FLORIDA POWER CORPORATION

CRYSTAL RIVER UNIT 3

DOCKET NUMBER 50-302 / LICENSE NUMBER DPR-72

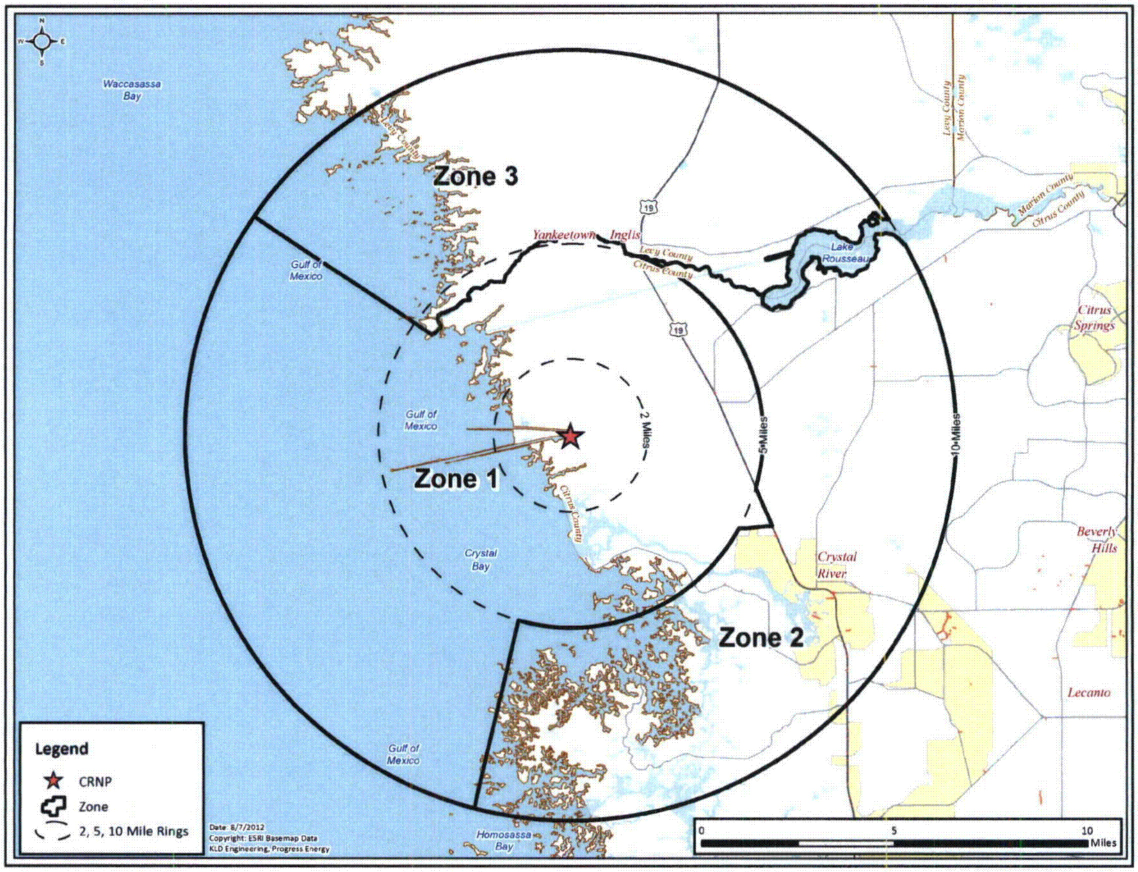
ENCLOSURE

Evacuation Time Estimates Report

ENGINEERING, P.C.

Crystal River Nuclear Plant

Development of Evacuation Time Estimates



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November 2012 **Final Report, Rev. 1** **KLD TR – 516**

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EXECUTIVE SUMMARY

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Crystal River Nuclear Plant (CRNP) located in Citrus County, Florida. ETE provide Duke Energy and State and local governments with site-specific information needed for Protective Action decision-making.

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

- Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, December 2011.
- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG-0654/FEMA-REP-1, Rev. 1, November 1980.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.
- Appendix E – Emergency Planning and Preparedness for Production and Utilization Facilities, 10CFR50.

Overview of Project Activities

This project began in March, 2012 and extended over a period of 5 months. The major activities performed are briefly described in chronological sequence:

- Attended "kick-off" meetings with Duke Energy personnel and emergency management personnel representing state and county governments.
- Accessed U.S. Census Bureau data files for the year 2010.
- Studied Geographical Information Systems (GIS) maps of the area in the vicinity of the CRNP, then conducted a detailed field survey of the highway network.
- Synthesized this information to create an analysis network representing the highway system topology and capacities within the Emergency Planning Zone (EPZ), plus a Shadow Region covering the region between the EPZ boundary and approximately 15 miles radially from the plant.
- Designed and sponsored a telephone survey of residents within the EPZ to gather focused data needed for this ETE study that were not contained within the census database. The survey instrument was reviewed and modified by the licensee and offsite response organization (ORO) personnel prior to the survey.
- Data collection forms (provided to the OROs at the kickoff meeting) were returned with data pertaining to employment, transients, and special facilities in each county.

- The traffic demand and trip-generation rates of evacuating vehicles were estimated from the gathered data. The trip generation rates reflected the estimated mobilization time (i.e., the time required by evacuees to prepare for the evacuation trip) computed using the results of the telephone survey of EPZ residents.
- Following federal guidelines, the EPZ is subdivided into 3 Zones. These zones are then grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 7 Evacuation Regions.
- The time-varying external circumstances are represented as Evacuation Scenarios, each described in terms of the following factors: (1) Season (Summer, Winter); (2) Day of Week (Midweek, Weekend); (3) Time of Day (Midday, Evening); and (4) Weather (Good, Rain). One special event scenario involving Manatee Fest in Crystal River was considered. One roadway impact scenario was considered wherein a single southbound lane was closed on U.S 19.
- Staged evacuation was considered for those regions wherein the 5 mile radius and sectors downwind to the EPZ boundary were evacuated.
- As per NUREG/CR-7002, the Planning Basis for the calculation of ETE is:
  - A rapidly escalating event at the plant wherein evacuation is ordered promptly and no early protective actions have been implemented.
  - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the Advisory to Evacuate until the stated percentage of the population exits the impacted Region, that represent "upper bound" estimates. This conservative Planning Basis is applicable for all initiating events.
- If the emergency occurs while schools are in session, the ETE study assumes that the children will be evacuated by bus directly to reception centers or evacuation shelters located outside the EPZ. Parents, relatives, and neighbors are advised to not pick up their children at school prior to the arrival of the buses dispatched for that purpose. The ETE for schoolchildren are calculated separately.
- Evacuees who do not have access to a private vehicle will either ride-share with relatives, friends or neighbors, or be evacuated by buses provided as specified in the county evacuation plans. Those in special facilities will likewise be evacuated with public transit, as needed: bus, van, or ambulance, as required. Separate ETE are calculated for the transit-dependent evacuees, for homebound functional needs population, and for those evacuated from special facilities.

<u>Computation of ETE</u>

A total of 84 ETE were computed for the evacuation of the general public. Each ETE quantifies the aggregate evacuation time estimated for the population within one of the 7 Evacuation Regions to evacuate from that Region, under the circumstances defined for one of the 12 Evacuation Scenarios (7 x 12 = 84). Separate ETE are calculated for transit-dependent evacuees, including schoolchildren for applicable scenarios.

Except for Region R02, which is the evacuation of the entire EPZ, only a portion of the people within the EPZ would be advised to evacuate. That is, the Advisory to Evacuate applies only to those people occupying the specified impacted region. It is assumed that 100 percent of the people within the impacted region will evacuate in response to this Advisory. The people occupying the remainder of the EPZ outside the impacted region may be advised to take shelter.

The computation of ETE assumes that 20% of the population within the EPZ but outside the impacted region, will elect to "voluntarily" evacuate. In addition, 20% of the population in the Shadow Region will also elect to evacuate. These shadow evacuees could impede those who are evacuating from within the impacted region. The impedance that could be caused by shadow evacuees is considered in the computation of ETE for the impacted region.

Staged evacuation is considered wherein those people within the 5-mile region evacuate immediately, while those beyond 5 miles, but within the EPZ, shelter-in-place. Once 90% of the 5-mile region is evacuated, those people beyond 5 miles begin to evacuate. As per federal guidance, 20% of people beyond 5 miles will evacuate even though they are advised to shelter-in-place.

The computational procedure is outlined as follows:

- A link-node representation of the highway network is coded. Each link represents a unidirectional length of highway; each node usually represents an intersection or merge point. The capacity of each link is estimated based on the field survey observations and on established traffic engineering procedures.
- The evacuation trips are generated at locations called "zonal centroids" located within the EPZ and Shadow Region. The trip generation rates vary over time reflecting the mobilization process, and from one location (centroid) to another depending on population density and on whether a centroid is within, or outside, the impacted area.
- The evacuation model computes the routing patterns for evacuating vehicles that are compliant with federal guidelines (outbound relative to the location of the plant), then simulate the traffic flow movements over space and time. This simulation process estimates the rate that traffic flow exits the impacted region.

The ETE statistics provide the elapsed times for 90 percent and 100 percent, respectively, of the population within the impacted region, to evacuate from within the impacted region. These statistics are presented in tabular and graphical formats. The 90th percentile ETE have been identified as the values that should be considered when making protective action decisions because the 100th percentile ETE are prolonged by those relatively few people who take longer to mobilize. This is referred to as the "evacuation tail" in Section 4.0 of NUREG/CR-7002.

<u>Traffic Management</u>

This study references the comprehensive traffic management plans provided by Citrus and Levy Counties, and identifies critical intersections.

Selected Results

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

- Figure 6-1 displays a map of the CRNP EPZ showing the layout of the 3 Zones that comprise, in aggregate, the EPZ.
- Table 3-1 presents the estimates of permanent resident population in each zone based on the 2010 Census data.
- Table 6-1 defines each of the 7 Evacuation Regions in terms of their respective groups of zones.
- Table 6-2 lists the Evacuation Scenarios.
- Table 7-1 and Table 7-2 are compilations of ETE for the general population. These data are the times needed to clear the indicated regions of 90 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated shadow evacuations from other regions within the EPZ and from the Shadow Region.
- Table 7-3 and Table 7-4 present ETE for the 5-mile region for un-staged and staged evacuations for the 90th and 100th percentiles, respectively.
- Table 8-7 and Table 8-8 present ETE for the schoolchildren in good weather and rain, respectively.
- Table 8-10 and Table 8-11 present ETE for the transit-dependent population in good weather and rain, respectively.
- Figure H-3 presents an example of an Evacuation Region (Region R03) to be evacuated under the circumstances defined in Table 6-1. Maps of all regions are provided in Appendix H.

Conclusions

- General population ETE were computed for 84 unique cases – a combination of 7 unique Evacuation Regions and 12 unique Evacuation Scenarios. Table 7-1 and Table 7-2 document these ETE for the 90th and 100th percentiles. These ETE range from 2:10 (hr:min) to 3:15 at the 90th percentile.
- Inspection of Table 7-1 and Table 7-2 indicates that the ETE for the 100th percentile are significantly longer than those for the 90th percentile. This is the result of the long trip generation "tail". As these stragglers mobilize, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand. See Figures 7-7 through 7-18.
- Inspection of Table 7-3 and Table 7-4 indicates that a staged evacuation provides no benefits to ETE (compare Regions R02, R03 and R04 with Regions R06, R05 and R07, respectively, in Tables 7-1 and 7-2). While staged evacuation does not provide a benefit, it slightly increases ETE Scenario 11 (Special Event) at the 90th percentile. See Section 7.6 for additional discussion.
- Comparison of Scenarios 8 (winter, weekend, midday, good weather) and 11 (winter,

weekend, midday, special event) in Table 7-2 indicates that the special event does not have a significant impact on the ETE for the 90th percentile with increases only up to 5 minutes. See Section 7.5 for additional discussion.

- Comparison of Scenarios 1 and 12 in Table 7-1 indicates that the roadway closure – one lane southbound on US 19/98 from the intersection with West Power Line St. to the edge of the Shadow Region at the intersection with West Mckinley St. – does have a material impact on 90th percentile ETE for keyhole regions which include Zone 2, with up to 20 minute increases in ETE. The roadway closure has no effect on regions which do not involve evacuating the City of Crystal River. See Section 7.5 for additional discussion.
- Crystal River is the most congested area during an evacuation, and is the last location in the EPZ to exhibit traffic congestion. All congestion within the EPZ clears by 2 hours and 10 minutes after the Advisory to Evacuate. See Section 7.3 and Figures 7-3 through 7-6.
- Separate ETE were computed for schools, medical facilities, transit-dependent persons, and homebound functional needs persons. Schools and medical facilities evacuating within a single wave have an average ETE that are within a similar range as the general population ETE at the 90th percentile. The average single-wave ETE for transit-dependent and homebound functional needs exceed the general population ETE at the 90th percentile. See Section 8.
- Table 8-5 indicates that there are enough buses and ambulances available to evacuate the transit-dependent population within the EPZ in a single wave; however, there are not enough wheelchair buses to evacuate the wheelchair-bound population in a single wave. The second-wave ETE for ambulances do exceed the general population ETE at the 90th percentile. See Sections 8.4 and 8.5.
- The general population ETE at the 90th percentile is insensitive to reductions in the base trip generation time of 5½ hours due to the traffic congestion within the EPZ. See Table M-1.
- The general population ETE is insensitive to the shadow evacuation of vehicles in the Shadow Region (with a 60% increase in shadow evacuation, the ETE for the 90th percentile does not change). See Table M-2.
- An increase in permanent resident population of 37% or more will result in ETE changes which meet the NRC criteria for updating ETE between decennial Censuses. See Section M.3.

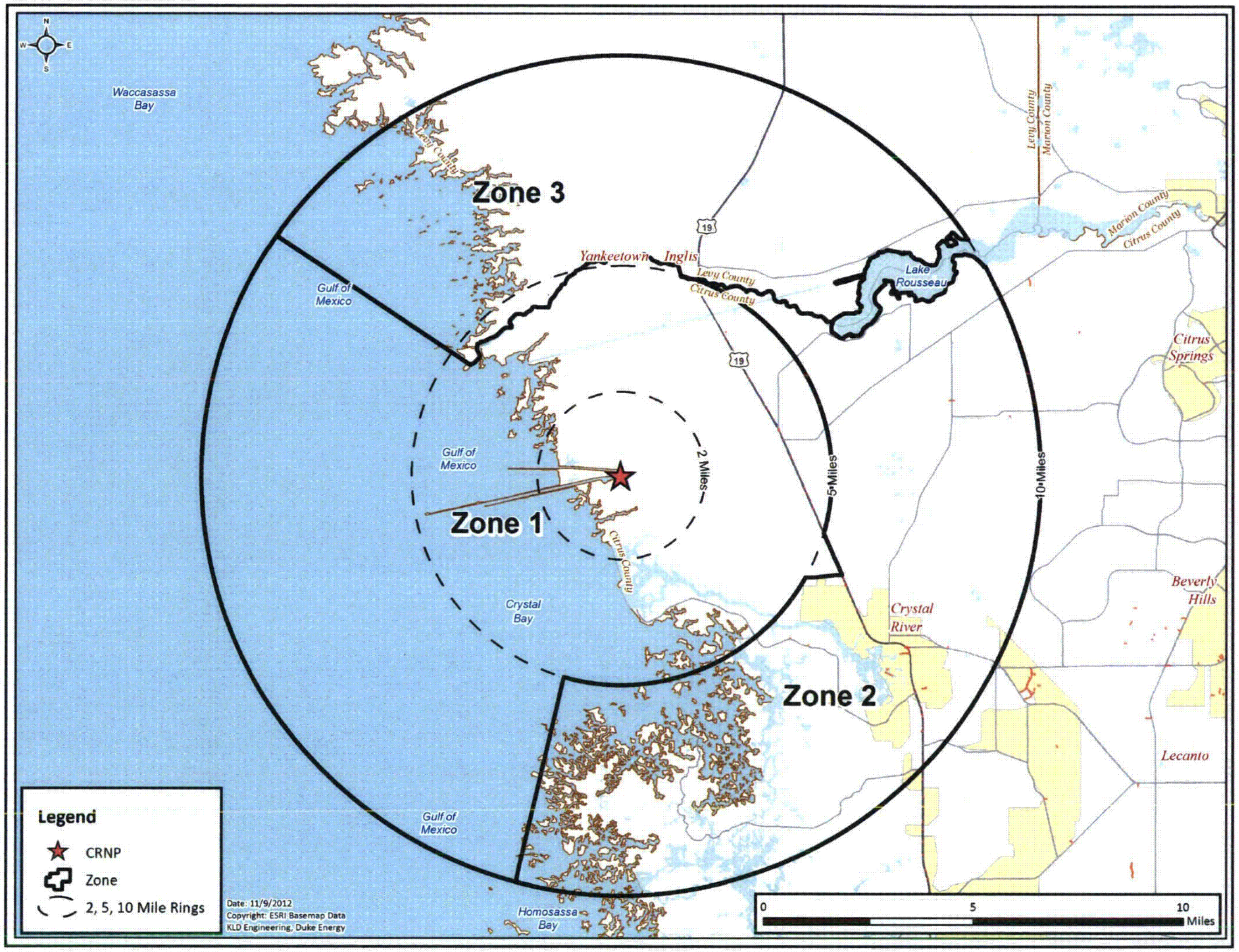


Figure 6-1. CRNP EPZ Zones

Table 3-1. EPZ Permanent Resident Population

Zone	2000 Population	2010 Population
1	1,244	1,397
2	14,483	14,178
3	3,000	2,825
TOTAL	**18,727**	**18,400**
EPZ Population Growth:		**-1.75%**

Table 6-1. Description of Evacuation Regions

Region	Description	Zone 1	Zone 2	Zone 3
		1	2	3
R01	5-Mile Radius	x		
R02	Full EPZ	x	x	x
Evacuate 5-Mile Radius and Downwind to the EPZ Boundary				
Region	Wind Direction Towards:	1	2	3
R03	NW, NNW, N, NNE	x		x
N/A	NE, ENE	See Region R02		
R04	E, ESE, SE, SSE, S	x	x	
N/A	SSW, SW, WSW, W, WNW	Refer to Region R01		
Staged Evacuation - 5-Mile Radius Evacuates, then Evacuate Downwind to 10 Miles				
Region	Wind Direction Towards:	1	2	3
R05	NW, NNW, N, NNE	x		x
R06	NE, ENE	x	x	x
R07	E, ESE, SE, SSE, S	x	x	
N/A	SSW, SW, WSW, W, WNW	See Region R01		
Shelter-in-Place until 90% ETE for R01, then Evacuate		Zone(s) Shelter-in-Place	Zone(s) Evacuate	

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	Weekend	Midday	Good	None
9	Winter	Weekend	Midday	Rain	None
10	Winter	Midweek, Weekend	Evening	Good	None
11	Winter	Weekend	Midday	Good	Special Event – Manatee Fest
12	Summer	Midweek	Midday	Good	Roadway Impact Closure of one southbound lane on U.S. 19

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Region	Midday		Midday		Evening	Midday		Midday		Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Good Weather	Rain	Good Weather	Special Event	Roadway Impact
Entire 5-Mile Region, and EPZ												
R01	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:10	2:10
R02	2:30	2:30	2:25	2:25	2:25	2:25	2:30	2:20	2:20	2:20	2:25	2:45
5-Mile Region and Keyhole to EPZ Boundary												
R03	2:20	2:20	2:20	2:20	2:20	2:20	2:20	2:15	2:20	2:20	2:15	2:20
R04	2:30	2:30	2:20	2:25	2:25	2:25	2:25	2:20	2:20	2:20	2:25	2:50
Staged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R05	2:35	2:35	2:35	2:40	2:40	2:35	2:35	2:35	2:35	2:40	2:35	2:35
R06	3:10	3:10	3:10	3:15	3:10	3:10	3:10	3:10	3:10	3:10	3:05	3:20
R07	3:10	3:15	3:10	3:15	3:15	3:10	3:10	3:10	3:15	3:15	3:10	3:25

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)
Region	Midday		Midday		Evening	Midday		Midday		Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Good Weather	Rain	Good Weather	Special Event	Roadway Impact
Entire 5-Mile Region, and EPZ												
R01	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R02	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40
5-Mile Region and Keyhole to EPZ Boundary												
R03	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40
R04	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40
Staged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R05	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40
R06	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40
R07	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40	5:40

Table 7-3. Time to Clear 90 Percent of the 5-Mile Region

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Weekend	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Region	Midday		Midday		Evening	Midday		Midday		Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Good Weather	Rain	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R01	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:10	2:10
R02	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:15	2:15
R03	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:10	2:10
R04	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:15	2:15
Staged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R05	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:10	2:10
R06	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:15	2:15
R07	2:10	2:15	2:15	2:15	2:15	2:10	2:10	2:10	2:15	2:10	2:15	2:15

Table 7-4. Time to Clear 100 Percent of the 5-Mile Region

	Summer		Summer		Summer	Winter		Winter		Winter	Summer	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Weekend	Midweek
Scenario:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Region	Midday		Midday		Evening	Midday		Midday		Evening	Midday	Midday
	Good Weather	Rain	Good Weather	Rain	Good Weather	Good Weather	Rain	Good Weather	Rain	Good Weather	Special Event	Roadway Impact
Unstaged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R01	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R02	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R03	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R04	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
Staged Evacuation - 5-Mile Region and Keyhole to EPZ Boundary												
R05	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R06	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35
R07	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35	5:35

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

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.S. (mi.)	Travel Time from EPZ Bdry to R.S. (min)	ETE to R.S. (hr:min)
CITRUS COUNTY SCHOOLS									
Academy of Environmental Science	90	15	9.2	52.9	11	2:00	15.1	21	2:20
Ark Angels Christian Preschool	90	15	3.8	14.9	16	2:05	15.8	22	2:25
Crystal River High School	90	15	2.4	49.0	3	1:50	15.1	21	2:10
Crystal River Middle School	90	15	3.1	14.1	14	2:00	11.0	15	2:15
Crystal River Preschool	90	15	2.5	48.6	4	1:50	15.8	22	2:15
Crystal River Primary School	90	15	9.2	53.9	11	2:00	15.6	21	2:20
Marine Science Station	90	15	9.0	52.2	11	2:00	15.6	21	2:20
LEVY COUNTY SCHOOLS									
Yankeetown School	0[1]	15	5.6	55.0	7	0:25	31.5	42	1:05
					Maximum for EPZ:	**2:05**		**Maximum:**	**2:25**
					Average for EPZ:	**1:50**		**Average:**	**2:10**

[1]According to Levy County, buses are located on site and do not require any time to mobilize.

Table 8-8. School Evacuation Time Estimates – Rain

School	Driver Mobilization Time (min)	Loading Time (min)	Dist. To EPZ Bdry (mi)	Average Speed (mph)	Travel Time to EPZ Bdry (min)	ETE (hr:min)	Dist. EPZ Bdry to R.S. (mi.)	Travel Time from EPZ Bdry to H.S. (min)	ETE to R.S. (hr:min)
CITRUS COUNTY SCHOOLS									
Academy of Environmental Science	100	20	9.2	47.6	12	2:15	15.1	23	2:35
Ark Angels Christian Preschool	100	20	3.8	13.0	18	2:20	15.8	24	2:45
Crystal River High School	100	20	2.4	44.2	4	2:05	15.1	23	2:30
Crystal River Middle School	100	20	3.1	12.6	15	2:15	11.0	17	2:35
Crystal River Preschool	100	20	2.5	43.9	4	2:05	15.8	24	2:30
Crystal River Primary School	100	20	9.2	48.8	12	2:15	15.6	24	2:40
Marine Science Station	100	20	9.0	46.0	12	2:15	15.6	24	2:40
LEVY COUNTY SCHOOLS									
Yankeetown School	0[1]	20	5.6	50.0	7	0:30	31.5	48	1:15
					Maximum for EPZ:	**2:20**		**Maximum:**	**2:45**
					Average for EPZ:	**2:00**		**Average:**	**2:30**

[1]According to Levy County, buses are located on site and do not require any time to mobilize.

Table 8-10. Transit-Dependent Evacuation Time Estimates – Good Weather

Route Number	Bus Number	One-Wave							Two-Wave						
		Mobilization (min)	Route Length (miles)	Route Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to E.S. (miles)	Travel Time to E.S. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	135	12.7	46.9	16	30	**3:05**	14.2	19	5	10	34	30	**4:45**
2	1, 2	120	14.7	48.8	18	30	**2:50**	14.2	19	5	10	35	30	**4:30**
	3, 4	125	14.7	53.0	17	30	**2:55**	14.2	19	5	10	35	30	**4:35**
	5, 6	130	14.7	54.8	16	30	**3:00**	14.2	19	5	10	35	30	**4:40**
	7, 8	135	14.7	55.0	16	30	**3:05**	14.2	19	5	10	35	30	**4:45**
	9, 10	140	14.7	54.5	16	30	**3:10**	14.2	19	5	10	35	30	**4:50**
	11	145	14.7	54.4	16	30	**3:15**	14.2	19	5	10	35	30	**4:55**
3	1, 2	135	4.8	55.0	5	30	**2:55**	32.5	43	5	10	49	30	**5:15**
						Maximum ETE:	**3:15**						**Maximum ETE:**	**5:15**
						Average ETE:	**3:05**						**Average ETE:**	**4:50**

Table 8-11. Transit-Dependent Evacuation Time Estimates - Rain

		One-Wave							Two-Wave						
Route Number	Bus Number	Mobilization (min)	Route Length (miles)	Route Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to E.S. (miles)	Travel Time to E.S. (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
1	1	145	12.7	35.8	21	40	3:30	14.2	21	5	10	39	40	5:25
2	1, 2	130	14.7	37.4	24	40	3:15	14.2	21	5	10	39	40	5:15
	3, 4	135	14.7	40.7	22	40	3:20	14.2	21	5	10	39	40	5:20
	5, 6	140	14.7	44.0	20	40	3:20	14.2	21	5	10	39	40	5:20
	7, 8	145	14.7	45.6	19	40	3:25	14.2	21	5	10	39	40	5:25
	9, 10	150	14.7	47.7	18	40	3:30	14.2	21	5	10	39	40	5:30
	11	155	14.7	48.8	18	40	3:35	14.2	21	5	10	39	40	5:35
3	1, 2	145	4.8	50.0	6	40	3:15	32.5	49	5	10	54	40	5:55
						Maximum ETE:	**3:35**						**Maximum ETE:**	**5:55**
						Average ETE:	**3:25**						**Average ETE:**	**5:30**

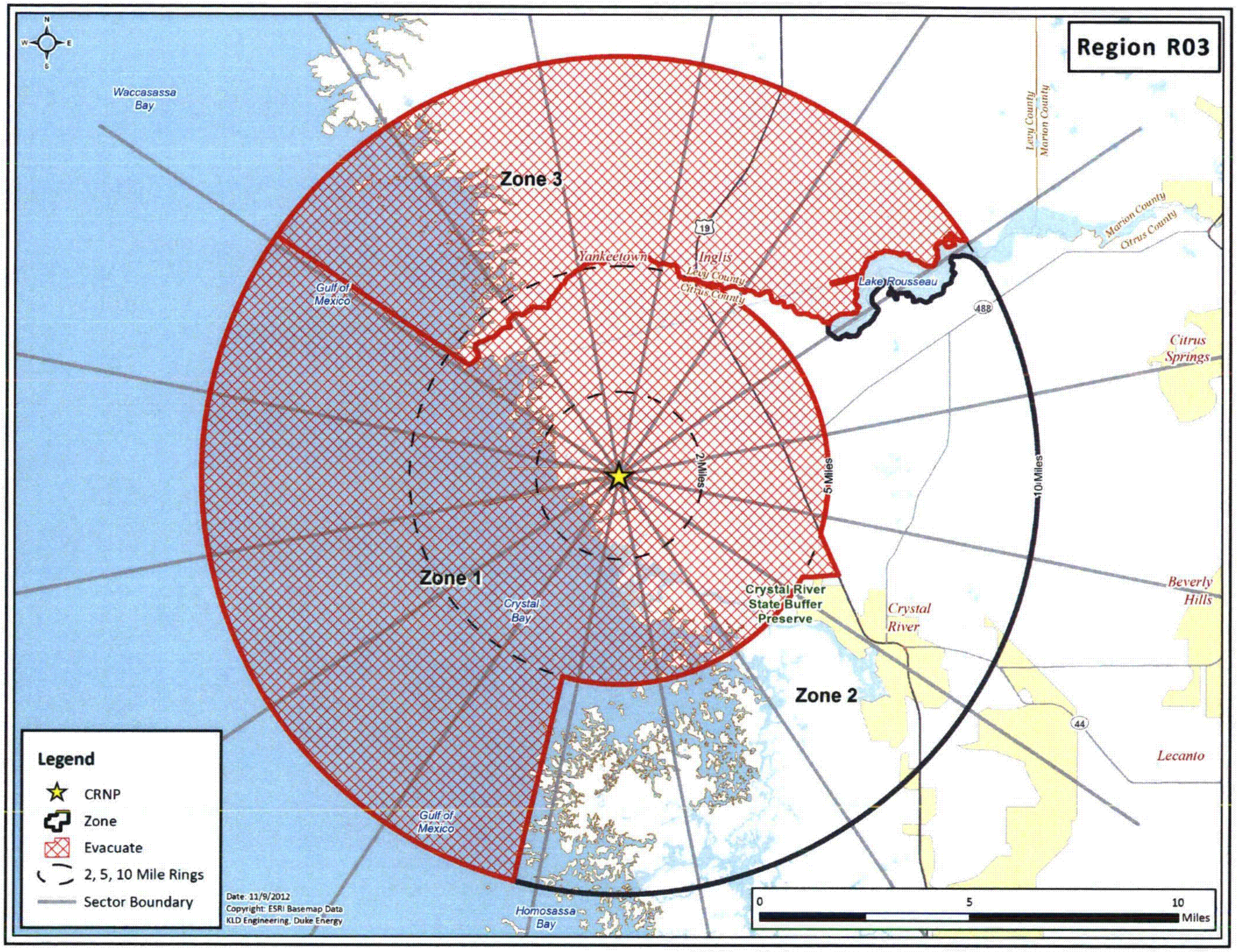


Figure H-3. Region R03

APPENDIX L

Zone Boundaries

L. ZONE BOUNDARIES

Zone 1	County: Citrus Defined as the area within the following boundary: Extends from 0-5 miles radially from the plant and extends out to 10 miles into the Gulf of Mexico. Bounded by the Withlacoochee River to the north.
Zone 2	County: Citrus Defined as the area within the following boundary: Extends from 5-10 miles radially from the plant within Citrus County, includes the town of Crystal River. Bounded by Lake Rousseau and the Withlacoochee River to the north.
Zone 3	County: Levy Defined as the area within the following boundary: Extends from 5-10 miles radially from the plant within Levy County, includes the towns of Yankeetown and Inglis. Bounded by Lake Rousseau and the Withlacoochee River to the south.

APPENDIX M

Evacuation Sensitivity Studies

M. EVACUATION SENSITIVITY STUDIES

This appendix presents the results of a series of sensitivity analyses. These analyses are designed to identify the sensitivity of the ETE to changes in some base evacuation conditions.

M.1 Effect of Changes in Trip Generation Times

A sensitivity study was performed to determine whether changes in the estimated trip generation time have an effect on the ETE for the entire EPZ. Specifically, if the tail of the mobilization distribution were truncated (i.e., if those who responded most slowly to the Advisory to Evacuate, could be persuaded to respond much more rapidly), how would the ETE be affected? The case considered was Scenario 6, Region 2; a winter, midweek, midday, good weather evacuation of the entire EPZ. Table M-1 presents the results of this study.

Table M-1. Evacuation Time Estimates for Trip Generation Sensitivity Study

Trip Generation Period	Evacuation Time Estimate for Entire EPZ	
	90th Percentile	100th Percentile
2 Hours 30 Minutes	2:20	2:45
3 Hours 30 Minutes	2:25	3:35
5 Hours 30 Minutes (Base)	2:25	5:40

The results confirm the importance of accurately estimating the trip generation (mobilization) times. The ETE for the 100th percentile closely mirror the values for the time the last evacuation trip is generated. In contrast, the 90th percentile ETE is very insensitive to truncating the tail of the mobilization time distribution. As indicated in Section 7.3, traffic congestion within the EPZ clears at about 2 hours after the ATE, well before the completion of trip generation time. The results indicate that programs to educate the public and encourage them toward faster responses for a radiological emergency, translates into shorter ETE at the 100th percentile. The results also justify the guidance to employ the [stable] 90th percentile ETE for protective action decision making.

M.2 Effect of Changes in the Number of People in the Shadow Region Who Relocate

A sensitivity study was conducted to determine the effect on ETE of changes in the percentage of people who decide to relocate from the Shadow Region. The case considered was Scenario 6, Region 2; a winter, midweek, midday, good weather evacuation for the entire EPZ. The movement of people in the Shadow Region has the potential to impede vehicles evacuating from an Evacuation Region within the EPZ. Refer to Sections 3.2 and 7.1 for additional information on population within the shadow region.

Table M-2 presents the evacuation time estimates for each of the cases considered. The results show that the ETE is not impacted by shadow evacuation from 0% to 60% at the 90th and 100th percentiles. Note, the telephone survey results presented in Appendix F indicate that 23% of households would elect to evacuate if advised to shelter. Thus, the base assumption of 20% non-compliance suggested in NUREG/CR-7002 is valid.

Table M-2. Evacuation Time Estimates for Shadow Sensitivity Study

Percent Shadow Evacuation	Evacuating Shadow Vehicles	Evacuation Time Estimate for Entire EPZ	
		90th Percentile	100th Percentile
0	0	2:25	5:40
15	4,155	2:25	5:40
20 (Base)	5,540	2:25	5:40
25	6,926	2:25	5:40
60	16,621	2:25	5:40

M.3 Effect of Changes in EPZ Resident Population

A sensitivity study was conducted to determine the effect on ETE if the resident population within the study area (EPZ plus Shadow Region) increases. As population in the study area changes over time, the time required to evacuate the public may increase, decrease, or remain the same. Since the ETE is related to the demand to capacity ratio present within the study area, changes in population will cause the demand side of the equation to change. The sensitivity study was conducted using the following planning assumptions:

1. The population within the study area was increased by varying amounts up to a 47% increase. Increases in population were applied to permanent residents only (as per federal guidance), in both the EPZ area and in the Shadow Region.
2. The transportation infrastructure remained fixed; the presence of new roads or highway capacity improvements were not considered.
3. The study was performed for the 5-Mile Region (R01) and the entire EPZ (R02).
4. The scenario which yielded the highest ETE values was selected as the case to be considered in this sensitivity study (Scenario 7). There were multiple cases that had the highest ETE value of 2:30. Scenario 7 was chosen because it is a winter, midweek, midday, rain scenario, which has approximately 2,000 more vehicles than the other cases which had an ETE of 2:30.
5. An additional Scenario which involved the Special Event (Scenario 11) was also considered.

Table M-3 presents the results of the sensitivity study. Section IV of Appendix E to 10 CFR Part 50, and NUREG/CR-7002, Section 5.4, require licensees to provide an updated ETE analysis to the NRC when a population increase within the EPZ causes ETE values (5-Mile Region or entire EPZ) to increase by 25 percent or 30 minutes, whichever is less. Note that all of the base ETE values are greater than 2 hours; 25 percent of the base ETE is always greater than 30 minutes. Therefore, 30 minutes is the lesser and is the criterion for updating.

Those percent population changes which result in ETE changes greater than 30 minutes are highlighted in red below – a 37% increase in the EPZ population for Scenario 7 – a 47% increase in EPZ population for Scenario 11. Duke Energy will have to estimate the EPZ population on an annual basis. If the EPZ population increases by 37% or more, an updated ETE analysis will be needed.

Table M-3. ETE Variation with Population Change

Scenario 7				
Resident Population	Base	Population Change		
		30%	35%	37%
	18,400	23,920	24,840	25,208
ETE for 90th Percentile				
Region	Base	Population Change		
		30%	35%	37%
5-MILE	2:10	2:10	2:10	2:10
FULL EPZ	2:30	2:55	2:55	3:00
ETE for 100th Percentile				
Region	Base	Population Change		
		30%	35%	37%
5-MILE	5:35	5:35	5:35	5:35
FULL EPZ	5:40	5:40	5:40	5:40
Scenario 11				
Resident Population	Base	Population Change		
		30%	45%	47%
	18,400	23,920	26,680	27,048
ETE for 90th Percentile				
Region	Base	Population Change		
		30%	45%	47%
5-MILE	2:10	2:10	2:20	2:10
FULL EPZ	2:25	2:40	2:50	2:55
ETE for 100th Percentile				
Region	Base	Population Change		
		30%	45%	47%
5-MILE	5:35	5:35	5:35	5:35
FULL EPZ	5:40	5:40	5:40	5:40

APPENDIX N

ETE Criteria Checklist

N. ETE CRITERIA CHECKLIST

Table N-1. ETE Review Criteria Checklist

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
1.0 Introduction		
a. The emergency planning zone (EPZ) and surrounding area should be described.	Yes	Section 1
b. A map should be included that identifies primary features of the site, including major roadways, significant topographical features, boundaries of counties, and population centers within the EPZ.	Yes	Figure 1-1
c. A comparison of the current and previous ETE should be provided and includes similar information as identified in Table 1-1, "ETE Comparison," of NUREG/CR-7002.	Yes	Table 1-3
1.1 Approach		
a. A discussion of the approach and level of detail obtained during the field survey of the roadway network should be provided.	Yes	Section 1.3
b. Sources of demographic data for schools, special facilities, large employers, and special events should be identified.	Yes	Section 2.1 Section 3
c. Discussion should be presented on use of traffic control plans in the analysis.	Yes	Section 1.3, Section 2.3, Section 9, Appendix G
d. Traffic simulation models used for the analyses should be identified by name and version.	Yes	Section 1.3, Table 1-3, Appendix B, Appendix C

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
e. Methods used to address data uncertainties should be described.	Yes	Section 3 – avoid double counting Section 5, Appendix F – 4.25% sampling error at 95% confidence interval for telephone survey
1.2 Assumptions		
a. The planning basis for the ETE includes the assumption that the evacuation should be ordered promptly and no early protective actions have been implemented.	Yes	Section 2.3 – Assumption 1 Section 5.1
b. Assumptions consistent with Table 1-2, "General Assumptions," of NUREG/CR-7002 should be provided and include the basis to support their use.	Yes	Sections 2.2, 2.3
1.3 Scenario Development		
a. The ten scenarios in Table 1-3, Evacuation Scenarios, should be developed for the ETE analysis, or a reason should be provided for use of other scenarios.	Yes	Tables 2-1, 6-2
1.3.1 Staged Evacuation		
a. A discussion should be provided on the approach used in development of a staged evacuation.	Yes	Sections 5.4.2, 7.2
1.4 Evacuation Planning Areas		
a. A map of EPZ with emergency response planning areas (ERPAs) should be included.	Yes	Figure 6-1
b. A table should be provided identifying the ERPAs considered for each ETE calculation by downwind direction in each sector.	Yes	Table 6-1, Table 7-5

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
c. A table similar to Table 1-4, "Evacuation Areas for a Staged Evacuation Keyhole," of NUREG/CR-7002 should be provided and includes the complete evacuation of the 2, 5, and 10 mile areas and for the 2 mile area/5 mile keyhole evacuations.	Yes	Table 6-1, Table 7-5
2.0 Demand Estimation		
a. Demand estimation should be developed for the four population groups, including permanent residents of the EPZ, transients, special facilities, and schools.	Yes	Permanent residents, employees, transients – Section 3, Appendix E Special facilities, schools – Section 8, Appendix E
2.1 Permanent Residents and Transient Population		
a. The US Census should be the source of the population values, or another credible source should be provided.	Yes	Section 3.1
b. Population values should be adjusted as necessary for growth to reflect population estimates to the year of the ETE.	Yes	2010 used as the base year for analysis. No growth of population necessary.
c. A sector diagram should be included, similar to Figure 2-1, "Population by Sector," of NUREG/CR-7002, showing the population distribution for permanent residents.	Yes	Figure 3-2
2.1.1 Permanent Residents with Vehicles		
a. The persons per vehicle value should be between 1 and 2 or justification should be provided for other values.	Yes	1.55 persons per vehicle – Table 1-3
b. Major employers should be listed.	Yes	Appendix E – Table E-3
2.1.2 Transient Population		

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
a. A list of facilities which attract transient populations should be included, and peak and average attendance for these facilities should be listed. The source of information used to develop attendance values should be provided.	Yes	Sections 3.3 - Transients 3.4 - Employees Appendix E
b. The average population during the season should be used, itemized and totaled for each scenario.	Yes	Tables 3-4, 3-5 and Appendix E itemize the transient population and employee estimates. These estimates are multiplied by the scenario specific percentages provided in Table 6-3 to estimate transient population by scenario.
c. The percent of permanent residents assumed to be at facilities should be estimated.	Yes	Sections 3.3 - transients 3.4 - employees
d. The number of people per vehicle should be provided. Numbers may vary by scenario, and if so, discussion on why values vary should be provided.	Yes	Sections 3.3 - transients 3.4 - employees
e. A sector diagram should be included, similar to Figure 2-1 of NUREG/CR-7002, showing the population distribution for the transient population.	Yes	Figure 3-6 – transients Figure 3-8 – employees
2.2 Transit Dependent Permanent Residents		
a. The methodology used to determine the number of transit dependent residents should be discussed.	Yes	Section 8.1, Table 8-1
b. Transportation resources needed to evacuate this group should be quantified.	Yes	Section 8.1, Tables 8-5, 8-9
c. The county/local evacuation plans for transit dependent residents should be used in the analysis.	Yes	Sections 8.1, 8.4

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
d. The methodology used to determine the number of people with disabilities and those with access and functional needs who may need assistance and do not reside in special facilities should be provided. Data from local/county registration programs should be used in the estimate, but should not be the only set of data.	Yes	Section 8.5
e. Capacities should be provided for all types of transportation resources. Bus seating capacity of 50% should be used or justification should be provided for higher values.	Yes	Section 2.3 – Assumption 10 Sections 3.5, 8.1, 8.2, 8.3
f. An estimate of this population should be provided and information should be provided that the existing registration programs were used in developing the estimate.	Yes	Table 8-1 – transit dependents Section 8.5 – functional needs
g. A summary table of the total number of buses, ambulances, or other transport needed to support evacuation should be provided and the quantification of resources should be detailed enough to assure double counting has not occurred.	Yes	Section 8-3, Section 8.4 – page 8-6 Table 8-5
2.3 Special Facility Residents		
a. A list of special facilities, including the type of facility, location, and average population should be provided. Special facility staff should be included in the total special facility population.	Yes	Table E-2 – list facilities, location, and population No correctional facilities exist within the EPZ
b. A discussion should be provided on how special facility data was obtained.	Yes	Section 8.3

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
c. The number of wheelchair and bed-bound individuals should be provided.	Yes	Section 8.3 Table 8-4
d. An estimate of the number and capacity of vehicles needed to support the evacuation of the facility should be provided.	Yes	Section 8.4 – page 8-9 Tables 8-4, 8-5
e. The logistics for mobilizing specially trained staff (e.g., medical support or security support for prisons, jails, and other correctional facilities) should be discussed when appropriate.	Yes	Section 3.5 Section 8.4 – Page 8-9 No correctional facilities exist within the EPZ.
2.4 Schools		
a. A list of schools including name, location, student population, and transportation resources required to support the evacuation, should be provided. The source of this information should be provided.	Yes	Table 8-2, E-1 Section 8.2
b. Transportation resources for elementary and middle schools should be based on 100% of the school capacity.	Yes	Table 8-2
c. The estimate of high school students who will use their personal vehicle to evacuate should be provided and a basis for the values used should be discussed.	Yes	Section 8.2
d. The need for return trips should be identified if necessary.	Yes	There are sufficient resources to evacuate schools in a single wave. However, Section 8.4 and Figure 8-1 discuss the potential for a multiple wave evacuation

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
2.5.1 Special Events		
a. A complete list of special events should be provided and includes information on the population, estimated duration, and season of the event.	Yes	Section 3.7
b. The special event that encompasses the peak transient population should be analyzed in the ETE.	Yes	Section 3.7
c. The percent of permanent residents attending the event should be estimated.	Yes	Section 3.7
2.5.2 Shadow Evacuation		
a. A shadow evacuation of 20 percent should be included for areas outside the evacuation area extending to 15 miles from the NPP.	Yes	Section 2.2 – Assumption 5 Figure 2-1 Section 3.2
b. Population estimates for the shadow evacuation in the 10 to 15 mile area beyond the EPZ are provided by sector.	Yes	Section 3.2 Figure 3-4 Table 3-3
c. The loading of the shadow evacuation onto the roadway network should be consistent with the trip generation time generated for the permanent resident population.	Yes	Section 5 – Table 5-8

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
2.5.3 Background and Pass Through Traffic		
a. The volume of background traffic and pass through traffic is based on the average daytime traffic. Values may be reduced for nighttime scenarios.	Yes	Section 3.6 Table 3-6 Section 6 Table 6-3
b. Pass through traffic is assumed to have stopped entering the EPZ about two hours after the initial notification.	Yes	Section 2.3 – Assumption 5 Section 3.6
2.6 Summary of Demand Estimation		
a. A summary table should be provided that identifies the total populations and total vehicles used in analysis for permanent residents, transients, transit dependent residents, special facilities, schools, shadow population, and pass-through demand used in each scenario.	Yes	Tables 3-7, 3-8
3.0 Roadway Capacity		
a. The method(s) used to assess roadway capacity should be discussed.	Yes	Section 4
3.1 Roadway Characteristics		
a. A field survey of key routes within the EPZ has been conducted.	Yes	Section 1.3
b. Information should be provided describing the extent of the survey, and types of information gathered and used in the analysis.	Yes	Section 1.3

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
c. A table similar to that in Appendix A, "Roadway Characteristics," of NUREG/CR-7002 should be provided.	Yes	Appendix K, Table K-1
d. Calculations for a representative roadway segment should be provided.	Yes	Section 4
e. A legible map of the roadway system that identifies node numbers and segments used to develop the ETE should be provided and should be similar to Figure 3-1, "Roadway Network Identifying Nodes and Segments," of NUREG/CR-7002.	Yes	Appendix K, Figures K-1 through K-30 present the entire link-node analysis network at a scale suitable to identify all links and nodes
3.2 Capacity Analysis		
a. The approach used to calculate the roadway capacity for the transportation network should be described in detail and identifies factors that should be expressly used in the modeling.	Yes	Section 4
b. The capacity analysis identifies where field information should be used in the ETE calculation.	Yes	Section 1.3, Section 4
3.3 Intersection Control		
a. A list of intersections should be provided that includes the total number of intersections modeled that are unsignalized, signalized, or manned by response personnel.	Yes	Appendix K, Table K-2
b. Characteristics for the 10 highest volume intersections within the EPZ are provided including the location, signal cycle length, and turn lane queue capacity.	Yes	Table J-1
c. Discussion should be provided on how signal cycle time is used in the calculations.	Yes	Section 4.1, Appendix C.

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
3.4 Adverse Weather		
a. The adverse weather condition should be identified and the effects of adverse weather on mobilization time should be considered.	Yes	Table 2-1, Section 2.3 – Assumption 9 Mobilization time – Table 2-2
b. The speed and capacity reduction factors identified in Table 3-1, "Weather Capacity Factors," of NUREG/CR-7002 should be used or a basis should be provided for other values.	Yes	Table 2-2 – based on HCM 2010. The factors provided in Table 3-1 of NUREG/CR-7002 are from HCM 2000.
c. The study identifies assumptions for snow removal on streets and driveways, when applicable.	N/A	Snow scenarios were not considered in this study.
4.0 Development of Evacuation Times		
4.1 Trip Generation Time		
a. The process used to develop trip generation times should be identified.	Yes	Section 5
b. When telephone surveys are used, the scope of the survey, area of survey, number of participants, and statistical relevance should be provided.	Yes	Appendix F
c. Data obtained from telephone surveys should be summarized.	Yes	Appendix F
d. The trip generation time for each population group should be developed from site specific information.	Yes	Section 5, Appendix F

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
4.1.1 Permanent Residents and Transient Population		
a. Permanent residents are assumed to evacuate from their homes but are not assumed to be at home at all times. Trip generation time includes the assumption that a percentage of residents will need to return home prior to evacuating.	Yes	Section 5 discusses trip generation for households with and without returning commuters. Table 6-3 presents the percentage of households with returning commuters and the percentage of households either without returning commuters or with no commuters. Appendix F presents the percent households who will await the return of commuters.
b. Discussion should be provided on the time and method used to notify transients. The trip generation time discusses any difficulties notifying persons in hard to reach areas such as on lakes or in campgrounds.	Yes	Section 5.4.3
c. The trip generation time accounts for transients potentially returning to hotels prior to evacuating.	Yes	Section 5, Figure 5-1
d. Effect of public transportation resources used during special events where a large number of transients should be expected should be considered.	Yes	Section 3.7
e. The trip generation time for the transient population should be integrated and loaded onto the transportation network with the general public.	Yes	Section 5, Table 5-8

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
4.1.2 Transit Dependent Residents		
a. If available, existing plans and bus routes should be used in the ETE analysis. If new plans should be developed with the ETE, they have been agreed upon by the responsible authorities.	Yes	Section 8.3 – page 8-8. Pre-established bus routes do not exist. Basic bus routes were developed for the ETE analysis – see Figure 8-2, Table 8-9.
b. Discussion should be included on the means of evacuating ambulatory and non-ambulatory residents.	Yes	Section 8.4, 8.5
c. The number, location, and availability of buses, and other resources needed to support the demand estimation should be provided.	Yes	Section 8.4, Table 8-5
d. Logistical details, such as the time to obtain buses, brief drivers, and initiate the bus route should be provided.	Yes	Section 8.4, Figure 8-1
e. Discussion should identify the time estimated for transit dependent residents to prepare and travel to a bus pickup point, and describes the expected means of travel to the pickup point.	Yes	Section 8.4
f. The number of bus stops and time needed to load passengers should be discussed.	Yes	Section 8.4
g. A map of bus routes should be included.	Yes	Figure 8-2
h. The trip generation time for non-ambulatory persons includes the time to mobilize ambulances or special vehicles, time to drive to the home of residents, loading time, and time to drive out of the EPZ should be provided.	Yes	Section 8.4, 8.5

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
i. Information should be provided to supports analysis of return trips, if necessary.	Yes	Section 8.4 Figure 8-1 Tables 8-10 and 8-11
4.1.3 Special Facilities		
a. Information on evacuation logistics and mobilization times should be provided.	Yes	Section 8-4, Tables 8-12 and 8-13
b. Discussion should be provided on the inbound and outbound speeds.	Yes	Sections 8.4
c. The number of wheelchair and bed-bound individuals should be provided, and the logistics of evacuating these residents should be discussed.	Yes	Tables 8-4, 8-12 though 8-12
d. Time for loading of residents should be provided	Yes	Section 8.4
e. Information should be provided that indicates whether the evacuation can be completed in a single trip or if additional trips should be needed.	Yes	Section 8.4, Table 8-5
f. If return trips should be needed, the destination of vehicles should be provided.	Yes	Section 8.4
g. Discussion should be provided on whether special facility residents are expected to pass through the reception center prior to being evacuated to their final destination.	Yes	Section 8.4
h. Supporting information should be provided to quantify the time elements for the return trips.	Yes	Section 8.4. - page 8-10

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
4.1.4 Schools		
a. Information on evacuation logistics and mobilization time should be provided.	Yes	Section 8.4
b. Discussion should be provided on the inbound and outbound speeds.	Yes	School bus routes are presented in Table 8-6. School bus speeds are presented in Tables 8-7 (good weather), and 8-8(rain). Outbound speeds are defined as the minimum of the evacuation route speed and the State school bus speed limit. Inbound speeds are limited to the State school bus speed limit.
c. Time for loading of students should be provided.	Yes	Tables 8-7 through 8-8, Discussion in Section 8.4
d. Information should be provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.	Yes	Section 8.4 – page 8-6
e. If return trips are needed, the destination of school buses should be provided.	Yes	Return trips are not needed
f. If used, reception centers should be identified. Discussion should be provided on whether students are expected to pass through the reception center prior to being evacuated to their final destination.	Yes	Table 8-3. Students are evacuated to relocation schools where they will be picked up by parents or guardians.

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
g. Supporting information should be provided to quantify the time elements for the return trips.	Yes	Return trips are not needed. Tables 8-7 and 8-8 provide time needed to arrive at relocation school, which could be used to compute a second wave evacuation if necessary
4.2 ETE Modeling		
a. General information about the model should be provided and demonstrates its use in ETE studies.	Yes	DYNEV II (Ver. 4.0.8.0). Section 1.3, Table 1-3, Appendix B, Appendix C.
b. If a traffic simulation model is not used to conduct the ETE calculation, sufficient detail should be provided to validate the analytical approach used. All criteria elements should have been met, as appropriate.	No	Not applicable as a traffic simulation model was used.
4.2.1 Traffic Simulation Model Input		
a. Traffic simulation model assumptions and a representative set of model inputs should be provided.	Yes	Appendices B and C describe the simulation model assumptions and algorithms Table J-2
b. A glossary of terms should be provided for the key performance measures and parameters used in the analysis.	Yes	Appendix A Tables C-1, C-2

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
4.2.2 Traffic Simulation Model Output		
a. A discussion regarding whether the traffic simulation model used must be in equilibration prior to calculating the ETE should be provided.	Yes	Appendix B
b. The minimum following model outputs should be provided to support review: 1. Total volume and percent by hour at each EPZ exit node. 2. Network wide average travel time. 3. Longest queue length for the 10 intersections with the highest traffic volume. 4. Total vehicles exiting the network. 5. A plot that provides both the mobilization curve and evacuation curve identifying the cumulative percentage of evacuees who have mobilized and exited the EPZ. 6. Average speed for each major evacuation route that exits the EPZ.	Yes	1. Table J-5. 2. Table J-3. 3. Table J-1. 4. Table J-3. 5. Figures J-1 through J-14 (one plot for each scenario considered). 6. Table J-4. Network wide average speed also provided in Table J-3.
c. Color coded roadway maps should be provided for various times (i.e., at 2, 4, 6 hrs., etc.) during a full EPZ evacuation scenario, identifying areas where long queues exist including level of service (LOS) "E" and LOS "F" conditions, if they occur.	Yes	Figures 7-3 through 7-6
4.3 Evacuation Time Estimates for the General Public		
a. The ETE should include the time to evacuate 90% and 100% of the total permanent resident and transient population	Yes	Tables 7-1, 7-2

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
b. The ETE for 100% of the general public should include all members of the general public. Any reductions or truncated data should be explained.	Yes	Section 5.4 – truncating survey data to eliminate statistical outliers Table 7-2 – 100^{th} percentile ETE for general public
c. Tables should be provided for the 90 and 100 percent ETEs similar to Table 4-3, "ETEs for Staged Evacuation Keyhole," of NUREG/CR-7002.	Yes	Tables 7-3, 7-4
d. ETEs should be provided for the 100 percent evacuation of special facilities, transit dependent, and school populations.	Yes	Section 8.4 Tables 8-7 through 8-8 - Schools Tables 8-10 through 8-11 – Transit-Dependent Tables 8-12 through 8-13 – Special Facilities Table 8-14 – Homebound Functional Needs
5.0 Other Considerations		
5.1 Development of Traffic Control Plans		
a. Information that responsible authorities have approved the traffic control plan used in the analysis should be provided.	Yes	Section 9, Appendix G
b. A discussion of adjustments or additions to the traffic control plan that affect the ETE should be provided.	Yes	Appendix G
5.2 Enhancements in Evacuation Time		

NRC Review Criteria	Criterion Addressed in ETE Analysis	Comments
a. The results of assessments for improvement of evacuation time should be provided.	Yes	Appendix M
b. A statement or discussion regarding presentation of enhancements to local authorities should be provided.	Yes	Section 7.5 (pg. 7-5). Results of the ETE study were formally presented to local authorities at the final project meeting. Recommended enhancements were discussed.
5.3 State and Local Review		
a. A list of agencies contacted and the extent of interaction with these agencies should be discussed.	Yes	Table 1-1
b. Information should be provided on any unresolved issues that may affect the ETE.	Yes	Comment resolution form was provided and any issues were resolved.
5.4 Reviews and Updates		
a. A discussion of when an updated ETE analysis is required to be performed and submitted to the NRC.	Yes	Appendix M, Section M.3
5.5 Reception Centers and Congregate Care Center		
a. A map of congregate care centers and reception centers should be provided.	Yes	Figure 10-1
b. If return trips are required, assumptions used to estimate return times for buses should be provided.	Yes	Section 8.4 discusses a multi-wave evacuation procedure. Figure 8-1
c. It should be clearly stated if it is assumed that passengers are left at the reception center and are taken by separate buses to the congregate care center.	Yes	Section 2.3 – Assumption 7h Section 10

Technical Reviewer ______________________________ Date ________________________

Supervisory Review ______________________________ Date ________________________

1 INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Crystal River Nuclear Plant (CRNP), located in Citrus County, Florida. ETE provide State, local governments, and Duke Energy with site-specific information needed for Protective Action decision-making.

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

- Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, November 2011.
- Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG 0654/FEMA REP 1, Rev. 1, November 1980.
- Analysis of Techniques for Estimating Evacuation Times for Emergency Planning Zones, NUREG/CR 1745, November 1980.
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

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

Table 1-1. Stakeholder Interaction

Stakeholder	Nature of Stakeholder Interaction
Duke Energy Emergency Preparedness	Attend Kick-Off meeting to define data requirements and set up contacts with local government agencies. Act as point of contact for data collection. Review and approve study assumptions. Coordinated a teleconference with the ORO's to discuss and collect their comments on the Draft Report. Attended Final Meeting where the results of the ETE study were formally presented.
Citrus and Levy County Emergency Management	Attend Kick-Off meeting to define data requirements and set up contacts with local government agencies. Provide Duke Energy with local emergency plans, special facility data, and major employment data. Review and approve study assumptions. Attended Final Meeting where the results of the ETE study were formally presented.
Florida State Emergency Management Office	Attend Kick-Off Meeting. Provide Florida State Radiological Emergency Plan. Attended Final Meeting where the results of the ETE study were formally presented.
Local and State Police Agencies	Obtain existing traffic management plans

1.1 Overview of the ETE Process

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

1. Information Gathering:
    a. Defined the scope of work in discussions with representatives from Duke Energy.
    b. Attended meetings with emergency planners from Florida EM, Citrus County EM, and Levy County EM to identify issues to be addressed and resources available.
    c. Conducted a detailed field survey of the highway system and of area traffic conditions within the Emergency Planning Zone (EPZ[1]) and Shadow Region.
    d. Obtained demographic data from the 2010 census.
    e. Conducted a random sample telephone survey of EPZ residents.
    f. Conducted a data collection effort to identify and describe schools, special facilities, major employers, transportation providers, and other important information.
2. Estimated distributions of Trip Generation times representing the time required by various population groups (permanent residents, employees, and transients) to prepare (mobilize) for the evacuation trip. These estimates are primarily based upon the random sample telephone survey.
3. Defined Evacuation Scenarios. These scenarios reflect the variation in demand, in trip generation distribution and in highway capacities, associated with different seasons, day of week, time of day and weather conditions.
4. Reviewed the existing traffic management plan to be implemented by local and state police in the event of an incident at the plant. Traffic control is applied at specified Traffic Control Points (TCP) located within the EPZ.
5. Used existing Zones to define Evacuation Regions. The EPZ is partitioned into 3 Zones along jurisdictional and geographic boundaries. "Regions" are groups of contiguous Zones for which ETE are calculated. The configurations of these Regions reflect wind direction and the radial extent of the impacted area. Each Region, other than those that approximate circular areas, approximates a "key-hole section" within the EPZ as recommended by NUREG/CR-7002.
6. Estimated demand for transit services for persons at "Special Facilities" and for transit-dependent persons at home.
7. Prepared the input streams for the DYNEV II system which computes ETE (See Appendices B and C).

[1] All references to EPZ refer to the plume exposure pathway EPZ.

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

b. Applied the procedures specified in the 2010 Highway Capacity Manual (HCM[2]) to the data acquired during the field survey, to estimate the capacity of all highway segments comprising the evacuation routes.

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

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

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

8. Executed the DYNEV II model to determine optimal evacuation routing and compute ETE for all residents, transients and employees ("general population") with access to private vehicles. Generated a complete set of ETE for all specified Regions and Scenarios.

9. Documented ETE in formats in accordance with NUREG/CR-7002.

10. Calculated the ETE for all transit activities including those for special facilities (schools, medical facilities, etc.), for the transit-dependent population and for homebound functional needs population.

1.2 The Crystal River Nuclear Plant Location

The Crystal River Nuclear Plant (CRNP) is located on the Gulf of Mexico approximately seven and one-half miles northwest of Crystal River, Florida. The site is approximately 35 miles southwest of Ocala, FL. The Emergency Planning Zone (EPZ) consists of parts of Citrus and Levy Counties in Florida. Figure 1-1 displays the area surrounding the CRNP. This map identifies the communities in the area and the major roads.

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

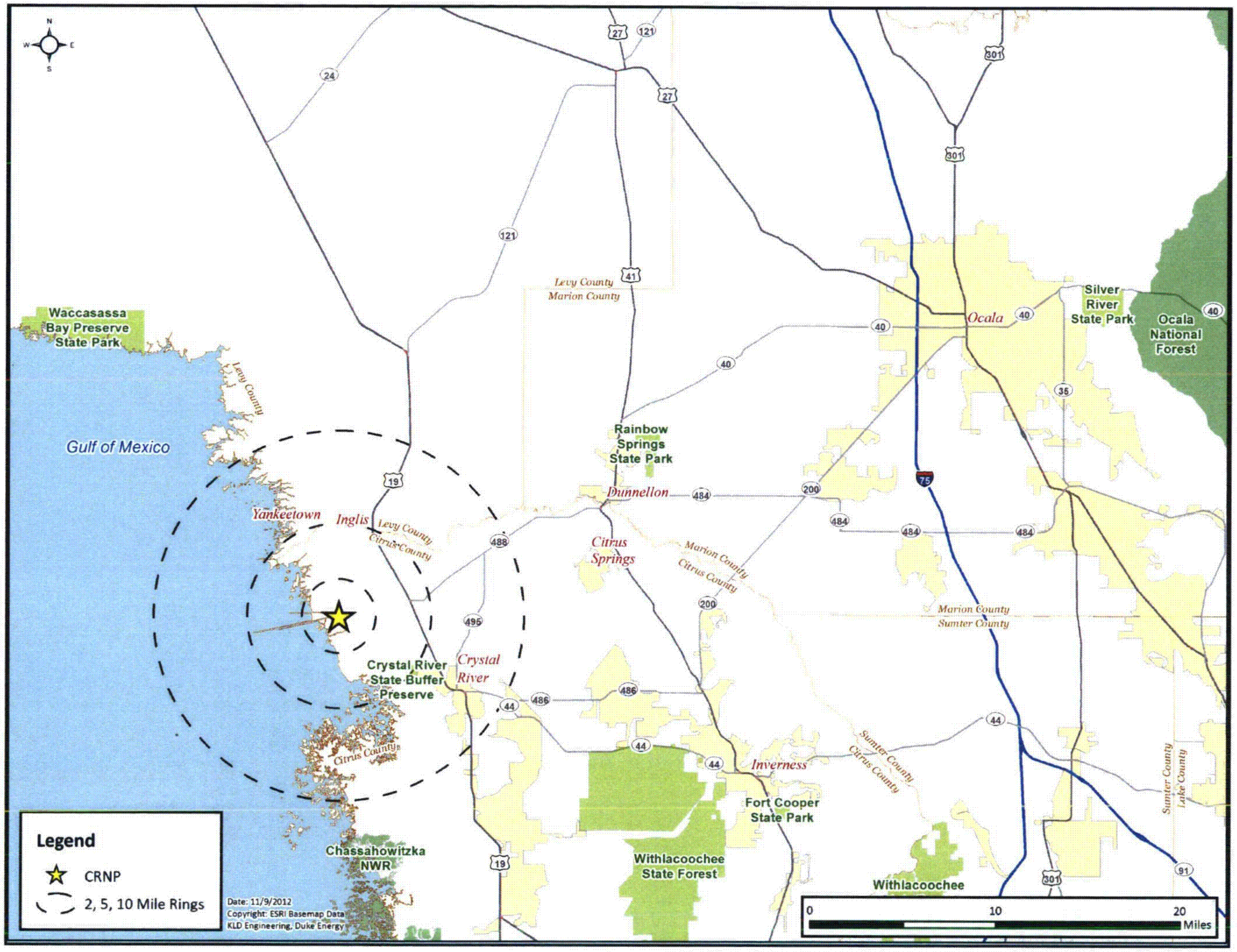


Figure 1-1. CRNP Location

1.3 Preliminary Activities

These activities are described below.

Field Surveys of the Highway Network

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

Table 1-2. Highway Characteristics

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

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

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

As documented on page 15-5 of the HCM 2010, the capacity of a two-lane highway is 1700 passenger cars per hour in one direction. For freeway sections, a value of 2250 vehicles per hour per lane is assigned, as per Exhibit 11-17 of the HCM 2010. The road survey has identified several segments which are characterized by adverse geometrics on two-lane highways which are reflected in reduced values for both capacity and speed. These estimates are consistent with the service volumes for LOS E presented in HCM Exhibit 15-30. These links may be identified by reviewing Appendix K. Link capacity is an input to DYNEV II which computes the ETE. Further discussion of roadway capacity is provided in Section 4 of this report.

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

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

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

<u>Telephone Survey</u>

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

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

<u>Computing the Evacuation Time Estimates</u>

The overall study procedure is outlined in Appendix D. Demographic data were obtained from several sources, as detailed later in this report. These data were analyzed and converted into vehicle demand data. The vehicle demand was loaded onto appropriate "source" links of the analysis network using GIS mapping software. The DYNEV II system was then used to compute ETE for all Regions and Scenarios.

<u>Analytical Tools</u>

The DYNEV II System that was employed for this study is comprised of several integrated computer models. One of these is the DYNEV (<u>DY</u>namic <u>N</u>etwork <u>EV</u>acuation) macroscopic simulation model, a new version of the IDYNEV model that was developed by KLD under contract with the Federal Emergency Management Agency (FEMA).

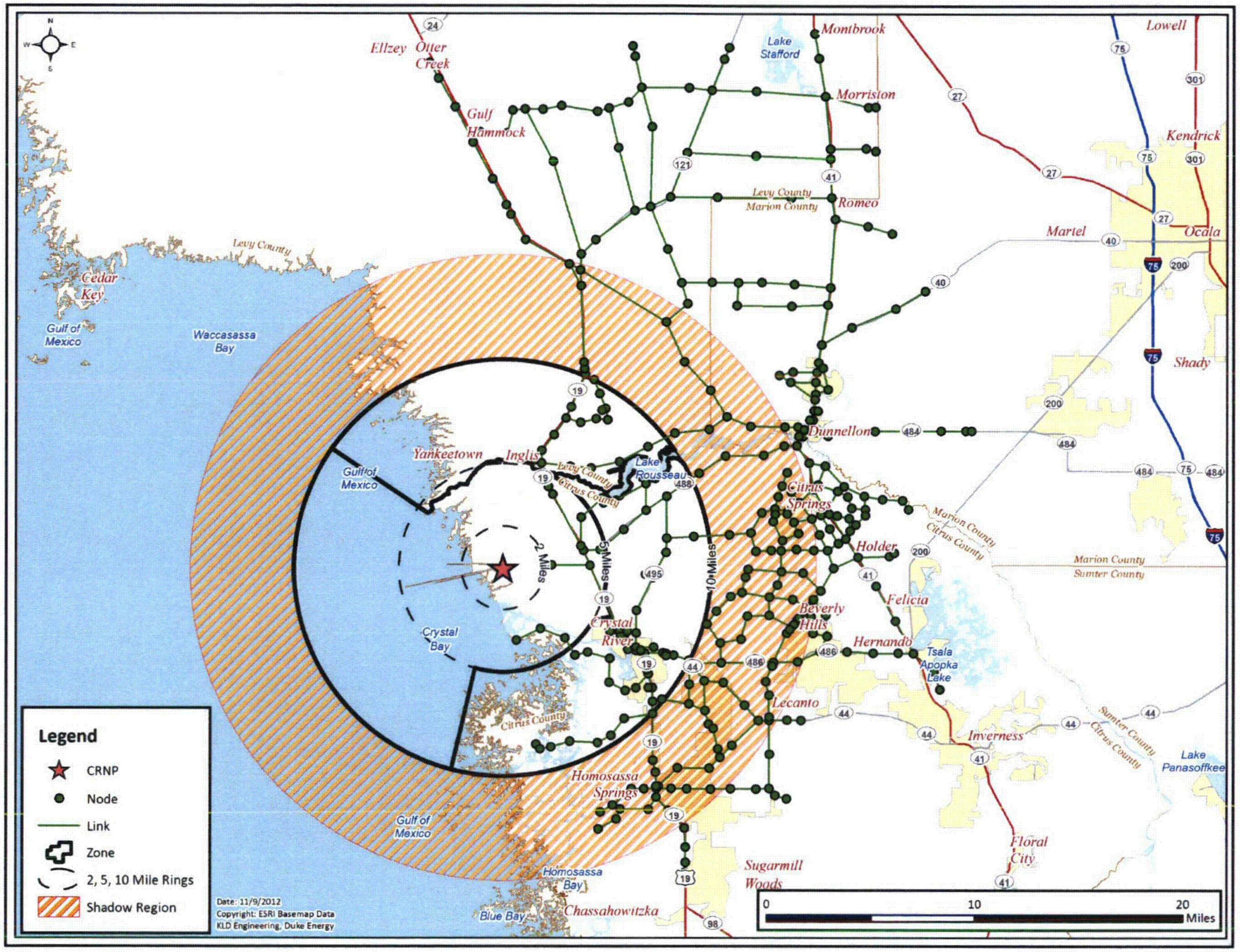


Figure 1-2. CRNP Link-Node Analysis Network

DYNEV II consists of four sub-models:

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

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

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

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

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

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

The evacuation analysis procedures are based upon the need to:

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

DYNEV II provides a detailed description of traffic operations on the evacuation network. This description enables the analyst to identify bottlenecks and to develop countermeasures that are designed to represent the behavioral responses of evacuees. The effects of these countermeasures may then be tested with the model.

1.4 Comparison with Prior ETE Study

Table 1-3 presents a comparison of the present ETE study with the 2008 study. The major factors contributing to the differences between the ETE values obtained in this study and those of the previous study can be summarized as follows:

- A decrease in permanent resident population and also in average persons/household.
- The highway representation is updated to reflect the HCM 2010.
- The previous study modeled all traffic signals as pretimed signals with fixed signal timings. NUREG/CR-7002 requires the ETE to consider actuated signals in the traffic simulation model where they exist in the real world. Actuated signals allocate green time based on the volume at each approach and will vary throughout the simulation. This adaptive intersection control has improved capacity at critical intersections along congested corridors, thus decreasing ETE.
- Dynamic evacuation modeling.

Table 1-3. ETE Study Comparisons

Topic	Previous ETE Study	Current ETE Study
Resident Population Basis	2000 US Census Data extrapolated to 2007 using block centroid method; Population = 23,309	ArcGIS Software using 2010 US Census blocks; area ratio method used. Population = 18,400
Resident Population Vehicle Occupancy	2.25 persons/household, 1.32 evacuating vehicles/household yielding: 1.70 persons/vehicle.	2.08 persons/household, 1.34 evacuating vehicles/household yielding: 1.55 persons/vehicle.
Employee Population	Employee estimates based on information provided by county emergency management offices about major employers in EPZ. 1.03 employees/vehicle based on telephone survey results. Employees = 797	Employee estimates based on information provided about major employers in EPZ. 1.02 employees per vehicle based on telephone survey results. Employees = 1,821

Topic	Previous ETE Study	Current ETE Study
Transit-Dependent Population	Estimates based upon U.S. Census data and the results of the telephone survey. A total of 596 people who do not have access to a vehicle, requiring 20 buses to evacuate.	Estimates based upon U.S. Census data and the results of the telephone survey. A total of 404 people who do not have access to a vehicle, requiring 14 buses to evacuate. An additional 46 homebound functional needs persons needed special transportation to evacuate (30 required a bus, 11 required a wheelchair-accessible vehicle, and 5 required an ambulance).
Transient Population	Transient estimates based on information gathered from each county within the EPZ. Transients = 3,214	Transient estimates based on information gathered from each county within the EPZ. Transients = 5,037
Special Facilities Population	Special facility population based on information provided by each county within the EPZ. Special Facility Population = 442 Buses required = 6 Wheelchair Bus Required = 14 Wheelchair Van Required = 4 Ambulances Required = 34	Special facility population based on information provided by each county within the EPZ. Current census = 438 Buses Required = 8 Wheelchair Buses Required = 18 Ambulances Required = 13
School Population	School population based on information provided by each county within the EPZ. School enrollment = 3,603 Buses required = 65	School population based on information provided by each county within the EPZ. School enrollment = 3,309 Buses required = 65 Vans required = 1
Shadow evacuation from within EPZ in areas outside region to be evacuated	It was assumed that 50% of the population within the circle defined by the distance to be evacuated but outside the evacuation region would voluntarily evacuate. It was assumed that 35% of the population within the annular area between the circle defined by the central "key hole" of the evacuation region and the EPZ boundary would voluntarily evacuate.	20 percent of the population within the EPZ, but not within the Evacuation Region (see Figure 2-1)

Topic	Previous ETE Study	Current ETE Study
Shadow Evacuation	30% of people outside of the EPZ within the shadow area would evacuate.	20% of people outside of the EPZ within the Shadow Region (see Figure 7-2)
Network Size	517 Links; 364 Nodes.	500 links; 339 nodes
Roadway Geometric Data	Field surveys conducted in February 2007. Major intersections were video archived. GIS shape-files of signal locations and roadway characteristics created during road survey. Road capacities based on 2000 HCM.	Field surveys conducted in March 2012. Roads and intersections were video archived. Road capacities based on 2010 HCM.
School Evacuation	Direct evacuation to designated Reception Center.	Direct evacuation to designated Relocation School.
Ridesharing	50 percent of transit-dependent persons will evacuate with a neighbor or friend.	50 percent of transit-dependent persons will evacuate with a neighbor or friend.
Trip Generation for Evacuation	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 15 and 300 minutes. Residents without commuters returning leave between 15 and 300 minutes. Employees and transients leave between 15 and 120 minutes. All times measured from the Advisory to Evacuate.	Based on residential telephone survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 and 330 minutes. Residents without commuters returning leave between 15 and 270 minutes. Employees and transients leave between 15 and 120 minutes. All times measured from the Advisory to Evacuate.
Weather	Normal or Rain. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain.	Normal or Rain. The capacity and free flow speed of all links in the network are reduced by 10% in the event of rain.
Modeling	IDYNEV System: TRAD and PC-DYNEV.	DYNEV II System – Version 4.0.8.0
Special Events	One considered – new plant construction at the proposed Levy Site.	Manatee Fest Total Special Event Population = 6,000 Transient Population = 3,600 Transient Vehicles = 1,731

Topic	Previous ETE Study	Current ETE Study
Evacuation Cases	6 Regions (central sector wind direction and each adjacent sector technique used) and 11 Scenarios producing 66 unique cases.	7 Regions (central sector wind direction and each adjacent sector technique used) and 12 Scenarios producing 84 unique cases.
Evacuation Time Estimates Reporting	ETE reported for 50, 90, 95, and 100th percentile population. Results presented by Region and Scenario.	ETE reported for 90th and 100th percentile population. Results presented by Region and Scenario.
Evacuation Time Estimates for the entire EPZ, 90th percentile	Winter Weekday Midday, Good Weather: 3:00 Summer Weekend, Midday, Good Weather: 2:45	Winter Weekday Midday, Good Weather: 2:20 Summer Weekend, Midday, Good Weather: 2:25

2 STUDY ESTIMATES AND ASSUMPTIONS

This section presents the estimates and assumptions utilized in the development of the evacuation time estimates. NUREG/CR-7002 was used as the basis for most of the assumptions provided in this section. KLD has been doing ETE studies for U.S. nuclear power plants for over 30 years, including 16 new plant applications during the last 5 years. During that time, KLD has worked with more than 100 state and county emergency management agencies. The new plant application ETE studies were reviewed extensively by the U.S. Nuclear Regulatory Commission (NRC) and refined through the Request for Additional Information (RAI) process. KLD developed a list of key project assumptions based on NUREG/CR-7002, on years of ETE experience and interaction with offsite agencies, and on feedback from the NRC through RAIs. The list was discussed with stakeholders at the project kickoff meeting. The list was then refined based on inputs from stakeholders and documented in a technical memo. The memo was approved by all stakeholders prior to computing ETE.

2.1 Data Estimates

1. Permanent resident population estimates are based upon Census 2010 data.
2. Estimates of employees who reside outside the EPZ and commute to work within the EPZ are based upon data obtained from surveys of major employers done by the county in which the employer resides.
3. Population estimates at special facilities are based on available data from county emergency management offices.
4. Roadway capacity estimates are based on field surveys and the application of the Highway Capacity Manual 2010.
5. Population mobilization times are based on a statistical analysis of data acquired from a random sample telephone survey of EPZ residents (see Section 5 and Appendix F).
6. The relationship between resident population and evacuating vehicles is developed from the telephone survey. Average values of 2.08 persons per household and 1.34 evacuating vehicles per household are used. The relationship between persons and vehicles for transients and employees is as follows:
    a. Employees: 1.02 employees per vehicle (telephone survey results) for all major employers.
    b. Parks: Vehicle occupancy varies based upon data gathered from local transient facilities.
    c. Special Events: Assumed transients attending Manatee Fest travel as a family unit in a single vehicle, and used the average household size taken from the telephone survey results of 2.08 persons to estimate the number of vehicles.

2.2 Study Methodological Assumptions

1. ETE are presented for the evacuation of the 90th and 100th percentiles of population for each Region and for each Scenario. The percentile ETE is defined as the elapsed time from the Advisory to Evacuate issued to a specific Region of the EPZ, to the time that Region is clear of the indicated percentile of evacuees. A Region is defined as a group of zones that is issued an Advisory to Evacuate. A scenario is a combination of circumstances, including time of day, day of week, season, and weather conditions.
2. Evacuation movements (paths of travel) are generally outbound relative to the plant to the extent permitted by the highway network. All major evacuation routes are used in the analysis.
3. Regions are defined by the underlying "keyhole" or circular configurations as specified in Section 1.4 of NUREG/CR-7002. These Regions, as defined, display irregular boundaries reflecting the geography of the zones included within these underlying configurations. Due to the geographic boundaries of the EPZ, there is no 2-mile region downwind to 10 miles; instead there is a 5-mile region downwind to the EPZ boundary.
4. As indicated in Figure 2-2 of NUREG/CR-7002, 100% of people within the impacted "keyhole" evacuate. 20% of those people within the EPZ, not within the impacted keyhole, will voluntarily evacuate. 20% of those people within the Shadow Region will voluntarily evacuate. See Figure 2-1 for a graphical representation of these evacuation percentages. Sensitivity studies explore the effect on ETE of increasing the percentage of shadow evacuees in the Shadow Region (see Appendix M).
5. A total of 12 "Scenarios" representing different temporal variations (season, time of day, day of week) and weather conditions are considered. These Scenarios are outlined in Table 2-1.
6. Scenario 12 considers the closure of a single lane on US-19 southbound, from the intersection with West Power Line St. to the end of the Shadow Region at the intersection with West McKinley St.

Table 2-1. Evacuation Scenario Definitions

Scenarios	Season	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Weekend	Midday	Good	None
9	Winter	Weekend	Midday	Rain	None
10	Winter	Midweek, Weekend	Evening	Good	None
11	Winter	Weekend	Midday	Good	Special Event – Manatee Fest
12	Summer	Midweek	Midday	Good	Roadway Impact Closure of one southbound lane on U.S. 19

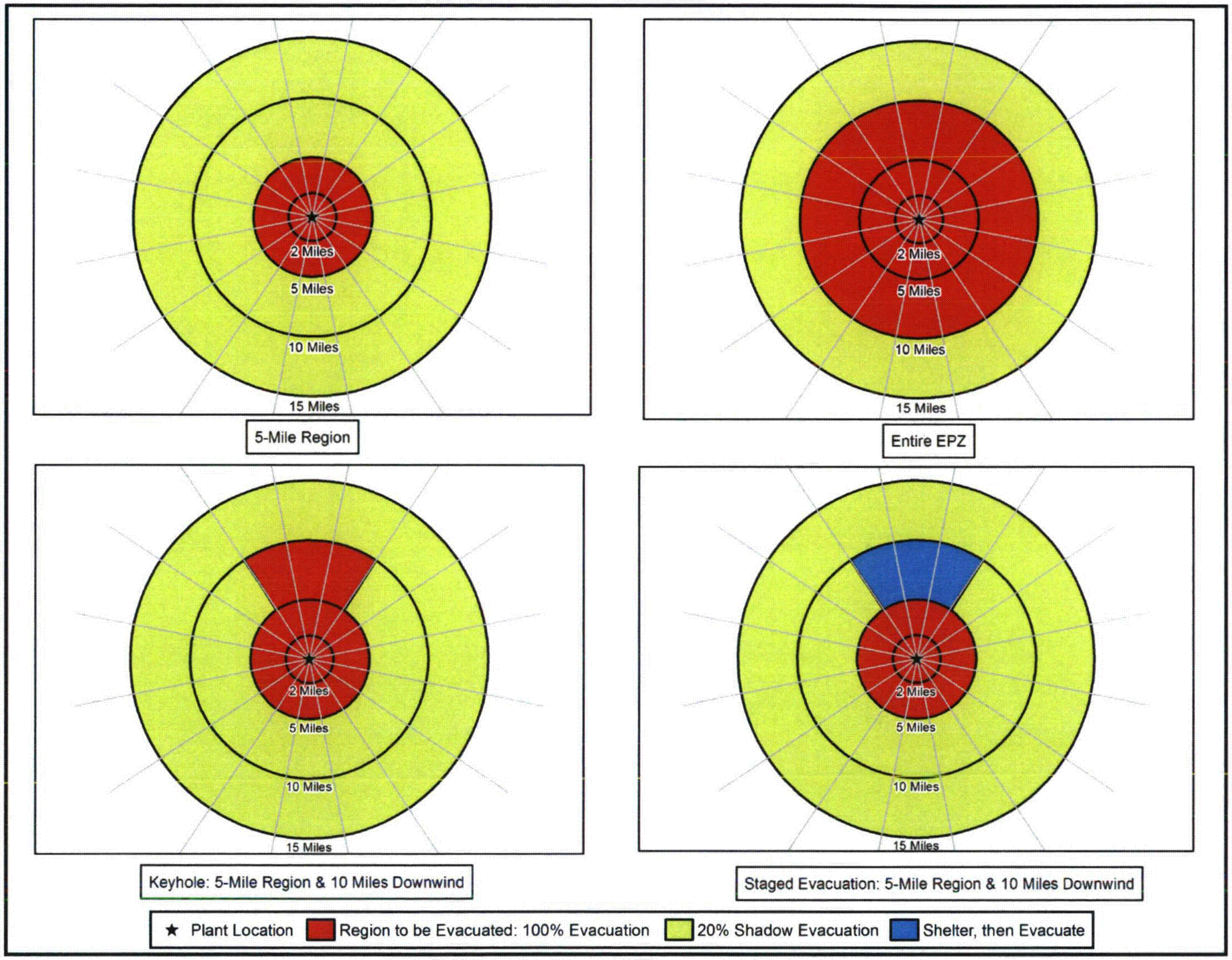


Figure 2-1. Shadow Evacuation Methodology

2.3 Study Assumptions

1. The Planning Basis Assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following:
    a. Advisory to Evacuate is announced coincident with the siren notification.
    b. Mobilization of the general population will commence within 15 minutes after siren notification.
    c. ETE are measured relative to the Advisory to Evacuate.
2. It is assumed that everyone within the group of zones forming a Region that is issued an Advisory to Evacuate will, in fact, respond and evacuate in general accord with the planned routes.
3. 37 percent of the households in the EPZ have at least 1 commuter; 50 percent of those households with commuters will await the return of a commuter before beginning their evacuation trip, based on the telephone survey results. Therefore 19 percent (37% x 50% = 19%) of EPZ households will await the return of a commuter, prior to beginning their evacuation trip. It is assumed that the responses to the telephone survey regarding the return of commuters prior to evacuating are applicable for this study.
4. The ETE will also include consideration of "through" (External-External) trips during the time that such traffic is permitted to enter the evacuated Region. "Normal" traffic flow is assumed to be present within the EPZ at the start of the emergency.
5. Access Control Points (ACP) will be staffed within approximately 120 minutes following the siren notifications, to divert traffic attempting to enter the EPZ. Earlier activation of ACP locations could delay returning commuters. It is assumed that no through traffic will enter the EPZ after this 120 minute time period.
6. Traffic Control Points (TCP) within the EPZ will be staffed over time, beginning at the Advisory to Evacuate. Their number and location will depend on the Region to be evacuated and resources available. The objectives of these TCP are:
    a. Facilitate the movements of all (mostly evacuating) vehicles at the location.
    b. Discourage inadvertent vehicle movements towards the plant.
    c. Provide assurance and guidance to any traveler who is unsure of the appropriate actions or routing.
    d. Act as local surveillance and communications center.
    e. Provide information to the emergency operations center (EOC) as needed, based on direct observation or on information provided by travelers.

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

7. Buses, ambulances, vans, and minivans will be used to transport those without access to private vehicles:
   a. If schools are in session, transport (buses) will evacuate students directly to the designated relocation school.
   b. It is assumed parents will pick up children at day care centers prior to evacuation.
   c. Buses, wheelchair vans and ambulances will evacuate patients at medical facilities and at any senior facilities within the EPZ, as needed.
   d. Transit-dependent general population will be evacuated to Reception Centers.
   e. Schoolchildren, if school is in session, are given priority in assigning transit vehicles.
   f. Bus mobilization time is considered in ETE calculations.
   g. Analysis of the number of required round-trips ("waves") of evacuating transit vehicles is presented.
   h. Transport of transit-dependent evacuees from reception centers to congregate care centers is not considered in this study.
8. Provisions are made for evacuating the transit-dependent portion of the general population to reception centers by bus, based on the assumption that some of these people will ride-share with family, neighbors, and friends, thus reducing the demand for buses. We assume that the percentage of people who rideshare is 50 percent. This assumption is based upon reported experience for other emergencies[1], and on guidance in Section 2.2 of NUREG/CR-7002.
9. One type of adverse weather scenario is considered. Rain may occur for either winter or summer scenarios. It is assumed that the rain begins earlier or at about the same time the evacuation advisory is issued. No weather-related reduction in the number of transients who may be present in the EPZ is assumed.

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

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

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

10. School buses used to transport students are assumed to transport 70 students per bus for elementary schools and 50 students per bus for middle and high schools, based on discussions with county offices of emergency management. Transit buses used to transport the transit-dependent general population are assumed to transport 30 people per bus.
11. The ETE are computed and presented in tabular format and graphically, in a format compliant with NUREG/CR-7002.
12. The models of the I-DYNEV System were recognized as state of the art by the Atomic Safety & Licensing Board (ASLB) in past hearings. (Sources: Atomic Safety & Licensing Board Hearings on Seabrook and Shoreham; Urbanik[3]). The models have continuously been refined and extended since those hearings and were independently validated by a consultant retained by the NRC. The new DYNEV II model incorporates the latest technology in traffic simulation and in dynamic traffic assignment.

Table 2-2. Model Adjustment for Adverse Weather

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time for General Population	Mobilization Time for Special Facilities and Transit Dependent Population
Rain	90%	90%	No Effect	10 Minute Increase
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.				

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

3 DEMAND ESTIMATION

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

1. An estimate of population within the EPZ, stratified into groups (resident, employee, transient).
2. An estimate, for each population group, of mean occupancy per evacuating vehicle. This estimate is used to determine the number of evacuating vehicles.
3. An estimate of potential double-counting of vehicles.

Appendix E presents much of the source material for the population estimates. Our primary source of population data, the 2010 Census, however, is not adequate for directly estimating some transient groups.

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

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

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

Furthermore, the number of vehicles at a location depends on time of day. For example, motel parking lots may be full at dawn and empty at noon. Similarly, parking lots at area parks, which are full at noon, may be almost empty at dawn. Estimating counts of vehicles by simply adding up the capacities of different types of parking facilities will tend to overestimate the number of transients and can lead to ETE that are too conservative.

Analysis of the population characteristics of the CRNP EPZ indicates the need to identify three distinct groups:

- Permanent residents - people who are year round residents of the EPZ.
- Transients - people who reside outside of the EPZ who enter the area for a specific purpose (lodging, recreation) and then leave the area.
- Employees - people who reside outside of the EPZ and commute to work within the EPZ on a daily basis.

For this study, employees and transients have different scenario percentages (see Table 6-3). For example, employees peak during the winter, weekday, midday scenarios while transients peak during winter weekends. For this reason, employees were treated separately than transients.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each Zone and by polar coordinate representation (population distribution). The CRNP EPZ is subdivided into 3 Zones. The EPZ is shown in Figure 3-1.

3.1 Permanent Residents

The primary source for estimating permanent population is the latest U.S. Census data. The average household size (2.08 persons/household – See Figure F-1) and the number of evacuating vehicles per household (1.34 vehicles/household – See Figure F-8) were adapted from the telephone survey results.

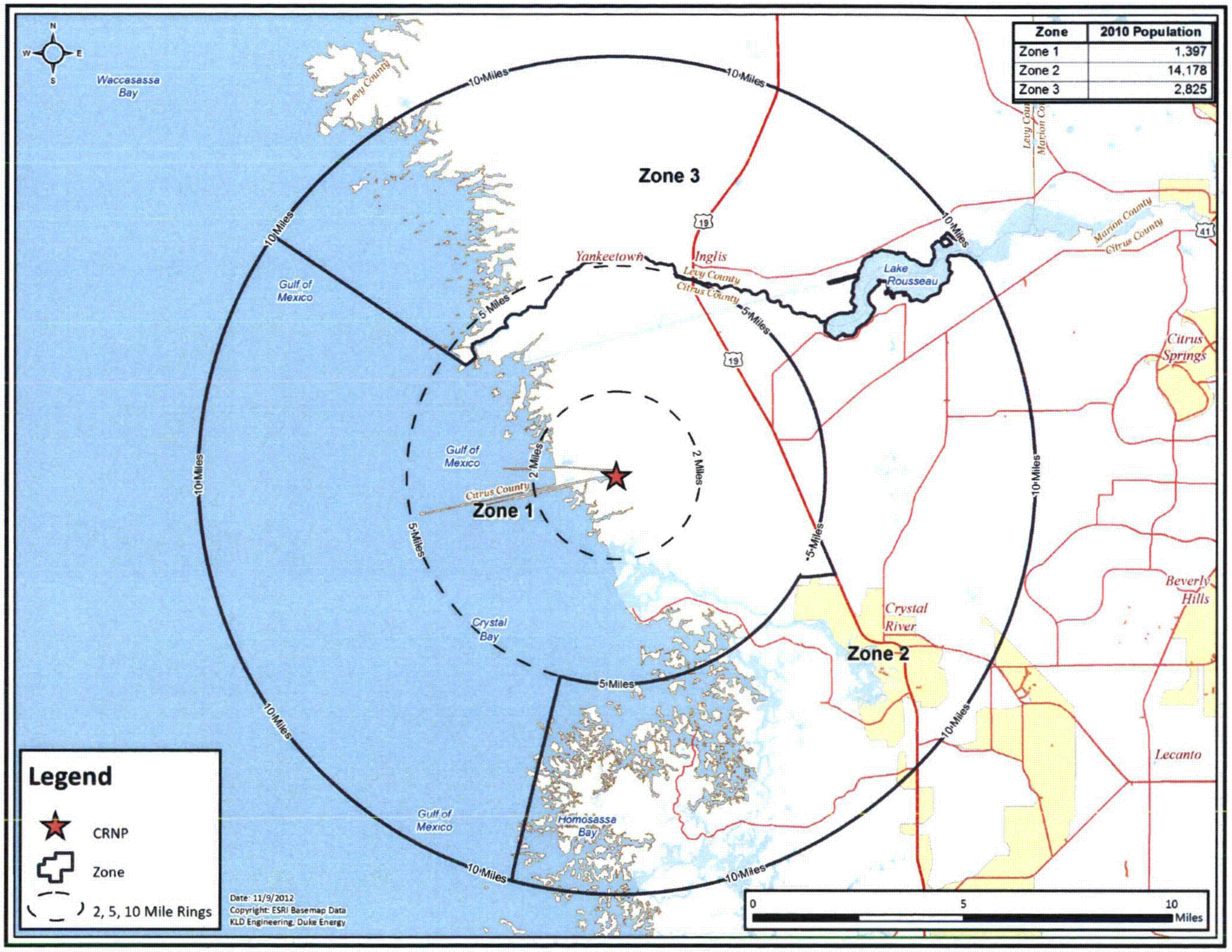
Population estimates are based upon Census 2010 data. The estimates are created by cutting the census block polygons by the Zone and EPZ boundaries. A ratio of the original area of each census block and the updated area (after cutting) is multiplied by the total block population to estimate the population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

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

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

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

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



Zone	2010 Population
Zone 1	1,397
Zone 2	14,178
Zone 3	2,825

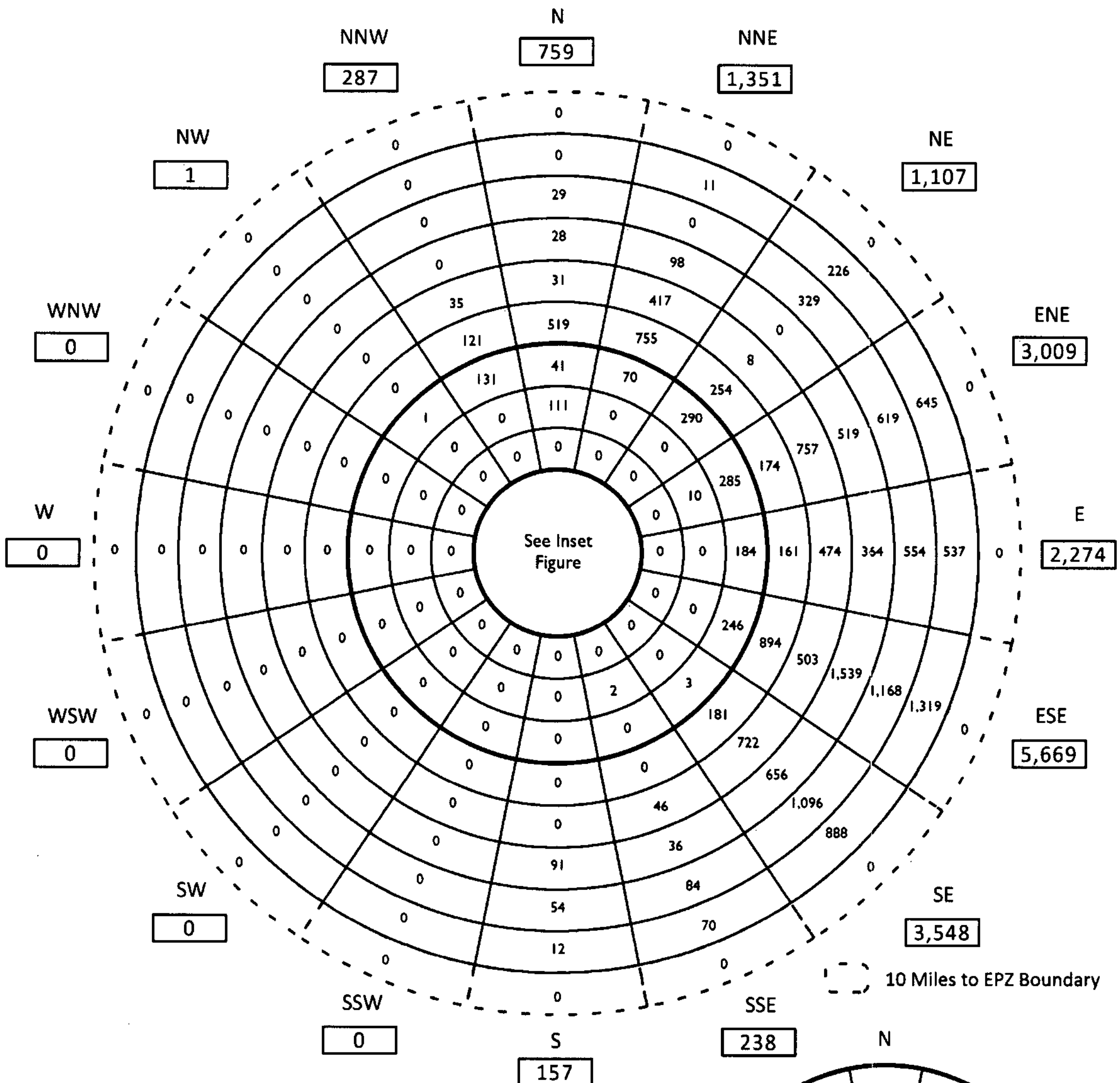
Figure 3-1. CRNP EPZ

Table 3-1. EPZ Permanent Resident Population

Zone	2000 Population	2010 Population
1	1,244	1,397
2	14,483	14,178
3	3,000	2,825
TOTAL	18,727	18,400
EPZ Population Growth:		-1.75%

Table 3-2. Permanent Resident Population and Vehicles by Zone

Zone	2010 Population	2010 Resident Vehicles
1	1,397	903
2	14,178	9,147
3	2,825	1,828
TOTAL	18,400	11,878



Resident Population

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	2	2
2 - 3	0	2
3 - 4	123	125
4 - 5	1,251	1,376
5 - 6	3,059	4,435
6 - 7	2,993	7,428
7 - 8	3,331	10,759
8 - 9	3,933	14,692
9 - 10	3,708	18,400
10 - EPZ	0	18,400
	Total:	18,400

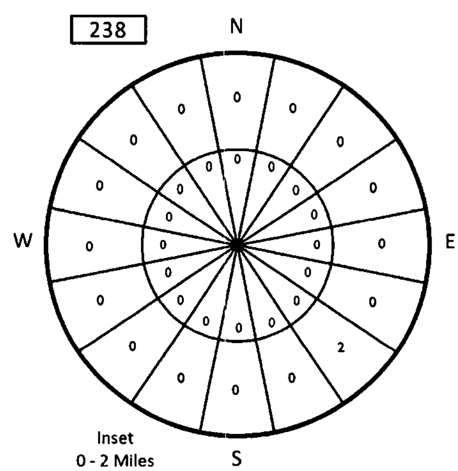
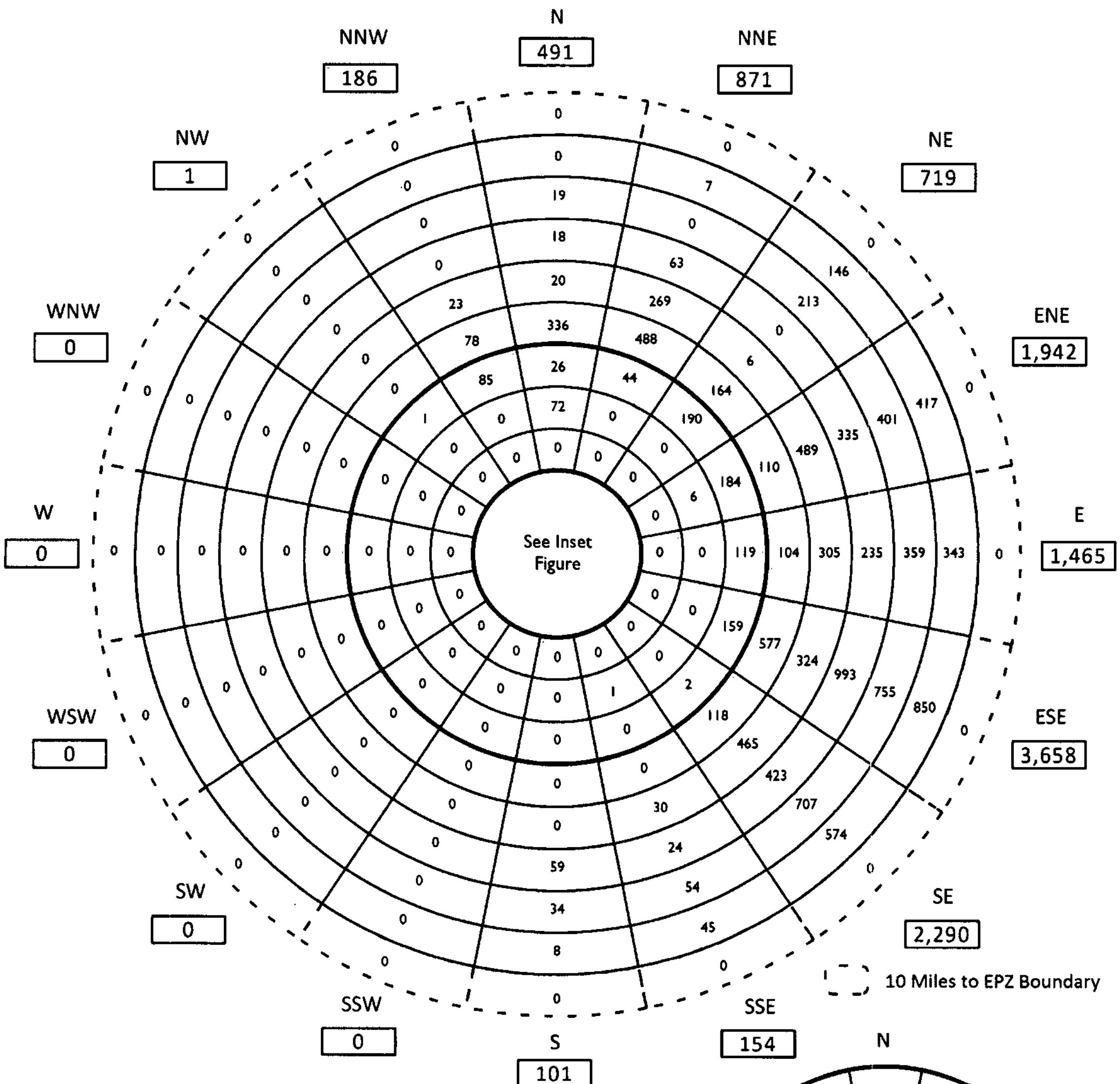


Figure 3-2. Permanent Resident Population by Sector



Resident Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	1	1
2 - 3	0	1
3 - 4	79	80
4 - 5	810	890
5 - 6	1,975	2,865
6 - 7	1,931	4,796
7 - 8	2,150	6,946
8 - 9	2,542	9,488
9 - 10	2,390	11,878
10 - EPZ	0	11,878
	Total:	11,878

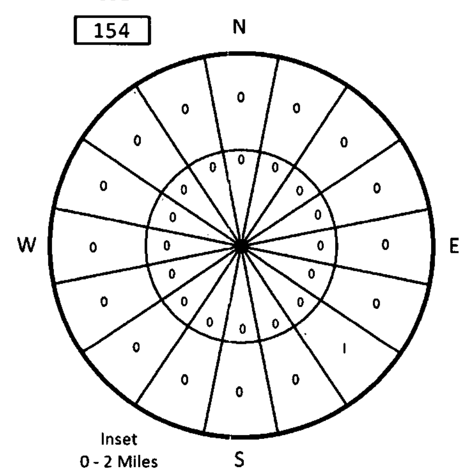


Figure 3-3. Permanent Resident Vehicles by Sector

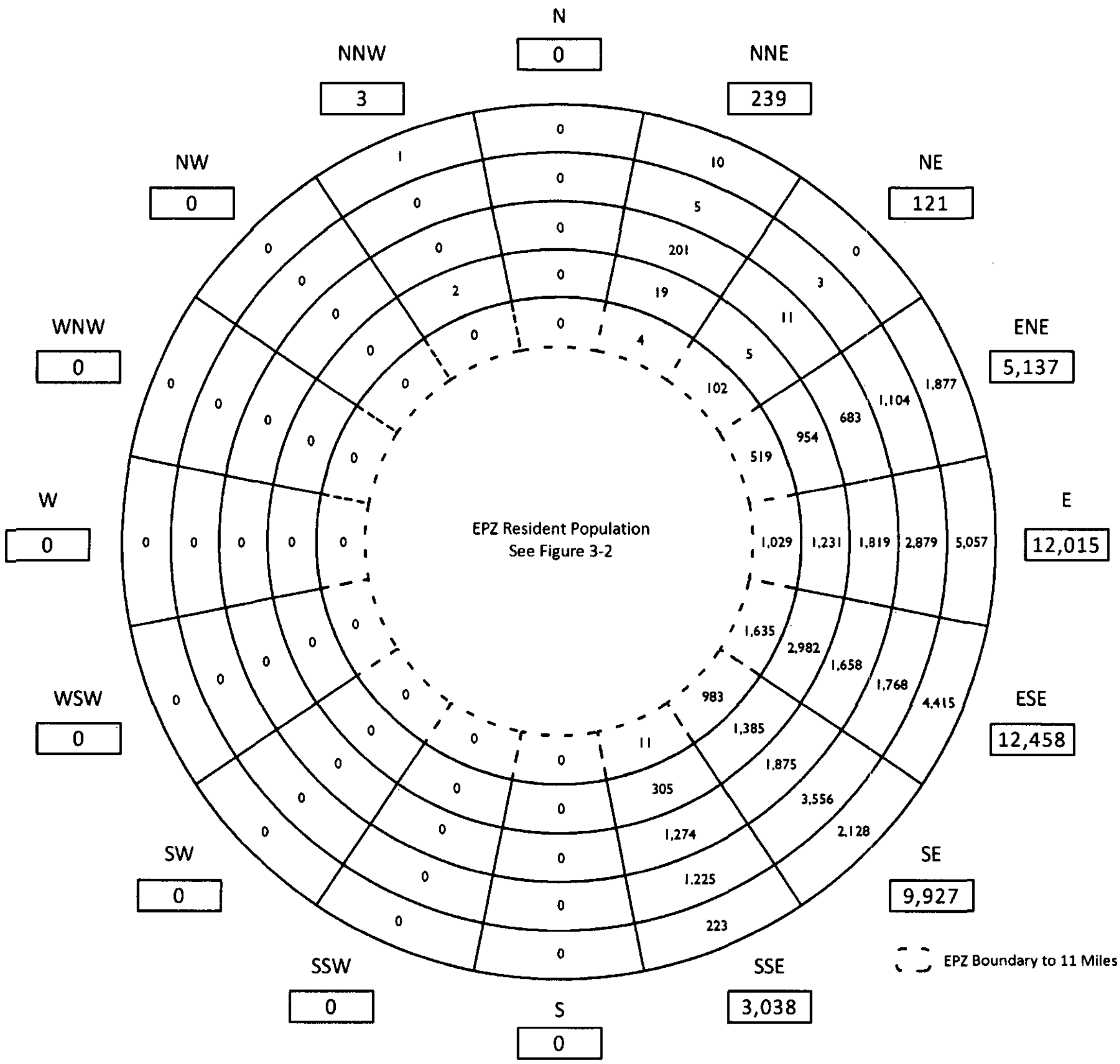
3.2 Shadow Population

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

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

Table 3-3. Shadow Population and Vehicles by Sector

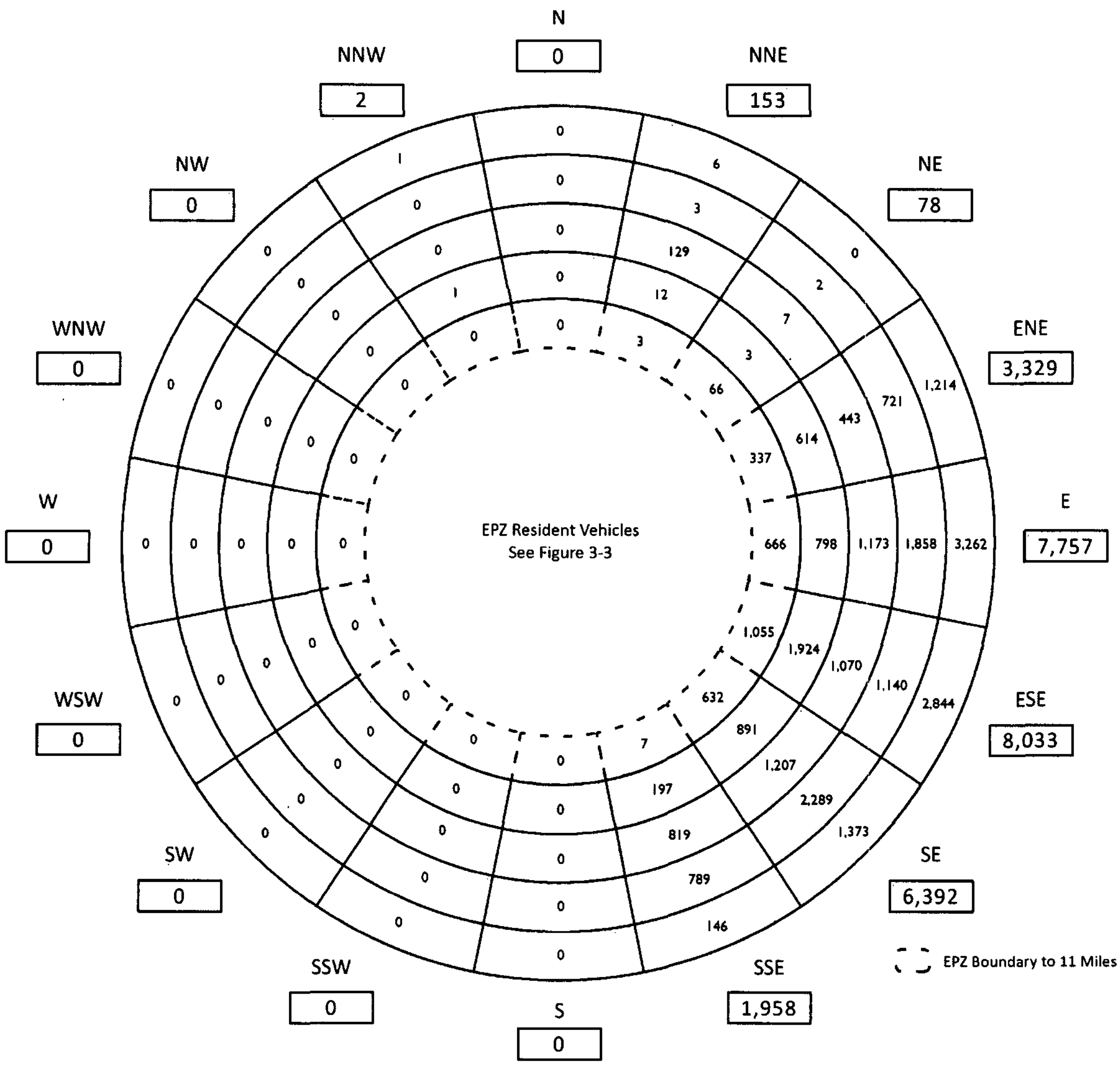
Sector	Population	Evacuating Vehicles
N	0	0
NNE	239	153
NE	121	78
ENE	5,137	3,329
E	12,015	7,757
ESE	12,458	8,033
SE	9,927	6,392
SSE	3,038	1,958
S	0	0
SSW	0	0
SW	0	0
WSW	0	0
W	0	0
WNW	0	0
NW	0	0
NNW	3	2
TOTAL	**42,938**	**27,702**



Shadow Population

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	4,283	4,283
11 - 12	6,883	11,166
12 - 13	7,521	18,687
13 - 14	10,540	29,227
14 - 15	13,711	42,938
	Total:	42,938

Figure 3-4. Shadow Population by Sector



Shadow Vehicles

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	2,766	2,766
11 - 12	4,440	7,206
12 - 13	4,848	12,054
13 - 14	6,802	18,856
14 - 15	8,846	27,702
	Total:	27,702

Figure 3-5. Shadow Vehicles by Sector

3.3 Transient Population

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

- Lodging Facilities
- Marinas
- Parks
- Campgrounds
- Beaches
- Golf Courses

Data were provided by Citrus and Levy Counties on lodging facilities within the EPZ and were used to determine the number of rooms, percentage of occupied rooms at peak times, and the number of people and vehicles per room for each facility. These data were used to estimate the number of transients and evacuating vehicles at each of these facilities. A total of 1,436 transients in 599 vehicles were assigned to lodging facilities in the EPZ.

Data were provided by Citrus and Levy Counties on the peak season and also the number of vehicles during that season of the marinas in the EPZ. These data were used to estimate the number of transients and evacuating vehicles at each of these facilities. A total of 72 transients and 35 vehicles were assigned to marinas in the EPZ.

Data were provided by Citrus and Levy Counties on parks within the EPZ and were used to determine the number of transients visiting each of those places on a day during their peak season. A total of 983 transients and 477 vehicles were assigned to parks within the EPZ.

Data provided by Citrus and Levy Counties on campgrounds within the EPZ was used to determine the number of campsites, peak occupancy, and the number of vehicles and people per campsite for each facility. These data were used to estimate the number of evacuating vehicles for transients at each of these facilities. A total of 2,330 transients and 1,233 vehicles were assigned to campgrounds in the EPZ.

There is one golf course within the EPZ. Data provided from Citrus County was used to determine the number of patrons and vehicles that visit the facility during a peak day and also what percentage makes up local residents. A total of 116 transients and 54 vehicles were assigned to golf courses within the EPZ.

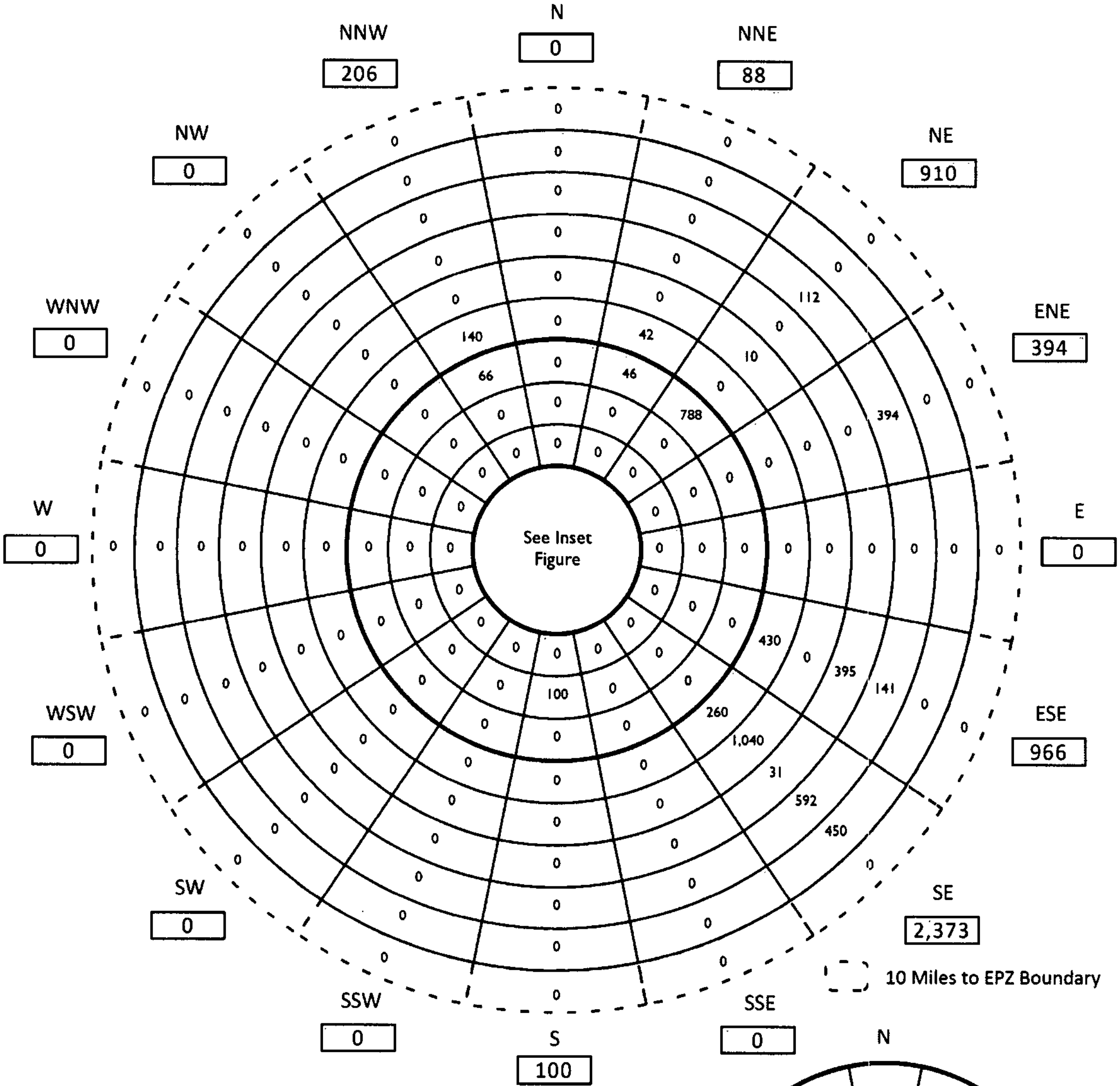
There is also only one beach within the EPZ. Data provided from Citrus County were used to determine the number of beach patrons on a typical day and also how many vehicles would be at the facility. A total of 100 transients and 50 vehicles were assigned to beaches within the EPZ.

Appendix E summarizes the transient data that were estimated for the EPZ. Table E-4 presents the number of transients visiting recreational areas, while Table E-5 presents the number of transients at lodging facilities within the EPZ.

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

Table 3-4. Summary of Transients and Transient Vehicles

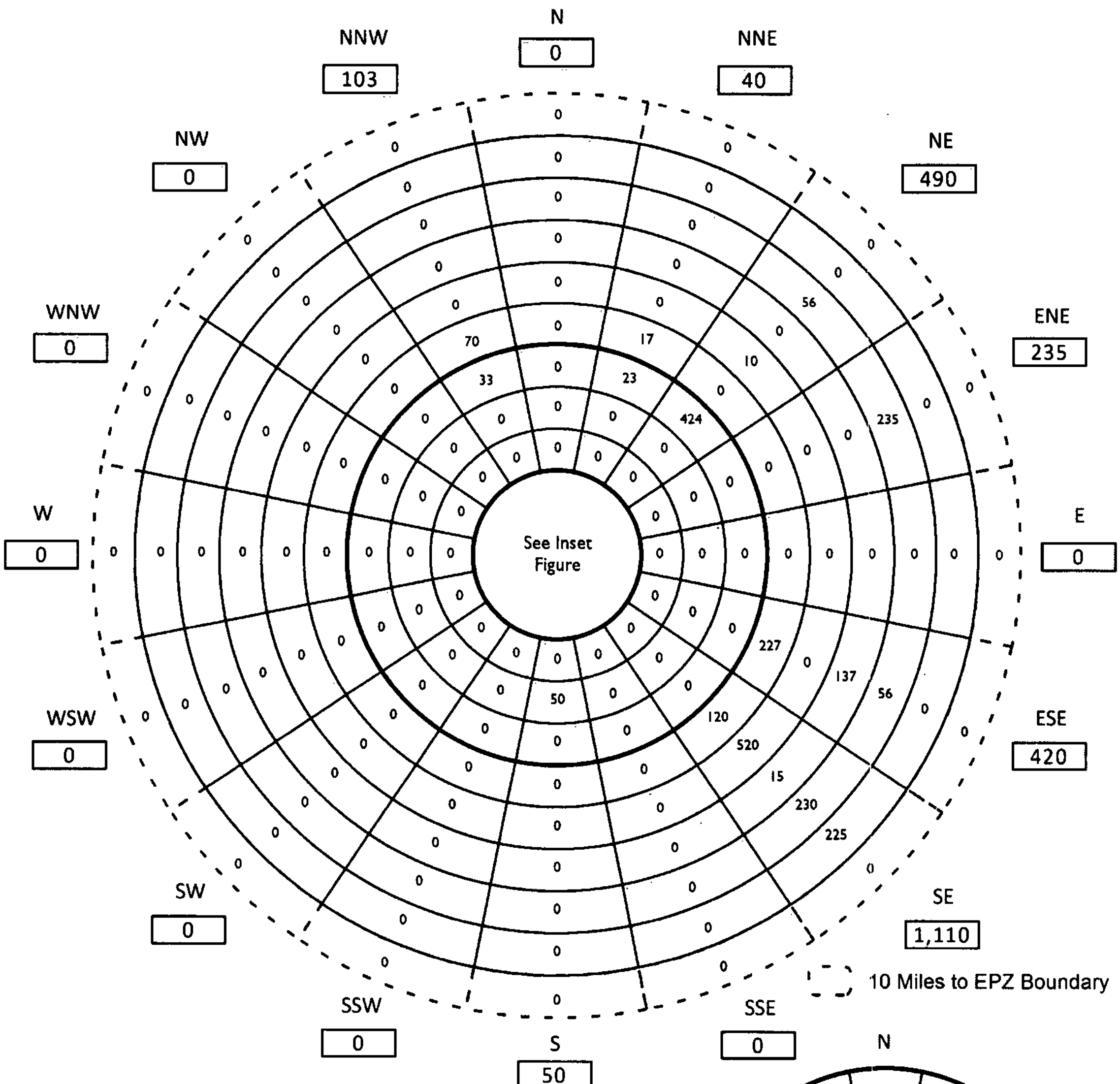
Zone	Transients	Transient Vehicles
1	1,156	580
2	3,521	1,692
3	360	176
TOTAL	**5,037**	**2,448**



Transients

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	0	0
2 - 3	0	0
3 - 4	100	100
4 - 5	900	1,000
5 - 6	872	1,872
6 - 7	1,050	2,922
7 - 8	426	3,348
8 - 9	1,239	4,587
9 - 10	450	5,037
10 - EPZ	0	5,037
	Total:	5,037

Figure 3-6. Transient Population by Sector



Transient Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	0	0
2 - 3	0	0
3 - 4	50	50
4 - 5	480	530
5 - 6	434	964
6 - 7	530	1,494
7 - 8	152	1,646
8 - 9	577	2,223
9 - 10	225	2,448
10 - EPZ	0	2,448
	Total:	2,448

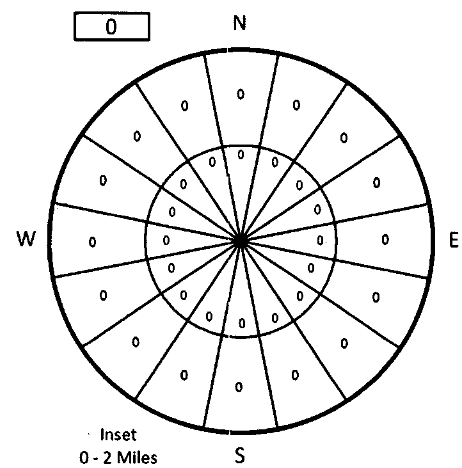


Figure 3-7. Transient Vehicles by Sector

3.4 Employees

Employees who work within the EPZ fall into two categories:

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

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

The number of employees at each facility was provided by Citrus and Levy counties. Data obtained from the US Census Longitudinal Employer-Household Dynamics from the OnTheMap Census analysis tool[1] were used to estimate the number of employees commuting into the EPZ. A vehicle occupancy of 1.02 employees per vehicle obtained from the telephone survey (See Figure F-7) was used to determine the number of evacuating employee vehicles for all major employers.

Table 3-5 presents non-EPZ Resident employee and vehicle estimates by Zone. Figure 3-8 and Figure 3-9 present these data by sector.

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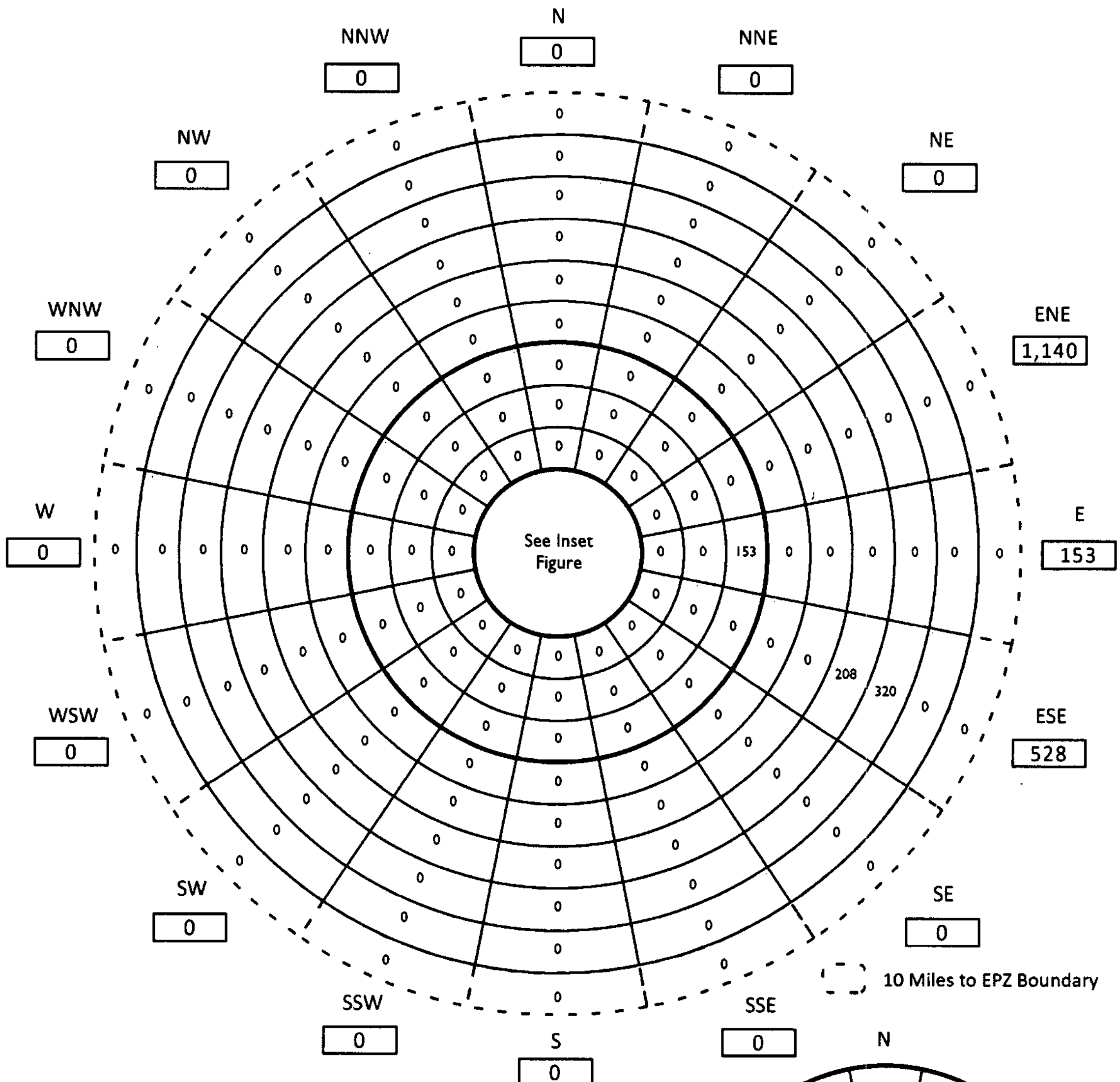
[1] http://onthemap.ces.census.gov/

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

Zone	Employees	Employee Vehicles
1	1,293	1,268
2	528	520
3	0	0
TOTAL	**1,821**	**1,788**



Employees

Miles	Subtotal by Ring	Cumulative Total
0 - 1	1,140	1,140
1 - 2	0	1,140
2 - 3	0	1,140
3 - 4	0	1,140
4 - 5	153	1,293
5 - 6	0	1,293
6 - 7	0	1,293
7 - 8	208	1,501
8 - 9	320	1,821
9 - 10	0	1,821
10 - EPZ	0	1,821
	Total:	1,821

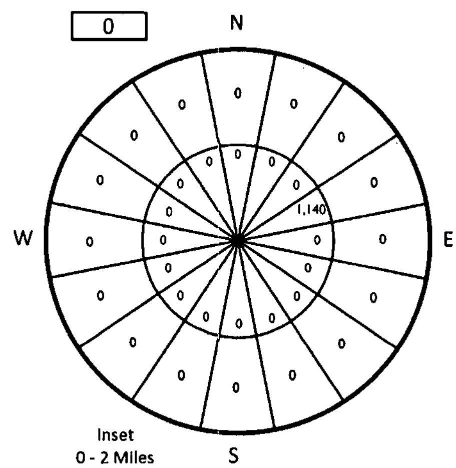
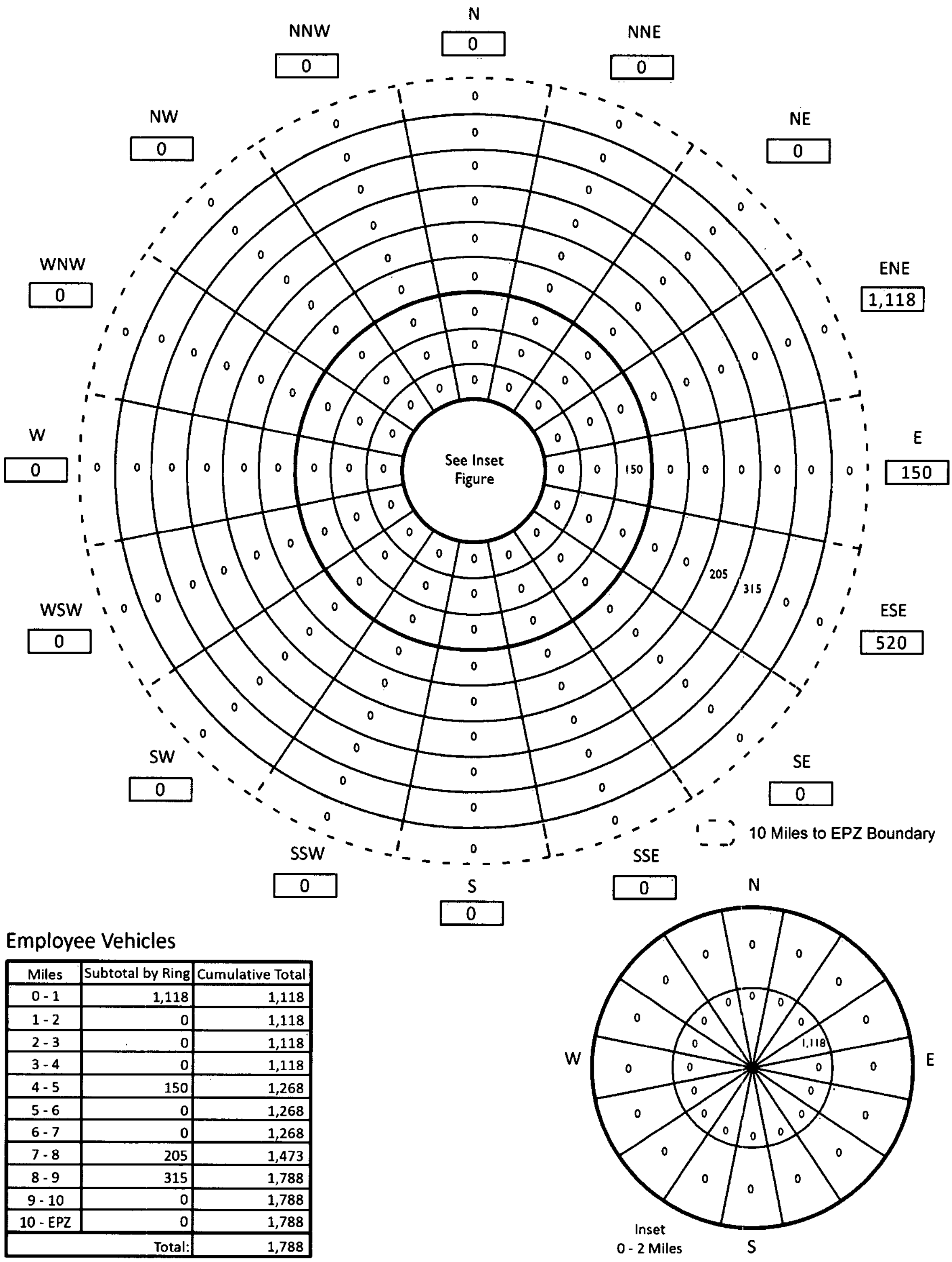


Figure 3-8. Employee Population by Sector



Employee Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	1,118	1,118
1 - 2	0	1,118
2 - 3	0	1,118
3 - 4	0	1,118
4 - 5	150	1,268
5 - 6	0	1,268
6 - 7	0	1,268
7 - 8	205	1,473
8 - 9	315	1,788
9 - 10	0	1,788
10 - EPZ	0	1,788
	Total:	1,788

Figure 3-9. Employee Vehicles by Sector

3.5 Medical Facilities

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

3.6 Total Demand in Addition to Permanent Population

Vehicles will be traveling through the EPZ (external-external trips) at the time of an emergency event. After the Advisory to Evacuate is announced, these through-travelers will also evacuate. These through vehicles are assumed to travel on the major routes traversing the EPZ – US 19/98. It is assumed that this traffic will continue to enter the EPZ during the first 120 minutes following the Advisory to Evacuate.

Average Annual Daily Traffic (AADT) data was obtained from Federal Highway Administration to estimate the number of vehicles per hour on the aforementioned routes. The AADT was multiplied by the K-Factor, which is the proportion of the AADT on a roadway segment or link during the design hour, resulting in the design hour volume (DHV). The design hour is usually the 30th highest hourly traffic volume of the year, measured in vehicles per hour (vph). The DHV is then multiplied by the D-Factor, which is the proportion of the DHV occurring in the peak direction of travel (also known as the directional split). The resulting values are the directional design hourly volumes (DDHV), and are presented in Table 3-6, for each of the routes considered. The DDHV is then multiplied by 2 hours (access control points – ACP – are assumed to be activated at 120 minutes after the advisory to evacuate) to estimate the total number of external vehicles loaded on the analysis network. As indicated, there are 2,196 vehicles entering the EPZ as external-external trips prior to the activation of the ACP and the diversion of this traffic. This number is reduced by 60% for evening scenarios (Scenarios 5 and 10) as discussed in Section 6.

3.7 Special Event

There were 6 potential special events that were considered for this study. The events and transient attendance are listed below:

- Rock Crusher Canyon Concert - 2,000 to 5,000
- Port Citrus - not open yet
- Stone Crab Jam – 3,500 to 5,000
- Construction of new plant – project is deferred to 2024
- Civil War Re-enactment – 2,000 to 5,000
- Scallop Jam – 2,500
- Manatee Fest – 12,000 to 15,000

After discussion with the counties, it was decided that Manatee Fest in downtown Crystal River should be used as the special event (Scenario 11) for this study. The event occurs during a weekend in January. According to Citrus County, between 12,000 and 15,000 people attend Manatee fest throughout the course of 2-3 days; in order to get the total number of people which attend the festival per day, 15,000 was divided by 2.5, therefore, 6,000 people were considered to be at the festival each day for this study. Of those 6,000 people, about 60% of them travel from outside the EPZ. Therefore, 3,600 attendees were considered to be transients. It was assumed that attendees travel to the event as a household unit in a single vehicle; therefore, the average household size of 2.08 was used for vehicle occupancy, resulting in a total of 1,731 additional vehicles, which were incorporated at various parking locations along the streets of downtown Crystal River. The special event vehicle trips were generated utilizing the same mobilization distributions as transients.

Public transportation is not provided for this event and was not considered in the special event analysis.

Table 3-6. CRNP EPZ External Traffic

Upstream Node	Downstream Node	Road Name	Direction	HPMS[1] AADT	K-Factor[2]	D-Factor[2]	Hourly Volume	External Traffic
8034	34	US-19	SB	9,300	0.118	0.5	549	1,098
8304	304	US-19	NB	9,300	0.118	0.5	549	1,098
							TOTAL:	**2,196**

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

3.8 Summary of Demand

A summary of population and vehicle demand for the study area is provided in Table 3-7 and Table 3-8, respectively. This summary includes all population groups described in this section and Section 8. Additional population groups – transit-dependent, special facility and school population – are described in greater detail in Section 8. A total of 37,997 people and 24,074 vehicles are considered in this study.

Table 3-7. Summary of Population Demand

Zone	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Schools	Shadow Population	External Traffic	Total
1	1,397	31	1,156	1,293	170	102	0	0	4,149
2	14,178	311	3,521	528	268	2982	0	0	21,788
3	2,825	62	360	0	0	225	0	0	3,472
Shadow	0	0	0	0	0	0	8,588	0	8,588
Total	**18,400**	**404**	**5,037**	**1,821**	**438**	**3,309**	**8,588**	**0**	**37,997**

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

Table 3-8. Summary of Vehicle Demand

Zone	Residents	Transit-Dependent	Transients	Employees	Special Facilities	Schools	Shadow Population	External Traffic	Total
1	903	2	580	1,268	24	6	0	0	2,783
2	9,147	22	1,692	520	41	115	0	0	11,537
3	1,828	4	176	0	0	10	0	0	2,018
Shadow	0	0	0	0	0	0	5,540	2,196	7,736
Total	**11,878**	**28**	**2,448**	**1,788**	**65**	**131**	**5,540**	**2,196**	**24,074**

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

4 ESTIMATION OF HIGHWAY CAPACITY

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

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

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

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

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

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

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

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

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

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

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", 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; 2 seconds of yellow time are indicated for each signal phase and 1 second of all-red time is assigned between signal phases, typically. If a signal is pre-timed, the yellow and all-red times observed during the road survey are used. A lost time (L) of 2.0 seconds is used for each signal phase in the analysis.

4.2 Capacity Estimation along Sections of Highway

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

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

The value of V_F can be expressed as:

$$V_F = R \times Capacity$$

where:

R = Reduction factor which is less than unity

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

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

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

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

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

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

4.3 Application to the CRNP 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 one category of road and, of course, intersection:

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

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 Intersections

Ref: HCM Chapters 18, 19, 20, 21

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

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

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

4.4 Simulation and Capacity Estimation

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

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

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

All simulation models must be calibrated properly with field observations that quantify the performance parameters applicable to the analysis network. Two of the most important of these are: (1) Free flow speed (FFS); and (2) saturation headway, h_{sat}. The first of these is estimated by direct observation during the road survey; the second is estimated using the concepts of the HCM 2010, as described earlier. These parameters are listed in Appendix K, for each network link.

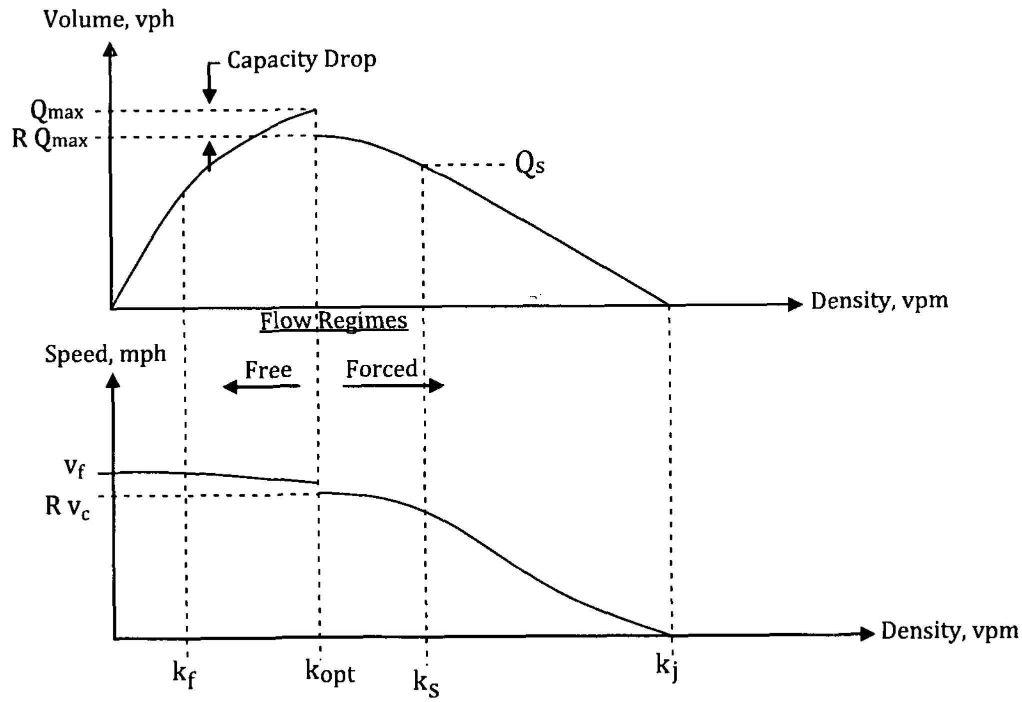

Figure 4-1. Fundamental Diagrams