4 ESTIMATION OF HIGHWAY CAPACITY

The ability of the road network to service vehicle demand is a major factor in determining how rapidly an evacuation can be completed. The capacity of a road is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane of roadway during a given time period under prevailing roadway, traffic and control conditions, as stated in the 2010 Highway Capacity Manual (HCM 2010).

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

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

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

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

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

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

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

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

As discussed in Section 2.3, it is necessary to adjust capacity figures to represent the prevailing conditions during inclement weather. Based on limited empirical data, weather conditions such as rain reduce the values of free speed and of highway capacity by approximately 10 percent. Over the last decade new studies have been made on the effects of rain on traffic capacity. These studies indicate a range of effects between 5 and 20 percent depending on wind speed and precipitation rates. As indicated in Section 2.3, we employ a reduction in free speed and in highway capacity of 10 percent and 20 percent for rain and snow, respectively.

Since congestion arising from evacuation may be significant, estimates of roadway capacity must be determined with great care. Because of its importance, a brief discussion of the major factors that influence highway capacity is presented in this section.

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

4.1 Capacity Estimations on Approaches to Intersections

At-grade intersections are apt to become the first bottleneck locations under local heavy traffic volume conditions. This characteristic reflects the need to allocate access time to the respective competing traffic streams by exerting some form of control. During evacuation, control at critical intersections will often be provided by traffic control personnel assigned for that purpose, whose directions may supersede traffic control devices. The existing traffic management plans documented in the county emergency plans are extensive and were adopted without change.

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

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

where:

$Q_{cap,m}$ = Capacity of a single lane of traffic on an approach, which executes

		movement, *m*, upon entering the intersection; vehicles per hour (vph)
h^m	=	Mean queue discharge headway of vehicles on this lane that are executing movement, *m*; seconds per vehicle
G	=	Mean duration of GREEN time servicing vehicles that are executing movement, *m*, for each signal cycle; seconds
L	=	Mean "lost time" for each signal phase servicing movement, *m*; seconds
C	=	Duration of each signal cycle; seconds
P_m	=	Proportion of GREEN time allocated for vehicles executing movement, *m*, from this lane. This value is specified as part of the control treatment.
m	=	The movement executed by vehicles after they enter the intersection: through, left-turn, right-turn, and diagonal.

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

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

where:

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

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

$$h_m \geq h_{sat}$$

That is, the turn-movement-specific discharge headways are always greater than, or equal to

[2]Lieberman, E., "Determining Lateral Deployment of Traffic on an Approach to an Intersection", McShane, W. & Lieberman, E., "Service Rates of Mixed Traffic on the far Left Lane of an Approach". Both papers appear in Transportation Research Record 772, 1980. Lieberman, E., Xin, W., "Macroscopic Traffic Modeling For Large-Scale Evacuation Planning", to be presented at the TRB 2012 Annual Meeting, January 22-26, 2012

the saturation discharge headway for through vehicles. These headways (or its inverse equivalent, "saturation flow rate"), may be determined by observation or using the procedures of the HCM 2010.

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

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

4.2 Capacity Estimation along Sections of Highway

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

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

The value of V_F can be expressed as:

$$V_F = R \times Capacity$$

where:

R = Reduction factor which is less than unity

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

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

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

The estimated value of capacity is based primarily upon the type of facility and on roadway geometrics. Sections of roadway with adverse geometrics are characterized by lower free-flow speeds and lane capacity. Exhibit 15-30 in the Highway Capacity Manual was referenced to estimate saturation flow rates. The impact of narrow lanes and shoulders on free-flow speed and on capacity is generally not material, particularly when flow is predominantly in one direction as is the case during an evacuation.

The procedure used here was to estimate "section" capacity, V_E, based on observations made traveling over each section of the evacuation network, based on the posted speed limits and travel behavior of other motorists and by reference to the 2010 HCM. The DYNEV II simulation model determines for each highway section, represented as a network link, whether its capacity would be limited by the "section-specific" service volume, V_E, or by the intersection-specific capacity. For each link, the model selects the lower value of capacity.

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

4.3 Application to the DBNPS Study Area

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

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

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

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

Each of these classifications will be discussed.

4.3.1 Two-Lane Roads

Ref: HCM Chapter 15

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

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

- Most sections of two-lane roads within the EPZ are classified as "Class I", with "level terrain"; some are "rolling terrain".
- "Class II" highways are mostly those within urban and suburban centers.

4.3.2 Multi-Lane Highway

Ref: HCM Chapter 14

Exhibit 14-2 of the HCM 2010 presents a set of curves that indicate a per-lane capacity ranging from approximately 1900 to 2200 pc/h, for free-speeds of 45 to 60 mph, respectively. Based on observation, the multi-lane highways outside of urban areas within the EPZ, service traffic with free-speeds in this range. The actual time-varying speeds computed by the simulation model reflect the demand: capacity relationship and the impact of control at intersections. A conservative estimate of per-lane capacity of 1900 pc/h is adopted for this study for multi-lane highways outside of urban areas, as shown in Appendix K.

4.3.3 Freeways

Ref: HCM Chapters 10, 11, 12, 13

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

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

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

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

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

Chapter 13 of the HCM 2010 presents procedures for estimating capacities of ramps and of "merge" areas. There are three significant factors to the determination of capacity of a ramp-freeway junction: The capacity of the freeway immediately downstream of an on-ramp or immediately upstream of an off-ramp; the capacity of the ramp roadway; and the maximum flow rate entering the ramp influence area. In most cases, the freeway capacity is the controlling factor. Values of this merge area capacity are presented in Exhibit 13-8 of the HCM 2010, and depend on the number of freeway lanes and on the freeway free speed. Ramp capacity is presented in Exhibit 13-10 and is a function of the ramp free flow speed. The DYNEV II simulation model logic simulates the merging operations of the ramp and freeway traffic in accord with the procedures in Chapter 13 of the HCM 2010. If congestion results from an excess of demand relative to capacity, then the model allocates service appropriately to the two entering traffic streams and produces LOS F conditions (The HCM does not address LOS F explicitly).

4.3.4 Intersections

Ref: HCM Chapters 18, 19, 20, 21

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

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

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

4.4 Simulation and Capacity Estimation

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

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

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

All simulation models must be calibrated properly with field observations that quantify the performance parameters applicable to the analysis network. Two of the most important of these are: (1) Free flow speed (FFS); and (2) saturation headway, h_{sat}. The first of these is estimated by direct observation during the road survey; the second is estimated using the concepts of the HCM, as described earlier. These parameters are listed in Appendix K, for each network link.

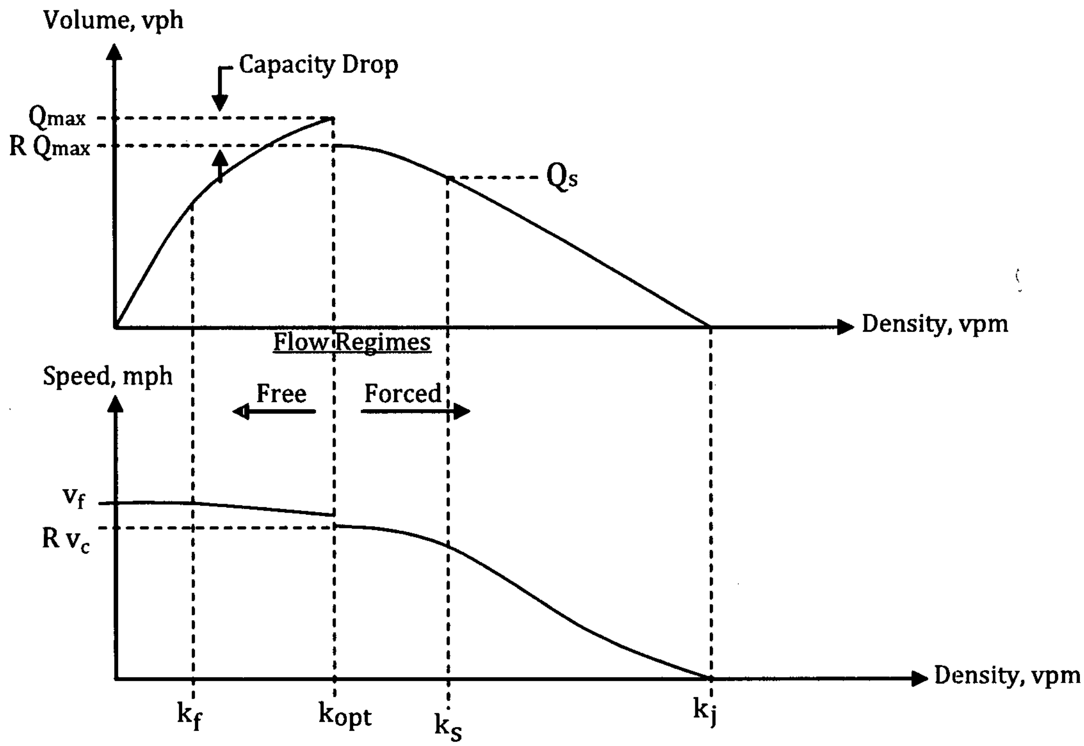


Figure 4-1. Fundamental Diagrams

5 ESTIMATION OF TRIP GENERATION TIME

Federal Government guidelines (see NUREG CR-7002) specify that the planner estimate the distributions of elapsed times associated with mobilization activities undertaken by the public to prepare for the evacuation trip. The elapsed time associated with each activity is represented as a statistical distribution reflecting differences between members of the public. The quantification of these activity-based distributions relies largely on the results of the telephone survey. The sum of these distributions describing the elapsed times of each activity, is the Trip Generation Time Distribution.

5.1 Background

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

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

At each level, the Federal guidelines specify a set of Actions to be undertaken by the licensee, and by State and Local offsite authorities. As a Planning Basis, we adopt a conservative posture, in accordance with Section 1.2 of NUREG/CR-7002, that a rapidly escalating accident will be considered in calculating the Trip Generation Time. The following assumptions apply:

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

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

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

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

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

The notification process consists of two events:

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

The population within the EPZ is dispersed over an area of approximately 160 square miles and people are engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident and, coincidentally, advising them to evacuate.

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

As indicated in Section 2.13 of NUREG/CR-6863, the estimated elapsed times for the receipt of notification can be expressed as a distribution reflecting the different notification times for different people within, and outside, the EPZ. By using time distributions, it is also possible to distinguish between different population groups and different day-of-week and time-of-day scenarios, so that accurate ETE may be computed.

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

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

5.2 Fundamental Considerations

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

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

Event Number	Event Description
1	Notification
2	Awareness of Situation
3	Depart Work
4	Arrive Home
5	Depart on Evacuation Trip

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

Table 5-1. Event Sequence for Evacuation Activities

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

These relationships are shown graphically in Figure 5-1.

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

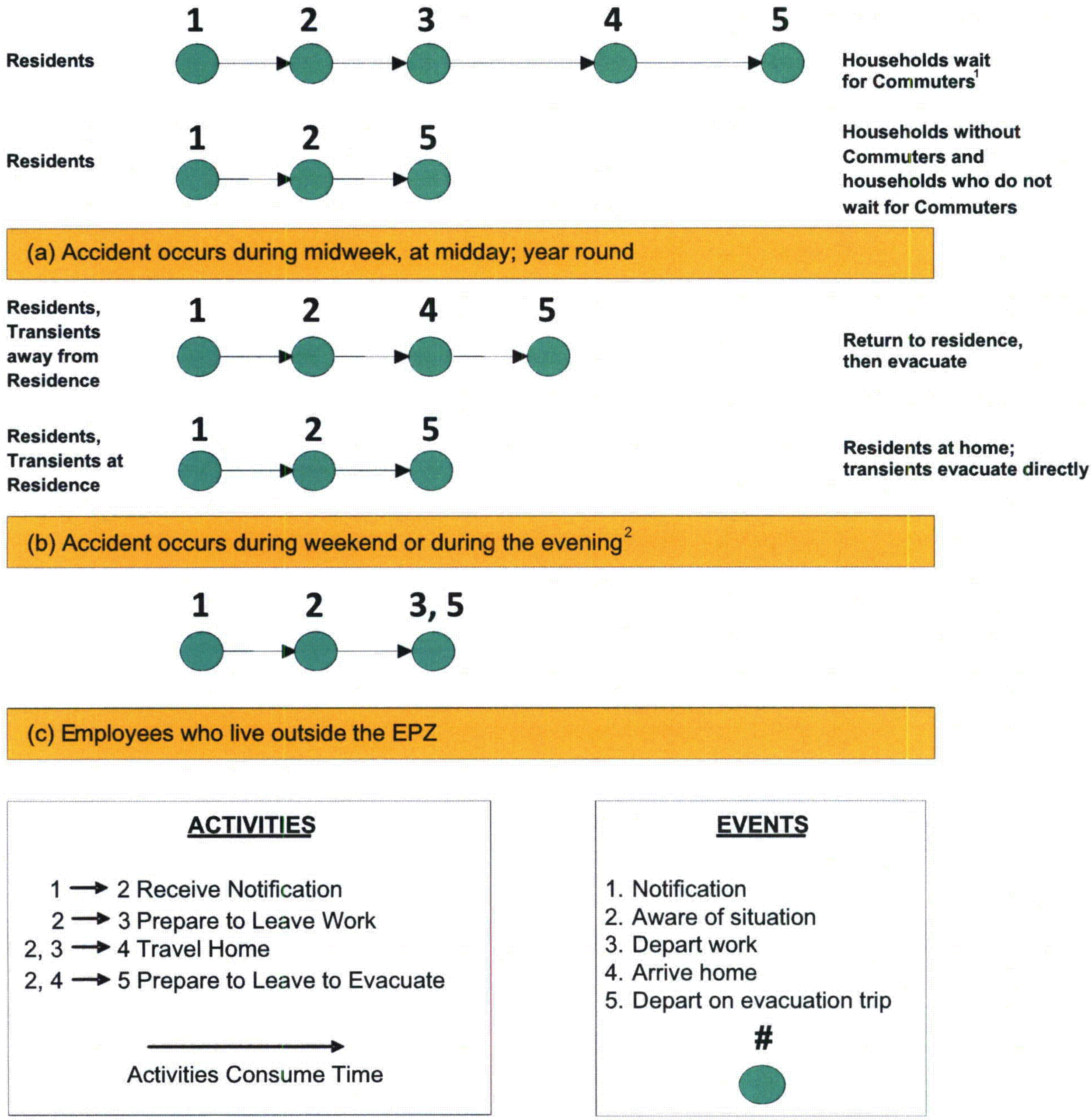
As such, an Activity changes the 'state' of an individual (e.g., the activity, 'travel home' changes the state from 'depart work' to 'arrive home'). Therefore, an Activity can be described as an 'Event Sequence'; the elapsed times to perform an event sequence vary from one person to the next and are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

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

Households with no commuters on weekends or in the evening/at night, will follow the applicable sequence in Figure 5-1(b). Transients will always follow one of the sequences of Figure 5-1(b). Some transients away from their residence could elect to evacuate immediately without returning to the residence, as indicated in the second sequence.

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

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



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

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

5.3 Estimated Time Distributions of Activities Preceding Event 5

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

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

It is assumed (based on the presence of sirens within the EPZ) that 85 percent of those within the EPZ will be aware of the accident within 30 minutes with the remainder notified within the following 15 minutes. The notification distribution is given below:

Table 5-2. Time Distribution for Notifying the Public

Elapsed Time (Minutes)	Percent of Population Notified
0	0
5	7
10	13
15	27
20	47
25	66
30	87
35	92
40	97
45	100

Distribution No. 2, Prepare to Leave Work: Activity 2 $\rightarrow$ 3

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

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

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work	Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0	35	90
5	39	40	91
10	55	45	93
15	66	50	93
20	73	55	93
25	75	60	100
30	90		

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

Distribution No. 3, Travel Home: Activity 2, 3 $\rightarrow$ 4

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

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

Elapsed Time (Minutes)	Cumulative Percent Returning Home	Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0	40	90
5	17	45	94
10	31	50	95
15	44	55	95
20	58	60	99
25	64	65	99
30	85	70	100
35	88		

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

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

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

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

Elapsed Time (Minutes)	Cumulative Percent Ready to Evacuate	Elapsed Time (Minutes)	Cumulative Percent Ready to Evacuate
0	0	90	90
5	5	95	90
10	10	100	90
15	16	105	90
20	29	110	93
25	42	115	95
30	55	120	98
35	57	125	98
40	59	130	98
45	61	135	99
50	69	140	99
55	77	145	99
60	85	150	99
65	86	155	99
70	87	160	99
75	88	165	99
80	89	170	99
85	89	175	100

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

Distribution No. 5, Snow Clearance Time Distribution

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

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

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

Elapsed Time (Minutes)	Cumulative Percent of Households Completing Activity	Elapsed Time (Minutes)	Cumulative Percent of Households Completing Activity
0	38	70	89
5	41	75	90
10	43	80	91
15	46	85	91
20	53	90	92
25	61	95	92
30	69	100	93
35	71	105	93
40	73	110	95
45	75	115	97
50	79	120	99
55	83	125	99
60	87	130	99
65	88	135	100

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

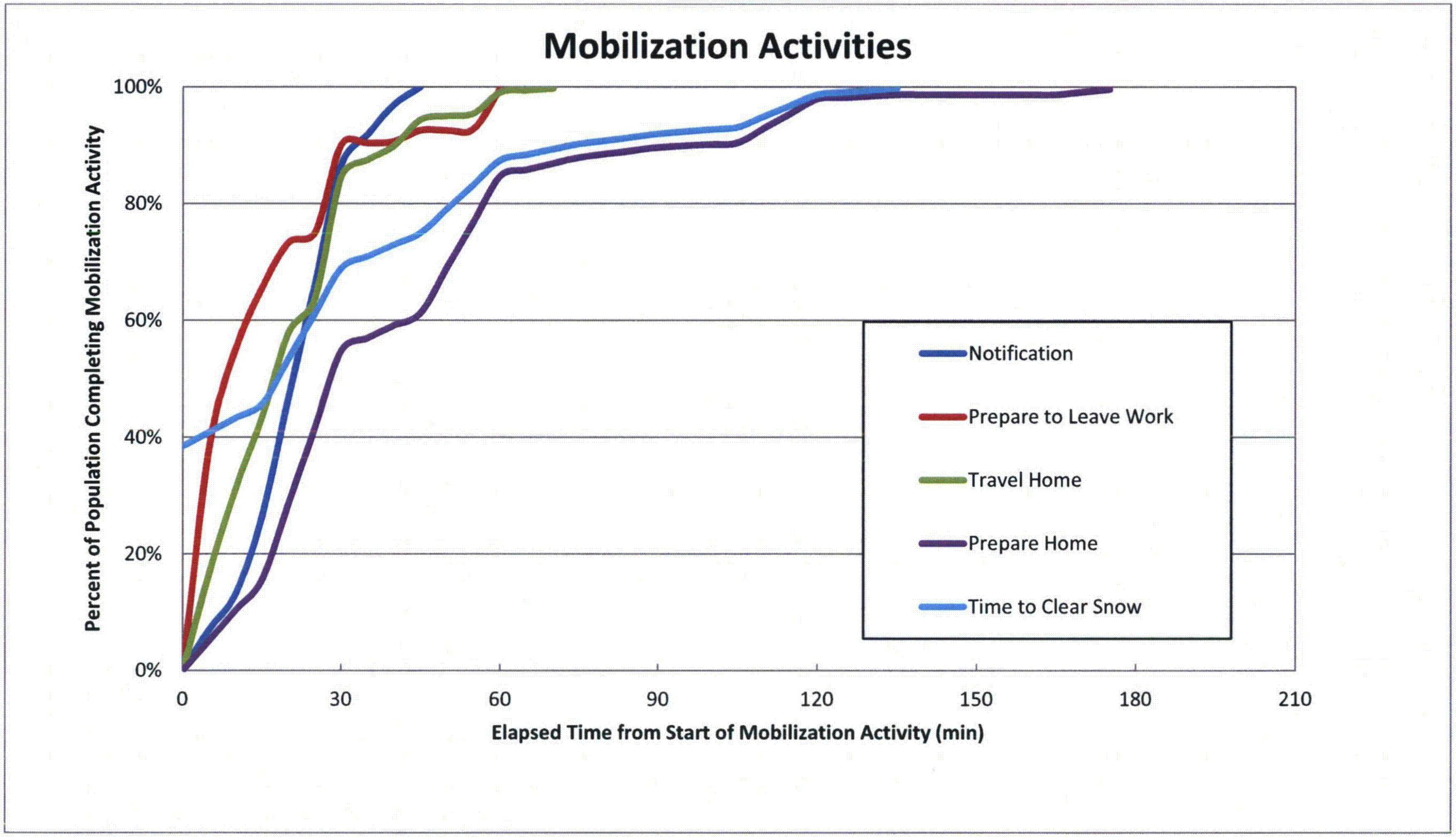


Figure 5-2. Evacuation Mobilization Activities

5.4 Calculation of Trip Generation Time Distribution

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

To calculate the time distribution of an event that is dependent on two sequential activities, it is necessary to "sum" the distributions associated with these prior activities. The distribution summing algorithm is applied repeatedly as shown to form the required distribution. As an outcome of this procedure, new time distributions are formed; we assign "letter" designations to these intermediate distributions to describe the procedure. Table 5-7 presents the summing procedure to arrive at each designated distribution.

Table 5-7. Mapping Distributions to Events

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

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

Table 5-8. Description of the Distributions

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ who live outside, and to Transients within the EPZ.
B	Time distribution of commuters arriving home (Event 4).
C	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip (Event 5).
D	Time distribution of residents without commuters returning home, leaving home to begin the evacuation trip (Event 5).
E	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip, after snow clearance activities (Event 5).
F	Time distribution of residents with no commuters returning home, leaving to begin the evacuation trip, after snow clearance activities (Event 5).

5.4.1 Statistical Outliers

As already mentioned, some portion of the survey respondents answer "don't know" to some questions or choose to not respond to a question. The mobilization activity distributions are based upon actual responses. But, it is the nature of surveys that a few numeric responses are inconsistent with the overall pattern of results. An example would be a case in which for 540 responses, almost all of them estimate less than two hours for a given answer, but 3 say "four hours" and 4 say "six or more hours".

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

In assessing outliers, there are three alternates to consider:

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

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

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

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

There is considerable statistical literature on the identification and treatment of outliers singly or in groups, much of which assumes the data is normally distributed and some of which uses nonparametric methods to avoid that assumption. The literature cites that limited work has been done directly on outliers in sample survey responses.

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

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

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

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

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

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

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

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

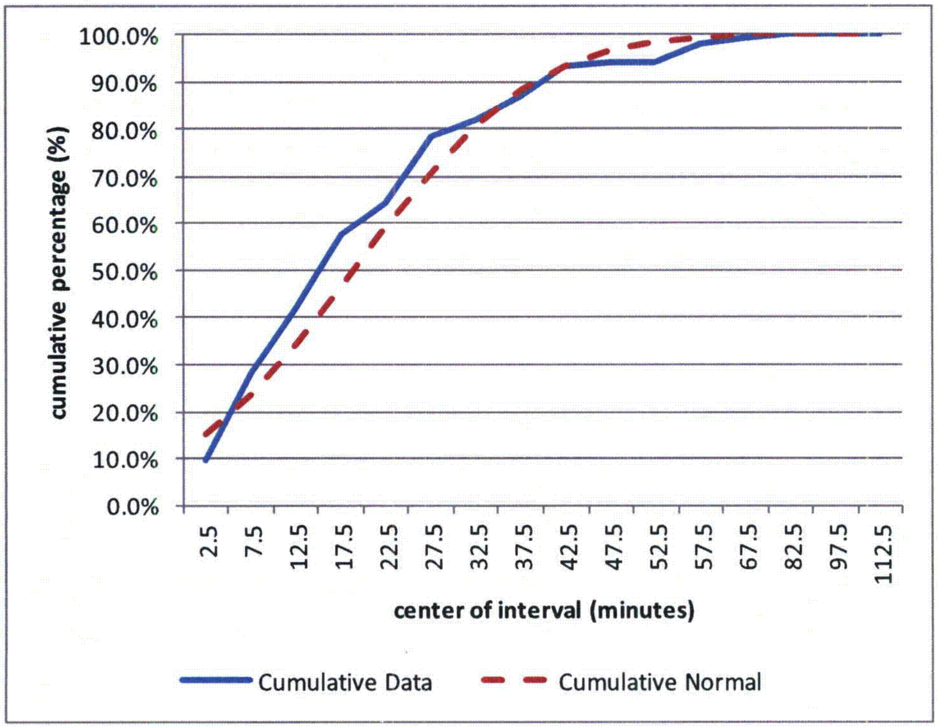


Figure 5-3. Comparison of Data Distribution and Normal Distribution

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

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

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

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

This is done by using the data sets and distributions under different scenarios (e.g., commuter returning, no commuter returning, no snow or snow in each). In general, these are additive, using weighting based upon the probability distributions of each element; Figure 5-4 presents the combined trip generation distributions designated A, C, D, E and F. These distributions are presented on the same time scale. (As discussed earlier, the use of strictly additive activities is a conservative approach, because it makes all activities sequential – preparation for departure follows the return of the commuter; snow clearance follows the preparation for departure, and so forth. In practice, it is reasonable that some of these activities are done in parallel, at least to some extent – for instance, preparation to depart begins by a household member at home while the commuter is still on the road.)

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

Figure 5-4 presents the resultant trip generation distributions for each of the population groups identified. The DYNEV II simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These histograms, which represent Distributions A, C, D, E and F, properly displaced with respect to one another, are tabulated in Table 5-9 (Distribution B, Arrive Home, omitted for clarity).

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

5.4.2 Staged Evacuation Trip Generation

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

1. Subareas comprising the 2 mile region are advised to evacuate immediately
2. Subareas comprising regions extending from 2 to 5 miles downwind are advised to shelter in-place while the 2 mile region is cleared
3. As vehicles evacuate the 2 mile region, people from 2 to 5 miles downwind continue preparation for evacuation
4. The population sheltering in the 2 to 5 mile region are advised to begin evacuating when approximately 90% of 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%

Assumptions

1. The EPZ population in Subareas beyond 5 miles will react as does the population in the 2 to 5 mile region; that is they will first shelter, then evacuate after the 90th percentile ETE for the 2 mile region
2. The population in the shadow region beyond the EPZ boundary, extending to approximately 15 miles radially from the plant, will react as they do for all non-staged

evacuation scenarios. That is 20% of these households will elect to evacuate with no shelter delay.

3. The transient population will not be expected to stage their evacuation because of the limited sheltering options available to people who may be at parks, on a beach, or other venues. Also, notifying the transient population of a staged evacuation would prove difficult.

4. Employees will also be assumed to evacuate without staging.

<u>Procedure</u>

1. Trip generation for population groups in the 2 mile region will be as computed based upon the results of the telephone survey and analysis.
2. Trip generation for the population subject to staged evacuation will be formulated as follows:
    a. Identify the 90th percentile evacuation time for the Subareas comprising the two mile region. This value, T_{Scen}^*, obtained from simulation results is scenario-specific. It will become the time at which the region being sheltered will be told to evacuate for each scenario.
    b. The resultant trip generation curves for staging are then formed as follows:
        i. The non-shelter trip generation curve is followed until a maximum of 20% of the total trips are generated (to account for shelter non-compliance).
        ii. No additional trips are generated until time T_{Scen}^*
        iii. Following time T_{Scen}^*, the balance of trips are generated:
            1. by stepping up and then following the non-shelter trip generation curve (if T_{Scen}^* is $\leq$ max trip generation time) or
            2. by stepping up to 100% (if T_{Scen}^* is > max trip generation time)
    c. Note: This procedure implies that there may be different staged trip generation distributions for different scenarios. NUREG/CR-7002 uses the statement "approximately 90 percent" as the time to end staging and begin evacuating. The trip generation distributions for residents tend to be similar for all scenarios except "Snow" where it is extended due to the need to clear driveways. Therefore, we define two values of T_{Scen}^*; one for non-snow scenarios and one for snow scenarios.
3. Staged trip generation distributions are created for the following population groups:
    a. Residents with returning commuters
    b. Residents without returning commuters
    c. Residents with returning commuters and snow conditions
    d. Residents without returning commuters and snow conditions

Figure 5-5 presents the staged trip generation distributions for both residents with and without returning commuters; the 90th percentile two-mile evacuation time is 135 minutes for non-snow scenarios and 155 minutes for snow scenarios. At the 90th percentile evacuation time, 20% of the population (who normally would have completed their mobilization activities for an un-staged evacuation) advised to shelter has nevertheless departed the area. These people do not comply with the shelter advisory. Also included on the plot are the trip generation distributions for these groups as applied to the regions advised to evacuate immediately.

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

Table 5-10 provides the trip generation histograms for staged evacuation. These data are used by the DYNEV II system.

5.4.3 Trip Generation for Waterways and Recreational Areas

The Ottawa County RERP Plan (Rev.24, Page II-A-8) indicates that the Ohio Department of Natural Resources (ODNR) ensures that staff and visitors at the Magee Marsh Wildlife Area are notified of the emergency. ODNR also maintains traffic control in areas designated for anchorage of boats and control vessel traffic in harbors and channels. ODNR provides the alternate aircraft pilots for waterway notification of recreational boaters on Lake Erie, as well as personnel, watercraft, and equipment. ODNR augments U.S. Coast Guard efforts and assists in marine traffic control.

The NOAA National Weather Service (NWS), over NOAA weather radio, will instruct the public to refer to an EAS station for emergency information. In addition, the NWS shall provide weather information upon request to responding federal, state or local agencies. The FAA will restrict air traffic within a ten-mile radius of the affected area when requested by Ohio EMA. Upon request, the Coast Guard will broadcast an emergency notice to mariners. In addition to broadcasting the notice to mariners, the Ninth District USCG stations will provide available resources (i.e., vessels, aircraft and personnel) to begin notifying boaters on Lake Erie.

As indicated in Table 5-2 , this study assumes 100% notification in 45 minutes. Table 5-9 indicates that all transients will have mobilized within 1 hour 45 minutes. It is assumed that this timeframe is sufficient time for boaters, campers and other transients to return to their vehicles and begin their evacuation trip.

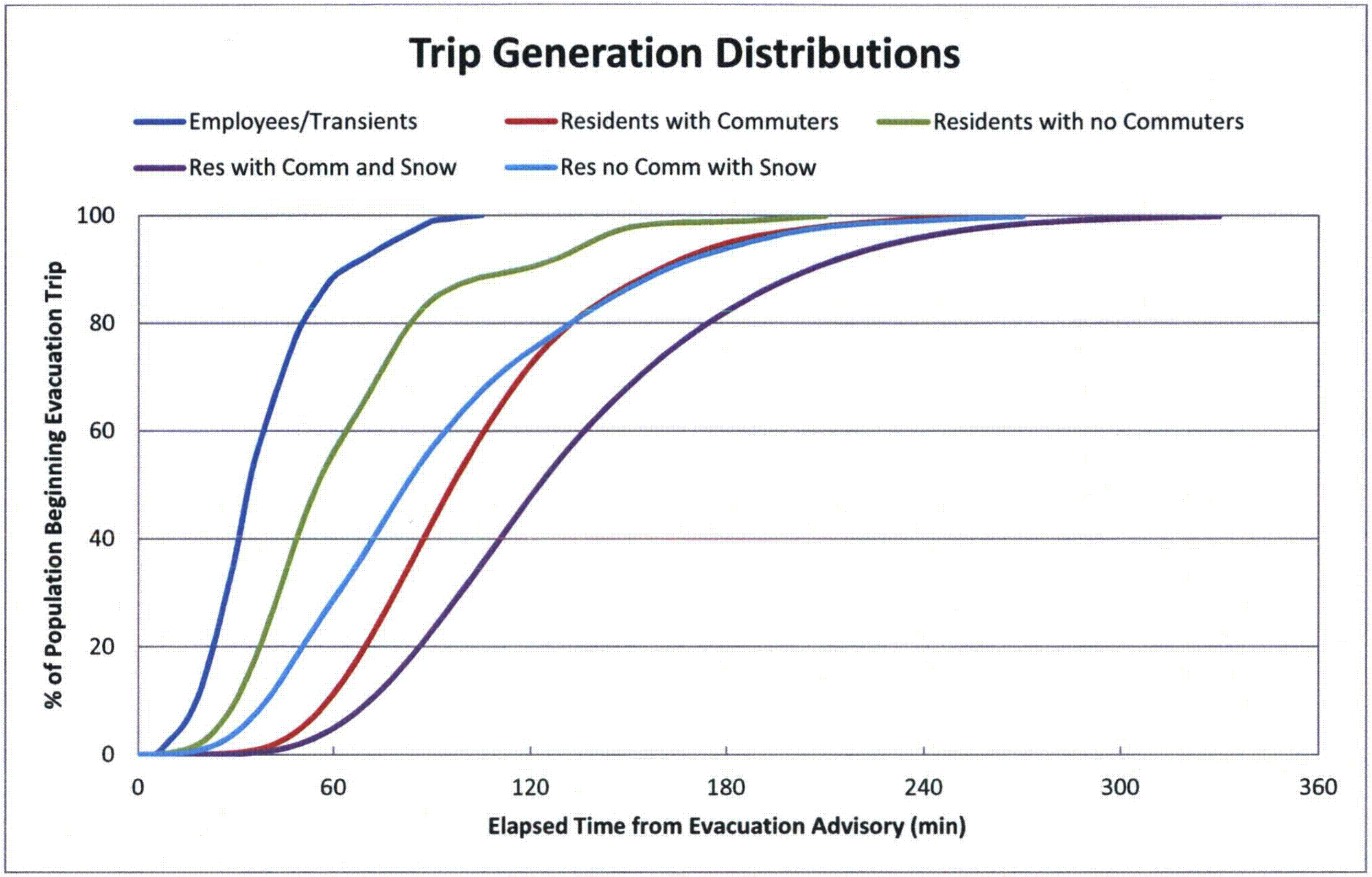


Figure 5-4. Comparison of Trip Generation Distributions

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

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period					
		Employees (Distribution A)	Transients (Distribution A)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	6	6	0	1	0	0
2	15	31	31	0	9	0	4
3	15	35	35	3	23	1	11
4	15	17	17	8	23	4	14
5	15	5	5	15	16	7	14
6	15	5	5	17	12	11	14
7	15	1	1	16	5	12	11
8	15	0	0	13	1	13	7
9	30	0	0	15	8	20	11
10	60	0	0	11	2	23	12
11	60	0	0	2	0	7	2
12	60	0	0	0	0	2	0
13	600	0	0	0	0	0	0

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

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

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period[1]			
		Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)	Residents With Commuters Snow (Distribution E)	Residents Without Commuters Snow (Distribution F)
1	15	0	0	0	0
2	15	0	2	0	1
3	15	1	5	0	2
4	15	1	4	1	3
5	15	3	3	1	3
6	15	4	3	3	2
7	15	3	1	2	3
8	15	2	0	3	1
9	30	73	80	4	2
10	60	11	2	77	81
11	60	2	0	7	2
12	60	0	0	2	0
13	600	0	0	0	0

[1]Trip Generation for Employees and Transients (see Table 5-9) is the same for Un-staged and Staged Evacuation.

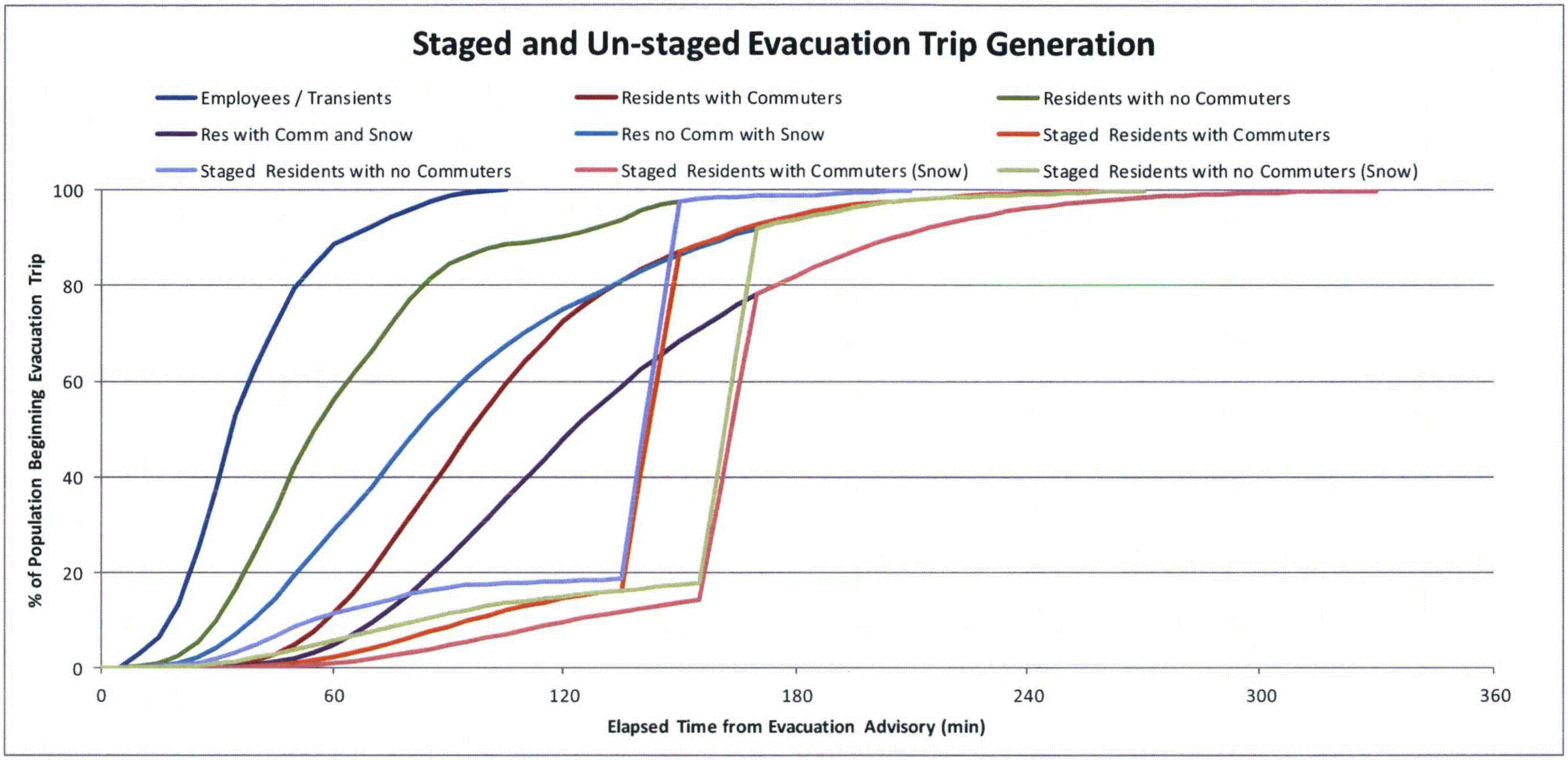


Figure 5-5. Comparison of Staged and Un-staged Trip Generation Distributions in the 2 to 5 Mile Region

6 DEMAND ESTIMATION FOR EVACUATION SCENARIOS

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

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

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

A total of 21 Regions were defined which encompass all the groupings of Subareas considered. These Regions are defined in Table 6-1. The Subarea configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a central circle centered at the power plant, and three adjoining sectors, each with a central angle of 22.5 degrees. The central sector coincides with the wind direction. These sectors extend to 5 miles from the plant (Regions R04 through R05) or to the EPZ boundary (Regions R06 through R18). Regions R01, R02 and R03 represent evacuations of circular areas with radii of 2, 5 and 10 miles, respectively. Regions R21 through R23 are identical to Regions R04 through R06; however, those Subareas between 2 miles and 5 miles are staged until 90% of the 2-mile region (Region R01) has evacuated. Note that based on local procedures, Subarea 10 evacuates under all circumstances. Thus, Subarea 10 is included in all Regions in Table 6-1.

A total of 14 Scenarios were evaluated for all Regions. Thus, there are a total of 14x21=294 evacuation cases. Table 6-2 is a description of all Scenarios.

Each combination of region and scenario implies a specific population to be evacuated. Table 6-3 presents the percentage of each population group assumed to evacuate for each scenario. Table 6-4 presents the vehicle counts for each scenario for an evacuation of Region R03 – the entire EPZ.

The vehicle estimates presented in Section 3 are peak values. These peak values are adjusted depending on the scenario and region being considered using scenario and region specific percentages; the scenario percentages are presented in Table 6-3, while the regional percentages are provided in Table H-1. The percentages presented in Table 6-3 were determined as follows:

The residents with commuters value during the week (when workforce is at its peak) is equal to the product of 47% (the number of households with at least one commuter) and 44% (the number of households with a commuter who would await the return of the commuter prior to evacuating). See assumption 3 in Section 2.3. It is assumed for weekend and evening scenarios that 10% of households with commuters will have a commuter at work during those times.

Employment is assumed to be at its peak during the winter, midweek, midday. Employment is reduced slightly (96%) for summer, midweek, midday scenarios. This is based on the assumption that 50% of the employees commuting into the EPZ will be on vacation for a week during the approximate 12 weeks of summer. It is further assumed that those taking vacation will be uniformly dispersed throughout the summer with approximately 4% of employees vacationing each week.

Transient activity is assumed to be at its peak during summer weekends and less (15%) during the week. Transient activity during the winter, midweek and weekend, is low – 5% to 10%.

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

$$20\% \times \left(1 + \frac{780}{2435 + 9{,}322}\right) = 21\%$$

One special event, National Rifle Matches at Camp Perry, was considered as Scenario 13. Thus, the special event traffic is 100% evacuated for Scenario 13, and 0% for all other scenarios.

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

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

Table 6-1. Description of Evacuation Regions

Region	Description	Subarea 1	2	3	4	5	6	7	8	9	10	11	12
R01	2-Mile Ring	X									X		X
R02	5-Mile Ring	X	X				X				X		X
R03	Full EPZ	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:	1	2	3	4	5	6	7	8	9	10	11	12
	N	Refer to Region R02											
R04	NNE, NE, ENE, E, ESE	X	X								X		X
	SE, SSE, S, SSW, SW, WSW, W	Refer to Region R01											
R05	WNW	X					X				X		X
	NW, NNW	Refer to Region R02											
Evacuate 2-Mile Radius and Downwind to the EPZ Boundary													
R06	N	X	X		X	X	X	X	X		X		X
R07	NNE	X	X	X	X	X	X	X	X		X		X
R08	NE, ENE	X	X	X	X	X					X		X
R09	E, ESE	X	X	X							X	X	X
R10	SE	X									X	X	X
	SSE, S, SSW, SW, WSW, W	Refer to Region R01											
R11	WNW	X					X	X	X	X	X		X
R12	NW	X	X				X	X	X	X	X		X
R13	NNW	X	X			X	X	X	X	X	X		X
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary													
R14	N	X	X			X	X	X	X		X		X
R15	NNE	X	X	X	X	X	X	X	X		X		X
R16	NE, ENE	X	X	X	X	X	X				X		X
R17	E, ESE	X	X	X			X				X	X	X
R18	SE	X	X				X				X	X	X
	SSE, S, SSW, SW, WSW, W	Refer to Region R02											
	WNW, NW	Refer to Region R12											
	NNW	Refer to Region R13											
Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles													
R19	N	X	X				X				X		X
R20	NNE, NE, ENE, E, ESE	X	X								X		X
R21	WNW	X					X				X		X
	NW, NNW	Refer to Region R19											

Subarea(s) Shelter-in-Place until 90% ETE for R01, then Evacuate	Subarea(s) Shelter-in-Place	Subarea(s) Evacuate

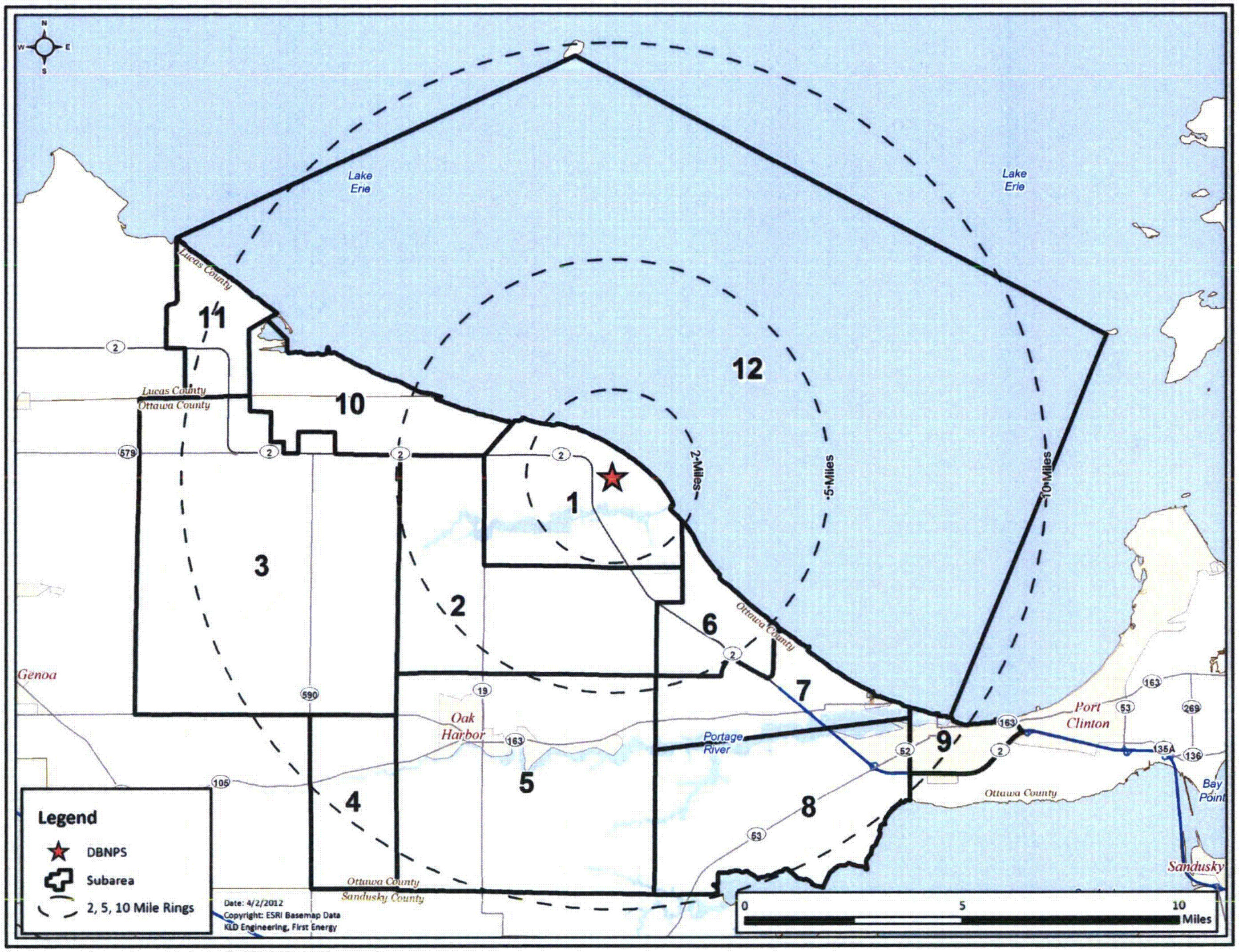


Figure 6-1. Davis-Besse Site EPZ Subareas

Table 6-2. Evacuation Scenario Definitions

Scenarios	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Midweek	Midday	Snow	None
9	Winter	Weekend	Midday	Good	None
10	Winter	Weekend	Midday	Rain	None
11	Winter	Weekend	Midday	Snow	None
12	Winter	Midweek, Weekend	Evening	Good	None
13	Summer	Weekend	Midday	Good	Special Event
14	Summer	Midweek	Midday	Good	Roadway Impact - Closure on Route 2 Eastbound

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

Scenario	Residents With Commuters in Household	Residents With No Commuters in Household	Employees	Transients	Shadow*	Special Events	School Buses	Transit Buses	External Through Traffic
1	21%	79%	96%	85%	21%	0%	10%	100%	100%
2	21%	79%	96%	85%	21%	0%	10%	100%	100%
3	10%	90%	10%	100%	20%	0%	0%	100%	100%
4	10%	90%	10%	100%	20%	0%	0%	100%	100%
5	10%	90%	10%	75%	20%	0%	0%	100%	40%
6	21%	79%	100%	5%	21%	0%	100%	100%	100%
7	21%	79%	100%	5%	21%	0%	100%	100%	100%
8	21%	79%	100%	5%	21%	0%	100%	100%	100%
9	10%	90%	10%	10%	20%	0%	0%	100%	100%
10	10%	90%	10%	10%	20%	0%	0%	100%	100%
11	10%	90%	10%	10%	20%	0%	0%	100%	100%
12	10%	90%	10%	10%	20%	0%	0%	100%	40%
13	10%	90%	10%	100%	20%	100%	0%	100%	100%
14	21%	79%	96%	85%	21%	0%	10%	100%	100%

Resident Households with Commuters ...... Households of EPZ residents who await the return of commuters prior to beginning the evacuation trip.
Resident Households with No Commuters . Households of EPZ residents who do not have commuters or will not await the return of commuters prior to beginning the evacuation trip.
Employees... EPZ employees who live outside the EPZ
Transients .... People who are in the EPZ at the time of an accident for recreational or other (non-employment) purposes.
Shadow .... Residents and employees in the shadow region (outside of the EPZ) who will spontaneously decide to relocate during the evacuation. The basis for the values shown is a 20% relocation of shadow residents along with a proportional percentage of shadow employees.
Special Events... Additional vehicles in the EPZ due to the identified special events.
School and Transit Buses .... Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus is equivalent to 2 passenger vehicles).
External Through Traffic............................Traffic on local highways and major arterial roads at the start of the evacuation. This traffic is stopped by access control approximately 2 hours after the evacuation begins.

Table 6-4. Vehicle Estimates by Scenario

Scenarios	Residents with Commuters	Residents without Commuters	Employees	Transients	Shadow	Special Events	School Buses	Transit Buses	External Traffic	Total Scenario Vehicles
1	2,431	9,326	780	5,885	2,324	-	16	28	36,850	57,640
2	2,431	9,326	780	5,885	2,324	-	16	28	36,850	57,640
3	243	11,514	81	6,924	2,195	-	-	28	36,850	57,835
4	243	11,514	81	6,924	2,195	-	-	28	36,850	57,835
5	243	11,514	81	5,193	2,195	-	-	28	14,740	33,994
6	2,431	9,326	813	346	2,331	-	156	28	36,850	52,281
7	2,431	9,326	813	346	2,331	-	156	28	36,850	52,281
8	2,431	9,326	813	346	2,331	-	156	28	36,850	52,281
9	243	11,514	81	692	2,195	-	-	28	36,850	51,603
10	243	11,514	81	692	2,195	-	-	28	36,850	51,603
11	243	11,514	81	692	2,195	-	-	28	36,850	51,603
12	243	11,514	81	692	2,195	-	-	28	14,740	29,493
13	243	11,514	81	6,924	2,195	851	-	28	36,850	58,686
14	2,431	9,326	780	5,885	2,324	-	16	28	36,850	57,640

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

7 GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the current results of the computer analyses using the DYNEV II System described in Appendices B, C and D. These results cover 21 Evacuation Regions within the Davis-Besse 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

We define "voluntary evacuees" as people who are within the EPZ in Subareas for which an Advisory to Evacuate has not been issued, yet who nevertheless elect to evacuate. We define "shadow evacuation" as 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 Davis-Besse Site addresses the issue of voluntary evacuees in the manner shown in Figure 7-1. Within the EPZ, 20 percent of people located in Subareas outside of the evacuation region who are not advised to evacuate are assumed to evacuate nevertheless. Similarly we will assume 20 percent of those people in the shadow evacuation region, outside of the EPZ extending to approximately 15 miles from the Davis-Besse site, will also choose to leave the area.

Figure 7-2 presents the area identified as the Shadow Evacuation 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 Evacuation Region were estimated using the same methodology that was used for permanent residents within the EPZ (see page 3-2). It is estimated that a total of 18,925 people reside in the Shadow Evacuation Region and that they would use 10,899 vehicles. We assume that 20 percent of these people will leave the area.

Traffic generated within this Shadow Evacuation Region, traveling away from the Davis-Besse site location, has a potential for impeding evacuating vehicles from within the Evacuation Region. We assume that the traffic voluntarily evacuating from within the Shadow Region represents 20 percent of the residents there, plus a proportionate number of employees in that region, as noted in the Shadow footnote to Table 6-3. 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. Subareas comprising the 2 mile region are advised to evacuate immediately.
2. Subareas 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 7-4 through Figure 7-6 presents the patterns of traffic congestion after the Advisory to Evacuate is issued for the case when the entire EPZ (Region R03) is advised to evacuate during the winter, midweek, midday period under good weather conditions (Scenario 6).

Traffic congestion, as the term is used here, is defined as Level of Service (LOS) F. LOS F is defined as follows (2010 HCM, 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. Congestion develops rapidly around concentrations of population and traffic bottlenecks.

Figure 7-4 presents the congestion patterns at 1 hour after the ATE. After 1 hour there is some congestion on the Route 163 approach to Route 2 and on the western edge of Port Clinton. The Sandusky Bay Bridge is seen to operate at capacity conditions with some congestion on its approach. Some minor congestion is noted at Route 19 as it departs the EPZ and at a number of locations in the shadow region. As shown in Figure 7-5, at 2 hours after the ATE, congestion is clearing in Port Clinton and is still evident on the approach to the Sandusky Bay Bridge. There is a single point of congestion as traffic departs Magee Marsh, but has dissipated everywhere else. Figure 7-6, at 3 hours after the ATE, shows that some residual congestion remains in the vicinity of the Jet Express parking area on the western edge of Port Clinton.

All congestion clears before the trip generation time of 4:30 hours (See Section 5); thus, the ETE for the 100^{th} percentile evacuation is dictated by the trip generation time. The 90^{th} percentile ETE should be considered when making protective action decisions, in order to avoid the long tail of the 100th percentile ETE. This observation is consistent with the findings of NUREG/CR-6953, Volume 2. The use of 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 also be considered.

7.4 Evacuation Rates

Evacuation is a continuous process, as implied by Figure 7-7 through Figure 7-20. 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 7-7, there is typically a long "tail" to these distributions. Vehicles begin to evacuate an area slowly at first, as people respond to the Advisory to Evacuate at different rates. Then traffic demand builds rapidly (slopes of curves increase). When the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand.

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

The Davis-Besse ETE under all conditions reflects the trip mobilization time. The levels of traffic congestion noted in Figure 7-4 through Figure 7-6 are limited in time and space. Where traffic congestion exists, it dissipates well before the end of the trip generation process. Generally trips are generated over a 4 hour 30 minute period (see Section 5). Consequently the 100^{th}

percentile evacuation time is represents this value. The entire EPZ is evacuated in just under 5 hours under the conditions in this scenario.

7.5 Evacuation Time Estimate (ETE) Results

Table 7-1 through Table 7-2 present the ETE values for all 21 Evacuation Regions and all 14 Evacuation Scenarios. Table 7-3 through Table 7-4 present the ETE values for 2-Mile region for both staged and un-staged 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 animation snapshots described above reflect the ETE statistics for the concurrent (un-staged) evacuation scenarios and regions, which are displayed in Figure 7-4 through Figure 7-6.

The Davis-Besse ETE under all conditions reflects the trip mobilization time. The levels of traffic congestion noted in Figure 7-4 through Figure 7-6 are limited in time and space. Where traffic congestion exists, it dissipates well before the end of the trip generation process. Generally trips are generated over 4 hour 30 minutes for good weather and rain conditions. (see Table 5-9). Consequently the 100th percentile evacuation time is represents this value. The entire EPZ is evacuated in just under 5 hours under good weather and rain conditions. Under snow conditions, where the trip mobilization time is extended due to the need to clear driveways of snow prior to departing, the travel speeds and highway capacities are reduced, the ETE is longer. The entire EPZ is evacuated in just under 6 hours under these conditions.

The Roadway Closure scenario (Scenario 14) has no significant impact on the 100th percentile ETE. However, the roadway closure scenario increases the 90th percentile ETE by up to 20 minutes in a full EPZ (Region R03) evacuation. The roadway closure is detailed in Figure 7-3.

7.6 Staged Evacuation Results

Table 7-3 and Table 7-4 present a summary of the staged evacuation results. Note that Regions R19, R20 and R21 are the same geographic areas as Regions R02, R04 and R06, respectively, except that a staged evacuation is performed. Note that the 2-mile region consists of Subareas 1 and 10; Subarea 10 actually extends about 9 miles to the west. These tables present the ETE for this 2 mile Region when each of the indicated regions extending to 5 miles, is evacuated. For example, the results for Region R02 indicate the time to clear this 2-mile region given that Region 02 is evacuated.

To determine whether the staged evacuation strategy is worthy of consideration, one must show that the ETE for this 2 Mile region can be reduced without significantly affecting the evacuating region between 2 miles and 5 miles. In all cases, as shown in these tables, the ETE for this 2 mile region is unchanged when a staged evacuation is implemented. The reason for this is the lack of material congestion when the evacuation is not staged, which extends into the 2 mile region. Thus, staging the evacuation provides no benefits to evacuees from within the 2 mile region. Results presented in Table 7-1 indicate that there is a material increase in 90th percentile ETE for the 5 mile regions when staged evacuation is used.

7.7 Guidance on Using ETE Tables

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

1. Identify the applicable **Scenario**:
    - Season
        - Summer
        - Winter (also Autumn and Spring)
    - Day of Week
        - Midweek
        - Weekend
    - Time of Day
        - Midday
        - Evening
    - Weather Condition
        - Good Weather
        - Rain
        - Snow
    - Special Event
        - National Rifle Matches at Camp Perry
        - Roadway Impact Closure (A lane on the limited access portion of Route 2 eastbound was 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 Table 7-1 and Table 7-2. 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 Table 7-1 and Table 7-2. For these conditions, Scenarios (7) and (10) for rain apply.
- The conditions of a winter evening (either midweek or weekend) and snow are not explicitly identified in Table 7-1 and Table 7-2. For these conditions, Scenarios (8) and (11) for snow apply.
- The seasons are defined as follows:
  - Summer assumes that public schools are not in session.
  - Winter (implies Spring and Autumn) considers that public schools are in session.
- Time of Day: Midday implies the time over which most commuters are at work or are travelling to/from work.

2. With the 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 power plant. The applicable distances and their associated candidate Regions are given below:
     - 2 Miles (Region R01)
     - To 5 Miles (Region R02 and R04, R05)
     - to EPZ Boundary (Regions R03, and R06 through R18)
   - Enter Table 7-5 and identify the applicable group of candidate Regions based on the distance that the selected Region extends from the Davis-Besse Site. Select the Evacuation Region identifier in that row from the first column of the Table.

3. Determine the **ETE for the Scenario** identified in Step 1 and the **Region** identified in Step 2, as follows:
   - The columns of 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.

Example

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

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

Table 7-1 is applicable because the 90^{th}-percentile population is desired. Proceed as follows:

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to Scenario 4.
2. Enter Table 7-5 and locate the Region described as "Evacuation 5-Mile Radius and Downwind to EPZ Boundary" for wind direction from the NE and identify Region R16 on that row.
3. Enter Table 7-1 to locate the data cell containing the value of ETE for Scenario 4 and Region R16. This data cell is in column (4) and in the row for Region R16; it contains the ETE value of 2:20.

Table 7-1. Time to Clear the Indicated Area of _90_ Percent of the Affected Population

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

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

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

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

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Region	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R01	2:15	2:15	2:25	2:25	2:00	1:45	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
R02	2:15	2:15	2:25	2:25	2:05	1:50	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
R04	2:15	2:15	2:25	2:25	2:05	1:50	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
R05	2:15	2:15	2:25	2:25	2:00	1:45	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
Staged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R19	2:15	2:15	2:25	2:25	2:05	1:50	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
R20	2:15	2:15	2:25	2:25	2:05	1:50	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15
R21	2:15	2:15	2:25	2:25	2:00	1:45	1:50	2:35	1:40	1:40	2:35	1:40	2:25	2:15

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

	Summer		Summer		Summer	Winter			Winter			Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek			Weekend			Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Midday		Midday		Evening	Midday			Midday			Evening	Midday	Midday
Region	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Snow	Good Weather	Rain	Snow	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R01	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
R02	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
R04	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
R05	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
Staged Evacuation - 2-Mile Ring and Keyhole to 5-Miles														
R19	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
R20	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30
R21	4:30	4:30	4:30	4:30	4:30	4:30	4:30	5:30	4:30	4:30	5:30	4:30	4:30	4:30

Table 7-5. Description of Evacuation Regions

Region	Description	Subarea 1	2	3	4	5	6	7	8	9	10	11	12
R01	2-Mile Ring	X									X		X
R02	5-Mile Ring	X	X				X				X		X
R03	Full EPZ	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:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	N	**Refer to Region R02**											
R04	NNE, NE, ENE, E, ESE	X	X								X		X
	SE, SSE, S, SSW, SW, WSW, W	**Refer to Region R01**											
R05	WNW	X					X				X		X
	NW, NNW	**Refer to Region R02**											
Evacuate 2-Mile Radius and Downwind to the EPZ Boundary													
R06	N	X	X		X	X	X	X	X		X		X
R07	NNE	X	X	X	X	X	X	X	X		X		X
R08	NE, ENE	X	X	X	X	X					X		X
R09	E, ESE	X	X	X							X	X	X
R10	SE	X									X	X	X
	SSE, S, SSW, SW, WSW, W	**Refer to Region R01**											
R11	WNW	X					X	X	X	X	X		X
R12	NW	X	X				X	X	X	X	X		X
R13	NNW	X	X			X	X	X	X	X	X		X
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary													
R14	N	X	X			X	X	X	X		X		X
R15	NNE	X	X	X	X	X	X	X	X		X		X
R16	NE, ENE	X	X	X	X	X	X				X		X
R17	E, ESE	X	X	X			X				X	X	X
R18	SE	X	X				X				X	X	X
	SSE, S, SSW, SW, WSW, W	**Refer to Region R02**											
	WNW, NW	**Refer to Region R12**											
	NNW	**Refer to Region R13**											
Staged Evacuation - 2-Mile Radius Evacuates, then Evacuate Downwind to 5 Miles													
R19	N	X	X				X				X		X
R20	NNE, NE, ENE, E, ESE	X	X								X		X
R21	WNW	X					X				X		X
	NW, NNW	**Refer to Region R19**											

Subarea(s) Shelter-in-Place until 90% ETE for R01, then Evacuate	Subarea(s) Shelter-in-Place	Subarea(s) Evacuate

Figure 7-1. Voluntary Evacuation Methodology

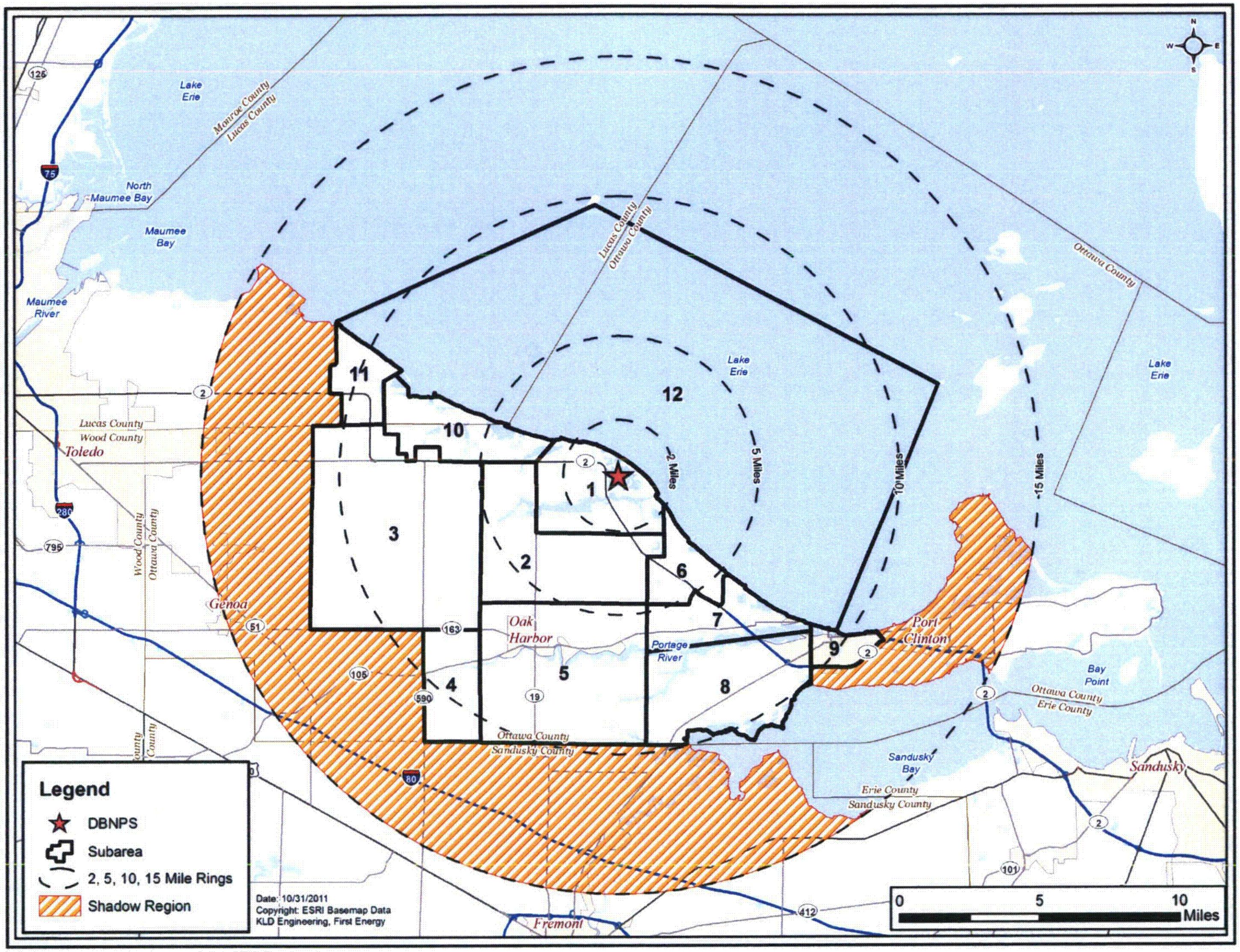


Figure 7-2. Davis-Besse Shadow Evacuation Region

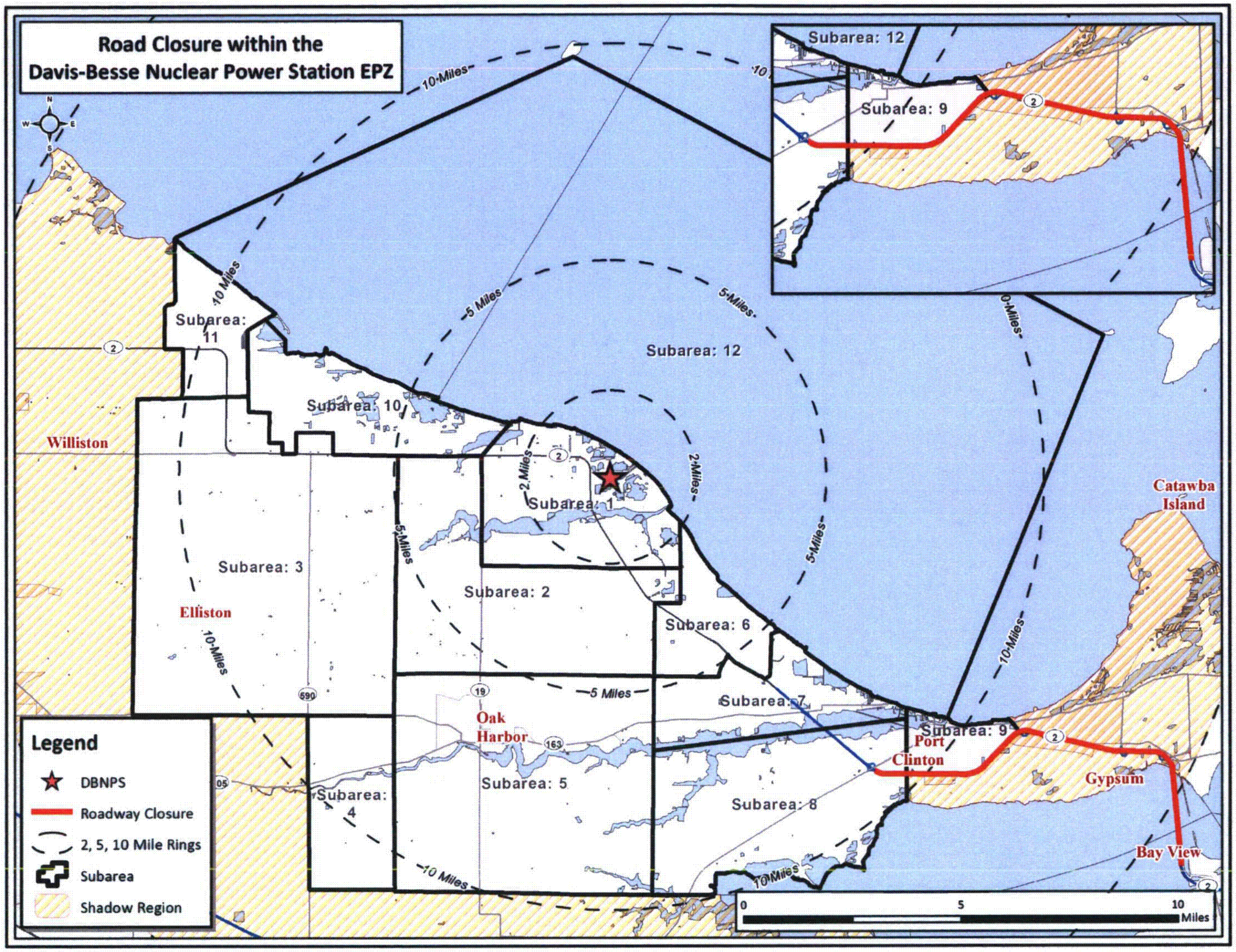


Figure 7-3. Roadway Closure (Scenario 14)

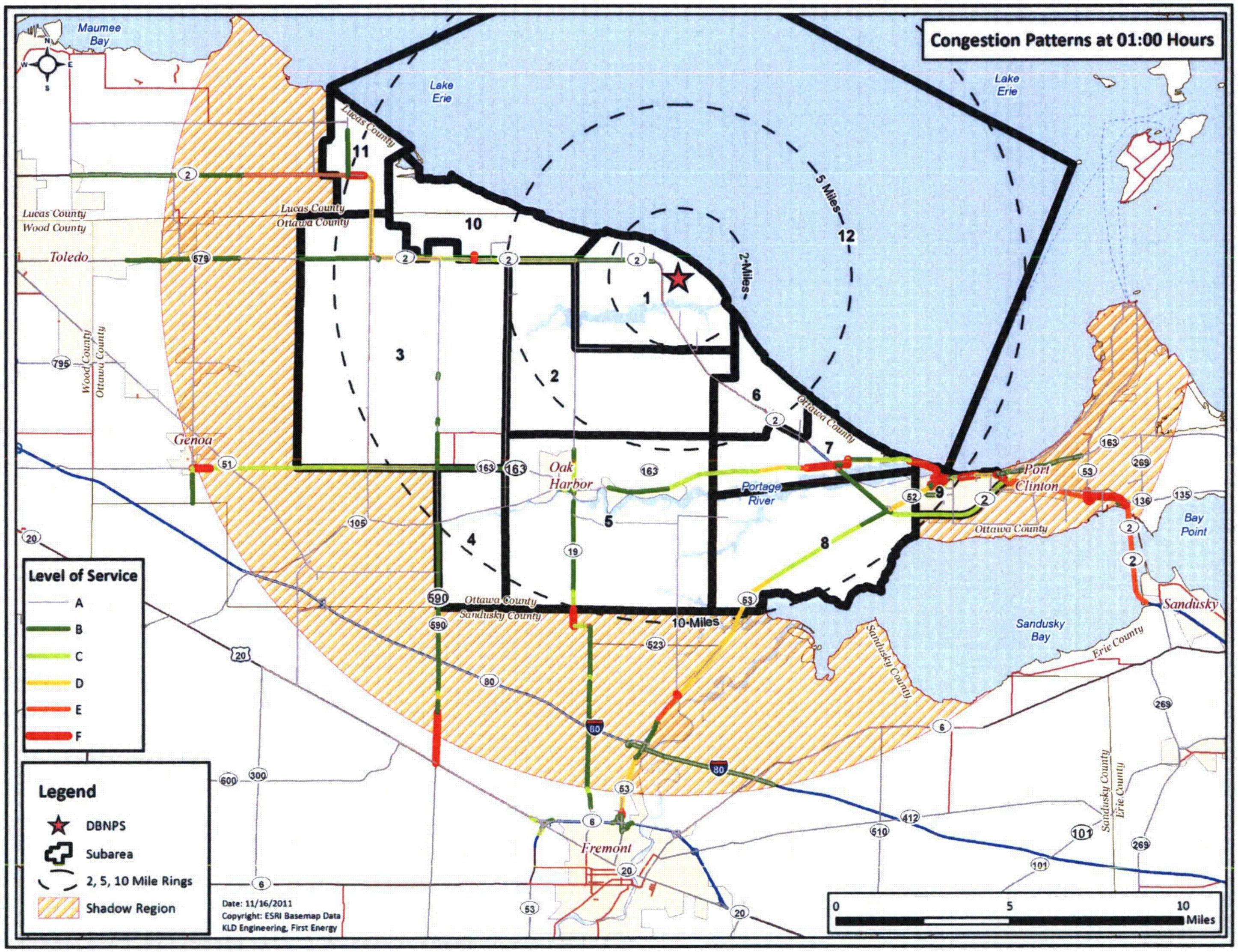


Figure 7-4. Congestion Patterns at 1 Hour after the Advisory to Evacuate

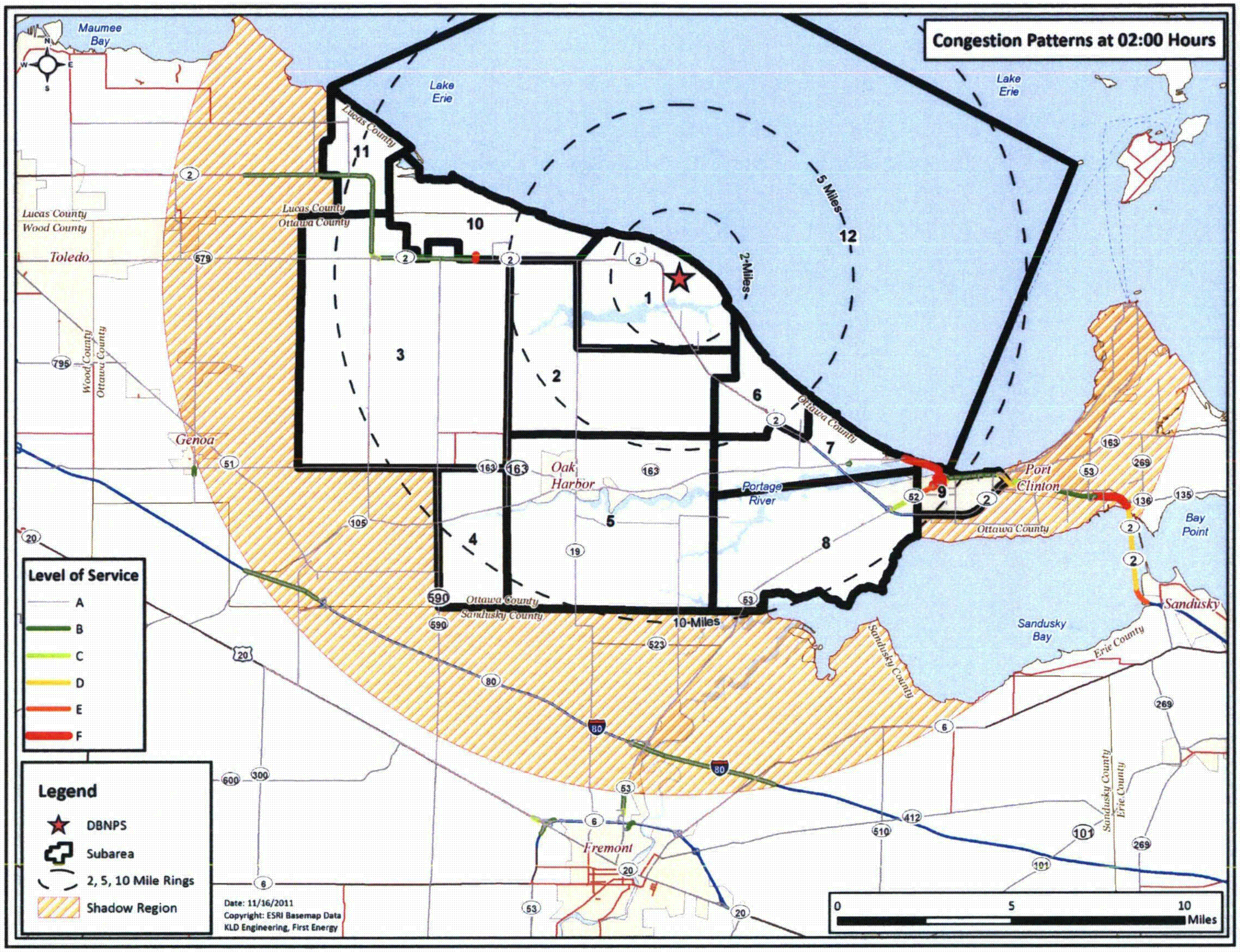


Figure 7-5. Congestion Patterns at 2 Hours after the Advisory to Evacuate

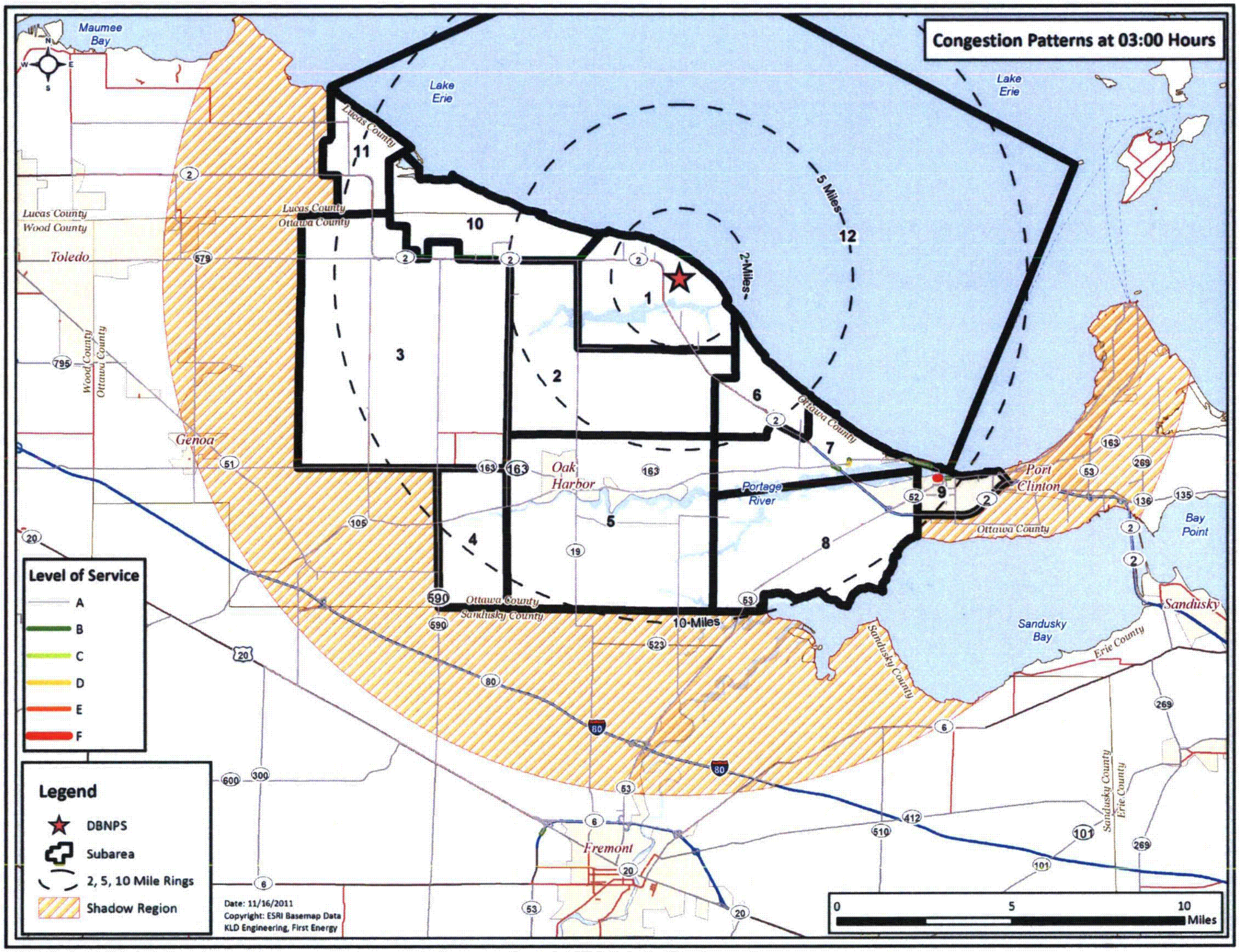


Figure 7-6. Congestion Patterns at 3 Hours after the Advisory to Evacuate

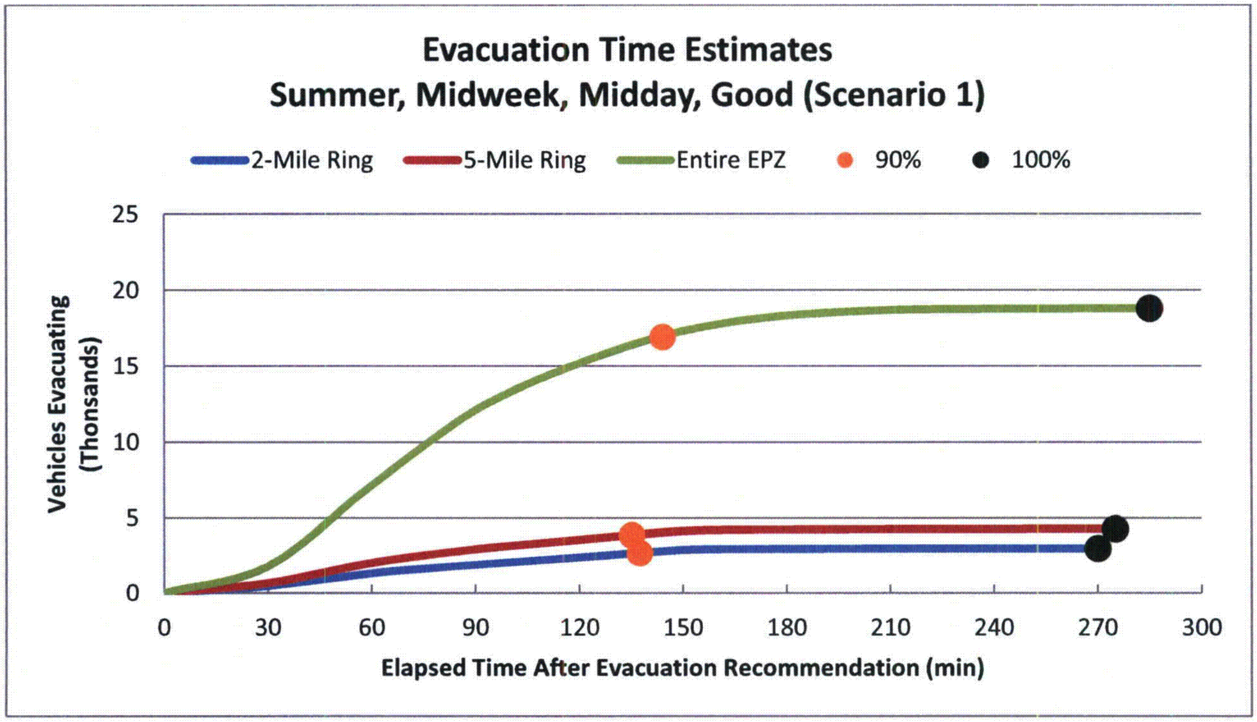


Figure 7-7. Evacuation Time Estimates - Scenario 1 for Region R03

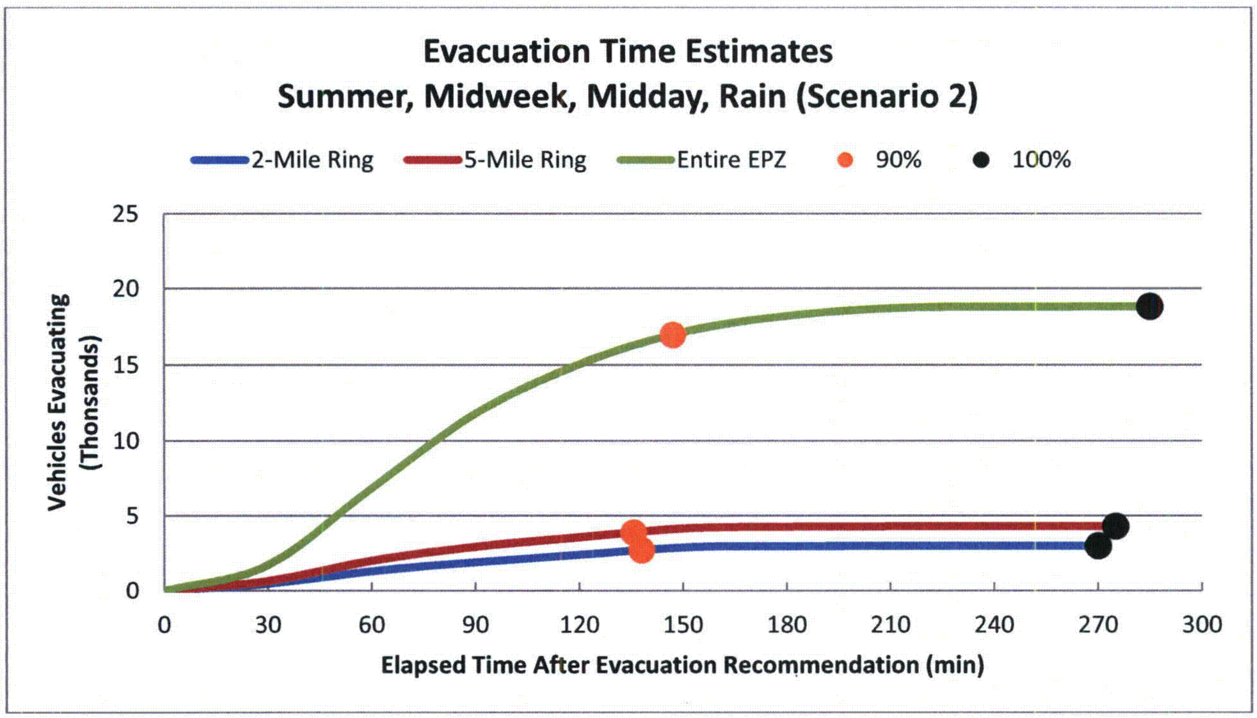


Figure 7-8. Evacuation Time Estimates - Scenario 2 for Region R03

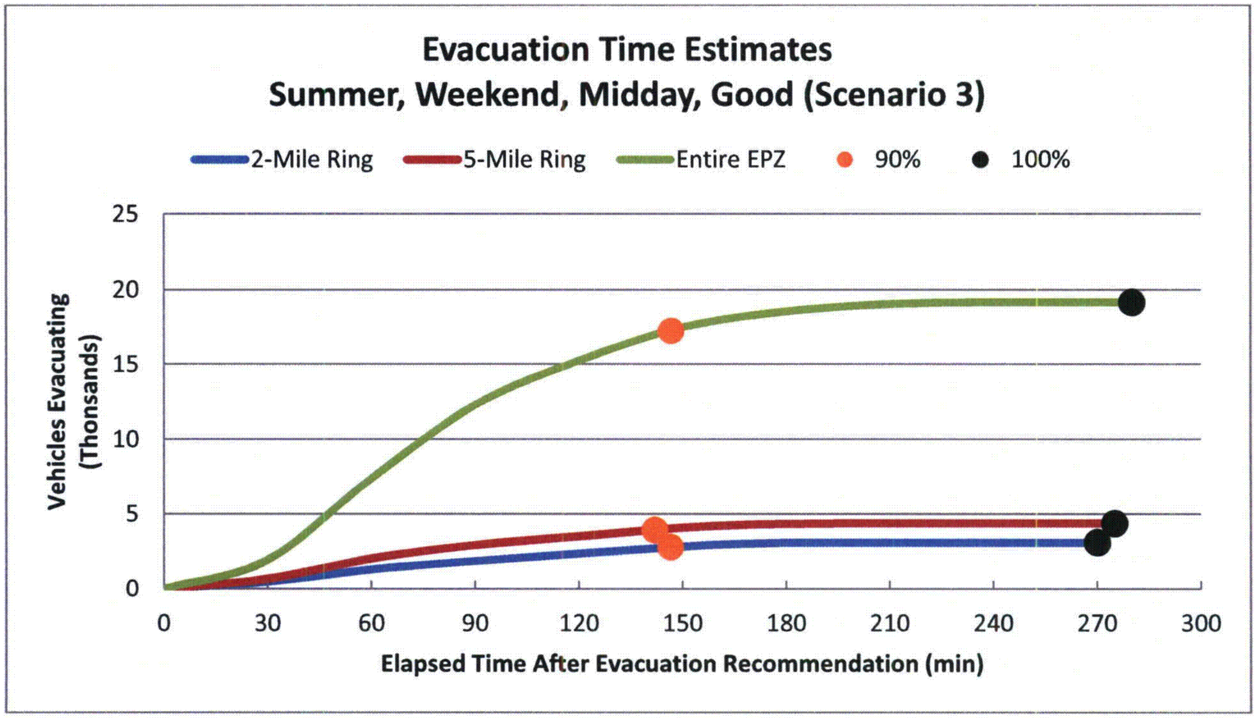


Figure 7-9. Evacuation Time Estimates - Scenario 3 for Region R03

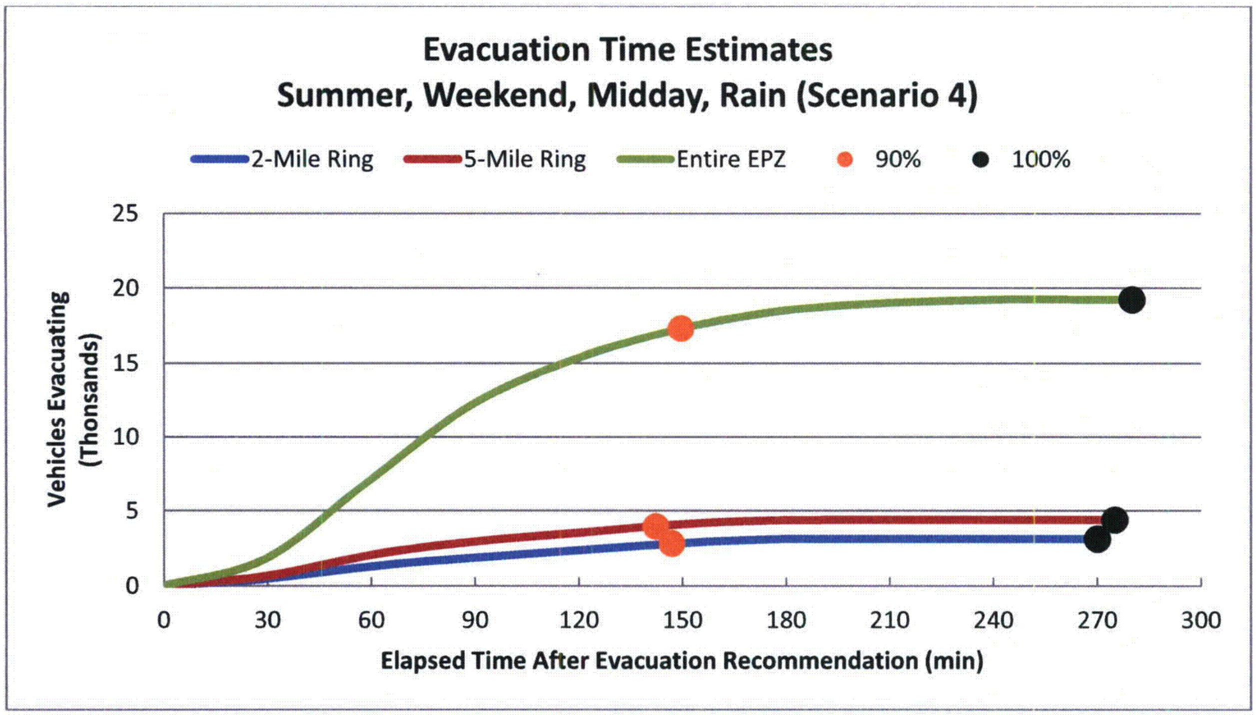


Figure 7-10. Evacuation Time Estimates - Scenario 4 for Region R03

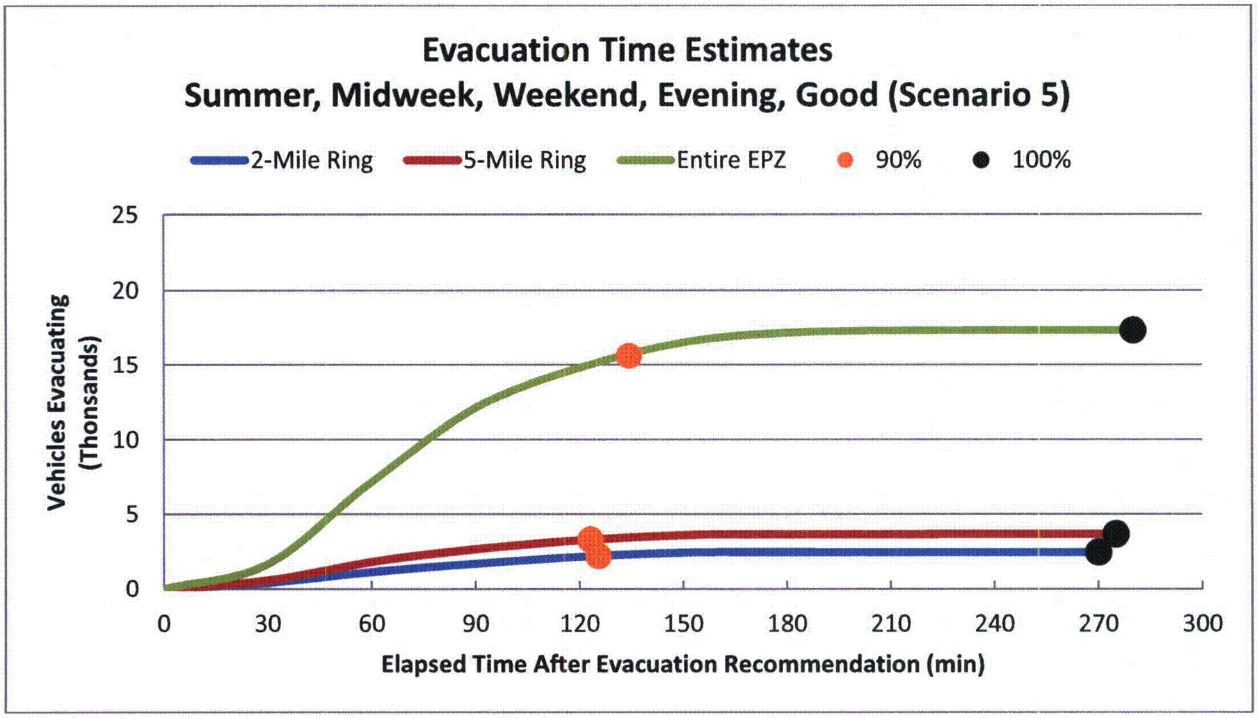


Figure 7-11. Evacuation Time Estimates - Scenario 5 for Region R03

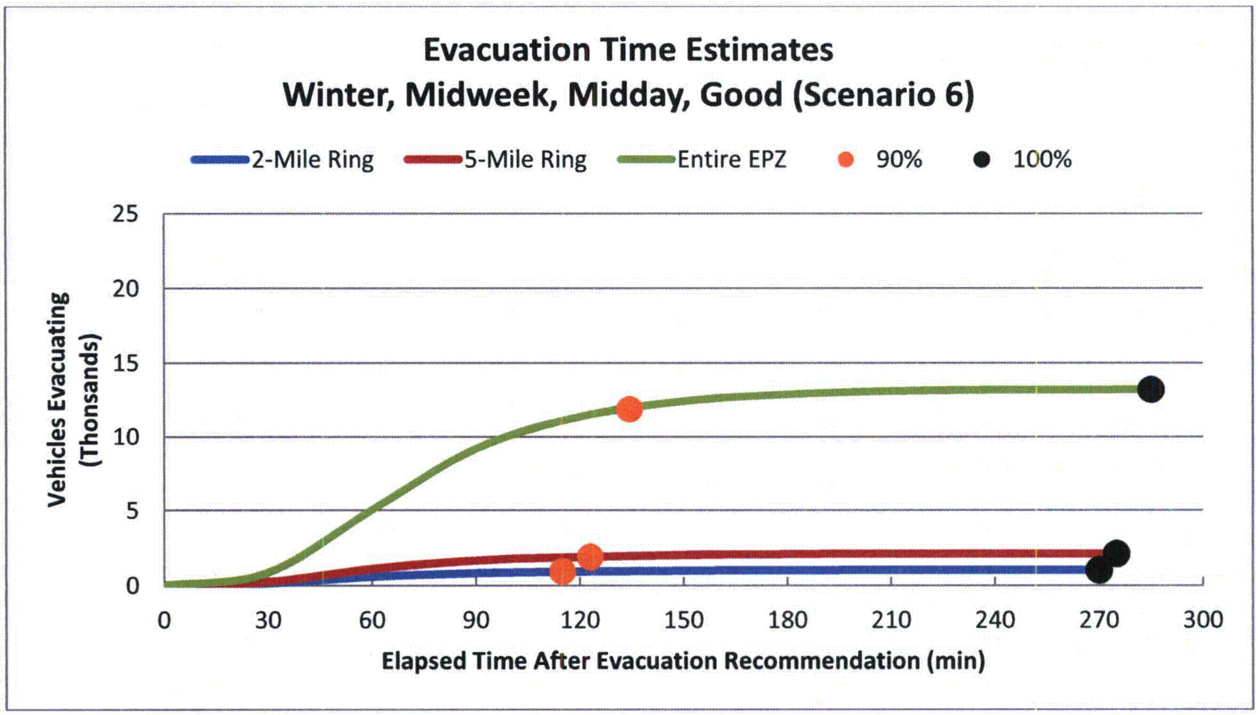


Figure 7-12. Evacuation Time Estimates - Scenario 6 for Region R03

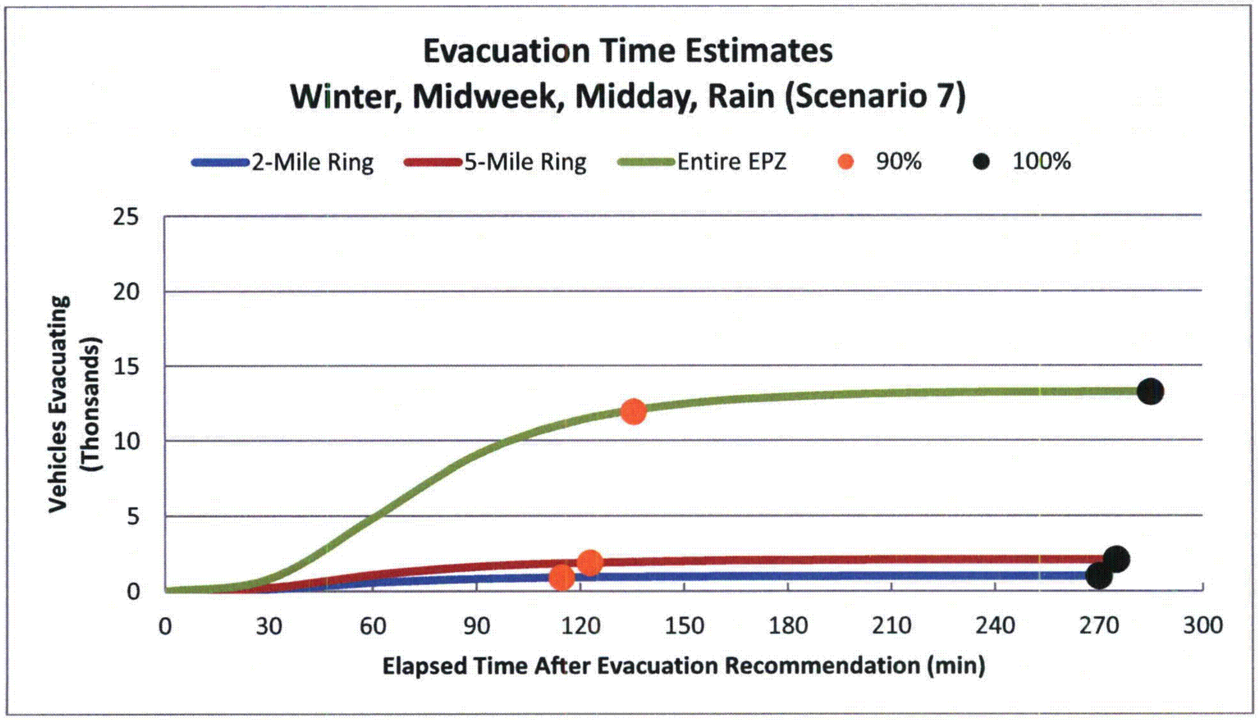


Figure 7-13. Evacuation Time Estimates - Scenario 7 for Region R03

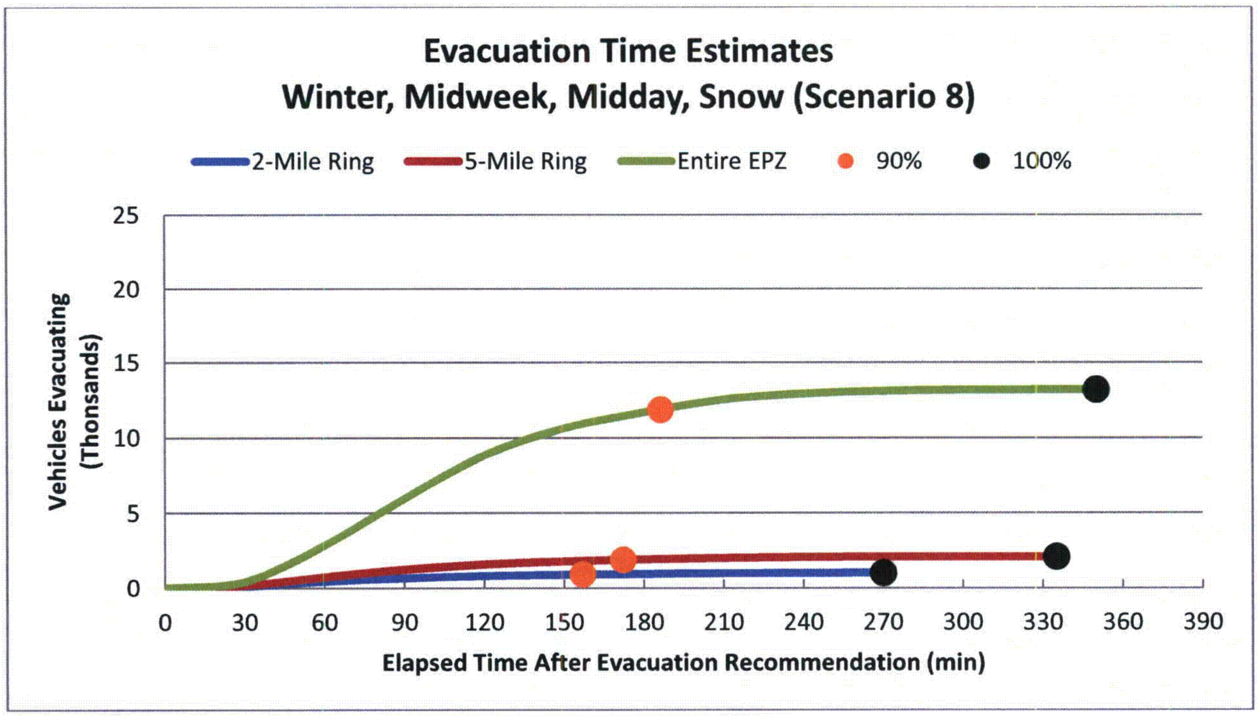


Figure 7-14. Evacuation Time Estimates - Scenario 8 for Region R03

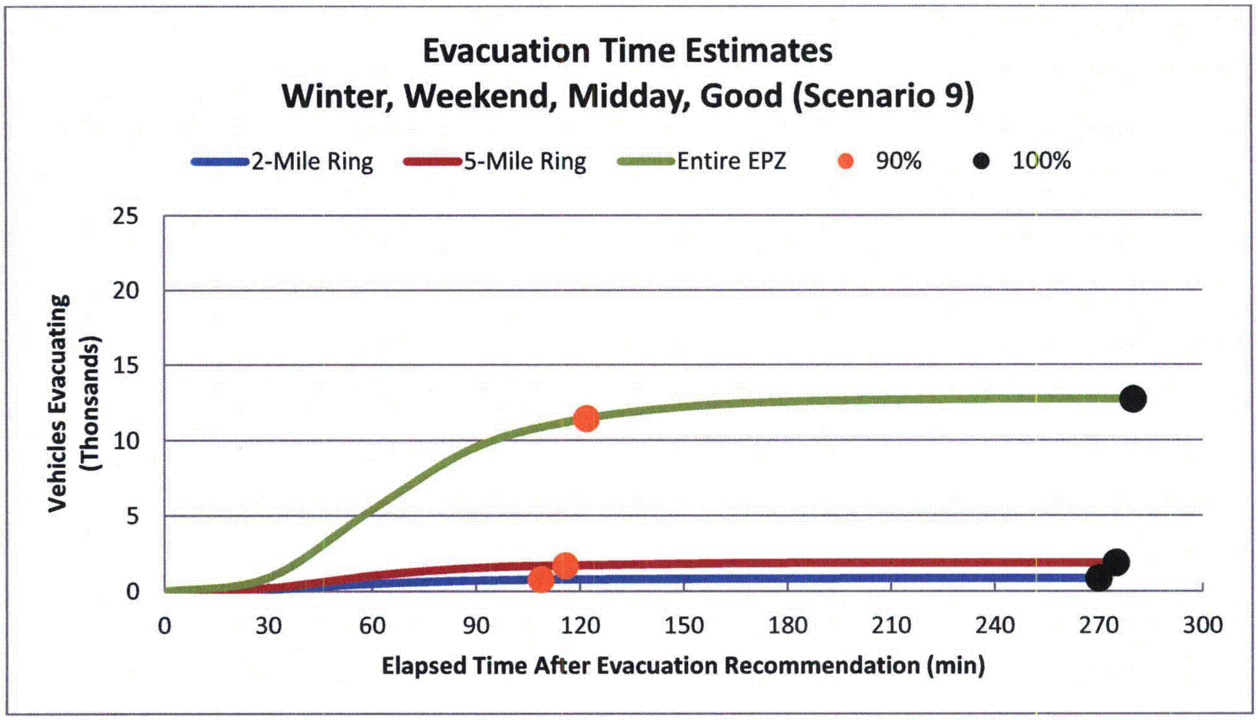


Figure 7-15. Evacuation Time Estimates - Scenario 9 for Region R03

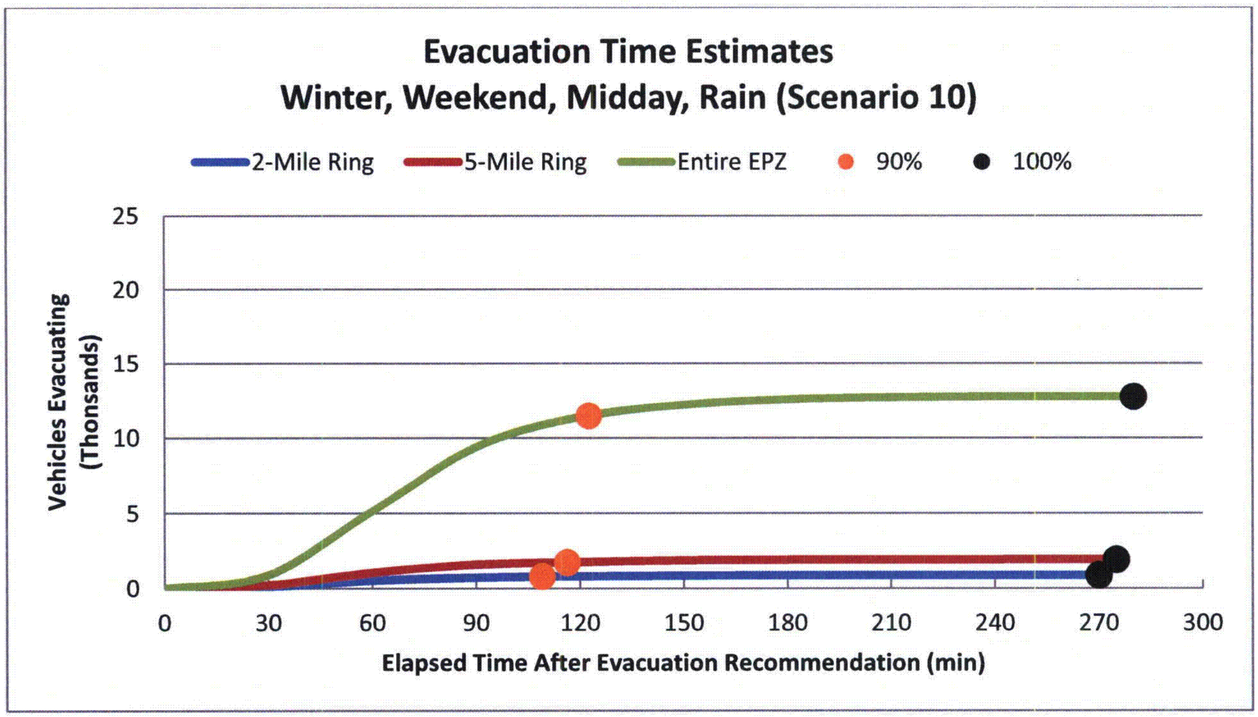


Figure 7-16. Evacuation Time Estimates - Scenario 10 for Region R03

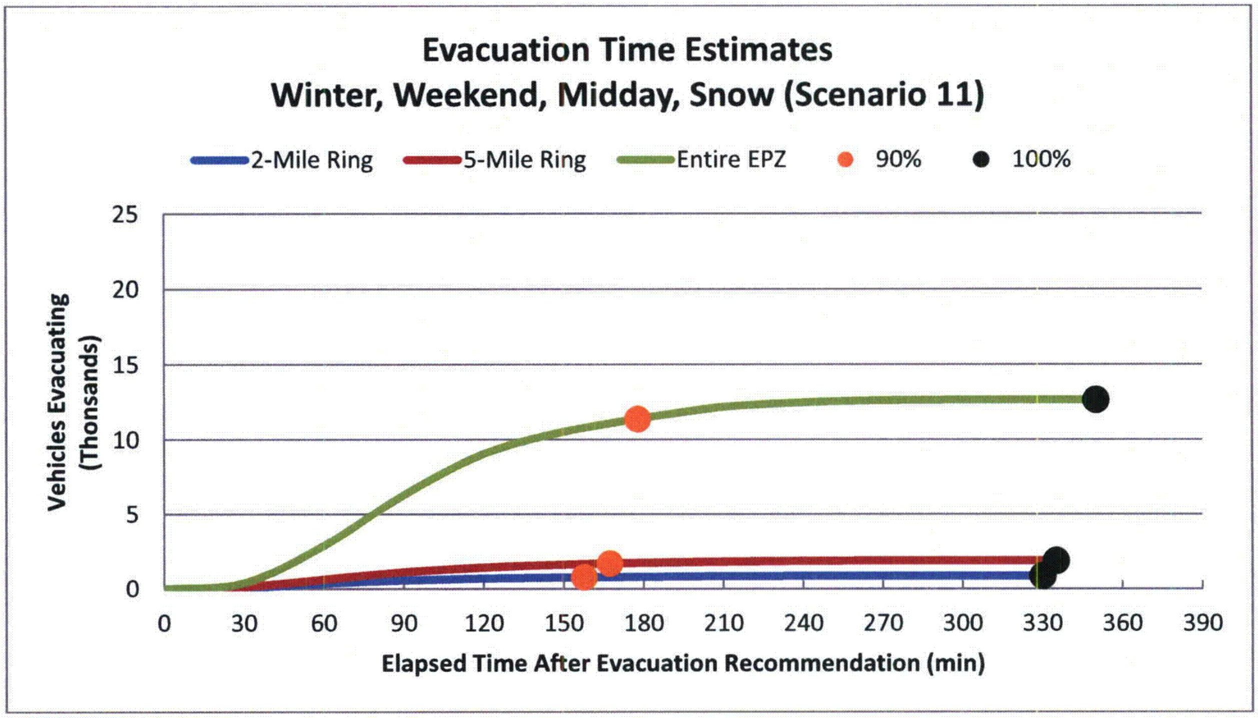


Figure 7-17. Evacuation Time Estimates - Scenario 11 for Region R03

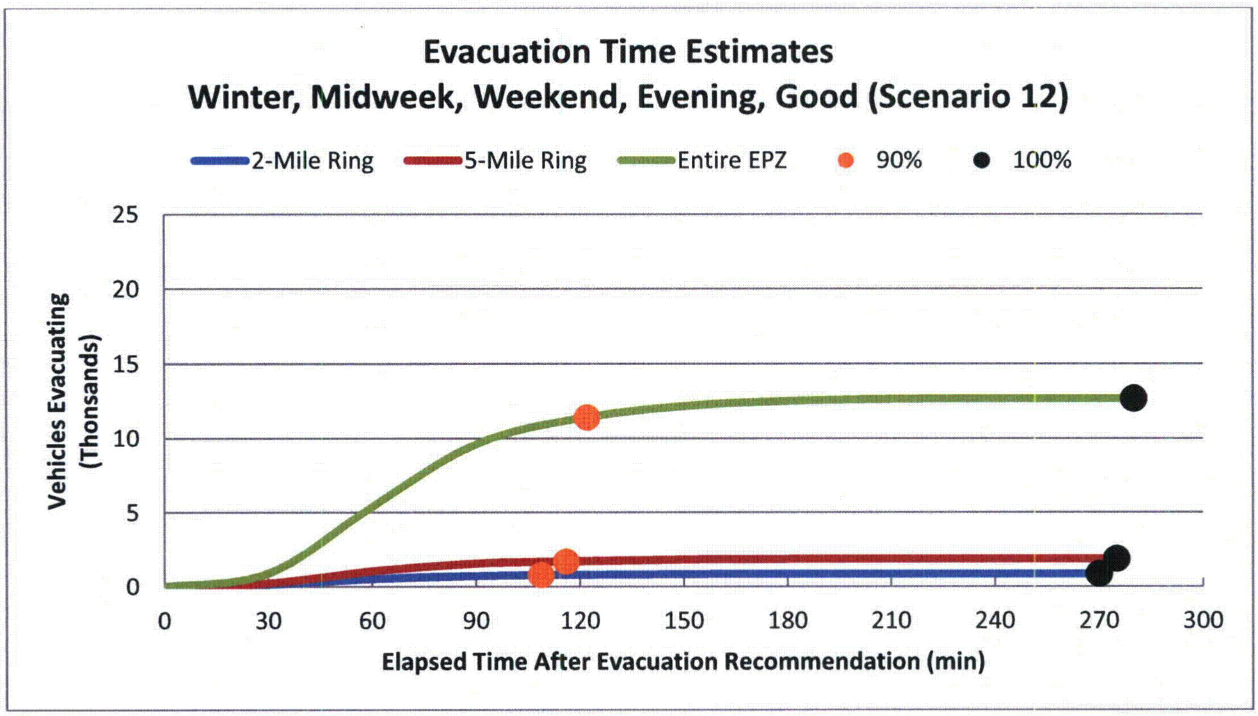


Figure 7-18. Evacuation Time Estimates - Scenario 12 for Region R03

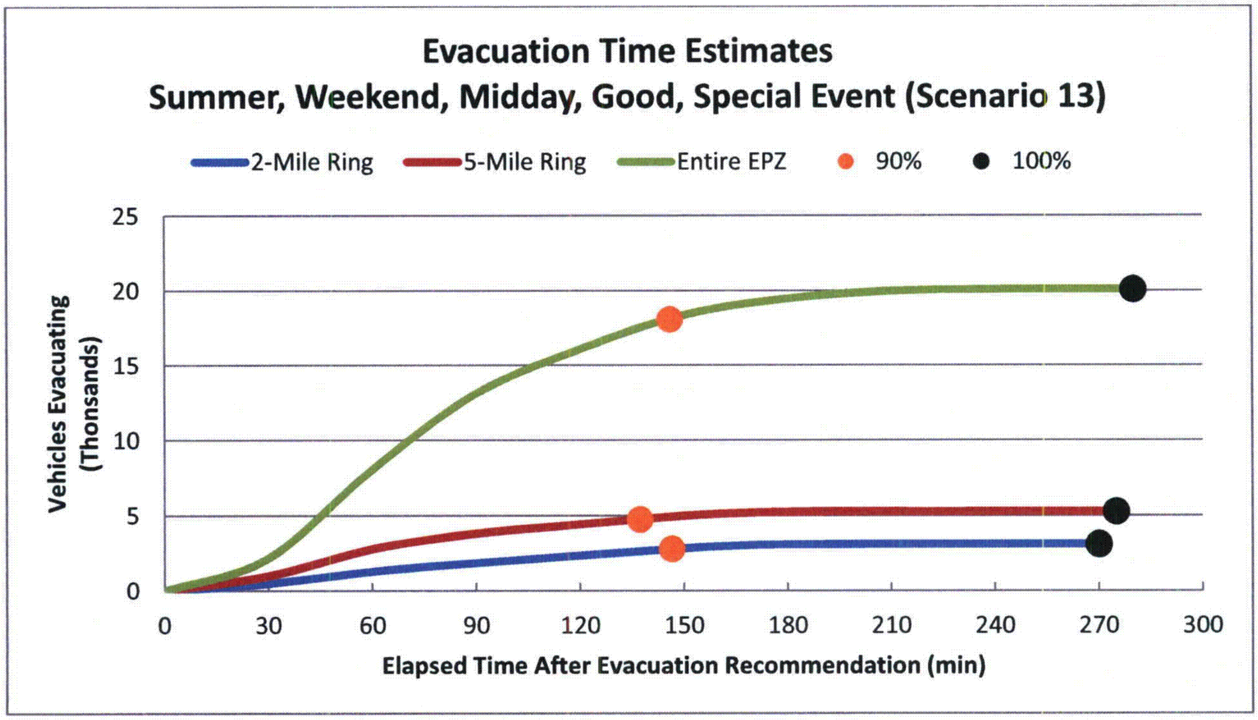


Figure 7-19. Evacuation Time Estimates - Scenario 13 for Region R03

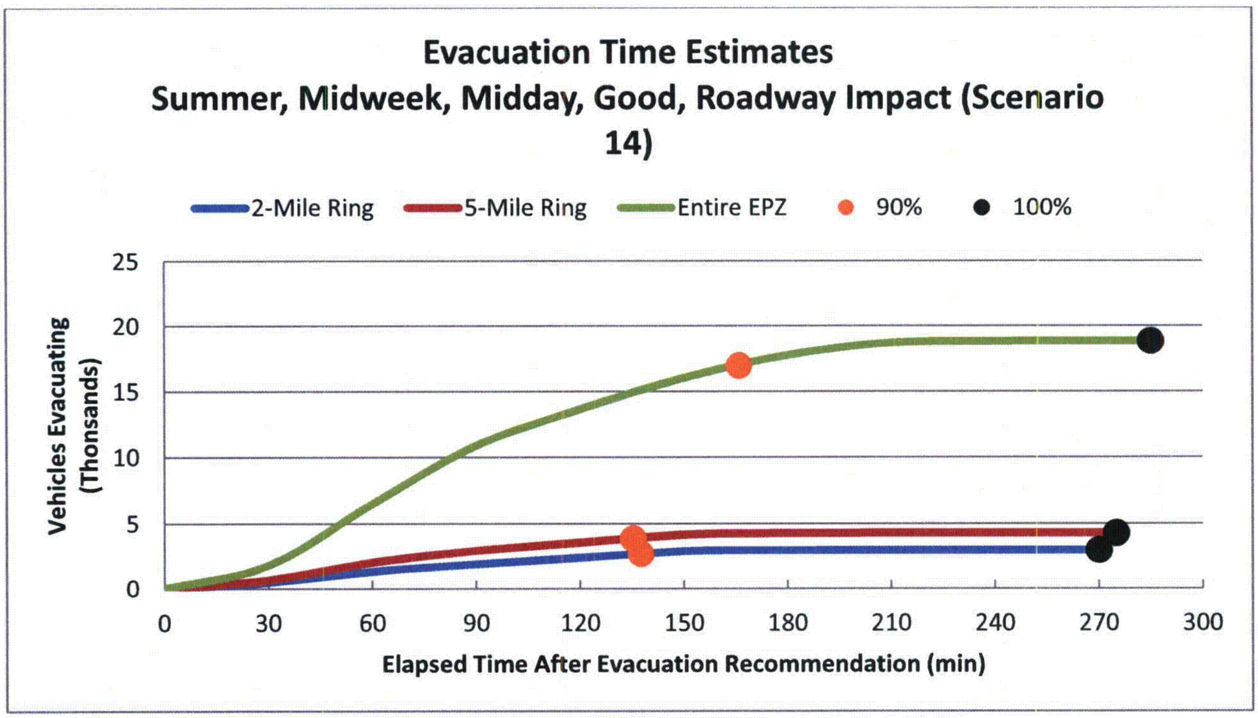


Figure 7-20. Evacuation Time Estimate - Scenario 14 for Region 03