MODELING WILDFIRE AT DIABLO CANYON

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INTRODUCTION

Late summer and early fall climatic conditions of dry weather with periods of offshore flow are typical along the central California coast, where Pacific Gas and Electric (PG&E) operates fossil fuel and nuclear generating facilities. This time of year is also known as the fire season in the area, and the periods of hot dry offshore flow produce the highest fire danger.

On August 14, 1994 an arson fire erupted along Highway 41 near Atascadero, California. Fed by offshore winds and dry fuel, the fire raged for four days, consuming over 48,000 acres. Electric generation from PG&E's nearby Morro Bay Power Plant was interrupted due to fire damage to transmission lines.

Wildfires can be a major threat to PG&E's electric facilities, a threat felt most keenly at PG&E's Diablo Canyon nuclear power plant, located less than 15 miles from the perimeter of the Highway 41 fire. Transmission lines serving Diablo Canyon converge near the plant through a canyon that is heavily vegetated with fire-adapted brush species. A raging wildfire through this canyon could threaten the operation of the plant by its impact on the transmission lines. To reduce this fire threat, vegetation management in the lands surrounding the plant is a high priority.

Using local vegetation conditions and nearby weather data at the time of the Highway 41 fire, we have employed a computer model called FARSITE to predict the behavior of a hypothetical wildfire near the power plant. Our primary objective for modeling fire behavior at Diablo Canyon is to demonstrate the value of a continuing vegetation management program that reduces fire threat to vital transmission lines. This paper explains the details of how we implemented this model, the importance of weather variables, and how we are using model results to aid the fuels management program at Diablo Canyon.

The FARSITE Model

FARSITE (Fire Area Simulator) is a model for spatially and temporally simulating the spread and behavior of fires under conditions of heterogeneous fuels, terrain, and weather. FARSITE was developed by Mark Finney, Systems for Environmental Management, with funding from the USDA Forest Service Intermountain Fire Science Lab (Finney 1995). It was first available in January 1995. FARSITE was developed by applying established fire behavior principals to heterogeneous fuel types as influenced by terrain and weather.

Earlier work by Rothermel (1972) led to development of the BEHAVE model. BEHAVE was developed to predict the rate of fire spread and other flaming front characteristics over a homogeneous fuel type for a specific slope, aspect, and elevation. Validations of the BEHAVE model have proved its usefulness over the years, but the limitations of homogenous vegetation and land types has restricted its practical use for a variety of applications. The ability of FARSITE to make fire simulations over heterogeneous terrain and fuel types permits more realistic and practical simulations.

With FARSITE's ability to utilize fuel, terrain and weather details, comes the burden of collecting and organizing the large quantity of data that FARSITE requires. A Geographic Information System (GIS) is a required tool for preparing the spatial data that FARSITE needs. Using a GIS, the fuels and terrain data are formatted into overlaying grids that represent the study area. FARSITE uses this grid data to drive the simulations and produces output files than can be transferred back to the GIS for presentation or further analyses.

STUDY AREA

The Diablo Canyon Power Plant is located on the central California coast near the city of San Luis Obispo (Figure 1). PG&E owns approximately 12,000 acres of undeveloped land surrounding the power plant. This land supports a mosaic of vegetation types adapted to a Mediterranean climate.

The greatest fire threat to the power plant occurs within the first mile or so east of the power plant within the Diablo Canyon. Here, several transmission lines converge at the power plant switching yard. A wildfire burning under these power lines could cause an electrical fault or damage the conductor or towers. It is likely that the power plant would be forced to shut down during a severe wildfire affecting the transmission lines.

The vegetation types in this canyon include annual grassland, coastal scrub, coast live oak woodland and a hard chaparral type dominated by blue blossom ceanothus. We developed data to create FARSITE simulations for 1,100 acres of property located within the canyon immediately behind the switching yard.

METHODS

Fuel Models

A set of 13 standard fuel models were developed for the BEHAVE model to describe the vegetation characteristics. Each fuel model is defined by the dry weight of woody stems that fall within three size classes- less than 0.25", 0.25 to 1", and 1" to 3" (Anderson 1982). To develop the BEHAVE fuel models, Rothermel studied empirical fire behavior data for each of the fuel model types that were burned under carefully controlled conditions. FARSITE uses these same standard fuel models and also permits the use of custom models to produce more accurate simulations.

In January 1995, we began collecting information about the fuel by walking their boundaries with global positioning system (GPS) receivers. Although GPS is a very efficient means of collecting positions, the magnitude of the study area and the complexity of the vegetation types required a different approach.

Our solution was to develop a digital ortho-rectified photograph from a custom aerial photo taken in September 1995. Using a GIS, we overlaid the GPS vegetation boundaries collected earlier on the ortho photo and completed the process of designating vegetation boundaries through "heads up" digitizing. This process produced a computer representation of fuel types as polygons that we assigned with fuel models that FARSITE would understand. The fuel models were initially assigned by a fire specialist familiar with BEHAVE models and coastal brush communities (Figure 2). In January 1996 we revisited these fuel model polygons on the ground to clip samples and obtain more accurate dry-weight estimates of the size classes mentioned above.

Terrain

FARSITE uses the slope, aspect and elevation when calculating the spread of fire. Again using the GIS, we derived this information from a U.S. Geological Survey (USGS) digital elevation model (DEM) of our study area. The USGS DEM is based upon a 7.5 minute USGS quadrangle using a 30-m grid spacing.

Meteorology

Weather is an important driver of wildfire. FARSITE uses several weather parameters contained in two separate files to drive the simulation of fire propagation. The "Weather Stream" input file contains site elevation and daily values of precipitation, minimum and maximum temperatures, the hour of the minimum and maximum temperature, and the minimum and maximum relative humidities. The "Wind Stream" input file contains hourly wind speed, wind direction and cloud cover values.

FARSITE interpolates the daily temperature and humidity maxima and minima to hourly values with a sine curve. It is assumed that the maximum humidity occurs at the time of minimum temperature, and the minimum humidity occurs at the time of maximum temperature. Temperature values are adjusted to terrain height using an adiabatic lapse rate of 3.5 deg. F/1,000 ft. FARSITE assumes winds are constant in space, which is a limitation in areas of complex terrain.

For the initial model run, weather data input files were prepared from data recorded at the primary meteorological station at the power plant facility. The weather station is located approximately one mile west of the study area. While this site is relatively close to the study area, there are concerns that the data may not be representative of flow in the complex terrain to the east of the power plant site. Weather data are also available from nearby ridgeline site, approximately 4 miles east of the study area. This site, called Davis Peak, is located at an elevation of 1,800 ft. For our initial simulation, weather data from the Power Plant site were used as input. One limitation of the present model is that there is no spatial variability in wind direction when a single weather stream is input.

RESULTS

Rate of Fire Spread

The predicted rate of fire spread is very dependent upon the time and place of ignition. Using a single point ignition, and the wind conditions recorded at the Diablo Canyon primary meteorological station at the of ignition of the Highway 41 fire, the modeled wildfire consumed approximately 250 acres per hour during a 2-hour simulated burn (Figure 3). By comparison, the Highway 41 fire consumed only 84 acres per hour just after its ignition. However, by the next day when the flaming front of the Highway 41 fire was several miles long, over 6,700 acres were consumed in only one hour![1]

Flame Length and Intensity

Outages can occur to the electric transmission system when wildfire heats the air below the conductors. The electrical resistance of air decreases with increasing temperature. It may be possible to calculate the likelihood of an outage as a function of the heat produced by a wildfire passing below the conductors. Although we have not yet made this calculation, our simulations do show that the flame height approaches the height of conductors in some locations.

[1] The Hiroshima atomic bomb was equivalent to 1,000 acres per hour of energy release.

Based upon observations of outages occurring in wildfire conditions (e.g. the 1994 Highway 41 fire and the 1991 Oakland Hills fire), it seems likely that the Diablo Canyon transmission system would experience an outage where flames approach the conductors. The range of conductor height within the Diablo Creek watershed is 45 to 70 ft. Figure 3 shows some locations where the flame height approaches this height.

DISCUSSION

The results of the fire simulations are dependent upon the wind speeds and directions provided to the model. Initial model runs were made using weather data at the coastal site. Model simulations using the ridgeline (Davis Peak) and combined coastal and ridgeline sites will soon be performed. Wind speed and direction time series from both sites for two days of the Highway 41 fire (Figure 4) show differences in flow patterns that could result in significantly different fire spread patterns.

Actual fire spread patterns in the Diablo Creek watershed may not be adequately modeled using either weather station due to the complex terrain in the vicinity of the switchyard. To address this problem we propose to conduct a low-cost field experiment and modeling study during the next fire season. The study involves setting up a portable weather station at the switchyard facility, then modeling fire spread and behavior using coastal, ridgeline and switchyard weather data on a case study basis. The case study selections will be based on highest fire danger episodes as determined by the local department of forestry office.

We have produced multiple simulations of wildfire in Diablo Canyon usiing the coast site weather data to address a variety of questions and needs. To meet our primary objective of gaining continuing support for the vegetation management program, we have used FARSITE as a valuable tool for simply communicating the concept of how wildfire could affect PG&E's transmission lines and towers. The predicted speed of a wildfire over the landscape using the same weather conditions as the Highway 41 fire is a sobering and useful reminder that continued vegetation management is justified.

FARSITE has other potential applications at Diablo Canyon and probably other locations in PG&E's service area. It is a particularly useful tool for planning prescribed fires that reduce the fire threat to PG&E facilities and also improve wildlife habitat. FARSITE could also be used to estimate the level of risk associated with different vegetation types growing near PG&E's electric transmission and distribution lines.

PG&E's Research and Development Department is currently taking a look at the usefulness of FARSITE for these and other applications. One of the critical issues in all applications will be how representative the weather data used as input to the model is to the modeled location.

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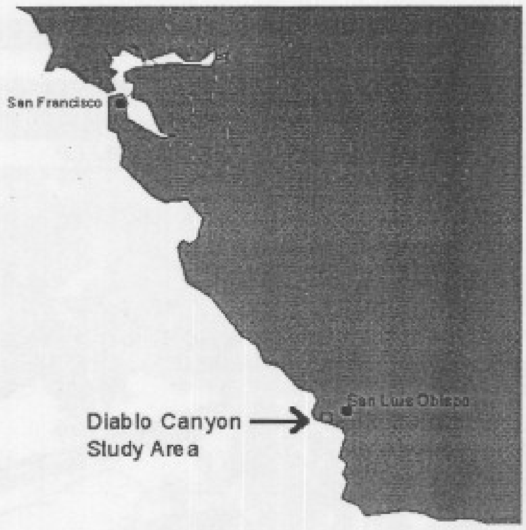

Figure 1. Diablo Canyon Study Area.

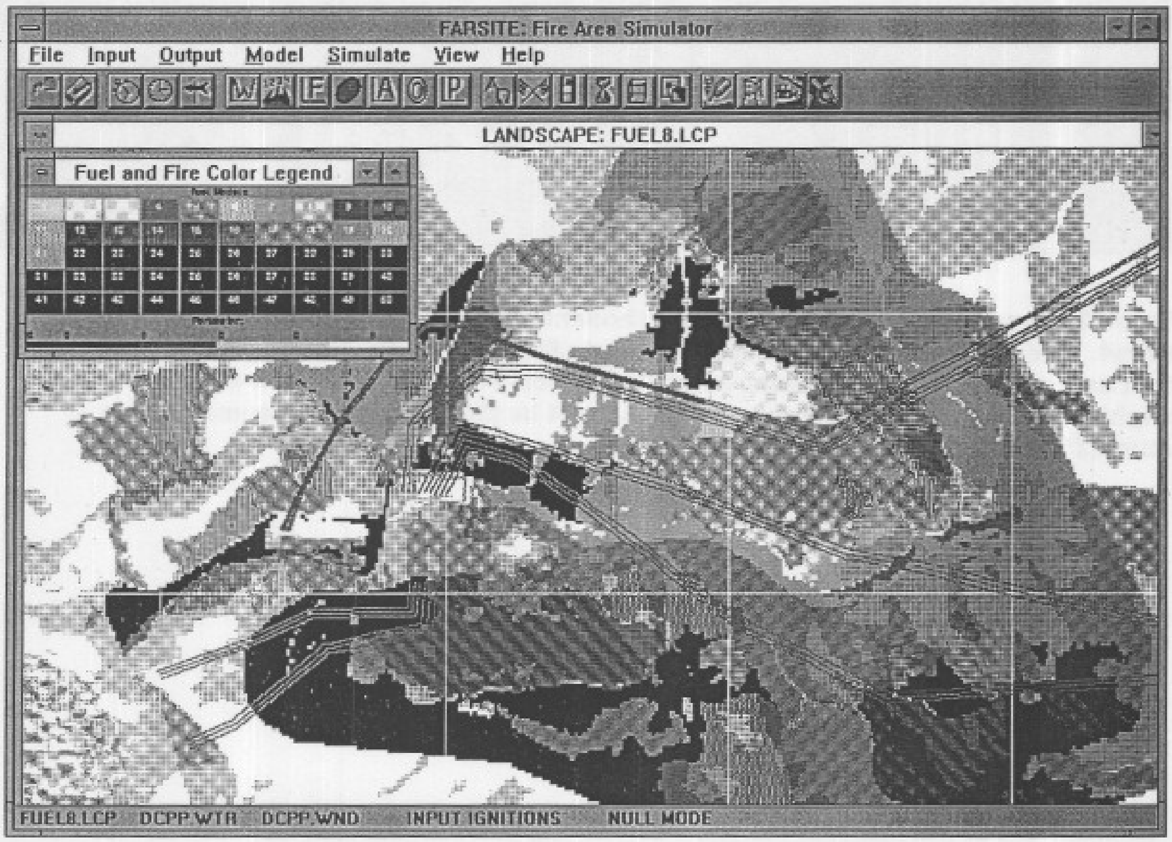

Figure 2. Mosaic of fuel models used for wildfire simulations in Diablo Canyon

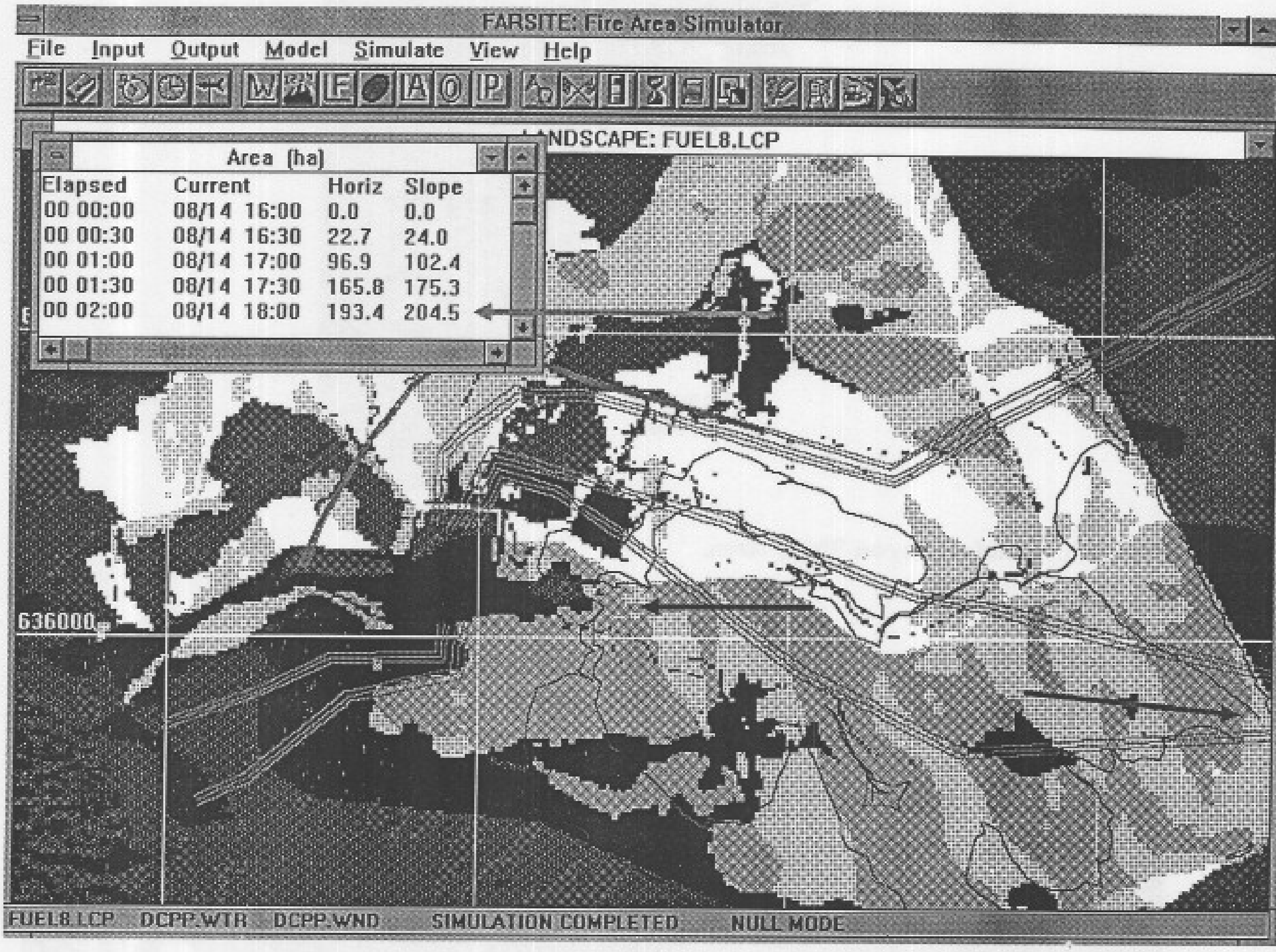

Figure 3. Simulated wildfire perimeter two hours following a single point ignition (middle arrow). Fire perimeter is color coded to indicate flame length (shows as grays). The lower right arrow shows where the flame length is predicted to be 35 ft. under a 45 ft. conductor height (black lines). The top arrow shows that 204 ha (504 ac.) were consumed in two hours (252 ac./hr.).

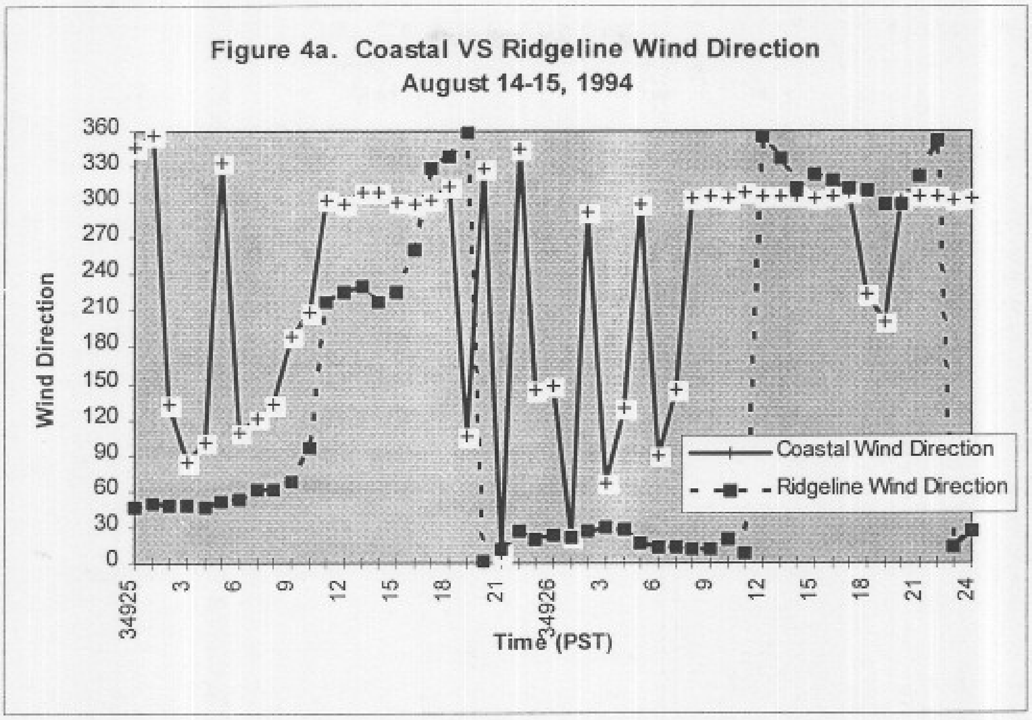
Figure 4a. Coastal VS Ridgeline Wind Direction
August 14-15, 1994
Wind Direction
Time (PST)
Coastal Wind Direction
Ridgeline Wind Direction
360
330
300
270
240
210
180
150
120
90
60
30
0
34925
3
6
9
12
15
18
21
34926
3
6
9
12
15
18
21
24

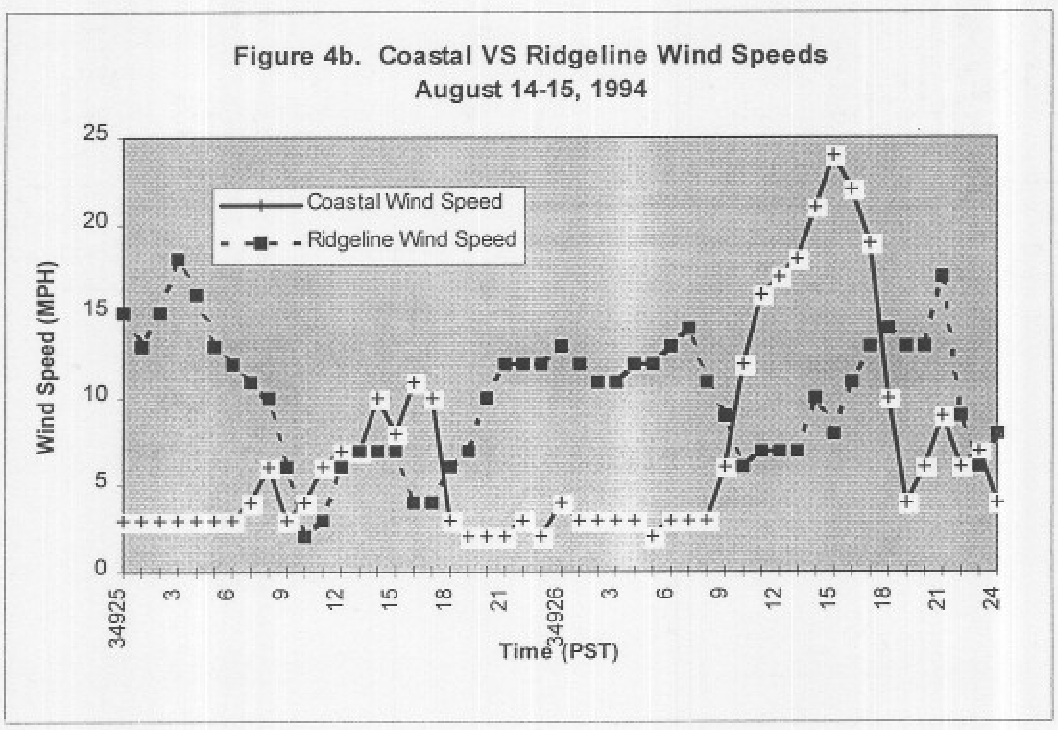
Figure 4b. Coastal VS Ridgeline Wind Speeds
August 14-15, 1994
Wind Speed (MPH)
Time (PST)
Coastal Wind Speed
Ridgeline Wind Speed
25
20
15
10
5
0
34925
3
6
9
12
15
18
21
34926
3
6
9
12
15
18
21
24