Palo Verde
Nuclear Generating Station
5871 S. Wintersburg Road
Tonopah, AZ 85354

102-08421-JF/SMB
April 1, 2022

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: **Palo Verde Nuclear Generation Station (PVNGS)**
Units 1, 2, and 3 and Independent Spent Fuel Storage Installation (ISFSI)
Docket Nos. 50-528, 50-529, 50-530 and 72-44
License Nos. NPF-41, NPF-51 and NPF-74
PVNGS Evacuation Time Estimate Study

Pursuant to Part 50, Appendix E of Title 10 of the Code of Federal Regulations (10 CFR) Arizona Public Service Company (APS) hereby submits the Evacuation Time Estimate (ETE) study report for the Palo Verde Nuclear Generating Station (PVNGS) and ISFSI.

The ETE study was completed as required by Section IV of Appendix E to 10 CFR Part 50. The guidance of NUREG CR-7002, *Criteria for Development of Evacuation Time Estimate Studies*, was used in developing the report. Appendix N of the APS ETE report provides a checklist corresponding to the evaluation criteria in Appendix B of NUREG CR-7002. Each of the NUREG CR-7002, Appendix B, criteria is addressed and cross-references provided to the sections of the report for each applicable criterion.

In accordance with 10 CFR 50.4(b), copies of this report are being forwarded to the NRC Region IV Administrator and the resident inspector. No commitments are being made to the NRC by this letter.

Should you have any questions or if additional information is needed regarding this Submittal, please contact Mr. Shaun M. Bernat, Emergency Preparedness Manager, at 623-393-2588.

Sincerely,

Bernat, Shaun M(Z06433) Digitally signed by Bernat, Shaun M(Z06433) Date: 2022.04.01 13:52:45 -07'00'

Shaun M. Bernat
Manager, Emergency Preparedness

Enclosure: Palo Verde Nuclear Generation Station Evacuation Time Estimate Study

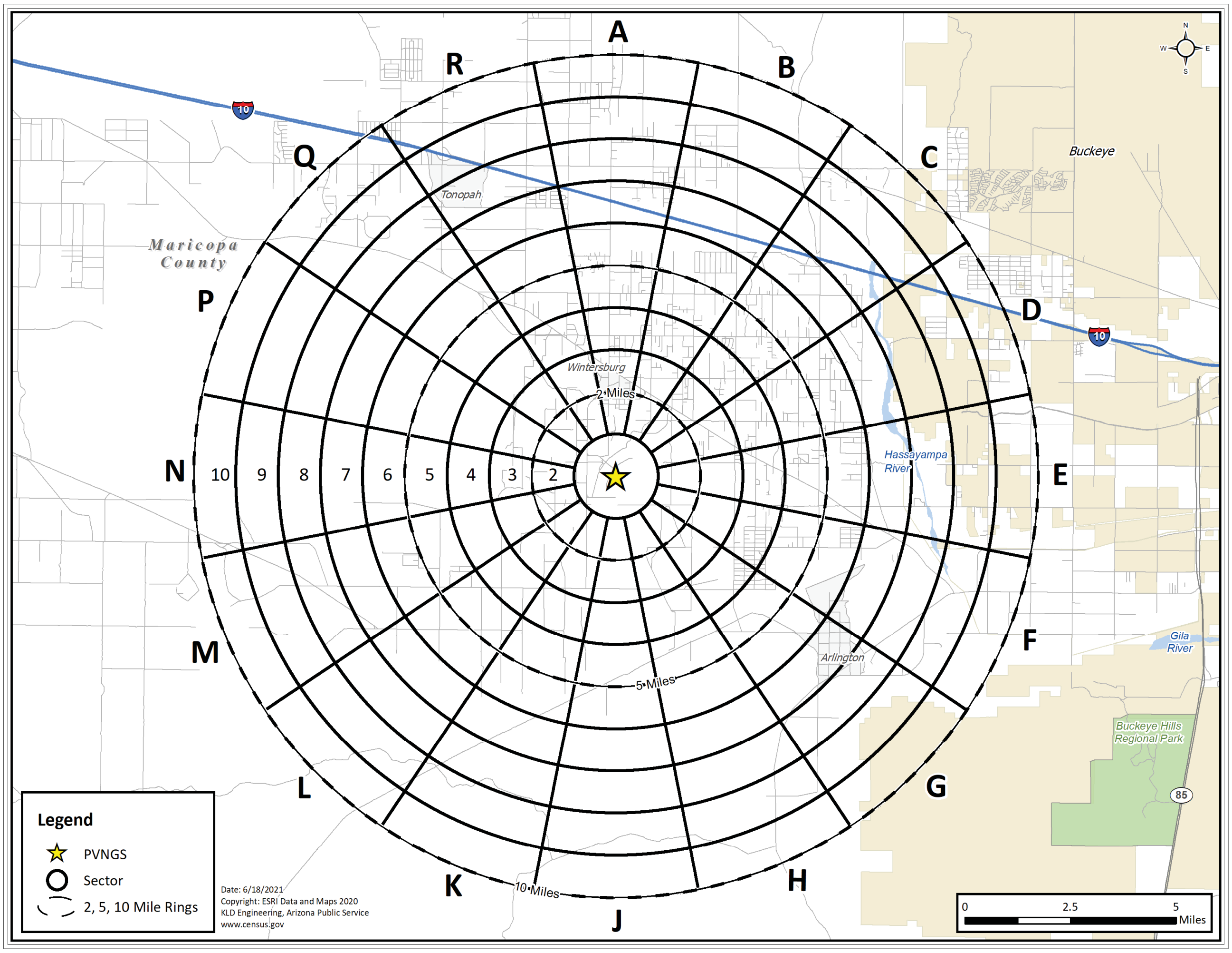
S. A. Morris	NRC Region IV Regional Administrator
S. P. Lingam	NRC NRR Project Manager for PVNGS
L. N. Merker	NRC Senior Resident Inspector for PVNGS

Enclosure

Palo Verde Nuclear Generation Station Evacuation Time Estimate Study

Palo Verde Nuclear Generating Station

Development of Evacuation Time Estimates



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February 24, 2022 **Final Report, Rev. 0** **KLD TR – 1226**

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Note: Appendix I intentionally skipped

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ACRONYM LIST

Table 1. Acronym List

ACRONYM	DEFINITION
AADT	Average Annual Daily Traffic
ACP	Access Control Point
ADEMA	Arizona Department of Emergency & Military Affairs
ANS	Alert and Notification System
APS	Arizona Public Service
ASLB	Atomic Safety and Licensing Board
ATE	Advisory to Evacuate
ATIS	Automated Traveler Information Systems
AZDOT	Arizona Department of Transportation
BFFS	Base Free Flow Speed
CR	County Road
COVID-19	Coronavirus Disease 2019
D	Destination
DDHV	Directional Design Hourly Volume
DHV	Design Hour Volume
DMS	Dynamic Message Sign
DTA	Dynamic Traffic Assignment
DTRAD	Dynamic Traffic Assignment and Distribution
DYNEV	Dynamic Network Evacuation
EAS	Emergency Alert System
EOC	Emergency Operations Center
EPZ	Emergency Planning Zone
EPFAQ	Emergency Planning Frequently Asked Question
ETE	Evacuation Time Estimate
EVAN	Evacuation Animator
EMA	Emergency Management Agency
FEMA	Federal Emergency Management Agency
FFS	Free Flow Speed
FHWA	Federal Highway Administration
GIS	Geographic Information System
HAR	Highway Advisory Radio
HCM	Highway Capacity Manual
HH	Household
HPMS	Highway Performance Monitoring System
I-	Interstate
ITS	Intelligent Transportation Systems

ACRONYM	DEFINITION
LOS	Level of Service
MCDEM	Maricopa County Department Emergency
MOE	Measures of Effectiveness
mi	miles
min	minutes
mph	Miles Per Hour
MUTCD	Manual of Uniform Traffic Control Devices
MTC	Manual Traffic Control
NB	Northbound
NOAA	The National Oceanic and Atmospheric Administration
NRC	United States Nuclear Regulatory Commission
O	Origin
O-D	Origin-Destination
ORO	Offsite Response Organization
PAR	Protective Action Recommendation
pce	Passenger Car Equivalent
pcphpl	passenger car per hour per lane
PSL	Path-Size-Logit
PVNGS	Palo Verde Nuclear Generating Station
QDF	Queue Discharge Flow
RCC	Reception and Care Center
RS	Relocation School
SH	State Highway
SR	State Route
SV	Service Volume
TA	Traffic Assignment
TCP	Traffic Control Point
TD	Trip Distribution
TI	Time Interval
TMP	Traffic Management Plan
UNITES	Unified Transportation Engineering System
USDOT	United States Department of Transportation
vph	Vehicles Per Hour
vpm	Vehicles Per Minute

EXECUTIVE SUMMARY

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Palo Verde Nuclear Generating Station (PVNGS) located in Maricopa County, Arizona. ETE are part of the required planning basis and provide Arizona Public Service Company (APS) 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:

- Title 10, Code of Federal Regulations, Appendix E to Part 50 (10CFR50), Emergency Planning and Preparedness for Production and Utilization Facilities, NRC, 2011.
- Emergency Planning and Preparedness for Production and Utilization Facilities, 10CFR50, Appendix E.
- Revision 1 of the Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, February 2021.
- FEMA "Radiological Emergency Preparedness Program Manual" (FEMA P-1028), December 2019
- Development of Evacuation Time Estimates for Nuclear Power Plants, NUREG/CR-6863, January 2005.

<u>Project Activities</u>

This project began in October 2020 and extended over a period of 15 months. The major activities performed are briefly described in chronological sequence:

- Conducted a virtual "kick-off" meeting with APS personnel and emergency management personnel representing state and county governments.
- Accessed the U.S. Census Bureau data files for the year 2020 projected to 2021 as well as the 2021 population data collected by Maricopa County.
- Obtained the estimates of employees who reside outside the EPZ and commute to work within the EPZ from APS.
- Studied Geographic Information Systems (GIS) maps of the area in the vicinity of the PVNGS, then conducted a detailed field survey of the highway network to observe any roadway changes relative to the previous ETE study done in 2011.
- Updated the 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 15 miles radially from the plant.

- Conducted a random sample online demographic 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.
- A data needs matrix was provided to APS and the offsite agencies at the kick-off meeting. Available data was provided for major employers, transients, and schools in Maricopa County by APS and Maricopa County Department of Emergency Management (MCDEM).
- 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 demographic survey of the EPZ residents.
- Following federal guidelines, the existing 145 Sectors within the EPZ were grouped within circular areas or "keyhole" configurations (circles plus radial sectors) that define a total of 52 Evacuation Regions (numbered R01 through R52).
- 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 an Outage at the Plant was considered. One roadway impact scenario was considered wherein a single lane was closed on Interstate (I)-10 eastbound (from S Wintersburg Rd (Exit 98) to the interchange with State Highway 85 (Exit 112)) for the duration of the evacuation.
- Staged evacuation was considered for those Regions wherein the 2-Mile Region and Sectors downwind to 5 miles are evacuated.
- As per NUREG/CR-7002, Rev 1, the Planning Basis for the calculation of ETE is:
    - A rapidly escalating accident at the plant that quickly assumes the status of a general emergency wherein evacuation is ordered promptly and no early protective actions have been implemented such that the Advisory to Evacuate (ATE) is virtually coincident with the siren alert.
    - While an unlikely accident scenario, this planning basis will yield ETE, measured as the elapsed time from the ATE 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 the reception and care centers located outside the EPZ. Parents, relatives, and neighbors are advised to not pick up their children at school prior to the arrival of the buses dispatched for that purpose. The ETE for 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 plan. Separate ETE are calculated for the transit-dependent evacuees, and for access and/or functional needs population.

Computation of ETE

A total of 624 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 52 Evacuation Regions to evacuate from that Region, under the circumstances defined for one of the 12 Evacuation Scenarios (52 x 12 = 624). Separate ETE are calculated for transit-dependent evacuees, including schoolchildren for applicable scenarios.

Except for Region R03, which is the evacuation of the entire EPZ, only a portion of the people within the EPZ would be advised to evacuate. That is, the ATE 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 the ATE. The people occupying the remainder of the EPZ outside the impacted region may be advised to take shelter.

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

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

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), and 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% and 100%, 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, Rev. 1.

Traffic Management

This study reviewed and analyzed the comprehensive existing traffic management plan provided by Maricopa County. Due to the location of traffic congestion within the EPZ, the implementation of Roadblocks did not impact the 90th or 100th percentile ETE. Thus, this study did not model the Roadblocks within the EPZ, except for those located on I-10 as they serve to discourage the external-external traffic from entering I-10. Refer to Section 9 and Appendix G.

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.

- Table 3-1 presents the estimates of permanent resident population in each Sector based on 2021 population data provided by MCDEM.
- Table 6-1 defines each of the 52 Evacuation Regions in terms of their respective groups of Sectors.
- Table 6-2 defines the Evacuation Scenarios.
- Tables 7-1 and 7-2 are compilations of ETE. These data are the times needed to clear the indicated regions of 90 and 100 percent of the population occupying these regions, respectively. These computed ETE include consideration of mobilization time and of estimated voluntary evacuations from other regions within the EPZ and from the Shadow Region.
- Tables 7-3 and 7-4 present ETE for the 2-Mile Region, when evacuating additional Sectors downwind to 5 miles for un-staged and staged evacuations for the 90th and 100th percentiles, respectively.
- Table 8-2 presents ETE for the schoolchildren in good weather.
- Table 8-4 presents ETE for the transit-dependent population in good weather.
- Figure 6-1 displays a map of the PVNGS EPZ showing the layout of the 145 Sectors that comprise, in aggregate, the EPZ.
- Figure H-8 presents an example of an Evacuation Region (Region R08) to be evacuated under the circumstances defined in Table 6-1. Maps of all Regions are provided in Appendix H.

Conclusions

- General population ETE were computed for 624 unique cases – a combination of 52 unique Evacuation Regions and 12 unique Evacuation Scenarios. Table 7-1 and Table 7-2 document these ETE for the 90th and 100th percentiles. The 90th percentile ETE range from 2:05 (hr:min) to 3:10. The 100th percentile ETE range from 5:45 to 5:55.
- The comparison of Table 7-1 and Table 7-2 indicates that the ETE for the 100th percentile are significantly longer than those for the 90th percentile. This is the result of the congestion within PVNGS and those accessing I-10 within the EPZ. When the system becomes congested traffic exist the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more route clear, and the last of the permanent residents 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. Congestion clears, however, before the completion of the trip generation time. As a result, the 100th percentile ETE is dictated by the time needed to mobilize. See Sections 7.3 through 7.5 and See Figures 7-3 through 7-19.
- Traffic congestion exists within PVNGS and those trying to access I-10 on S 399th Avenue and S Salome Highway (east of the plant). All congestion within the EPZ clears by 2 hour and 55 minutes after the ATE. See Section 7.3 and Figures 7-3 through 7-7.
- Inspection of Table 7-3 and Table 7-4 indicates that a staged evacuation provides no benefits to evacuees from within the 2-Mile Region (compare Regions R02, R04 through R19 with Regions R36 through R52, respectively, in Tables 7-1 and 7-2). See Section 7.6 for additional discussion.
- The comparison of Scenarios 6 (winter, midweek, midday) and 11 (winter, midweek, midday) in Table 7-1 and Table 7-2 indicates that the special event (outage at PVNGS) has a significant impact on the 90th percentile ETE for the 2-Mile Region (Region R01) and keyhole regions with wind from the north, west and southwest. The additional employee vehicles increase the 90th percentile ETE by up to 40 minutes and has no impact to the 100th percentile ETE. See Section 7.5 for additional discussion.
- Comparison of Scenarios 1 and 12 in Table 7-1 indicates that the roadway closure – one lane eastbound on I-10 from the interchange with S Wintersburg Rd (Exit 98) to the interchange with State Highway 85 (Exit 112) has no impact on the 90th percentile ETE for all Regions except for Region R03. During an evacuation of the full EPZ, the 90th percentile ETE increases by 25 minutes. There is no impact to the 100th percentile ETE, as the trip generation (plus the travel time to the EPZ boundary) dictates the ETE. See Section 7.5 for additional discussion.
- Separate ETE were computed for schools, transit-dependent persons and access and/or functional needs persons. The average single-wave ETE for schools is 2 hours and 5 minutes less than the general population 90th percentile ETE; the average single—wave ETE for the transit-dependent and access and/or functional needs people are longer than the general population ETE at the 90th percentile by 50 minutes and 2 hours and 30 minutes, respectively. See Section 8.

- Table 8-1 indicates that there are not enough buses and paratransit vehicles available to evacuate the transit-dependent and access and/or functional needs population within the EPZ in a single wave. A second-wave is necessary for schools, transit-dependent and access and/or functional needs population. See Section 8.
- A reduction in the base trip generation time of 4 hours and 45 minute reduces the general population ETE at the 90th percentile by 30 minutes. An increase in mobilization time by 1 hour increase the 90th percentile ETE by 1 hour. The general population 100th percentile ETE reduces by 1 hour and increases by 1 hour when the trip mobilization is reduced and increased, respectively. See Appendix M and Table M-1.
- The general population ETE is insensitive to the voluntary evacuation of vehicles in the Shadow Region (Eliminating the shadow evacuation (0%) has no impact to the 90th and 100th percentile ETEs. Tripling the shadow evacuation percentage (60%) increase the 90th percentile ETE by 5 minutes and has no impact to the 100th percentile ETE). See Appendix M and Table M-2.
- An increase in permanent resident population (EPZ plus Shadow Region) of 143% or greater results in an increase in the longest 90th percentile ETE of 30 minutes, for the full EPZ (Region R03), which meets the federal criterion for performing a fully updated ETE study between decennial Censuses. See Appendix M and Table M-3.

Table 3-1. EPZ Permanent Resident Population

Sector	2011 Population[1]	2021 Population[2]
1-Mile Ring	41	24
A[3]	1,714	1,951
B	1,566	1,398
C	1,493	1,324
D	2,939	1,490
E	1,120	893
F	923	585
G	475	420
H	157	68
J	30	0
K	7	6
L	60	35
M	94	99
N	21	4
P	0	0
Q	590	384
R	1,244	1,031
EPZ TOTAL	**12,474**	**9,712**
EPZ Population Growth (2011 – 2021):		**-22.14%**

[1] Maricopa County Palo Verde Population Survey – Residents, December 2011
[2] Maricopa County Palo Verde Population Survey – Residents, September 2021
[3] Stage Stop RV Park is located in Sector A. The population at this facility is assumed to be included with the permanent resident population due to the large population reported within Sector A between 2 and 3 miles of the plant and presence of electrical hook-ups at the facility.

Table 6-1. Description of Evacuation Regions

Radial Regions																																			
				Sector																															
Region	Description	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R01	2-Mile Region	X	X																																		
R02	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles																																			
				Sector																															
Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R04	S	X	X	X		X																														X	
R05	SSW	X	X	X		X		X																													
R06	SW	X	X			X		X		X																											
R07	WSW	X	X					X		X		X																									
R08	W	X	X							X		X		X																							
R09	WNW	X	X									X		X		X																					
R10	NW	X	X											X		X		X																			
R11	NNW	X	X													X		X		X																	
R12	N	X	X															X		X		X															
R13	NNE	X	X																	X		X		X													
R14	NE	X	X																			X		X		X											
R15	ENE	X	X																					X		X		X									
R16	E	X	X																					X		X		X		X		X					
R17	ESE	X	X																							X		X		X		X		X			
R18	SE	X	X	X																								X		X		X		X			
R19	SSE	X	X	X																												X		X			

Sector(s) Evacuate | Sector(s) Shelter-in-Place

Evacuate 2-Mile Region and Downwind to EPZ Boundary

Region	Wind Direction From:	PVNGS	2-Mile Radius	A 2-5	A 5-10	B 2-5	B 5-10	C 2-5	C 5-10	D 2-5	D 5-10	E 2-5	E 5-10	F 2-5	F 5-10	G 2-5	G 5-10	H 2-5	H 5-10
R20	S	X	X	X	X	X	X												
R21	SSW	X	X	X	X	X	X	X	X										
R22	SW	X	X			X	X	X	X	X	X								
R23	WSW	X	X					X	X	X	X	X	X						
R24	W	X	X							X	X	X	X	X	X				
R25	WNW	X	X									X	X	X	X	X	X		
R26	NW	X	X											X	X	X	X	X	X
R27	NNW	X	X													X	X	X	X
R28	N	X	X															X	X
R29	NNE	X	X																
R30	NE	X	X																
R31	ENE	X	X																
R32	E	X	X																
R33	ESE	X	X																
R34	SE	X	X	X	X														
R35	SSE	X	X	X	X														

Region	Wind Direction From:	J 2-5	J 5-10	K 2-5	K 5-10	L 2-5	L 5-10	M 2-5	M 5-10	N 2-5	N 5-10	P 2-5	P 5-10	Q 2-5	Q 5-10	R 2-5	R 5-10
R20	S															X	X
R21	SSW																
R22	SW																
R23	WSW																
R24	W																
R25	WNW																
R26	NW																
R27	NNW	X	X														
R28	N	X	X	X	X												
R29	NNE	X	X	X	X	X	X										
R30	NE			X	X	X	X	X	X								
R31	ENE					X	X	X	X	X	X						
R32	E					X	X	X	X	X	X	X	X	X	X		
R33	ESE							X	X	X	X	X	X	X	X	X	X
R34	SE									X	X	X	X	X	X	X	X
R35	SSE													X	X	X	X

Staged Evacuation - 2-Mile Region Evacuates, then Evacuate Downwind to 5 Miles

Region	Wind Direction From:	PVNGS	2-Mile Radius	A 2-5	A 5-10	B 2-5	B 5-10	C 2-5	C 5-10	D 2-5	D 5-10	E 2-5	E 5-10	F 2-5	F 5-10	G 2-5	G 5-10	H 2-5	H 5-10
R36	5-Mile Region	X	X	X		X		X		X		X		X		X		X	
R37	S	X	X	X		X													
R38	SSW	X	X	X		X		X											
R39	SW	X	X			X		X		X									
R40	WSW	X	X					X		X		X							
R41	W	X	X							X		X		X					
R42	WNW	X	X									X		X		X			
R43	NW	X	X											X		X		X	
R44	NNW	X	X													X		X	
R45	N	X	X															X	
R46	NNE	X	X																
R47	NE	X	X																
R48	ENE	X	X																
R49	E	X	X																
R50	ESE	X	X																
R51	SE	X	X	X															
R52	SSE	X	X	X															

Region	Wind Direction From:	J 2-5	J 5-10	K 2-5	K 5-10	L 2-5	L 5-10	M 2-5	M 5-10	N 2-5	N 5-10	P 2-5	P 5-10	Q 2-5	Q 5-10	R 2-5	R 5-10
R36	5-Mile Region	X		X		X		X		X		X		X		X	
R37	S															X	
R38	SSW																
R39	SW																
R40	WSW																
R41	W																
R42	WNW																
R43	NW																
R44	NNW	X															
R45	N	X		X													
R46	NNE	X		X		X											
R47	NE			X		X		X									
R48	ENE					X		X		X							
R49	E					X		X		X		X		X			
R50	ESE							X		X		X		X		X	
R51	SE									X		X		X		X	
R52	SSE													X		X	

Sector(s) Evacuate (red) | Sector(s) Shelter-in-Place (white) | Sector(s) Shelter-in-Place until 90% ETE for R01, then Evacuate (blue)

Table 6-2. Evacuation Scenario Definitions

Scenarios	Season[4]	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	Midweek	Midday	Good	Special Event: Outage at PVNGS
12	Summer	Midweek	Midday	Good	Roadway Impact: Lane Closure on I-10 Eastbound

[4] Winter means that school is in session, at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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 2-Mile Region, 5-Mile Region, and EPZ												
R01	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R02	2:45	2:45	2:50	2:50	2:50	2:45	2:45	2:50	2:50	2:50	3:00	2:45
R03	2:45	2:45	2:40	2:40	2:50	2:45	2:45	2:40	2:40	2:50	2:55	3:10
2-Mile Region and Keyhole to 5 Miles												
R04	2:35	2:35	2:50	2:50	2:50	2:35	2:35	2:50	2:50	2:50	2:55	2:35
R05	2:40	2:40	2:50	2:50	2:50	2:40	2:40	2:50	2:50	2:50	2:55	2:40
R06	2:20	2:20	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R07	2:15	2:15	2:40	2:40	2:40	2:20	2:20	2:40	2:40	2:40	2:50	2:15
R08	2:15	2:15	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:15
R09	2:10	2:10	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:10
R10	2:10	2:10	2:35	2:40	2:35	2:10	2:10	2:35	2:40	2:35	2:45	2:10
R11	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R12	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R13	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R14	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R15	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R16	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R17	2:10	2:10	2:35	2:40	2:35	2:10	2:10	2:35	2:40	2:35	2:45	2:10
R18	2:20	2:25	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R19	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:50	2:25

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
2-Mile Region and Keyhole to EPZ Boundary												
R20	2:25	2:25	2:25	2:25	2:40	2:25	2:25	2:25	2:25	2:40	2:45	2:25
R21	2:30	2:30	2:25	2:25	2:45	2:30	2:30	2:25	2:25	2:45	2:45	2:30
R22	2:20	2:20	2:25	2:25	2:40	2:20	2:20	2:25	2:25	2:40	2:45	2:20
R23	2:30	2:30	2:35	2:35	2:45	2:30	2:30	2:35	2:35	2:45	2:50	2:30
R24	2:30	2:30	2:35	2:35	2:45	2:30	2:30	2:35	2:35	2:45	2:55	2:30
R25	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:55	2:25
R26	2:15	2:15	2:45	2:45	2:45	2:15	2:15	2:45	2:45	2:45	2:50	2:15
R27	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R28	2:05	2:05	2:20	2:20	2:20	2:05	2:05	2:20	2:20	2:20	2:45	2:05
R29	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R30	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R31	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R32	2:10	2:10	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:10
R33	2:05	2:05	1:50	1:50	2:30	2:10	2:10	1:50	1:50	2:30	2:35	2:05
R34	2:15	2:15	2:10	2:10	2:40	2:20	2:20	2:10	2:10	2:40	2:40	2:15
R35	2:20	2:25	2:20	2:20	2:40	2:20	2:20	2:20	2:20	2:40	2:40	2:20

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5 Miles												
R36	2:55	2:55	3:00	3:00	3:00	2:55	2:55	3:00	3:00	3:00	3:00	2:55
R37	2:50	2:50	2:55	2:55	2:55	2:50	2:50	2:55	2:55	2:55	2:55	2:50
R38	2:50	2:50	2:55	2:55	2:55	2:50	2:50	2:55	2:55	2:55	2:55	2:50
R39	2:45	2:45	2:55	2:55	2:55	2:45	2:45	2:55	2:55	2:55	2:50	2:45
R40	2:40	2:40	2:50	2:50	2:50	2:35	2:40	2:50	2:50	2:50	2:50	2:40
R41	2:35	2:35	2:45	2:45	2:45	2:30	2:35	2:45	2:45	2:45	2:50	2:35
R42	2:25	2:30	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:50	2:25
R43	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:45	2:25
R44	2:05	2:05	2:40	2:40	2:40	2:10	2:10	2:40	2:40	2:40	2:45	2:05
R45	2:05	2:05	2:20	2:20	2:20	2:05	2:05	2:20	2:20	2:20	2:45	2:05
R46	2:05	2:05	2:30	2:30	2:30	2:10	2:10	2:30	2:30	2:30	2:45	2:05
R47	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R48	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R49	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R50	2:20	2:20	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R51	2:45	2:45	2:50	2:50	2:50	2:40	2:45	2:50	2:50	2:50	2:50	2:45
R52	2:45	2:45	2:50	2:50	2:50	2:40	2:45	2:50	2:50	2:50	2:50	2:45

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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 2-Mile Region, 5-Mile Region, and EPZ												
R01	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R02	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R03	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
2-Mile Region and Keyhole to 5 Miles												
R04	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R05	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R06	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R07	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R08	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R09	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R10	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R11	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R12	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R13	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R14	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R15	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R16	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R17	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R18	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R19	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
2-Mile Region and Keyhole to EPZ Boundary												
R20	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R21	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R22	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R23	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R24	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R25	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R26	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R27	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R28	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R29	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R30	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R31	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R32	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R33	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R34	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R35	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5 Miles												
R36	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R37	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R38	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R39	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R40	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R41	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R42	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R43	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R44	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R45	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R46	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R47	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R48	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R49	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R51	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R52	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
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
Un-staged Evacuation – 2-Mile Region and 5-Mile Region												
R01	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R02	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
Un-staged Evacuation - 2-Mile Region and Keyhole to 5-Miles												
R04	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R05	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R06	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R07	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R08	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R09	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R10	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R11	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R12	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R13	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R14	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R15	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R16	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R17	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R18	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R19	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5-Miles												
R36	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R37	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R38	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R39	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R40	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R41	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R42	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R43	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R44	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R45	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R46	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R47	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R48	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R49	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R50	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R51	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R52	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Un-staged Evacuation – 2-Mile Region and 5-Mile Region												
R01	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R02	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
Un-staged Evacuation - 2-Mile Region and Keyhole to 5-Miles												
R04	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R05	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R06	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R07	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R08	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R09	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R10	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R11	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R12	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R13	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R14	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R15	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R16	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R17	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R18	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R19	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5-Miles												
R36	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R37	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R38	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R39	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R40	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R41	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R42	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R43	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R44	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R46	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R47	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R48	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R49	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R50	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R51	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R52	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45

Table 8-2. 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 RCC (mi.)	Travel Time from EPZ Bdry to RCC (min)	ETA to RCC (hr:min)
MARICOPA COUNTY SCHOOLS									
Crossroads Academy	10	8	12.4	62.7	12	**0:30**	19.0	18	**0:50**
Ruth Fisher Elementary School	10	15	13.2	61.2	13	**0:40**	19.0	18	**1:00**
Tonopah Valley High School	10	15	13.2	61.2	13	**0:40**	19.0	18	**1:00**
Winters Well Elementary School	20	15	9.8	61.3	10	**0:45**	8.4	8	**0:55**
Arlington Elementary School	10	15	8.4	50.9	10	**0:35**	8.4	8	**0:45**
Palo Verde Elementary School	10	15	-	0.0	0	**0:25**	10.8	10	**0:35**
					Maximum for EPZ:	**0:45**		**Maximum:**	**1:00**
					Average for EPZ:	**0:40**		**Average:**	**0:50**

Table 8-4. Transit-Dependent Evacuation Time Estimates – Good Weather

		One-Wave						Two-Wave						
Route Number	Number of Buses	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to RCC (miles)	Travel Time to RCC (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
4	1	165	22.5	63.3	21	30	**3:40**	29.8	28	5	10	71	30	**6:05**
5	1-2	165	12.4	61.0	12	30	**3:30**	36.7	34	5	10	58	30	**5:50**
6	1	165	13.8	53.0	16	30	**3:35**	38.0	35	5	10	63	30	**6:00**
						Maximum ETE:	**3:40**						**Maximum ETE:**	**6:05**
						Average ETE:	**3:35**						**Average ETE:**	**6:00**

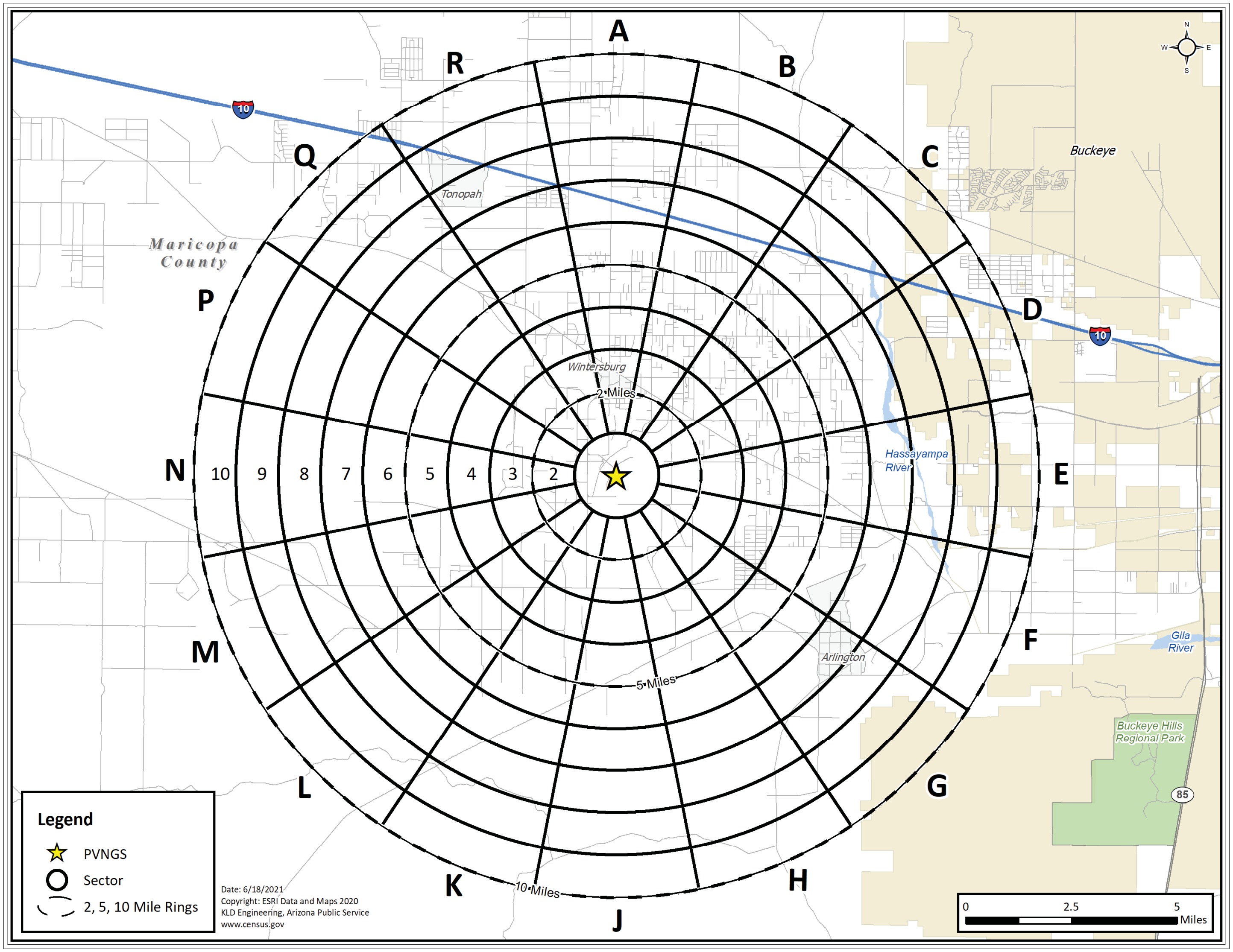

Figure 6-1. PVNGS EPZ Sectors

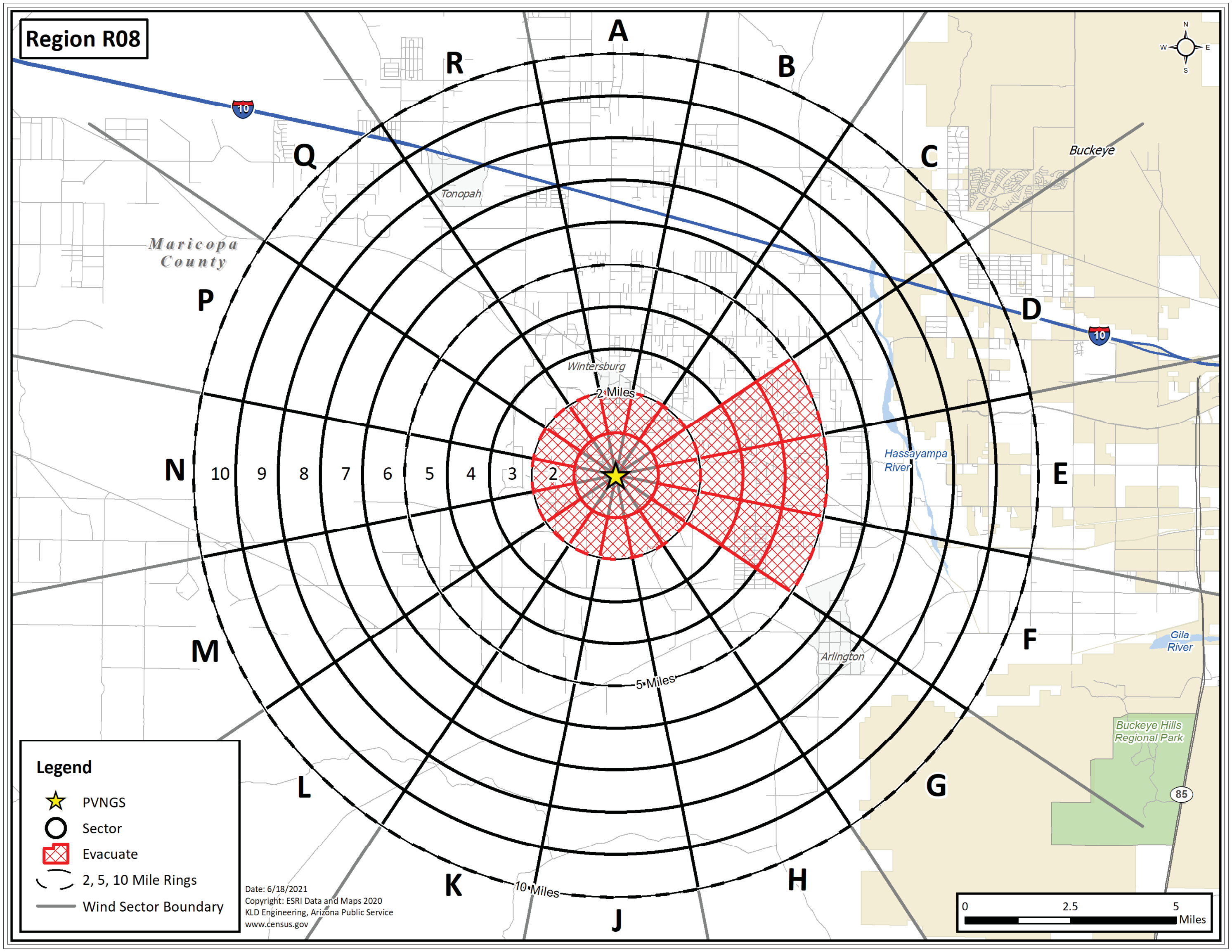

Figure H-8. Region R08

1 INTRODUCTION

This report describes the analyses undertaken and the results obtained by a study to develop Evacuation Time Estimates (ETE) for the Palo Verde Nuclear Generating Station (PVNGS), located in Maricopa County, Arizona. This ETE study provides Arizona Public Service (APS), 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:

- Title 10, Code of Federal Regulations, Appendix E to Part 50 (10CFR50), Emergency Planning and Preparedness for Production and Utilization Facilities, NRC, 2011.
- Emergency Planning and Preparedness for Production and Utilization Facilities, 10CFR50, Appendix E.
- Revision 1 of the Criteria for Development of Evacuation Time Estimate Studies, NUREG/CR-7002, February 2021.
- FEMA "Radiological Emergency Preparedness Program Manual" (FEMA P-1028), December 2019
- 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.

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 APS.
    b. Attended meetings with emergency planners from Arizona Department of Emergency & Military Affairs (ADEMA) and Maricopa County Department Emergency (MCDEM) to discuss methodology, project assumptions and resources available.
    c. Conducted a detailed field survey of the highway system and of area traffic conditions within the Emergency Planning Zone (EPZ) and Shadow Region.
    d. Obtained demographic EPZ data from MCDEM and Shadow Region data from the 2020 Census, projected to the year 2021 (see Section 3.1 and Section 3.2).
    e. Conducted a random sample demographic survey of EPZ residents.

f. Conducted a data collection effort to identify and describe schools, motels, 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 demographic 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 was reviewed at specified Traffic Control Points and Access Control Points (Roadblocks) located within the EPZ and roadblocks stopping external traffic was only considered.

5. Used existing Sectors to define Evacuation Regions. The EPZ is partitioned into 145 sectors by compass direction and radial distance from the plant. "Regions" are groups of contiguous Sectors 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 "keyhole section" within the EPZ as recommended by NUREG/CR-7002, Rev. 1.

6. Estimated demand for transit services for children at schools and for transit-dependent persons at home.

7. Prepared the input streams for the DYNEV II.

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

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

   c. Applied the procedures specified in the 2016 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.

   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 PVNGS.

[2] Highway Capacity Manual (HCM 2016), Transportation Research Board, National Research Council, 2016.

8. Executed the DYNEV II system 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, Rev. 1.
10. Calculated the ETE for all transit activities including those for schools, for the transit-dependent population and for the access and/or functional needs population.

1.2 The Palo Verde Nuclear Generating Station Location

The PVNGS is located in Tonopah, Maricopa County, Arizona. The site is approximately 55 miles west of Phoenix, Arizona. The EPZ is entirely within Maricopa County. Figure 1-1 shows the location of the PVNGS relative to Phoenix. This map also identifies the communities in the area and the major roads.

1.3 Preliminary Activities

These activities are described below.

Field Surveys of the Highway Network

In 2020, 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.

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 2016 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 15-46 in the HCM 2016 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 geographic 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. Roadway types were assigned based on the following criteria:

- Freeway: limited access highway, 2 or more lanes in each direction, high free flow speeds
- Freeway ramp: ramp on to or off of a limited access highway
- Major arterial: 3 or more lanes in each direction

- Minor arterial: 2 or more lanes in each direction
- Collector: single lane in each direction
- Local roadway: single lane in each direction, local road with low free flow speeds

As documented on page 15-6 of the HCM 2016, the capacity of a two-lane highway is 1,700 passenger cars per hour in one direction. For freeway sections, a value of 2,250 vehicles per hour per lane is assigned, as per Exhibit 12-7 of the HCM 2016. 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 2016 Exhibit 15-46. 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. Roadblocks, if modeled, at locations which have control devices are represented as actuated signals in the DYNEV II.

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 used to compute ETE, as per NUREG/CR-7002, Rev.1 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.

The 2012 link-node analysis network was updated to include the constructed roundabout and parking lots along W Baseline Road within PVNGS. Aerial imagery and the road survey were used to update the network.

<u>Demographic Survey</u>

An online demographic survey was performed in 2020 to gather information needed for the ETE study. Appendix F presents the survey instrument, the procedures used and tabulations of data compiled from the survey returns along with discussion validating the use of the survey results in this study.

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

Computing the Evacuation Time Estimates

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

Analytical Tools

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

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. 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 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 plant.

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 2012 ETE study (KLD TR-513, dated December 2012, Rev. 1). The 90th percentile ETE for the full EPZ (Region R03) in this study, increases by as much as 40 minutes (1 hour for roadway impact) for summer, midweek, midday scenario when compared with the 2012 study. The 100th percentile ETE for the full EPZ increases by as much as 45 minutes. The major factors contributing to the differences between the ETE values obtained in this study and those of the previous study are:

- The permanent resident population in the EPZ decreased by 9.2%, resulting in less evacuating vehicles, which can reduce ETE.
- The permanent resident population in the Shadow Region was projected to 2021 and grew by 44%. This population increase results in more vehicles evacuating in the Shadow Region, which reduces the available roadway capacity for EPZ evacuees and can increase ETE.
- The number of employees commuting into the EPZ increased by 49.8%, which results in an increase in vehicular demand that can decrease the 90th percentile ETE, as it will take quicker to reach an evacuation of 90% of the population.
- The completion of a roundabout, parking lots, and a second entrance/exit at PVNGS was included in this study. The roundabout decreases the roadway capacity and speed while PVNGS employees evacuate, increasing the congestion within the 2-Mile Region and prolonging the 90th percentile ETE.
- External traffic on major roadway, I-10, increases the number of vehicles traversing the EPZ by approximately 34.2%. The increase in external traffic on I-10 reduces the available capacity to evacuees and increases delays at ramps as evacuees try to gain access to I-10. Ultimately, this increase in traffic, increases congestion within the EPZ and prolongs ETE.

- Trip generation times increased by at most 45 minutes for permanent residents and reduced by at most 15 minutes for employees/transients based on data collected from the demographic survey. As a result, vehicles are generated over a longer period of time which can reduce overall congestion but is directly correlated with the increase of the 100th percentile ETE for this site. Since all congestion clears prior to the end of trip generation time, the 100th percentile ETE is dictated by the time needed to mobilize (plus a 10 minute travel time to the EPZ boundary).

The various factors, discussed above, that can increase ETE outweigh those that can reduce ETE, thereby explaining why the 90th and 100th percentile ETE have significantly increased in this study relative to the 2012 ETE study.

Table 1-1. Stakeholder Interaction

Stakeholder	Nature of Stakeholder Interaction
Arizona Public Service (APS)	Attended meetings to define methodology and data requirements. Set up contacts with local government agencies. Provided recent PVNGS employee data. Reviewed and approved all project assumptions. Engaged in the ETE development and were informed of the study results.
Maricopa County Department of Emergency Management (MCDEM)	Met to discuss project methodology, key project assumptions and to define data needs. Provided county emergency plans, special facility data and existing traffic management plans. Reviewed and approved all project assumptions. Engaged in the ETE development and were informed of the study results..
Arizona Department of Emergency & Military Affairs (DEMA)	Obtain state emergency plan.

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.

Table 1-3. ETE Study Comparisons

Topic	Previous ETE Study	Current ETE Study
Resident Population Basis	Used data supplied by Maricopa County; Population = 12,474 Vehicles = 6,289	Used data supplied by Maricopa County; Population = 9,712 Vehicles = 5,712
Resident Population Vehicle Occupancy	2.90 persons/household, 1.46 evacuating vehicles/household yielding: 1.99 persons/vehicle.	2.65 persons/household, 1.56 evacuating vehicles/household yielding: 1.70 persons/vehicle.
Employee Population	Employee estimates based on information provided about major employers in EPZ. 1.08 employees per vehicle based on telephone survey results. Employees = 2,715 Vehicles = 1,607	Employee estimates based on information provided about major employers in EPZ. 1.18 employees per vehicle based on demographic survey results. Employees = 3,035 Vehicles = 2,408
Transit-Dependent Population	Estimates based upon U.S. Census data and the results of the telephone survey. A total of 455 people who do not have access to a vehicle, requiring 16 buses to evacuate. An additional 627 access and/or functional needs persons needing special transportation to evacuate (525 require a bus, 102 require a paratransit vehicle).	Estimates based upon data provided by MCDEM and the results of the demographic survey. A total of 59 people who do not have access to a vehicle, 4 buses were used but 2 buses were required to evacuate . An additional 354 access and/or functional needs persons need special transportation to evacuate (284 require a bus, 70 require a paratransit vehicle).
Transient Population	Transient estimates based upon information provided about transient attractions in EPZ. Transients = 1,061 Transient Vehicles = 708	Transient estimates based upon information provided about transient attractions in EPZ. Transients = 23 Transient Vehicles = 8
Special Facilities Population	There are currently no special facilities other than schools (see below) located within the 10-mile EPZ.	There are currently no special facilities other than schools (see below) located within the 10-mile EPZ.
School Population	School population based on information provided by MCDEM within the EPZ and Shadow Region. School enrollment = 1,410 Buses = 25	School population based on information provided by MCDEM within the EPZ and Shadow Region. School enrollment = 2,746 Buses = 51

Topic	Previous ETE Study	Current ETE Study
Shadow Population	ArcGIS software using 2010 US Census blocks and projecting out to 2011 using the compound growth rate of 2000 Census and 2010 census data; area ratio method used. Population = 9,546 Vehicles = 4,841	ArcGIS software using 2020 US Census blocks and projecting out to 2021 using the compound growth rate of 2010 Census and 2020 census data; area ratio method used. Population = 11,911 Vehicles = 6,973
Voluntary evacuation from within EPZ in areas outside region to be evacuated	20% of the population within the EPZ, but not within the Evacuation Region (see Figure 2-1)	20% of the population within the EPZ, but not within the Evacuation Region (see Figure 2-1)
Shadow Evacuation	20% of people outside of the EPZ within the Shadow Region (see Figure 7-2)	20% of people outside of the EPZ within the Shadow Region (see Figure 7-2)
Network Size	272 links; 194 nodes	402 links; 297 nodes
Roadway Geometric Data	Field surveys conducted in February 2012. Roads and intersections were video archived. Road capacities based on 2010 HCM.	Field surveys conducted in October 2020. Roads and intersections were video archived. Aerial imagery used for additional roadways which were not included in the field surveys. Road capacities based on HCM 2016.
School Evacuation	Direct evacuation to designated Reception and Care Center.	Direct evacuation to designated Reception and Care Center.
Ridesharing	50 percent of transit-dependent persons will evacuate with a neighbor or friend.	72 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 30 and 300 minutes. Residents without commuters returning leave between 15 and 240 minutes. Employees and transients leave between 15 and 120 minutes. All times measured from the Advisory to Evacuate.	Based on residential demographic survey of specific pre-trip mobilization activities: Residents with commuters returning leave between 30 and 345 minutes. Residents without commuters returning leave between 15 and 285 minutes. Employees and transients leave between 15 and 105 minutes. All times measured from the Advisory to Evacuate.

Topic	Previous ETE Study	Current ETE Study
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	DYNEV II System – Version 4.0.8.0	DYNEV II System – Version 4.0.20.0
Special Events	Outage at PVNGS Special Event Population = 1,560 additional employees	Outage at PVNGS Special Event Population = 1,304 additional employees
Evacuation Cases	52 Regions (central sector wind direction and each adjacent sector technique used) and 12 Scenarios producing 624 unique cases.	52 Regions (central sector wind direction and each adjacent sector technique used) and 12 Scenarios producing 624 unique cases.
Evacuation Time Estimates Reporting	ETE reported for 90th 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, Midweek, Midday, Good Weather: 2:10 Rain: 2:10 Summer, Weekend, Midday, Good Weather: 2:10 Rain: 2:15	Winter, Midweek, Midday, Good Weather: 2:45 Rain: 2:45 Summer, Weekend, Midday, Good Weather: 2:45 Rain: 2:45
Evacuation Time Estimates for the entire EPZ, 100th percentile	Winter, Midweek, Midday, Good Weather: 5:10 Rain: 5:10 Summer, Weekend, Midday, Good Weather: 5:10 Rain: 5:10	Winter, Midweek, Midday, Good Weather: 5:55 Rain: 5:55 Summer, Weekend, Midday, Good Weather: 5:55 Rain:5:55

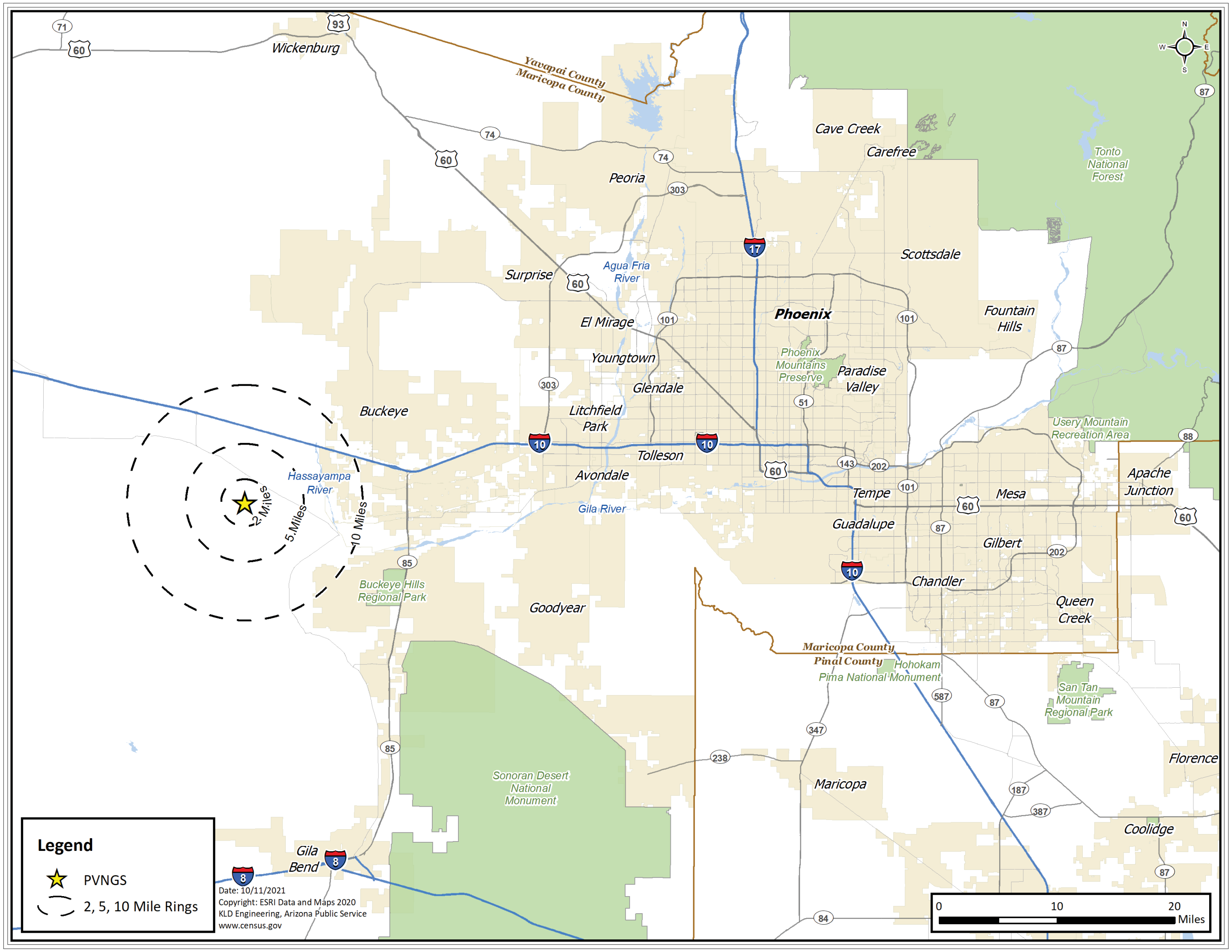

Figure 1-1. Palo Verde Nuclear Generating Station Location

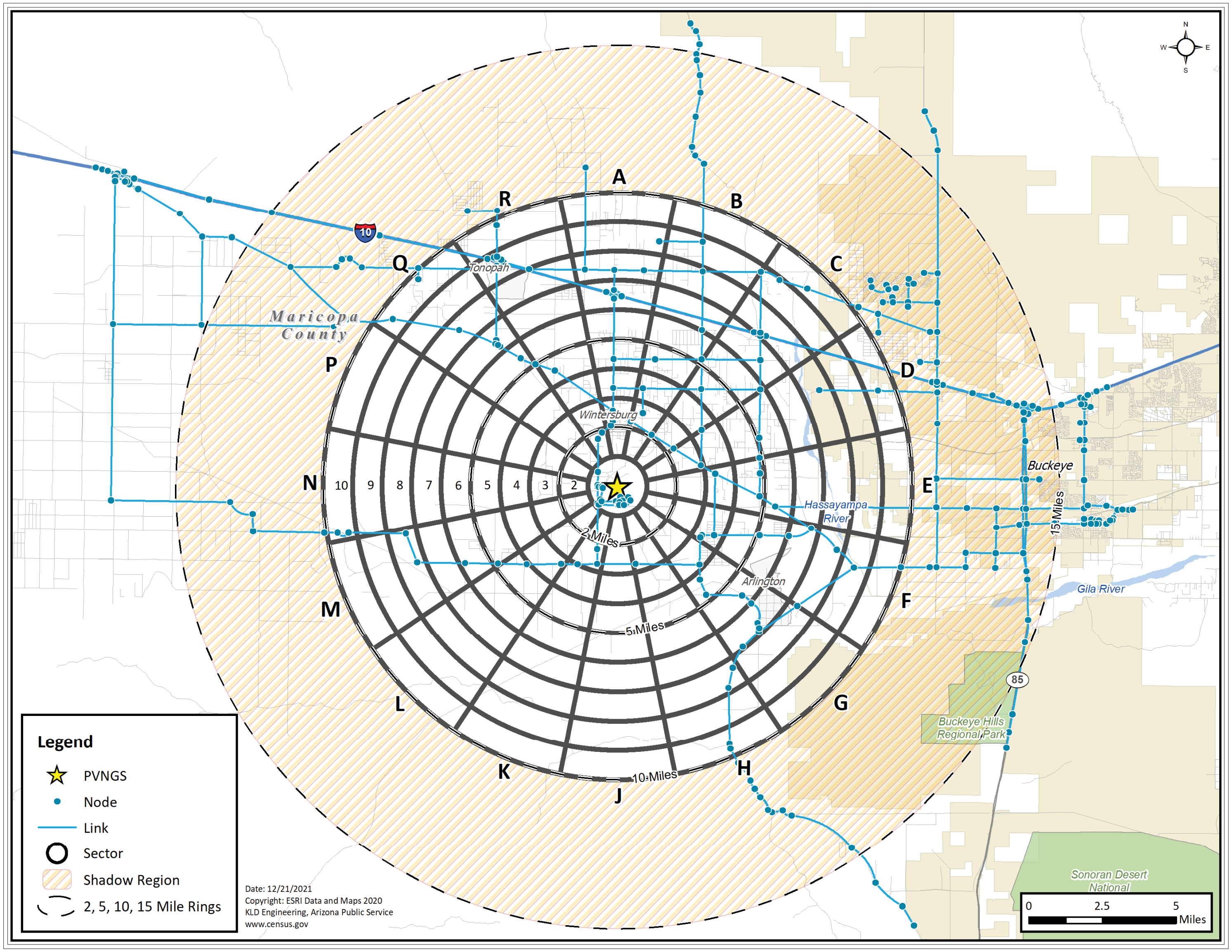

Figure 1-2. PVNGS Link-Node Analysis Network

2 STUDY ESTIMATES AND ASSUMPTIONS

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

2.1 Data Estimate Assumptions

1. The permanent resident population are based on the 2020 U.S. Census population from the Census Bureau website[1] within the Shadow Region and the 2021 population data provided by Maricopa County within the Emergency Planning Zone (EPZ). (See Section 3.1.)
2. Estimates of employees who reside outside the EPZ and commute to work within the EPZ, along with the population estimates at transient and special facilities are based upon data provided by Maricopa County and Arizona Public Service (APS). (See Sections 3.3, 3.4, and 3.7.)
3. The relationship between permanent resident population and evacuating vehicles is based on Census data and the results of the demographic survey (see Appendix F). Values of 2.65 persons per household (Figure F-1) and 1.56 evacuating vehicles per household (Figure F-9) are used for the permanent resident population.
4. Employee vehicle occupancies are based on the results of the demographic survey. For this study, 1.18 employees per vehicle is used. In addition, it is assumed there are two people per carpool, on average. (See Figure F-7.)
5. There are 210 inmates from Arizona State Prison working at Hickman's Farms. It is assumed they are located at the 32911 Ward Road, Buckeye location and are included in the number of total employees provided. They will evacuate in buses.
6. On average, the relationship between persons and vehicles for transients and the special event is as follows:
   a. Transient Population at Saguaro Mineral Wells Motel (See Section 3.3 and Appendix E): 2.88 people per vehicle (based on data provided)
   b. Special Event (See Section 3.7.): 1.18 people per vehicle (based on the employee vehicle occupancies)
   c. Where data was not provided, the average household size is assumed to be the vehicle occupancy rate for transient facilities and the special event.
7. The maximum bus speed assumed within the EPZ is 65 miles per hour (mph) based on Arizona Department of Public Safety laws[2] for buses and average posted speed limits on roadways within the EPZ.

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[1] www.census.gov
[2] https://www.azdps.gov/sites/default/files/media/arizona-minimum-standards-for-school-buses-and-school-bus-drivers.pdf

8. Roadway capacity estimates are based on field surveys performed in 2020 (verified by aerial imagery), and the application of the Highway Capacity Manual 2016. Based on discussions with APS and Maricopa County, no roadway construction projects (affecting roadway capacity estimates) will be considered for this study.

2.2 Methodological Assumptions

1. The Planning Basis Assumption for the calculation of ETE is a rapidly escalating accident that requires evacuation, and includes the following[3] (as per NRC guidance):
    a. Advisory to Evacuate (ATE) notification is announced coincident with the siren alerting.
    b. Mobilization of the general population will commence within 15 minutes after siren alerting.
    c. The ETE are measured relative to the ATE.
2. The center-point of the plant is located at the center of the Unit 2 containment building 33°23’13.92”N, 112°51’52.2”W.
3. The DYNEV II[4] system is used to compute ETE in this study.
4. Evacuees will drive safely, travel radially away from the plant to the extent practicable given the highway network, and obey all control devices and traffic guides. All major evacuation routes are used in the analysis.
5. The existing EPZ and Sector boundaries are used. See Figure 3-1.
6. The Shadow Region extends to 15 miles radially from the plant or approximately 5 miles radially from the EPZ boundary, as per NRC guidance. See Figure 7-2.
7. One hundred percent (100%) of the people within the impacted keyhole will evacuate. Twenty percent (20%) of the population within the Shadow Region and within Sectors of the EPZ not advised to evacuate will voluntarily evacuate, as shown in Figure 2-1, as per NRC guidance. Sensitivity studies explore the effect on ETE of increasing the percentage of voluntary evacuees in the Shadow Region (see Appendix M).
8. Shadow population characteristics (household size, evacuating vehicles per household, and mobilization time) is assumed to be the same as that of the permanent resident population within the EPZ.

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[3] We emphasize that the adoption of this planning basis is <u>not</u> a representation that these events will occur within the indicated time frame. Rather, these assumptions are necessary in order to:
1. Establish a temporal framework for estimating the Trip Generation distribution in the format recommended in Section 2.13 of NUREG/CR-6863.
2. Identify temporal points of reference that uniquely define "Clear Time" and ETE.

It is likely that a longer time will elapse between the various stages of an emergency. See Section 5.1 for more detail.

[4] 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). 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.

9. The ETE are presented at the 90th and 100th percentiles, as well as in graphical and tabular format, as per NRC guidance. The percentile ETE is defined as the elapsed time from the ATE issued to a specific Region of the EPZ, to the time that Region is clear of the indicated percentile of evacuees.
10. This study does not assume that roadways are empty at the start of the first time period. Rather, there is a 30-minute initialization period (often referred to as “fill time” in traffic simulation) wherein the traffic volumes from the first time period are loaded onto roadways in the study area. The amount of initialization/fill traffic that is on the roadways in the study area at the start of the first time period depends on the scenario and the region being evacuated. See Section 3.10.
11. To account for boundary conditions beyond the study area, this study will assume a 25% reduction in capacity on two-lane roads and multi-lane highways for roadways that have traffic signals downstream. The 25% reduction in capacity is based on the prevalence of actuated traffic signals in the study area and the fact that the evacuating traffic volume will be more significant than the competing traffic volume at any downstream signalized intersections, thereby warranting a more significant percentage (75% in this case) of the signal green time. There is no reduction in capacity for freeways due to boundary conditions.
12. The ETE also includes 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. See Section 3.9 and 3.10.

2.3 Assumptions on Mobilization Times

1. Trip generation time (also known as mobilization time, or the time required by evacuees to prepare for the evacuation) are based upon the results of the demographic survey (See Section 5 and Appendix F). It is assumed that stated events take place in sequence such that all preceding events must be completed before the current event can occur.
2. One hundred percent (100%) of the EPZ population can be notified within 45 minutes, in accordance with the 2019 Federal Emergency Management Agency (FEMA) Radiological Emergency Preparedness Program Manual.
3. Commuter percentages (and percentage of residents awaiting the return of a commuter) are based on the results of the demographic survey. According to the survey results, 49.1% of the households in the EPZ have at least 1 commuter (see Section F.3.1.); approximately 49.86% of those households with commuters will await the return of a commuter before beginning their evacuation trip (see Section F.3.2.). Therefore, approximately 24% (49.1% x 49.86% = 24.48%) of EPZ households will await the return of a commuter, prior to beginning their evacuation trip.

2.4 Transit Dependent Assumptions

1. The percentage of transit-dependent people who will rideshare with a neighbor or friend are based on the results of the demographic survey. According to the survey results, 72% of the transit-dependent population will rideshare.

2. Transit vehicles are used to transport those without access to private vehicles:
    a. Schools and childcare centers
        i. If schools are in session, buses or passenger car/vans will evacuate students directly to the designated reception and care centers.
        ii. For the schools that are evacuated via buses/vans/cars, it is assumed no school children will be picked up by their parents prior to the arrival of the buses.
        iii. Schoolchildren, if school is in session, are given priority in assigning transit vehicles.
    b. Transit-dependent permanent residents:
        i. Transit-dependent general population are evacuated to reception and care centers. Discussions with the County of Maricopa stated no buses are available for the transit-dependent general population.
        ii. Access and/or functional needs population may require county assistance (ambulance, bus or wheelchair transport) to evacuate. This is considered separately from the general population ETE, as per NRC guidance. Discussions with the County of Maricopa stated that individuals who need access and/or functional assistance will need to call 9-1-1 and request emergency assistance, and Maricopa County Sheriff's Office will handle as resources allow.
        iii. Households with 3 or more vehicles were assumed to have no need for transit vehicles.
    c. Hickman Farms
        i. The 210 inmates from Arizona State Prison evacuates using buses.
        ii. The buses are included within the employee total vehicles. (See Section 3.4.)
    d. Analysis of the number of required round-trips ("waves") of evacuating transit vehicles is presented.
    e. Transport of transit-dependent evacuees from reception centers to congregate care centers is not considered in this study.

3. Transit vehicle capacities:
    a. School buses = 70 students per bus for primary schools and 50 students per bus for middle/high schools
    b. Crossroads Academy Passenger Vans = 15 students per van
    c. Crossroads Academy Passenger Cars = 4 students and 1 adult per car
    d. Transit-dependent buses and buses used for the Inmates at Hickman's Farm = 30 persons per bus

   e. Ambulatory transit-dependent persons = 30 persons per bus
   f. Paratransit Vehicles:
      i. Ambulances = 2 bedridden persons (includes advanced and basic life support)
      ii. Wheelchair vans = 4 wheelchair bound persons
      iii. Wheelchair buses = 15 wheelchair bound persons

4. Transit vehicles mobilization times:
   a. Crossroads Academy passenger vans/cars and Arlington School, Tonopah Valley High School and Ruth Fisher School buses are already at the school and can be mobilized within 10 minutes of the ATE. Winters Well Elementary School buses will arrive at the school within 20 minutes.
   b. Transit dependent buses are mobilized when approximately 90% of residents with no commuters have completed their mobilization at 165 minutes of the ATE. (See Section 5.)

5. Transit Vehicle loading times:
   a. School buses are loaded in 15 minutes.
   b. Crossroads Academy Passenger Vans and Cars are loaded in 8 minutes.
   c. Transit Dependent buses require 1 minute of loading time per passenger.
   d. Buses for ambulatory patients require 1 minute of loading time per ambulatory passenger.
   e. Wheelchair transport or paratransit vehicles require 5 minutes of loading time per passenger.
   f. Ambulances are loaded in 15 minutes per bedridden passenger.

6. It is assumed that drivers for all transit vehicles identified in Table 8-1 are available.

2.5 Traffic and Access Control Assumptions

1. Traffic Control Points and Access Control Points (Roadblocks) as defined in the approved county and state emergency plans were considered in the ETE analysis, as per NRC guidance. Evacuation simulations indicated that implementing the TCPs and roadblocks did not significantly impact the ETE. Based on the simulation results, the only TCPs and roadblocks considered in the ETE results documented in this report are those located on I-10 to stop the flow of traffic into the area. While Roadblocks are not necessary to evacuate the EPZ expediently, staffing these locations does still provide value during an evacuation such as guiding those evacuees who are not familiar with the area and serving as fixed point surveillance if there is an incident on one of the major evacuation routes. See Section 9 and Appendix G for additional information.

2. The roadblocks (on I-10 and at I-10 ramps) are assumed to be staffed approximately 45 minutes and 20 minutes after the ATE, as per Maricopa County and the Arizona Department of Public Safety, respectively. For this study, it is assumed that no through traffic will enter the EPZ on I-10 after this 45-minute time period. Earlier activation of roadblock locations could delay returning commuters.

3. It is assumed that all transit vehicles and other responders entering the EPZ to support the evacuation are unhindered by personnel manning the I-10 roadblocks.

2.6 Scenarios and Regions

1. A total of 12 "Scenarios" representing different temporal variations (season, time of day, day of week) and weather conditions are considered. Scenarios to be considered are defined in Table 2-1:
   a. An outage at PVNGS will be considered as the special event (single or multi-day event that attracts a significant population into the EPZ; recommended by NRC guidance) for Scenario 11.
   b. As per NRC guidance, one segment of one of the highest volume roadways will be out of service or one lane outbound on a freeway must be closed for a roadway impact scenario. This study will consider the closure of one lane on Interstate-10 (I-10) Eastbound, from the interchange with N Wintersburg Rd (Exit 98) to Miller Rd (Exit 114) for the roadway impact scenario – Scenario 12.
2. 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.
3. Adverse weather scenarios affect roadway capacity and the free flow highway speeds. The capacity and free flow speed are reduced by 10% for rain, based on recent transportation engineering research. The factors are shown in Table 2-2.
4. It is assumed that employment is reduced slightly in the summer for vacations.
5. It is also assumed that mobilization and loading times for transit vehicles are slightly longer in adverse weather. It is assumed that mobilization times are 10 minutes longer in rain. It is assumed that loading times are 5 minutes longer in rain. Refer to Table 2-2.
6. Regions are defined by the underlying "keyhole" or circular configurations as specified in Section 1.4 of NUREG/CR-7002, Rev 1. All 16 cardinal and intercardinal wind direction keyhole configurations are considered. Regions to be considered are defined in Table 6-1. It is assumed that everyone within the group of Sectors forming a Region that is issued an ATE will, in fact, respond and evacuate in general accord with the planned routes.
7. Staged evacuation is considered as defined in NUREG/CR-7002, Rev. 1 – those people between 2 and 5 miles will shelter-in-place until 90% of the 2-Mile Region has evacuated, then they will evacuate. See Regions R36 through R52 in Table 6-1.

Table 2-1. Evacuation Scenario Definitions

Scenario	Season[5]	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	Midweek	Midday	Good	Special Event: Outage at PVNGS
12	Summer	Midweek	Midday	Good	Roadway Impact: Single Lane Closure on I-10 Eastbound

Table 2-2. Model Adjustment for Adverse Weather

Scenario	Highway Capacity*	Free Flow Speed*	Mobilization Time for General Population	Mobilization Time for Schools/Transit Vehicles	Loading Time for Schools/ Transit Vehicles
Rain	90%	90%	No Effect	10-minute increase	5-minute increase/10-minute increase
*Adverse weather capacity and speed values are given as a percentage of good weather conditions. Roads are assumed to be passable.					

[5] Winter means that school is in session, at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

Figure 2-1. Voluntary Evacuation Methodology

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 (e.g., resident, employee, transient, special facilities, etc.).
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 2021 data collected by Maricopa County, 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 within the EPZ could be counted as a resident and again as an employee.

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. 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 PVNGS 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 and then leave the area.
- Employees - people who reside outside of the EPZ and commute to work within the EPZ on a daily basis.

Estimates of the population and number of evacuating vehicles for each of the population groups are presented for each Sector and by polar coordinate representation (population rose). The PVNGS EPZ is subdivided into 145 Sectors. The Sectors comprising the EPZ are shown in Figure 3-1.

3.1 Permanent Residents

The permanent resident population estimates are based upon 2021 data collected by Maricopa County. The Maricopa County Department of Emergency Management (MCDEM) compiles and updates the 10-mile EPZ population demographics annually. This information is derived from

electric utility connects/disconnects, special surveys and information provided from the county planning department. MCDEM geo-codes the addresses which summarizes population by EPZ Sector. This compiled information is provided to PVNGS who then revises the onsite Emergency Plan annually to include the updated demographics.

Table 3-1 provides the permanent resident population within the EPZ, by Sector, for 2011 and 2021 based on the data provided by MCDEM.

To estimate the number of vehicles, the 2021 permanent resident population is divided by the average household size and then multiplied by the average number of evacuating vehicles per household. The average household size (2.65 persons/household) was estimated using the 2021 demographic survey results (see Appendix F, Sub-section F.3.1). The number of evacuating vehicles per household (1.56 vehicles/household – See Appendix F, Sub-section F.3.2) was adapted from the demographic survey results.

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 PVNGS. This population "rose" was constructed using GIS software.

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

- Assume 50 percent of all households vacation for a 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.

3.2 Shadow Population

A portion of the population living outside the evacuation area extending to 15 miles radially from PVNGS may elect to evacuate without having been instructed to do so. This area is called the Shadow Region. Based upon NUREG/CR-7002, Rev. 1 guidance, it is assumed that 20 percent of the permanent resident population, based on U.S. Census Bureau data, in the Shadow Region will elect to evacuate.

The shadow population estimates are based upon the U.S. 2020 Census data with an availability date of September 16, 2021. The shadow population is estimated by cutting the census block polygons by the Shadow Region boundary. A ratio of the original area of each census block and the updated area (after cutting) is multiplied by the total block population to estimate what the

population is within the Shadow Region. This methodology (referred to as the "area ratio method") assumes that the population is evenly distributed across a census block. The 2020 Census data was then extrapolated to September 2021 using the compound growth formula. The compound growth rate was computed by comparing the 2010 Census and 2020 Census data, outlined in Table 3-3.

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 3-4, Figure 3-4 and Figure 3-5 present estimates of the shadow population and vehicles, by Sector. Note, the 2020 Census includes residents living in group quarters, such as skilled nursing facilities, group homes, etc. These people are transit dependent (will not evacuate in personal vehicles). To avoid double counting vehicles, the vehicle estimates for these people have been removed. The resident vehicles in Table 3-4 and Figure 3-5 have been adjusted accordingly.

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 (lodging). Transients may spend less than one day or stay overnight at motels. The PVNGS EPZ has one facility that attracts transients, the Saguaro Mineral Wells Motel.

The number of rooms, percentage of occupied rooms at peak times, and the number of people and vehicles per room for Saguaro Mineral Wells Motel was confirmed by Arizona Public Service (APS). This data was used to estimate the number of transients and evacuating vehicles at this motel.

Appendix E summarizes the transient data that was estimated for the EPZ. Table E-3 presents the number of transients at Saguaro Mineral Wells Motel. Table 3-5 presents transient population and transient vehicle estimates by Sector. Figure 3-6 and Figure 3-7 present these data by Sector and distance from the plant. A total of 23 transients evacuating in 8 vehicles (an average vehicle occupancy of 2.88 transients per vehicle) are in the EPZ.

3.4 Employees

Employees who work within the EPZ fall into two categories:

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

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

Data provided by APS and MCDEM were used to estimate the number of employees commuting into the EPZ. Since not all employees are working at facilities within the EPZ at one time, the

maximum shift number was used. Table E-2 in Appendix E presents the employees (Max Shift) and employees who are not residents of the EPZ. A vehicle occupancy of 1.18 employees per vehicle obtained from the demographic survey (See Appendix F, Sub-section F.3.1, "Commuter Travel Modes") was used to determine the number of evacuating employee vehicles for all major employers.

Based on the data provided by APS, there are 2,611 employees at PVNGS; approximately 95% of the employees travel from outside of the EPZ. As such, there are 2,480 (2,611 x 95% = 2,480) employees commuting into the EPZ. Applying the vehicle occupancy of 1.18 employees per vehicle discussed above, resulting in 2,102 (2,480 ÷ 1.18 = 2,102) employee vehicles.

According to Hickman's Family Farms, inmates from the Arizona State Prison are transported to the farm (located in Sector E-6). During a max shift, there are 210 inmates working at Hickman's Family Farms. These inmates would evacuate on buses. Assuming a capacity of 30 people per bus, 7 buses (14 vehicles) were considered at this facility. For this reason, the number of vehicles used in this study at this facility reflects the number of employees commuting into the EPZ plus the 14 buses needed for the inmates.

Table 3-6 presents the employee and employee vehicles commuting into the EPZ by Sector. Figure 3-8 and Figure 3-9 present these data by Sector.

3.5 Transit Dependent Population

The 2020 demographic survey (see Appendix F) results were used to estimate the portion of the population requiring transit service, including:

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

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

Table 3-7 presents the estimated calculations of transit-dependent people. Note the following:

- Estimates of persons requiring transit vehicles include schoolchildren. For those evacuation scenarios where children are at school when an evacuation is ordered, separate transportation is provided for the schoolchildren. The actual need for transit vehicles by residents is thereby less than the given estimates. However, estimates of transit vehicles are not reduced when schools are in session.
- It is reasonable and appropriate to consider that many transit-dependent persons will evacuate by ride-sharing with neighbors, friends or family. For example, nearly 80 percent of those who evacuated from Mississauga, Ontario who did not use their own cars, shared a ride with neighbors or friends. Other documents report that approximately 70 percent of transit dependent persons were evacuated via ride sharing. **Based on the results of the demographic survey, 72% of the transit-dependent population will rideshare.**

The estimated number of bus trips needed to service transit-dependent persons is based on an estimate of an average bus occupancy of 30 persons at the conclusion of the bus run. Transit vehicle seating capacities typically equal or exceed 60 children on average (roughly equivalent to 40 adults). If transit vehicle evacuees are two thirds adults and one third children, then the number of "adult seats" taken by 30 persons is 20 + (2/3 x 10) = 27. On this basis, the average load factor anticipated is (27/40) x 100 = 68 percent. Thus, if the actual demand for service exceeds the estimates of Table 3-7 by 50 percent, the demand for service can still be accommodated by the available bus seating capacity.

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

Table 3-7 indicates that transportation must be provided for 59 people. Therefore, a total of 2 bus runs are required to transport this population to reception and care centers. In order to service all of the transit-dependent population and have at least one bus drive through each of the Sectors picking up transit-dependent people, 4 bus runs are used in the ETE calculations (even though only 2 buses are needed from a capacity standpoint). These buses are represented as two vehicles in the ETE simulations due to their larger size and more sluggish operating characteristics.

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

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

Where,

A = Percent of households with commuters

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

$$P = 3{,}665 \times [0.00 + 0.225 \times (1.72 - 1) \times 0.491 \times 0.509 + 0.491 \times (2.56 - 2) \times (0.491 \times 0.509)^2] = 211$$

$$B = ((1 - 0.72) \times P) \div 30 = (0.28 \times 211) \div 30 = 2$$

These calculations, based on the 2020 demographic survey results, are explained as follows:

- There were no households (HH) with no vehicles available, so the term 0.00 represents those who do not have access to a vehicle.
- The members of HH with one (1) vehicle away (22.5%), who are at home equals (1.72-1). The number of HH where the commuter will not return home is equal to (3,665 x 0.225 x 0.72 x 0.491 x 0.509), as 49.1% of EPZ households have a commuter, 50.9% of which would not return home in the event of an emergency. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms.

- The members of HH with two (2) vehicles that are away (49.1%), who are at home, equals (2.56-2). The number of HH where neither commuter will return home is equal to 3,665 x 0.491 x 0.56 x $(0.491 \times 0.509)^2$. The number of persons who will evacuate by public transit or ride-share is equal to the product of these two terms (the last term is squared to represent the probability that neither commuter will return).
- Households with 3 or more vehicles are assumed to have no need for transit vehicles.
- The total number of persons requiring public transit is the sum of such people in HH with no vehicles, or with 1 or 2 vehicles that are away from home.

The estimate of transit-dependent population in Table 3-7 is far less than the number of registered transit-dependent persons in the EPZ as provided by MCDEM (discussed below in Section 3.8.

3.6 School Population Demand

Table 3-8 presents the school population and transportation requirements for the direct evacuation of all schools within the study area for the 2020-2021 school year. This information was provided by MCDEM. The column in Table 3-8 entitled “Buses/Passenger Vans Required” specifies the number of buses/passenger vans required for each school under the following set of assumptions and estimates:

- No students will be picked up by their parents prior to the arrival of the buses.
- While many high school students commute to school using private automobiles (as discussed in Section 2.4 of NUREG/CR-7002, Rev. 1), the estimate of buses required for school evacuation does not consider the use of these private vehicles.
- Bus capacity, expressed in students per bus, is set to 70 for primary schools and 50 for middle and high schools.
- Crossroads Academy Passenger Vans and Passenger Cars = 15 students per van and 4 students and 1 adult, respectively.
- Those staff members who do not accompany the students will evacuate in their private vehicles.
- No allowance is made for student absenteeism, typically 3 percent daily.
- Palo Verde Elementary School will be evacuated (even though it is in the Shadow Region) in the event of an emergency at the PVNGS according to MCDEM.

Implementation of a process to confirm individual school transportation needs prior to bus dispatch may improve bus utilization. In this way, the number of buses dispatched to the schools will reflect the actual number needed. The need for buses would be reduced by any high school students who have evacuated using private automobiles (if permitted by school authorities). Those buses originally allocated to evacuate schoolchildren that are not needed due to children being picked up by their parents, can be gainfully assigned to service other facilities or those persons who do not have access to private vehicles or to ride-sharing.

School buses/passenger vans are represented as two vehicles in the ETE simulations due to their larger size and more sluggish operating characteristics.

3.7 Special Event

During the kick-off meeting, an outage at the plant was determined to draw the most people into the EPZ, as per NRC Guidance. As such, an outage at the plant is considered as the special event (Scenario 11) for the ETE study. The plant outages occur during the weekdays in March and October. This event is considered a multi-day event.

Data obtained from APS personnel indicate there are 826 additional workers during an outage at peak times. Additionally, there are approximately 478 special projects support contractors that are on site during an outage, of which 71% work during the day and 29% work at night. During max shift, there are a total of 1,304 additional employees at the PVNGS site. Using a vehicle occupancy factor of 1.18 obtained from the demographic survey, there are a total of 1,105 additional vehicles at the plant during an outage. These vehicles were incorporated at the PVNGS parking lots on W Baseline Road.

Public transportation is not provided for this event and was not considered in the special event analysis. The special event vehicle trips were generated utilizing the same mobilization distributions as employees.

3.8 Access and/or Functional Needs Population

The MCDEM has a registration for transit-dependent and access and/or functional needs persons. Based on the type of transportation required (data provided by MCDEM) there are 354 access and/or functional needs people (284 buses and 70 paratransit)[1] within the EPZ, as shown in Table 3-9. Buses and paratransit buses needed to evacuate the access and/or functional needs population are represented as two vehicles in the ETE simulations due to their larger size and more sluggish operating characteristics.

3.9 External Traffic

Vehicles will be traveling through the EPZ (external-external trips) at the time of an emergency event. After the Advisory to Evacuate (ATE) is announced, these pass-through travelers will also evacuate. These through vehicles are assumed to travel on the major route traversing the EPZ – Interstate (I)-10. It is assumed that this traffic will continue to enter the study area during the first 45 minutes following the ATE. (See Section 9 and Appendix G for further discussion.)

Average Annual Daily Traffic (AADT) data was obtained from the Arizona Department of Transportation (AZDOT) to estimate the number of vehicles per hour on I-10. 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

[1] Breakdown of the access and/or functional needs population provided directly by MCDEM.

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 3-10, for each of the routes considered. The DDHV is then multiplied by 0.75 hours (Roadblocks are assumed to be activated at 45 minutes – 0.75 hours – after the ATE based upon information provided by MCDEM and APS) to estimate the total number of external vehicles loaded on the analysis network. As indicated, there are 3,070 vehicles entering the EPZ as external-external trips prior to the activation of the Roadblock and the diversion of this traffic. This number is reduced by 60% for evening scenarios (Scenarios 5 and 10) as discussed in Section 6.

3.10 Background Traffic

Section 5 discusses the time needed for the people in the EPZ to mobilize and begin their evacuation trips. As shown in Table 5-8, there are 14 time periods during which traffic is loaded on to roadways in the study area to model the mobilization time of people in the EPZ. Note, there is no traffic generated during the 15th time period, as this time period is intended to allow traffic that has already begun evacuating to clear the study area boundaries.

This study does not assume that roadways are empty at the start of Time Period 1. Rather, there is a 30-minute initialization time period (often referred to as “fill time” in traffic simulation) wherein the traffic volumes from Time Period 1 are loaded onto roadways in the study area. The amount of initialization/fill traffic that is on the roadways in the study area at the start of Time Period 1 depends on the scenario and the region being evacuated (see Section 6). There are 1,829 vehicles on the roadways in the study area at the end of fill time for an evacuation of the entire EPZ (Region R03) under Scenario 1 (summer, midweek, midday, with good weather) conditions.

3.11 Summary of Demand

A summary of population and vehicle demand is provided in Table 3-10 and Table 3-12, respectively. This summary includes all population groups described in this section. A total of 19,260 people and 13,808 vehicles are considered in this study.

Table 3-1. EPZ Permanent Resident Population

Sector	2011 Population[2]	2021 Population[3]
1-Mile Ring	41	24
A[4]	1,714	1,951
B	1,566	1,398
C	1,493	1,324
D	2,939	1,490
E	1,120	893
F	923	585
G	475	420
H	157	68
J	30	0
K	7	6
L	60	35
M	94	99
N	21	4
P	0	0
Q	590	384
R	1,244	1,031
EPZ TOTAL	**12,474**	**9,712**
EPZ Population Growth (2011 – 2021):		**-22.14%**

[2] Maricopa County Palo Verde Population Survey – Residents, December 2011
[3] Maricopa County Palo Verde Population Survey – Residents, September 2021
[4] Stage Stop RV Park is located in Sector A. The population at this facility is assumed to be included with the permanent resident population due to the large population reported within Sector A between 2 and 3 miles of the plant and presence of electrical hook-ups at the facility.

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

Sector	2021 Population	2021 Resident Vehicles
1-Mile Ring	24	14
A[5]	1,951	1,149
B	1,398	821
C	1,324	780
D	1,490	877
E	893	525
F	585	344
G	420	247
H	68	40
J	0	0
K	6	4
L	35	20
M	99	58
N	4	2
P	0	0
Q	384	225
R	1,031	606
EPZ TOTAL	**9,712**	**5,712**

Table 3-3. Shadow Population Growth Rate

Year	Population
2010	6,180
2020	11,143
Growth Rate**:	6.1%

$$\text{Population Growth Rate} = \left(\frac{2020\ Population}{2010\ Population}\right)^{\frac{1}{2020-2010}} - 1$$

2021 Population = 2020 Population x (1 + Population Growth Rate)

**Growth rate used exclusively for extrapolating shadow population

[5] Stage Stop RV Park is located in Sector A. The population at this facility is assumed to be included with the permanent resident population due to the large population reported within Sector A between 2 and 3 miles of the plant and presence of electrical hook-ups at the facility.

Table 3-4. Shadow Population and Vehicles by Sector

Sector	2021 Population	Evacuating Vehicles
N	344	200
NNE	32	19
NE	6,002	3,531
ENE	2,919	1,703
E	1,992	1,157
ESE	200	117
SE	2	2
SSE	23	14
S	0	0
SSW	0	0
SW	0	0
WSW	0	0
W	0	0
WNW	51	30
NW	106	62
NNW	240	138
TOTAL	11,911	6,973

Table 3-5. Summary of Transients and Transient Vehicles

Sector	Transients	Transient Vehicles
1-Mile Ring	0	0
A	0	0
B	0	0
C	0	0
D	0	0
E	0	0
F	0	0
G	0	0
H	0	0
J	0	0
K	0	0
L	0	0
M	0	0
N	0	0
P	0	0
Q	0	0
R	23	8
TOTAL	23	8

Table 3-6. Summary of Employees and Employee Vehicles Commuting into the EPZ

Sector	Employees	Employee Vehicles
1-Mile Ring	2,480	2,102
A	0	0
B	0	0
C	0	0
D	57	48
E	221	23
F	0	0
G	0	0
H	243	206
J	0	0
K	0	0
L	0	0
M	0	0
N	0	0
P	0	0
Q	0	0
R	34	29
TOTAL	**3,035**	**2,408**

Table 3-7. Transit-Dependent Population Estimates

2021 EPZ Population	Survey Average HH Size with Indicated No. of Vehicles			Estimated No. of Households	Survey Percent HH with Indicated No. of Vehicles			Survey Percent HH with Commuters	Survey Percent HH with Non-Returning Commuters	Total People Requiring Transport	Estimated Ridesharing Percentage	People Requiring Public Transit	Percent Population Requiring Public Transit
	0	1	2		0	1	2						
9,712	0.00	1.72	2.56	3,665	0.0%	22.5%	49.1%	49.1%	50.9%	211	72%	59	0.6%

Table 3-8. School Population Demand Estimates

Sector	School Name	Enrollment	Buses/Passenger Vans Required
A	Tonopah Valley High School	810	17
A	Ruth Fisher Middle School	731	15
A	Crossroads Academy	15	1
C	Winters Well Elementary School	460	7
F	Arlington Elementary School	280	4
Shadow Region	Palo Verde Elementary School[6]	450	7
	STUDY AREA TOTAL:	**2,746**	**51**

Table 3-9. Access and/or Functional Needs Demand Summary

Population Group	Population	Vehicles deployed
Ambulatory	284	10
Wheelchair Bound	70	7
EPZ TOTAL:	**354**	**17**

Table 3-10. PVNGS EPZ External Traffic

Upstream Node	Downstream Node	Road Name	Direction	AZDOT AADT[7]	K-Factor[8]	D-Factor[8]	Hourly Volume	External Traffic
8023	137	I-10	Eastbound	38,266	0.107	0.5	2,047	1,535
8021	20	I-10	Westbound	38,266	0.107	0.5	2,047	1,535
							TOTAL:	**3,070**

[6] Palo Verde Elementary School is located in the Shadow Region. MCDEM indicated these schools would evacuate in the event of an emergency at the PVNGS.
[7] https://azdot.gov/sites/default/files/media/2021/09/2020-AADT-Interstate.pdf
[8] HCM 2016

Table 3-11. Summary of Population Demand[9]

Sector	Permanent Residents	Transit-Dependent	Transients	Employees	Schools	Special Event	Shadow Population[10]	External Traffic	Total
1-Mile Ring	24	0	0	2,480	0	1,304	0	0	3,808
A	1,951	12	0	0	1,556	0	0	0	3,519
B	1,398	9	0	0	0	0	0	0	1,407
C	1,324	8	0	0	460	0	0	0	1,792
D	1,490	9	0	57	0	0	0	0	1,556
E	893	5	0	221	0	0	0	0	1,119
F	585	4	0	0	280	0	0	0	869
G	420	3	0	0	0	0	0	0	423
H	68	0	0	243	0	0	0	0	311
J	0	0	0	0	0	0	0	0	0
K	6	0	0	0	0	0	0	0	6
L	35	0	0	0	0	0	0	0	35
M	99	1	0	0	0	0	0	0	100
N	4	0	0	0	0	0	0	0	4
P	0	0	0	0	0	0	0	0	0
Q	384	2	0	0	0	0	0	0	386
R	1,031	6	23	34	0	0	0	0	1,094
Shadow Region	0	0	0	0	450[11]	0	2,382	0	2,832
Total	**9,712**	**59**	**23**	**3,035**	**2,746**	**1,304**	**2,382**	**0**	**19,261**

[9] The MCDEM provided the access and/or functional needs population by transportation breakdown directly, no spatial distribution of the transportation was provided. As such, they are not included in this table.
[10] Shadow Population has been reduced to 20%. Refer to Figure 2-1 for additional information.
[11] According to MCDEM, Palo Verde Elementary School evacuates even though it is located in the Shadow Region.

Table 3-12. Summary of Vehicle Demand[12]

Sector	Permanent Residents	Transit-Dependent	Transients	Employees	Schools[13]	Special Event	Shadow Population[14]	External Traffic	Total
1-Mile Ring	14	0	0	2,102	0	1,105	0	0	3,221
A	1,149	2	0	0	66	0	0	0	1,217
B	821	2	0	0	0	0	0	0	823
C	780	2	0	0	14	0	0	0	796
D	877	0	0	48	0	0	0	0	925
E	525	0	0	23	0	0	0	0	548
F	344	0	0	0	8	0	0	0	352
G	247	2	0	0	0	0	0	0	249
H	40	0	0	206	0	0	0	0	246
J	0	0	0	0	0	0	0	0	0
K	4	0	0	0	0	0	0	0	4
L	20	0	0	0	0	0	0	0	20
M	58	0	0	0	0	0	0	0	58
N	2	0	0	0	0	0	0	0	2
P	0	0	0	0	0	0	0	0	0
Q	225	0	0	0	0	0	0	0	225
R	606	0	8	29	0	0	0	0	643
Shadow Region	0	0	0	0	14[15]	0	1,395	3,070	4,479
Total	**5,712**	**8**	**8**	**2,408**	**102**	**1,105**	**1,395**	**3,070**	**13,808**

[12] The MCDEM provided the access and/or functional needs population by transportation breakdown directly, no spatial distribution of the transportation was provided. As such, they are not included in this table.
[13] Buses and Passenger Vans evacuating children from schools are represented as two passenger vehicles. Refer to Section 3.6 and Section 8 for additional information.
[14] Shadow Population has been reduced to 20%. Refer to Figure 2-1 for additional information.
[15] According to MCDEM, Palo Verde Elementary School evacuates even though it is located in the Shadow Region.

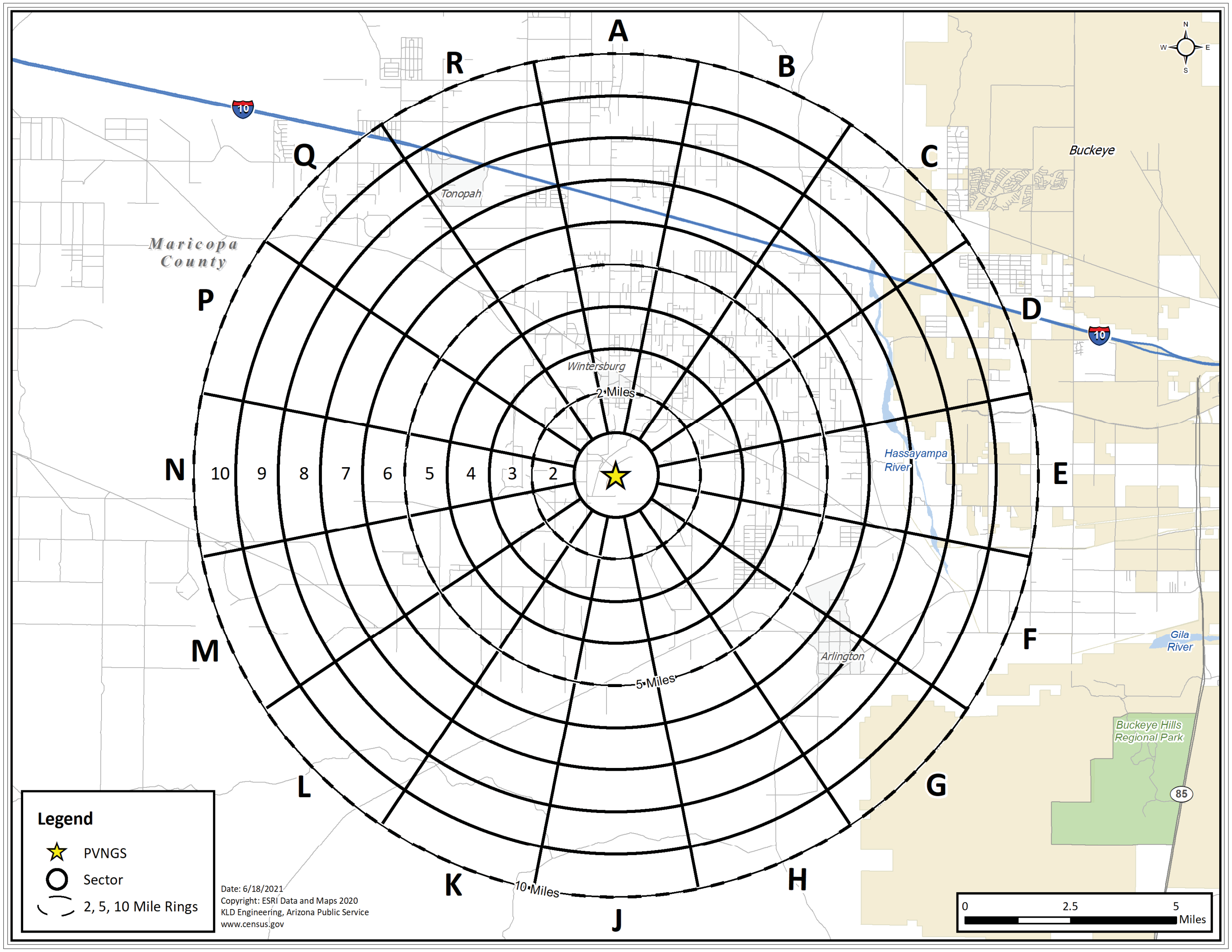
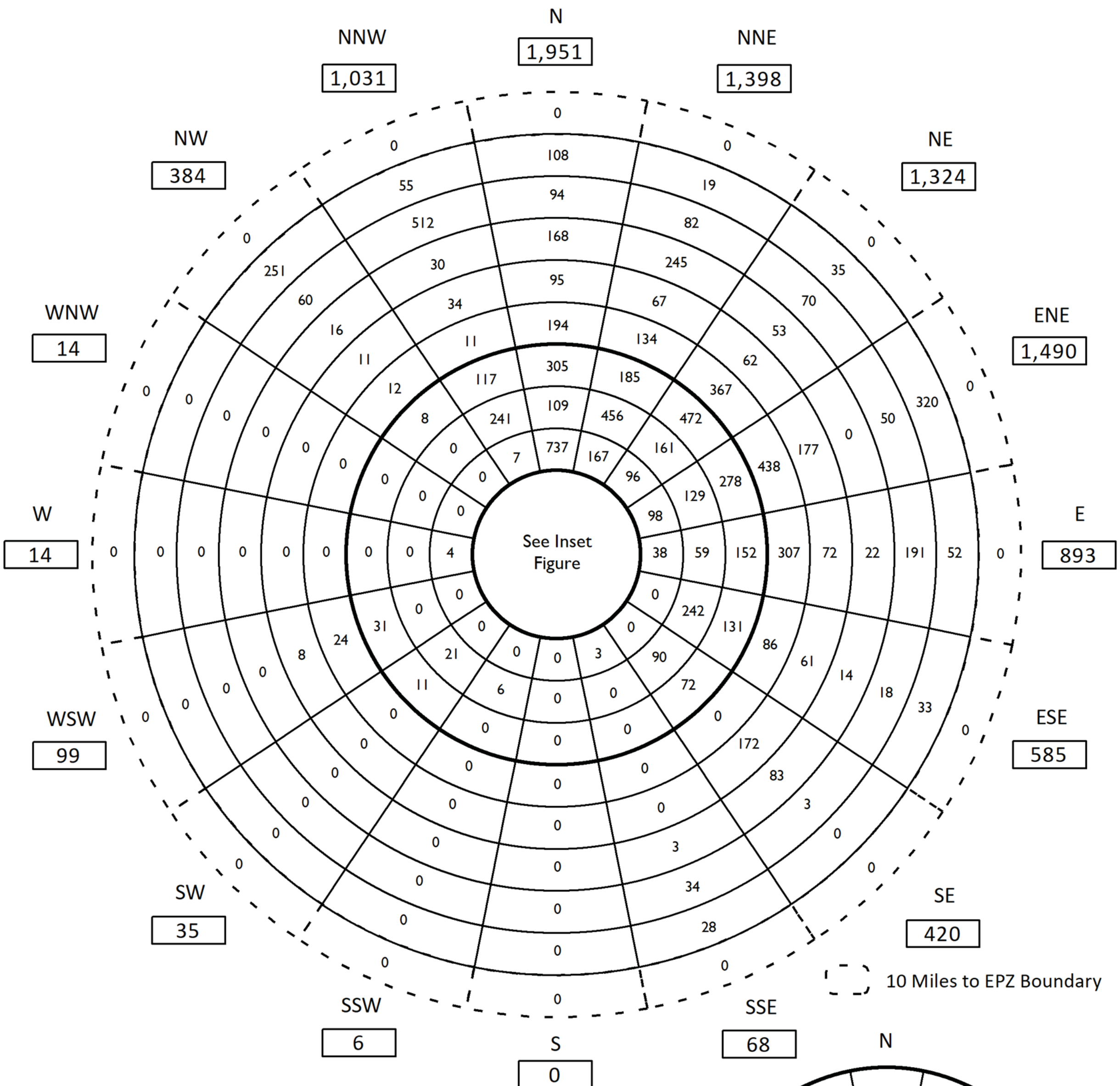
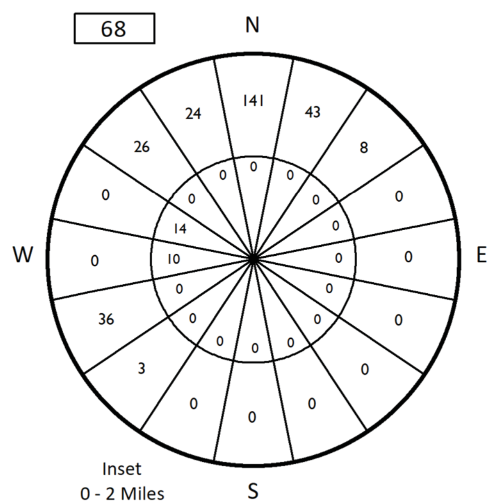


Figure 3-1. Sectors Comprising the PVNGS EPZ

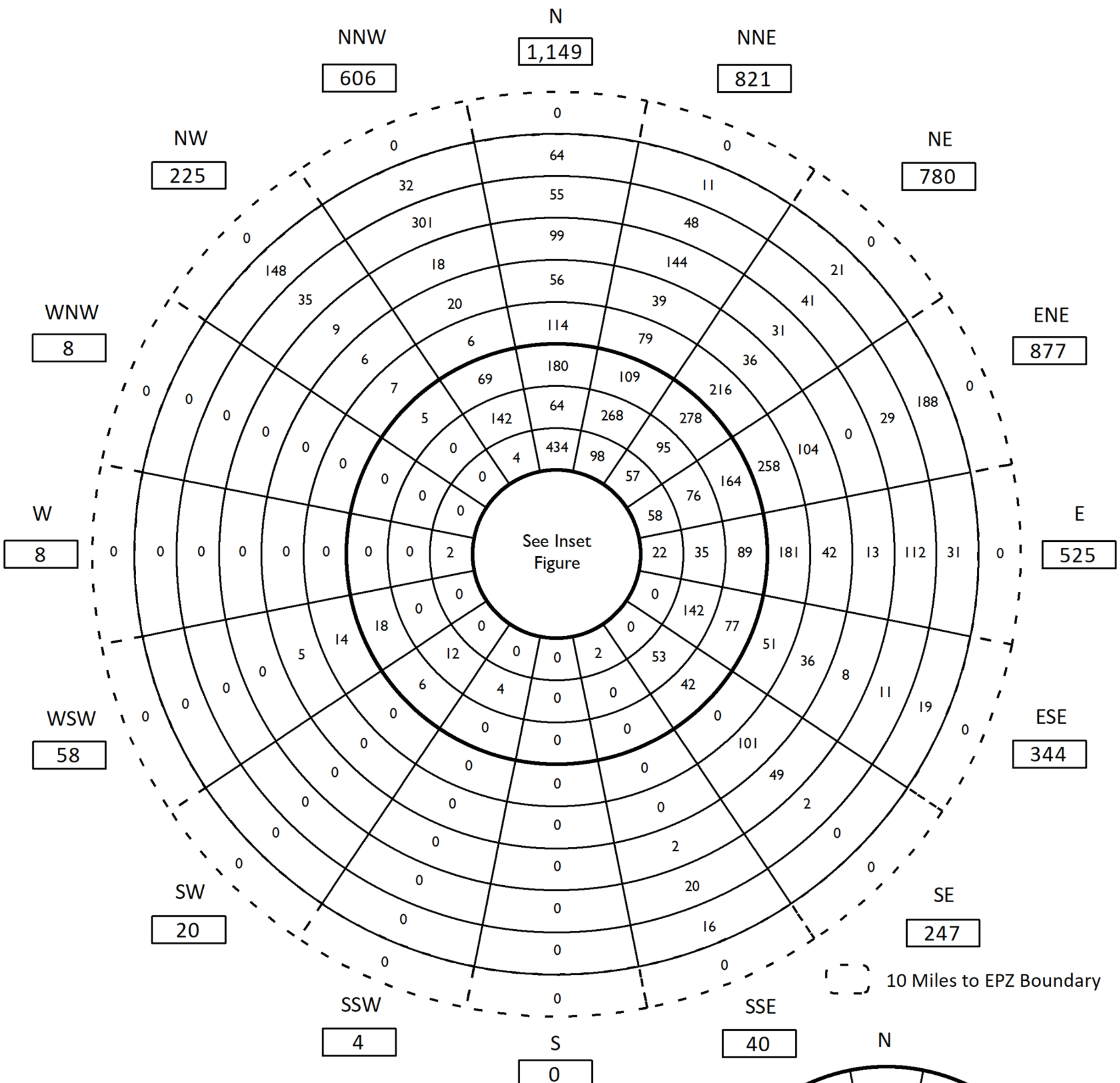




2021 Permanent Resident Population

Miles	Subtotal by Ring	Cumulative Total
0 - 1	24	24
1 - 2	281	305
2 - 3	1,150	1,455
3 - 4	1,514	2,969
4 - 5	1,762	4,731
5 - 6	1,573	6,304
6 - 7	759	7,063
7 - 8	634	7,697
8 - 9	1,114	8,811
9 - 10	901	9,712
10 - EPZ	0	9,712
	Total:	9,712

Figure 3-2. Permanent Resident Population by Sector



Resident Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	14	14
1 - 2	165	179
2 - 3	677	856
3 - 4	891	1,747
4 - 5	1,037	2,784
5 - 6	926	3,710
6 - 7	445	4,155
7 - 8	373	4,528
8 - 9	654	5,182
9 - 10	530	5,712
10 - EPZ	0	5,712
	Total:	5,712

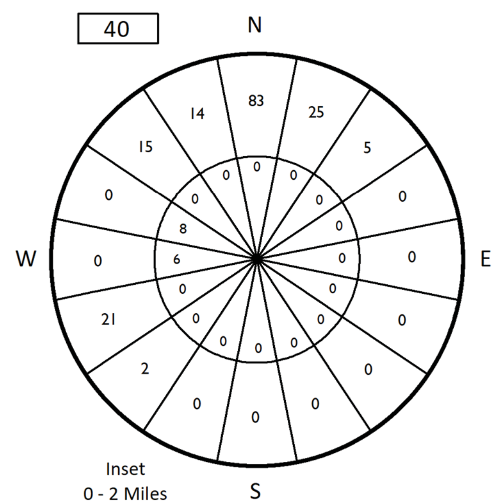
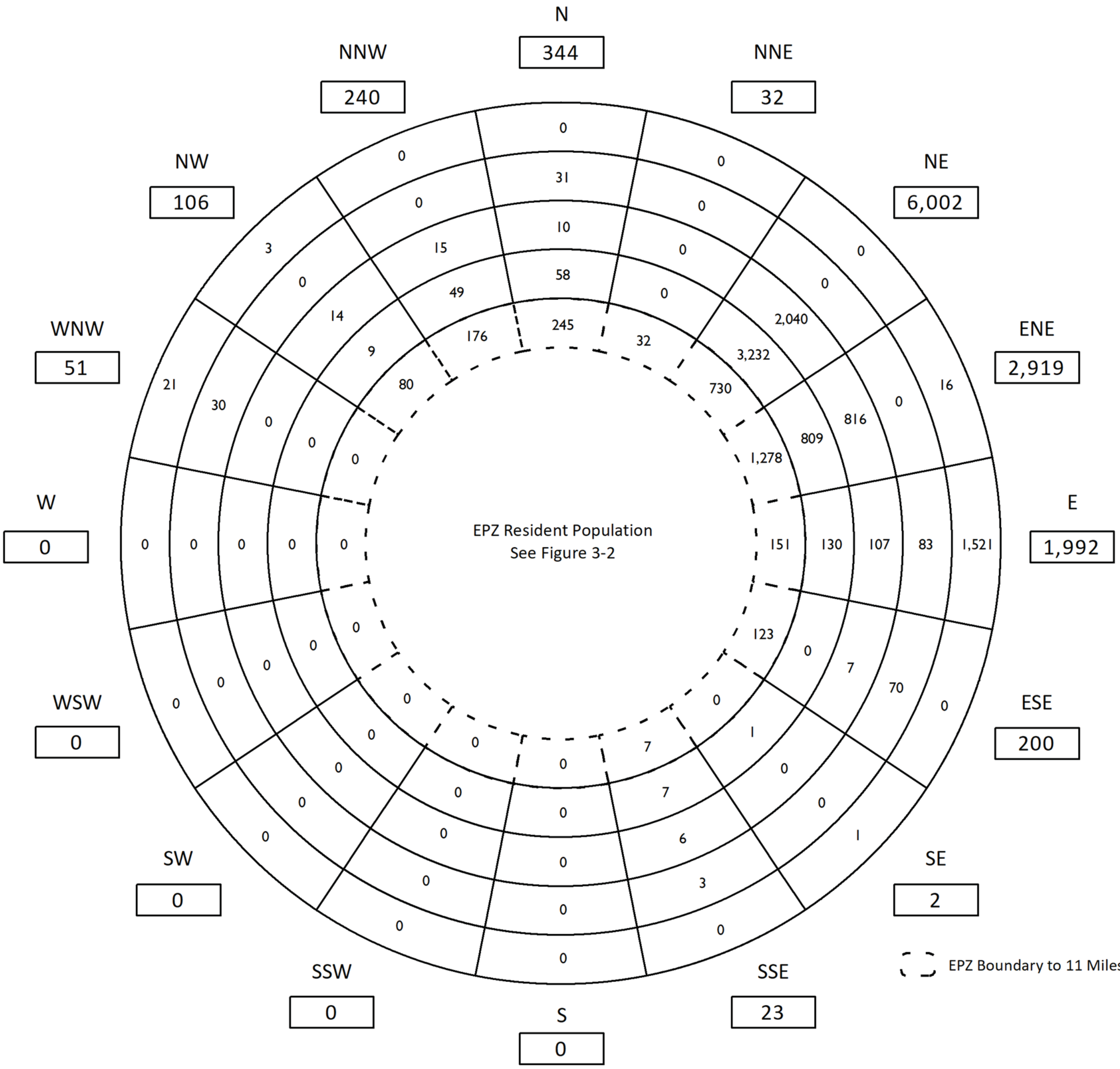


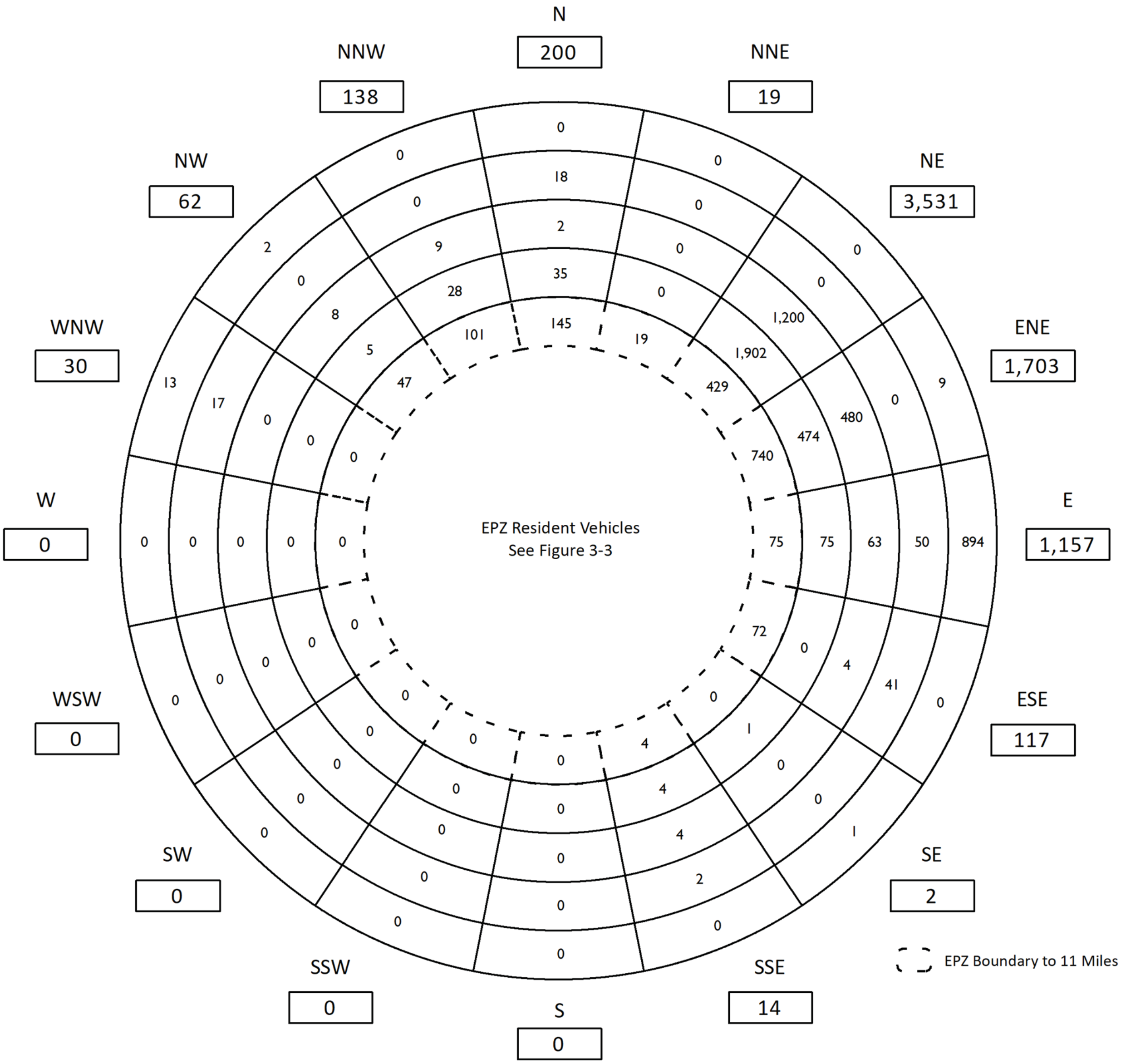
Figure 3-3. Permanent Resident Vehicles by Sector



2021 Extrapolated Shadow Population

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	2,822	2,822
11 - 12	4,295	7,117
12 - 13	3,015	10,132
13 - 14	217	10,349
14 - 15	1,562	11,911
	Total:	11,911

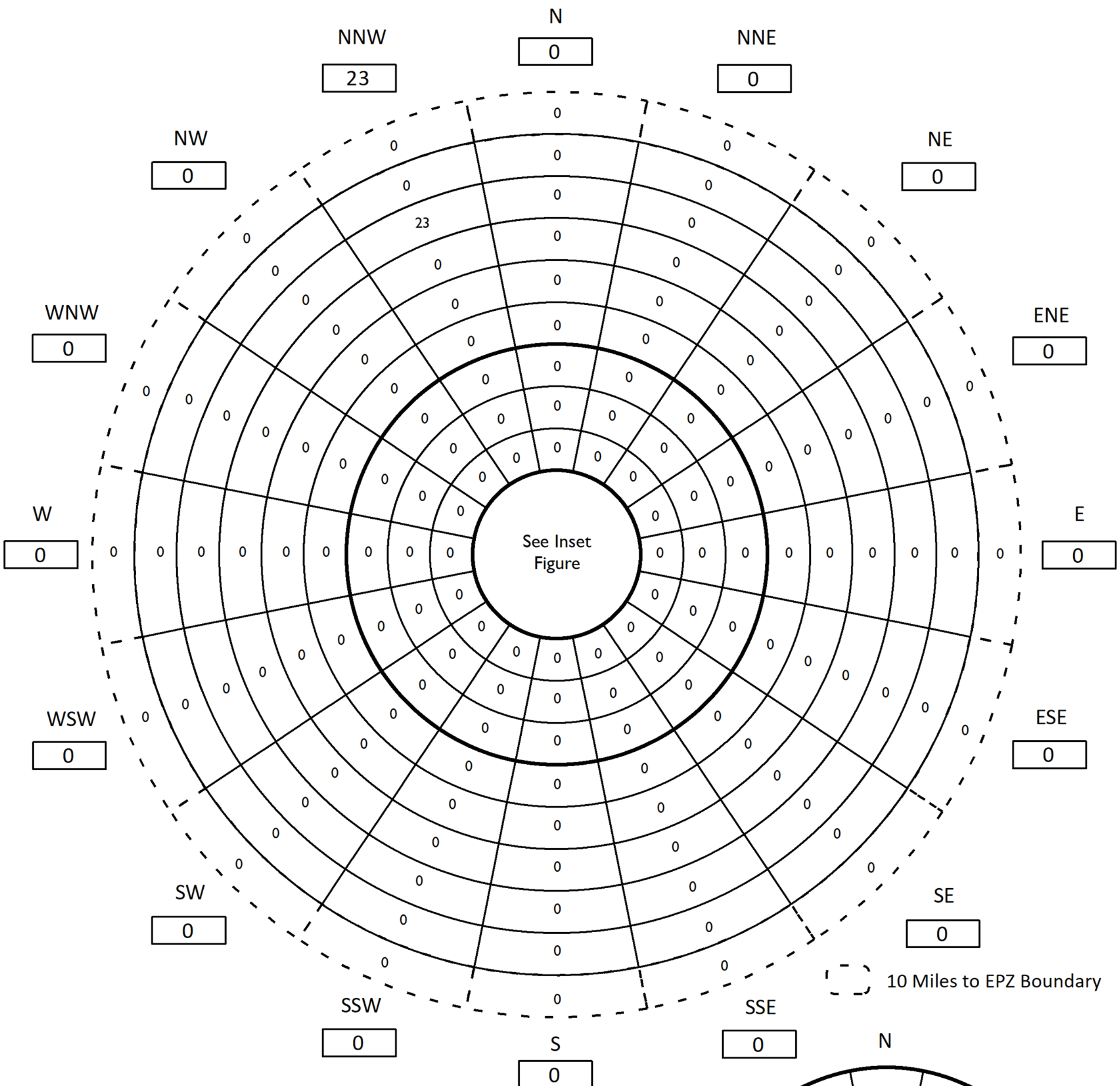
Figure 3-4. Shadow Population by Sector



Shadow Vehicles

Miles	Subtotal by Ring	Cumulative Total
EPZ - 11	1,632	1,632
11 - 12	2,524	4,156
12 - 13	1,770	5,926
13 - 14	128	6,054
14 - 15	919	6,973
	Total:	6,973

Figure 3-5. Shadow Vehicles by Sector



Transients

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	0	0
2 - 3	0	0
3 - 4	0	0
4 - 5	0	0
5 - 6	0	0
6 - 7	0	0
7 - 8	0	0
8 - 9	23	23
9 - 10	0	23
10 - EPZ	0	23
	Total:	23

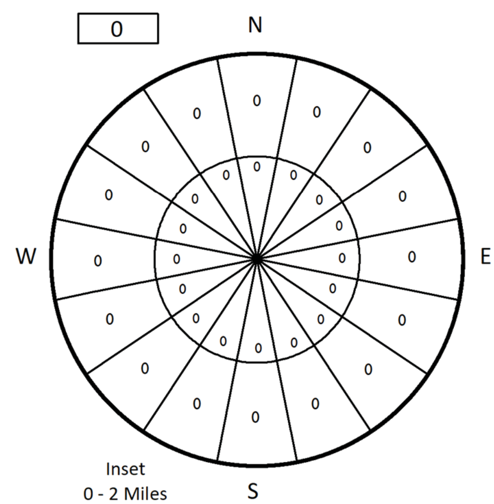
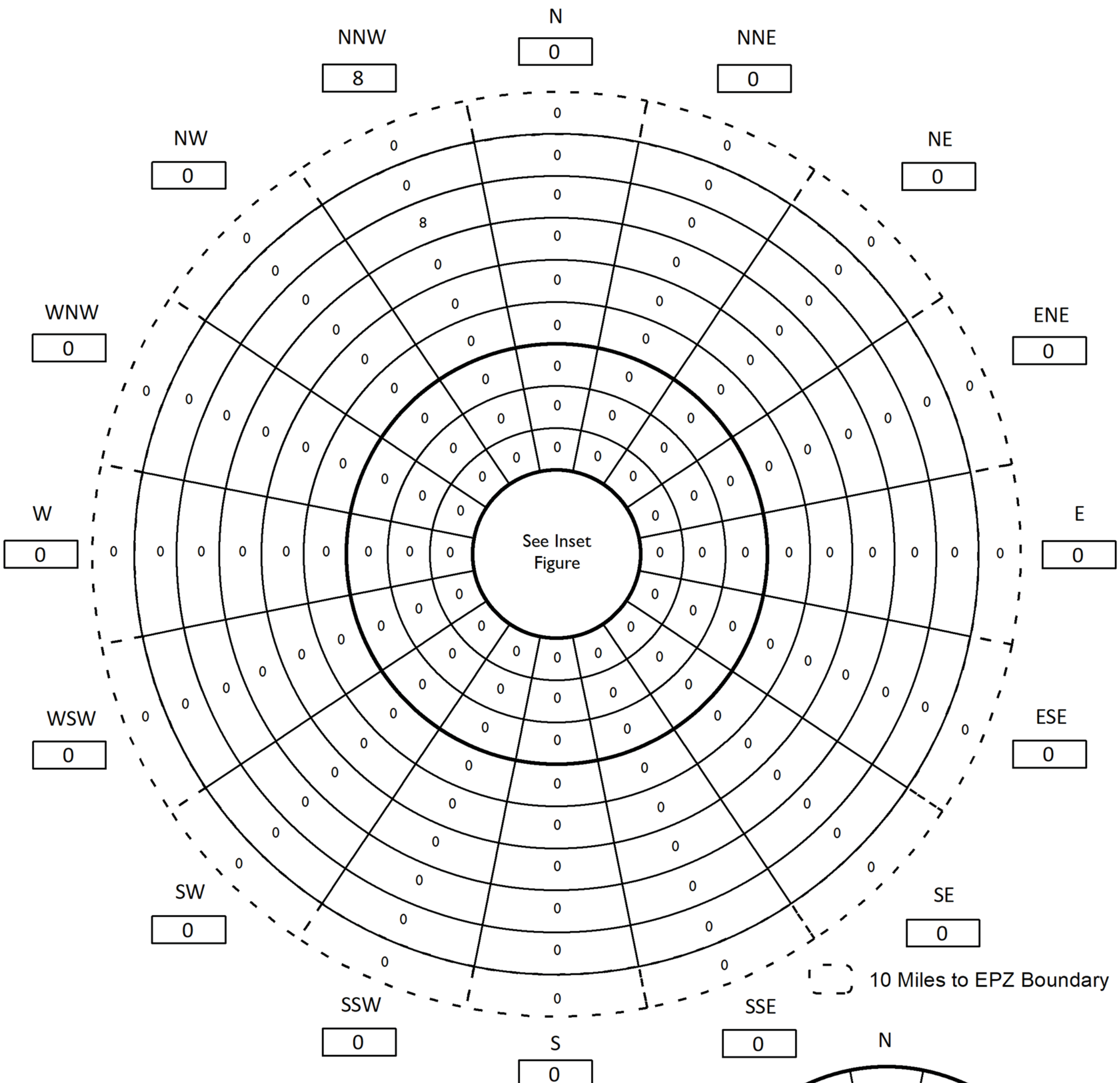


Figure 3-6. Transient Population by Sector



Transient Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	0	0
1 - 2	0	0
2 - 3	0	0
3 - 4	0	0
4 - 5	0	0
5 - 6	0	0
6 - 7	0	0
7 - 8	0	0
8 - 9	8	8
9 - 10	0	8
10 - EPZ	0	8
	Total:	8

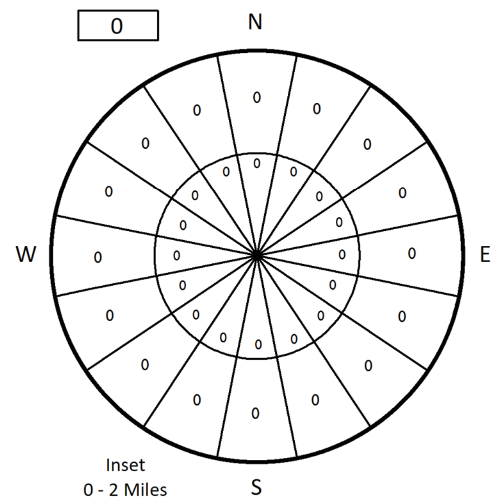
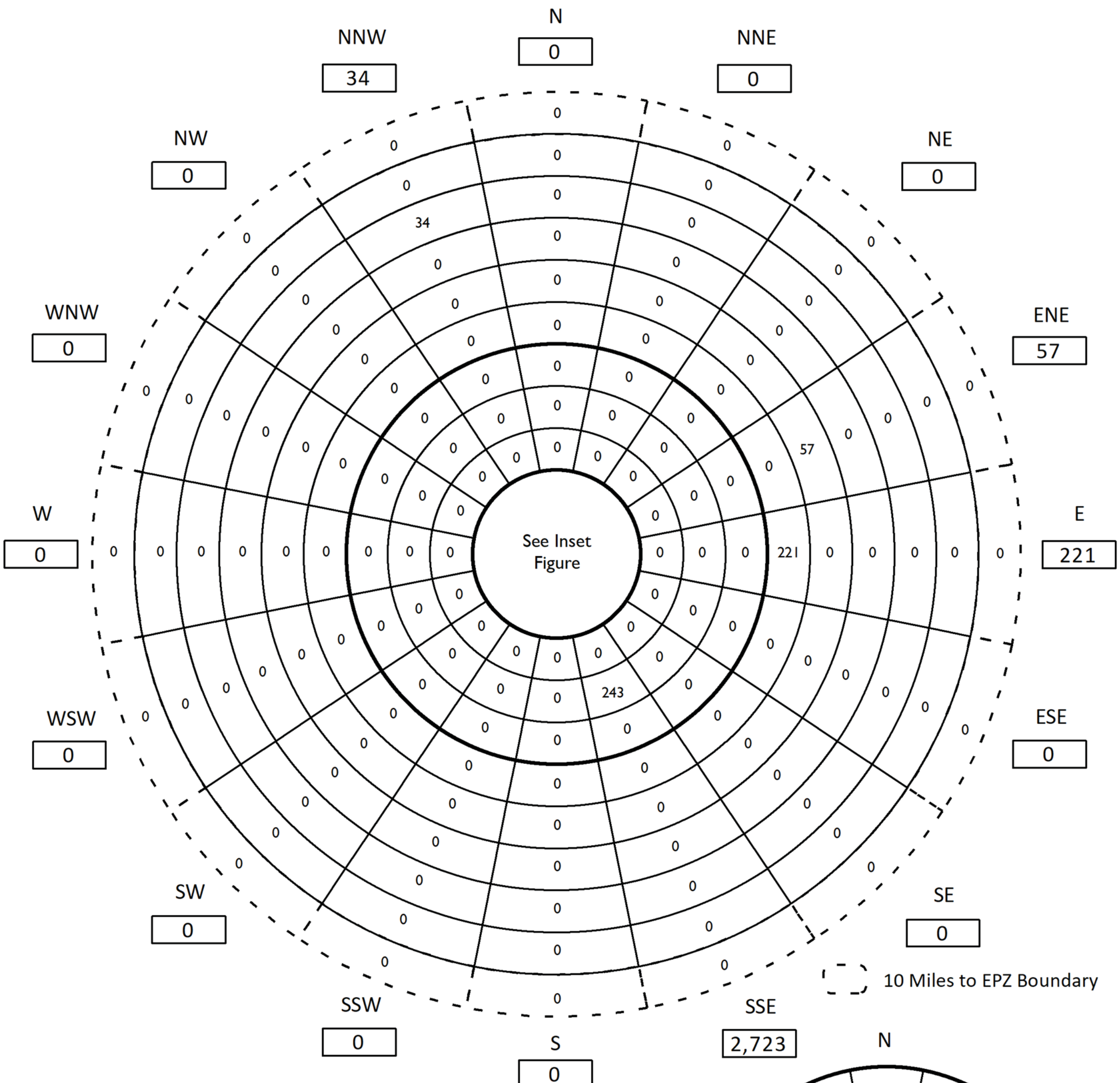


Figure 3-7. Transient Vehicles by Sector



Employees

Miles	Subtotal by Ring	Cumulative Total
0 - 1	2,480	2,480
1 - 2	0	2,480
2 - 3	0	2,480
3 - 4	243	2,723
4 - 5	0	2,723
5 - 6	221	2,944
6 - 7	57	3,001
7 - 8	0	3,001
8 - 9	34	3,035
9 - 10	0	3,035
10 - EPZ	0	3,035
	Total:	3,035

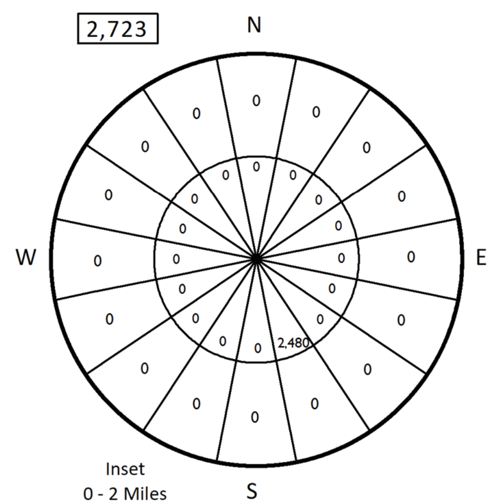
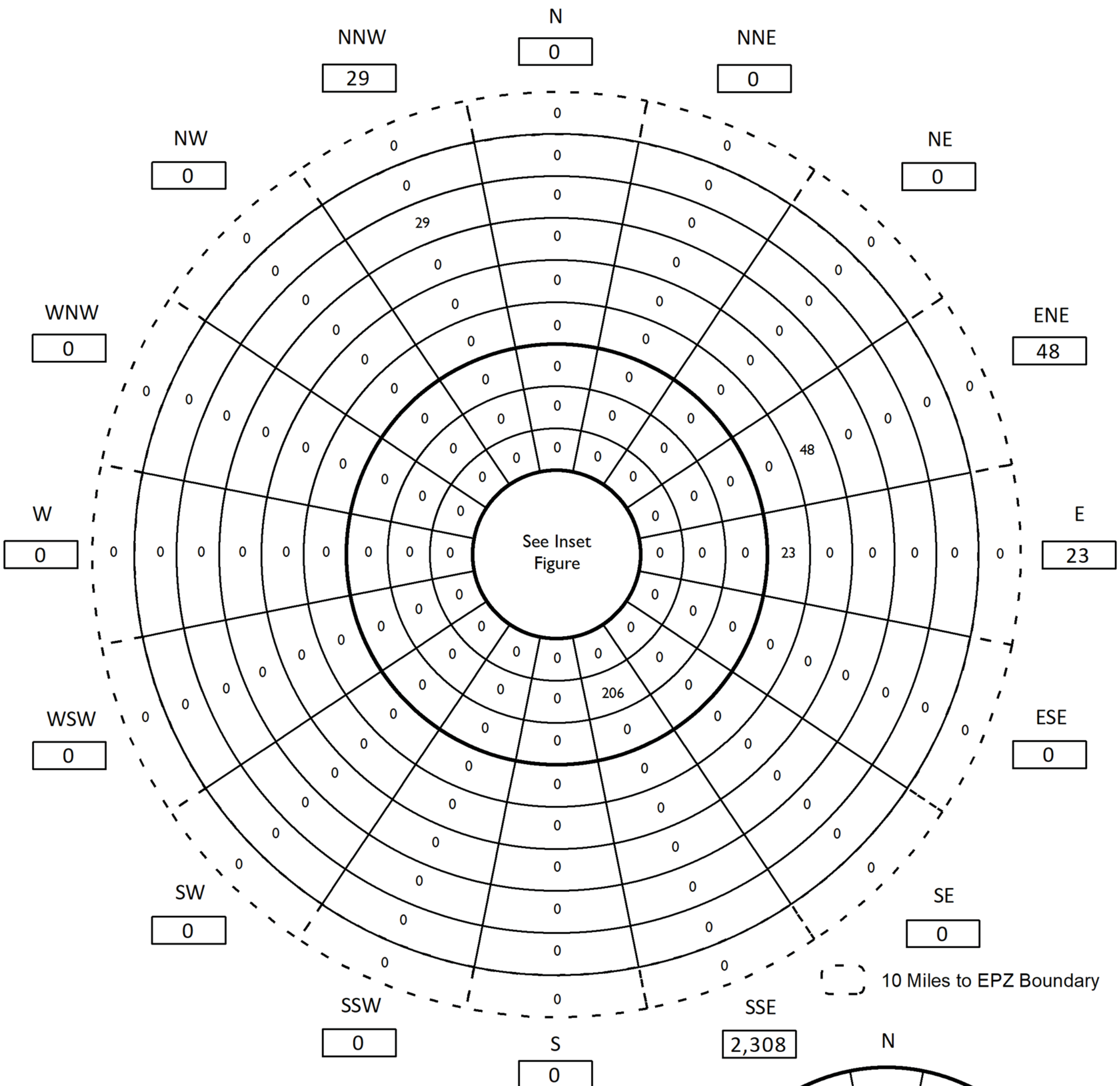


Figure 3-8. Employee Population by Sector



Employee Vehicles

Miles	Subtotal by Ring	Cumulative Total
0 - 1	2,102	2,102
1 - 2	0	2,102
2 - 3	0	2,102
3 - 4	206	2,308
4 - 5	0	2,308
5 - 6	23	2,331
6 - 7	48	2,379
7 - 8	0	2,379
8 - 9	29	2,408
9 - 10	0	2,408
10 - EPZ	0	2,408
	Total:	2,408

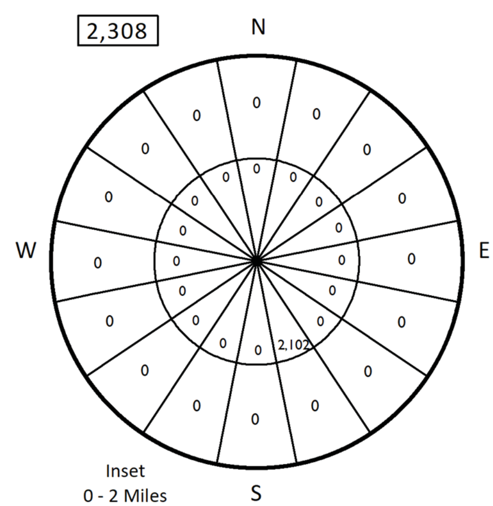


Figure 3-9. Employee Vehicles by Sector

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 2016 Highway Capacity Manual (HCM 2016). This section discusses how the capacity of the roadway network was estimated.

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". Service volume (SV) 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 SV at the upper bound of LOS E, only.

Thus, in simple terms, SV is the maximum traffic that can travel on a road and still maintain a certain perceived level of quality to a driver based on the A, B, C, rating system (LOS). Any additional vehicles above the SV would drop the rating to a lower letter grade.

This distinction is illustrated in Exhibit 12-37 of the HCM 2016. 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, wind speed)

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 2016. Consequently, lane and shoulder widths at the narrowest points were observed during the road survey and these observations were recorded, but no detailed

[1] A very rough estimate of BFFS might be taken as the posted speed limit plus 10 mph (HCM 2016 Page 15-15).

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. Free flow speeds ranged from 20 to 75 mph. Capacity is estimated from the procedures of the HCM 2016. For example, HCM 2016 Exhibit 7-1(b) shows the sensitivity of SV at the upper bound of LOS D to grade (capacity is the SV at the upper bound of LOS E).

The amount of traffic that can flow on a roadway is effectively governed by vehicle speed and spacing. The faster that vehicles can travel when closely spaced, the higher the amount of flow. As discussed in Section 2.6, it is necessary to adjust capacity figures to represent the prevailing conditions. Adverse conditions like inclement weather, construction, and other incidents tend to slow traffic down and often, also increase vehicle-to-vehicles separation, thus decreasing the amount of traffic flow. Based on limited empirical data, weather conditions such as rain reduce the values of free-flow 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 2.6, 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. See Appendix G for more information.

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,

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

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 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 2016.

The above discussion is necessarily brief given the scope of this Evacuation Time Estimate (ETE) report and the complexity of the subject of intersection capacity. In fact, Chapters 19, 20 and 21 in the HCM 2016 address this topic. The factors, F_1, F_2, …, influencing saturation flow rate are identified in equation (19-8) of the HCM 2016.

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 SV (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 SV increases as demand volume and density increase, until the SV 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 SV) 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.

[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 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 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 ETE 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 15-46 in the HCM 2016 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 HCM 2016. The DYNEV II simulation

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

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.

4.3 Application to the PVNGS 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:

> 2016 Highway Capacity Manual (HCM 2016)
> Transportation Research Board
> National Research Council
> Washington, D.C.

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

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

Each of these classifications will be discussed.

4.3.1 Two-Lane Roads

Ref: HCM 2016 Chapter 15

Two lane roads comprise the majority of highways within the study area. The per-lane capacity of a two-lane highway is estimated at 1,700 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 3,200 pc/h. The HCM 2016 procedures then estimate 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 study area 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 Multilane Highway

Ref: HCM 2016 Chapter 12

Exhibit 12-8 of the HCM 2016 presents a set of curves that indicate a per-lane capacity ranging from approximately 1,900 to 2,300 pc/h, for free-speeds of 45 to 70 mph, respectively. Based

on observation, the multilane highways outside of urban areas within the study area, service traffic with free-speeds in this range. The actual time-varying speeds computed by the simulation model reflect the demand and capacity relationship and the impact of control at intersections. A conservative estimate of per-lane capacity of 1,900 pc/h is adopted for this study for multilane highways outside of urban areas, as shown in Appendix K.

4.3.3 Freeways

Ref: HCM 2016 Chapters 10, 12, 13, 14

Chapter 10 of the HCM 2016 describes a procedure for integrating the results obtained in Chapters 12, 13 and 14, which compute capacity and LOS for freeway components. Chapter 10 also presents a discussion of simulation models. The DYNEV II simulation model automatically performs this integration process.

Chapter 12 of the HCM 2016 presents procedures for estimating capacity and LOS for “Basic Freeway Segments". Exhibit 12-37 of the HCM 2016 presents capacity vs. free speed estimates, which are provided below.

Free Speed (mph):	55	60	65	70+
Per-Lane Capacity (pc/h):	2,250	2,300	2,350	2,400

The inputs to the simulation model are highway geometrics, free-speeds and capacity based on field observations. The simulation logic calculates actual time-varying speeds based on demand: capacity relationships. A conservative estimate of per-lane capacity of 2,250 pc/h is adopted for this study for freeways, as shown in Appendix K.

Chapter 13 of the HCM 2016 presents procedures for estimating capacity, speed, density and LOS for freeway weaving sections. The simulation model contains logic that relates speed to demand volume: capacity ratio. The value of capacity obtained from the computational procedures detailed in Chapter 13 depends on the "Type" and geometrics of the weaving segment and on the "Volume Ratio" (ratio of weaving volume to total volume).

Chapter 14 of the HCM 2016 presents procedures for estimating capacities of ramps and of "merge" areas. There are three significant factors to the determination of capacity of a ramp-freeway junction: The capacity of the freeway immediately downstream of an on-ramp or immediately upstream of an off-ramp; the capacity of the ramp roadway; and the maximum flow rate entering the ramp influence area. In most cases, the freeway capacity is the controlling factor. Values of this merge area capacity are presented in Exhibit 14-10 of the HCM 2016 and depend on the number of freeway lanes and on the freeway free speed. Ramp capacity is presented in Exhibit 14-12 and is a function of the ramp FFS. The DYNEV II simulation model logic simulates the merging operations of the ramp and freeway traffic in accord with the procedures in Chapter 14 of the HCM 2016. If congestion results from an excess of demand

relative to capacity, then the model allocates service appropriately to the two entering traffic streams and produces LOS F conditions (The HCM 2016 does not address LOS F explicitly).

4.3.4 Intersections

Ref: HCM 2016 Chapters 19, 20, 21, 22

Procedures for estimating capacity and LOS for approaches to intersections are presented in Chapter 19 (signalized intersections), Chapters 20, 21 (un-signalized intersections) and Chapter 22 (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.

4.4 Simulation and Capacity Estimation

Chapter 6 of the HCM 2016 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 involving several HCM chapters. 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 2016 – 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 2016 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) 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 2016, as described earlier. These parameters are listed in Appendix K, for each network link.

It is important to note that simulation is a mathematical representation of an assumed set of conditions using the best available knowledge and understanding of traffic flow and available inputs. Simulation should not be assumed to be a prediction of what will happen under any event because a real evacuation can be impacted by an infinite number of things – many of which will differ from these test cases – and many others cannot be taken into account with the tools available.

4.5 Boundary Conditions

As illustrated in Figure 1-2 and in Appendix K, the link-node analysis network used for this study is finite. The analysis network does extend well beyond the 15-mile radial study area in some locations in order to model intersections with other major evacuation routes beyond the study area. However, the network does have an end at the destination (exit) nodes as discussed in Appendix C. Beyond these destination nodes, there may be signalized intersections or merge points that impact the capacity of the evacuation routes leaving the study area. Rather than neglect these "boundary conditions", this study assumes a 25% reduction in capacity on two-lane roads (Section 4.3.1 above) and multilane highways (Section 4.3.2 above). There is no reduction in capacity for freeways due to boundary conditions. The 25% reduction in capacity is based on the prevalence of actuated traffic signals in the study area and the fact that the evacuating traffic volume will be more significant than the competing traffic volume at any downstream signalized intersections, thereby warranting a more significant percentage (75% in this case) of the signal green time.

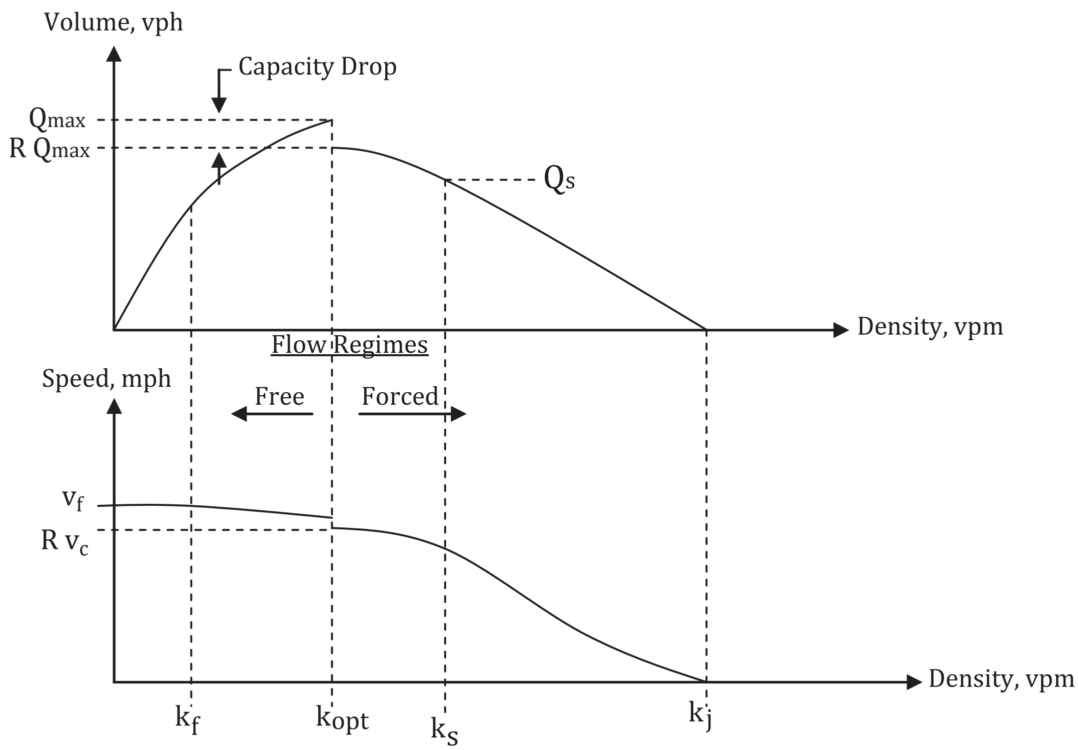


Figure 4-1. Fundamental Diagrams

5 ESTIMATION OF TRIP GENERATION TIME

Federal guidance (see NUREG CR-7002, Rev. 1) specify that the planner estimate the distributions of elapsed times associated with mobilization activities undertaken by the public to prepare for the evacuation trip. The elapsed time associated with each activity is represented as a statistical distribution reflecting differences between members of the public. The quantification of these activity-based distributions relies largely on the results of the demographic survey. We define the sum of these distributions of elapsed times as the Trip Generation Time Distribution.

5.1 Background

In general, an accident at a nuclear power plant is characterized by the following Emergency Classification Levels (see Section C of Part IV of Appendix E of 10 CFR 50 for details):

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

At each level, the Federal guidelines specify a set of Actions to be undertaken by the licensee, and by the state and local offsite agencies. As a Planning Basis, we will adopt a conservative posture, in accordance with Section 1.2 of NUREG/CR-7002, Rev. 1, that a rapidly escalating accident at the plant wherein evacuation is ordered promptly and no early protective actions have been implemented will be considered in calculating the Trip Generation time. We will assume:

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

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

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

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

For example, suppose one hour elapses from the siren alert to the ATE. In this case, it is reasonable to expect some degree of spontaneous evacuation by the public during this one-hour period. As a result, the population within the Emergency Planning Zone (EPZ) will be lower when the ATE is announced, than at the time of the siren alert. In addition, many will engage in preparation activities to evacuate, in anticipation that an Advisory will be broadcasted. Thus, the time needed to complete the mobilization activities and the number of people remaining to evacuate the EPZ after the ATE, will both be somewhat less than the estimates presented in this

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

The notification process consists of two events:

1. Transmitting information using the alert and notification systems (ANS) available within the EPZ (e.g., sirens, telephone, door-to-door contact, loud speakers).
2. Receiving and correctly interpreting the information that is transmitted.

The population within the EPZ is dispersed over an area of approximately 315 square miles and is engaged in a wide variety of activities. It must be anticipated that some time will elapse between the transmission and receipt of the information advising the public of an accident.

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

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

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

As indicated in Section 4.1 of NUREG/CR-7002, Rev. 1, the information required to compute trip generation times is typically obtained from a demographic survey of EPZ residents. Such a survey was conducted in support of this ETE study for this site. Appendix F discusses the survey sampling plan, documents the survey instrument utilized, and provides the survey results. It is important to note that the shape and duration of the evacuation trip mobilization distribution is important at sites where traffic congestion is not expected to cause the ETE to extend beyond the trip generation time period. The remaining discussion will focus on the application of the trip generation data obtained from the demographic survey to the development of the ETE documented in this report.

5.2 Fundamental Considerations

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

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

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

Associated with each sequence of events are one or more activities, as outlined in Table 5-1.

These relationships are shown graphically in Figure 5-1.

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

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

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

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

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

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

5.3 Estimated Time Distributions of Activities Preceding Event 5

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

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

Federal regulations (10CFR50 Appendix E, Item IV.D.3) stipulate, "[t]he design objective of the prompt public alert and notification system shall be to have the capability to essentially complete the initial alerting and initiate notification of the public within the plume exposure pathway EPZ within about 15 minutes". Furthermore, the 2019 Federal Emergency Management (FEMA) Radiological Emergency Preparedness (REP) Program Manual Part V Section B.1 Bullet 3 states that "Notification methods will be established to ensure coverage within 45 minutes of essentially 100% of the population.

Given the federal regulations and guidance, and the assumed presence of sirens within the EPZ, it is assumed that 100 percent of the population in the EPZ can be notified within 45 minutes. The assumed distribution for notifying the EPZ population is provided in Table 5-2. The distribution is plotted in Figure 5-2.

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

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

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

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

Distribution No. 4, Prepare to Leave Home: Activity 2, 4 $\rightarrow$ 5

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

5.4 Calculation of Trip Generation Time Distribution

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

To calculate the time distribution of an event that is dependent on two sequential activities, it is necessary to "sum" the distributions associated with these prior activities. The distribution summing algorithm is applied repeatedly to form the required distribution. As an outcome of this procedure, new time distributions are formed; we assign "letter" designations to these intermediate distributions to describe the procedure. Table 5-6 presents the summing procedure to arrive at each designated distribution.

Table 5-7 presents a description of each of the final trip generation distributions achieved after the summing process is completed.

5.4.1 Statistical Outliers

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

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

In assessing outliers, there are three alternatives to consider:

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

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

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

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

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

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

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

1) It is recognized that the overall trip generation distributions are conservative estimates, because they assume a household will do the mobilization activities sequentially, with no overlap of activities;
2) The individual mobilization activities (prepare to leave work, travel home, prepare home) are reviewed for outliers, and then the overall trip generation distributions are created (see Figure 5-1, Table 5-6, Table 5-7);
3) Outliers can be eliminated either because the response reflects a special population (e.g., access and/or functional needs, transit dependent) or lack of realism, because the purpose is to estimate trip generation patterns for personal vehicles;
4) To eliminate outliers,
    a) the mean and standard deviation of the specific activity are estimated from the responses,
    b) the median of the same data is estimated, with its position relative to the mean noted,
    c) the histogram of the data is inspected, and
    d) all values greater than 3.5 standard deviations are flagged for attention, taking special note of whether there are gaps (categories with zero entries) in the histogram display.

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

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

5) As a practical matter, even with outliers eliminated by the above, the resultant histogram, viewed as a cumulative distribution, is not a normal distribution. A typical situation that results is shown below in Figure 5-3.
6) In particular, the cumulative distribution differs from the normal distribution in two key aspects, both very important in loading a network to estimate evacuation times:
    a) Most of the real data is to the left of the “normal” curve above, indicating that the network loads faster for the first 80-85% of the vehicles, potentially causing more (and earlier) congestion than otherwise modeled;
    b) The last 10-15% of the real data “tails off” slower than the comparable “normal” curve, indicating that there is significant traffic still loading at later times.

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

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

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

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

The DYNEV II simulation model is designed to accept varying rates of vehicle trip generation for each origin centroid, expressed in the form of histograms. These histograms, which represent Distributions A, C, and D, properly displaced with respect to one another, are tabulated in Table 5-8 (Distribution B, Arrive Home, omitted for clarity).

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

5.4.2 Staged Evacuation Trip Generation

As defined in NUREG/CR-7002, Rev. 1, staged evacuation consists of the following:

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

Assumptions

1. The EPZ population in Sectors beyond 5 miles will react as does the population in the 2 to 5-Mile Region; that is, they will first shelter, then evacuate after the 90th percentile ETE for the 2-Mile Region, with the exception of the 20% non-compliance.

2. The population in the Shadow Region beyond the EPZ boundary, extending to 15 miles radially from the plant, will react as they do for all non-staged evacuation scenarios. That is 20% of these households will elect to evacuate with no shelter delay.
3. The transient population will not be expected to stage their evacuation because of the limited sheltering options available to people who may be at parks, on a beach, or at other venues. Also, notifying the transient population of a staged evacuation would prove difficult.
4. Employees will also be assumed to evacuate without first sheltering.

<u>Procedure</u>

1. Trip generation for population groups in the 2-Mile Region will be as computed based upon the results of the demographic survey and analysis.
2. Trip generation for the population subject to staged evacuation will be formulated as follows:
    a. Identify the 90th percentile evacuation time for the Sectors comprising the 2-Mile Region. This value, T_{Scen}^*, is obtained from simulation results. It will become the time at which the region being sheltered will be told to evacuate for each scenario.
    b. The resultant trip generation curves for staging are then formed as follows:
        i. The non-shelter trip generation curve is followed until a maximum of 20% of the total trips are generated (to account for shelter non-compliance).
        ii. No additional trips are generated until time T_{Scen}^*
        iii. Following time T_{Scen}^*, the balance of trips are generated:
            1. by stepping up and then following the non-shelter trip generation curve (if T_{Scen}^* is $\leq$ max trip generation time) or
            2. by stepping up to 100% (if T_{Scen}^* is > max trip generation time)
    c. Note: This procedure implies that there may be different staged trip generation distributions for different scenarios, however, that was not the case for this site NUREG/CR-7002, Rev. 1, uses the statement "approximately 90th percentile" as the time to end staging and begin evacuating. The value of T_{Scen}^* is about 2:15 (hrs:mins) for all scenarios on average (2:45 minutes for the special event scenario) (see Region R01 in Table 7-1).
    d. Note: Since approximately 92 percent of the 2-Mile Region is comprised of employees, the T_{Scen}^* value of 2:15 is dictated by the trip generation of these population groups as opposed to the trip generation of the permanent residents.
3. Staged trip generation distributions are created for the following population groups:
    a. Residents with returning commuters
    b. Residents without returning commuters

Figure 5-5 and Table 5-9 present the staged trip generation distributions for both residents with and without returning commuters and employees. At T_{Scen}^*, 20 percent of the permanent resident population (who normally would have completed their mobilization activities for an un-staged evacuation) advised to shelter has nevertheless departed the area. These people do not comply with the shelter advisory. Also included on the plot are the trip generation distributions for these groups as applied to the regions advised to evacuate immediately.

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

Figure 5-5 and Table 5-9 provides the trip generation histograms for staged evacuation.

5.4.3 Trip Generation for Recreational Areas

The State of Arizona/Maricopa County Offsite Emergency Response Plan for Palo Verde Generating Station (November 2017) established the basic notification process of notifying the public when an incident is occurring or has occurred at the Palo Verde Nuclear Generating Station. Transients will be notified by siren alerting system signals and other alerting methods. Maricopa County is responsible for activating the alter and warning system in the 10-mile EPZ. If siren system fails, telephone, door-to-door contact or loudspeakers mounted on patrol vehicles will be used.

As discussed in Section 2.3, this study assumes a rapidly escalating general emergency. As indicated in Table 5-2, this study assumes 100% notification in 45 minutes. Table 5-8 indicates that all transients will have mobilized within 1 hour 45 minutes. It is assumed that this timeframe is sufficient time for transients to return to their vehicles or lodging facilities and begin their evacuation trip.

Table 5-1. Event Sequence for Evacuation Activities

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

Table 5-2. Time Distribution for Notifying the Public

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

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

Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work	Elapsed Time (Minutes)	Cumulative Percent Employees Leaving Work
0	0.0%	40	88.9%
5	25.5%	45	93.1%
10	41.5%	50	95.4%
15	55.6%	55	96.4%
20	64.7%	60	99.7%
25	67.6%	65	99.8%
30	81.0%	70	99.9%
35	85.6%	75	100.0%

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

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

Elapsed Time (Minutes)	Cumulative Percent Returning Home	Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0.0%	55	86.5%
5	2.9%	60	93.9%
10	12.5%	65	95.0%
15	21.1%	70	95.6%
20	29.4%	75	96.5%
25	37.4%	80	97.3%
30	47.0%	85	98.2%
35	55.3%	90	99.0%
40	68.7%	95	99.4%
45	77.0%	100	99.7%
50	83.4%	105	100.0%

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

Table 5-5. Time Distribution for Population to Prepare to Leave Home

Elapsed Time (Minutes)	Cumulative Percent Returning Home	Elapsed Time (Minutes)	Cumulative Percent Returning Home
0	0.0%	135	89.8%
15	3.5%	150	91.4%
30	19.9%	165	91.7%
45	32.3%	180	93.8%
60	53.8%	195	96.2%
75	66.9%	210	97.6%
90	71.5%	225	97.8%
105	72.8%	240	98.7%
120	79.6%	255	100.0%

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

Table 5-6. Mapping Distributions to Events

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

Table 5-7. Description of the Distributions

Distribution	Description
A	Time distribution of commuters departing place of work (Event 3). Also applies to employees who work within the EPZ who live outside, and to Transients within the EPZ.
B	Time distribution of commuters arriving home (Event 4).
C	Time distribution of residents with commuters who return home, leaving home to begin the evacuation trip (Event 5).
D	Time distribution of residents without commuters returning home, leaving home to begin the evacuation trip (Event 5).

Table 5-8. Trip Generation Histograms for the EPZ Population for Un-Staged Evacuation

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period			
		Employees (Distribution A)	Transients (Distribution A)	Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)
1	15	5%	5%	0%	0%
2	15	25%	25%	0%	3%
3	15	33%	33%	0%	9%
4	15	22%	22%	1%	14%
5	15	10%	10%	4%	16%
6	30	5%	5%	16%	26%
7	30	0%	0%	25%	9%
8	30	0%	0%	19%	13%
9	30	0%	0%	14%	3%
10	30	0%	0%	9%	4%
11	30	0%	0%	5%	1%
12	30	0%	0%	3%	2%
13	30	0%	0%	2%	0%
14	30	0%	0%	2%	0%
15	600	0%	0%	0%	0%

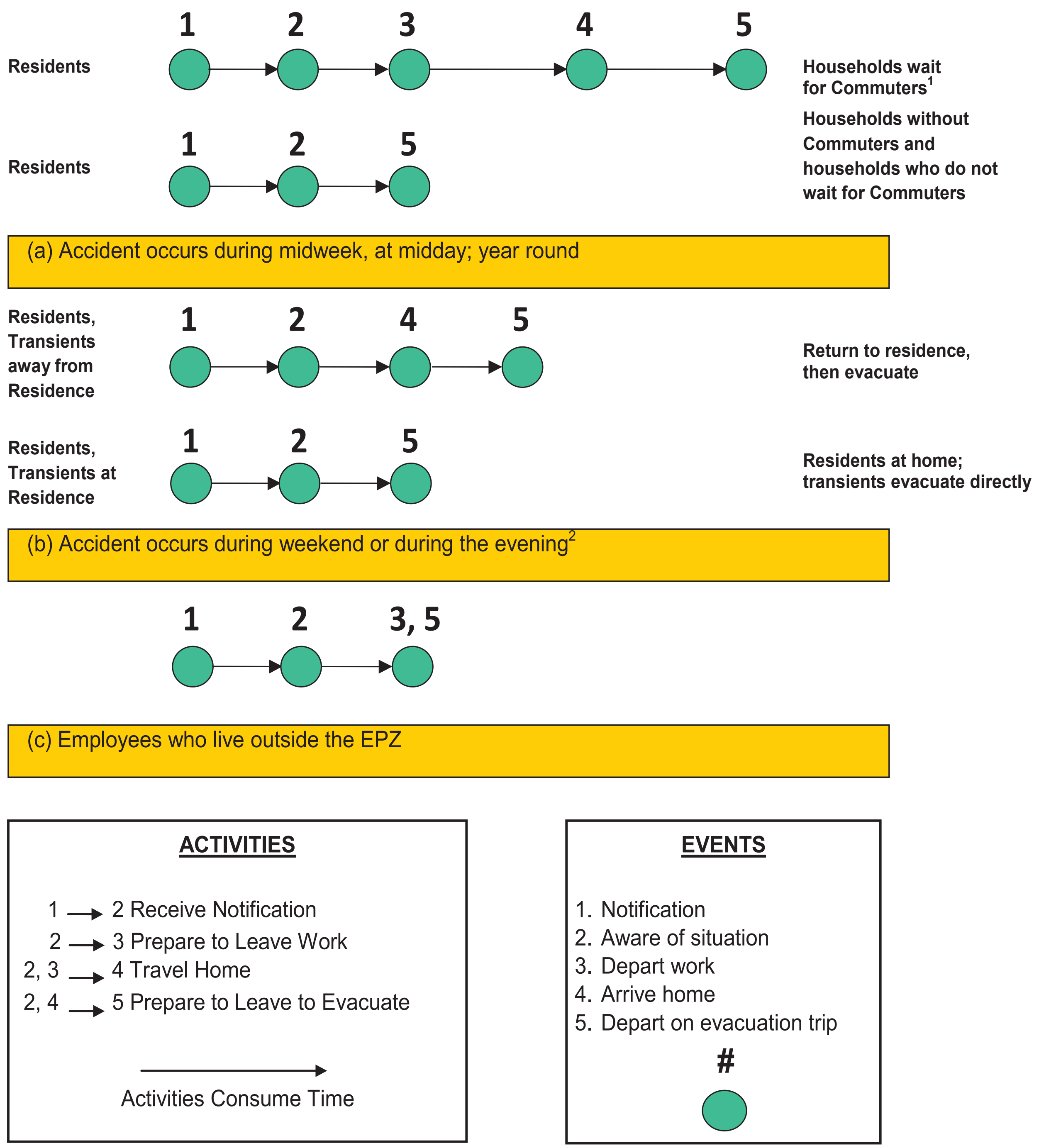
NOTE:

- Shadow vehicles are loaded onto the analysis network (Figure 1-2) using Distributions C.
- Special event vehicles are loaded using Distribution A.

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

Time Period	Duration (Min)	Percent of Total Trips Generated Within Indicated Time Period[1]	
		Residents with Commuters (Distribution C)	Residents Without Commuters (Distribution D)
1	15	0%	0%
2	15	0%	1%
3	15	0%	1%
4	15	0%	3%
5	15	1%	3%
6	30	3%	6%
7	30	5%	1%
8	30	56%	75%
9	30	14%	3%
10	30	9%	4%
11	30	5%	1%
12	30	3%	2%
13	30	2%	0%
14	30	2%	0%
15	600	0%	0%

[1] Trip Generation for Employees and Transients (see Table 5-8) is the same for Un-Staged and Staged Evacuation.



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

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

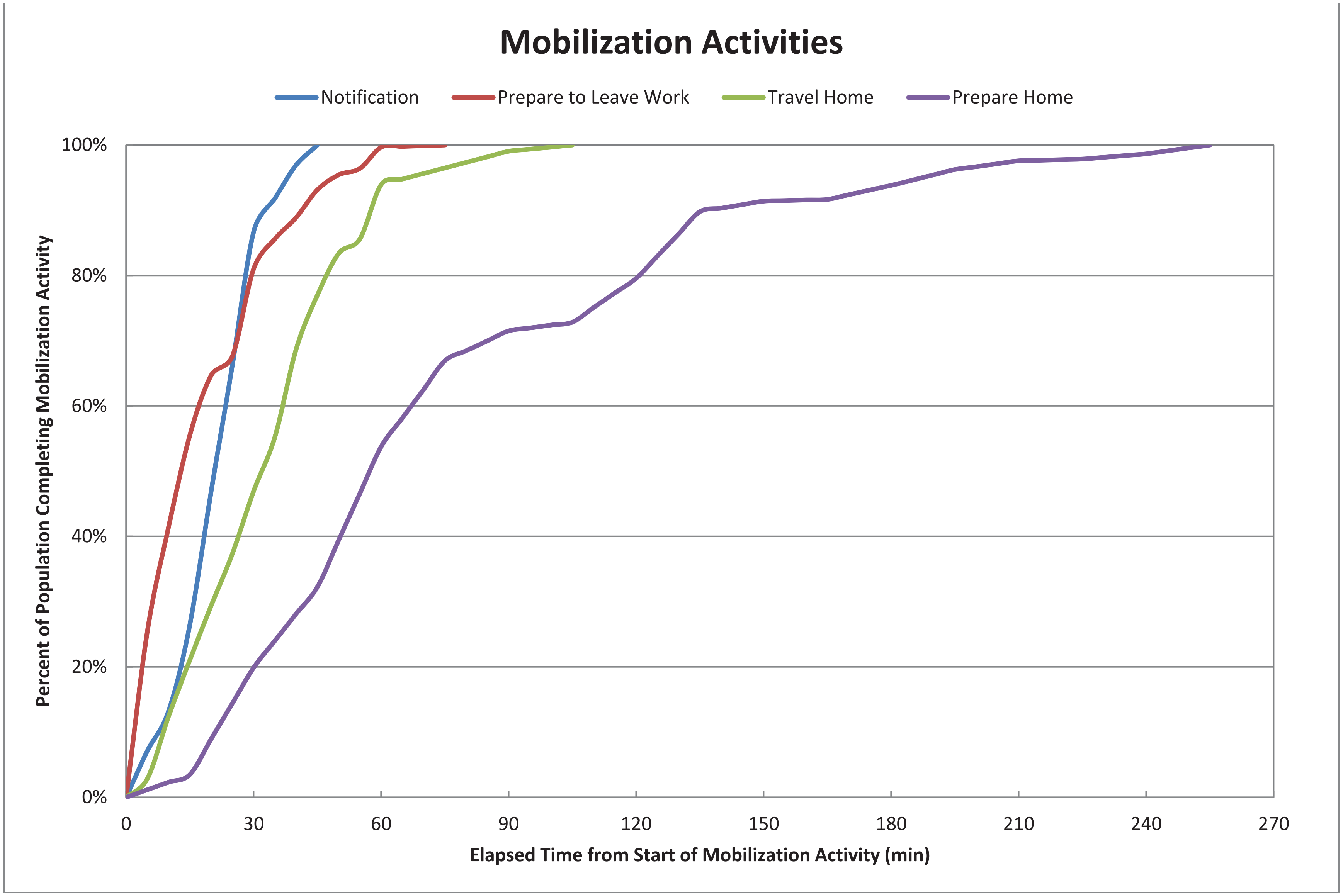


Figure 5-2. Time Distributions for Evacuation Mobilization Activities

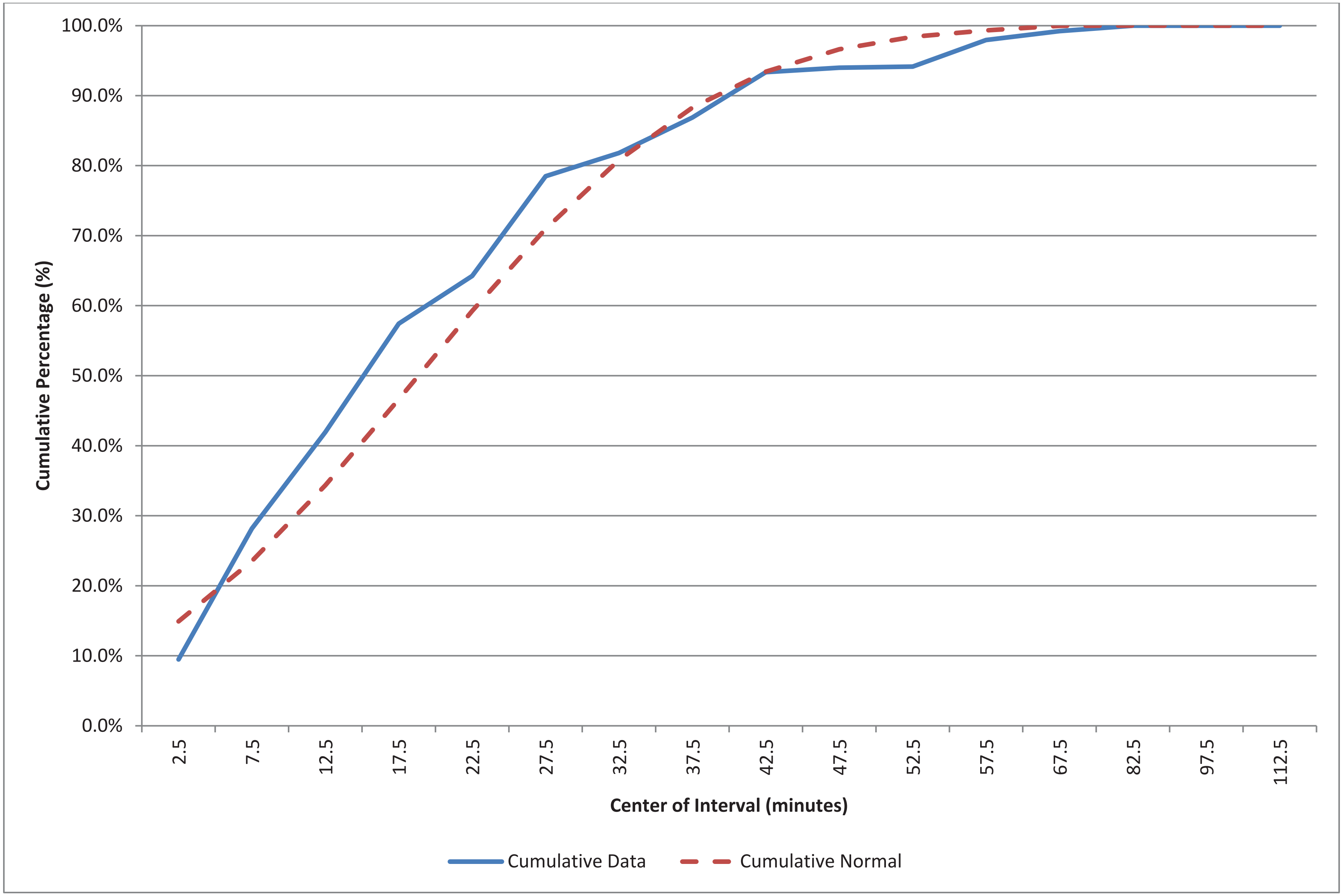


Figure 5-3. Comparison of Data Distribution and Normal Distribution

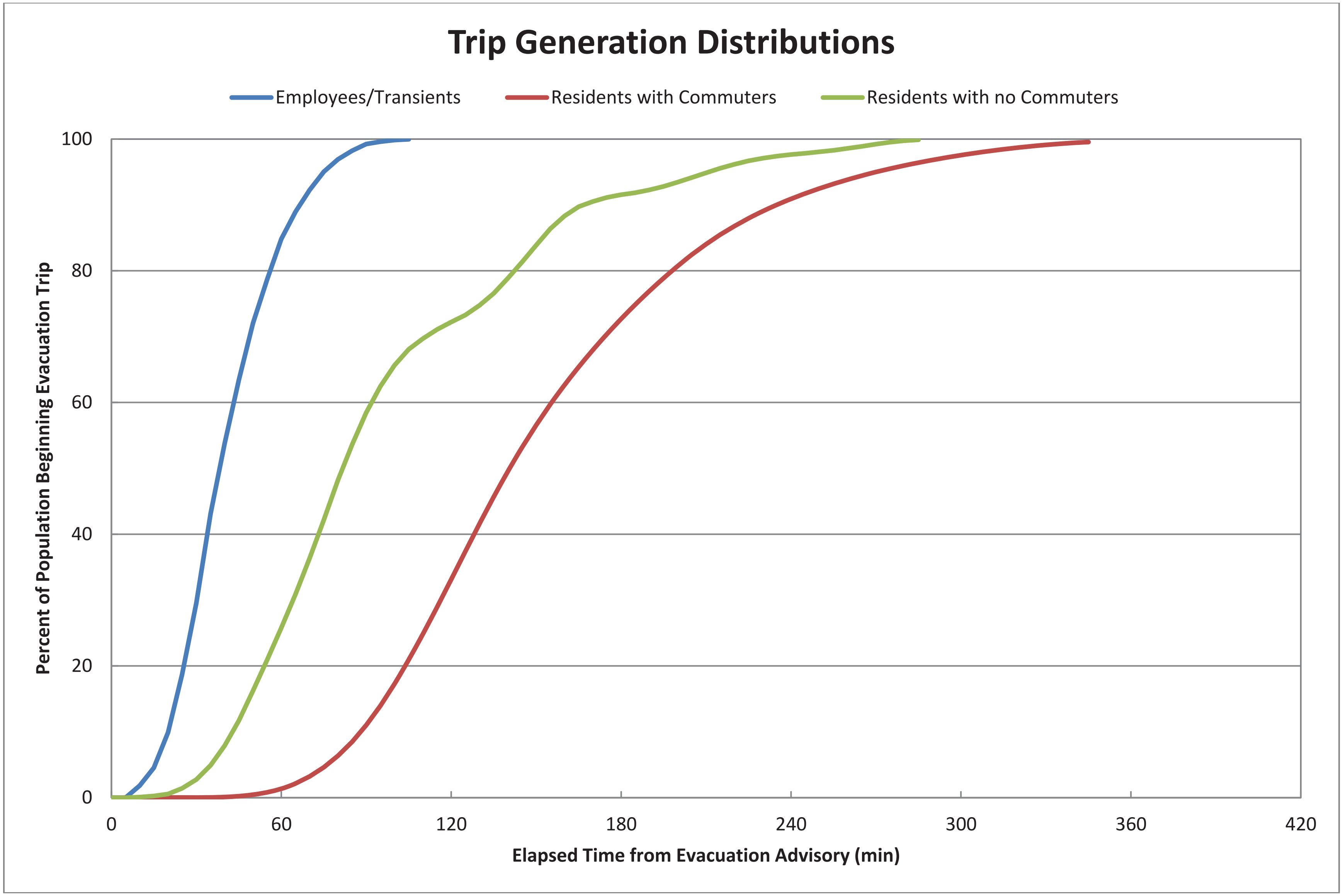


Figure 5-4. Comparison of Trip Generation Distributions

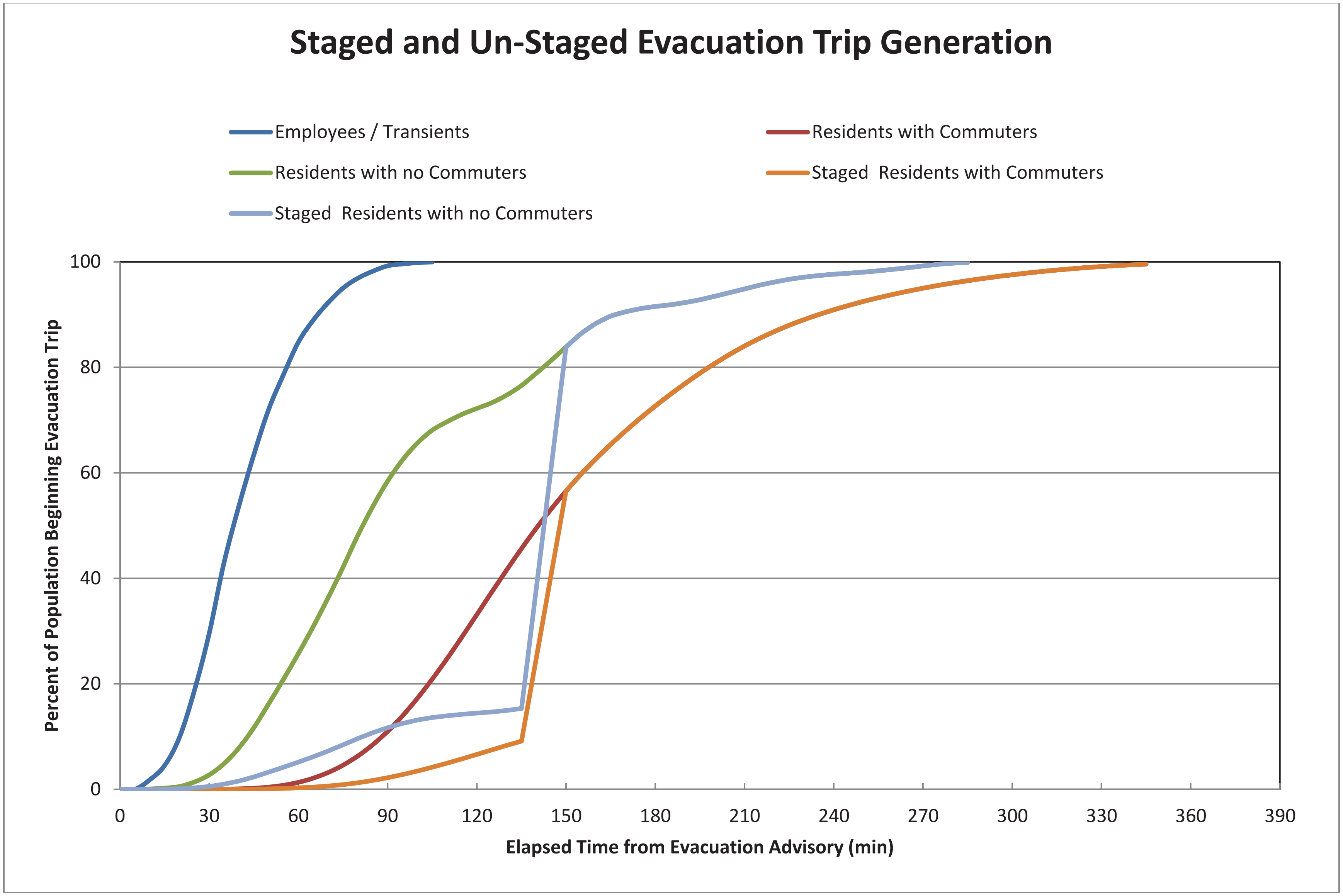


Figure 5-5. Comparison of Staged and Un-Staged Trip Generation Distributions in the 2 to 5 Mile Region

6 EVACUATION CASES

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

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

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

A total of 52 Regions were defined which encompass all the groupings of Sectors considered. These Regions are defined in Table 6-1. The Sector configurations are identified in Figure 6-1. Each keyhole sector-based area consists of a central circle centered at the power plant, and three adjoining sectors, each with a central angle of 22.5 degrees, as per NUREG/CR-7002, Rev. 1 guidance. The central sector coincides with the wind direction. These sectors extend to 5 miles from the plant (Regions R04 through Region R19) or to the EPZ boundary (Regions R20 through R35). Regions R01, R02 and R03 represent evacuations of circular areas with radii of 2, 5 and 10 miles, respectively. Regions R36 through R52 are identical to Regions R02, R04 through R19, respectively; however, those sectors between 2 miles and 5 miles are staged until 90% of the 2-Mile Region (Region R01) has evacuated. For Regions, where the wind is blowing from the east, east-southeast or southeast, two sectors on either side of the central sector (5 sectors total) are considered due to the swirling effect of the wind in the mountain range to the west of the plant.

A total of 12 Scenarios were evaluated for all Regions. Thus, there are a total of 52 x 12 = 624 evacuation cases. Table 6-2 provides a description of all Scenarios.

Each combination of region and scenario implies a specific population to be evacuated. The population group and the vehicle estimates presented in Section 3 and Appendix E are peak values. These peak values are adjusted depending on the Scenario and Region being considered, using Scenario and Region specific percentages; such that the average population is considered for each evacuation case. The Scenario percentages are presented in Table 6-3, while the Region percentages are provided in Table H-1. Table 6-4 presents the vehicle counts for each scenario for an evacuation of Region R03 – the entire EPZ, based on the scenario percentages in Table 6-3. The percentages presented in Table 6-3 were determined as follows:

The number of residents with commuters during the week (when workforce is at its peak) is equal to 24.48% (round down to 24%), which is the product of 49.1% (the number of households with at least one commuter – see Figure F-6) and 49.86% (the number of households with a commuter that would await the return of the commuter prior to evacuating – see Figure F-10). See assumption 3 in Section 2.3. It is estimated for weekend and evening

scenarios that 2% of those households with returning commuters will have a commuter at work during those times.

Employment is assumed to be at its peak (100%) during the winter, midweek, midday scenarios. Employment is reduced slightly (96%) for summer, midweek, midday scenarios. This is based on the estimation that 50% of the employees commuting into the EPZ will be on vacation for a week during the approximate 12 weeks of summer. It is further estimated that those taking vacation will be uniformly dispersed throughout the summer with approximately 4% of employees vacationing each week. It is assumed that only 10% of the employees are working in the evenings and during the weekends.

Based on the previous study, APS stated that transient activity is estimated to be at its peak (100%) during winter evenings and less (75%) during winter days, 40% during summer evenings and 30% during summer days. During an outage at the plant (Scenario 11), most of the transient attractions are occupied by outage workers who are already counted as special event population. Thus, the transient percentage is significantly less – 10% - for this scenario.

As noted in the shadow footnote to Table 6-3, the shadow percentages are computed using a base of 20% (see assumption 7 in Section 2.2); to include the employees within the Shadow Region who may choose to evacuate, the voluntary evacuation is multiplied by a scenario-specific proportion of employees to permanent residents in the Shadow Region. For example, using the values provided in Table 6-4 for Scenario 1, the shadow percentage is computed as follows:

$$20\% \times \left(1 + \frac{2{,}312}{1{,}397 + 4{,}315}\right) = 28.1\%$$

One special event – an outage at the plant – was considered as Scenario 11. Thus, the special event traffic is 100% evacuated for Scenario 11, and 0% for all other scenarios. As discussed above, since most of the additional outage workers stay at the transient facility in the EPZ, the percentage of transients was reduced to 10% for this scenario.

All schools in the study area (including Palo Verde Elementary School) is estimated that summer school enrollment is approximately 10% of enrollment during the regular school year for summer, midweek, midday scenarios. School is not in session during weekends and evenings, thus no buses (no passenger vans at Crossroads Academy) for school children are needed under those circumstances. As discussed in Section 7, schools are in session during the winter season, midweek, midday and 100% of buses will be needed under those circumstances.

Transit buses for the transit-dependent population are set to 100% for all scenarios as it is assumed that the transit-dependent population is present in the EPZ for all scenarios.

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

Table 6-1. Description of Evacuation Regions

Radial Regions

Region	Description	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R01	2-Mile Region	X	X																																
R02	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles

Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R04	S	X	X	X		X																												X	
R05	SSW	X	X	X		X		X																											
R06	SW	X	X			X		X		X																									
R07	WSW	X	X					X		X		X																							
R08	W	X	X							X		X		X																					
R09	WNW	X	X									X		X		X																			
R10	NW	X	X											X		X		X																	
R11	NNW	X	X													X		X		X															
R12	N	X	X															X		X		X													
R13	NNE	X	X																	X		X		X											
R14	NE	X	X																			X		X		X									
R15	ENE	X	X																					X		X		X							
R16	E	X	X																					X		X		X		X		X			
R17	ESE	X	X																							X		X		X		X		X	
R18	SE	X	X	X																								X		X		X		X	
R19	SSE	X	X	X																												X		X	

Sector(s) Evacuate | Sector(s) Shelter-in-Place

Evacuate 2-Mile Region and Downwind to EPZ Boundary																																			
		Sector																																	
Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R20	S	X	X	X	X	X	X																											X	X
R21	SSW	X	X	X	X	X	X	X	X																										
R22	SW	X	X			X	X	X	X	X	X																								
R23	WSW	X	X					X	X	X	X	X	X																						
R24	W	X	X							X	X	X	X	X	X																				
R25	WNW	X	X									X	X	X	X	X	X																		
R26	NW	X	X											X	X	X	X	X	X																
R27	NNW	X	X													X	X	X	X	X	X														
R28	N	X	X															X	X	X	X	X	X												
R29	NNE	X	X																	X	X	X	X	X	X										
R30	NE	X	X																			X	X	X	X	X	X								
R31	ENE	X	X																					X	X	X	X	X	X						
R32	E	X	X																					X	X	X	X	X	X	X	X	X	X		
R33	ESE	X	X																							X	X	X	X	X	X	X	X	X	X
R34	SE	X	X	X	X																							X	X	X	X	X	X	X	X
R35	SSE	X	X	X	X																											X	X	X	X

Staged Evacuation - 2-Mile Region Evacuates, then Evacuate Downwind to 5 Miles																																			
		Sector																																	
Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R36	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R37	S	X	X	X		X																												X	
R38	SSW	X	X	X		X		X																											
R39	SW	X	X			X		X		X																									
R40	WSW	X	X					X		X		X																							
R41	W	X	X							X		X		X																					
R42	WNW	X	X									X		X		X																			
R43	NW	X	X											X		X		X																	
R44	NNW	X	X													X		X		X															
R45	N	X	X															X		X		X													
R46	NNE	X	X																	X		X		X											
R47	NE	X	X																			X		X		X									
R48	ENE	X	X																					X		X		X							
R49	E	X	X																					X		X		X		X		X			
R50	ESE	X	X																							X		X		X		X		X	
R51	SE	X	X	X																								X		X		X		X	
R52	SSE	X	X	X																												X		X	

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

Table 6-2. Evacuation Scenario Definitions

Scenarios	Season[1]	Day of Week	Time of Day	Weather	Special
1	Summer	Midweek	Midday	Good	None
2	Summer	Midweek	Midday	Rain	None
3	Summer	Weekend	Midday	Good	None
4	Summer	Weekend	Midday	Rain	None
5	Summer	Midweek, Weekend	Evening	Good	None
6	Winter	Midweek	Midday	Good	None
7	Winter	Midweek	Midday	Rain	None
8	Winter	Weekend	Midday	Good	None
9	Winter	Weekend	Midday	Rain	None
10	Winter	Midweek, Weekend	Evening	Good	None
11	Winter	Midweek	Midday	Good	Special Event: Outage at PVNGS
12	Summer	Midweek	Midday	Good	Roadway Impact: Lane Closure on I-10 Eastbound

[1] Winter means that school is in session, at normal enrollment levels (also applies to spring and autumn). Summer means that school is in session at summer school enrollment levels (lower than normal enrollment).

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

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Events	School Buses/Passenger Vans	Transit Buses	External Through Traffic
1	24%	76%	96%	30%	28%	0%	10%	100%	100%
2	24%	76%	96%	30%	28%	0%	10%	100%	100%
3	2%	98%	10%	30%	21%	0%	0%	100%	100%
4	2%	98%	10%	30%	21%	0%	0%	100%	100%
5	2%	98%	10%	40%	21%	0%	0%	100%	40%
6	24%	76%	100%	75%	28%	0%	100%	100%	100%
7	24%	76%	100%	75%	28%	0%	100%	100%	100%
8	2%	98%	10%	75%	21%	0%	0%	100%	100%
9	2%	98%	10%	75%	21%	0%	0%	100%	100%
10	2%	98%	10%	100%	21%	0%	0%	100%	40%
11	24%	76%	100%	10%	28%	100%	100%	100%	100%
12	24%	76%	96%	30%	28%	0%	10%	100%	100%

Resident Households with Commuters ....Households of EPZ residents who await the return of commuters prior to beginning the evacuation trip.
Resident Households with No Commuters ..Households of EPZ residents who do not have commuters or will not await the return of commuters prior to beginning the evacuation trip.
Employees ....EPZ employees who live outside the EPZ
Transients ....People who are in the EPZ at the time of an accident for recreational or other (non-employment) purposes.
Shadow ....Residents and employees in the Shadow Region (outside of the EPZ) who will spontaneously decide to relocate during the evacuation. The basis for the values shown is a 20% relocation of shadow residents along with a proportional percentage of shadow employees.
Special Event ....Additional vehicles in the EPZ due to the identified special event.
School and Transit Buses ....Vehicle-equivalents present on the road during evacuation servicing schools and transit-dependent people (1 bus/passenger van is equivalent to 2 passenger vehicles).
External Through Traffic ....Traffic passing through the EPZ on interstates/freeways and major arterial roads at the start of the evacuation. This traffic is stopped by barricades (on I-10) 45 minutes after the evacuation begins.

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

Scenario	Households With Returning Commuters	Households Without Returning Commuters	Employees	Transients	Shadow	Special Events	School Buses/Passenger Vans[3]	Transit Buses	External Through Traffic	Total Scenario Vehicles
1	1,397	4,315	2,312	2	1,959	0	10	12	3,070	13,077
2	1,397	4,315	2,312	2	1,959	0	10	12	3,070	13,077
3	140	5,572	241	2	1,453	0	0	12	3,070	10,490
4	140	5,572	241	2	1,453	0	0	12	3,070	10,490
5	140	5,572	241	3	1,453	0	0	12	1,228	8,649
6	1,397	4,315	2,408	6	1,983	0	102	12	3,070	13,293
7	1,397	4,315	2,408	6	1,983	0	102	12	3,070	13,293
8	140	5,572	241	6	1,453	0	0	12	3,070	10,494
9	140	5,572	241	6	1,453	0	0	12	3,070	10,494
10	140	5,572	241	8	1,453	0	0	12	1,228	8,654
11	1,397	4,315	2,408	1	1,983	1,105	102	12	3,070	14,393
12	1,397	4,315	2,312	2	1,959	0	10	12	3,070	13,077

[2] Vehicle estimates are for an evacuation of the entire EPZ (Region R03)
[3] The school bus/passenger vans include the 14 vehicles (7 buses) from Palo Verde Elementary School, as the school evacuates even though the school is outside of the EPZ.

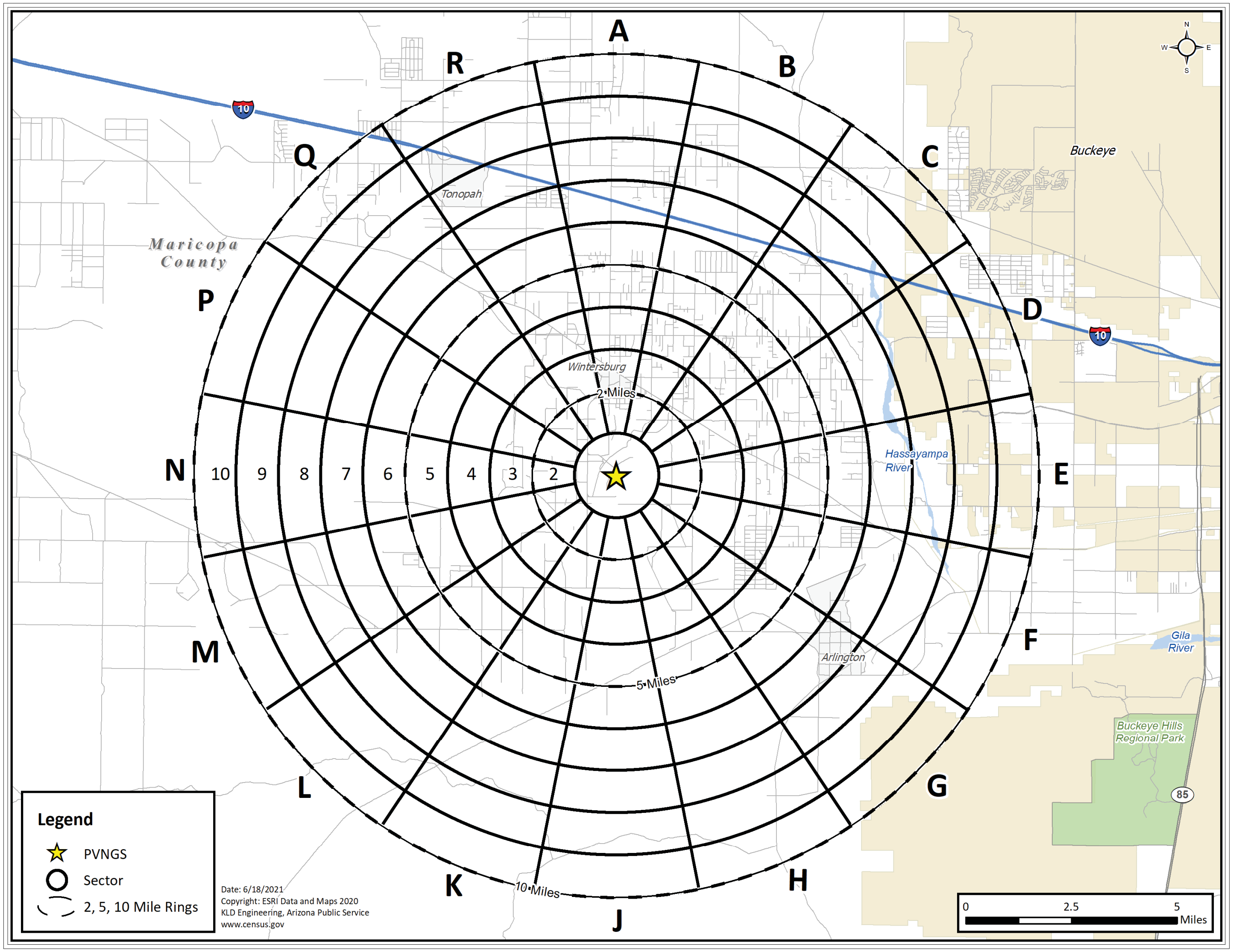


Figure 6-1. PVNGS EPZ Sectors

7 GENERAL POPULATION EVACUATION TIME ESTIMATES (ETE)

This section presents the ETE results of the computer analyses using the DYNEV II System described in Appendices B, C and D. These results cover 52 Evacuation Regions within the PVNGS Emergency Planning Zone (EPZ) and the 12 Evacuation Scenarios discussed in Section 6.

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

7.1 Voluntary Evacuation and Shadow Evacuation

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

The ETE for the PVNGS EPZ addresses the issue of voluntary evacuees in the manner shown in Figure 7-1. Within the EPZ, 20 percent of permanent residents located in Sectors outside of the Evacuation Region who are not advised to evacuate, are assumed to elect to evacuate. Similarly, it is assumed that 20 percent of those permanent residents in the Shadow Region will choose to leave the area.

Figure 7-2 presents the area identified as the Shadow Region. This region extends radially from the plant to cover a region between the EPZ boundary and 15 miles. The population and number of evacuating vehicles in the Shadow Region were estimated using the 2020 U.S. Census data from the Census Bureau website[1] projected to September 2021. As discussed in Section 3.2, it is estimated that a total of 11,911 permanent residents reside in the Shadow Region; 20 percent of them would evacuate. See Table 6-4 for the number of evacuating vehicles from the Shadow Region.

Traffic generated within this Shadow Region (including external-external traffic), traveling away from the plant location, has the potential for impeding evacuating vehicles from within the Evacuation Region. All ETE calculations include this shadow traffic movement.

[1] www.census.gov

7.2 Staged Evacuation

As defined in NUREG/CR-7002, Rev.1, staged evacuation consists of the following:

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

See Section 5.4.2 for additional information on staged evacuation.

7.3 Patterns of Traffic Congestion during Evacuation

Figure 7-3 through Figure 7-7. Congestion Patterns at 2 Hours and 55 Minutes after the Advisory to Evacuat illustrate the patterns of traffic congestion that arise for the case when the entire EPZ (Region R03) is advised to evacuate during the summer, midweek, midday period under good weather conditions (Scenario 1).

Traffic congestion, as the term is used here, is defined as Level of Service (LOS) F. LOS F is defined as follows (HCM 2016):

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

All highway "links" which experience LOS F are delineated in these Figures by a thick red line; all others are lightly indicated.

At 30 minutes after the ATE, Figure 7-3 displays congestion on W Baseline Road caused by the PVNGS employee vehicles evacuating from the major parking lots along W Baseline Road. A roundabout, constructed on W Baseline Road between S Wintersburg Road and the plant's parking lots, delay the plant employee evacuees due to the reduced capacity and speed of the roundabout. At this time, 30% of employees and transients have begun their evacuation trip, while only 3% of permanent residents (without commuters) have mobilized. Minimal traffic congestion (LOS B) exists on S Wintersburg Road and W Salome Highway eastbound as plant employees are evacuating toward Buckeye, located east of the plant. Minimal traffic congestion (LOS B) exists on I-10 eastbound and westbound as external traffic continues on I-10 before the Roadblocks are established.

At 1 hour after the ATE, Figure 7-4 displays minimal to heavy levels of traffic congestion (LOS B, C and D) within the EPZ. W Baseline Road, east of the roundabout, at the plant site, still exhibits a LOS F. At this time, approximately 85% of employees have mobilized. Congestion (LOS D) exists on I-10 eastbound, as a large number of vehicles evacuating on I-10 eastbound merge with the traffic on I-10 within the Shadow Region. This congestion on I-10 propagates the traffic to the single-lane on-ramp and eventually causing congestion (LOS C) at S 339th Avenue which then delays vehicles from W Van Buren Street. This delay also causes moderate congestion (LOS C) on W Van Buren Street.

At 1 hour and 45 minutes after the ATE, Figure 7-5 displays congestion persisting on W Baseline Road at the plant, including the roundabout where plant employees from the parking lots are evacuating. At this point, all (100%) employees and transients have mobilized and 24% of permanent residents have begun their evacuation trip. S 339th Avenue is showing increased congestion (LOS D) due to vehicles accessing I-10 from a single-lane on-ramp which acts as a bottleneck and meters the flow of traffic. Due to this metering of traffic flow, congestion has increased to LOS F on W Van Buren Street, as vehicles are trying to make a left onto S 339th Avenue.

At 2 hours and 15 minutes, Figure 7-6 displays the plant and the 2-Mile Region are clear of congestion. Moderate levels of traffic congestion (LOS B and C) exist on I-10 eastbound, W Salome Highway and W Baseline Road located east of the plant and within Buckeye. At this point, approximately 70% of permanent residents have mobilized and 81% have successfully evacuated the EPZ.

At 2 hours and 55 minutes after the ATE, Figure 7-7. shows that the EPZ and study area are now clear of congestion. Therefore, any evacuees who depart after this time encounters no traffic congestion or delay. At this time, approximately 90% of the population have mobilized and approximately 92% have successfully evacuated the EPZ. This indicates that the trip generation plus the time to travel to EPZ boundary (5 hours and 55 minutes) is dictating the 100^{th} percentile ETE. The last of the visible congestion is located outside of the study area on I-10 eastbound east of Miller Road, which clears 5 minutes later at 3 hours after the ATE.

7.4 Evacuation Rates

Evacuation is a continuous process, as implied by Figure 7-8 through Figure 7-19. These figures display the rate at which traffic flows out of the indicated areas for the case of an evacuation of the full EPZ (Region R03) under the indicated conditions. One figure is presented for each scenario considered.

As indicated in Figure 7-8 through Figure 7-19, there is typically a long "tail" to these distributions due to mobilization and not congestion (low population demand). Vehicles begin to evacuate an area slowly at first, as people respond to the ATE at different rates. Then traffic demand builds rapidly (slopes of curves increase). When the system becomes congested, traffic exits the EPZ at rates somewhat below capacity until some evacuation routes have cleared. As more routes clear, the aggregate rate of egress slows since many vehicles have already left the EPZ. Towards the end of the process, relatively few evacuation routes service the remaining demand.

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

7.5 Evacuation Time Estimate Results

Table 7-1 through Table 7-2 present the ETE values for all 52 Evacuation Regions and all 12 Evacuation Scenarios. Table 7-3 through Table 7-4 present the ETE values for the 2-Mile Region for both staged and un-staged keyhole regions downwind to 5 miles. The tables are organized as follows:

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

The animation snapshots described in Section 7.3, reflect the ETE statistics for the concurrent (un-staged) evacuation scenarios and regions, which are displayed in Figure 7-3 through Figure 7-7. There is minimal traffic congestion with the EPZ, which results in ETE values which parallel mobilization time; this is reflected in the ETE statistics:

- The 2-Mile Region (R01) consists of mostly plant employees. The congestion within this region, is mostly based on the plant employees exiting the site to access S Wintersburg Road. As such, the 90th percentile ETE for this region is between 2:05 (hr:min) and 2:15 for all scenarios (excluding the special event) which mimics the rapidly mobilizing employees and congestion within PVNGS. As shown in Figure 5-4, employees fully mobilize in 1 hours and 45 minutes. The additional 30 minutes is the result of the congestion accessing the roundabout slightly west of the plant parking lots, as discussed in Section 7.3.
- The 5-Mile Region (R02) is mostly clear of congestion except for W Salome Highway east of the plant. R02 has more permanent resident vehicles than R01, which increases the mobilization time (see Figure 5-4 – mobilization time is longer for permanent residents than for employees/transients). As a result, the 90th percentile ETE for the R02 ranges between 2:45 and 2:50 (excluding the special event).
- The 90th percentile ETE for the full EPZ (Region R03) ranges between 2:40 and 2:55 (excluding the roadway impact). This is comparable or 10 minutes shorter (during weekend midday scenarios) when compared to R02. During the weekend, the number of employees within the 5-Mile Region is less. As such, the congestion due to employees is considerably reduced within the 2-Mile and 5-Mile Region allowing R03 to reach the 90th percentile ETE more quickly than in R02.
- The 100th percentile ETE for all Regions and for all Scenarios parallel mobilization time, as congestion within the EPZ dissipates, so no speed and capacity reductions exist, as displayed in Figure 7-7. The 100th percentile ETE ranges from 5 hours and 45 minutes to 5 hours and 55 minutes (mobilization time plus 10 minutes to travel out of the EPZ).

Comparison of Scenarios 6 and 11 in Table 7-1 indicates that the Special Event – an outage at the plant – has a significant impact on the ETE for the 90th percentile and no impact to the 100th percentile ETE. As discussed in Section 3.6, an additional 1,105 vehicles are present at the plant during an outage. The additional vehicles increase the congestion on W Baseline Road within the plant site, extending the ETE for the 2-Mile Region (R01) by 40 minutes. For those keyhole regions with wind from the north, west and southwest, the ETE is largely dictated by plant employees and the congestion on W Salome Highway due to the additional vehicles; therefore the 90th percentile ETE for these regions are also significantly impacted by the additional outage employees (with increases of up to 40 minutes). Even with the additional vehicles present for the special event, traffic congestion within the EPZ still clears before the mobilization time. As a result, the 100th percentile ETE are not impacted by the special event.

Comparison of Scenarios 1 and 12 in Table 7-1 indicates that the roadway closure – single lane eastbound on I-10 from the interchange with S Wintersburg Road (Exit 98) to the interchange with State Highway 85 (Exit 112) – has no impact on the 90th percentile ETE for all Regions except for Region R03. During an evacuation of the full EPZ, the 90th percentile ETE increases by

25 minutes. Congestion is visible on I-10 eastbound or from roads accessing I-10 eastbound, outside of the 5-Mile Region. As such, the closure of a single lane reduces the roadway capacity, prolonging traffic congestion and ETE. For all other Regions, the interstate never experiences sustained traffic congestion (LOS F), as shown in Figure 7-3 through Figure 7-7. Congestion Patterns at 2 Hours and 55 Minutes after the Advisory to Evacuate, which means it has excess capacity to service the evacuating traffic demand. The ramps to access the interstate are bottlenecks, not the mainline of the interstate. There is no impact to the 100th percentile ETE, as the trip generation (plus the travel time to the EPZ boundary) dictates the ETE.

7.6 Staged Evacuation Results

Table 7-3 and Table 7-4 present a comparison of the ETE compiled for the concurrent (un-staged) and staged evacuation studies. Note that Regions R36 through R52 are the same geographic areas as Regions R02, R04 through R19, respectively. The times shown in Table 7-3 and Table 7-4 are when the 2-Mile Region is 90% clear and 100% clear, respectively.

The objective of a staged evacuation is to show that the ETE for the 2-Mile Region can be significantly reduced (30 minutes or 25%, whichever is less) without significantly impacting the region between 2 miles and 5 miles. In all cases, as shown in Table 7-3 and Table 7-4, the 90th and 100th percentile ETE for the 2-Mile Region is unchanged when a staged evacuation is implemented for all scenarios. As discussed in Section 7.3 and shown in Figure 7-3 through Figure 7-7, there is little to no congestion beyond 2 miles of the PVNGS.

To determine the effect of staged evacuation on residents beyond the 2-Mile Region, the ETE for Regions R02, R04 through R19 are compared to R36 through R52, respectively, in Table 7-1 and Table 7-2. A comparison of ETE between these similar regions reveals that staging increases the ETE for those in the 2 to 5-mile area by at most 25 minutes for the 90th percentile and has no impact on the 100th percentile. The increase in the 90th percentile ETE is due to the evacuating vehicles, beyond the 2-Mile Region, sheltering and delaying the start of their evacuation. As shown in Figure 5-5, staging the evacuation causes a significant "spike" (sharp increase) in mobilization (trip-generation rate) or evacuating vehicles. This spike oversaturates evacuation routes, which increases traffic congestion and prolongs ETE.

In summary, staging evacuation provides no benefits to evacuees within the 2-Mile Region and adversely impacts evacuees located beyond the 2 miles from the plant.

7.7 Guidance on Using ETE Tables

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

1. Identify the applicable **Scenario** (Step 1)**:**
    - Season
        - Summer
        - Winter (also Autumn and Spring)

- Day of Week
  - Midweek
  - Weekend
- Time of Day
  - Midday
  - Evening
- Weather Condition
  - Good Weather
  - Rain
- Special Event – An Outage at PVNGS
- Roadway Impact – Single Lane Closure on I-20 Eastbound
- Evacuation Staging
  - No, Staged Evacuation is not considered
  - Yes, Staged Evacuation is considered

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

- The conditions of a summer evening (either midweek or weekend) and rain are not explicitly identified in the Tables. For these conditions, Scenarios (2) and (4) apply.
- The conditions of a winter evening (either midweek or weekend) and rain are not explicitly identified in the Tables. For these conditions, Scenarios (7) and (9) for rain apply.
- The seasons are defined as follows:
  - Summer assumes public school is in session at summer school enrollment levels (lower than normal enrollment).
  - Winter (includes Spring and Autumn) considers that public schools are in session at normal enrollment levels.
- Time of Day: Midday implies the time over which most commuters are at work or are travelling to/from work.

2. With the desired percentile ETE and Scenario identified, now identify the **Evacuation Region** (Step 2):
   - Determine the projected azimuth direction of the plume (coincident with the wind direction). This direction is expressed in terms of compass orientation: from S, SSW, SW, …
   - Determine the distance that the Evacuation Region will extend from the nuclear power plant. The applicable distances and their associated candidate Regions are given below:
     - 2 Miles (Region R01)
     - To 5 Miles (Region R02, R04 through R19)
     - To EPZ boundary (to 10 Miles) (Regions R03, R20 through R35)

- Enter Table 7-5 and identify the applicable group of candidate Regions based on the distance that the selected Region extends from the plant. Select the Evacuation Region identifier in that row, based on the azimuth direction of the plume, from the first column of the Table.

3. Determine the **ETE Table based on the percentile selected. Then, for the Scenario** identified in Step 1 and the **Evacuation Region** identified in Step 2, proceed as follows:
   - The columns of Table 7-1 are labeled with the Scenario numbers. Identify the proper column in the selected Table using the Scenario number defined in Step 1.
   - Identify the row in this table that provides ETE values for the Region identified in Step 2.
   - The unique data cell defined by the column and row so determined contains the desired value of ETE expressed in Hours:Minutes.

<u>Example</u>

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

- Sunday, August 10th at 4:00 AM.
- It is raining.
- Wind direction is from the northeast (NE).
- Wind speed is such that the distance to be evacuated is judged to be a 2 mile radius and downwind to 10 miles (to EPZ boundary).
- The desired ETE is that value needed to evacuate 90th percent of the population from within the impacted Region.
- A staged evacuation is not desired.

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

1. Identify the Scenario as summer, weekend, evening and raining. Entering Table 7-1, it is seen that there is no match for these descriptors. However, the clarification given above assigns this combination of circumstances to Scenario 4.
2. Enter Table 7-5 and locate the Region described as “Evacuate 2-Mile Region and Downwind to EPZ Boundary ” for wind direction from the NE and read Region R30 in the first column of that row.
3. Enter Table 7-1 to locate the data cell containing the value of ETE for Scenario 4 and Region R30. This data cell is in column (4) and in the row for Region R30; it contains the ETE value of 2:25.

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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 2-Mile Region, 5-Mile Region, and EPZ												
R01	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R02	2:45	2:45	2:50	2:50	2:50	2:45	2:45	2:50	2:50	2:50	3:00	2:45
R03	2:45	2:45	2:40	2:40	2:50	2:45	2:45	2:40	2:40	2:50	2:55	3:10
2-Mile Region and Keyhole to 5 Miles												
R04	2:35	2:35	2:50	2:50	2:50	2:35	2:35	2:50	2:50	2:50	2:55	2:35
R05	2:40	2:40	2:50	2:50	2:50	2:40	2:40	2:50	2:50	2:50	2:55	2:40
R06	2:20	2:20	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R07	2:15	2:15	2:40	2:40	2:40	2:20	2:20	2:40	2:40	2:40	2:50	2:15
R08	2:15	2:15	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:15
R09	2:10	2:10	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:10
R10	2:10	2:10	2:35	2:40	2:35	2:10	2:10	2:35	2:40	2:35	2:45	2:10
R11	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R12	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R13	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R14	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R15	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R16	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R17	2:10	2:10	2:35	2:40	2:35	2:10	2:10	2:35	2:40	2:35	2:45	2:10
R18	2:20	2:25	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R19	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:50	2:25

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
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
2-Mile Region and Keyhole to EPZ Boundary												
R20	2:25	2:25	2:25	2:25	2:40	2:25	2:25	2:25	2:25	2:40	2:45	2:25
R21	2:30	2:30	2:25	2:25	2:45	2:30	2:30	2:25	2:25	2:45	2:45	2:30
R22	2:20	2:20	2:25	2:25	2:40	2:20	2:20	2:25	2:25	2:40	2:45	2:20
R23	2:30	2:30	2:35	2:35	2:45	2:30	2:30	2:35	2:35	2:45	2:50	2:30
R24	2:30	2:30	2:35	2:35	2:45	2:30	2:30	2:35	2:35	2:45	2:55	2:30
R25	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:55	2:25
R26	2:15	2:15	2:45	2:45	2:45	2:15	2:15	2:45	2:45	2:45	2:50	2:15
R27	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R28	2:05	2:05	2:20	2:20	2:20	2:05	2:05	2:20	2:20	2:20	2:45	2:05
R29	2:05	2:05	2:20	2:20	2:20	2:10	2:10	2:20	2:20	2:20	2:45	2:05
R30	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R31	2:05	2:05	2:25	2:25	2:25	2:10	2:10	2:25	2:25	2:25	2:45	2:05
R32	2:10	2:10	2:40	2:40	2:40	2:15	2:15	2:40	2:40	2:40	2:50	2:10
R33	2:05	2:05	1:50	1:50	2:30	2:10	2:10	1:50	1:50	2:30	2:35	2:05
R34	2:15	2:15	2:10	2:10	2:40	2:20	2:20	2:10	2:10	2:40	2:40	2:15
R35	2:20	2:25	2:20	2:20	2:40	2:20	2:20	2:20	2:20	2:40	2:40	2:20

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5 Miles												
R36	2:55	2:55	3:00	3:00	3:00	2:55	2:55	3:00	3:00	3:00	3:00	2:55
R37	2:50	2:50	2:55	2:55	2:55	2:50	2:50	2:55	2:55	2:55	2:55	2:50
R38	2:50	2:50	2:55	2:55	2:55	2:50	2:50	2:55	2:55	2:55	2:55	2:50
R39	2:45	2:45	2:55	2:55	2:55	2:45	2:45	2:55	2:55	2:55	2:50	2:45
R40	2:40	2:40	2:50	2:50	2:50	2:35	2:40	2:50	2:50	2:50	2:50	2:40
R41	2:35	2:35	2:45	2:45	2:45	2:30	2:35	2:45	2:45	2:45	2:50	2:35
R42	2:25	2:30	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:50	2:25
R43	2:25	2:25	2:45	2:45	2:45	2:25	2:25	2:45	2:45	2:45	2:45	2:25
R44	2:05	2:05	2:40	2:40	2:40	2:10	2:10	2:40	2:40	2:40	2:45	2:05
R45	2:05	2:05	2:20	2:20	2:20	2:05	2:05	2:20	2:20	2:20	2:45	2:05
R46	2:05	2:05	2:30	2:30	2:30	2:10	2:10	2:30	2:30	2:30	2:45	2:05
R47	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R48	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R49	2:05	2:05	2:35	2:35	2:35	2:10	2:10	2:35	2:35	2:35	2:45	2:05
R50	2:20	2:20	2:45	2:45	2:45	2:20	2:20	2:45	2:45	2:45	2:50	2:20
R51	2:45	2:45	2:50	2:50	2:50	2:40	2:45	2:50	2:50	2:50	2:50	2:45
R52	2:45	2:45	2:50	2:50	2:50	2:40	2:45	2:50	2:50	2:50	2:50	2:45

Table 7-2. Time to Clear the Indicated Area of *__100__* Percent of the Affected Population

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
2-Mile Region and Keyhole to EPZ Boundary												
R20	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R21	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R22	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R23	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R24	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R25	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R26	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R27	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R28	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R29	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R30	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R31	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R32	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R33	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R34	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55
R35	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55	5:55

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5 Miles												
R36	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R37	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R38	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R39	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R40	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R41	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R42	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R43	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R44	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R45	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R46	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R47	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R48	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R49	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R51	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50
R52	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50	5:50

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Un-staged Evacuation – 2-Mile Region and 5-Mile Region												
R01	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R02	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
Un-staged Evacuation - 2-Mile Region and Keyhole to 5-Miles												
R04	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R05	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R06	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R07	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R08	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R09	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R10	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R11	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R12	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R13	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R14	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R15	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R16	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R17	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R18	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R19	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5-Miles												
R36	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R37	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R38	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R39	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R40	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R41	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R42	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R43	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R44	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R45	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R46	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R47	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R48	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R49	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R50	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R51	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05
R52	2:05	2:05	2:15	2:15	2:15	2:05	2:05	2:15	2:15	2:15	2:45	2:05

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

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Un-staged Evacuation – 2-Mile Region and 5-Mile Region												
R01	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R02	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
Un-staged Evacuation - 2-Mile Region and Keyhole to 5-Miles												
R04	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R05	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R06	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R07	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R08	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R09	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R10	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R11	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R12	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R13	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R14	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R15	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R16	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R17	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R18	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R19	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45

	Summer		Summer		Summer	Winter		Winter		Winter	Winter	Summer
	Midweek		Weekend		Midweek Weekend	Midweek		Weekend		Midweek Weekend	Midweek	Midweek
Scenario:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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
Staged Evacuation – 5-Mile Region, 2-Mile Region and Keyhole to 5-Miles												
R36	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R37	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R38	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R39	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R40	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R41	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R42	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R43	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R44	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R46	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R47	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R48	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R49	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R50	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R51	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45
R52	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45	5:45

Table 7-5. Description of Evacuation Regions

Radial Regions																																			
				Sector																															
		PVNGS	2-Mile	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
Region	Description		Radius	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R01	2-Mile Region	X	X																																
R02	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles																																			
				Sector																															
	Wind Direction	PVNGS	2-Mile	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
Region	From:		Radius	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R04	S	X	X	X		X																												X	
R05	SSW	X	X	X		X		X																											
R06	SW	X	X			X		X		X																									
R07	WSW	X	X					X		X		X																							
R08	W	X	X							X		X		X																					
R09	WNW	X	X									X		X		X																			
R10	NW	X	X											X		X		X																	
R11	NNW	X	X													X		X		X															
R12	N	X	X															X		X		X													
R13	NNE	X	X																	X		X		X											
R14	NE	X	X																			X		X		X									
R15	ENE	X	X																					X		X		X							
R16	E	X	X																					X		X		X		X		X			
R17	ESE	X	X																							X		X		X		X		X	
R18	SE	X	X	X																								X		X		X		X	
R19	SSE	X	X	X																												X		X	

Sector(s) Evacuate | Sector(s) Shelter-in-Place

Evacuate 2-Mile Region and Downwind to EPZ Boundary																																			
Region	Wind Direction From:	PVNGS	2-Mile Radius	Sector																															
				A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R20	S	X	X	X	X	X	X																											X	X
R21	SSW	X	X	X	X	X	X	X	X																										
R22	SW	X	X			X	X	X	X	X	X																								
R23	WSW	X	X					X	X	X	X	X	X																						
R24	W	X	X							X	X	X	X	X	X																				
R25	WNW	X	X									X	X	X	X	X	X																		
R26	NW	X	X											X	X	X	X	X	X																
R27	NNW	X	X													X	X	X	X	X	X														
R28	N	X	X															X	X	X	X	X	X												
R29	NNE	X	X																	X	X	X	X	X	X										
R30	NE	X	X																			X	X	X	X	X	X								
R31	ENE	X	X																					X	X	X	X	X	X						
R32	E	X	X																					X	X	X	X	X	X	X	X	X	X		
R33	ESE	X	X																							X	X	X	X	X	X	X	X	X	X
R34	SE	X	X	X	X																							X	X	X	X	X	X	X	X
R35	SSE	X	X	X	X																											X	X	X	X

Staged Evacuation - 2-Mile Region Evacuates, then Evacuate Downwind to 5 Miles																																			
Region	Wind Direction From:	PVNGS	2-Mile Radius	Sector																															
				A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R36	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R37	S	X	X	X		X																												X	
R38	SSW	X	X	X		X		X																											
R39	SW	X	X			X		X		X																									
R40	WSW	X	X					X		X		X																							
R41	W	X	X							X		X		X																					
R42	WNW	X	X									X		X		X																			
R43	NW	X	X											X		X		X																	
R44	NNW	X	X													X		X		X															
R45	N	X	X															X		X		X													
R46	NNE	X	X																	X		X		X											
R47	NE	X	X																			X		X		X									
R48	ENE	X	X																					X		X		X							
R49	E	X	X																					X		X		X		X		X			
R50	ESE	X	X																							X		X		X		X		X	
R51	SE	X	X	X																								X		X		X		X	
R52	SSE	X	X	X																												X		X	

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

Figure 7-1. Voluntary Evacuation Methodology

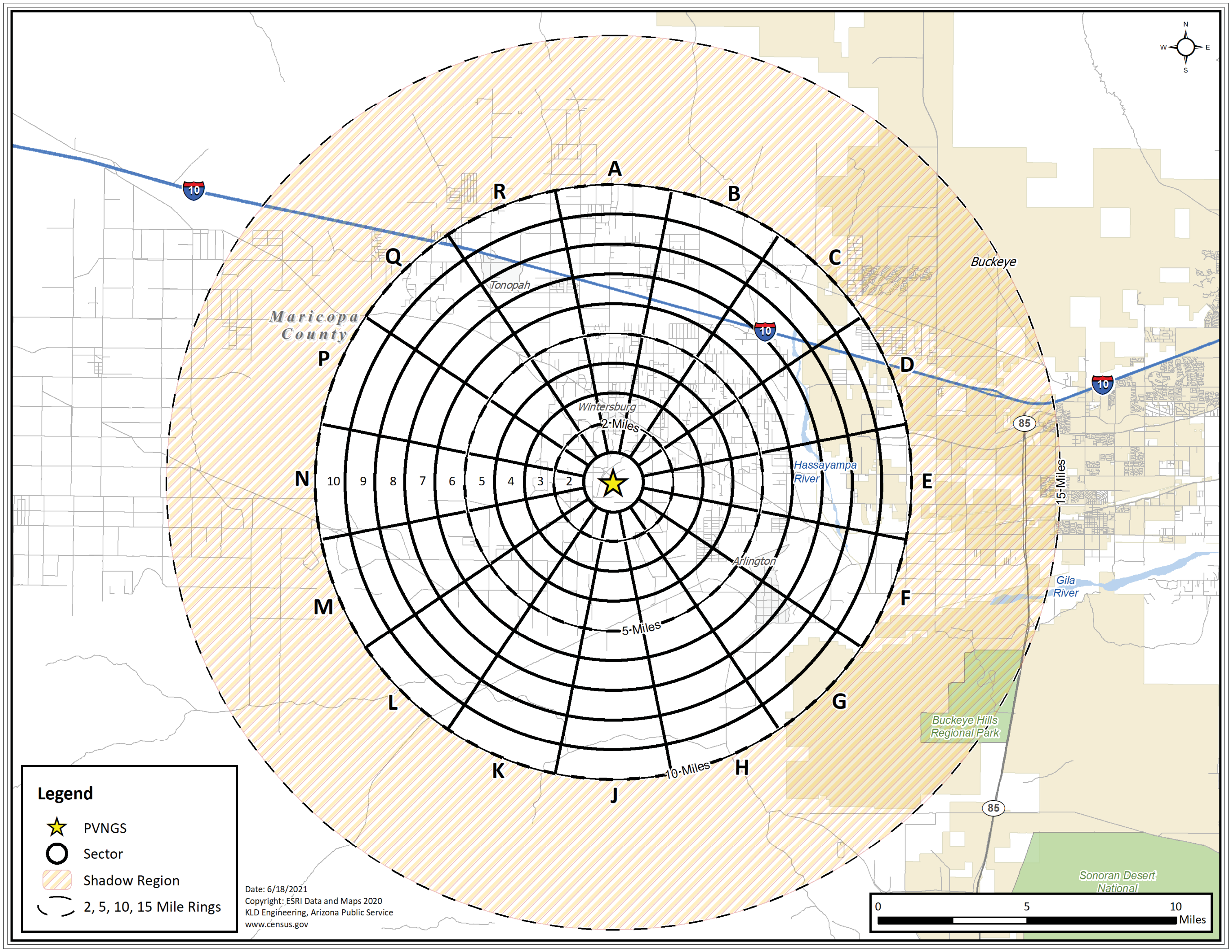


Figure 7-2. Palo Verde Shadow Region

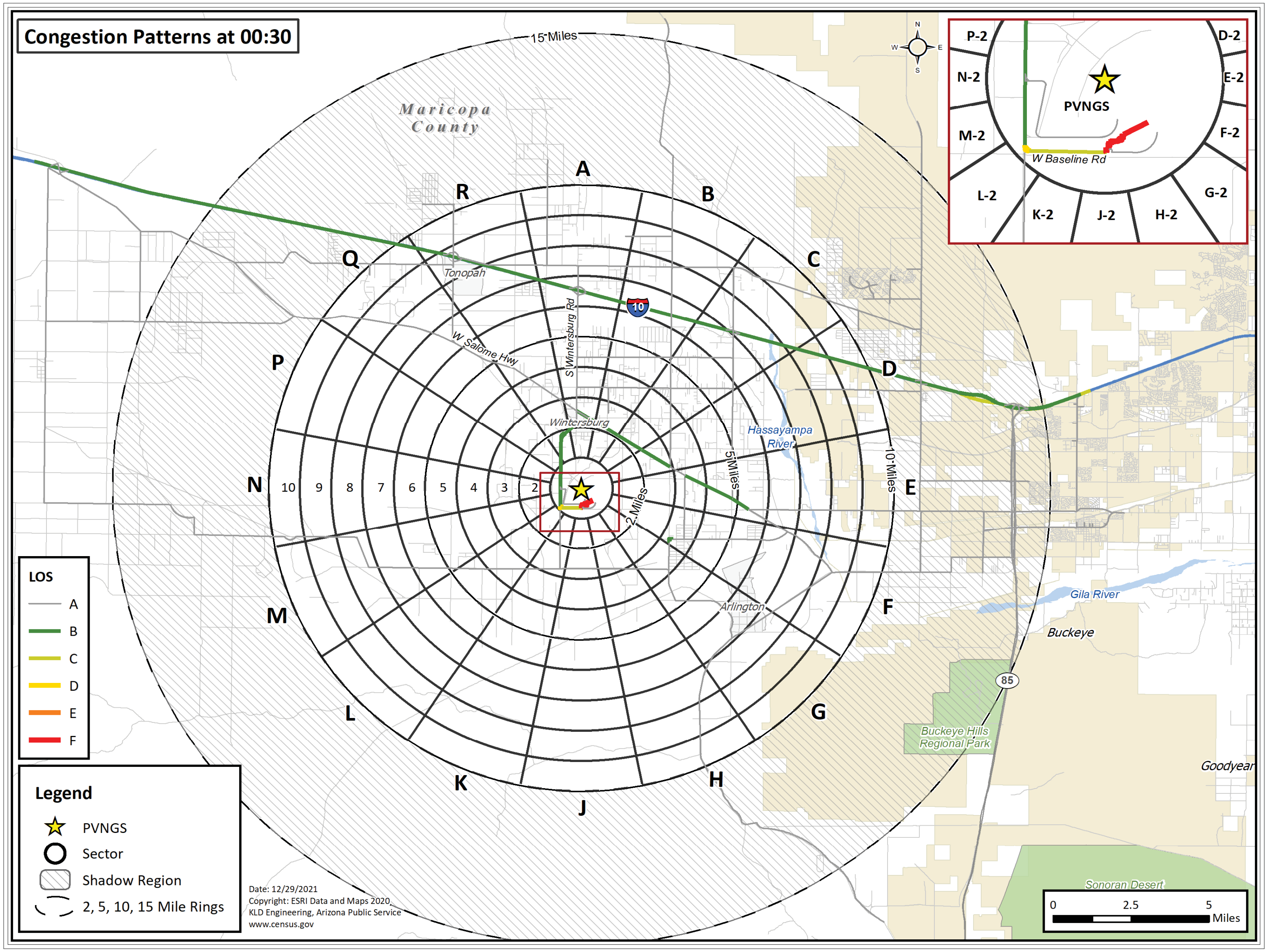


Figure 7-3. Congestion Patterns at 30 Minutes after the Advisory to Evacuate

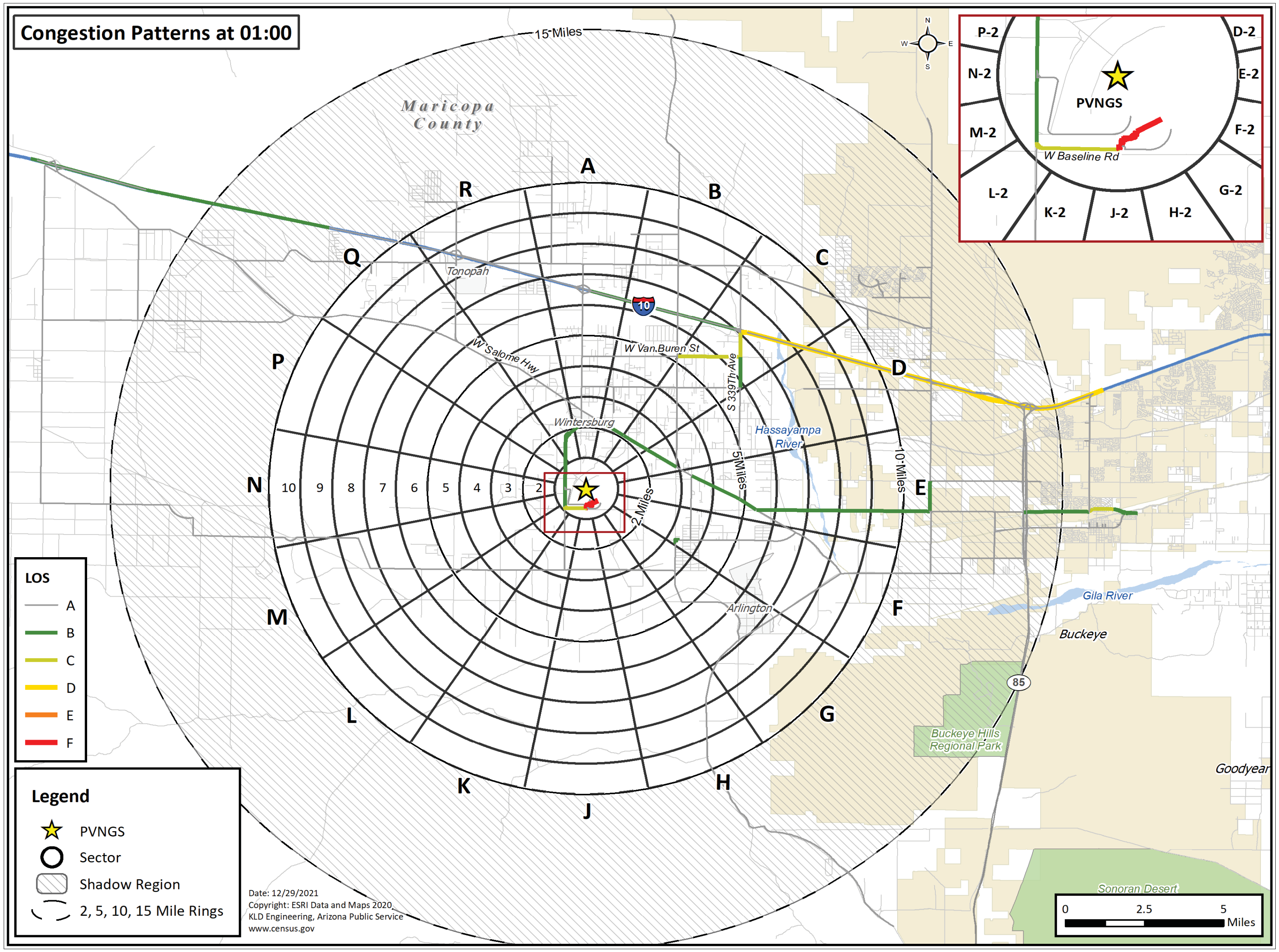


Figure 7-4. Congestion Patterns at 1 Hour after the Advisory to Evacuate

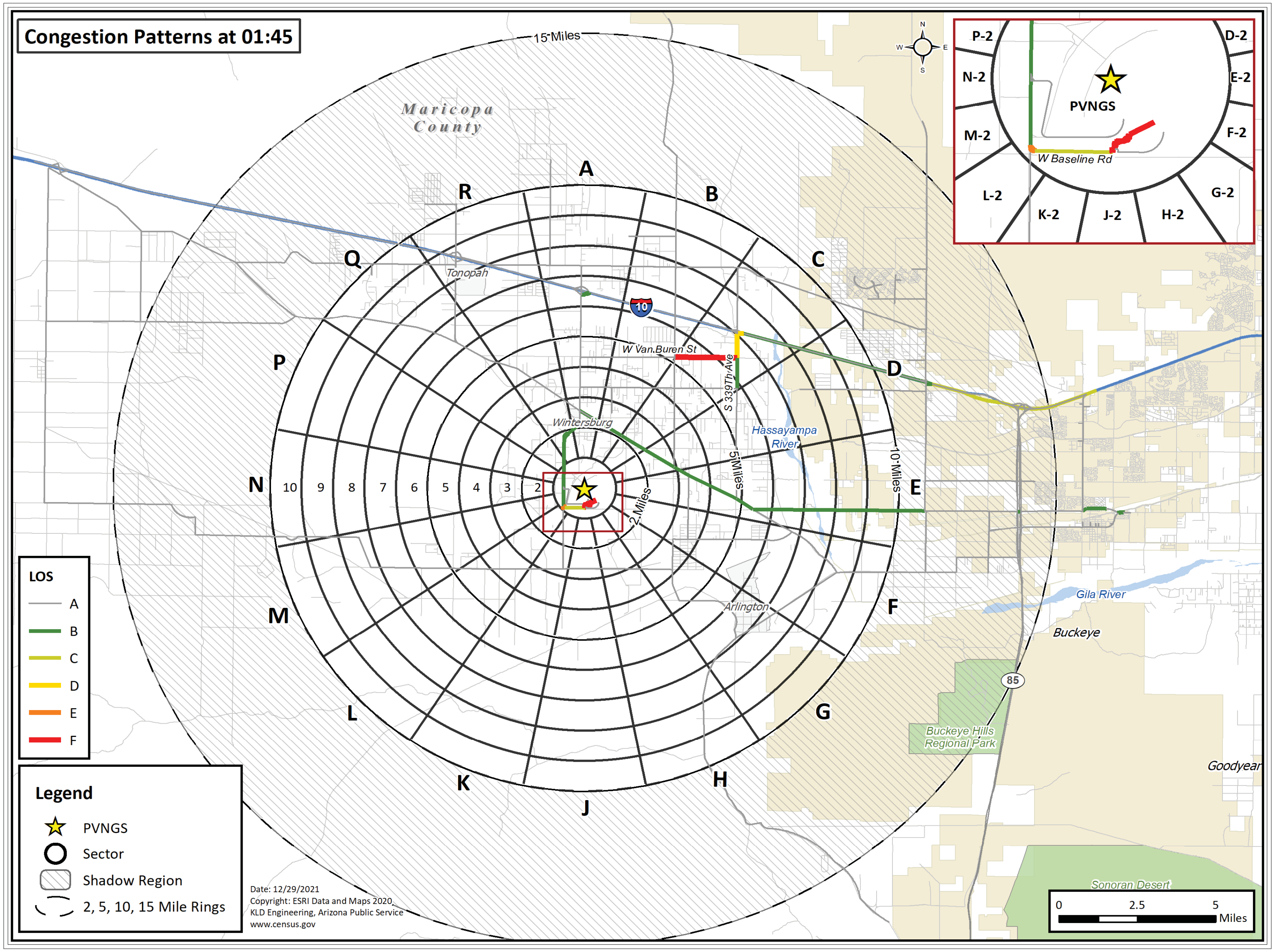


Figure 7-5. Congestion Patterns at 1 Hour and 45 Minutes after the Advisory to Evacuate

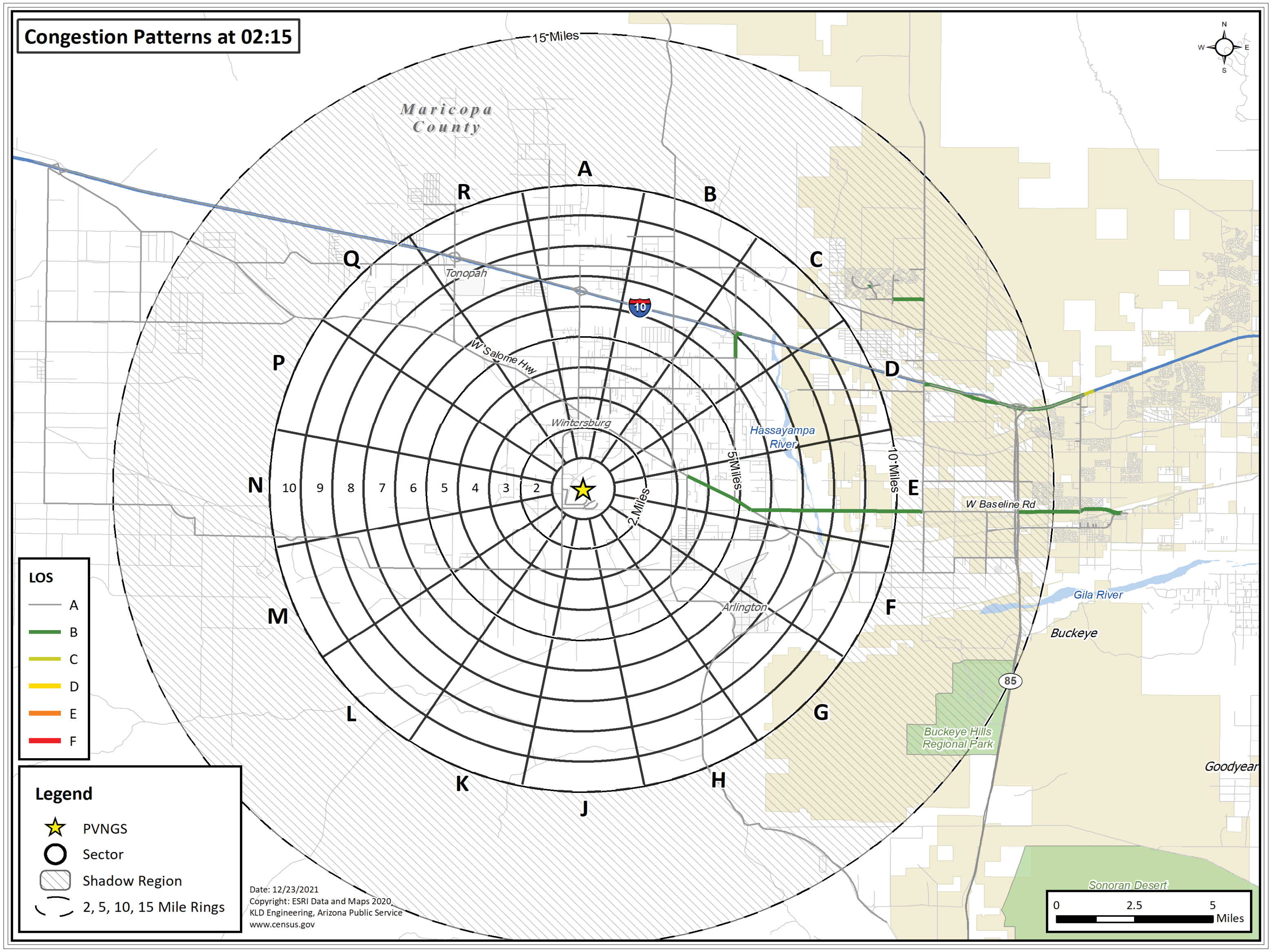


Figure 7-6. Congestion Patterns at 2 Hours and 15 Minutes after the Advisory to Evacuate

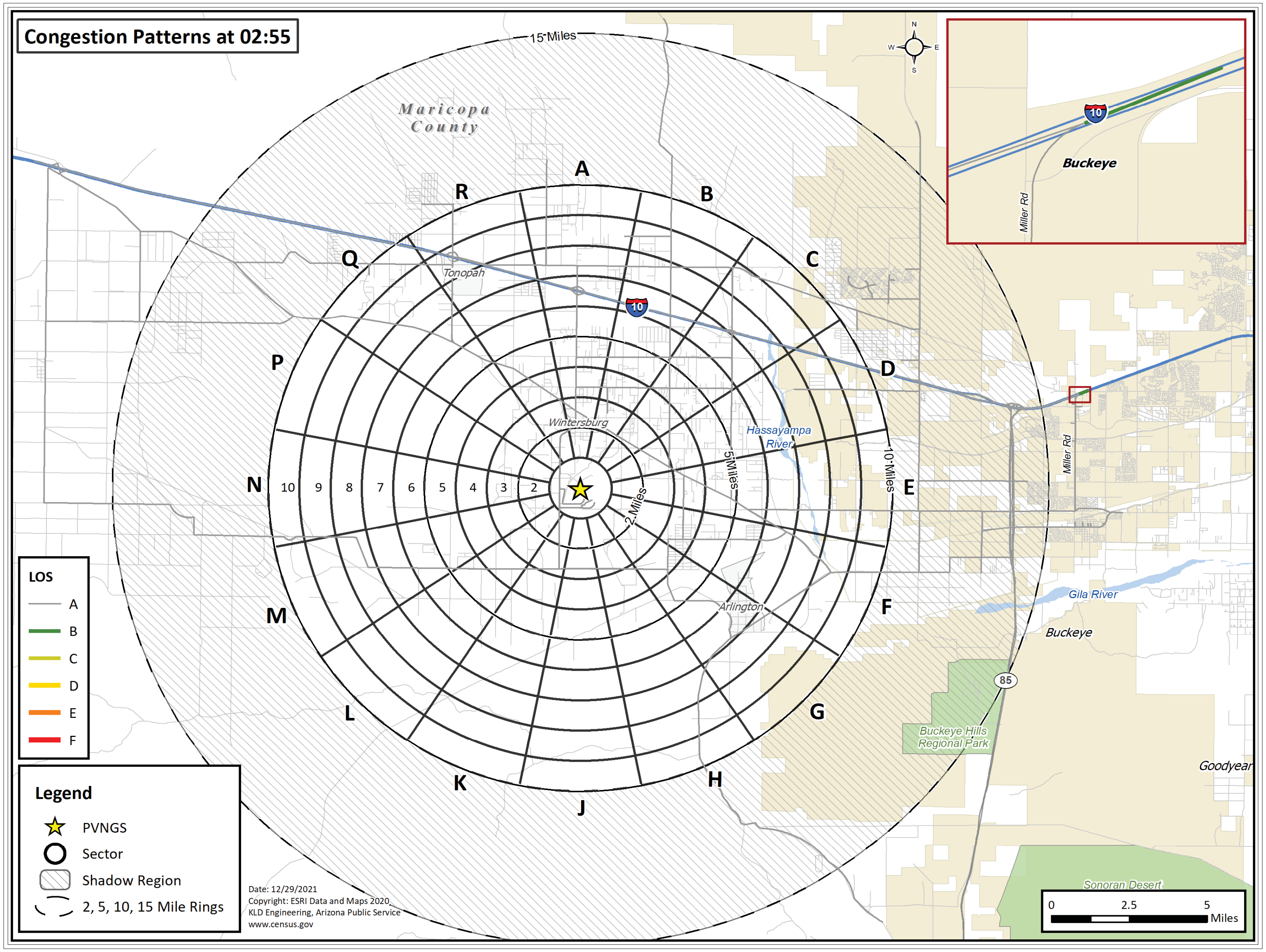


Figure 7-7. Congestion Patterns at 2 Hours and 55 Minutes after the Advisory to Evacuate

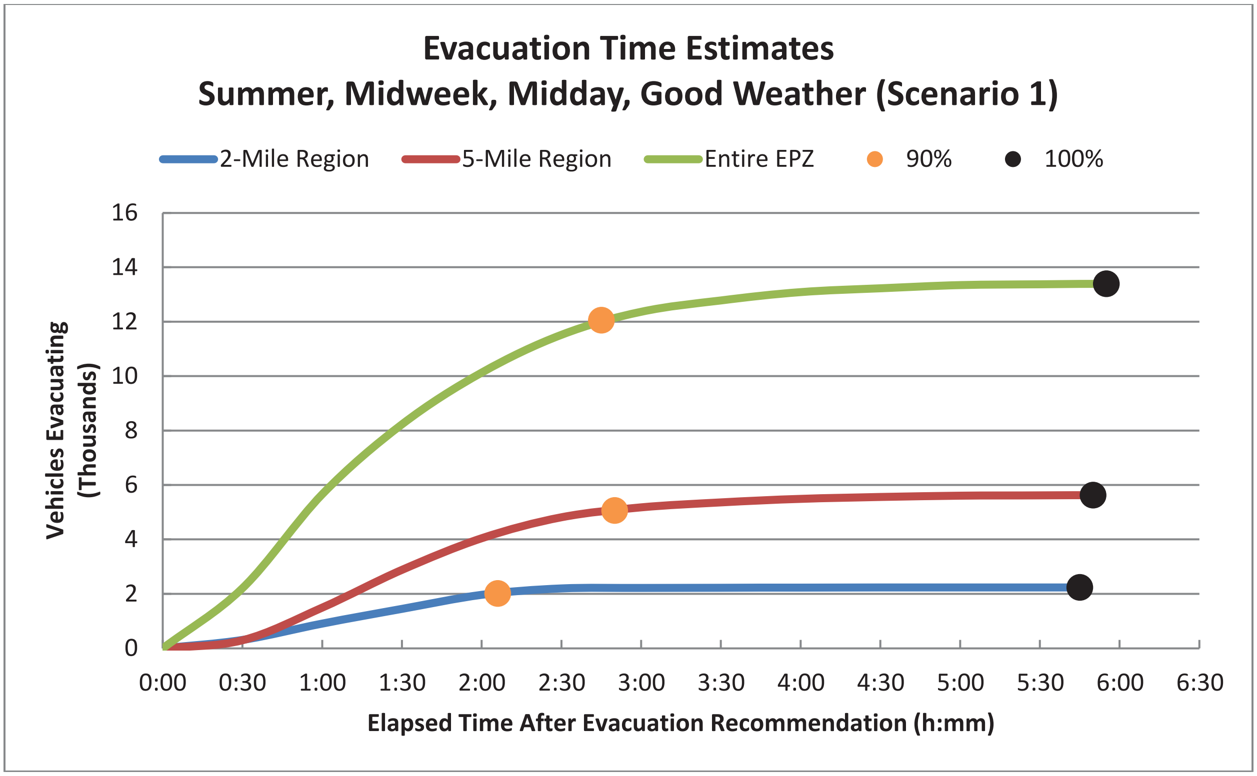


Figure 7-8. Evacuation Time Estimates - Scenario 1 for Region R03

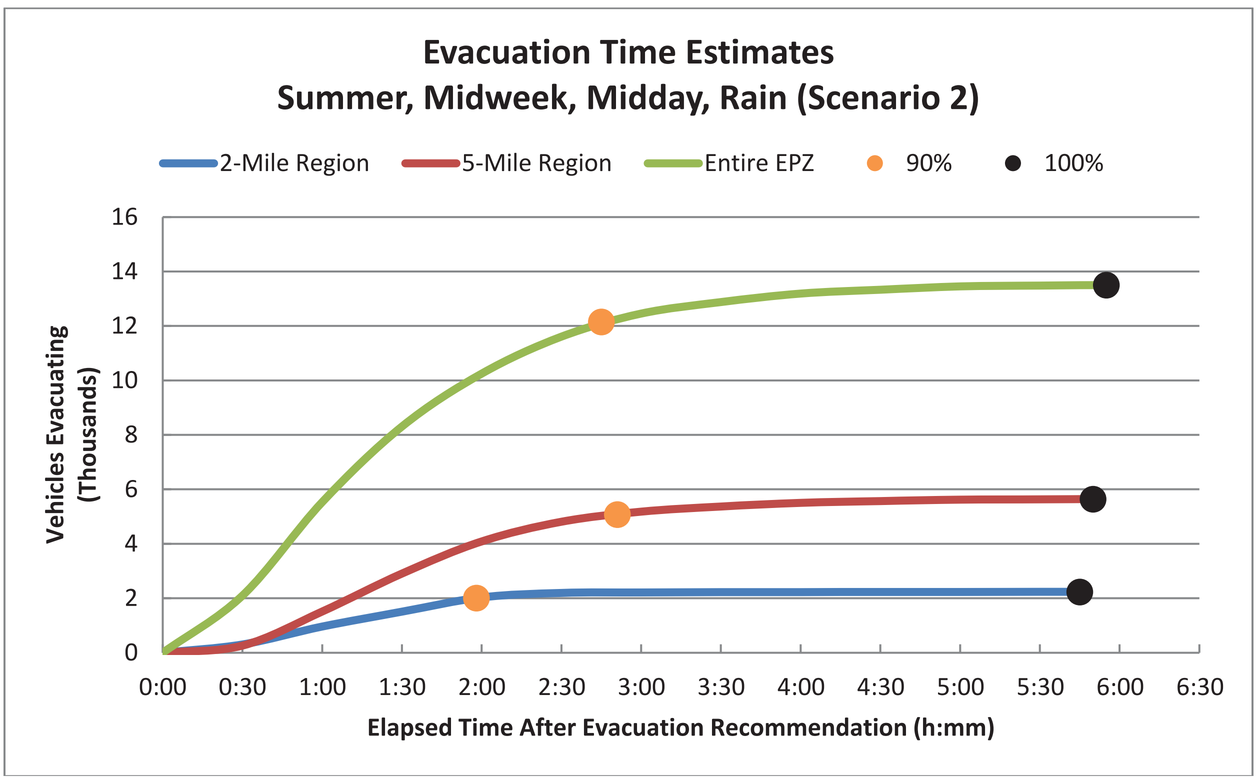


Figure 7-9. Evacuation Time Estimates - Scenario 2 for Region R03

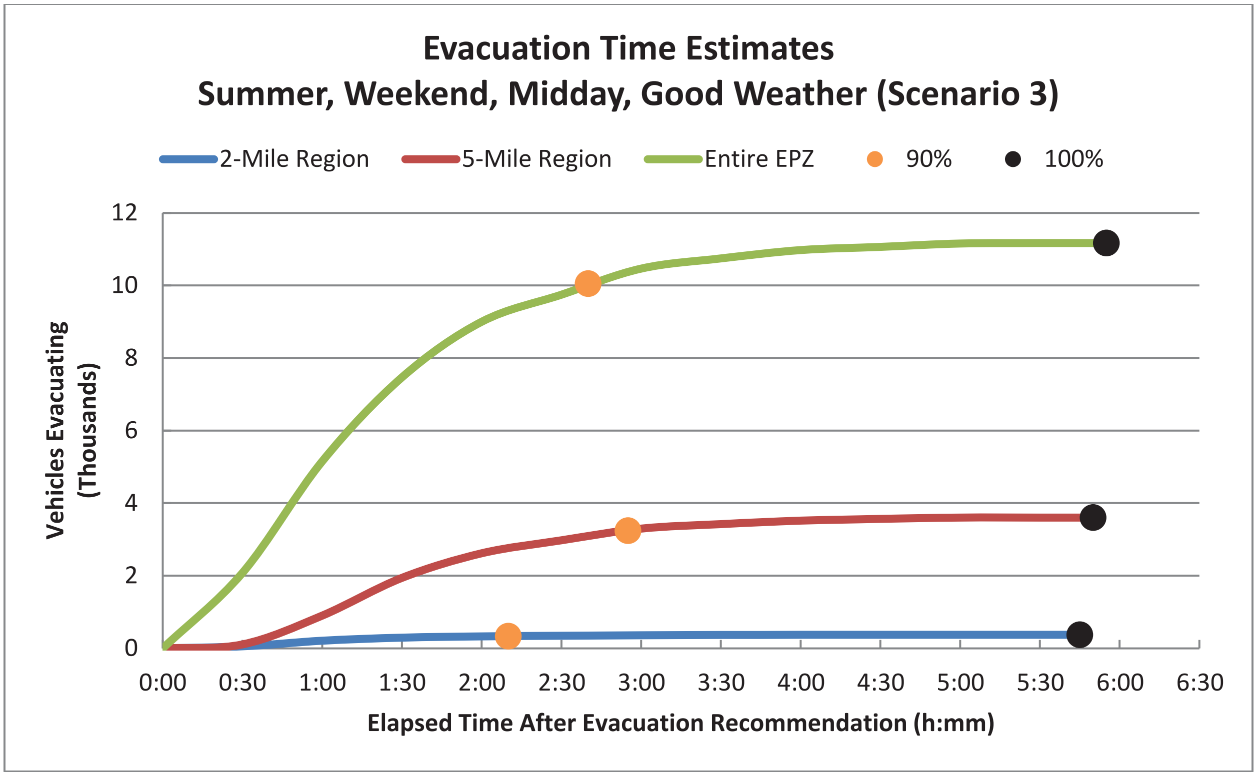


Figure 7-10. Evacuation Time Estimates - Scenario 3 for Region R03

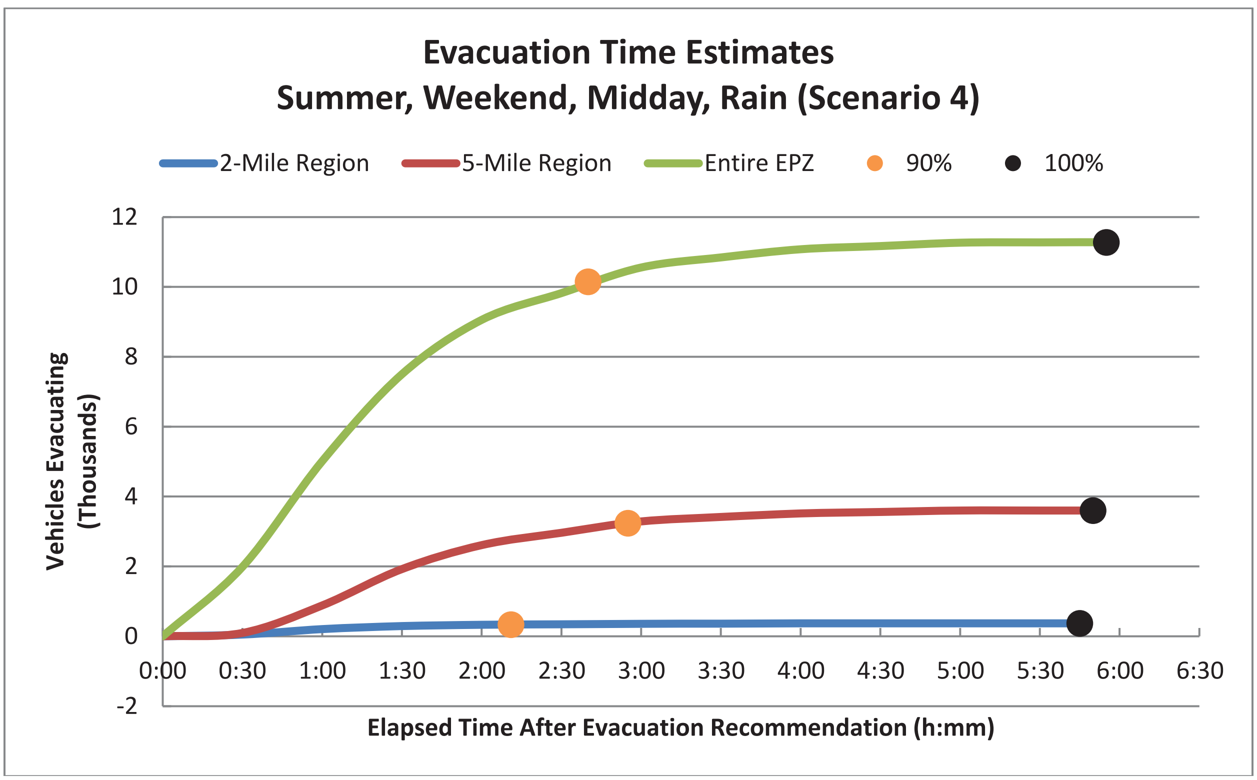


Figure 7-11. Evacuation Time Estimates - Scenario 4 for Region R03

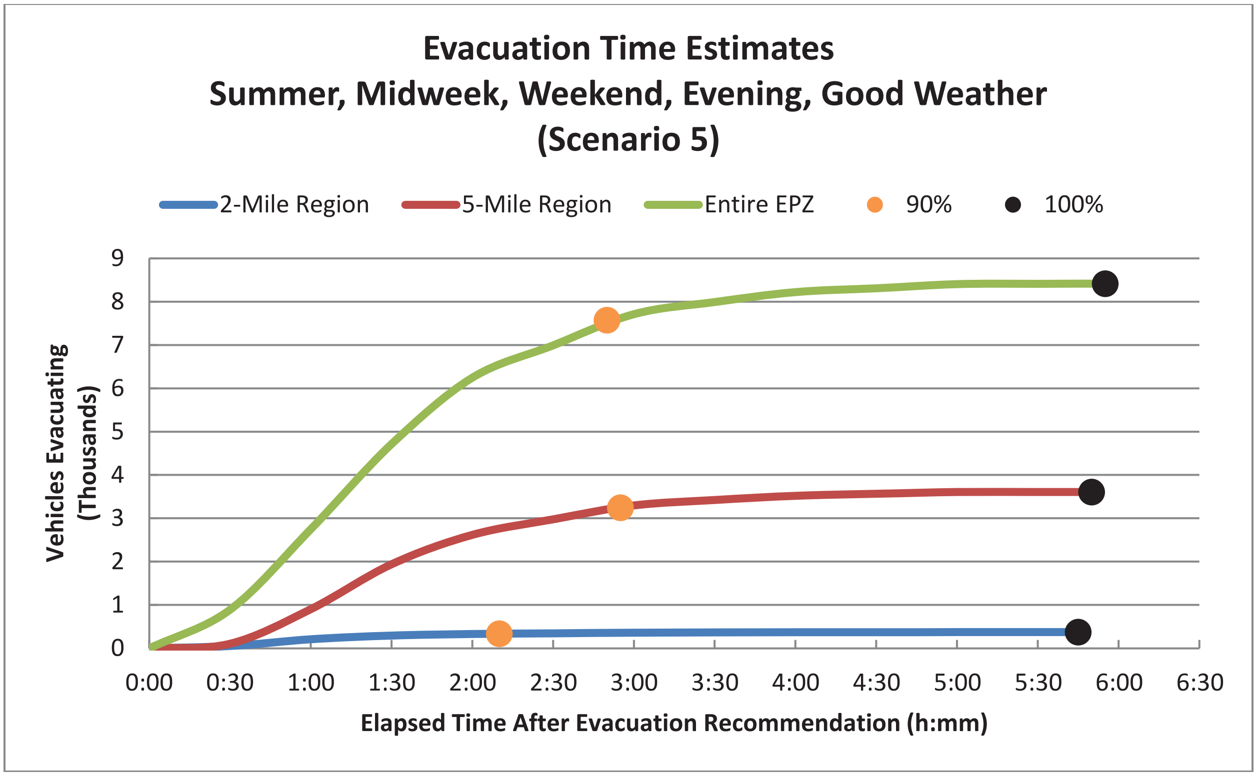


Figure 7-12. Evacuation Time Estimates - Scenario 5 for Region R03

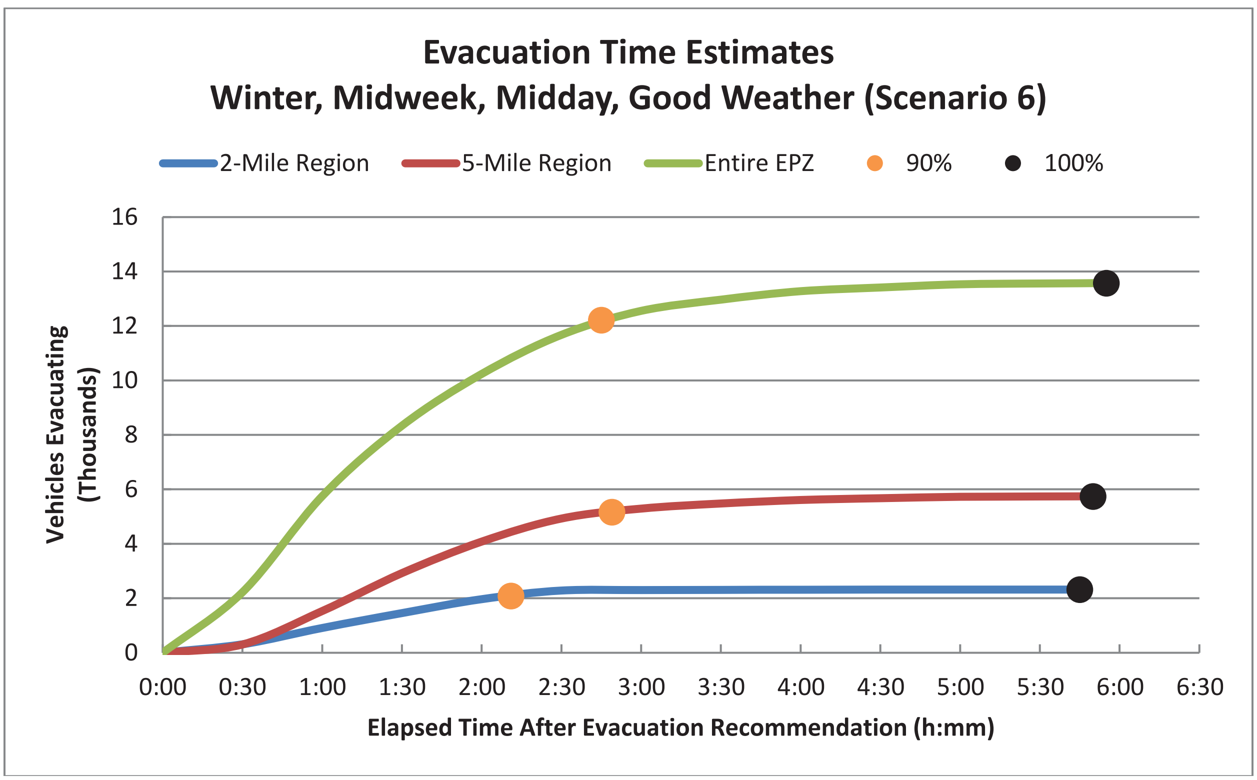


Figure 7-13. Evacuation Time Estimates - Scenario 6 for Region R03

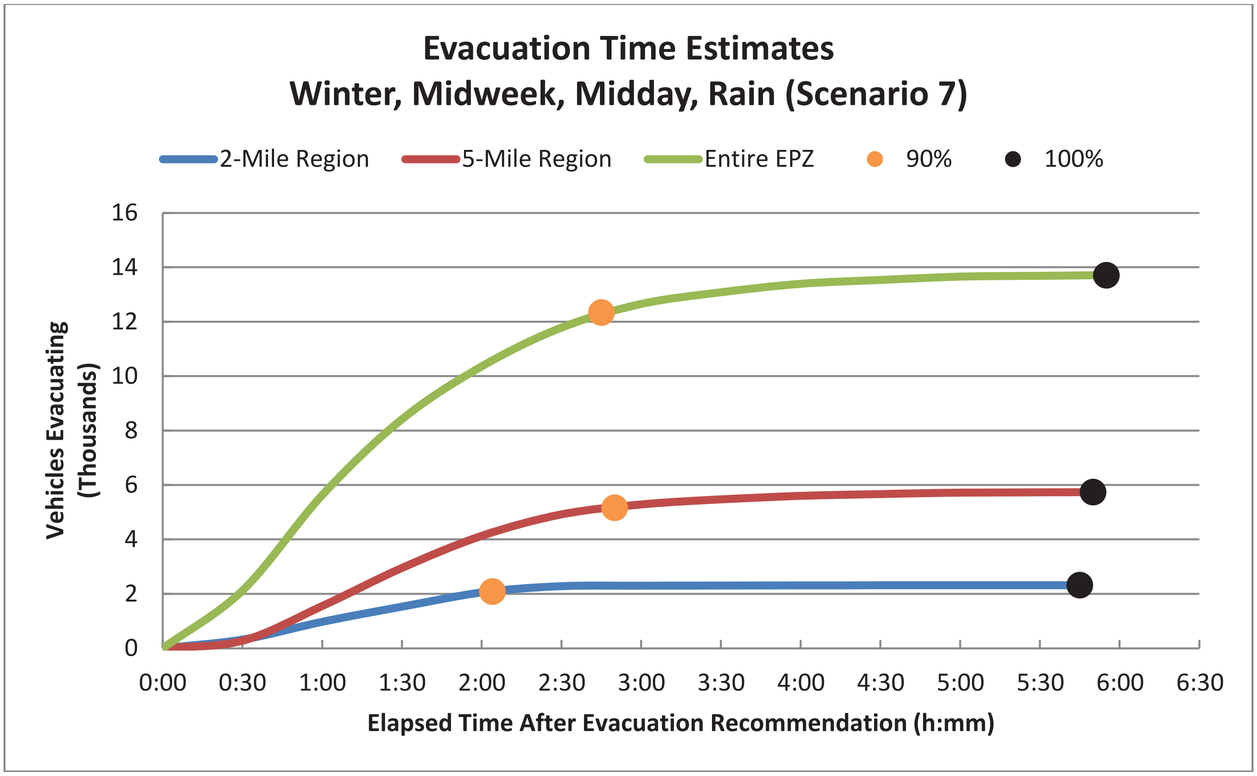


Figure 7-14. Evacuation Time Estimates - Scenario 7 for Region R03

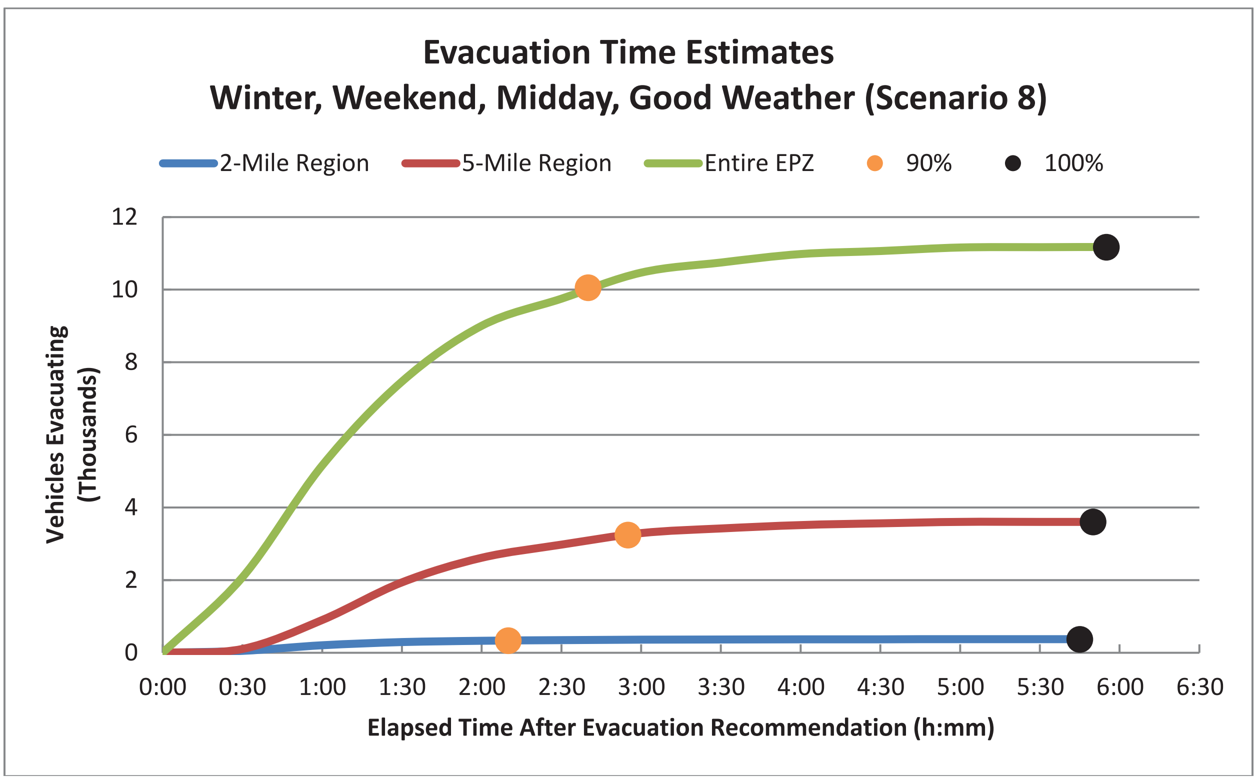


Figure 7-15. Evacuation Time Estimates - Scenario 8 for Region R03

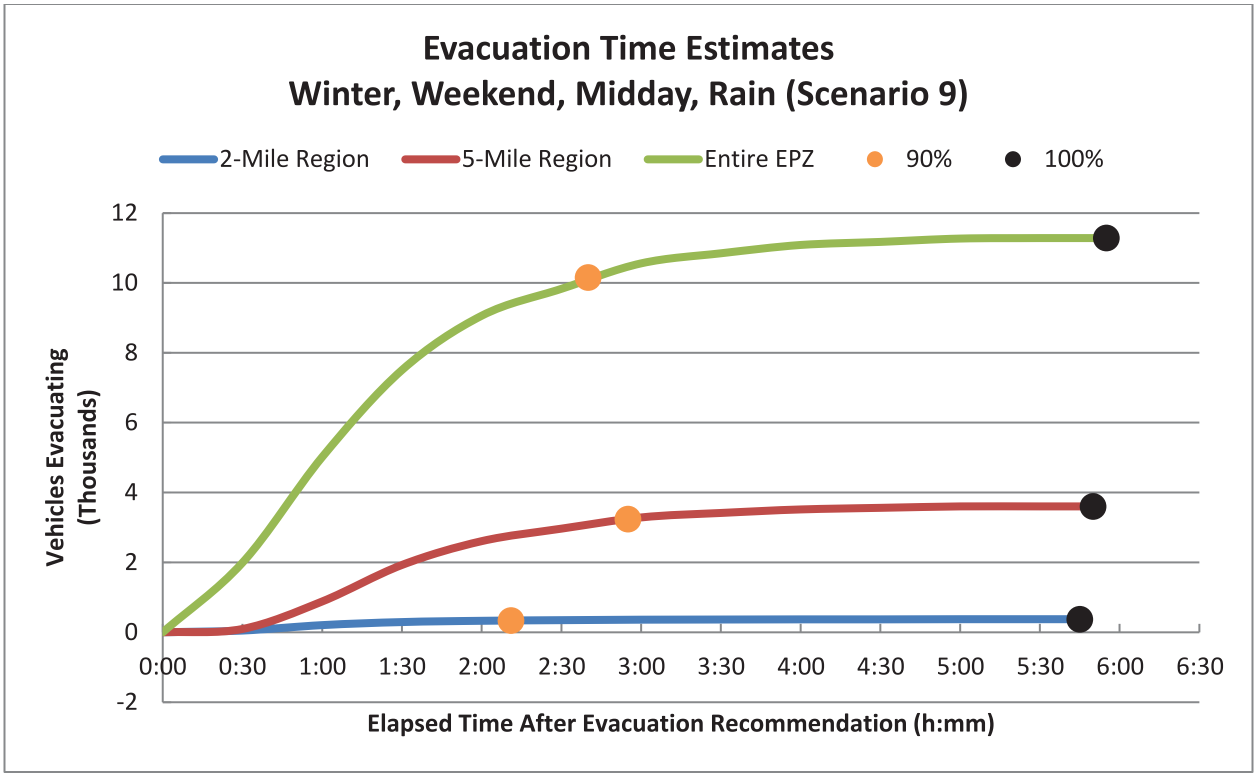


Figure 7-16. Evacuation Time Estimates - Scenario 9 for Region R03

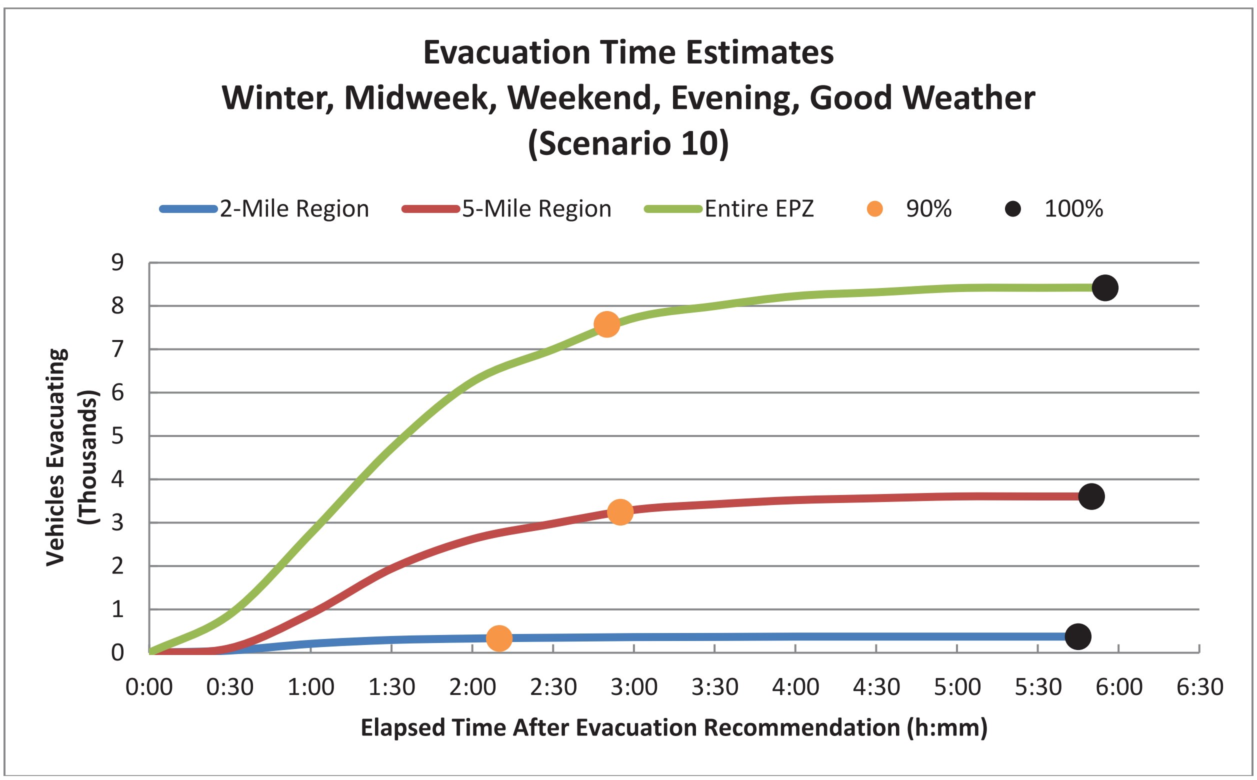


Figure 7-17. Evacuation Time Estimates - Scenario 10 for Region R03

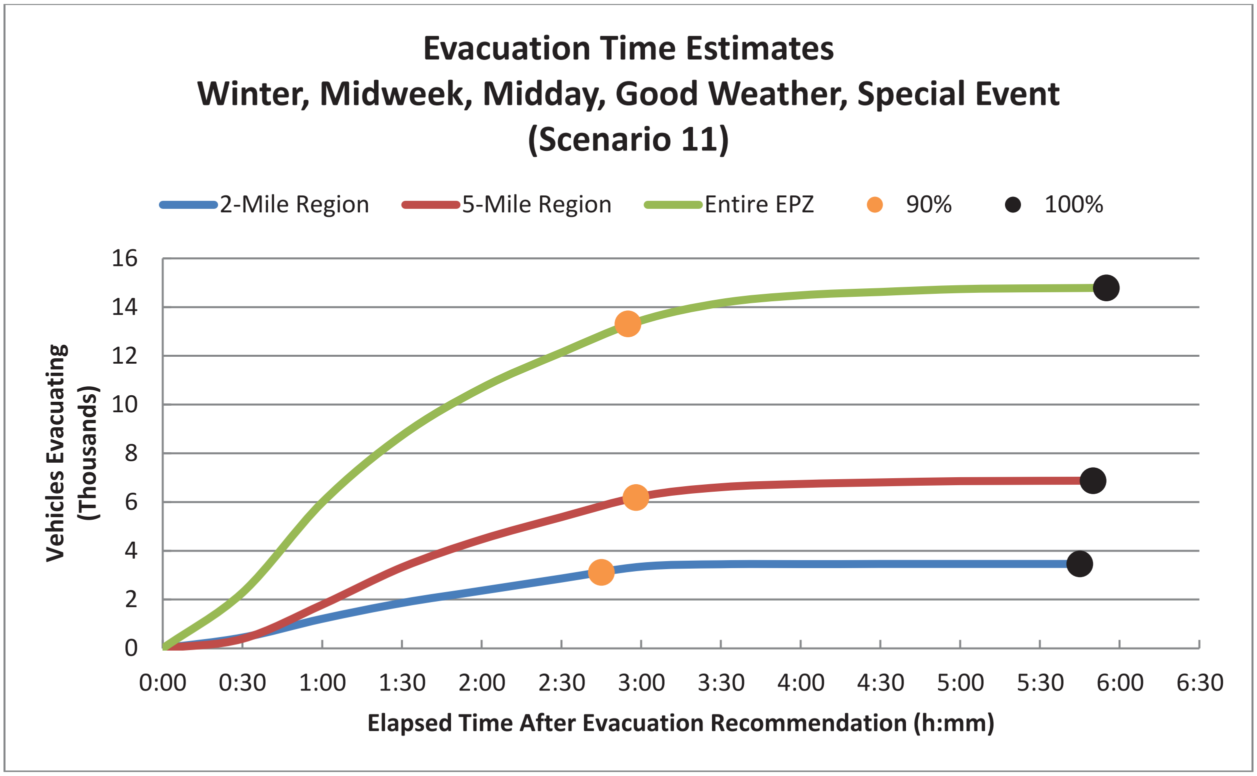


Figure 7-18. Evacuation Time Estimates - Scenario 11 for Region R03

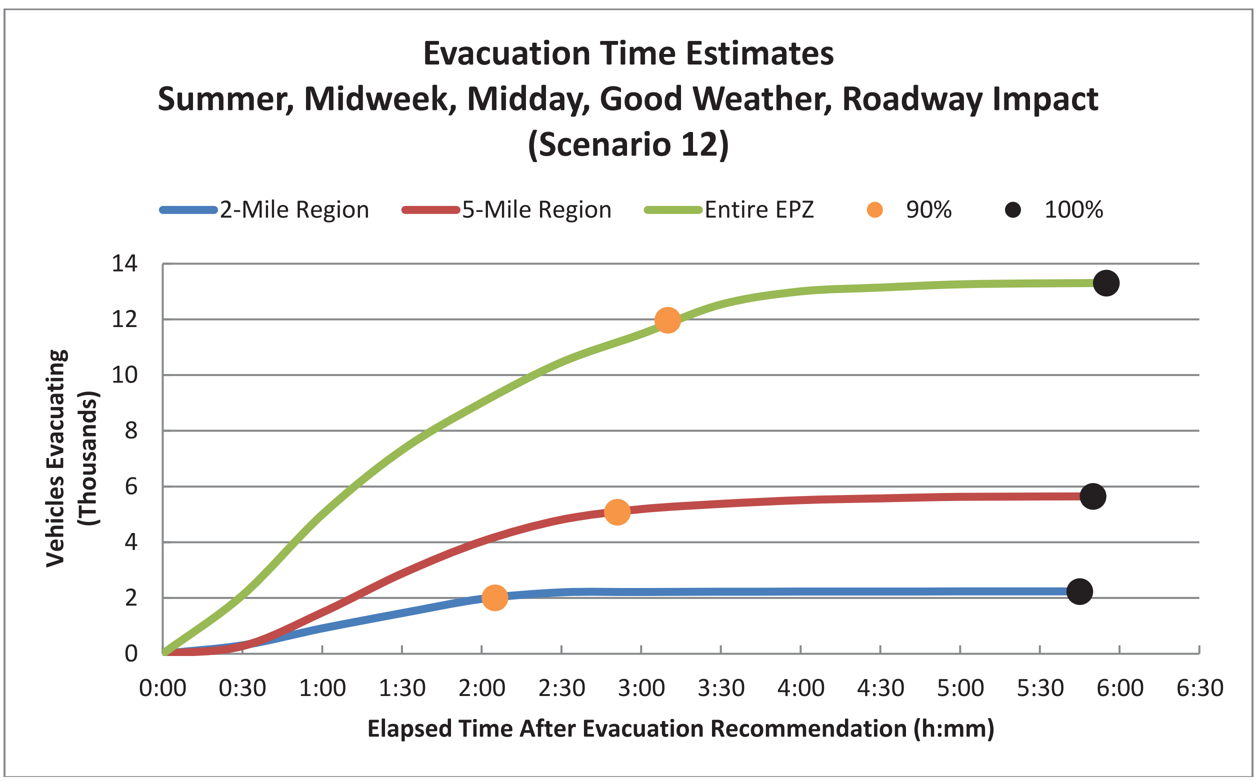


Figure 7-19. Evacuation Time Estimates - Scenario 12 for Region R03

8 TRANSIT-DEPENDENT AND SPECIAL FACILITY EVACUATION TIME ESTIMATES

This section details the analyses applied and the results obtained in the form of evacuation time estimates (ETE) for transit vehicles (buses, passenger vans, and paratransit vehicles). The demand for transit service reflects the needs of three population groups:

- residents with no vehicles available,
- residents of special facilities such as schools, and
- access and/or functional needs population.

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

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

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

These activities consume time. Based on discussion with the offsite agencies, it is estimated that bus mobilization time is 10 minutes of the Advisory to Evacuate (ATE) at Crossroads Academy, Arlington School, Tonopah Valley High School and Ruth Fisher School, as buses and drivers remain at the schools throughout the day. Winters Well Elementary School buses will arrive at the school within 20 minutes extending from the ATE to the time when buses first arrive at the school to be evacuated.

During this mobilization period, other mobilization activities are taking place. One of these is the action taken by parents, neighbors, relatives and friends to pick up children from school prior to the arrival of buses, so that they may join their families. Virtually all studies of evacuations have concluded that this "bonding" process of uniting families is universally prevalent during emergencies and should be anticipated in the planning process. The current public information disseminated to residents of the Palo Verde Nuclear Generating Station (PVNGS) EPZ indicates that schoolchildren will be evacuated to reception and care centers (RCC) prior to the evacuation of the general public, and parents should pick schoolchildren up at the RCC.

As discussed in Section 2, this study assumes a rapidly escalating event at the plant wherein evacuation is ordered promptly and no early protective actions have been implemented. Therefore, children are evacuated to the RCC. This report provides estimates of buses under the assumption that no children will be picked up by their parents (in accordance with NUREG/CR-7002, Rev. 1) to present an upper bound estimate of buses required. Picking up children at school could add to traffic congestion at the schools, delaying the departure of the buses

evacuating schoolchildren, which may have to return in a subsequent "wave" to the EPZ to evacuate the transit-dependent population.

The procedure for computing transit-dependent ETE is to:

- Estimate demand for transit service (discussed in Section 3)
- Estimate time to perform all transit functions
- Estimate route travel times to the EPZ boundary and to the RCC

8.1 ETEs for Transit Dependent People

EPZ bus resources are assigned to evacuating schoolchildren (if schools are in session at the time of the ATE) as the first priority in the event of an emergency. In the event that the allocation of buses dispatched from the depots to the various facilities and to the bus routes is somewhat "inefficient", or if there is a shortfall of available drivers, then there may be a need for some buses to return to the EPZ from the RCC after completing their first evacuation trip, to complete a "second-wave" of providing transportation service to evacuees. For this reason, the ETE for the transit-dependent population will be calculated for both a single-wave transit evacuation and for two waves. Of course, if the impacted Evacuation Region is other than R03 (the entire EPZ), then there will likely be ample transit resources relative to demand in the impacted Region and this discussion of a second-wave would likely not apply. A list of the available transportation resources was provided by the County of Maricopa and is shown in Table 8-1. It is assumed that there are enough drivers available to man all resources listed in Table 8-1.

When school evacuation needs are satisfied, subsequent assignments of buses to service the transit-dependent should be sensitive to their mobilization time. Clearly, the buses should be dispatched after people have completed their mobilization activities and are in a position to board the buses when they arrive at the various routes shown graphically in Figure 10-2.

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

<u>Activity: Mobilize Drivers (A→B→C)</u>

Mobilization time is the elapsed time from the ATE until the time the buses arrive at the school to be evacuated or to their designated route. Based on discussions with the County of Maricopa and discussed above, for a rapidly escalating radiological emergency with no observable indication before the fact, drivers would require 10 minutes to mobilize at the Crossroads Academy, Arlington School, Tonopah Valley High School and the Ruth Fisher School because the passenger vans/buses and drivers remain on-site during the school day. Drivers would require 20 minutes to be contacted, to travel to the depot, be briefed and to travel to Winters Well Elementary School, as buses are not on-site. Mobilization time is slightly longer in adverse weather – 20 minutes (30 minutes for Winters Well Elementary School) when raining.

The buses dispatched from the depots to service the transit-dependent evacuees will be scheduled so that they arrive at their respective routes after their passengers have completed their mobilization. As shown in Figure 5-4 (Residents with no Commuters), 90% of the evacuees will complete their mobilization when the buses will begin their routes, approximately 165 minutes after the ATE. Two groups of buses will be dispatched. Mobilization time is 10 minutes longer in rain to account for slower travel speeds and reduced roadway capacity.

<u>Activity: Board Passengers (C→D)</u>

As discussed in Section 2.4, a loading time of 15 minutes (20 minutes for rain) for all school buses, except for the Crossroads Academy passenger vans, where the loading time is 8 minutes (13 minutes for rain).

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

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

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

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

Assigning reasonable estimates:

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

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

<u>Activity: Travel to EPZ Boundary (D→E)</u>

The transportation resources available were provided by Maricopa County. Table 8-1 summarizes the available capacity of transportation resources and the transportation resource capacity needed to evacuate schools, transit-dependent population, and access and/or functional needs (discussed below in Section 8.2). These numbers indicate there aren't sufficient resources available to evacuate all the schools, transit-dependent population, and access and/or functional needs population in a single-wave.

Evacuation of Schools

The buses servicing Arlington Elementary School, Tonopah Valley High School, Ruth Fisher School and Palo Verde Elementary School are ready to begin their evacuation trips at 25 minutes (35 minutes for Winters Well Elementary School buses and 18 minutes for Crossroads Academy passenger vans) after the ATE – a 10-minute mobilization time (20 minutes for Winters Well Elementary School buses) plus a 15 minute loading time (8 minutes for Crossroads Academy passenger vans) – in good weather.

The UNITES software discussed in Section 1.3 was used to define bus routes along the most likely path from a school being evacuated to the EPZ boundary, traveling toward the appropriate RCC. This is done in UNITES by interactively selecting the series of nodes from the school to the EPZ boundary. Each bus route is given an identification number and is written to the DYNEV II input stream. DYNEV computes the route length and outputs the average speed for each 5 minute interval, for each bus route. The specified bus routes are documented in Section 10 in Table 10-2 (refer to the maps of the link-node analysis network in Appendix K for node locations). Data provided by DYNEV during the appropriate timeframe depending on the mobilization and loading times (i.e., 18 to 35 minutes after the ATE for good weather) were used to compute the average speed for each route, as follows:

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

The average speed computed (using this methodology) for the buses servicing the EPZ is shown in Table 8-2 and Table 8-3 for school evacuation, and in Table 8-4 and Table 8-5 for the transit-dependent persons, which are discussed later. The travel time to the EPZ boundary was computed for each bus using the computed average speed and the distance to the EPZ boundary along the most likely route out of the EPZ. The travel time from the EPZ boundary to the RCC was computed assuming an average speed of 65 mph and 60 mph (10% less) for good weather and rain, respectively. Speeds were reduced in Table 8-2, Table 8-3, Table 8-4 and Table 8-5 to 65 mph (60 mph for rain – 10% decrease) for those calculated bus speeds which exceed 65 mph, as the school bus speed limit for state routes in Arizona is 65 mph.

Table 8-2 (good weather) and Table 8-3 (rain) present the ETEs (rounded up to the nearest 5 minutes) for schools in the EPZ:

1. The elapsed time from the ATE until the bus exits the EPZ; and
2. The elapsed time until the bus reaches the School RCC.

The evacuation time out of the EPZ can be computed as the sum of times associated with Activities A→B→C, C→D, and D→E (For example: 10 min. + 15 + 13 = 0:40 for Ruth Fisher Elementary School, with good weather). The average single-wave ETE (40 minutes), for schools, is significantly less (2 hours and 5 minutes) than the 90th percentile ETE for evacuation of the general population in the entire EPZ (Region R03) under winter, midweek, midday, with good weather (Scenario 6) conditions and will not impact protective action decision making.

The evacuation time to the School RCC is determined by adding the time associated with Activity E→F (discussed below), to this EPZ evacuation time.

As shown in Table 8-1, there is a shortfall of school buses for evacuation of children in a single wave, if the entire EPZ is evacuated at once (a highly unlikely event) at Ruth Fisher Middle School, Tonopah Valley High School and Winters Well Elementary School. As these three schools use the same bus transportation resources, the following representative ETE is provided to estimate the additional time needed for a second-wave evacuation of these schools.

The travel time from the RCC back to the EPZ boundary and then back to the school was computed assuming an average speed of 65 mph (good weather) and 60 mph (rain) as buses will be traveling counter to evacuating traffic. Times and distances are based on averages for Ruth Fisher Middle School, Tonopah Valley High School and Winters Well Elementary School in the EPZ for good weather:

a. School buses arrive at the RCC: 1:00 on average (the average ETA of Ruth Fisher Middle School, Tonopah Valley High School and Winters Well Elementary School (1:00 + 1:00 + 0:55)/3, see Table 8-2)
b. Bus unload students (5 minutes) and driver takes 10-minute rest: 15 minutes.
c. Bus returns to schools: 25 minutes (average distance from EPZ boundary to RCC - 15.5 miles plus the average distance to EPZ boundary - 12.0 miles - traveling at 65 mph in good weather)
d. Loading Time: 15 minutes
e. Bus complete second-wave of service along route: 14 minutes (average distance to EPZ boundary - 12.0 miles – at network wide average speed at 1:55 of 53 mph)
f. Bus exits EPZ at time: 1:00 + 0:15 + 0:25 + 0:15 + 0:14 = 2:10 (rounded to nearest 5 minutes) after the ATE.

Given the average single-wave ETE for schools is 0:55 (see Table 8-2); a second-wave would require an additional hour and 15 minutes, on average. The average second-wave ETE (2 hours and 5 minutes), of Ruth Fisher Middle School, Tonopah Valley High School and Winters Well Elementary School is considerably less (40 minutes) than the 90th percentile ETE for evacuation of the general population in the entire EPZ (Region R03) under winter, midweek, midday, with good weather (Scenario 6) conditions and also will not impact protective action decision making.

Evacuation of Transit-Dependent Population

Discussions with the County of Maricopa stated no buses are available for the transit-dependent general population, as such, fixed bus routes would not be used for the evacuation of transit-dependent people within the PVNGS EPZ. KLD developed a set of transit routes that would encompass the most populated areas of the EPZ. Buses servicing the transit-dependent evacuees will first travel along these routes, then proceed out of the EPZ. Buses will travel along the major routes in the EPZ as described in Table 10-1 and shown graphically in Figure 10-2. These routes are only used in this study for the purpose of computing ETE. No pre-established transit dependent bus routes exist in the county emergency plans. On page PP-7 of the State of Arizona – Maricopa County Offsite Emergency Response Plans, it states that Maricopa County Department of Emergency Management will respond to the requests for transportation from those residents of the Plume Exposure Pathway EPZ.

As discussed in Section 3.6, four (4) buses are needed to service the transit-dependent population, as shown in Table 10-1, which ensures there is one bus service for each Sector within the EPZ.

Table 8-4 and Table 8-5 present the transit-dependent population ETEs for each bus route calculated using the above procedures (as discussed under School Evacuation) for good weather and rain, respectively.

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

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

For example, the ETE for the Transit Dependent Bus Route 4, servicing the 1-Mile Ring, and Sectors A, Q and R, is computed as 165 + 21 + 30 = 3:40 for good weather (rounded up to nearest 5 minutes). Here, 21 minutes is the time to travel 22.5 miles at 63.3 mph, the average speed output by the model for this route starting at 165 minutes. The average single-wave ETE (3 hours and 35 minutes) for transit-dependent people is 50 minutes longer than the general population 90th percentile ETE (2 hours and 45 minutes) for the evacuation of the entire EPZ for Scenario 6 conditions and could impact the protective action decision making.

The ETE for a second-wave (discussed below) is presented in the event there is a shortfall of available buses or bus drivers, as previously discussed and shown in Table 8-1.

<u>Activity: Travel to RCCs (E→F)</u>

The distances from the EPZ boundary to the RCCs are measured using GIS software along the most likely route from the EPZ exit point to the RCC. The RCCs are mapped in Figure 10-3. For a single-wave evacuation, this travel time outside the EPZ does not contribute to the ETE.

Assumed bus speeds of 65 mph and 60 mph for good weather and rain, respectively, will be applied for this activity for buses servicing schools and the transit-dependent population.

For a second-wave evacuation, the ETE for buses must be considered separately, since it could exceed the ETE for the general population.

Activity: Passengers Leave Bus (F→G)

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

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

The buses assigned to return to the EPZ to perform a “second-wave” evacuation of transit-dependent evacuees will be those that have already evacuated transit-dependent people who mobilized more quickly. The first wave of transit-dependent people departs the bus, and the bus then returns to the EPZ, travels to its route and proceeds to pick up more transit-dependent evacuees along the route. The travel time back to the EPZ is equal to the travel time to the RCC. Bus travel times within the EPZ are computed using average speeds computed by DYNEV, using the aforementioned methodology that was used for school evacuation.

The second-wave ETE for the Transit Dependent Bus Route 4 is computed as follows for good weather:

- Bus arrives at RCC at 4:08 in good weather (3:40 to exit EPZ + 28 minutes travel time to RCC).
- Bus discharges passengers (5 minutes) and driver takes a 10-minute rest: 15 minutes.
- Bus returns to EPZ and completes second-wave of evacuation along the route: 28 minutes (bus returns to EPZ boundary, equal to travel time to RCC) + 21 minutes (bus returns to start of the route traveling counter to evacuation traffic, 22.5 miles @ 65mph) + 21 minutes (bus completes second-wave service along route, 22.5 miles @ 61.4 mph – average speed along route output by DYNEV at 5 hours and 5 minutes when the bus begins second-wave evacuation along route)) = 71 minutes
- Bus completes pick-ups along route: 30 minutes.
- Bus exits EPZ at time 3:40 + 0:28 + 0:15 + 1:18 + 0:30 = 6:05 (rounded to nearest 5 minutes) after the ATE.

The ETE for the completion of the second-wave for all transit-dependent bus routes are provided in Table 8-4 and Table 8-5.

The average ETE (6 hours) for a second-wave evacuation of transit-dependent people is 3 hours and 15 minutes longer than the ETE for the general population at the 90th percentile for an evacuation of the entire EPZ (Region R03) under winter, midweek, midday, good weather conditions (Scenario 6) and could impact the protective action decision making.

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

8.2 ETEs for Access and/or Functional Needs Population

The access and/or functional needs population registered within the EPZ was provided by the County of Maricopa and is further discussed in Section 3.9. Table 8-6 summarizes the ETE for access and/or functional needs people. The table is categorized by type of vehicle required and then broken down by weather condition. The table takes into consideration the deployment of multiple vehicles (not filled to capacity) to reduce the number of stops per vehicle. Due to the limitations on driving for access and/or functional needs persons, it is assumed they will be picked up from their homes. Furthermore, it is conservatively assumed that households that have ambulatory and wheelchair bound and bedridden people households are spaced 3 miles apart. Paratransit vehicles and bus speeds approximate 40 mph between households in good weather (10% slower in rain). A mobilization time of 165 minutes were used (175 minutes for rain). Loading time of 1 minute per person are assumed for ambulatory and 5 minutes per person for wheelchair bound and bedridden people. The last household is assumed to be 5 miles from the EPZ boundary, and the network-wide average speed, capped at 65 mph (60 mph for rain), after the last pickup is used to compute travel time.

ETE is computed by summing mobilization time, loading time at first household, travel to subsequent households, loading time at subsequent households, and travel time to EPZ boundary. All ETE are rounded to the nearest 5 minutes.

For example, assuming no more than one access and/or functional needs person per household implies that 284 ambulatory households need to be serviced. While only 10 buses for ambulatory patients are needed from a capacity perspective, if 21 buses are deployed to service these households, then each would require about 14 stops. The following outlines the ETE calculations for a bus:

1. Assume 21 buses are deployed, each with about 14 stops, to service a total of 284 households.
2. The ETE is calculated as follows:
    a. Buses arrive at the first pickup location: 165 minutes
    b. Load household members at first pickup: 1 minute
    c. Travel to subsequent pickup locations: 13 @ 5 minutes (3 miles @ 40 mph) = 59 minutes
    d. Load household members at subsequent pickup locations: 13 @ 1 minute = 13 minutes
    e. Travel to EPZ boundary: 5 minutes (5 miles @ 58.5 mph – blended network wide average speed at 238 minutes).

ETE: 165 + 1 + 59 + 13 + 5 = 4:05 (rounded up to the nearest 5 minutes)

The average ETE (4 hours and 5 minutes) of all the access and/or functional needs population within the EPZ is longer (2 hours and 30 minutes) than the 90th percentile ETE for evacuation of the general population in the entire EPZ (Region R03) under winter, midweek, midday, with good weather (Scenario 6) conditions. Therefore, the evacuation of access and/or functional needs population will impact the protective action decision-making.

A second-wave ETE, for the access and/or functional needs population needing buses and paratransit vehicles, is needed. The following outlines the ETE calculations if a second-wave ETE is computed for buses as follows for good weather:

a. School buses arrive at RCC (average value from Table 8-2): 50 minutes.
b. Unload students at RCC (5 minutes) and driver takes a 10-minute rest: 15 minutes
c. Travel time back to EPZ: 13 minutes (average time of "Travel Time from EPZ bdry to RCC" from Table 8-2 and Table 8-3)
d. Bus travels to all stops: 14 stops @ 5 minutes = 63 minutes
e. Loading time at all stops: 14 stops @ 1 minutes = 14 minutes
f. Travel time to EPZ boundary: : 6 minutes (5 miles @ 53.7 mph – blended network wide average speed at 240 minutes)

ETE: 0:50 + 0:15 + 0:13 + 0:63 + 0:14 + 0:06 = 2:45 (rounded up to the nearest 5 minutes)

The average ETE (3 hours) for a second-wave evacuation of access and/or functional needs population within the EPZ is 15 minutes longer than the ETE for the general population at the 90th percentile for an evacuation of the entire EPZ (Region R03) under winter, midweek, midday, with good weather conditions (Scenario 6) and could impact the protective action decision making.

Table 8-1. Summary of Transportation Resource

Transportation Resource	Buses	Passenger Vans	Paratransit Vehicles
Resources Available			
Ruth Fisher Elementary /Tonopah Valley High School/Winters Well Elementary School	30	0	0
Arlington Elementary School	7	0	0
Palo Verde Elementary School[1]	8	0	0
Crossroads Academy	0	2	0
TOTAL:	**45**	**2**	**0**
Resources Needed			
Schools (Table 3-8):	50	1	0
Transit-Dependent Population (Table 3-12):	4	0	0
Access and/or Functional Needs Population (Table 3-9):	10	0	7
TOTAL TRANSPORTATION NEEDS:	**64**	**1**	**7**

[1] Palo Verde Elementary School is located in the Shadow Region. MCDEM indicated these schools would evacuate in the event of an emergency at the PVNGS.

Table 8-2. 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 RCC (mi.)	Travel Time from EPZ Bdry to RCC (min)	ETA to RCC (hr:min)
MARICOPA COUNTY SCHOOLS									
Crossroads Academy	10	8	12.4	62.7	12	**0:30**	19.0	18	**0:50**
Ruth Fisher Elementary School	10	15	13.2	61.2	13	**0:40**	19.0	18	**1:00**
Tonopah Valley High School	10	15	13.2	61.2	13	**0:40**	19.0	18	**1:00**
Winters Well Elementary School	20	15	9.8	61.3	10	**0:45**	8.4	8	**0:55**
Arlington Elementary School	10	15	8.4	50.9	10	**0:35**	8.4	8	**0:45**
Palo Verde Elementary School[2]	10	15	0.0	0.0	0	**0:25**	10.8	10	**0:35**
					Maximum for EPZ:	**0:45**		**Maximum:**	**1:00**
					Average for EPZ:	**0:40**		**Average:**	**0:50**

Table 8-3. 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 RCC (mi.)	Travel Time from EPZ Bdry to RCC (min)	ETA to RCC (hr:min)
MARICOPA COUNTY SCHOOLS									
Crossroads Academy	20	13	12.4	54.8	14	**0:50**	19.0	19	**1:10**
Ruth Fisher Elementary School	20	20	13.2	54.5	14	**0:55**	19.0	19	**1:15**
Tonopah Valley High School	20	20	13.2	54.5	14	**0:55**	19.0	19	**1:15**
Winters Well Elementary School	30	20	9.8	48.2	12	**1:05**	8.4	8	**1:15**
Arlington Elementary School	20	20	8.4	45.4	11	**0:55**	8.4	8	**1:05**
Palo Verde Elementary School[2]	20	20	0.0	0.0	0	**0:40**	10.8	11	**0:55**
					Maximum for EPZ:	**1:05**		**Maximum:**	**1:15**
					Average for EPZ:	**1:00**		**Average:**	**1:10**

[2] Palo Verde Elementary School is located in the Shadow Region. MCDEM indicated that this school would evacuate in the event of an emergency at the PVNGS.

Table 8-4. Transit-Dependent Evacuation Time Estimates - Good Weather

		One-Wave							Second-Wave					
Route Number	Number of Buses	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to RCC (miles)	Travel Time to RCC (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
4	1	165	22.5	63.3	21	30	**3:40**	29.8	28	5	10	71	30	**6:05**
5	1-2	165	12.4	61.0	12	30	**3:30**	36.7	34	5	10	58	30	**5:50**
6	1	165	13.8	53.0	16	30	**3:35**	38.0	35	5	10	63	30	**6:00**
						Maximum ETE:	**3:40**						**Maximum ETE:**	**6:05**
						Average ETE:	**3:35**						**Average ETE:**	**6:00**

Table 8-5. Transit-Dependent Evacuation Time Estimates - Rain

		One-Wave							Second-Wave					
Route Number	Number of Buses	Mobilization (min)	Route Length (miles)	Speed (mph)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)	Distance to RCC (miles)	Travel Time to RCC (min)	Unload (min)	Driver Rest (min)	Route Travel Time (min)	Pickup Time (min)	ETE (hr:min)
4	1	175	22.5	58.1	23	40	**4:00**	29.8	30	5	10	73	40	**6:40**
5	1-2	175	12.4	56.1	13	40	**3:50**	36.7	37	5	10	61	40	**6:25**
6	1	175	13.8	48.6	17	40	**3:55**	38.0	38	5	10	67	40	**6:35**
						Maximum ETE:	**4:00**						**Maximum ETE:**	**6:40**
						Average ETE:	**3:55**						**Average ETE:**	**6:35**

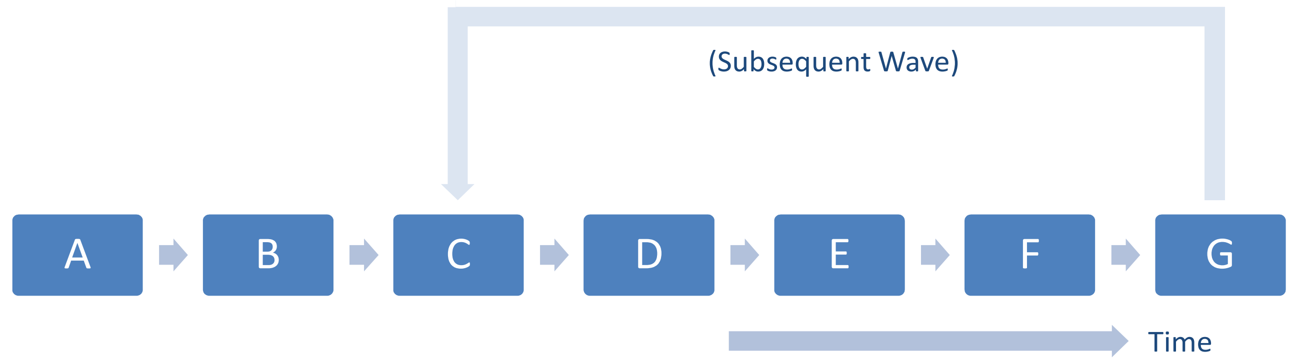
Table 8-6. Access and/or Functional Needs Population Evacuation Time Estimates

Vehicle Type	People Requiring Vehicle	Vehicles deployed	Stops	Weather Conditions	Mobilization Time (min)	Loading Time at 1st Stop (min)	Travel to Subsequent Stops (min)	Total Loading Time at Subsequent Stops (min)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Buses	284	21	14	Good	165	1	59	13	5	**4:05**
				Rain	175		65		5	**4:20**
Paratransit Vehicles	70	7	10	Good	165	5	41	45	5	**4:25**
				Rain	175		45		5	**4:35**
									Maximum ETE:	**4:35**
									Average ETE:	**4:25**

Table 8-7. Access and/or Functional Needs Population Evacuation Time Estimates – Second-Wave for Buses and Paratransit Vehicles

Vehicle Type	People Requiring Vehicle	Vehicles deployed	Stops	Weather Conditions	One Wave ETE[3] (hr:min)	Unload Passengers (min)	Driver Rest (min)	Travel Time Back to EPZ[4] (min)	Travel to All Stops (min)	Total Loading Time at All Stops (min)	Travel Time to EPZ Boundary (min)	ETE (hr:min)
Buses	284	21	14	Good	0:50	5	10	13	63	14	6	**2:45**
				Rain	1:10	5	10	14	70		6	**3:10**
Paratransit Vehicles	70	7	10	Good	0:50	5	10	13	45	10	6	**2:25**
				Rain	1:10	5	10	14	50		6	**2:50**
											Maximum ETE:	**3:10**
											Average ETE:	**3:00**

[3] Average ETA to the RCC from Table 8-2 and Table 8-3, respectively.
[4] Average of travel time from EPZ boundary to the RCC from Table 8-2 and Table 8-3, respectively.



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

Figure 8-1. Chronology of Transit Evacuation Operations

9 TRAFFIC MANAGEMENT STRATEGY

This section discusses the suggested Traffic Management Plan (TMP) that is designed to expedite the movement of evacuating traffic. The resources required to implement the TMP include:

- Personnel with the capabilities of performing the planned control functions of traffic guides (preferably, not necessarily, law enforcement officers).
- The Manual on Uniform Traffic Control Devices (MUTCD) published by the Federal Highway Administration (FHWA) of the U.S.D.O.T. provides guidance for Traffic Control Devices to assist these personnel in the performance of their tasks. All state and most county transportation agencies have access to the MUTCD, which is available on-line: http://mutcd.fhwa.dot.gov which provides access to the official PDF version.
- A written plan that defines all Traffic Control Points and Access Control Points (Roadblocks) locations, provides necessary details and is documented in a format that is readily understood by those assigned to perform traffic control.

The functions to be performed in the field are:

1. <u>Facilitate</u> evacuating traffic movements that safely expedite travel out of the EPZ.
2. <u>Discourage</u> traffic movements that move evacuating vehicles in a direction which takes them significantly closer to the power plant, or which interferes with the efficient flow of other evacuees.

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

For example:

- A driver may be traveling home from work or from another location, to join other family members prior to evacuating.
- An evacuating driver may be travelling to pick up a relative, or other evacuees.
- The driver may be an emergency worker entering the area being evacuated to perform an important emergency service.

The implementation of a TMP <u>must</u> also be flexible enough for the application of sound judgment by the traffic guide.

The TMP is the outcome of the following process:

1. The PVNGS 10-Mile Emergency Planning Zone with Roadblocks Figure, provided by Maricopa County and discussed in the Maricopa County Emergency Operations Plan, serve as the basis of the traffic management plan, as per NUREG/CR-7002, Rev. 1. Initially, the ETE analysis treated all controlled intersections that are existing Roadblock locations as being controlled by actuated signals. The Roadblocks were then removed except for those located on I-10 (to stop external-external traffic), as discussed below.

Appendix K identifies the number of intersections that were ultimately modeled as Roadblocks.

2. Evacuation simulations were run using DYNEV II with the TMP and then run again incorporating only the Roadblocks on I-10, to predict traffic congestion during evacuation. The evacuation simulations using Roadblocks on I-10 is what is discussed in Section 7.3 and as seen in Figures 7-3 through 7-7. These simulations help to identify the best routing and critical intersections that experience pronounced congestion during evacuation. Any critical intersections that would benefit from traffic or access control which are not already identified on I-10 are examined. No additional Roadblocks were identified as part of this study.
3. Prioritization of Roadblocks (See Appendix G for more detail.):
    a. Application of traffic and access control at some Roadblocks will have a more pronounced influence on expediting traffic movements than at other Roadblocks. For example, Roadblocks controlling traffic originating from areas in close proximity to the power plant could have a more beneficial effect on minimizing potential exposure to radioactivity than those located far from the power plant. Key locations for manual traffic control (MTC) was analyzed and their impact to ETE was quantified, as per NUREG/CR-7002, Rev. 1.
    b. This analysis determined that the TMP were not beneficial during the evacuation and simulations were run using only the Roadblocks on I-10.

Appendix G documents the existing TMP and list of priority Roadblocks using the process enumerated above.

9.1 Assumptions

The ETE calculations documented in Sections 7 and 8 assume that the TMP is not implemented (except on I-10) during evacuation.

The ETE calculations reflect the assumption that all “external-external” trips are interdicted and diverted after 45 minutes have elapsed from the Advisory to Evacuate (ATE).

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

Study Assumptions 1, 2, and 3 in Section 2.5 discuss the Roadblocks operations.

9.2 Additional Considerations

The use of Intelligent Transportation Systems (ITS) technologies can reduce the manpower and equipment needs, while still facilitating the evacuation process. Dynamic Message Signs (DMS) can also be placed within the EPZ to provide information to travelers regarding traffic conditions, route selection, and reception center information. The DMS placed outside of the EPZ will warn motorists to avoid using routes that may conflict with the flow of evacuees away from the power plant. Highway Advisory Radio (HAR) can be used to broadcast information to

evacuees during egress through their vehicle's stereo systems. Automated Traveler Information Systems (ATIS) can also be used to provide evacuees with information. Internet websites can provide traffic and evacuation route information before the evacuee begins their trip, while the on board navigation systems (GPS units), and smartphones can be used to provide information during the evacuation trip.

These are only several examples of how ITS technologies can benefit the evacuation process. Consideration should be given that ITS technologies can be used to facilitate the evacuation process, and any additional signage placed should consider evacuation needs.

10 EVACUATION ROUTES AND RECEPTION CENTERS

10.1 Evacuation Routes

Evacuation routes are comprised of two distinct components:

- Routing from Sectors being evacuated to the boundary of the Evacuation Region and thence out of the Emergency Planning Zone (EPZ).
- Routing of transit-dependent evacuees (schools and residents, employees or transients who do not own or have access to a private vehicle) from the EPZ boundary to reception and care centers.

Evacuees will select routes within the EPZ in such a way as to minimize their exposure to risk. This expectation is met by the DYNEV II model, routing traffic away from the location of the plant to the extent practical. The DTRAD model satisfies this behavior by routing traffic to balance traffic demand relative to the available highway capacity to the extent possible. See Appendices B through D for further discussion. The major evacuation routes for the EPZ are presented in Figure 10-1. These routes will be used by the general population evacuating in private vehicles and by the transit-dependent population evacuating in buses. Transit-dependent evacuees will be routed to reception centers. General population may evacuate to a reception center or some alternate destination (e.g., lodging facility, relative's home, campground) outside the EPZ.

The routing of transit-dependent evacuees from the EPZ boundary to reception and care centers is designed to minimize the amount of travel outside the EPZ, from the points where these routes cross the EPZ boundary. The three bus routes shown graphically in Figure 10-2 and described in Table 10-1 were designed by KLD, as no pre-established transit-dependent bus routes exist within the county emergency plans. The routes were designed to service the transit-dependent population within each Sector. This does not imply that these exact routes would be used in an emergency. It is assumed that residents will walk to the nearest major evacuation route and flag down a passing bus, and that they can arrive at the roadway within the 165-minute bus mobilization time (good weather). These routes are only used in this study for the purpose of computing ETE.

Schools were routed along the most likely path from the school being evacuated to the EPZ boundary, traveling toward the nearest reception and care center.

The specified bus routes for all the transit-dependent population are documented in Table 10-2 (refer to the maps of the link-node analysis network in Appendix K for node locations). This study does not consider the transport of evacuees from reception centers to congregate care centers if the county does make the decision to relocate evacuees.

10.2 Reception and Care Centers

According to current public information issued to EPZ residents, evacuees living within the EPZ will be directed to the appropriate reception and care center location. The current public information lists the reception and care centers. It is assumed that the transit-dependent evacuees will be routed to the nearest reception and care centers. Figure 10-3 presents a map showing the reception and care centers for evacuees. Table 10-3 presents a list of the reception and care centers for each evacuating school in the EPZ. It is assumed that all school evacuees will be taken to the closest reception and care center and will be subsequently picked up by parents or guardians. No school evacuees will be picked up by parents prior to the arrival of the buses.

Table 10-1. Summary of Transit-Dependent Bus Routes

Route	No. of Buses	Route Description	Sector(s) Serviced	Length (mi.)
4	1	Transit Dependent Bus Route 2	1-Mile Ring, A, Q and R	22.5
5	2	Transit Dependent Bus Route 1	B, C, D, E and F	12.4
6	1	Transit Dependent Bus Route 3	G, H, J, K, L, M, N and P	13.8
Total:	4			

Table 10-2. Bus Route Descriptions

Bus Route Number	Description	Nodes Traversed from Route Start to EPZ Boundary
1	Arlington Elementary School	147, 79, 82, 80, 130, 45, 46, 47, 187, 151
2	Ruth Fisher Elementary School/Tonopah Valley High School	86, 153, 126, 87, 134, 67, 11, 12
3	Winters Well Elementary School	149, 148, 113, 67, 11, 12
4	Transit Dependent Bus Route 2	25, 26, 189, 193, 27, 38, 30, 117, 136, 7, 8, 9, 10, 11, 12
5	Transit Dependent Bus Route 1/ Crossroads Academy	25, 186, 185, 184, 116, 83, 44, 157, 45, 46, 47, 187, 151
6	Transit Dependent Bus Route 3	238, 100, 174, 81, 147, 79, 82, 80, 130, 45, 46, 47, 187, 151

Table 10-3. School Reception and Care Centers

School	Reception and Care Center
Arlington Elementary School	Buckeye Youngker High School
Palo Verde Elementary School[1]	Buckeye Youngker High School
Tonopah Valley High School	Goodyear Desert Edge High School
Ruth Fisher Middle School	
Winters Well Elementary School	Buckeye Youngker High School
Crossroads Academy	Goodyear Desert Edge High School

[1] Palo Verde Elementary School is outside of the study area. Maricopa County Radiological Emergency Preparedness Plan indicates that this school would evacuate in the event of an emergency at the PVNGS.

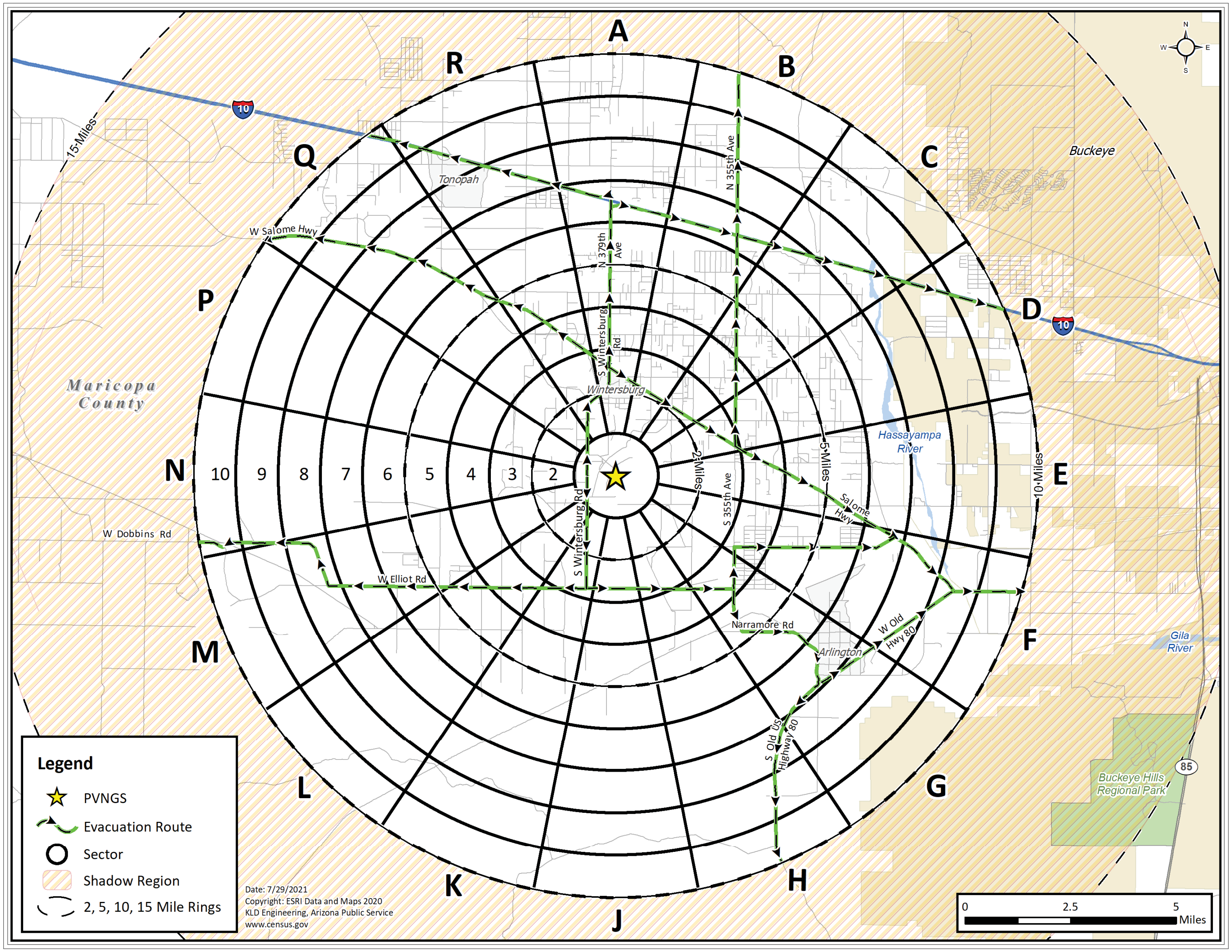


Figure 10-1. Evacuation Route

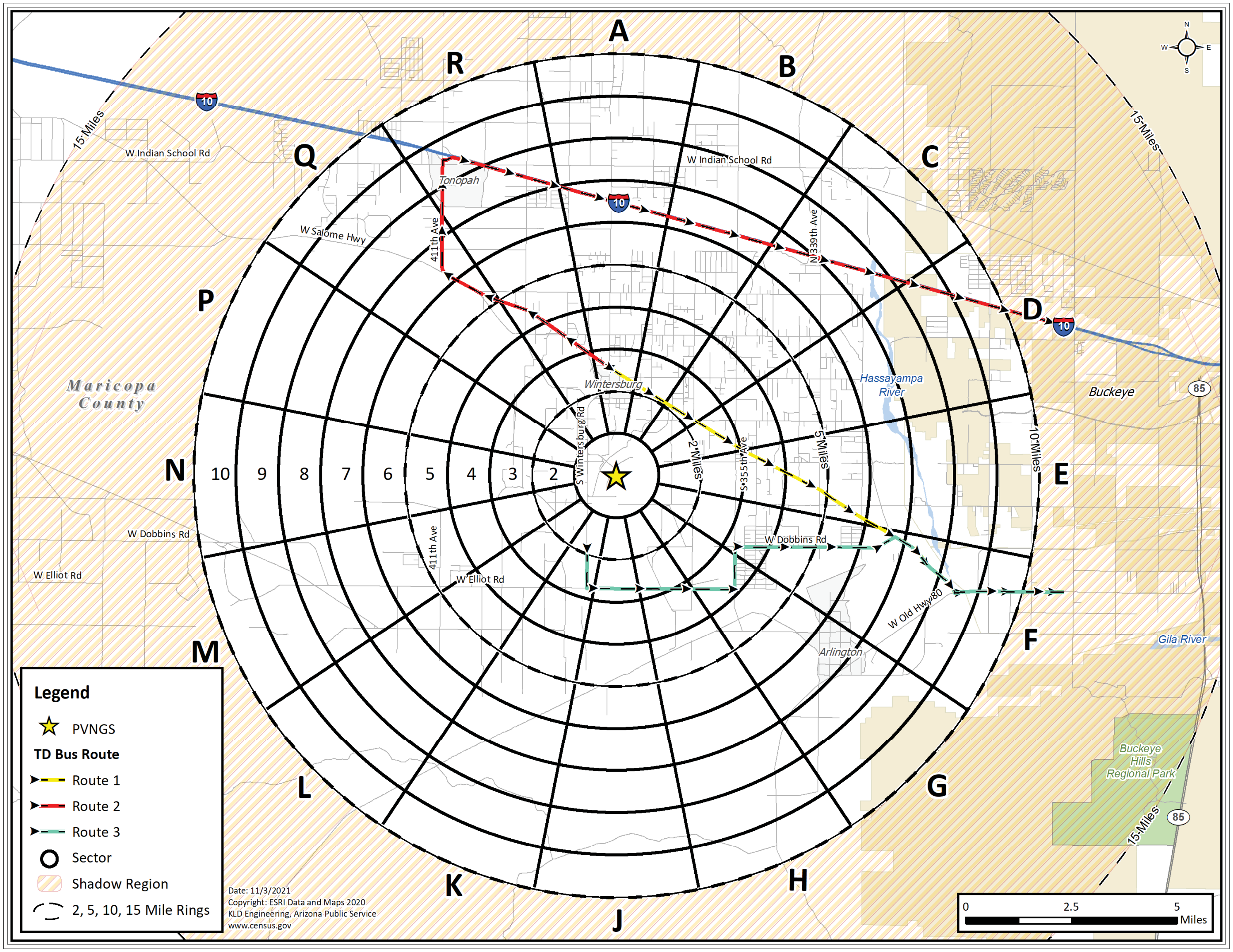


Figure 10-2. Transit-Dependent Bus Routes

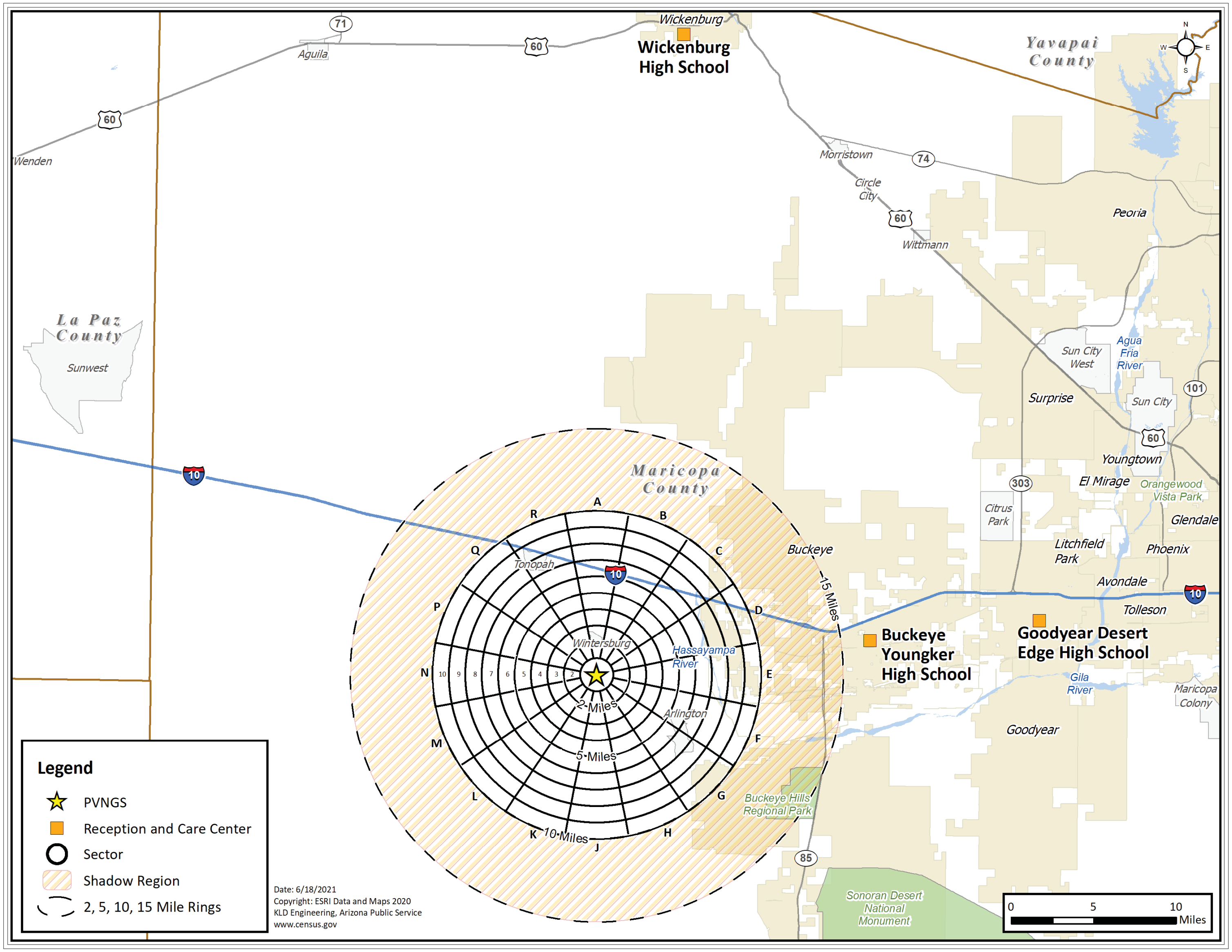


Figure 10-3. Reception and Care Centers

APPENDIX A

Glossary of Traffic Engineering Terms

A. GLOSSARY OF TRAFFIC ENGINEERING TERMS

Table A-1. Glossary of Traffic Engineering Terms

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

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

APPENDIX B

DTRAD: Dynamic Traffic Assignment and Distribution Model

B. DYNAMIC TRAFFIC ASSIGNMENT AND DISTRIBUTION MODEL

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

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

B.1 Overview of Integrated Distribution and Assignment Model

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

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

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

B.2 Interfacing the DYNEV Simulation Model with DTRAD

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

B.2.1 DTRAD Description

DTRAD is the DTA module for the DYNEV II System.

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

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

- It is assumed that drivers not only select the best route (i.e., lowest cost path) but some also select less attractive routes. The algorithm implemented by DTRAD archives several "efficient" routes for each O-D pair from which the drivers choose.

- The choice of one route out of a set of possible routes is an outcome of "discrete choice modeling". Given a set of routes and their generalized costs, the percentages of drivers that choose each route is computed. The most prevalent model for discrete choice modeling is the logit model. DTRAD uses a variant of Path-Size-Logit model (PSL). PSL overcomes the drawback of the traditional multinomial logit model by incorporating an additional deterministic path size correction term to address path overlapping in the random utility expression.

- DTRAD executes the traffic assignment (TA) algorithm on an abstract network representation called "the path network" which is built from the actual physical link-node analysis network. This execution continues until a stable situation is reached: the volumes and travel times on the edges of the path network do not change significantly from one iteration to the next. The criteria for this convergence are defined by the user.
- Travel "cost" plays a crucial role in route choice. In DTRAD, path cost is a linear summation of the generalized cost of each link that comprises the path. The generalized cost for a link, a, is expressed as

$$c_a = \alpha t_a + \beta l_a + \gamma s_{a,}$$

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

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

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

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

  The value of d_o = 10 miles, the outer distance of the EPZ. Note that the supplemental cost, $s_{a,}$ of link, a, is (high, low), if its downstream node, n, is (near, far from) the power plant.

B.2.2 Network Equilibrium

In 1952, John Wardrop wrote:

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

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

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

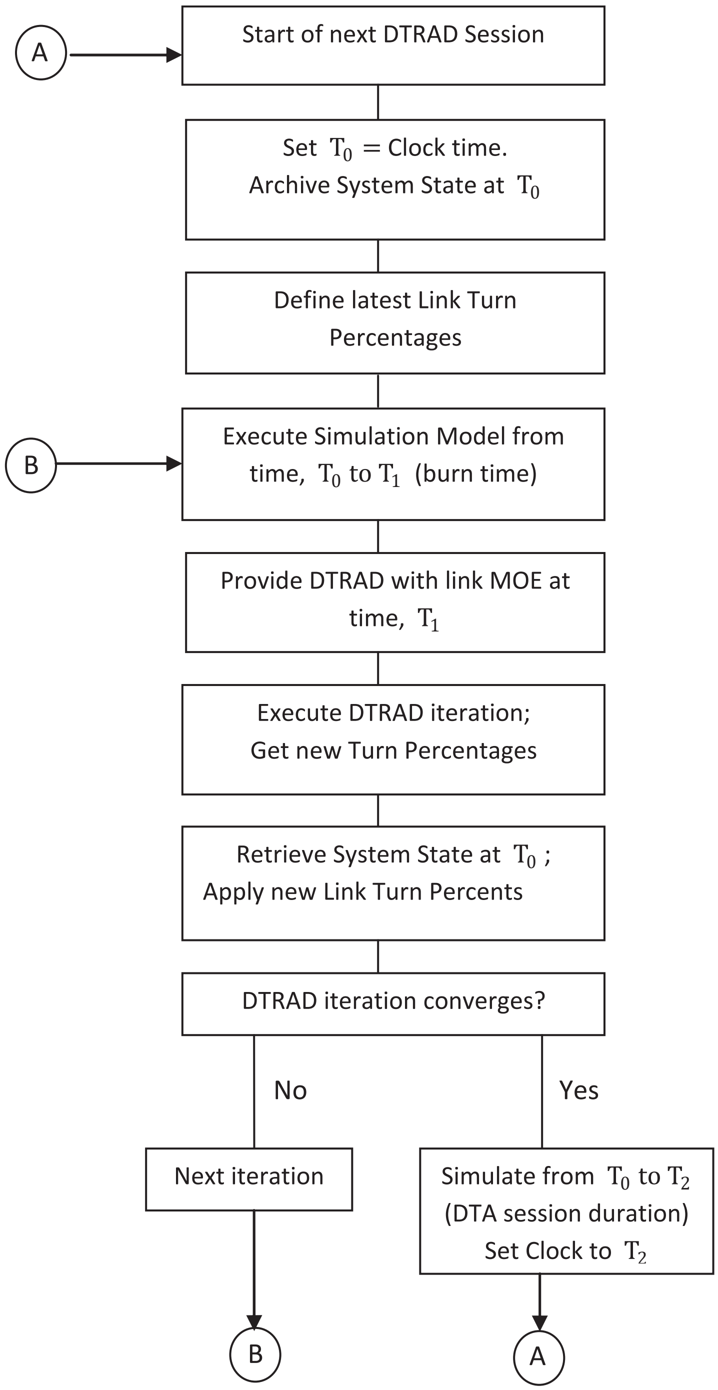


Figure B-1. Flow Diagram of Simulation-DTRAD Interface

APPENDIX C

DYNEV Traffic Simulation Model

C. DYNEV TRAFFIC SIMULATION MODEL

This appendix describes the DYNEV traffic simulation model. The DYNEV traffic simulation model is a *macroscopic* model that describes the operations of traffic flow in terms of aggregate variables: vehicles, flow rate, mean speed, volume, density, queue length, *on each link*, for each turn movement, during each Time Interval (simulation time step). The model generates trips from "sources" and from Entry Links and introduces them onto the analysis network at rates specified by the analyst based on the mobilization time distributions. The model simulates the movements of all vehicles on all network links over time until the network is empty. At intervals, the model outputs Measures of Effectiveness (MOE) such as those listed in Table C-1.

Model Features Include:

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

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

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

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

C.1 Methodology

C.1.1 The Fundamental Diagram

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

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

C.1.2 The Simulation Model

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

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

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

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

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

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

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

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

6. Else $(Q_b \prec \text{Cap})$
   $O_Q = Q_b$, $\text{RCap} = \text{Cap} - O_Q$

7. If $M_b \leq \text{RCap}$, then

8. If $t_1 > 0$, $O_M = M_b, O_E = \min\left(\text{RCap} - M_b, \frac{t_1 \text{Cap}}{TI}\right) \geq 0$
   $Q'_e = E_1 - O_E$
   If $Q'_e > 0$, then

Calculate Q_e , M_e with Algorithm A

Else

$Q_e = 0$, $M_e = E_2$

End if

Else $(t_1 = 0)$

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

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

End if

9. Else $(M_b > RCap)$

$O_E = 0$

If $t_1 > 0$, then

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

Calculate Q_e and M_e using Algorithm A

10. Else $(t_1 = 0)$

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

If $M_d > RCap$, *then*

$O_M = RCap$

$Q'_e = M_d - O_M$

Apply Algorithm A to calculate Q_e and M_e

Else

$O_M = M_d$

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

End if

End if

End if

End if

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

where k_b = density at the beginning of the TI

k_e = density at the end of the TI

k_m = density at the mid-point of the TI

All values of density apply only to the moving vehicles.

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

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

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

End if

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

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

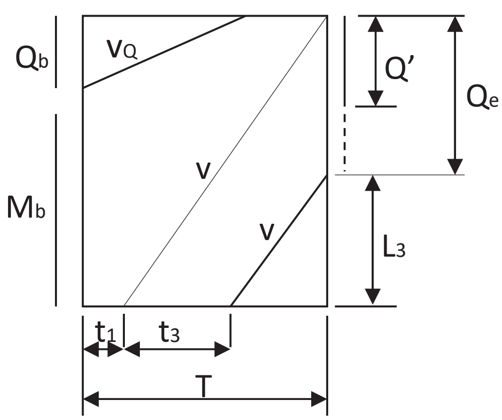
The number of excess vehicles that cause spillback is: $SB = Q_e + M_e - \frac{(L-W) \cdot LN}{L_v}$, where W is the width of the upstream intersection. To prevent spillback, meter the outflow from the feeder approaches and from the source flow, S, during this TI by the amount, SB. That is, set

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

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

Algorithm A

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



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

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

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

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

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

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

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

C.1.3 Lane Assignment

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

C.2 Implementation

C.2.1 Computational Procedure

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

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

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

The solution of the unit problem yields the values of the number of vehicles, O, that discharge from the link over the time interval and the number of vehicles that remain on the link at the end of the time interval as stratified by queued and moving vehicles: Q_e and M_e. The

procedure considers each movement separately (multi-piping). After all network links are processed for a given network sweep, the updated consistent values of entering flows, E; metering rates, M; and source flows, S are defined so as to satisfy the "no spillback" condition. The procedure then performs the unit problem solutions for all network links during the following sweep.

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

C.2.2 Interfacing with Dynamic Traffic Assignment (DTRAD)

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

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

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

Additional details are presented in Appendix B.

Table C-1. Selected Measures of Effectiveness Output by DYNEV II

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

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

HIGHWAY NETWORK

- Links defined by upstream and downstream node numbers
- Link lengths
- Number of lanes (up to 9) and channelization
- Turn bays (1 to 3 lanes)
- Destination (exit) nodes
- Network topology defined in terms of downstream nodes for each receiving link
- Node Coordinates (X,Y)
- Nuclear Power Plant Coordinates (X,Y)

GENERATED TRAFFIC VOLUMES

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

TRAFFIC CONTROL SPECIFICATIONS

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

DRIVER'S AND OPERATIONAL CHARACTERISTICS

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

DYNAMIC TRAFFIC ASSIGNMENT

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

INCIDENTS

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

Table C-3. Glossary

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

Q_b , Q_e	The number of queued vehicles on the link, of a particular turn movement, at the [beginning, end] of the time interval.
Q_{max}	The maximum flow rate that can be serviced by a link for a particular movement in the absence of a control device. It is specified by the analyst as an estimate of link capacity, based upon a field survey, with reference to the HCM 2016.
R	The factor that is applied to the capacity of a link to represent the "capacity drop" when the flow condition moves into the forced flow regime. The lower capacity at that point is equal to RQ_{max} .
RCap	The remaining capacity available to service vehicles of a particular movement after that queue has been completely serviced, within a time interval, expressed as vehicles.
S_x	Service rate for movement x, vehicles per hour (vph).
t_1	Vehicles of a particular turn movement that enter a link over the first t_1 seconds of a time interval, can reach the stop-bar (in the absence of a queue down-stream) within the same time interval.
TI	The time interval, in seconds, which is used as the simulation time step.
v	The mean speed of travel, in feet per second (fps) or miles per hour (mph), of moving vehicles on the link.
v_Q	The mean speed of the last vehicle in a queue that discharges from the link within the TI. This speed differs from the mean speed of moving vehicles, v.
W	The width of the intersection in feet. This is the difference between the link length which extends from stop-bar to stop-bar and the block length.

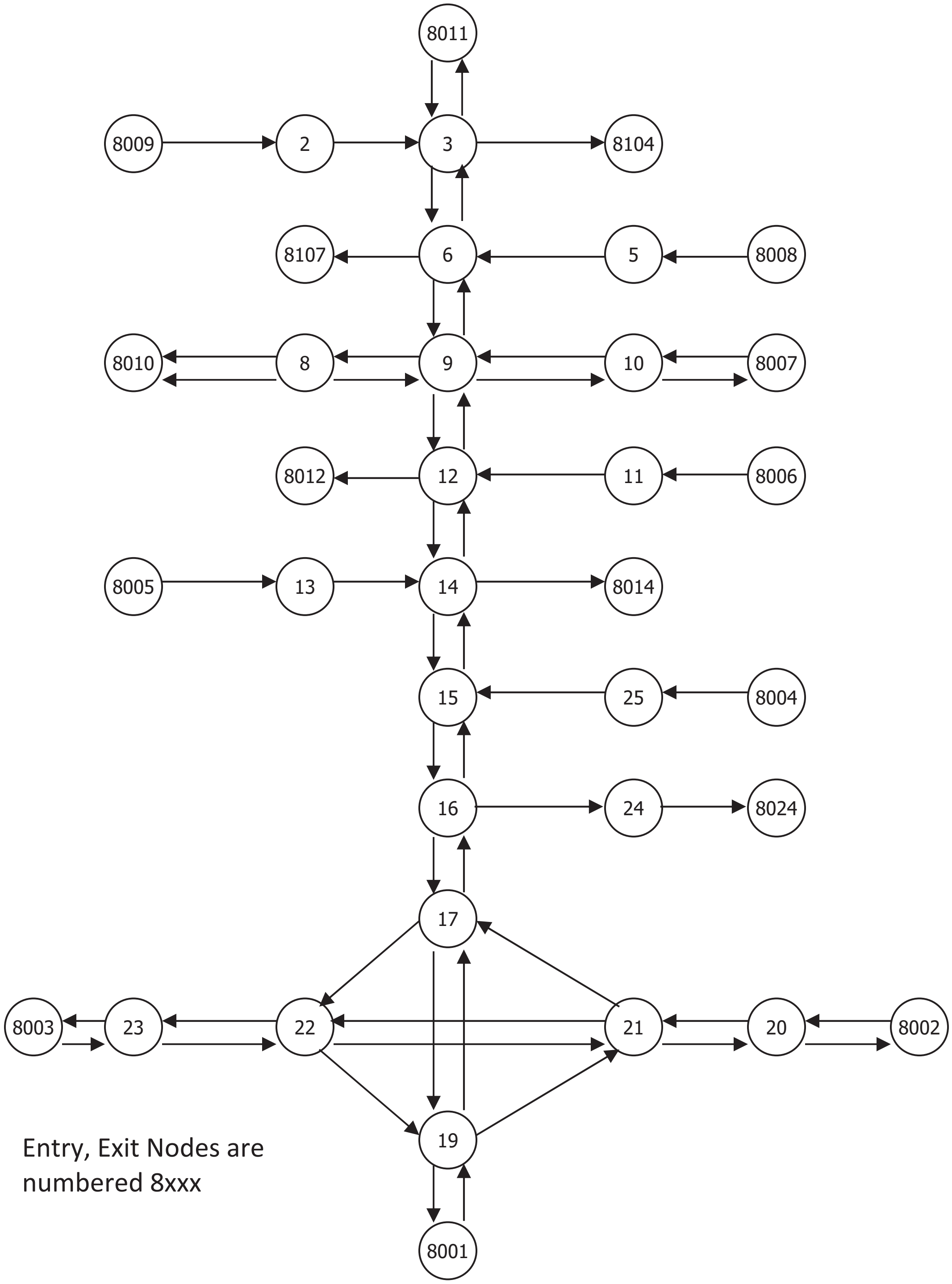


Figure C-1. Representative Analysis Network

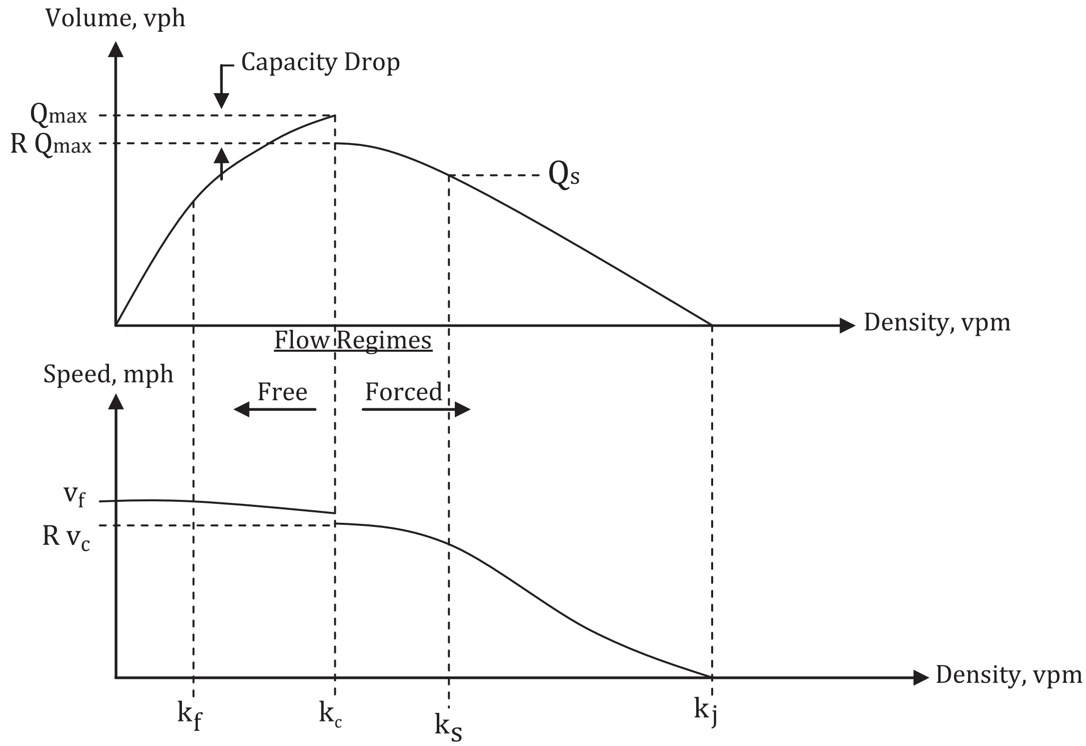


Figure C-2. Fundamental Diagrams

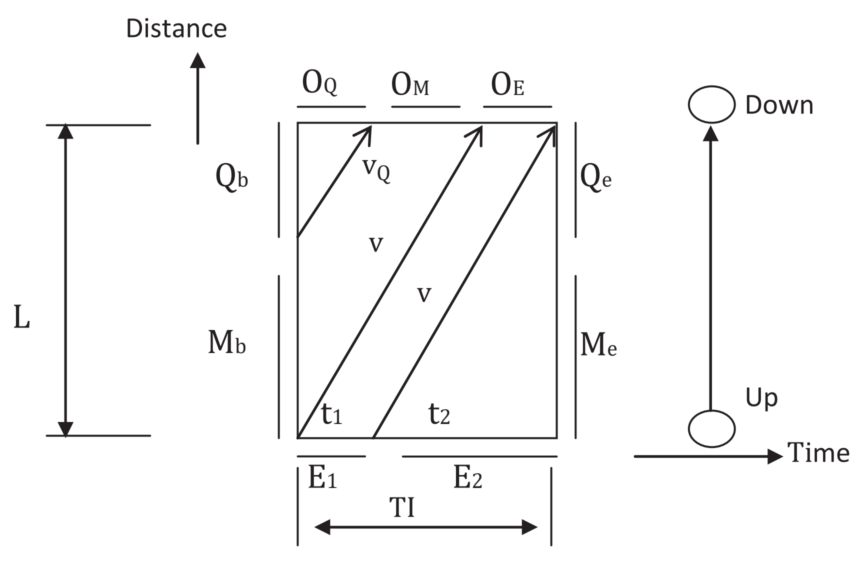


Figure C-3. A UNIT Problem Configuration with $t_1 > 0$

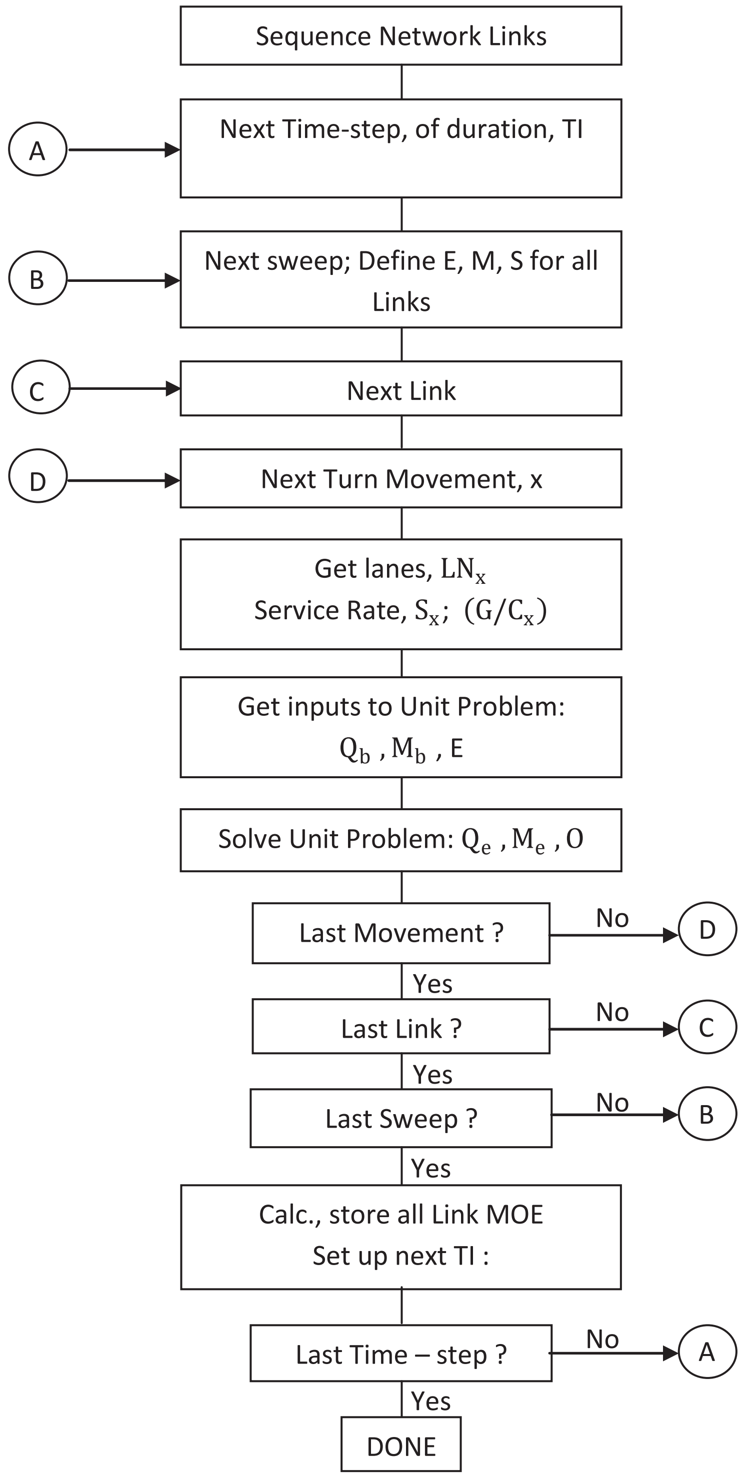


Figure C-4. Flow of Simulation Processing (See Glossary: Table C-3)

APPENDIX D

Detailed Description of Study Procedure

D. DETAILED DESCRIPTION OF STUDY PROCEDURE

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

Step 1

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

Step 2

The 2021 EPZ residential population was obtained from the Maricopa County Department of Emergency Management (MCDEM). The 2020 Census block population information was obtained in GIS format and was extrapolated to 2021 using the compound growth formula in order to estimate the permanent resident population within the Shadow Region and to define the spatial distribution and demographic characteristics of the population within the study area. Employee and transient data were obtained from MCDEM and emergency management personnel at APS. Information concerning schools within the EPZ was obtained from Maricopa County.

Step 3

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

Step 4

Next, a physical survey of the roadway system in the study area was conducted to determine any changes to the roadway network since the previous study. This survey included consideration of the geometric properties of the highway sections, the channelization of lanes on each section of roadway, whether there are any turn restrictions or special treatment of traffic at intersections, the type and functioning of traffic control devices, gathering signal timings for pre-timed traffic signals (if any exist within the study area), and to make the necessary observations needed to estimate realistic values of roadway capacity. Roadway characteristics were also verified using aerial imagery.

Step 5

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

Step 6

A computerized representation of the physical roadway system, called a link-node analysis network, was updated using the most recent UNITES software (see Section 1.3) developed by KLD. Once the updated geometry of the network was completed, the network was calibrated using the information gathered during the road survey (Step 4) and information obtained from aerial imagery. Estimates of highway capacity for each link and other link-specific characteristics were introduced to the network description. Traffic signal timings were input accordingly. The link-node analysis network was imported into a GIS map. The 2021 permanent resident population data (Step 2) were overlaid in the map, and origin centroids where trips would be generated during the evacuation process were assigned to appropriate links.

Step 7

The EPZ is subdivided into 145 Sectors. Based on wind direction and speed, Regions (groupings of Sectors that may be advised to evacuate,) were developed.

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

Step 8

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

Step 9

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

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

Step 10

The results generated by the prototype evacuation case are critically examined. The examination includes observing the animated graphics (using the EVAN software – see Section 1.3) and reviewing the statistics output by the model. This is a labor-intensive activity, requiring the direct participation of skilled engineers who possess the necessary practical experience to interpret the results and to determine the causes of any problems reflected in the results.

Essentially, the approach is to identify those bottlenecks in the network that represent locations where congested conditions are pronounced and to identify the cause of this congestion. This cause can take many forms, either as excess demand due to high rates of trip generation, improper routing, a shortfall of capacity, or as a quantitative flaw in the way the physical system was represented in the input stream. This examination leads to one of two conclusions:

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

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

Step 11

There are many "treatments" available to the user in resolving apparent problems. These treatments range from decisions to reroute the traffic by assigning additional evacuation destinations for one or more sources, imposing turn restrictions where they can produce significant improvements in capacity, changing the control treatment at critical intersections so as to provide improved service for one or more movements, adding minor routes (which are paved and traversable) that were not previously modelled but may assist in an evacuation and increase the available roadway network capacity, or in prescribing specific treatments for channelizing the flow so as to expedite the movement of traffic along major roadway systems. Such "treatments" take the form of modifications to the original prototype evacuation case input stream. All treatments are designed to improve the representation of evacuation behavior.

Step 12

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

Step 13

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

Step 14

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

Step 15

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

Step 16

Once vehicular evacuation results are accepted, average travel speeds for transit and special facility routes are used to compute ETE for transit-dependent permanent residents, schools and access and/or functional needs population.

Step 17

The simulation results are analyzed, tabulated and graphed. Traffic management plans are analyzed, and traffic control points are prioritized, if applicable. Additional analysis is conducted to identify the sensitivity of the ETE to changes in some base evacuation conditions and model assumptions. The results are then documented, as required by NUREG/CR-7002, Rev. 1.

Step 18

Following the completion of documentation activities, the ETE criteria checklist (see Appendix N) is completed. An appropriate report reference is provided for each criterion provided in the checklist.

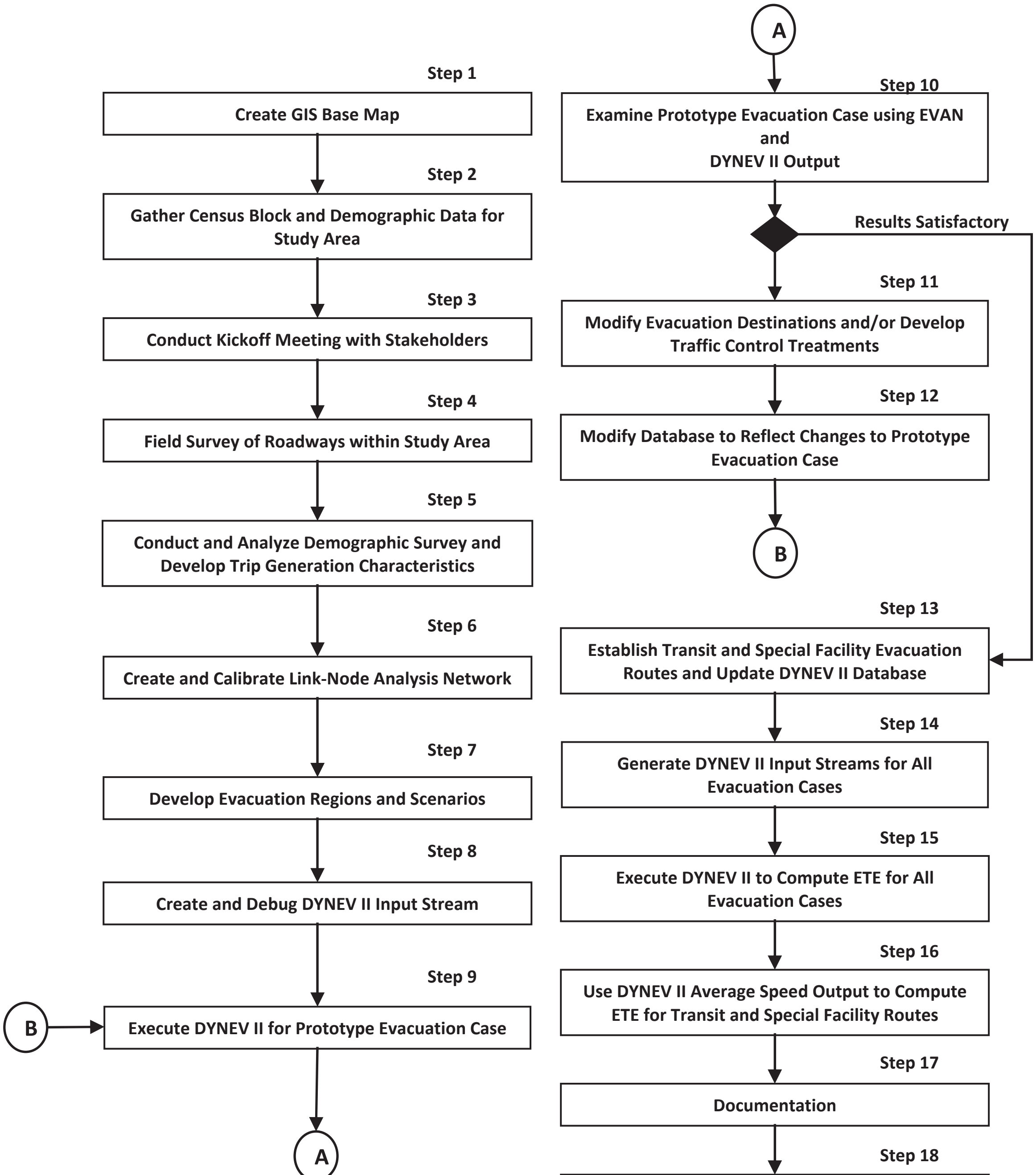


Figure D-1. Flow Diagram of Activities

APPENDIX E

Facility Data

E. FACILITY DATA

The following tables list population information, as of November 2021, for special facilities, transient facilities and major employers that are located within the PVNGS EPZ. Special facilities are defined as schools, medical facilities and correctional facilities. Note, however that there are no medical facilities or correctional facilities in the PVNGS EPZ. Thus, special facilities within the EPZ consist of schools only. Employment data is summarized in the table for major employers. Transient population data is included in the table for lodging facilities.

The location of the facility is defined by its straight-line distance (miles) and direction (magnetic bearing) from the center point of the plant. Maps of each school, major employer, and lodging facility are also provided.

Table E-1. Schools within the Study Area

Sector	Distance (miles)	Dire-ction	School Name	Street Address	Municipality	Enroll-ment
MARICOPA COUNTY, AZ						
A-3	2.6	N	Crossroads Academy	38013 W Salome Hwy	Tonopah	15
A-8	7.2	N	Tonopah Valley High School	38201 W Indian School Rd	Tonopah	810
A-8	7.3	N	Ruth Fisher Middle School	36201 W Indian School Rd	Tonopah	731
C-5	4.7	NE	Winters Well Elementary School	35220 W Buckeye Rd	Tonopah	460
F-4	3.3	ESE	Arlington Elementary School	9410 S 355th Ave	Arlington	280
S.R.	11.1	ESE	Palo Verde Elementary School[1]	10700 S Palo Verde Rd	Palo Verde	450
					Maricopa County Subtotal:	*2,746*
					EPZ TOTAL:	**2,746**

Table E-2. Major Employers within the EPZ

Sector	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Employees (Max Shift)	% Employees Commuting into the EPZ	Employees Commuting into the EPZ	Employee Vehicles Commuting into the EPZ
MARICOPA COUNTY, AZ									
PVNGS	-	-	PVNGS	5801 S Wintersburg Rd	Tonopah	2,611	95%	2,480	2,102
D-7	6.7	ENE	Hickman's Family Farms[2]	1909 S 331st Ave	Tonopah	96	59%	57	48
E-6	6.0	E	Hickman's Family Farms[2,3]	32911 Ward Rd	Buckeye	239	92%	221	23
H-4	3.7	SSE	Sun Streams 2	11801 S 363rd Ave	Arlington	250	97%	243	206
R-9	8.8	NNW	Hickman's Family Farms[2]	41717 W Indian School Rd	Tonopah	112	30%	34	29
					Maricopa County Subtotal:	*3,308*	-	*3,035*	*2,408*
					EPZ TOTAL:	**3,308**	**-**	**3,035**	**2,408**

[1] According to Maricopa County Emergency Plans, Palo Verde Elementary School would evacuate even though it is located in the Shadow Region.
[2] Hickman's Family Farms has multiple locations in the EPZ with a total of 447 employees per single shift.
[3] According to Hickman's Family Farms, there are 210 inmates from the Arizona State Prison currently working at Hickman's Family Farm. Based on the data provided, these inmates are included in the 239 employees (Max Shift) at 32911 Ward Rd. Of the remaining 29 employees (239 – 210 = 29), approximately 11 people reside outside of the EPZ. Assuming a capacity of 30 people per bus, 7 buses (14 vehicles) will be needed to transport the 210 inmates plus 9 vehicles for the remaining 11 employees (11 non-inmate employees ÷ 1.18 employee vehicle occupancy rate), which results in a total of 23 employee vehicles.

Table E-3. Lodging Facilities within the EPZ

Sector	Distance (miles)	Dire-ction	Facility Name	Street Address	Municipality	Transients	Vehicles
MARICOPA COUNTY, AZ							
R-9	8.2	NNW	Saguaro Mineral Wells Motel	3847 N 411th Ave	Tonopah	23	8
					Maricopa County Subtotal:	*23*	*8*
					EPZ TOTAL:	**23**	**8**

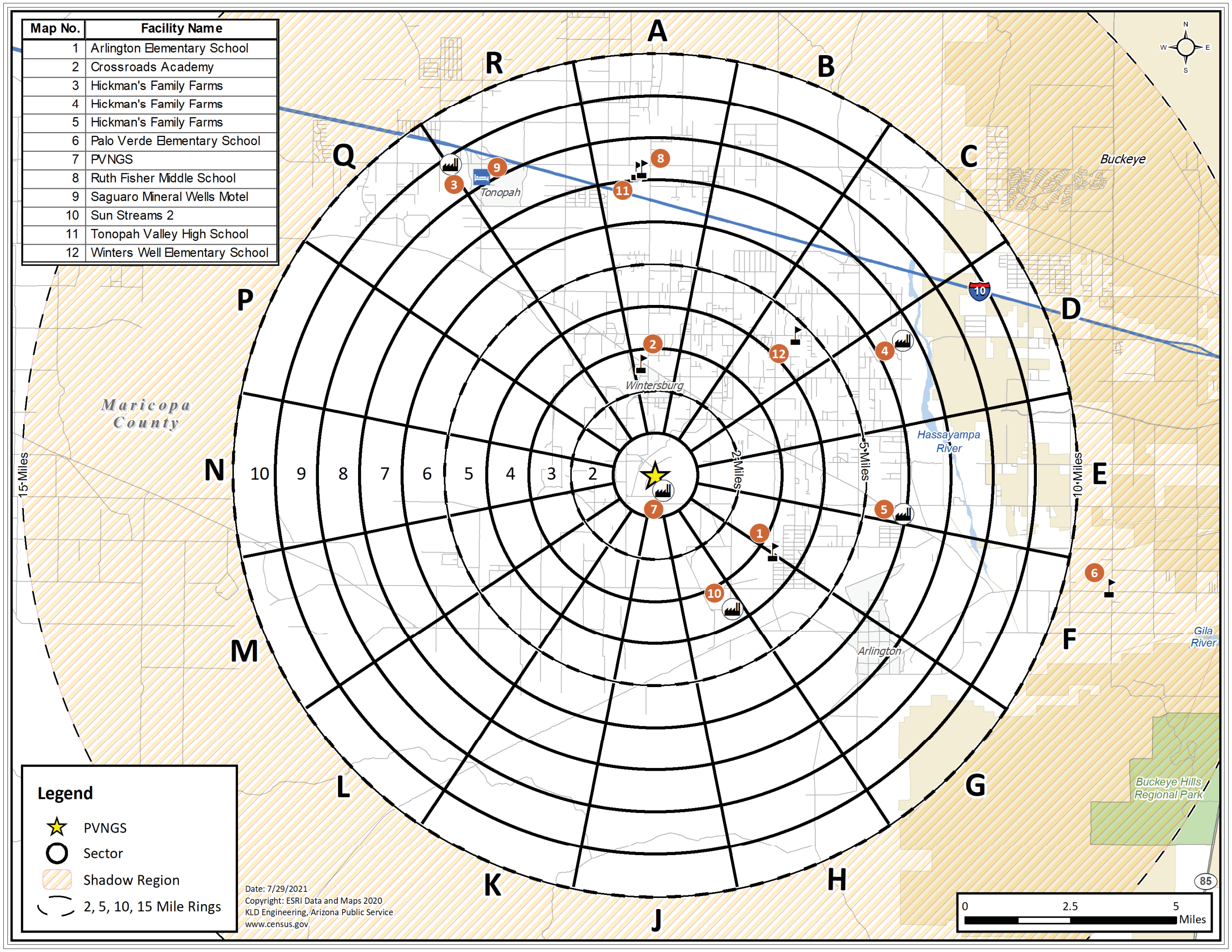


Figure E-1. Schools, Lodging Facilities and Major Employers within the Study Area

APPENDIX F

Demographic Survey

F. DEMOGRAPHIC SURVEY

F.1 Introduction

The development of evacuation time estimates (ETEs) for the Palo Verde Nuclear Generating Station (PVNGS) Emergency Planning Zone (EPZ) requires the identification of travel patterns, car ownership and household size of the population within the EPZ. Demographic information can be obtained from Census data. The use of this data has several limitations when applied to emergency planning. First, the Census data do not encompass the range of information needed to identify the time required for preliminary activities (mobilization) that must be undertaken prior to evacuating the area. Secondly, Census data do not contain attitudinal responses needed from the population of the EPZ and consequently may not accurately represent the anticipated behavioral characteristics of the evacuating populace.

These concerns are addressed by conducting a demographic survey of a representative sample of the EPZ population. The survey is designed to elicit information from the public concerning family demographics and estimates of response times to well defined events. The design of the survey includes a limited number of questions of the form "What would you do if …?" and other questions regarding activities with which the respondent is familiar ("How long does it take you to …?").

F.2 Survey Instrument and Sampling Plan

Attachment A presents the final survey instrument used for the demographic survey. A draft of the instrument was submitted to stakeholders for comment. Comments were received and the survey instrument was modified accordingly, prior to conducting the survey.

Following the completion of the instrument, a sampling plan was developed. Since the demographic survey discussed herein was performed in October 2020 and the 2020 Census data had not been released, 2010 Census data was used to develop the sampling plan.

A sample size of approximately 370 **completed** survey forms yields results with a sampling error of ±5% at the 95% confidence level. The sample must be drawn from the EPZ population. A list of zip codes in the EPZ was developed using geographic information system (GIS) software. This list is shown in Table F-1. Along with each zip code, an estimate of the population and number of households in each area was determined by overlaying 2010 Census data and the EPZ boundary, again using GIS software. The proportional number of desired completed survey interviews for each area was identified, as shown in Table F-1. Note that the average household size computed in Table F-1 was an estimate for sampling purposes and was not used in the ETE study.

The results of the survey exceeded the sampling plan. A total of 392 completed samples were obtained corresponding to a sampling error of ±4.5% at the 95% confidence level based on the 2010 Census data. Table F-1 also shows the number of samples obtained within each zip code.

F.3 Survey Results

The results of the survey fall into two categories. First, the household demographics of the area can be identified. Demographic information includes such factors as household size, automobile ownership, and automobile availability. The distributions of the time to perform certain pre-evacuation activities are the second category of survey results. These data are processed to develop the trip generation distributions used in the evacuation modeling effort, as discussed in Section 5.

A review of the survey instrument reveals that several questions have a "Don't know" or "Decline to State" entry for a response. It is accepted practice in conducting surveys of this type to accept the answers of a respondent who offers a "Don't know" or who declines to answer a few questions. To address the issue of occasional Don't know/declined responses from a large sample, the practice is to assume that the distribution of these responses is the same as the underlying distribution of the positive responses. In effect, the Don't know/declined responses are ignored and the distributions are based upon the positive data that is acquired.

F.3.1 Household Demographic Results

Household Size

Figure F-1 presents the distribution of household size within the EPZ, based on the responses to the demographic survey. The average household contains 2.65 people. According to the 2020 Census data the average household size is 3.15 people per household, which is 18.9% higher than the value obtained from the demographic survey. This falls outside of the sampling error of ±4.5%. However, each year, Maricopa County undertakes a population analysis within the PVNGS EPZ based on electrical hookup information. The data gathered by the county indicates an average household size of 2.75 people. The difference between the county data and survey data is 3.8%, which does not exceed the sampling error of 4.5%. It was determined that the value obtained from the demographic survey (2.65 people) will be used for this study. The close agreement between the average household size obtained from the survey and from the county data is an indication of the reliability of the survey.

Automobile Ownership

The average number of automobiles available per household in the EPZ is 2.30. It should be noted that all households within the EPZ have access to an automobile according to the demographic survey. The distribution of automobile ownership is presented in Figure F-2. Figure F-3 and Figure F-4 present the automobile availability by household size.

Ridesharing

The majority (72%) of the households surveyed responded that they would share a ride with a neighbor, relative, or friend if a car was not available to them when advised to evacuate in the event of an emergency, as shown in Figure F-5.

Commuters

Figure F-6 presents the distribution of the number of commuters in each household. Commuters are defined as household members who travel to work or college on a daily basis. The data shows an average of 0.81 commuters per household in the EPZ, and approximately 49.1% of households have at least one commuter.

Commuter Travel Modes

Figure F-7 presents the mode of travel that commuters use on a daily basis. The vast majority (82%) of commuters use their private automobiles to travel to work or college. The data shows an average of 1.18 commuters per vehicle, assuming 2 people per vehicle – on average – for carpools.

Impact of COVID-19 on Commuters

Figure F-8 presents the distribution of the number of commuters in each household that were temporarily impacted by the COVID-19 pandemic. The data shows an average of 0.54 commuters per household were affected by the COVID-19 pandemic. Approximately 69% of households indicated that no commuter in their household had a work and/or school commute that was temporarily impacted by the COVID-19 pandemic. Approximately 31% of households indicated someone in their household was impacted.

F.3.2 Evacuation Response

Questions were asked to gauge the population's response to an emergency. These are now discussed:

"How many vehicles would your household use during an evacuation?" The response is shown in Figure F-9. On average, evacuating households would use 1.56 vehicles.

"Would your family await the return of other family members prior to evacuating the area?" Of the survey participants who responded, 49.86% said they would await the return of other family members before evacuating and 50.14% indicated that they would not await the return of other family members, as shown in Figure F-10.

"Emergency officials advise you to shelter-in-place in an emergency because you are not in the area of risk. Would you?" This question is designed to elicit information regarding compliance with instructions to shelter-in-place. The results, as shown in Figure F-11, indicate that 90% of households who are advised to shelter-in-place would do so; the remaining 10% would choose to evacuate the area.

Note the baseline ETE study assumes 20%of households will not comply with the shelter advisory, as per Section 2.5.2 of NUREG/CR-7002, Rev. 1. Thus, the data obtained above is considerably lower than the federal guidance recommendation. A sensitivity study was conducted to estimate the impact of shadow evacuation non-compliance of shelter advisory on ETE – see Appendix M.

"Emergency officials advise you to shelter-in-place in an emergency and possibly evacuate later while people in other areas are advised to evacuate now. Would you?" This question is designed to elicit information specifically related to the possibility of a staged evacuation. That is, asking a population to shelter-in-place now and then to evacuate after a specified period of time.

Results indicate that 71.6% of households would follow instructions and delay the start of evacuation until so advised, while the balance of 28.4% would choose to begin evacuating immediately, as shown in Figure F-12.

F.3.3 Time Distribution Results

The survey asked several questions about the amount of time it takes to perform certain pre-evacuation activities. These activities involve actions taken by residents during the course of their day-to-day lives. Thus, the answers fall within the realm of the responder's experience.

The mobilization distributions provided below are the result of having applied the analysis described in Section 5.4.1 on the component activities of the mobilization.

As discussed in Section F.3.1 and shown in Figure F-8, the majority (69.3%) of respondents indicated no commuters were impacted by the COVID-19 pandemic; therefore the results for the time distribution of commuters (time to prepare to leave work/college and time to travel home from work/college) were used as is in this study.

"How long does it take the commuter to complete preparation for leaving work?" Figure F-13 presents the cumulative distribution; in all cases, the activity is completed by about 75 minutes. Eighty-one percent (81%) can leave within 30 minutes.

"How long would it take the commuter to travel home?" Figure F-14 presents the work to home travel time for the EPZ. Seventy-seven percent (77%) of commuters can arrive home within 45 minutes of leaving work; all within 105 minutes.

"How long would it take the family to pack clothing, secure the house, and load the car?" Figure F-15 presents the time required to prepare for leaving on an evacuation trip. In many ways this activity mimics a family's preparation for a short holiday or weekend away from home. Hence, the responses represent the experience of the responder in performing similar activities.

The distribution shown in Figure F-15 has a long "tail." Approximately 91% of households can be ready to leave home within 2 hours and 30 minutes; the remaining households require up to an additional 1 hour and 45 minutes.

Table F-1. PVNGS Demographic Survey Sampling Plan

Zip Code	EPZ Populations (2010)	EPZ Households within Zip Code (2010)	Required Samples	Samples Obtained
85322	675	223	36	13
85326	522	156	25	126
85343	48	12	2	3
85354	5,601	1,845	293	124
85396	277	86	14	126
Total	**7,123**	**2,322**	**370**	**392**
		Average Household Size:	**3.07**	

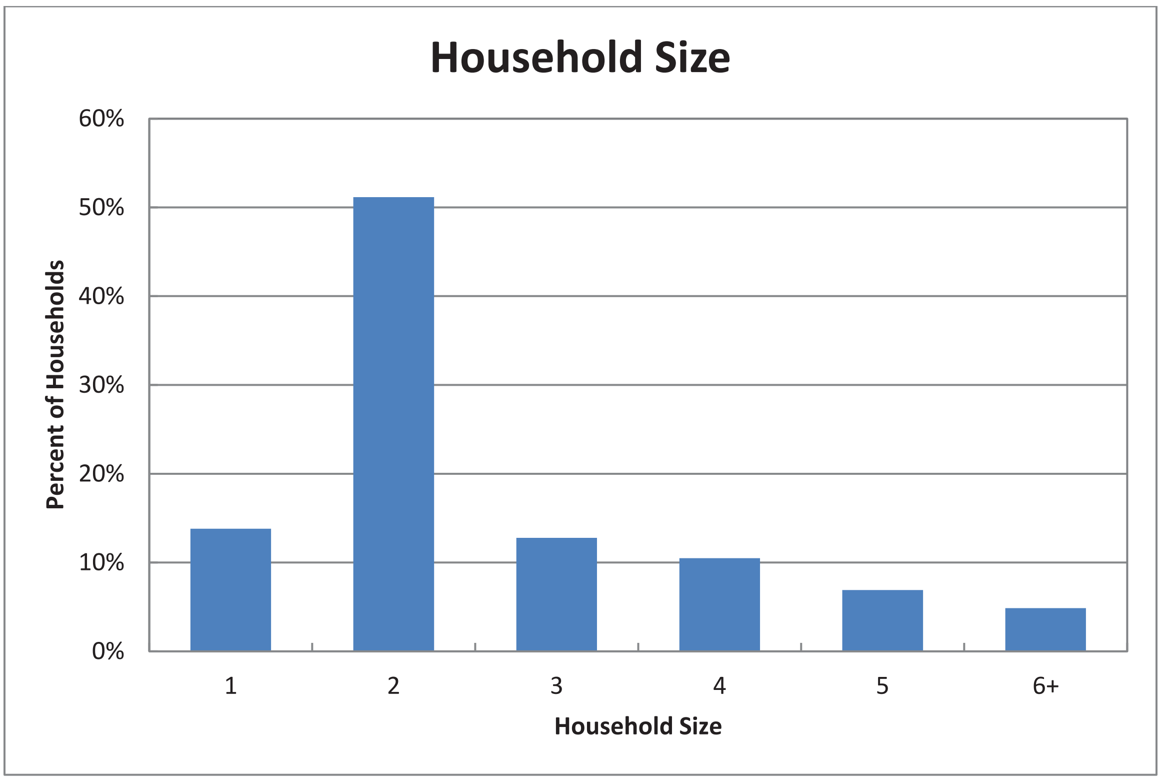


Figure F-1. Household Size in the EPZ

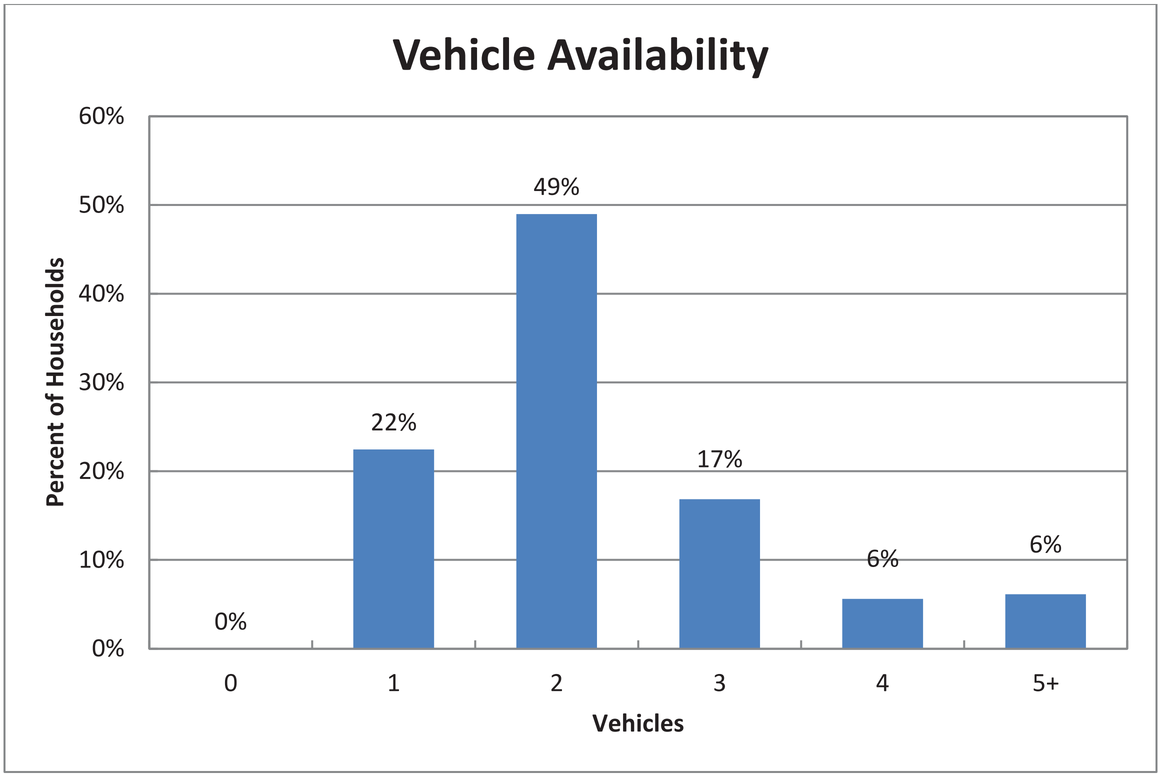


Figure F-2. Vehicle Availability

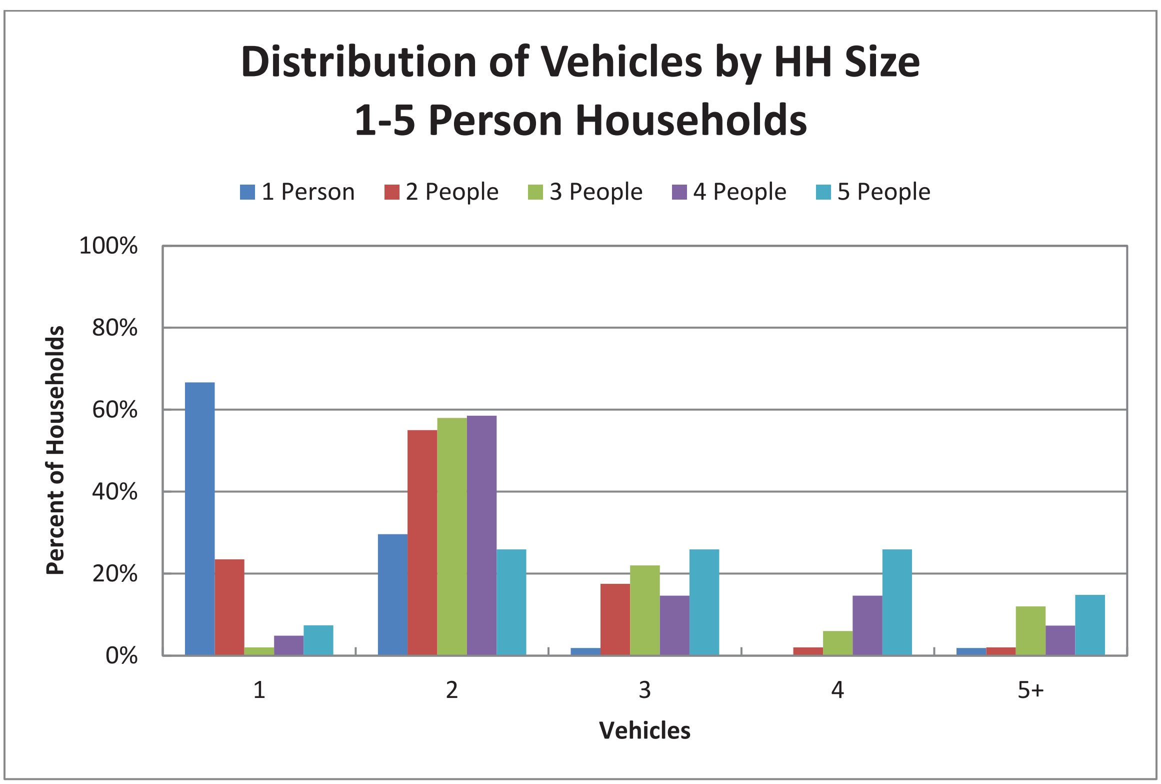


Figure F-3. Vehicle Availability - 1 to 5 Person Households

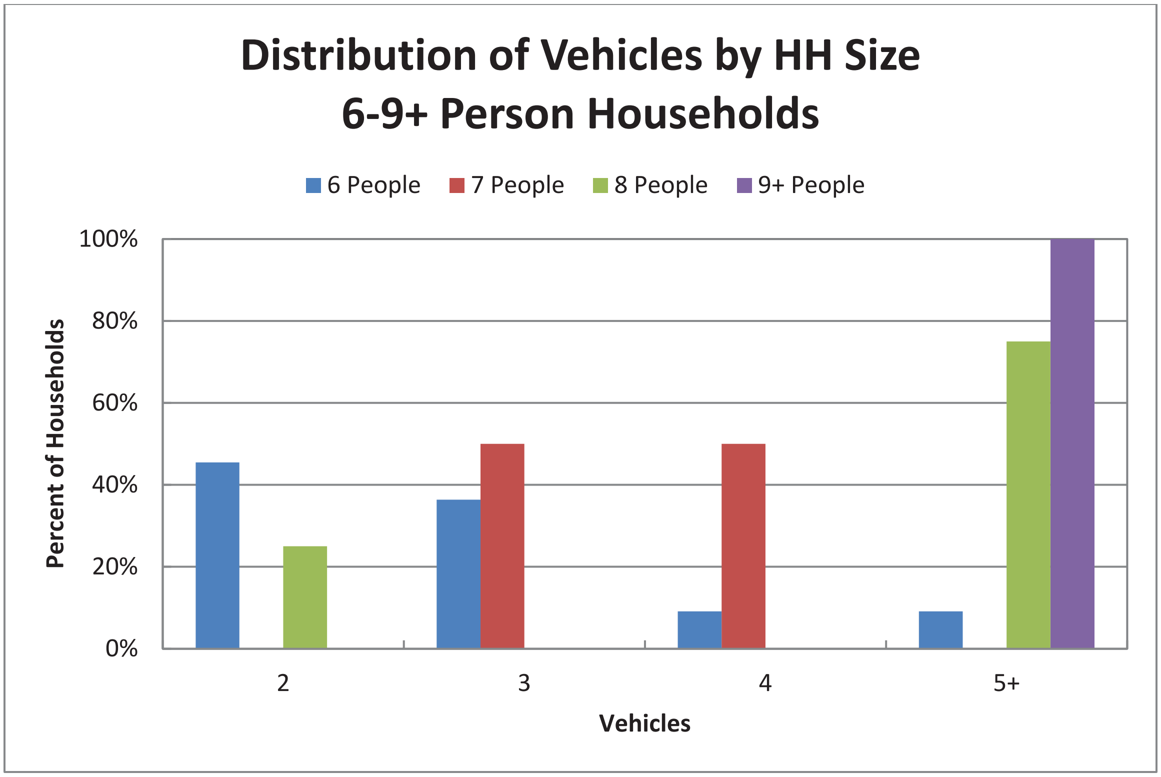


Figure F-4. Vehicle Availability - 6 to 9+ Person Households

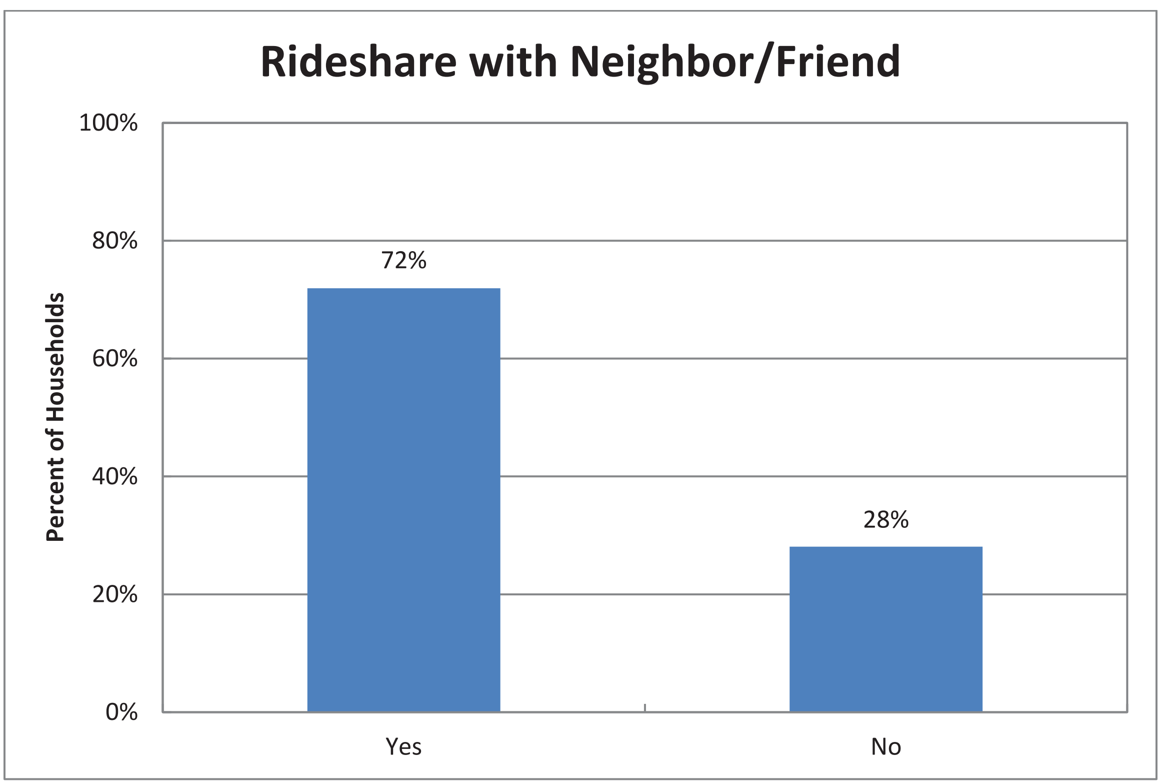


Figure F-5. Household Ridesharing Preference

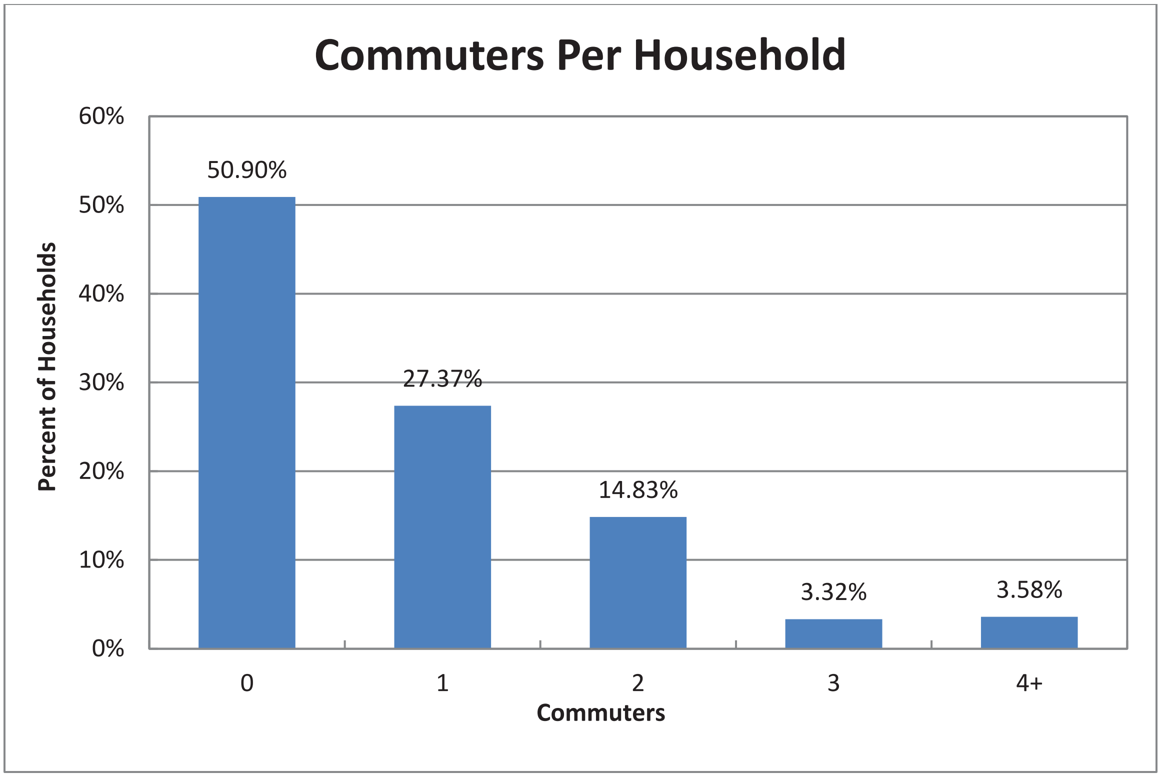


Figure F-6. Commuters in Households in the EPZ

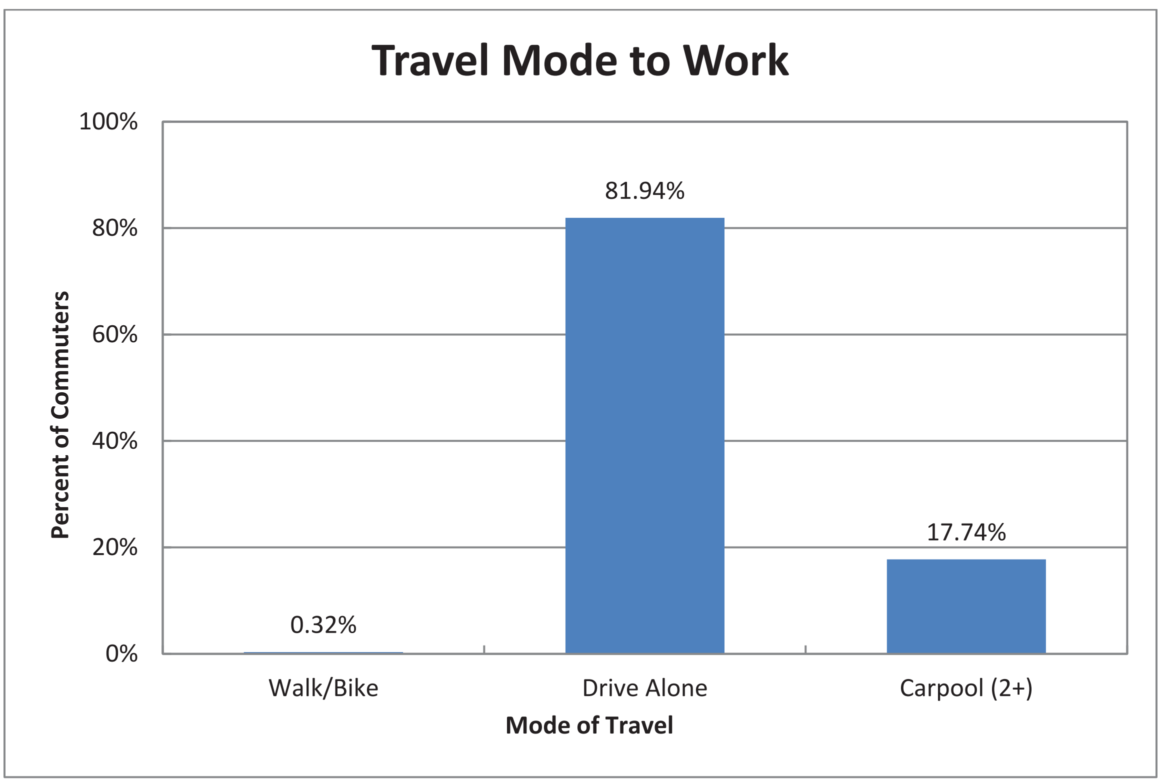


Figure F-7. Modes of Travel in the EPZ

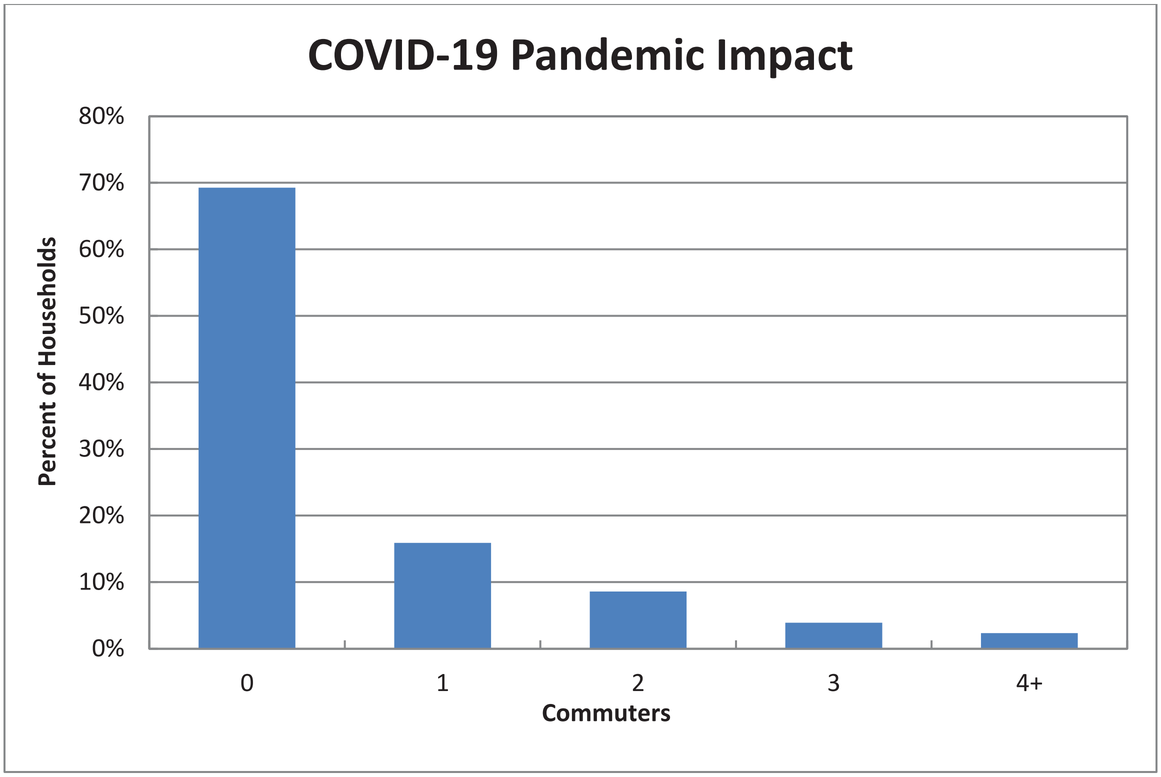


Figure F-8. Commuters Impacted by COVID-19

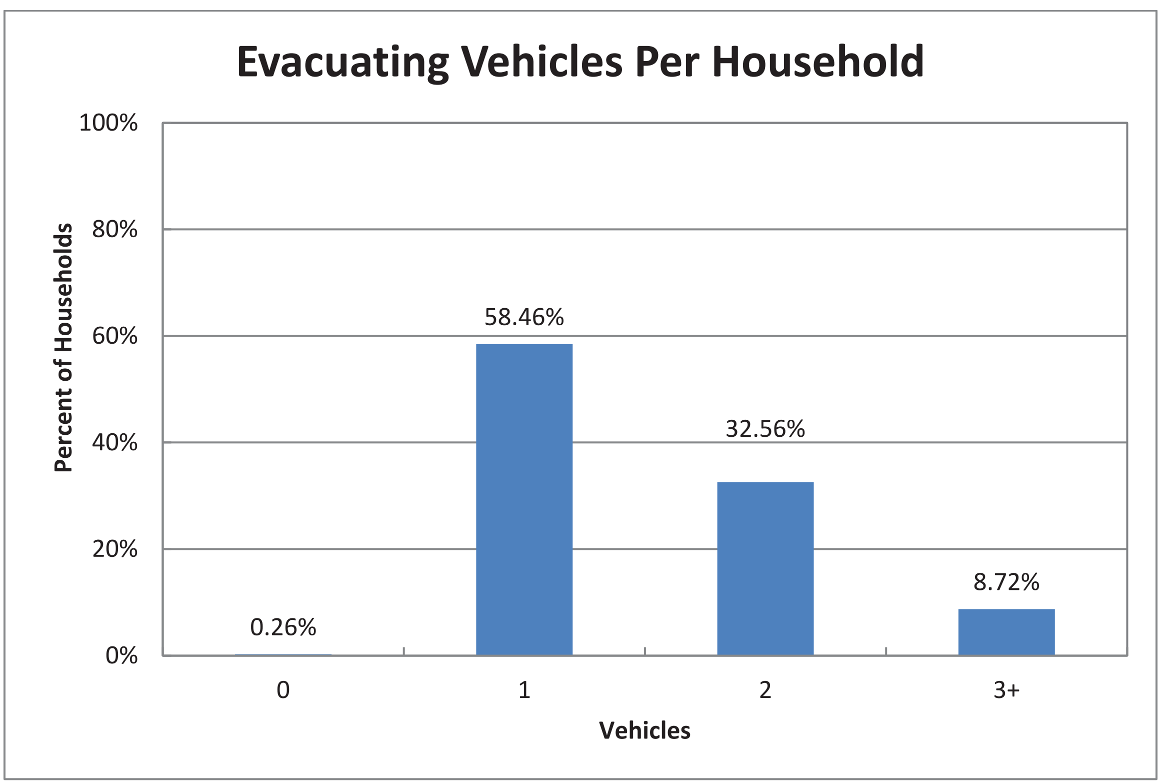


Figure F-9. Number of Vehicles Used for Evacuation

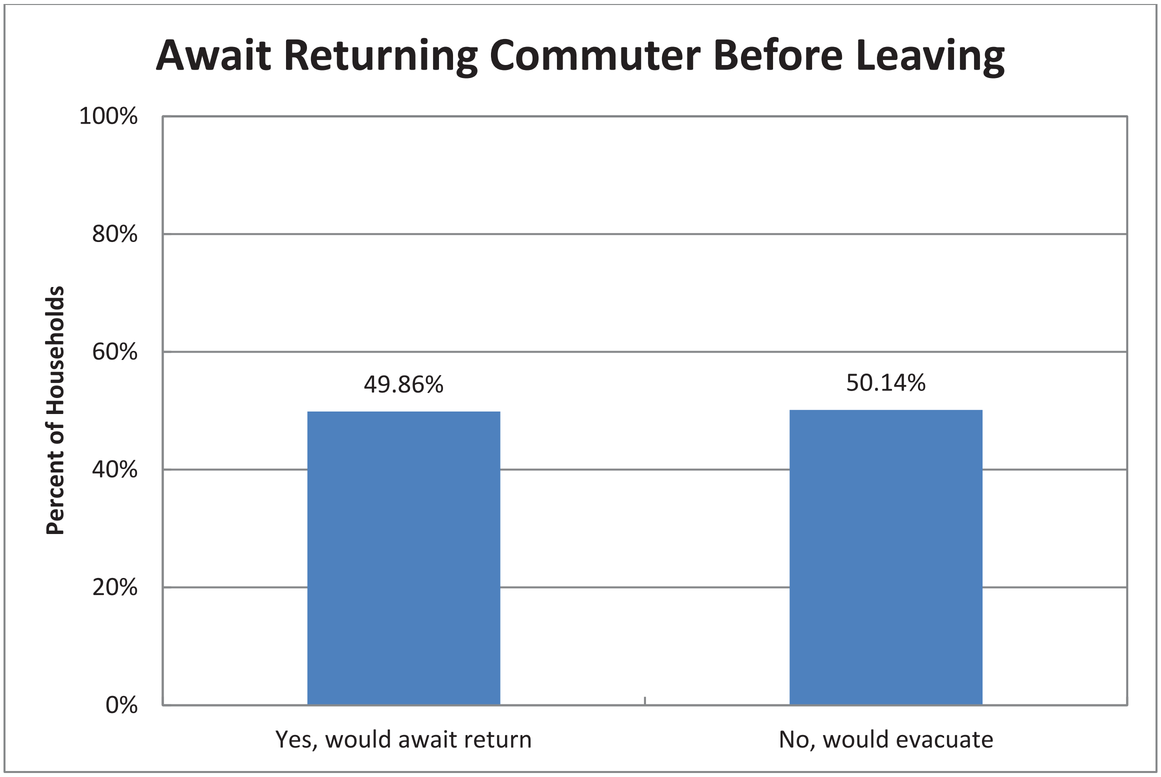


Figure F-10. Percent of Households that Await Returning Commuter Before Leaving

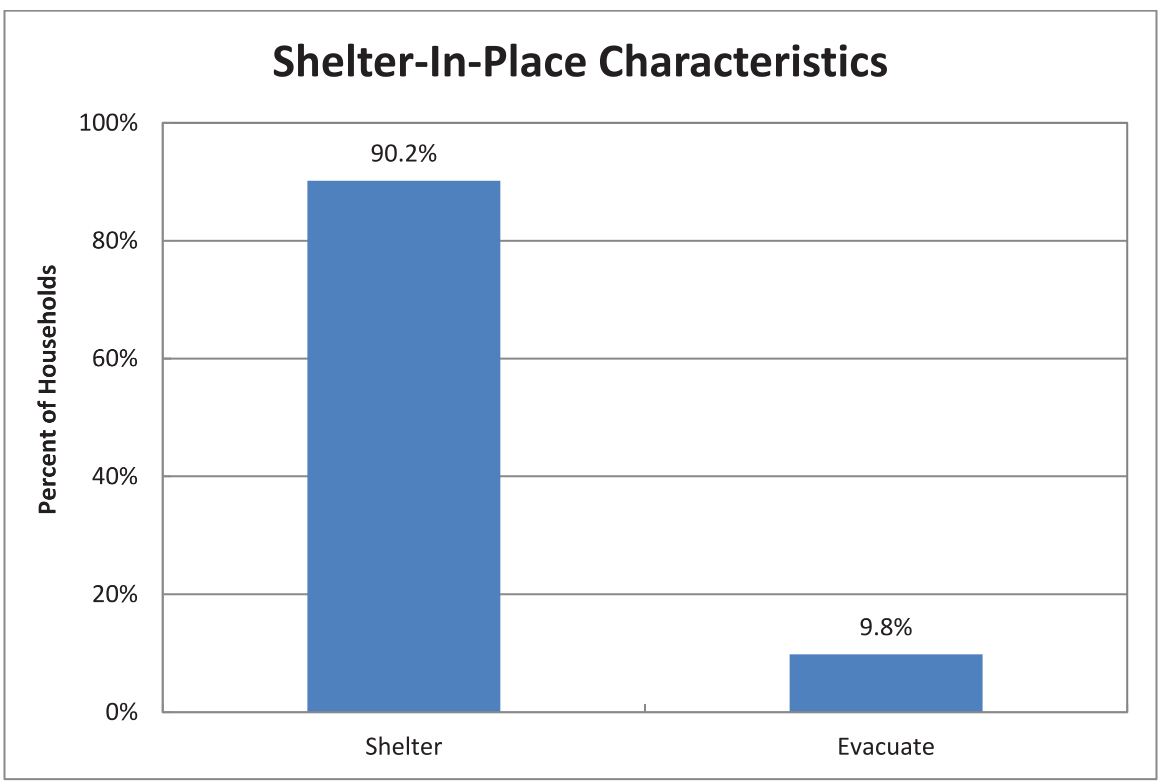


Figure F-11. Shelter-in-Place Characteristics

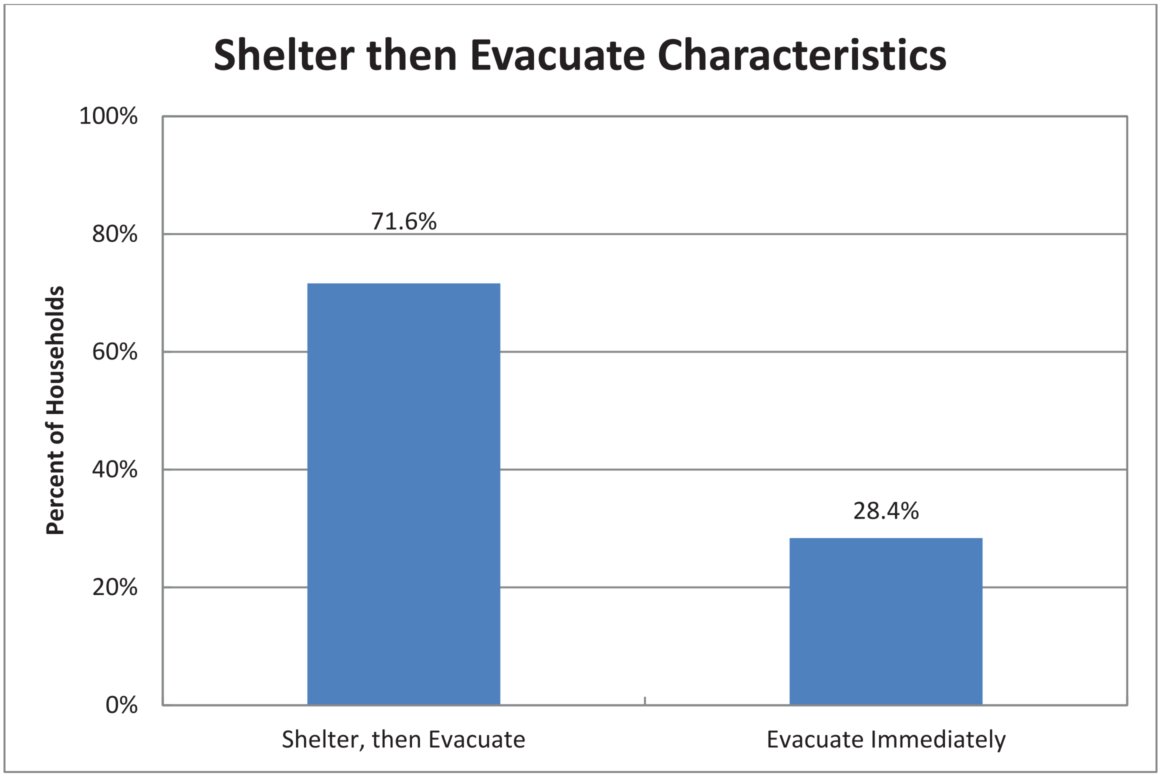


Figure F-12. Shelter then Evacuate Characteristics

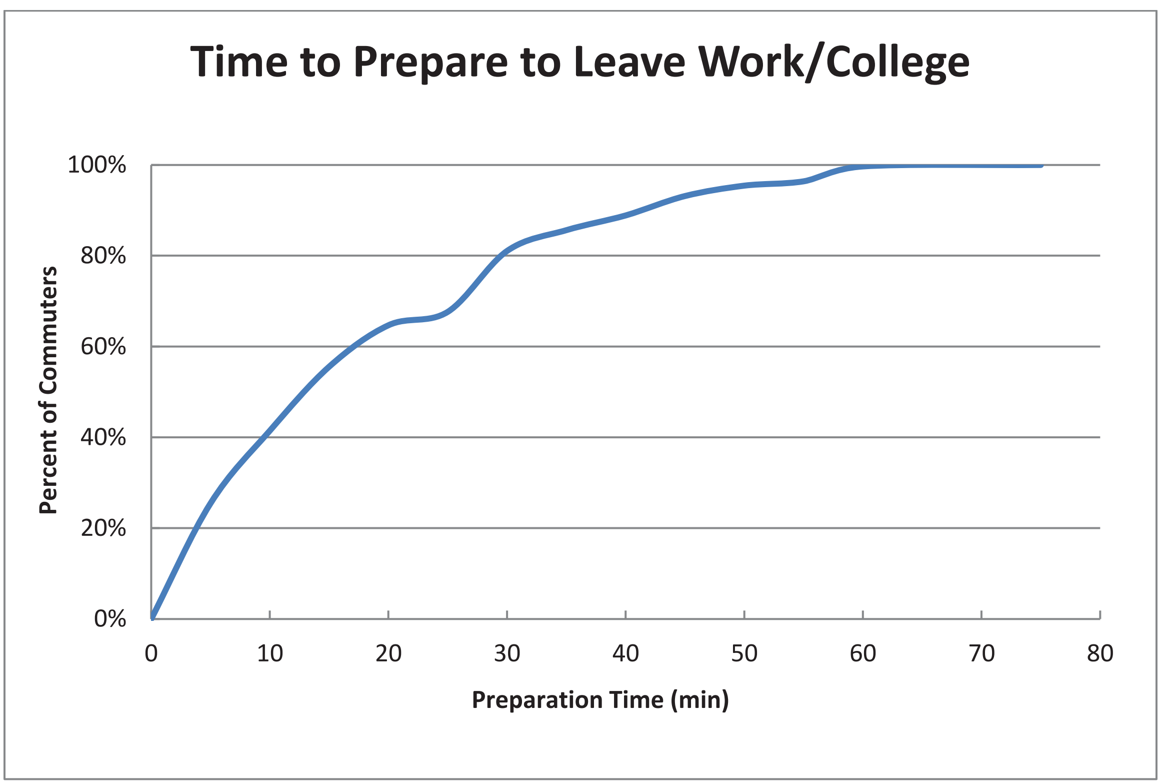


Figure F-13. Time Required to Prepare to Leave Work/College

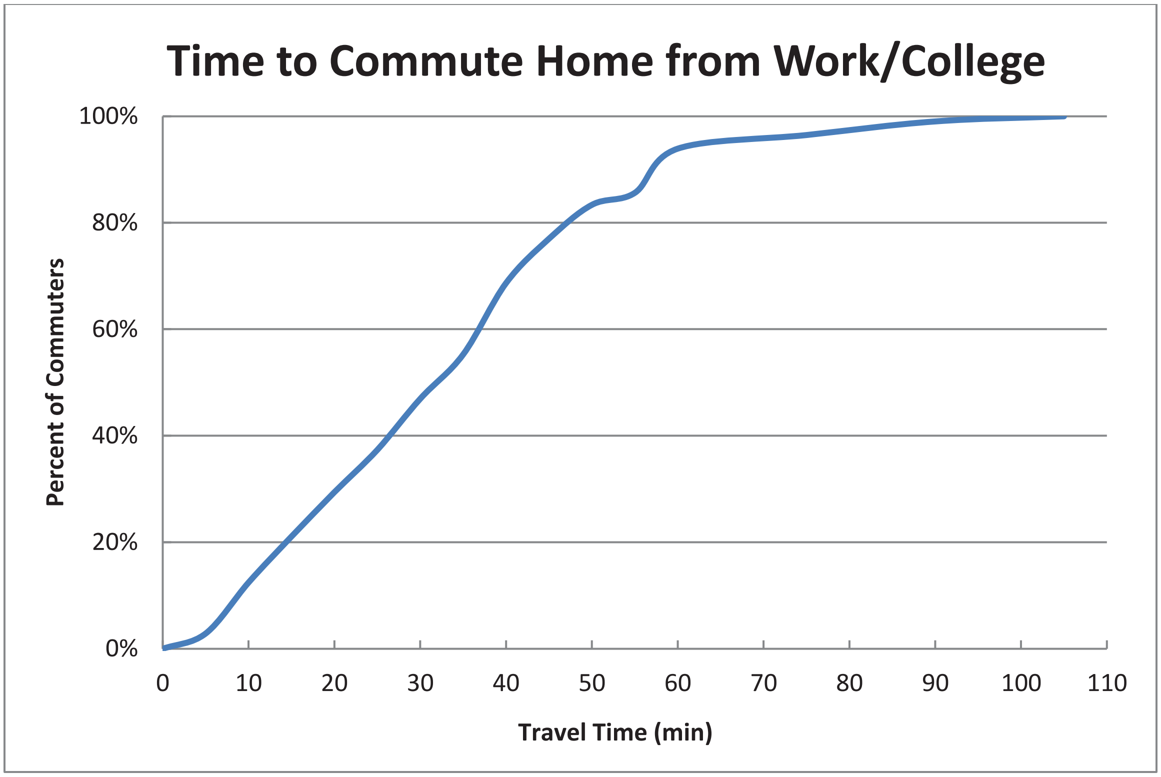


Figure F-14. Work/College to Home Travel Time

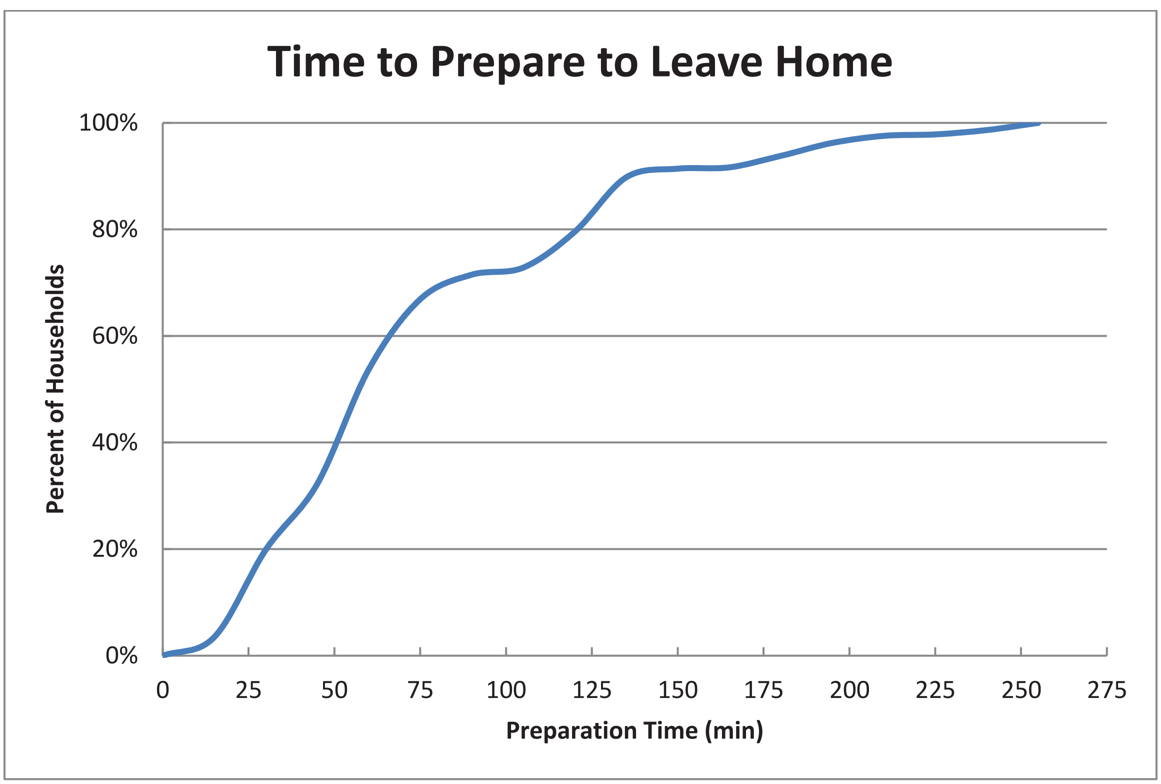


Figure F-15. Time to Prepare Home for Evacuation

ATTACHMENT A

Demographic Survey Instrument

Evacuation Time Estimate Study -Demographic Survey

* Required

Purpose

The purpose of this survey is to identify local behavior during emergency situations. The information gathered in this survey will be shared with Arizona Public Service and Maricopa County to enhance emergency response plans in your area. Your responses will greatly contribute to local emergency preparedness. **Please only complete one survey per household. Please have the head of the household (18 years or older) complete the survey.** Do not provide your name or any personal information, and the survey will take less than 5 minutes to complete.

1. 1. What is your home zip code? *

____

2. 2. In total, how many running cars, or other vehicles are usually available to the household?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE OR MORE
- ZERO (NONE)
- DECLINE TO STATE

3. 3. In an emergency, could you get a ride out of the area with a neighbor or friend?

Mark only one oval.

- YES
- NO
- DECLINE TO STATE

4. 4. How many vehicles would your household use during an evacuation?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE OR MORE
- ZERO (NONE)
- I WOULD EVACUATE BY BICYCLE
- I WOULD EVACUATE BY BUS
- DECLINE TO STATE

5. 5. How many people usually live in this household?

Mark only one oval.

- ONE
- TWO
- THREE
- FOUR
- FIVE
- SIX
- SEVEN
- EIGHT
- NINE
- TEN
- ELEVEN
- TWELVE
- THIRTEEN
- FOURTEEN
- FIFTEEN
- SIXTEEN
- SEVENTEEN
- EIGHTEEN
- NINETEEN OR MORE
- DECLINE TO STATE

Skip to question 6

COVID-19

6. 6. How many people in your household have a work and/or school commute that has been temporarily impacted due to the COVID-19 pandemic?

Mark only one oval.

- ZERO
- ONE
- TWO
- THREE
- FOUR OR MORE
- DECLINE TO STATE

Commuters

7. 7. How many people in the household commute to a job, or to college on a daily basis? *

Mark only one oval.

- ZERO *Skip to question 52*
- ONE *Skip to question 8*
- TWO *Skip to question 9*
- THREE *Skip to question 10*
- FOUR OR MORE *Skip to question 11*
- DECLINE TO STATE *Skip to question 52*

Mode of Travel

8. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1				

Skip to question 12

Mode of Travel

9. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	◯	◯	◯	◯
Commuter 2	◯	◯	◯	◯

Skip to question 14

Mode of Travel

10. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	◯	◯	◯	◯
Commuter 2	◯	◯	◯	◯
Commuter 3	◯	◯	◯	◯

Skip to question 18

Mode of Travel

11. 8. Thinking about each commuter, how does each person usually travel to work or college?

Mark only one oval per row.

	Walk/Bicycle	Drive Alone	Carpool-2 or more people	Don't know
Commuter 1	◯	◯	◯	◯
Commuter 2	◯	◯	◯	◯
Commuter 3	◯	◯	◯	◯
Commuter 4	◯	◯	◯	◯

Skip to question 24

Travel Home From Work/College

12. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

13. If Over 2 Hours for Question 9-1, Specify Here
leave blank if your answer for Question 9-1, is under 2 hours.

____

Skip to question 32

Travel Home From Work/College

14. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

15. If Over 2 Hours for Question 9-1, Specify Here
leave blank if your answer for Question 9-1 , is under 2 hours.

____

16. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

17. If Over 2 Hours for Question 9-2, Specify Here
leave blank if your answer for Question 9-2, is under 2 hours.

____

Skip to question 34

Travel Home From Work/College

18. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

19. If Over 2 Hours for Question 9-1, Specify Here
leave blank if your answer for Question 9-1, is under 2 hours.

____

20. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

21. If Over 2 Hours for Question 9-2, Specify Here
leave blank if your answer for Question 9-2, is under 2 hours.

22. 9-3. How much time on average, would it take Commuter #3 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

23. If Over 2 Hours for Question 9-3, Specify Here
leave blank if your answer for Question 9-3, is under 2 hours.

Skip to question 38

Travel Home From Work/College

24. 9-1. How much time on average, would it take Commuter #1 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

25. If Over 2 Hours for Question 9-1, Specify Here

leave blank if your answer for Question 9-1, is under 2 hours.

26. 9-2. How much time on average, would it take Commuter #2 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

27. If Over 2 Hours for Question 9-2, Specify Here

leave blank if your answer for Question 9-2, is under 2 hours.

28. 9-3. How much time on average, would it take Commuter #3 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

29. If Over 2 Hours for Question 9-3, Specify Here

leave blank if your answer for Question 9-3, is under 2 hours.

30. 9-4. How much time on average, would it take Commuter #4 to travel home from work or college?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

31. If Over 2 Hours for Question 9-4, Specify Here

leave blank if your answer for Question 9-4, is under 2 hours.

Skip to question 44

Preparation to leave Work/College

32. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

33. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

Skip to question 52

Preparation to leave Work/College

34. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

35. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

36. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

37. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

Skip to question 52

Preparation to leave Work/College

38. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

39. If Over 2 Hours for Question 10-1, Specify Here

leave blank if your answer for Question 10-1, is under 2 hours.

40. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

41. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

42. 10-3. Approximately how much time would it take Commuter #3 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

43. If Over 2 Hours for Question 10-3, Specify Here
leave blank if your answer for Question 10-3, is under 2 hours.

Skip to question 52

Preparation to leave Work/College

44. 10-1. Approximately how much time would it take Commuter #1 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

45. If Over 2 Hours for Question 10-1, Specify Here
leave blank if your answer for Question 10-1, is under 2 hours.

46. 10-2. Approximately how much time would it take Commuter #2 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

47. If Over 2 Hours for Question 10-2, Specify Here

leave blank if your answer for Question 10-2, is under 2 hours.

48. 10-3. Approximately how much time would it take Commuter #3 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

49. If Over 2 Hours for Question 10-3, Specify Here

leave blank if your answer for Question 10-3, is under 2 hours.

50. 10-4. Approximately how much time would it take Commuter #4 to complete preparation for leaving work or college prior to starting the trip home?

Mark only one oval.

- 5 MINUTES OR LESS
- 6-10 MINUTES
- 11-15 MINUTES
- 16-20 MINUTES
- 21-25 MINUTES
- 26-30 MINUTES
- 31-35 MINUTES
- 36-40 MINUTES
- 41-45 MINUTES
- 46-50 MINUTES
- 51-55 MINUTES
- 56 - 1 HOUR
- OVER 1 HOUR, BUT LESS THAN 1 HOUR 15 MINUTES
- BETWEEN 1 HOUR 16 MINUTES AND 1 HOUR 30 MINUTES
- BETWEEN 1 HOUR 31 MINUTES AND 1 HOUR 45 MINUTES
- BETWEEN 1 HOUR 46 MINUTES AND 2 HOURS
- OVER 2 HOURS
- DECLINE TO STATE

51. If Over 2 Hours for Question 10-4, Specify Here

leave blank if your answer for Question 10-4, is under 2 hours.

____

Skip to question 52

Additional Questions

52. 11. If you were advised by local authorities to evacuate, how much time would it take the household to pack clothing, medications, secure the house, load the car, and complete preparations prior to evacuating the area?

Mark only one oval.

- LESS THAN 15 MINUTES
- 15-30 MINUTES
- 31-45 MINUTES
- 46 MINUTES - 1 HOUR
- 1 HOUR TO 1 HOUR 15 MINUTES
- 1 HOUR 16 MINUTES TO 1 HOUR 30 MINUTES
- 1 HOUR 31 MINUTES TO 1 HOUR 45 MINUTES
- 1 HOUR 46 MINUTES TO 2 HOURS
- 2 HOURS TO 2 HOURS 15 MINUTES
- 2 HOURS 16 MINUTES TO 2 HOURS 30 MINUTES
- 2 HOURS 31 MINUTES TO 2 HOURS 45 MINUTES
- 2 HOURS 46 MINUTES TO 3 HOURS
- 3 HOURS TO 3 HOURS 15 MINUTES
- 3 HOURS 16 MINUTES TO 3 HOURS 30 MINUTES
- 3 HOURS 31 MINUTES TO 3 HOURS 45 MINUTES
- 3 HOURS 46 MINUTES TO 4 HOURS
- 4 HOURS TO 4 HOURS 15 MINUTES
- 4 HOURS 16 MINUTES TO 4 HOURS 30 MINUTES
- 4 HOURS 31 MINUTES TO 4 HOURS 45 MINUTES
- 4 HOURS 46 MINUTES TO 5 HOURS
- 5 HOURS TO 5 HOURS 30 MINUTES
- 5 HOURS 31 MINUTES TO 6 HOURS
- OVER 6 HOURS
- WILL NOT EVACUATE
- DECLINE TO STATE

53. If Over 6 Hours for Question 11, Specify Here

leave blank if your answer for Question 11, is under 6 hours.

____

54. 12. Please choose one of the following:

Mark only one oval.

- ( ) I would await the return of household members to evacuate together.
- ( ) I would evacuate independently and meet other household members later.
- ( ) Decline to State

55. 13. Emergency officials advise you to shelter-in-place in an emergency because you are not in the area of risk. Would you:

Mark only one oval.

- ( ) SHELTER-IN-PLACE
- ( ) EVACUATE
- ( ) DECLINE TO STATE

56. 14. Emergency officials advise you to shelter-in-place now in an emergency and possibly evacuate later while people in other areas are advised to evacuate now. Would you:

Mark only one oval.

- ( ) SHELTER-IN-PLACE
- ( ) EVACUATE
- ( ) DECLINE TO STATE

APPENDIX G

Traffic Management Plan

G. TRAFFIC MANAGEMENT PLAN

NUREG/CR-7002, Rev.1 indicates that the existing traffic control points and access control points (Roadblocks) identified by the offsite agencies should be used in the evacuation simulation modeling. The Roadblock location map for the Emergency Planning Zone (EPZ) was provided by the County of Maricopa.

This traffic management plan (TMP) was reviewed and the Roadblocks were modeled accordingly. An analysis of the Roadblock locations was performed and it was determined to model the ETE simulations with no Roadblocks, except those located on Interstate (I)-10, as discussed in Section G.2.

G.1 Roadblocks

As discussed in Section 9, Roadblocks (manned by the County of Maricopa) that are within the EPZ at intersections (which are controlled) were initially modeled as actuated signals. If an intersection has a pre-timed signal, stop, or yield control, and the intersection is identified as a Roadblock, the control type was changed to an actuated signal in the DYNEV II system, in accordance with Section 3.3 of NUREG/CR-7002, Rev. 1. Roadblocks at existing actuated traffic signalized intersections were essentially left alone. These Roadblocks, as shown in the County of Maricopa Map, are mapped as blue dots in Figure G-1. These locations were ultimately not considered in this study. (See Section G.2.)

It is assumed that the Roadblocks (manned by the State of Arizona) on I-10 will be established within 45 minutes of the advisory to evacuate (ATE) to discourage through travelers from using major through routes which traverse the EPZ. As discussed in Section 3.9, external traffic was only considered on I-10 in this analysis. The generation of these external trips (3,070 vehicles during day conditions, 1,228 vehicles in evening conditions) ceased at 45 minutes after the ATE in the simulation. These Roadblocks, as shown in the County of Maricopa Map, are mapped as red squares in Figure G-1.

G.2 Analysis of Key Roadblock Locations

As discussed in Section 5.2 of NUREG/CR-7002, Rev. 1, manual traffic control (MTC) at intersections could benefit from ETE analysis. The Roadblocks locations contained within the TMP were analyzed to determine key locations where MTC would be most useful and can be readily implemented. As previously mentioned, signalized intersections that were actuated based on field data collection were essentially left as actuated traffic signals in the model, with modifications to green time allocation as needed. Other controlled intersections (pre-timed signals, stop signs and yield signs) were changed to actuated traffic signals to represent the MTC that would be implemented according to the TMP.

Table G-1 shows a list of the controlled intersections that were identified as Roadblocks in the TMP that were not previously actuated signals, including the type of control that currently exists at each location. To determine the impact of MTC at these locations, a summer,

midweek, midday, good weather scenario (Scenario 1) evacuation of the entire EPZ (Region R03) was simulated wherein these intersections were treated as Roadblocks (with MTC). These results were compared to the results presented in Section 7 (where these intersections were not treated as Roadblocks). The ETE had no change in the 90th and 100th percentile ETE when MTC was present at these intersections.

As shown in Figure 7-3 through Figure 7-7, the southern and western portion of the EPZ experience very little traffic congestion during an evacuation of the EPZ. As such, the Roadblocks in the southern and western portion of the EPZ do not help the ETE. The northern and eastern portion of the EPZ experiences traffic congestion, as heavy traffic flows exist within PVNGS and on both the north (on S 339th Avenue) and east (on W Van Buren Street and W Salome Highway) direction, as vehicles evacuate PVNGS and the area. When heavy traffic persists in competing directions, MTC provides no benefit since both approaches need equal amounts of green time. As a result, the Roadblocks in the northern and eastern portion of the Study Area do not help the ETE as well. In addition, traffic congestion clears prior to the completion of trip generation. The 100th percentile ETE is dictated by trip generation (plus 10 minute travel time to EPZ boundary). As such, there is no impact to the 100th percentile ETE.

Therefore, the implementation of Roadblocks has no impacts to ETE. Thus, we did not consider the Roadblocks (mapped as blue dots in Figure G-1) for this study, except for those located on I-10 (mapped as red squares in Figure G-1) as they serve to discourage the external-external traffic from entering I-10. While Roadblocks are not necessary to evacuate the EPZ expediently, staffing these locations does still provide value during an evacuation such as guiding those evacuees who are not familiar with the area and serving as fixed point surveillance if there is an incident on one of the major evacuation routes.

Table K-1 provides the number of nodes with each control type. If the existing control on I-10 was changed due to being a Roadblock, the control type is indicated as “Roadblock” in Table K-1.

Table G-1. List of Key Roadblock Locations

Roadblock	UNITES Node #	Previous Control	Roadblock	UNITES Node #	Previous Control
A1	150	Stop Control	E17	152	Stop Control
A3	112	Stop Control		50	Stop Control
B5	135	Stop Control	E18	77	Stop Control
A8	154	Stop Control	F1	82	No Control
ADOT1	59	No Control	F2	130	No Control
AJ2	100	Stop Control	F3	45	Stop Control
B2	173	Stop Control	F6	47	Stop Control
B7	126	Stop Control	F11	49	No Control
C2	149	Stop Control	G1	81	Stop Control
C3	148	Stop Control	G3	159	Stop Control
C4	113	Stop Control	G4	160	No Control
C6	114	Stop Control	G5	68	Stop Control
C7	67	Stop Control	H3	70	No Control
C8	134	Stop Control	M2	101	No Control
C9	87	Stop Control	N1	105	No Control
D1	116	No Control	P1	32	No Control
D7	196	No Control	Q1	38	No Control
D10	197	Stop Control	Q3	190	No Control
D12	90	Stop Control	Q4	39	Stop Control
E1	83	Stop Control	R2	26	No Control
E2	44	No Control	R5	117	No Control
E3	157	No Control	R7	222	Stop Control

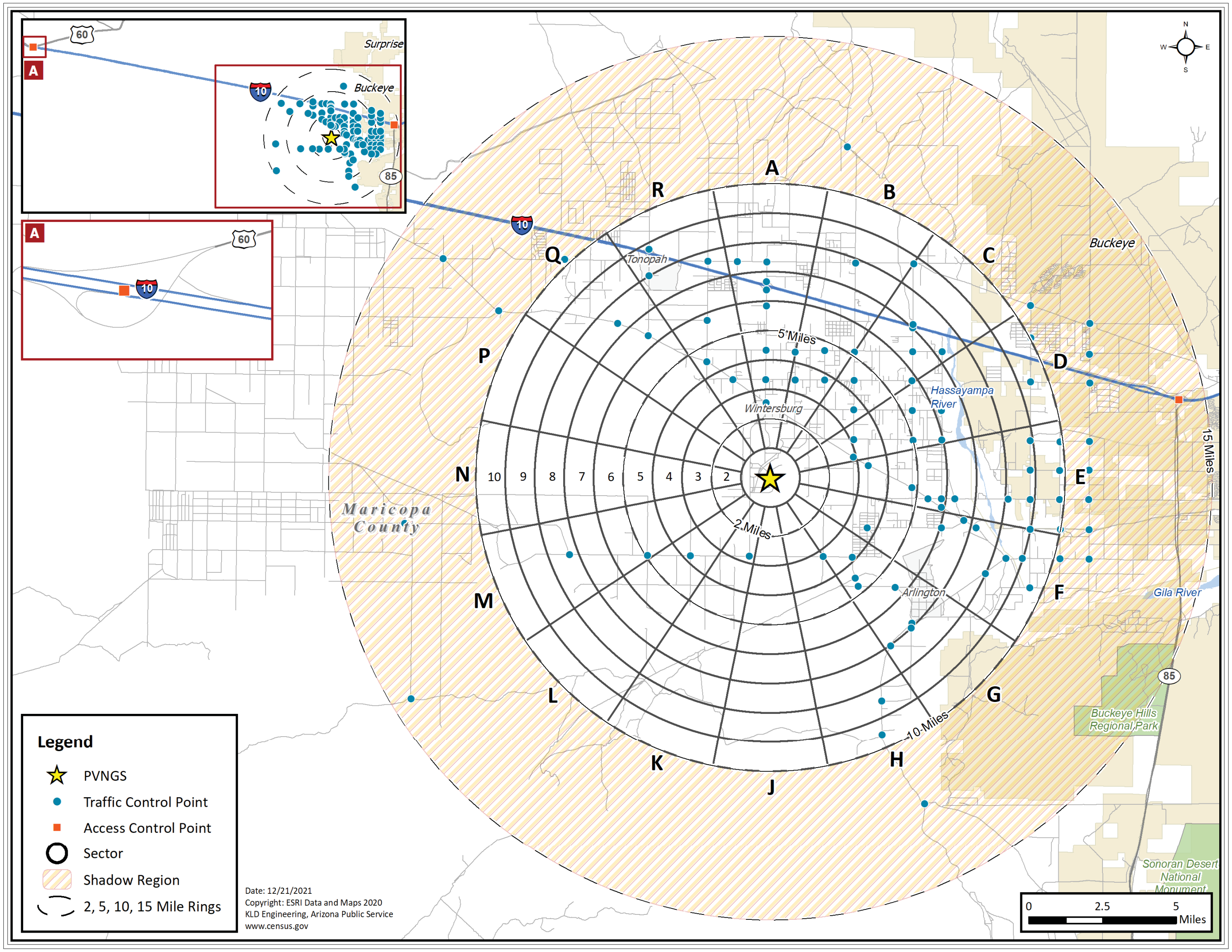


Figure G-1. Roadblocks for the PVNGS Site

APPENDIX H

Evacuation Regions

H EVACUATION REGIONS

This appendix presents the evacuation percentages for each Evacuation Region (Table H-1) and maps of all Evacuation Regions (Figure H-1 through Figure H-52). The percentages presented in Table H-1 are based on the methodology discussed in assumption 7 of Section 2.2 and shown in Figure 2-1.

Note the baseline ETE study assumes 20 percent of households will not comply with the shelter advisory, as per Section 2.5.2 of NUREG/CR-7002, Rev. 1.

Table H-1. Percent of Sector Population Evacuating for Each Region

Radial Regions

Region	Description	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R01	2-Mile Region	X	X																																
R02	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R03	Full EPZ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Evacuate 2-Mile Region and Downwind to 5 Miles

Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R04	S	X	X	X		X																												X	
R05	SSW	X	X	X		X		X																											
R06	SW	X	X			X		X		X																									
R07	WSW	X	X					X		X		X																							
R08	W	X	X							X		X		X																					
R09	WNW	X	X									X		X		X																			
R10	NW	X	X											X		X		X																	
R11	NNW	X	X													X		X		X															
R12	N	X	X															X		X		X													
R13	NNE	X	X																	X		X		X											
R14	NE	X	X																			X		X		X									
R15	ENE	X	X																					X		X		X							
R16	E	X	X																					X		X		X		X		X			
R17	ESE	X	X																							X		X		X		X		X	
R18	SE	X	X	X																								X		X		X		X	
R19	SSE	X	X	X																												X		X	

Sector(s) Evacuate | Sector(s) Shelter-in-Place

Evacuate 2-Mile Region and Downwind to EPZ Boundary																																			
		Sector																																	
Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R20	S	X	X	X	X	X	X																													X	X
R21	SSW	X	X	X	X	X	X	X	X																												
R22	SW	X	X			X	X	X	X	X	X																										
R23	WSW	X	X					X	X	X	X	X	X																								
R24	W	X	X							X	X	X	X	X	X																						
R25	WNW	X	X									X	X	X	X	X	X																				
R26	NW	X	X											X	X	X	X	X	X																		
R27	NNW	X	X													X	X	X	X	X	X																
R28	N	X	X															X	X	X	X	X	X														
R29	NNE	X	X																	X	X	X	X	X	X												
R30	NE	X	X																			X	X	X	X	X	X										
R31	ENE	X	X																					X	X	X	X	X	X								
R32	E	X	X																					X	X	X	X	X	X	X	X	X	X				
R33	ESE	X	X																							X	X	X	X	X	X	X	X	X	X		
R34	SE	X	X	X	X																							X	X	X	X	X	X	X	X		
R35	SSE	X	X	X	X																											X	X	X	X		
Staged Evacuation - 2-Mile Region Evacuates, then Evacuate Downwind to 5 Miles																																			
		Sector																																	
Region	Wind Direction From:	PVNGS	2-Mile Radius	A		B		C		D		E		F		G		H		J		K		L		M		N		P		Q		R	
				2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10	2-5	5-10
R36	5-Mile Region	X	X	X		X		X		X		X		X		X		X		X		X		X		X		X		X		X		X	
R37	S	X	X	X		X																														X	
R38	SSW	X	X	X		X		X																													
R39	SW	X	X			X		X		X																											
R40	WSW	X	X					X		X		X																									
R41	W	X	X							X		X		X																							
R42	WNW	X	X									X		X		X																					
R43	NW	X	X											X		X		X																			
R44	NNW	X	X													X		X		X																	
R45	N	X	X															X		X		X															
R46	NNE	X	X																	X		X		X													
R47	NE	X	X																			X		X		X											
R48	ENE	X	X																					X		X		X									
R49	E	X	X																					X		X		X		X		X					
R50	ESE	X	X																							X		X		X		X		X			
R51	SE	X	X	X																								X		X		X		X			
R52	SSE	X	X	X																												X		X			

Legend: Sector(s) Evacuate | Sector(s) Shelter-in-Place | Sector(s) Shelter-in-Place until 90% ETE for R01, then Evacuate

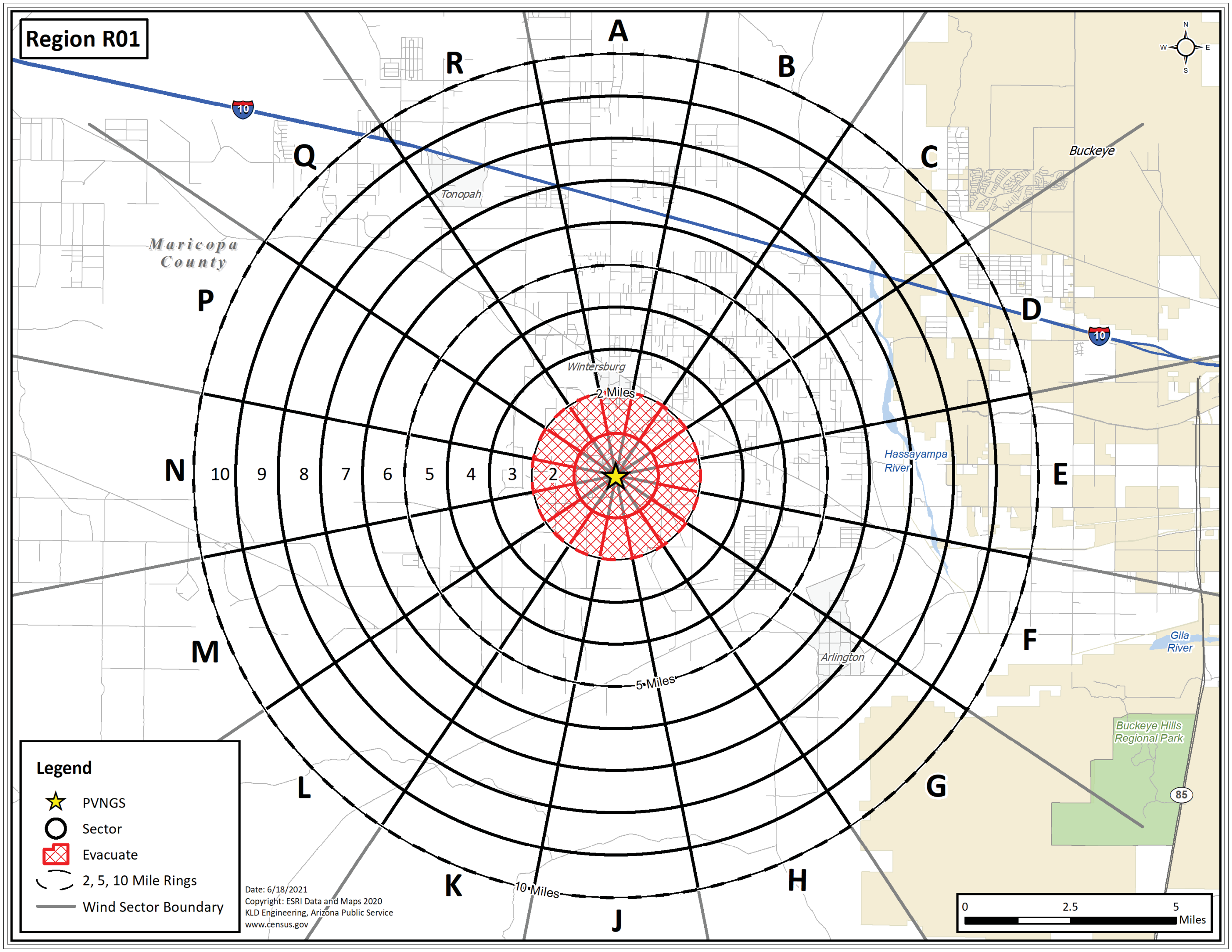


Figure H-1. Region R01

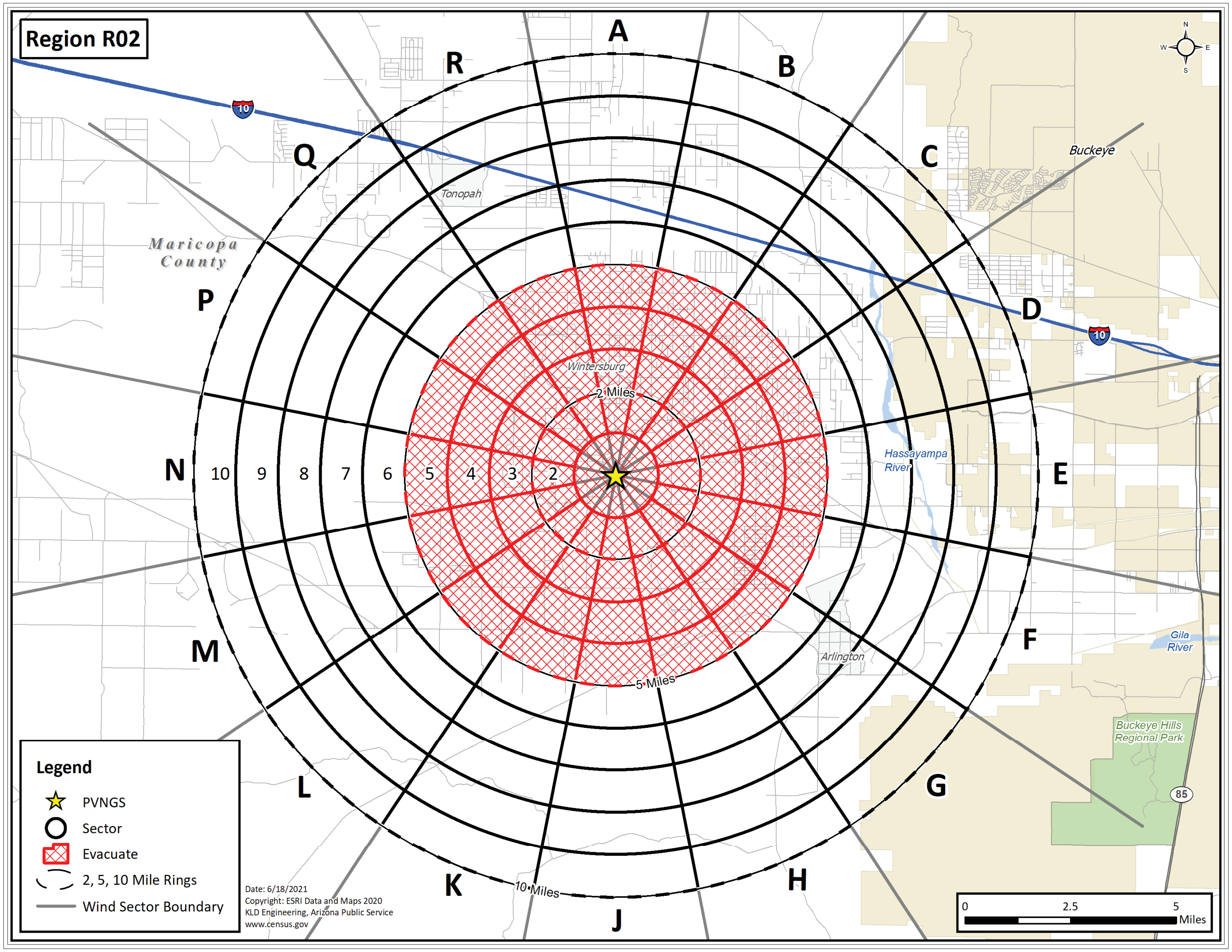


Figure H-2. Region R02

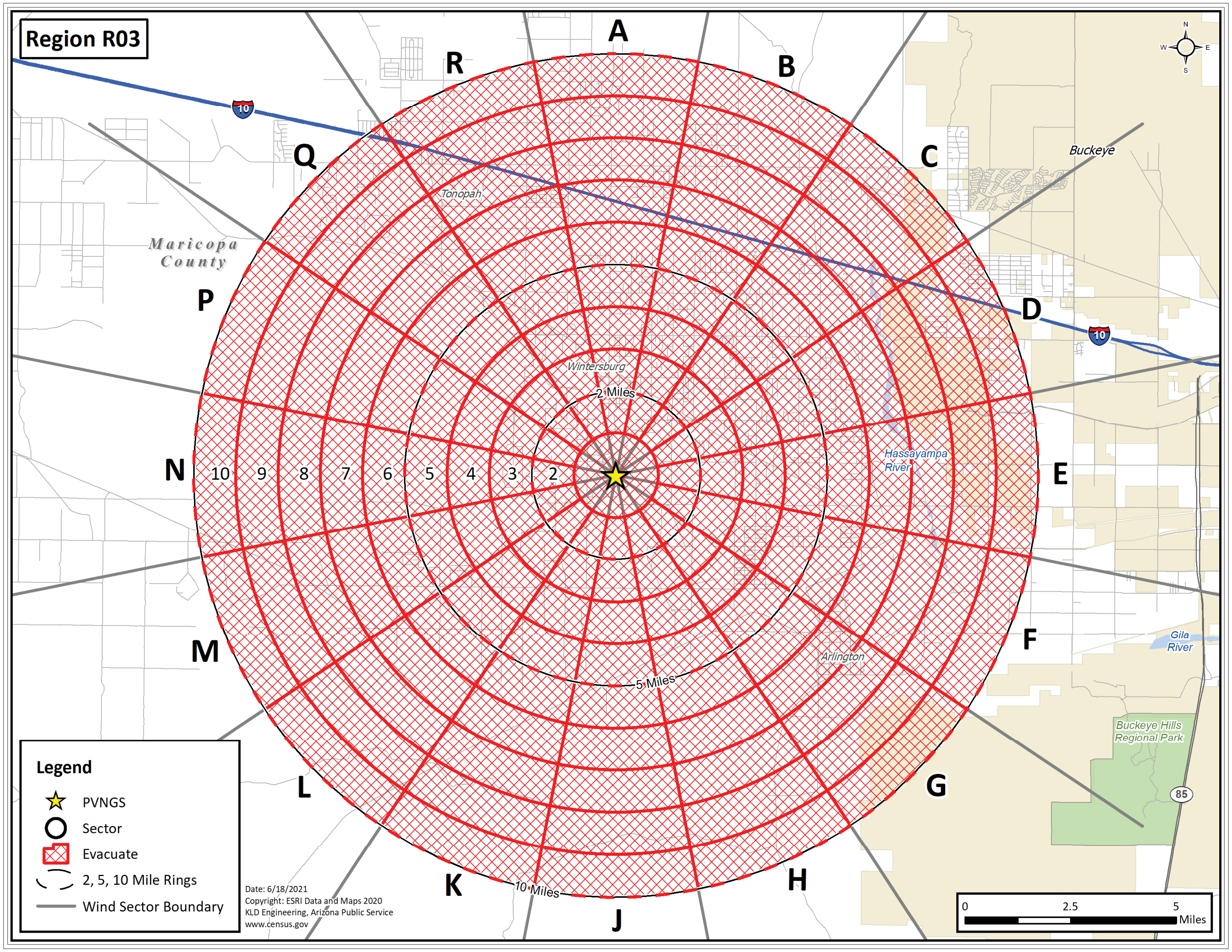
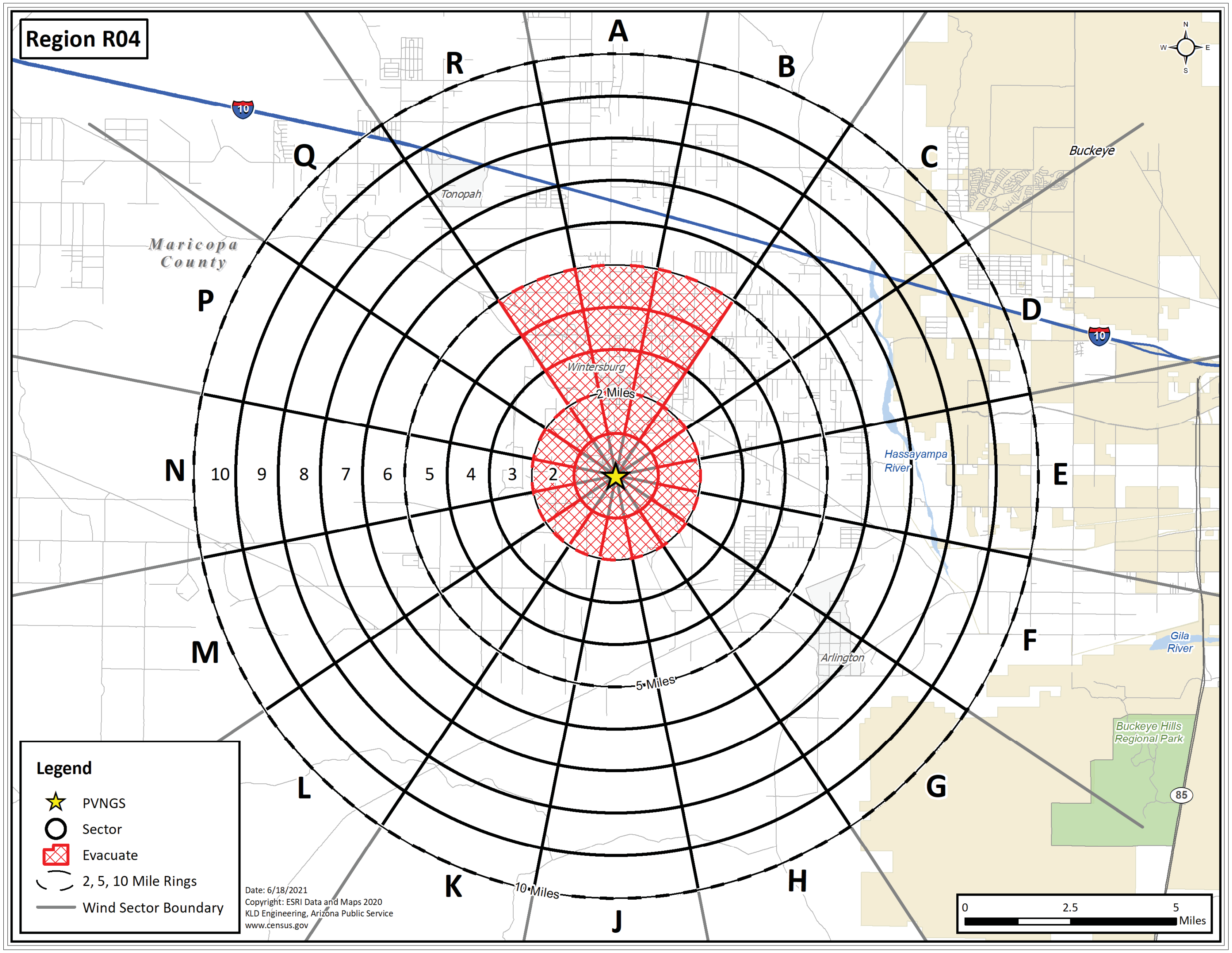


Figure H-3. Region R03



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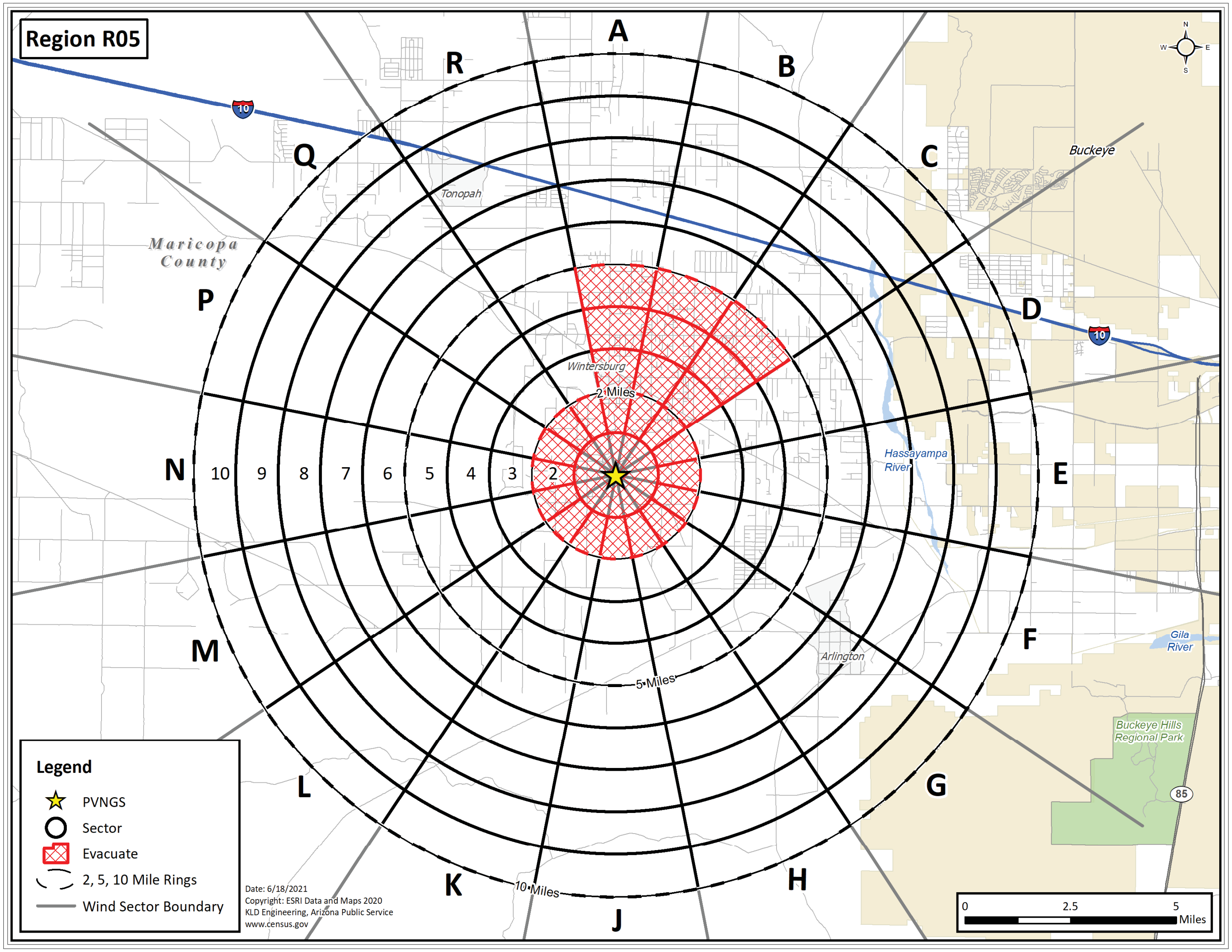

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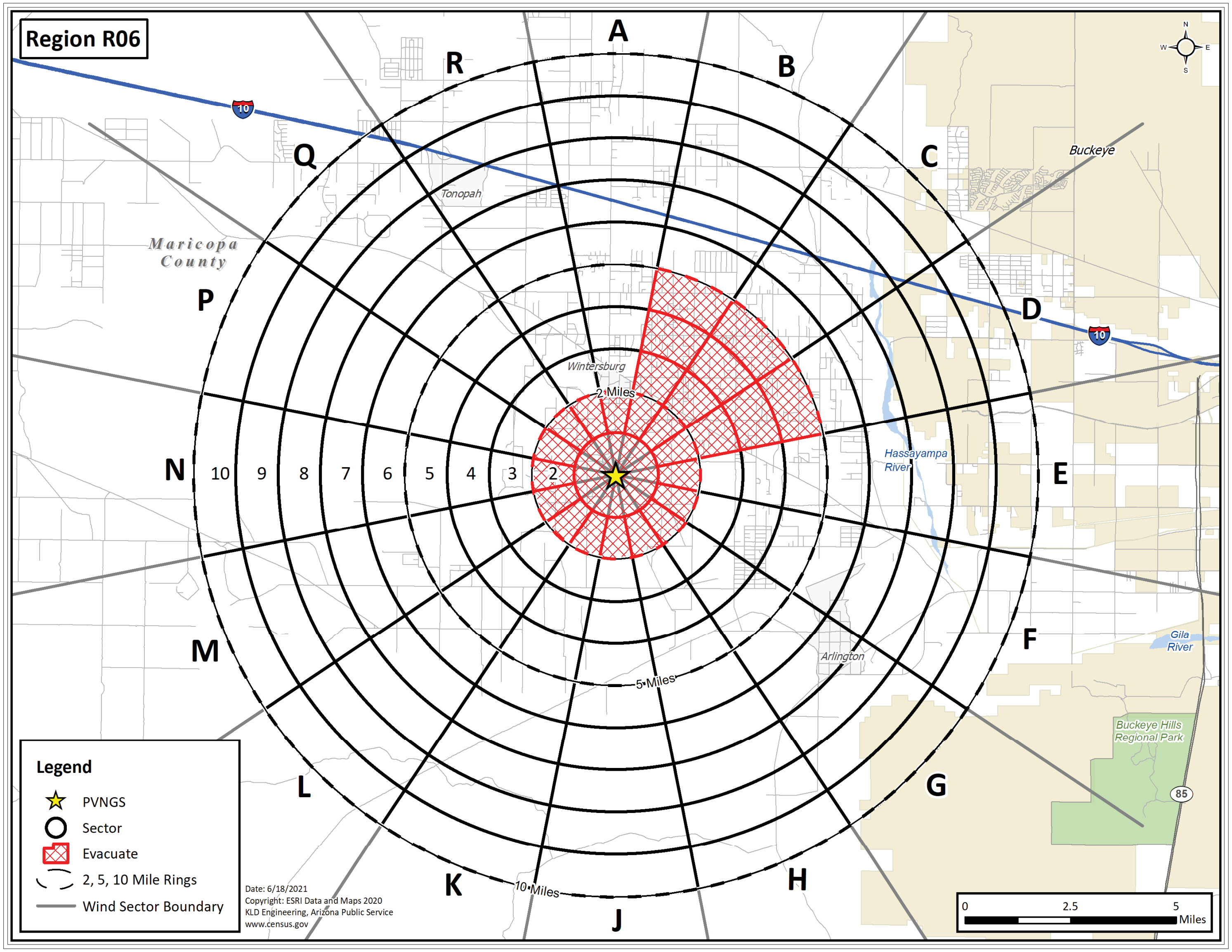

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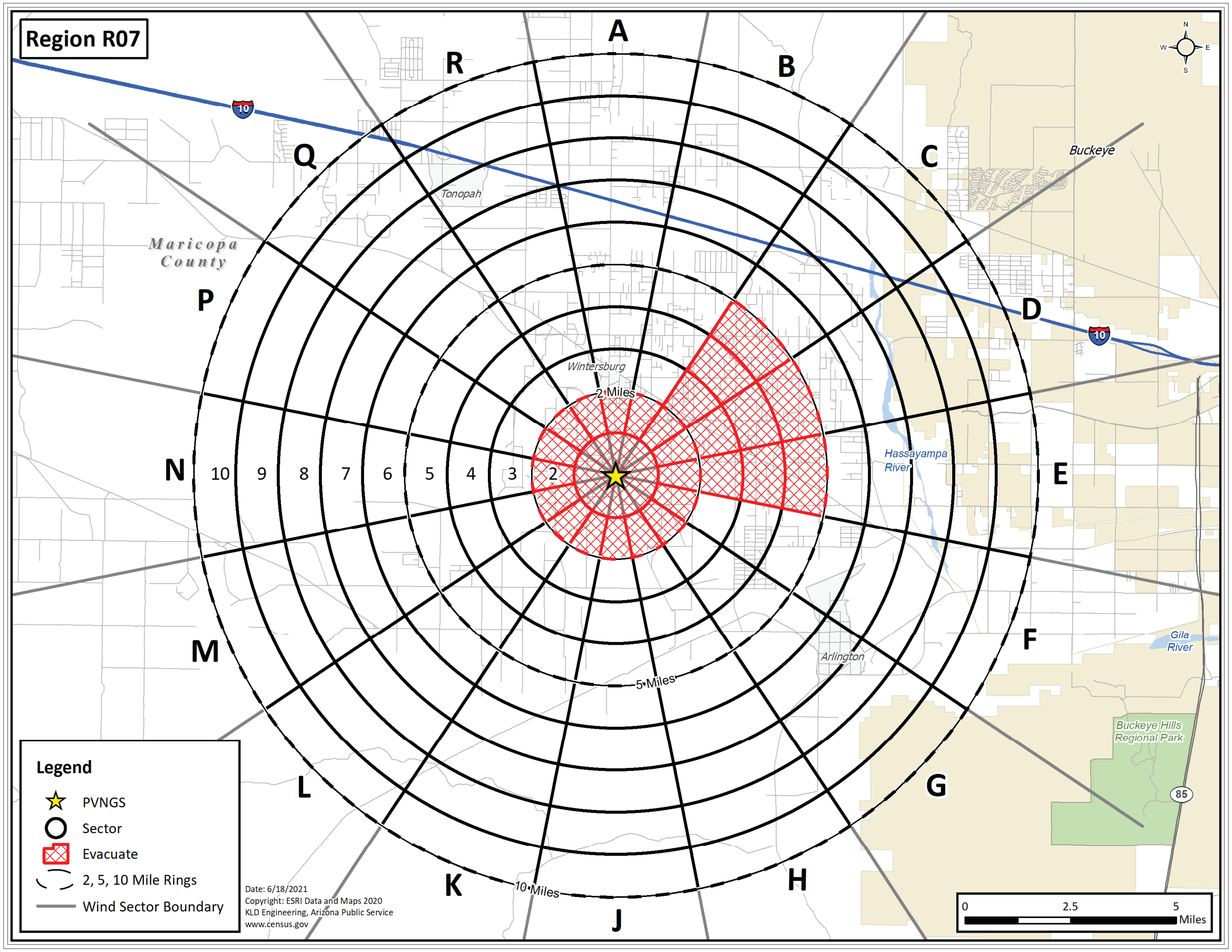

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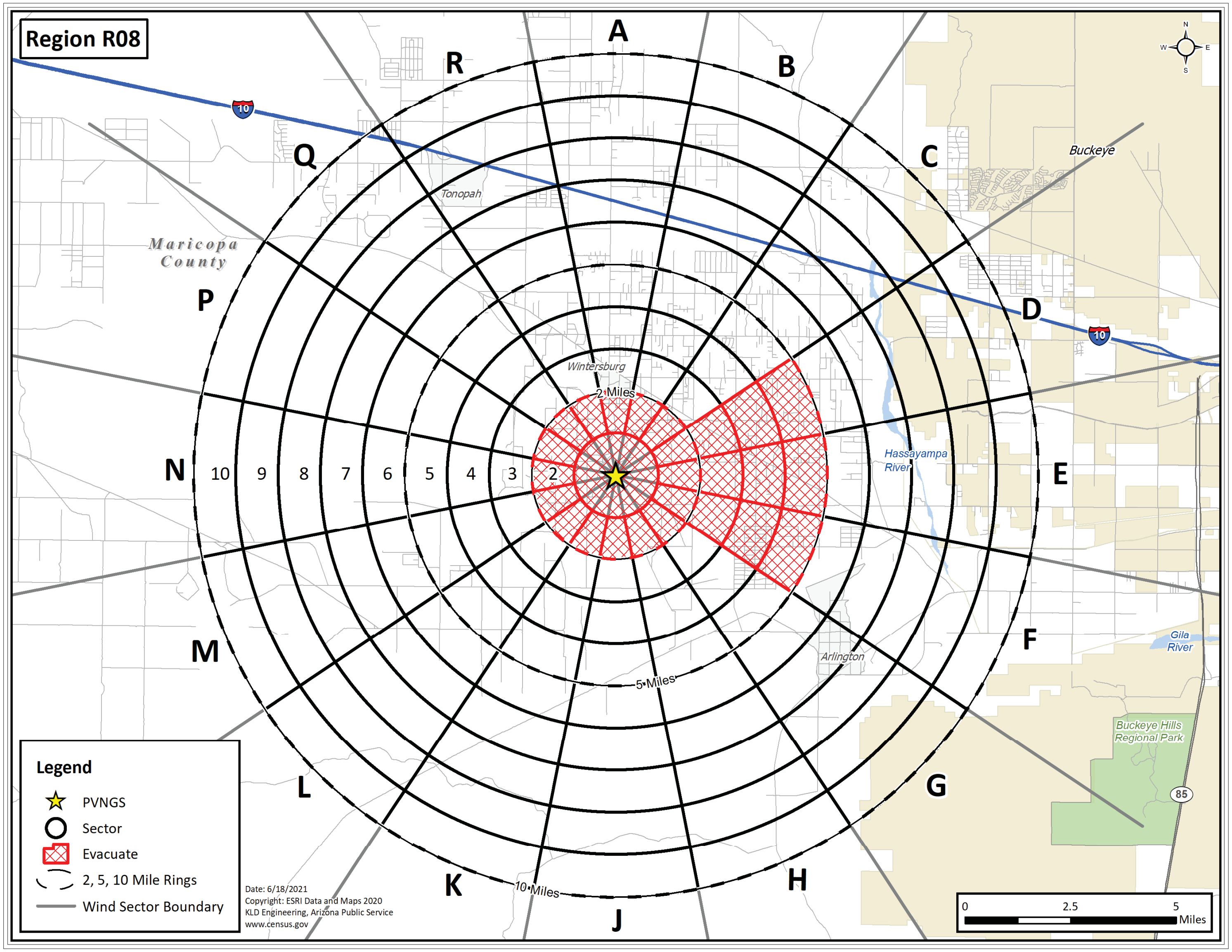

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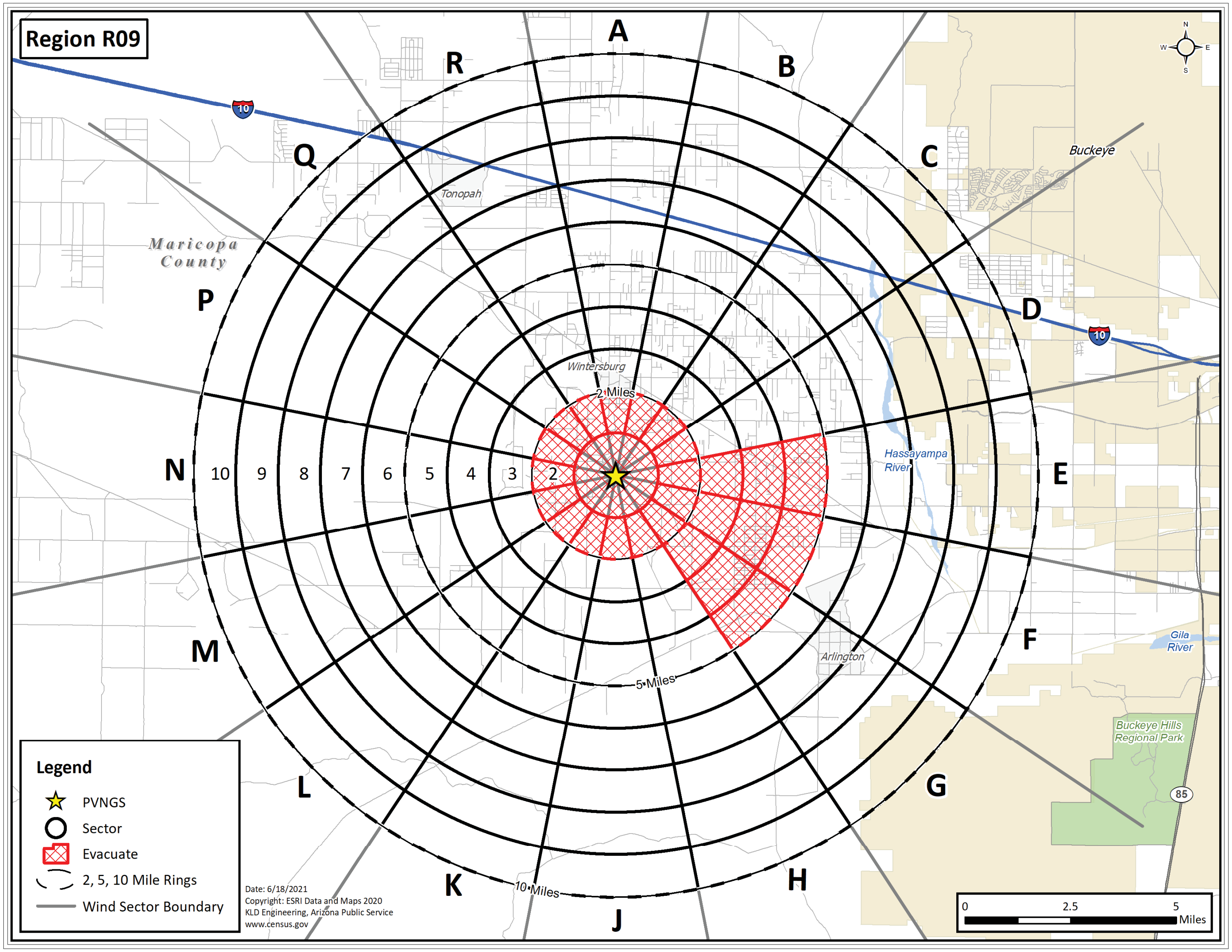

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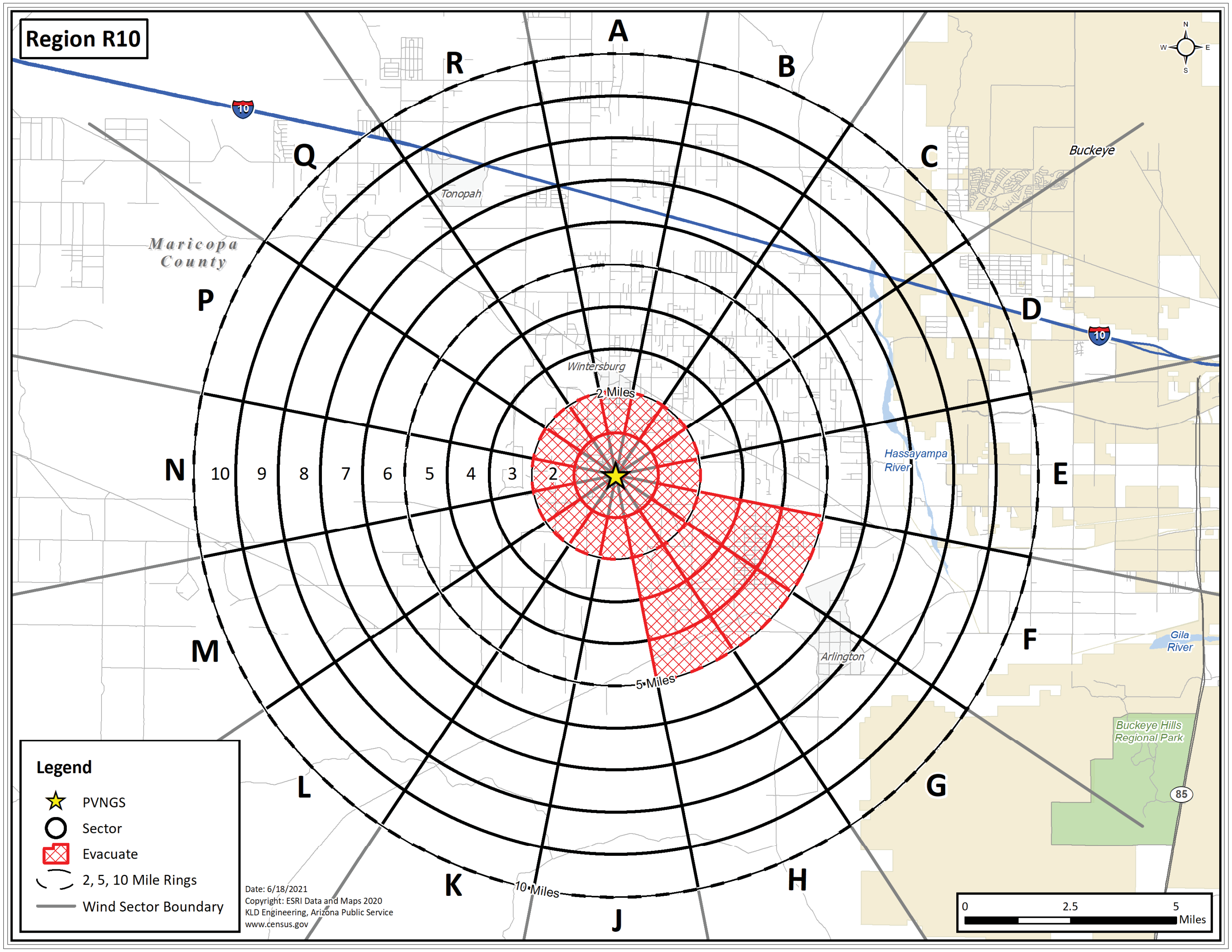

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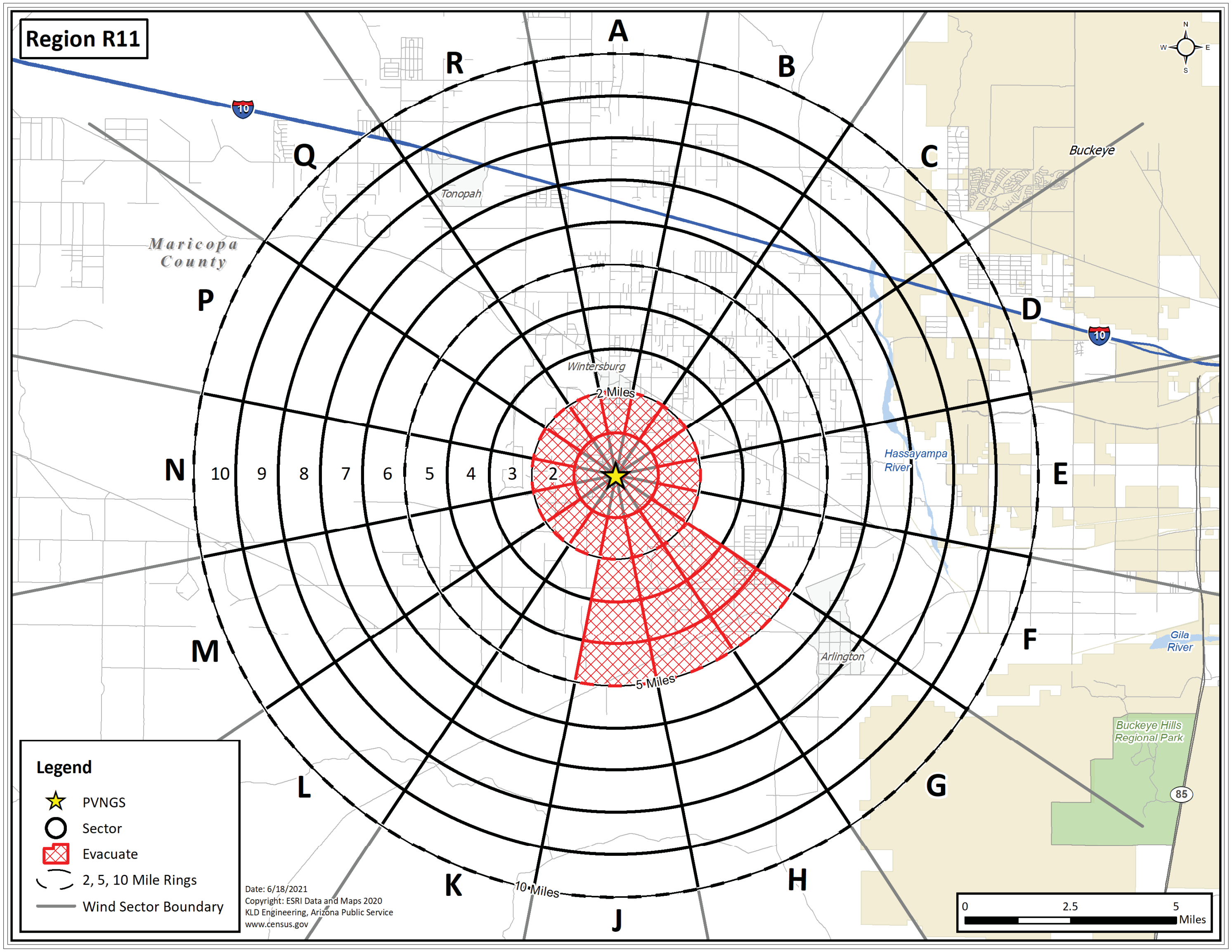

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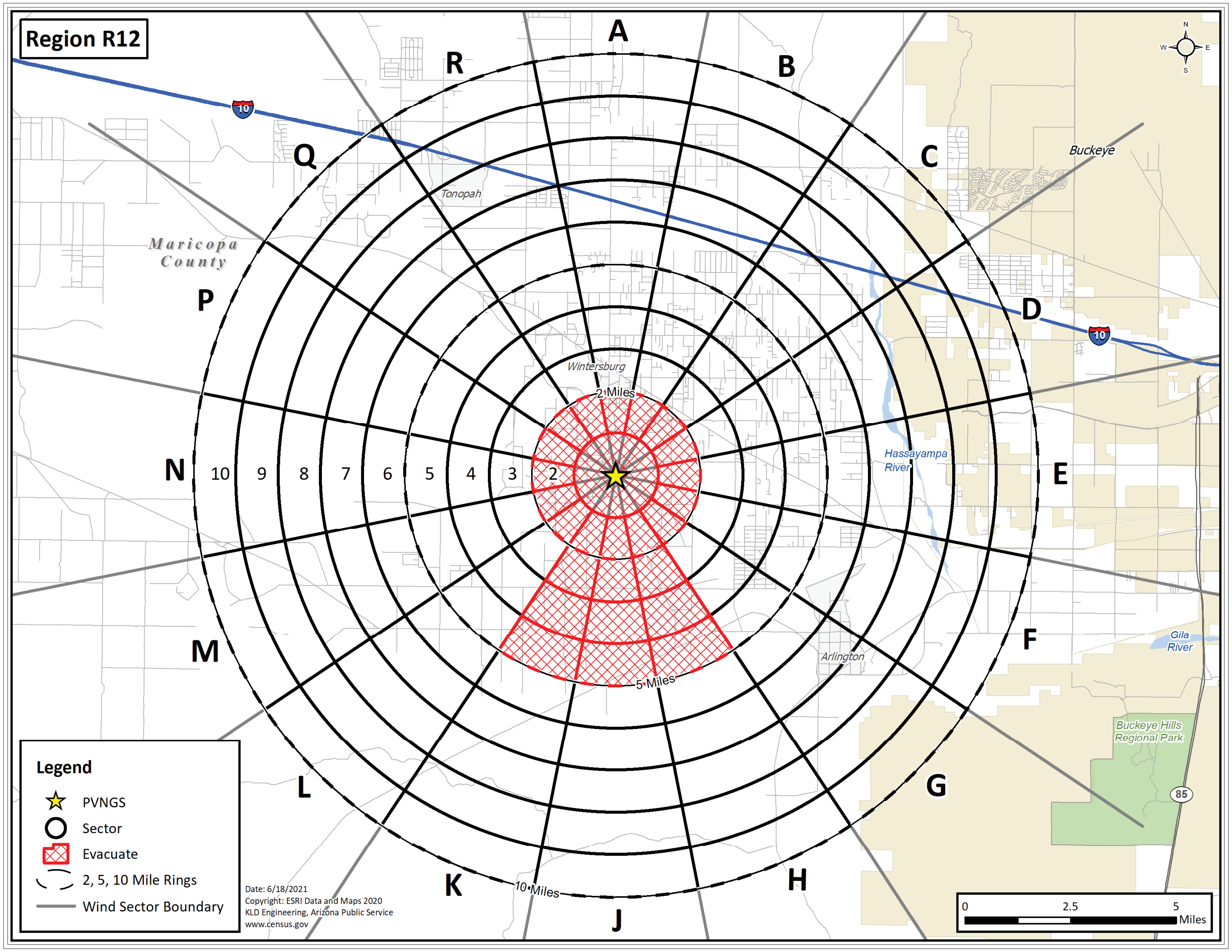

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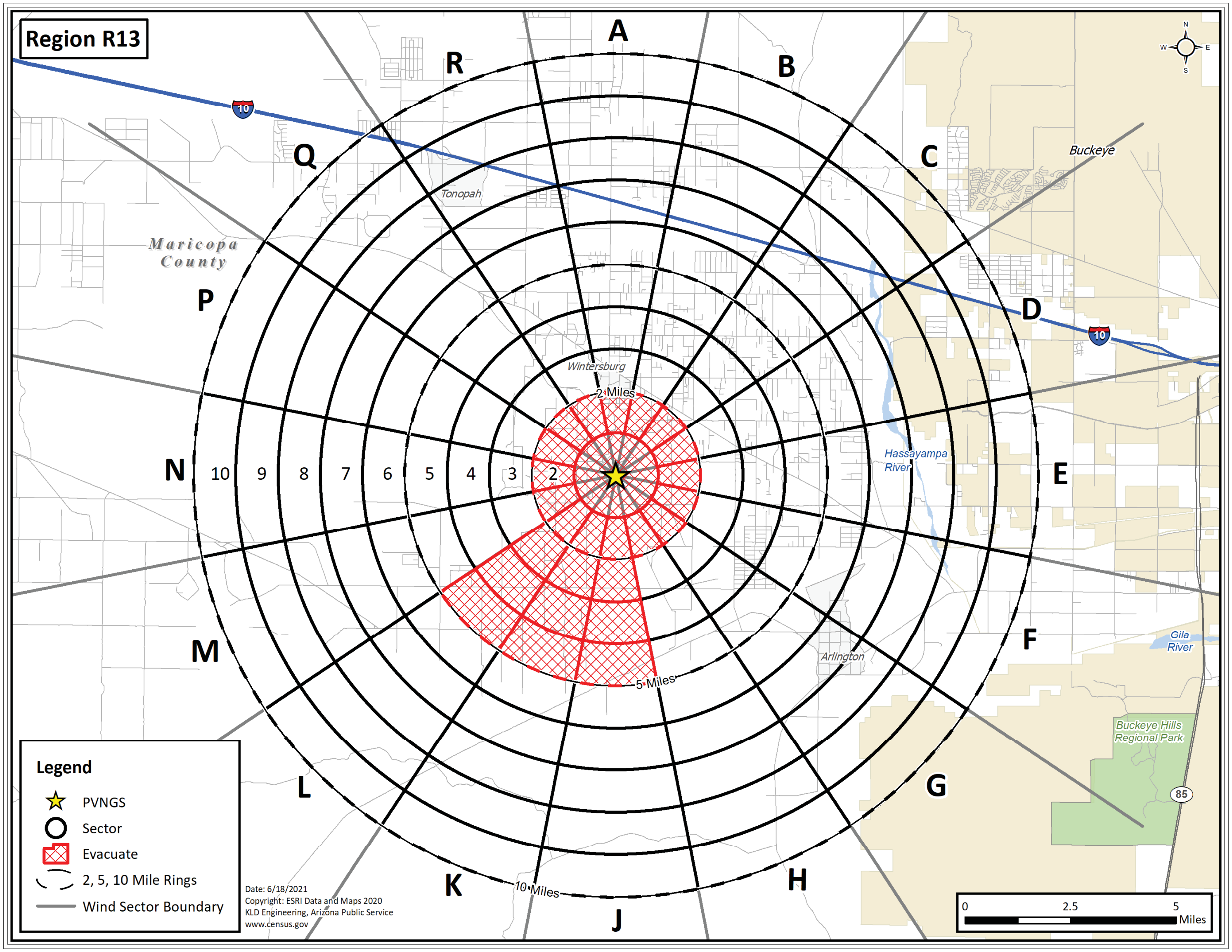

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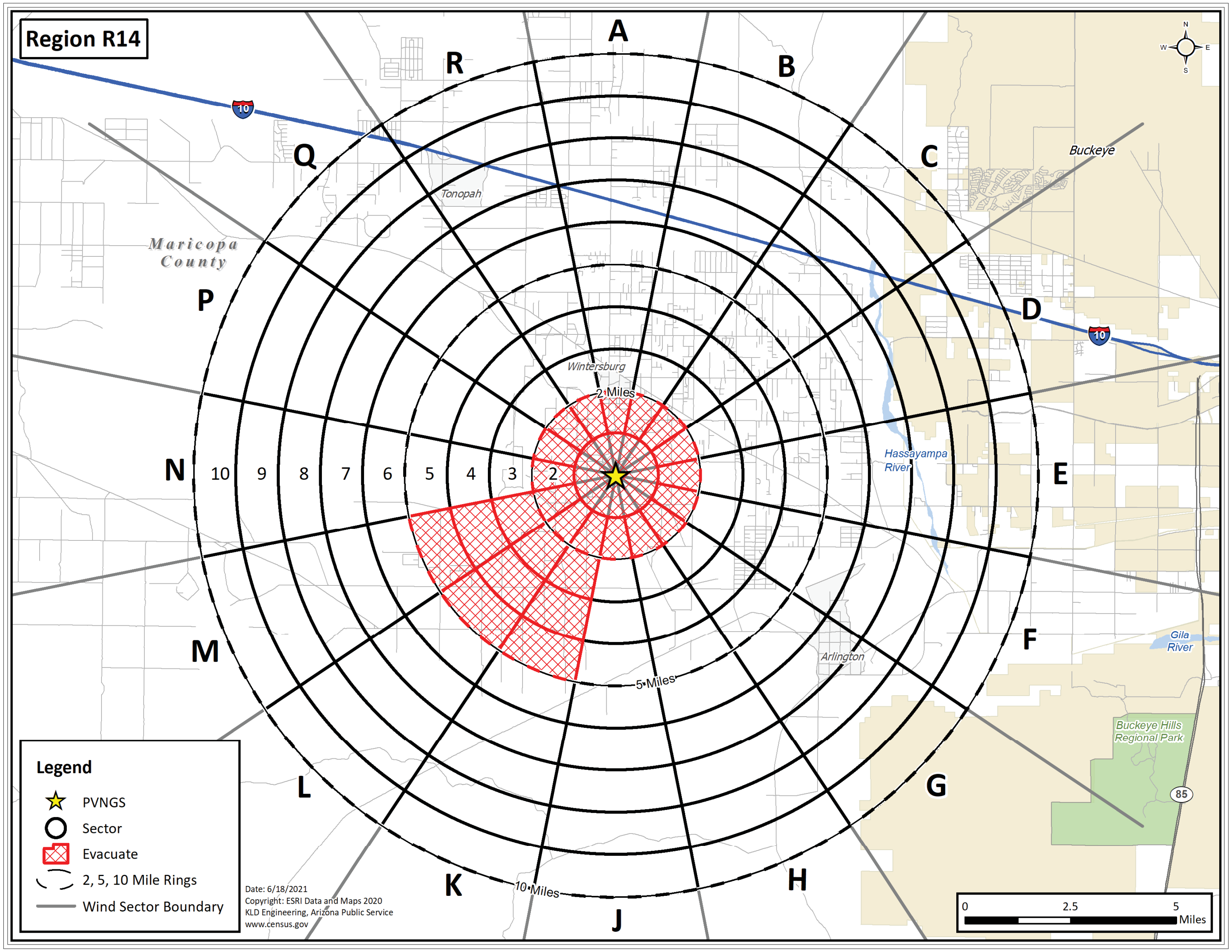

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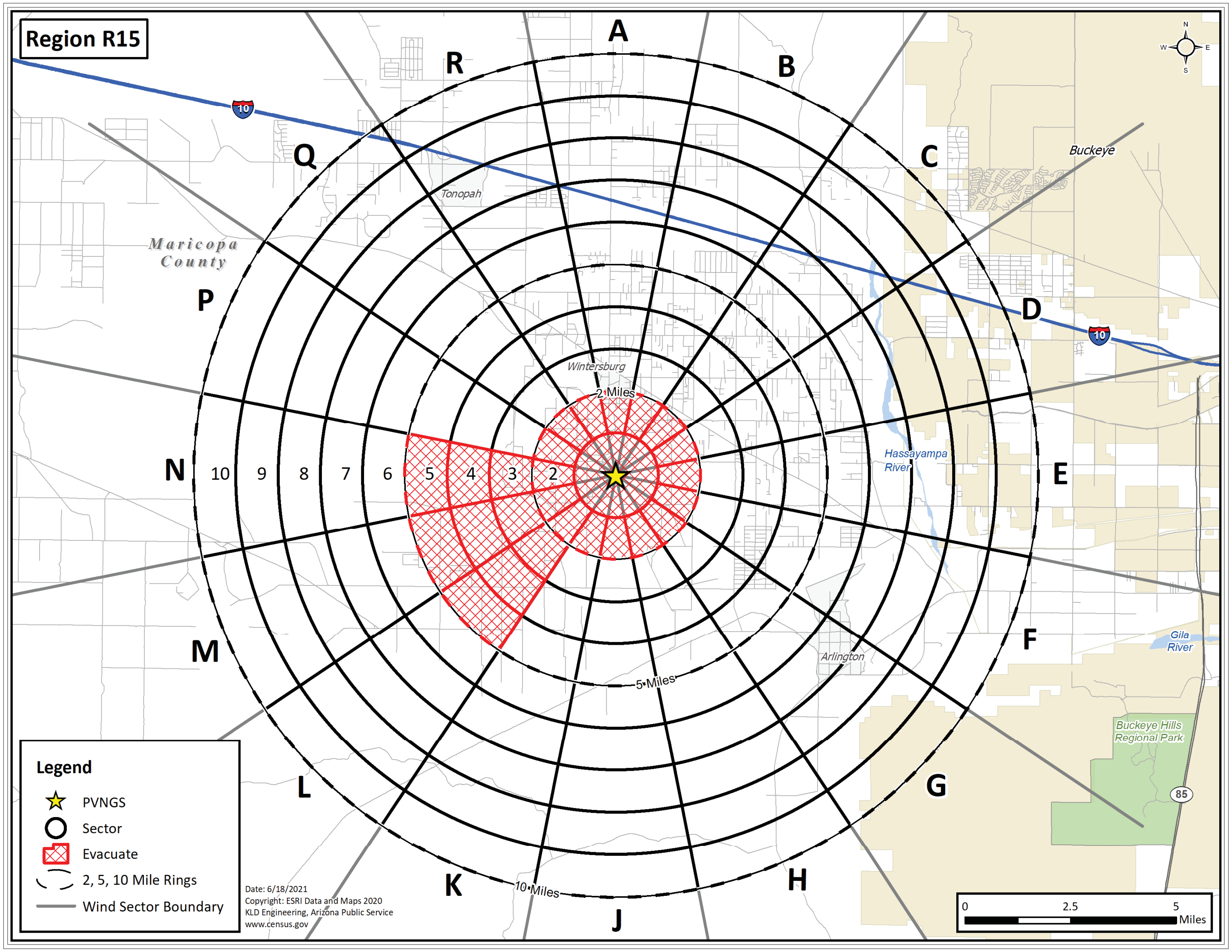

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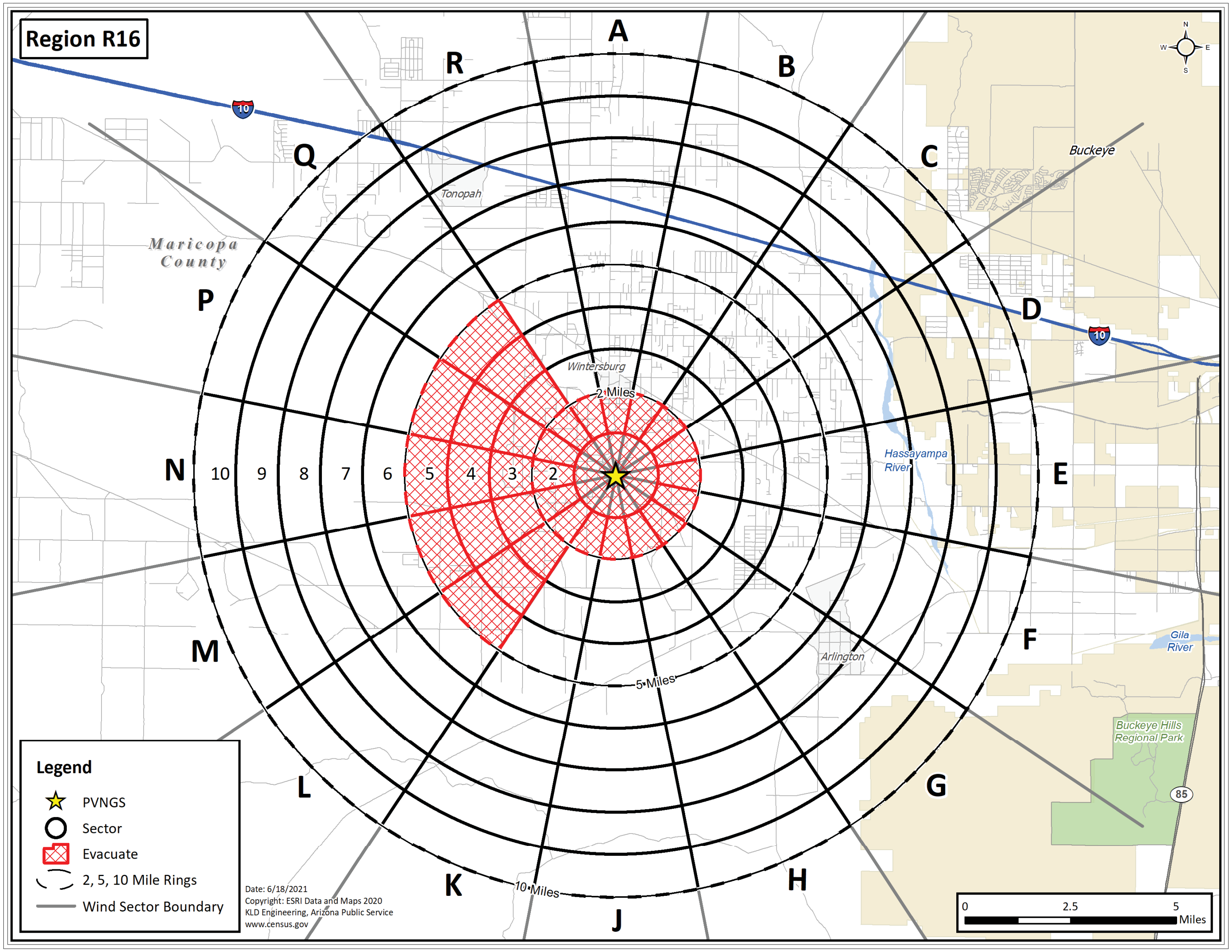

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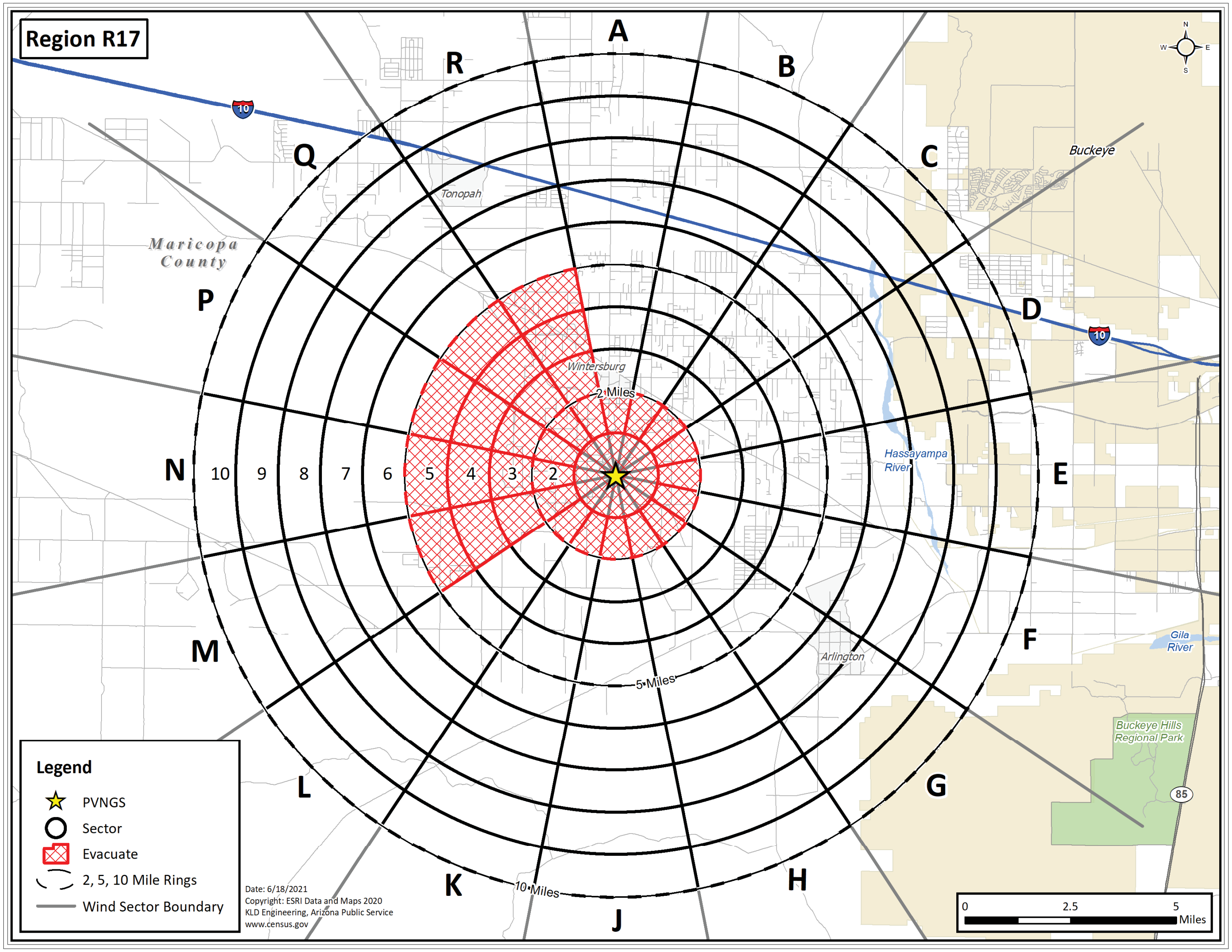

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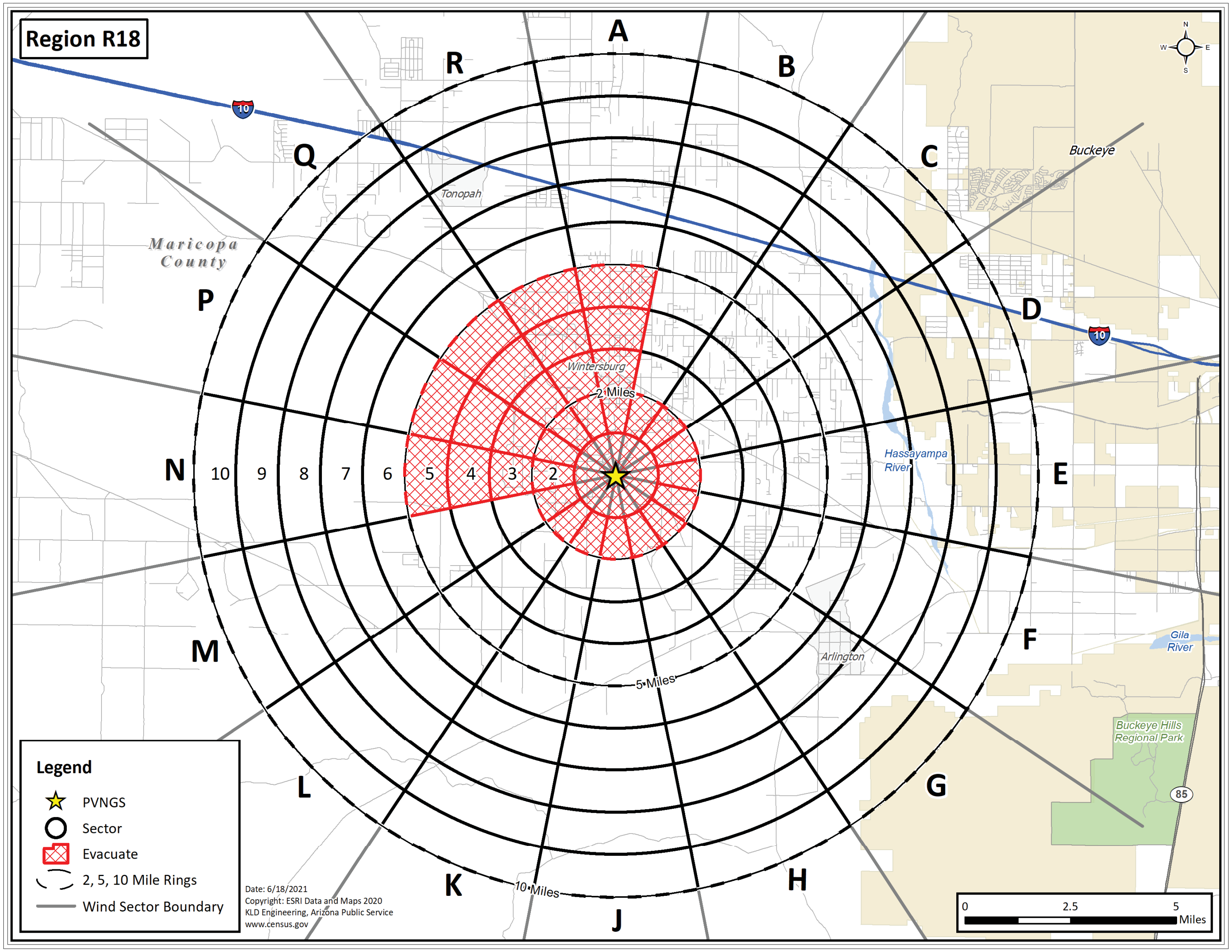

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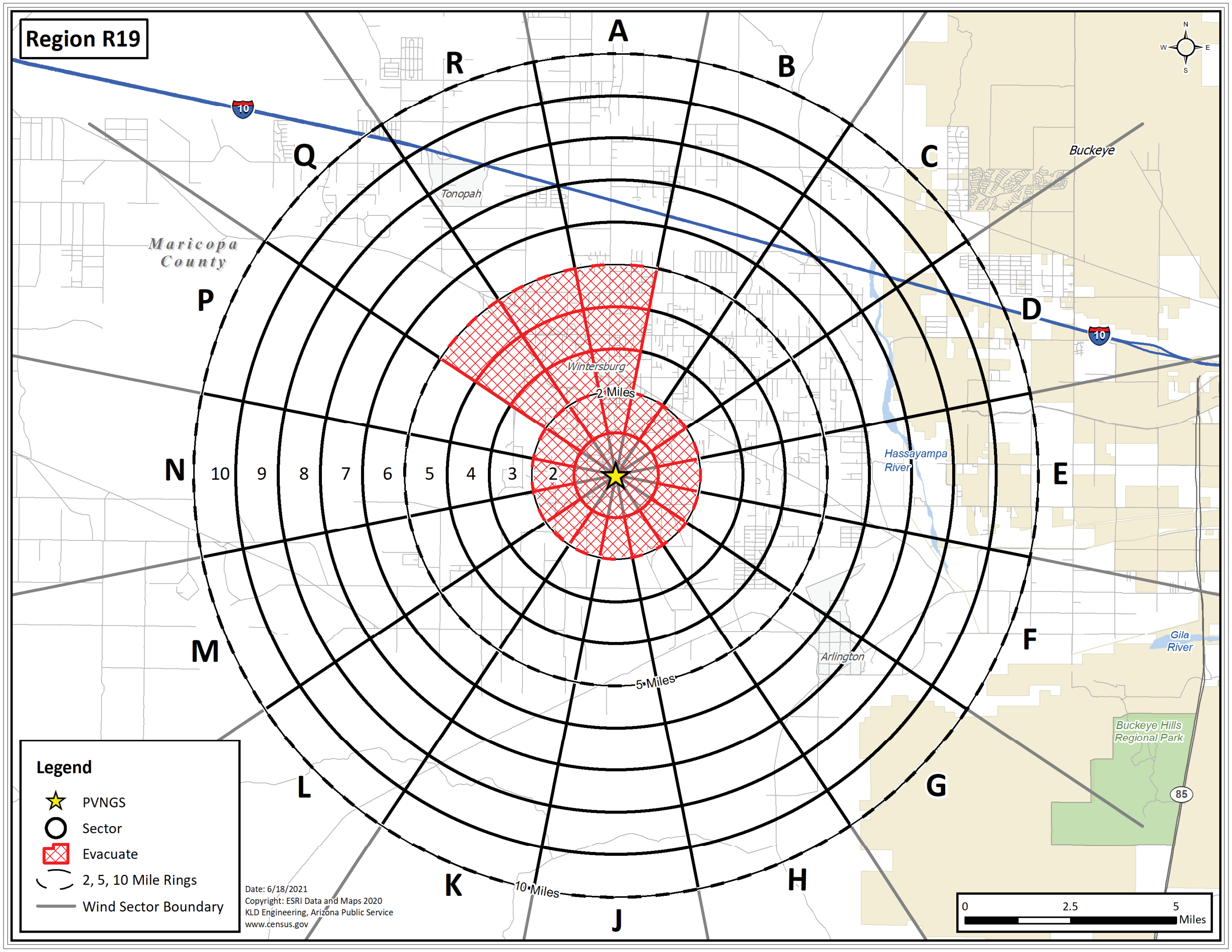

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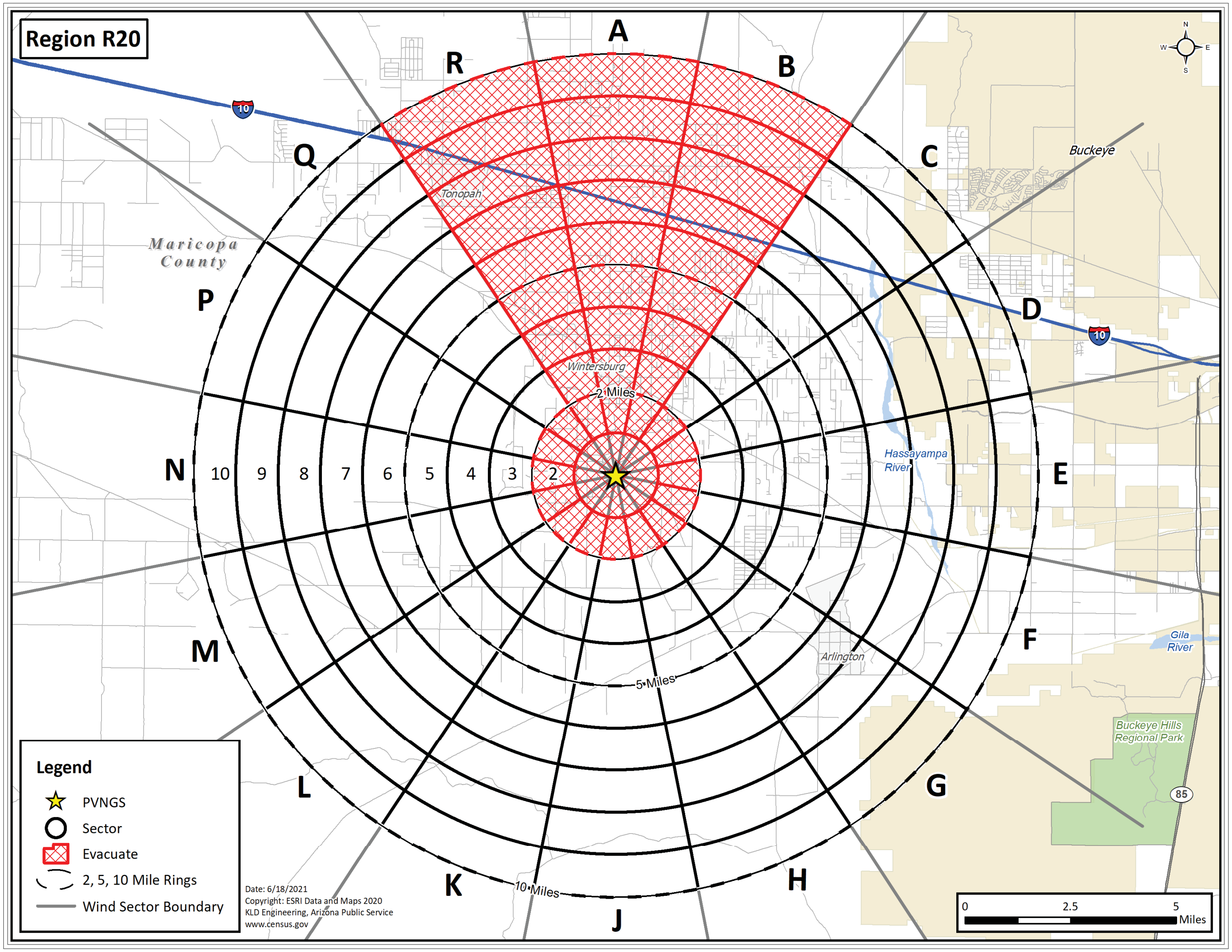
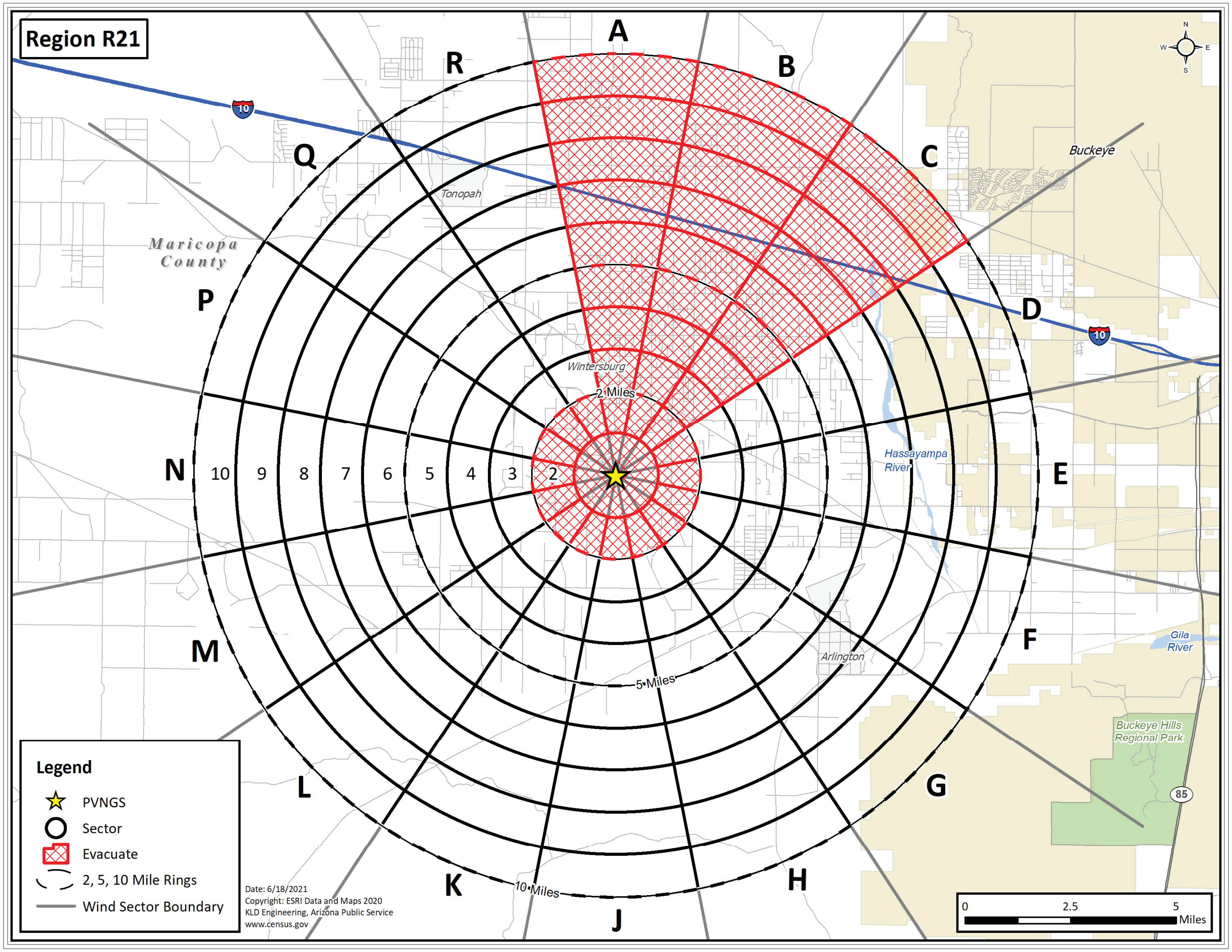


Figure H-20. Region R20



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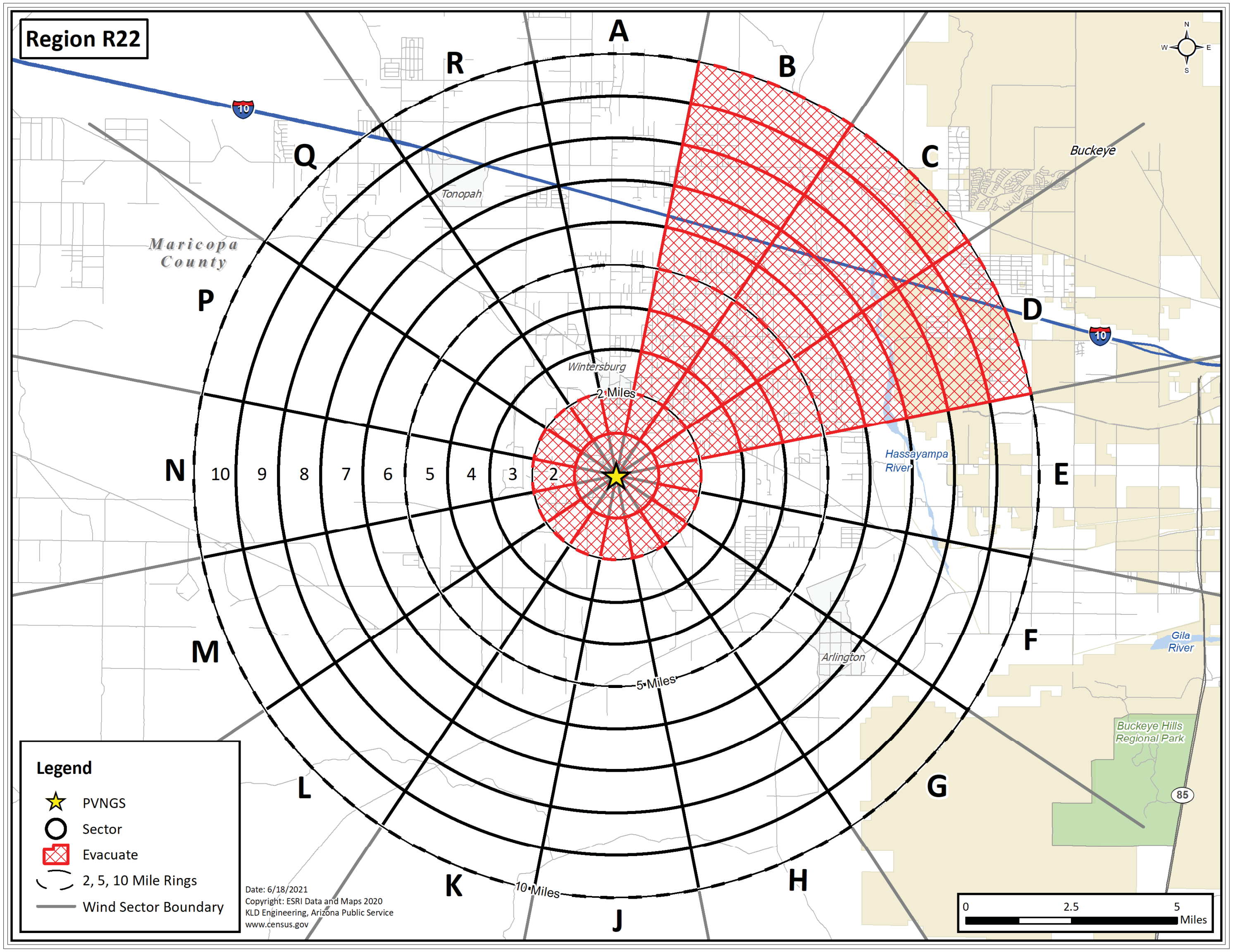


Figure H-22. Region R22

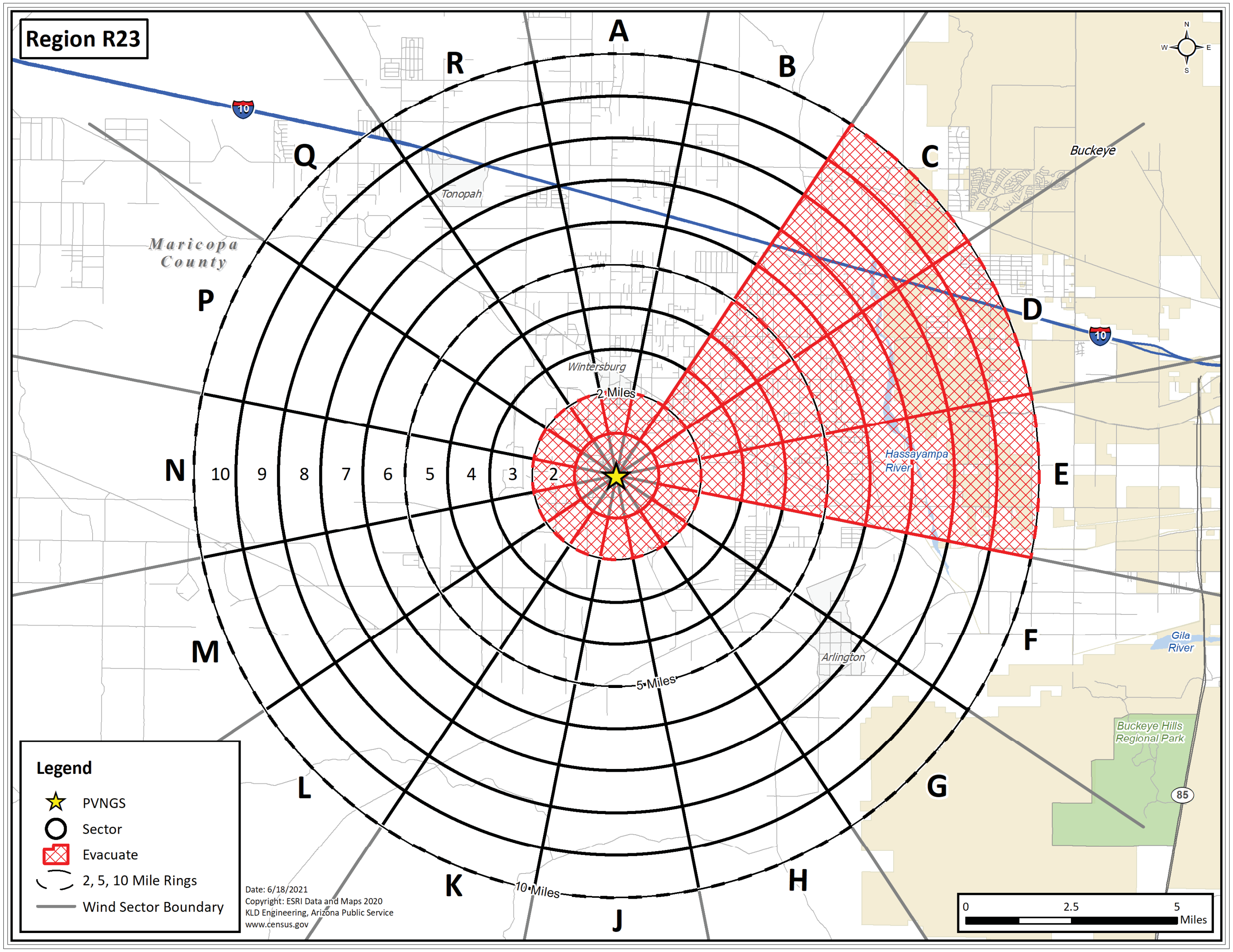
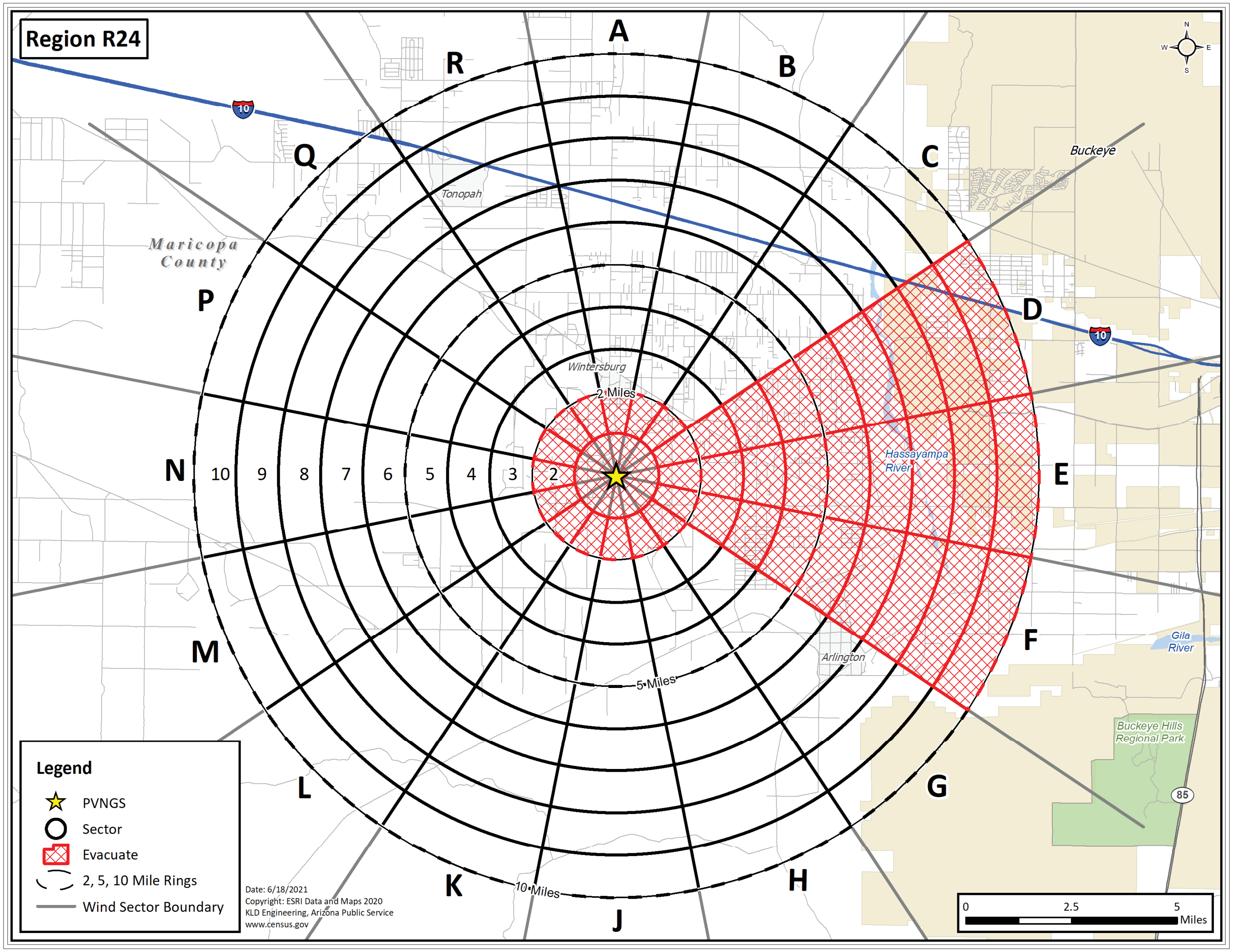


Figure H-23. Region R23



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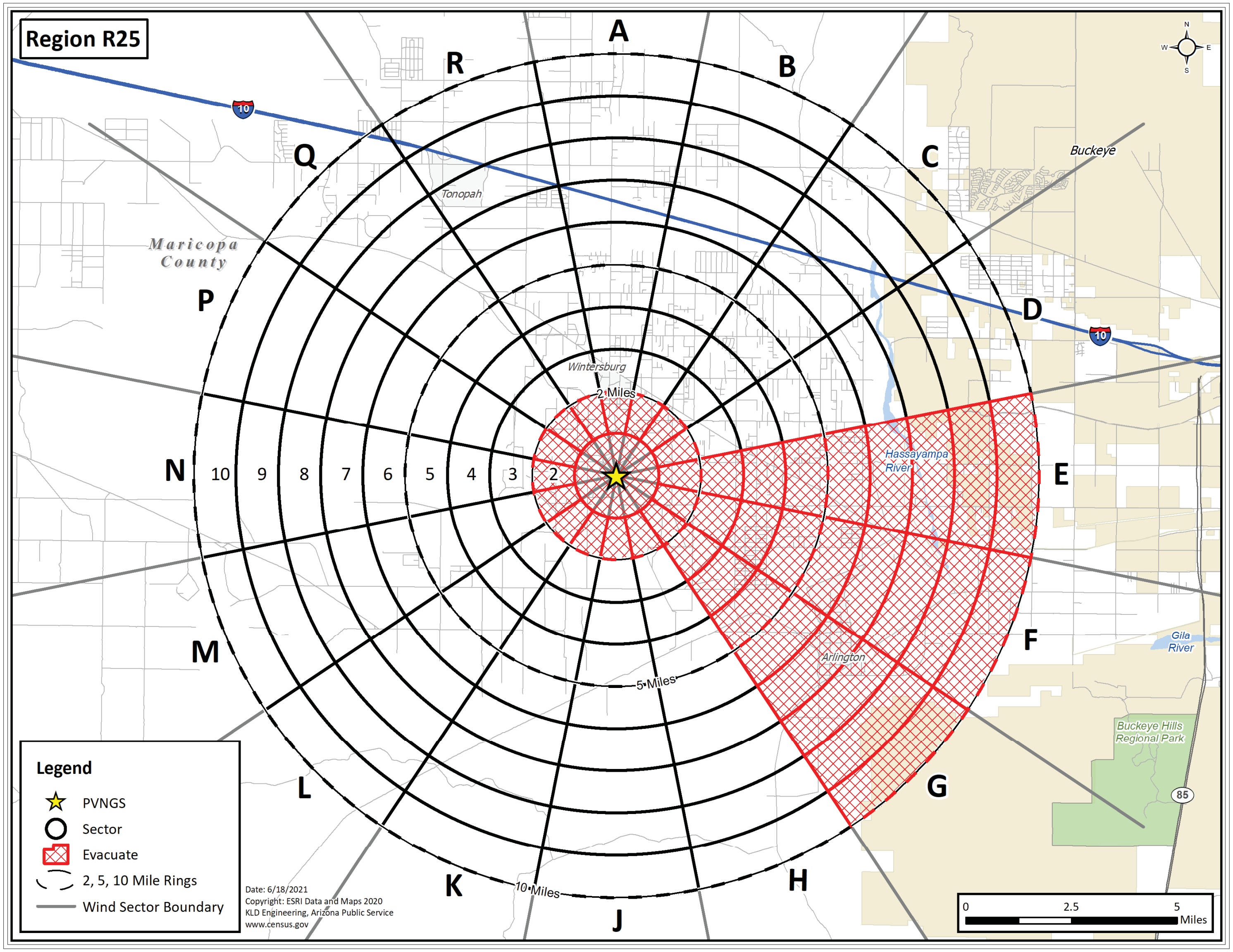

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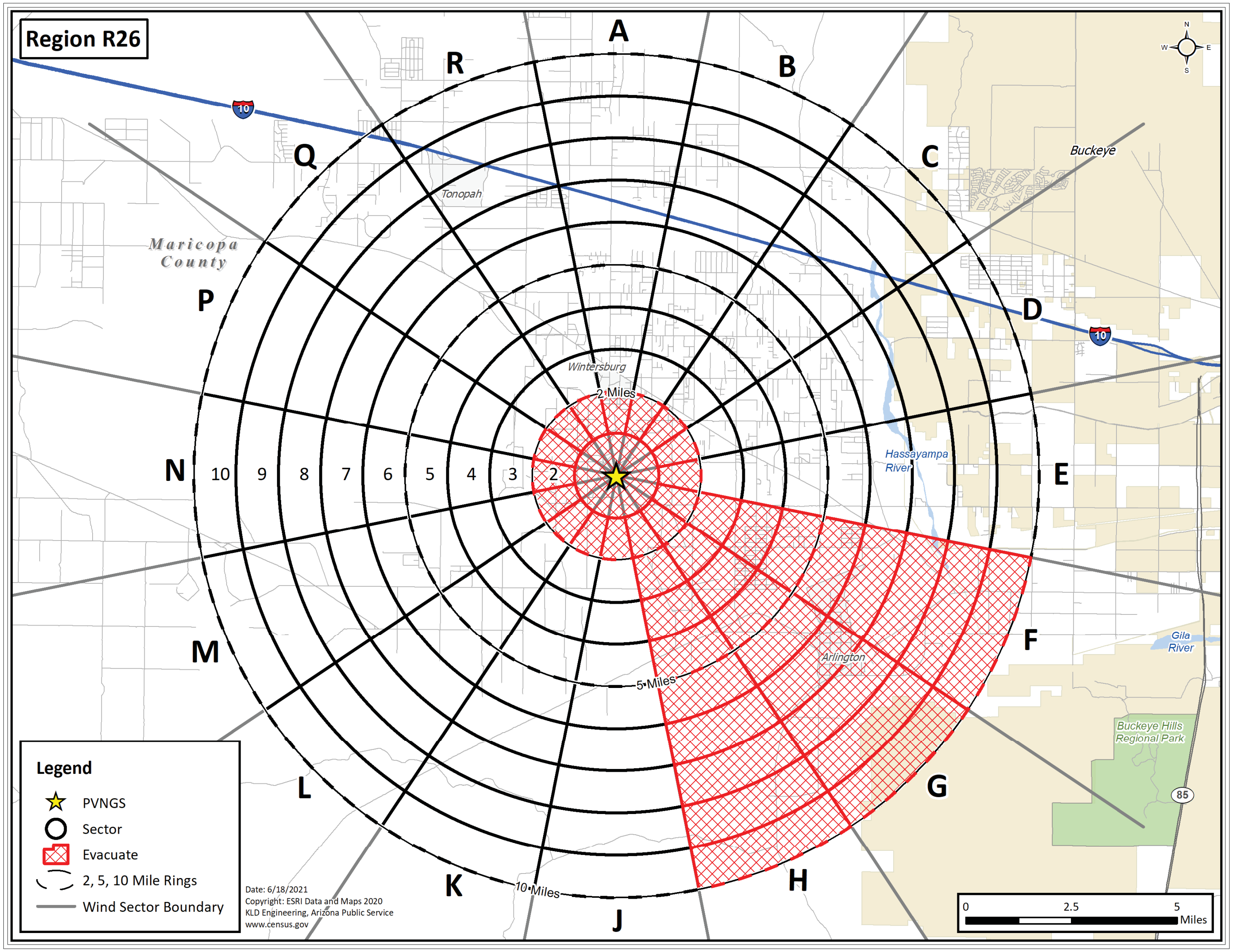

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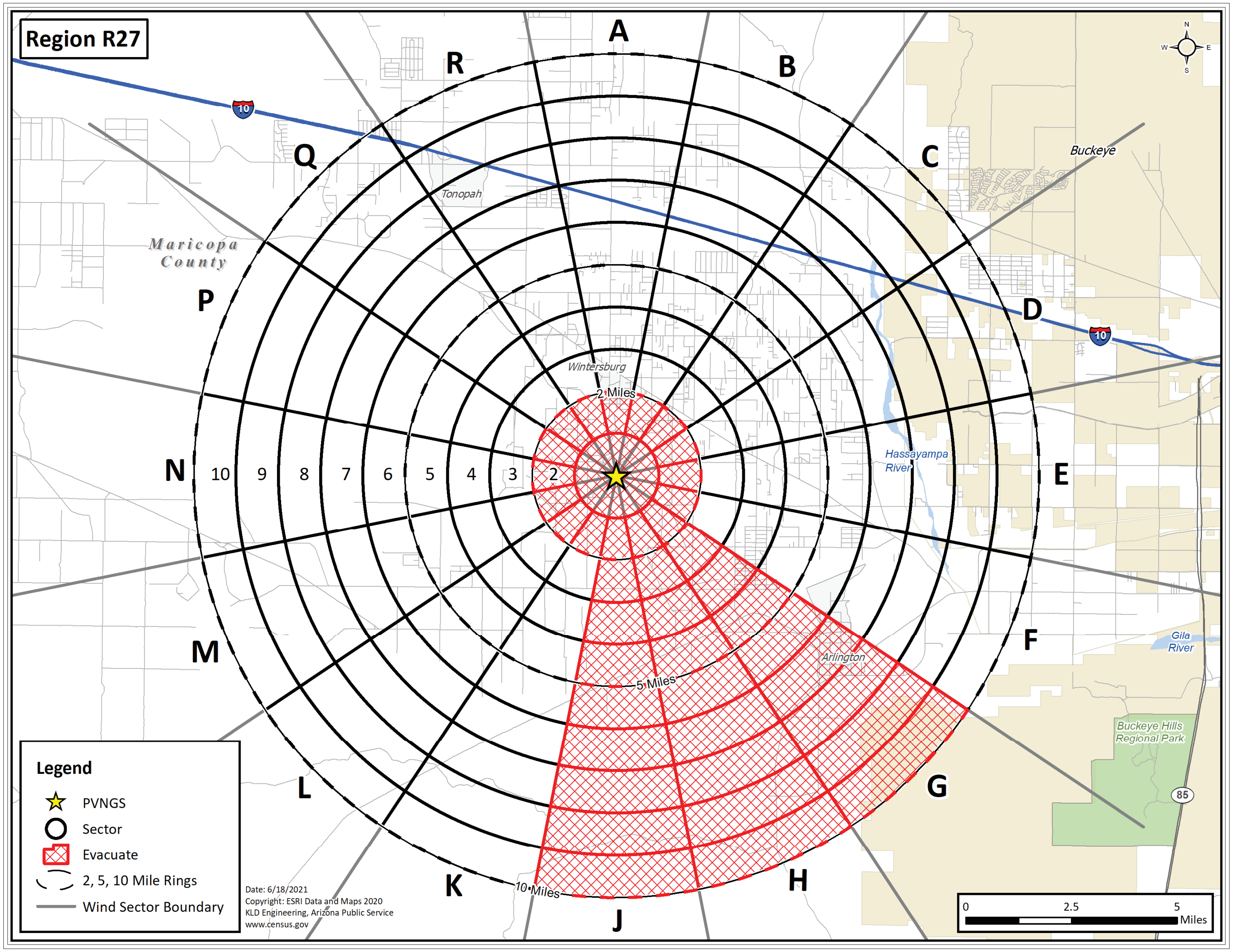

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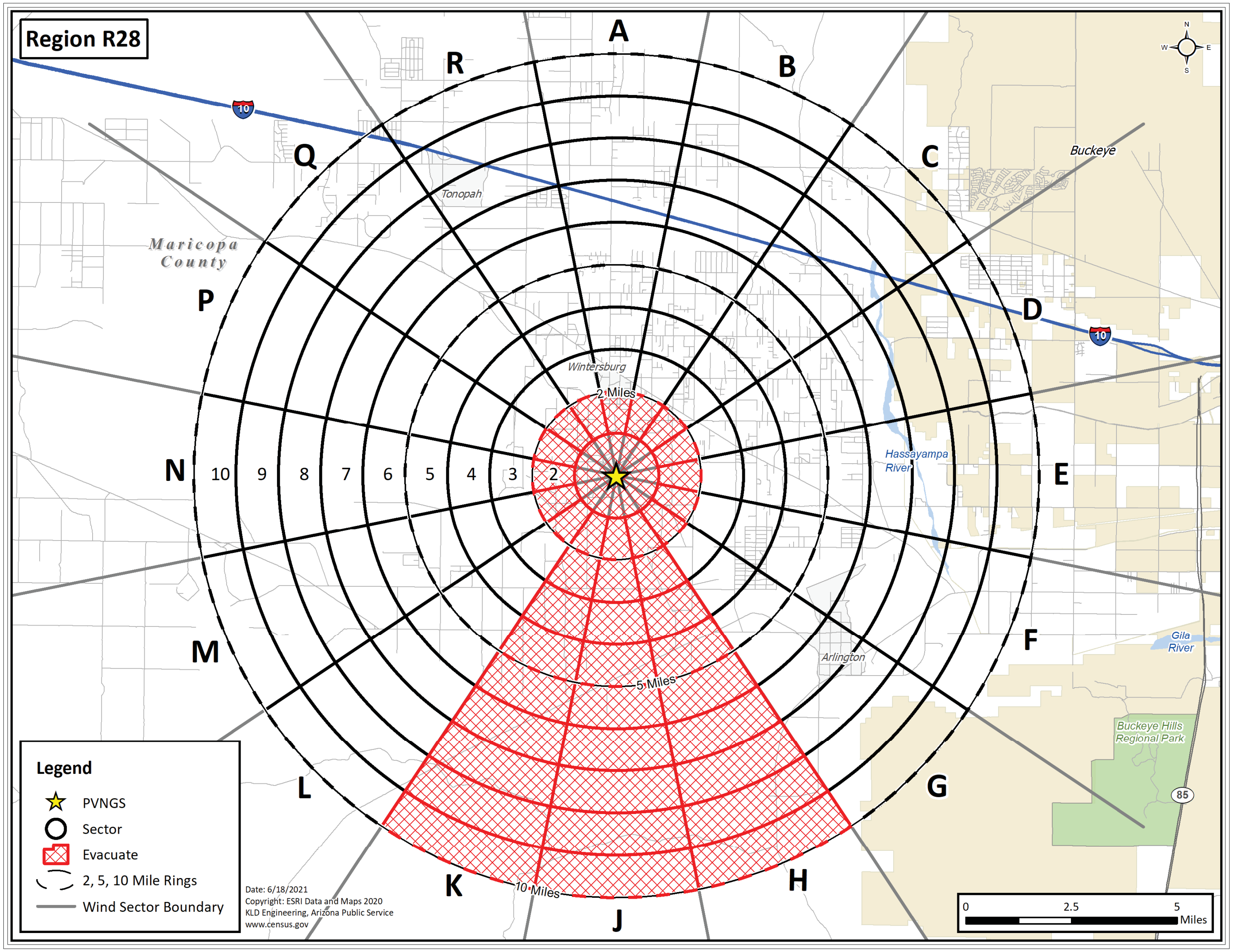

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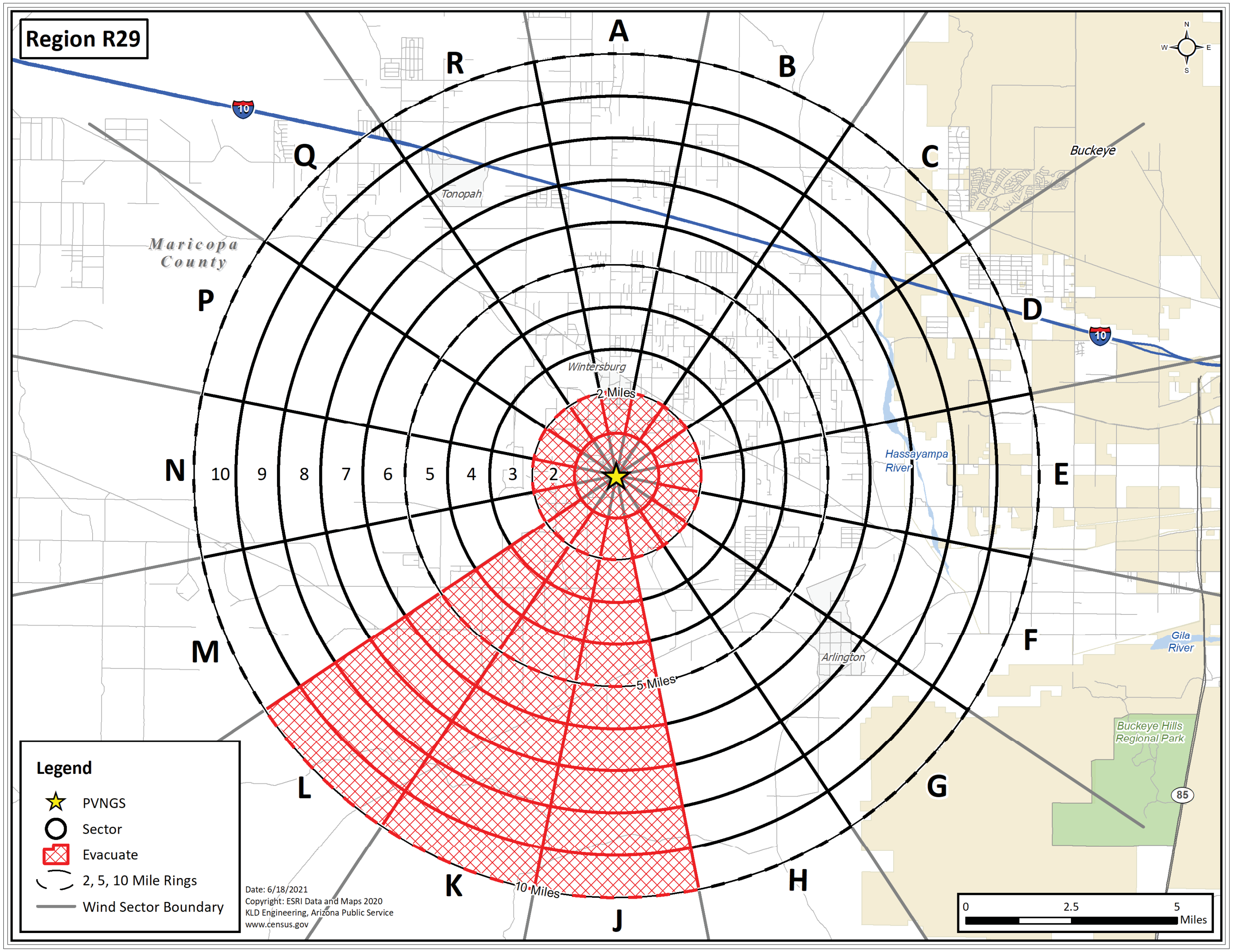


Figure H-29. Region R29

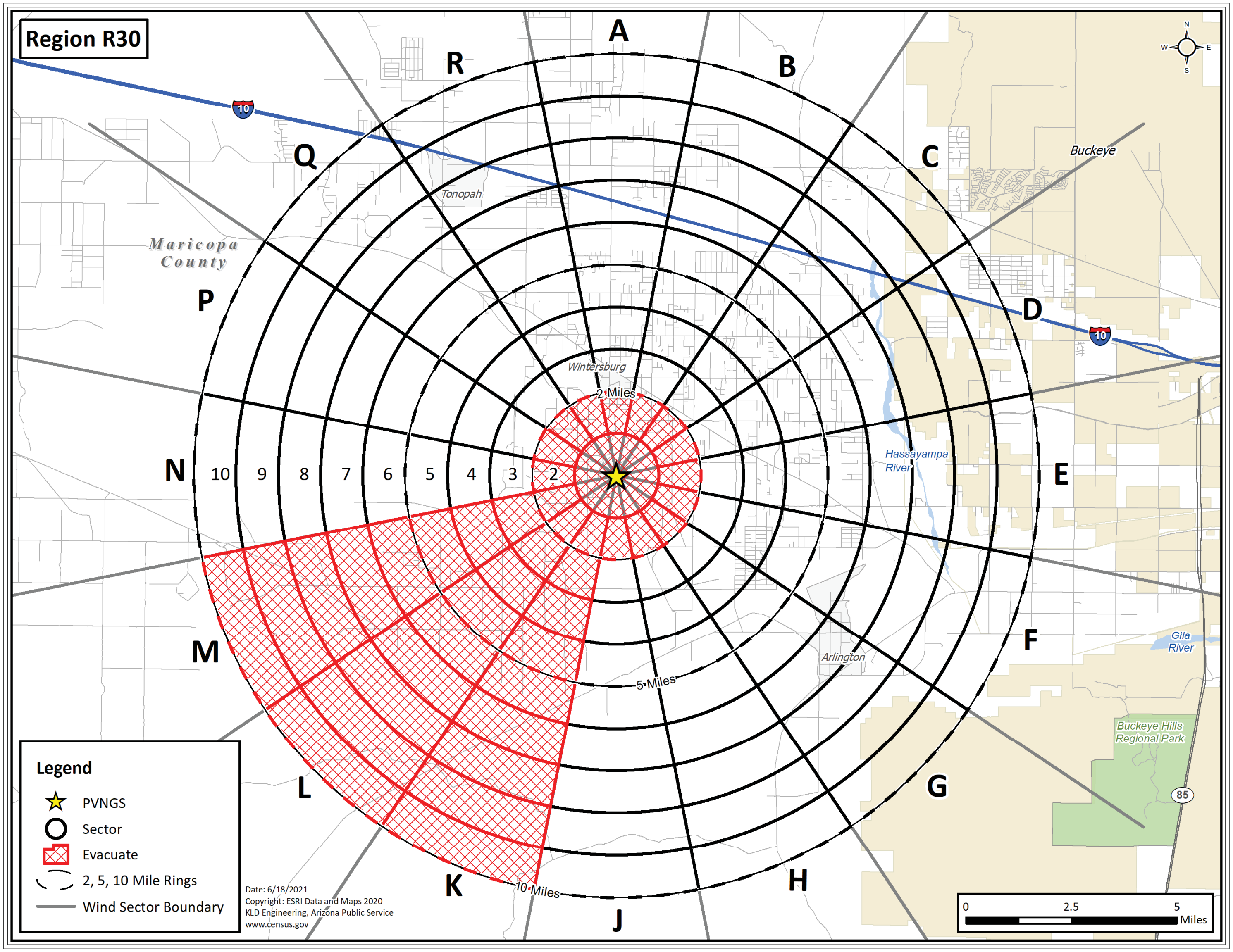


Figure H-30. Region R30

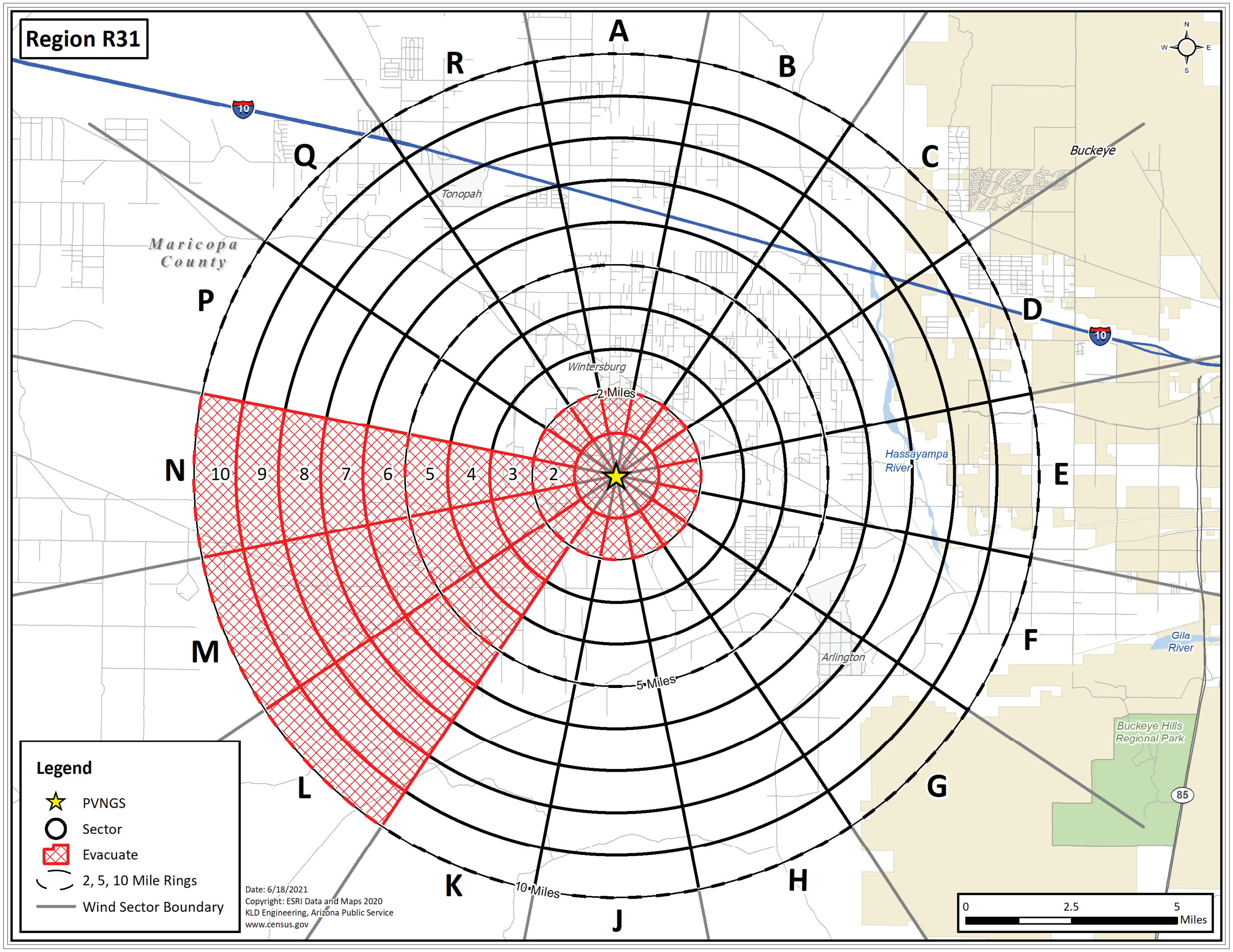


Figure H-31. Region R31

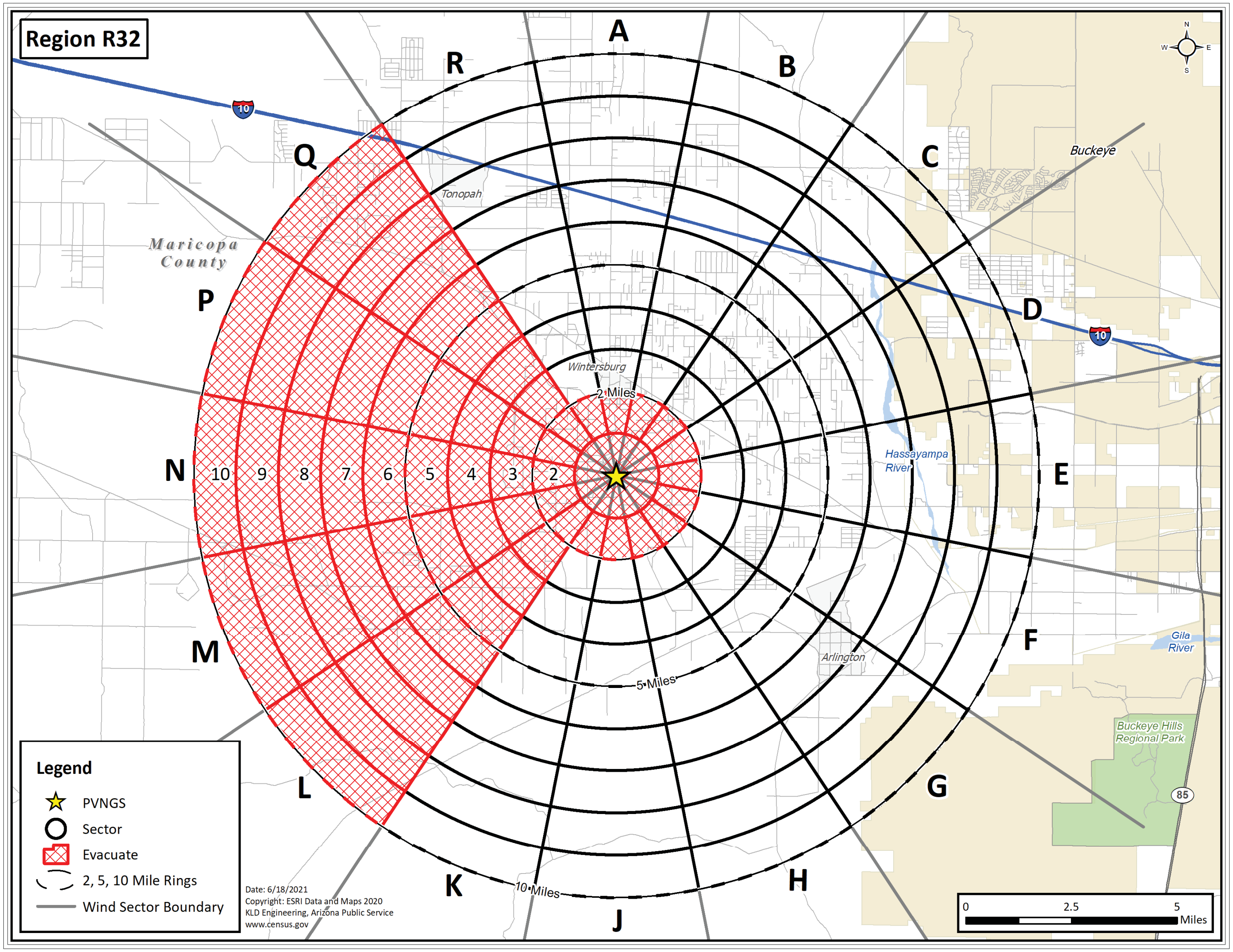


Figure H-32. Region R32

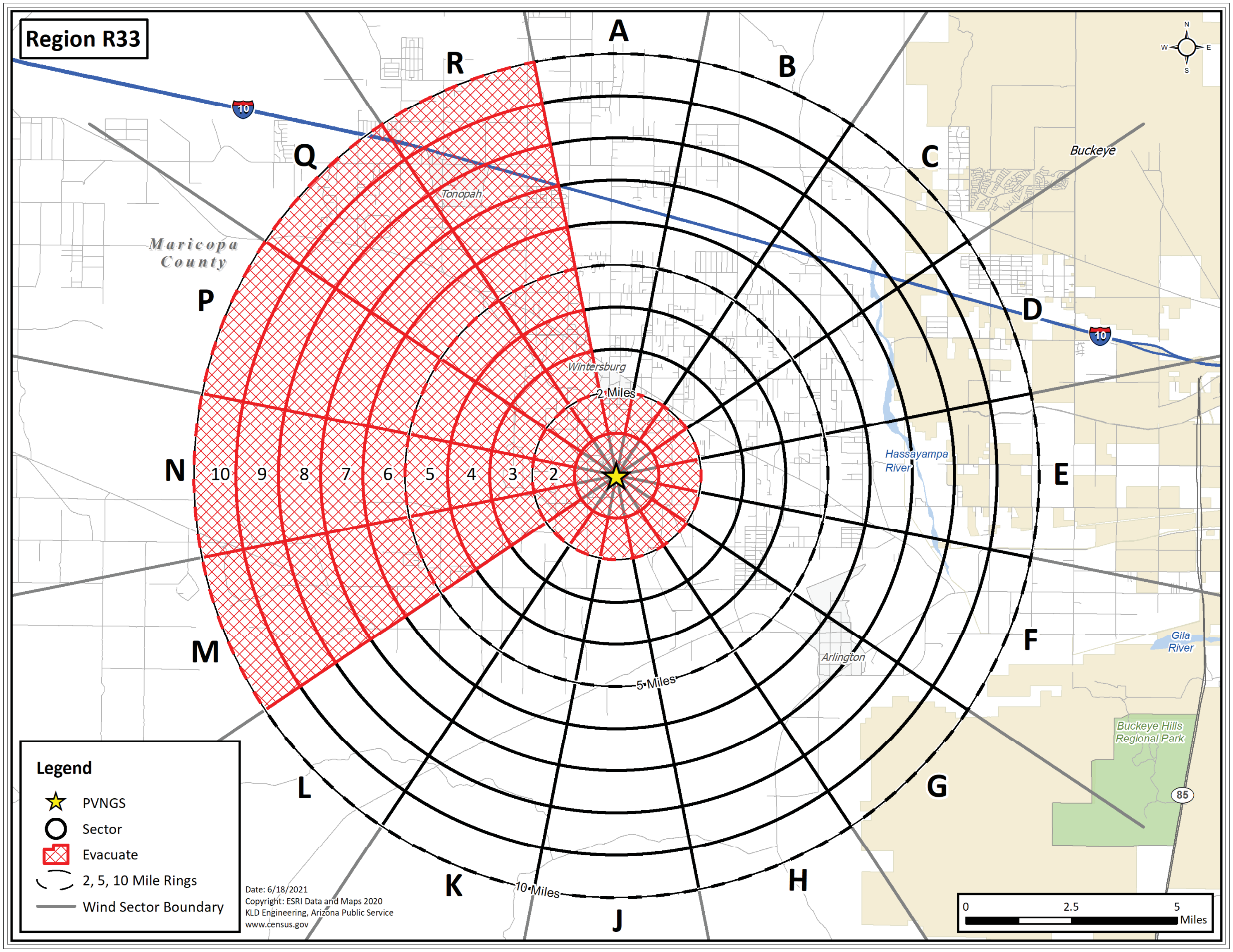


Figure H-33. Region R33

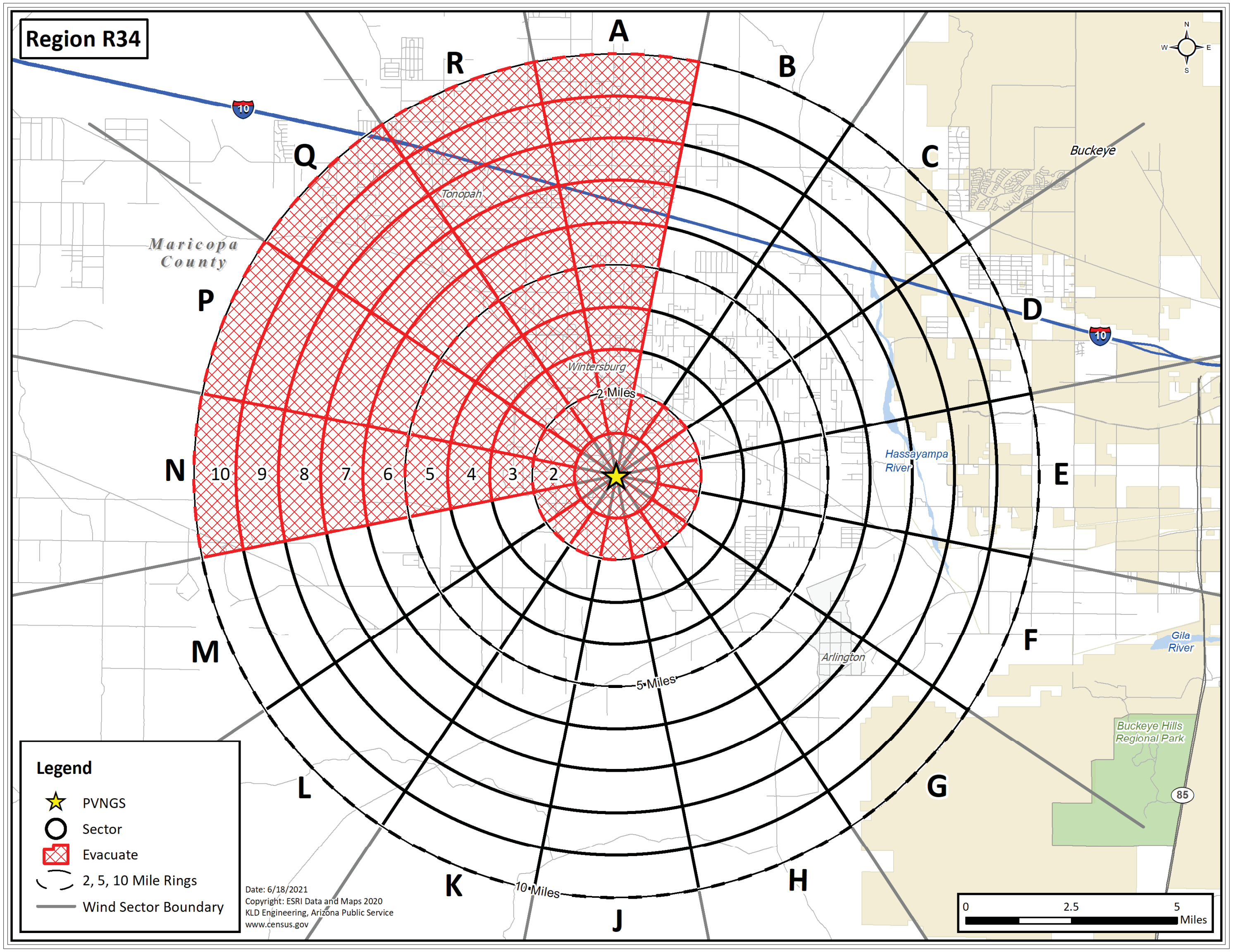


Figure H-34. Region R34

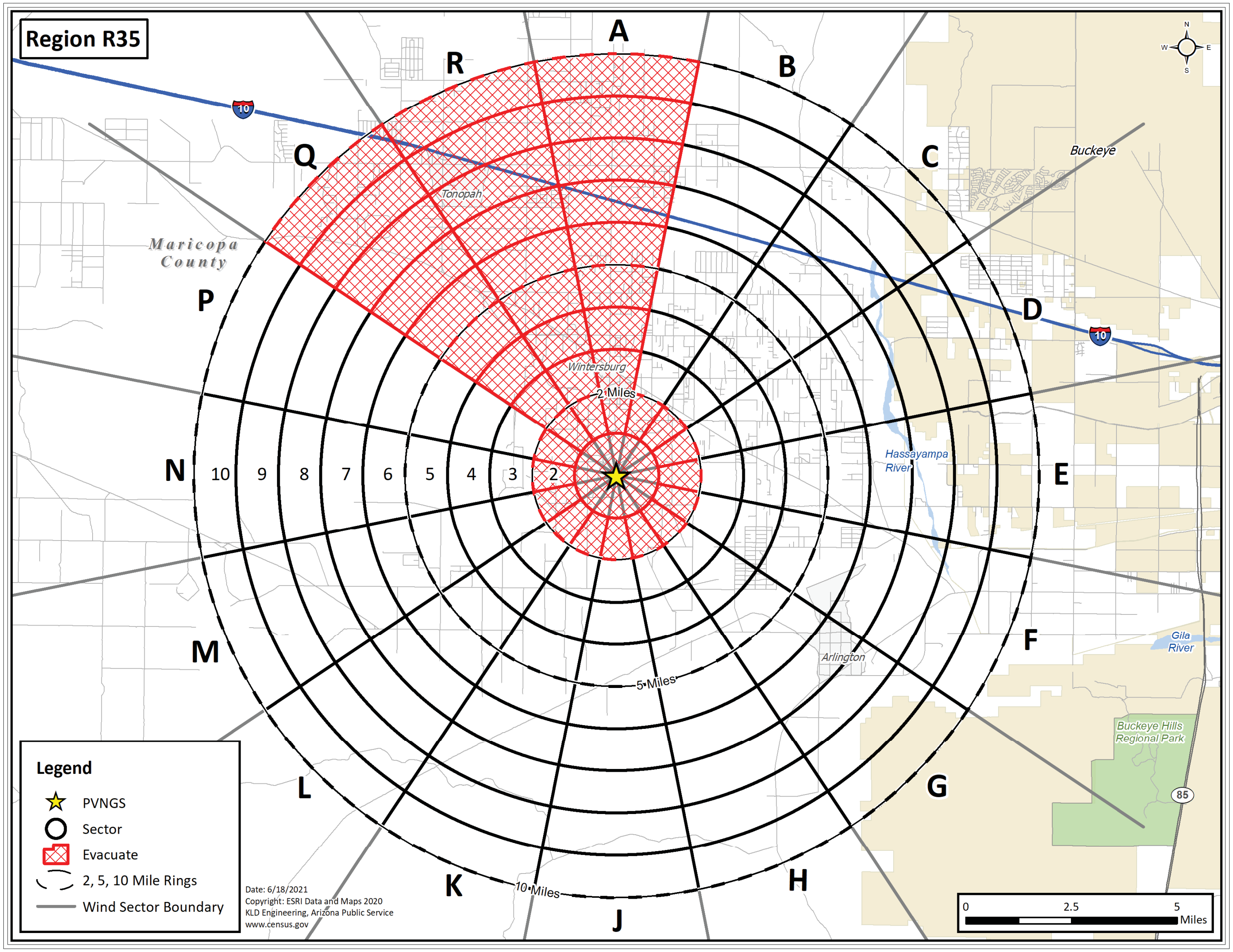
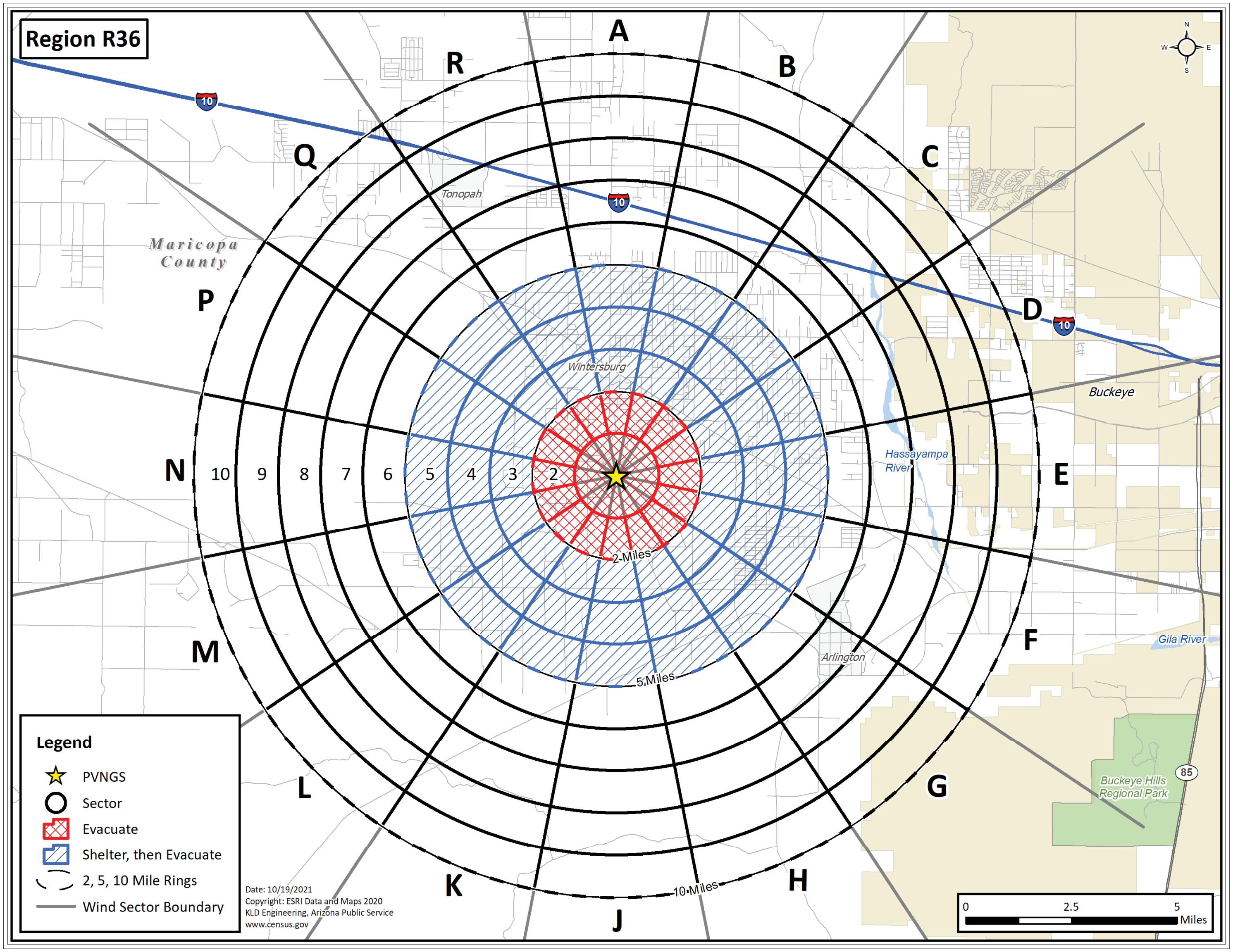


Figure H-35. Region R35



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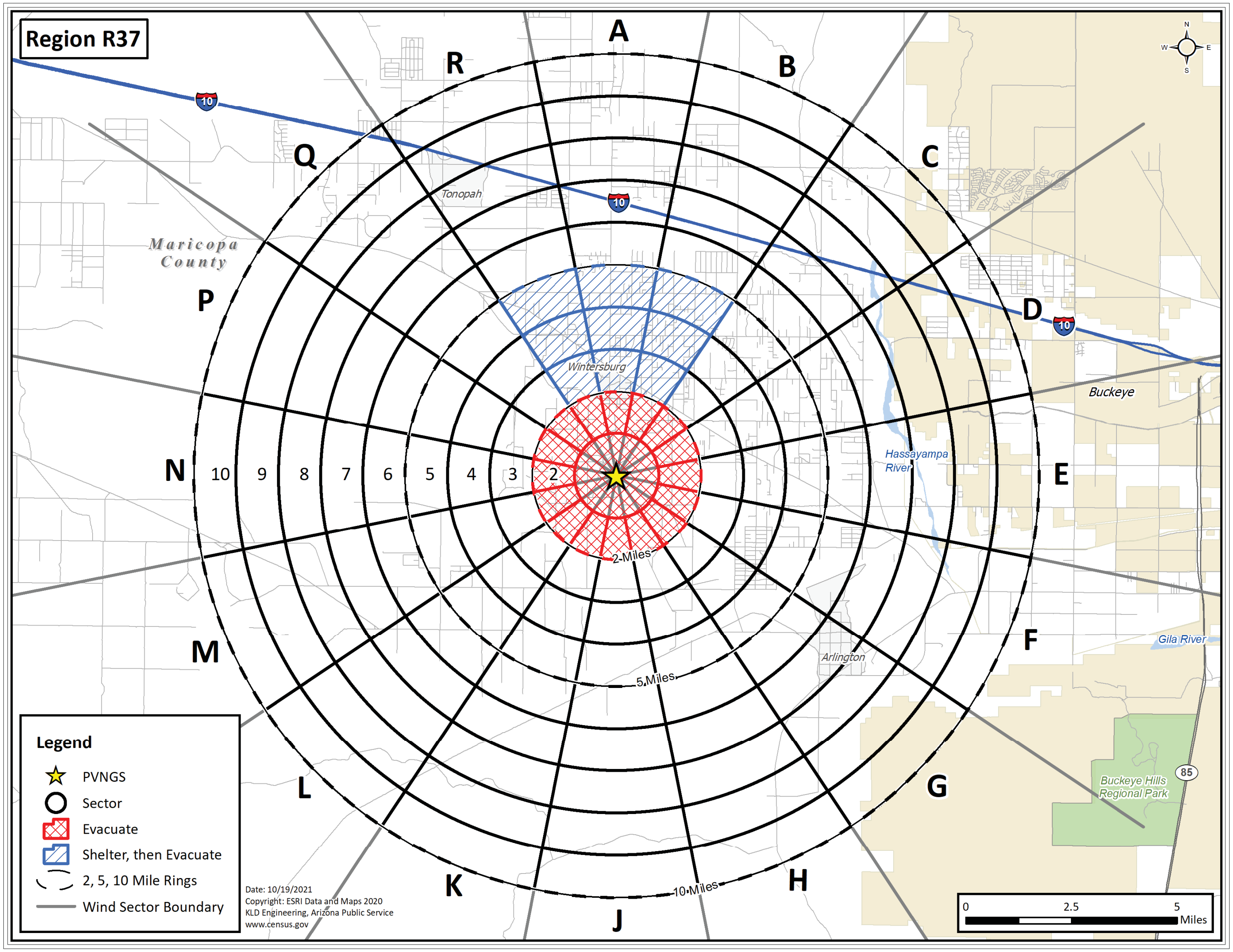

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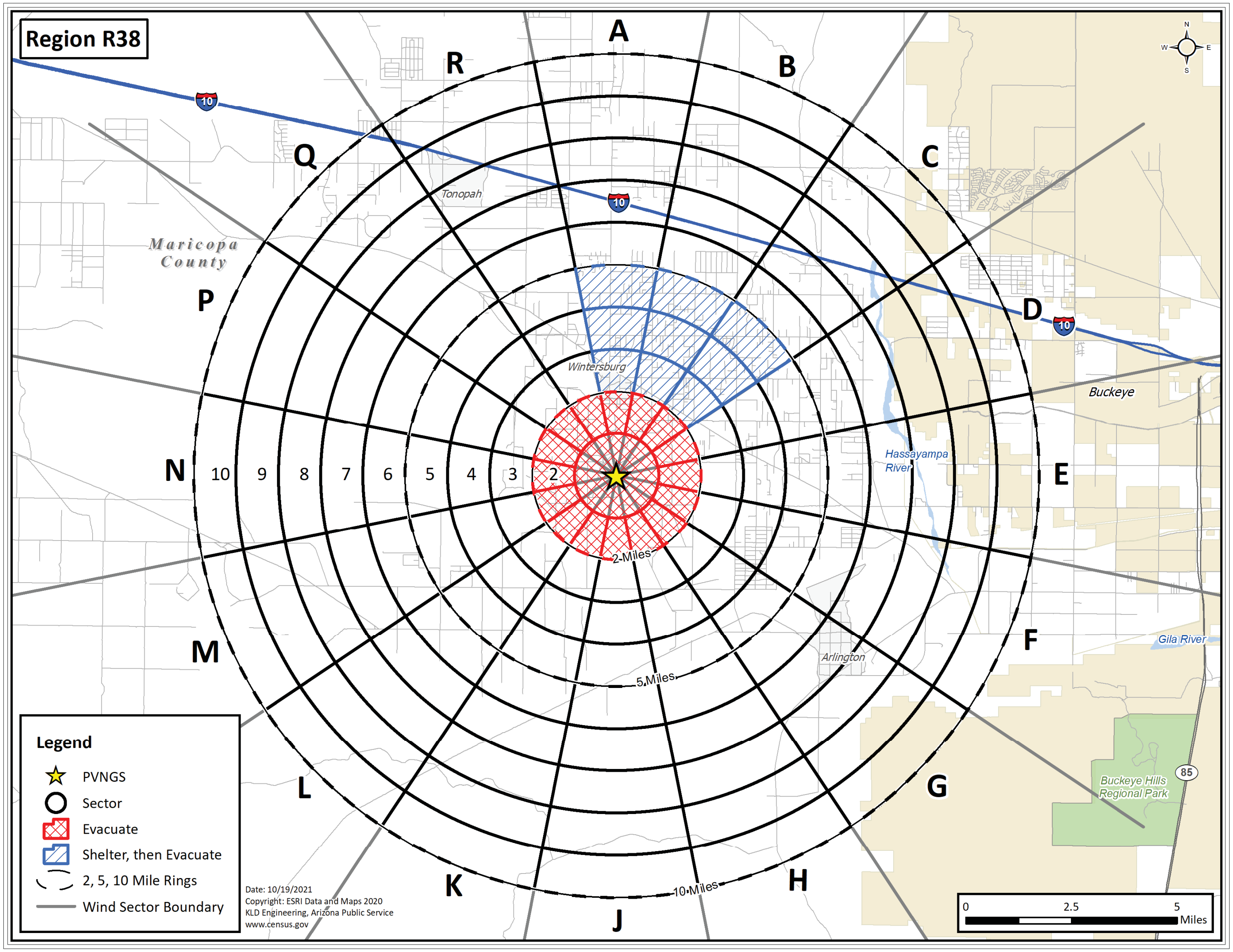

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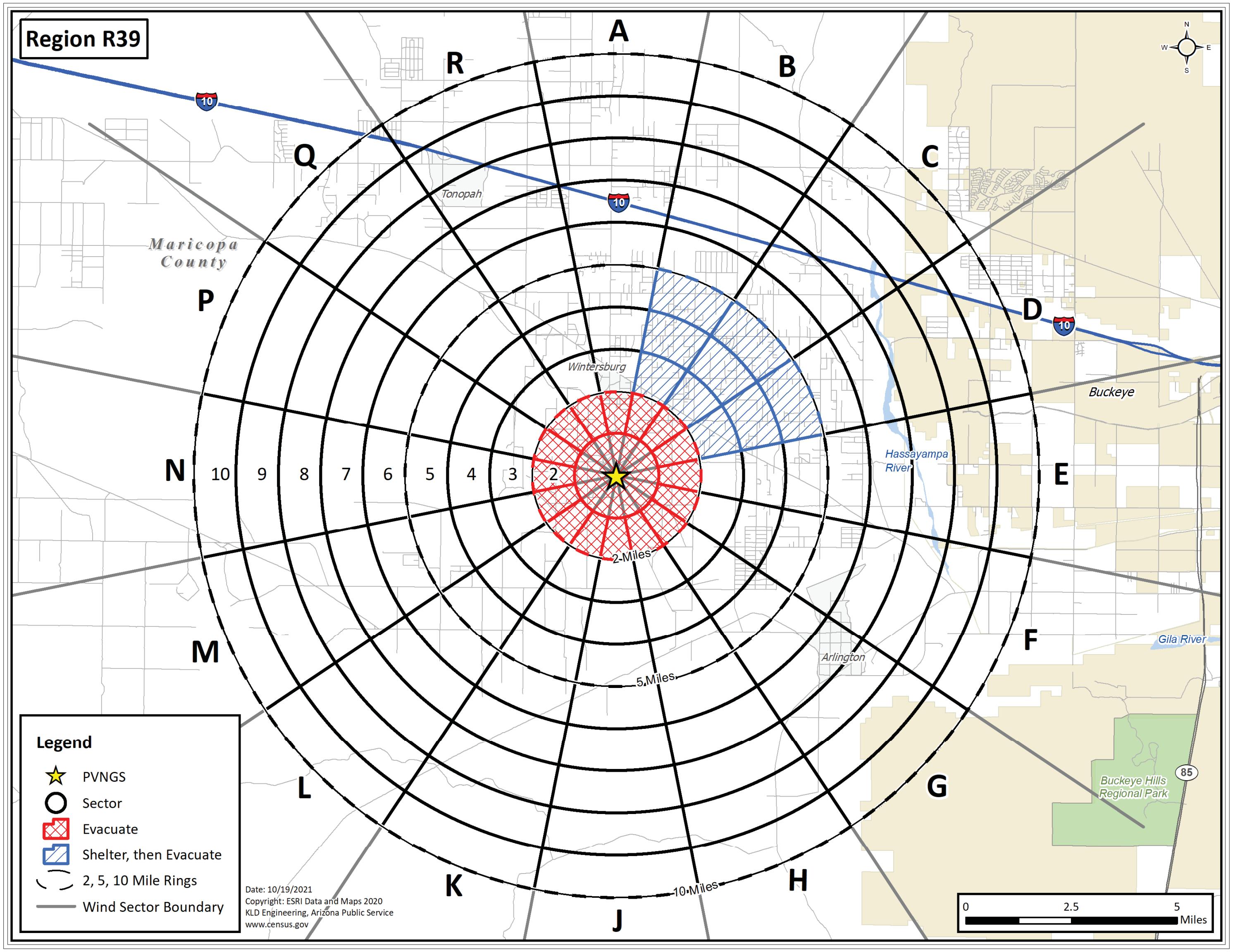

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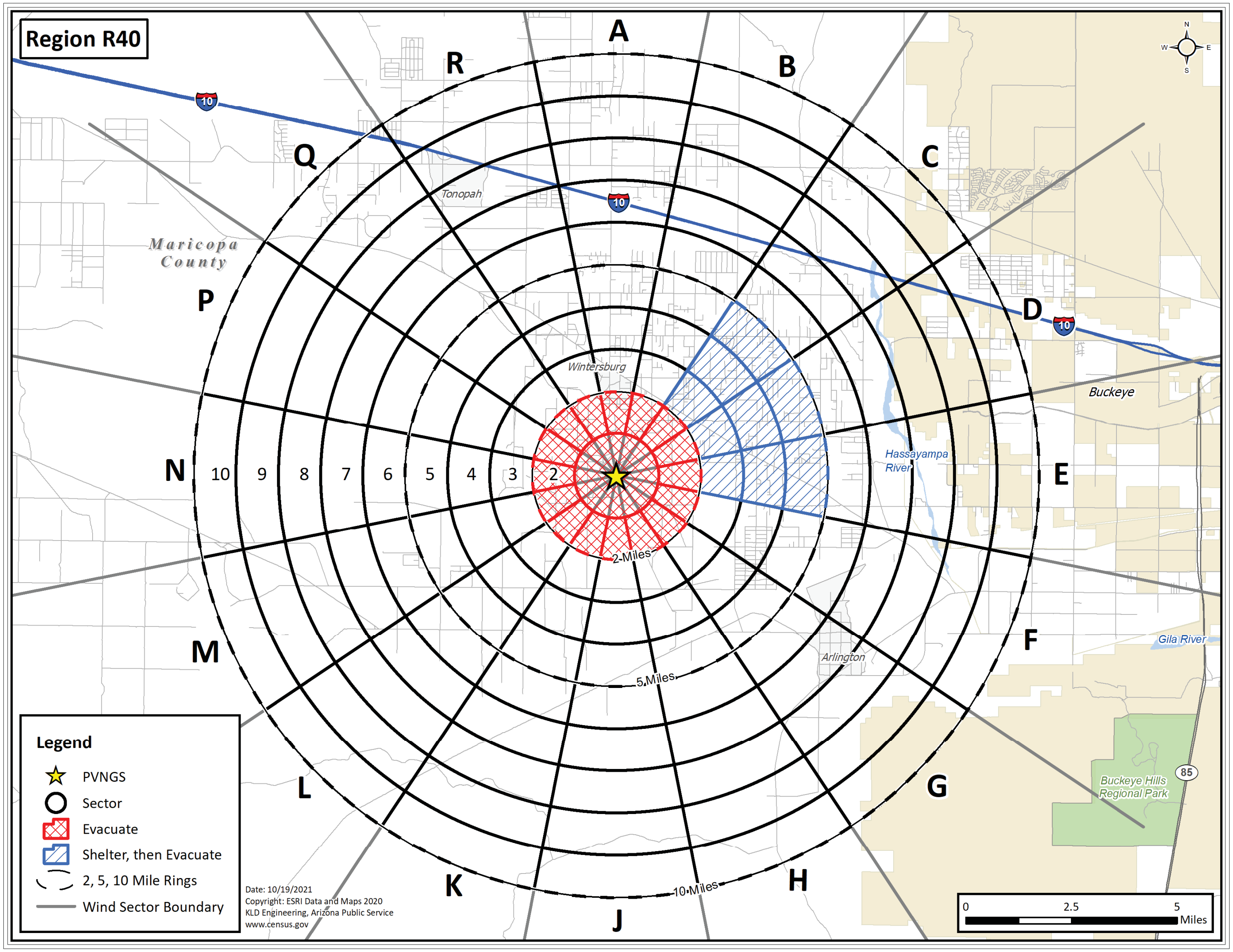


Figure H-40. Region R40

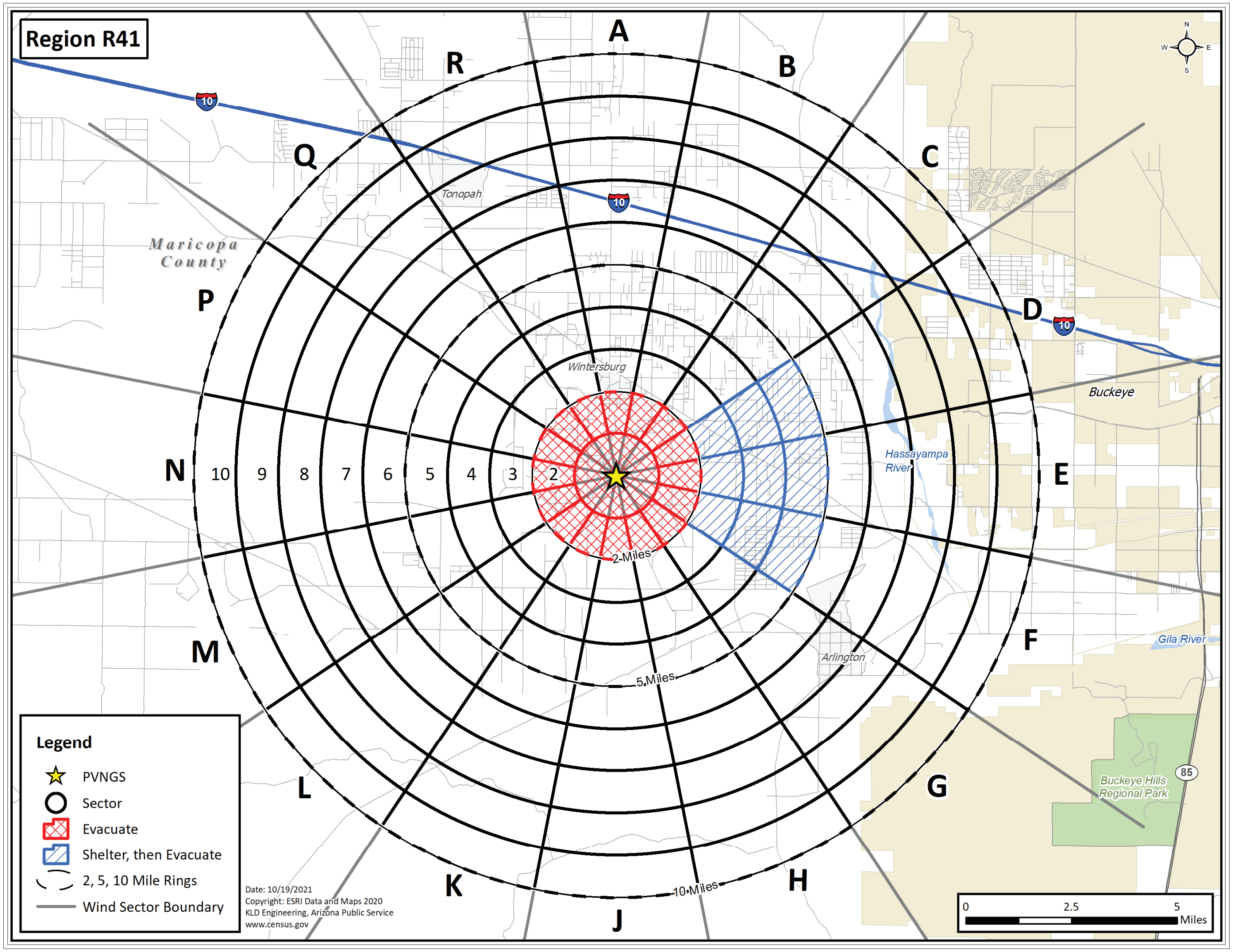


Figure H-41. Region R41

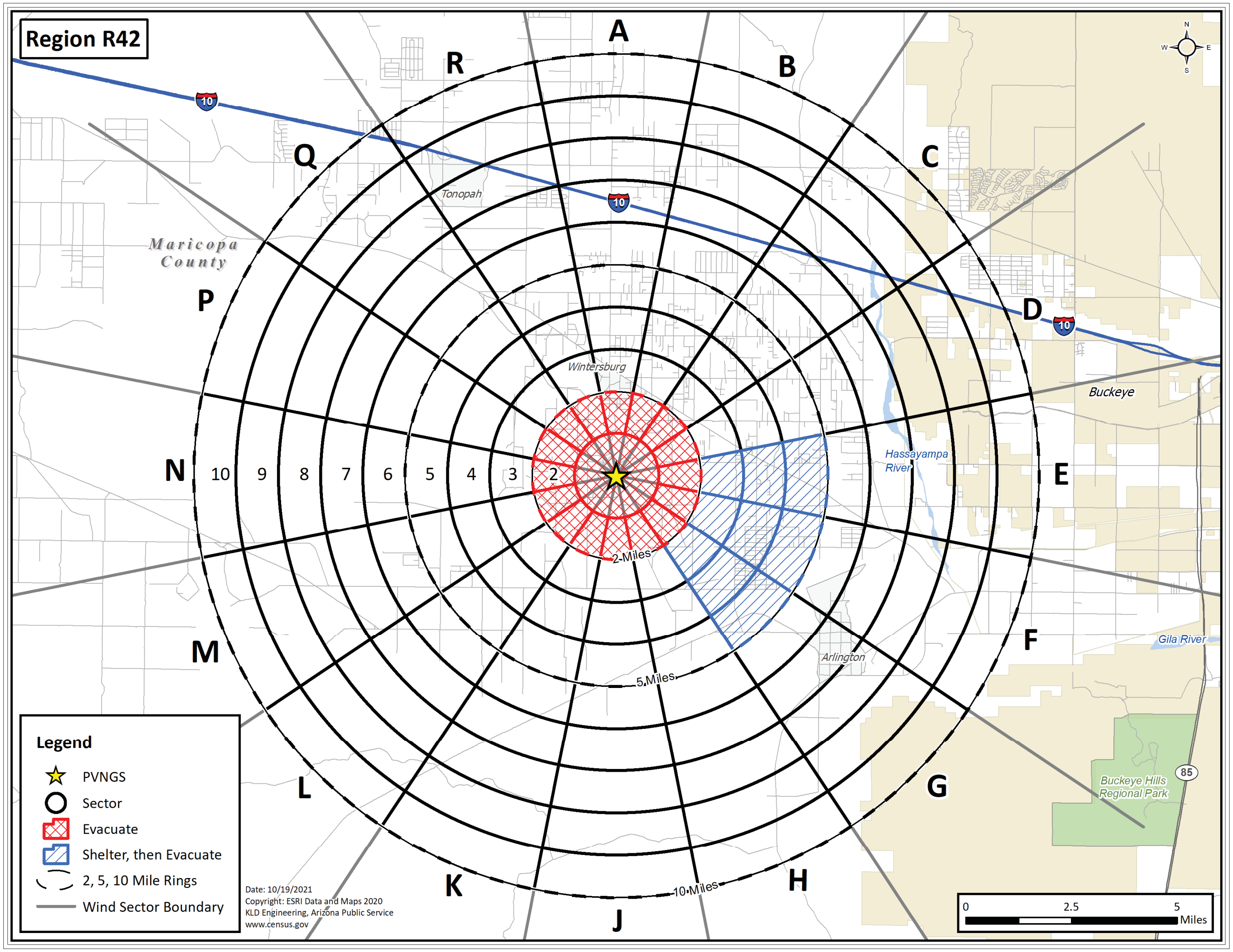


Figure H-42. Region R42

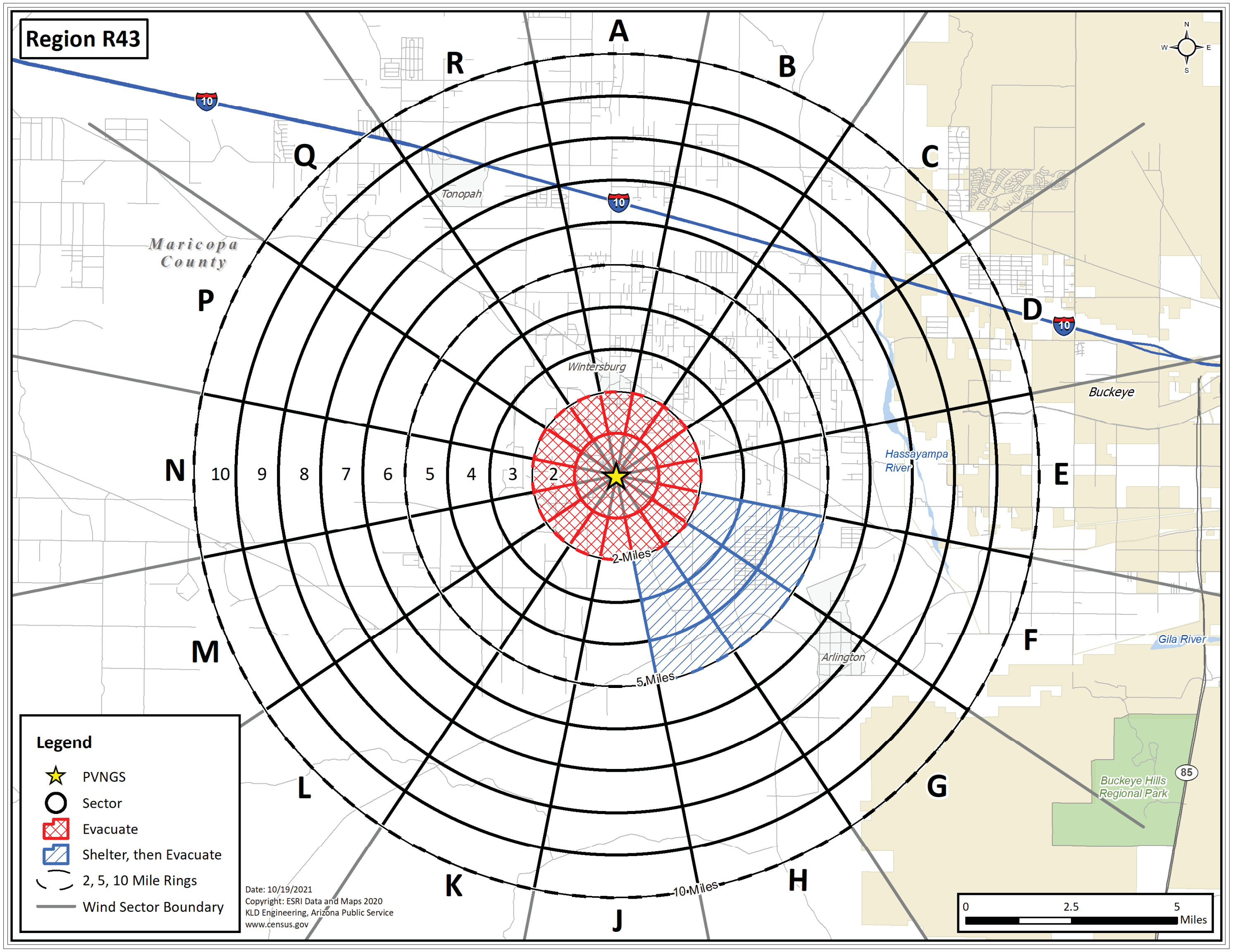
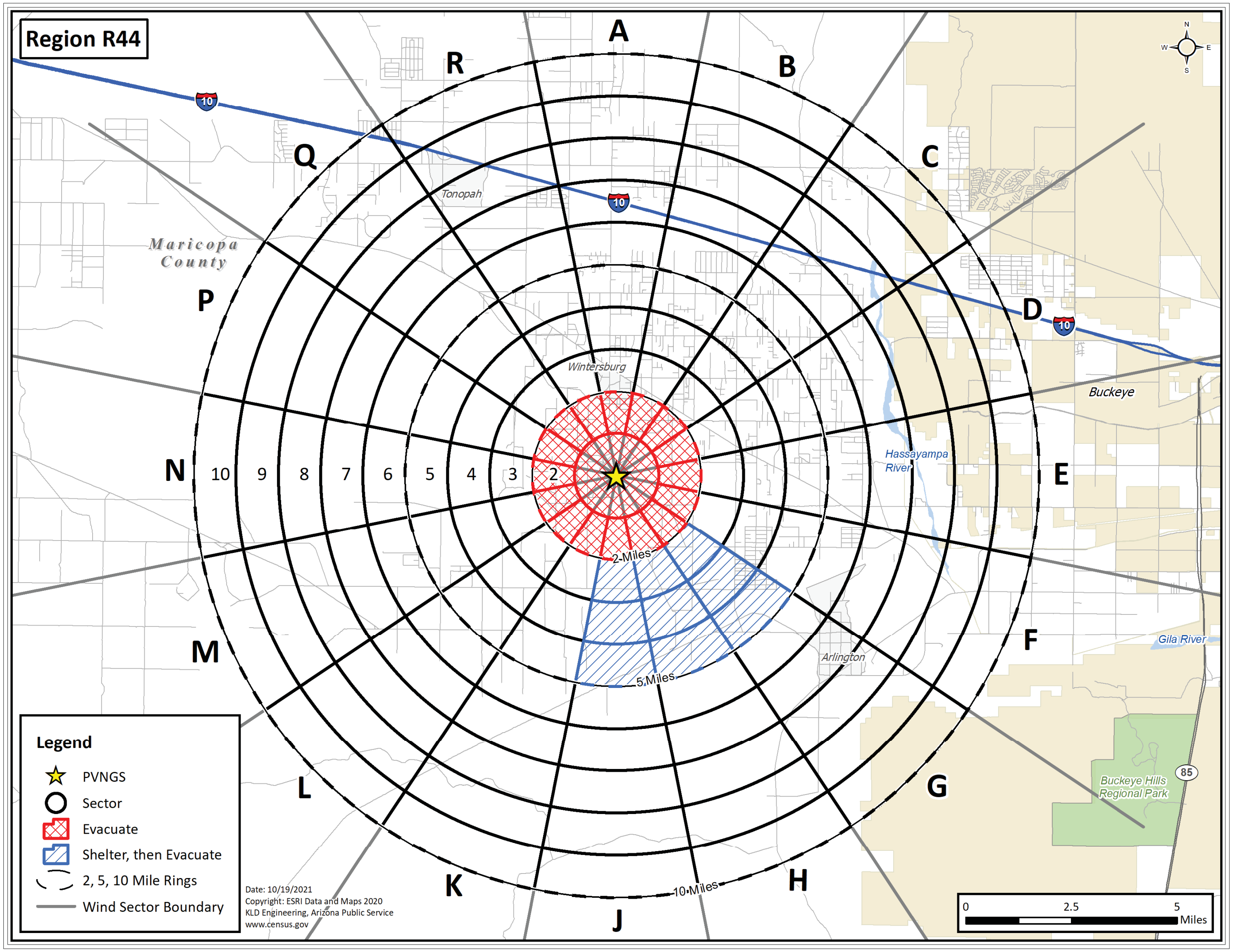


Figure H-43. Region R43



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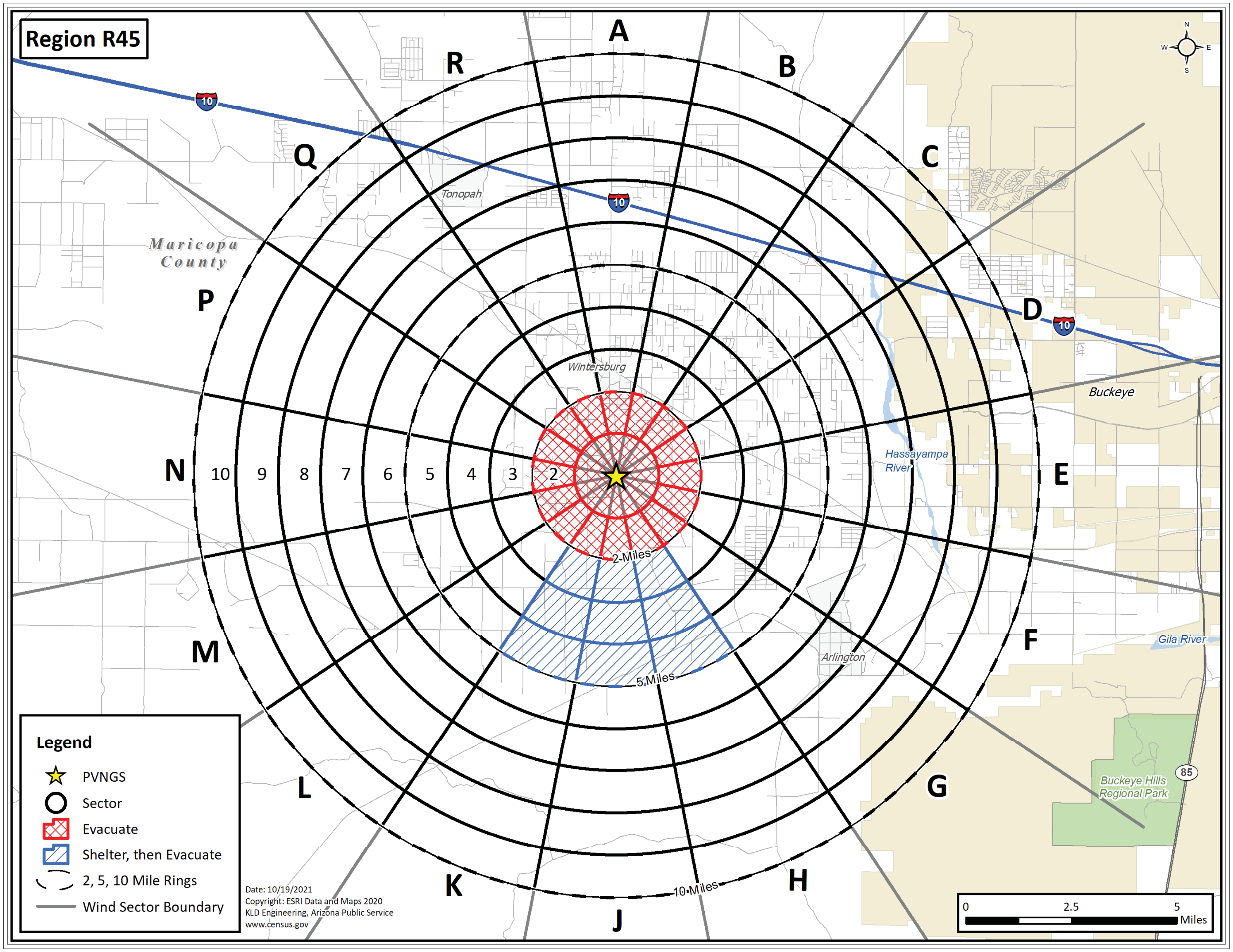

Figure H-45. Region R45

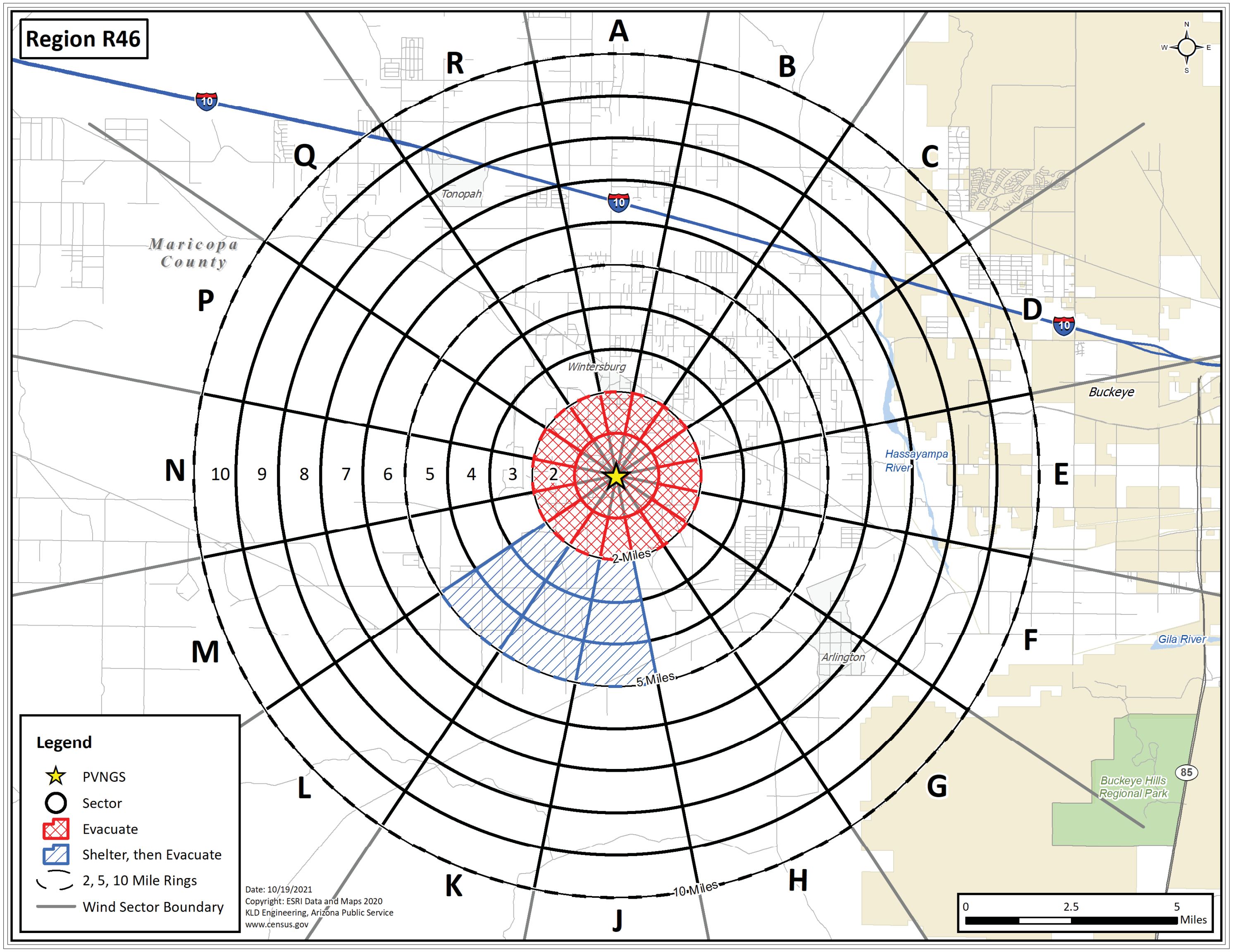

Figure H-46. Region R46

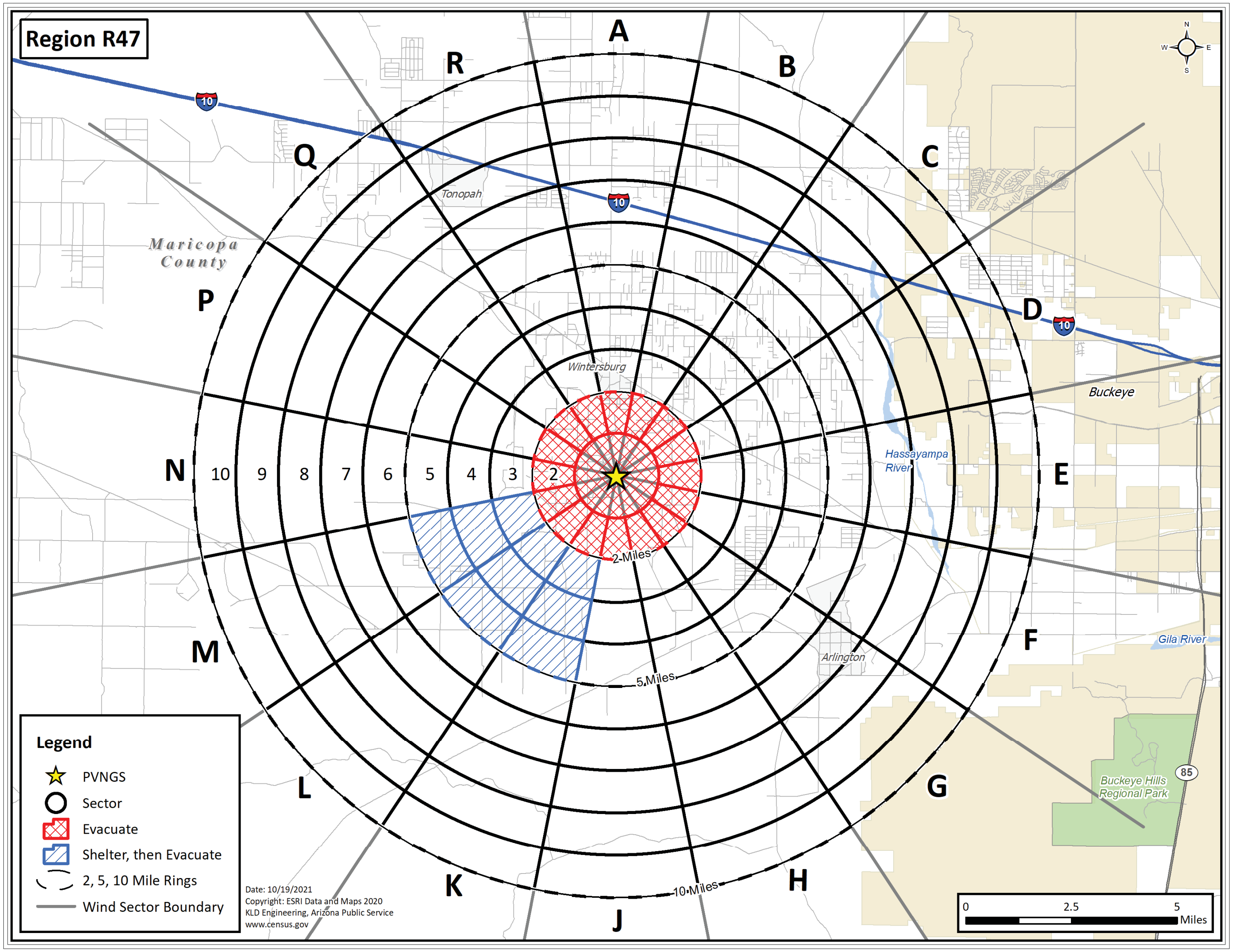

Figure H-47. Region R47

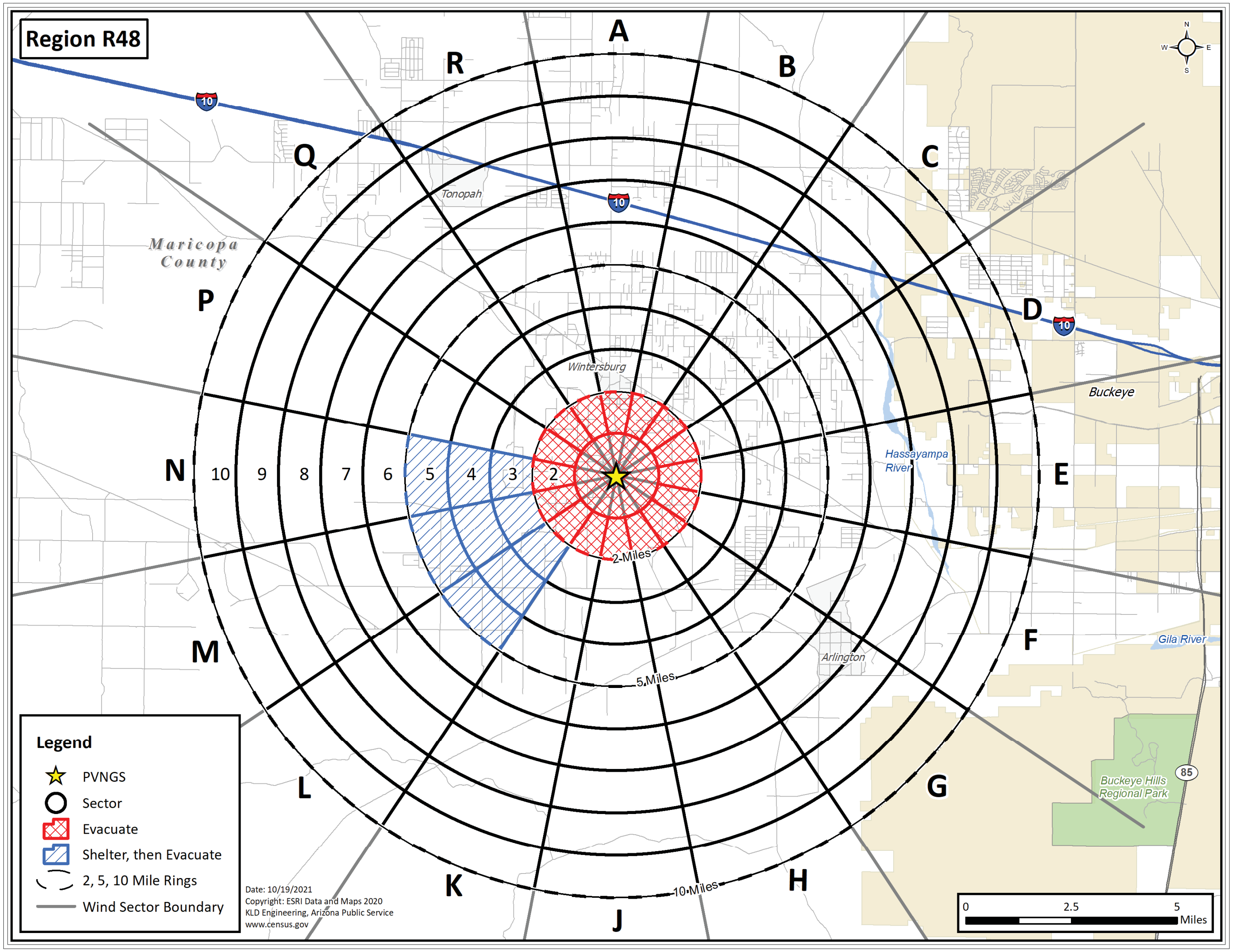

Figure H-48. Region R48

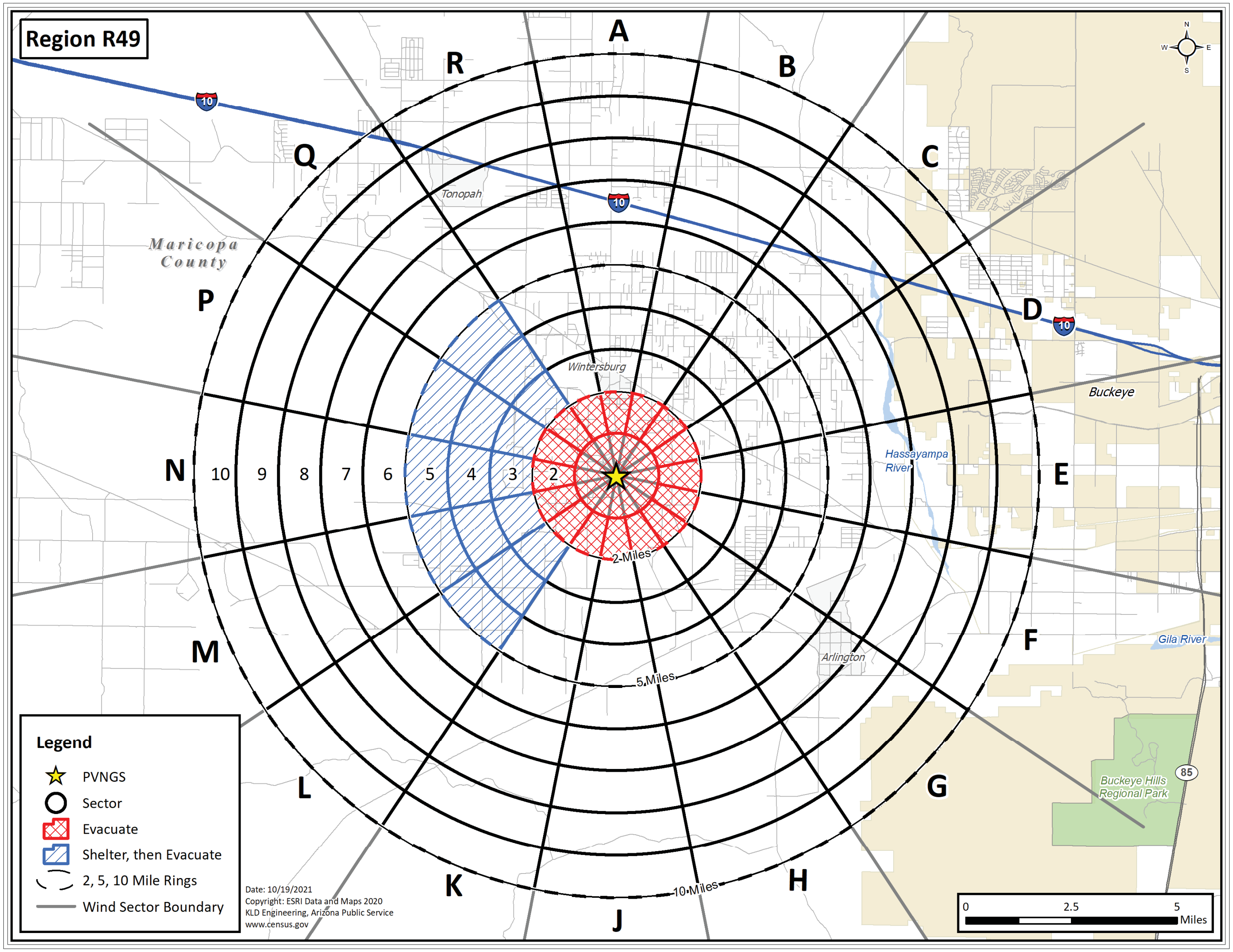

Figure H-49. Region R49

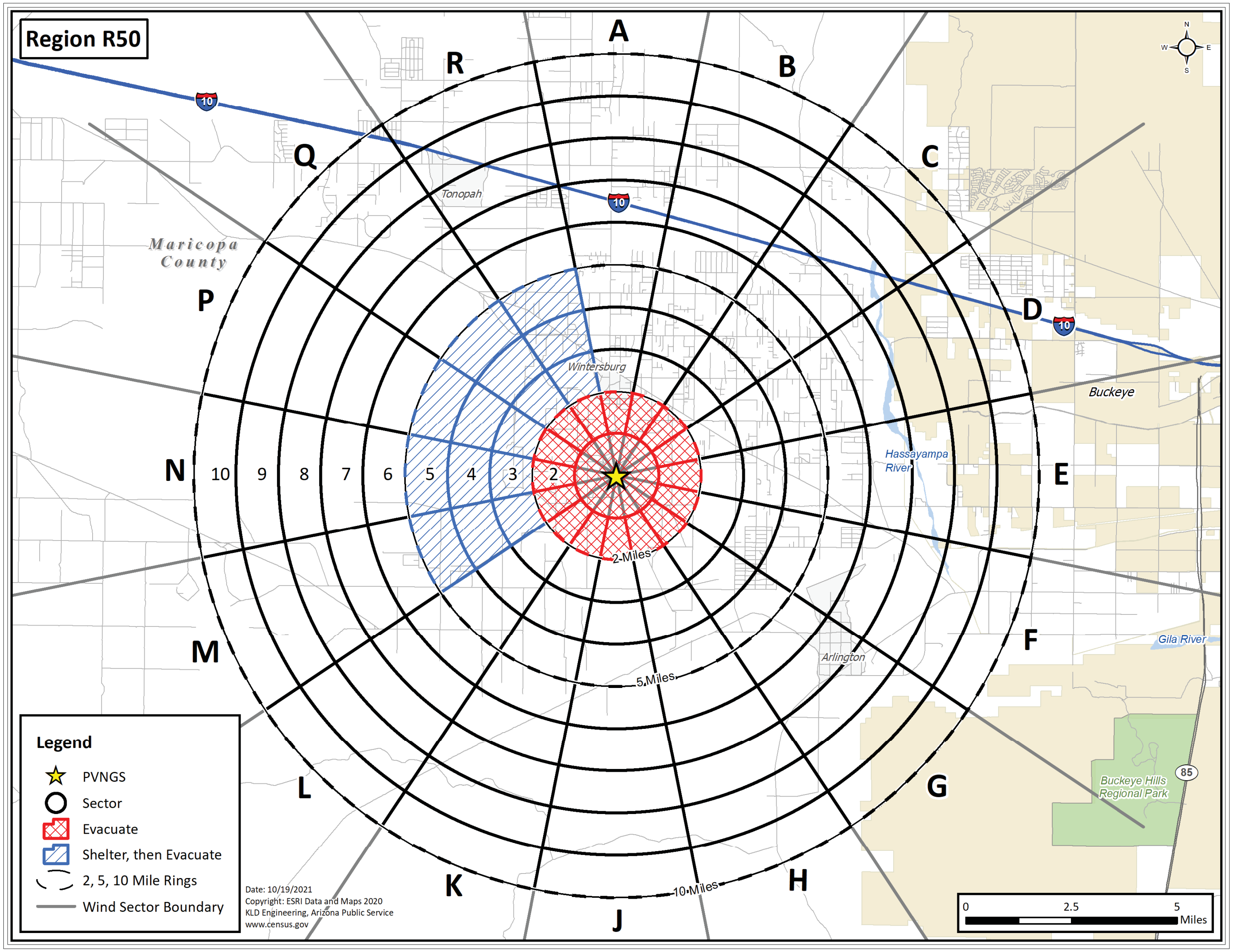

Figure H-50. Region R50

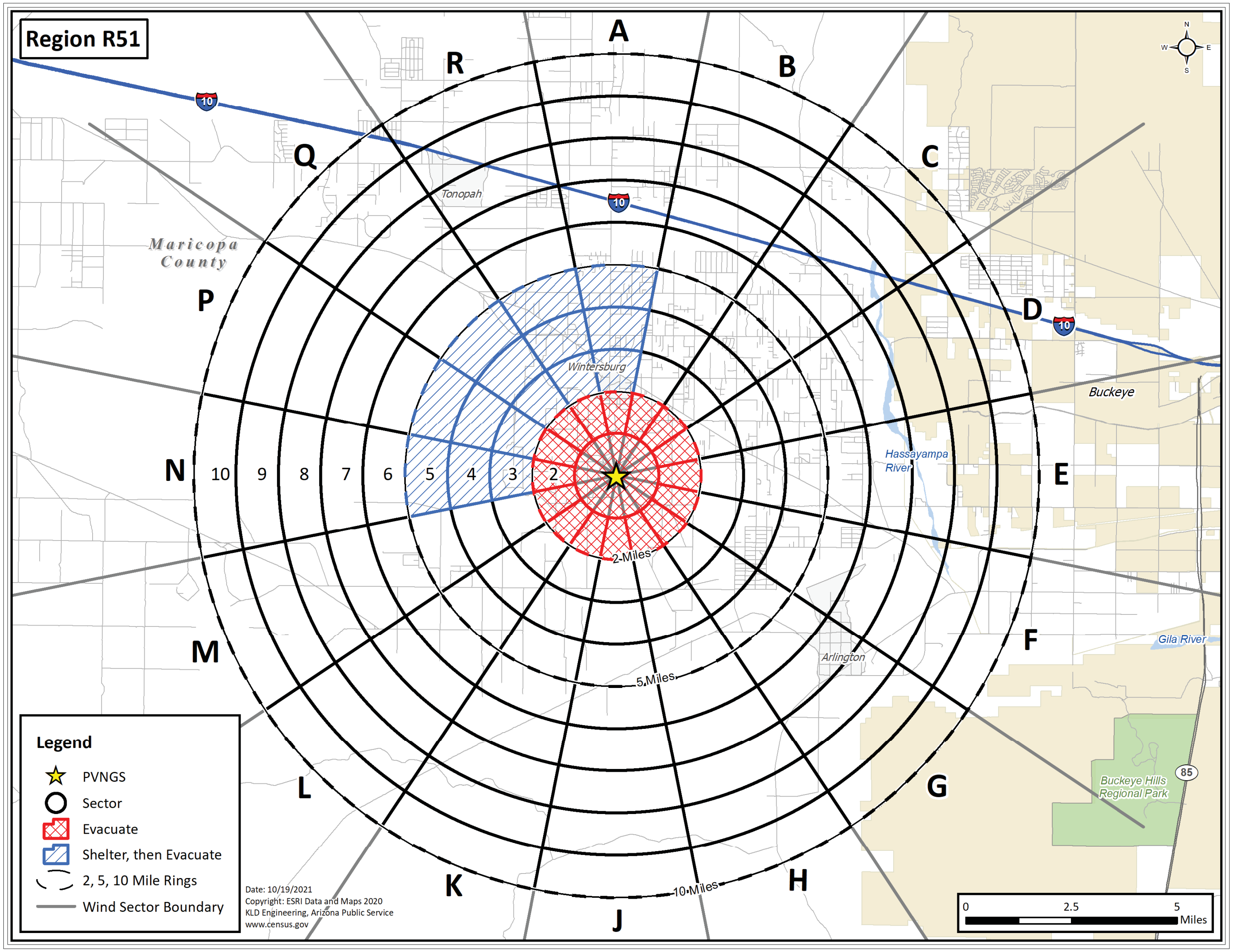

Figure H-51. Region R51

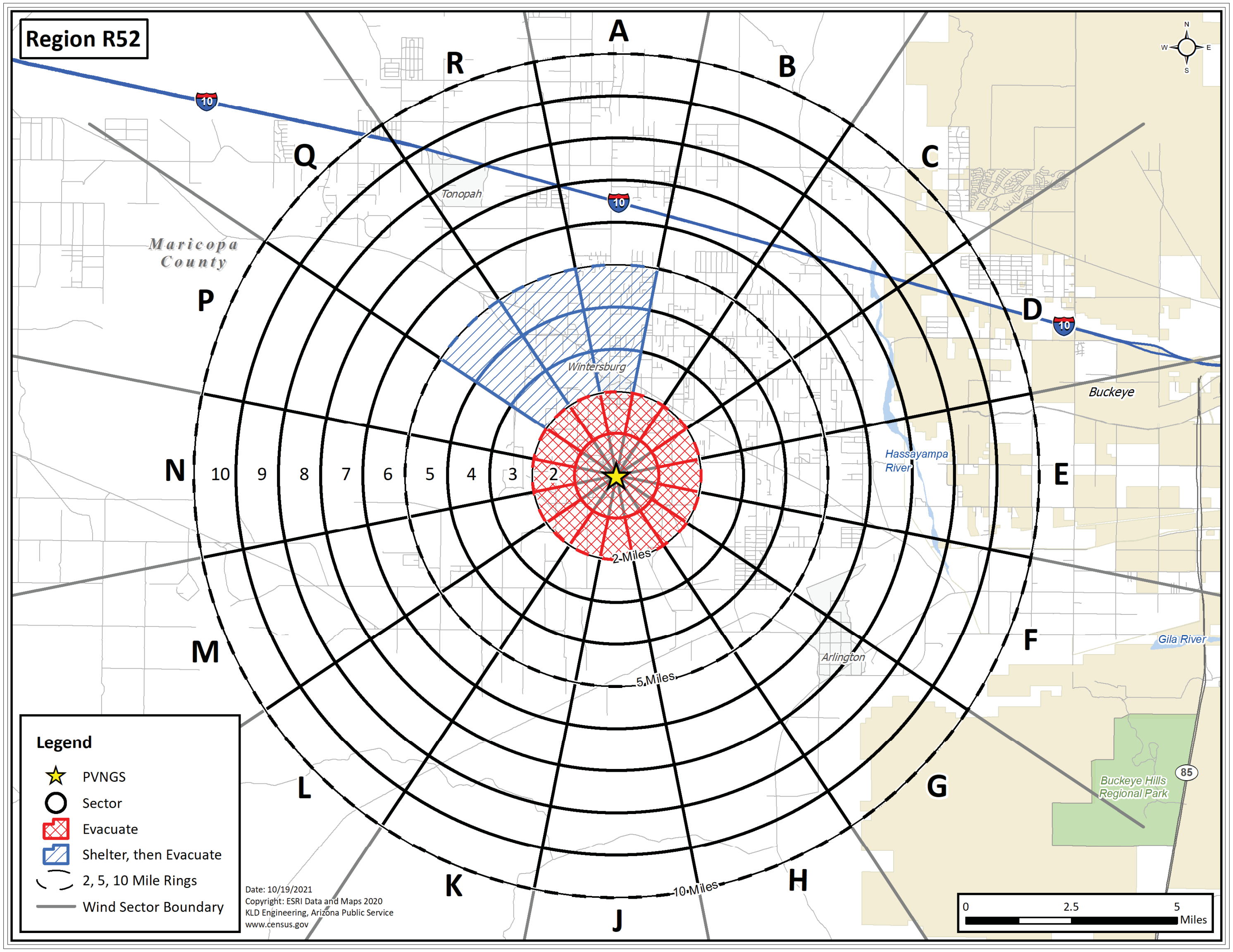

Figure H-52. Region R52

APPENDIX J

Representative Inputs to and Outputs from the DYNEV II System

J. REPRESENTATIVE INPUTS TO AND OUTPUTS FROM THE DYNEV II SYSTEM

This appendix presents data input to and output from the DYNEV II System.

Table J-1 provides source (vehicle loading) and destination information for several roadway segments (links) in the analysis network. In total, there are a total of 97 source links (origins) in the model The source links are shown as centroid points in Figure J-1. On average, evacuees travel a straight-line distance of 9.9 miles to exit the network.

Table J-2 provides network–wide statistics (average travel time, average delay time[1] average speed and number of vehicles) for an evacuation of the entire EPZ (Region R03) for each scenario. Rain scenarios (Scenarios 2, 4, 7 and 9) exhibit slower average speeds, higher delays and longer average travel times than good weather scenarios. Scenario 12 (single lane closed on Interstate (I)-10 eastbound) exhibits the slowest average speed, highest delays and longest travel time due to the combination of the reduced capacity of I-10.

Table J-3 provides statistics (average speed and travel time) for the major evacuation route, I-10, for an evacuation of the entire EPZ (Region R03) under Scenario 1 conditions. As discussed throughout the report roadblocks on I-10 is established 45 minutes after the advisory to evacuate (ATE). As such, the average speeds are slower and travel times are longer during the first hour of the evacuation when external trips are still traveling along I-10.

Table J-4 provides the number of vehicles discharged and the cumulative percent of total vehicles discharged for each link exiting the analysis network, for an evacuation of the entire EPZ (Region R03) under Scenario 1 conditions. Refer to the figures in Appendix K for a map showing the geographic location of each link.

Figure J-2 through Figure J-13 plot the trip generation time versus the ETE for each of the 12 Scenarios considered. The distance between the trip generation and ETE curves is the travel time. Plots of trip generation versus ETE are indicative of the level of traffic congestion during evacuation. For low population density sites, the curves are close together, indicating short travel times and minimal traffic congestion. For higher population density sites, the curves are farther apart indicating longer travel times and the presence of traffic congestion. Even though the site is sparsely populated, the large number of employees at the PVNGS site causes congestion over the first 2 hours and 15 minutes following the ATE. As seen in Figure J-2 through Figure J-13, the curves are spatially separated for about 2 hours and 30 minutes during midweek, midday scenarios, due to the employees evacuating the EPZ and then become closer together as a result of the minimal traffic congestion in the EPZ after this time, which was discussed in detail in Section 7.3. During weekend and evening scenarios, there are less PVNGS employees, so the curves for those scenarios are close together.

[1] Computed as the difference of the average travel time and the average ideal travel time under free flow condition.

Table J-1. Sample Simulation Model Input

Link Number	Upstream Node	Downstream Node	Vehicles Entering Network on this Link	Directional Preference	Destination Nodes	Destination Capacity
303	226	225	113	N	8021	4,500
					8198	1,275
258	183	149	92	NE	8021	4,500
121	81	147	53	SE	8062	3,800
					8198	1,275
					8021	4,500
219	154	86	225	N	8021	4,500
					8198	1,275
160	114	113	216	NE	8021	4,500
105	68	180	52	SE	8062	3,800
					8198	1,275
					8021	4,500
175	124	125	20	N	8021	4,500
					8198	1,275
116	77	191	20	E	8021	4,500
280	203	277	13	E	8198	1,275

Table J-2. Selected Model Outputs for the Evacuation of the Entire EPZ (Region R03)

Scenario	1	2	3	4	5	6
Network-Wide Average Travel Time (Min/Veh-Mi)	1.0	1.1	1.0	1.0	1.0	1.0
Network-Wide Average Delay Time (Min/Veh-Mi)	0.0	0.1	0.0	0.0	0.0	0.0
Network-Wide Average Speed (mph)	60.0	53.7	60.0	57.5	60.0	60.0
Total Vehicles Exiting Network	15,250	15,346	12,566	12,660	9,591	15,477
Scenario	**7**	**8**	**9**	**10**	**11**	**12**
Network-Wide Average Travel Time (Min/Veh-Mi)	1.1	1.0	1.0	1.0	1.0	1.6
Network-Wide Average Delay Time (Min/Veh-Mi)	0.1	0.0	0.0	0.0	0.0	0.5
Network-Wide Average Speed (mph)	53.5	60.0	57.5	60.0	58.7	38.2
Total Vehicles Exiting Network	15,576	12,568	12,666	9,607	16,641	15,250

Table J-3. Average Speed (mph) and Travel Time (min) for Major Evacuation Routes (Region R03, Scenario 1)

		Elapsed Time (hours)											
		1		2		3		4		5		6	
Route Name	Length (miles)	Speed (mph)	Travel Time (min)	Speed	Travel Time	Speed	Travel Time	Speed	Travel Time	Speed	Travel Time	Speed	Travel Time
I-10 Eastbound	34.9	56.2	37.3	72.6	28.9	70.4	29.8	69.0	30.4	66.3	31.6	64.3	32.6
I-10 Westbound	34.9	56.5	37.1	75.0	27.9	74.2	28.2	73.5	28.5	72.2	29.0	75.0	27.9

Table J-4. Simulation Model Outputs at Network Exit Links for Region R03, Scenario 1

Network Exit Link	Upstream Node	Downstream Node	Elapsed Time (hours)					
			1	2	3	4	5	6
			Cumulative Vehicles Discharged by the Indicated Time					
			Cumulative Percent of Vehicles Discharged by the Indicated Time					
114	75	76	35	109	154	167	171	172
			0.7%	1.0%	1.1%	1.1%	1.1%	1.1%
141	99	205	11	246	575	737	795	821
			0.2%	2.4%	4.2%	5.0%	5.3%	5.4%
279	202	52	87	308	403	431	440	441
			1.7%	3.0%	3.0%	2.9%	2.9%	2.9%
282	206	200	9	51	84	98	104	105
			0.2%	0.5%	0.6%	0.7%	0.7%	0.7%
290	213	137	1,966	2,538	2,636	2,690	2,710	2,714
			39.0%	24.6%	19.5%	18.3%	17.9%	17.8%
388	302	198	224	819	1,201	1,278	1,305	1,310
			4.5%	7.9%	8.9%	8.7%	8.6%	8.6%
390	303	20	2,704	6,261	8,493	9,311	9,607	9,687
			53.7%	60.6%	62.7%	63.3%	63.5%	63.5%

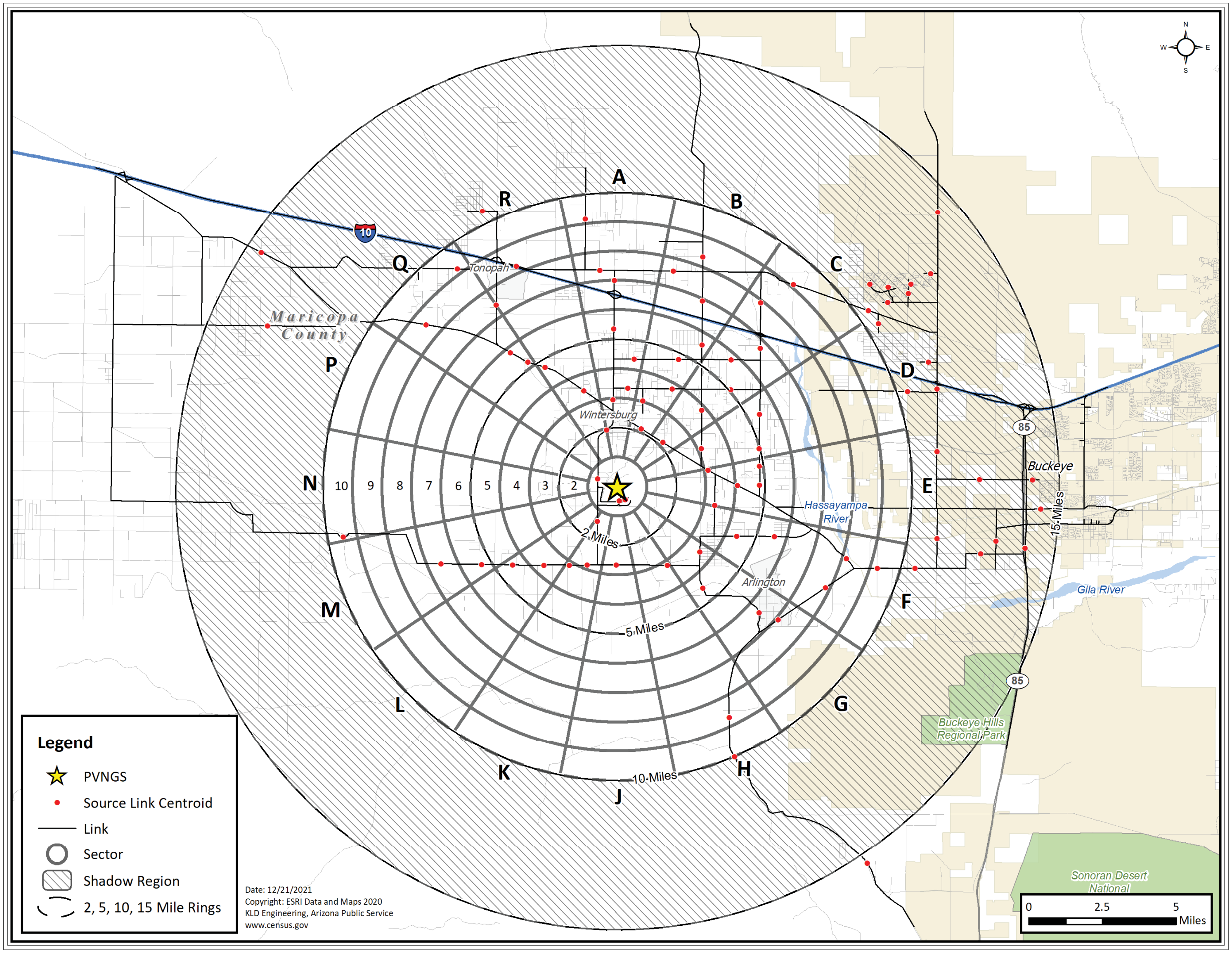

Figure J-1. Network Sources/Origins

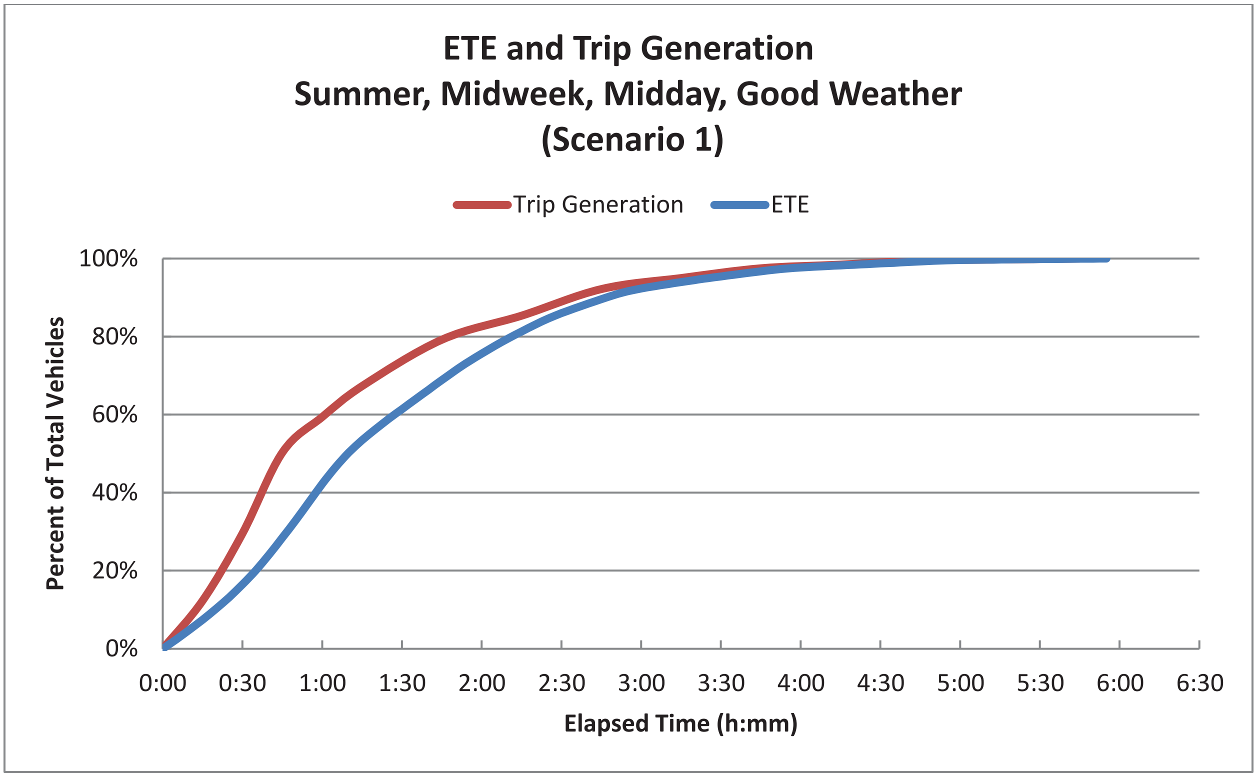

Figure J-2. ETE and Trip Generation: Summer, Midweek, Midday, Good Weather (Scenario 1)

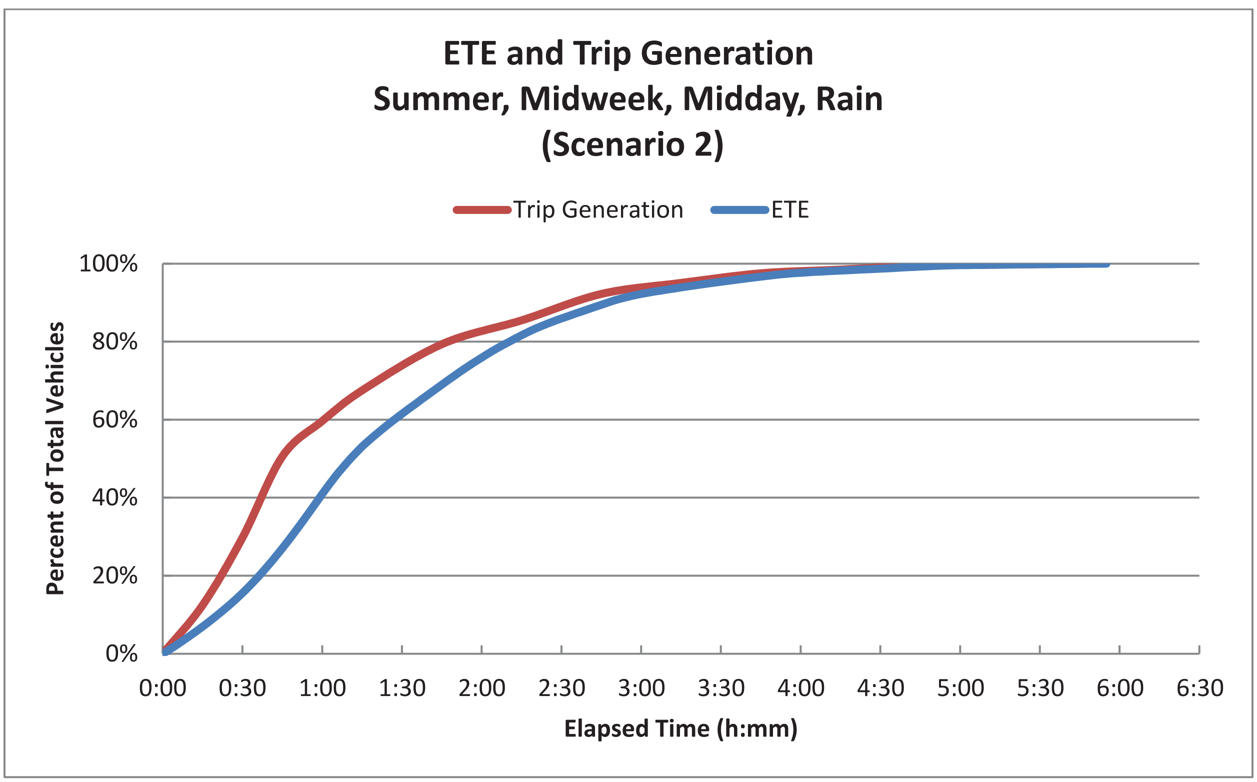

Figure J-3. ETE and Trip Generation: Summer, Weekend, Midday, Rain (Scenario 2)

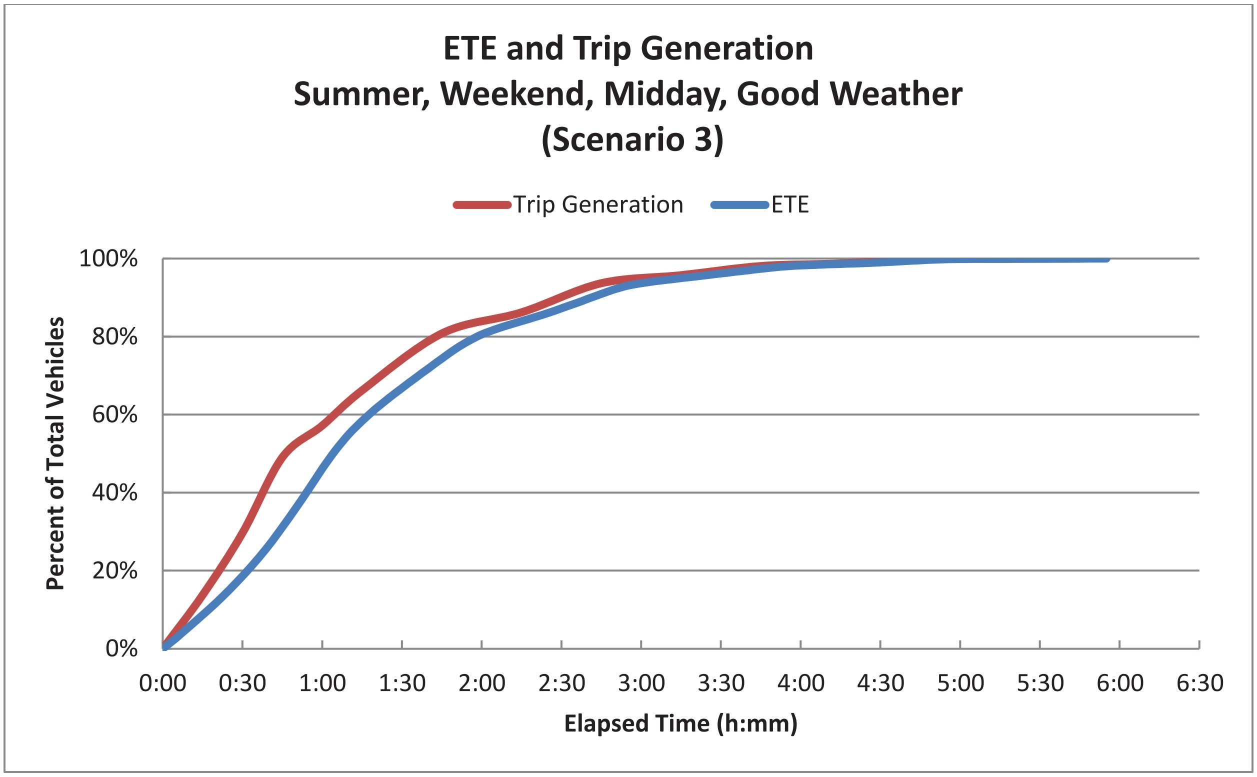

Figure J-4. ETE and Trip Generation: Summer, Weekend, Midday, Good Weather (Scenario 3)

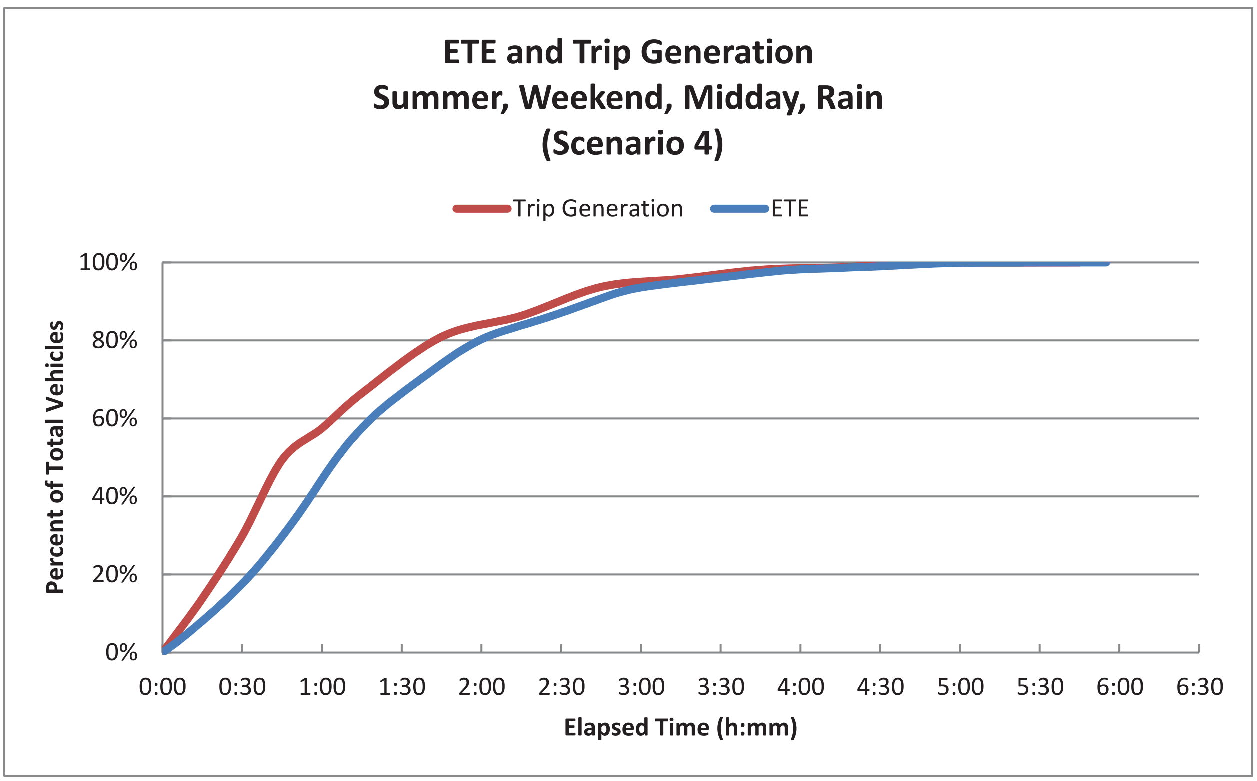

Figure J-5. ETE and Trip Generation: Summer, Midweek, Midday, Rain (Scenario 4)

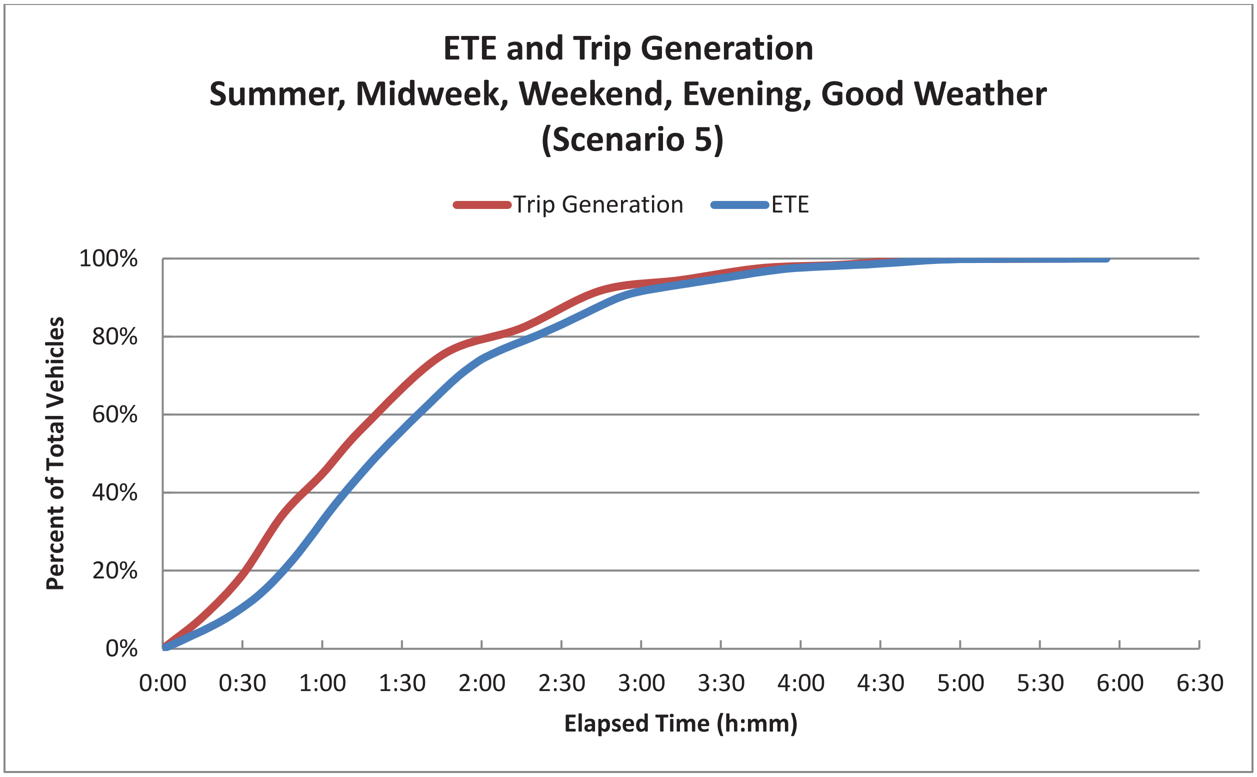

Figure J-6. ETE and Trip Generation: Summer, Midweek, Weekend, Evening, Good Weather (Scenario 5)

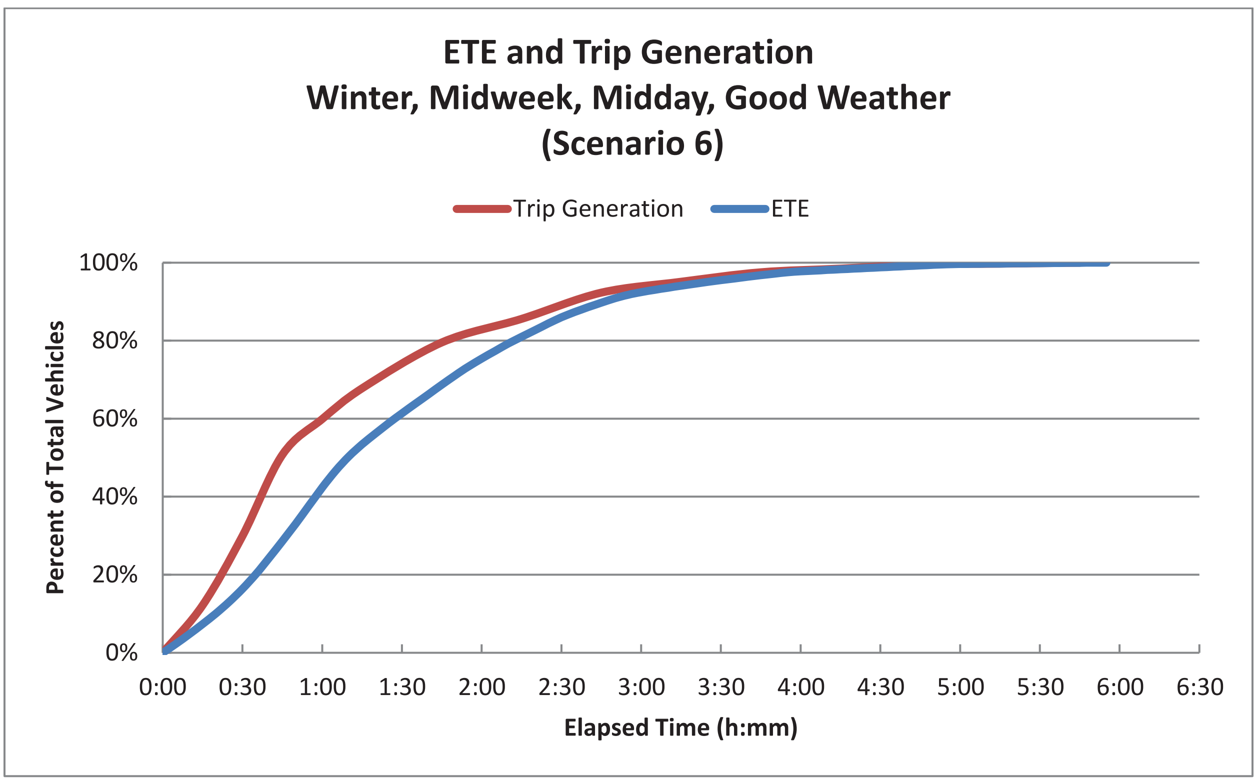

Figure J-7. ETE and Trip Generation: Winter, Midweek, Midday, Good Weather (Scenario 6)

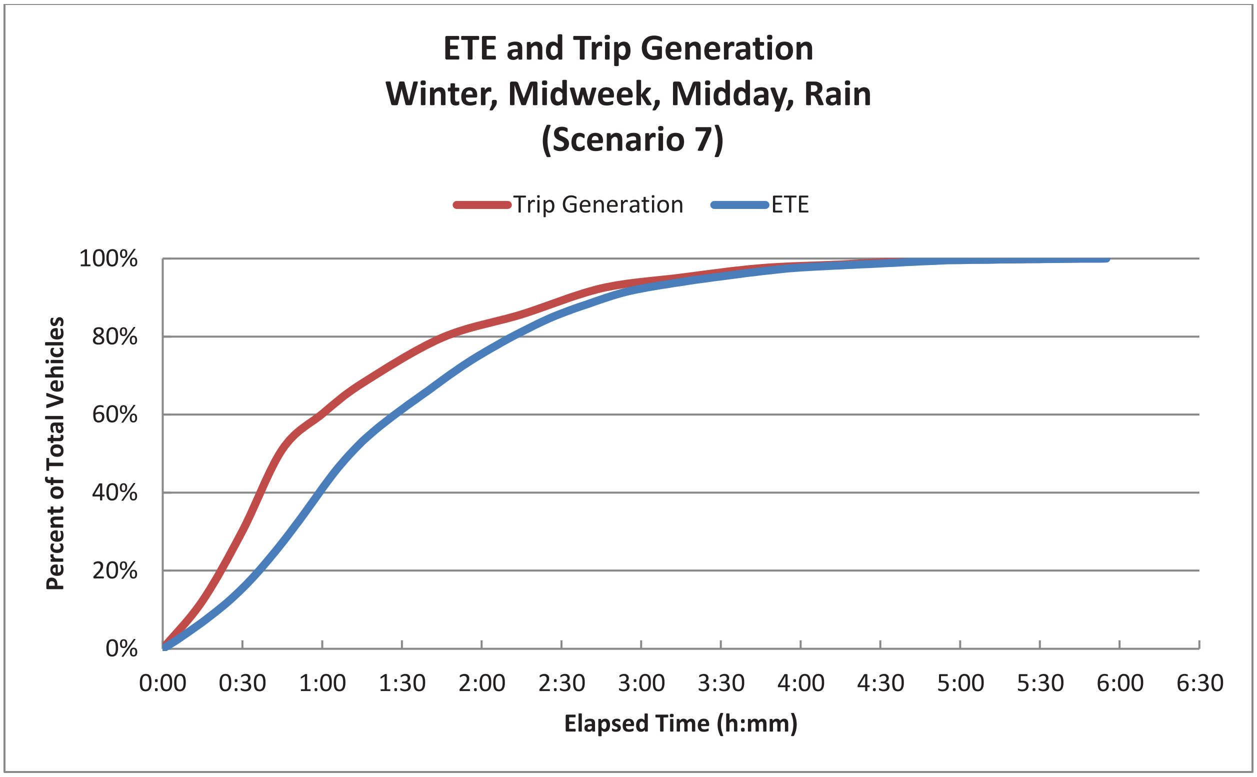

Figure J-8. ETE and Trip Generation: Winter, Midweek, Midday, Rain (Scenario 7)

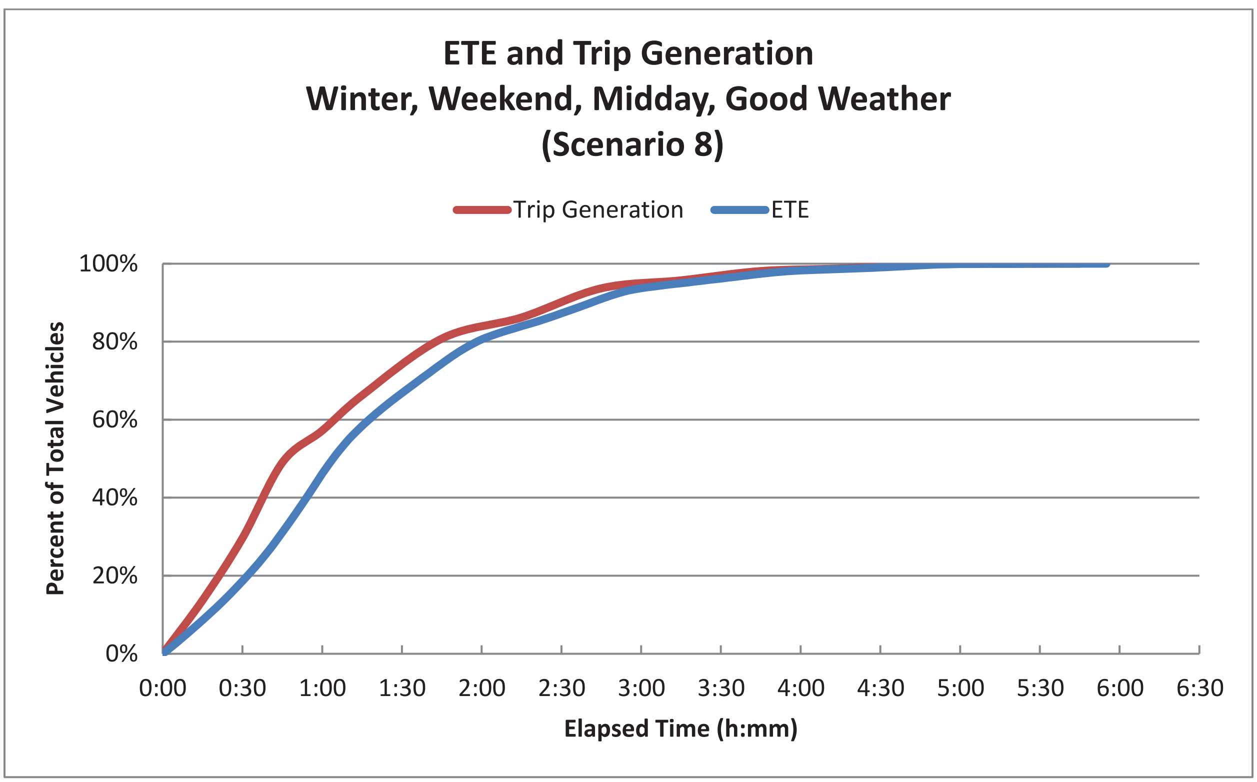

Figure J-9. ETE and Trip Generation: Winter, Weekend, Midday, Good Weather (Scenario 8)

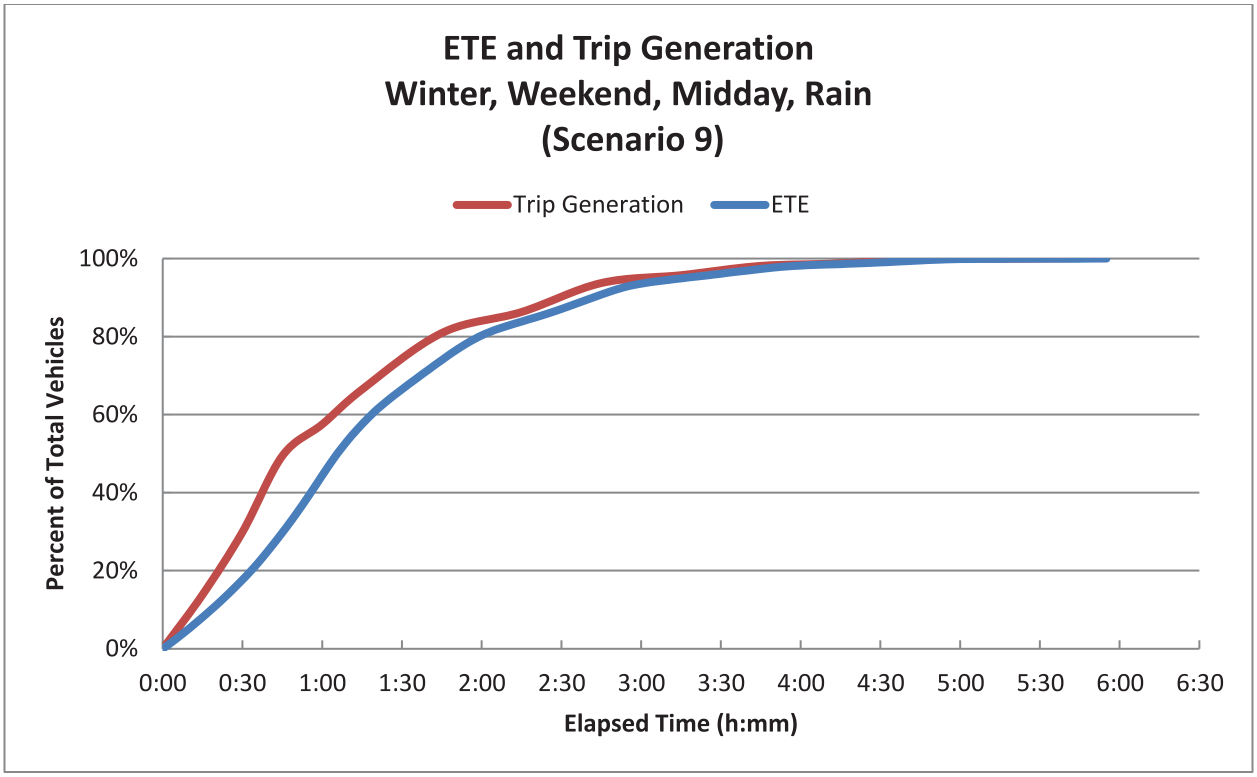

Figure J-10. ETE and Trip Generation: Winter, Weekend, Midday, Rain (Scenario 9)

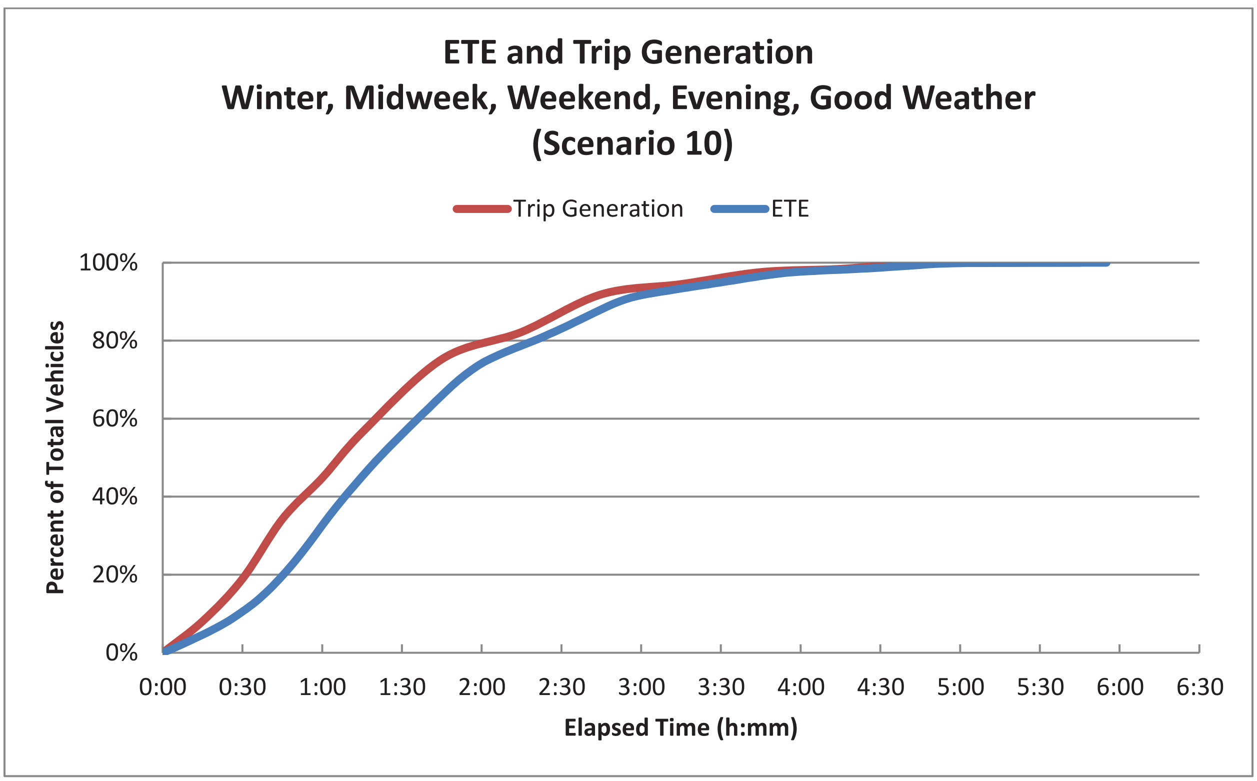

Figure J-11. ETE and Trip Generation: Winter, Midweek, Weekend, Evening, Good Weather (Scenario 10)

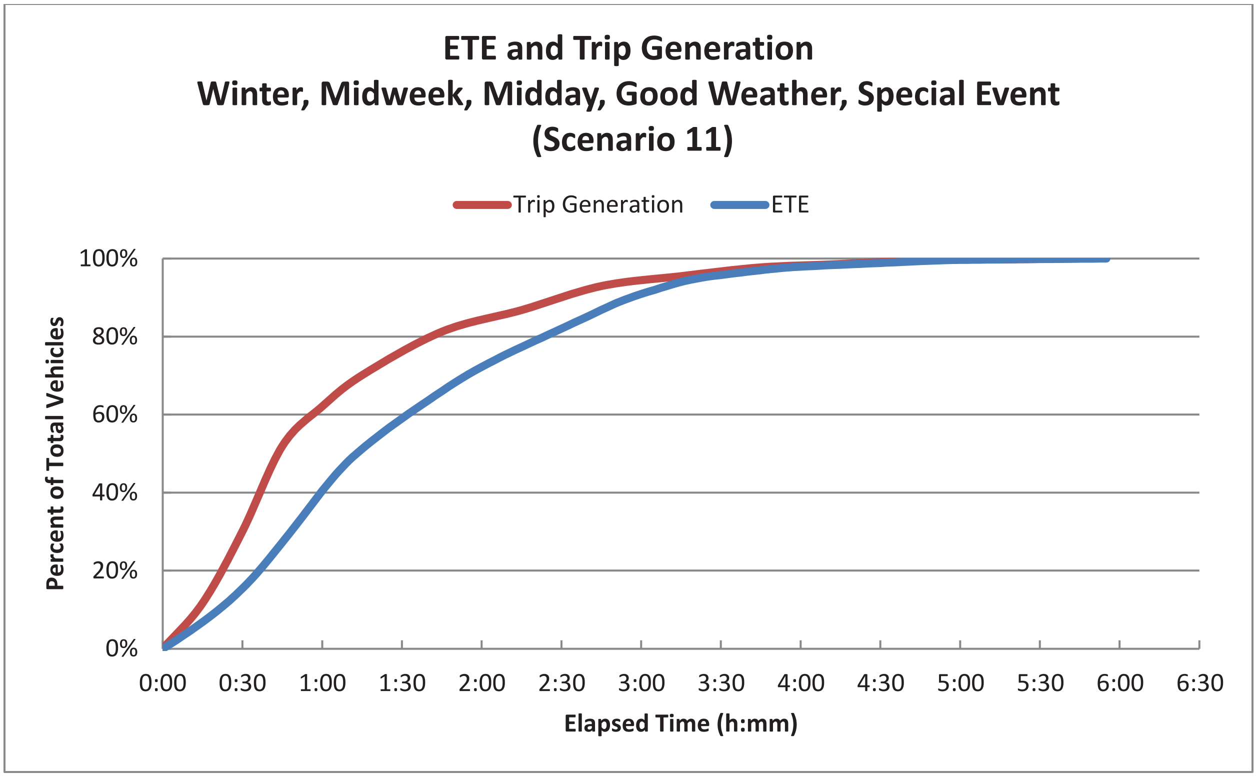

Figure J-12. ETE and Trip Generation: Winter, Midweek, Midday, Good Weather, Special Event (Scenario 11)

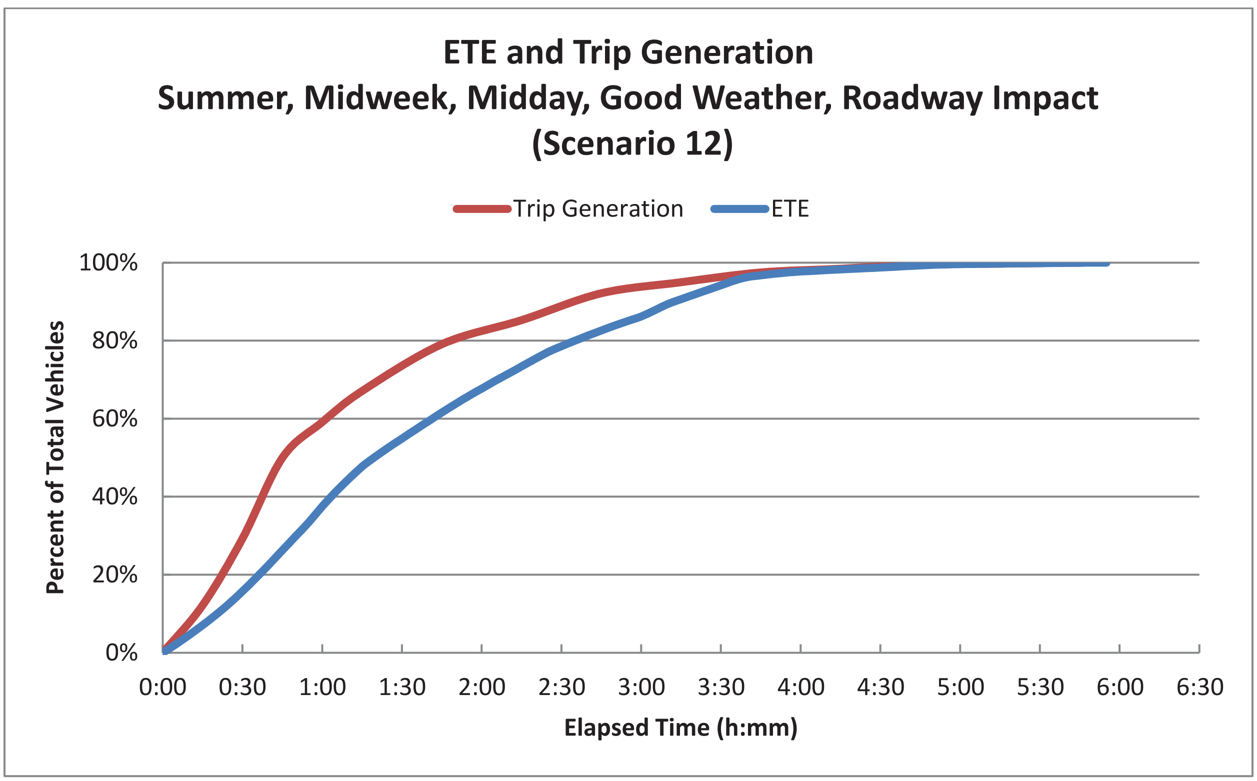

Figure J-13. ETE and Trip Generation: Summer, Midweek, Midday, Good Weather, Roadway Impact (Scenario 12)

APPENDIX K

Evacuation Roadway Network

K. EVACUATION ROADWAY NETWORK

As discussed in Section 1.3, a link-node analysis network was constructed to model the roadway network within the study area. Figure K-1 provides an overview of the link-node analysis network. The figure has been divided up into 30 more detailed figures (Figure K-2 through Figure K-31) which show each of the links and nodes in the network.

The analysis network was calibrated using the observations made during the field surveys conducted in October 2020.

Table K-1 summarizes the number of nodes by the type of control (stop sign, yield sign, pre-timed signal, actuated signal, roadblocks, uncontrolled).

Table K-1. Summary of Nodes by the Type of Control

Control Type	Number of Nodes
Uncontrolled	224
Pretimed	0
Actuated	12
Stop	52
Roadblocks	3
Yield	6
Total:	**297**

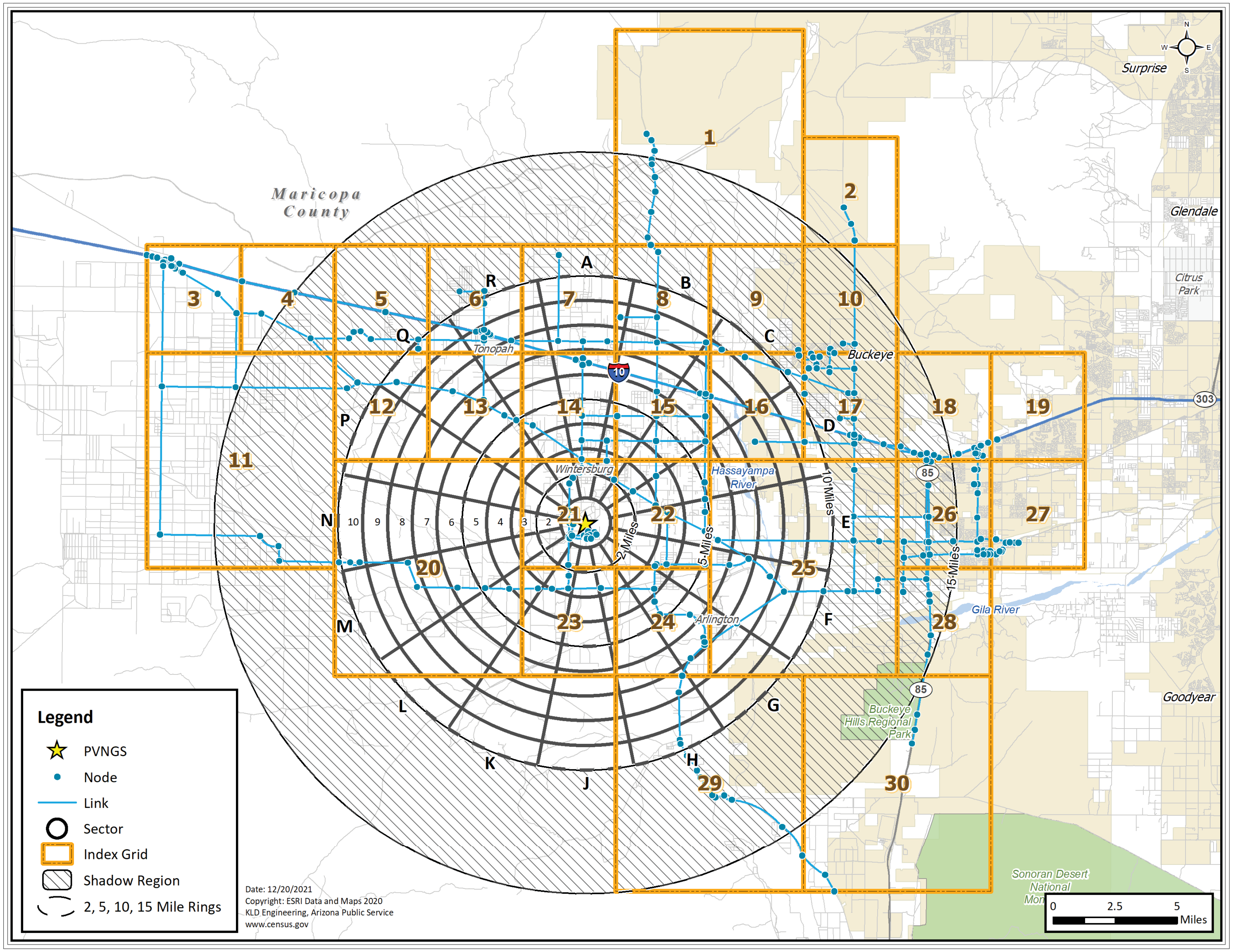

Figure K-1. PVNGS Link-Node Analysis Network

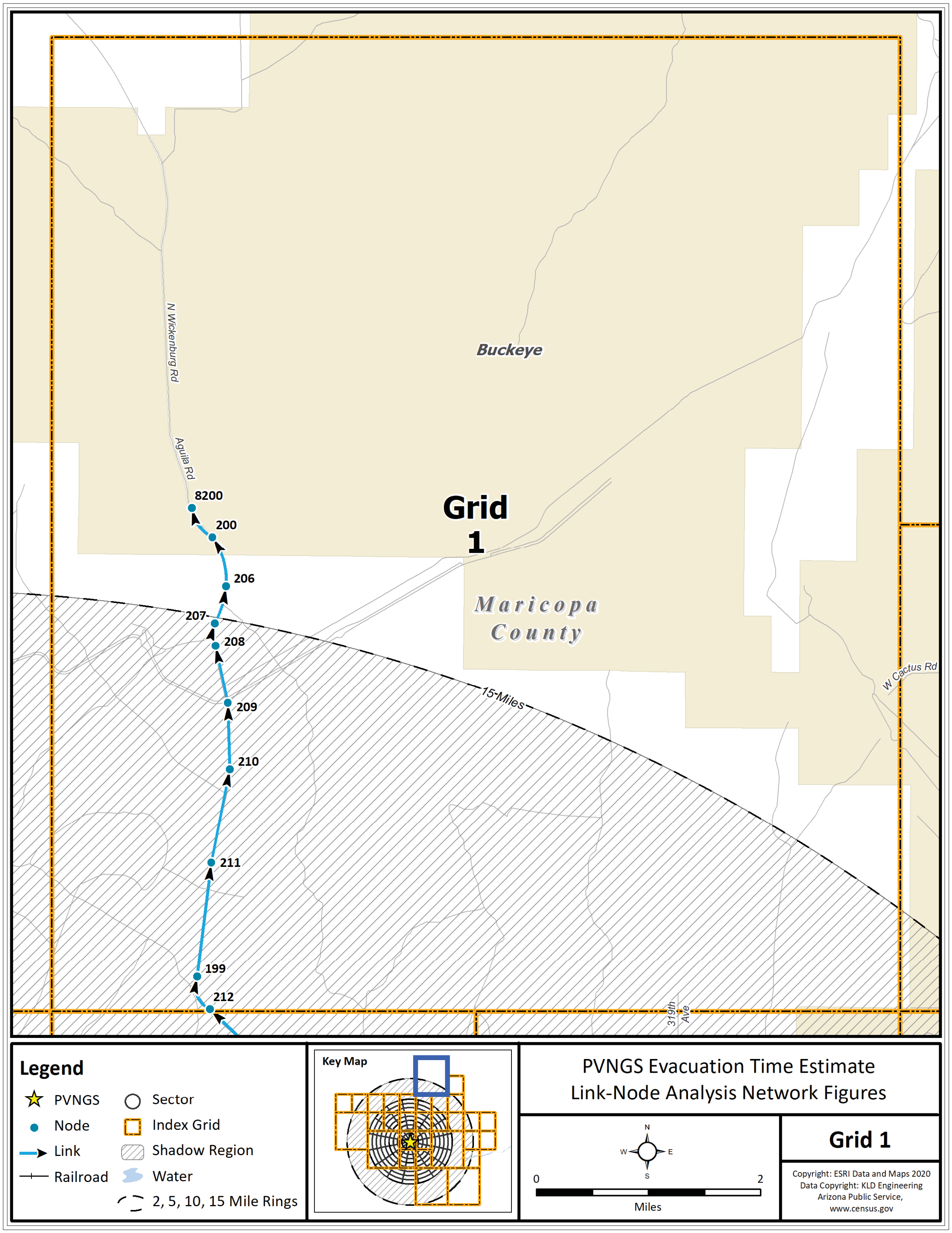

Figure K-2. Link-Node Analysis Network – Grid 1

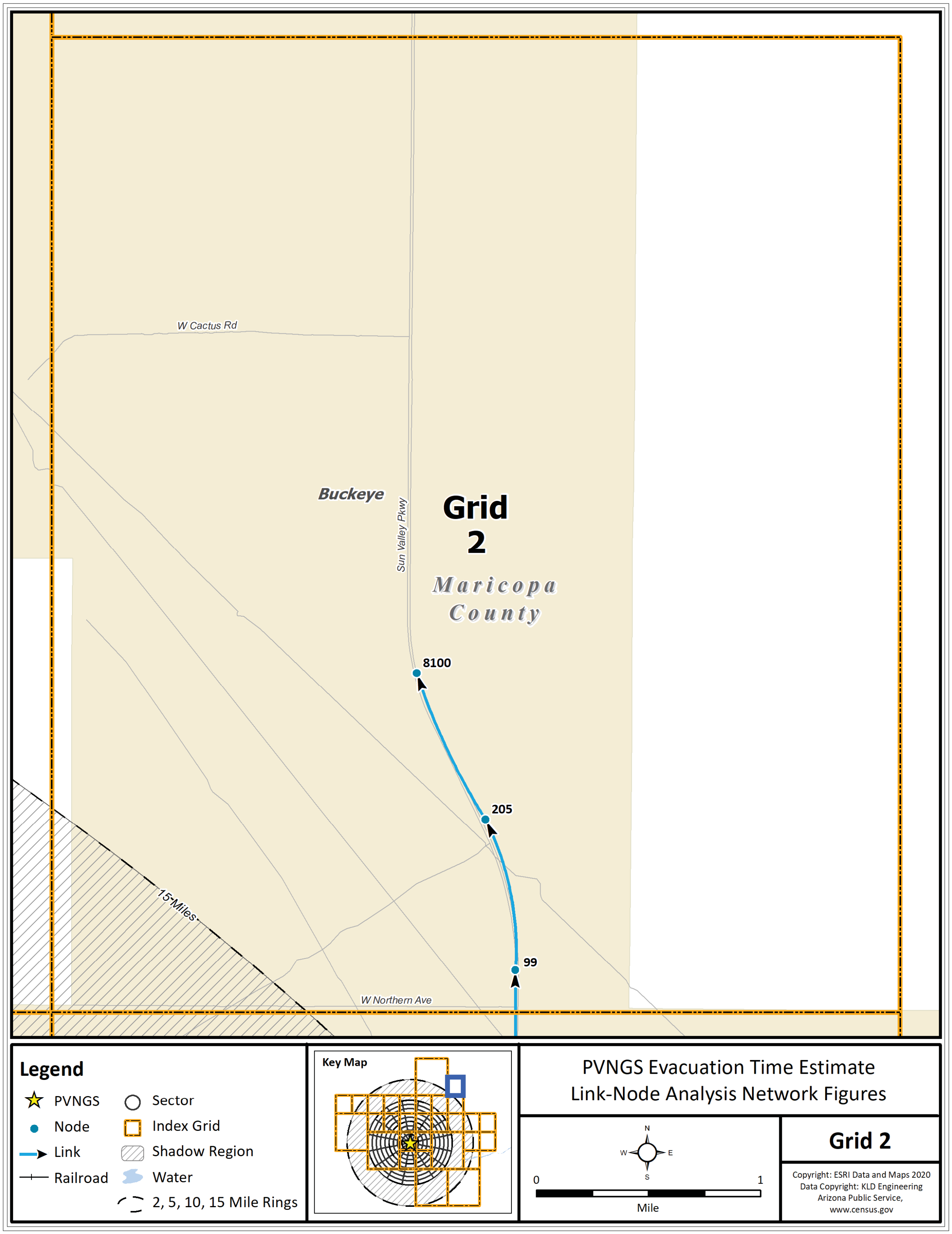

Figure K-3. Link-Node Analysis Network – Grid 2

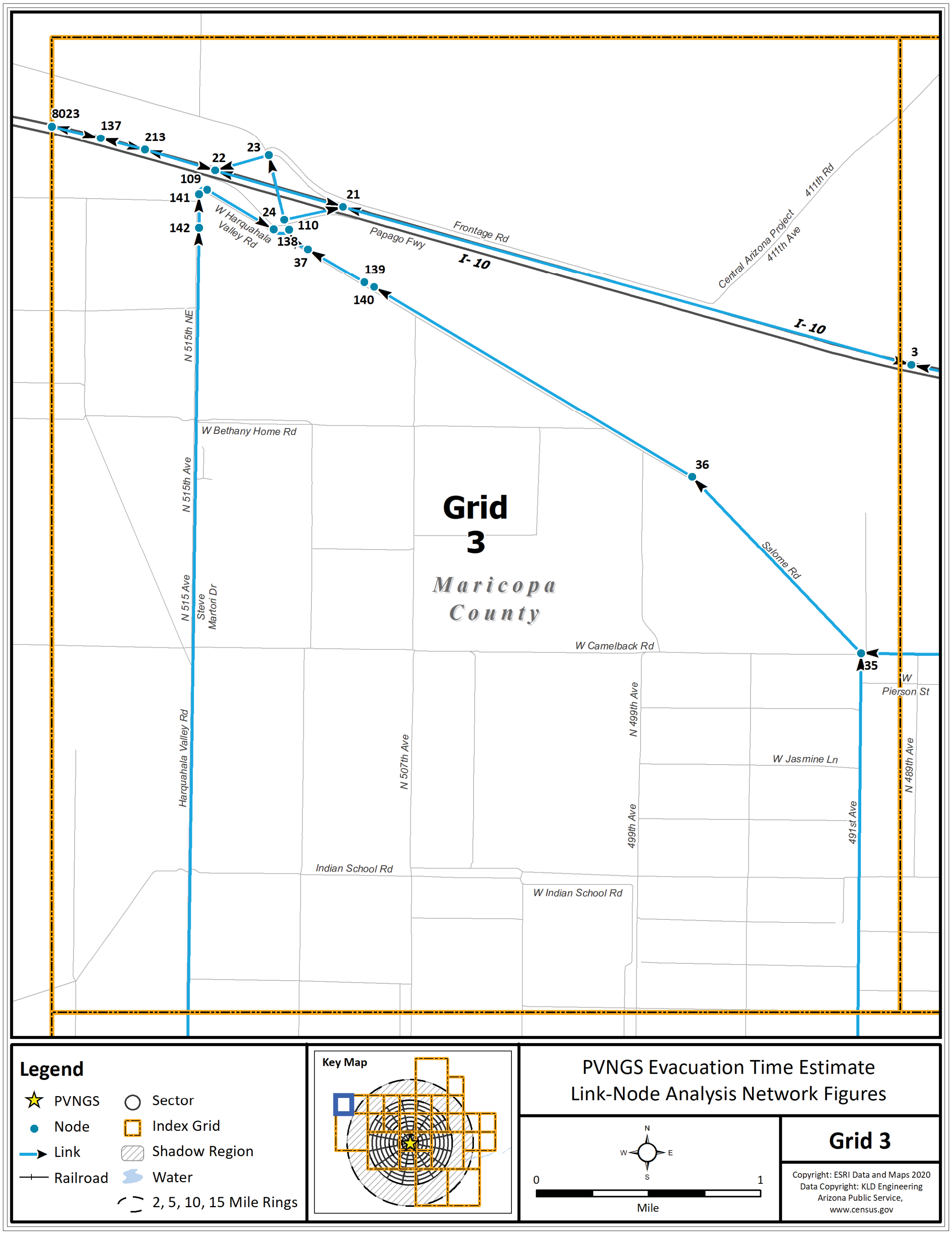

Figure K-4. Link-Node Analysis Network – Grid 3

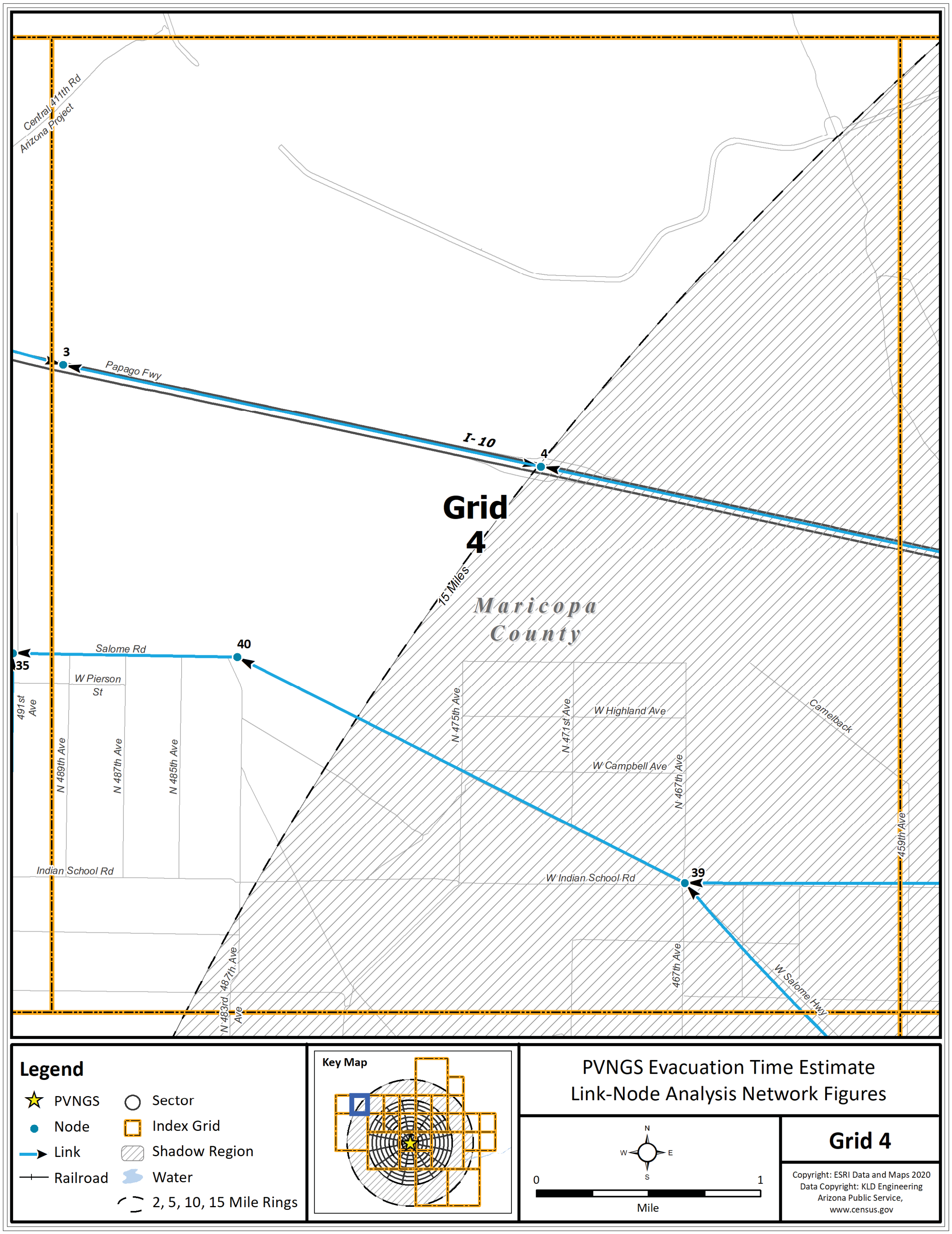

Figure K-5. Link-Node Analysis Network – Grid 4

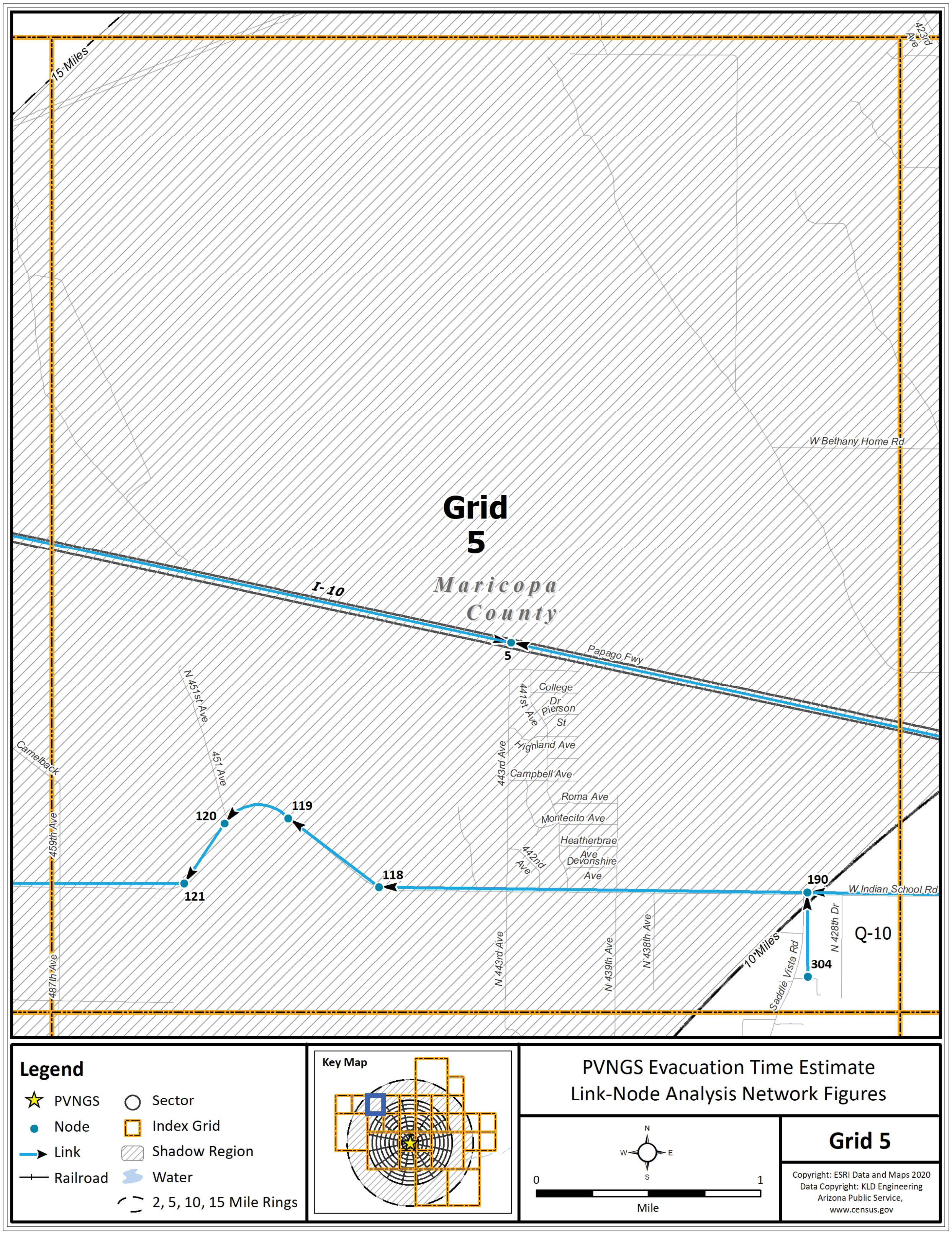

Figure K-6. Link-Node Analysis Network – Grid 5

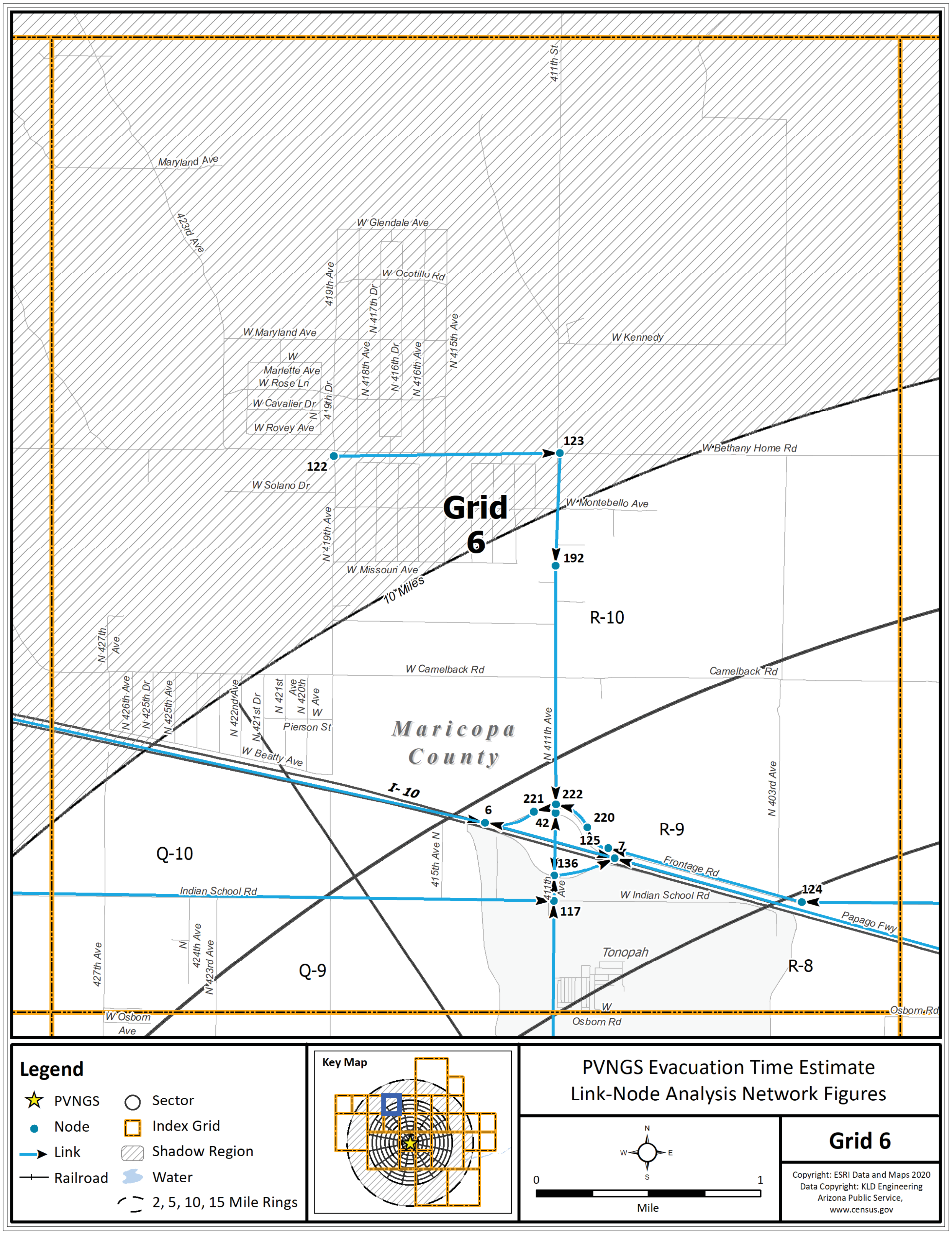

Figure K-7. Link-Node Analysis Network – Grid 6

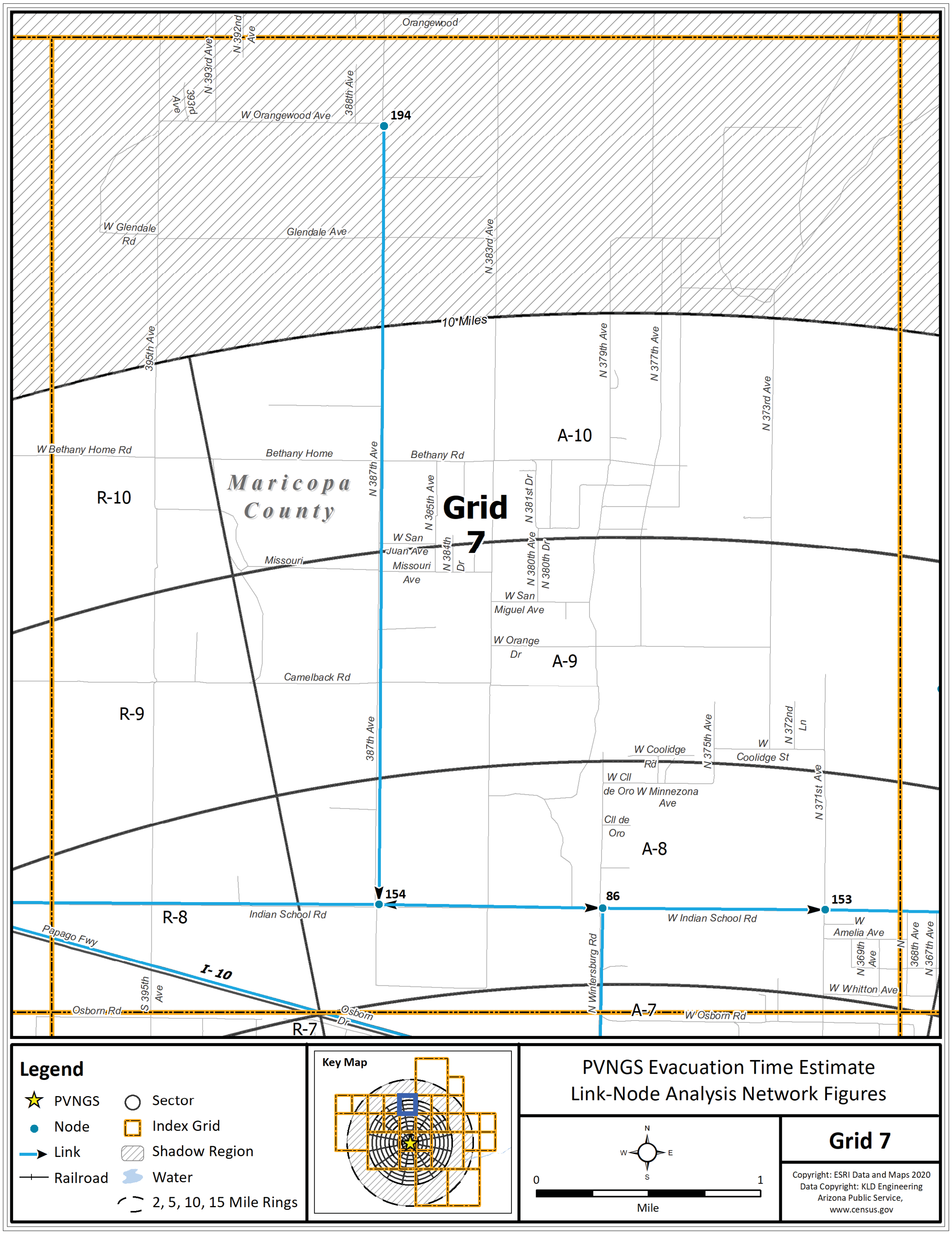

Figure K-8. Link-Node Analysis Network – Grid 7

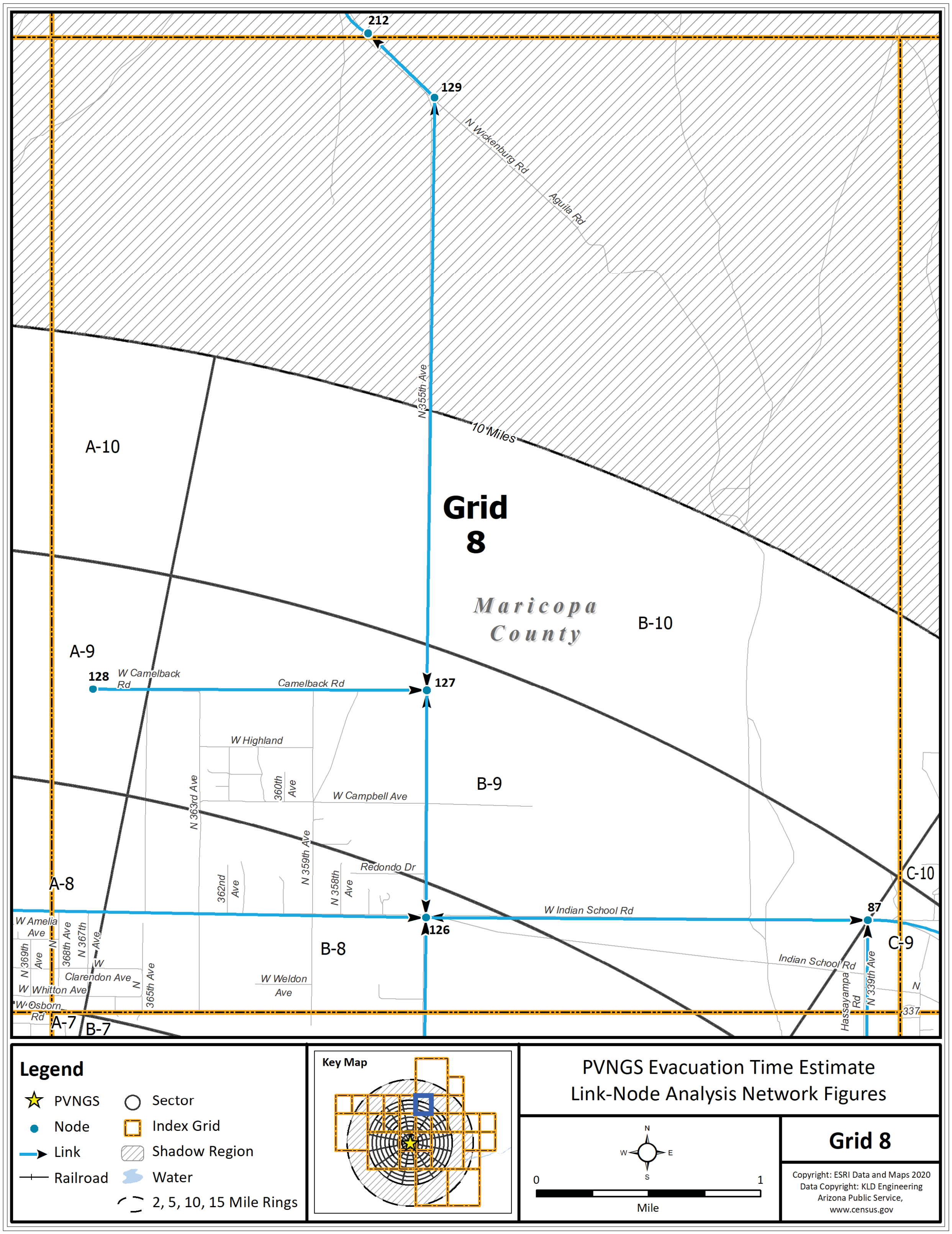

Figure K-9. Link-Node Analysis Network – Grid 8

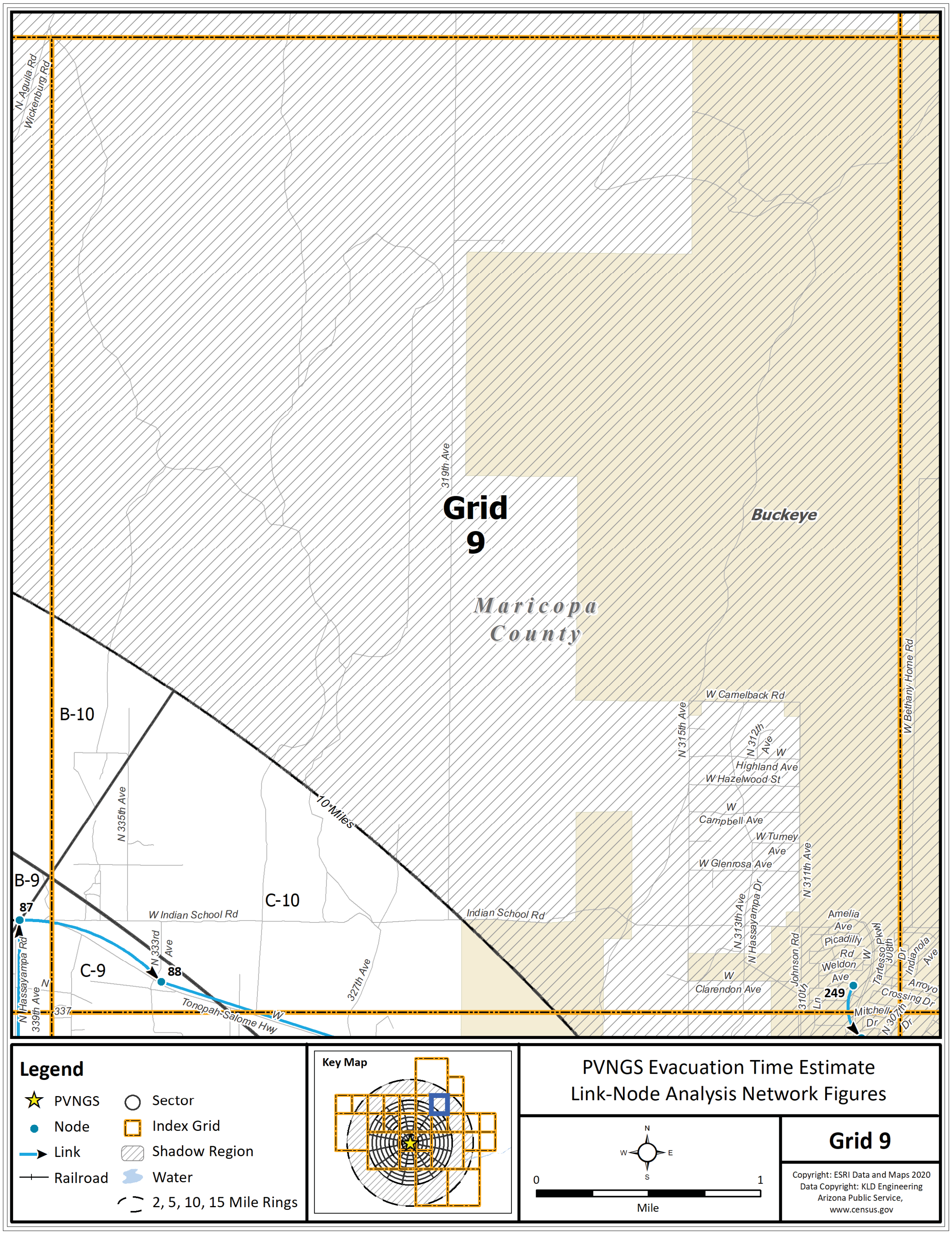

Figure K-10. Link-Node Analysis Network – Grid 9

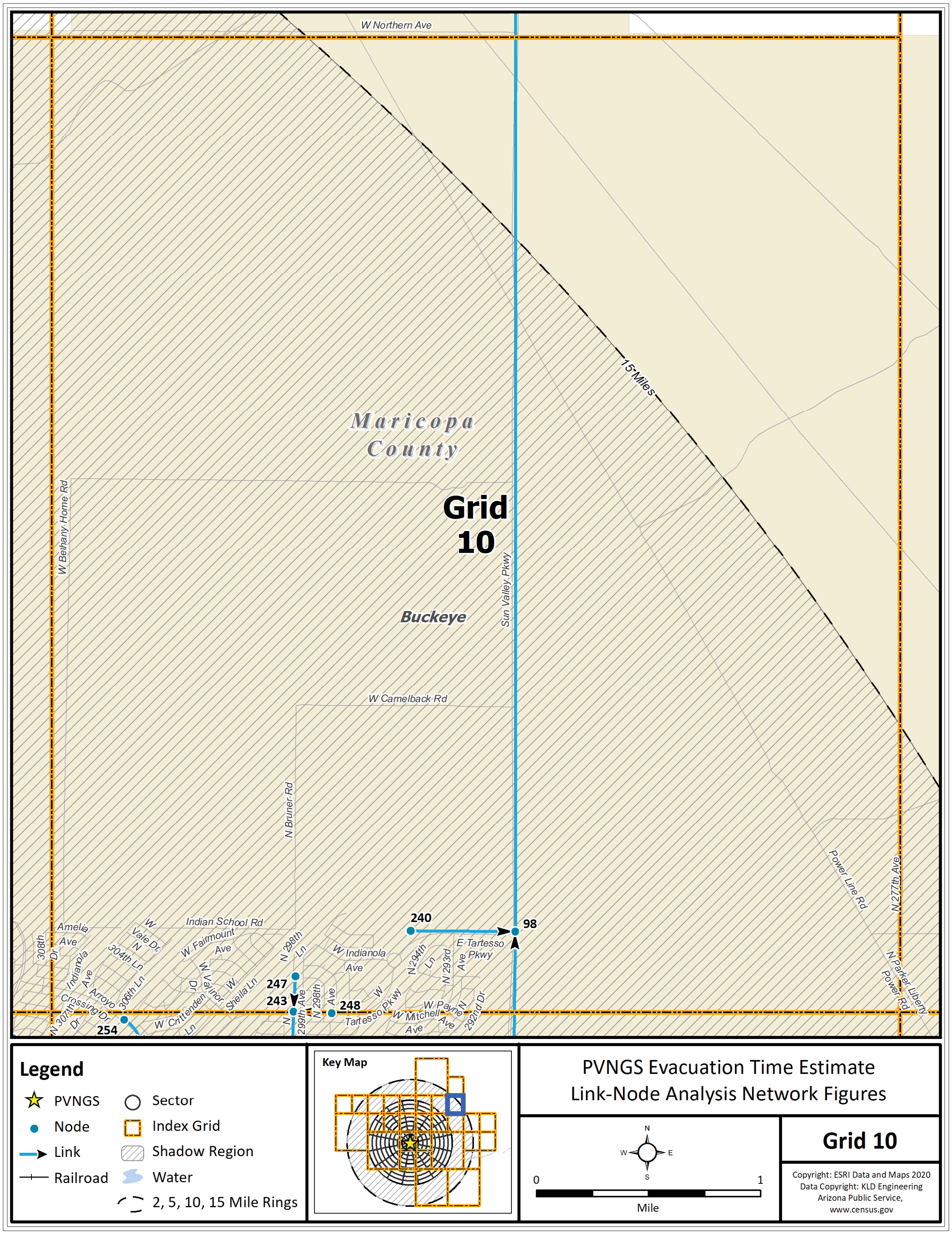

Figure K-11. Link-Node Analysis Network – Grid 10

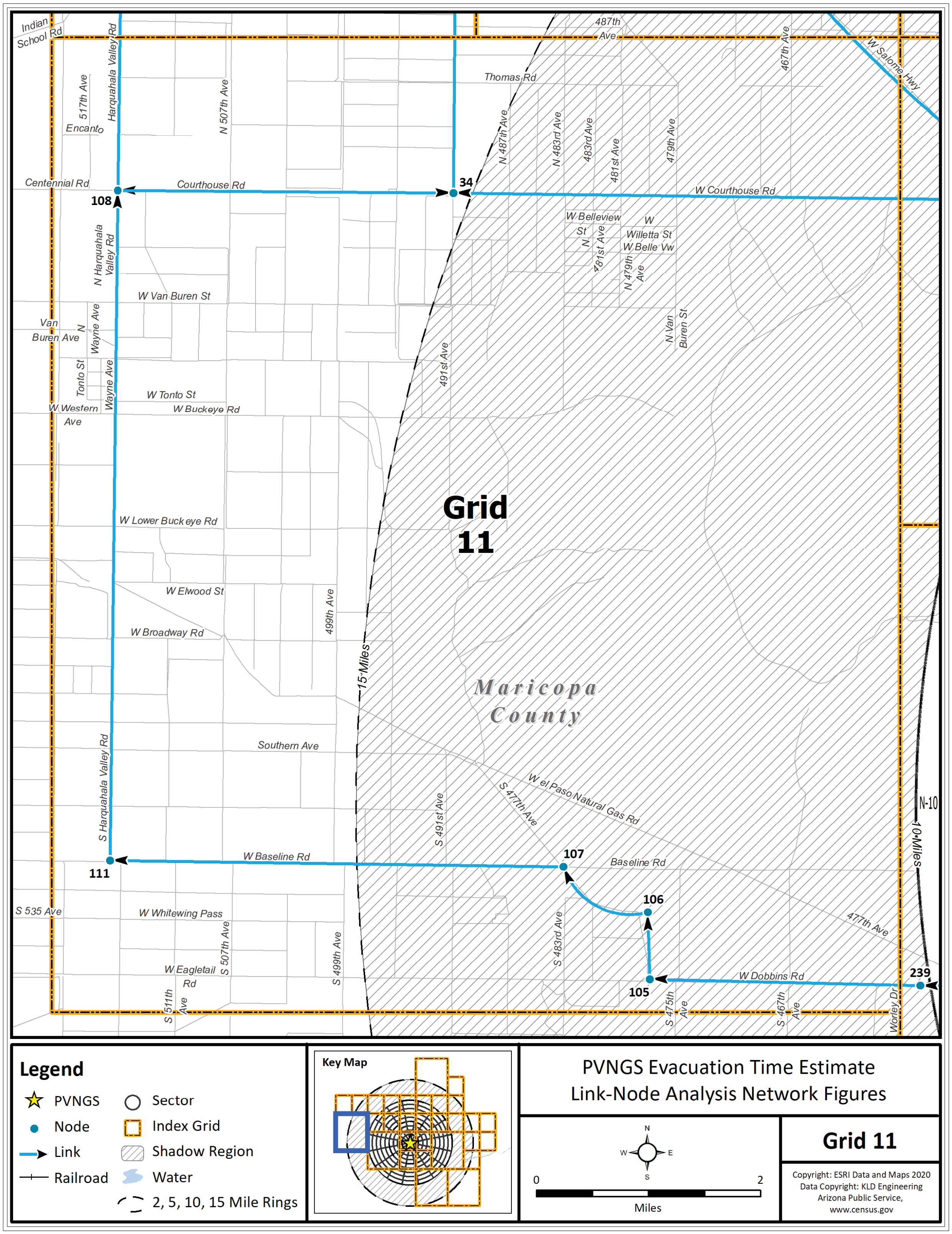

Figure K-12. Link-Node Analysis Network – Grid 11

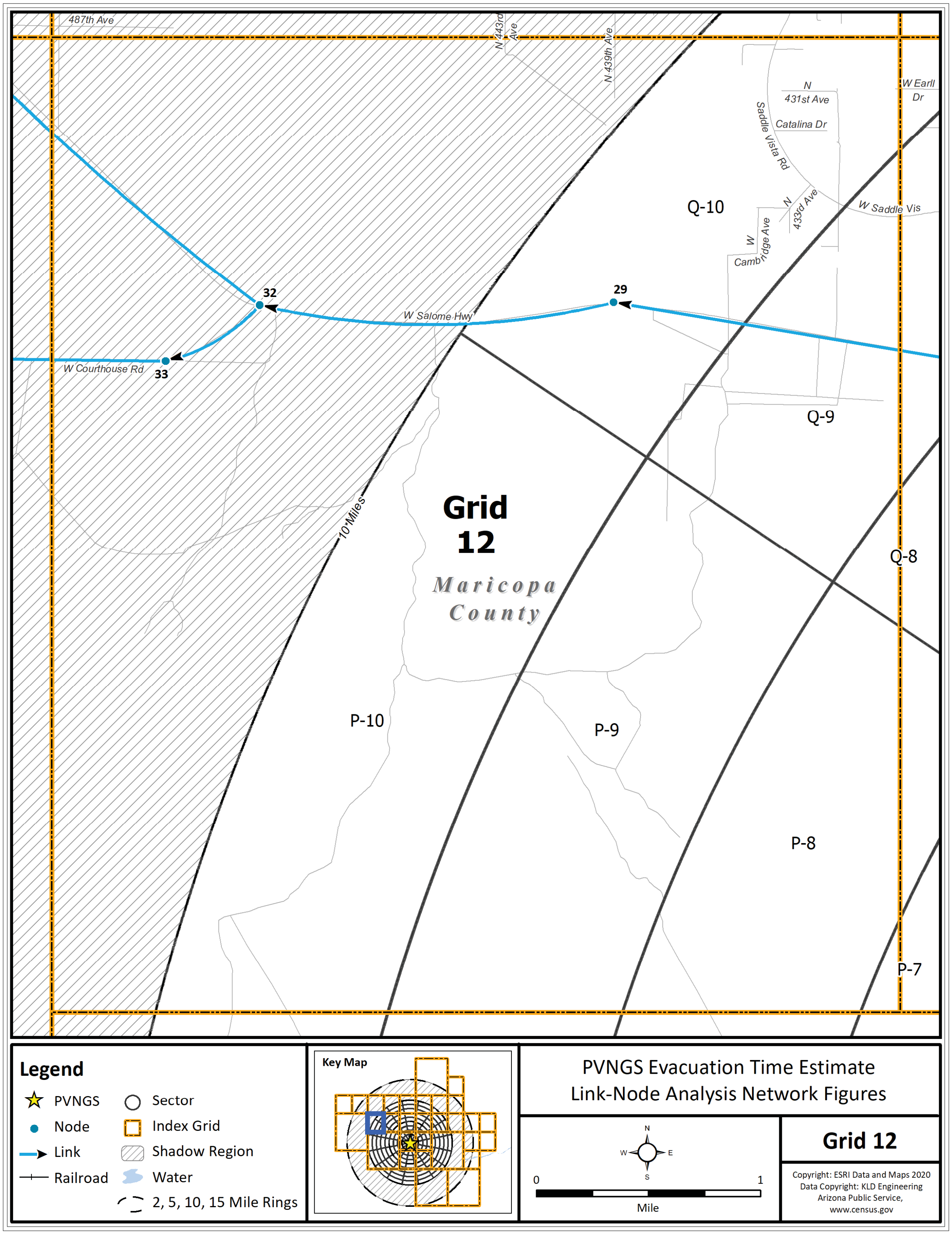

Figure K-13. Link-Node Analysis Network – Grid 12

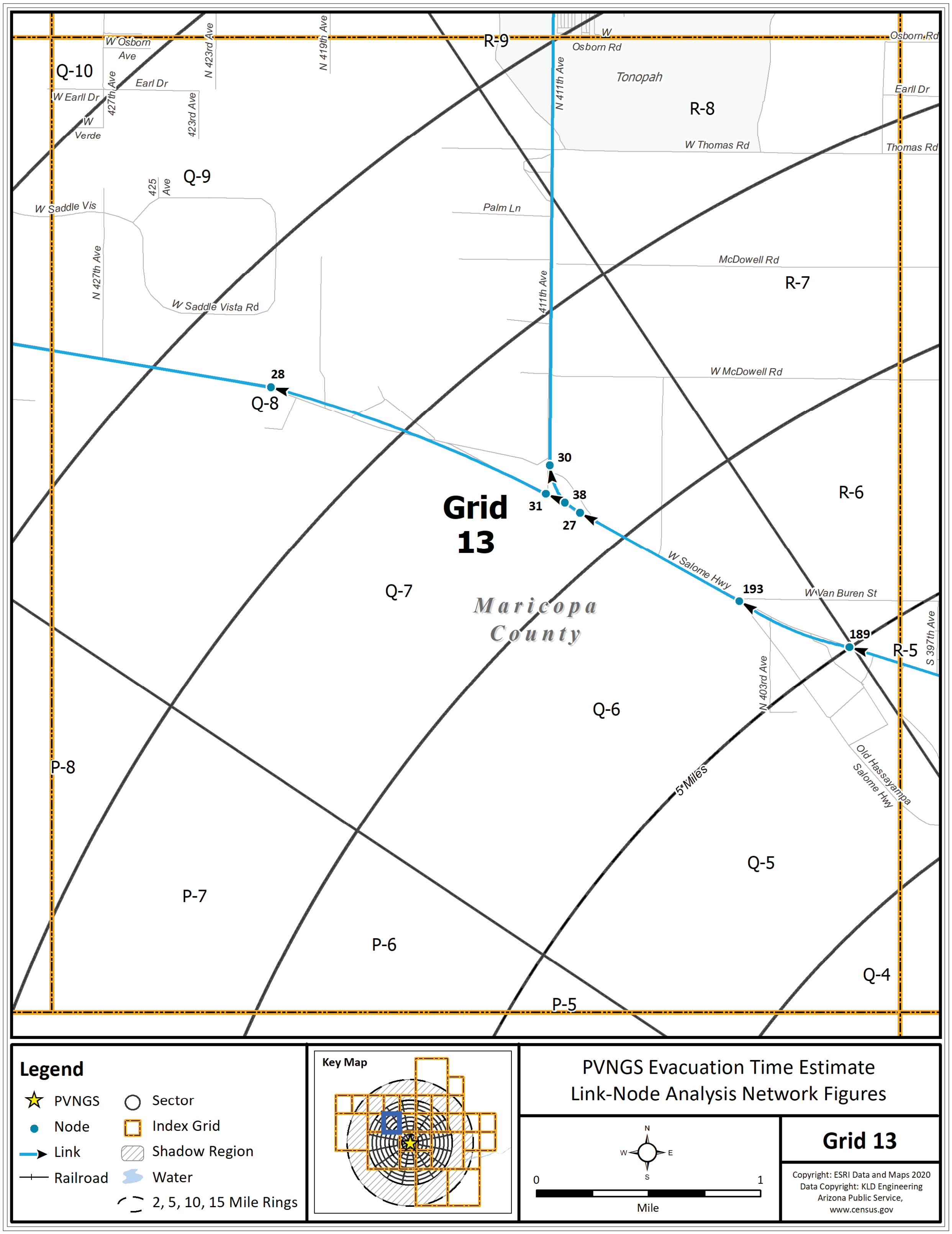

Figure K-14. Link-Node Analysis Network – Grid 13

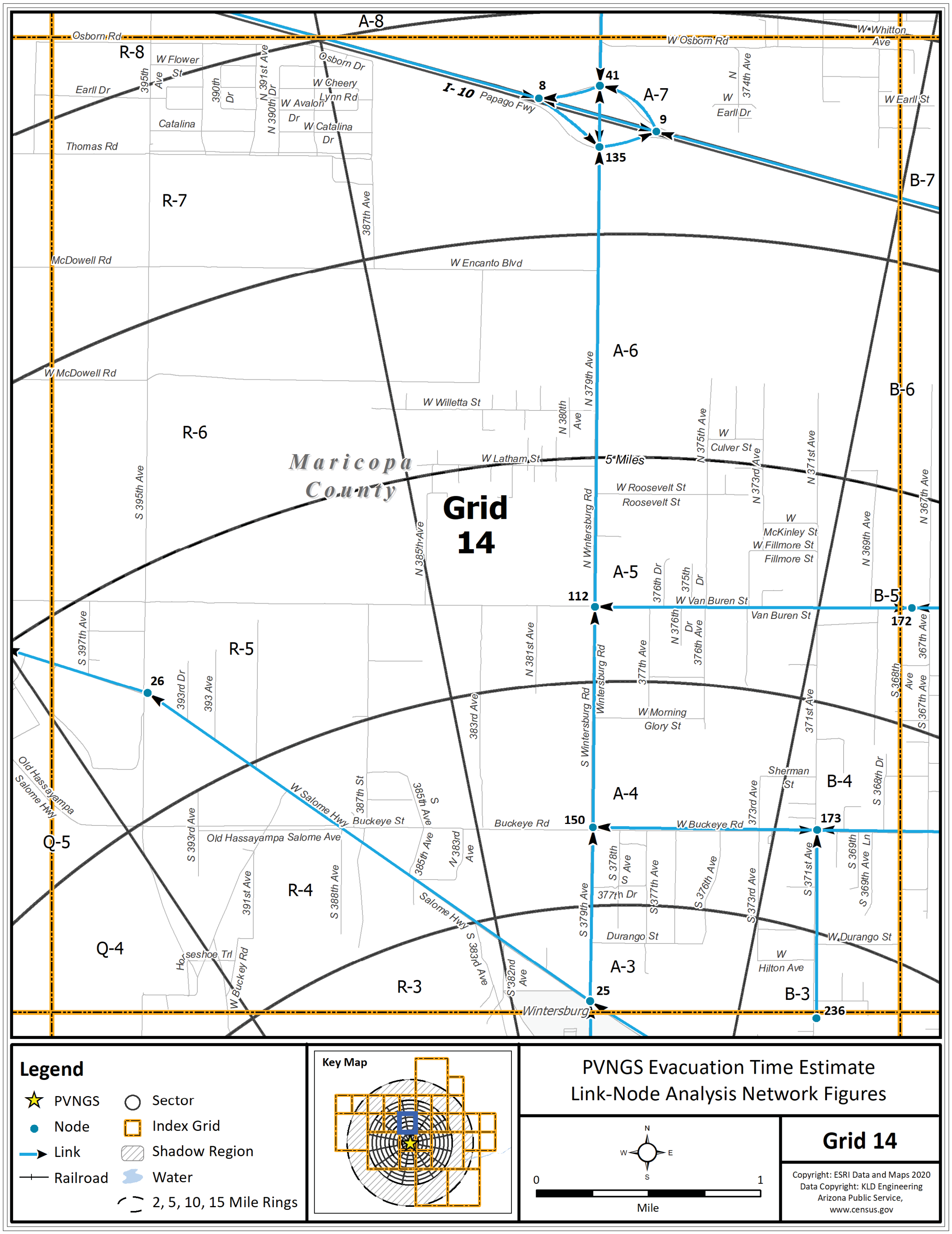

Figure K-15. Link-Node Analysis Network – Grid 14

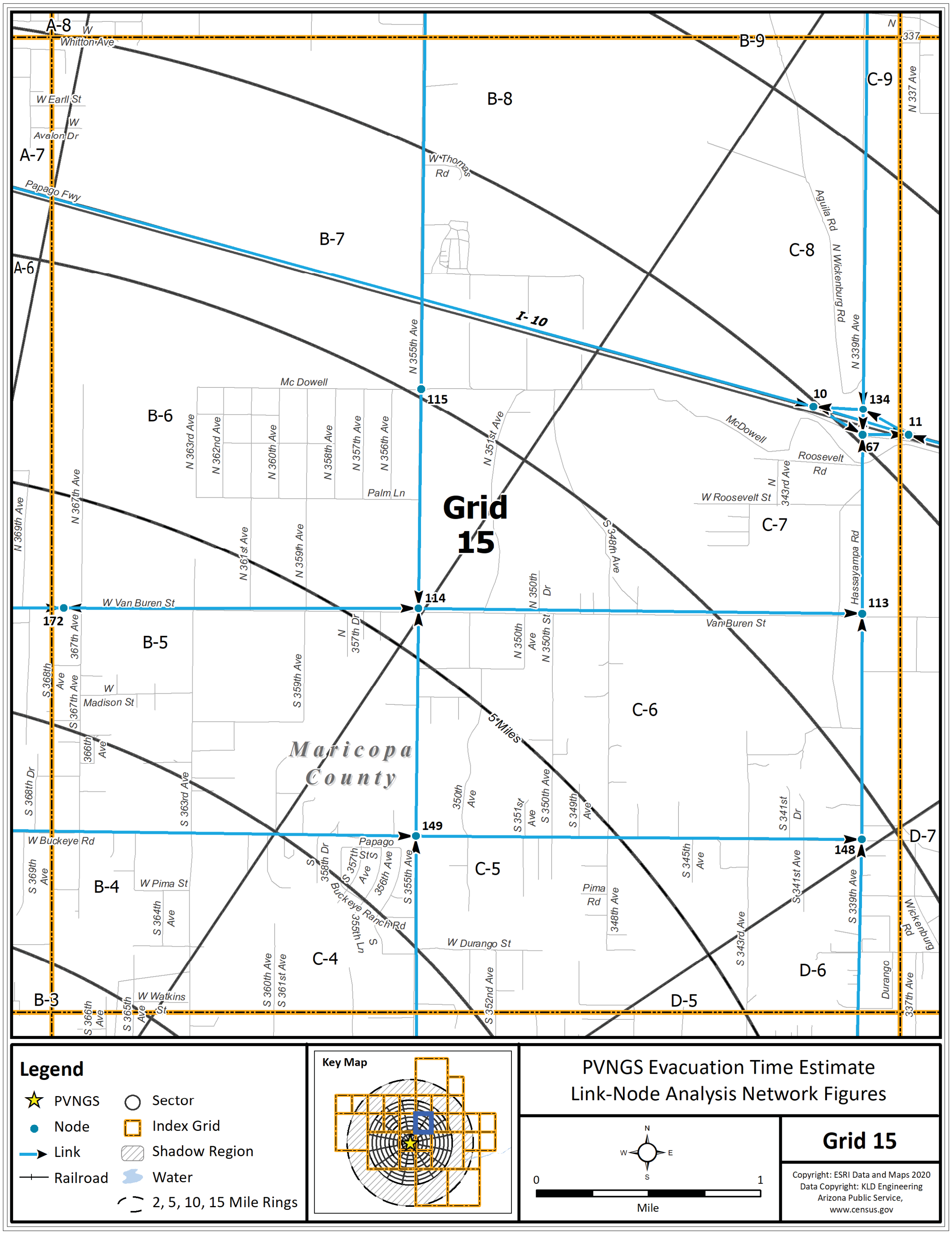

Figure K-16. Link-Node Analysis Network – Grid 15

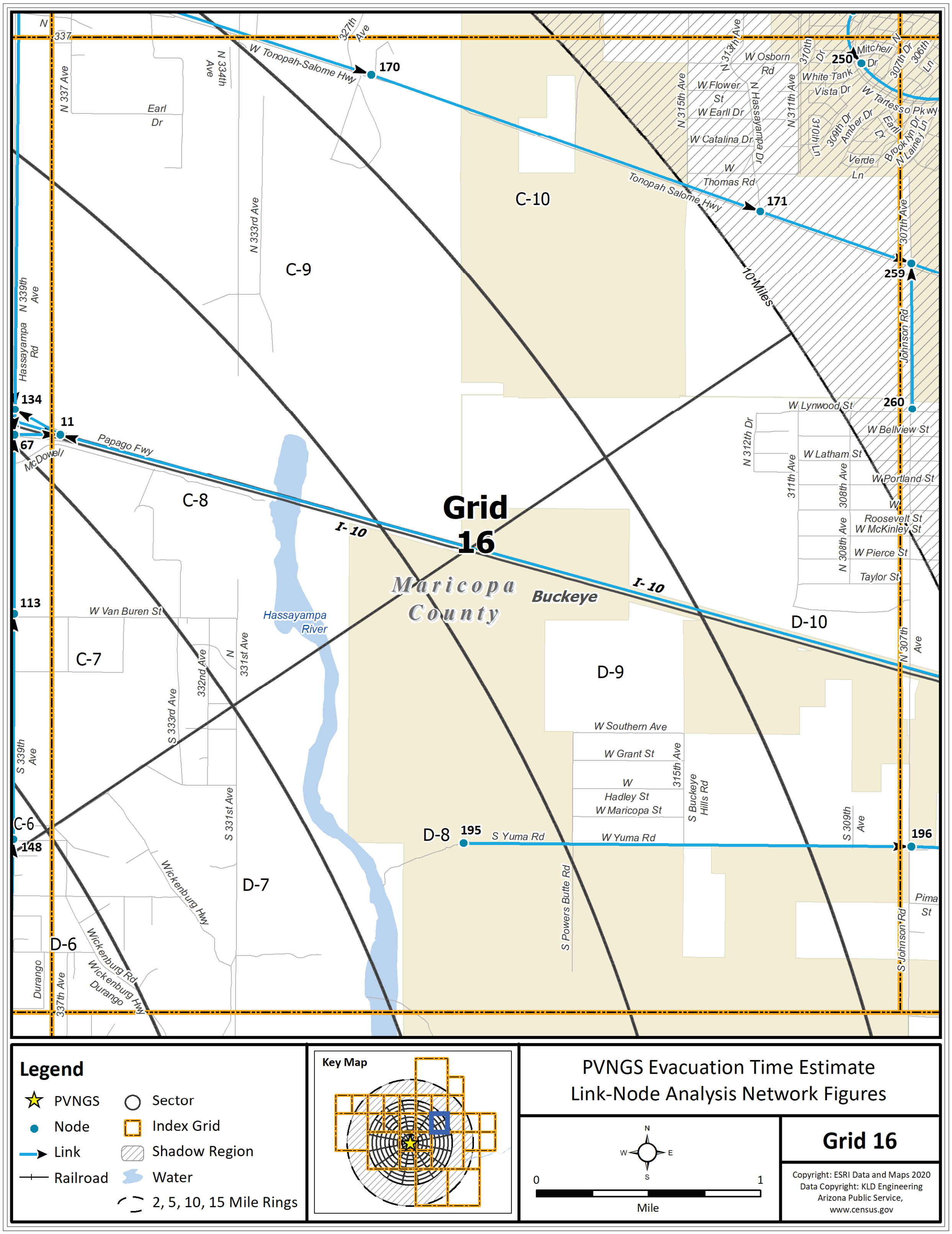

Figure K-17. Link-Node Analysis Network – Grid 16

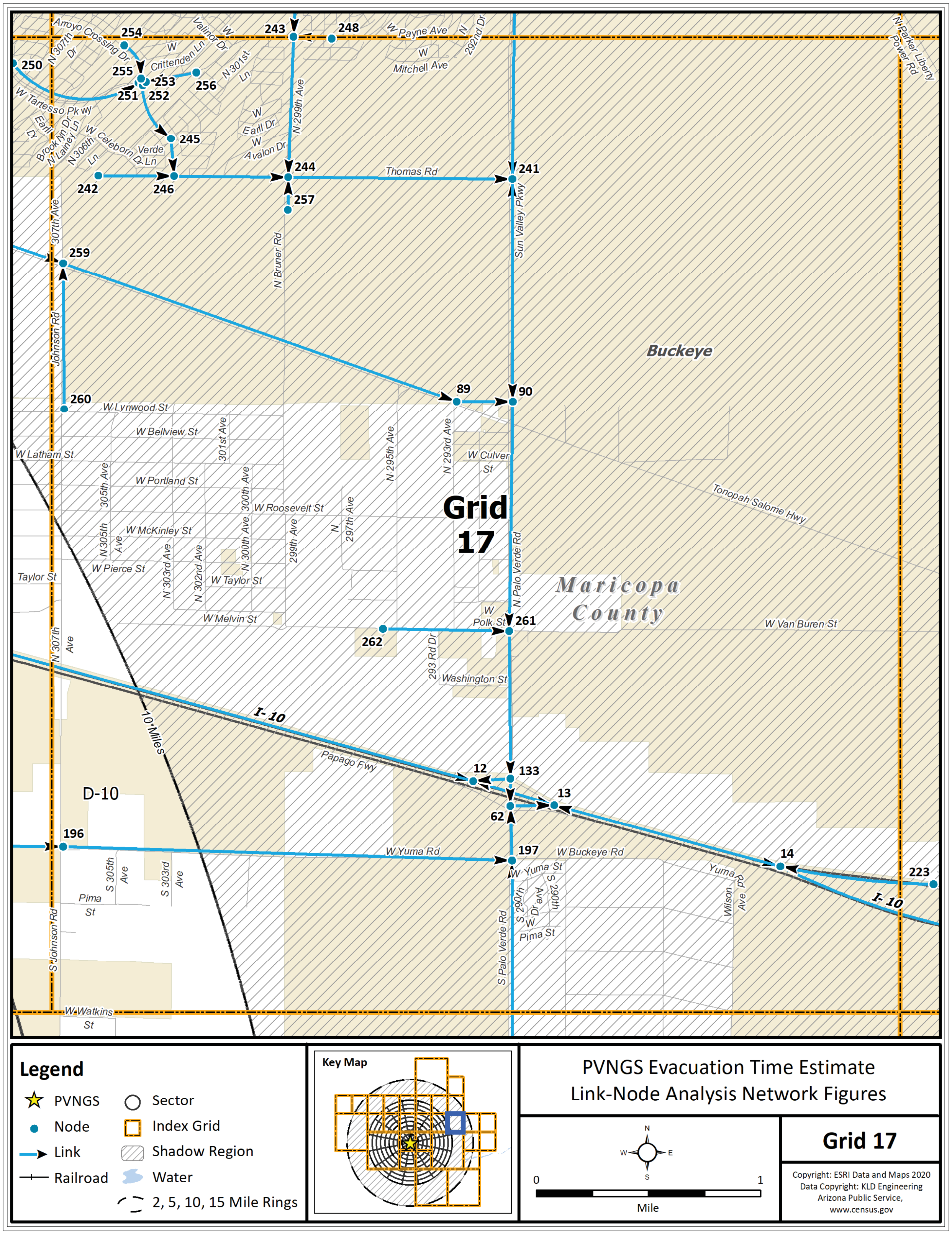

Figure K-18. Link-Node Analysis Network – Grid 17

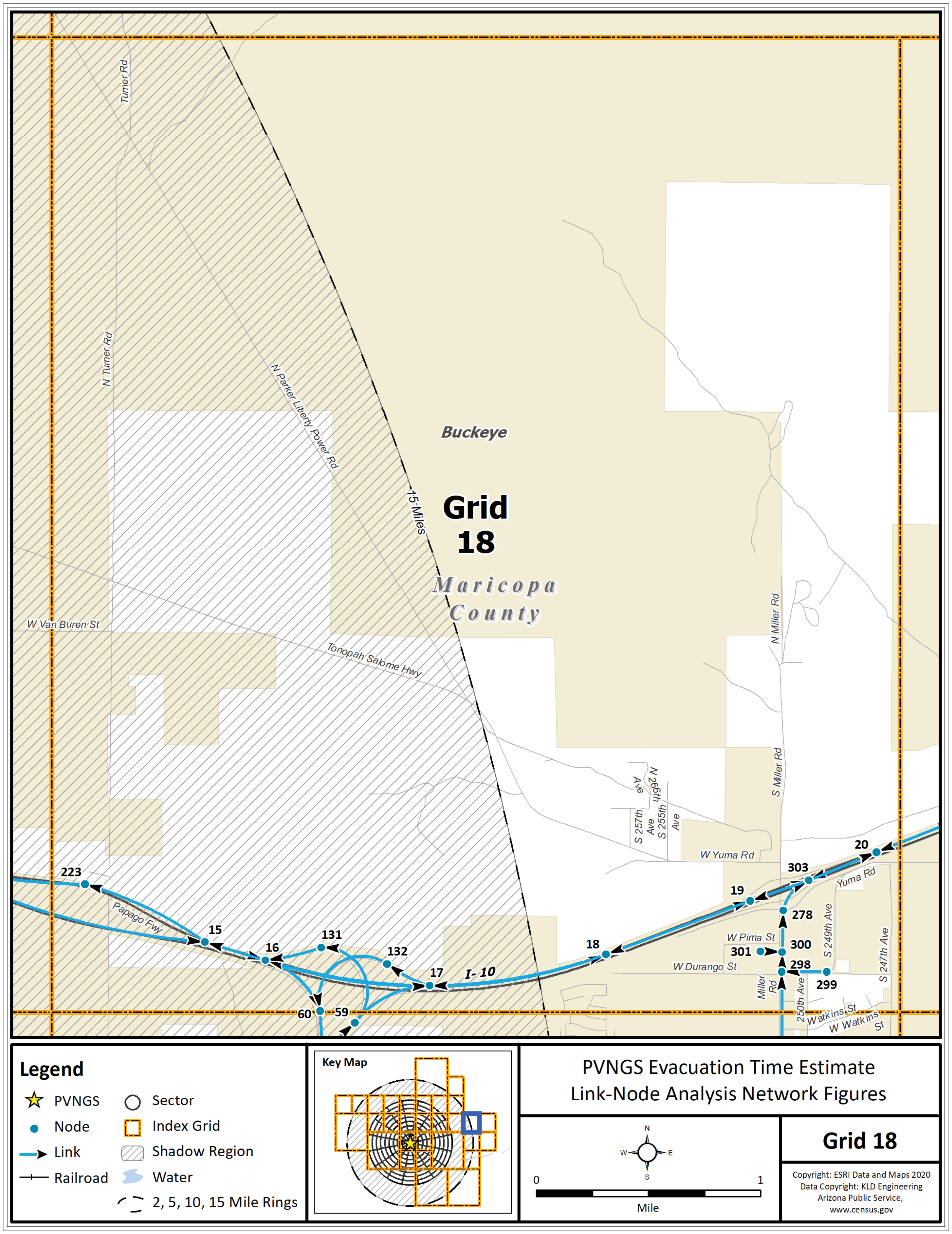

Figure K-19. Link-Node Analysis Network – Grid 18

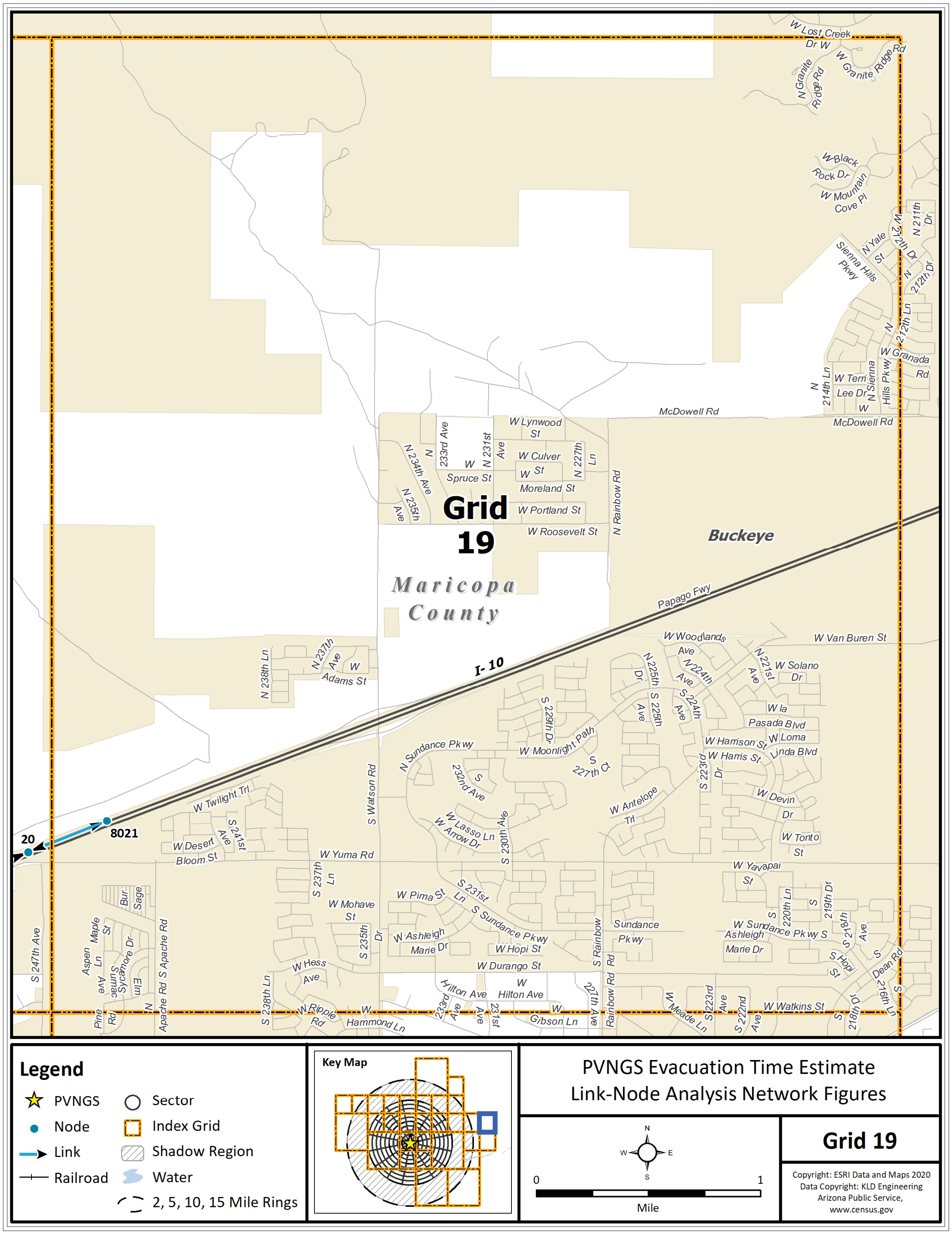

Figure K-20. Link-Node Analysis Network – Grid 19

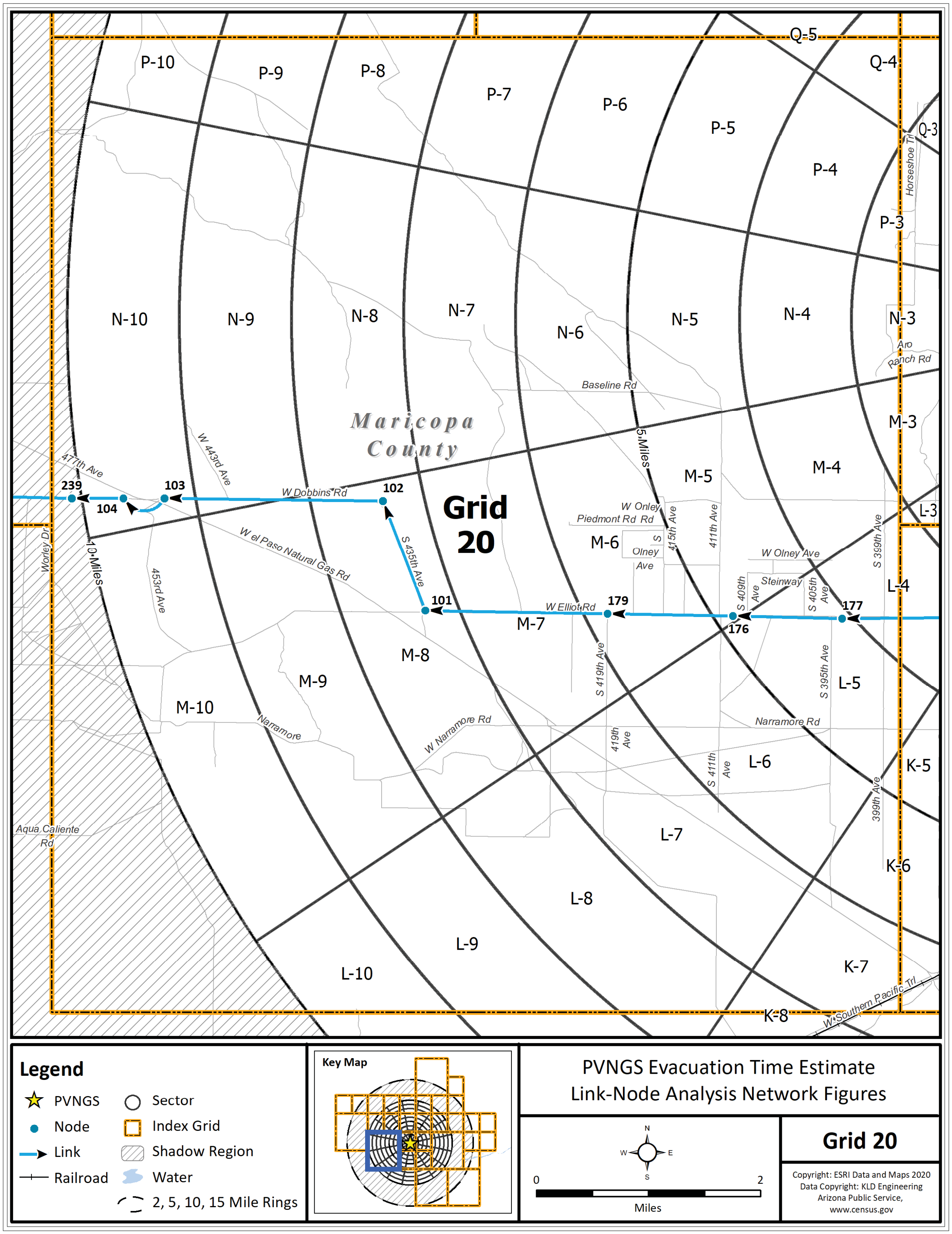

Figure K-21. Link-Node Analysis Network – Grid 20

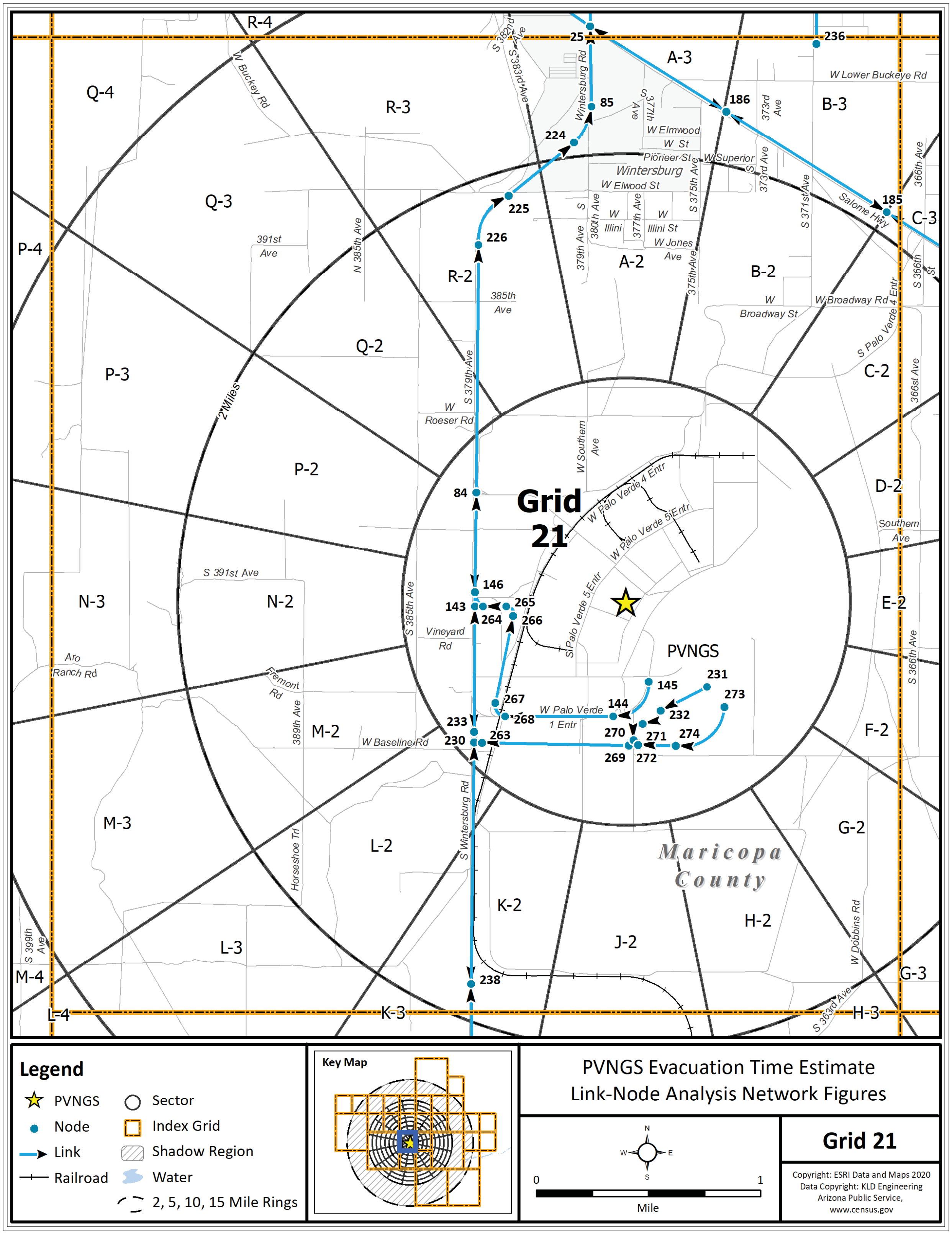

Figure K-22. Link-Node Analysis Network – Grid 21

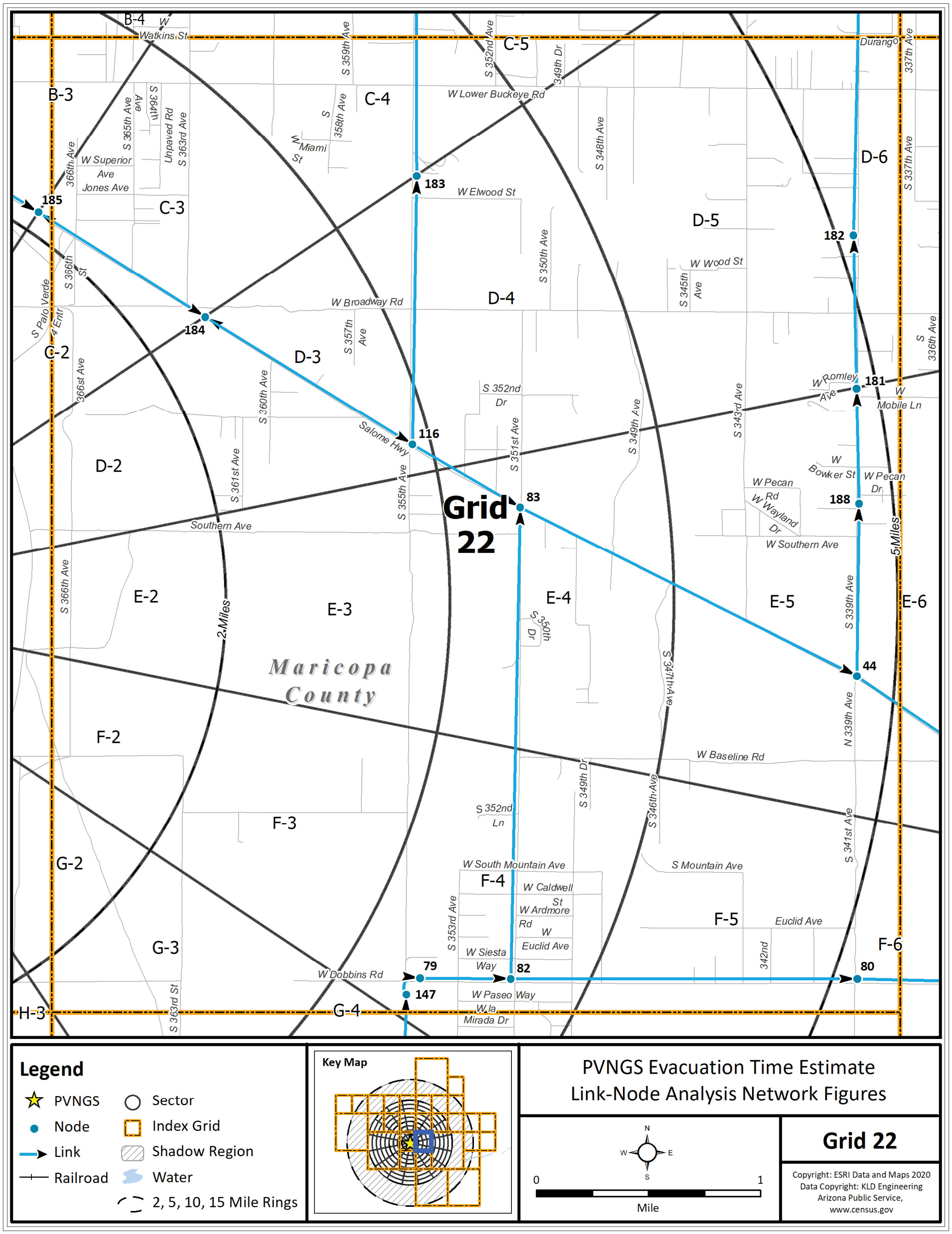

Figure K-23. Link-Node Analysis Network – Grid 22

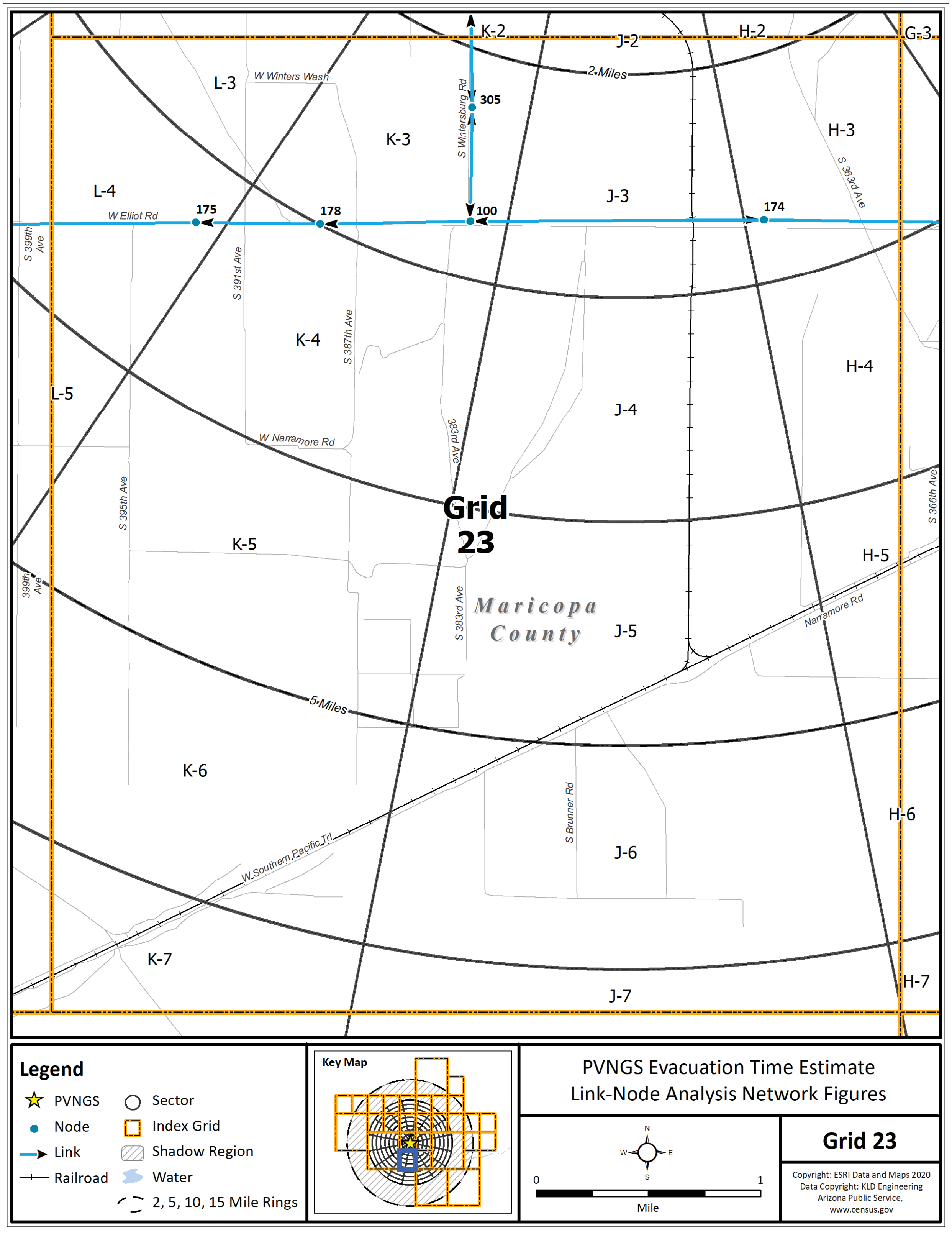

Figure K-24. Link-Node Analysis Network – Grid 23

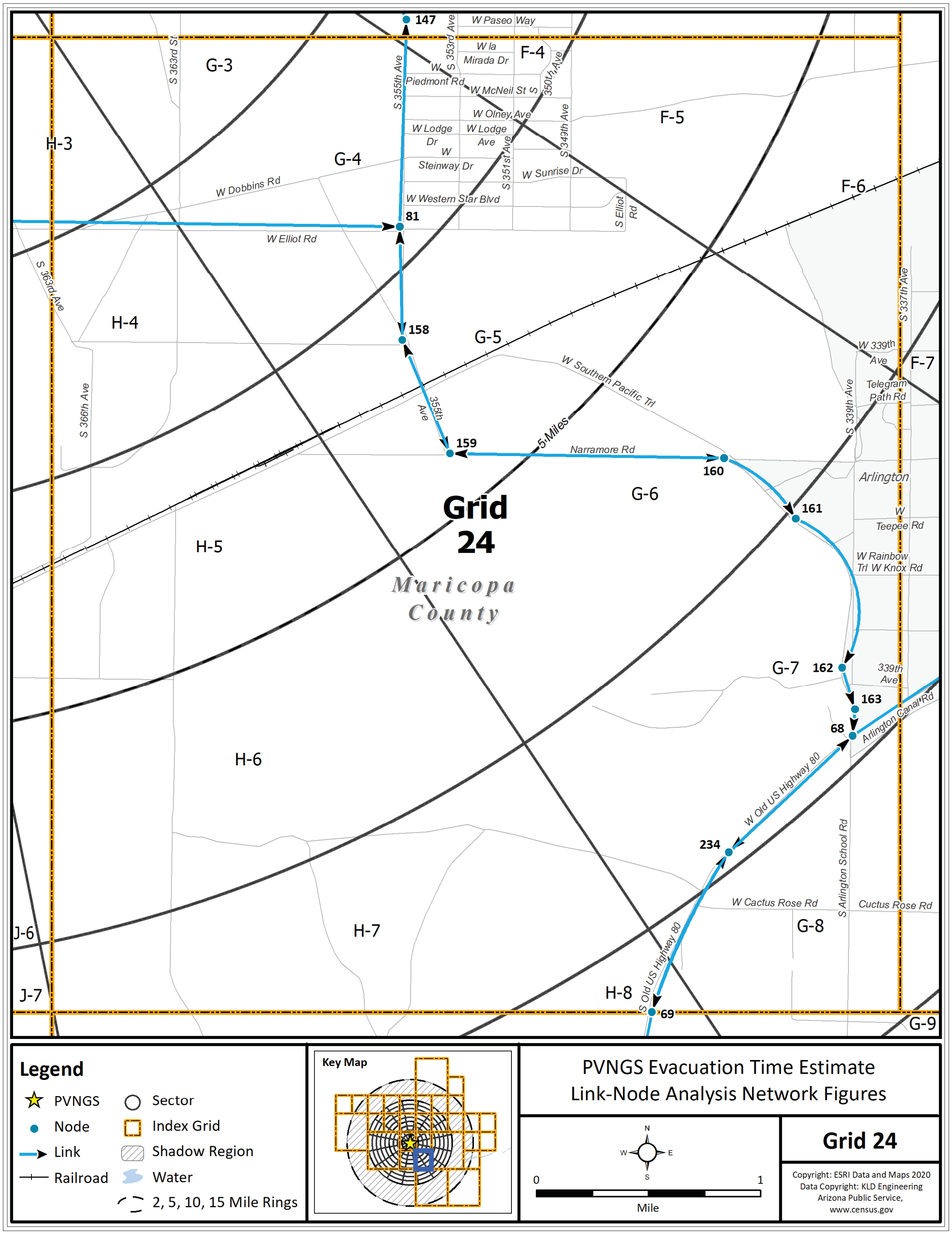

Figure K-25. Link-Node Analysis Network – Grid 24

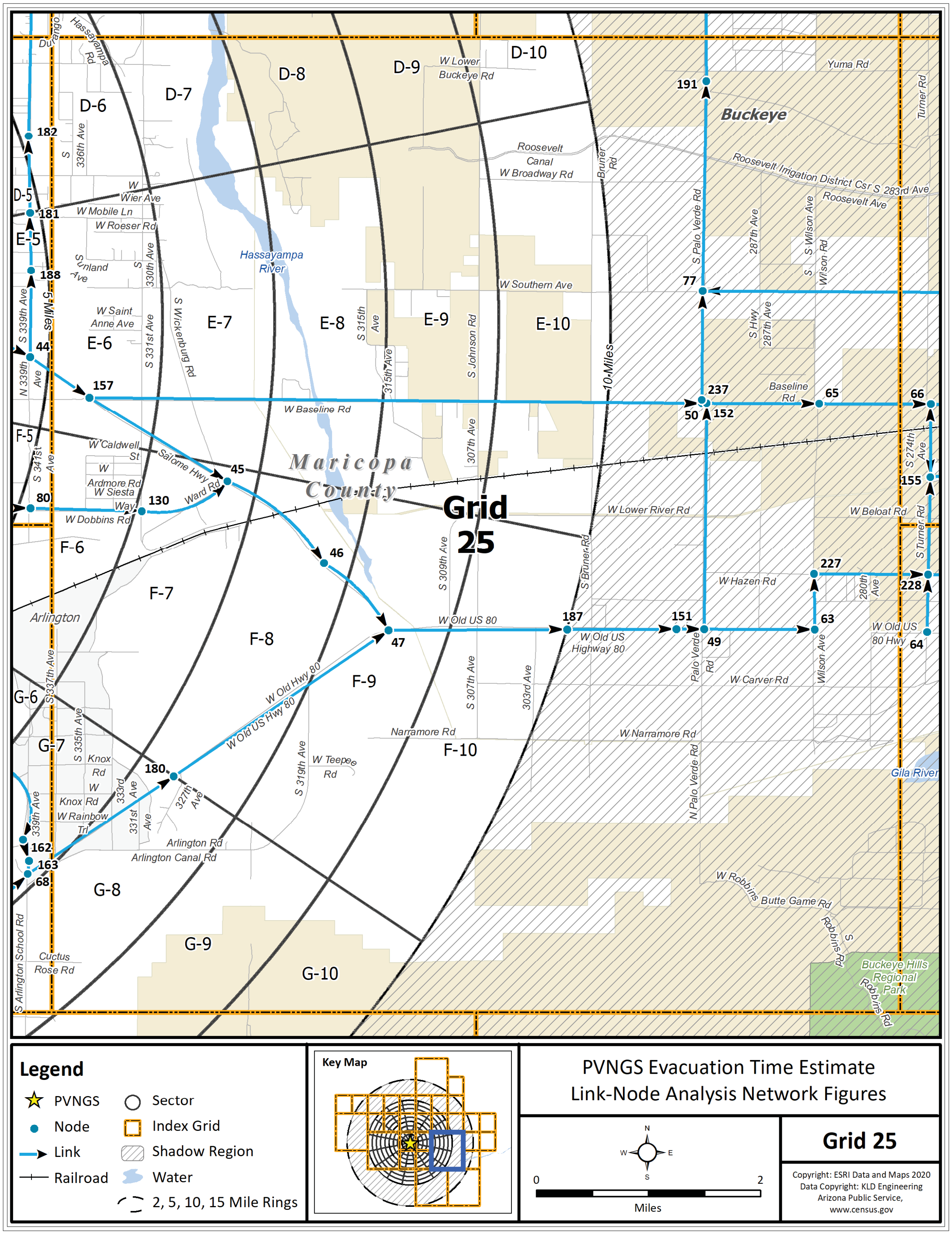

Figure K-26. Link-Node Analysis Network – Grid 25

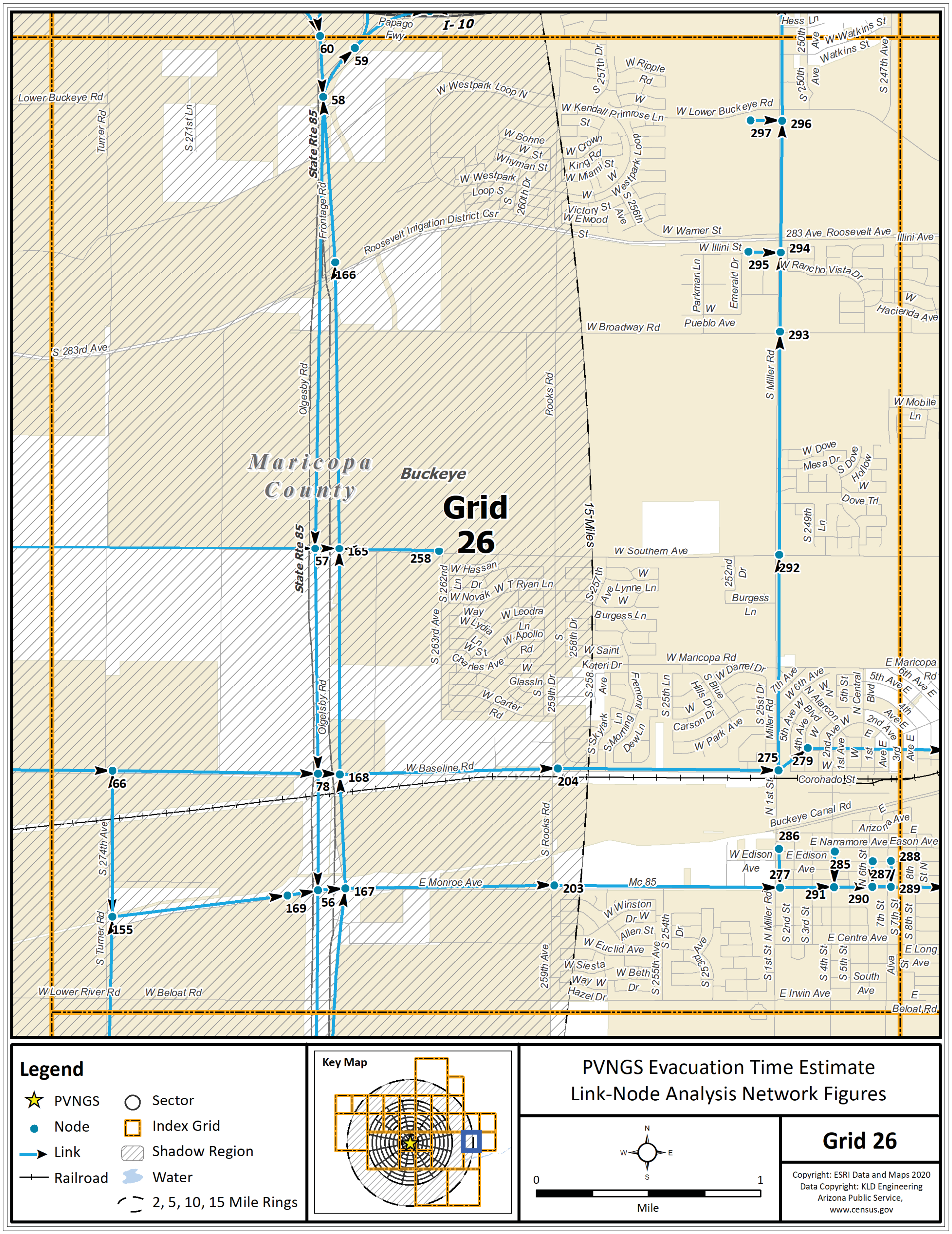

Figure K-27. Link-Node Analysis Network – Grid 26

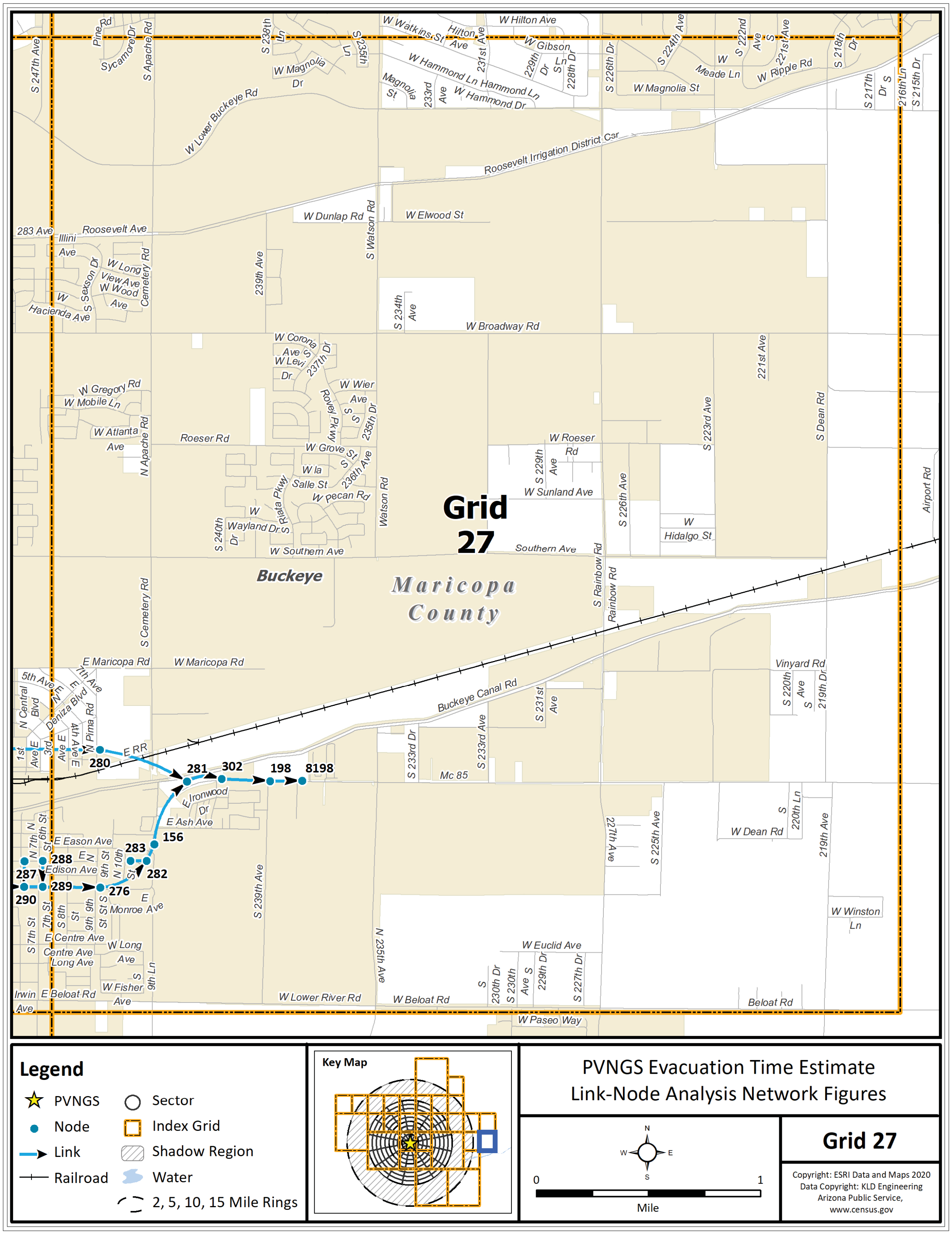

Figure K-28. Link-Node Analysis Network – Grid 27

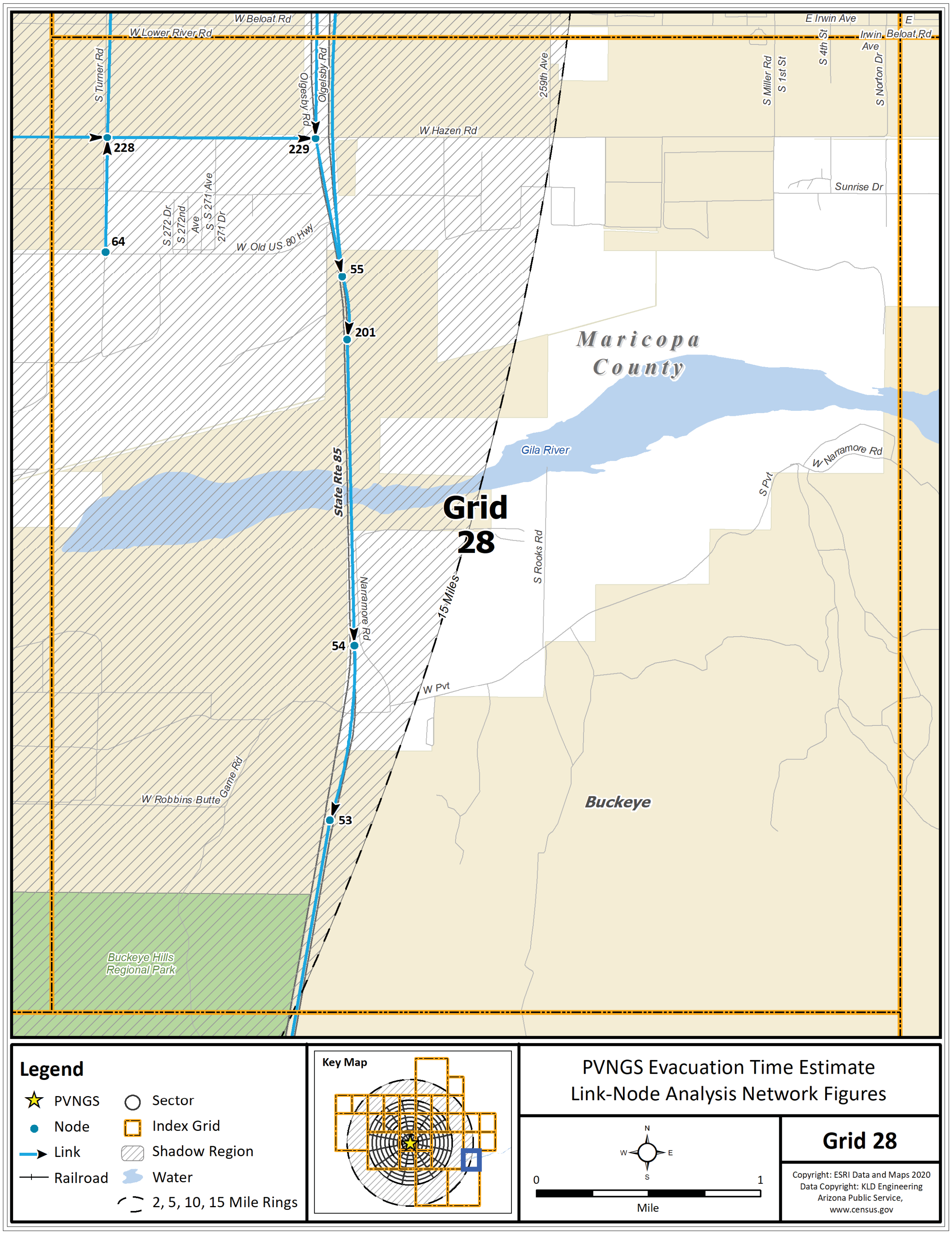

Figure K-29. Link-Node Analysis Network – Grid 28

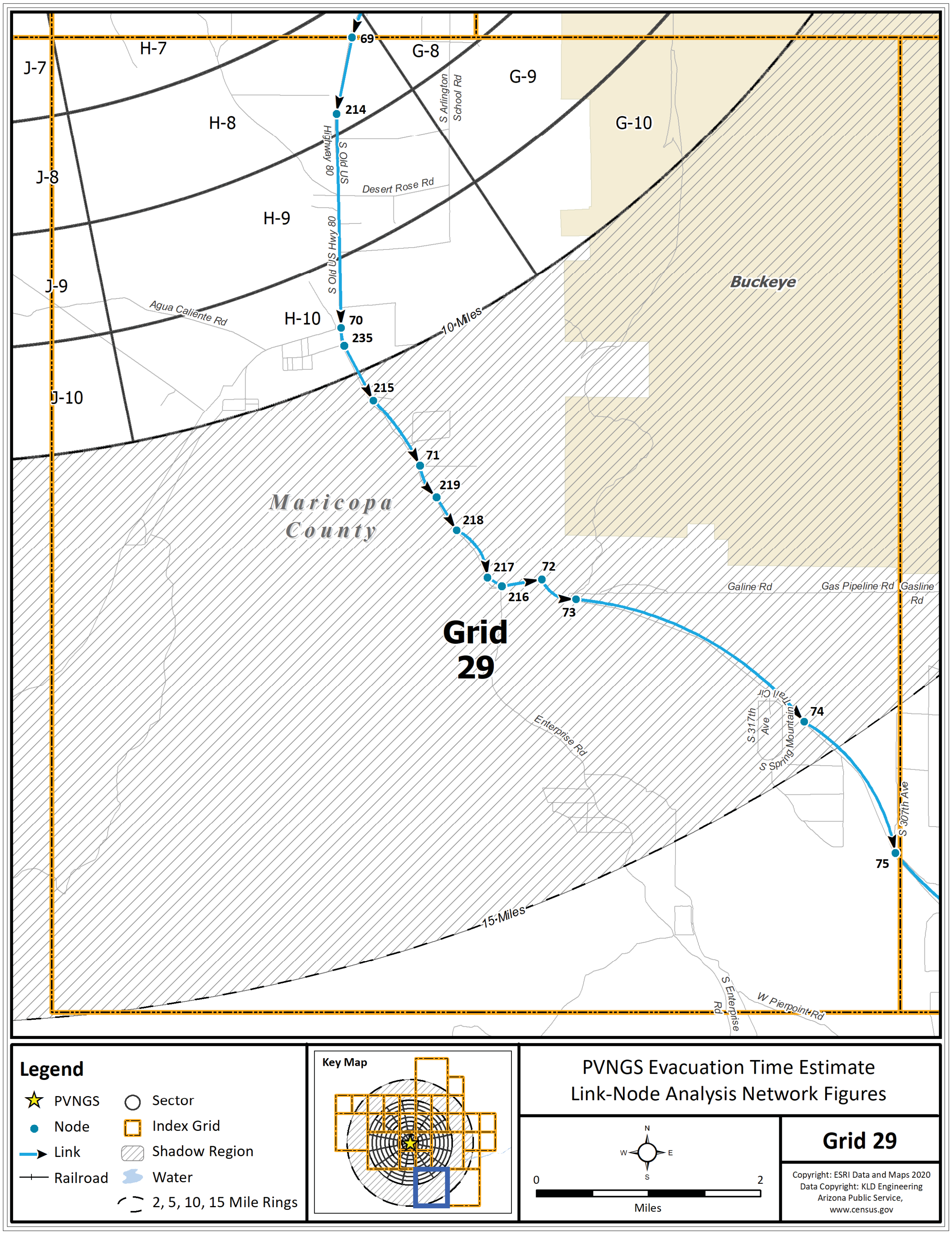

Figure K-30. Link-Node Analysis Network – Grid 29

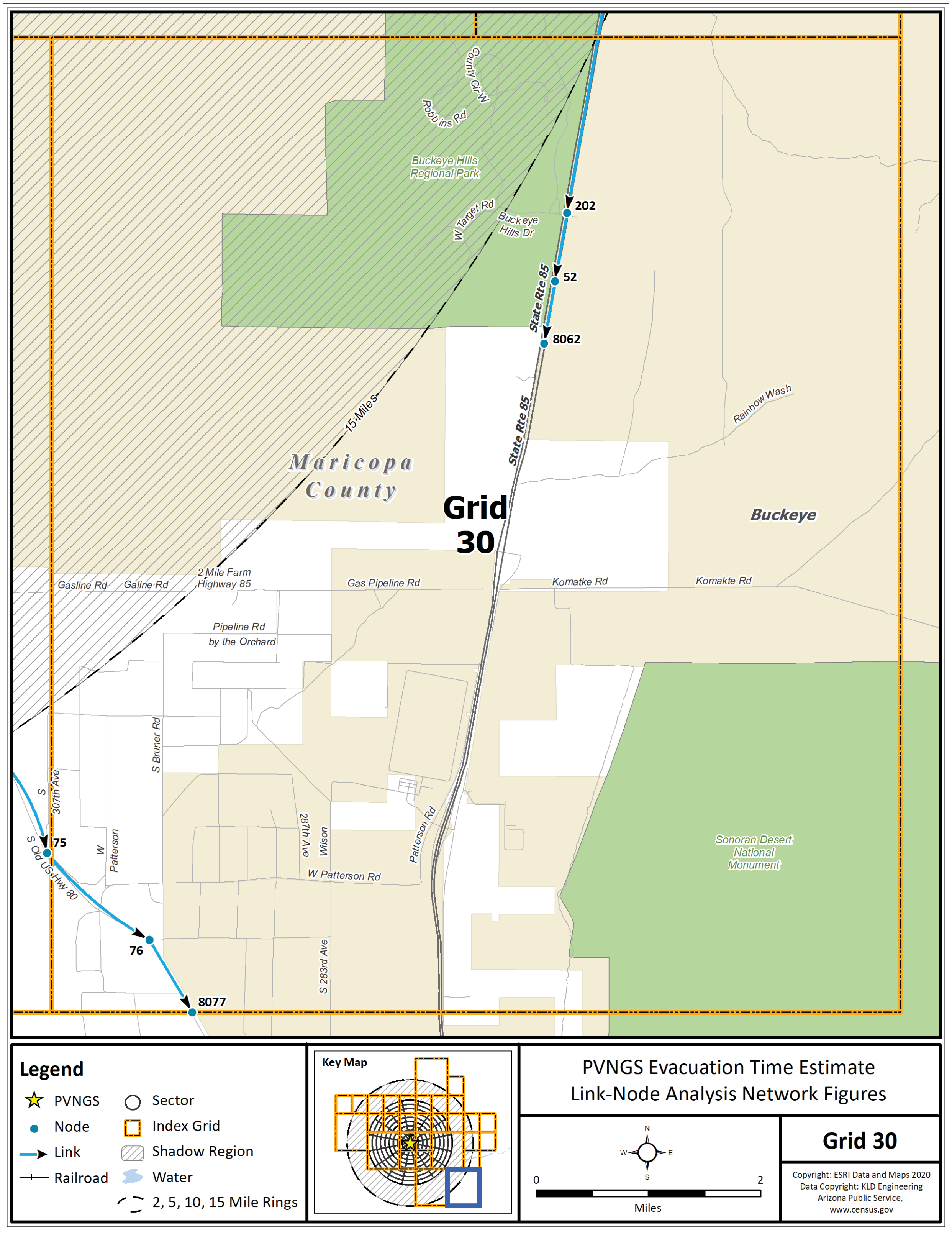

Figure K-31. Link-Node Analysis Network – Grid 30

APPENDIX L

Sector Boundaries

L. SECTOR BOUNDARIES

The emergency plans for the Palo Verde Nuclear Generating Station (PVNGS) indicate the use of a sector approach instead of emergency response planning areas. The Sectors are broken up by compass direction (22.5° each) and radial distance (1 mile increments) from the plant. The one mile region consists of primarily the plant site. There are a total of 145 Sectors as shown in Figure L-1.

According to the latest public information brochure, permanent residents are instructed to determine their Sector letter and mile ring closest to where their home is located and to record it for future reference.

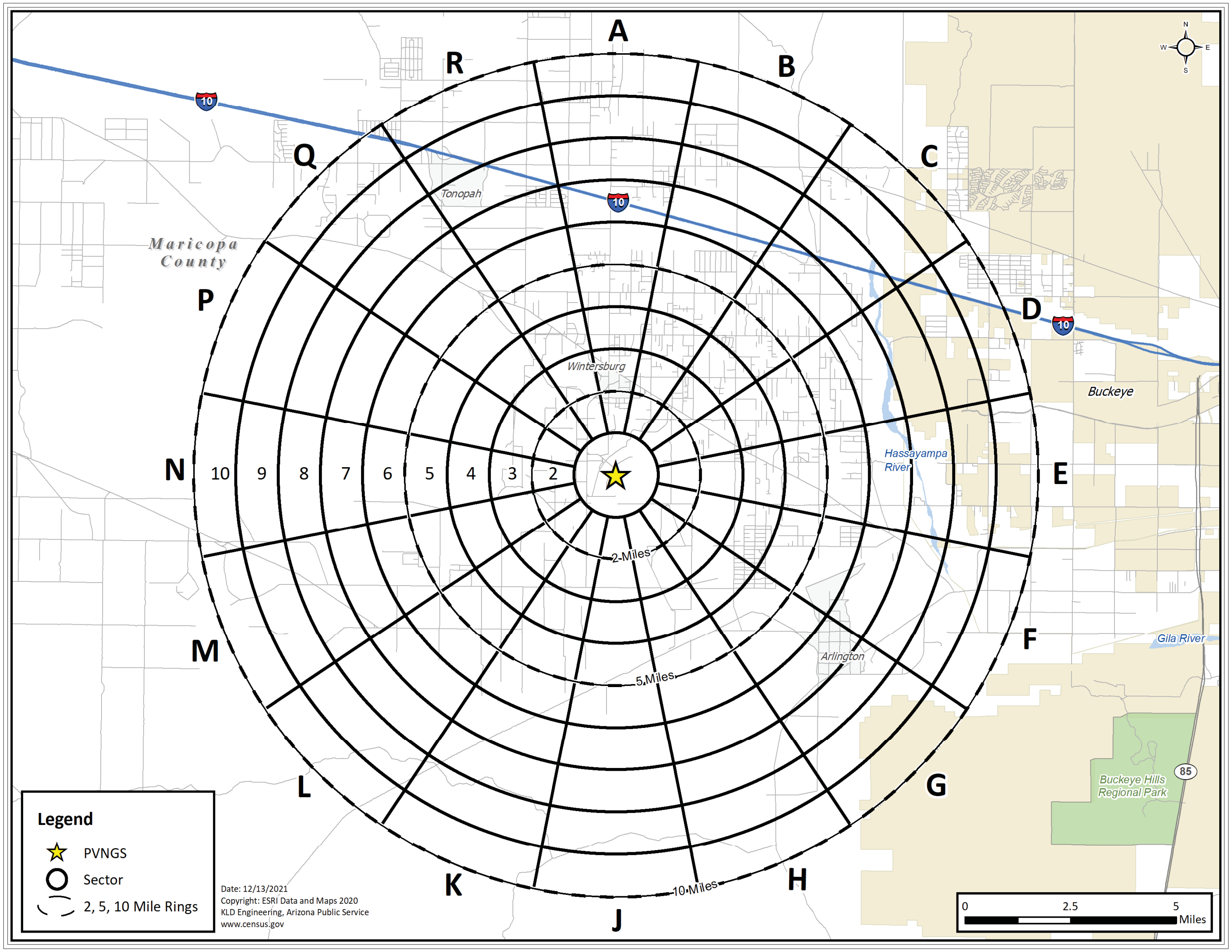

Figure L-1. PVNGS Sectors

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 Evacuation Time Estimates (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 Emergency Planning Zone (EPZ). Specifically, if the tail of the mobilization distribution were truncated (i.e., if those who responded most slowly to the Advisory to Evacuate (ATE), could be persuaded to respond much more rapidly) or if the tail were elongated (i.e., spreading out the departure of evacuees to limit the demand during peak times), how would the ETE be affected? The case considered was Scenario 1, Region 3; a summer, midweek, midday, with good weather evacuation of the entire EPZ. Table M-1 presents the results of this study.

If evacuees mobilize one hour quicker, the 90th percentile ETE is reduced by 30 minutes, and the 100th percentile ETE is reduced by 1 hour – a significant change. An increase in mobilization time by 1 hour increases the 90th and 100th percentile ETE by 1 hour.

As indicated in Section 7.3, traffic congestion within the EPZ clears at 2 hours and 55 minutes after the ATE, well before the completion of trip generation time. As such, congestion dictates the 100th percentile until 2 hours and 55 minutes after the ATE. After this time, trip generation (plus a 10-minute travel time to the EPZ boundary), dictates the 100th percentile ETE.

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 due to changes in the percentage of people who decide to relocate from the Shadow Region. The case considered was Scenario 1, Region 3; a summer, midweek, midday, with 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 ETE for each of the cases considered. The results show that eliminating the shadow evacuation (0%) has no impact to the 90th and 100th percentile ETEs. Tripling the shadow percentage (60%) increases the 90th percentile ETE by 5 minutes and has no impact to the 100th percentile ETE. Full evacuation (100%) of the Shadow Region increases the 90th and 100th percentile ETE by 5 minutes – minimal impact.

Note, the demographic survey results presented in Appendix F indicate that approximately 10% of households would elect to evacuate if advised to shelter, which differs from the assumption of 20% non-compliance suggested in NUREG/CR-7002, Rev 1. A sensitivity study was considered using the 10% shadow evacuation and the 90th and 100th percentile ETEs were not impacted.

The Shadow Region for PVNGS is sparsely populated except near Buckeye, outside of Sectors C, D, E, F and G. As shown in Figures 7-3 through 7-7, there is some congestion in the Shadow Region to gain access to I-10 but does not propagate into the EPZ (after 2 hours and 55 minutes), such that the EPZ evacuees would be delayed. Therefore, any additional shadow residents that decide to voluntarily evacuate are accommodated by the excess capacity available in the study area such that ETE are not significantly impacted. In addition, the trip generation (plus a 10-minute travel time to the EPZ boundary), dictates the 100th percentile ETE.

M.3 Effect of Changes in EPZ Resident Population

A sensitivity study was conducted to determine the effect on ETE due to changes in the permanent resident population within the study area (EPZ plus Shadow Region). 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 and could impact ETE.

As per the NRC's response to the Emergency Planning Frequently Asked Question (EPFAQ) 2013-001, the ETE population sensitivity study must be conducted to determine what percentage increase in permanent resident population causes an increase in the 90th percentile ETE of 25% or 30 minutes, whichever is less. The sensitivity study must use the scenario with the <u>longest 90th percentile ETE</u> (excluding the roadway impact scenario and the special event scenario if it is a one day per year special event).

Thus, the sensitivity study was conducted using the following planning assumptions:

1. The percent change in population within the study area was increased by up to 143%. Changes in population were applied to permanent residents only (as per federal guidance), in both the EPZ and the Shadow Region.
2. The transportation infrastructure remained fixed (as presented in Appendix K); the presence of future proposed roadway changes and/or highway capacity improvements were not considered.
3. The study was performed for the 2-Mile Region (R01), the 5-Mile Region (R02) and the entire EPZ (R03).
4. The scenario (excluding roadway impact) which yielded the <u>longest 90th percentile ETE</u> values was selected as the case to be considered in the sensitivity study (Scenario 11 - Winter, Midweek, Midday, with Good Weather, Special Event). The Special Event considered is a refueling outage at the plant, which is justified due to the duration of the outage, which could last more than a month.

Table M-3 presents the results of the sensitivity study. Section IV of Appendix E to 10 CFR Part 50, and NUREG/CR-7002, Rev 1, Section 5.4, require licensees to provide an updated ETE analysis to the NRC when a population increase within the EPZ causes <u>the longest 90th percentile ETE</u> values (for the 2-Mile Region, 5-Mile Region or entire EPZ) to increase by 25% or 30 minutes, whichever is less. All base ETE values are greater than 2 hours; 25 percent of these base ETE is always greater than 30 minutes. Therefore, the criterion for updating is 30 minutes.

Those percent population changes which result in the longest 90th percentile ETE change greater than or equal to 30 minutes are highlighted in red in Table M-3 – a 143% or greater increase in the full EPZ population. APS will have to estimate the full EPZ population on an annual basis. If the full EPZ population increases by 143% or more, an updated ETE analysis will be needed.

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

Trip Generation Time	Evacuation Time Estimate for Entire EPZ	
	90th Percentile	100th Percentile
4 Hours 45 Minutes	2:15	4:55
5 Hours 45 Minutes (Base)	2:45	5:55
6 Hours 45 Minutes	3:45	6:55

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

Percent Shadow Evacuation	Evacuating Shadow Vehicles[1]	Evacuation Time Estimate for Entire EPZ	
		90th Percentile	100th Percentile
0	0	2:45	5:55
10	980	2:45	5:55
20 (Base)	1,959	2:45	5:55
40	3,918	2:50	5:55
60	5,877	2:50	5:55
80	7,836	2:50	5:55
100	9,795	2:50	6:00

Table M-3. Evacuation Time Estimates for Variation with Population Change

EPZ and 20% Shadow Permanent Resident Population	Base	Population Change		
		141%	142%	143%
	12,094	29,147	29,268	29,389
ETE for the 90th Percentile				
		Population Change		
Region	**Base**	**141%**	**142%**	**143%**
2-MILE	2:45	2:45	2:45	2:45
5-MILE	3:00	3:05	3:05	3:05
FULL EPZ	2:55	3:20	3:20	**3:25**
ETE for the 100th Percentile				
		Population Change		
Region	**Base**	**141%**	**142%**	**143%**
2-MILE	5:45	5:45	5:45	5:45
5-MILE	5:50	5:50	5:50	5:50
FULL EPZ	5:55	6:00	6:00	6:00

[1] The Evacuating Shadow Vehicles, in Table M-2, represent the residents and employees who will spontaneously decide to relocate during the evacuation. The basis, for the base values shown, is a 20% relocation of shadow residents along with a proportional percentage of shadow employees. See Section 6 for further discussion.

APPENDIX N

ETE Criteria Checklist

N. ETE CRITERIA CHECKLIST

Table N-1. ETE Review Criteria Checklist

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
1.0 Introduction		
a. The emergency planning zone (EPZ) and surrounding area is described.	Yes	Section 1
b. A map is included that identifies primary features of the site including major roadways, significant topographical features, boundaries of counties, and population centers within the EPZ.	Yes	Figures 1-1, 3-1, 6-1
c. A comparison of the current and previous ETE is provided including information similar to that identified in Table 1-1, "ETE Comparison."	Yes	Table 1-3
1.1 Approach		
a. The general approach is described in the report as outlined in Section 1.1, "Approach."	Yes	Section 1.1, Section 1.3, Appendix D, Table 1-1,
1.2 Assumptions		
a. Assumptions consistent with Table 1-2, "General Assumptions," of NUREG/CR-7002 are provided and include the basis to support use.	Yes	Section 2
1.3 Scenario Development		
a. The scenarios in Table 1-3, "Evacuation Scenarios," are developed for the ETE analysis. A reason is provided for use of other scenarios or for not evaluating specific scenarios.	Yes	Table 2-1, Section 6, Table 6-2

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
1.4 Evacuation Planning Areas		
a. A map of the EPZ with emergency response planning areas (ERPAs) is included.	Yes	Figure 3-1, Figure 6-1
1.4.1 Keyhole Evacuation		
a. A table similar to Table 1-4 "Evacuation Areas for a Keyhole Evacuation", is provided identifying the ERPAs considered for each ETE calculation by downwind direction.	Yes	Table 6-1, Table 7-5, Table H-1
1.4.2 Staged Evacuation		
a. The approach used in development of a staged evacuation is discussed.	Yes	Section 7.2
b. A table similar to Table 1-5, "Evacuation Areas for a Staged Evacuation," is provided for staged evacuations identifying the ERPAs considered for each ETE calculation by downwind direction.	Yes	Table 7-3, Table 7-4
2.0 Demand Estimation		
a. Demand estimation is developed for the four population groups (permanent residents of the EPZ, transients, special facilities, and schools).	Yes	Section 3
2.1 Permanent Residents and Transient Population		
a. The U.S. Census is the source of the population values, or another credible source is provided.	Yes	Section 3.1, 2021 Population Data provided by MCDEM (within EPZ) and 2020 U.S. Census Data extrapolated to 2021 (within Shadow Region)
b. The availability date of the census data is provided.	Yes	Section 3.2

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
c. Population values are adjusted as necessary for growth to reflect population estimates to the year of the ETE.	Yes	Section 3.1, Section 3.2
d. A sector diagram, similar to Figure 2-1, "Population by Sector," is included showing the population distribution for permanent residents.	Yes	Figure 3-2
2.1.1 Permanent Residents with Vehicles		
a. The persons per vehicle value is between 1 and 3 or justification is provided for other values.	Yes	Section 3.1. Appendix F
2.1.2 Transient Population		
a. A list of facilities that attract transient populations is included, and peak and average attendance for these facilities is listed. The source of information used to develop attendance values is provided.	Yes	Section 3.3, Table E-3
b. Major employers are listed.	Yes	Section 3.4, Table E-2
c. The average population during the season is used, itemized and totaled for each scenario.	Yes	Table 3-5, Table 3-6 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 – see Table 6-4.
d. The percentage of permanent residents assumed to be at facilities is estimated.	Yes	Section 3.3 and Section 3.4

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
e. The number of people per vehicle is provided. Numbers may vary by scenario, and if so, reasons for the variation are discussed.	Yes	Section 3.3 and Section 3.4
f. A sector diagram is included, similar to Figure 2-1, "Population by Sector", is included showing the population distribution for the transient population.	Yes	Figure 3-6 (transients) and Figure 3-8 (employees)
2.2 Transit Dependent Permanent Residents		
a. The methodology (e.g., surveys, registration programs) used to determine the number of transit dependent residents is discussed.	Yes	Section 3.5
b. The State and local evacuation plans for transit dependent residents are used in the analysis.	Yes	Section 8.1
c. 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 is provided. Data from local/county registration programs are used in the estimate.	Yes	Section 3.9
d. Capacities are provided for all types of transportation resources. Bus seating capacity of 50 percent is used or justification is provided for higher values.	Yes	Item 3 of Section 2.4
e. An estimate of the transit dependent population is provided.	Yes	Section 3.5, Table 3-7, Table 3-9

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
f. A summary table showing the total number of buses, ambulances, or other transport assumed available to support evacuation is provided. The quantification of resources is detailed enough to ensure that double counting has not occurred.	Yes	Table 3-9, Table 8-1
2.3 Special Facility Residents		
a. Special facilities, including the type of facility, location, and average population, are listed. Special facility staff is included in the total special facility population.	N/A	No special facilities (other than schools which are discussed below) exist within the EPZ.
b. The method of obtaining special facility data is discussed.	N/A	
c. An estimate of the number and capacity of vehicles assumed available to support the evacuation of the facility is provided.	N/A	
d. The logistics for mobilizing specially trained staff (e.g., medical support or security support for prisons, jails, and other correctional facilities) are discussed when appropriate.	N/A	
2.4 Schools		
a. A list of schools including name, location, student population, and transportation resources required to support the evacuation, is provided. The source of this information should be identified.	Yes	Table 3-8, Table E-1, Section 3.6
b. Transportation resources for elementary and middle schools are based on 100 percent of the school capacity.	Yes	Section 3.6

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
c. The estimate of high school students who will use personal vehicle to evacuate is provided and a basis for the values used is given.	Yes	Section 3.6
d. The need for return trips is identified.	Yes	Section 8.1
2.5 Other Demand Estimate Considerations		
2.5.1 Special Events		
a. A complete list of special events is provided including 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 is analyzed in the ETE.	Yes	Section 3.7
c. The percentage of permanent residents attending the event is estimated.	Yes	Section 3.7
2.5.2 Shadow Evacuation		
a. A shadow evacuation of 20 percent is included consistent with the approach outlined in Section 2.5.2, "Shadow Evacuation".	Yes	Item 7 of Section 2.2, Figure 2-1 and Figure 7-1, Section 3.2
b. Population estimates for the shadow evacuation in the shadow region beyond the EPZ are provided by sector.	Yes	Section 3.2, Table 3-4, Figure 3-4
c. The loading of the shadow evacuation onto the roadway network is consistent with the trip generation time generated for the permanent resident population.	Yes	Section 5 – Table 5-8 (footnote)

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	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 3.9 and Section 3.10
b. The method of reducing background and pass-through traffic is described.	Yes	Section 2.2 – Assumptions 11 and 12 Section 2.5 Section 3.9 and Section 3.10 Table 6-3 – External Through Traffic footnote
c. Pass-through traffic is assumed to have stopped entering the EPZ about two (2) hours after the initial notification.	Yes	45 minutes was used. Section 2.5, Section 3.9
2.6 Summary of Demand Estimation		
a. A summary table is provided that identifies the total populations and total vehicles used in the analysis for permanent residents, transients, transit dependent residents, special facilities, schools, shadow population, and pass-through demand in each scenario.	Yes	Table 3-11, Table 3-12, and Table 6-4
3.0 Roadway Capacity		
a. The method(s) used to assess roadway capacity is discussed.	Yes	Section 4
3.1 Roadway Characteristics		
a. The process for gathering roadway characteristic data is described including the types of information gathered and how it is used in the analysis.	Yes	Section 1.3, Appendix D

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. Legible maps are provided that identify nodes and links of the modeled roadway network similar to Figure A-1, "Roadway Network Identifying Nodes and Links," and Figure A-2, "Grid Map Showing Detailed Nodes and Links."	Yes	Appendix K
3.2 Model Approach		
a. The approach used to calculate the roadway capacity for the transportation network is described in detail, and the description identifies factors that are expressly used in the modeling.	Yes	Section 4
b. Route assignment follows expected evacuation routes and traffic volumes.	Yes	Appendix B and Appendix C
c. A basis is provided for static route choices if used to assign evacuation routes.	N/A	Static route choices are not used to assign evacuation routes. Dynamic traffic assignment is used.
d. Dynamic traffic assignment models are described including calibration of the route assignment.	Yes	Appendix B and Appendix C
3.3 Intersection Control		
a. A list that includes the total numbers of intersections modeled that are unsignalized, signalized, or manned by response personnel is provided.	Yes	Table K-1
b. The use of signal cycle timing, including adjustments for manned traffic control, is discussed.	Yes	Section 4, Appendix G
3.4 Adverse Weather		
a. The adverse weather conditions are identified.	Yes	Assumption 2 and 3 of Section 2.6

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. The speed and capacity reduction factors identified in Table 3-1, "Weather Capacity Factors," are used or a basis is provided for other values, as applicable to the model.	Yes	Table 2-2
c. The calibration and adjustment of driver behavior models for adverse weather conditions are described, if applicable.	N/A	Driver behavior is not adjusted for adverse weather conditions.
d. The effect of adverse weather on mobilization is considered and assumptions for snow removal on streets and driveways are identified, when applicable.	N/A	Snow is not considered for this site.
4.0 Development of Evacuation Times		
4.1 Traffic Simulation Models		
a. General information about the traffic simulation model used in the analysis is provided.	Yes	Section 1.3, Table 1-3, Appendix B, Appendix C
b. If a traffic simulation model is not used to perform the ETE calculation, sufficient detail is provided to validate the analytical approach used.	N/A	Not applicable since a traffic simulation model was used.
4.2 Traffic Simulation Model Input		
a. Traffic simulation model assumptions and a representative set of model inputs are provided.	Yes	Section 2, Appendix J
b. The number of origin nodes and method for distributing vehicles among the origin nodes are described.	Yes	Appendix J, Appendix C
c. A glossary of terms is provided for the key performance measures and parameters used in the analysis.	Yes	Appendix A, Table C-1 and Table C-3

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.3 Trip Generation Time		
a. The process used to develop trip generation times is identified.	Yes	Section 5
b. When surveys are used, the scope of the survey, area of the survey, number of participants, and statistical relevance are provided.	Yes	Appendix F
c. Data used to develop trip generation times are summarized.	Yes	Appendix F, Section 5
d. The trip generation time for each population group is developed from site-specific information.	Yes	Section 5
e. The methods used to reduce uncertainty when developing trip generation times are discussed, if applicable.	Yes	N/A
4.3.1 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 before 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. Section 2.3, Assumption 3

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. The trip generation time accounts for the time and method to notify transients at various locations.	Yes	Section 5
c. The trip generation time accounts for transients potentially returning to hotels before evacuating.	Yes	Section 5, Figure 5-1
d. The effect of public transportation resources used during special events where a large number of transients are expected is considered.	Yes	Section 3.7
4.3.2 Transit Dependent Permanent Residents		
a. If available, existing and approved plans and bus routes are used in the ETE analysis.	N/A	Established bus routes do not exist. Basic bus routes were developed for the ETE analysis. Section 8.1 under Evacuation of Transit-Dependent Population, Section 20
b. The means of evacuating ambulatory and non-ambulatory residents are discussed.	Yes	Section 8.2
c. Logistical details, such as the time to obtain buses, brief drivers and initiate the bus route are used in the analysis.	Yes	Section 8.1, Figure 8-1
d. The estimated time for transit dependent residents to prepare and then travel to a bus pickup point, including the expected means of travel to the pickup point, is described.	Yes	Section 8.1 under Evacuation of Transit-Dependent Population
e. The number of bus stops and time needed to load passengers are discussed.	Yes	Section 8.1, Table 8-6 and Table 8-7
f. A map of bus routes is included.	Yes	Figure 10-2

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
g. The trip generation time for non-ambulatory persons including the time to mobilize ambulances or special vehicles, time to drive to the home of residents, time to load, and time to drive out of the EPZ, is provided.	Yes	Section 8.2
h. Information is provided to support analysis of return trips, if necessary.	Yes	Section 8.1 and 8.2
4.3.3 Special Facilities		
a. Information on evacuation logistics and mobilization times is provided.	N/A	No special facilities (other than schools which are discussed below) exist within the EPZ.
b. The logistics of evacuating wheelchair and bed bound residents are discussed.	N/A	
c. Time for loading of residents is provided.	N/A	
d. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.	N/A	
e. Discussion is provided on whether special facility residents are expected to pass through the reception center before being evacuated to their final destination.	N/A	
f. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.	N/A	
4.3.4 Schools		
a. Information on evacuation logistics and mobilization times is provided.	Yes	Section 2.4, Section 8.1, Table 8-2 and Table 8-3

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
b. Time for loading of students is provided.	Yes	Section 2.4, Section 8.1, Table 8-2 and Table 8-3
c. Information is provided that indicates whether the evacuation can be completed in a single trip or if additional trips are needed.	Yes	Section 8.1
d. If used, reception centers should be identified. A discussion is provided on whether students are expected to pass through the reception center before being evacuated to their final destination.	Yes	Section 8.1, Table 10-3
e. Supporting information is provided to quantify the time elements for each trip, including destinations if return trips are needed.	Yes	Section 8.1, Table 8-2 and Table 8-3
4.4 Stochastic Model Runs		
a. The number of simulation runs needed to produce average results is discussed.	N/A	DYNEV does not rely on simulation averages or random seeds for statistical confidence. For DYNEV/DTRAD, it is a meso-scopic simulation and uses dynamic traffic assignment model to obtain the "average" (stable) network work flow distribution. This is different from microscopic simulation, which is monte-carlo random sampling by nature relying on different seeds to establish statistical confidence. Refer to Appendix B for more details.
b. If one run of a single random seed is used to produce each ETE result, the report includes a sensitivity study on the 90 percent and 100 percent ETE using 10 different random seeds for evacuation of the full EPZ under Summer, Midweek, Daytime, Normal Weather conditions.	N/A	

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.5 Model Boundaries		
a. The method used to establish the simulation model boundaries is discussed.	Yes	Section 4.5
b. Significant capacity reductions or population centers that may influence the ETE and that are located beyond the evacuation area or shadow region are identified and included in the model, if needed.	Yes	Section 4.5
4.6 Traffic Simulation Model Output		
a. A discussion of whether the traffic simulation model used must be in equilibration prior to calculating the ETE is provided.	Yes	Appendix B
b. The minimum following model outputs for evacuation of the entire EPZ are provided to support review: 1. Evacuee average travel distance and time. 2. Evacuee average delay time. 3. Number of vehicles arriving at each destination node. 4. Total number and percentage of evacuee vehicles not exiting the EPZ. 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. Appendix J, Table J-2 2. Table J-2 3. Table J-4 4. None and 0%. 100 percent ETE is based on the time the last vehicle exits the evacuation area 5. Figures J-2 through J-13 (one plot for each scenario considered) 6. Table J-3
c. Color coded roadway maps are provided for various times (e.g., at 2, 4, 6 hrs.) during a full EPZ evacuation scenario, identifying areas where congestion exists.	Yes	Figure 7-3 through Figure 7-7

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
4.7 Evacuation Time Estimates for the General Public		
a. The ETE includes the time to evacuate 90 percent and 100 percent of the total permanent resident and transient population.	Yes	Table 7-1 and Table 7-2
b. Termination criteria for the 100 percent ETE are discussed, if not based on the time the last vehicle exits the evacuation zone.	N/A	100 percent ETE is based on the time the last vehicle exits the evacuation zone.
c. The ETE for 100 percent of the general public includes all members of the general public. Any reductions or truncated data is explained.	Yes	Section 5.4.1 – truncating survey data to eliminate statistical outliers Table 7-2 – 100th percentile ETE for general population
d. Tables are provided for the 90 and 100 percent ETEs similar to Table 4-3, "ETEs for a Staged Evacuation," and Table 4-4, "ETEs for a Keyhole Evacuation."	Yes	Table 7-3 and Table 7-4
e. ETEs are provided for the 100 percent evacuation of special facilities, transit dependent, and school populations.	Yes	Section 8
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 are discussed.	Yes	Section 9, Appendix G
b. Adjustments or additions to the traffic control plan that affect the ETE is provided.	Yes	Section 9, Appendix G

NRC Review Criteria	Addressed in ETE Analysis (Yes/No/NA)	Comments
5.2 Enhancements in Evacuation Time		
a. The results of assessments for enhancing evacuations are provided.	Yes	Appendix M
5.3 State and Local Review		
a. A list of agencies contacted is provided and the extent of interaction with these agencies is discussed.	Yes	Table 1-1
b. Information is provided on any unresolved issues that may affect the ETE.	Yes	Results of the ETE study were formally presented to state and local agencies at the final project meeting. Comments on the draft report were provided and were addressed in the final report. There are no unresolved issues.
5.4 Reviews and Updates		
a. The criteria for when an updated ETE analysis is required to be performed and submitted to the NRC is discussed.	Yes	Appendix M, Section M.3
5.4.1 Extreme Conditions		
a. The updated ETE analysis reflects the impact of EPZ conditions not adequately reflected in the scenario variations.	N/A	This ETE is being updated as a result of the availability of US Census Bureau decennial census data.
5.5 Reception Centers and Congregate Care Center		
a. A map of congregate care centers and reception centers is provided.	Yes	Figure 10-3