Tierra Robles Area Evacuation Traffic Study

Prepared for
Shasta Red LLC

January 2020

This report is prepared with the assistance of De Lapide & Associates, Inc.

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1.0 Background

1.1 Tierra Robles Residential Project

The 715-acre Tierra Robles Planned Development project (TRPD) proposes the construction of housing on 166 parcels in the wildland-urban intermix area east of the City of Redding in Shasta County, California. Figure 1-1 depicts the location and neighboring area of the proposed development. By virtue of its location, the development may be susceptible to wildfire hazards. In recognition of the potential for such a hazard, this evacuation traffic study assesses how long it would take to clear the development and neighboring areas of residents and visitors under specified emergency scenarios. The highlighted roadways on Figure 1-1 depict the through-roads in the area, the outer roadways demarcate the approximate evacuation area, and the figure also shows potential locations for temporary refuge during evacuations.

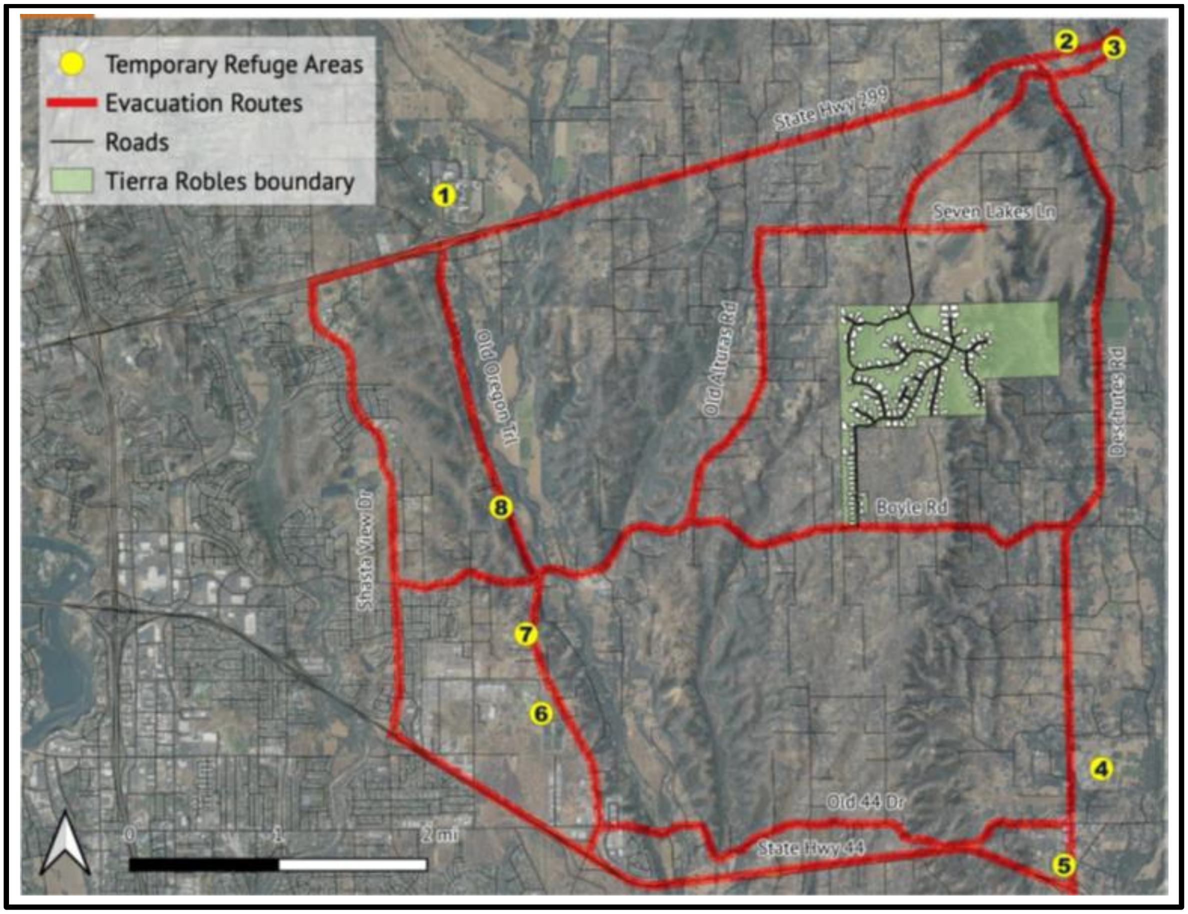
1.2 Study Purpose

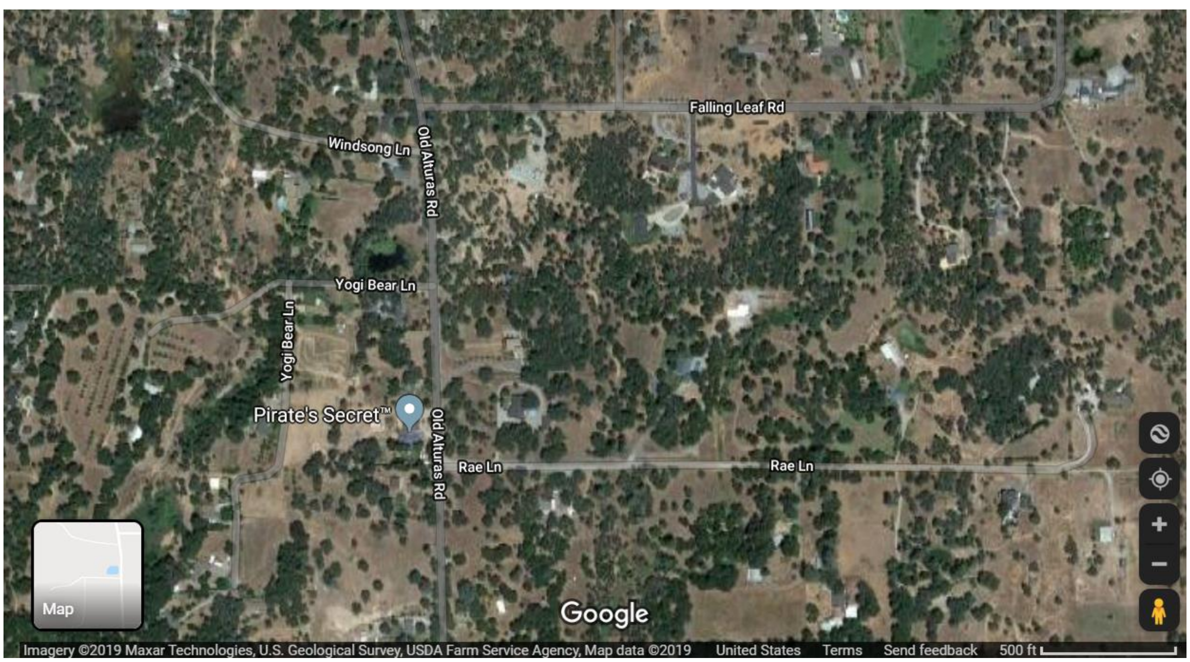
This study conducted tests of emergency evacuation under various scenarios to identify operational performance throughout the area road network as residents seek to exit via through-roads. Based on the tests, the assessment is to identify minimum time needed to evacuate neighborhoods or areas under the emergency scenarios and to confirm or modify key evacuation routes and temporary refuge areas. In so doing, the objective is to illustrate potential impacts if certain key routes are cut off or are unusable during wildfire events. The evacuation-access modeling procedure focused on routes that would be usable for effective departures while allowing access for first responders.

1.3 Area Road Network

Close examination of the area road network reveals a web of multiple single-access roads. A single access road allows residents to come into an area by a specific route and depart by returning in the reverse direction only; there is no secondary access for entry or exit. This type of network configuration forces residents to use particular through-roads to get into or out of areas no matter the direction of evacuation. The predominance of this type of network poses some restriction on which way traffic must flow under various evacuation scenarios. It is discernible from study area maps, for instance, that certain residential enclaves take singular access from CA 299; residents in those areas must use CA 299 whether evacuation is toward the north, south, east, or west. Most of the roadways in the study area are two-lane, two-way roads, but are designed to operate at varying speeds from 25 miles per hour (mph) to 60 mph according to Shasta County Geographic Information Systems (GIS) data. A two-lane, two-way road consists of two opposing lanes of undivided traffic.

Figure 1-1: Tierra Robles Location and Study Area





Single-access roads intersect Old Alturas Rd (a through-road) within the wildland-urban intermix area

2.0 Study Approach

2.1 Evacuation Scenarios

Human settlement activity in the project area and the network of through-roads suggest an evacuation area envelope bound approximately by CA 299 to the north, CA 44 to the south, Old Oregon Trail on the west, and Deschutes Road on the east. Figure 2-1 highlights the through-roads in the study area network. Depending on the origin of a wildfire, one can discern the following five potential evacuation scenarios:

1. Split evacuations toward all directions north, south, east, and west of the project area
2. All evacuations to the north – toward Refuge Areas 1, 2, and 3
3. All evacuations to the south – toward Refuge Areas 4, 5, and 6
4. All evacuations to the east – toward Refuge Areas 2, 3, 4, and 5
5. All evacuations to the west – toward Refuge Areas 1, 6, 7, and 8

The availability of multiple refuge areas under each scenario poses an advantage as traffic flow would distribute to multiple locations instead of one. The distribution of traffic can result in lower evacuation times than if all motorists headed to a single location.

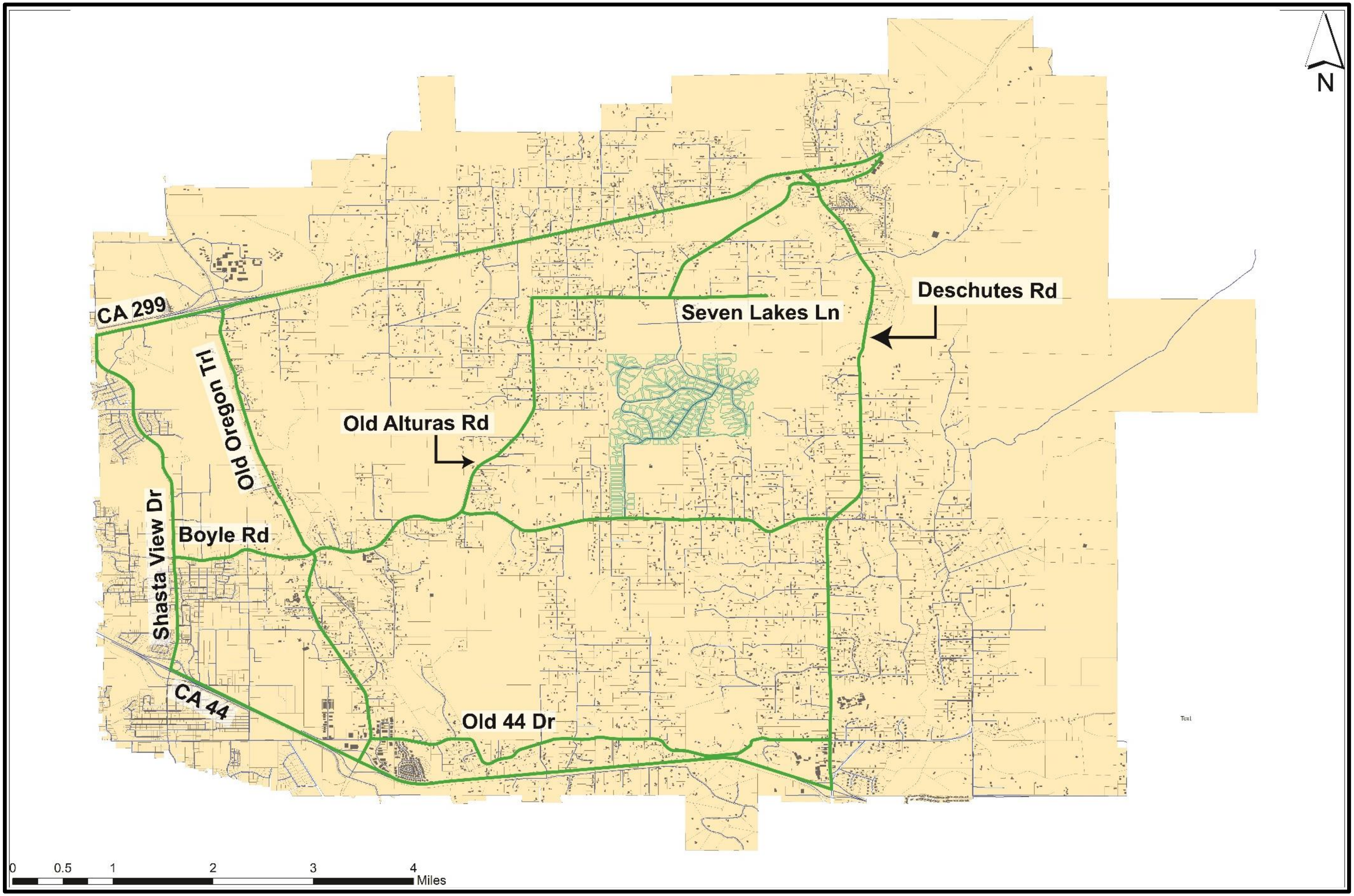
2.2 Data Compilation & Assumptions

The Evacuation Impact Assessment involved compilation of relevant data, application of an evacuation modeling tool including simulation of traffic flow through the network, and mapping of results. The analytical approach calculated the evacuation travel time across relevant roadway segments. For context, Figure 2-1 depicts a slightly extended geographic area than the evacuation area and study network.

2.2.1 Base Geographic Information Systems (GIS) Data

Shasta County provided the necessary geospatial datasets or layers via its website. The data include the roadway network and its geometric characteristics (segment lengths, number of lanes, and design speeds); buildings by type (residential, community, and accessory); and assessor's parcel information. The information consolidated into Geographic Information Systems (GIS) files were joined to extract tables for the roadway network with special focus on such attributes for street segments as identification number, street name, roadway segment length, design speed, the number of lanes on each roadway segment, and the types and numbers of buildings on each roadway segment.

Figure 2-1: Tierra Robles Area Study Network



2.2.2 US Census Data: Vehicle Availability

US Census data aided the determination of the average number of vehicles per dwelling unit in the area, which produced the assumption that each household would evacuate with an average of two automobiles. The summary of assumptions later in this section explains the treatment for potential number of vehicles to evacuate from community and municipal facilities and other non-residential sites, if they are not among the temporary refuge areas.

2.3 Integration of Tierra Robles Development

Compilation of the database for the evacuation study obviated the integration of the layout of the Tierra Robles Planned Development (from AutoCAD) with GIS data. This enabled the estimation and inclusion of trips to be generated by the development during evacuation events in the analysis. Figure 2-1 highlights the proposed layout of the Tierra Robles development within the study area. All other GIS maps in this report include the road network within the development.

2.4 Selection of Refuge Areas

Examination of building types in Figure 2-2 reveals that areas designated in Figure 1-1 as “temporary refuge areas” are among the large, community facilities in the area. The largest of them is the campus of Shasta College. Figure 2-3 annotates potential refuge locations with aerial images that are labelled for corresponding location numbers.

Approach to Shasta College (Refuge Area 1) depicts wildland-urban intermix area

Figure 2-2: Key Building Types in Tierra Robles Study Area

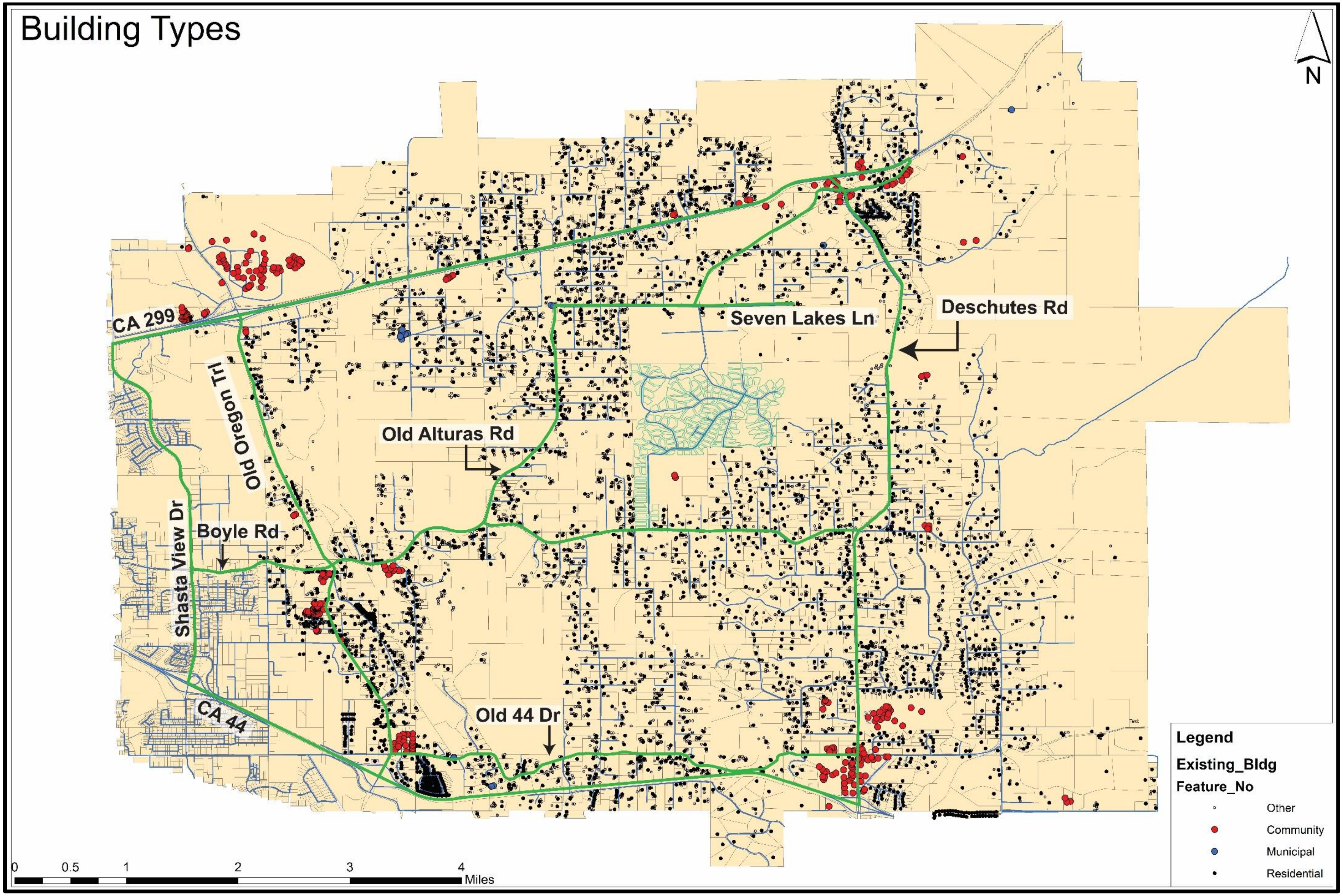
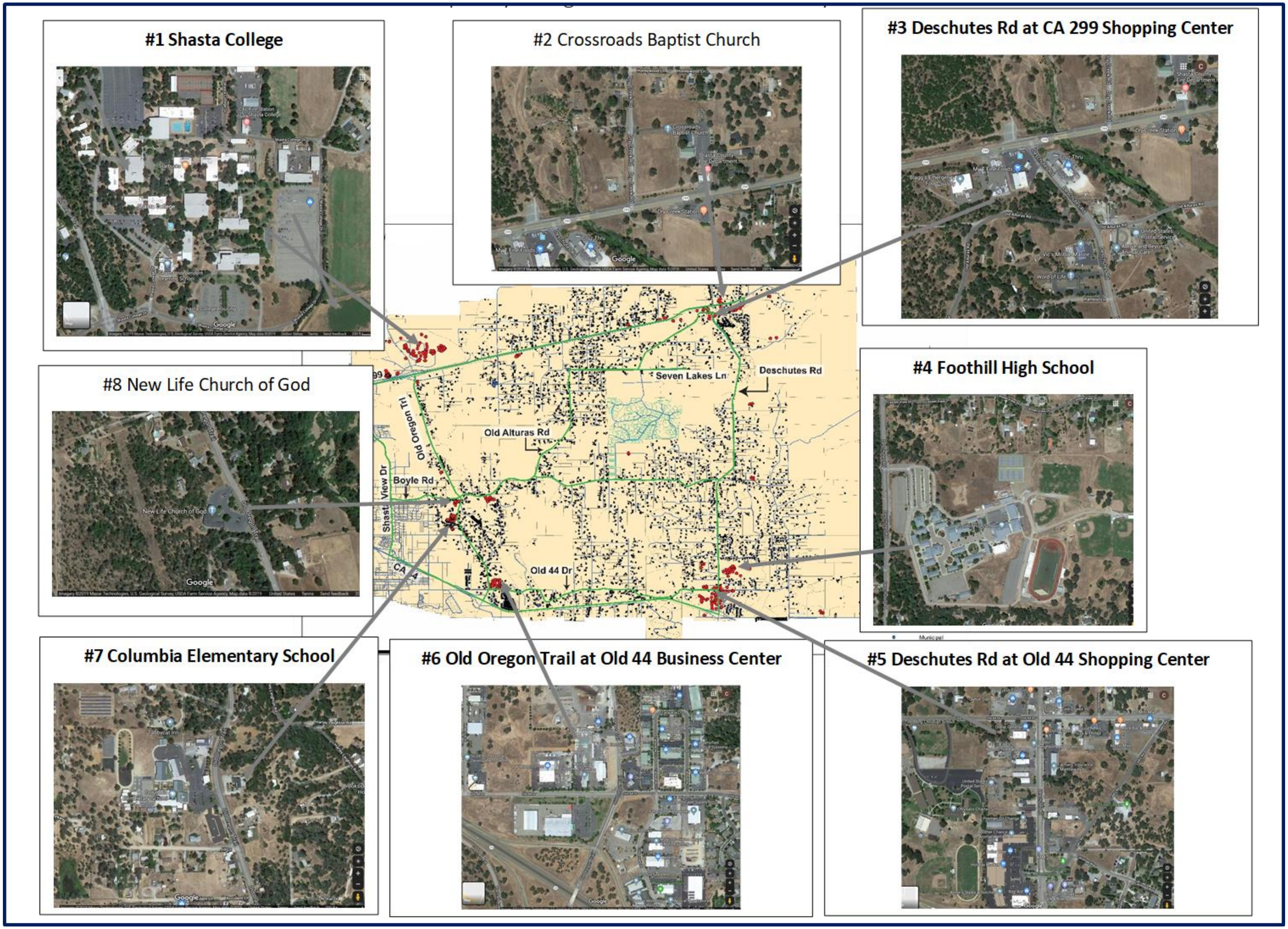


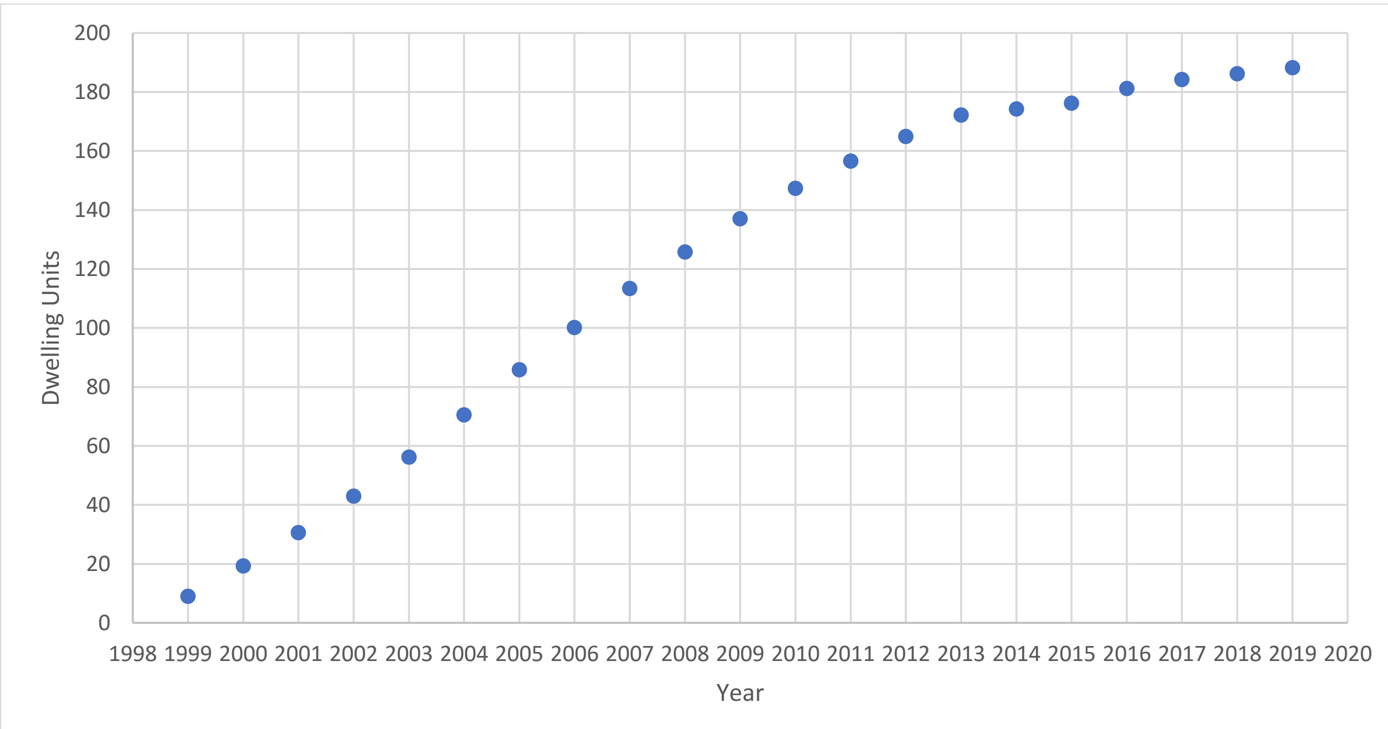
Figure 2-3: Temporary Refuge Areas in Tierra Robles Study Area



2.5 Background Growth

Cumulative trends over two decades in new home construction within one mile of Tierra Robles depict tapering off as shown in Figure 2-4. This is expected over time as vacant available land begins to deplete. The trend suggests an average growth of three new home constructions per year over the last half decade. Applying this statistic results in a projection of approximately 45 units in additional construction by 2035. For analysis, the 45 units are added to the large parcel due north of the Tierra Robles development. This assures generation of vehicle trips for background growth in addition to trips from the Tierra Robles Planned Development (TRPD) and from other existing buildings.

Figure 2-4: Cumulative Trends in Homes Constructed (within one mile of the TRPD)



2.6 Network Vehicle Volumes

The traffic volume anticipated to flow through the study network was estimated according to best practice assumptions in traffic flow analysis. Table 2-1 is a summary of the key assumptions. Projections indicate the equivalent of approximately 7,410 passenger cars would flow through the study network as motorists head toward appropriate refuge areas. Table 2-2 is a summary of traffic volume estimates for evacuation events.

Assigned volumes assumed the use of any or all 8 designated refuge areas, as appropriate, as evacuation destinations for particular circumstances that are captured under the five scenarios. The selection of through-roads for assigned volumes assumed motorists would head toward the closest refuge areas under specific scenarios. Evacuation paths were determined as the shortest travel distance paths to the nearest applicable refuge areas.

Table 2-1: Key Assumptions in Data Compilation

Traffic Generator	Assumption	Source for Assumption
Residential buildings	average of 2 vehicles per housing unit	US Census
Through traffic on major highways	average of peak hour volumes over segments in study area on CA 299 (660) and CA 44 (475)	Caltrans counts
Shasta Community College	either closed in advance of evac or shelter in place during evac; also designated temporary refuge area #1	
Other community buildings	user traffic accounted for in local and thru volume estimates	
Random elements (e.g. caretakers)	2 per municipal or community building	
Background housing growth	average of 3 per year over next 15 years	Recent growth rate implied in Shasta County development data
Heavy vehicles	using 3.5 percent at 1 heavy vehicle equivalent to 2 passenger cars; all fractional parts rounded up to full digit on each roadway segment	per Caltrans counts for main roads in study area

Table 2-2: Summary of Traffic Volume Estimates for Evacuation Events

Item	Volume
Traffic volume without adjustments (vehicles)	7,124
Universal Adjustments	
3.5% heavy vehicle (HV) adjustment	249
Rounding up adjustment	33
Subtotal adjustments	283
Subtotal typical network volume (passenger cars)	**7,407**
Scenario-Dependent Adjustments	
Potential additional CA 299 thru volume (passenger cars)	660
Potential additional CA 44 thru volume (passenger cars)	475
Grand total maximum potential network volume (passenger cars)	8,542

3.0 Evaluation of Evacuation Scenarios

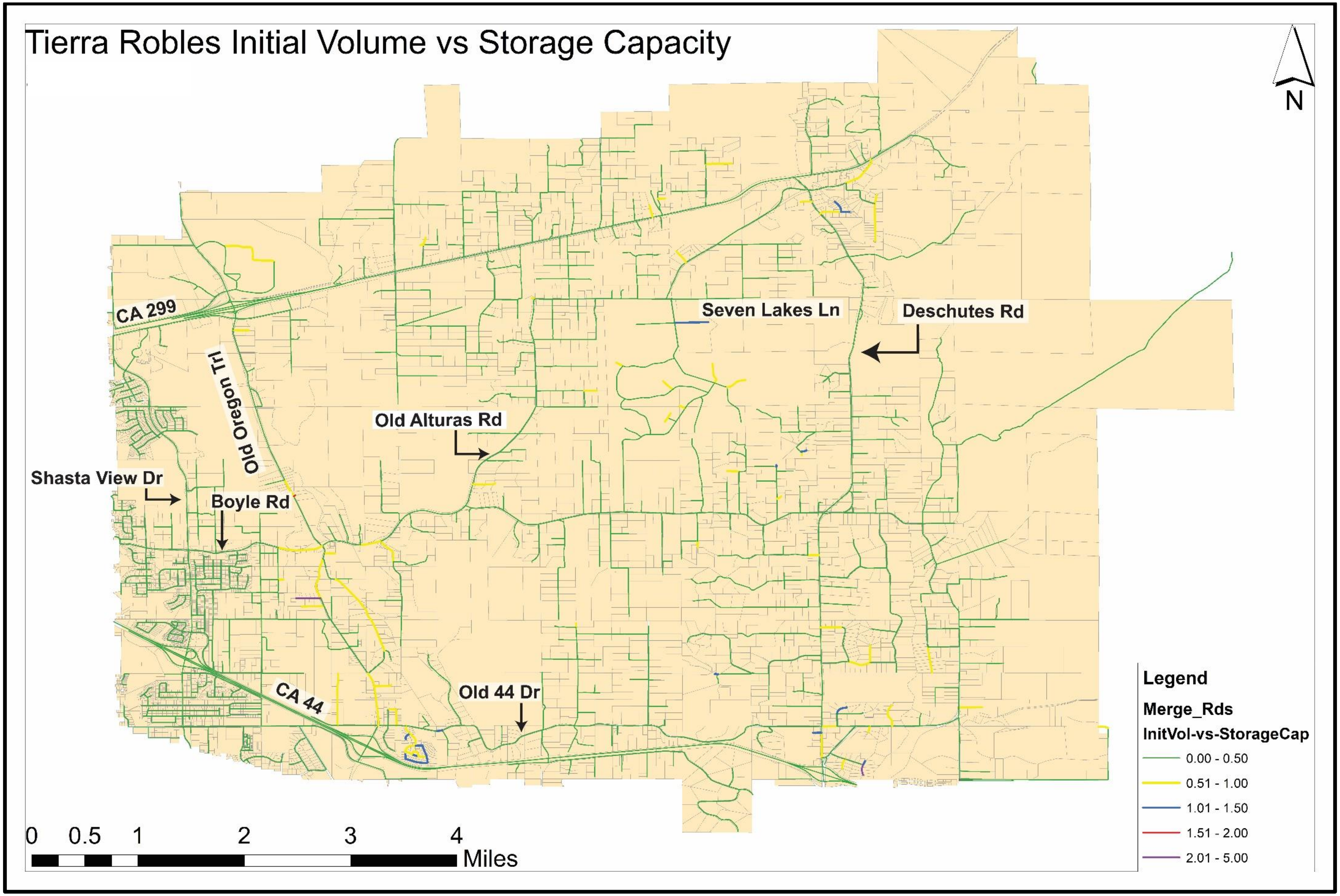
3.1 Startup Network Storage Density

Evaluation of each scenario involved simulation of traffic flow from all parcels to the nearest temporary refuge areas. Figure 3-1 shows the initial levels of impact on all street segments. The through-roads and major arterials as well as local streets would largely be unaffected during the beginning phase of evacuation as street segments appear to have enough room to store vehicles. This initial result is virtually the same for all scenarios as it only shows the initial conditions when residents spill onto adjoining streets that directly front the properties. Storage is the number of one-directional lanes multiplied by segment length (in feet) and divided by 25 feet, which is the assumed length per passenger car including spacing between adjacent vehicles. In this and subsequent results maps, the legends indicate the following:

- Roadway segments with green or yellow colors depict demand volumes that would be below the one-directional storage capacities.
- Segments in red or purple colors depict demand volumes that would be well above the one-directional storage capacities.

A typical two-lane, two-way road providing through-road access to intersecting single-access roads and driveways

Figure 3-1: Startup Network Storage Density



3.2 Volume Consolidation on Local & Arterial Streets

The next set of five figures show the secondary levels of impact on both arterial and local street segments during the middle of evacuations under the five scenarios tested. The maps illustrate the transition of vehicles loading onto arterial street segments from local street segments. As more and more vehicles from various residential enclaves load onto the assigned arterial street segments, the densities of the arterial street segments increase. Volume to storage capacity (VSC) ratios increase progressively along major arterial streets as traffic accumulates toward the exit segments leading to designated temporary refuge areas. The purple arterial street segments show that cumulated volumes would reach 2 or more times the storage capacity during evacuation. These maps therefore flag roadway segments where motorists are likely to experience congestion and delay during evacuation. Typically, a problematic downstream segment would for some time exhibit the inability to accommodate all vehicles wanting to traverse it from upstream segments forming queueing conditions.

Figure 3-2.1 shows that nearly all through-roads are likely to exhibit periods of queueing. Notable exceptions are CA 44 in the south and the northern half of Old Oregon Trail on the west. This condition is anticipated to occur even though this scenario would distribute traffic toward all directions for access to all temporary storage areas. This is a “baseline” scenario against which to view all others.

Figure 3-2.2 also shows that nearly all through-roads are likely to exhibit periods of queueing. The most notable exception is CA 44 in the south. Although all traffic is to evacuate to the single cardinal direction of the north, results are not noticeably different from the “baseline”. Two factors explain this phenomenon. The prevalence of single access roads would force traffic flow in particular directions for many residents irrespective of the cardinal direction of the evacuation. The availability of multiple refuge areas countered the network limitations resulting in similar results as the “baseline”.

Figure 3-2.3 shows the results for when all traffic is to evacuate to the single cardinal direction of the south. Results are not noticeably different from the “baseline” and are generally like those of the northern evacuation scenario. Again, nearly all through-roads are likely to exhibit periods of queueing. The most notable exception is CA 44 in the south. The two factors of single access roads and multiple refuge areas explain this phenomenon.

Figure 3-2.4 shows the results for when all traffic is to evacuate to the single cardinal direction of the east. Results are not noticeably different from the “baseline” and indicate that all through-roads are likely to exhibit periods of queueing. The notable exception is the northern half of Old Oregon Trail on the west, but

CA 44 in the south would now be among the roadways to exhibit queueing. The two factors of single access roads and multiple refuge areas explain this phenomenon.

Figure 3-2.5 shows the results for when all traffic is to evacuate to the single cardinal direction of the west. Results are not noticeably different from the "baseline" and are generally like evacuation to the east. Like all other scenarios, all through-roads are likely to exhibit periods of queueing. The notable exceptions are the northern half of Old Oregon Trail on the west, and the mid-section of the upper Deschutes Road. Again, CA 44 in the south would be among the roadways to exhibit queueing. The two factors of single access roads and multiple refuge areas explain this phenomenon.

Deschutes Road Entrance to Foothill High School (Refuge Area 4)

Figure 3-2.1: Accumulated Volume to Storage Capacity – Scenario 1 (Evacuation toward All Directions)

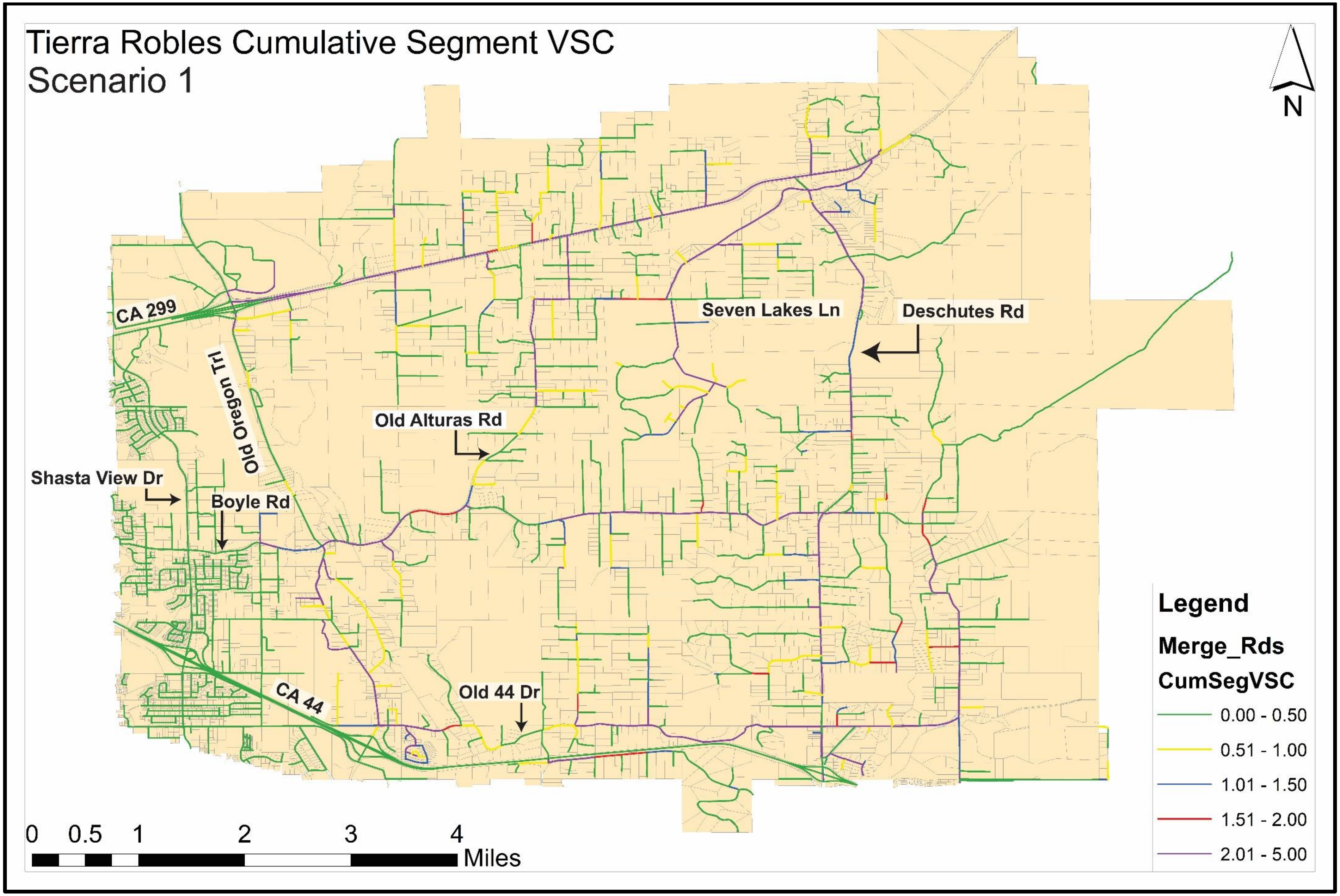


Figure 3-2.2: Accumulated Volume to Storage Capacity – Scenario 2 (Evacuation toward North Direction)

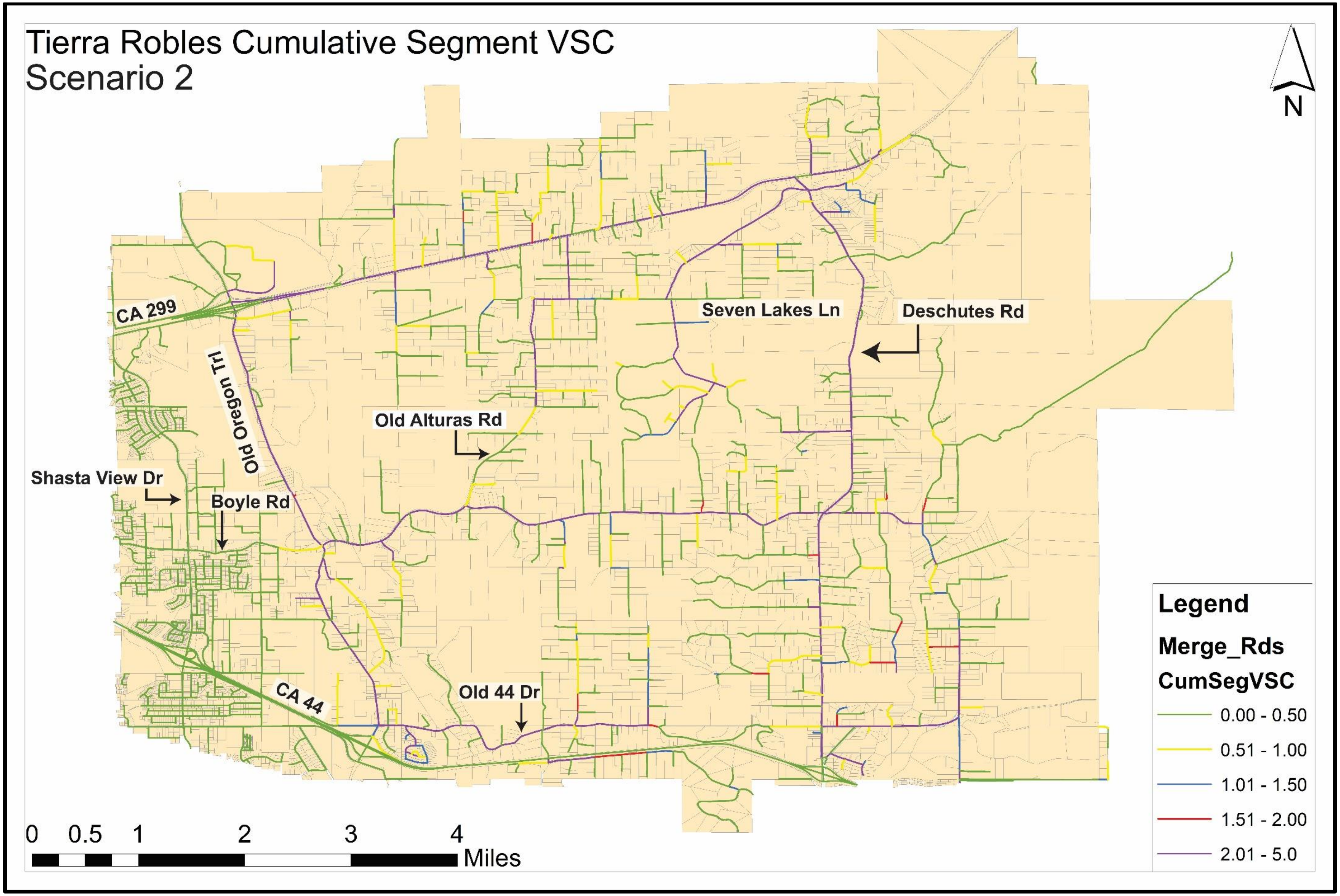


Figure 3-2.3: Accumulated Volume to Storage Capacity – Scenario 3 (Evacuation toward South Direction)

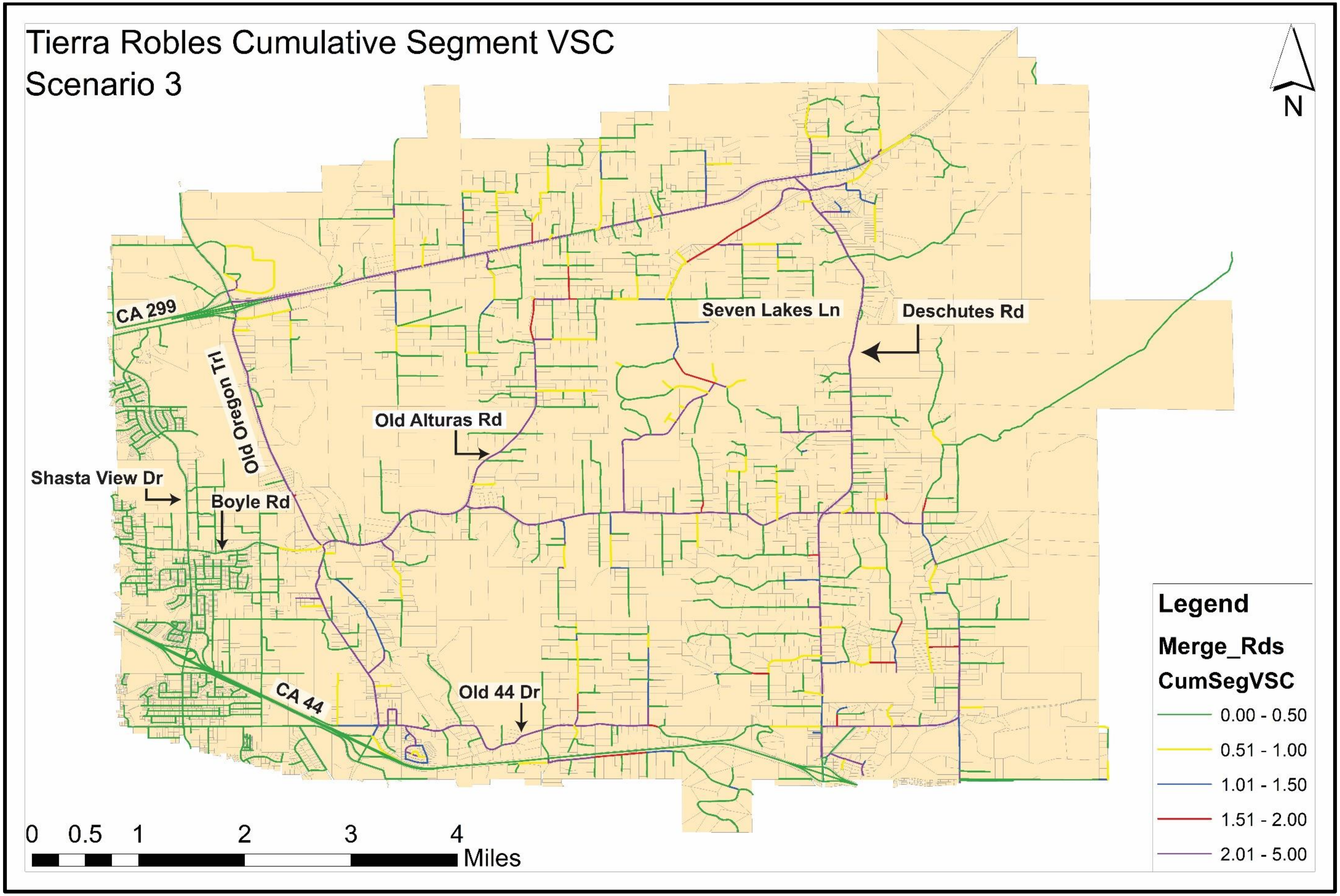


Figure 3-2.4: Accumulated Volume to Storage Capacity – Scenario 4 (Evacuation toward East Direction)

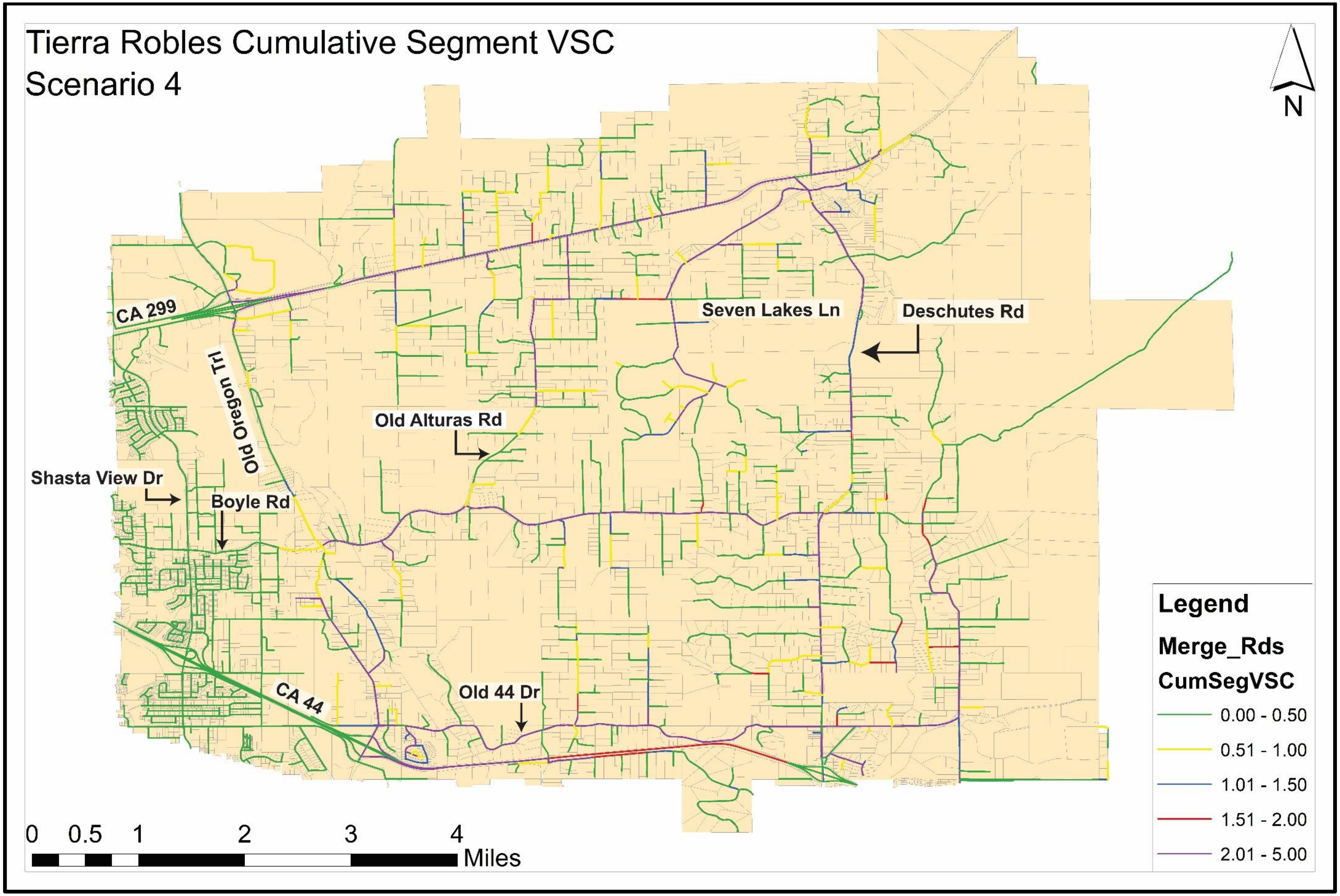
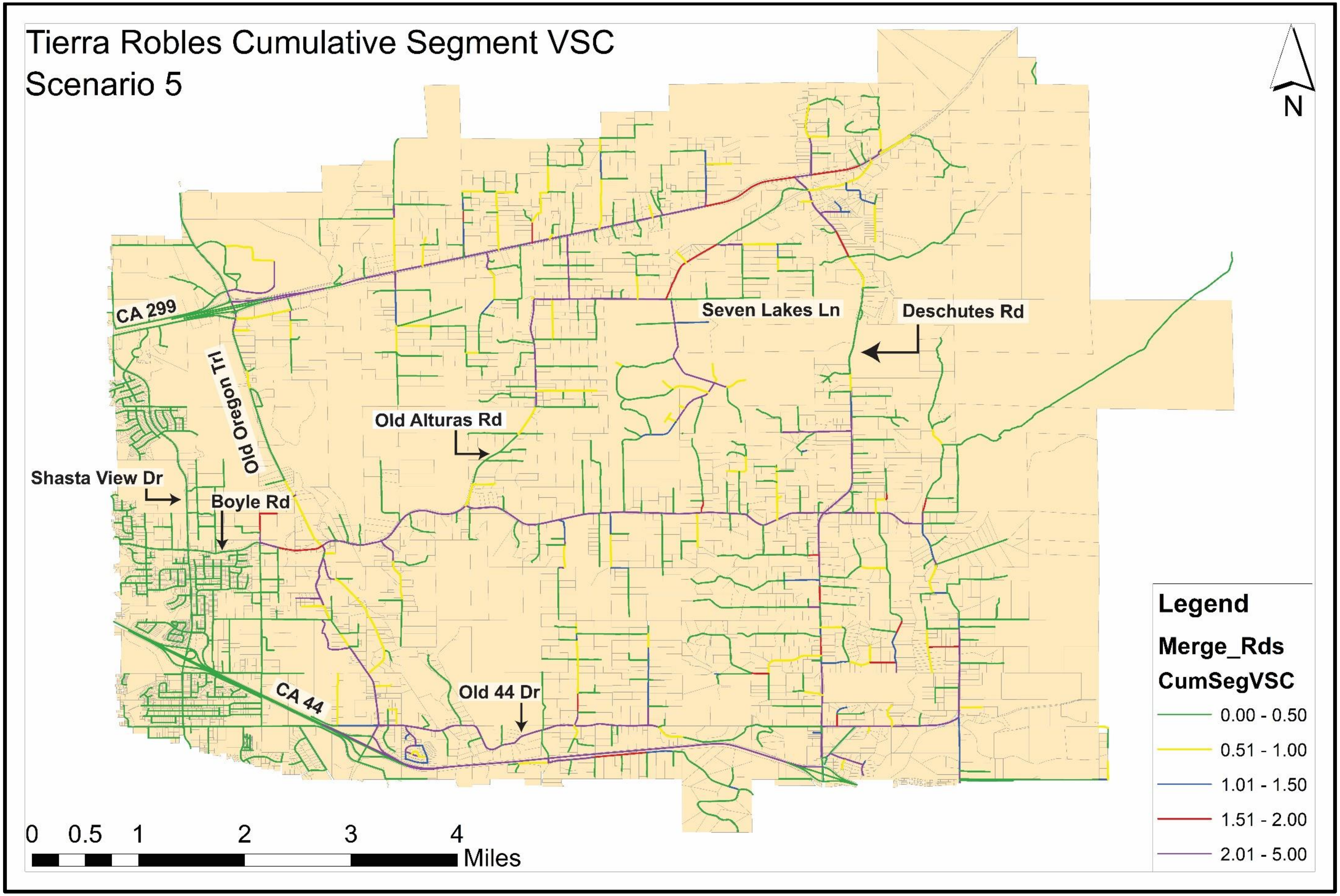


Figure 3-2.5: Accumulated Volume to Storage Capacity – Scenario 5 (Evacuation toward West Direction)



3.3 Time (hours) to Clear All Segments

The time to clear out traffic volumes on individual segments is a function of cumulative demand volume versus throughput capacity. The analysis applies the one directional throughput capacity appropriate for the type of roadway in accordance with the Highway Capacity Manual. The next set of five figures show time to clear demand volumes (in hours) on respective roadway segments throughout the study network. The information also reflects the volume to capacity ratios. The figures illustrate the progression of travel time in hours on critical through-roads during evacuations under the five scenarios. The travel time posted are the times that it would take for demand volumes to traverse respective street segments. The longest travelled segments, which are typically closest to the temporary refuge areas, are anticipated to take as low as 0.7 hours and as high as 2.2 hours under various evacuation scenarios.

Figure 3-3.1 *for evacuation to all directions* shows that all local streets and nearly all through-roads would require less than half an hour (shown in green) for cumulated demand volumes to traverse respective roadway segments. The exceptions are road segments on approach to Refuge Area 3 and 4 on Deschutes Road and Refuge Area 5 on Old State Route 44 shown in yellow, which would take a little less than three quarters of an hour. This finding bodes well for the evacuation test under this “baseline” scenario which distributes evacuation toward all cardinal directions to access all temporary refuge areas. Under the “baseline” scenario, therefore, all traffic takes less than an hour to traverse each bottleneck along the way despite the delay and queueing conditions anticipated for most through-roads as explained in the previous section.

Figure 3-3.2 *for evacuation to the north direction* also shows that all local streets and most through-roads would require less than half an hour (shown in green) for cumulated demand volumes to traverse respective roadway segments under this scenario. The exceptions are road segments in the northern half of Old Oregon Trail in the west on approach to Refuge Area 1 and on the northern half of Deschutes Road in the east on approach to Refuge Area 3. Under the north scenario, therefore, the most problematic roadway segments on approaches to the two major Refuge Areas 1 and 3 would potentially take 2 hours or a little more for all traffic to pass through.

Figure 3-3.3 *for evacuation to the south direction* shows similar results as for evacuation to the north with one notable exception. Under this scenario, the longest travelled segments would shift to the southern half of Old Oregon Trail in the west on approach to Refuge Area 6 and on the southern half of Deschutes Road in the east on approach to Refuge Area 4. Under the south scenario, therefore, the most problematic roadway segments on approaches to the two major Refuge Areas 6 and 4 would potentially take a little less than 2 hours for traffic to dissipate.

Figure 3-3.4 *for evacuation to the east direction* shows the least impactful single directional evacuation. Under this scenario, the longest travelled segments would be toward the east along CA 299 on approach to Refuge Area 3, Boyle Road via the lower portion of Deschutes Road on approach to Refuge Area 4, and on Old State Highway 44 on approach to Refuge Area 5. Under the east scenario, therefore, the most problematic roadway segments would potentially take a little less than 1 hour for traffic to dissipate.

Figure 3-3.5 *for evacuation to the west direction* shows evacuation results which depict a reversal of the results for the east evacuation. Results indicate a little more delay on approaches to Refuge Area 1 on CA 299 and Refuge Area 7 on Old Oregon Trail. Under the west scenario, therefore, the most problematic roadway segments would potentially take a little more than 1.5 hours for traffic to dissipate.

Old 44 Dr at Deschutes Road – example bottleneck where motorists can experience delay during evacuation

Figure 3-3.1: Time to Clear Segments & Volume to Capacity Ratios – Scenario 1 (Evacuation toward All Directions)

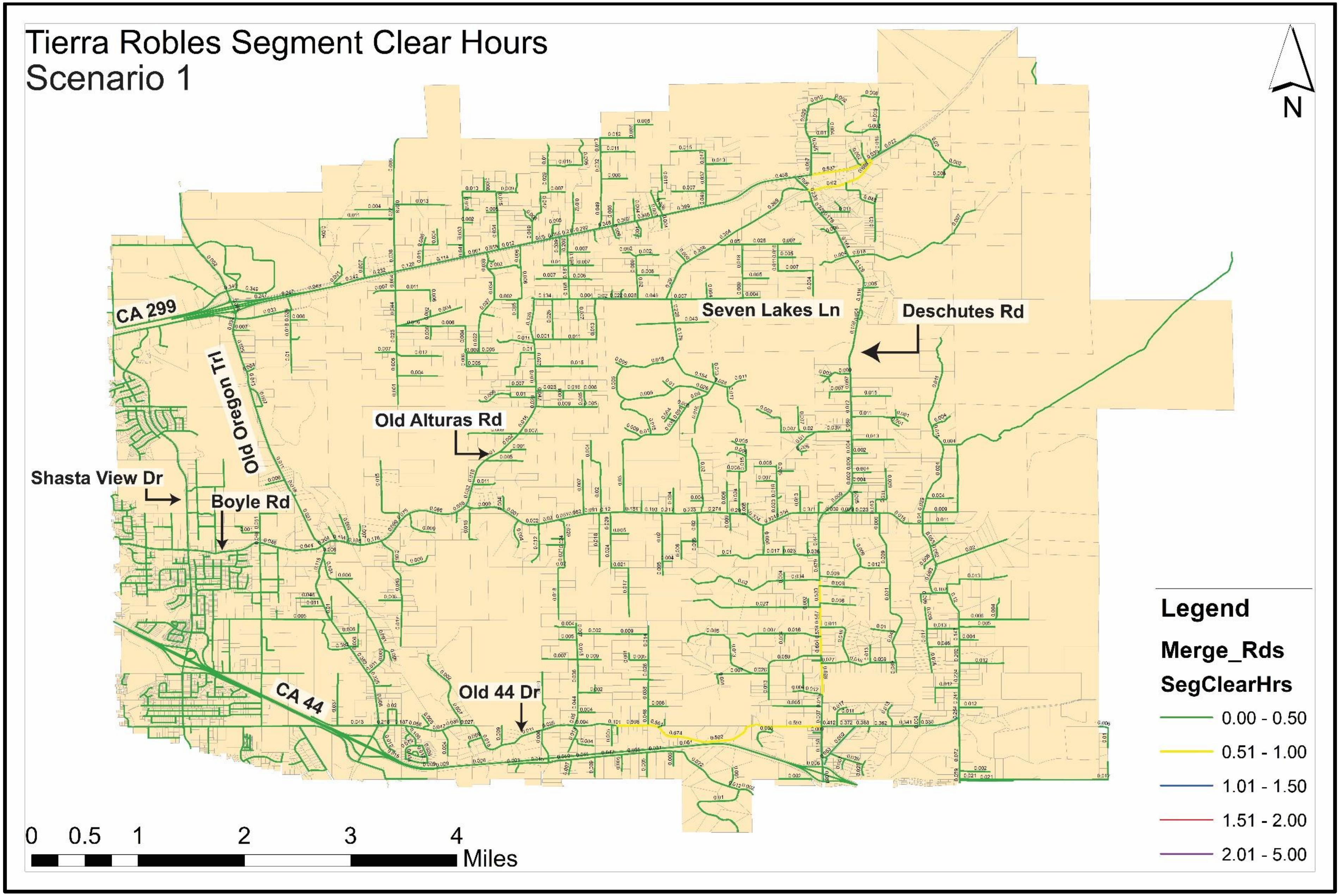


Figure 3-3.2: Time to Clear Segments & Volume to Capacity Ratios – Scenario 2 (Evacuation toward North Direction)

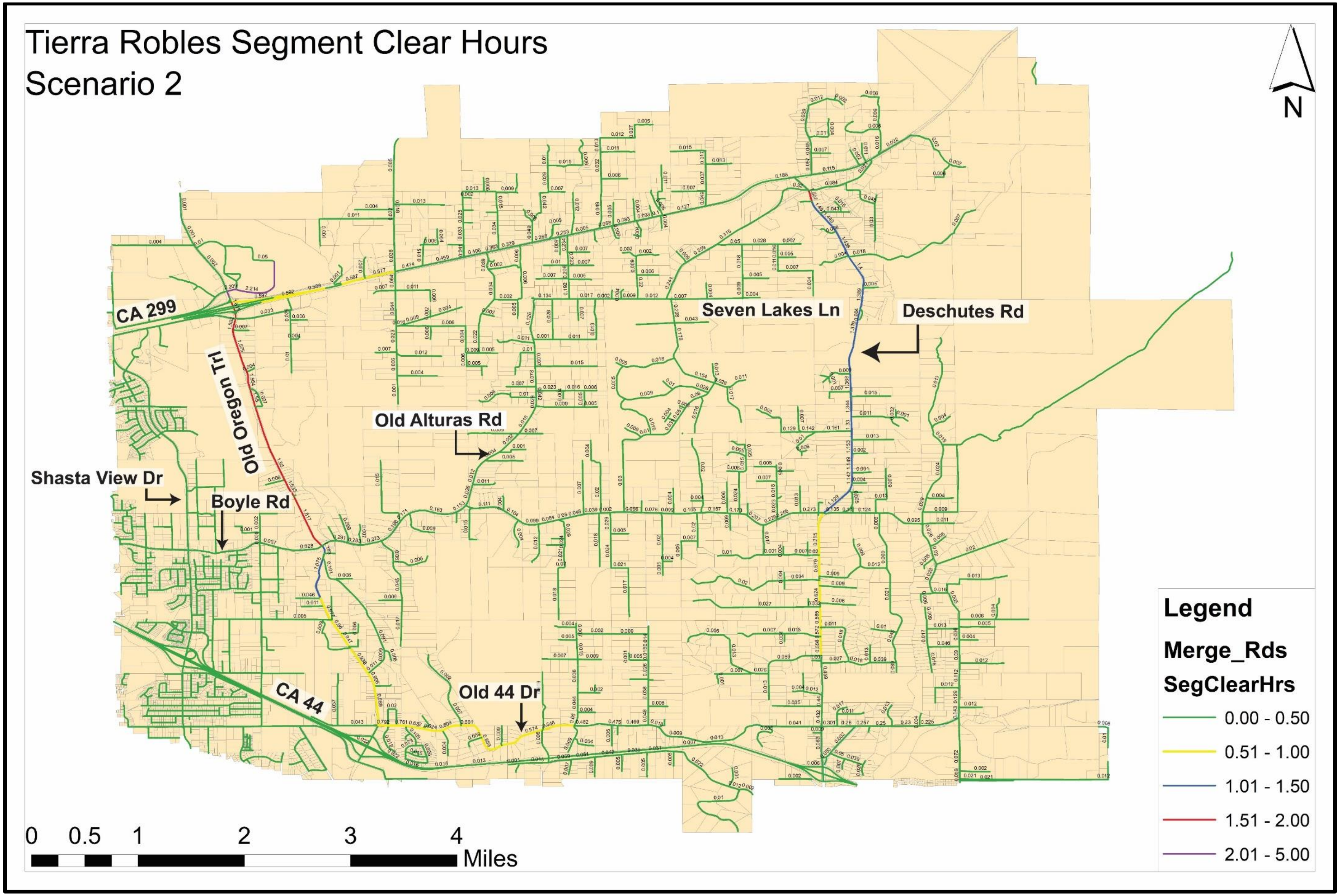


Figure 3-3.3: Time to Clear Segments & Volume to Capacity Ratios – Scenario 3 (Evacuation toward South Direction)

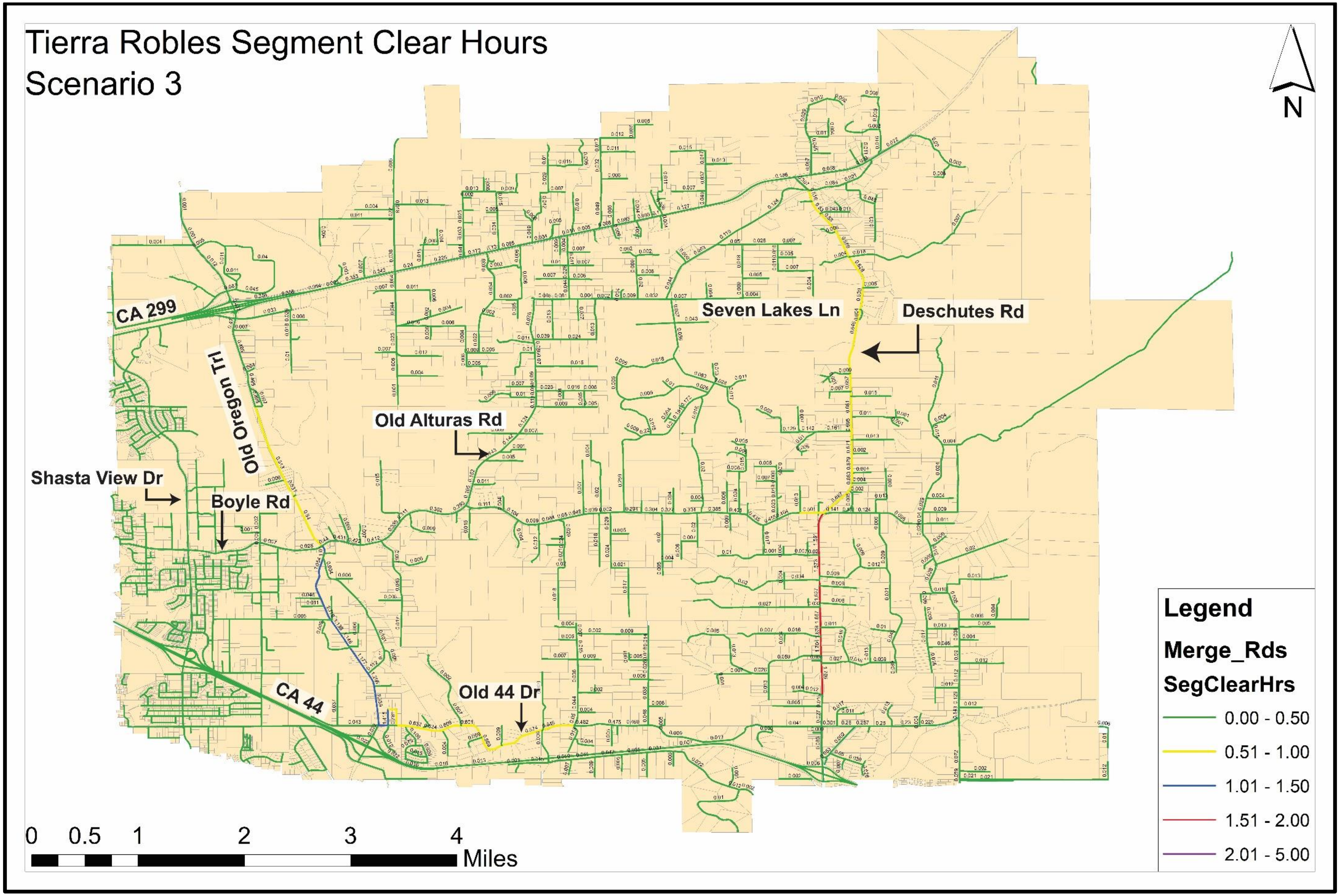


Figure 3-3.4: Time to Clear Segments & Volume to Capacity Ratios – Scenario 4 (Evacuation toward East Direction)

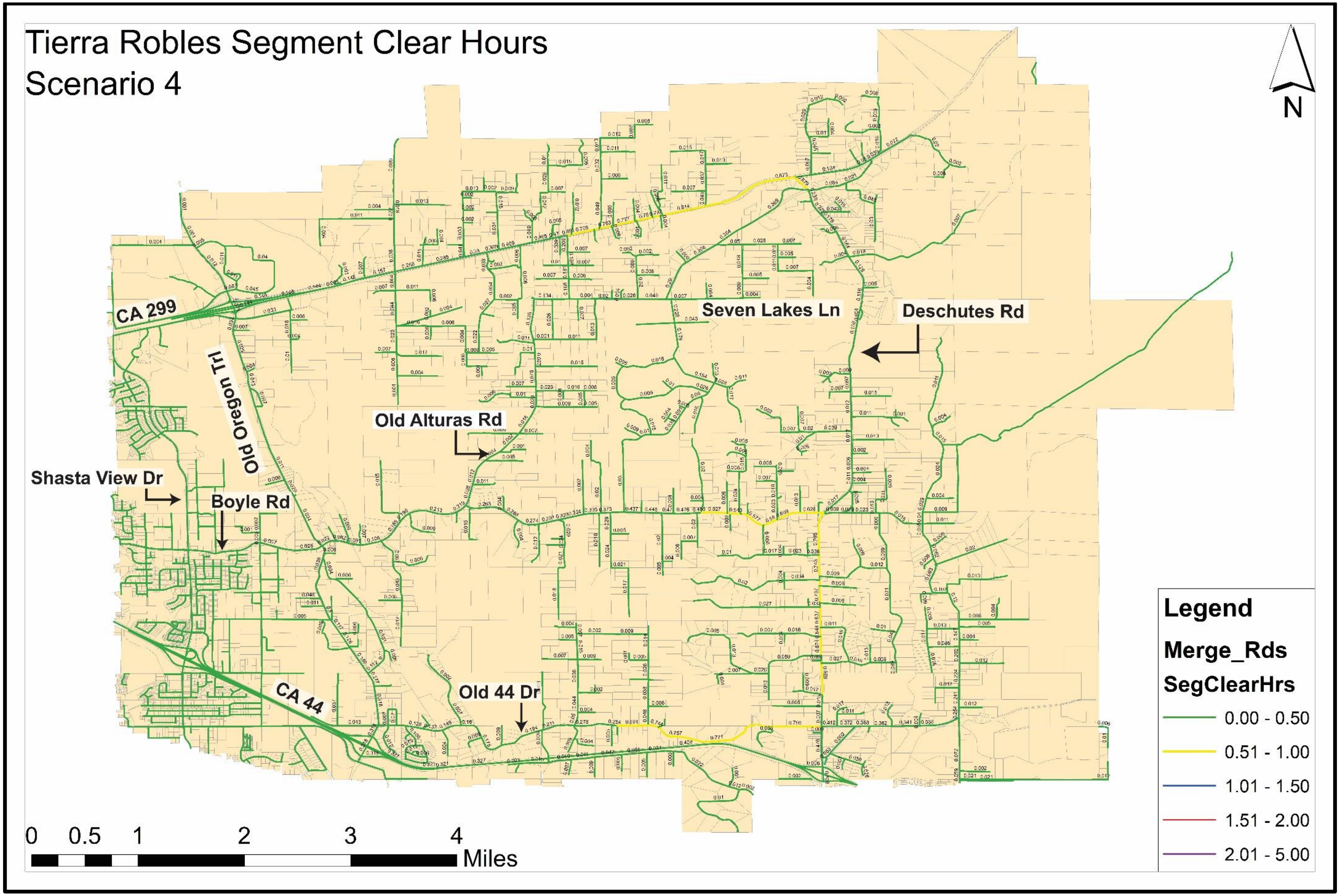
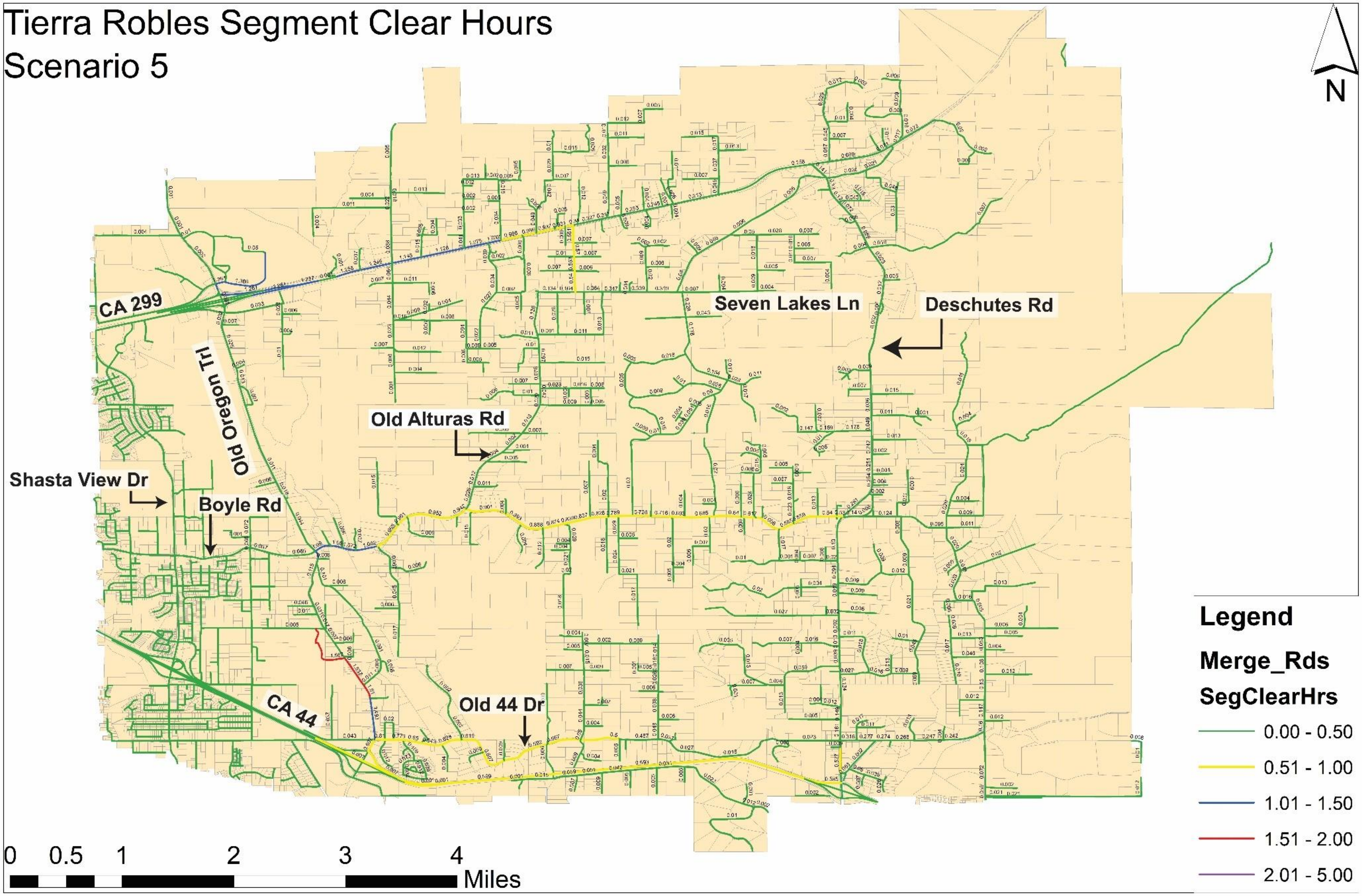


Figure 3-3.5: Time to Clear Segments & Volume to Capacity Ratios – Scenario 5 (Evacuation toward West Direction)



4.0 Summary Results of Evacuation Assessment

4.1 Comparative Performance Summaries

Analysis of queue formation on individual roadway segments revealed that it would take no less than 0.7 hours and up to 2.2 hours for anticipated volumes of vehicles to traverse the heaviest travelled segments, which are typically in the proximity of temporary refuge areas. Not only would it take the farthest-travelling vehicles some time to get to the refuge areas, there is anticipated delay on other roadway segments along the way. This is a worst-case analysis, which assumes all existing and planned housing units are occupied at the time of evacuation. The evacuation model accounted for the two factors of occupancy and delay in the resulting estimate of slightly higher overall evacuation times than those reported in the previous section for individual roadway segments. The next set of five tables show summaries of evacuation results that include residual delays along the way. The times are estimates of how long it would take to completely evacuate the Tierra Robles study area under optimal throughput conditions.

Table 4-1 shows the summary for the "baseline" scenario under which evacuation is toward all cardinal directions to access all temporary refuge areas. This would be a likely scenario when fire begins in a central location of the study area without obstructing any of the through-roads. It provides the most favorable evacuation scenario in terms of number of available refuge locations against which to compare all other scenarios.

Clearly, the two most proximate refuge locations to most of the area residents are Refuge Area 3 and Refuge Area 4 which the last sets of vehicles would reach in approximately one and two-third hours. Note that it would take about three-quarters of an hour to traverse the longest-delayed roadway segment under this scenario, but residual delay at multiple segments along the way would nearly double the travel time for the last sets of vehicles to reach these refuge locations.

Refuge Area 2 and Refuge Area 8 are located near other major refuge areas and are offside relative to the travel paths enabled by the configuration of the area road network. Thus, it became apparent from the simulation of flows through the study network under this first scenario and under subsequent scenarios, that areas 2 and 8 are minor locations compared to all the others. Few residents can reach these two refuge locations without passing by another more major location.

Table 4-1: Model Summary for Scenario 1 (Evacuation toward All Directions)

Scenario	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
All Directions	1	833	20	41	0.69	3.6	5.3
All Directions	2 & 3	2,213	18	101	1.68	4.2	2.5
All Directions	4	2,125	18	97	1.61	4.0	2.5
All Directions	5	630	20	32	0.53	2.6	4.9
All Directions	6	637	22	30	0.50	1.7	3.3
All Directions	7	950	18	46	0.77	3.6	4.7
All Directions	8	19	18	2	0.04	0.5	14.0

Table 4-2 shows the summary for the scenario under which evacuation is toward the north cardinal direction to access Refuge Areas 1, 2, and 3. This would be a likely scenario when fire begins south of the study area.

The most proximate refuge locations to most of the area residents are Refuge Area 1 and Refuge Area 3 which the last sets of vehicles would reach in approximately two hours and three and a half hours respectively. Note that it would take about two and a half hours to traverse the longest-delayed roadway segment under this scenario, but residual delay at multiple segments along the way would increase the travel time for the last sets of vehicles to reach these refuge locations by approximately another hour.

Table 4-2: Model Summary for Scenario 2 (Evacuation toward North Direction)

Scenario	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
North Direction	1	2,439	18	114	1.90	6.0	3.1
North Direction	2	582	21	27	0.45	1.2	2.7
North Direction	3	4,386	17	198	3.30	8.5	2.6

Table 4-3 shows the summary for the scenario under which evacuation is toward the south cardinal direction to access Refuge Areas 4, 5, and 6. This would be a likely scenario when fire begins north of the study area.

The most proximate refuge locations to most of the area residents are Refuge Area 4 and Refuge Area 6 which the last sets of vehicles would reach in nearly two hours and three and a half hours respectively. Note that it would take about two hours to traverse the longest-delayed roadway segment under this scenario, but residual delay at multiple segments along the way would increase the travel time for the last sets of vehicles to reach these refuge locations by approximately an hour and a half.

Table 4-3: Model Summary for Scenario 3 (Evacuation toward South Direction)

Scenario	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
South Direction	4	4,338	17	194	3.23	4.1	1.3
South Direction	5	630	24	27	0.46	0.5	1.2
South Direction	6	2,439	18	113	1.88	6.3	3.4

Table 4-4 shows the summary for the scenario under which evacuation is toward the east cardinal direction to access Refuge Areas 2, 3, 4, and 5. This would be a likely scenario when fire begins west of the study area.

The most proximate refuge locations to most of the area residents are Refuge Area 3 and Refuge Area 4 which the last sets of vehicles would reach in nearly two and a quarter hours. Note that it would take about one hour to traverse the longest-delayed roadway segment under this scenario, but residual delay at multiple segments along the way would increase the travel time for the last sets of vehicles to reach these refuge locations by approximately one and a quarter hours.

Table 4-4: Model Summary for Scenario 4 (Evacuation toward East Direction)

Scenario	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
East Direction	2	314	21	27	0.45	1.2	2.7
East Direction	3	2,750	19	133	2.22	5.3	2.4
East Direction	4	3,074	15	138	2.31	5.9	2.6
East Direction	5	1,268	19	61	1.02	4.0	4.0

Table 4-5 shows the summary for the scenario under which evacuation is toward the west cardinal direction to access Refuge Areas 1, 6, 7, and 8. This would be a likely scenario when fire begins east of the study area. This might even be the most likely scenario given the pattern of development and proximity of the wildland-urban interface to the eastern boundary of the study area.

The most proximate refuge locations to most of the area residents are Refuge Area 1 and Refuge Area 7 which the last sets of vehicles would reach in nearly two and a half hours. Note that it would take about one and a half hours to traverse the longest-delayed roadway segment under this scenario, but residual delay at multiple segments along the way would increase the travel time for the last sets of vehicles to reach these refuge locations by approximately one hour.

Table 4-5: Model Summary for Scenario 5 (Evacuation toward West Direction)

Scenario	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
West Direction	1	3,046	17	137	2.28	6.4	2.8
West Direction	6	1,268	18	67	1.11	6.3	5.6
West Direction	7	3,074	15	146	2.43	8.5	3.5
West Direction	8	19	18	2	0.04	0.5	14.0

4.2 Evolution in Travel Speeds & Time by Evacuation Regime

Travel speed during evacuation activity is anticipated to occur in multiple regimes. For simplicity, these could be summarized into three regimes. The early departures would have little to no inhibition during travel and thus experience close to everyday travel speeds and travel times discounted only by minor delay as they slow down while traversing intersections along the way. Latter departures would experience congestion with associated drop in travel speed and increases in travel time. The last batch of evacuees would bear the brunt of inhibition from each other, recurrent congestion, residual queuing delay, and at the end experience abysmal overall speeds of less than 3 miles per hour and the longest travel times that are upward of two and three hours depending on the evacuation scenario. Tables 4-1 through 4-5 in the previous subsection show estimates of average network travel speeds during early departures and late departures respectively.

Light traffic on Old Alturas Road in the western portion of the study area

Moderate traffic on Dana Drive west of the study area in Redding, CA

5.0 Isolating the Effect of the Tierra Robles Development

This section isolates the effect of the Tierra Robles Development on evacuation time. The purpose is to demonstrate whether the absence of the proposed development is likely to have significant effects on potential evacuation scenarios. The flip side of the answer to this inquiry is whether the Tierra Robles development would significantly aid deterioration in evacuation times. Since each evacuation scenario has multiple refuge areas, the first step is to select those temporary refuge areas that include a partial or the entire traffic from Tierra Robles. Table 5-1 includes all refuge areas with the longest clearance times by scenario and identifies those that include traffic from Tierra Robles. Depending on the scenario, four out of eight refuge areas (#1, #3, #4, and #7) would contain traffic from the proposed development. This produced a total of eight instances of those refuge areas with the longest clearance times across the five scenarios.

Table 5-1: Longest Clearance Times to Refuge Areas by Evacuation Scenario

Scenario & Direction	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)	Include Traffic from Tierra Robles?
1-All	3	2,213	18	101	1.68	4.2	2.5	Yes (p)
1-All	4	2,125	18	97	1.61	4	2.5	Yes (p)
2-North	1	2,439	18	114	1.90	6	3.1	No
2-North	3	4,386	17	198	3.30	8.5	2.6	Yes (w)
3-South	4	4,338	17	194	3.23	4.1	1.3	Yes (w)
3-South	6	2,439	18	113	1.88	6.3	3.4	No
4-East	3	2,815	19	133	2.22	5.3	2.4	Yes (p)
4-East	4	2,867	15	138	2.22	5.9	2.7	Yes (p)
5-West	1	3,046	17	137	2.28	6.4	2.8	Yes (p)
5-West	7	3,074	15	146	2.43	8.5	3.5	Yes (p)

Notes: Yes (p) - yes, partial Tierra Robles development traffic included
Yes (w) - yes, entire Tierra Robles development traffic included
No - no Tierra Robles development traffic included

Table 5-2 shows the estimated characteristics of traffic flow without the Tierra Robles development. Overall, even with removal of Tierra Robles traffic, network speeds and related clearance times would not change significantly and thus would not produce enough relief for arrival at the refuge areas with the longest clearance times to make noticeable differences on evacuation.

Table 5-3 shows the estimated reductions in vehicles and clearance times. The last sets of vehicles to arrive at refuge areas would endure nearly the same levels of delay through the network. Estimates of gains in their travel speeds would be no more than 0.3 miles per hour, if any. Indeed, estimates suggest Tierra Robles would generate and add a little less than 5 percent of the passenger car equivalent traffic volume to the study area traffic during evacuations. Without Tierra Robles, the largest travel time savings for the last sets of vehicles to arrive at refuge areas would be no more than 15 minutes out of the maximum estimate of nearly 3.5 hours.

Table 5-2: Longest Clearance Times to Refuge Areas without Tierra Robles Development Traffic

Scenario & Direction	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
1-All	3	1,920	18	88	1.47	4.2	2.8
1-All	4	2,073	18	94	1.57	4.0	2.5
2-North	1	2,439	18	114	1.90	6	3.1
2-North	3	4,029	17	183	3.05	8.5	2.8
3-South	4	3,980	17	179	2.99	4.1	1.4
3-South	6	2,439	18	113	1.88	6.3	3.4
4-East	3	2,713	19	120	2.00	5.3	2.6
4-East	4	3,023	15	136	2.27	5.9	2.6
5-West	1	2,740	17	124	2.07	6.4	3.1
5-West	7	3,023	15	144	2.39	8.5	3.6

Table 5-3: Changes in Flow Characteristics with & without Tierra Robles Development Traffic

Scenario & Direction	Refuge Area	Vehicles (passenger cars)	Early Departure Network Speed (mph)	Total Clearance Time (minutes)	Total Clearance Time (hours)	Max Travel Distance (miles)	Last Vehicle Speed (mph)
1-All	3	-293	0	-13	-0.21	0.0	0.3
1-All	4	-52	0	-3	-0.04	0.0	0.0
2-North	1	0	0	0	0.00	0.0	0.0
2-North	3	-357	0	-15	-0.25	0.0	0.2
3-South	4	-358	0	-15	-0.24	0.0	0.1
3-South	6	0	0	0	0.00	0.0	0.0
4-East	3	-307	0	-13	-0.22	0.0	0.2
4-East	4	-52	0	-2	-0.04	0.0	0.0
5-West	1	-306	0	-13	-0.21	0.0	0.3
5-West	7	-52	0	-2	-0.04	0.0	0.1

Note: "change" equals characteristic without Tierra Robles minus characteristic with Tierra Robles

6.0 Conclusions

The evacuation traffic study yielded insights into potential performance in traffic flow under multiple evacuation scenarios. Key observations from the analyses are the following:

1. *The study area road network* reveals a web of multiple single-access roads. The prevalence of single access roads would force traffic flow toward particular directions for many residents irrespective of the cardinal direction of evacuation. The availability of multiple refuge areas countered this network limitation. It is advantageous to have multiple refuge areas as traffic flow would distribute to multiple locations under each scenario.
2. *Upon the initial push to evacuate*, most roadway segments are anticipated to have enough linear feet of one-directional storage capacity to accommodate the numbers of vehicles from adjoining parcels. Close examination reveals that few very short segments in about half a dozen residential enclaves are the exception where storage capacity would be insufficient as Figure 3-1 shows in blue, red, or purple lines. However, these are not among the critical segments along through routes where vehicles from many other areas would converge on the way to temporary refuge areas.
3. *Results of traffic flow simulations* and illustrative maps flag roadway segments where motorists are likely to experience congestion and delay during evacuations. Typically, a problematic downstream segment would for some time exhibit the inability to accommodate all vehicles wanting to traverse it from upstream segments forming queueing conditions.
4. *Analysis of queue formation* on individual roadway segments revealed that it would take no less than 0.7 hours and up to 2.2 hours for anticipated volumes of vehicles to traverse the heaviest travelled segments, which are typically in the proximity of temporary refuge areas. However, it is noteworthy that not only would it take the farthest-travelling vehicles some time to get to the refuge areas, there is anticipated delay on multiple roadway segments along the way. The last batch of evacuees would bear the brunt of inhibition from each other, recurrent congestion, residual queuing delay, and at the end experience abysmal overall speeds of less than 3 miles per hour and the longest travel times that are upward of two and three hours depending on the evacuation scenario.
5. *Isolation of traffic from Tierra Robles* indicate that the development would generate and add a little less than 5 percent of the passenger car equivalent traffic volume to the study area traffic during evacuations. Without Tierra Robles, the largest travel time savings for the last sets of vehicles to arrive at refuge areas would be no more than 15 minutes out of the maximum estimate of nearly 3.5 hours. Therefore, even with removal of Tierra Robles traffic, network speeds and related clearance times

would not change significantly and thus would not produce enough relief for arrival at refuge areas with the longest clearance times to make noticeable differences on evacuation.

6. It is widely agreed that nobody can foretell what the evacuation parameters would be under actual conditions. That is why this study analyzed multiple plausible scenarios as surrogates for what could happen. The fundamental lessons from the analysis are:
    a. Single-point evacuations would not work; multiple refuge centers that use different travel paths are desirable.
    b. Authorities need to direct residents to the "nearest" refuge centers for efficient results. Beyond the initial directions, law enforcement and emergency personnel would make real time decisions in giving further directions to residents.
    c. A study such as this can help demarcate evacuation zones to balance flows to refuge areas.
7. *Tierra Robles Development* – This analysis does not reveal a reason to prevent the Tierra Robles development from moving forward. While the development would add to the volume of traffic in the area, the absence of the development would not produce sufficient relief for arrival at refuge areas with the longest clearance times to make noticeable differences on evacuation under existing levels of development in the wildland-urban intermix area. The added traffic volume from the Tierra Robles development is deemed insignificant to overall traffic volumes.

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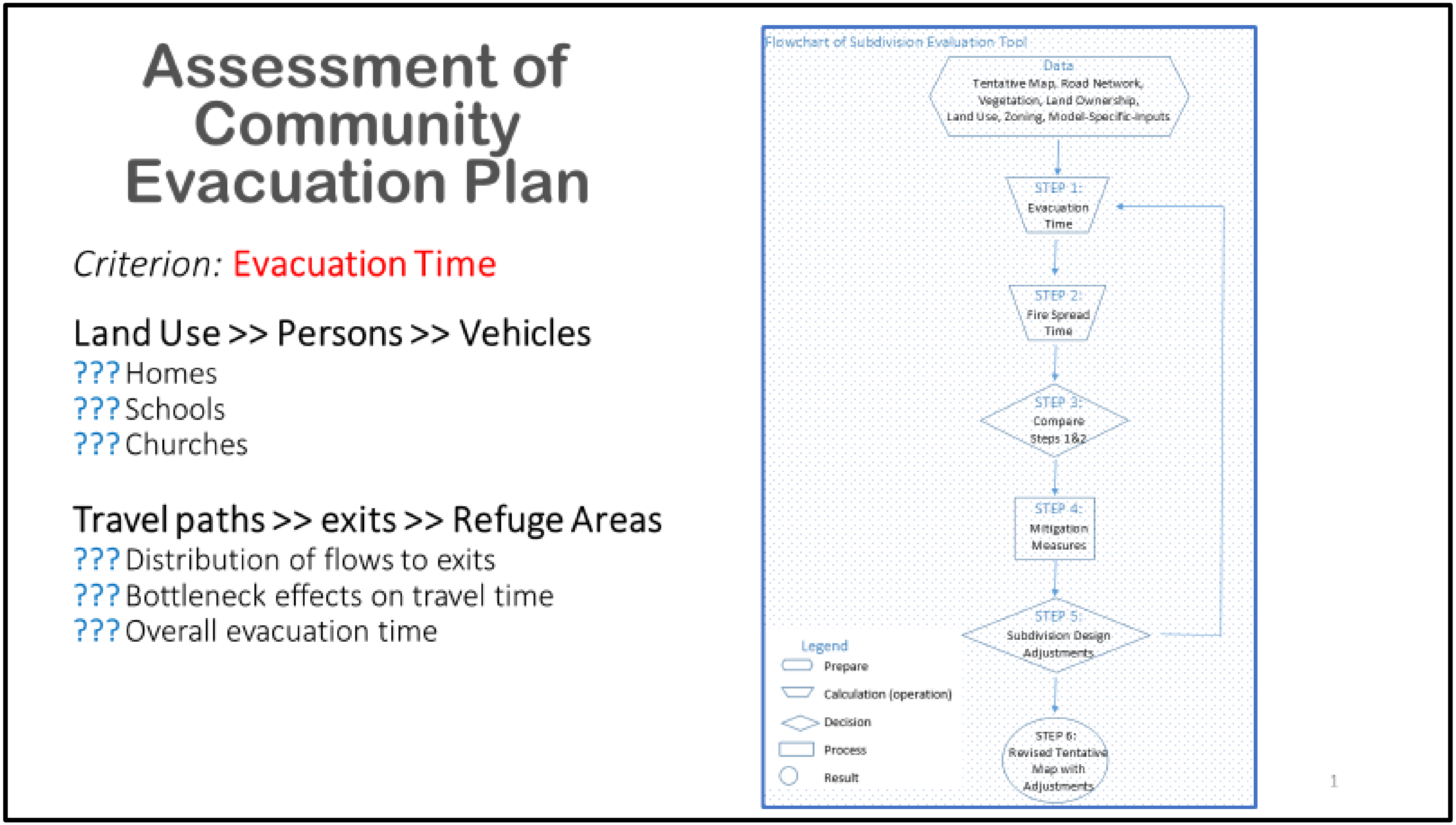
Age and sex, Table S0101

Housing units, Table B25001

Tenure by vehicles available, Table B25044

Appendix 1: Technical & Background Information

A1.1 Conceptual Framework for Evacuation Assessment & Planning



A1.2 Census Data & Vehicle Availability

B25044
TENURE BY VEHICLES AVAILABLE
Universe: Occupied housing units more information
2013-2017 American Community Survey 5-Year Estimates

	Shasta County, California		Redding city, California	
	Estimate	Margin of Error	Estimate	Margin of Error
Total:	70,486	+/-734	36,410	+/-603
Owner occupied:	44,095	+/-832	19,079	+/-487
No vehicle available	1,312	+/-175	648	+/-131
1 vehicle available	10,989	+/-571	5,322	+/-418
2 vehicles available	17,980	+/-612	8,032	+/-472
3 vehicles available	9,189	+/-537	3,612	+/-313
4 vehicles available	3,430	+/-352	1,114	+/-214
5 or more vehicles	1,195	+/-157	351	+/-107
Renter occupied:	26,391	+/-827	17,331	+/-547
No vehicle available	3,533	+/-382	2,548	+/-365
1 vehicle available	12,477	+/-691	8,437	+/-524
2 vehicles available	7,558	+/-497	4,631	+/-434
3 vehicles available	2,261	+/-348	1,371	+/-258
4 vehicles available	400	+/-133	259	+/-111
5 or more vehicles available	162	+/-65	85	+/-41

Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates

	Shasta Co	Redding
Vehicles Available	**Vehicles**	**Vehicles**
0	0	0
1	10989	5322
2	35960	16064
3	27567	10836
4	13720	4456
5	5975	1755
All Owners	**94211**	**38433**
0	0	0
1	12477	8437
2	15116	9262
3	6783	4113
4	1600	1036
5	810	425
All Renters	**36786**	**23273**
All HH Vehicles	**130,997**	**61,706**
Avg vehicles: Owner HH	2.1	2.0
Avg vehicles: Renter HH	1.4	1.3
Avg vehicles: ALL HH	1.9	1.7

Assumed average vehicles per household = 2

Appendix 2: What Can We Learn from Butte County?

A2.1 Anecdotal Comparison

Paradise

The 2018 Camp Fire in Paradise, California is known as the deadliest and most destructive wildfire in California (Baldassari, 2018). Much of the loss was due to issues with the evacuation routes. The emergency alerts system also had major issues, as emergency officers and city officials did not notify four areas that were at risk and residents did not have enough time to evacuate. The evacuation routes were extremely congested and led to cars being abandoned as people evacuated on foot. Some people were trapped inside their vehicles, which caused at least four deaths (CBS SF, 2018) while some walkers could not travel fast enough out of harm's way. The Camp Fire led to a total loss of 84 lives and many injuries (Lewin, 2019).

A decade earlier, a Butte County Grand Jury report on fires that occurred in 2008, stated that the majority of the roads in Paradise had serious capacity limitations, and there were no ideal evacuation routes due to lack of compliance with fire regulations and significant constraints due to road conditions and structure. It took three hours to travel eleven miles from Paradise to Highway 70 (Butte County, 2009). The next section includes additional excerpts from the Grand Jury report. The following assessment is particularly notable from that report:

> There are four available southbound evacuation routes from Paradise: Skyway, Neal, Clark, and Pentz Roads. There are no adequate northbound evacuation routes. During the Humboldt Fire Incident, Skyway, Neal, and Clark Roads were closed to all civilian traffic. This left only Pentz Road available for evacuation, with *only one southbound lane being used*. It took three hours to travel eleven miles from Paradise to Highway 70. Pentz Road has *limited emergency pull off areas* for temporarily parking disabled vehicles.

A2.2 Summary from 2009 Butte County Grand Jury Report

The wildfires in the foothills of Butte County

The wildfires in the foothills of Butte County during the summer of 2008 were the most severe in recent history. Some of the grim statistics were:

- 60,000 acres burned
- 200 homes lost or heavily damaged
- One fire related death reported
- Injuries to fire personnel

By some miracle, the Humboldt Fire Incident did not cross the West Branch of the Feather River. Had this occurred, property damage could have been huge and thousands of lives could have been threatened in Paradise and the Upper Ridge.

Three of four major evacuation routes south from Paradise, Skyway, Neal and Clark Roads, were closed due to heavy smoke and fire. The fourth evacuation route, Pentz Road, was jammed with single-lane traffic, making the trip from Paradise to Highway 70 nearly three hours long.

Forest Route 171 north of Magalia currently does not qualify as a viable evacuation route. This route includes ten miles of dirt road between Inskip and Butte Meadows. Even if upgraded as planned, this route will not be classified as an evacuation route. Additional evacuation routes are necessary. The Grand Jury recommends that affected communities come together to form a Benefit Assessment District to address their safety needs.

While this report focused on the areas affected by the 2008 wildfires, the Grand Jury is equally concerned about other communities in the Butte County foothill areas, including Cohasset, Berry Creek, Forbestown, Forest Ranch, and others.

Evacuation Routes from Paradise

Paradise currently has approximately 30,000 residents. There are four available southbound evacuation routes from Paradise, Skyway, Neal, Clark and Pentz Roads. There are no adequate northbound evacuation routes.

During the Humboldt Fire Incident, Skyway, Neal and Clark Roads were closed to all civilian traffic. This left only Pentz Road available for evacuation, with only one southbound lane being used. It took three hours to travel eleven miles from Paradise to Highway 70. Pentz Road has limited emergency pull off areas for temporarily parking disabled vehicles.

Skyway below Paradise is an existing high capacity road. If the fire fuel was removed in a few areas adjacent to the road between Paradise and Chico, and the grassed median and shoulders were disked in the late spring each year, the availability of this high capacity evacuation route would be improved.

Notes