APPENDIX B – SDG&E POWER LINE FIRES

B1. Data Sources

B1.1. SDG&E Fire History

Distribution: Open

Data Requests: MGRA-30

File Name: MGRA-30a.xls

Location: http://www.sdge.com/sunrisepowerlink/info/MGRADR2ReponseFeb6-07.doc

Description: List of all fires initiated by or related to SDG&E personnel or equipment

Fields: Date Started, Incident #, Incident Name, District Location, System, Acres, Responsible Party, Cause Related Comments

Restrictions & Limitations: Only since February of 2004

Processing: Created derivative Excel spreadsheet SDGE_fires_Mbar.xls[1].

B1.2. Mesowest Weather Data

Distribution: Open

Location: http://www.met.utah.edu/mesowest/

Description: Data for RAWS and other weather stations in a database searchable by web interface. Hourly data can be obtained for any date extending back to the time that collection started for a particular station. This data is displayed in graphical (and optionally tabular) form for windows extending from 12 hours up to 30 days.

Fields: Temperature, relative humidity, wind speed (sustained & gust), wind direction, precipitation

Restrictions & Limitations: Data for SD County RAWS stations goes back to 1999, with many coming on-line between 1999 and 2001. Non-RAWS stations sometimes lack wind gust data. Data quality is considered marginal for older data. Anomalous functioning can often be identified by "wild swings" in measurements for one parameter or another, or by missing blocks of data.

Processing: RAWS data was downloaded for a window surrounding key wind events with a width of at least 12 hours.

B1.3. Poisson statistics calculator

For determining confidence levels and statistical uncertainties for small values, the Poisson.rb[2] calculator was used (available from M-bar Technologies & Consulting). This calculator estimates the probability of a random event occurring within a specified interval for a given distribution mean. It is used iteratively to determine 90% confidence

[1] Attached as SDGEFire.xls

[2] Attached as Poisson.rb

levels. For a two-tailed distribution, this entails determining the 95% upper and 95% lower interval.

B2. Analyses

B2.1. Wind-caused fires

B2.1.1. Goal

The goal of this analysis is to determine whether any power line fires in the SDG&E sample provided in response to MGRA data request MGRA-30 were caused by strong winds, and if so, whether these were larger than other power line-related fires.

B2.1.2. Description

SDG&E has provided the history of all power line-related fires for the period from February 2004 to December 2006. In all, these records contained data on 87 power line-related fires within the SDG&E service area. One of the causes of some of the fires was wind, and this allows us to see whether the wind-caused fires had larger affected areas.

B2.1.3. Methods

The data in the MGRA 30a.xls data file provided by SDG&E was reprocessed into the file *SDGE_fires_Mbar.xls,* attached below.

SDGE_fires_Mbar.xls

File B1 – A processed version of MGRA 30a.xls, this contains the SDG&E fire data from Feb. 2004 to Dec. 2006. It contains tallies of different fire and line characteristics used in the analysis below[3].

Different event characteristics were tallied. Because the goal of this sub-section is to determine the characteristics of power line fires rather than the nature of the cause, the distribution line data has remained in the sample.

The sample was divided into two subsets: those in which wind was a factor in causing the fault which initiated the fire (colored in magenta) and those in which it was not. The average and mean fire sizes were calculated for each sample.

[3] Attached as SDGEFire.xls

B2.1.4. Analysis

The vast majority of fires reported in the sample were quite small (< .1 acre). A few large events drove the statistics, which is typical of wildland fire data. For this reason, a simple average will tend to overemphasize the rarer large events, so the median was also calculated for the samples, since this shows the size of events that are more "typical" for the class being sampled. The results are shown in Table B-1.

	No wind	Wind
Acres burned (total)	52.1	300.3
Number of fires	80	7
Average size	0.65125	42.9
Median size	0.1	2

Table B-1 – Summary of fire sizes for SDG&E fire data from 2004 to 2006, broken into categories classified by SDG&E as wind-related and not wind-related. Wind events were rarer but were responsible for most of the burned acreage.

It is evident that events caused by wind faults, though relatively rare were more destructive than those that occurred during calm conditions, and were responsible for most of the acreage burned during the measurement period.

B2.1.5. Limitations

The sample contains distribution line as well as transmission line data, and therefore should only be used as a guide for fire characteristics, and not causes. Transmission line data is analyzed in the next section. The short duration and limited geographic extent of the sample limits the statistical power of the conclusions.

B2.1.6. Conclusions

Eighty seven fires related to power lines were recorded in this sample. Fires started during periods of high wind are widely known to be the most destructive. For power lines, this is exacerbated by the fact that the wind in fact initiates power line fires. Even in the limited, short-duration sample of fires provided by SDG&E this trend is clearly evident. The fact that none of the fires in the sample was "catastrophic" in size is an artifact of the short duration and limited geographic area studied, and is also a credit to effective fire suppression. However, there is a long "tail" out to very large fire sizes, and so we can reasonably expect that in the future, very large and damaging fires will be initiated by power lines under high-wind conditions in the SDG&E service area.

B2.2. Transmission line fires

B2.2.1. Goal

To determine the causes and frequency of fires related to transmission lines (as opposed to distribution lines) in the SDG&E service area.

B2.2.2. Description

Fires are caused by both distribution lines and transmission lines, though one might suppose that the general mechanisms responsible for fires caused by each might be different. Distribution lines tend to be lower in height, thus making them more prone to tree limb contact. Poles also tend to be less robust. Distribution networks also have many transformers and other components not found on the transmission networks. Hence, the frequency of fire related to the distribution network cannot be extrapolated in a straightforward way to that related to the transmission network. For that reason, we extract out the transmission line data for examination with the intent to apply this to SPL components.

B2.2.3. Methods

SDG&E has specified which fires were caused by transmission lines and which were caused by distribution lines. Unfortunately they did not specify the voltage of the transmission lines. This was easily remedied in this analysis by cross-referencing the fire record to the outage history (see Appendix A for outage history analysis).

For ease of use, the transmission line fires have been extracted into a separate sheet in the Excel file *SDGE_fires_Mbar.xls* called "SDGE Transmission Lines".

B2.2.4. Analysis

Nine fires were related to transmission lines in the 35 month period studied. This gives a raw rate of 3.1 fires per year. According to Table A-2 (SDG&E transmission line lengths) the total length of transmission lines in the SDG&E service area is 1,430 miles, yielding a fire probability rate of .0022 fires yr^{-1} mi^{-1}.

However, as also noted in Appendix A, the fault rates tend to be lower for high voltage transmission lines. While the fire data provided by SDG&E does not give the voltage of the transmission line, these records can be cross-referenced with the outage history to determine the tension of the line involved. Since the dataset is limited, we include the entire set below:

Date	Incident	Location	Voltage[4] (kV)	Acres	Cause
3/15/2005	Otay Substation	Metro	69	0.1	Mylar balloon into 69 kV, 10 x 60 spot
7/3/2005	Miller Valley	Mountain Empire	69	19	Mid-line slap, static line (Contractor)
7/12/2005	Eastlake	Metro	69	0.1	Dust, dirt on insulator/relay, sm. Spot
7/28/2005	San Clemente	Orange County	69	1	Corrosion/wire down, 1 acre brush fire
8/5/2005	Corte Chrisalida	Northeast	69	0.1	Mylar balloon into conductor, sm.spot
2/7/2006	Hidden Valley	North Coast	69	0.1	Kite tail into insulators
9/9/2006	Grapevine	Ramona	69	5	Wire down, gun shot, 5 acre fire
10/27/2006	Boulder Creek	Mountain Empire	69	2	Hvy. wind, wire down, 2 acre fire
12/27/2006	Cmp. Pendleton	North Coast	230	3	Hvy. wind, wire down, 3 acre fire

Table B-2 – Fires related to transmission lines in the 2004-2006 fire history provided by SDG&E. Voltage levels were determined by cross-referencing to the Outage History.

The general causes are summarized in the table below.

[4] Obtained by cross-referencing to the SDG&E Outage History which was analyzed in Appendix A.

Cause	**Events**	**Rate ($yr^{-1}mi^{-1}$)**
Human (maintenance, vandalism)	2	4.8e-4
Kites & balloons	3	7.2e-4
Equipment failure	2	4.8e-4
Wind-induced failure	2	4.8e-4

Table B-3 – A summary of causes of transmission line fires occurring in the SDG&E service area from 2004 to 2006.

Incidents involving kites and balloons would be expected to be more frequent in areas where there is a higher population density. For the SPL, this would be a concern in the areas west of the Sycamore Canyon substation. Wind-induced failures are more likely to occur in areas where the wind is more intense. This will be addressed in a separate section.

The December, 2006 Camp Pendleton fire, which was ignited by a 230 kV line, provides a key benchmark. Although it is only one event, it places a lower limit on the probability range which can be postulated for the occurrence of such fires. For 387 miles of line in the service area, this gives a raw rate of .0009 fires per year per line mile.

It is interesting to note that in the sample of wind-outages recorded by SDG&E analyzed in Section A2.1 (Wind Outages), all of the transmission line outages recorded were from 69 kV lines. The Pendleton 230 kV event was missed in this sample; only in the fire event record is wind noted as a factor. Weather station data record this as an event of borderline significance. It should be noted that the outage history extends well before this sample. In fact of the 14 wind events causing reported outages, 12 of them *occurred before the fire record began!* Of the two remaining events, ***both were causes of significant wildland fires (Boulder Creek and Camp Pendleton).***

During the period spanned by the fire history, 55 "fault-related" outages likely due to equipment failure occurred (see Appendix A2-3, fault rates). Of these, only two were responsible for starting a wildland fire, a rate of around 4%.

There were no fires reported for 500 kV lines. Due to the very limited sample size, the fact that there is a significantly shorter run of 500 kV line in the SDG&E service area than there is 230 kV or 69kV, and the lower fault rate observed on 500 kV lines (Appendix A2.3.4), alternative hypotheses are consistent with this observation:

1. 500 kV lines do not produce fires at an appreciable rate compared to 230 kV and 69 kV lines. This is supported by the lower measured fault rate in A2.3.4.

2. 500 kV lines produce fires at the same rate as 230 kV lines. This is within the statistical uncertainties of both Appendix A2.3.4 and the small number of 230 kV fires observed (one).

3. The fire rate for 500 kV lines will vary as the fault rate. Hence if we know the number of faults for both 230 kV and 500 kV lines, and we know the number of fires for 230 kV lines we can predict the fire rate for 500 kV.

B2.2.5. Limitations

The conclusions that can be drawn from these studies are weakened by the small numbers falling into each category. To help clarify the statistical significance of the numbers observed, 90% confidence levels for the "expected mean" are presented in the table below. The idea is that if you observe one event, it is justifiable to reach conclusions regarding what the "expected value" is permitted to be, both on the high side and on the low side. For a 90% confidence interval, there is a 5% chance that the "real" expected value is lower than the lowest bound and a 5% chance that it is higher than the highest bound. This was calculated with the Poisson.rb calculator, using a manual iterative method. Of course, this only takes statistical fluctuations into account. Effects which inject systematic correlations between the observables may be much larger.

Observed events	Low end 90%CL	High end 90%CL
1	.1	4.8
2	.35	6.3
3	.8	7.8
4	1.4	9.0

Table B-4 – This table demonstrates a 90% confidence range for events with low statistics using a Poisson probability distribution. The low end distribution is the value of the mean of a Poisson distribution that would produce the observed number of events *or more* 5% of the time. The high end is the mean value that would produce the observed number of events *or fewer* 5% of the time. Note that the spread between low and high goes from a factor of 48 for one observed event down to a factor of 6 for four events.

Note that there is no fire data for 500kV lines. Hypotheses regarding fire probabilities on these lines can't be tested against data we have.

B2.2.6. Conclusions

Since this sampling was initiated, there have been no “extreme” wind events such as those observed in 2002 and 2003. It should be noted that the SDG&E outage history shows that fires were correlated with some of outages occurring during these events. In spite of the absence of “extreme” wind events, there have been significant wildland fires caused by transmission lines in the observed period..

Based on the outage history (primarily the Camp Pendleton event) and the network size, a rough estimate of .0009 events per year per mile can be given. Statistical uncertainties on this number give us a statistical 90% confidence interval of .00009 to .0043 events per mile per year.

Another significant cause of power line fires in the SDG&E service area was the capture of human-released materials such as mylar balloons and kite tails by the wire and insulators. These did not cause significant damage in the cases studied. Yet another cause were faults created due to component failure. Only about 4% of component failures caused fires.

In conclusion, wind-initiation of power line faulting and subsequent fire is the scenario of greatest concern with respect to the fire risk posed by the proposed SPL.

B2.3. SPL fire rate prediction

B2.3.1. Goal

Using the results from the previous section, we predict a rate for fire along the SPL.

B2.3.2. Description

Extrapolating from the results in Appendix A and B, we calculate a predicted fire rate for the SPL.

B2.3.3. Methods

We take the fire rate per year per mile calculated in the previous section and multiply it by the length of the proposed SPL route and the number of years the line will be in service. For 500 kV transmission lines, which had no fires associated with them, we analyze the case where they are and are not the cause of wildland fires.

B2.3.4. Analysis

Based on recent fire history and using the one observed 230 kV fire as the basis for prediction, the fire rate for the 54-mile 230 kV segment of the proposed SPL route would be 54 * .0009 = .05 / year, or one fire per 20 years. Statistical uncertainty on this ranges from 1 per 200 years to one every four years. For the 91-mile 500 kV segment, things are even more uncertain, and depend on assumptions regarding fault and fire rates for the 500 kV network.

Only about 20 miles of the 500 kV SPL route covers significantly flammable vegetation (Appendix E). If fire rates for 230 kV and 500 kV for wind events are actually the same, this would give a fire rate for the line as a whole of .068 / year, or one fire every 15 years, with a 90% confidence level range from 1 per 150 years to one every three years. Under other hypotheses which hold that 500 kV lines and structures are more robust than 230 kV lines and structures, the 230 kV segment dominates the probability and the previous paragraph holds.

B2.3.5. Limitations

Prediction of the future based on extrapolation from recent data carries with it the implicit assumption that conditions are remaining constant, which may be a poor assumption if current climate models are correct. Furthermore, there are other factors that make SPL "unlike" other routes in the County. There are numerous factors that could increase or decrease the predicted fire rate. Among factors increasing the risk for this particular route is the heavy flammable vegetation along the route. Factors decreasing fire risk would include separation from population centers for much of the route, thereby reducing the risk of balloon/kite incidents.

Some factors that would INCREASE fire risk would be:

- If a larger fraction of this line traverses flammable vegetation than is otherwise typical in the SDG&E service area.
- If climate change causes a lengthening of the fire season, as predicted in recent scientific work[5].
- If the routes selected are more subject to extreme wind conditions than is typical of the rest of the transmission network.
- If the route was more subject to aviation hazards than other segments of the network.
- There were no 'extreme' events, such as those that occurred during 2002-2003 in the sample analyzed.

Some factors that would DECREASE fire risk would be:

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[5] Westerling, A. L., et al.; Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity; Science; v. 313; pp. 940-943; 18 Aug 2006

- If removal from population centers decreases the likelihood of balloon or kite incidents.

- If the SPL were engineered to be more robust than is typical of other 230 kV distribution lines.

B2.3.6. Conclusions

Based on fire data collected by SDG&E, and making the assumption of existing climate and vegetation, as well as assuming that SPL would be no more or no less likely than other lines to initiate fire, we predict a rate of one induced fire per 20 years along the 230 kV segment of the SPL route, with a 90% confidence level statistical uncertainty ranging from 1 per 200 years to 1 every 4 years. Under the hypothesis that the fire rates for 500 kV and 230 kV lines are expected to be the same, this rate increases to every 15 years, with the uncertainties adjusted by the same ratio.