# Wildfire Evacuation Modeling

**City of Colorado Springs**
**Office of Emergency Management**
**Pikes Peak Area Council of Government**

**Submitted by:**
**Kenneth Hughlett, BS**
**Emergency Management Coordinator**
**375 Printers Parkway**
**Colorado Springs, CO 80910**
**khughlett@springsgov.com**
**719-385-7228 (Office)**
**719-491-0386 (Mobile)**
**719-385-7387 (Fax)**

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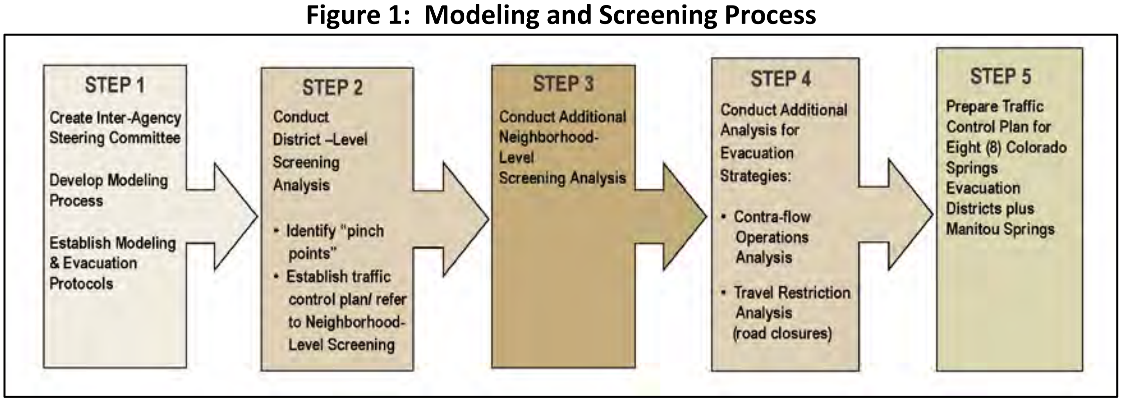
Colorado Springs covers approximately 193 square miles and sits at an altitude of 6,035 feet above sea level. The City lies in the foothills of the Rocky Mountains with more than 35,000 homes in the Wildland Urban Interface (WUI) area. The combination of high-risk hazard areas and large numbers of out-of-state visitors who are unfamiliar with local conditions and emergency response capabilities represent a unique emergency planning and response challenge. Evacuation of the WUI presents a unique challenge that no one entity could address. The Colorado Springs Office of Emergency Management partnered with the Pikes Peak Area Council of Governments (PPACG) to create evacuation plans to prepare for the rapid egress of residents in the event of a wildfire, or other disaster.

Evacuation protocols, communication/notification procedures, evacuation routes and traffic control plans must be established well in advance of actual wildfire events to support rapid-response evacuation of neighborhoods under wildfire threat. Evacuation protocols (e.g. no-entry, evacuation of special populations, etc.) and communication/notification procedures for this plan were established based on local policies and procedures, supported by national standards and experience. Regional simulation analysis was used to develop localized evacuation routes and traffic control plans for the twenty-one WUI neighborhoods identified by the Colorado Springs Fire Department (CSFD) Wildfire Mitigation Plan.

The PPACG Travel Model was used to support the regional simulations. PPACG is the designated Metropolitan Planning Organization (MPO) for the Colorado Springs Urbanized Area, and the PPACG model is the official MPO travel demand model. The model is used to support federally-mandated transportation and air quality planning. The basic structure and function of the model includes a demand side (traffic defined as internal one to zone trips) and a supply side (the roadway network). The model data base includes model year scenarios for: 2005, 2010, 2015, 2020, 2025, 2030, and 2035. Within each model year scenario, eight time-of-day sub-models represent peak and off-peak travel conditions.

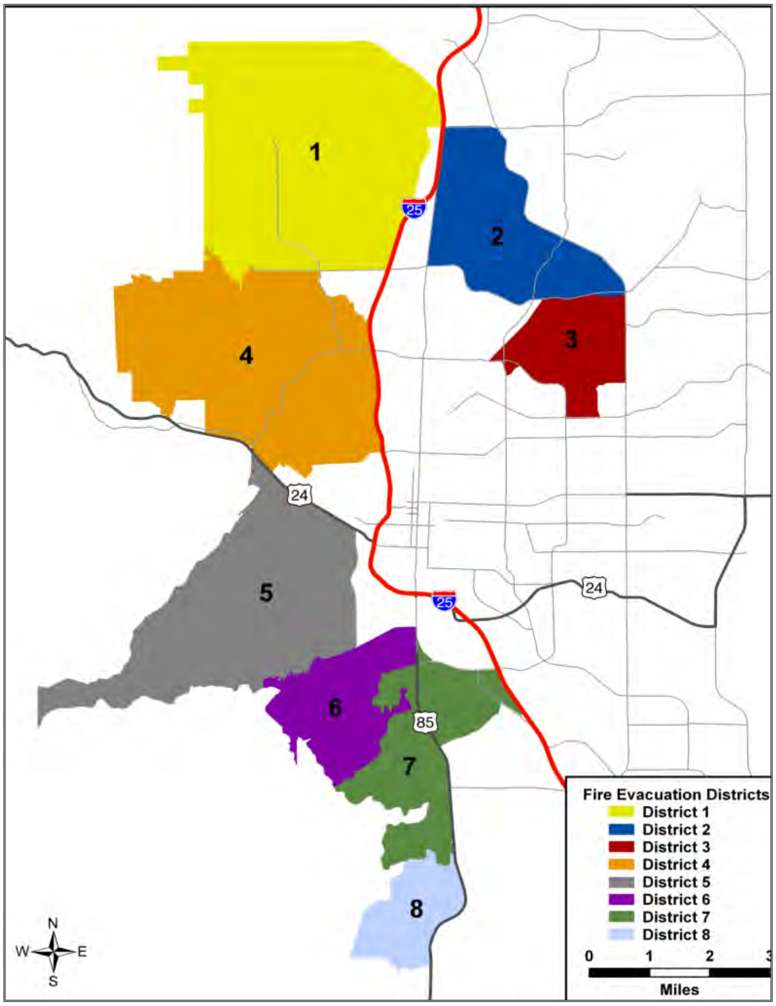
An iterative process was used to evaluate regional traffic flow under evacuation conditions, with a focus on evaluating the ability of identified evacuation routes to carry anticipated traffic loads including identification of potential “pinch points.” Alternative traffic control strategies were tested and optimized, and final evacuation traffic control plans were then developed for sixteen identified evacuation areas including groupings of twenty-one neighborhoods that comprise the Colorado Springs Wildland Urban Interface. The full modeling support process used five main conceptual steps including: 1) Study Design, 2) District-level Screening, 3) Neighborhood-level Screening, 4) Evacuation Strategy Testing, and 5) Traffic Control Plan Development (see **Figure 1**).

**Figure 1: Modeling and Screening Process**



To streamline model scenario development, Wildland Urban Interface neighborhoods were grouped to form eight larger evacuation districts for which initial screening simulation analysis was completed (see **Figure 2**). The selection of the neighborhoods for inclusion in each of the eight evacuation districts was based on the extended area outside the neighborhood(s) to which wildfire might be expected to spread, as well as consideration of common evacuation routes.

**Figure 2: Fire Evacuation Districts in Colorado Springs**




PPACG's 2010 model year scenario was selected for the wildfire evacuation analysis as the condition that most closely represents the "existing condition." For application to evacuation modeling, the basic zone-based travel demand and network-based supply components of the 2010 model scenario were adapted to represent evacuation districts or neighborhoods and associated evacuation populations. A new model scenario, within which PPACG traffic analysis zones were grouped to form the larger district or neighborhood, was created for each evaluated evacuation area.

Evacuee traffic data sets were also developed for each model scenario and modeled area, be it district or neighborhood, based on U.S. Census household counts and vehicle ownership rates. Three auto evacuation scenarios were developed for each area (evacuation of one vehicle per household, two vehicles per household and all vehicles), and sensitivity testing was conducted to select a final scenario for continued modeling. Evacuation of two vehicles per household was selected as the final modeling assumption.

Custom “background traffic” model trip tables were also developed for each scenario, in which background trip destinations within the area to be evacuated were eliminated/prohibited. Background trip destinations within known wildfire prone areas (the foothills west of Colorado Springs) were also eliminated/prohibited for all neighborhood scenarios.

After the district-level screening simulations were completed, more detailed neighborhood-level simulations were completed for two of the eight evacuation districts. Both of the districts selected for neighborhood-level evaluation are characterized by: 1) large physical size, 2) large evacuee populations, and 3) a relatively limited evacuation route network. Because of the large size of these two districts, it is unlikely that either would require full evacuation at once, and clear that more orderly evacuation could be achieved by incremental evacuation of one included neighborhood at a time.

Another model adaptation for evacuation simulation was the incremental assignment of “background” traffic, followed by assignment of evacuation traffic to the model roadway network. To support analysis of the effect of normal non-evacuation, ”background” traffic on evacuation of each of the districts or neighborhoods, “worst-case,” PM Peak Hour background traffic was first assigned to the roadway network to simulate worst-case congestion evacuating residents might encounter on evacuation routes. Non-evacuation traffic was not allowed to enter the evacuation area, either as a destination or to pass-through in route to another destination. Otherwise, non-evacuation traffic was unrestricted. Evacuation traffic was then assigned to network that was already “congested” by the presence of worst-case PM Peak Hour non-evacuation traffic. Additional model adaptations were also implemented to represent neighborhood and multi-neighborhood district-level evacuation populations, to represent neighborhood and district-level evacuation traffic flow, and to account for the effects of non-evacuation “background” traffic flows on neighborhood and larger district evacuation. With evacuation population and model network adaptations in place, the evacuation of each multi-neighborhood district or individual neighborhood was simulated under alternative evacuation scenarios. Scenarios prohibiting non-evacuation access to the affected neighborhood, restricting key evacuation routes to evacuation traffic only, and implementing contra-flow operations on key evacuation routes were iteratively tested and optimized through simulation of progressively more restrictive traffic control schemes.

Technical direction and oversight for the analysis was provided by a Technical Steering Committee led by the City of Colorado Springs Office of Emergency Management, with active membership from the CSFD, City Traffic Engineering, the Colorado Springs Police Department and PPACG. The Steering Committee initially provided direction in defining the evacuation scenarios to be modeled. Alternative evacuation scenarios were identified both by evacuation populations (evacuation area, residents, mobility impaired, businesses, school children) and evacuation protocols (shelter-in-place, use of public transport, use of school buses, allowed/not allowed to enter area to retrieve belonging). The Steering Committee also provided supporting data (e.g. off-site shelter locations, operational requirements for shelter-in-place, etc., and established additional modeling assumptions (e.g. time-of-day for background traffic, preferred evacuation routes). Finally, as a part of ongoing coordination with the evacuation modeling technical team, the Steering Committee provided input and oversight as the modeling team identified evacuation routes, traffic control measures, and staffing/resource requirements for the CSFD Wildfire Mitigation Plan based on modeling results.

For the purpose of the simulation-based screening analysis the following assumptions were applied:

- Evacuation route capacity was defined as an hourly "carrying capacity" of the route roadway segments. Capacity was calculated within the simulation model for each discrete roadway segment by taking the number of lanes times the capacity of each lane. Within the PPACG model, roadway capacity per lane is linked to the roadway's functional classification (freeway, arterial, collector, local street). When "bottlenecks" are present, capacity is reduced, causing traffic to slow down or divert.

- Volume to Capacity (V/C) ratio was used to screen evacuation route adequacy, based on an evacuation duration target of one-hour. V/C ratio is a measure of congestion on a roadway segment. It is defined as the modeled hourly traffic divided by the hourly carrying capacity of the road. V/C ratios and color codes used in this analysis were established as:
  - Green: Volume / Capacity Ratio is less than 0.85
  - Yellow: Volume / Capacity Ratio is between 0.85 and 1.00
  - Red: Volume / Capacity Ratio is greater than 1.00

- Evacuee Destinations - Traffic evacuating from focus districts is assumed to go to one of four types of destinations: Official Shelters (15%); other households in the area (60%); motels (15%); or out of the County entirely (Denver area, Pueblo area or other –10%). Areas west of Colorado Springs (Teller County) are not included as destinations for evacuees.

- Number Cars of Permitted to Evacuate - In the Fire Evacuation scenarios, each household in the affected area was permitted to drive up to two vehicles away from the home. Sensitivity testing performed with residents permitted to drive three vehicles away from the home showed extreme congestion hot spots. It was understood that people would not willingly leave their second car behind if a driver was available to drive it away and thus one vehicle evacuation was not used. Census analysis showed that most households have at least two vehicles.

- Background Traffic - Fire evacuation of affected areas does not take place in a vacuum. The unaffected areas continue about their everyday business. To simulate a representative slice of background traffic, the PM peak was hour was used.

In the wake of a number of planned and unplanned evacuations that have taken place throughout the U.S. in recent years, the need for applied transportation planning and modeling in the area of emergency evacuation strategy has never been stronger. The project involved a MPO traffic model adapted for use as a wildfire evacuation planning tool and the results used by the emergency response community of Colorado Springs. The project addressed model inputs and assumptions, emergency scenarios, traffic control strategies, shelters or destinations of evacuees, and evacuation time frames. On the model side project addressed networks, household auto ownership assumptions, evacuee shelter locations, group quarters, road capacity, transit use, contra-flow assumptions, background traffic, and the next step of moving the evacuation model results to a actionable tool for use by emergency responders. The project utilized a year-long collaboration with the heads of the fire and police emergency response in Colorado Springs and feedback from these groups improved evacuation response planning. While the emergency evacuation model was developed and refined for western mountainous cities like Colorado Springs that have residential areas in very dry foothill-type terrain, the approach has value for other areas of the west as well as flat areas where planned evacuation may take place.