Table of Contents

List of Figures

List of Tables

1 Technical Model Documentation

1.1 Purpose

The Office of Energy Infrastructure (OEIS) requires transparency in risk calculation methodologies supporting Wildfire Mitigation. Per the guidelines, OEIS has specific requirements for technical documentation, substantiation, and data governance of the models used in risk calculations for the WMP. This template outlines the required technical documentation and substantiation for the models, while the WMP Data Governance Framework covers the data governance requirements for the models.

1.2 Applicability

The applicability of the model documentation and governance applies to models included in the Wildfire Mitigation Plan (WMP) filed with the OEIS for San Diego Gas & Electric (SDG&E).

Through its participation in Energy Safety led joint Investor Owned Utilities (IOU) risk modeling working groups and internally driven improvements, SDG&E has incorporated several updates and enhancements to the Wildfire Next Generation System (WiNGS)-Planning models. The WiNGS-Planning model versions referred to in this document span versions 1.0, 2.0, and latest version 3.0. WiNGS-Planning 1.0 is relevant to circuit segments that were scoped for mitigation in the years 2022 through 2024. Version 2.0 is the most recent production version of the model and is relevant to scoping starting in 2025. WiNGS-Planning 3.0 is the latest version and is referred to when describing the most recent improvements to the model.

Between WiNGS-Planning 1.0 and WiNGS-Planning 2.0, data quality was been enhanced by more accurately capturing hardening miles within the High Fire Threat District (HFTD), improving the methodology behind calculating the overhead-to-underground mileage conversion contingency factor, and updating the data incorporated from the Technosylva's Wildfire Risk Reduction Model (WRRM). Updated data was also incorporated, such as the effectiveness of different mitigations at reducing wildfire risk and refreshing historical ignition counts to enhance the model's estimated ignition rates. A data refresh between model versions presents the most up to date and accurate information to inform decisions regarding grid hardening strategy. Components such as historical wind, weather station additions, Public Safety Power Shutoff (PSPS) de-energization history, system assets, information regarding vulnerable customers, and vegetation data have all been updated.

Updated data has also been incorporated that reflects additional information gained through implementation of wildfire mitigation projects. For instance, additional data associated with the Strategic Undergrounding Program, such as avoided costs associated with fewer vegetation management activities, reduced PSPS scope, and reduced maintenance costs are all included, which allows for life cycle costs to be modeled. In addition, undergrounding cost per mile has decreased by approximately 12 percent, resulting in an increased Risk Spend Efficiency (RSE) associated with the undergrounding of electric lines.

Enhancements from WiNGS-Planning 2.0 to 3.0 focus on reproducibility with major architectural changes from Excel to Python, allowing for code version control. Another major enhancement is the ability to directly gauge risk reduction over time with the inclusion of scoping data. It is important to note that WiNGS-Planning versions 1.0, 2.0, and 3.0 use fundamentally similar logic and changes have been kept minimal during the architectural transition from Excel to Python.

2 Technical Documentation

2.1 Problem or Function

2.1.1 Problem Modeled

Define the problem modeled for function performed by the program, for example, calculation of fire growth, smoke spread, people movement, etc.

The WiNGS-Planning model evaluates both wildfire and PSPS impacts at the sub-circuit/segment level to inform investment decisions by determining which initiatives provide the greatest benefit per dollar spent in reducing both wildfire risk and PSPS impact.

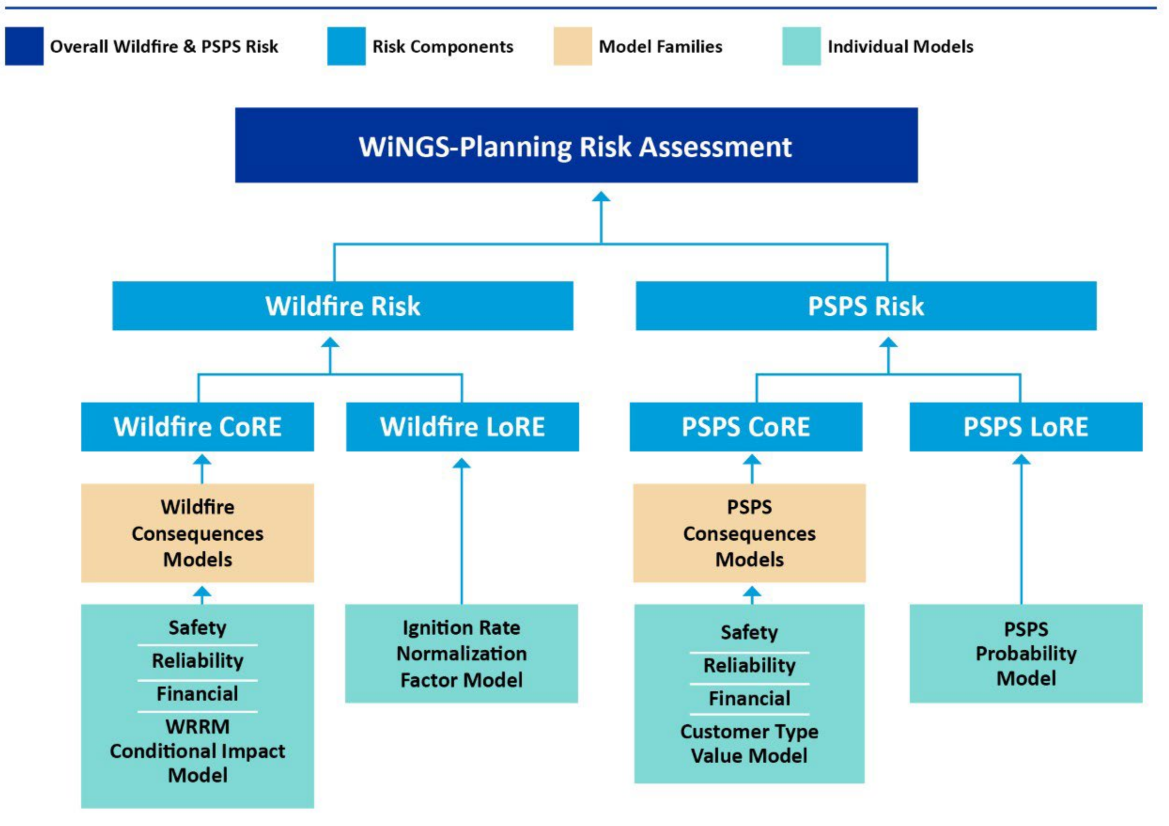
2.1.2 Problem Environment

Describe the total fire problem environment. General block or flow diagrams may be included here.

The WiNGS-Planning model was developed to aid with the allocation of grid hardening initiatives across HFTD segments based on an assessment of both wildfire risk and PSPS impacts. WiNGS-Planning is built upon the Multi Value Attribute Function (MAVF) framework in Risk Assessment Mitigation Phase (RAMP) and evaluates both wildfire and PSPS impacts at the sub-circuit/segment level. A segment is composed of one or many spans located between two supervisory control and data acquisition (SCADA) sectionalizers in the electric network. The segment level of data granularity is required to establish the segment parameters. Information is used to inform investment decisions by determining and prioritizing mitigation based on RSEs, improving wildfire safety, and limiting the impact of PSPS de-energizations on customers.

The WiNGS-Planning model risk calculation process is described in the Figure 1:

Figure 1: WiNGS-Planning Risk Calculation Process Flow Diagram



Overall Wildfire and PSPS Risk (dark blue box) – The total expected annualized impact from Wildfire and PSPS events at a specific location. This metric is a summation of the Wildfire and PSPS risk scores.

Overall Wildfire and PSPS Risk (turquoise boxes in Figure 1):

- Wildfire risk – The total expected annualized impacts from ignitions at a specific location. This considers the likelihood that an ignition will occur, the likelihood the ignition will transition into a wildfire, and the potential consequences – considering hazard intensity, exposure potential, and vulnerability – the wildfire will have for each community it reaches.
- PSPS risk – The total expected annualized impacts from a PSPS de-energization at a specific location. This considers two factors: (1) the likelihood a PSPS de-energization will be required due to environmental conditions exceeding design conditions, and (2) the potential consequences of the PSPS de-energization for each affected community, considering exposure potential and vulnerability.

Intermediate risk components (turquoise in Figure 1):

- Wildfire likelihood of risk event (LoRE) – The total anticipated annualized number of fires reaching each spatial location resulting from utility-related ignitions at each location in the service territory. This considers the ignition likelihood and the likelihood that an ignition will transition into a wildfire based on the probabilistic weather conditions in the area.
- Wildfire consequence of risk event (CoRE) – The total anticipated adverse effects from a wildfire on each community it reaches. This considers the wildfire hazard intensity, the wildfire exposure potential, and the inherent wildfire vulnerabilities of communities at risk.
- PSPS LoRE – The likelihood of a PSPS given a probabilistic set of environmental conditions.
- PSPS CoRE – The total anticipated adverse effects from a PSPS for a community. This considers the PSPS exposure potential and inherent PSPS vulnerabilities of communities at risk (see definitions in the following list).

Model Families (orange boxes in Figure 1)

- Wildfire Consequence Models – Models that determine expected outcome of Company-triggered ignitions converted to MAVF scoring metrics based upon outputs from WRRM.
- PSPS Consequence Models – Models that produce the expected customer impact varied by customer type for PSPS events converted to MAVF scoring metrics.

Individual Models (aqua boxes in Figure 1)

- Ignition Rate Normalization Factor Model – Model that determines the rate of expected annual ignitions assessed at circuit-segment granularity.
- PSPS Probability Model – Model that determines the probability and rate that a circuit segment will experience a PSPS de-energization within a year based on historical data.
- MAVF – See SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-5, dated 5-17-2021.
- WRRM Conditional Impact Model – Model developed by Technosylva to quantify the impact across multiple metrics (e.g., building impacted, acres burned, flame length, rate of spread, etc.) tied to ignitions caused by company-owned assets. This model uses fire model simulation software to produce a range of expected fire spread rasters and produces statistics for expected impact and fire spread conditions.
- Customer Type Value Model – Model used to determine the effects of PSPS de-energizations on vulnerable customer types including Medical Baseline, Life Support, Essential, and Sensitive.

Inputs to risk components

- WRRM Conditional Impact

  - Acres Burned – Acres burned per WRRM fire simulation. Max acres burned per segment is used in the MAVF calculation.
  - Buildings Destroyed – Buildings destroyed per WRRM fire simulation. Max buildings destroyed per segment is used.
- MAVF
  - Safety – See SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-5, dated 5-17-2021.
  - Reliability - See SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-5, dated 5-17-2021.
  - Financial - See SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-5, dated 5-17-2021.

- Ignition Rate Normalization Factor Model
  - Ignition Events – Annual Ignitions within the HFTD.
  - Overhead Mileage – Overhead circuit miles per circuit segment.
  - Wind Speed – Max wind speed based on past events.
  - Tree Strike – Potential number of trees that have the ability to contact overhead conductors based on the tree inventory, where the tree point is buffered by the height of its canopy and intersected with the circuit segment to determine the number of potential contacts.
  - CHI – Circuit Health Index (CHI) model developed to determine the robustness of a circuit based on a range of criteria.
  - Conductor Age – Average conductor age per circuit segment.
  - Hardening State – Miles and percentage of underground and overhead hardened based on traditional hardening approaches and installation of covered conductor.

- Customer Type Value Model
  - MBL – Customers registered as Medical Baseline (MBL) are defined as customers who rely on life support equipment, have life-threatening illnesses, multiple sclerosis, scleroderma, are paraplegic or quadriplegic, or have a compromised immune system.
  - Urgent - Customers registered as Urgent are defined as a customer whose mission supports regional emergency response (certain Police, Fire Dept., hospitals).
  - Essential - Customers registered as Essential are defined as essential public health, safety, and security uses.
  - Sensitive - Customers registered as Sensitive are defined as customers who are particularly sensitive to service quality and reliability due to the nature or size of their load or due to recent poor performance (i.e., Sony). This category also covers special events that have a high visibility (Super Bowl, Republican Convention).

- PSPS Probability Model

- High Fire Days – High Fire Days as defined by Meteorology, namely Santa Ana Wind days, that fall in the season window ranging roughly September 1 through December 31, plus any winter/spring Red Flag Warning (RFW) days.
- Alert Speeds – Wind speeds thresholds at which individual SCADA sectionalizing switches may be subject to the consideration of a PSPS de-energization due to the risk of wildfire.
- Hardening State – Miles and percentage of underground and overhead hardened based on traditional hardening approaches and installation of covered conductor.

2.1.3 Background Environment

Include any desirable background information, such as feasibility studies or justification statements.

The WiNGS-Planning model is designed to utilize risk modeling to guide SDG&E in making data-driven system hardening investment planning decisions to mitigate both wildfire and PSPS risks. This model builds on the same RSE methodology described in RAMP 2021 and evaluates risk at a circuit segment level of granularity to inform investment decisions by determining which initiatives provide the greatest benefit per dollar spent in reducing both wildfire risk and PSPS impact. WiNGS Planning is the latest endeavor in an evolutionary process towards SDG&E's efforts to become a more risk informed, data driven utility.

WRRM was originally used in the same capacity as the current WiNGS-Planning model. In its originally conceived state, WRRM contained ignition likelihood scores that were used in conjunction with wildfire consequence scores to produce an overall fire risk status of assets in the HFTD. With the advent of the WiNGS-Planning model, the need for Technosylva to produce likelihood scores was mitigated and as such, the WRRM model used in WiNGS-Planning was relegated to wildfire consequence only.

2.2 Technical Description

2.2.1 Theoretical and Mathematical Foundations

Convey a thorough understanding of the theoretical and mathematical foundations, referencing the open literature where appropriate.

The WiNGS Planning model is essentially a weighted sum model that incorporates high-level variables of wildfire LoRE, wildfire CoRE, PSPS LoRE, and PSPS CoRE with associated weightings and scaling factors for each variable.

2.2.1.1 MAVF

The WiNGS Planning model makes use of the MAVF as described in SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-5, dated 5-17-2021. The MAVF is used to standardize wildfire and PSPS consequences. Table 1 and Table 2 describe the MAVF units, weights, and scaling factors.

Table 1: Risk Quantification Framework Top-Level Attributes

Attribute	Measurement Unit	Scale	Weight	Description
Health & Safety	Safety Index	0-20	60%	Measures average safety consequences if a risk were to occur in terms of potential fatalities and/or serious injuries
Financial	U.S. Dollars	$0-$500M	17%	Measures average financial consequences if a risk were to occur such as financial damage to property
Reliability	Reliability Index	0-1	23%	Measures average reliability consequences if a risk were to occur in terms of SAIDI and SAIFI

Table 2: Risk Quantification Framework Safety Index

Safety Sub-Attributes	Value
Fatality	1
Serious Injury	0.25
Acres Burned	0.00005

2.2.1.2 RSE

SDG&E refers to its MAVF as the Risk Quantification Framework. It is used to analyze risk by estimating current risk scores (pre-mitigation risk scores) and forecasting future risk scores if new activities are started or current ones are ceased (post-mitigation risk scores). This is an evolving framework used to inform quantitative risk assessments, including for wildfire and PSPS risk in the mitigation RSE calculation and for WiNGS-Planning and WiNGS-Ops models, and remains subject to ongoing changes and development. For more information on the Risk Quantification Framework, see SDGE 2021 RAMP filing, dated May 17, 2021.

In order to effectively apply appropriate mitigations to each circuit segment, RSEs are incorporated into the final model decision-making process. As described in RAMP, RSEs are numerical values that attempt to portray changes in risk scores per dollar spent. The risk score that is developed is meant to represent the current risk situation. The current situation for each risk attempts to consider existing activities (known as Controls), current work standards, and all other current characteristics, such as asset conditions and environmental conditions. A risk score is calculated by multiplying the LoRE and the CoRE. The risk score that results from using the Risk Quantification Framework is the baseline used when calculating RSEs. Next, a second estimate for LoRE and CoRE that considers a change in a risk-reducing activity is estimated. For mitigations, the second LoRE and CoRE are estimated assuming the new activity is in place. For Controls, the second LoRE and CoRE reflect the estimated risk if the activity is ceased. For more information on RSEs see SDGE RAMP-C Risk Quantification Framework and Risk Spend Efficiency, page C-26, dated May 17,2021.

For the purposes of the WiNGS-Planning model, wildfire RSE is the present value of the wildfire risk reduction divided by the total mitigation cost. The present value of the wildfire mitigation is determined by calculating the wildfire risk reduction over the course of the mitigation lifetime and accounting for a benefit discount rate. A readability multiplier is also used to make the RSE value more intelligible.

2.3 Theoretical Foundation

2.3.1 Phenomenon and Physical Laws (Model Basis)

Describe the theoretical basis of the phenomenon and the physical laws on which the model is based.

The fundamental phenomenon that the WiNGS-Planning model seeks is that of mitigating wildfire caused by electric distribution assets. While the distribution electric system contains an inherent element of ignition risk, it is essential that ignitions do not become wildfires. In order to accomplish this theoretical goal, mitigations in the form of installing covered conductor and undergrounding electric lines are employed. If cost were no object, the most effective mitigation for wildfire risk would be to underground the overhead lines. While this would be the most effective means of mitigation, the cost of each mitigation must also be considered in order to be most effective. The WiNGS-Planning model employs risk calculations for ignition likelihood, ignition consequence, PSPS likelihood, and PSPS consequence to gauge the risk of wildfire for circuit segments in the HFTD. To make sure that mitigations are applied in a responsible manner, each segment is evaluated in ascending wildfire risk order for which mitigation is economically feasible using the RSE methodology described in Section 2.2.1.

2.3.2 Governing Equations

Present the governing equations and the mathematical model employed.

The governing equation for WiNGS-Planning is

$$Risk = LoRE \times CoRE$$

Where LoRE is the likelihood and CoRE is the consequence of an event.

The basic formula for an RSE is as follows:

$$RSE = \frac{Risk\ Reduction \times Lifetime\ of\ Benefit}{Total\ Cost}$$

2.3.3 Independent Review Results

Provide the results of any independent review of the theoretical basis of the model. Guide E1355 recommends a review by one or more recognized experts fully conversant with the chemistry and physics of the fire phenomena but not involved with the production of the model.

An independent third-party review of data and inputs took place in August 2022, which resulted in several data and model governance findings. Recommendations included:

1. Migrate Excel + Frontline to Python
2. Control the source with Git
3. Version model releases
4. Apply coding standards
5. Automate manual steps in code
6. Decompose functionality into discrete, testable components
7. Create unit and end-to-end testing
8. Convert optimization to Python

Many of these recommendations have been implemented by the Python and Amazon Web Services (AWS) migration or are in progress.

In November 2022, another independent review took place, which evaluated model code, infrastructure, and data management processes according to best practices. Industry-recognized standards, such as the AWS Well Architected Approach and the 12-factor application development pattern, were referenced in this review process to assemble industry recognized best practices.

This review highlighted how WiNGS-Planning currently aligns to best practices across key competency areas. Table 3 shows findings and recommendations focused on testing and automation in future enhancements:

Table 3: Findings and Recommendations

Review Category	Current Highlights	Future Recommendations
Data Management and Governance	Input files are automatically versioned and promoted across environments using a pipeline.	Structure results in a database (e.g., Glue DB or RDS) for easier access and use parquet format Describe model output results with data cataloging tool Collibra Leverage S3 to align to enterprise data retention policies
Development Practices	Source control with Git is used to enforce versioning and audit trail. Functional programming practices are observed for readability and performance.	Organize updates to codebase in release notes and development notes to document changes over time

Review Category	Current Highlights	Future Recommendations
	READ.ME and other documentation are generated and updated.	
Enterprise Standards and Security	Enterprise templates are used for CI/CD pipelines and IaC to reduce development time and streamline updates. Sempra's CARB internal board approved the WiNGS-Planning AWS architecture to ensure use of white-listed services and alignment with IT standards. Only enterprise approved third-party packages are used in code.	Leverage DevSecOps pipeline templates for testing, where applicable Use a scanning tool on third-party packages to detect security risks, e.g., malicious code
Observation and Monitoring	Console logging and logging to AWS CloudWatch are enabled for easy debugging.	Visualize logging with a dashboard for easy and more transparent identification of issues Leverage Prefect 2.0 functionality for enhanced monitoring, logging, and native visualization
Automation	Task orchestrator Prefect.io. is used to establish how model calculations and dataflow are executed	Establish ground truth for testing and use as basis for unit, integration, and environment testing to: • Ensure input data is being transformed and aggregated as expected • Ensure calculations are creating intermittent outputs as expected • Detect variance in results (against ground truth) • Test changes to code to compare results against ground truth (integration testing can be added to CI/CD pipeline) • Integrate testing in PR process—issues are caught earlier, before merge

2.4 Mathematical Foundation

2.4.1 Techniques, Procedures, Algorithms

Describe the mathematical techniques, procedures, and computational algorithms employed to obtain numerical solutions.

2.4.1.1 Weighted Sum Model

The weighted sum model is a multi-criteria decision analysis methodology for evaluating a dependent variable as a function of several weighted independent variables. It is a well-known and often used framework for problems that have independent variables that are comprised of discrete factors that all have varying degrees of contributing significance to the dependent variable being solved for. The weighted sum model can be expressed as:

$$WS = \sum_{i=1}^{N} W_i X_i$$

Where WS is the weighted sum output, W_i is the weight of the variable, X_i is the independent variable, and N is the total number of dependent variables.

This method is employed as the framework of the MAVF, the Customer Type Value Model for PSPS Consequence, and the foundational methodology in the Ignition Rate Normalization Factor Model. The Ignition Rate Normalization Factor Model is unique in its application of the weighted sum approach in that it uses as a step-by-step weight adjustment process as opposed to a traditional weighted sum equation application.

2.4.1.2 Normalization

Normalization procedures in mathematical functions are performed to scale values to predefined numbers or within a defined range. This process is implemented within the MAVF for each attribute weight, as well as in the Ignition Rate Normalization Factor Model, to maintain annual ignition rate across the scoped system after every weight adjustment process.

2.4.1.3 LoRE

Likelihood of Risk Event (LoRE) leverages a variety of data to calculate the likelihood of a risk event occurring in a year. The unit of this metric is the expected annual rate of a risk event occurring.

Wildfire LoRE

Historical data was used as a starting point for consideration of likelihoods. Data was considered from both reportable ignitions (since 2014) and from large fire history (since 1970) reported.

Changes were considered from the historic likelihood of fires and are primarily due to system hardening programs, climate change, increased overhead miles relative to previous timeframes, and change in vegetation relative to previous timeframes. Because these changes are not precisely known, models were used to estimate the actual range of current likelihoods.

The likelihood of a risk event is determined by prorating historical annual ignition rates by the mileage of the segment and adjusting to account for wind speed, historical tree strikes, vegetation density, asset hardening, and asset health. Asset health is determined by evaluating conductor age and the CHI originally developed as part of the Circuit Risk Index (CRI) model. The CHI serves as a proxy for wire-down incidents due to pole deterioration-related conditions. The value is a unitless index calculated at the individual pole level and the median pole value and is used to determine the segment CHI. For non-HFTD segments with no CHI value, the average CHI value of all of the non-HFTD pole values was used in place. Similarly, for HFTD segments with no CHI value, the average CHI value of HFTD pole values were used in place.

Wildfire Adjustment Rate

For the last step in the ignition likelihood calculation, a wildfire adjustment is applied to obtain the Wildfire LoRE score. The adjustment is based on the analysis described in Section 2.4.1.4 and equates to a scenario stating one substantial fire will occur every 15 years.

PSPS LoRE

Historical data ranging from 2017 onwards was pulled from the reporting database Oracle Utility Analytics (OUA) and its source system Network Management System (NMS).

Historical PSPS de-energizations are analyzed to estimate likelihood and impact of future PSPS de-energizations. The number of PSPS de-energizations has a large variance from year to year depending on the weather and the occurrence of wildfires. Additional reasons for changes in likelihood may be due to updated notions of when to perform PSPS de-energizations based on analysis of the relationship between wildfire risk and PSPS impacts.

2.4.1.4 CoRE

CoRE is calculated utilizing the MAVF framework. The MAVF framework is based on three specific attributes related to a risk event (see Table 1)

Wildfire consequence

The wildfire consequence calculation is based on WRRM simulations and utilizes key metrics derived from the model including maximum acres affected per segment and maximum buildings destroyed multiplied by appropriate constants, which are then inserted into the MAVF. WRRM integrates historical fire weather scenarios with wildfire spread modeling to calculate fire behavior metrics surrounding the location of individual assets. The modeled outputs derived from WRRM include summary statistics derived from ensemble wildfire simulations, which includes metrics such as total acres burned, flame length, rate of spread (ROS), and buildings impacted.

Consequence outputs were derived from WRRM using historical fires to create or “fit” a probability distribution from large fires considering financial loss. The probability distribution is the estimation of the extent of financial losses that may occur if a large utility-associated wildfire occurs. The probability distribution is not a precise statistical forecast, but it is a useful estimation for wildfire risk discussions. The probability distribution currently used is not permanent and will continue to be modified as new information becomes available.

Wildfire consequence is quantified using the MAVF as described in RAMP-C Risk Quantification Framework and Risk Spend Efficiency, May 17, 2021.

- Financial: CoRE was partially calculated for each attribute from the Monte Carlo modeling by extracting the expected values of the output consequences.
- Reliability: Data was extracted from the reliability database for fire-related outages to determine reliability impacts.
- Safety: Safety impacts during a fire vary and are difficult to quantify, therefore a ratio was applied to the financial data.
- CoRE Output: Financial, reliability, and safety values were then used as inputs for the Enterprise Risk Management Framework to determine the CoRE value.

PSPS consequence

Consequence values are assigned for safety, reliability, and finance and those values span three different customer classes. See Section 2.2.1.1 for details on MAVF and the weighted sum model, and Section 2.4.2.2 for details on calculations of PSPS consequence.

2.4.1.5 Mitigation Assessment Algorithms

Once the baseline risk per segment has been established, the next step is evaluating the effect and costs of different mitigations. For each mitigation in the model there is an associated percentage decrease in wildfire risk and PSPS impact. For wildfire risk mitigation effectiveness, internal and external subject matter expertise is used to estimate the impact of a mitigation on various wildfire triggers (e.g., animal contact, vegetation contact). Where possible, additional analyses are conducted using internal data (e.g., historical fault data). For PSPS impact reduction, internal subject matter expertise and historical event data are used to estimate the reduction in PSPS likelihood for the individual segment probability tied to each mitigation. The cost of the mitigation is determined by utilizing the average cost per mile and applying it to the circuit-segment. For strategic undergrounding of electric lines, a mileage contingency related to conversion is also considered. With the risk reduction and cost assessment analyzed at the circuit-segment granularity, a cost benefit value is calculated for each mitigation tied to each circuit-segment in the WiNGS-Planning model scope.

Because the PSPS risk on a segment is influenced by the maximum upstream segment PSPS probability, mitigations that occur upstream of segments influence the risk of PSPS on downstream segments. Thus, the PSPS impact on a segment cannot be looked at in isolation and must be considered with the other segments on the same circuit and their respective mitigations via the use of a dynamic model. The dynamic nature of the WiNGS-Planning model updates the maximum upstream probability of a segment as mitigations upstream are determined.

2.4.1.6 Mitigation Scenario Analysis

The WiNGS-Planning model analyzes and compares different long-term investment planning portfolios and scenarios. Utilizing varied constraints and risk target goals, including risk reduction percentages, total scenario cost, and RSE thresholds for mitigation considerations, different scenarios can be run across the full scope of circuit-segments considered. This results in a unique set of mitigations chosen across the full scope of circuit-segments and the scenario outputs (e.g., total risk reduction, total cost, strategic underground mitigation mileage) that result from their implementation. WiNGS-Planning analyzes each circuit-segment for installation of covered conductor, strategic undergrounding of electric lines, or no-mitigation to optimize and compare the risk reduction and associated cost. Currently, RSE outputs from WiNGS-Planning are used to inform how to invest in mitigations that reduce risk. Although the risk reduction targets are often aimed at cost effectiveness, annual performance objectives, mileage targets, and other limitations and constraints are also considered to inform investment decisions.

2.4.2 Equations and Implementation

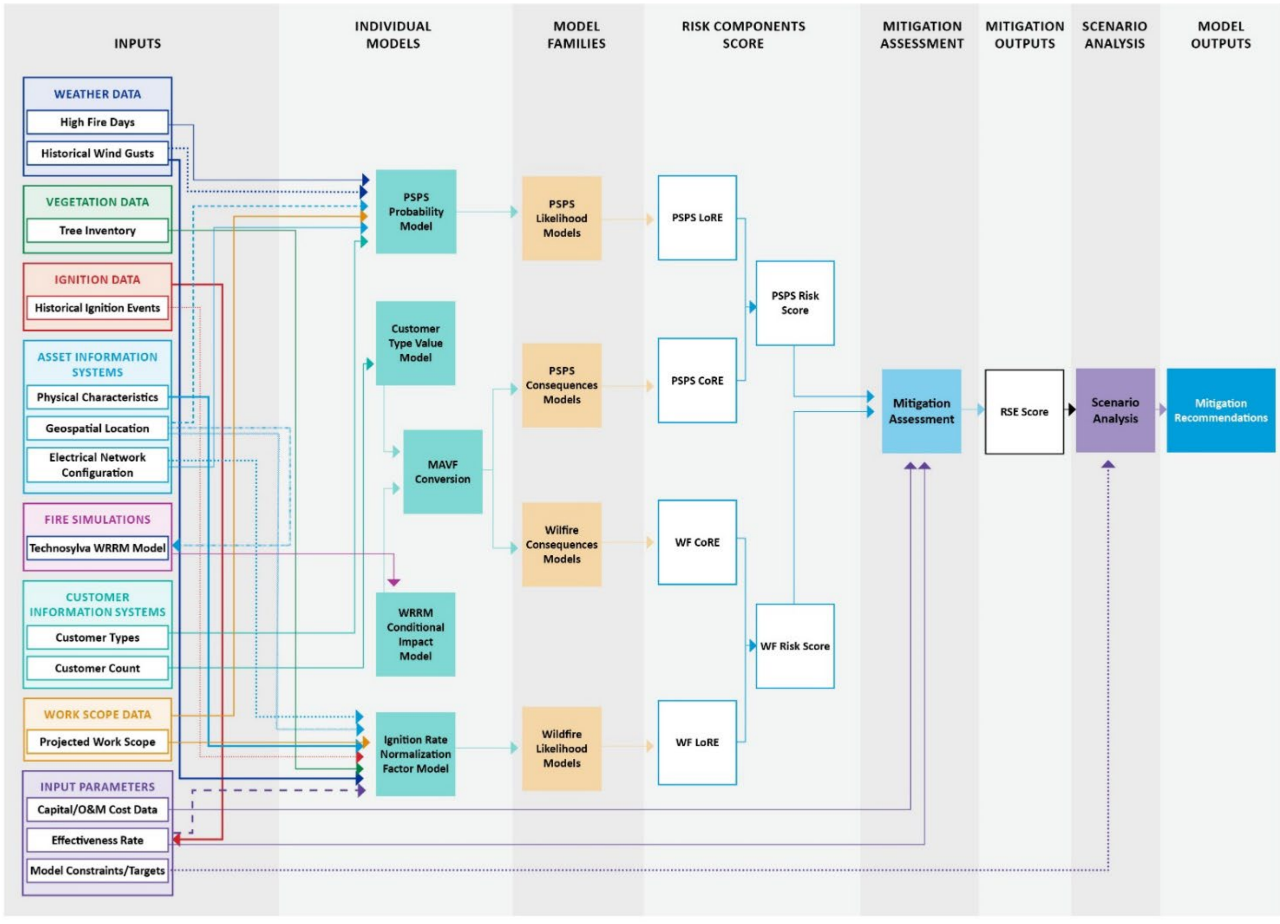
Present the mathematical equations in conventional terminology and show how they are implemented in the code.

The main components in the WiNGS-Planning model are Wildfire LoRE and CoRE and PSPS LoRE and CoRE. Each of these components could be viewed as individual models within the parabola of the WiNGS-Planning model. These components are connected and play a pivotal role in risk quantification as well as mitigation selection.

The Wildfire Risk and PSPS risk scores are combined to form an overall segment risk score. Wildfire Risk, PSPS Risk, and Overall Wildfire and PSPS Risk are all analyzed to help identify high and low risk segments across the service territory according to the risk score.

A general model process flow diagram depicting the various model elements and process steps and their interactions is detailed in Figure 2.

Figure 2: WiNGS-Planning Model Process Flow Diagram



2.4.2.1 Overall Risk

Wildfire Risk

The Wildfire Risk Score is the product of Wildfire (WF) LoRE and WF CoRE

$$WF\ Risk\ =\ WF\ LoRE\ \times\ WF\ CoRE$$

PSPS Risk

The PSPS Risk Score is the product of PSPS LoRE and PSPS CoRE

$$PSPS\ Risk\ =\ PSPS\ LoRE\ \times\ PSPS\ CoRE$$

Overall Wildfire and PSPS Risk

The Overall Wildfire and PSPS Risk is the summation of WF Risk and PSPS Risk

$$Overall\ Wildfire\ and\ PSPS\ Risk\ =\ WF\ Risk +\ PSPS\ Risk$$

2.4.2.2 Intermediate Risk Components

Wildfire LoRE

The Wildfire LoRE, or the annual rate of expected wildfire at the circuit-segment level, is computed using an Ignition Rate Normalization Factor Model, utilizing attributes such hardening state, tree strike density, and asset health, to make adjustments to a base ignition rate derived from the proportion of overhead mileage for each circuit-segment compared to the whole of the scoped system.

Wildfire CoRE

Wildfire CoRE is derived from WRRM. Using the maximum acres and maximum buildings destroyed, this data is converted to the MAVF.

See Section 2.4.2.4 for the equation that is employed using the MAVF framework to compute the Wildfire CoRE score for each circuit-segment.

General MAVF Component Equation:

$$Total\ WF\ CoRE\ =\ \sum_{i=1}^{3} WF\ \ CoRE_i$$

Where Total WF CoRE is the final wildfire CoRE score, WF $CoRE_i$ is the wildfire CoRE component of attribute “i”, and i is one of the three MAVF attribute components (Safety, Financial, Reliability)

PSPS LoRE

PSPS LoRE comes from Meteorology subject matter expertise and is based on the probability that a segment or its upstream segments will experience a PSPS de-energization during a High Fire Day based on their assessed Alert Speed thresholds as well the historical average number of High Fire Days observed. PSPS LoRE can be expressed as the following equation:

$$PSPS\ LoRE\ =\ Incremental\ Upstream\ PSPS\ Probability\ \times Annual\ Avg\ High\ Fire\ Days$$

The Incremental Upstream PSPS Probability can be expressed as the following equation:

$$\begin{aligned} &Incremental\ Upstream\ PSPS\ Probability \\ &\qquad = Max(Select\ PSPS\ Probability\ -\ Maximum\ Upstream\ PSPS\ Probability,\ 0) \end{aligned}$$

Where the Select PSPS Probability is the probability of a select circuit-segment SCADA switch hitting its set alert speed threshold during a High Fire Day event and the Maximum Upstream PSPS Probability is the highest PSPS probability of a Circuit-Segment from a select Circuit-Segment up to its associated Circuit Breaker.

PSPS CoRE

PSPS CoRE is a MAVF value based on the consequence of a PSPS de-energization occurring with respect to the expected duration of the de-energization and the number and types of customers that would be affected downstream of the SCADA sectionalizing switch that would be opened to implement the PSPS de-energization. The baseline risk inputs are the number of minutes within an expected PSPS event, the count of downstream customers, and the associated customer types tied to those counts.

See Section 2.4.2.4 for the equation that is employed using the MAVF framework to compute the PSPS CoRE score for each circuit-segment.

General MAVF Component Equation:

$$Total\ PSPS\ CoRE = \sum_{i\,=\,1}^{3} PSPS\ \ CoRE_i$$

Where Total PSPS CoRE is the final PSPS CoRE Score, PSPS $CoRE_i$ is the PSPS CoRE component of attribute *i*, and *i* is one of the three MAVF attribute components (Safety, Financial, Reliability)

2.4.2.3 Model Families

Wildfire Consequence Models

This consists of all individual models utilized to compute the consequence component of the Wildfire Risk Score, namely the WF CoRE. For the WiNGS-Planning model, it utilizes WRRM output, embedded within the MAVF weighted-sum framework, as part of its larger Wildfire Consequence Model.

See Section 2.4.2.4 for attribute equations that are employed using the MAVF framework to compute the WF CoRE score for each circuit-segment from the WRRM outputs.

PSPS Consequence Models

This consists of all individual models utilized to compute the consequence component of the PSPS Risk Score, namely the PSPS CoRE. A Customer Value Model, embedded within the MAVF weighted-sum framework, is utilized as part of the larger Consequence Model.

See Section 2.4.2.4 for attribute equations that are employed using the MAVF framework to compute the PSPS CoRE score for each circuit-segment from the Customer Value Model output.

2.4.2.4 Individual Models

MAVF Attributes Calculations for PSPS and Wildfire, for Wings-Planning 3.0, the model currently in-development.

Table 4: MAVF Attribute Calculations for PSPS and Wildfire

	PSPS Methodology*	Wildfire Methodology*
Safety	number of affected customers × PSPS duration × Serious Injuries and Fatalities (SIF) per customer-minutes	acres impacted x SIF per acres burned + structures destroyed x SIF per structure impacted
Reliability	SAIDI + SAIFI (based on PSPS duration)	SAID + SAIFI (based on pole restoration duration)
Financial	number of affected customers × dollars per affected customer	structures destroyed × dollars per structure + acres impacted × dollars per acre + acres impacted × suppression dollars per acre

** Note: normalization multipliers are implied and not listed explicitly in the equations detailed in the table*

WRRM Conditional Impact Model

WRRM is used as the basis for wildfire consequence in the WiNGS-Planning model. This model was developed by Technosylva and consists of outputs relating to buildings, acres, and population affected based on numerous model simulations using SDG&E assets as ignition points. In addition to the affected conditions, attributes such as fire behavior index and flame length are also provided to gauge wildfire spread. The current model derives outputs using an 8-hour simulation duration, which is the assumed typical first burning period. Other burn periods are currently being evaluated.

WRRM is delivered annually prior to fire season and undergoes a comparison with the previous year's submission. This involves the examination of column header changes, measurement changes, quantile changes, and general format changes. Error detection is currently automated within the WiNGS-Planning 3.0 development version model, which will be released in 2023 for future scoping. This error detection tracks changes to output columns including every quantile for acres, buildings, population, fire behavior index, flame length, rate of spread, and buildings destroyed upon every model run. Thus, if an unwanted change in one of the WRRM columns were to occur, it would be caught via this detection method and further examined by staff data scientists.

How PSPS CoRE is modeled and used for developing the WMP is outlined in the following steps:

- Safety Consequence: Estimated based on historical PSPS events across California and reviewed to understand the frequency, duration, and magnitude (customer affected) of PSPS de-energizations. As the safety impact of a PSPS de-energization is not the same for all customer types, a Customer Type Value Consequence is estimated to represent different levels of Safety impacts. Based on subject matter expert assumptions, different weighting (or scaling factors) is applied to each customer meter to increase the number of Serious Injuries and Fatalities (SIFs) downstream of each SCADA Sectionalizing device. Customer Type Value Consequence incudes:
    - Critical Facilities and Critical Infrastructure: Customers based on the California Public Utilities Commission's (CPUC's) De-Energization proceeding definition
    - Community Vulnerability: Access and Functional Needs (AFN) customers based on CPUC's definition of AFN customers
    - Other: All other customers that do not fall in either the critical or AFN categories
- Reliability: Subject matter expert assumptions for System Average Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) estimates are based on review of historical SAIDI and SAIFI values associated with past PSPS events in the service territory.
- Financial: Per customer and per PSPS de-energization, a potential financial impact is estimated based on subject matter expert assumptions.

The Safety, Reliability, and Financial modeling approach for the PSPS Risk model continues to be refined as new data, assumptions, or additional information is evaluated.

SDG&E regularly works with industry experts, academia, government agencies, and other stakeholders to better understand and quantify the impact of catastrophic wildfires, e.g., through analyses on estimated wildfire spread, acres burned, and buildings impacted or destroyed.

Ignition Rate Normalization Factor Model

This model uses an annual ignition rate, which is distributed proportionally to each segment based on overhead HFTD mileage. The ignition rate for each segment is then adjusted for the maximum recorded wind gust based on the associated weather station. The ignition rate is further adjusted for vegetation using Tree Strike data. A subsequent asset health adjustment is factored in using both the CHI and the average conductor per segment. An ignition rate adjustment is then made to account for the significant wildfire rate of one expected wildfire every 15 years. The final rate adjustment is done to account for existing and future projected hardening state mileage percentages for each circuit-segment.

The generalized factor adjustment process implementation is depicted below:

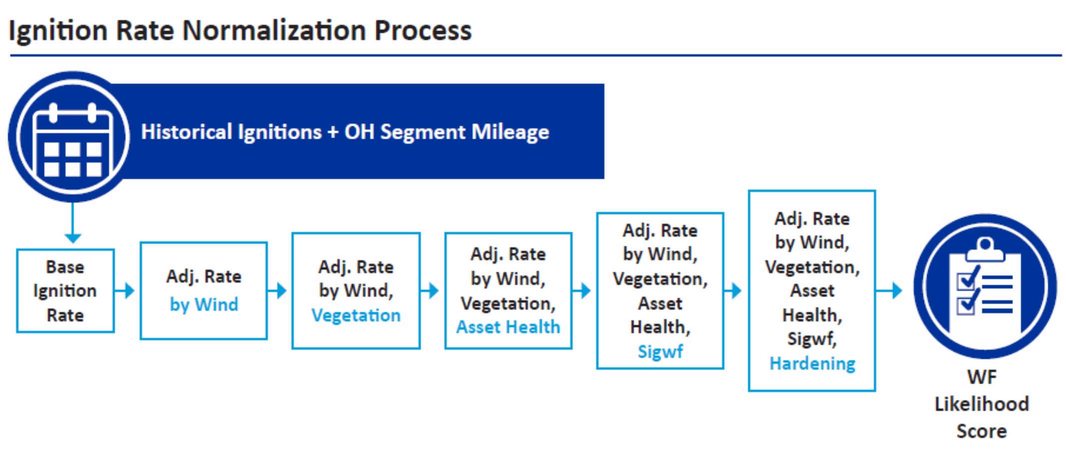
$$Adj.Ignition\ Rate = Initial\ Ignition\ Rate \times Ignition\ Adj.Factor_i \times Normalization\ Factor_i$$

Where, Initial Ignition Rate is the initial ignition rate prior to implementation of adjustment factor *i*, Ignition Adj. Factor$_i$ is the adjustment factor metric tied to the adjustment factor *i,* Normalization Factor$_i$ is the normalization factor tied to adjustment factor *i,* Adj. Ignition Rate is the adjusted ignition rate after implementation of adjustment factor *i* and *i* is the specific adjustment factor (e.g., wind speed, tree strikes, etc.).

The normalization part of the process implementation is performed to maintain the same global annual ignition rate after each adjustment step. Thereby, the ignition rate is adjusted relatively among each circuit-segment according to each individual risk factor, while the global ignition rate across the full scope of circuit-segments remains constant.

Figure 3 shows the high-level model process, depicting the step-by-step adjustment approach to the ignition rate from the base ignition rate to the Wildfire LoRE, namely the resulting annual circuit-segment wildfire rate.

Figure 3: Ignition Rate Normalization Process



Customer Type Value Model

The Customer Type Value Model is utilized to help assess the consequence a PSPS de-energization has to the downstream customers from a select SCADA sectionalizing device. The main feature of the model is consideration of varied customers types, each with its own weighted effect on the total customer value scoring on a select SCADA sectionalizing device or circuit-segment. Each customer type is associated with a weighted multiplier unique to each of the MAVF attributes that are considered. The Customer Type Value Model utilizes the weight-sum model approach in its foundation, to help determine a Total Customer Value Score that will represent the customer scoring impact of each SCADA sectionalizing device or circuit-segment, thereby giving WiNGS-Planning a way to compare the impact of the PSPS consequence across each SCADA sectionalizing device or circuit-segment.

The high-level formulas that go into the model code can be depicted by the following equations:

$$Customer\ Value\ Score_i = Std.\ Customer\ Count + \sum_{j=1}^{4} Customer\ Type\ Count_j \times Customer\ Type\ Multiplier_{ij}$$

$$Total\ Customer\ Value\ Score = \sum_{i=1}^{3} Customer\ Value\ Score_i \times MAVF\ Attribute\ Weight_i$$

Where, MAVF Attribute Weight$_i$ is the weighted percentage of MAVF attribute *i,* Customer Type Multiplier$_{ij}$ is the multiplier tied to customer type *j* and MAVF attribute *i,* Customer Type Count$_j$ is the count of downstream customers of customer type *j,* Std. Customer Count is the count of customers not grouped to a specified customer type category, Customer Value Score$_i$ is the customer Value Score of MAVF attribute *i, i* is the specific MAVF attribute (i.e. Safety, Reliability, or Financial), and *j* is the specific Customer Type (i.e. Urgent, Essential, etc.)

PSPS Probability Model

The PSPS probability model indicates the likelihood of PSPS occurrence for SDG&E-owned weather stations based on historical data. The probability represents the likelihood that the wind speeds measured at the weather station closest to the segment will exceed a set wind speed threshold [e.g., 50 miles per hour (mph)] in a year. These are determined by analyzing historical data. Probabilities are calculated using daily peak wind gusts during Santa Ana wind conditions, defined as days when winds are blowing from the east, relative humidity is 30 percent or below, and at least one weather station has recorded wind gusts in excess of 40 mph. Data spans the typical Santa Ana wind season, from September 1 through May 15. In WiNGS-Planning 3.0 (in-development), data is limited to the highest fire season, from September 1 through December 30, with the additional inclusion of any RFW days that occur in spring. This is also defined as a High Fire Day. The methodology update in calculating the PSPS probabilities currently in-development is done to expand the wind climatology and more accurately reflect the wind potential present during PSPS events.

A standard probability function is used as such:

$$PSPS\ Probability = \frac{Number\ of\ days\ threshold\ reached}{Total\ number\ of\ Santa\ Ana\ wind\ days}$$

where thresholds include operational PSPS alert speeds used in the current year (current PSPS probability), 50 mph (PSPS probability for traditional hardening), and 60 mph (PSPS probability for covered conductor).

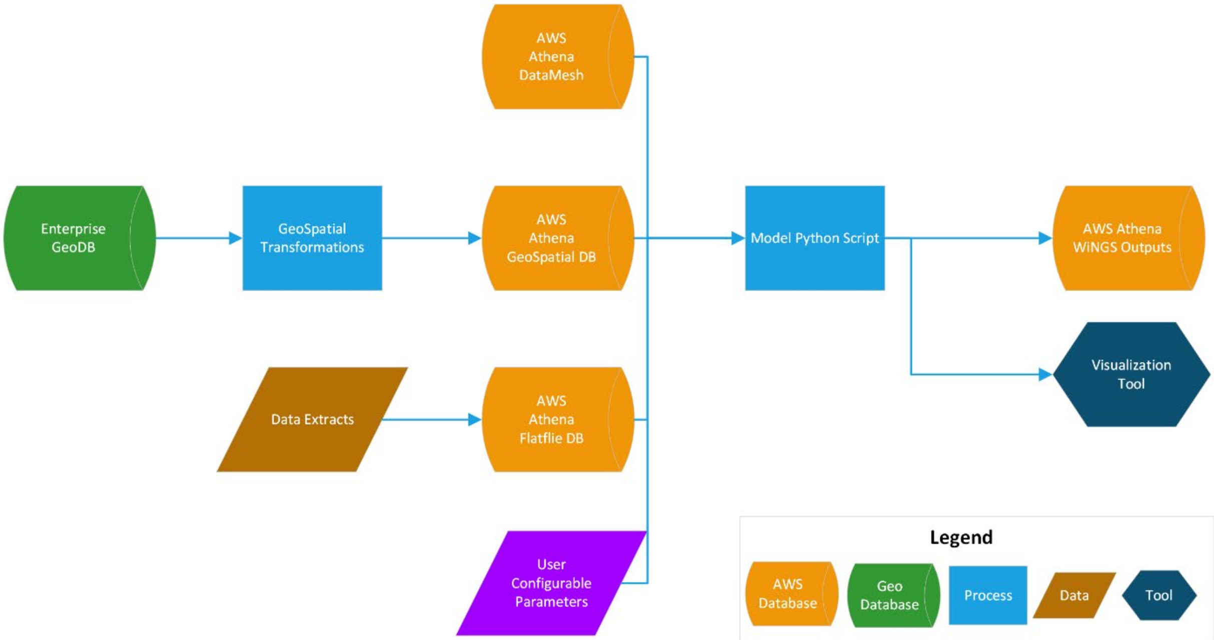
Probabilities are then linked to sectionalizing devices using weather station associations to that location. This connection between device and weather station is assessed annually by Meteorology and Electric Distribution Operations to account for any system changes. This analysis is done prior to fire season and used operationally during PSPS de-energizations. For devices not included in the operational association list, device locations are mapped out and tied to the most representative weather station based on subject matter expertise of the terrain and wind patterns.

2.4.2.5 Future Development

The latest iteration of the model, WiNGS-Planning version 3.0, has been upgraded to run through an automation process flow. Upgrades include how the model ingests, processes, cleans, calculates, outputs, reports, and exports data. The benefits of the automation make it so that transparency, traceability, accuracy, speed, and validation of the model elements at every stage of the process is maximized.

A high-level automation process diagram of the elements involved in the model is depicted in Figure 4, showing the connection between different processes, architectures, data sources, data extracts, and applications.

Figure 4: WiNGS-Planning Automation Process



Directed acyclic graph (DAG) diagrams depicting the programmatic process flow of the model during a single model run are created programmatically for two main coding path flows that serve to query, process, and produce model data, from to start to finish. The DAG diagrams serve two primary functions. During the model run, they serve to flag the model run as a success or failure. In the case of a failure, they function to effectively isolate the programmatic step where the model failed as a debugging and model verification feature. Additionally, they help depict the computational step-by-step functional coding process flow, for a fully exhausting process flow breakdown where needed.

2.4.3 Limitations (see Guide ASTM E 1895)

Identified the limitations of the model based on the algorithms and numerical techniques.

2.4.3.1 Limitations

The WiNGS-Planning model is one tool in a multi-layered decision process that aids in the application of wildfire mitigations for investment planning decisions. While the WiNGS-Planning model presents a quantitative mitigation decision, it is vital that the proposed mitigations undergo subject matter expertise review. This is accomplished by the desktop feasibility analysis that accompanies the scoping process, which includes geography, loading, specific standards, environmental, and other projects. Analysis and inputs of the model continue to be improved and expanded; however, the model alone does not dictate investment planning.

Another limitation surrounds the circuit segment units used in the model. When grouping many assets together, the WiNGS-Planning model must make decisions based on group rather than individual asset conditions. While the individual asset conditions make up the circuit segment statistics, information is generalized as part of the aggregation process. For instance, the model uses the average conductor age to adjust the ignition rate, however, the average conductor age simplifies the characteristics of the individual spans that comprise the circuit segment. Due to the nature of the circuit segment configuration, it is possible that a new span will skew the average towards a newer average age rather than the majority age for the segment. Improvements to model statistics are expected to mature during the current WMP cycle. Considering the limitations of the segment level aggregation process, the circuit segment continues to remain the most viable unit of measure for the application of mitigation decisions. Span level mitigation applications are impractical because network connectivity is obfuscated at this granular level when individual spans are mitigated without the consideration of the electric network. In addition, PSPS mitigation is difficult to accomplish when mitigating individual spans without mitigating the segment and upstream segments where they reside. On the other hand, whole circuit mitigations may take years to accomplish and could leave high risk spans outside of the circuits being mitigated without a timely mitigation plan. Considering the drawbacks of span level and whole circuit solutions, the circuit segment is the most practical unit for the application of mitigation decisions.

2.5 Data Libraries

Provide background information on the source, contents, and use of data libraries.

Data used for the WiNGS-Planning model is collected from enterprise resources and centralized in an AWS-based cloud environment. Data sources that are external to the enterprise are brought into AWS in raw format and transformed into structured data where necessary. All data in the cloud data repository must be structured at this time. Refresh schedule varies based on the source system refresh rate. All additional data transformations are done in accordance with machine learning modeling best practices to prepare the data for ingestion and prediction.

Table 5: Data Libraries

Data Element	Description	Data Sources	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity
Segment Length	Spans coalesced into segments and broken into different lengths based on HFTD Tier	GIS Production: PRO_VAQ_ELEC/ PriOHConductor	2011-2022	Quarterly	Span level dissolved to segment level – Accuracy within 50 feet	Source data updated daily via GIS As-built drawings
Hardening Status	Steel poles coupled with low/medium-risk conductor and/or	GIS Production: PRO_VAQ_ELEC/ OverheadStructure	2011-2022	Quarterly	Pole level – Accuracy within 50 feet	Source data updated daily via GIS As-built drawings. ESH

Data Element	Description	Data Sources	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity
	covered conductor applications	Electric System Hardening scoping data				scoping data provided as needed
Conductor Age	Average age of spans on a segment	GIS Production: PRO_VAQ_ELEC/ PriOHConductor and WorkHistory	2011-2022	Quarterly	Span level – Accuracy within 50 feet	Source data updated daily via GIS As-built drawings
Tree Strike Data*	Count of trees which have the potential to strike lines	GIS Production: PRO_VAQ_ELEC/ PriOHConductor and Veg Mgmt Tree Inventory	2011-2021	Quarterly	Spans - Accuracy within 50 feet, Trees - GPS'd Accuracy within 50 feet	Source data updated daily via GIS As-built drawings and Vegetation Management inspections
Circuit Connectivity	Tabular Data Network relationships used for upstream downstream relationships	GIS Production: PRO_VAQ_ELEC/ AtRiskCustomerSCADA and AtRiskDownstreamSCADA	2011-2022	Quarterly	Point and line features - Accuracy within 50 feet	Source data updated daily via GIS As-built drawings and GIS automated nightly processes
Wind Speed	Maximum historic wind speed for segment	OSI Pi wind anemometer data feeds	2011-2022	Quarterly	Anemometer location based on related pole. Accuracy within 50 feet	Source data updated every 15 minutes
PSPS Probabilities	The likelihood of wind speeds at weather station closest to a segment will exceed a set wind speed threshold in a year	Meteorology	2022	As needed	Closest weather Station to a segment is used: GIS accuracy is within 50 feet	Source wind speed data updated every 15 minutes
Historical Ignitions	Ignitions recorded by fire coordination team	Fire Coordination: Ignition spreadsheet	2014-2021	As needed	Varies: Finest accuracy at pole or span level. Crudest accuracy at circuit level	Sporadic, based on fire events
CHI*	A unitless index figure representing	GIS, PRiME Pole loading model	2019	One time run	Span level accuracy	n/a

Data Element	Description	Data Sources	Collection Period	Collection Frequency	Spatial Granularity	Temporal Granularity
	an asset health estimate					
WRRM*	Leverages historical high-resolution weather data to establish the impact of a potential high consequence fire event	Fire data, GIS, Wind, vegetation	Q4 2022	As needed	Pole level accuracy	Based on worst fire conditions
Annual RFW Data*	Dates of RFWs as declared by the National Weather Service	National Weather Service forecast product archives	Q4 2021	As needed	Fire weather zones	Sporadic, based on level of
Number of Customers	Count of customer on a segment	GIS Production: PRO_VAQ_ELEC/ AtRiskCustomerSCADA	2011-2022	Quarterly	Point and line feature - Accuracy within 50 feet	Source data updated daily via GIS As-built drawings and GIS automated
Customer Type	High risk customers	GIS Production: PRO_VAQ_ELEC/ AtRiskCustomerSCADA	2011-2022	Quarterly	Accurate to the transformer. Customer points are not mapped	Source data updated daily via GIS As-built drawings and GIS automated
Outage Duration	SAIDIDAT	OUA	2011-2021	Quarterly	Mapped to the up and downstream structures for the affected circuit of an outage	Source data updated daily

*External data dependencies

2.5.1 External Dependencies

The WiNGS Planning model is dependent on both internal Enterprise data processes with robust maintenance protocols and external data sources with varying maintenance procedures.

WRRM consequence data is provided by Technosylva and is received on an annual basis. Additions or changes to the model output is discussed with the consultant.

Tree Strike data is provided by GIS Surveyors Inc. (GSI) and is run on an as-needed basis.

The CHI referenced for WiNGS-Planning was produced by a consultant with outputs generated internally. This data is expected to be replaced in 2023 with the version of CHI used in the WiNGS-Ops model.

2.6 Substantiation

Provide the results of any model substantiation processes used to verify, validate and calibrate the model to ensure the model is correct and suitable to an application.

The new architecture for the WiNGS-Planning model lends itself well to automated substantiation of the model. Within AWS, each model run is saved with a timestamp as well as version number. The version schema allows for tracking software patches, minor enhancements, and major enhancements. With the incorporation of Azure Dev Ops, development is conducted in a versioned environment where new functionality is conducted within branches. Each branch must undergo a quality control review where the model is run and tested for accuracy and errors before it is merged with the master branch. This method of substantiation is adherent to software development best practices and ensures that new functionality is reviewed by multiple people before being accepted.

2.6.1 Verification

Describe efforts to verify the model is working as designed and that the equations are properly being solved (e.g., independent review of source code, testing, user training, and certification).

2.6.1.1 Data Quality Verification

GIS Electric System data

Data obtained from geographic information system (GIS) is digitized internally from As-built drawings and undergoes a rigorous series of quality assurance tests prior to being released as official As-built GIS features. Field quality validation is accepted on an as-needed basis.

Outage data

Outage data undergoes an internal audit process by qualified reliability staff to verify the details surrounding the outage. The reliability staff obtains outage information from the OUA application and verifies the relevant details of the outage (such as root causes, time stamps, and customer counts) and its effects using NMS.

Ignition data

Ignition data is collected and investigated by qualified fire coordinators. This data includes information on fires started by SDG&E electric assets.

Weather data

Weather data is collected by real time location system (RTLS) units [anemometers and Remote Automated Weather Stations (RAWS)] and coalesced into the OSI Pi database. Meteorology maintains relationships between the weather stations and electric assets.

Vegetation data

Vegetation data is collected and maintained by Vegetation Management, who has ongoing maintenance on this data to ensure inspection information is current and correct.

2.6.1.2 Data Modification Process

The WiNGS-Planning model undergoes various data conversion and data aggregation to obtain a segment-granular level of analysis. These include:

- Aggregation of pole age and conductor age metrics to form average pole age and average conductor age associated to each segment
- Utilization of subject matter expertise to match weather station data to associated segments with appropriate wind/weather conditions
- Tree strike data calculation utilizing height of tree as a buffer distance against the conductor feature to calculate tree strike count and tree strike length
- Imputation of CHI values where missing for a segment utilizing average values of available data, grouped by HFTD and non-HFTD designations.

During initial data gathering and processing, queries are validated with GIS data model experts to ensure the data returned by each query is consistent with the intention of the analyst. The GIS data model is highly normalized and contains a myriad of relationships which are not obvious to navigate. Cooperative development with internal GIS Business Solutions staff is a necessary part of the complicated data processing involved with the WiNGS-Planning model.

2.6.1.3 Model Verification

Quality control of the WiNGS-Planning model is accomplished via the PyTest.py script. The WiNGS-Planning model produces a report after each run that performs a quality test of certain metrics, including record count differences for each column, between model versions. Likewise, value differences are calculated row by row. i.e., risk rank change on a specific segment. The row-by-row value difference verifies that changes to the output occur how and when they are intended. When differences are found between model versions, developers troubleshoot the reasons for any discrepancies. For instance, during a recent update, the WiNGS-Planning model contained about 30 more segments than the previous version. Prior to accepting the code changes, the team researched the exact differences between versions and discovered that the updates were valid and reflected the most recent As-built data model. This solidified the notion that the software patch lent itself more towards reproducible research than the previous method, which required multiple software products and models to run the updates.

Verification is further handled at runtime via the use of assert functions. A variety of statements are employed to make sure that values meet certain quality thresholds before the code is allowed to proceed to the next step throughout the model.

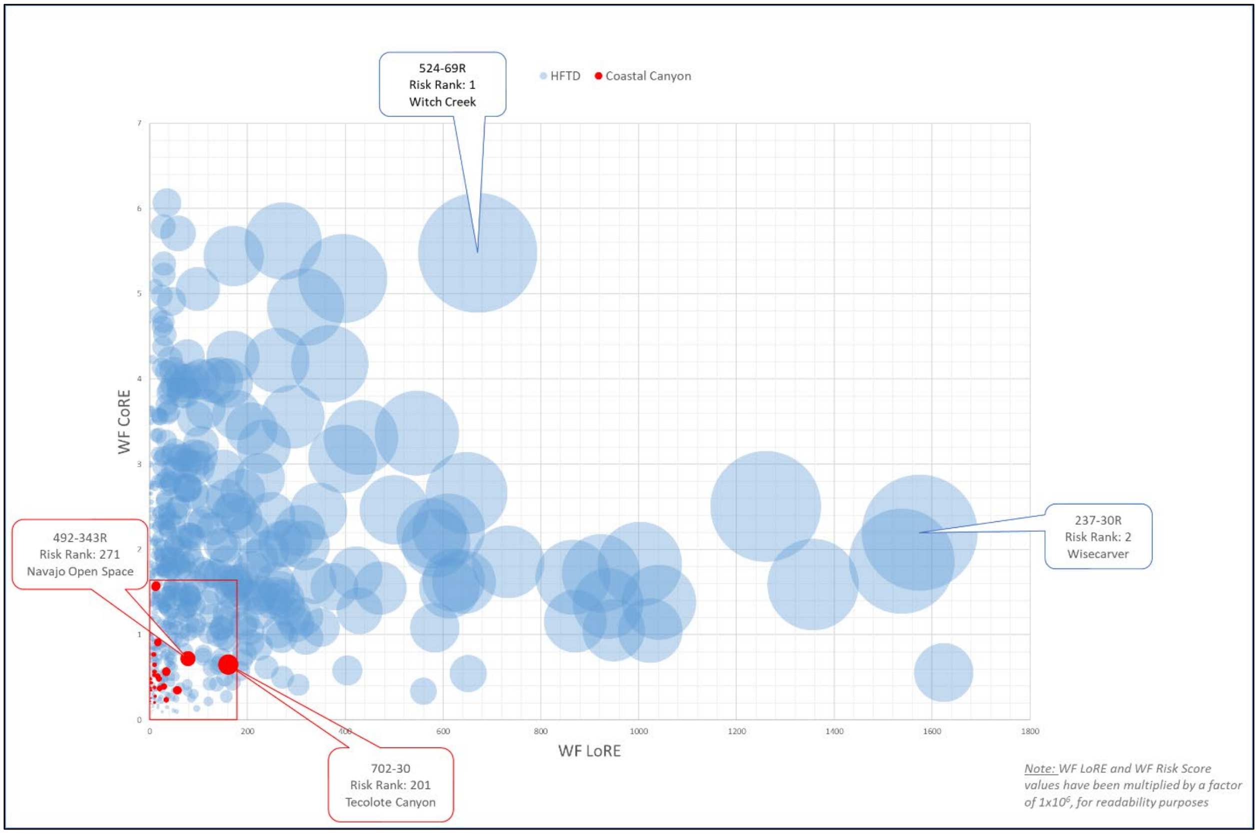
2.6.2 Validation

Identify existing data that can be used to validate model performance. Describe how model predictions are compared to observations from historical events or experiments.

Validation of the WiNGS-Planning model is currently handled using a variety of methods. The first method, conducted by the development team, involves a geospatial validation process. The output of the model is joined to the WiNGS Segment geospatial feature class where it is overlayed with a variety of risk associated map layers, such as HFTD and Tree density (points). The top scoring wildfire risk segments are compared to these datasets to verify the segment's geographic setting in relation to the risk layers. Likewise, the lowest scoring segments are compared to the highest wildfire risk ranked segments to make sure that the geospatial data correlates with the model's risk output.

A major validation effort that was completed in 2022 involved the assessment of whether the model was capturing the highest risk segments. The criteria for inclusion into the study area was that the segment has to intersect the HFTD or have experienced a PSPS de-energization in the past. To test whether these criteria validly selected the highest risk segments, a study was conducted to run coastal canyon segments through the model. The results of this analysis can be seen in Figure 5, which shows that costal canyon segments are at a relatively low risk while HFTD segments are at a relatively high risk.

Figure 5: WiNGS-Planning Validation Results



The most robust validation step occurs during the scoping process and is carried out by scoping engineers. Subject matter expertise provides a realistic assessment of the proposed mitigations in the context of appropriate application of mitigations as well as construction feasibility. While proposed WiNGS-Planning segment mitigations form the basis of construction scoping, every mitigation is scrutinized by scoping engineers prior to the development of a construction portfolio. During the scoping process, a thorough review of the proposed mitigations is conducted by subject matter experts, who are familiar with the segments in question as well as their environmental setting.

This review, which is referred to as the Desktop Feasibility Study, is conducted on model results to judge the validity and practicality of the proposed mitigations. The key steps of the Desktop Feasibility Study are listed below:

1. WiNGS-Planning model results are referenced to determine the appropriate mitigation for the segment that will be hardened
2. Initial fire hardening scope is developed using a detailed methodology
3. The initial scope is reviewed in Future Scope Editor

4. Stakeholders perform a scope review
5. The initial scope is published

Sensitivity analyses are employed to validate the RSEs and mitigation sections of the WiNGS-Planning model. In this analysis, constants, including cost per mile estimates and RSE thresholds, are adjusted to determine how sensitive the mitigation recommendations are to different size variable adjustments.

2.6.3 Calibration

Describe how model inputs and parameters are modified to achieve better agreement for a specific scenario. Calibration limits the propagation of error by correcting new data but they have limited effectiveness in improving the quality of the forecast.

The model weights, constants, and scaling factors were calibrated for the model results to make readable sense. This calibration was conducted on WiNGS-Planning version 1.0. Improved calibration on ignition variables is expected to be incorporated as a process into the model within the current WMP cycle.