INDEPENDENT LAKE TAHOE BASIN WILDFIRE EVACUATION ANALYSIS

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Prepared for:
TahoeCleanAir.org

Prepared By:

PYROANALYSIS

PyroAnalysis LLC
1095 Hilltop Drive, Suite 200,
Redding, CA 96003
Pyroanalysis.com

In Collaboration with Ladris AI

LADRIS™

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FOREWORD

This independent analysis was commissioned by TahoeCleanAir.org.

TahoeCleanAir.org is a Nevada 501(c)(3) non-profit corporation. One of its organizational purposes is to support safe and effective wildfire evacuation and take the steps necessary to help champion this purpose.

Based on over 400 wildfire evacuation simulations, this first-of-its-kind, publicly transparent analysis is informational only and aimed at increasing public and governmental land-use planners awareness of possible evacuation outcomes. Research and analysis were achieved using AI technology, coupled with subject matter expertise.

Simulation analyses have been completed for five geographical areas within the Lake Tahoe Basin and will be published in four phases, beginning with the Placer/Tahoe and Washoe/Tahoe study areas.

DISCLAIMER

Community wildfire evacuation planning and decisions regarding evacuation during an actual emergency are the responsibility of Lake Tahoe Basin government planning agencies, law enforcement, and fire response resources. This analysis is not intended as advice or judgment in emergency situations. This independent analysis does not suggest mitigation options that may help to provide enhanced wildfire evacuation timing. Education in these options is readily available from local and regional government agencies including law enforcement and fire response agencies.

The simulations and information contained in this independent analysis are informational only, and not intended to take the place of, nor should the simulations and information herein be utilized in connection with, official government evacuation planning or emergency event decision-making, including but not limited to determining evacuation routes during an actual emergency event. Using expert review tools, such as evacuation modeling software, this document analyzes the evacuation factors, considerations, and estimated travel times associated with various community emergency evacuation simulations. Evacuation modeling software does not account for all potential evacuation scenarios, vehicle collisions, fire-compromised roads, erratic human behaviors, or regional evacuations. While efforts have been made to ensure the accuracy, completeness, and usefulness of the information in this report, the authors and distributors of this study do not accept any liability for errors, omissions, or inaccuracies in the content nor for any actions taken based on this information.

SUMMARY

The Tahoe Basin is an internationally renowned destination. Annual visitation to the 323-square-mile Tahoe Basin (207,000 acres) now exceeds that of America's most popular national park, the Great Smoky Mountains, which spans 816 square miles (522,419 acres). One report indicates Tahoe receives 60 million person trips annually. Many visitors are unaware that Tahoe spans two states, five counties, and multiple communities.[1]

Following the 2021 Caldor Fire, grassroots community groups have expressed the need for a basinwide Lake Tahoe roadway capacity evacuation analysis based on recent data and advanced technology.

With this in mind, TahoeCleanAir.org commissioned an emergency evacuation study by PyroAnalysis, LLC. PyroAnalysis is a fire and emergency management consulting firm with extensive experience and expertise in community evacuation planning, land use planning and development solutions, and fire behavior and threat analysis.

Using Ladris AI evacuation modeling software, PyroAnalysis' fire and evacuation subject matter experts studied community roadways to identify evacuation routes, estimate the number of vehicles used by residents and visitors in an evacuation, and anticipate impediments to a timely evacuation. The team's findings were used to design and produce hundreds of possible emergency evacuation simulations. The modeling results, found in this report, provide sample baseline evacuation time estimates for a variety of no-notice evacuation scenarios (no-notice vs. planned evacuation is discussed on the next page) for five study areas within the basin: Placer/Tahoe; Washoe/Tahoe; Douglas/Tahoe; Eldorado/South Shore Tahoe (including the communities of Meyers and Fallen Leaf, California); West Shore/Tahoe; (balance of West Shore Placer and El Dorado county communities south of Sunnyside). The findings for the Lake Tahoe Basin (see Figure 1) will be released in phases.

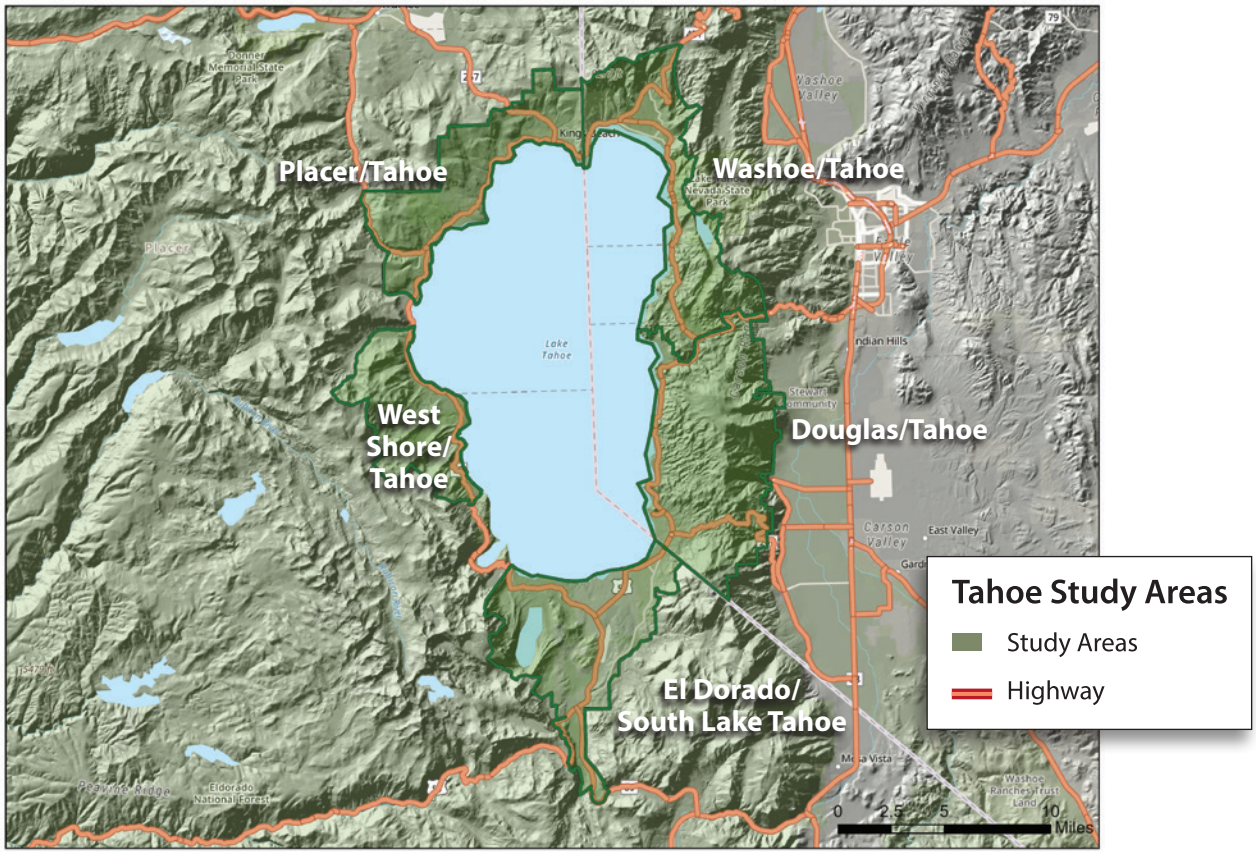

Figure 1.1: Tahoe Basin Study Areas

APPROACH AND METHODOLOGY

To estimate the time required to evacuate communities within the Tahoe Basin, evacuation experts conducted hundreds of evacuation simulations using Ladris AI's science-based modeling software to analyze travel times and other transportation and movement factors during simulated emergency evacuations.

Ladris AI provides visual and statistical analysis of traffic patterns for every road segment, address point, and vehicle origin and destination at every moment over the course of an evacuation simulation. Ladris AI has no constraints on the type or extent of the geographic region that can be modeled. It allows for transportation demand modeling, dynamic traffic assessment, and multimodal transportation analysis to help communities plan for safe evacuation. This software is commonly used by state and local government agencies across the US.

COMMUNITY EVACUATION ANALYSIS

Emergency evacuations are either no-notice events or planned events. No-notice evacuations are ordered when an emerging incident poses a sudden and immediate threat to human life. Historically, no-notice evacuations have overwhelmed emergency responder resources and defied the rapid implementation of emergency operation plans. Studies of no-notice wildfire events consistently report irrational human behavior during the evacuation, especially when evacuees are confronted with smoke and flames from an approaching wildfire. Evacuees often lack familiarity with available evacuation routes and encounter debris (e.g., fallen trees, utility lines, or power poles) and other unexpected obstacles on the roadway, which can result in egress routes being blocked by vehicle collisions and disabled vehicles. The chaos is exacerbated when emergency responders must access the incident using the same routes used by exiting evacuees.

Planned evacuations are coordinated hours or days before the evacuation is initiated, allowing law enforcement, state and county road departments, offices of emergency management, and fire departments to collaborate for an organized movement of the population to pre-identified safe areas where adequate sustenance and shelter are available for evacuees. Even with such coordination and pre-planning, planned evacuations from Tahoe Basin communities may require 9 or more hours, as seen during the Caldor Fire evacuation in 2021.

"Caldor Fire Evacuation"

Justin Sulliva via Getty Images

EVACUATION TRAVEL TIME ASSESSMENT

Total Count of Evacuating Vehicles

The simulations used in this analysis were designed using hypothetical no-notice evacuation events. Residents and visitors are assumed to evacuate by vehicle. Evacuees begin departing within minutes of notice, with all evacuees starting their route to safety within a 60-minute time frame. All simulations represent an evacuation during Lake Tahoe's peak tourist summer months between the hours of 1 p.m. and 5 p.m.

To accurately estimate the time required to evacuate an area within the Tahoe Basin during a no-notice emergency event, the total number of vehicles using the evacuation routes during peak use periods must be estimated using the following methodology:

Vehicles Already in Transit and on the Roadway During an Evacuation (i.e., Background Traffic)

In July 2023, nearly 60,000 visitors per day used Tahoe Basin road systems to access the abundant recreation offered around Lake Tahoe.[2] Thus, vehicles in transit within the evacuation study area must be considered in terms of the number of vehicles sharing the roadways during an evacuation. To illustrate, during the month of July, when main routes around Lake Tahoe are heavily congested, it is estimated that 2,000+ vehicles are in transit on the 9.5-mile section of Highway 28 between Tahoe City and Kings Beach. Without considering these vehicles as part of the evacuation, the total number of vehicles using the travel routes cannot be accurately projected. For this reason, Ladris AI's Live Traffic tool and monthly average daily traffic (MADT) data, which consider background traffic in the modeling scenarios, were both used to generate traffic flow modeling outputs.

Housing and Lodging Units

Studies of wildfire evacuations in California have found that between 1.2 and 1.9 vehicles per household are used to evacuate during wildfires.[3] Therefore, for modeling, it is assumed that 1.5 vehicles are used to evacuate each residential housing unit and 1 vehicle is used to evacuate each occupied lodging unit (hotel room).

Short-term Rentals and Tourist Accommodation Units

There are an estimated 9,000 short-term rental properties in the Tahoe Basin. In July 2023, the average occupancy rate for all rentals was 75%; short-term rentals in North Lake Tahoe had a slightly higher occupancy rate of 80%.[4] Short-term rentals are often rented by several friends or families who may arrive in separate vehicles. Thus, it is reasonable to assume that the number of vehicles used during the evacuation from short-term rental properties is greater than the assumed 1.5 vehicles per household calculated for full-time residential properties in the Tahoe Basin.

Employees Commuting to Area Restaurants, Shops, and Recreational Venues

The number of out-of-town employees is included in the final vehicle counts used for each scenario.

Parked Vehicles

With more than 60,000 visitors per day enjoying the beaches, trails, restaurants, shops, and accommodations in Lake Tahoe in July, finding a place to park is increasingly difficult. Beach parking and trailhead parking lots are at maximum capacity on most summer weekends and holidays. An estimated number of parked vehicles was added to the total vehicle count in each study area to account for the number of parked vehicles used in an evacuation.[5]

Seasonal Road Construction Projects

Miles-long vehicle queues at road construction traffic control points are a daily reality for commuters traveling Tahoe Basin roads during the summer months. Harsh winter conditions and Lake Tahoe Basin environmental regulations mean major highway and roadway construction projects can happen only during the limited shoulder and the summer months. Many of these construction projects include open trenches that reduce roadways to a single lane, making it difficult to quickly open both lanes for emergency responder access and the timely egress of evacuees. Using Ladris AI software, road construction scenarios that reduce Highway 28 from two lanes to one lane were modeled to understand how ongoing summer road construction could impact evacuee travel times.

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ADDITIONAL CONSIDERATIONS AND IMPEDIMENTS TO TIMELY EVACUATION

Pedestrians and Cyclists

More than 2,100,000 individuals visit Lake Tahoe each year for abundant and diverse recreation,[6] including the myriad of hiking and biking trails that crisscross the basin and lakeshore. In July 2023, Sand Harbor alone hosted 274,820 visitors, an average of nearly 9,000 daily visitors.

Evacuating Lake Tahoe communities includes notifying and accounting for thousands of recreators who may be miles from their vehicles or accommodations. Another consideration are the trails being used by those with mobility impairments. They too may need special assistance in returning to their vehicles for evacuation.

Locating and notifying pedestrians and cyclists is an immense undertaking for first responders. Even first responders with other evacuation assignments, such as traffic control, may be redeployed to search for trail users and to help those needing special assistance.

The preceding factors as well as those listed below must be evaluated in the analysis of the time and human resources necessary to complete a community-wide evacuation during a no-notice emergency event. Numerous large-scale wildfire evacuations have taught us that evacuation plans that rely on personnel to clear intersections, reprogram traffic signals, or support contraflow strategies often fail when unforeseen events prevent the execution of even the most well-planned and exercised evacuation plan.[7]

Choke Points

Choke points are geographical locations where the flow of evacuees is slowed, significantly restricted, or stopped. Evacuees may experience the compounding issues of these bottlenecks, such as vehicle accidents and extended travel times.

Limited Road Capacity

Tahoe Basin roadways are narrow, have limited lanes, are not designed to handle high volumes of traffic, and can become congested quickly. As stated in the Placer County Tahoe Basin Area Plan, Environmental Impact Statement (EIS), **"Emergency evacuation conditions would likely result in traffic demand that exceeds roadway capacities under any scenario and at any hour."**[8]

Tahoe Basin traffic demand that exceeds roadway capacity during a panicked wildfire evacuation can cause immediate, temporary, and longer-term auto collisions, as well as pedestrian injury. These incidents become choke points, further decreasing evacuation times and placing the public in potential peril.

A traffic calming strategy now common in the area, known as a Road Diet, is a roadway reconfiguration typically converting an undivided roadway to a divided one with through lanes and one center two-way left-turn lane, may improve traffic conditions under normal circumstances. However, during an emergency, when intersections and roadways are already overtaxed by routine daily traffic, a Road Diet can result in additional congestion.

Area Familiarity and Communication Barriers

As an international tourist destination, Lake Tahoe is visited by hundreds of thousands of guests from around the world. Some visitors not familiar with the local geography or evacuation routes may also experience evacuation orders in a language they do not understand, hampering their ability to receive clear directions to safe evacuation routes.

Variances in Public Alert Systems

Emergency service agencies within the Tahoe Basin use several different emergency notification systems to alert residents and visitors about emergencies such as wildfires, severe weather, and other critical situations in the Lake Tahoe Basin. Key systems include CivicReady, CodeRED, PlacerAlert, and El Dorado County Emergency Alert. South Lake Tahoe uses CivicReady by AlertSense, which notifies of not only emergency situations but also civic affairs. CodeRED, operated by OnSolve, delivers time-sensitive information via phone calls, text messages, and emails and is used by jurisdictions such as Douglas County, Carson City, South Lake Tahoe, and Washoe County. PlacerAlert by Nixle, operated by Everbridge, provides emergency alerts, advisory messages, community information, and traffic updates and is utilized by Placer County. In contrast, El Dorado County utilizes El Dorado County Emergency Alert operated by Rave. Rave's system automatically transfers residents from CodeRED to El Dorado County Emergency Alert.

While all the emergency alert systems serve similar purposes, they operate independently and require separate subscriptions. CodeRED allows for precise geographical targeting and is used by multiple jurisdictions within the Lake Tahoe Basin for emergency notifications. PlacerAlert offers notifications through text messages, emails, and social media, with a focus on reporting out from law enforcement agencies and municipal governments. Residents and visitors must subscribe to use these services; those who have not subscribed may be alerted to an evacuation order within an affected area via Wireless Emergency Alerts (WEA), but only if they have a capable mobile device.

Power Loss Prior to and During the Event

Power outages have been a significant challenge during emergencies, as demonstrated during the 2019 Kincade Fire, which burned 77,758 acres in Sonoma County, California, and displaced 200,000 evacuees. There was a disruption in communication channels due to the power loss, making it difficult for emergency services to relay evacuation orders and updates effectively. Residents who relied on internet and cable services found themselves without access to crucial information, exacerbating confusion and anxiety.[9]

Time to Contact and Gather Family Members

Family evacuation behaviors are influenced by factors such as prior experience, risk perception, and communication methods. Research shows that families with prior evacuation experience are more likely to quickly assess their environment, confirm warnings, and contact family members. This preparation can significantly reduce the time needed to gather and evacuate. Risk perception also plays a crucial role; individuals who recognize the severity of an impending disaster are more proactive in complying with evacuation orders and mobilizing their families. Timing also matters—evacuation orders issued during the day see higher compliance and quicker family mobilization times compared to those issued at night.[10]

Courtesy of TahoeCleanAir.org

Courtesy of TahoeCleanAir.org

Vulnerable Populations

In El Dorado and Placer Counties, approximately 22% of the population is 65 and older, while in Washoe County, around 16% of the population falls into this age group. Nearly 8% of those living in El Dorado and Placer Counties and 9% of the population of Washoe County are challenged with chronic health conditions or other disabilities. These individuals may struggle with mobility issues, need specialized medical care, and often depend on caregivers for transportation, complicating their ability to evacuate swiftly and safely.

Economically disadvantaged populations, including those living below the poverty line (approximately 9% in El Dorado County, 7% in Placer County, and 11% in Washoe County),[11] are at a heightened risk during disasters. Limited access to private transportation, timely information, and adequate housing can significantly impede their ability to prepare for and safely react to emergencies. The geographic isolation and limited infrastructure of the Lake Tahoe Basin compound these challenges, underscoring the urgent need for targeted support and resources to ensure equitable disaster preparedness.

First Responder Access

Ingress for emergency responders may be significantly hindered during an evacuation. Roads often become congested with evacuating vehicles, leading to gridlock. The confusion and panic that typically accompany no-notice evacuations can lead to vehicle accidents, slowing or otherwise impeding the progress of emergency vehicles. Infrastructure damaged in a wind-driven or fast- moving wildfire, such as downed powerlines and power poles, can make it difficult for emergency responders to get where they are needed.[12]

Effects of Smoke and Panic on Evacuee Behavior

Smoke and panic impact the efficiency and safety of wildfire evacuations, creating considerable challenges for both evacuees and emergency responders. Studies on the effects of alarm, flame, and smoke on subjects' emotions in buildings have found that the initial alarm or notification was the most significant cause of panic. The combined effects of smoke and panic not only slow down the evacuation process but also significantly increase the risks of injury and fatalities.[13]

The presence of smoke from wildfires drastically reduces visibility, making it difficult for people to identify safe paths and exit routes. Smoke inhalation can lead to acute respiratory issues, further slowing evacuees and complicating their escape. The disorientation caused by thick smoke can cause individuals to lose their sense of direction, which can result in them taking longer, more dangerous routes or becoming trapped.

Panic can impair individual and group decision-making, leading to poor judgment and potentially life-threatening decisions and behaviors. For example, fearing being alone or having misunderstood directions, people may choose more congested routes, leading to bottlenecks and increased risk for accidents, instead of following safer, less crowded routes. Such panic-induced behaviors disrupt coordination and communication, which are crucial for effective evacuations.

Contraflow

Contraflow is a traffic management strategy to increase the capacity of roads by reversing the traffic flow of one or more of the traffic lanes. Theoretically, contraflow allows more vehicles to leave the danger zone simultaneously. This method is particularly effective in planned evacuations. In these instances, sufficient time and personnel are available to brief mutual aid law enforcement officers on the plan and effectively control intersections. The implementation

of contraflow requires a large number of personnel and may not be able to achieve its intended outcome during no-notice evacuations when the availability of first responders is limited. Additionally, assisting agencies from outside the area may not be familiar with the contraflow plan, hampering coordination efforts. While contraflow presents a promising solution to enhance evacuation efficiency, its effectiveness largely depends on the preparedness and cooperation of the affected communities, responsiveness of the authorities involved, and adequate resources to manage multiple intersections.

Cell Tower Reliability

When mobile networks fail, first responders' and government agencies' ability to disseminate emergency alerts and updates is severely hindered, leading to delayed evacuations and increased risk to human life. The absence of mobile communication also complicates community coordination during emergencies, leaving families and neighbors unable to reunite or coordinate evacuation plans and reduces the ability of residents to contact emergency services for assistance or updates.

The disruption of mobile communication affects traffic management and resource allocation as well. Real-time updates on evacuation routes are essential for ensuring the safe and efficient movement of people. Additionally, coordinating fuel, food, and medical supplies becomes more challenging, impacting evacuee support. The psychological impact of communication loss is also significant; the inability to contact loved ones and receive timely information increases stress and anxiety among evacuees, exacerbating the trauma of the wildfire experience.

Social Media

Social media plays an important role in wildfire evacuations, providing both significant benefits and potential drawbacks. On the positive side, online platforms are powerful channels for the rapid dissemination of information, allowing authorities to issue evacuation orders, update road closures, help people visualize the situation with maps and graphical tips, and share shelter locations with a broad audience in real-time. Local communities and government agencies in the Lake Tahoe Basin frequently use these platforms to reach residents quickly and efficiently. On platforms and forums that are community-focused, neighbors can directly coordinate support and share hyperlocal information.


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The influence of social media on wildfire evacuations also carries risks. The spread of misinformation, false alarms, and rumors can mislead the public and divert emergency resources from actual threats. This can cause unnecessary panic and confusion, leading to ill-informed decisions or undue stress. The overwhelming volume of updates from multiple sources, even credible and verified information, can contribute to information fatigue, which may lead to inaction.

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ENVIRONMENTAL CHARACTERISTICS AND FIRE HISTORY OF THE TAHOE BASIN

Topography

The Tahoe Basin was formed by faulting between the Carson Range and the Sierra Nevada. Rough, snow-capped mountains, dense forests, and alpine meadows punctuate the region. The elevations in the Tahoe Basin range from 6,200 feet at the lakeshore to more than 10,000 feet at the crest of the basin's majestic mountain peaks. Snow runoff from the mountains filled the basin, creating the breathtaking Lake Tahoe. The unique topography of the basin—including steep slopes and deep drainage—creates complex weather patterns throughout the Lake Tahoe region.

Weather

Warm, dry summers and wet, cold winters are typical in Tahoe. The basin's rainfall amounts range from 30–40 inches annually on the eastern side of the lake to 70–90 inches annually on the western shore. Most precipitation falls in the winter as snow; an occasional monsoonal summer rain contributes a small percentage to the area's total annual precipitation.

Lightning is the cause of many of the region's wildfires, with most wildfires reported during the months of July through September. When droughts delay the anticipated fall and winter precipitation, fast-moving and damaging wildfires, driven by the dry offshore fall wind patterns, can quickly spread through the forests and into the nearby communities.

Three common weather patterns present the most severe potential for significant fire growth in the Tahoe Basin. In the first weather pattern, persistent subtropical high pressure builds over the western United States, resulting in long-lasting hot and dry weather in the basin. Occasionally, this high-pressure center will entrain moisture from the Gulf of California or the Gulf of Mexico, causing widespread lightning outbreaks. Under these circumstances, firefighting resources become overtaxed, and some fires escape initial suppression efforts. The second weather pattern is the breakdown of the upper ridge of high pressure, which brings strong southwesterly winds following a sustained period of hot and dry weather that left the forest fuels tinder dry. The numerous canyons on the west side of the basin funnel and accelerate these southwesterly winds, exponentially increasing the explosive behavior of wildfires on the

basin's west side. The third pattern, typically experienced in the fall or winter, is rare but worth mentioning; it occurs when a trough of high-pressure builds in the Great Basin and a concurrent trough off the Pacific coast generates easterly or northerly foehn (dry downslope) winds—a particularly dangerous weather pattern if experienced during a sustained fall drought.

Found only across the Sierra Front in western Nevada including the Tahoe Basin, the Washoe Zephyr winds are common during the summer months. These thermally induced winds occur during the afternoons and result from a regional-scale thermal gradient between the Nevada desert and the Sierra Nevada range. These winds can be gusty and strong and quickly spread any wildfire in the area.

Fuels

Timber dominates the basin, with lodgepole pine and mixed conifer on the wetter sites and ponderosa and Jeffrey pine on the drier eastern edges. The timber has been disturbed by harvesting and insect attacks. Large-diameter dead and down fuels are widespread in the basin. There is also a multilayered canopy with shade-tolerant white fir and other species filling open spaces. Timber canopy coverage is near 100% in many areas, and canopy base height is nearly ground level in many areas. Some shrubs, such as bitterbrush, manzanita, and ceanothus, growing two to six feet in height, are common. In some places where the brush is in the understory of timber, the dead conifer needles are suspended in the shrub canopy (needle drape), providing ladder fuels to the brush and timber crowns, which accelerate fire spread.

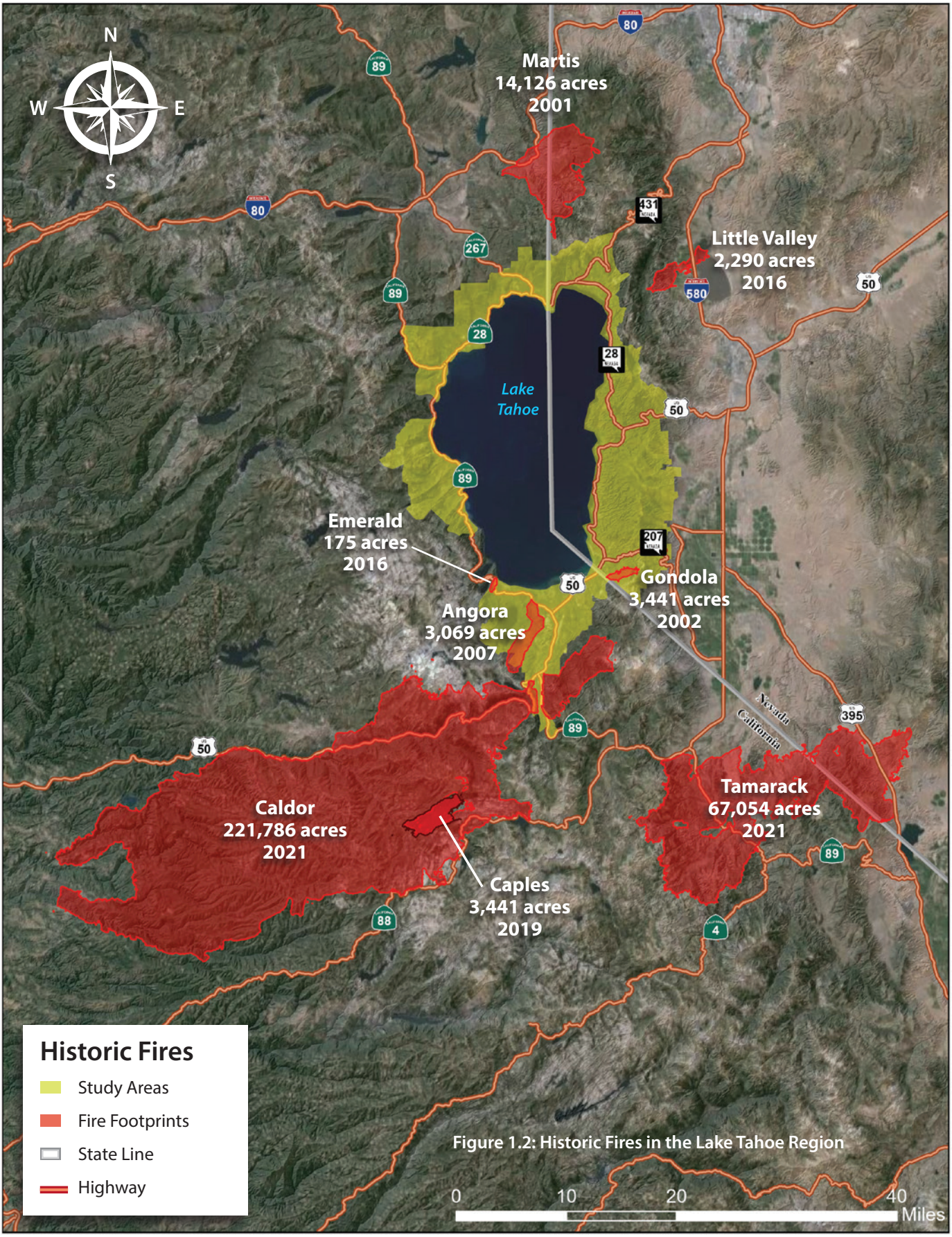

Figure 1.2: Historic Fires in the Lake Tahoe Region

TAHOE REGION FIRE HISTORY

The Tahoe Basin faces the danger of wildfires originating not only within the basin but also in neighboring forests and communities. Since 2021, two wildfires have burned over the Sierra Nevada crest. The Caldor and Dixie Fires were seminal events that signaled a change in the wildfire growth potential existing in the Sierra Nevada and graphically exposed the increasing wildfire threat to the Tahoe Basin.

The Tahoe Basin's unique environmental factors, coupled with human activity, create significant challenges related to wildfire firefighting and evacuations, as is obvious when studying a number of fires that have threatened or penetrated the Tahoe Basin.

Caldor Fire, 2021

The 2021 Caldor Fire is freshest in the minds of many, a mega-fire in what was already a historic fire season. The Caldor Fire burned 221,786 acres over 68 days. More than 50,000 residents were evacuated, and nearly 1,100 structures were destroyed or severely damaged, including homes and economic drivers such as a Tahoe resort. Strong and fluctuating wind, as well as hot and dry weather conditions, exacerbated the situation.

The Caldor Fire began at 6:54 p.m. on August 14, 2021, and was considered fully contained at 8:18 a.m. on October 21. It started east of Omo Ranch, south of the community of Grizzly Flats, and traveled across El Dorado, Alpine, and Amador Counties. Winds remained gusty and erratic during the more than two months firefighters battled the blaze.

The Caldor became a crown fire that quickly traveled across the tree canopy. Sometimes it grew at a rate of 10,000 to 40,000 acres per day. For example, it severely damaged the town of Grizzly Flats when it exploded in intensity, burning more than 53,000 acres in a day. Subsequent evacuation orders for populated tourist towns resulted in evacuation routes being congested with stop-and-go traffic for hours.

Tamarack Fire, 2021

Reported just before noon on July 4, 2021, the Tamarack Fire burned 67,054 acres along the California-Nevada border before it was fully contained at 10:16 p.m. on October 25. It began in the Humbolt-Toiyabe National Forest with a single tree struck by lightning. The fire was initially thought to be isolated from fuel, but strong

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winds, high temperatures, and low humidity allowed it to spread to a dense fuel source that sustained the fire's forward spread. The town of Markleeville, at the base of the forest's steep canyons, suffered only minor damage, thanks in large part to its fuel-reduction project.

Caples Escape Burn, 2019

The Caples Escape Burn began as part of the Caples Creek Watershed Restoration Project in late September 2019. It became a wildfire on October 10 at approximately 10 a.m. when shifting winds increased to 10–30 miles per hour (mph), sending embers outside the prescribed area and igniting a 250-acre spot fire across the creek. The wildfire burned 2,355 acres of Eldorado National Forest, 15 miles southwest of Lake Tahoe and three miles west of Kirkwood. The fire stopped growing on October 18.

Little Valley Escaped Burn, 2016

In October 2016, the Nevada Division of Forestry set a prescribed burn. Nearly two weeks into the planned burn, the winds changed quickly and dramatically, transforming the controlled burn into a fast-moving and destructive fire just south of Reno. In the early evening of October 13, 2016, the weather station at Little Valley recorded winds out of the west at 15 mph with gusts up to 39 mph; seven hours later, just after midnight on the 14th, the wind was at 19 mph, with gusts up to 87 mph. The relative humidity was 32%. Five days later, the fire was contained; it had destroyed 23 homes and burned 2,290 acres.

Angora Fire, 2007

The Angora Fire started at 2:10 p.m. on June 24, 2007, and was contained by July 2. But it spread with such rapidity that by that first night, more than 100 people were in evacuation shelters. Overall, more than 3,000 were evacuated.

The Angora Fire burned nearly 3,100 acres of the North Upper Truckee and Angora Ridge neighborhoods of El Dorado County, in the process destroying 254 residences and racking up an estimated $141 million in property damage. Wind gusts up to 30 mph and low humidity

contributed to the fast-moving spread; the first house was lost within the first hour, and the blaze continued to be a dynamic "firestorm," ever-changing and forceful, an incident commander on the fire said.[14]

Gondola Fire, 2002

For four days over the 2002 Fourth of July holiday, the Gondola Fire threatened the Lake Tahoe South Shore communities, which were busy with residents and vacationers alike. By the end, the fire had consumed 3,441 acres, hundreds of people had been evacuated, and 550 structures had been threatened. Suppression costs rose to more than $3 million.

The Gondola Fire began in rocky terrain at about 12:30 p.m. on July 2. Strong winds of 30 mph simultaneously pushed the fire in two directions. Although the terrain was steep, and some people had to be evacuated from unusual places, such as the Heavenly Mountain Resort gondola, the location also offered firefighters some advantages, both natural and manmade. More than 300,000 gallons of water came directly from Lake Tahoe, and the resort's ski runs served as fire breaks. The Gondola Fire was considered contained on July 6.

Martis Fire, 2001

The Martis Fire that started on June 17, 2001, destroyed very little property but devastated the mountainous forest between Reno and Truckee. It had burned about 12,000 acres within its first six or seven hours, and at one point, it was moving at 2,000 acres per hour. One California Department of Forestry crew member said he saw an ember grow into a two-acre blaze in about a minute.[15] The fire ultimately burned 14,126 acres.

Known also as the Juniper Fire because it started with a campfire in the Juniper Hills area, it fed on the fuel-dense forest—as it so easily could, because the preceding winter had been the driest in 129 years. Winds were light, but the extreme dryness was all the fire needed. It stopped only when it reached the upper parts of Bronco and Grey Canyons, at more than 8,000 feet, where the higher moisture content made fire control possible.

MODELING ASSUMPTIONS
Placer /Tahoe Study Area

Example, evacuation routes for the Placer/ Tahoe communities are limited to four routes: Highway 89 north toward Truckee, Highway 89 South toward South Lake Tahoe, State Route 28 to State Route 267 over Brockway Pass, and State Route 28 into Incline Village to Mt. Rose Summit.

The average estimated time required to evacuate to complete a no-notice evacuation of the Placer/Tahoe Study Area during peak summer months is between 9 and 10 hours or more. To illustrate, simulation scenarios 1 through 5 of the Ladris AI modeling outcomes are provided in Tables 1.1 through 1.5.

All scenarios simulate an evacuation of 80% of the study area's population during Lake Tahoe's peak tourist summer months, between 1 p.m. and 5 p.m. Residents and visitors are assumed to evacuate by vehicle, with departures occurring within minutes of notice; all evacuees start their route to safety within 60 minutes of notification.

Residential Housing and Lodging Units

Placer County GIS identifies 11,285 unique address points in the greater Placer/Tahoe Study Area. Many of these address points are multi-residential properties (i.e., hotels, motels, campgrounds, and condominiums) that must be considered when calculating the number of vehicles used in an evacuation scenario. A large number of seasonal properties are available throughout the Tahoe Lake area. Demand for seasonal housing fluctuates considerably throughout the year, with the peak months of July and August having a 75% to 80% occupancy rate. Therefore, for the Placer/Tahoe analysis, it is conservatively estimated that approximately 13,000 vehicles will be used to evacuate all lodging accommodations and residential properties in the Placer/Tahoe Study Area.

Parked Vehicles

In 2015, LSC Transportation Consultants estimated that 4,349 legal parking spaces were available within Tahoe City and Kings Beach. These study results were consistent with the Placer County Resort Triangle Transportation Plan parking study conducted in 2019. Both studies noted that illegal parking is an issue, with the 64-Acres

Park area experiencing up to 148% of parking spaces being used when "impacted by recreational parking demand associated with rafting on the Truckee River as well as persons driving to the area to bicycle or walk along the shared paths or visit the beach."[16] Using these studies as a guide, parked vehicles are included as a variable in the estimated time required to evacuate the Placer/Tahoe Study Area.

Placer/Tahoe Study Area Simulation Modeling

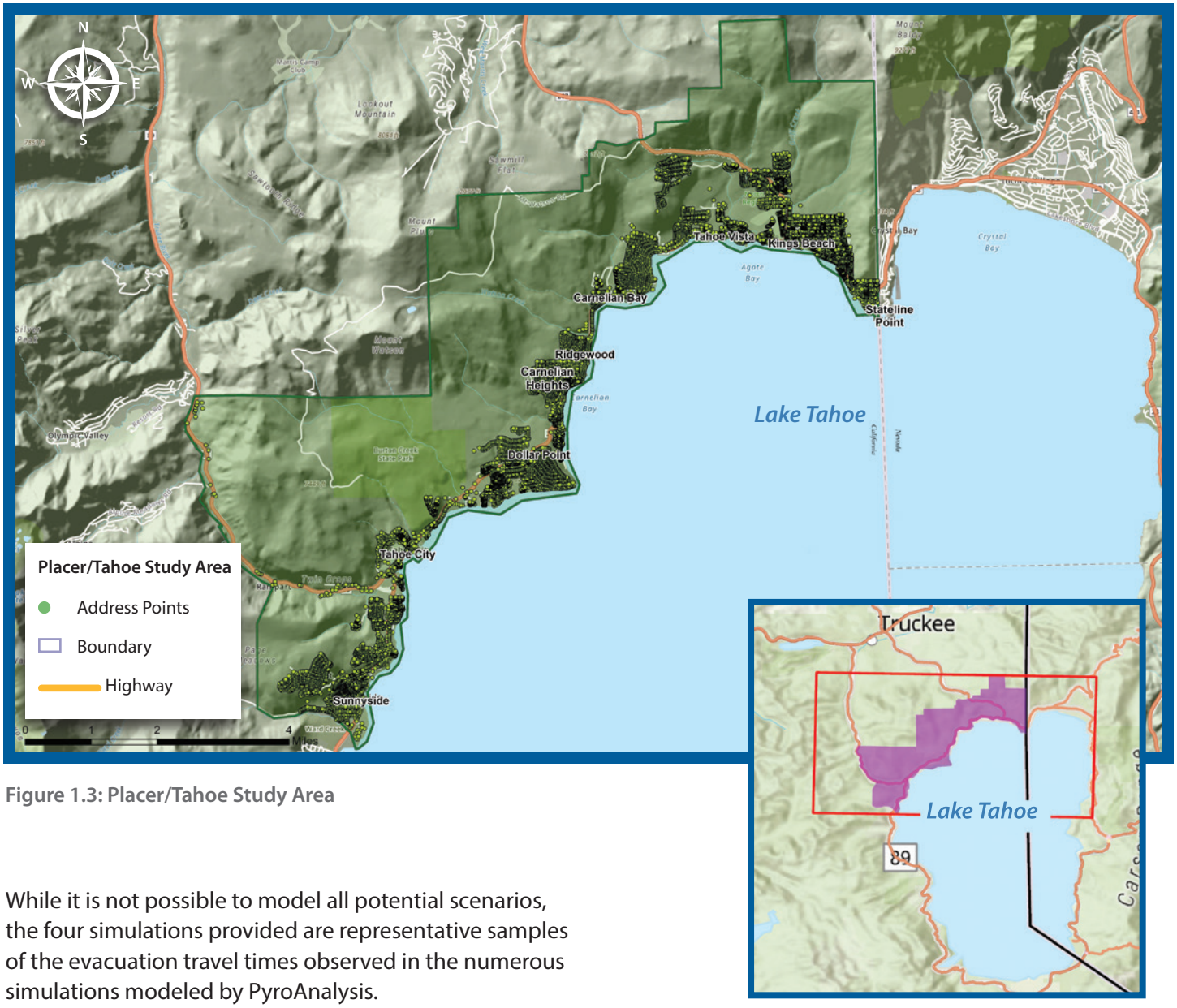

Figure 1.3: Placer/Tahoe Study Area

While it is not possible to model all potential scenarios, the four simulations provided are representative samples of the evacuation travel times observed in the numerous simulations modeled by PyroAnalysis.

Simulation 1

Table 1.1: Placer/Tahoe Simulation 1

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the west, requiring the closure of Highway 89 north of the Highway 28 junction in Tahoe City. Evacuation routes leading south and east from Tahoe City and north and east of Kings Beach are open and unimpeded. It is estimated that 9 hours and 2 minutes are required to complete the evacuation of the study area with one evacuation route closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
17,577	All Roads South, and East of Tahoe City and North and East of Kings Beach	89 NB	9 Hours, 2 Minutes

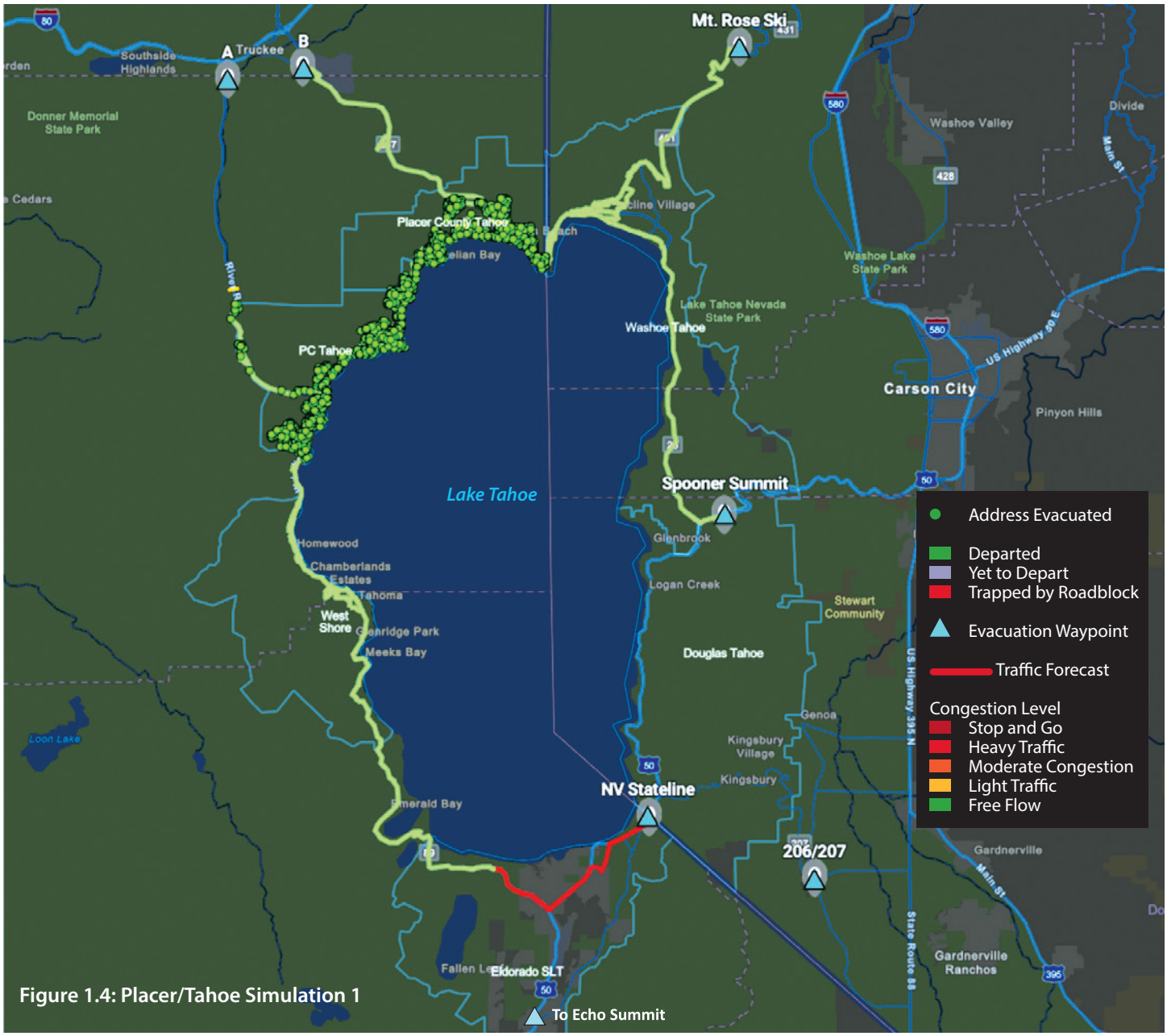

Figure 1.4: Placer/Tahoe Simulation 1

Simulation 2

Table 1.2: Placer/Tahoe Simulation 2

Map simulates end of interactive run time

This scenario represents a fast-moving wildfire approaching the study area from the west and requiring the total closure of Highway 89 north and south of Tahoe City. Evacuation routes leading east from Tahoe City and north and east of Kings Beach are open and unimpeded. It is estimated that 9 hours and 37 minutes are required to complete the evacuation of the study area with two evacuation routes closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
17,577	Roads East of Tahoe City and North and East of Kings Beach	89 NB/SB	9 Hours, 37 Minutes

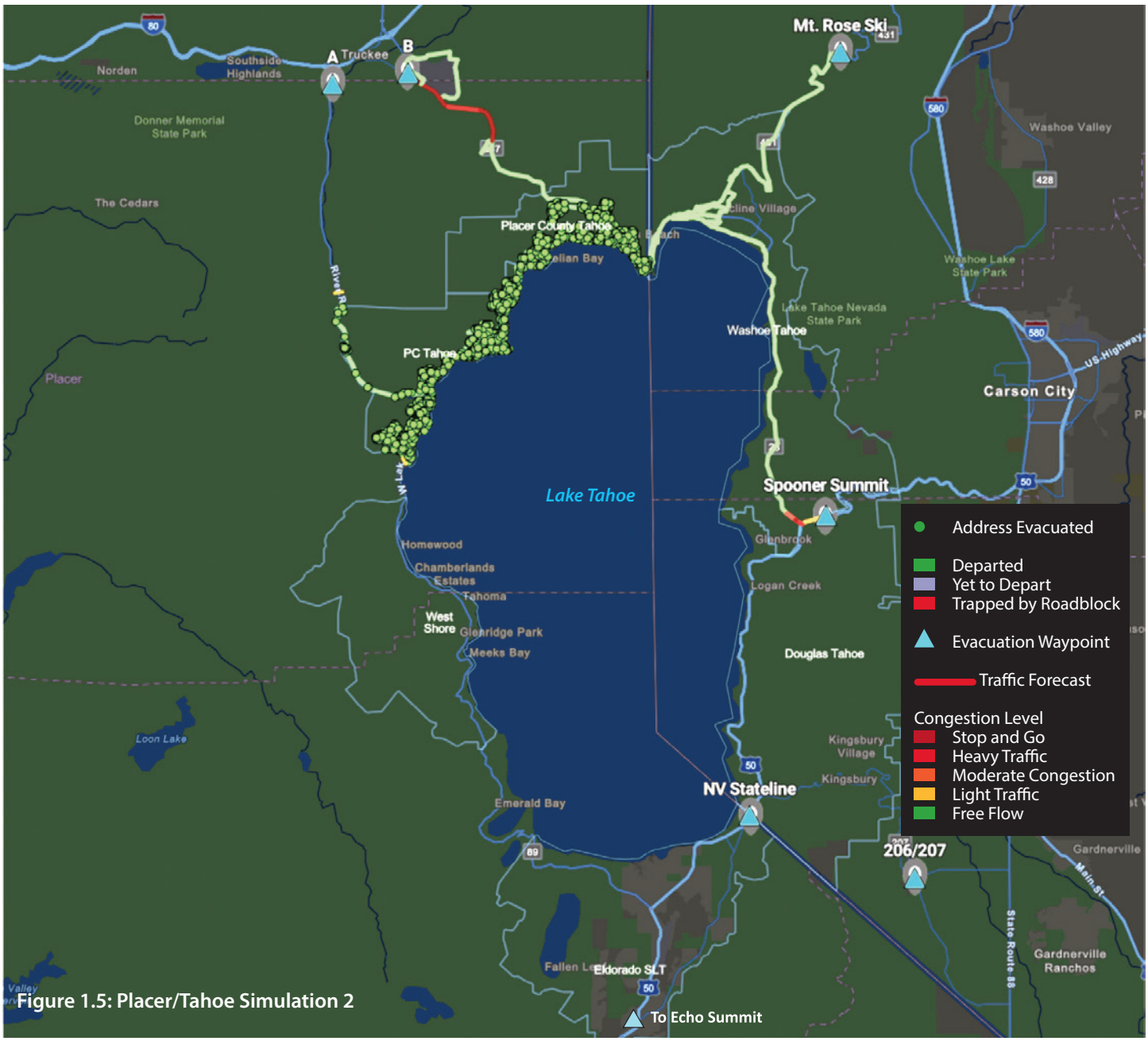

Figure 1.5: Placer/Tahoe Simulation 2

Simulation 3

Table 1.3: Placer/Tahoe Simulation 3

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the north, requiring the closure of Highway 89 north of Tahoe City and Highway 267 north of Kings Beach. Evacuation routes leading east and south from Tahoe City and west and east of Kings Beach are open and unimpeded. It is estimated that 13 hours and 19 minutes are required to complete the evacuation of the study area, with two evacuation routes closed. The evacuation of 18,080 vehicles was used to capture the population influx of July 4, 2024.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
18,080	Roads East and South from Tahoe City and West and East of Kings Beach	89 NB 267 NB	13 Hours, 19 Minutes

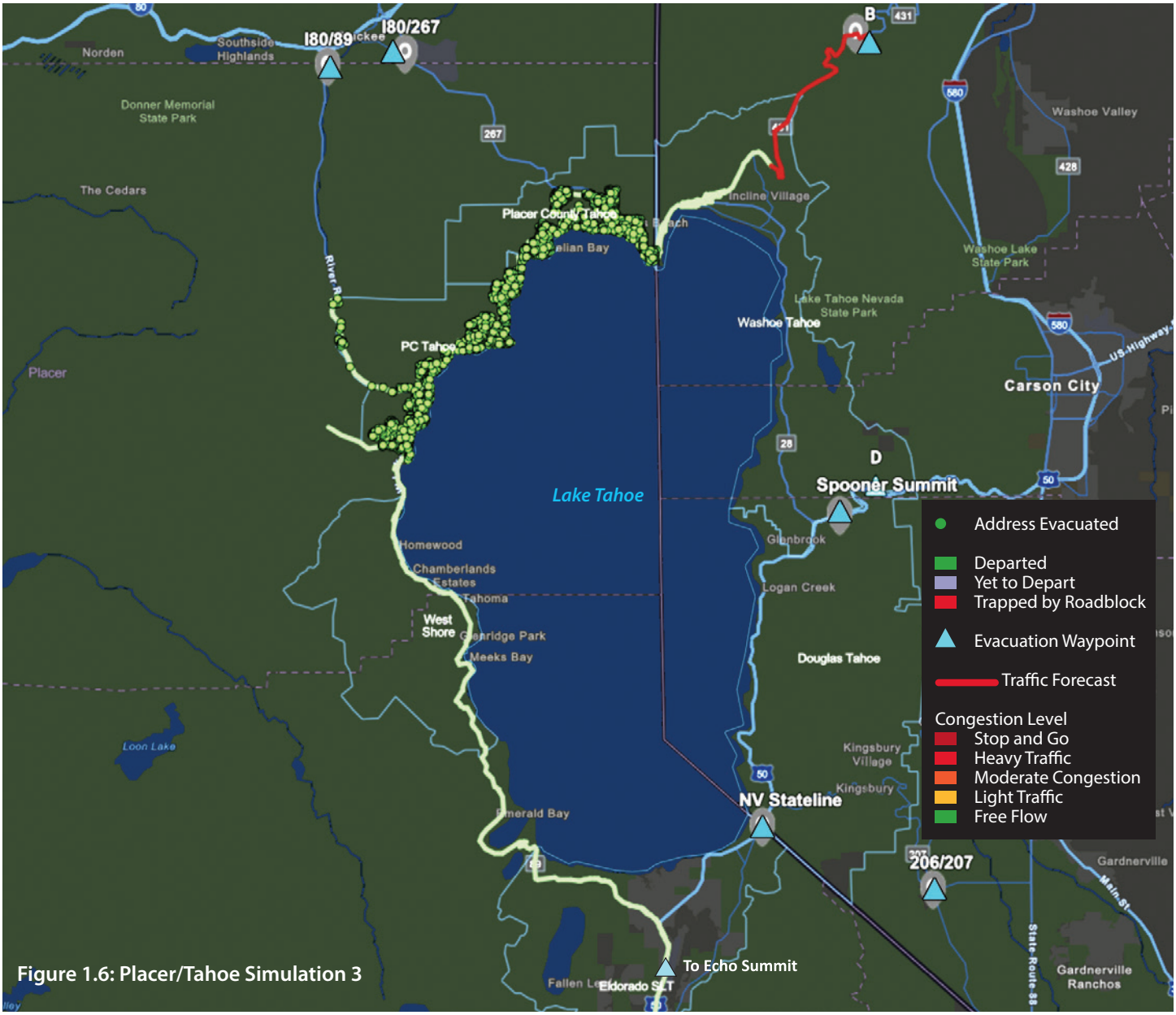

Figure 1.6: Placer/Tahoe Simulation 3

Simulation 4

Table 1.4: Placer/Tahoe Simulation 4

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the east near the California-Nevada border, requiring the closure of Nevada State Route 28 toward Incline Village at the state line. Evacuation routes leading west and north from Kings Beach are open and unimpeded, as are routes north and south from Tahoe City. It is estimated that 9 hours and 44 minutes are required to complete the evacuation of the study area with one evacuation route closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
17,577	All Roads West of the State Line and North and West of Kings Beach and North and South of Tahoe City	28 EB	9 Hours, 44 Minutes

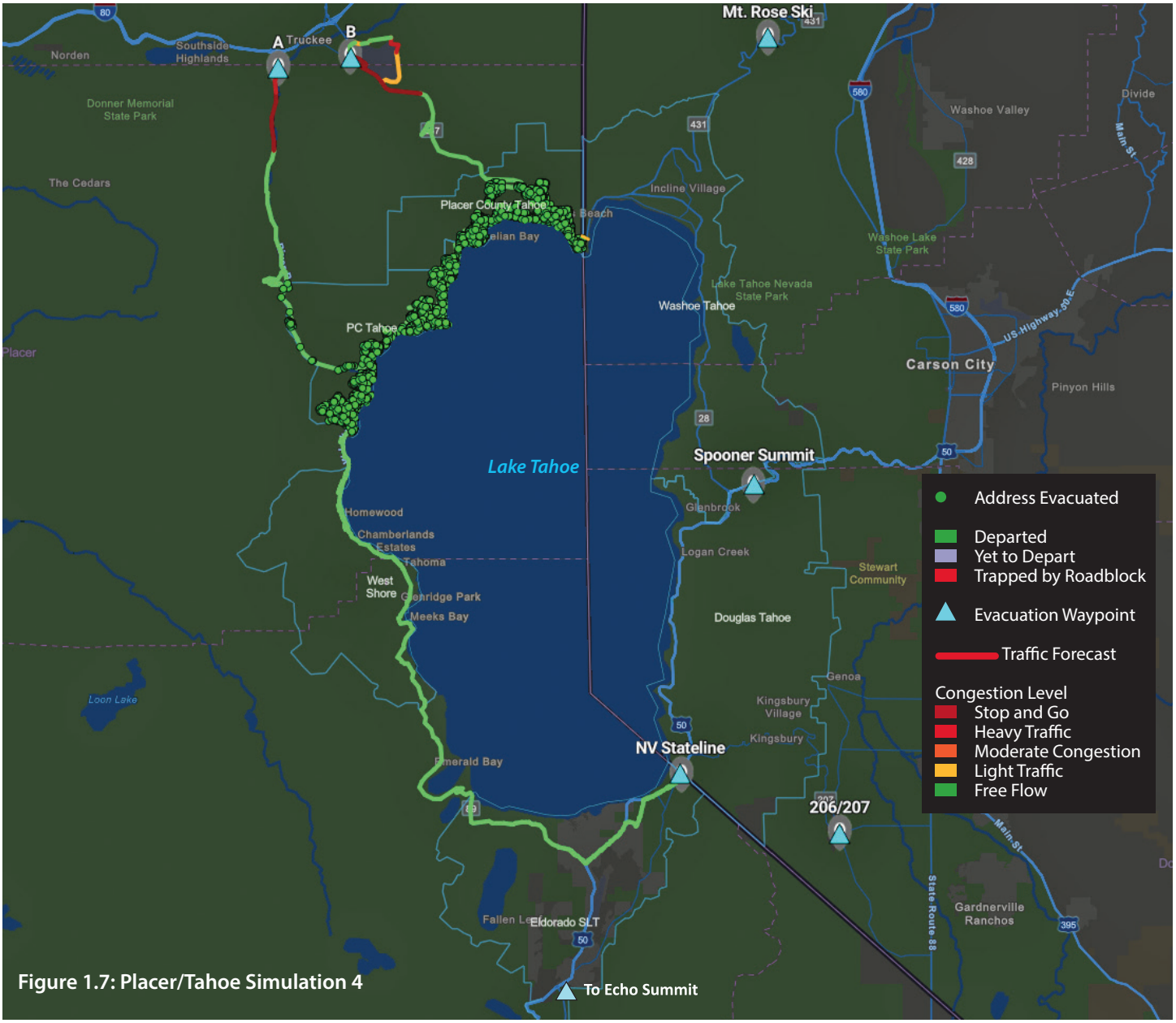

Figure 1.7: Placer/Tahoe Simulation 4

Simulation 5

Table 1.5: Placer/Tahoe Simulation 5

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the east near the California-Nevada border, requiring the closure of Nevada State Route 28 toward Incline Village at the state line and at Highway 267 north of Kings Beach. Evacuation routes leading west to Tahoe City and north and south from Tahoe City are open and free of impediments. It is estimated that 13 hours and 16 minutes are required to complete the evacuation of the study area with two evacuation routes closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
17,577	All Roads to the West and South	28 EB, 267 NB	13 Hours, 16 Minutes

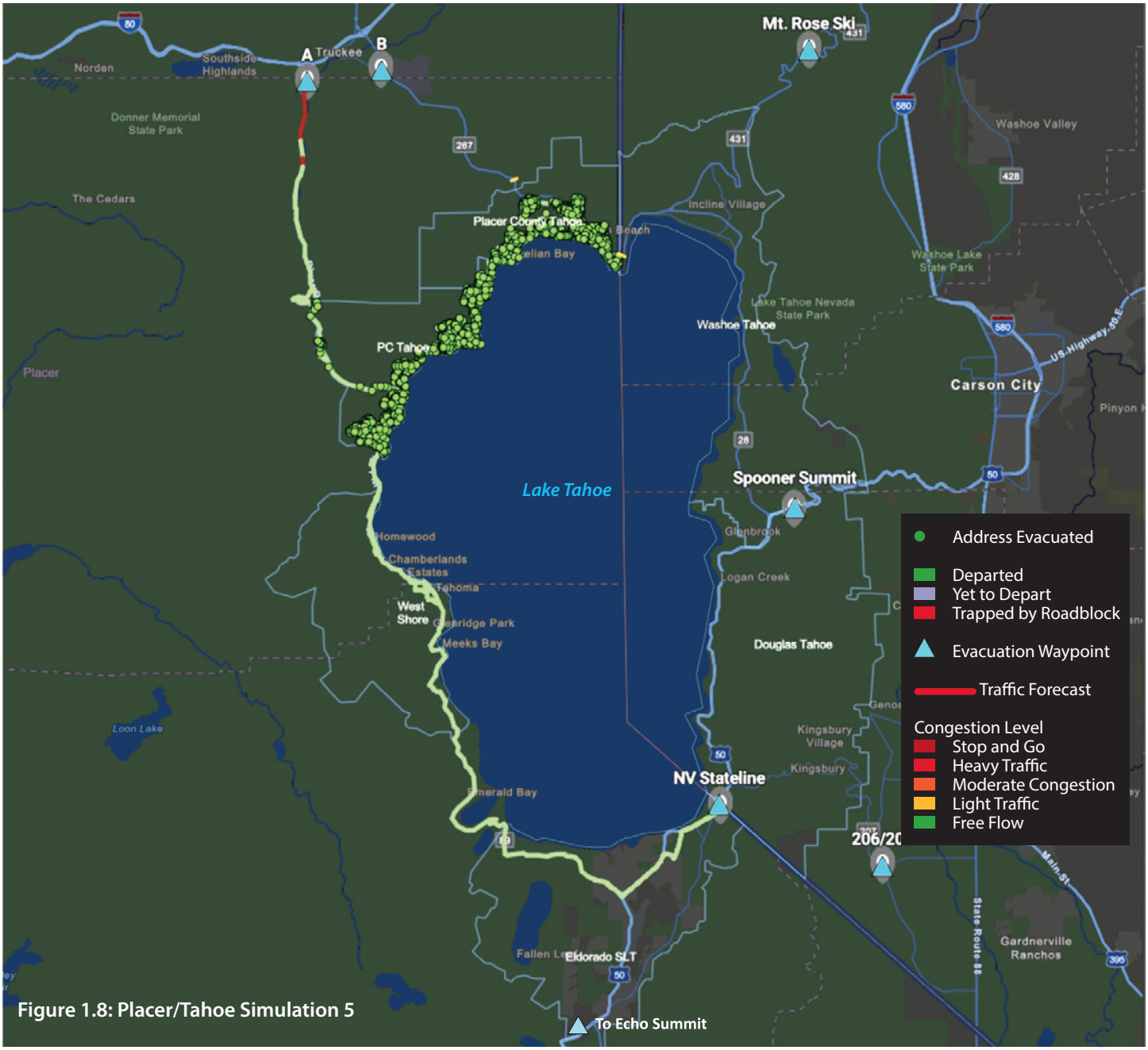

Figure 1.8: Placer/Tahoe Simulation 5

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WASHOE/TAHOE STUDY AREA ADDENDUM

SUMMARY

The Washoe/Tahoe Study Area includes the geographical area of Washoe County, Nevada, within the US Forest Service Lake Tahoe Basin Management Unit (LTBMU) boundaries. Communities within the study area include Crystal Bay and Incline Village.

Crystal Bay, with an estimated population of 337, was developed as a residential community from the 1920s through the 1930s. In the 1950s, several resort casinos were built in the area, transforming it into a tourist destination. Incline Village was developed in the early 1960s and has a population of 9,462, with approximately 769 vacation rentals adding to the community's seasonal population.[17]

Incline Village attracts hundreds of thousands of visitors annually and offers a wide range of recreational activities. These activities include the internationally renowned East Shore Trail, Sand Harbor State Park, various hiking and biking trails, concerts, community celebrations, as well as major sporting events for running, biking, softball, soccer, and world-class golfing.

Washoe/Tahoe Study Area Simulation Modeling

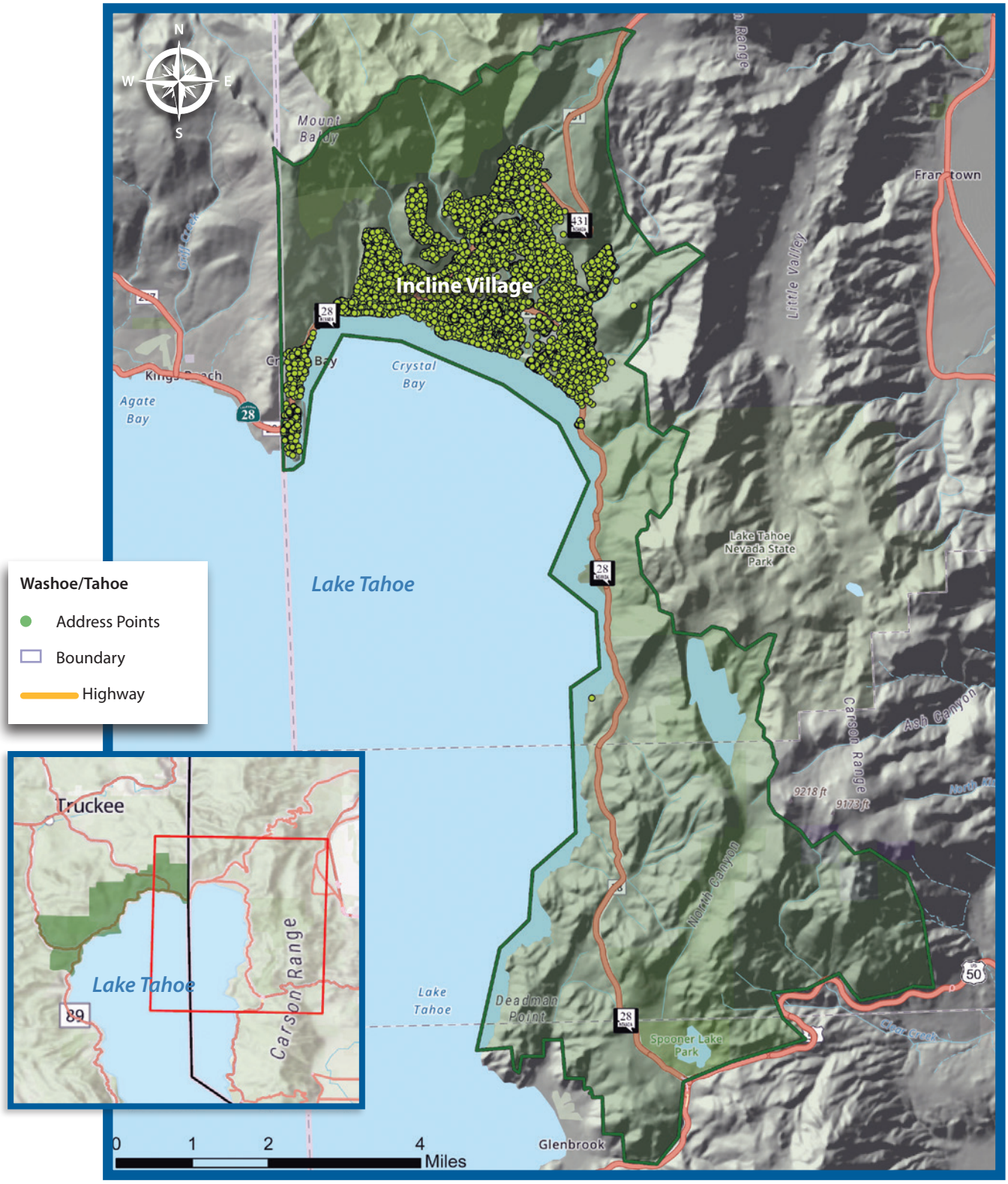


Figure 2.1: Washoe/Tahoe Study Area

CONSIDERATIONS AND IMPEDIMENTS TO TIMELY EVACUATION

Evacuation Travel Routes

There are three primary travel routes serving these Washoe /Tahoe communities:

- Nevada State Route 28 from Incline Village, heading south toward Highway 50
- Nevada State Route 28 from Incline Village, heading west toward the Nevada-California state line
- Nevada State Route 431 from Incline Village, heading northeast toward Mt. Rose Summit

Nevada State Route 28 is generally a tight two-lane highway with few turnouts and narrow shoulders, while Nevada State Route 431 is broader and has many turnouts and wide shoulders.

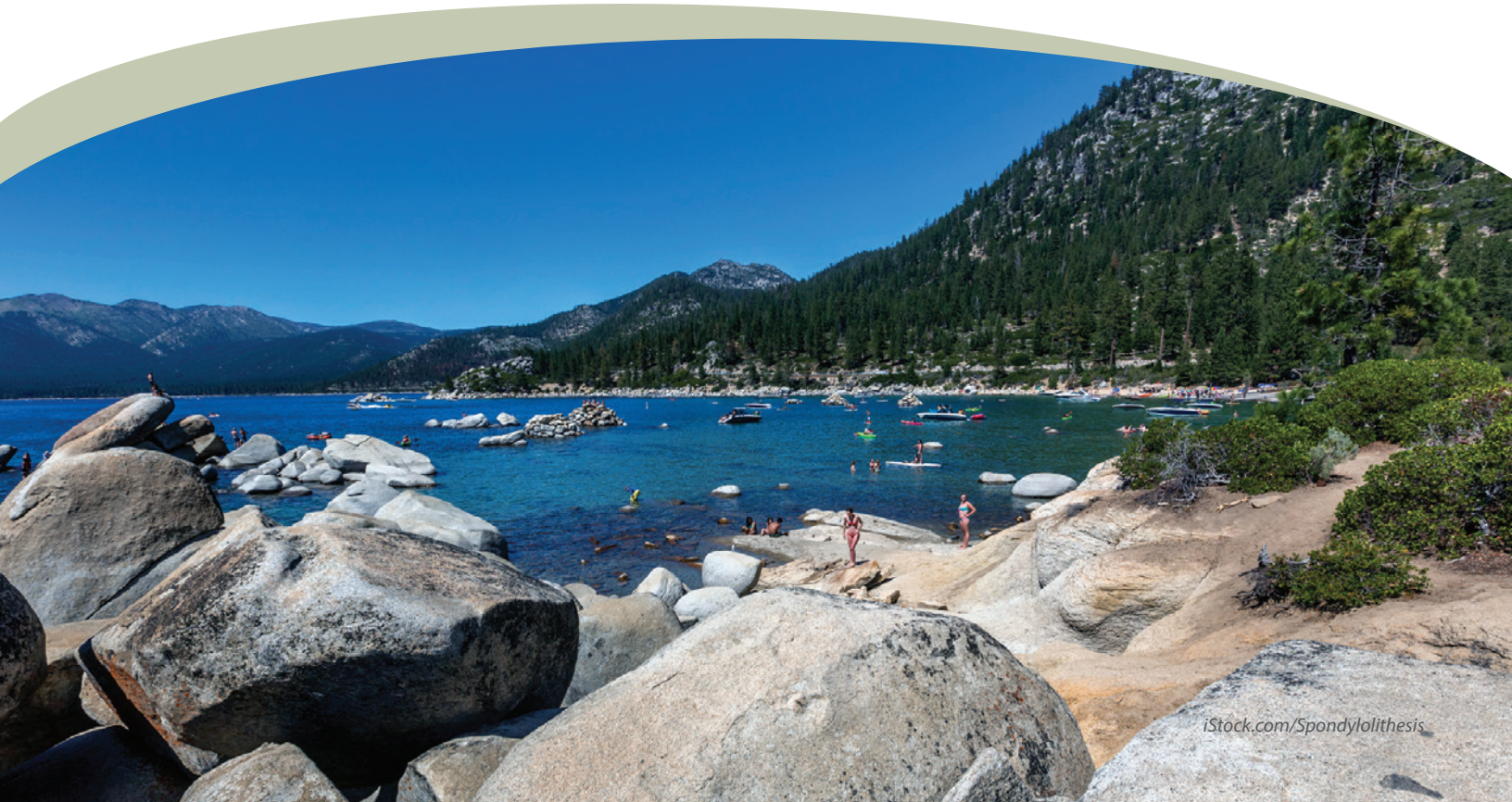
It is not possible to model all potential scenarios; however, it can be assumed that the visitor population and limited roadway capacity, as discussed next, will likely increase the time required to evacuate the study area.

East Shore Trail and Sand Harbor State Park Visitors

The paved East Shore Trail opened in June 2019 and is three miles long. It stretches from a paid parking area at Tunnel Creek in Incline Village to Sand Harbor State Park. According to data from the Tahoe Regional Planning Authority (TRPA), the trail sees 1,000 to 3,000 visitor trips daily from May through August, while Sand Harbor State Park is visited by hundreds of thousands of visitors during the summer months, as illustrated in Table 2.1.

Sand Harbor State Park Data	Total Monthly Visitors	Daily Average
June 2023	248,288	8,276
July 2023	278,819	8,994
August 2023	232,846	7,511

Table 2.1: Sand Harbor State Park Visitors



iStock.com/Spondylolithesis


Courtesy of TahoeCleanAir.org

Incline Village / Crystal Bay Daily Traffic Conditions

Heading north from Hwy 50, narrow Nevada State Route 28, travels through steep upslope and downslope grades toward Incline Village. It intersects with State Route 431 before continuing to the Nevada-California state line or toward Mt. Rose Summit. This route is used by public and private service vehicles, light and heavy construction equipment, delivery trucks, and logging trucks, in addition to vehicles for personal use.

In Incline Village, State Route 28 has a pedestrian caution light at the eastern corner of Northwood and Southwood Boulevards, near the skate park. There is also a stoplight at its western intersection with Northwood and Southwood and one at the intersection with Village Boulevard; there is a traffic circle at the intersection of State Route 28 and State Route 431. Most vehicle crashes in Incline Village are reported at the western intersection of Northwood and Southwood Boulevards at State Route 28.

During peak tourist season, the roads in Incline Village, Crystal Bay, and the surrounding area experience heavy traffic, causing significant congestion and long traffic queues. The combination of resident and nonresident vehicle traffic and the hundreds of parked vehicles that line both sides of State Route 28 from Sand Harbor to the Washoe-Douglas County line is likely to increase emergency evacuation travel times.

Public Parking on State Route 28

On a July afternoon, nearly 1,000 vehicles were observed parked along the steep incline of State Route 28 between Incline Village and Highway 50. Families and day trekkers, including young children and pets, use the roadside parking to access the lake. Notifying and evacuating this large number of visitors will pose a significant challenge, especially when they're lakeside and away from their vehicles.

The highway south of Sand Harbor to the Washoe-Douglas County line is often densely packed with parked vehicles, which, along with pedestrian traffic, reduces the road capacity. Due to inadequate parking for emergency vehicles and fire engines, first responders may need to block one highway lane for that purpose when responding to an incident, leading to a bottleneck of evacuating civilians.

Expected Fire Spread Under Wind and Slope Conditions

Incline Village and Crystal Bay, like most communities in the Tahoe Basin, were developed adjacent to the steep mountain slopes encircling Lake Tahoe. The steep, rugged terrain, abundant forest fuel, and fluctuating daily (diurnal) winds increase the risk of a major wildfire impacting Lake Tahoe's east and north shore communities. If a wildfire resists fire suppression efforts and is spread by the wind, steep slopes, and firebrands, the fast-moving fire is likely to block egress routes and complicate timely evacuation.


Courtesy of TahoeCleanAir.org

WASHOE/TAHOE STUDY AREA SIMULATIONS

While it is not possible to model all potential scenarios, the four simulations provided are samples of the evacuation travel times observed in the numerous simulations modeled by PyroAnalysis.

Simulation 1

Table 2.2: Washoe/Tahoe

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire requiring the evacuation of the study area. All evacuation routes are open and unimpeded. It is estimated that 7 hours and 20 minutes are required to complete the evacuation of the study area with no evacuation routes closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
13,151	All Open	None	7 Hours, 20 Minutes

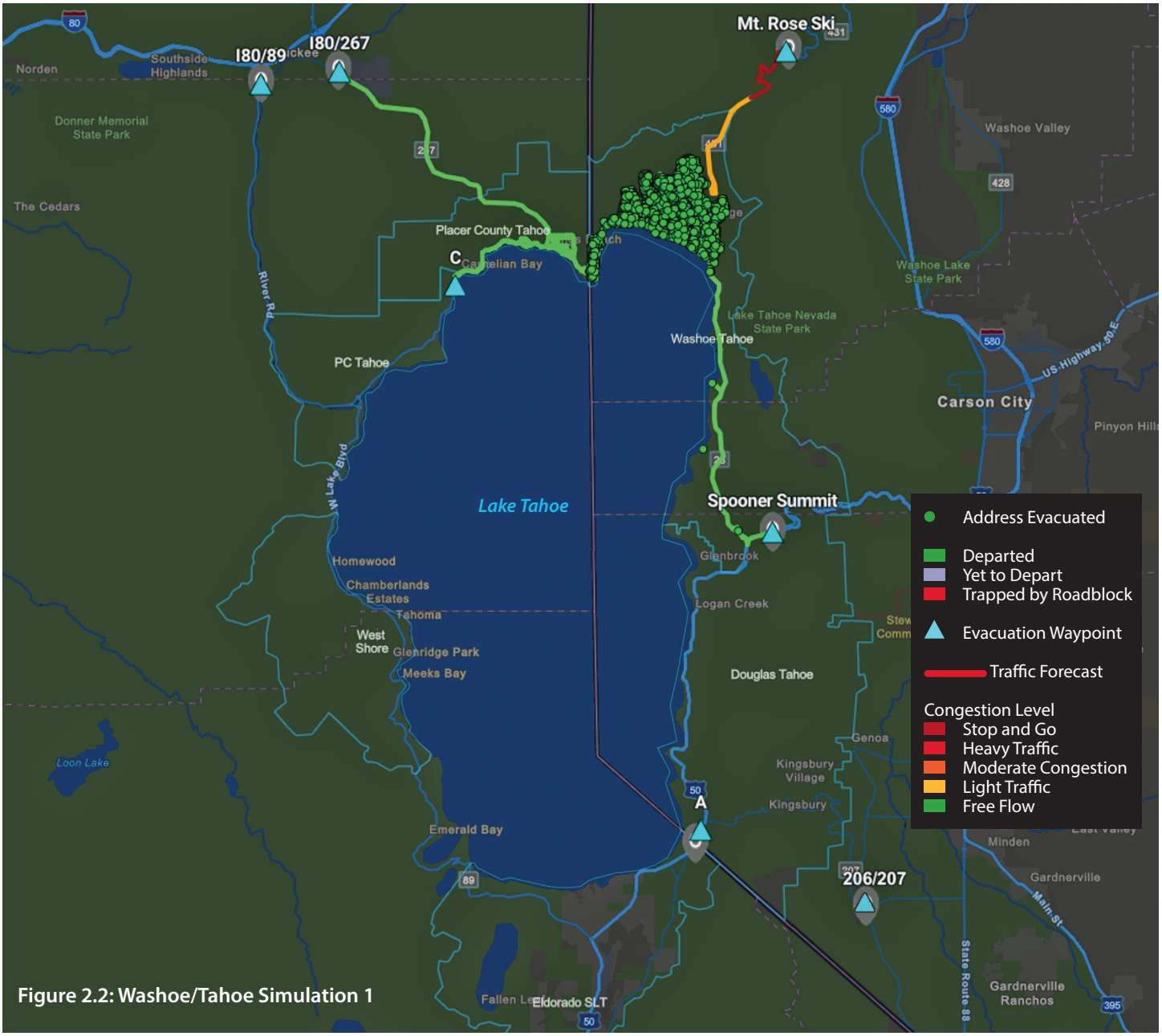


Figure 2.2: Washoe/Tahoe Simulation 1

Simulation 2

Table 2.3: Washoe/Tahoe

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the west, near the California-Nevada border, requiring the closure of Nevada State Route 28 towards King's Beach. Evacuation routes leading east, northeast, and south of Incline Village are open and unimpeded. It is estimated that 9 hours and 8 minutes are required to complete the evacuation of the study area with one evacuation route closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
13,151	All Roads East of the Stateline	28 WB at State Line	9 Hours, 8 Minutes

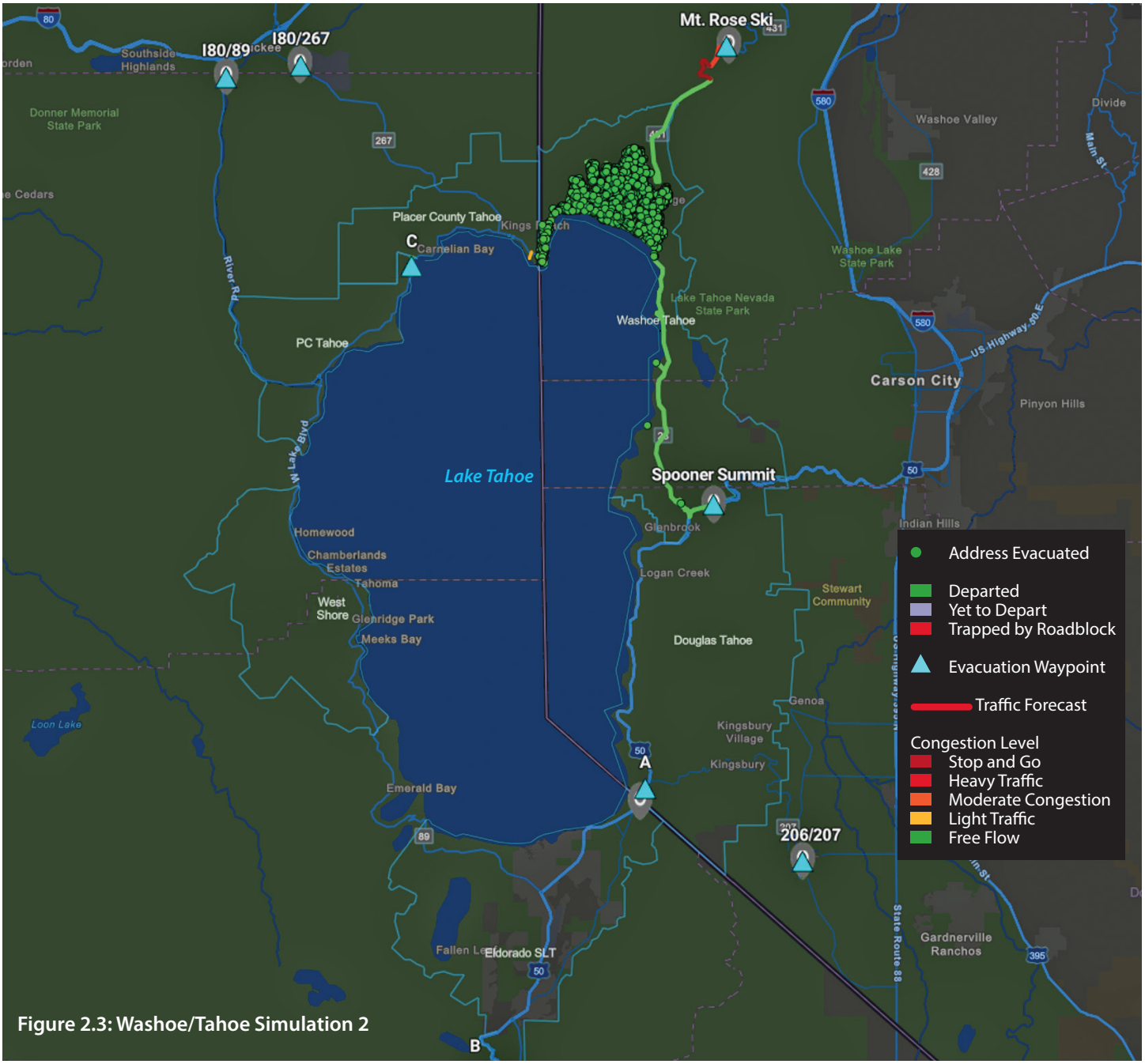


Figure 2.3: Washoe/Tahoe Simulation 2

Simulation 3

Table 2.4: Washoe/Tahoe

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the northeast, requiring the closure of Nevada State Route 431 towards Mt. Rose. Evacuation routes leading west, and south from Incline Village are open and unimpeded. It is estimated that 8 hours and 56 minutes are required to complete the evacuation of the study area with one evacuation route closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
13,151	All Roads South and West from Incline Village	431 at Fairview	8 Hours, 56 Minutes

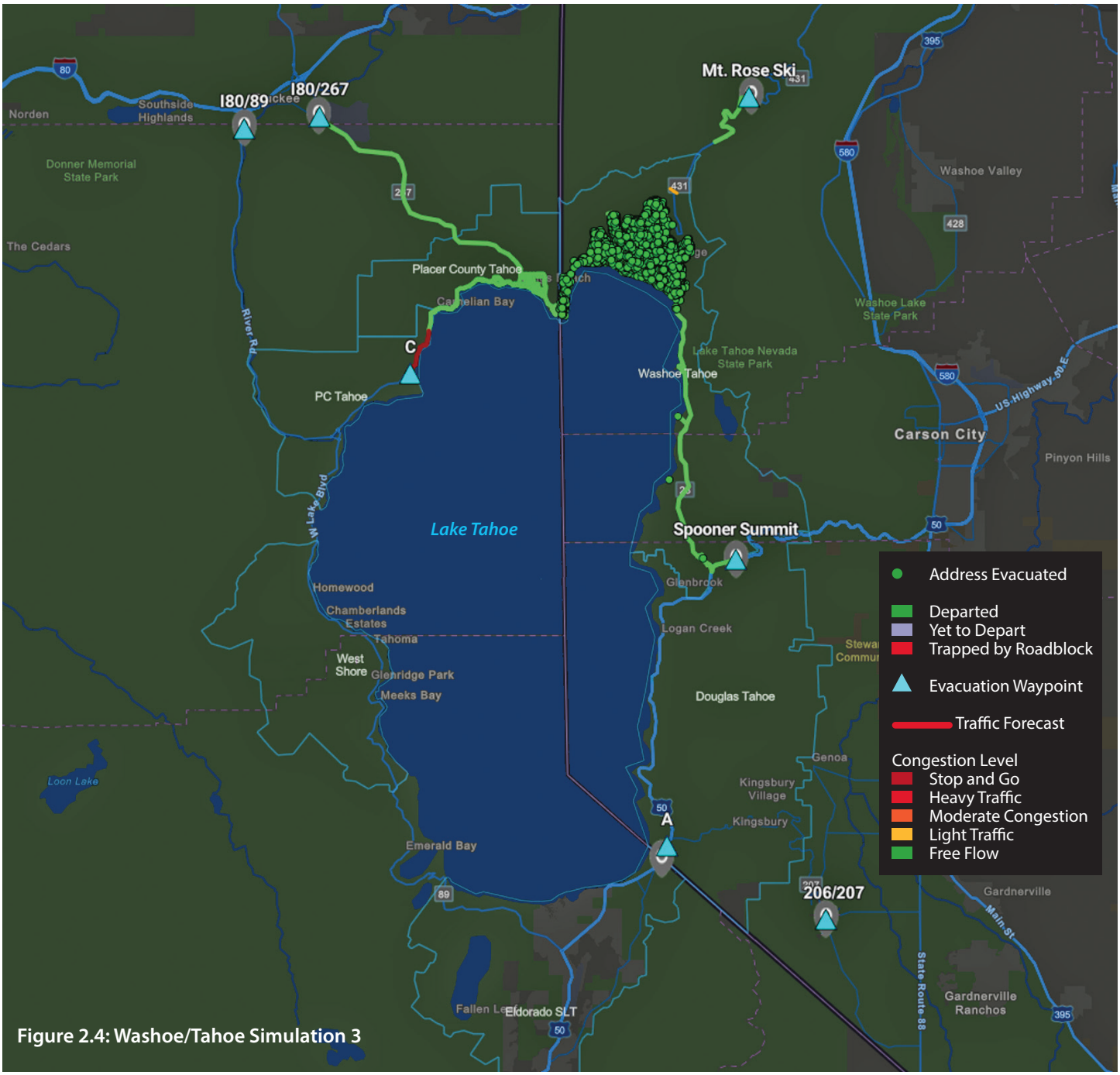


Figure 2.4: Washoe/Tahoe Simulation 3

Simulation 4

Table 2.5: Washoe/Tahoe

Map simulates end of interactive run time

This simulation represents a fast-moving wildfire approaching the study area from the south, requiring the closure of Nevada State Route 28 near Sand Harbor. Evacuation routes leading north and west from Incline Village are open and unimpeded. It is estimated that 8 hours and 59 minutes are required to complete the evacuation of the study area with one evacuation route closed.

Total Evacuating Vehicles	Evacuation Route(s)	Roads Blocked	Total Evacuation Time
13,151	All Roads North and West	28 at Sand Harbor	8 Hours, 59 Minutes

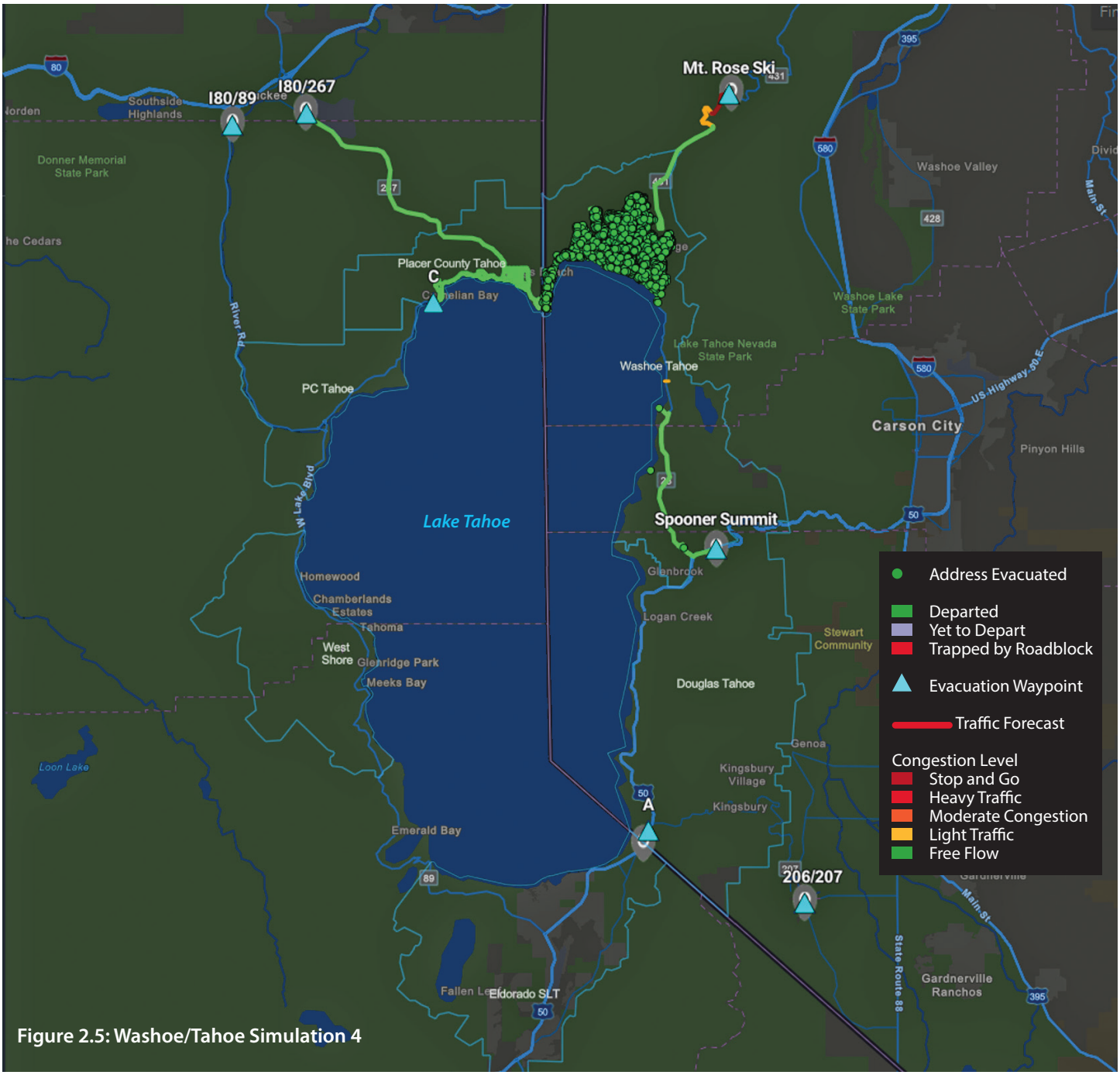


Figure 2.5: Washoe/Tahoe Simulation 4

PROJECT CONSULTANT TEAM: BRIEF BIOGRAPHIES

For a complete biography of each subject matter expert, see https://pyroanalysis.com/ourteam.

SHANE LAUDERDALE

- Bachelor's degree in fire prevention technology from Cogswell Polytechnical College and an associate's degree in fire technology from Shasta Community College
- Founder, PyroAnalysis: Since 1998, assisting communities, developers, and attorneys in interpreting and applying fire and emergency management principles
- Certified instructor: Has inspired thousands of fire service professionals to create innovative strategies to combat fire and other disasters
- Curriculum contributor: California State Fire Marshal Fire Officer and Fire Investigator certification curriculums
- Multiple roles, City of Redding (CA) Fire Department: Over 25 years, served as firefighter, fire apparatus engineer, arson investigator/inspector, fire captain, operations battalion chief, deputy chief of administration, and fire operations chief
- Fire Chief, Fire Department, City of Chico (CA)
- Lead: Worked with Ladris AI to complete the recent Nevada County, CA, Fire Evacuation Study, https://www.nevadacountyca.gov/DocumentCenter/View/53213/Nevada_County_Evacuation_Study_2024

Notable Incidents:

- Operations Section Chief and Branch Director, Thomas Fire, 2017
- Operations Section Chief, Oroville Spillway Failure, 2017
- Operations Section Chief and Branch Director, Camp Fire, 2018
- Operations Section Chief, Kincade Fire, 2019
- Operations Section Chief, Butte Complex, 2020

JOHN MESSINA

- Bachelor's degree in geography, with an emphasis on geographical information systems (GIS), from Chico State University
- 33 years in the fire service profession
- Assistant Region Chief: Overseeing the CAL FIRE's Northern Region Operations and Resource Management Program and providing leadership to six operational units
- Several positions in operations, aviation, and administration, including executive-level chief officer with CAL FIRE
- Unit Chief of the Butte Unit: From 2020 through 2022, served as the fire chief for Butte County, the Town of Paradise, and the cities of Gridley and Biggs through cooperative fire protection agreements
- Operation section Chief and incident commander, CAL FIRE Incident Management Team, 14 years

Notable Incidents

- Operation Section Chief, Oroville Spillway Emergency, 2017
- Incident Commander, Camp Fire, 2018
- CAL FIRE Agency Administrator, North Complex, 2020, and Dixie Fire, 2021, emergency responses
- Intimately involved in the recovery and rebuilding process for the Town of Paradise after the Camp Fire

DON BULLARD

- Associate's degree in fire protection technology from the College of San Mateo
- Firefighter, California Department of Forestry and Fire Protection, Santa Clara County
- Multiple roles, Woodside Fire Protection District (WFPD): Over 35 years, served as firefighter, engineer, fire inspector, fire investigator, deputy fire marshal, and battalion chief
- Specialized training: Designing Ladris-based evacuation simulations, land use planning, the CEQA process, emergency preparedness and evacuation planning, and defensible space and fuel mitigation programs to reduce the risks of wildland fire to communities

ERIC SCOVEL

- Certificate in GIS from Chico State University
- Nearly 40 years in the fire service
- Volunteer firefighter, Lakeshore Fire Department, Lake County
- Fire engineer, Marin County Fire Departmen.
- Member, CAL FIRE Incident Management Team, 12 years

Ladris

https://www.ladris.com/customers

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[17] AirDna.co