

EVM Effectiveness analysis

January 2023



Executive Summary

➤ Executive Summary:

The objective of this analysis is to provide a measure of the effectiveness of Enhanced Vegetation Management (EVM) work since the program started in 2019.

Approach:

The analysis focuses on EVM pole-to-pole segments (PtPS), which allows to precisely capture EVM work start and completion dates. PtPS are then aggregated at the Circuit Segment (CS) level (PKA circuit protection zones), and event incidence rates are computed for each CS where EVM work has been performed. For better data representativity, the shortest CS have been grouped together based on geographic proximity.

The analysis aims at comparing incidence rates on a 1-year window preceding EVM work, with the incidence rate on the 1-year window immediately following work completion and verification. The incidence rates have been normalized to account for weather effects.

More than 233k work-completed PtPS were considered in the analysis, which covers about 6300 miles.

Results:

A paired Wilcoxon T-test has been conducted to compare the before and after EVM incidence rates across the same pool of grouped CS, which allows to eliminate random inter-CS variations (such as tree density, topology, terrain features etc.).

Outages + PSPS Damages and Hazards (295 events):

Using the results of the Wilcoxon test (non-normality of event rate differences), one can conclude that the median of incidence rates after EVM is significantly smaller than before EVM, for the following weather signals, with a type I risk of 5%:

- Low Snow (abundant snow-loading) | -75% incidence rate after EVM
- Blue Sky | - 60% incidence rate after EVM
- Winter storm | -29% incidence rate after EVM

Ignitions (6 events):

There is not enough ignition data to directly measure the effect of EVM on ignition rates. However, most ignitions having historically happened concomitantly to outages during fire season, the results shown above suggest that EVM is effective at reducing the outage rate by 60% on Blue Sky days and will ultimately have a positive effect on ignition reduction.

Notes:

The measured EVM effectiveness assumes a 1-year window after work has been conducted and is expected to decrease past that horizon, unless similar work is done in the subsequent years.

Scope and methodology

➤ Definitions:

- Poles-to-pole segments (PtPS): EVM segments
- Circuit Segments (CS): Latest and official vintage of Circuit Segments (former Circuit Protection Zones)

➤ Data sources:

From Foundry:

- Evm PtPS data: *conductorsegment_workflow_base*
- Ignitions data: *ignitions_2013_and_beyond_All_ignitions_clean*
- Outages data: *agg_outages*
- PSPS damage and Hazard: *PSPS_Damage_Hazard_Data_Clean*
- Pixels and CS geometries: *WDRM_V3_evm_pixels_weighted_px_assignments*

➤ EVM effectiveness Scope:

- ~900k pole-to-pole segments, 28k total miles
- ~1000 Circuit Segments with EVM-worked PtPS
- Events (Outages/Ignitions) starting January 2018 to January 2023

➤ Methodology overview

1. Mapping PtPs to CS
2. Aggregate PtPs information at CS level
 - Number, miles of PtPS segments
 - EVM work start/end date for each PtPS
3. Event (ignition / outages) mapping to closest PtPS
4. Statistical analysis at CS level

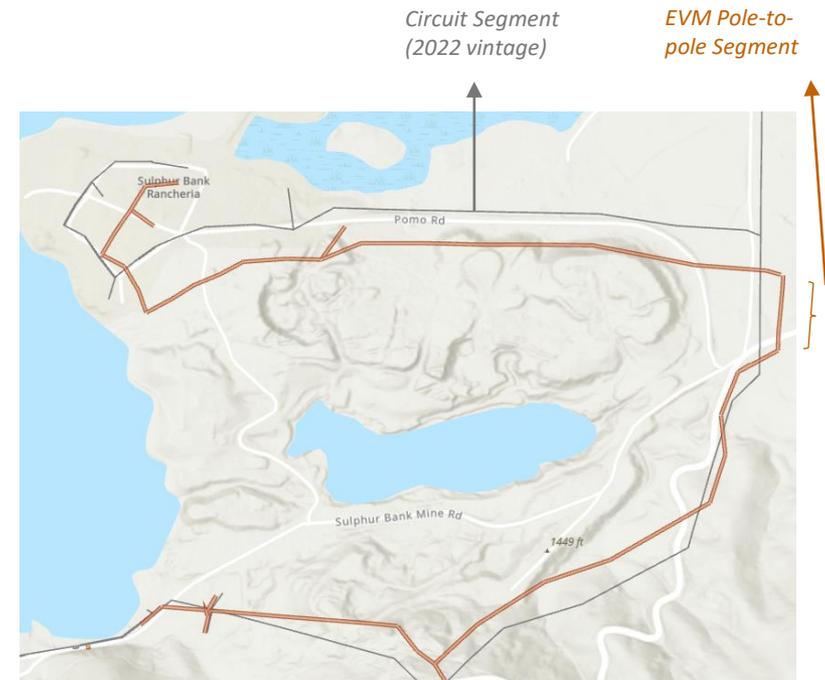


Figure 1: Example of differences between EVM PtPS geometries and 2022 CS vintage

Mapping PtPS to Circuit Segments

➤ Why start at PtPS level:

- Allows to access precise EVM work start/end dates
- Small units allows for higher CS level aggregations while retaining precise EVM work information

➤ Mapping:

- PtPS are mapped to the closest CS within a ~110m radius
- In case of multiple CS within radius, closest CS is chosen (based on average shortest distance across 10-equally spaced points along PtPS)

➤ PtPS with no CS within radius:

- Account for ~4% of all PtPS
- Most are outside HFTD, with no nearby CS

➤ Results (base for following analysis):

96% of all PtPS mapped to CS:

- 872K PtPS / 908K total

Rest is assigned to cpz according to old vintage

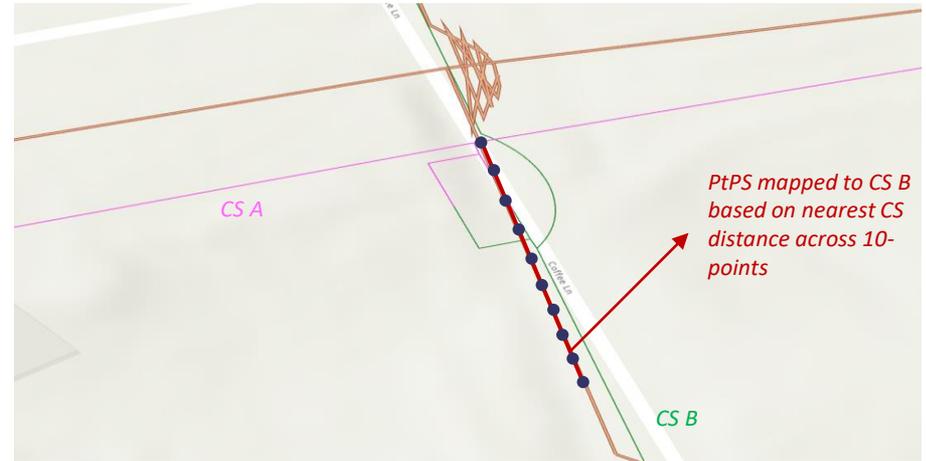


Figure 2: Example of CS mapping based on shortest 10-point distance

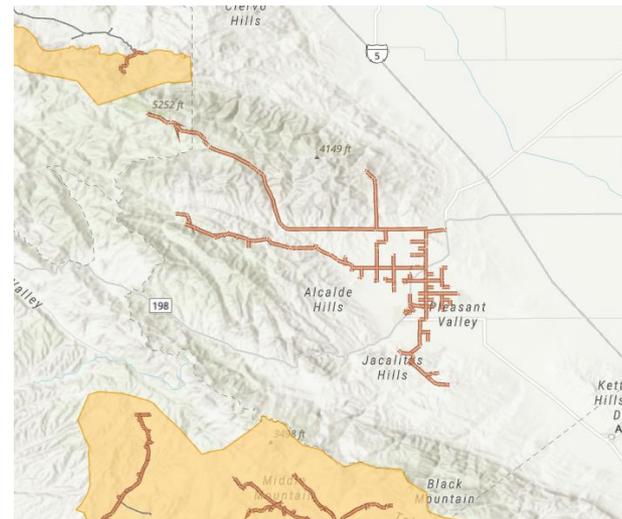


Figure 3: Example of PtPS with no reference CS, outside HFTD (PtPS belong to older vintage CPZ = COALINGA NO 2 11059260)

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Scope of analysis and methodology

Scope of Analysis:

- PtPS with EVM work completed (299K)
 - Allows before VS after treatment comparison on same segment (robust paired T-test)
 - Random interPtPS variation is eliminated
- PtPS with complete 1-year observation window before and after EVM (233K)
 - Covers full cycle (winter and fire season)
 - Analysis can be refreshed every day, as EVM work completed 1 year ago becomes available
- Limitations:
 - All EVM work completed in last rolling year is out-of-scope.
 - Omits events outside of observation windows

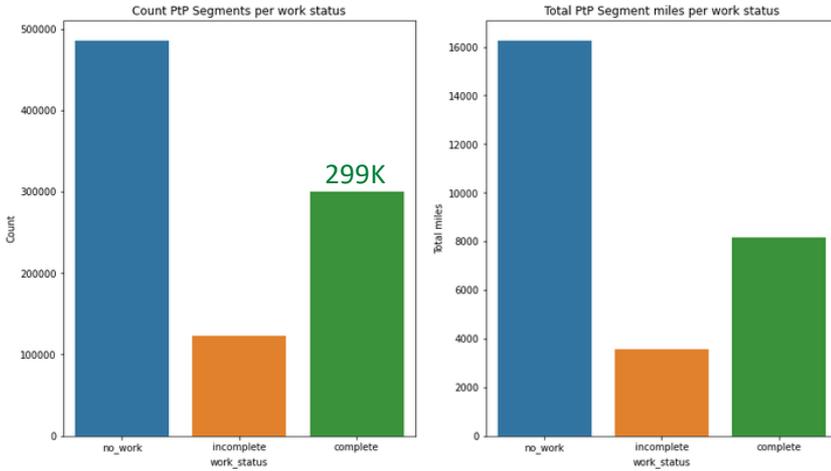
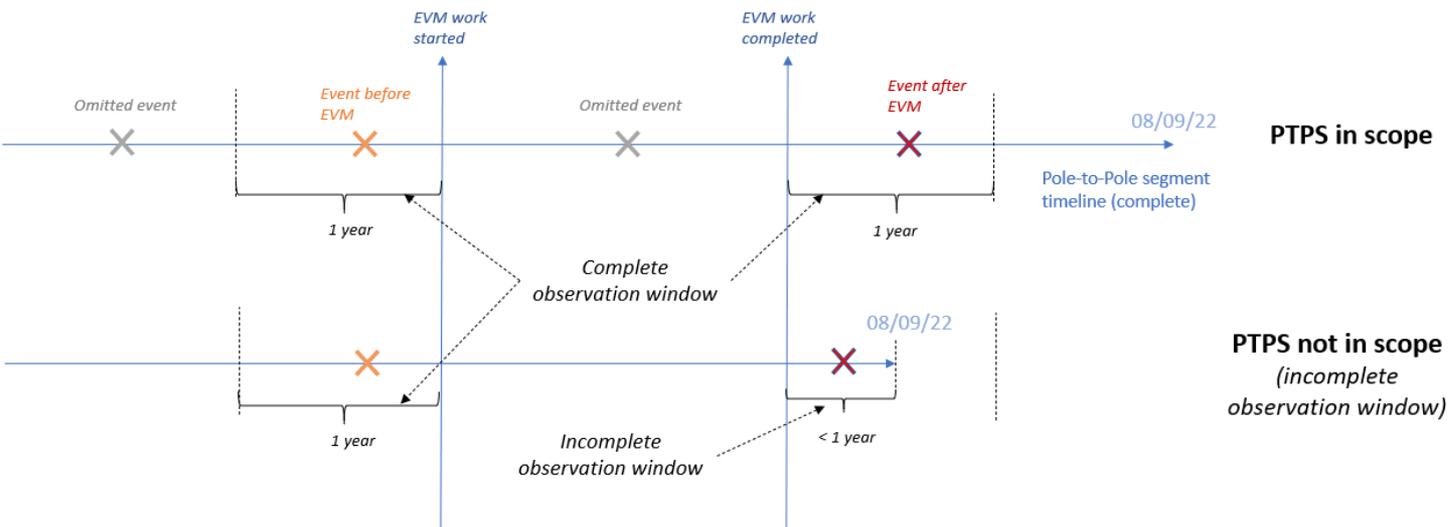


Figure 4: PtPS count and miles based on work status



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Events considered

Outages

- 18634 outages:
 - January 2018 – present
 - Vegetation caused
 - Vegetation Inspected
 - Excluding secondary conductor outages

- ~10400 mapped to PtPs (~120m radius)
 - ~7000 unworked PtPS
 - ~2250 incomplete PtPS
 - ~1200 work-completed PtPS

- **352 outages** on in-scope PtPS
(within observation windows)

PSPS damages and hazards

- 721 damages & hazards:
 - January 2018 – present
 - Vegetation caused
 - PSPS inspected/QC
 - Excluding secondary conductor D&H

- ~450 mapped to PtPs (~120m radius)
 - ~240 unworked PtPS
 - ~125 incomplete PtPS
 - ~90 work-completed PtPS

- **19 D&H** on in-scope PtPS
(within observation windows)

Outages / PSPS D&H T-test results

Outages / PSPS D&H per Weather signals

Case	Num outspss before	Num outspss after	Mean incidence rate** before EVM	Mean incidence rate** after EVM	Delta	Wilcoxon's Paired t-test-stats	Wilcoxon's P-value
all	261	110	0.0599	0.0264	-56%	14720	0.00%
WinterStorm + LowSnow +lightning	156	55	0.2250	0.1317	-41%	6095	0.00%
WinterStorm	86	44	0.2127	0.1992	-6%	2232	0.71%
LowSnow	61	7	0.4172	0.1089	-74%	956	0.00%
BlueSky	50	20	0.0169	0.0073	-57%	1519	0.18%
Wind*	31	30	0.1287	0.0946	-27%	590	49.18%

Table 1: Paired t-test (Wilcoxon) results on mean outage/D&H rate before/after EVM across CS, per weather signals, after grouping all CS shorter than 1 mile by geographic proximity.

Results and interpretations (using $\alpha = 5\%$ significance level):

Using the results of the Wilcoxon test (non-normality of event rate differences), one can conclude that the median of incidence rates after EVM is significantly smaller than before EVM, for the following weather signals, with a type I risk of 5%:

- Low Snow (delta = -74%)
- Blue Sky (delta = -57%)
- Winter Storm (delta = -6%)

Remark on ignition rates:

There is not enough ignition data to directly measure the effect of EVM on ignition rates (see previous August study). However, most ignitions having historically happened concomitantly to outages during fire season, the results shown above suggest that EVM is effective at reducing the outage rate on Blue Sky days and will ultimately have a positive effect on ignition reduction.

**Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS*

***Incidence rate = Num of events / year of weather signal / miles.*

Mean Incidence rate = Mean (of incidence rate) across grouped Circuit Segments

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Tree failure outages - T-test results

Tree failure related Outages per Weather signals

Only tree failure outages (veg_cdolip_cause = "Tree - fell into line")							
Case	Num outspsp before	Num outspsp after	Mean incidence rate before EVM	Mean incidence rate after EVM	Delta	Wilcoxon's Paired t-test-stats	Wilcoxon's P-value
all	170	73	0.0373	0.0169	-55%	8622	0.00%
WinterStorm + LowSnow +lightning	120	42	0.1749	0.0935	-47%	3696	0.00%
WinterStorm	66	34	0.1631	0.1316	-19%	1455	1.28%
LowSnow	50	4	0.3224	0.0892	-72%	629	0.00%
BlueSky	25	10	0.0068	0.0029	-57%	395	2.04%
Wind*	9	17	0.0402	0.0631	57%	115	93.78%

Table 2: Paired t-test (Wilcoxon) results on mean outage rate before/after EVM across CS for **tree failure related outages**, per weather signals, after grouping all CS shorter than 1 mile by geographic proximity.

Results and interpretations (using $\alpha = 5\%$ significance level):

Using the results of the Wilcoxon test (non-normality of event rate differences), one can conclude that the median of incidence rates (**for tree failure related outages**) after EVM is significantly smaller than before EVM, for the following weather signals, with a type I risk of 5%:

- Low Snow (delta = -72%)
- Blue Sky (delta = -57%)
- Winter Storm (delta = -19%)

*Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS

**Incidence rate = Num of events / year of weather signal / miles.

Mean Incidence rate = Mean (Incidence rate) across grouped Circuit Segments

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Outages / PSPS D&H System wide

Outages / PSPS D&H across whole EVM system

Case	Num outpsps before	Num outpsps after	Incidence rate on whole system before EVM	Incidence rate on whole system after EVM	Delta
all	261	110	0.0416	0.0175	-58%
WinterStorm + LowSnow +lightning	156	55	0.1631	0.0811	-50%
WINSTORM	86	44	0.1520	0.1082	-29%
LOWSNOW	61	7	0.2588	0.0657	-75%
BlueSky	50	20	0.0115	0.0045	-60%
WIND*	31	30	0.0738	0.0646	-12%

Table 3: Incidence rates per weather signals on whole EVM work-completed system (no aggregation at CS level)

**Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS*

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Limitations of EVM effectiveness analysis

Discussion on the limitations of the methodology:

While this analysis focuses on segments where EVM work has been conducted and validated, it does not factor in the potential effects of other PG&E risk mitigation programs, which may limit/enhance the risk reduction imputable solely to EVM work. As such, the figures presented in this analysis should be regarded only as estimations of the true EVM risk reduction impact.

Here is a list of other Risk Mitigation programs which could lead to a distortion of the EVM risk reduction signal, provided that the deployment of such programs intersects with the scope of the retained EVM segments, as well as the associated observation window:

System hardening:

Covered conductors, changes in equipment and structure should positively impact outage rates, while the nature of EVM work accomplished in proximity to hardened assets can be different than for non-hardened assets.

System inspection:

ROW clearance may enhance EVM mitigation (easier access and visibility)

EPSS:

EPSS may lead to inflated outage rates when comparing with historical baseline (although it should lead to decreased ignition rates)

PSPS:

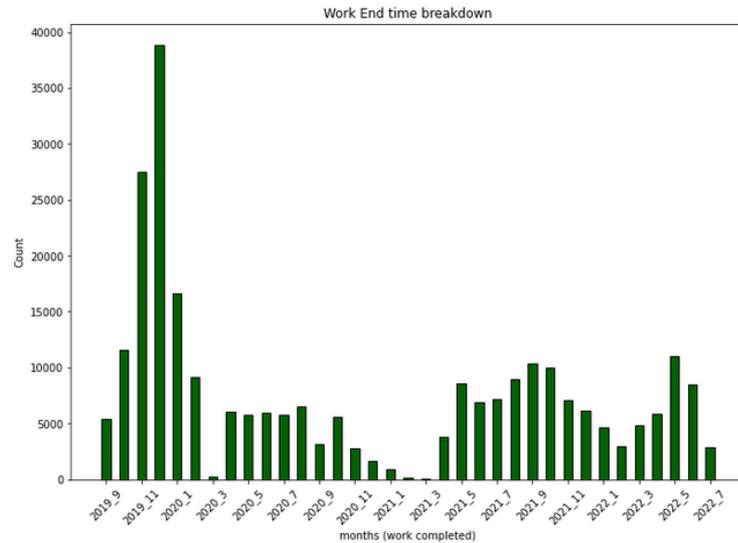
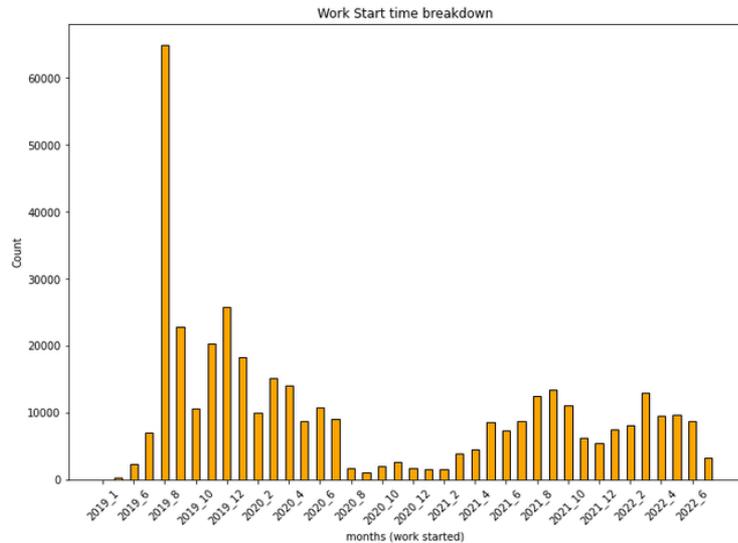
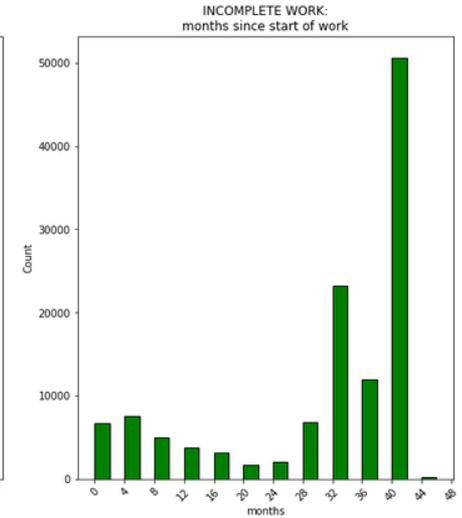
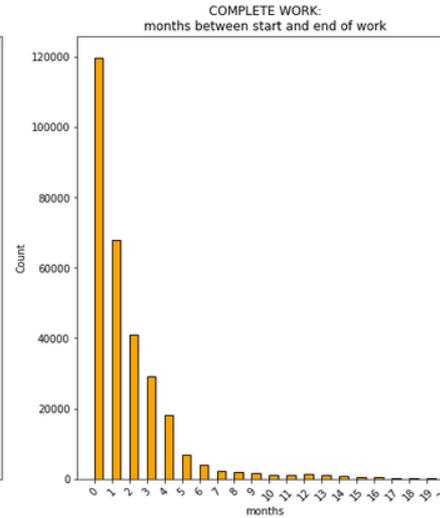
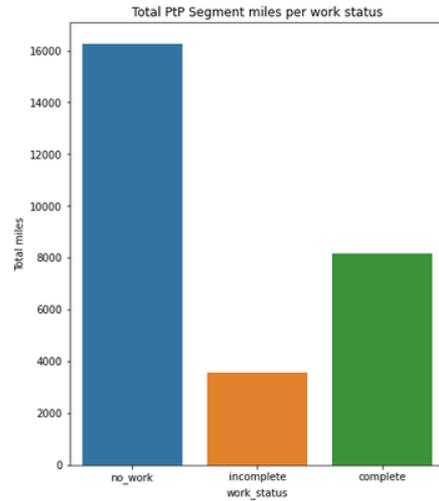
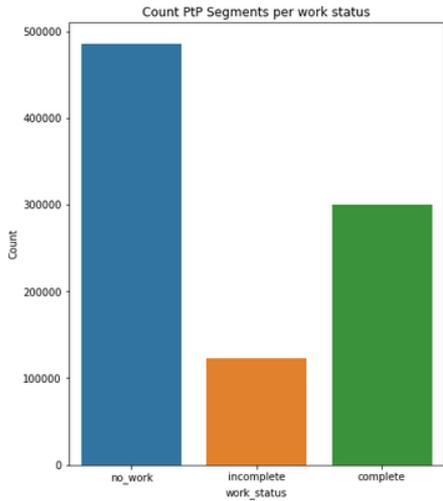
D&H are taken into account in this analysis (although transposition to ignition is unclear). After each PSPS event, vegetation inspection is done and subsequent VM work that could positively impact outage rate.

Undergrounding:

Whenever undergrounding is done, EVM effect is nullified.



Appendix A: PtPS statistics

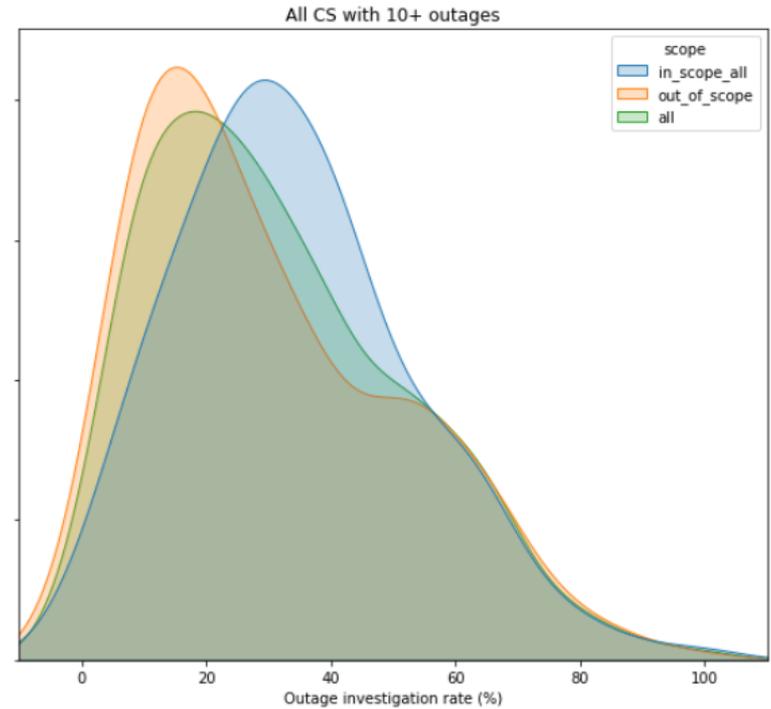
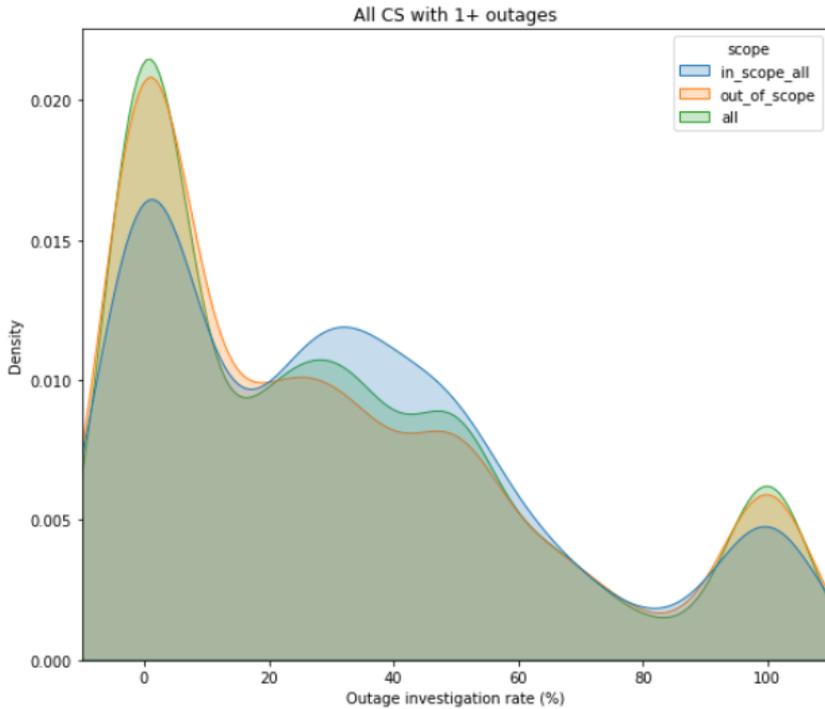


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Appendix B: Outage Vegetation Investigation Rates

Distribution of outage investigation rate across CS

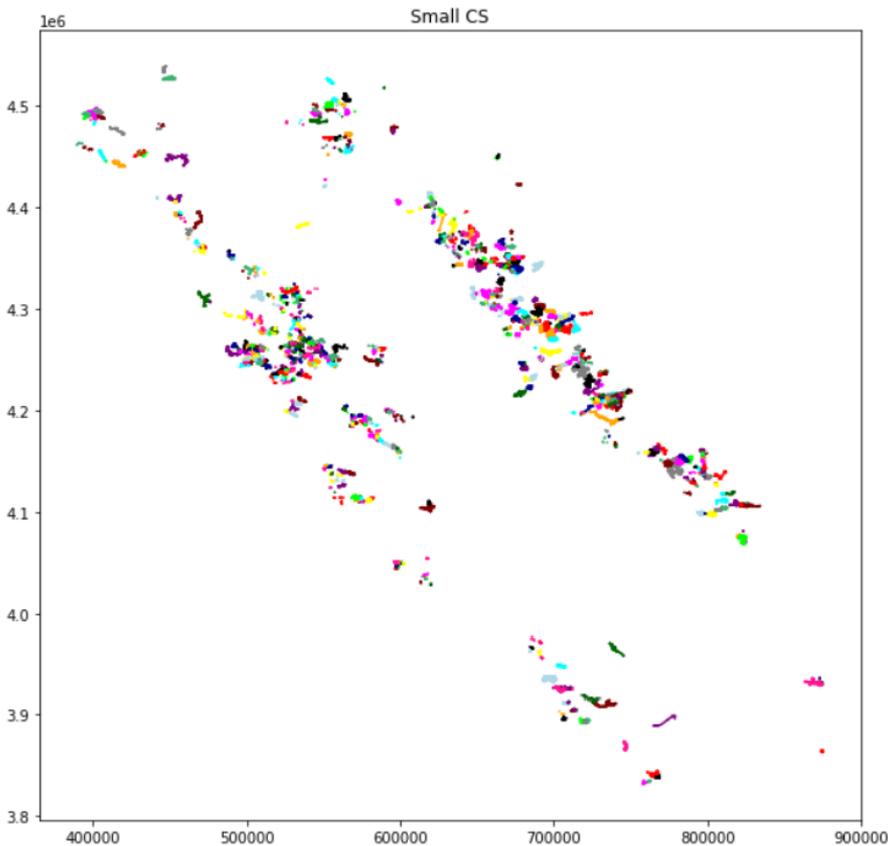


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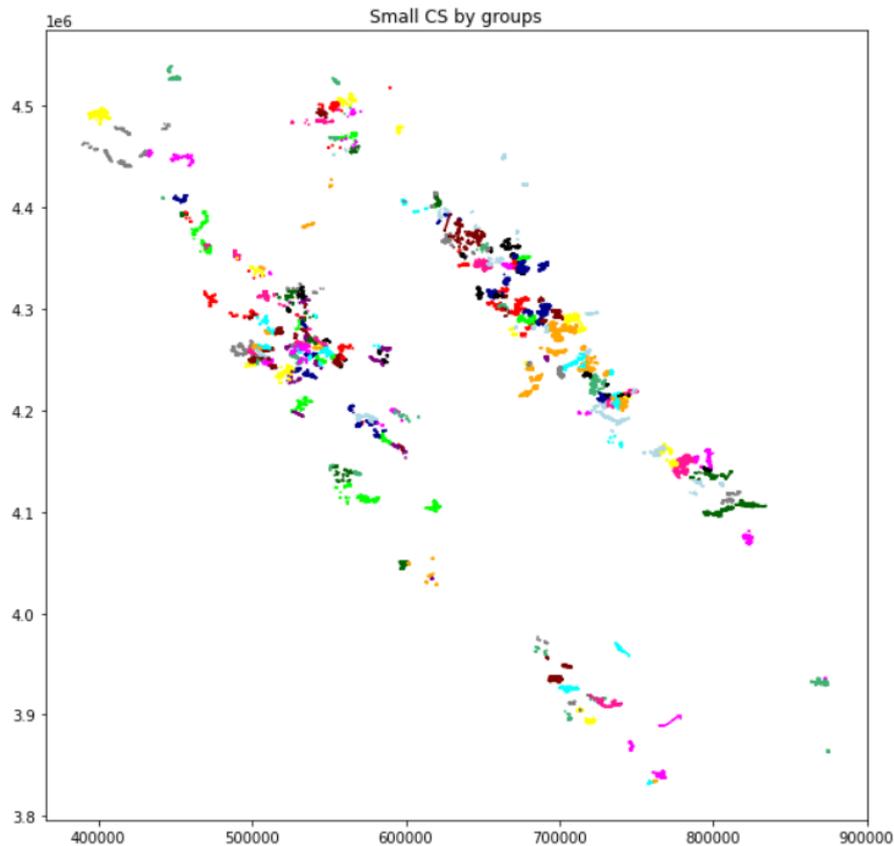


Appendix C: Shortest Circuit Segment groupings by geographical proximity

Small CS before grouping



Small CS after grouping



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Appendix D: Outages / PSPS D&H T-test results for all vegetation outages (veg inspected and non veg inspected)

Outages / PSPS D&H per Weather signals | veg and non veg-inspected

Case	Num outspss before	Num outspss after	Mean incidence rate before EVM	Mean incidence rate after EVM	Delta	Wilcoxon's Paired t-test-stats	Wilcoxon's P-value
all	405	218	0.0946	0.0549	-42%	23588	0.00%
WinterStorm + LowSnow +lightning	255	122	0.3877	0.2960	-24%	10801	0.00%
WinterStorm	125	75	0.3211	0.2920	-9%	4365	2.71%
LowSnow	115	40	1.0821	0.9003	-17%	2177	0.08%
BlueSky	77	42	0.0269	0.0144	-46%	3567	0.17%
Wind*	43	48	0.1441	0.1678	16%	944	88.84%

Table 4: Paired t-test (Wilcoxon) results on mean outage/D&H rate before/after EVM across CS, per weather signals, for veg and non veg-inspected outages, after grouping all CS shorter than 1 mile by geographic proximity.

Results and interpretations (using $\alpha = 5\%$ significance level):

Using the results of the Wilcoxon test (non-normality of event rate differences), one can conclude that the median of incidence rates after EVM is significantly smaller than before EVM, for the following weather signals, with a type I risk of 5%:

- Low Snow (delta = -17%)
- Blue Sky (delta = -46%)
- Winter Storm (delta = -9%)

Remark on ignition rates:

There is not enough ignition data to directly measure the effect of EVM on ignition rates (see previous August study). However, most ignitions having historically happened concomitantly to outages during fire season, the results shown above suggest that EVM is effective at reducing the outage rate on Blue Sky days and will ultimately have a positive effect on ignition reduction.

*Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS

**Incidence rate = Num of events / year of weather signal / miles.

Mean Incidence rate = Mean (Incidence rate) across grouped Circuit Segments

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Outages / PSPS D&H System wide

Outages / PSPS D&H across whole EVM system | veg and non veg-inspected

OUTAGES ACROSS WHOLE EVM SYSTEM (NO AGGREGATION)

Case	Num outspss before	Num outspss after	Incidence rate on whole system before EVM	Incidence rate on whole system after EVM	Delta
all	405	218	0.0646	0.0348	-46%
WinterStorm + LowSnow +lightning	255	122	0.2614	0.1772	-32%
WINSTORM	125	75	0.2222	0.1769	-20%
LOWSNOW	115	40	0.4596	0.4243	-8%
BlueSky	77	42	0.0176	0.0095	-46%
WIND*	43	48	0.1021	0.1066	4%

Table 5: Incidence rates per weather signals on whole EVM work-completed system (no aggregation at CS level), for all outages (veg-inspected and non veg-inspected)

*Wind includes the following Weather Signals: NorthEast, NorthWest and PSPS

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Thank You

Vegetation Asset Strategy and Analytics

