. In this manner, the simulation model processes the traffic flow over time until the end of the run. Note that there is no space-discretization other than the specification of network links.

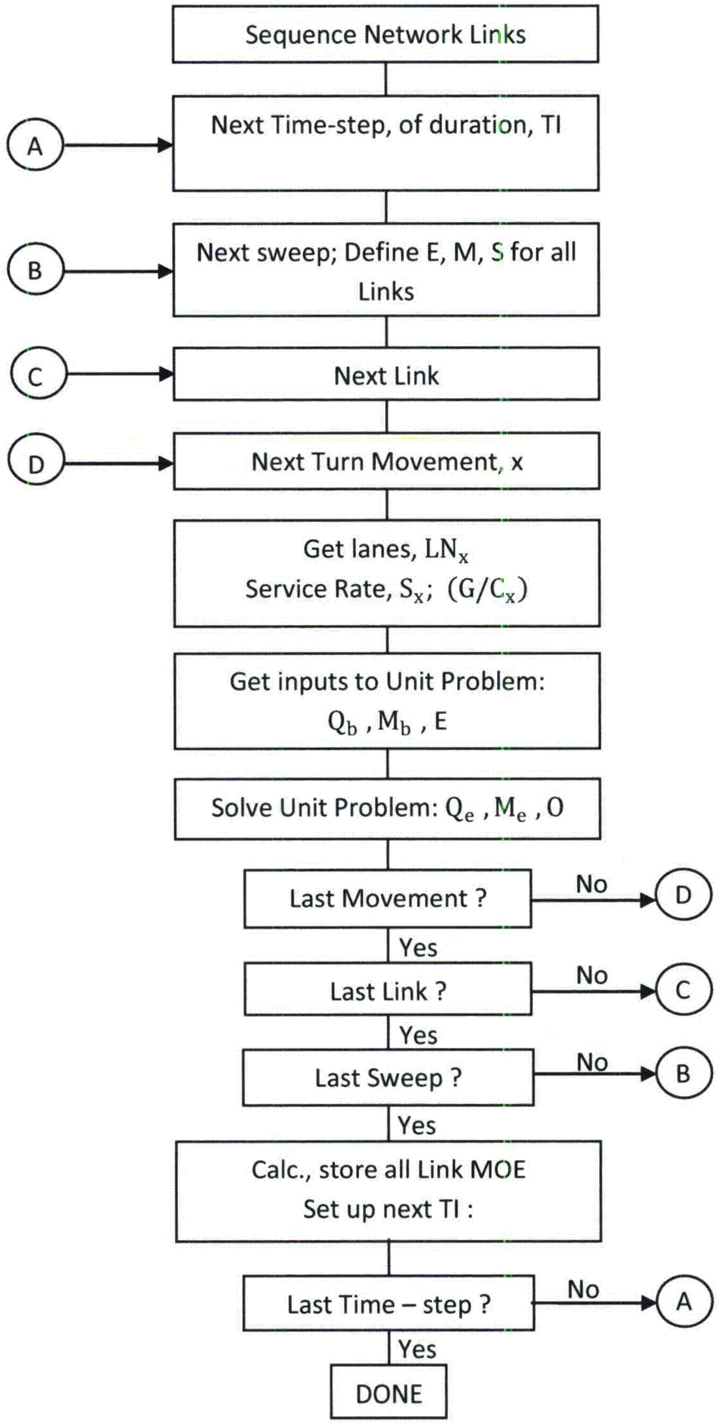


Figure C-4. Flow of Simulation Processing (See Glossary: Table C-3)

Interfacing with Dynamic Traffic Assignment (DTRAD)

The **DYNEV II** system reflects NRC guidance that evacuees will seek to travel in a general direction away from the location of the hazardous event. Thus, an algorithm was developed to identify an appropriate set of destination nodes for each origin based on its location and on the expected direction of travel. This algorithm also supports the DTRAD model in dynamically varying the Trip Table (O-D matrix) over time from one DTRAD session to the next.

Figure B-1 depicts the interaction of the simulation model with the DTRAD model in the **DYNEV II** system. As indicated, **DYNEV II** performs a succession of DTRAD "sessions"; each such session computes the turn link percentages for each link, that remain constant for the session duration, $[T_0, T_2]$, specified by the analyst. The end product is the assignment of traffic volumes from each origin to paths connecting it with its destinations in such a way as to minimize the network-wide cost function. The output of the DTRAD model is a set of updated link turn percentages which represent this assignment of traffic.

As indicated in Figure B-1, the simulation model supports the DTRAD session by providing it with operational link MOE that are needed by the path choice model and included in the DTRAD cost function. These MOE represent the operational state of the network at a time, $T_1 \leq T_2$, which lies within the session duration, $[T_0, T_2]$. This "burn time", $T_1 - T_0$, is selected by the analyst. For each DTRAD iteration, the simulation model computes the change in network operations over this burn time using the latest set of link turn percentages computed by the DTRAD model. Upon convergence of the DTRAD iterative procedure, the simulation model accepts the latest turn percentages provided by the DTA model, returns to the origin time, T_0, and executes until it arrives at the end of the DTRAD session duration at time, T_2. At this time the next DTA session is launched and the whole process repeats until the end of the **DYNEV II** run.

Additional details are presented in Appendix B.

APPENDIX D

Detailed Description of Study Procedure

D. DETAILED DESCRIPTION OF STUDY PROCEDURE

This appendix describes the activities that were performed to compute 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 the flow diagram.

Step 1

The first activity was to obtain Emergency Planning Zone (EPZ) boundary information and create a Geographic Information System (GIS) base map. The base map extends beyond the Shadow Region which extends approximately 15 miles (radially) from the power plant location. The base map incorporates the local roadway topology, a suitable topographic background and the EPZ and PAZ boundaries.

Step 2

2010 Census block information was obtained in GIS format. This information was used to estimate the resident population within the EPZ and Shadow Region and to define the spatial distribution and demographic characteristics of the population within the study area. Employee data were estimated using the U.S. Census Bureau's Longitudinal Employer-Household Dynamics interactive website[1], and from phone calls to major employers. Transient data were obtained from local/state emergency management agencies and from phone calls to transient attractions. Information concerning schools, medical, and other types of special facilities within the EPZ were obtained from county and municipal sources, augmented by telephone contacts with the identified facilities.

Step 3

A kickoff meeting was conducted with major stakeholders (state and local emergency managers, on-site and off-site utility emergency managers, local and state law enforcement agencies). The purpose of the kickoff meeting was to present an overview of the work effort, identify key agency personnel, and indicate the data requirements for the study. Specific requests for information were presented to local emergency managers. Unique features of the study area were discussed to identify the local concerns that should be addressed by the ETE study.

Step 4

Next, a physical survey of the roadway system in the study area was conducted to determine the geometric properties of the highway sections, 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, gathering signal timings for pre-timed traffic signals, and to make the necessary observations needed to estimate realistic values of roadway capacity.

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[1]http://lehdmap.did.census.gov/

Step 5

A telephone survey of households within the EPZ was conducted to identify household dynamics, trip generation characteristics, and evacuation-related demographic information of the EPZ population. This information was used to determine important study factors including the average number of evacuating vehicles used by each household, and the time required to perform pre-evacuation mobilization activities.

Step 6

A computerized representation of the physical roadway system, called a link-node analysis network, was developed using the UNITES software developed by KLD. Once the geometry of the network was completed, the network was calibrated using the information gathered during the road survey (Step 4). Estimates of highway capacity for each link and other link-specific characteristics were introduced to the network description. Traffic signal timings were input accordingly. The link-node analysis network was imported into a GIS map. 2010 Census data were overlaid in the map, and origin centroids where trips would be generated during the evacuation process were assigned to appropriate links.

Step 7

The EPZ is subdivided into 13 Protective Action Zones (PAZs). Based on wind direction and speed, Regions (groupings of PAZs) that may be advised to evacuate, were developed.

The need for evacuation can occur over a range of time-of-day, day-of-week, seasonal, and weather-related conditions. Scenarios were developed to capture the variation in evacuation demand, highway capacity, and mobilization time, for different time of day, day of the week, time of year, and weather conditions.

Step 8

The input stream for the DYNEV II model, which integrates the dynamic traffic assignment and distribution model, DTRAD, with the evacuation simulation model, was created for a prototype evacuation case – the evacuation of the entire EPZ for a representative scenario.

Step 9

After creating this input stream, the DYNEV II System was executed on the prototype evacuation case to compute evacuating traffic routing patterns consistent with the appropriate NRC guidelines. DYNEV II contains an extensive suite of data diagnostics which check the completeness and consistency of the input data specified. The analyst reviews all warning and error messages produced by the model and then corrects the database to create an input stream that properly executes to completion.

The model assigns destinations to all origin centroids consistent with a (general) radial evacuation of the EPZ and Shadow Region. The analyst may optionally supplement and/or replace these model-assigned destinations, based on professional judgment, after studying the topology of the analysis highway network. The model produces link and network-wide measures of effectiveness as well as estimates of evacuation time.

Step 10

The results generated by the prototype evacuation case are critically examined. The examination includes observing the animated graphics (using the EVAN software which operates on data produced by DYNEV II) and reviewing the statistics output by the 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 perceived problems reflected in the results.

Essentially, the approach is to identify those bottlenecks 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, either as excess demand due to high rates of trip generation, improper routing, a shortfall of capacity, or as a quantitative flaw in the way the physical system was represented in the input stream. This examination leads to one of two conclusions:

- The results are satisfactory or
- The input stream must be modified accordingly

This decision requires, of course, the application of the user's judgment and experience based upon the results obtained in previous applications of the model and a comparison of the results of the latest prototype evacuation case iteration with the previous ones. If the results are satisfactory in the opinion of the user, then the process continues with Step 13. Otherwise, proceed to Step 11.

Step 11

There are many "treatments" available to the user in resolving apparent problems. These treatments range from decisions to reroute the traffic by assigning additional evacuation destinations for one or more sources, 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. Such "treatments" take the form of modifications to the original prototype evacuation case input stream. All treatments are designed to improve the representation of evacuation behavior.

Step 12

As noted above, the changes to the input stream must be implemented to reflect the modifications undertaken in Step 11. At the completion of this activity, the process returns to Step 9 where the DYNEV II System is again executed.

Step 13

Evacuation of transit-dependents and special facilities are included in the evacuation analysis. Fixed routing for transit buses and for school buses, ambulances, and other transit vehicles are introduced into the final prototype evacuation case data set. DYNEV II generates route-specific speeds, over time, for use in the estimation of evacuation times for the transit dependent and special facility population groups.

Step 14

The prototype evacuation case was used as the basis for generating all region and scenario-specific evacuation cases to be simulated. This process was automated through the UNITES user interface. For each specific case, the population to be evacuated, the trip generation distributions, the highway capacity and speeds, and other factors are adjusted to produce a customized case-specific data set.

Step 15

All evacuation cases are executed using the DYNEV II System to compute ETE. Once results were available, quality control procedures were used to assure the results were consistent, dynamic routing was reasonable, and traffic congestion/bottlenecks were addressed properly.

Step 16

Once vehicular evacuation results were accepted, average travel speeds for transit and special facility routes were used to compute evacuation time estimates for transit-dependent permanent residents, schools, hospitals, and other special facilities.

Step 17

The simulation results were analyzed, tabulated, and graphed. The results were then documented, as required by NUREG/CR-7002.

Step 18

Following the completion of documentation activities, the ETE criteria checklist was completed. An appropriate report reference was provided for each criterion provided in the checklist.

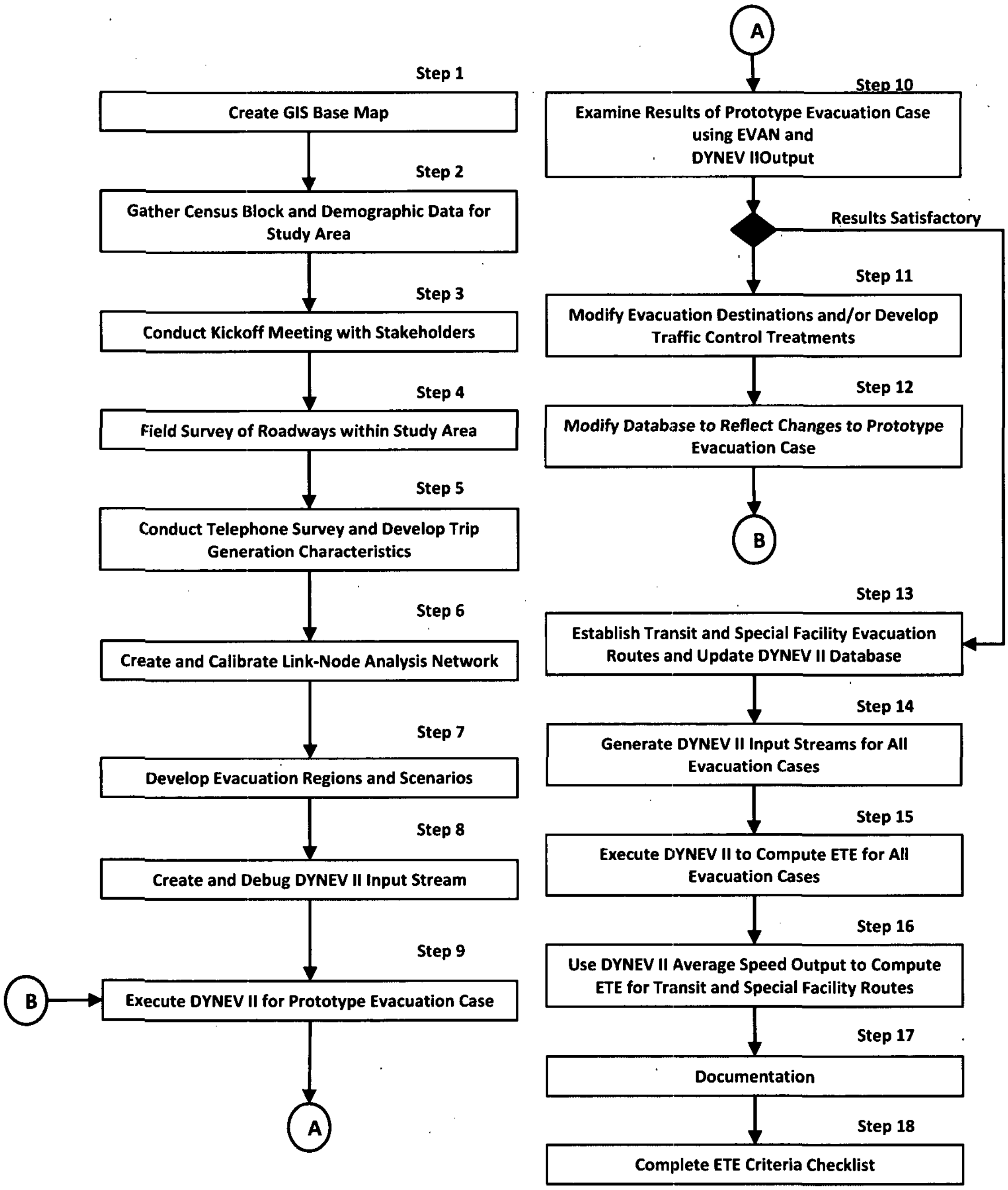

Figure D-1. Flow Diagram of Activities

APPENDIX E

Special Facility Data

E. SPECIAL FACILITY DATA

The following tables list population information, as of June 2011, for special facilities that are located within the VCSNS EPZ. Special facilities are defined as schools, day care centers, hospitals and other medical care facilities, and correctional facilities. Transient population data is included in the table for recreational areas. Employment data are included in the table for major employers. Each table is grouped by county. The location of the facility is defined by its straight-line distance (miles), direction (magnetic bearing) from the center point of the plant, and by its PAZ. Maps identifying the location of each special facility, recreational area, and major employer are also provided.

Table E-1. Schools within the EPZ

PAZ	Distance (miles)	Dire-ction	School Name	Street Address	Municipality	Phone	Enroll-ment	Staff
				FAIRFIELD COUNTY				
A-2	6.4	NNE	McCrorey-Liston Elementary School	1978 STHY 215-South	Blair	(803) 635-9490	219	37
C-2	11.1	E	Kelly Miller Elementary School	255 Kelly Miller Rd	Winnsboro	(803) 635-2961	270	50
						Fairfield County Subtotal:	*489*	*87*
				LEXINGTON COUNTY				
D-2	9.5	S	Abner Montessori School	432 E Boundary Street	Chapin	(803) 345-9428	116	20
D-2	9.3	SSW	Alternative Academy	107 Columbia Ave	Chapin	(803) 309-9421	120	17
D-2	11.2	S	Chapin Elementary School	940 Old Bush River Rd	Chapin	(803) 309-9421	845	105
D-2	9.2	S	Chapin High School	300 Columbia Ave	Chapin	(803) 309-9421	1,293	156
D-2	11.1	S	Chapin Middle School	1130 Old Lexington Highway	Chapin	(803) 309-9421	1,100	122
D-2	10.8	S	Crooked Creek Park Afterschool Program*	1098 Old Lexington Highway	Chapin	(803) 345-6181	100	20
						Lexington County Subtotal:	*3,474*	*420*
				NEWBERRY COUNTY				
E-2	9.1	SW	Little Mountain Elementary	692 Mill St	Little Mountain	(803) 945-7721	373	40
E-2	10.9	WSW	Mid-Carolina High School	6794 USHY 76	Prosperity	(803) 364-2134	699	87
E-2	10.9	WSW	Mid-Carolina Middle School	6834 USHY 76	Prosperity	(803) 364-3634	600	75
F-2	6.7	WSW	Pomaria-Garmany Elementary	7288 USHY 176	Pomaria	(803) 321-2651	392	50
						Newberry County Subtotal:	*2,064*	*252*
						EPZ TOTAL:	**6,027**	**759**

*These students at Crooked Creek Park Afterschool Program are already included in the enrollments for Chapin Elementary School and Chapin Middle School and are therefore not included in total enrollment.

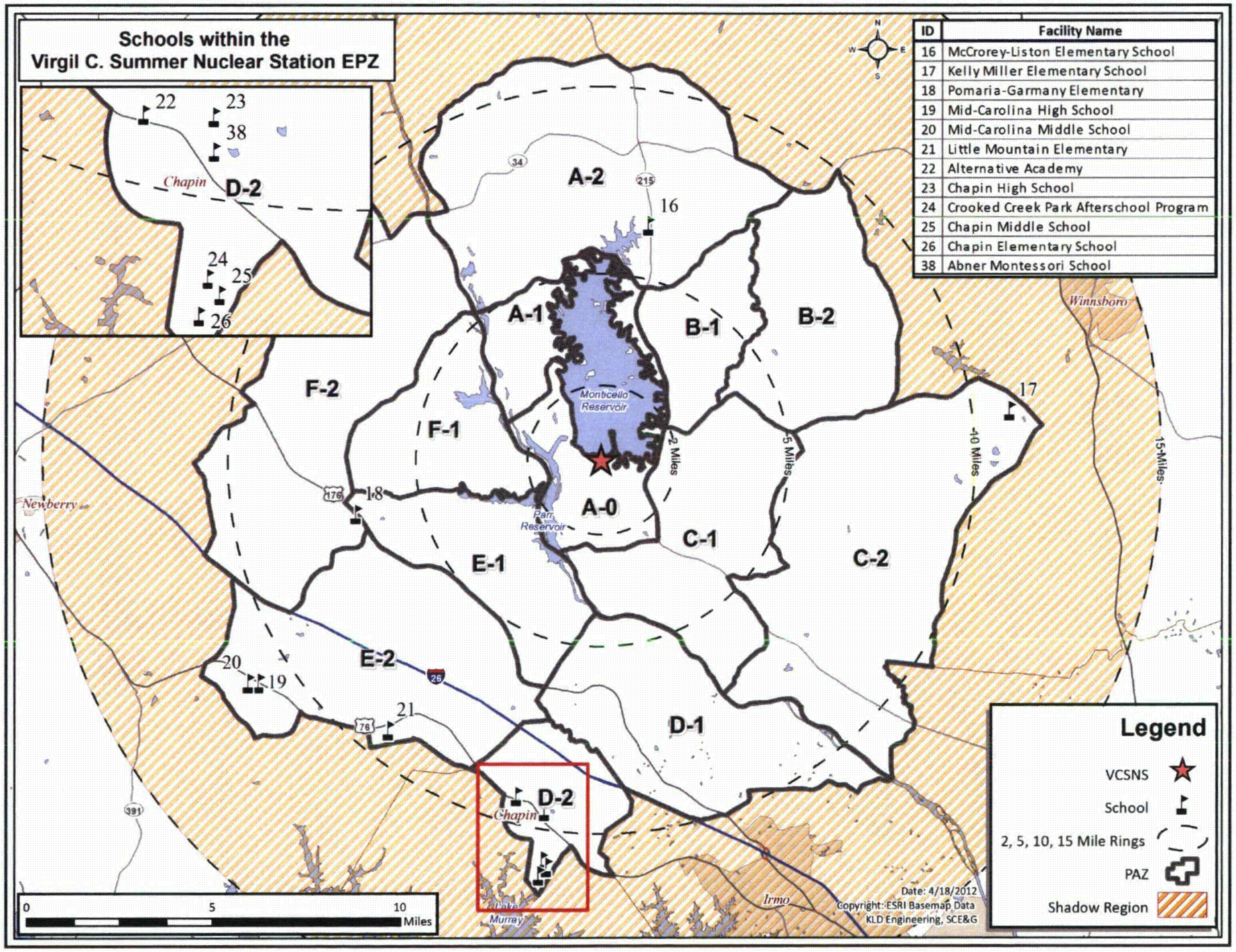

Figure E-1. Schools within the EPZ

Table E-2. Medical Facilities within the EPZ

PAZ	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Phone	Cap-acity	Current Census	Ambul-atory Patients	Wheel-chair Patients	Bed-ridden Patients
LEXINGTON COUNTY											
D-2	9.5	S	Generations of Chapin	431 E. Boundary St	Chapin	(803) 345-1911	64	60	30	15	3
						Lexington County Subtotal:	64	60	30	15	3
						EPZ TOTAL:	64	60	30	15	3

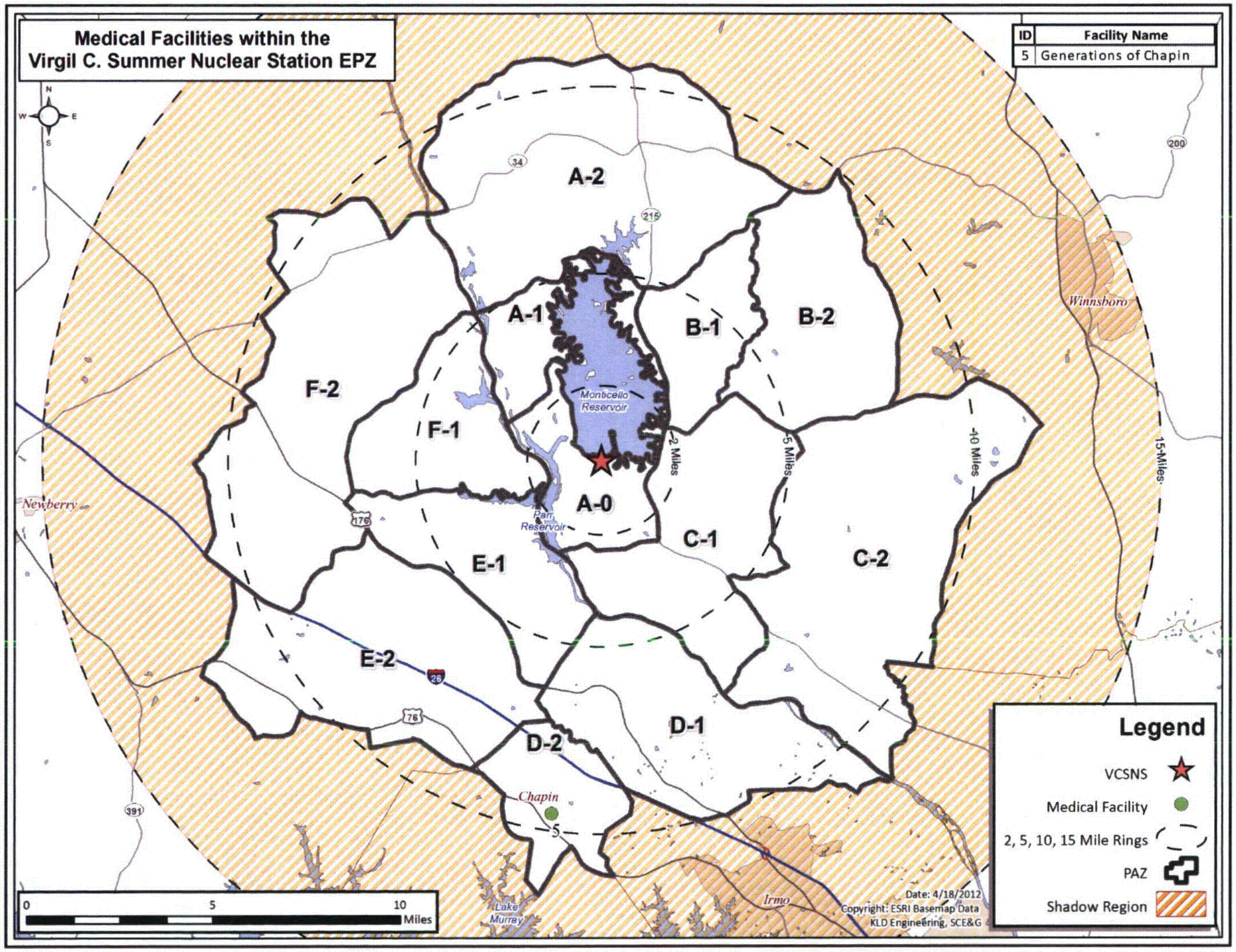

Figure E-2. Medical Facilities within the EPZ

Table E-3. Major Employers within the EPZ

PAZ	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Phone	Employees (max shift)	% Non-EPZ	Employees (Non EPZ)
FAIRFIELD COUNTY									
A-0	---	---	VC Summer Nuclear Station	576 Stairway Rd	Jenkinsville	(803) 931-5208	693	90%	624
						Fairfield County Subtotal:	*693*	-	*624*
LEXINGTON COUNTY									
D-2	9.6	S	Central Label Products	300 E Boundary St.	Chapin	(803) 345-5481	75	25%	19
D-2	9.6	S	CoreLogic	450 E. Boundary St.	Chapin	(803) 941-1200	135	67%	90
D-2	9.1	S	Ellet Brothers	267 Columbia Ave	Chapin	(803) 345-3751	100	68%	68
D-2	9.5	S	General Information Services	917 Chapin Road	Chapin	(803) 941-1900	340	78.5%	267
						Lexington County Subtotal:	*650*	-	*444*
NEWBERRY COUNTY									
E-2	11.6	WSW	Georgia Pacific Corporation	191 Georgia Pacific Blvd	Prosperity	(803) 364-3472	100	90%	90
						Newberry County Subtotal:	*100*	-	*90*
						EPZ TOTAL:	**1,443**	-	**1,158**

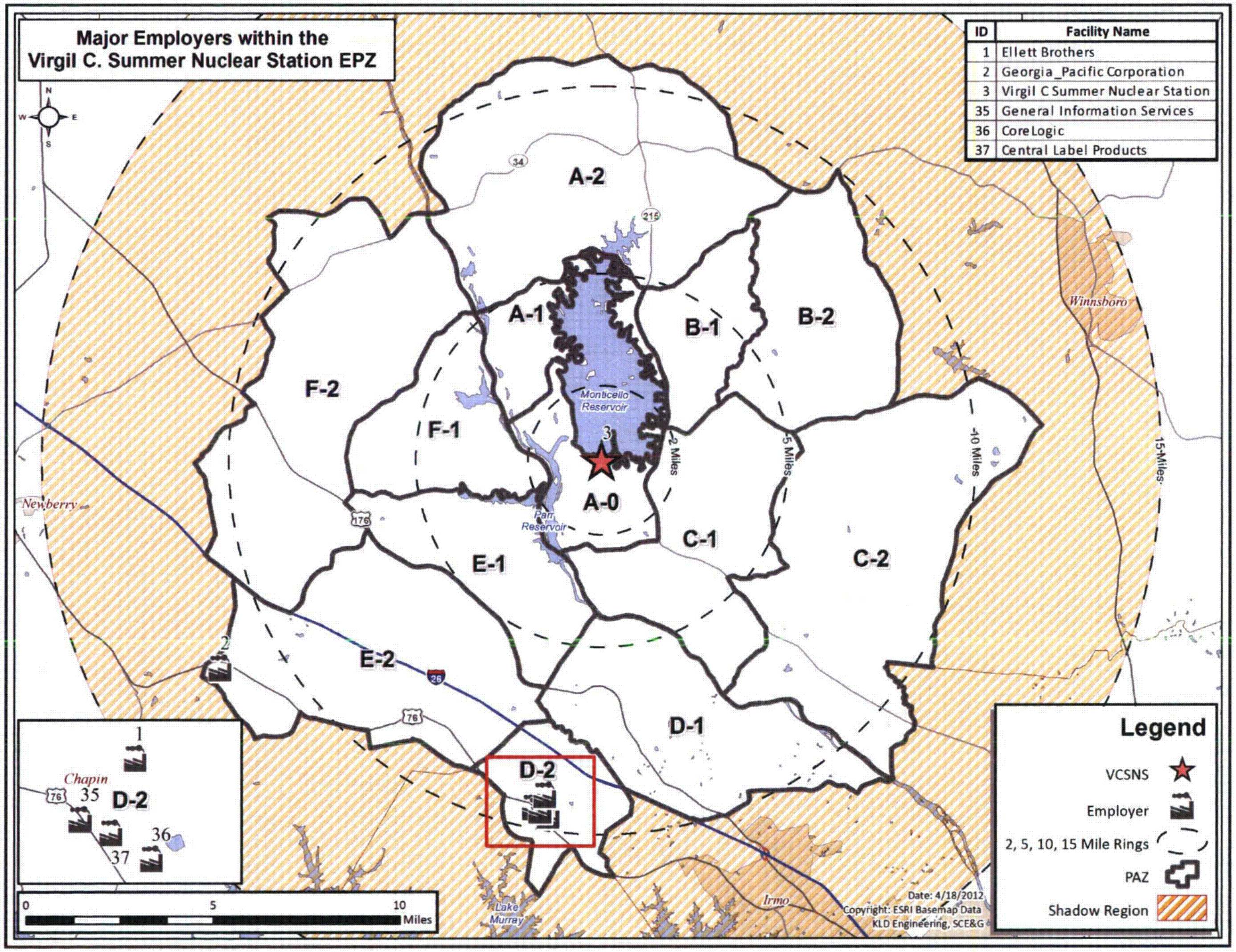

Figure E-3. Major Employers within the EPZ

Table E-4. Recreational Areas within the EPZ

PAZ	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Phone	Transients	Vehicles
FAIRFIELD COUNTY								
A-1	2.6	N	Highway 215 Public Boat Ramp	STHY 215	Jenkinsville	(803) 748-3000	13	5
A-1	2.4	N	Lake Monticello Park	Baltic Circle	Jenkinsville	(803) 748-3000	13	5
A-1	5.3	N	Unnamed Boat Ramp	Meadow Lake Rd	Jenkinsville	(803) 748-3000	5	2
A-1	5.4	N	Unnamed Boat Ramp	Meadow Lake Rd	Jenkinsville	(803) 748-3000	13	5
A-2	5.7	N	Unnamed Beach	Hemlock Ln	Jenkinsville	(803) 748-3000	27	10
						Fairfield County Subtotal:	*71*	*27*
LEXINGTON COUNTY								
D-2	11.0	S	Lake Murray Golf Center	2032 Old Hilton Rd	Chapin	(803) 345-6112	9	6
						Lexington County Subtotal:	*9*	*6*
NEWBERRY COUNTY								
E-2	9.2	WSW	Mid Carolina Club	3593 Kibler Bridge Rd	Prosperity	(803) 364-3193	15	10
F-1	2.7	WSW	Canon's Creek Boat Ramp for Parr Reservoir	Broad River Rd	Pomaria	(803) 748-3000	13	5
F-1	3.6	WNW	Unnamed Boat Ramp for Parr Reservoir	Broad River Rd	Pomaria	(803) 748-3000	13	5
						Newberry County Subtotal:	*41*	*20*
						EPZ TOTAL:	**121**	**53**

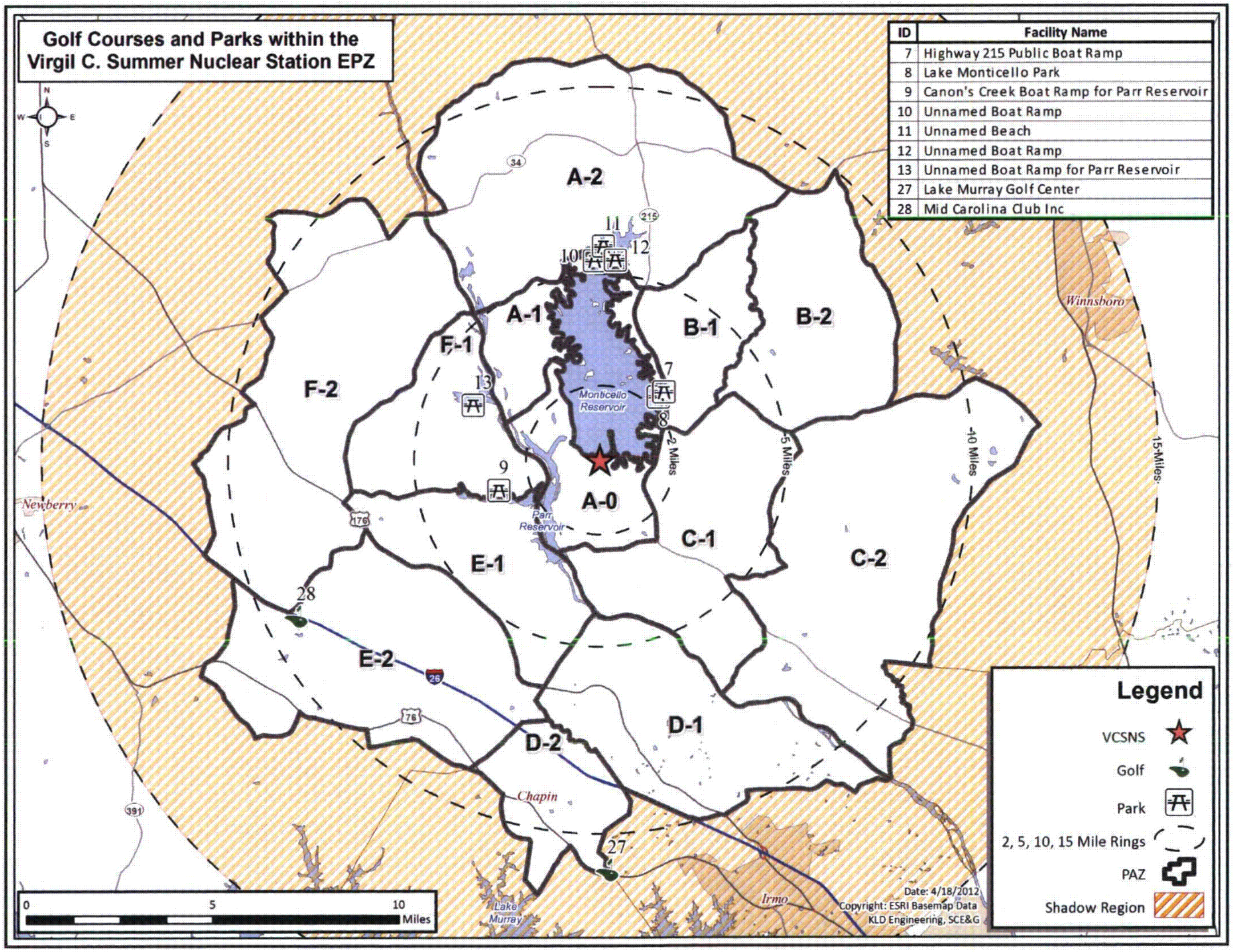

Figure E-4. Recreational Areas within the EPZ

Table E-5. Lodging Facilities within the EPZ

PAZ	Distance (miles)	Direction	Facility Name	Street Address	Municipality	Phone	Transients	Vehicles
There are no lodging facilities within the VC Summer EPZ								
						Subtotal:	*0*	*0*
						EPZ TOTAL:	**0**	**0**

Table E-6. Correctional Facilities within the EPZ

PAZ	Distance (miles)	Direction	Facility Name	Street Address	Municipality	Phone	Capacity
There are no Correctional Facilities within the VC Summer EPZ.							
						Subtotal:	*0*
						EPZ TOTAL:	**0**