A MILLIMAN AND CORELOGIC REPORT

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Town of Paradise
California Resilience Challenge
Task 1 to Task 4

Risk Reduction, Climate Change, and Insurance Premiums

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Executive Summary

Wildfire mitigation is an emerging subject of great importance in the insurance industry and in society as a whole. Changes in the environment and housing stock in recent years have contributed to steady increases in wildfire risk—in fact, 15 of the 20 most destructive wildfires in California history occurred in the period between 2015 and now.[1]

With funding from the California Resilience Challenge Grant, the Town of Paradise formed a team of experts including Milliman, Inc. (Milliman) and CoreLogic to study the impact of mitigation strategies on wildfires. Using the Town of Paradise as a case study, the team performed a scientifically supported review of how various approaches to wildfire mitigation could impact wildfire risk and Homeowners insurance premiums in California's wildland urban interface ("WUI").

This report, prepared by Milliman and CoreLogic on behalf of the Town of Paradise, estimates the financial benefits of selected risk reduction actions through the lens of a probabilistic catastrophe model. We consider scenarios representing possible actions individual homeowners and the community could take and estimate the reduction in risk attributable to each of the actions. We were requested to assess the comparative efficacy of alternative strategies by modeling a "best case" scenario of individual mitigation actions in combination with other community actions; this assumption allows an illustration of the extent of potential benefits, but should not be interpreted as a projection of expected future scenarios.

The key findings of our analysis are:

1. Mitigation actions by individual homeowners can meaningfully reduce risk. If all homeowners carry out the actions recommended under the Insurance Institute for Business & Home Safety ("IBHS")'s Wildfire Prepared Home Program^{TM}, the aggregate wildfire expected loss for the Town of Paradise is estimated to decrease by 53% relative to pre-Camp Fire conditions.
2. Wildfire Informed Development Patterns ("WIDP") is the strategic planning of development patterns informed by wildfire risk, and can reduce the average expected losses of individual properties. By selectively decreasing the number of structures within town boundaries, focusing on rebuilding in areas with lower wildfire risk and being intentional with land use planning, WIDP can reduce average losses by up to 15% per property.
3. External buffers (implementation of well-maintained areas with low fire spread potential on the border of the town) are effective in lowering aggregate risk. Implementing all five buffers recommended by the Conservation Biology Institute[2] could reduce aggregate expected losses by 35%, even when no additional individual or community mitigation is performed.
4. Individual mitigation actions, WIDP, and external buffers each has lower but meaningful marginal risk reduction benefits when modeled in combination with each other. We estimate that performing all three actions would yield an average reduction in expected loss per property of up to 75%% in high-risk areas like the Town of Paradise, which corresponds to a 55% reduction in average total premium when the net cost of reinsurance is not considered.
5. Climate change is expected to adversely impact wildfire risk for the Town of Paradise. Under the Representative Concentration Pathway ("RCP") 4.5 trajectory adopted by the Intergovernmental Panel on Climate Change ("IPCC"), expected losses due to wildfire are expected to increase by 17% in the year 2040 compared to the 2018 baseline (before the Camp Fire), all else being equal.

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[1] CAL FIRE (2022). Top 20 Most Destructive California Wildfires. Retrieved November 14, 2022. https://www.fire.ca.gov/media/t1rdhizr/top20_destruction.pdf.

[2] Conservation Biology Institute (2020). Paradise Nature-Based Fire Resilience Project. Retrieved November 30, 2022. https://www.paradiseprpd.com/files/fcda41b0a/1.Paradise.Final.Report.2020.0715.pdf

6. Wildfire risk may contribute up to 70% of average insurance premium in Paradise. If no risk reduction actions are implemented, we estimate that the total Homeowners insurance premium would be on average over $4,000 per year, of which about $3,000 would be attributable to the wildfire peril.
7. The California Department of Insurance ("CDI") currently does not allow the cost of reinsurance to be reflected in Homeowners insurance premiums—this is expected to drive an expected deficit, and is a key reason why insurers are reluctant to write in high wildfire risk areas like the Town of Paradise. As wildfire risk is reduced through risk reduction techniques, the estimated deficit shrinks both in dollars and as a percentage of the total premium.

In evaluating these findings, several caveats and limitations should be considered:

- These findings are specific to the Town of Paradise and may not apply to other geographies. Other communities may have material differences in home density and environmental variables, which may impact the benefit of the risk reduction techniques discussed in this paper.
- These estimates are based on available data, including a portfolio of the housing stock in the Town of Paradise prior to the 2018 Camp Fire and a notional portfolio of possible new construction. Different reasonable assumptions may yield materially different results.
- As noted above, the mitigation scenarios assume a 100% compliance rate with IBHS Wildfire Prepared Home mitigation standards within the Town of Paradise. This is not intended to be reflective of reality because of possible reluctance to comply, as well as surviving / existing structures not meeting these standards. It is intended to serve as a starting point for understanding the comparative efficacy of alternative home- and community-level strategies.
- The estimates for insurance premiums assume pricing consistent with the CoreLogic wildfire model and industry non-catastrophe losses. We derived a permissible loss ratio using industry data. Individual insurance companies will likely make different assumptions regarding losses and expenses, which would result in different premiums. A different catastrophe model would likely have produced different expected loss estimates.
- The estimated cost of reinsurance uses profit multiples derived from Insurance Linked Securities, as well as an assumed reinsurance structure for the Town of Paradise. Reinsurance contracts are highly customized and may be materially different from the one presented.
- Although we incorporated the above-mentioned assumptions for purposes of the analysis, at present neither the use of catastrophe models to set total wildfire premium nor the inclusion of the net cost of reinsurance is currently allowed for admitted homeowners policies under California regulations. As noted in the text, these restrictions on risk-based pricing represent significant disincentives for insurers to write business in the WUI. To the extent that actual premiums allowed under California regulations differ from the risk-based premiums assumed in this analysis, results are likely to differ as well.
- In addition to the above, insurers do not make underwriting decisions solely based on approved rates and rate levels, particularly due to the financial perils of being too concentrated in any particular geographic location. It is important to understand that a single carrier or a few carriers would not be able to insure every risk in Paradise, even at adequate premium, due to concentration risk.
- It is uncertain whether climate change will follow the RCP 4.5 trajectory. If the climate changes in a way that differs from that assumed by the RCP 4.5 trajectory the expected losses for the Town of Paradise may differ.
- The science of wildfire risk modeling is continuously evolving, and estimates such as the ones presented in this study are expected to change as new data becomes available and models are enhanced.

Opportunities for Future Studies

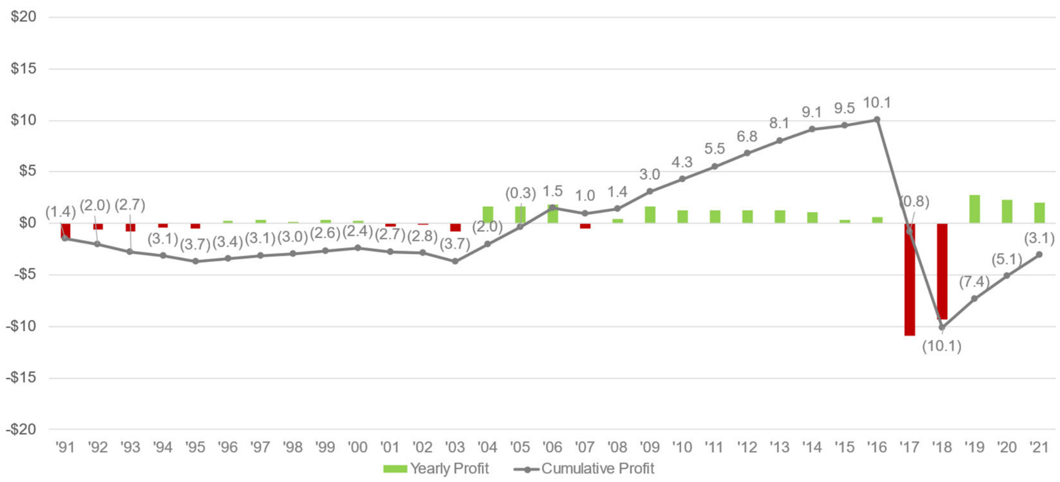
Today, the behavior of fire spread within the built environment is not well understood. In particular, the fire science of how structures ignite, collapse, and affect neighboring structures is not as evolved as that of other fuel types. As scientists gain a better understanding of how fires propagate and transition within the built environment, it will be beneficial to revisit these modeling exercises to refine the approach. For example, with a better grasp of the probable pathways fires can take within a community, policymakers can more strategically allocate resources to mitigate homes and parcels on those pathways to disrupt fire spread. In addition, local fire protection agencies will also be able to more efficiently direct and leverage their resources by focusing on key areas of the community.

Background

The Camp Fire ravaged the Town of Paradise in 2018, causing widespread destruction and loss of life. Started by downed powerlines, the catastrophic fire destroyed over 18,000 structures—over 90% of the town's structures—and claimed 85 lives.[3,4]

The fire's impact extended beyond the town and it is necessary to understand the historical context in order to understand this impact. Following the 2017 and 2018 wildfire seasons, California insurers recognized a clear reality that significant changes were necessary to preserve the viability of their California business. These two years' wildfire season losses wiped out twice the combined underwriting profits for the past 26 years, leaving the insurance industry with an aggregate underwriting loss of over $10 billion for the California Homeowners line of business since 1991.[5] Figure 1, below, shows that despite subsequent premium increases and overall profitable years in 2019, 2020, and 2021, the California Homeowners insurance industry still has not recovered from the $20 billion loss during 2017 and 2018.

FIGURE 1: CALIFORNIA HOMEOWNERS MULTIPLE PERIL ESTIMATED PROFITS



Notes:

1996 - 2021 data from P&C Combined Industry Annual Statement data from SNL.com.
1991-1995 Earned Premium and Loss Ratio data from the California Department of Insurance. Expense ratios for 1991-1995 are estimated as the average of 1996-1998.
Profit is based on direct industry earned premium, losses, and expenses.
Excludes impact of reinsurance and investment income.

Moreover, the existing regulatory and legislative framework for California Homeowners insurance is not readily adaptable to delivering quantifiable benefits to insurance providers from wildfire risk mitigation measures. While the California Department of Insurance has recently passed a regulation requiring consideration of wildfire mitigation actions in rates, the inability for insurers to use catastrophe models to set catastrophe loads, or to reflect the net cost of reinsurance in premiums, are still large disincentives to write business in the WUI. Many insurers responded by either increasing premiums or increasing non-renewals in high-risk areas, leading to an insurance affordability and availability crisis in many communities, beyond those directly affected by wildfires.

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[3] CAL FIRE (2022). Top 20 Most Destructive California Wildfires. Retrieved November 14, 2022. https://www.fire.ca.gov/media/t1rdhizr/top20_destruction.pdf.

[4] Town of Paradise, CA (2022). Housing Element 2022. Retrieved November 30, 2022. https://www.townofparadise.com/planning/page/housing-element-2022.

[5] Xu, E., Webb, C., Evans, D. (2019). Wildfire catastrophe models could spark the changes California needs. Retrieved November 30, 2022. https://assets.milliman.com/ektron/Wildfire_catastrophe_models_could_spark_the_changes_California_needs.pdf

Unlike other forms of property loss risk, such as hurricane and earthquake, significant wildfire risk mitigation in the WUI depends on mitigation at a community scale, or even a regional scale. However, there is currently no direct connection between the implementation of community scale wildfire risk mitigation and the delivery of affordable and available insurance to homeowners on a long-term basis. While there is a consensus that the unprecedented scale of wildfire risk to homes in the WUI demands a level of wildfire risk mitigation heretofore unseen in the State of California, the key question that remains unanswered is how to prioritize various mitigation action options.

Since the Camp Fire destroyed most of Paradise, the town now has the opportunity to rebuild in a way that reduces risk and addresses the affordability and availability challenges. The Town of Paradise is the ideal test case of how to deliver a comprehensive and scientifically supported structure for community-based planning and mitigation actions to reduce wildfire risk and maximize the opportunity for sustainable Homeowners insurance.

This project is divided into seven tasks:

- **Task 1:** Establish a baseline and measure current wildfire risk if Paradise is built back the same as before
- **Task 2:** Overlay mitigation, adaptation, and buffers
- **Task 3:** Stress test for future climate scenarios
- **Task 4:** Model insurance market behavior, estimate Homeowners wildfire premiums, and develop metrics for affordability
- **Task 5:** Model community-based insurance options
- **Task 6:** Link funding options with recommended risk mitigation measures
- **Task 7:** Conduct whole community planning process leading to implementation of mitigation and resilience project identified

This rest of this report discusses the methodologies and findings for Tasks 1 to 4. Exhibits supporting our analysis are provided in the Appendix.

Methodology

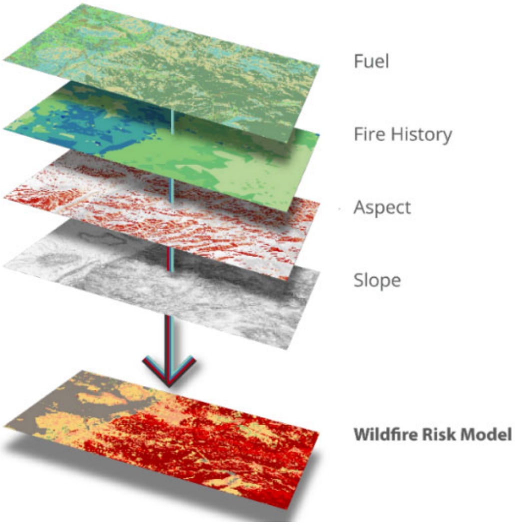
WILDFIRE CATASTROPHE MODELS

Extreme wildfire events are sufficiently uncommon that historical data cannot simply be averaged to estimate the risk of future losses. Further, changes in climate conditions and the built environment renders historical data inapplicable to make forecasts without adjustment. A way to address these problems is to use catastrophe models. Catastrophe models are probabilistic models that incorporate the scientific understanding of the wildfire hazard, as well as detailed information about the exposures, and use modern computing power to simulate thousands or even millions of stochastic events. The simulated outcomes are summarized to provide a view into low-frequency, high-severity risks. For a more in-depth discussion of catastrophe models, see Dietzen and Chamberlain (2022)[6].

This analysis uses CoreLogic's 30-meter resolution high definition U.S. Wildfire Model, released in August 2022, included in the Risk Quantification and Engineering (RQE™), version 22.1 ("CoreLogic Wildfire Model"). The model was initially developed in 1998 and has been regularly updated and enhanced since that initial release.

The CoreLogic Wildfire Model covers the states of Arizona, California, Colorado, Florida, Idaho, Montana, New Mexico, Nevada, Oklahoma, Oregon, Texas, Utah, Washington and Wyoming. The current model characterizes the fuel load in California, Oregon, and Washington using LANDFIRE 2016 Remap fuel data. This characterization of wildfire fuel represents a significant improvement in the fuel characterization compared to prior versions of the dataset.

FIGURE 2: BASELINE STRUCTURE DISTRIBUTION



Source: https://www.corelogic.com/wp-content/uploads/sites/4/downloadable-docs/wildfire-report_0919-01-screen.pdf

The model considers the science behind fire ignition and spread, the local conditions of a property such as vegetation cover, topography, and other factors that drive wildfire risk. The fire vulnerability or building damage are based on primary property characteristics like the structure type, occupancy type, age, and number of stories, and secondary structural modifiers such as vegetation clearance, roofing fire class, and the presence of fire resistive windows or siding. Figure 2 illustrates some of the pieces that comprise a wildfire risk model.

For this project, CoreLogic made custom modifications to the model to consider the effects of WIDP, buffers, and climate change. Along with the model, CoreLogic also made available its proprietary parcel level property dataset with detailed exposure information representing the built environment subject to wildfire damage.

TASK 1: ESTABLISH A BASELINE AND MEASURE CURRENT WILDFIRE RISK IF PARADISE BUILT BACK THE SAME AS BEFORE

To establish a baseline against which possible future mitigation actions can be compared, we applied the CoreLogic Wildfire Model to its proprietary structure level data representing single family residential homes, multi-family housing, and small commercial buildings of less than 10,000 square feet in the Town of Paradise prior to the Camp Fire. This Baseline scenario is intended to reflect the conditions—both in terms of actual building locations, structural characteristics, and mitigation status — of the Town prior to the Camp Fire. However, it is important to note that this portfolio of structures is not intended to encompass all of the Town of Paradise, so while figures are comparable

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[6] Dietzen, G., Chamberlain, M. Taking Catastrophe Models Out of The Black Box (2022). https://www.milliman.com/en/insight/taking-catastrophe-models-out-of-the-black-box

between different scenarios within this report, the aggregate dollar amounts are not the total loss including, for example, large commercial structures and infrastructure. In this analysis, the Total Insured Values (TIVs) include the standard Homeowners insurance coverages of building (including the detached structures), contents, and time element (living expenses) which were based on the replacement cost value of each property contained in the CoreLogic proprietary property database. Table 1, below, shows the distribution of the structures and the TIVs:

TABLE 1: BASELINE STRUCTURE DISTRIBUTION

STRUCTURE TYPE	COUNT	TOTAL INSURED VALUE
Single Family Residential	11,539	$5,408 M
Multi-family Housing	74	$60 M
Small Commercial	552	$619 M

Many of the variables needed to understand the vulnerability of a structure, such as location, are known. For those variables that are not known, CoreLogic either imputed a value or treated the value as unknown. When unknown the vulnerability is assumed to be the average case of the possible values of the variables or to represent the most prevailing feature for each particular exposure group.[7] The resulting Average Annual Loss ("AAL") by location and in aggregate, as well as the Exceedance Probability ("EP") curve, are the metrics used to estimate wildfire risk if Paradise built back the same as it was before the Camp Fire.

The analysis considers both perils of fire and smoke. Demand surge, the increase in labor and construction materials that follows many natural catastrophes due to collective demand significantly exceeding local available supply, was also included.

TASK 2: OVERLAY MITIGATION, ADAPTATION, AND BUFFERS

Several risk-limiting measures are available that may reduce expected losses to the level that makes Paradise a more attractive location for insurers. This task evaluates the use of property mitigation (home hardening to lower risk and magnitude of potential wildfire damage), adaptation (thoughtful planning of land use within the Town's boundaries by considering wildfire risk), and external buffers (implementation of well-maintained areas with low fire spread on the border of the town).

Structure Level Mitigation

The CoreLogic Wildfire Model has vulnerability settings that enable it to reflect structure level mitigation. This allows for a quantification of expected loss reduction and, consequently, the potential decrease in insurance premiums if Paradise required structures to comply with specific home-hardening standards. As each home-hardening measure comes at a different cost, it is important for the Town to assess which mitigation efforts provide sufficient benefit to justify their implementation. On the other hand, it is also imperative to understand whether mitigation alone provides sufficient expected loss reduction.

The Insurance Institute for Building & Home Safety ("IBHS"), an advisor for this project, is the leading national source of science regarding what causes homes to burn and how to reduce the chance that homes will ignite. IBHS recently launched its Wildfire Prepared Home™ program, which allows homeowners to achieve a designation showing that they have taken science-based actions to meaningfully reduce their home's wildfire risk.[8] The IBHS Wildfire Prepared Home™ and Wildfire Prepared Home Plus™ designation standards are used to inform the setting of CoreLogic's structural secondary modifiers to reflect the Base Mitigation scenario and the Plus Mitigation scenario. These two mitigation scenarios represent possible sets of mitigation actions requiring varying degrees of effort. The Base

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[7] See Exhibit 1.4 for detailed treatment of unknown variables.

[8] IBHS (2022). Wildfire Prepared Home – A Program of IBHS. Retrieved November 14, 2022. https://wildfireprepared.org/

Mitigation scenario is similar to the Town's newly implemented home-hardening standards, while the Plus Mitigation scenario adds well-maintained defensible space and fire-resistive building materials requirements. In the Base Mitigation scenario, appurtenant structures such as garages and wooden decks are assumed to be untreated for fire resistance, and consequently the 0-5 feet noncombustible zone is not considered cleared. The Plus Mitigation scenario assumes the absence of untreated combustible attachments as well as fire resistive siding and windows. This is intended to represent a plausible, but optimistic, view of the Town's potential mitigation efforts.

Table 2, below, shows the secondary modifier settings in the CoreLogic model for each of the scenarios.

TABLE 2: SECONDARY MODIFIER SETTINGS FOR MITIGATION SCENARIOS

	MITIGATION SCENARIO	
SECONDARY MODIFIER	BASE MITIGATION	PLUS MITIGATION
Class A Roof	Yes	Yes
Clearance – Noncombustible Zone (0-5 feet)	No	Yes
Clearance - Lean, Clean and Green (5-30 feet)	Yes	Yes
Clearance – Reduced Fuel Zone 3 (30-100 feet)	Yes	Yes
Fire Resistive Siding	Default*	Yes
Combustible Attachments	Yes	No
Fire Resistive Windows	No	Yes

* See Exhibit 1.4 for details about the default treatment of secondary modifiers.

Adaptation

Since most buildings in Paradise were destroyed in the Camp Fire, adaptation is feasible in ways that are impossible in most urban areas. Adaptation in this context consists of the modification of land use practices to reduce risk—for example, by clearing land and creating more green space and parks throughout the Town to serve as internal firebreaks. Similarly, strategically rebuilding homes in a manner that provides greater defensible space will result in a reduction in risk from embers and radiant heat from the ignition of nearby structures should a fire occur. We refer to this strategic planning of land use and zoning as Wildfire Informed Development Patterns ("WIDP").

To assess the potential benefits of WIDP, the Town selected a scenario in which 25% of parcels are converted to low-flammability land like parks or parking lots. Modifying the underlying fuel load in the CoreLogic model to reflect the added open space then provides a view of risk reduction by strategically placing firebreaks within town boundaries.

In order to select parcels to be converted to internal firebreaks for this analysis, we used damage assessment reports compiled by the California Department of Forestry and Fire Protection ("CAL FIRE") Damage Inspection Specialists ("DINS") to analyze damage to structures from the Camp Fire. We created a model using variables that 1) are most highly correlated with damage ratios, and 2) are relevant to the rebuilding process[9]. The resulting model calculates a risk score for each pre-Camp Fire structure, which was then used to prioritize parcels to be selected to be an internal firebreak.

Parcels that are designated as internal firebreaks are to be cleared of structures—they are assumed to be well-maintained and have minimal fire spread. As discussed earlier, these could be areas designated for green land uses such as parkland, open areas, or other low ignition-risk land uses.

Unlike risks due to other natural disasters like earthquake and flood, wildfire risk to a property is highly influenced by the vulnerability of neighboring structures that can serve as fuels, greatly increasing the hazard to a property. As a result, the process of assessing the effect of clearing parcels needs to be an interactive one: since the clearing of a

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[9] For example, distance to the nearest structure is pertinent to land use planning, whereas structural variables like year built, while predictive of losses, do not aid the assessment of whether a structure should be (re)erected at a location.

nearby parcel can lower the wildfire risk to a structure, the risk score needs to be recalculated every time a parcel is cleared.

For this exercise, the prioritization process starts with assuming 100% of the pre-Camp Fire residential structures are rebuilt, and follows the following steps until 75% of the original residential housing stock remains:

1. Calculate a risk score for each structure in the dataset
2. Select the destroyed structure[10] with the highest risk score
3. Designate the parcel of the selected structure as an internal firebreak, “clearing” the structures from the parcel
4. Refresh variables such as distance to the nearest location, and recalculate the score

The goal of WIDP is achieved by electing not to rebuild on the selected parcels.

CoreLogic’s Wildfire Model was then applied to this new set of locations to assess the reduction in aggregate risk. It should be noted that the Town is in the process of rebuilding and the housing stock is constantly changing, so the exact set of parcels designated as internal firebreaks in this exercise should not be taken as a recommendation, but instead as an illustration of the benefit of WIDP and strategically placing internal firebreaks.

Buffers

Internal firebreaks lie between structures within the town boundaries, while buffers are firebreaks established at the edge of Paradise. The Conservation Biology Institute (“CBI”), The Nature Conservancy, and the Paradise Recreation and Park District (“PRPD”), have defined Wildfire Risk Reduction Buffers (“WRRBs”) around Paradise between the urban area and the wildland.[11] Similar to internal firebreaks, WRRB zones comprise green land uses or “greenbelts” or parkland, and other low ignition-risk land uses. Using a combination of available data, local knowledge, and feedback from the PRPD staff, CBI prioritized parcels to make up buffers around the Paradise and Magalia urban areas. Figure 3, below, shows the five resulting buffers that CBI recommended:

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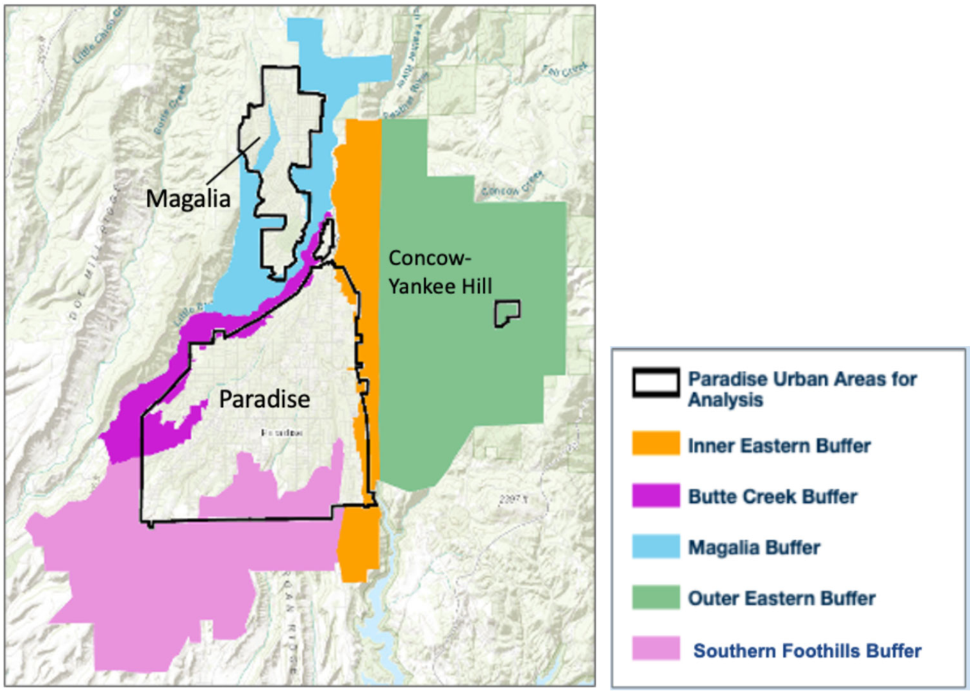
[10] It is undesirable to remove a surviving structure for the purpose of WIDP / internal firebreaks.

[11] Conservation Biology Institute (June 2020). Paradise Nature-Based Fire Resilience Project. Retrieved November 14, 2022. https://consbio.org/reports/paradise-nature-based-fire-resilience-project/

FIGURE 3: THE FIVE WILDLAND RISK-REDUCTION BUFFERS FROM CBI REPORT



The buffers recommended by CBI were incorporated into the CoreLogic model, in which vegetation and underlying fuel layers within the buffers were modified to reflect the result of proactive land use management. CoreLogic then calculated the AALs and EP curves for the modified environment.

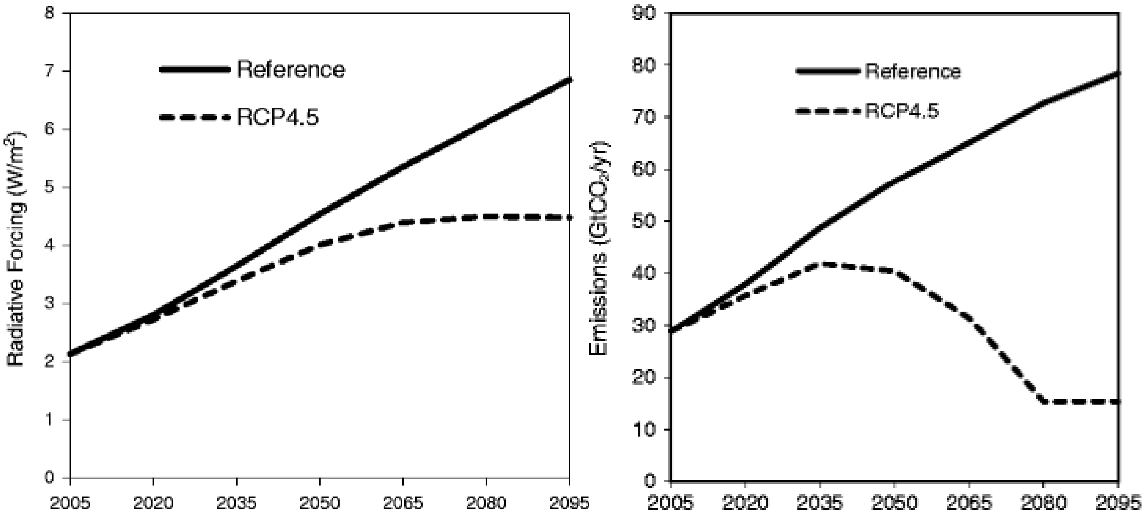
TASK 3: STRESS TEST FOR FUTURE CLIMATE SCENARIOS

Changing climate conditions and human development factors have modified the risk of large wildfires for different geographic regions and dominant vegetation types in the contiguous United States. Warmer temperatures and altered wind patterns may lead to more frequent fire weather conditions. Changes in precipitation and runoff modify fuel conditions. Meteorological projections alone are a poor metric for this changing risk, as increased air temperatures are insufficient to explain the spatial changes in wildfire frequencies over the historical period or under future climate change, not accounting for crucial factors like population growth and land cover change.

To quantify future climate conditions of Paradise, we leveraged the Representative Concentration Pathways (“RCPs”) trajectories published by the IPCC. These RCPs describe different climate futures, all of which are considered possible depending on the volume of future greenhouse gas emissions. The RCP scenarios are generated by dynamic-recursive models called Global Change Assessment Models (“GCAMs”), which are integrated assessment tools with representations of the economy, energy sector, land use, and water linked to climate models and can be used to explore climate change mitigation policies.

The RCP 4.5 scenario is described by the IPCC as an “intermediate scenario.” The emissions in RCP 4.5 peak around 2040, then decline. Figures 4A and 4B show the emissions from energy and industrial sources and the resulting total radiative forcing projected by the scenario. The reference scenario of the GCAM used to generate RCP 4.5 is included for comparison—the reference scenario includes no explicit policies to limit carbon emissions, and therefore fossil fuels continue to dominate global energy consumption. The RCP 4.5 scenario was chosen by the project team as the future climate scenario for this study.

FIGURE 4A (LEFT): TOTAL RADIATIVE FORCING (W/M^{-2}) OF THE GCAM REFERENCE AND RCP4.5 SCENARIOS
FIGURE 4B (RIGHT): CO_2 EMISSIONS FROM ENERGY AND INDUSTRIAL SOURCES IN THE GCAM REFERENCE AND RCP 4.5 SCENARIOS



Source: Thomson, A.M., Calvin, K.V., Smith, S.J. *et al.* RCP4.5: a pathway for stabilization of radiative forcing by 2100. *Climatic Change* **109**, 77 (2011). https://doi.org/10.1007/s10584-011-0151-4

The climate change versions of the CoreLogic wildfire model consider statistical data derived from California's Fourth Climate Change Assessment (Westerling, 2018)[12], as well as climate-shifted data from Missoula Fire Sciences Laboratory's FSim burn probability model (Thompson et al., 2011)[13]. This data was used to determine changes in annual burn probability (ABP) for different fire intensity levels (FIL) and frequencies of large wildfires of varying size classes.

The California Fourth Assessment data were derived from a downscaling of meteorological and hydrological data using the Localized Constructed Analogs (LOCA) statistical technique (Pierce et al., 2014)[14] for four CMIP5 climate models (CanESM2, CNRM-CM5, HadGEM2-ES, and MIROC5). These meteorological drivers were then combined with changes in vegetation and human population to derive a stochastic dataset of wildfire perimeters for the entire state.

The U.S. Forest Service FSim model simulates hundreds of thousands of large wildfire events over the course of many synthetic seasons. These seasons combine historical weather, terrain, and fuel conditions. Fire suppression is also accounted for in the model. Aggregating the fire perimeters from these synthetic seasons allows for an estimate of the annual burn APB of every grid cell in the model domain, which covers the Continental U.S. at 270m resolution. The pattern of ABP reflects the general likelihood of a fire occurrence across the landscape and can be combined with probabilities of various FIL. These intensity levels are based on categories of flame lengths calculated from the FSim model and give an estimate of the likelihood of a certain intensity of burn, assuming there is already an active fire.

Given that the FSim model produces estimates of ABP based on historical wildfire occurrence and upon calibration against observed fire distributions, the differences in ABP from one grid cell to the next can be explained by variations in regional climate and human activities, as well as by terrain and land cover. In this methodology, climate and human drivers of present-day fire occurrence are isolated and used to construct a surrogate model of APB for three separate classes of FIL. The surrogated approach developed here by CoreLogic leverages statistical models trained on present conditions to produce shifted FSim burn probability fields using future meteorological and human development variables.

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[12] Westerling, A. L. (2018). Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events with a Warming Climate: a Report for California's Fourth Climate Change Assessment (p. 57). Sacramento, CA: California Energy Commission. http://ibecproject.com/PREDEIR_0002479.pdf

[13] Thompson, M. P., Calkin, D. E., Finney, M. A., Ager, A. A., & Gilbertson-Day, J. W. (2011). Integrated national-scale assessment of wildfire risk to human and ecological values. Stochastic Environmental Research and Risk Assessment, 25(6), 761-780. doi: 10.1007/s00477-011-0461-0

[14] Pierce, D.W., D.R. Cayan and B.L. Thrasher, (2014). Statistical Downscaling Using Localized Constructed Analogs (LOCA). Journal of Hydrometeorology, 15,2558-2585. doi:10.1175/JHM-D-14-0082.1

CoreLogic used the resultant RCP 4.5 climate change model, forecast to the 2040 timeframe on the baseline exposure set to first understand what the pre-Camp Fire wildfire risk would be under these future climate change conditions. This climate change model was then run with Base mitigation, WIDP, and buffers applied, outputting the calculated AALs and EP curves. Given that the projection of wildfire risk to 2040 only spans 18 years of climate change, the impacts may not be very sensitive to the selection of RCP scenario. In contrast, we expect that the results would differ more for projections farther into the future.

In tasks 1-3, we considered the following eight scenarios:

1. Baseline
2. Base Mitigation
3. Plus Mitigation
4. Baseline with WIDP
5. Baseline with WIDP and all buffers
6. Base Mitigation with WIDP and buffers
7. Baseline at 2040 climate expectations
8. Base Mitigation with WIDP and all buffers at 2040 climate expectations

In addition, we produced model results for each of the five individual buffers recommended by the CBI report.

TASK 4: MODEL INSURANCE MARKET BEHAVIOR, ESTIMATE HOMEOWNERS WILDFIRE PREMIUMS, AND DEVELOP METRICS FOR AFFORDABILITY

A major concern of current and future residents of the Town of Paradise is the availability and affordability of insurance. While the reduction in wildfire risk arising from mitigation or adaptation plans is desirable in itself, it is also important because of the potential for reduction in insurance rates. Using AALs from the CoreLogic model and industry data, we estimated the premium that would reflect an average insurer's full costs under each scenario.

Loss and Expense Components

A premium consists of a loss component and an expense component. The loss component (also called "pure premium") is an estimate of the average amount that insurers must pay to indemnify the policyholder. The expense component is an estimate of the expenses incurred when paying and processing claims, as well as those associated with acquiring, underwriting, and servicing policies. We included the profit provision, which provides for the required return on capital, with the expense component.

We used the CoreLogic Wildfire Model AALs as an estimate of the wildfire expected losses under each scenario. Since the AALs are ground-up losses, the resulting premium reflects the cost to insure properties, and does not take into account policy characteristics like limits and deductibles which shift the financial burden between the insurer and the insured. To the extent that deductibles and limits exist on a policy, the premium that an insured pays would be decreased accordingly.

The non-catastrophe all other perils (AOP) portion of losses was estimated based on the pure premiums in the ISO Fast Track Plus Report, which aggregates Homeowners insurance loss data and trends by state and form. We then loaded the pure premiums for expenses to produce an estimated average premium. The details are shown in Exhibit 2.

The expense component of the premium was taken from California (and countrywide where not state-specific) industry aggregations[15]. This includes commissions, acquisition costs, allocated and unallocated loss adjustment expenses, premium taxes, licenses and fees, and other general expenses. We included a 5% profit and contingency provision

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[15] Commission and premium tax are from industry aggregate California Exhibit of Premiums and Losses (Statutory Page 14), while other quantities are from industry aggregate countrywide Insurance Expense Exhibit (IEE).

with expenses, which historically has been a typical profit and contingency provision[16] for most lines of property and casualty insurance. All expenses are assumed to be variable, so the indicated premium equals the pure premium divided by one minus the variable expense and profit provision.

Net Cost of Reinsurance

Typically, in states other than California, the expense provision includes the net cost of reinsurance. Currently, the California Department of Insurance does not permit reinsurance costs to be included in approved rates, which is a key impediment to insurers writing business in areas of high wildfire risk within California. We calculated the estimated premium with and without reinsurance cost and show the expected deficit to insurers due to rates not being permitted to reflect reinsurance costs.

The net cost of reinsurance is estimated using Insurance Linked Securities (ILS). ILS are “financial securitizations of insurance risks”[17]. One common type of insurance-linked securities are catastrophe bonds, or “cat bonds”. Through catastrophe bonds, insurers or reinsurers (the “sponsors") are able to transfer insurance / reinsurance risk to investors. Like traditional fixed-income securities, catastrophe bonds require a collateral (“principal”) and provide interest payments in return. Unlike traditional fixed-income securities, catastrophe bonds specify a natural disaster—if this prespecified event does not occur, the bonds are no different from their traditional counterparts in that the principal is returned. However, if the prespecified event occurs, the sponsor’s right to the principal is “triggered”, meaning that investors will lose some or all of their principal and unpaid interest payments. Because of this, the expected excess return investors receive on catastrophe bonds is analogous to the profit load that reinsurance companies charge the ceding insurance company. Catastrophe bonds can be used to estimate the profit load a reinsurer may demand. We reviewed catastrophe bonds issued from April 1, 2018 to March 31, 2021 from Lane Financial LLC’s annual securitization reviews. A curve was fit to the profit multiples versus average probability of attachment and exhaustion of the bonds.

The net cost of reinsurance must be calculated in layers because the profit load increases as the probability of attachment decreases. For each layer, the net cost of reinsurance is equal to the expected loss in the layer multiplied by the average profit multiple in the layer. The expected loss in the layer is equal to the occurrence exceedance probability curve loss multiplied by the percent of total reinsurance amount that the layer encompasses. For each layer, the area under the curve is calculated to estimate the average profit multiple by layer.

For this analysis, it is assumed that insurers of the Town purchase reinsurance that has a 5% probability of attachment and a 0.5% probability of exhaustion. In other words, there will be a 1 in 20 year chance of a loss that is large enough to trigger the reinsurance and a 1 in 200 year chance of a loss so large that it exceeds the available reinsurance. In practice, reinsurance coverage is expressed in dollars (e.g. an attachment point of $5 million and a limit of $1 billion). However, the representation of reinsurance structure in terms of attachment and ruin probabilities allows for a consistent view of risk appetite, so that reinsurance costs under different scenarios can be compared.

It is important to note that the analysis assumes an insurer operating solely in the Town of Paradise. Without the benefit of diversification, which is discussed in a later section, this hypothetical insurer would experience a high cost of reinsurance. For insurers that operate in multiple geographically diverse regions, the tail risk will decrease and cost of reinsurance will reduce correspondingly.

WIDP MODEL

Using the DINS data from the Camp Fire, we created a logistic regression to determine a risk score for each location in the Town. The target variable was whether a structure was destroyed. The DINS data reports the damage ratio of each structure, and all structures with damage ratios greater than 50% were classified as destroyed. Predictor variables were selected based on a literature review of variables likely to be predictive of fire risk and included both variables

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[16] Actuarial Standards Board (2011). Actuarial Standard of Practice No. 30, Appendix 1. Retrieved November 30, 2022. https://www.actuarialstandardsboard.org/wp-content/uploads/2014/02/asop030_148.pdf

[17] Captive.com (2015). Insurance-Linked Securities (ILS) Market Explained. Retrieved November 30, 2022. https://www.captive.com/articles/insurance-linked-securities-(ils)-market-explained

related to individual building characteristics (such as year built) and not specific to individual buildings (such as distance between houses or density of houses within a housing cluster).

All variables were standardized prior to the model being fitted, where each variable is transformed to have a mean of 0 and standard deviation of 1. *Aspect* is a geographical variable that describes the compass direction that a topographic slope faces[18].

The final model includes the following variables:

- Structure type (Single Family vs Multiple Family)
- Number of stories
- Mobile home size (if a mobile home)
- Year built (before / after 1997[19])
- Distance to nearest structure
- Parcel area
- Aspect

The goal of the model is not to assess the effectiveness of individual mitigation actions, but to inform the rebuilding process. As such, focus was given to variables such as the type and size of structure, as well as environmental variables such as distance to nearest structure and aspect. Some variables were tested but were not included in the final model either for the parsimony of the model or because the variables were statistically insignificant. Examples of these variables include slope, elevation, housing dispersion, cluster housing density, and distance to nearest fire station.

In general, mobile homes were found to have a higher risk of being destroyed in a wildfire event. For non-mobile home residences, multi-family and multi-story structures tend to have lower wildfire risk. Intuitively, older homes tend to be less resistant to fire since they are less likely to meet current building codes. We assume any new structures are built to current building codes.

We found that *Distance to Nearest Structure* had a different effect on the damage ratio for structures that are within 10 meters versus those that are more than 10 meters apart. Figure 5 below shows this relationship:

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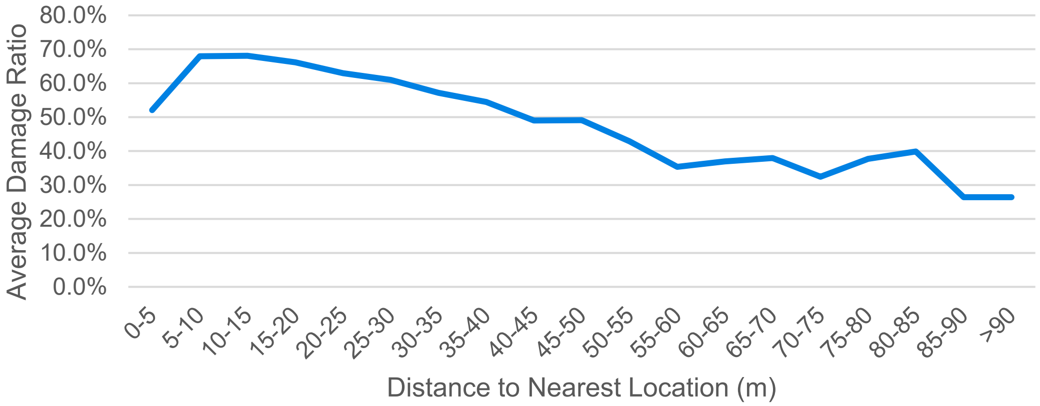
[18] A cosine transformation was performed on the variable to represent the southwest slope direction.

[19] The threshold of 1997 is informed by Knapp, E.E., Valachovic, Y.S., Quarles, S.L. *et al* (2021). Housing arrangement and vegetation factors associated with single-family home survival in the 2018 Camp Fire, California. *fire ecol* **17**, 25. Retrieved November 14, 2022. https://doi.org/10.1186/s42408-021-00117-0

FIGURE 5: DAMAGE RATIO BY DISTANCE TO NEAREST LOCATION (METERS)



A possible explanation is that structures that are very close together indicate a lack of vegetation and other combustible materials (other than neighboring structures); and to the extent that neighboring structures are not ignited, there is little fuel surrounding the structure to catch fire. An interaction was added to the model to account for this observation.

The variable *Parcel Size* showed statistical significance after accounting for *Distance to Nearest Structure*: areas where houses are on larger parcels had a lower risk of being destroyed. *Aspect* had a small but statistically significant coefficient—this may be because of the particular wind and fire conditions of the Camp Fire.

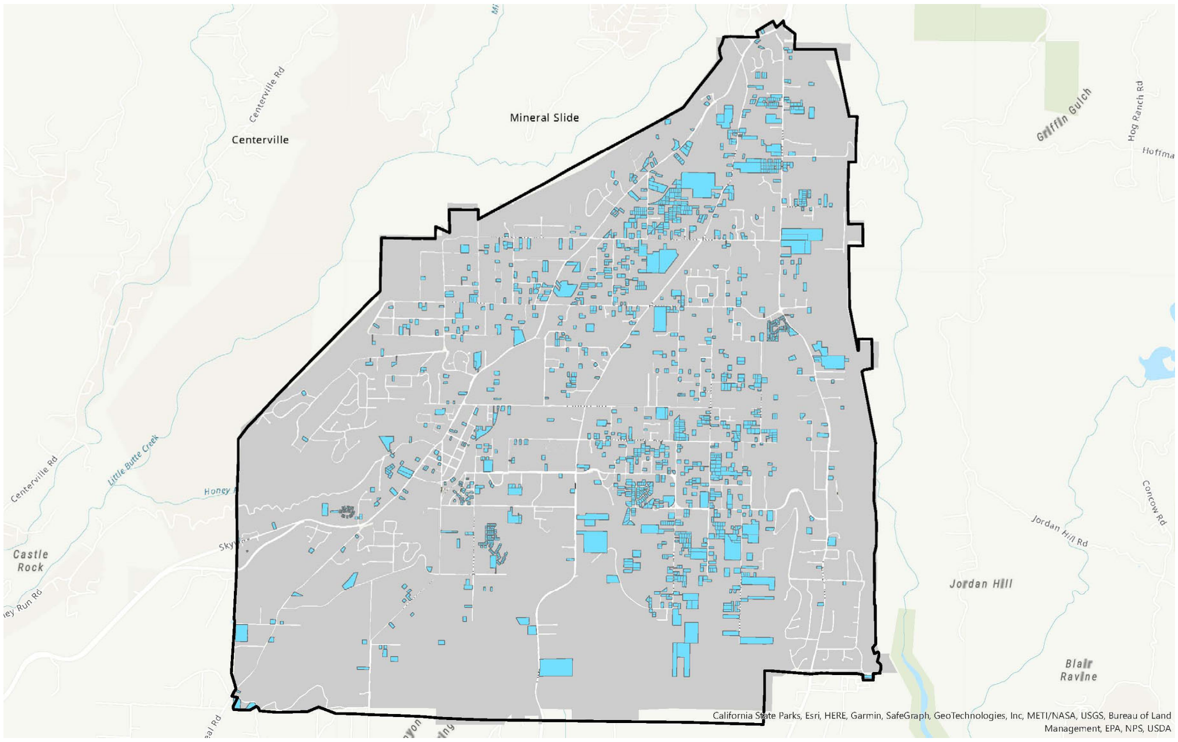
The regression output of the final model is displayed in Table 3, below.

TABLE 3: REGRESSION OUTPUT OF WIDP MODEL

VARIABLE	Coefficient	Standard Error	z	P>|z|	95% Confidence Interval - Lower	95% Confidence Interval - Upper
Mobile Home	0.147	0.006	23.218	0.000	0.135	0.160
Multiple Residence	-0.084	0.012	-6.798	0.000	-0.108	-0.060
Single Story Structure	-0.048	0.007	-7.173	0.000	-0.061	-0.035
Multi Story Structure	-0.116	0.009	-12.522	0.000	-0.134	-0.098
Single Wide Mobile Home	0.102	0.013	8.114	0.000	0.077	0.127
Double Wide Mobile Home	0.079	0.009	8.857	0.000	0.062	0.097
Triple Wide Mobile Home	0.075	0.015	5.031	0.000	0.046	0.104
Built After 1997	-0.353	0.013	-27.944	0.000	-0.378	-0.328
Neighboring Structure within 10 meters	-0.634	0.044	-14.394	0.000	-0.721	-0.548
Distance to Nearest Structure	-0.825	0.031	-26.889	0.000	-0.885	-0.765
Interaction[Neighboring Structure within 10 meters : Distance to Nearest Structure]	0.673	0.048	13.989	0.000	0.578	0.767
Parcel Area (sqm)	-0.724	0.032	-22.584	0.000	-0.787	-0.661
Aspect	-0.050	0.013	-3.924	0.000	-0.075	-0.025

Figure 6, below, shows the parcels selected for WIDP by the above model. Table 4 shows the distribution of the exposures after WIDP, which may be compared to Table 1.

FIGURE 6: PARCELS SELECTED TO REMAIN CLEAR BY THE WIDP PROCEDURE



California State Parks, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA

TABLE 4: WIDP SCENARIO STRUCTURE DISTRIBUTION

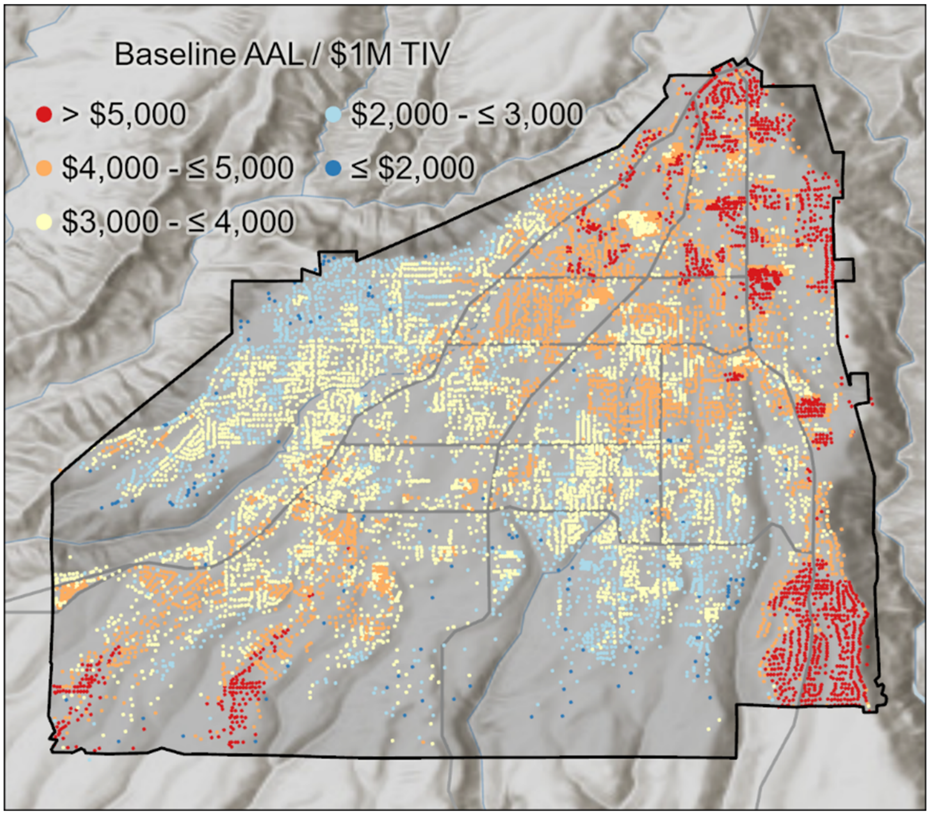
STRUCTURE TYPE	STRUCTURE COUNT	TOTAL INSURED VALUE (MILLION)
Single Family Residential	8,675	$4,264
Multi-family Housing	70	$56.6
Small Commercial	535	$604

Findings

AVERAGE ANNUAL LOSS

The CoreLogic Wildfire Model results show that prior to the Camp Fire, residential and small commercial locations in the Town of Paradise could have expected *average* annual losses ranging from $152 to over $77,000. This translates to about $24 million, in aggregate, for the whole town. Since property values differ by location, it is helpful to divide AALs by the total property TIVs, so that the resulting metric is comparable across different regions of the town. Figure 7 below shows a map of the AAL per million dollars of TIV in this baseline scenario in a diverging color scale, where the spectrum from blue to red represent structures with the lowest to highest AAL to TIV ratios.

FIGURE 7: CORELOGIC WILDFIRE MODEL AAL / $1M TIV BY LOCATION



In general, structures on the border of the Town in the northeast, southeast, and southwest have higher expected losses as a fraction of their TIV.

The various mitigation and adaptation scenarios provide a range of reduction in AALs, corresponding to reductions to overall risk. Table 5 below shows for each scenario the estimated total AAL and the percent reduction compared to the baseline scenario. This does not include the WIDP scenarios, which have different numbers of exposures for each scenario.

TABLE 5: SUMMARY OF AGGREGATE AVERAGE ANNUAL LOSS BY SCENARIO

SCENARIO	ESTIMATED TOTAL AAL	DIFFERENCE FROM BASELINE
Baseline	$23.900 M	0%
Base Mitigation	$11.259 M	-52.9%
Plus Mitigation	$7.867 M	-67.1%
All External Buffers	$ 15.663 M	-34.5%
Baseline under 2040 Climate	$ 27.835 M	+16.5%

* Base Mitigation with WIDP & External Buffers under 2040 Climate is compared against Baseline under 2040 Climate

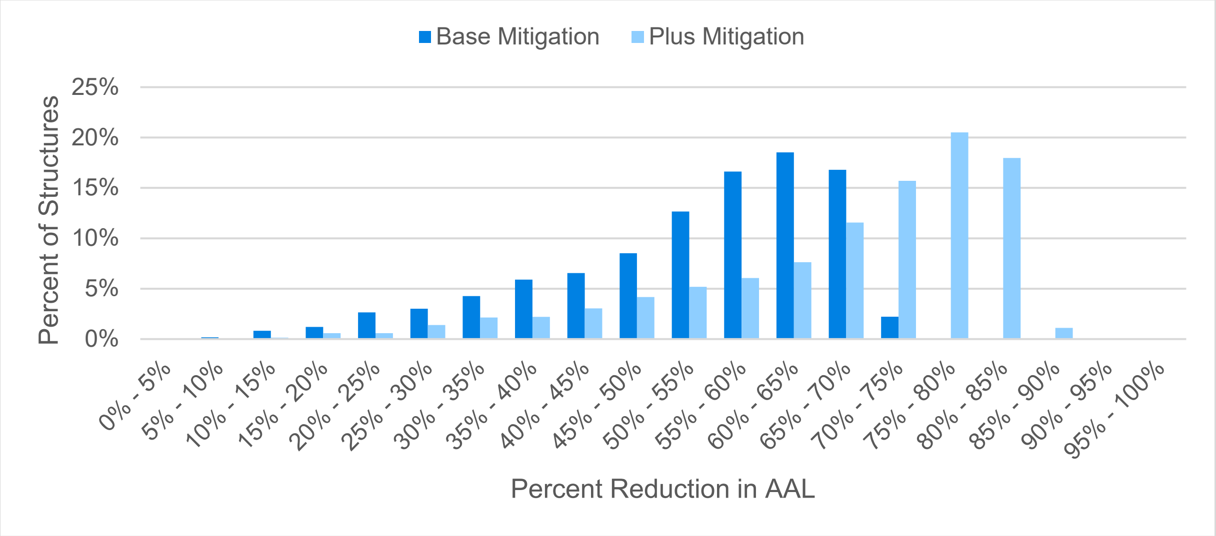
Mitigation

As shown in Table 5, Base Mitigation can reduce average losses by 52.9%. Base Mitigation includes the installation of roofs with a class A fire rating and the clearance of space around properties. This reduction is for the Town of Paradise in aggregate—in general, homes in higher risk territories would see a bigger benefit for upgrading a roof and implementing defensible space.[20]

In the Plus Mitigation scenario, properties are also fitted with fire resistive windows and sidings and have all combustible attachments removed, in addition to the requirements of the Base Mitigation scenario. We estimate that these additional mitigation actions would further decrease the AALs by 14.2%, resulting in a 67.1% total reduction in AAL compared to the pre-Camp Fire baseline scenario.

It is also helpful to consider the distribution of the risk reduction. Figure 8, below, shows a histogram of the percentage reduction in AAL resulting from individual property level mitigation. The bars show the distribution of percentage reduction in AAL for each pre-Camp Fire structure due to the two mitigation scenarios. As expected, the more stringent Plus Mitigation results in higher reduction in general.

FIGURE 8: HISTOGRAM OF PERCENT REDUCTION IN AAL



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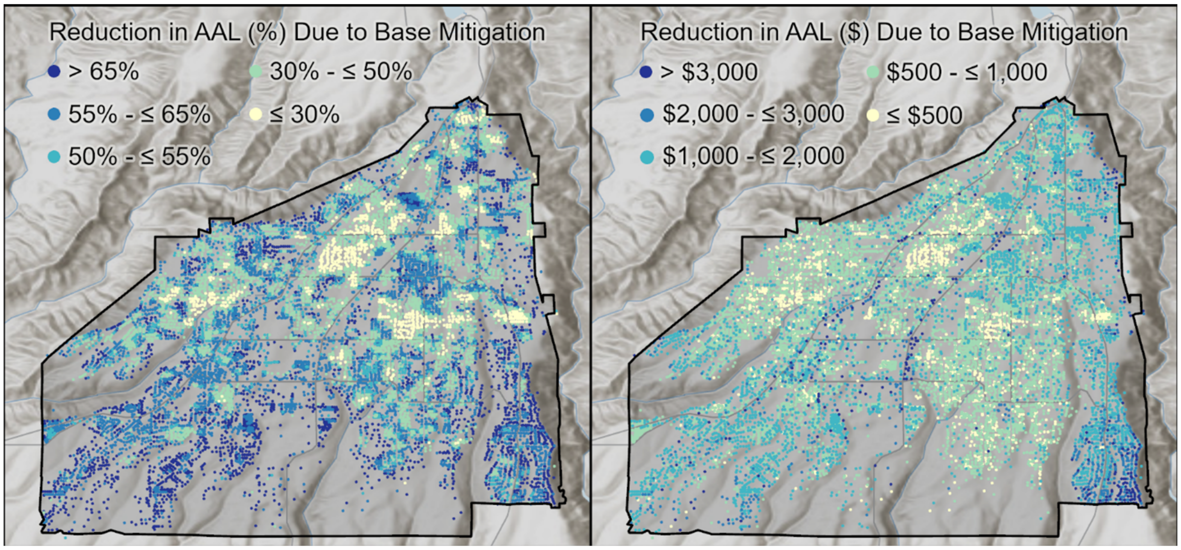
[20] Brinkmann et al (2022). Catastrophe Models for Wildfire Mitigation: Quantifying Credits and Benefits to Homeowners and Communities, p. 38-39. Retrieved November 30, 2022. https://www.milliman.com/en/insight/catastrophe-models-for-wildfire-mitigation

Figure 9 below shows the change in AAL from the Baseline scenario to the Base Mitigation scenario.

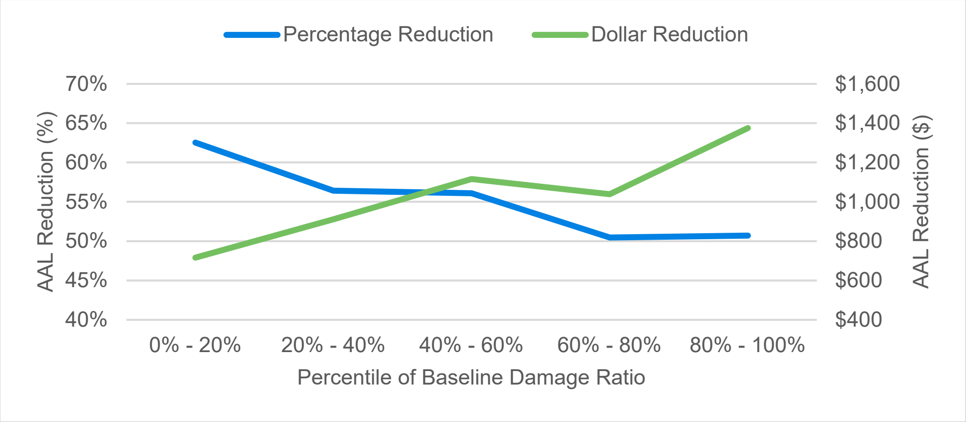
FIGURE 9A (LEFT): CHANGE IN AAL DUE TO BASE MITIGATION, IN PERCENTAGE OF BASELINE AAL
FIGURE 9B (RIGHT): CHANGE IN AAL DUE TO BASE MITIGATION, IN DOLLARS



Comparing Figures 9A and 9B, we can see that the percentage and dollar reduction in AAL do not always align. For example, many properties along the northwestern border of the town receive a sizable percentage reduction in AAL, but not a large dollar reduction. The converse is also true: properties with smaller percentage reduction in AAL tend to have larger dollar reduction in AAL. This phenomenon is discussed in the recent whitepaper written by Milliman[21] and published by the Casualty Actuarial Society, which shows that low risk territories may see a larger reduction in risk, while higher risk territories may see a larger reduction in dollars. This is because in higher risk areas, extreme events tend to be more severe so the risk reduction power of individual property mitigation is limited. However, in high risk territories, expected losses are significant to begin with, so any reduction translates to a larger dollar amount.

Figure 10 illustrates this relationship with the percentage reduction (blue) plotted on the left axis and dollar reduction (green) plotted on the right axis, for structures with different baseline damage ratio relativities (x-axis).

FIGURE 10: AAL REDUCTION DUE TO BASE MITIGATION, IN PERCENT AND IN DOLLARS



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[21] Brinkmann et al (2022). Catastrophe Models for Wildfire Mitigation: Quantifying Credits and Benefits to Homeowners and Communities, p. 35-36. Retrieved November 30, 2022. https://www.milliman.com/en/insight/catastrophe-models-for-wildfire-mitigation

WIDP

Because the WIDP scenario assumes a decreased number of structures in the town, it is necessary to compare the average AAL by location instead of the aggregate AAL. Table 6, below, shows the average AAL by location within the Paradise town boundaries as well as the estimated average total premium excluding the net cost of reinsurance:

TABLE 6: SUMMARY OF AVERAGE AAL AND TOTAL PREMIUM BY LOCATION BY SCENARIO

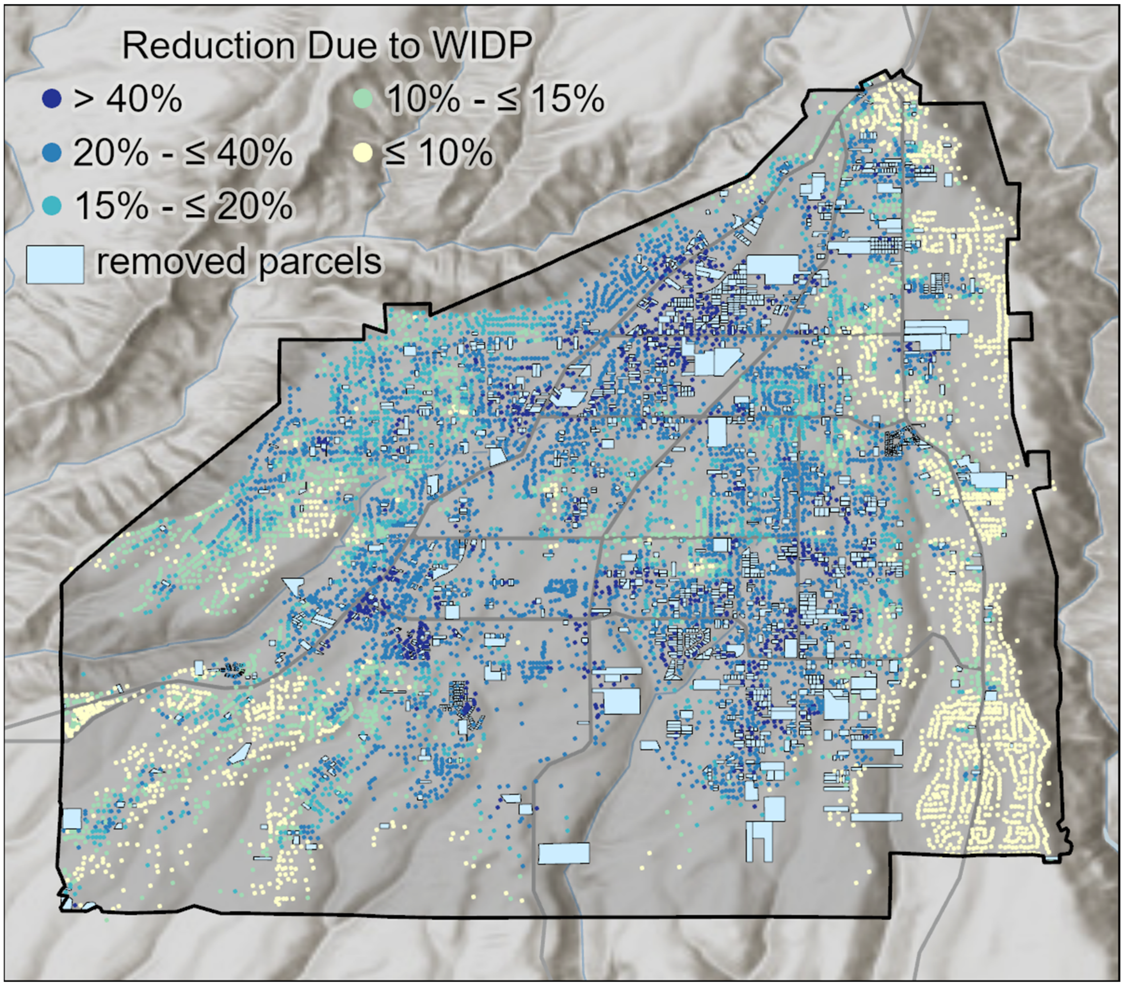
SCENARIO	ESTIMATED AVERAGE LOCATION AAL	AAL DIFFERENCE FROM BASELINE	ESTIMATED AVERAGE TOTAL PREMIUM	PREMIUM DIFFERENCE FROM BASELINE
Baseline	$ 1,965	0%	$ 4,654	0%
Base Mitigation	$ 926	-52.9%	$ 2,839	-39.0%
Plus Mitigation	$ 647	-67.1%	$ 2,352	-49.5%
WIDP	$ 1,680	-14.5%	$ 4,156	-10.7%
WIDP with External Buffers	$ 1,089	-44.6%	$ 3,124	-32.9%
Base Mitigation with WIDP & External Buffers	$ 502	-74.5%	$ 2,099	-54.9%
Baseline under 2040 Climate	$ 2,288	+16.5%	$ 5,219	+12.1%
Base Mitigation with WIDP & External Buffers under 2040 Climate*	$ 574	-74.9%*	$ 2,226	-57.3%

* Base Mitigation with WIDP & External Buffers under 2040 Climate is compared against Baseline under 2040 Climate

As expected, the estimated reduction in AAL for scenarios not involving WIDP are identical to those in Table 5. This is because they assume no change in the number of structures. On the other hand, the selected WIDP scenario results in 23.7% of parcels being cleared. The reduction in AAL relative to the reduction in structures highlights the effectiveness of the action: by dedicating 23.7% of parcels to green spacing, the town is able to reduce total AAL by 34.8%, which corresponds to a 14.5% reduction in average AAL by location.

As discussed in the methodology section, wildfire risk to a property is highly influenced by neighboring structures. The presence of a nearby vulnerable structure can increase the likelihood of ignition for a property, while the absence of nearby structures could serve as a fuel break. Figure 11, below, shows the percentage reduction in AAL in the Town due to WIDP. Parcels that are designated as internal firebreaks, or “cleared”, are highlighted in light blue. The reduction in AAL of the remaining structures are shown on the map in a color scale.

FIGURE 11: REDUCTION IN AAL (%) DUE TO WIDP



This map shows two important observations: 1) clearing parcels reduces AAL for other structures, and 2) the reduction in AAL is highest for structures closest to cleared parcels, then the reduction decreases as distance from the cleared parcel increases. In general, the WIDP process resulted in the most AAL reduction in the center of the town, whereas properties along the edges of the town saw less benefit due to WIDP.

Buffers

When combined with WIDP, external buffers are found to further reduce risk by an additional 30.1% on a per-location basis, bringing the total average AAL reduction per location to 44.6%, if all five buffers from Figure 3 are implemented. We estimate the stand-alone risk reduction of implementing just the external buffers without WIDP to be 34.5%. The benefits of WIDP and external buffers are approximately multiplicative—the effect of the combined mitigation is slightly larger than the combination of the individual effects[22]. In other words, there is synergy between WIDP and external buffers to product a combined effect greater than the aggregation of their separate effects.

The implementation of external buffers requires significant financial resources; in addition, the acquisition and easement of parcels may not be feasible in certain situations—for example, if there is historical value in preserving the parcel in its current state. Table 7, below, summarizes the reduction in total AAL for the Town if buffers recommended

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[22] 44.6% (combined reduction) is slightly larger than 44.0% (the product of reductions) = 1 - [1 - 34.5% (buffer standalone reduction)] * [1 - 14.5% (WIDP standalone reduction)]

by the CBI are implemented individually. In its report recommending external buffers, the CBI presented a summary of the change in number of acres categorized as “highest ignition risk” due to the implementation of individual buffers; these numbers are included for reference.

Like the combination of WIDP and buffers, we note that the result of multiplying all the reduction in AAL of the individual stand-alone buffers, assuming independence, results in a 30.8% reduction. This is slightly less than the actual combined reduction of 34.5%. This shows that there is an added benefit of completing multiple actions, beyond just the “sum” of the individual actions.

TABLE 7: SUMMARY OF AVERAGE AAL BY LOCATION BY SCENARIO

SCENARIO	CHANGE IN AAL	CBI CHANGE IN ACRES WITH HIGHEST IGNITION CATEGORY
Inner Eastern	-11.9%	-64%
Magalia	-3.4%	-47%
Outer Eastern	-8.8%	N/A*
Butte Creek	-2.9%	-1%
Southern Foothills	-8.2%	-5%

Not tested as a stand-alone buffer in the CBI paper.

Climate Stress Testing

Two scenarios were created to evaluate the effects of future climate expectations on the results of this study. In Table 8, below, the AALs in the conditions of the selected climate scenario at 2040 are compared to the corresponding scenario with the current climate.

TABLE 8: SUMMARY OF AGGREGATE AAL BY CLIMATE SCENARIO

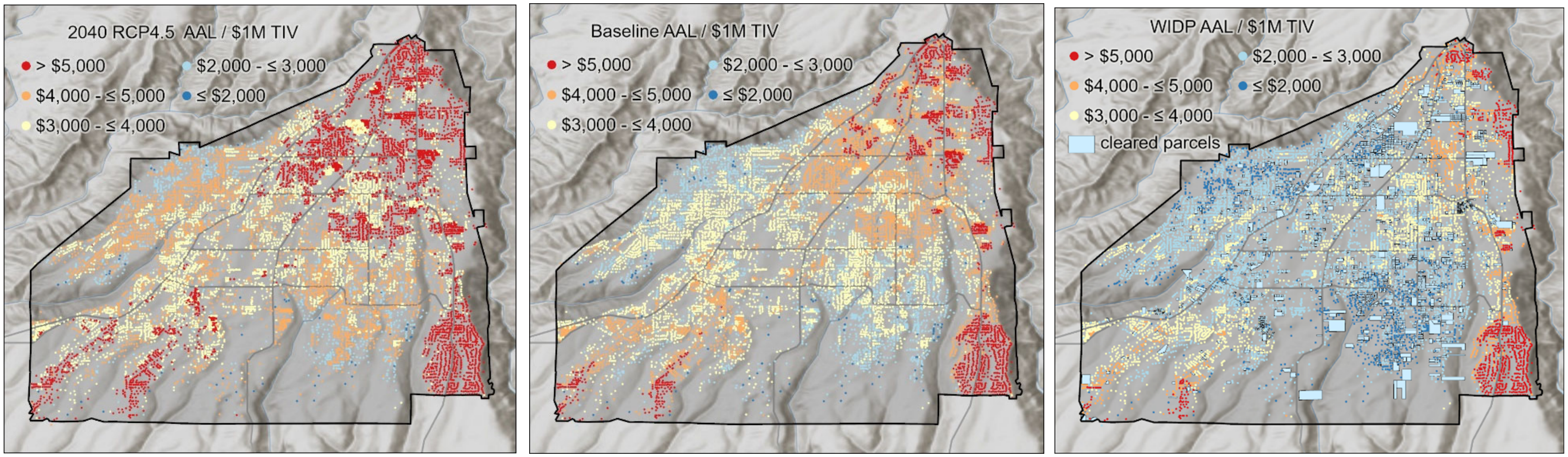
SCENARIO	ESTIMATED TOTAL AAL		CHANGE DUE TO CLIMATE
	CURRENT CLIMATE CONDITIONS	RCP4.5 2040 CLIMATE CONDITIONS	
Baseline under 2040 Climate	$23.900 M	$27.835 M	16.5%
Base Mitigation with WIDP & External Buffers under 2040 Climate	$ 4.656 M	$5.330 M	14.5%
Risk Reduction	80.5%	80.9%	

In both scenarios we see that the wildfire risk will be higher with future climate expectations (a 16.5% and a 14.5% increase in wildfire risk). The combination of base mitigation, WIDP, and external buffers is expected to yield a reduction in AAL of 80.5% in current climate conditions and 80.9% under 2040 conditions.

Summary of Selected Scenarios

Figure 12, on the next page, shows a panel of maps of the AAL / $1M TIV ratio of each location for selected scenarios side by side:

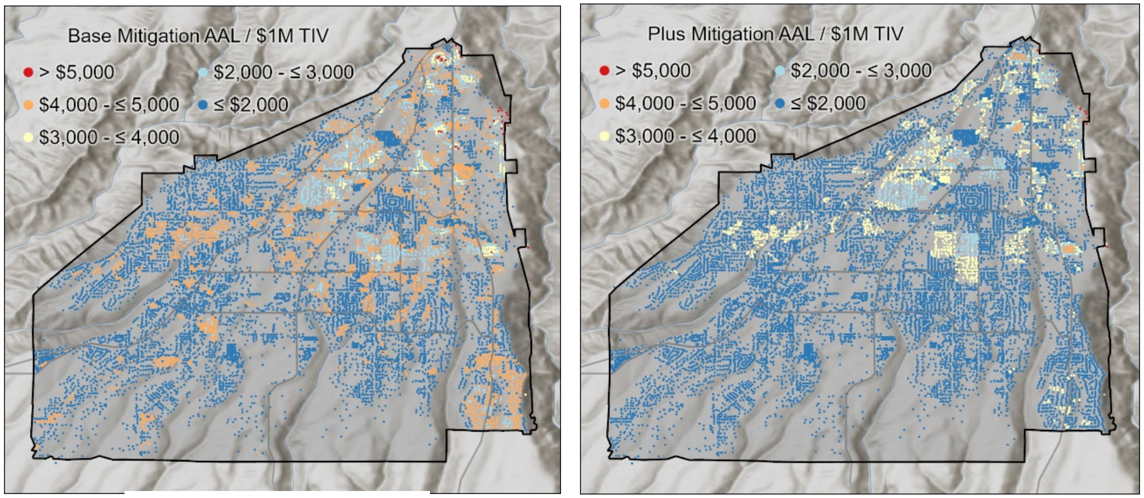
FIGURE 12: CORELOGIC V22.1 AAL / $1M TIV FOR SELECTED SCENARIOS



2040 RCP4.5 Scenario

Baseline Scenario

WIDP Scenario



Base Mitigation Scenario

Plus Mitigation Scenario

EXCEEDANCE PROBABILITY (EP) CURVES

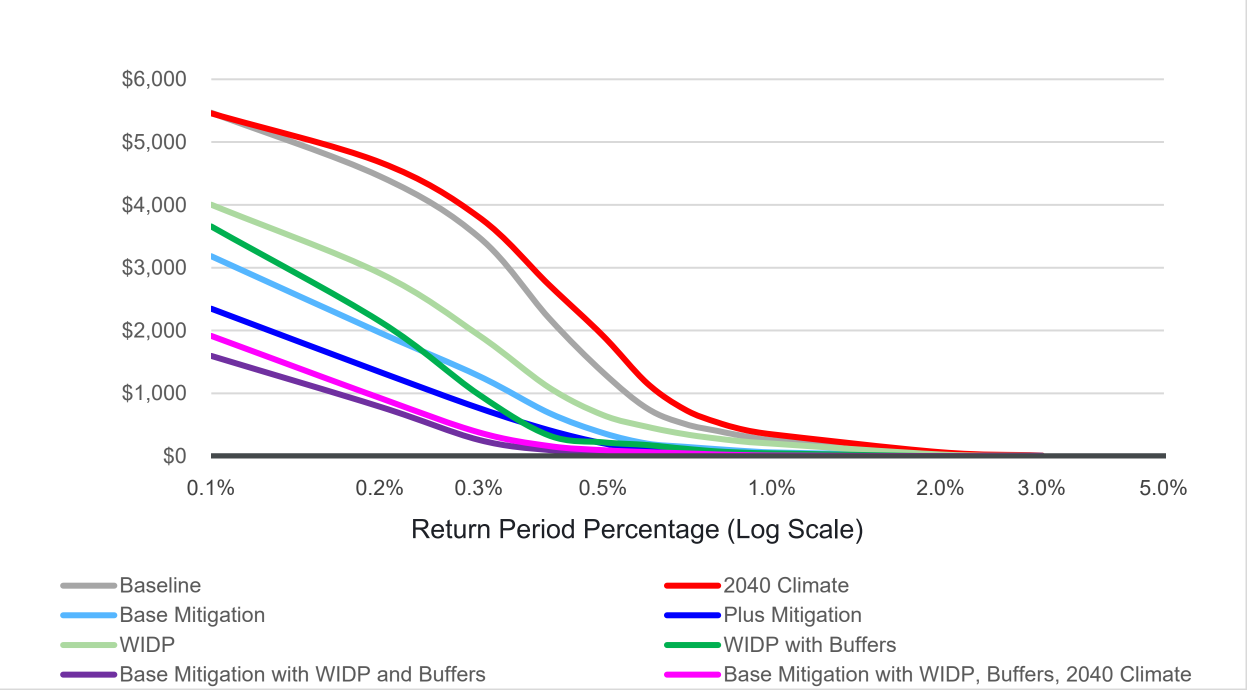
The expected loss is just one aspect of risk. To understand what losses *could* be, instead of what losses *are expected to be on average*, one needs to consider EP Curves. EP Curves are another key metric produced by probabilistic catastrophe models. They provide the likelihood that a loss of a given size or greater will occur in any year—the annual exceedance probability. This is often summarized by key return period loss levels. For example, a 1% annual probability of exceedance corresponds to a 100 year return period loss (i.e. 1/100 = 1%).

We reviewed the EP curves on an Aggregate Exceedance Probability ("AEP") and Occurrence Exceedance Probability ("OEP") basis. AEP curves are based on the total aggregate losses for a given year, while OEP curves are based on the largest single loss for a given year. While recent history has demonstrated that it is common for there to be multiple impactful regional wildfires in a given year, the probability of multiple such fires to directly impact a region with the size of the study area is relatively small compared to the probability of a single fire impacting that area. As a result, the AEP curves and OEP curves are very similar. The discussion focuses on the AEP curves but the conclusions based on the OEP curves would be identical.

Figure 13, below, shows the AEP curve for each of the eight scenarios.

The grey line shows the baseline scenario: If the town was built back exactly the same as pre-Camp Fire standards, the town should expect a 1 in 100 year loss of $254 million. The Camp Fire, which destroyed over 90% of structures in the Town of Paradise, is analogous to the magnitude of a 1 in 1000 year loss in the model results, where close to 90% of the Total Insured Value (TIV) is destroyed.

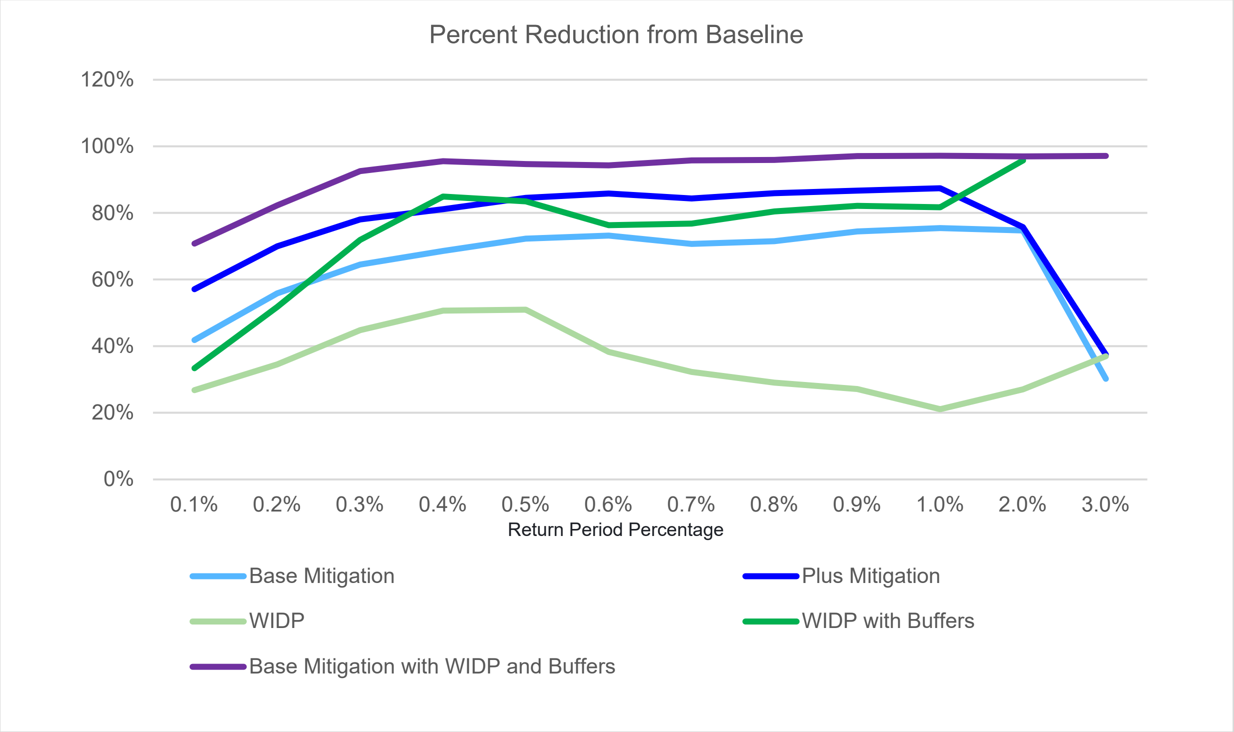
FIGURE 13: AGGREGATE EXCEEDANCE PROBABILITY CURVE, ALL SCENARIOS



The mitigation and adaptation actions are expected to not only decrease the average annual losses, but also reduce some of the worst-case outcomes by as much as half. For example, in the baseline scenario, a 1-in-1000 year loss is expected to be $5.5 billion in aggregate. If mitigation is performed as in the Base Mitigation scenario, this figure decreases by 42% to $3.2 billion. If WIDP and buffers are implemented on top of individual property mitigation, the 1-in-1000 year loss is expected to decrease by 71%, compared to the baseline scenario, to $1.6 billion.

The effectiveness of risk reduction techniques generally decreases for the most extreme events. Figure 14, below, shows the reduction in OEP curve loss amounts by return period for the Base Mitigation, Plus Mitigation, WIDP, and WIDP with External Buffers, and Base Mitigation with WIDP and Buffers scenarios. In general, the maximum reduction is achieved in mid-to-lower return periods (less extreme events). The risk reduction in all five scenarios started to decrease around the 250-year return period through the 1000-year return period. This is intuitive: in events like the Camp Fire, the extreme level of convection, radiation, and ember cast will likely overpower much of risk mitigation techniques. Home hardening features like class A fire roofs and fire resistive sidings are generally not designed to be fireproof, but rather to delay ignition so that firefighters have more time to react and residents have time to remove themselves from the structure. Moreover, with large fires and high wind conditions, ember spotting becomes the main source of fire transmission, so defensible space and buffers will become less effective.

FIGURE 14: PERCENT REDUCTION FROM BASELINE IN OEP CURVE LOSS AMOUNTS BY RETURN PERIOD



Note: Both WIDP scenarios in this graph do not include property-level mitigation.

INSURANCE PREMIUM

Estimated Insurance Premium and Net Cost of Reinsurance

The indicated total premium was calculated for each of the eight scenarios using the AAL output of CoreLogic's Wildfire Model and industry data.

As discussed above, the CDI does not allow the Net Cost of Reinsurance to be reflected in Homeowners premiums. For this analysis, indicated total premium is shown alongside the Net Cost of Reinsurance to illustrate the deficit an insurer would expect from excluding this cost. The details of the calculation and its components are shown in Exhibit 2. Both versions of indicated total premiums (including and excluding Net Cost of Reinsurance) and the premium deficit of excluding Net Cost of Reinsurance are shown in Table 9, below. As discussed in the methodology section, this analysis assumes no benefit of diversification, so the resulting estimated cost of reinsurance and premium deficit should be treated as the high ends of the range of possible values.

TABLE 9: SUMMARY OF ESTIMATED AVERAGE PREMIUM

SCENARIO	ESTIMATED AVERAGE PREMIUM BY EXPOSURE		PREMIUM DEFICIT
	INCLUDING NET COST OF REINSURANCE	EXCLUDING NET COST OF REINSURANCE	
Baseline	$5,850	$4,159	28.9%
Base Mitigation	$3,002	$2,537	15.5%
Plus Mitigation	$2,362	$2,102	11.0%
Baseline with WIDP	$5,162	$3,714	28.1%
Baseline with WIDP and buffers	$3,215	$2,792	13.2%
Base Mitigation with WIDP and buffers	$1,934	$1,876	3.0%
Baseline at 2040 climate expectations	$7,210	$4,663	35.3%
Base Mitigation with WIDP, buffers, at 2040 climate	$2,144	$1,989	7.3%

The difference between the eight scenarios is driven by the wildfire AALs and the Net Cost of Reinsurance. Scenarios with higher AALs per location have a higher wildfire premium and a higher Net Cost of Reinsurance based on the calculation discussed in the Methodology section. On the other hand, the scenarios with more risk reduction measures applied have lower indicated premiums as well as lower Net Cost of Reinsurance. The lower cost of reinsurance is due to the reduction in losses in the tail of the distribution, as discussed in the EP Curves section. Because extreme events in these scenarios have much lower losses than extreme events in the baseline scenario, the expected ceded portion of losses is much lower, even if the Town maintains the same reinsurance structure (5% probability of attachment and 0.5% probability of ruin). As a result, the expected premium deficit due to Net Cost of Reinsurance not being included is also lower in the risk reduction scenarios. In other words, insurance premiums will tend to be more in line with the indicated total cost of risk transfer if risk reduction measures are put into effect, and companies can be more confident that their rates are closer to adequate for the risk.

However, in all the scenarios modeled for the Town of Paradise, there is still a premium deficit when the cost of reinsurance is excluded from the premium. The deficit caused by not being able to include these costs in the premium is a key reason why insurers are reluctant to write in high wildfire risk areas, such as Paradise.

Benefit of Diversification

As noted in earlier sections, this case study assumes a hypothetical insurance company that operates solely in the Town of Paradise. In reality, insurance companies write policies in geographically diverse areas, so that their portfolios are diversified. The danger of having a concentrated portfolio is that one large event like the 2018 Camp Fire can wipe out the whole book. On the other hand, a portfolio that has, say, 10% of its policies in the Town of Paradise, would only have 10% of its portfolio experience losses in an event like the 2018 Camp Fire.

The value of diversification lies in the statistical independence of insured properties. In the case where a company's portfolio is geographically diverse, it is unlikely that one catastrophic wildfire event will affect multiple geographies. While the expected loss to TIV ratio will stay the same despite diversification[23], EP curves are sub-additive. In other words, a geographically diverse insurer would charge the same premium (not including the Net Cost of Reinsurance) as one that is not geographically diverse, but the former should expect less severe extreme events. An estimation of the benefit of diversification is highly dependent on the specific correlation assumptions of the losses and is beyond the scope of this discussion, but it is important to know that diversification is a key aspect to successful risk management for any insurer.

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[23] The expected value of a sum of random variables is the sum of the expected values of the random variables, regardless of correlation.

Limitations

USE OF REPORT

The data and exhibits in this report are provided to support the conclusions contained herein, are limited to the scope of work specified by the Town of Paradise associated with the California Resilience Challenge Grant, and may not be suitable for other purposes. Milliman and CoreLogic are available to answer any questions regarding this report or any other aspect of our review.

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DATA RELIANCES

In performing this analysis Milliman and CoreLogic relied upon information obtained from the Town of Paradise, CDI, IBHS, and other sources. Milliman and CoreLogic have not audited or verified this data and information. If the underlying data or information is inaccurate or incomplete, the results of the analysis may likewise be inaccurate or incomplete. In that event, the results of the analysis may not be suitable for the intended purpose.

Milliman and CoreLogic performed a limited review of the data used directly in the analysis for reasonableness and consistency. Milliman and CoreLogic did not find material defects in the data. If there are material defects in the data, it is possible that they would be uncovered by a detailed, systematic review and comparison of the data to search for data values that are questionable or relationships that are materially inconsistent. Such a detailed review was beyond the scope of this assignment.

MODEL RELIANCES

This analysis is based on the CoreLogic Risk Quantification and Engineering U.S. Wildfire Model, version 22.1. To the extent that the model used is biased, the resulting analysis may be biased.

UNCERTAINTY

Differences between the projections and actual amounts in this report depend on the extent to which future experience conforms to the assumptions made for the analyses. It is certain that actual experience will not conform exactly to the assumptions to be used in these analyses. Actual amounts will differ from projected amounts to the extent that actual experience is better or worse than expected.

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Appendix

See attached exhibits.