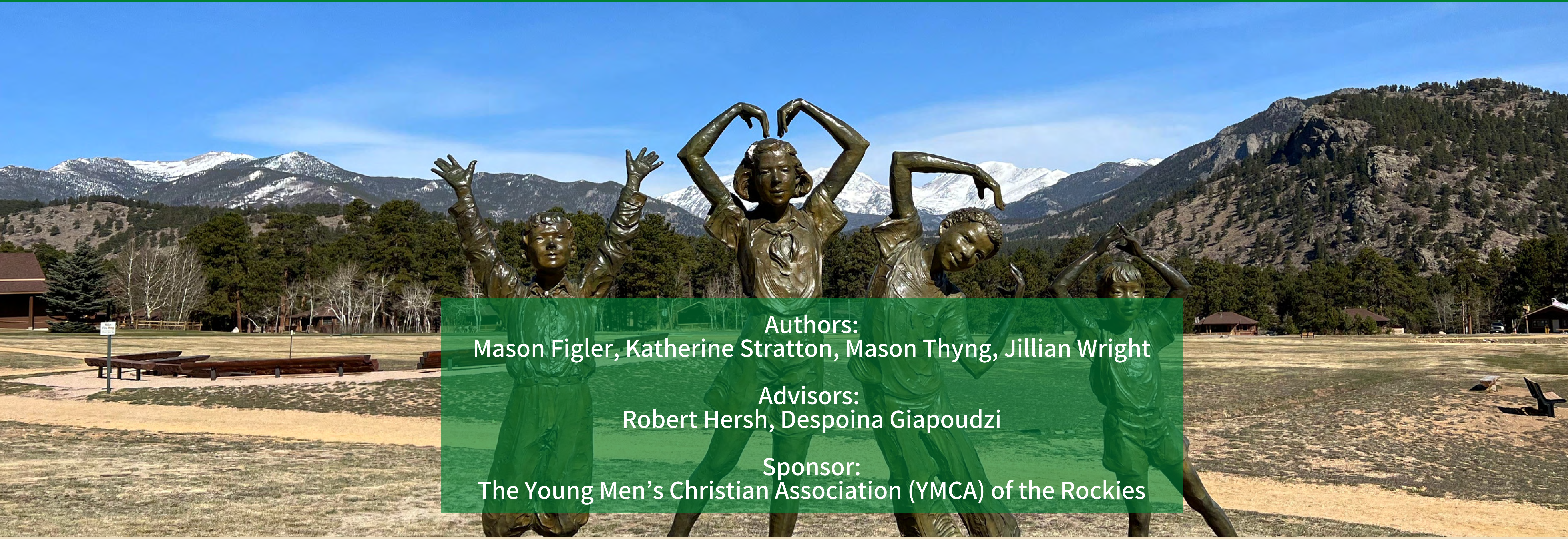
ASSESSING WILDFIRE RISK TO THE BUILT ENVIRONMENT AT THE ESTES PARK YMCA



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Sponsor:
The Young Men's Christian Association (YMCA) of the Rockies

Assessing Wildfire Risk to the Built Environment at the YMCA

An Interactive Qualifying Project submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfilment of the requirements for the degree of Bachelor of Science

by
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Report Submitted to:

The Young Men's Christian Association (YMCA) of the Rockies
Organization

Professors Robert Hersh and Despoina Giapoudzi
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I. Abstract

The YMCA of the Rockies, located in Estes Park, Colorado, faces increasing risks of wildfire due to the impacts of climate change. Our goal was to identify cost-effective measures to help the YMCA better protect its built environment from wildfires. We assessed the external vulnerability of structures at the Y based on ignition points, and conducted a cost-analysis to identify risk-reducing improvements to both the structure composition and surrounding landscaping, to increase the overall resilience of the campus against wildfire.

II. Acknowledgements

Throughout our IQP experience, we engaged with several people that helped us create a successful project. We would like to thank our sponsor, the YMCA of the Rockies, especially Donovan Colegrove, Kelly Wilkerson, and Troy Husler. Their contribution to our group allowed our work to be as successful as possible. We would also like to thank our advisors, Robert Hersh and Despoina Giapoudzi, for their advice and insight throughout the entire IQP process. They guided with the right connections and ideas that inspired many aspects of our project.

We would like to thank The Estes Park Fire District for their contribution to our work. Their expertise of wildfire risk guided us to a proper and in-depth analysis of the YMCA's property. The information and data collected from our assessments greatly improved with the knowledge that they shared.

III. Authorship

Chapter/Section	Primary Author(s)	Secondary Author(s)	Editor(s)
Abstract	Wright	Wright, Figler	Figler
Executive Summary	Stratton, Wright	Stratton	Stratton
Introduction	ALL	Stratton, Wright	ALL
Background	ALL	ALL	ALL
Methods	Figler, Stratton, Wright	ALL	ALL
Findings	Figler, Stratton, Wright	ALL	ALL
Recommendations/Conclusion	Figler, Wright	ALL	Stratton

"ALL" indicates that every author participated for a particular job in the indicated section

Meet The Team

Mason Figler

My name is Mason Figler and I am double majoring in Robotics Engineering and Electrical and Computer Engineering at WPI. I am from Baltimore, MD and after completing this IQP project I have gained many invaluable experiences. The standout memory is of the people. Everyone at the YMCA was always friendly and supportive of in any way possible. Getting to experience the wonders that the YMCA and Estes Park has to offer will always be held to me and I am thankful for this IQP.

Katherine Stratton

I'm Katherine (Katie) Stratton, and I'm is a Biology & Biotechnology major and theatre minor at WPI. Both personally and professionally, I am interested in studying aspects of fire ecology and how fires affect the surroundings they burn in. I am also interested in an introduction to coding through the project. I am very thankful to the YMCA for allowing our team to contribute to their beautiful campus through our IQP, and for being given the chance to explore Estes Park.

Mason Thyng

I'm Mason Thyng and I'm an aerospace engineer at Worcester Polytechnic Institute. I was born and raised in the town of Candia New Hampshire and this is my first time visiting Colorado. I've loved the outdoors since I was a young child, and my time as a Boy Scout instilled in me the desire to protect it.

Jillian Wright

My name is Jillian Wright and I'm majoring in Computer Science. I'm from Cape Cod, MA and this IQP project has opened my eyes to the risk of wildfire not only to the environment of Colorado, but the mentality of the people who live here. I am very thankful for the opportunity to work to make the YMCA a safer place for everyone. Exploring Colorado has been such a unique and fun experience that I will never forget.

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VI. Executive Summary

Background

Our sponsor, the Young Men's Christian Association of the Rockies (YMCA), is a resort based in Estes Park, Colorado that has faced an increased threat of wildfires for the past few decades. The main campus is surrounded on three sides by Rocky Mountain National Park, and uses wildfire mitigation techniques such as forest thinning and controlled burns to protect its property.

Wildfires have become more frequent and severe in the dry climate of the Rocky Mountains due to climate change, encroaching development on wildlands, and fuel buildup in the western forests. The YMCA itself has been threatened by fires in the past, the most recent occurrence being the East Troublesome Fire, where high winds and low humidity spread a forest fire from Rocky Mountain National Park across the Continental Divide before stopping at Estes Park's western slope. This fire was extremely destructive, decimating 193,812 acres of wildland and nearly 400 structures. The Estes Park Center of the YMCA was forced to evacuate, and if the fire had not stopped due to wind shifts and significant snowfall, it would have burned the YMCA campus.

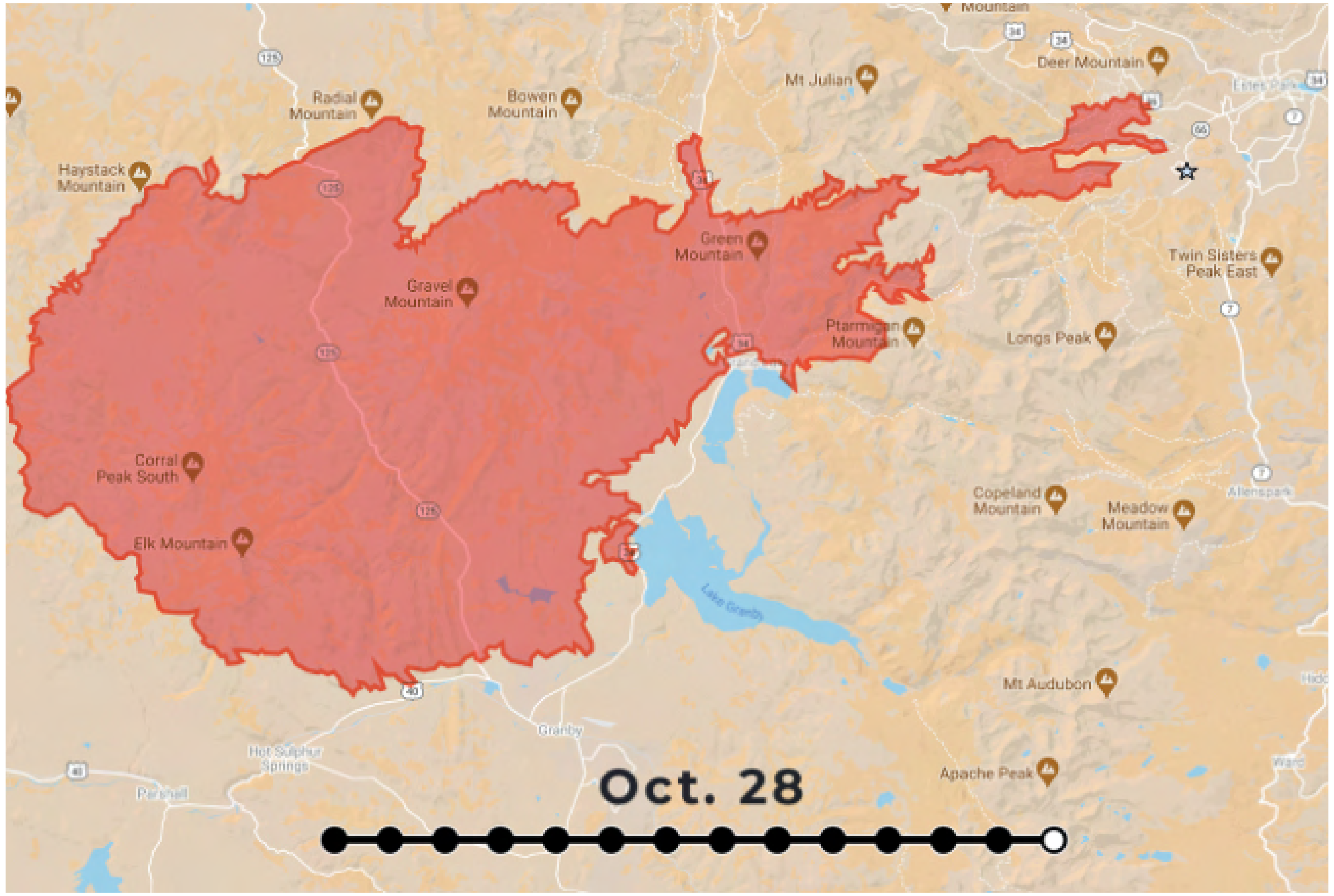

Figure A: A map of the total area burned during the peak of the East Troublesome Fire. The star represents the location of the YMCA of the Rockies (Beaty, 2020)

Goal and Objectives

The YMCA, one of the major tourist draws to Estes Park, Colorado, sought to better protect its main campus from wildfire threats, especially its guest cabins that are scattered deep within the wooded areas of the Y. This IQP project was designed to develop recommendations for the YMCA to retrofit its cabins and other vulnerable structures using alternative materials with the goal of reducing wildfire risk.

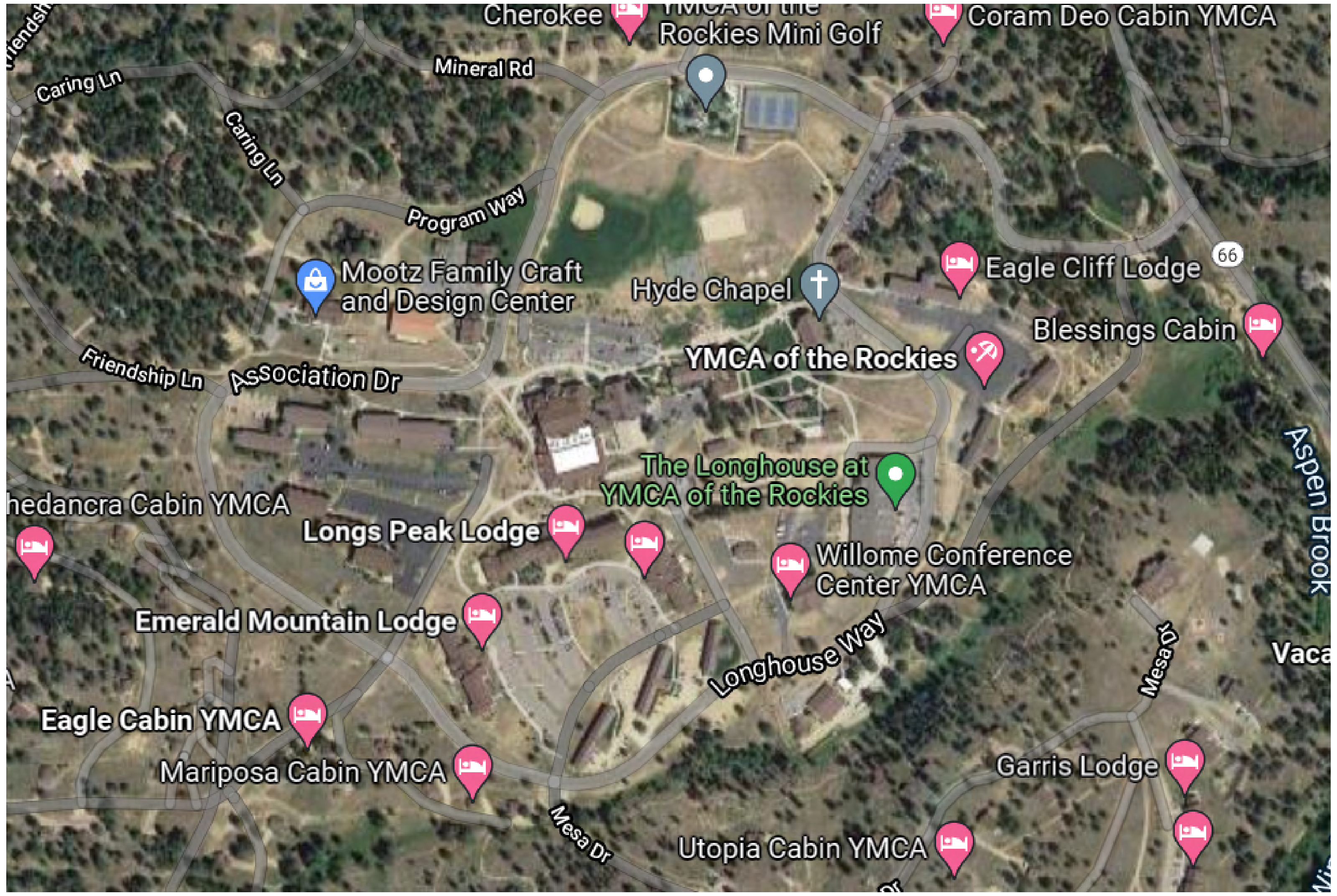

Figure B: A close-up map of the YMCA of the Rockies main campus (Google, 2022)

To achieve our goal we identified the following objectives:

- Obtain local perspectives of fire risk at the YMCA through key-informant interviews
- Assess the cabins' current fire vulnerabilities to wildfire through photo documentation, blueprint analysis, and in-depth data collection during assessment tours
- Create an interactive map that will allow the YMCA staff to analyze data regarding its cabins and to make decisions about retrofitting and maintenance
- Conduct a cost analysis of potential retrofitting modifications to the cabins

Vulnerabilities, Concerns, and Limitations

We conducted several semi-structured interviews with YMCA staff to understand their concerns on wildfires affecting the campus and the various constraints on implementing new mitigation strategies, as well as what mitigation techniques were being used at the time to prevent wildfires.

Cost Analysis on Building Materials

To better tailor our recommendations to the YMCA for fire resistant building materials, we compared the costs of using pine log siding to the cost of using fiber cement siding, which is significantly more fire resistant. This was done by analyzing invoices for the 7 cabins built in 2021. We also calculated the prices of changing their roofing materials from asphalt architectural tiles to aluminum panels, and how much it would cost on average to add gutter covers and eave soffit covers to the roofs of the buildings. The composite material that the YMCA has been using recently to build porches, Trex, only has a Class C Fire rating, so we also explored how much it would cost to use an alternative composite material with a Class A Fire rating.

Assessing Cabins for Wildfire Risk

From our interviews with the Estes Valley Fire District's Senior Fire Inspector, the YMCA's Head Groundskeeper, and the YMCA's Head of Buildings and Maintenance, we learned how to identify and prioritize each potential fire hazard within a building's defensible space, including plant proximity, debris presence, and non-organic hazards such as deck chairs or grills. "Defensible space," as defined by the Home Ignition Zone model for home fire safety, is the space around a building which should be modified to better defend the building, creating a barrier between the wildland and the home. In the case of this project, a cabin's defensible space was defined as the 30 foot radius around the cabin walls. Once identified, we constructed a standard assessment form for the cabins on campus and assessed in person each cabin and vulnerable building in the Estes Park Center.

Analyzing and Visualizing Risk

To better visualize the collected data and gain a better understanding of where the vulnerable buildings were located, we connected the cabin assessment data to several maps created in Google Reports (Figure C). The interactive maps give the staff at the YMCA the ability to better visualize patterns within the data on a spatial basis. These maps displayed the location of each cabin and highlighted the risks from the vegetation in proximity to each cabin and each structure's vulnerability score. This scoring was constructed through research on vulnerable aspects of homes from the Colorado State Forest Service, FireWise, and the Insurance Institute of Buildings and Home Safety. The main method of representing the vulnerability score was through a heat map, which displayed clustered areas of vulnerable cabins (Figure D).

How Vulnerable are the YMCA's Cabins to Wildfire

Once the vulnerability of each cabin was calculated, we determined that the average cabin is vulnerable to wildfire but not extremely so. The most vulnerable cabins had scores above 50 points, often caused by combustible siding and decking materials and plant proximity within the cabin's defensible space. The most vulnerable buildings were Bison (114 points) and the Mountainside Lodge (133 points), located at the very end of Mountainside Drive. The least vulnerable cabins were the newest ones, since they were built using more fire-resistant materials and had less damage. These cabins were often located on Mesa Drive and Association Road. The lowest cabin score was 5, belonging to Ponderosa cabin.

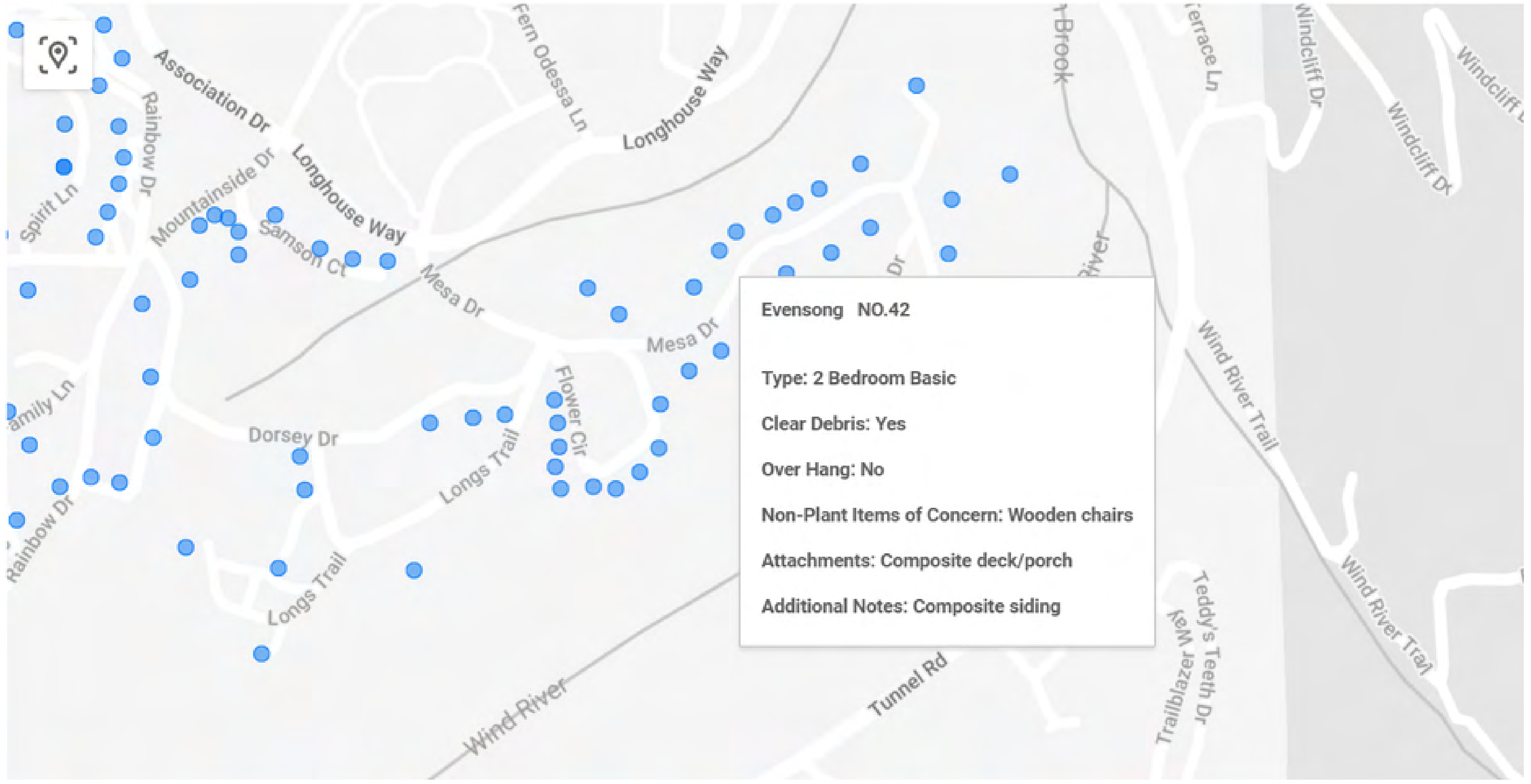

Figure C: User Interface Mockup of Map

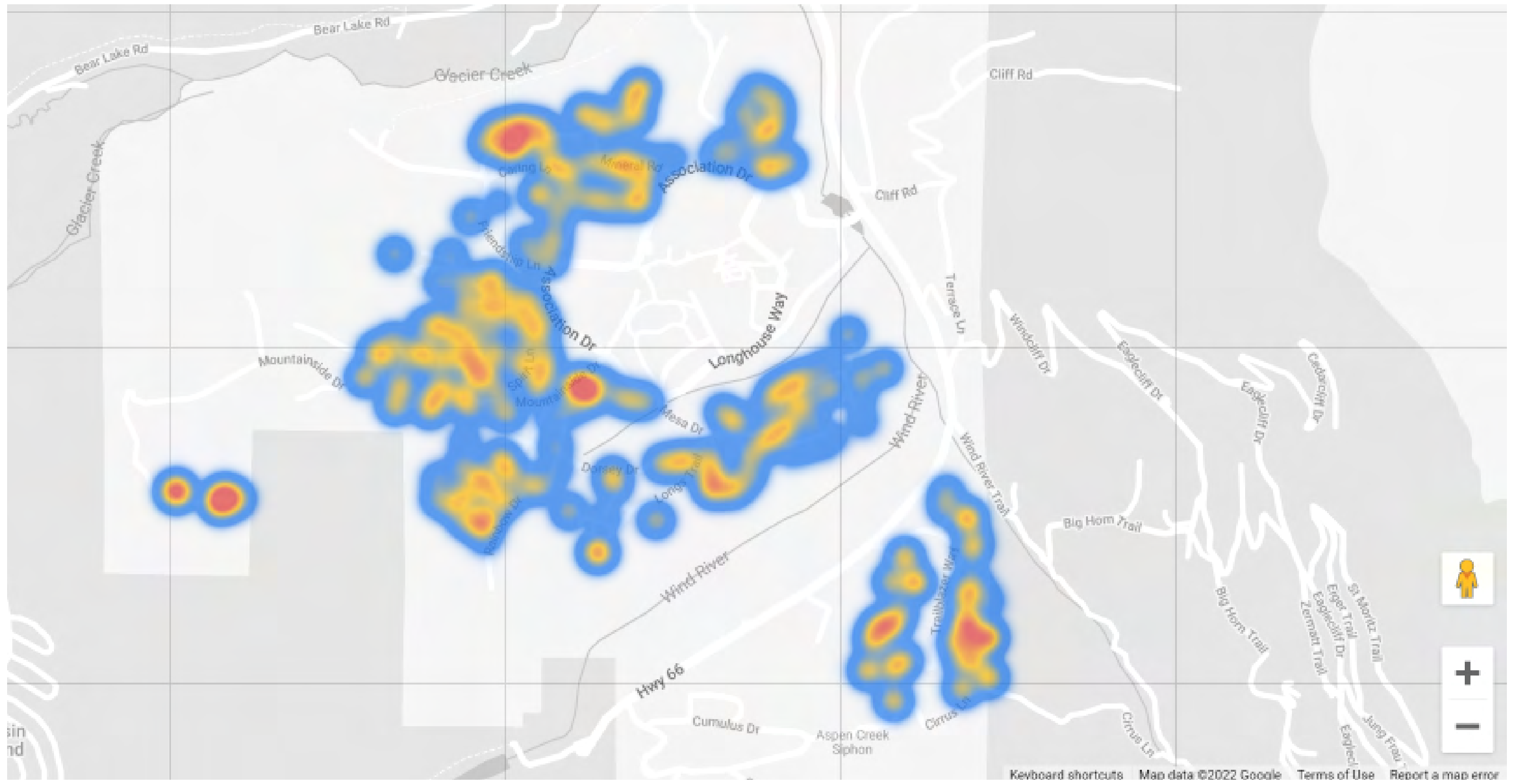

Figure D: Heat map of campus showing areas with highest cabin vulnerability.

Costs of Building with Fire Resistant Materials

From our research, using metal roofs instead of asphalt tiles would not provide any more protection than needed, and would cost significantly more than the tile roofs since it would require replacing every single roof on campus. As for gutter and eave soffit covers, it would cost only an additional couple hundred dollars, making them ideal for a capital project to add to several cabins per year. If a capital project is not possible, the cost is small enough that their additions can be folded into the cost of the cabin adoption program. To account for the cost of the additions, we suggest the YMCA cabin adoption cost for donors be increased approximately 4% to cover the additional costs of gutter covers and soffit covers specifically.

Constraints on Implementing Effective Wildfire Mitigation

The YMCA was limited in what it could do for building retrofitting since all cabins are updated on a 25 year basis depending on who donates to adopt a cabin, with the exception of the lifetime donation cabins. It can only update up to 7 cabins per year, and the time window during which renovations can occur is slim and often obstructed by weather patterns. Another limitation identified was that there are simply not enough feet on the ground to thoroughly identify all potential fuel risks around each cabin and remove them.

What Can the YMCA Do?

Vegetation

We recommend that tree overhangs should have limbs removed to around 10 feet above the roof. Vegetation within 5 feet of the building or under porches, should be removed altogether. Finally, all types of debris should be removed: branches, logs, duff, and any dead standing or fallen trees found around the building. This removal will largely eliminate the risk that the vegetation will ignite the building.

Existing Buildings

For what the Y should do for existing buildings, wooden siding materials should be replaced with fiber cement panels, and any porches made of wood should instead be replaced with composite decking material if the deck in on an incline. If not on an incline and instead on flat land, the porch should be made out of cement.

The smaller-scale factors to consider mainly consist of maintenance tasks. Any gutters that are filled should be cleaned out at least twice a year, as many are filled with pine needles. Any holes in siding should be repaired or filled using caulking if they will not be renovated soon through the cabin adoption program. All branches resting on power lines should be removed, and all miscellaneous surrounding items should be removed so they are at least 30 ft away from the building. We suggest the costs of these tasks be covered by the Buildings and Grounds' operating budget.

The cabins that require immediate attention are Bison, Mountainside Lodge, Eagle, Blue Bird, Blue Bell, Oriole, and Wren's Nest, as well as any cabin with a vulnerability score above 50 points. Other than those cabins, the YMCA should focus on retrofitting the oldest cabins first, as they are in the worst shape.

Additions for New Buildings

New buildings should utilize fiber cement siding due to its high fire class rating. It would cost more to use said material, but as the YMCA currently uses fiber cement siding for most of its newest projects we believe it is a feasible recommendation. Porches should be made of composite railing and cement flooring instead of wood if possible, and composite siding when not. Gutter covers should be implemented as well as covered eaves, which can be financed through a proposed capital project. Regarding location, building at the top of an incline should be avoided if possible, especially if that slope is westward facing. Locations surrounded by dense forests or a large number of trees should be avoided. Any plants within 5 ft of the structure should be avoided, as well as building near juniper, whether that means finding a new location or removing the plants during construction. Finally, general debris such as pinecones and pine needles, as well as any tall grasses, should be cleared around the structure before it is finalized. The expenses for clearing these plants are low enough to be financed through Building and Grounds' operating budget.

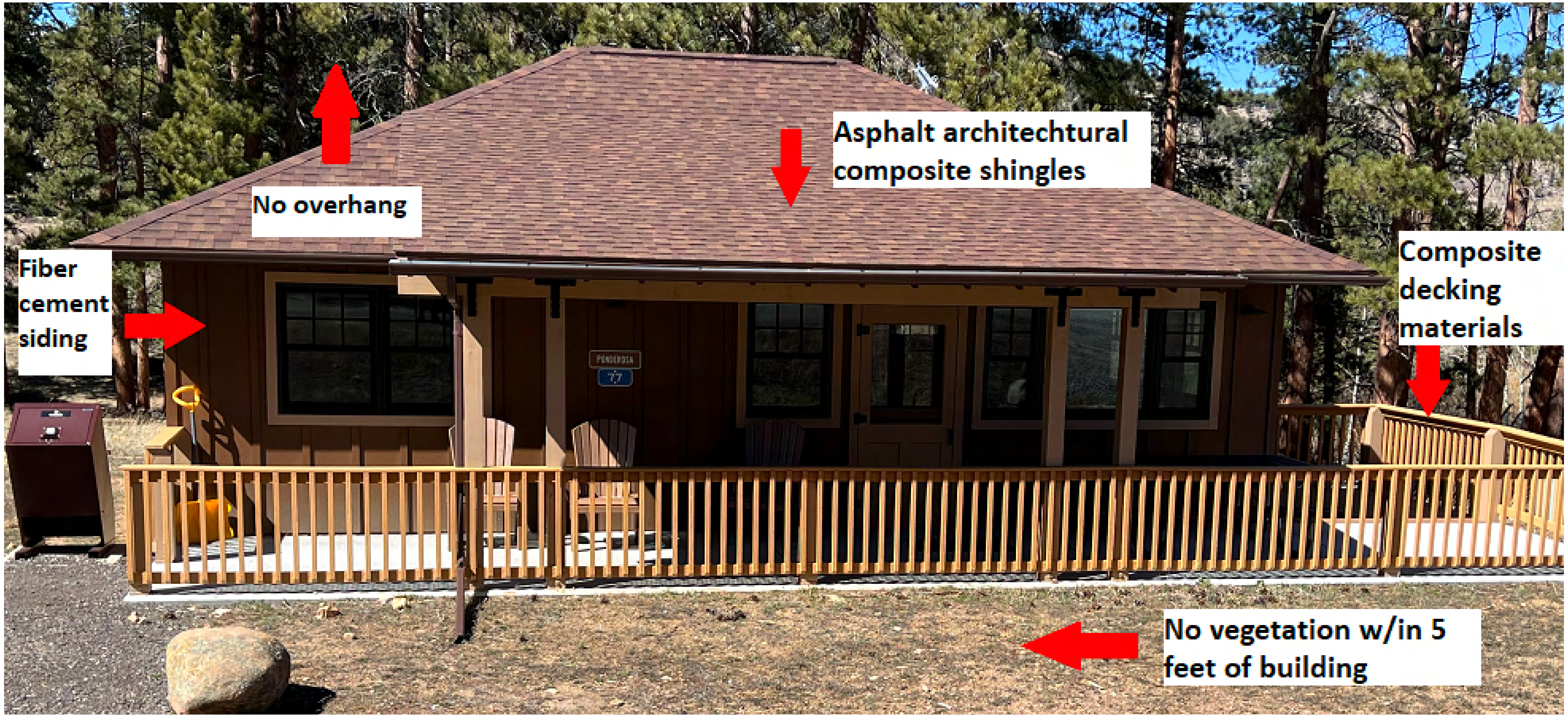

Figure E: Diagram of cabin (Ponderosa) with proposed retrofitting changes

CHAPTER 1: INTRODUCTION

Photograph of a firefighter closely monitoring a controlled burn in the woods of Madison, New Hampshire (Cavan/Alamy Stock Photo, 2019).

1.0 Introduction

Over the past twenty years, wildfires have increased in both frequency and severity on a national scale. In the US, the average acreage burned annually between 1990 and 2000 averaged 3.7 million acres, while between 2010 and 2020, 7.1 million acres went up in flames, creating a 42% increase of acres burned in the past 10 years (Hoover & Hanson, 2021). While wildfires are a natural occurrence that benefit the environment, conditions such as climate change and encroaching urbanization on wildlands have caused these fires to exhibit new erratic and highly destructive behavior in recent years, leaving heavily forested areas more susceptible to wildfires.

Colorado, specifically the Rocky Mountains region, had grown especially vulnerable to wildfires, with the top three wildfires in Colorado history occurring in 2020 alone (Wright, 2022). Climate change in the area had decreased the yearly snowpack and caused drought conditions, which increased the volume of potential fuels. As recently as October 2020, the East Troublesome Fire, spurred on by high winds and low humidity, swept through Colorado and destroyed 193,812 acres of wildland and nearly 400 structures (Encyclopedia Staff, 2020). This fire swept through the Rocky Mountain National Park and crossed the Continental Divide before stopping at the western edge of Estes Park. The YMCA of the Rockies, as figure 1 indicates, was dangerously close to being destroyed and was forced to evacuate the campus. The location of the YMCA is indicated with a black star in the upper right portion of the map (East Troublesome Fire Information, n.d.) (Figure 1 - Right).

The YMCA has put many practices in place that focus on reducing wildfire risk in terms of forest thinning and fuel reduction treatments. About 10-12 years ago, there was a Rocky Mountain pine beetle infestation, and all of the trees killed have since been removed by staff. Slash piles were accumulated in the summer and burned in the winter. There was a focus on fuels located on the mountainside above the property, as there is a dense lodgepole forest that needs constant attention and maintenance. To complement the wildfire risk reduction efforts at the landscape scale, the YMCA has prioritized the protection of the 232 cabins on its main campus, most of which are surrounded by forest.

Our goal for this project was to identify cost effective measures to help the YMCA better protect its cabins from wildfires. We identified the current fire vulnerabilities of the cabins through a series of key informant interviews with local fire protection experts and the YMCA's groundskeepers. We also assessed vulnerabilities by analyzing the cabin blueprints, collecting data through photo documentation, and conducting an assessment survey. We used the data to construct a database for the YMCA to use and update for both regular maintenance and retrofits, and we mapped the data to identify vulnerable areas, noting if there are clusters of cabins with similar issues. Using this map and database, we conducted a cost analysis of potential retrofitting modifications to determine which cabin upgrades were most feasible for the YMCA to implement in the future.

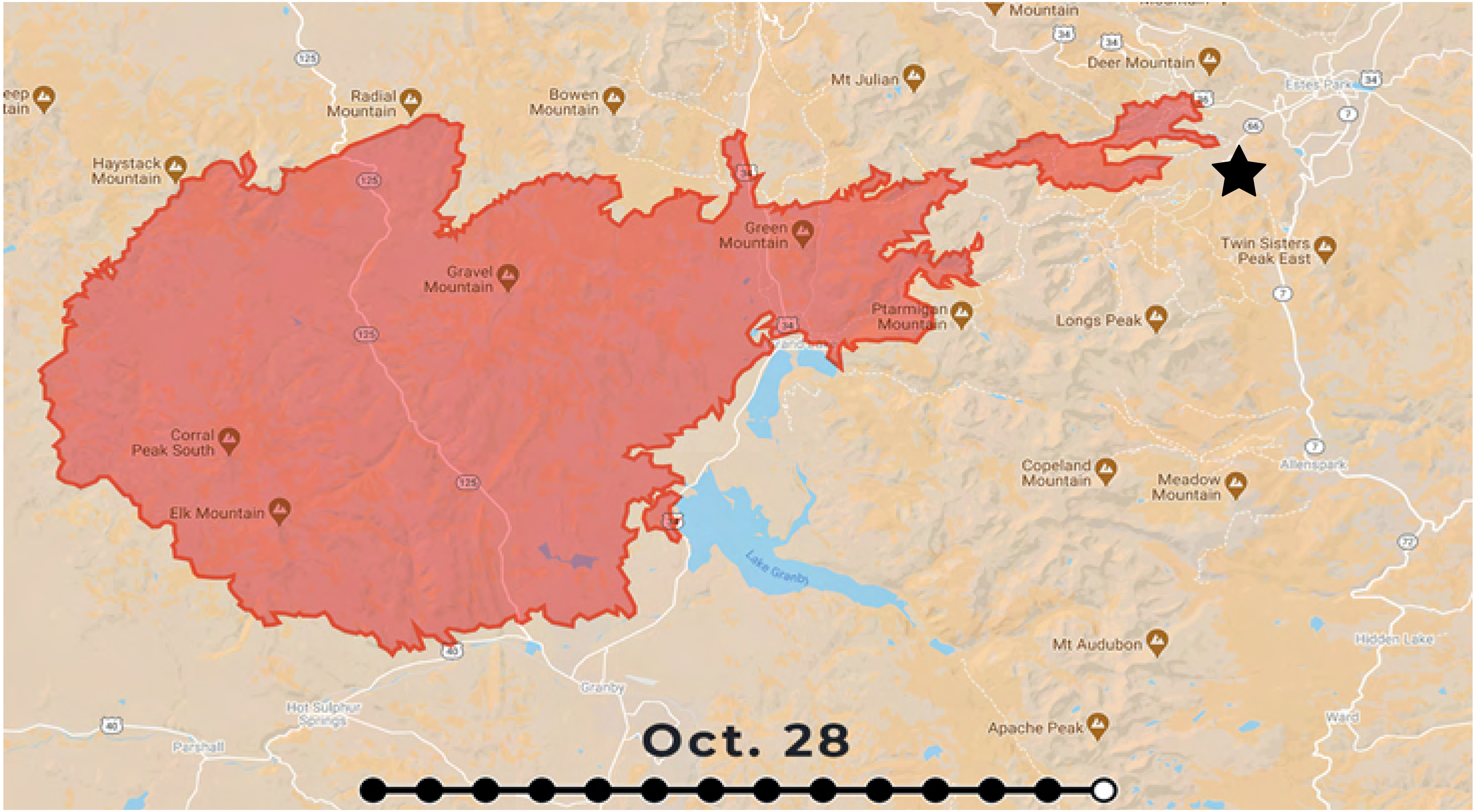

Figure 1: A map of the total area burned during the peak of the East Troublesome Fire. The star represents the location of the YMCA of the Rockies (Beaty, 2020)

CHAPTER 2: CONTEXT

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Photograph of Kruger Rock Fire burning through a forest (Sangosti, 2021).

2.0 Context

2.1 Causes of Wildfire

The US state of Colorado is home to mountains, alpine tundra, and many acres of land completely covered by forests and grasslands. These forests, while remaining an important ecosystem for all different kinds of wildlife, are extremely susceptible to devastating wildfires, caused by climatic, ecological, and social changes. The threat of wildfires in the Rocky Mountain Region has increased exponentially over the past few decades. Since 1984, 99% of the land burned by wildfires in the western United States have occurred in 2002, 2012, 2016, 2017, and 2020, and the gap between years is getting smaller (Higuera, Shuman, & Wolf, 2021). Section 1 of this chapter contains a brief overview of these changes and how they have led to an increase in life-threatening wildfires in the western United States. Section 2.2 discusses the different organizations that work to prevent and protect people and land from wildfires on a national, state and local level and how the organizations interact, while section 2.3 touches on the specific fire protection strategies used by organizations and individuals both to protect lands and structures from wildfires. Finally, section 2.4 provides an overview on fire risk analyses and how they are applied at both the YMCA of the Rockies and the town of Estes Park.

Climate Change

Climate change has increased the risk of wildfires over the past couple of decades, and has caused several key environmental changes, including the moisture in the soil, the types of flora in the area, and the levels of humidity in the air. These climatic changes have increased the length of the dry season and trended the Rockies area towards a dryer environment, causing a drought. The climate changes are also expanding the habitats of tree-infesting beetles, which kill trees and provide even more fuel to the fire. Westerling et al. (2016) states that fuel availability and flammability caused by changes in temperature and precipitation is the major contributing factor to wildfire risk.

Drought

According to the United States Environmental Protection Agency (EPA), the average temperature within the 48 continental United States has increased quickly since the 1970s, with an average increase of 0.31 to 0.54 degrees Fahrenheit per decade since 1979 (US EPA, 2016). These increased temperatures in such a short period of time led the Rocky Mountain Region to experience abnormally increased drought conditions, which only exacerbated the region's fire risk situation. There are three types of drought an environment can experience: meteorological (dry conditions caused by lack of precipitation), agricultural (lack of soil moisture), and hydrological (lack of water runoff) (National Oceanic and Atmospheric Administration, n.d.; U.S Department of Commerce, 2020). All three have impacted the Rocky Mountain Region's wildland to increase wildfire risk, but most of the damage is done by meteorological and hydrological drought.

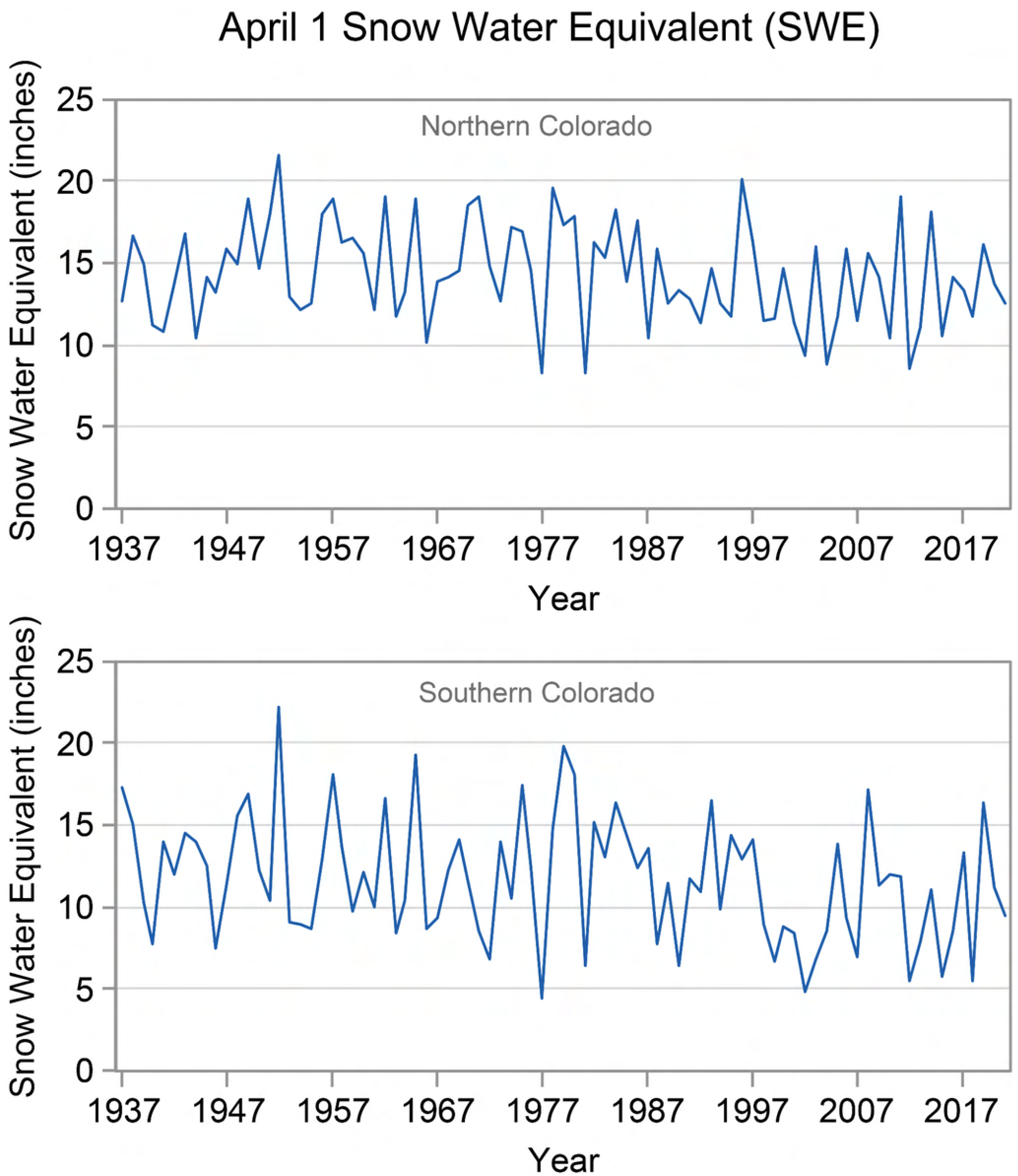


Figure 2: A chart of annual snow water equivalent (SWE) levels in inches in northern (top) and southern (bottom) Colorado, between the years 1937 and 2021 (Frankson, 2022).

Climate scientists claim that drought brought on by climate change is causing an increase in the potential for very large fires. As the seasonal temperatures in the Rockies rise, there is less snowpack during the winter. This snow accumulation from the winter melts from the more mountainous areas once the seasons change, providing moisture for the more forested areas at lower elevations throughout the summer and fall (Barbero, Abatzoglou, Larkin, Kolden, & Stocks, 2015). In the case of the Rockies, meteorological drought has contributed to hydrological drought, since the precipitation in the winter affects the amount of moisture the rest of the mountains get from the snowmelt. Figure 2 shows a chart of the annual snow water equivalent (SWE), or the amount of moisture contained within the snowpack, in inches for both northern and southern Colorado. According to the Colorado State Climate Summary of 2022, there is a decrease in SWE over the years in southern Colorado of 0.42 inches per decade, and of 0.26 inches per decade in northern Colorado (Frankson et al., 2022).

As stated above, drought due to changes in precipitation and temperature is a major contributing factor to increased fire risk due to the dry conditions increasing the availability and flammability of fuels, but it depends on the climate type. In arid climates, fuel availability is the larger issue, since the environment is sparsely vegetated to begin with and thus any increase in fuel availability may lead to a fire risk. In more moist climates -- such as the Rocky Mountains, as noted by Westerling et al (2016) -- there is an excess of vegetation that under normal conditions cannot be used as fuel because of its water content. However, when drought occurs due to lack of precipitation and temperature changes, there is not enough water in the environment to sustain its normal levels of vegetation, and thus the flora dies. This flora death leads to an increase in fuels available, causing bigger, hotter, and longer-burning wildfires that are next to impossible to put out by human means once started (Westerling et al., 2016).

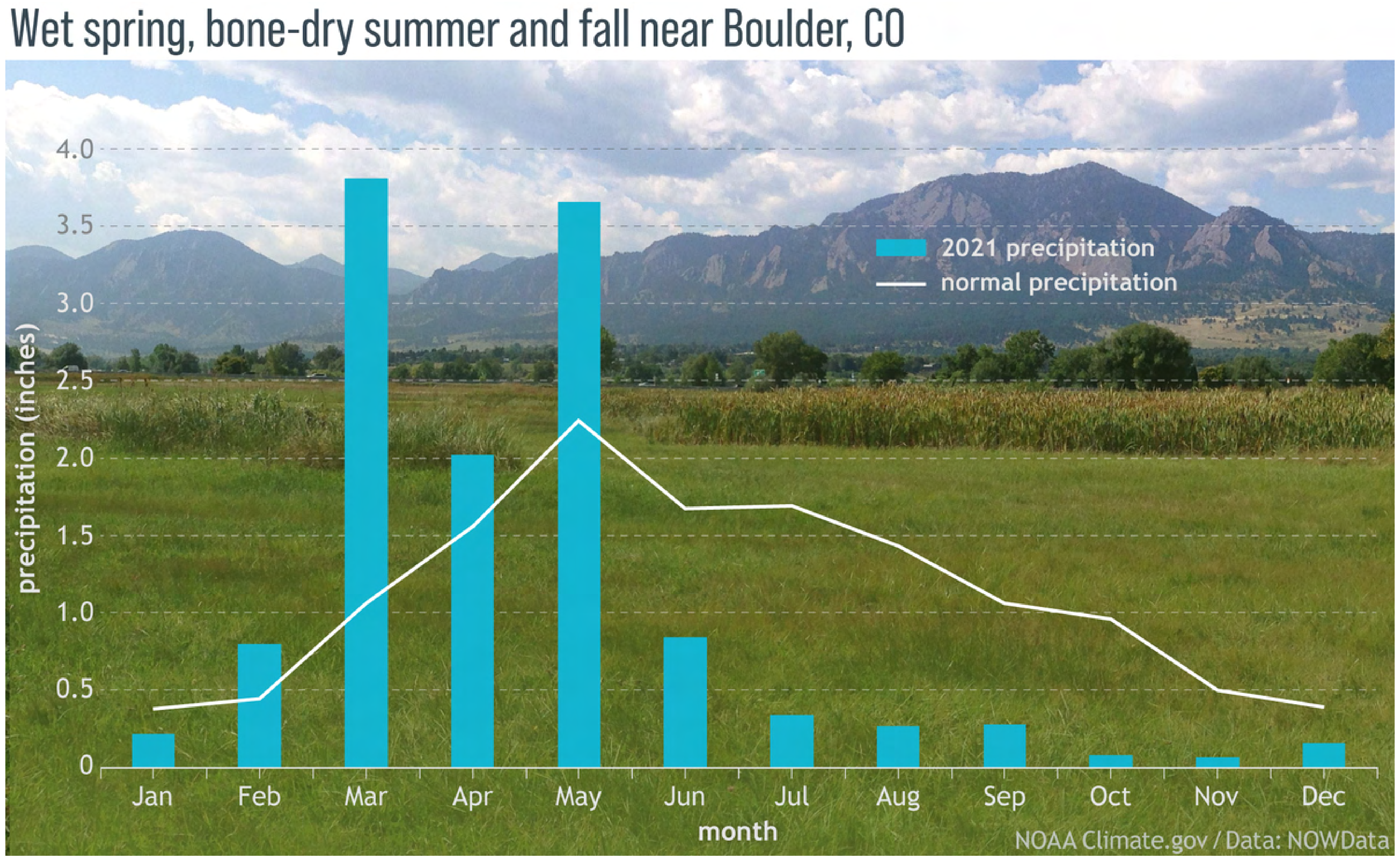


Figure 3: Monthly precipitation in 2021 at the Boulder, Colorado, weather station (blue bars) compared to average (white line). Background photo shows the foothills area in September 2014. NOAA Climate.gov image, based on data from NWS Denver-Boulder Forecast Office and photo by Flickr user MikeB, used under a Creative Commons license.

Currently, Colorado is experiencing the longest, most severe drought that the state has seen since at least 800 AD, according to climate scientist Brad Udall of Colorado State University's Colorado Water Institute. Udall highlights how even though the April 1st snowpack for the past two years has been close to 100% its average amount, the spring runoff has decreased dramatically. The overall warmer temperatures, with peaks in June, July, and August that drain soil moisture, has led to a massive dropoff in snowpack runoff. For example, in 2000 the Colorado River Basin, the area in which the Colorado River and all of its feeding streams reside, was 95% full. In fall of 2021, the reservoirs were at the lowest levels on record, barely reaching 39% capacity (Outcalt, 2022).

Some may argue that Colorado's drought conditions only pose an issue during the summer months due to snowfall during the winter and thus drought should not be a major contributing factor towards the state's current wildfire crisis. While this is incorrect, there are times when Colorado gets above average rainfall during the wet season, which can also pose a fire risk. In a news article posted by the NOAA's website Climate.gov, author Michon Scott explains that it was the increased rainfall during the spring and severely decreased precipitation during the summer that helped lead to the severity of the Marshall Fire that swept through Colorado on December 31st, 2021. Figure 3 shows a graph that details the monthly precipitation in 2021 of Boulder, Colorado. In this graph, it clearly shows how Boulder experienced precipitation in March and May far above what the area usually experiences, and then in June and onwards the area experienced precipitation levels far below average.

When the spring months were unusually wet, it encouraged increased vegetation growth. However, when the summer came and brought with it hot and dry conditions that persisted throughout the rest of the year, this vegetative increase all dried out and created large stores of available fuel for a potential wildfire (Scott, 2022).

2.2 History of Fire Prevention in the US

To understand current methods of fire prevention, it is helpful to consider the history of fire prevention. Prior to the early 2000s, the National Forest Service's policy was based on the notion that the only way to mitigate the effects of forest fires was to completely suppress any fire possible, ignoring the positive effects forest fires have on the health of forests and the safety of those living near forested areas. In the 1930s, the US federal government implemented two plans: the Civilian Conservation Corps, a work relief program that helped set the framework for infrastructure at national parks, and the 10 a.m. policy. The purpose of these policies was to fight fires and build fire breaks, as well as eliminate any potential fire by 10 a.m. the day after the fire was initially reported. This policy, unfortunately, promoted fire fuels to accumulate over time, causing fires to increase in size and ferocity when they are lit (Tidwell, 2010). While fire exclusion helps prevent damage to structures such as homes built on the edge of wildland vegetation, or Wildland Urban Interface (WUI), it can cause significant harm to the health of the local ecosystem. According to the Rocky Mountain Research Station, the policy of fire exclusion and the resulting fuel buildup and change in forest ecology has made it more difficult to suppress fires as they occur, putting people who live in forested areas at greater risk of dangerous wildfires (Keane et al., 2002).

While the number of annual wildfires have decreased within the US over the last few decades, the damage the fires cause has increased drastically. According to data collected by the National Interagency Coordination Center (NICC) in its annual Wildland Fire Summary and Statistics Report, while there was an average of 78,600 wildland fires annually in the 1990s, these fires only burned a total of 3.3 million acres per year. However, when the average annual number of fires between 2000 and 2020 was significantly lower than that in the 1990s (70,600 fires annually on average), they burned nearly twice as many acres annually, destroying 7.0 million acres of land per year (Hoover & Hanson, 2021). Figure 4 is a representation of the data collected from that study. The gray peaks on the chart indicate the number of acres burned annually in the billions between 1991 and 2020, while the red line represents the annual number of fires in the thousands.

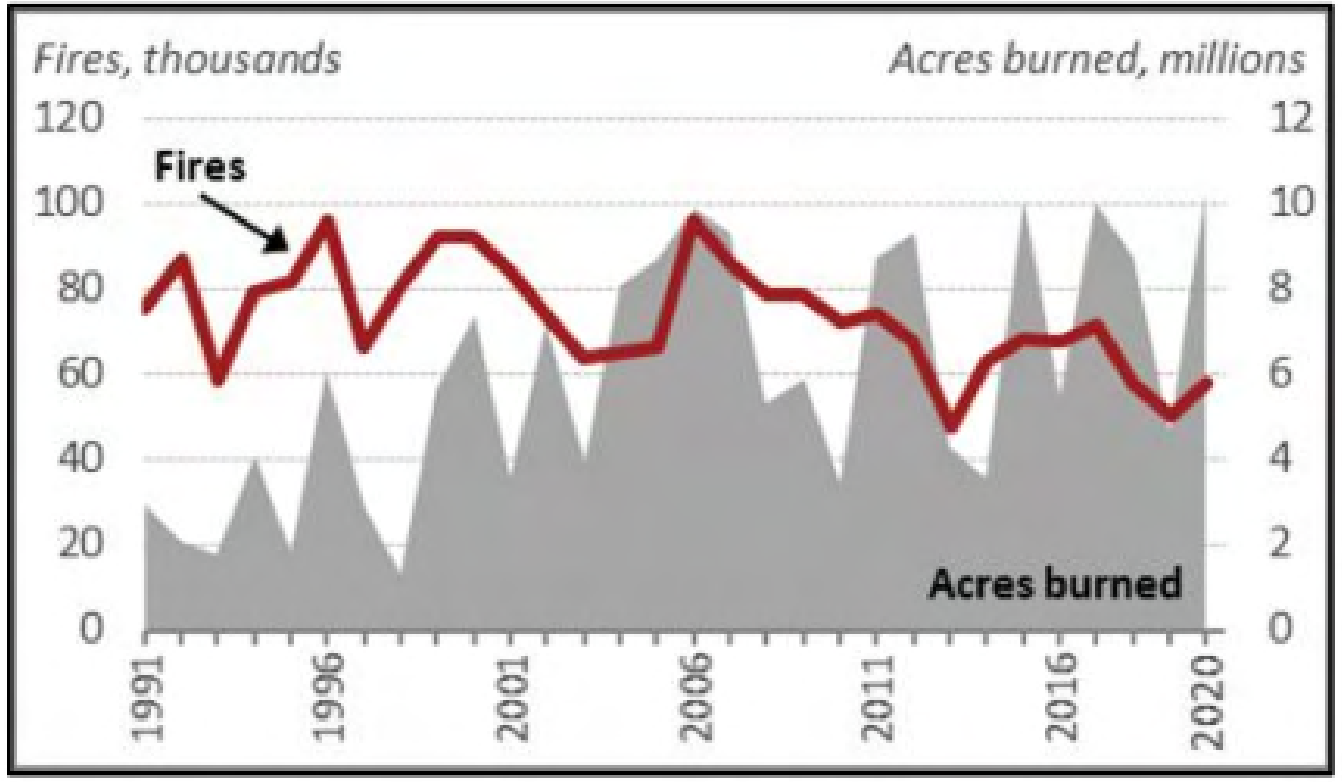


Figure 4: Chart of number of fires and amount of acres burned per year between 1991-2020 (Congressional Research Service, 2021).

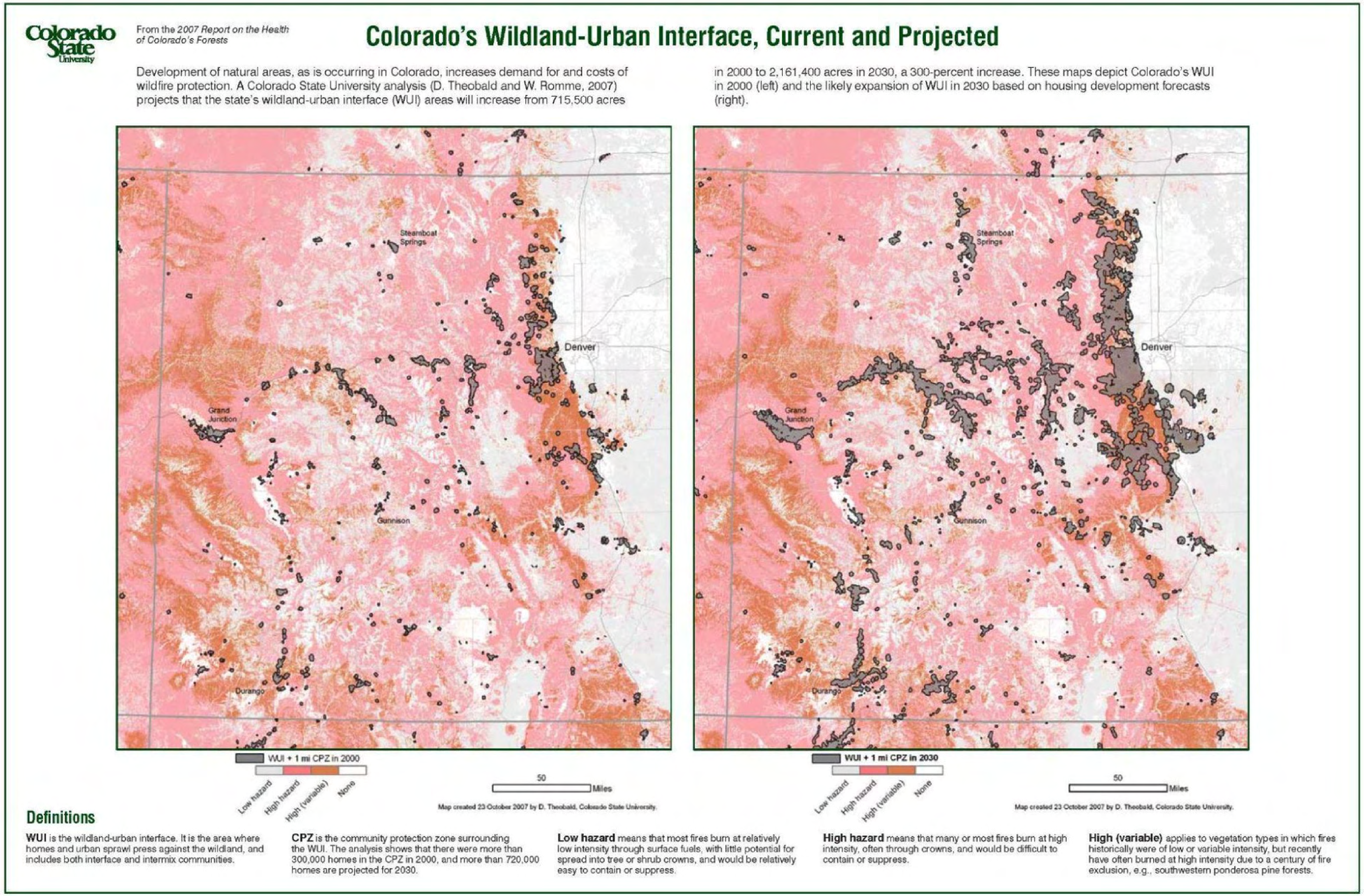


Figure 5: Map displaying the current (left) and projected (right) areas covered by the wildlife urban interface. The dark gray areas indicate the WUI with 1 mile of the Community Protection Zone (Colorado State University, 2007).

The Wildland-Urban Interface

Increased wildfire risk is not only caused by climatic and ecological issues, but by social issues as well. One such problem is the expansion of the WUI, the area in which houses and native vegetation intersect. Back in 2010, the WUI was found to cover 9.5% of the land in the continental United States, with 41% more houses being built in the area between 1990 and 2010. (Volker et al., 2018). While these properties are often viewed as desirable for the beautiful scenery that surrounds them, they pose a large risk when it comes to keeping people safe from wildfires. Living in the WUI puts people in very close contact with flammable vegetation, increasing the possibility of people sparking wildfires while also not allowing controlled burns to occur for fear of damaging homes (Volker et al., 2018). In later sections, we will discuss how structures in the WUI, such as residential homes, can be modified to better protect them from fire damage and prevent them from spreading a forest fire.

2.3 Current Strategies to Combat Wildfire

With many organizations actively fighting wildfire across the United States, it is important to examine their current strategies and how they are applied to reduce risk. Current wildfire mitigation strategies around the world encompass two major areas: broad-scale landscapes similar to national forests, and a more meticulous approach focusing on structural risks and their immediate surroundings. The strategies of the meticulous approach apply across neighborhoods to better protect them against wildfires. These strategies focus mainly on fuel management around buildings, fire-resistant housing composition, and reducing dead branches and limbs near the property. These three areas of focus are applied differently to each building since each home situation is unique.

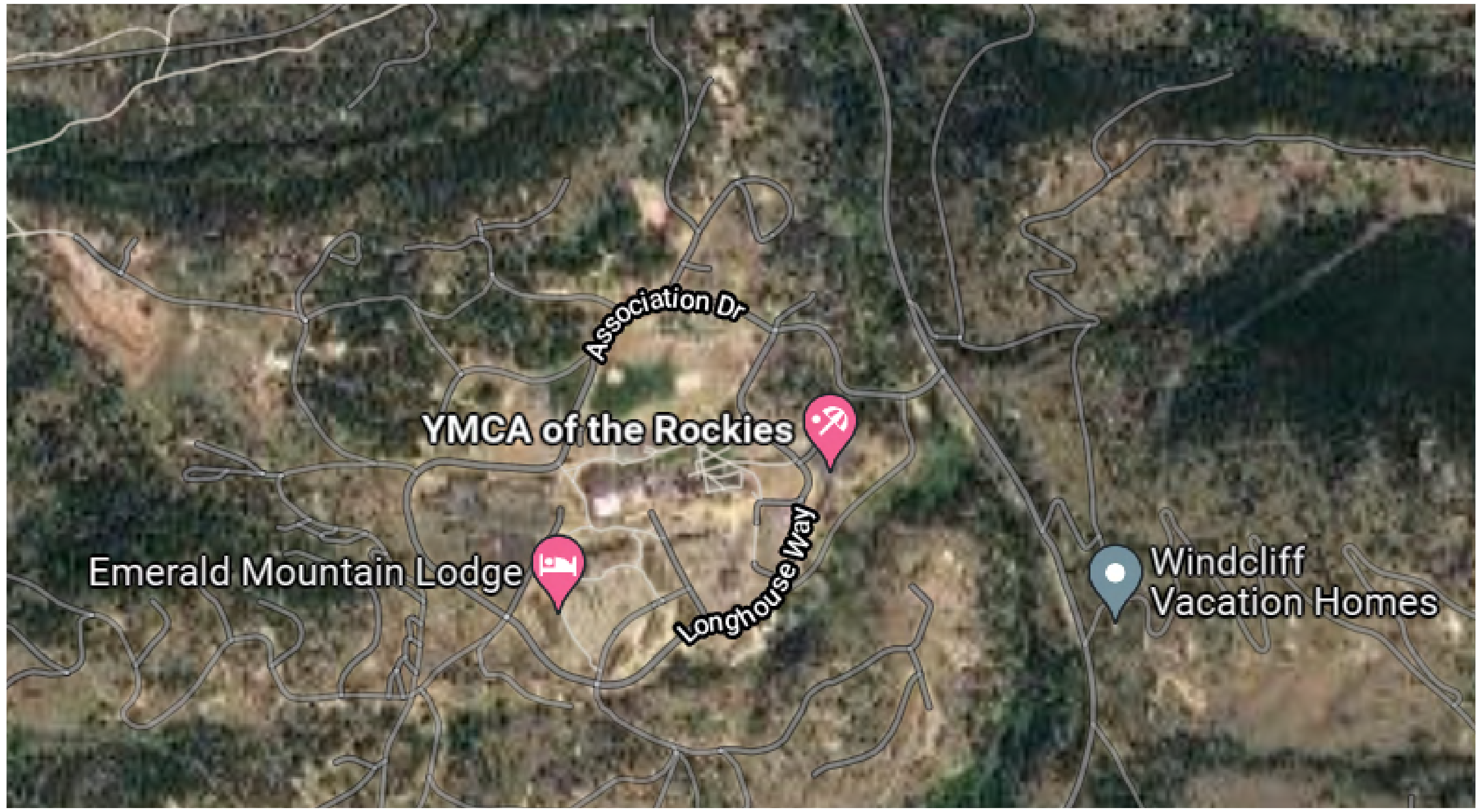
Proactive Small-Scale Strategies Against Wildfires

Different mitigation plans that help protect lives from wildfires can occur on a smaller scale and still be effective. Specifically, focusing on houses and other buildings that fall within the Wildland-Urban Interface (WUI). In terms of fire mitigation, these buildings all have a defensible space that is located between the structure and wildlands, and it prevents or slows fires from reaching them (Norton et al., 2019). This defensible space provides a barrier of protection by moving fuel away from the building to reduce the speed at which a fire spreads. It also provides a safe zone for firefighters to work within. Small-scale mitigations efforts consist mainly of general upkeep around a property. To reduce the spread of fire, the efforts primarily focus on the distances between shrubbery, the heights of branches on trees, and removing vines and dead vegetation from the house (Norton et al., 2019). Increasing these distances reduces the spread of fire from one shrub to another. The removal of dead or low-hanging branches is important because these branches are the first ones to ignite. Finally, removing vines and dead vegetation eliminates a wildfire's ability to climb the building and reduces the amount of fuel around the building. Overall, incorporating these strategies into areas around a building creates a safer and more proactive mitigation effort on a small scale.

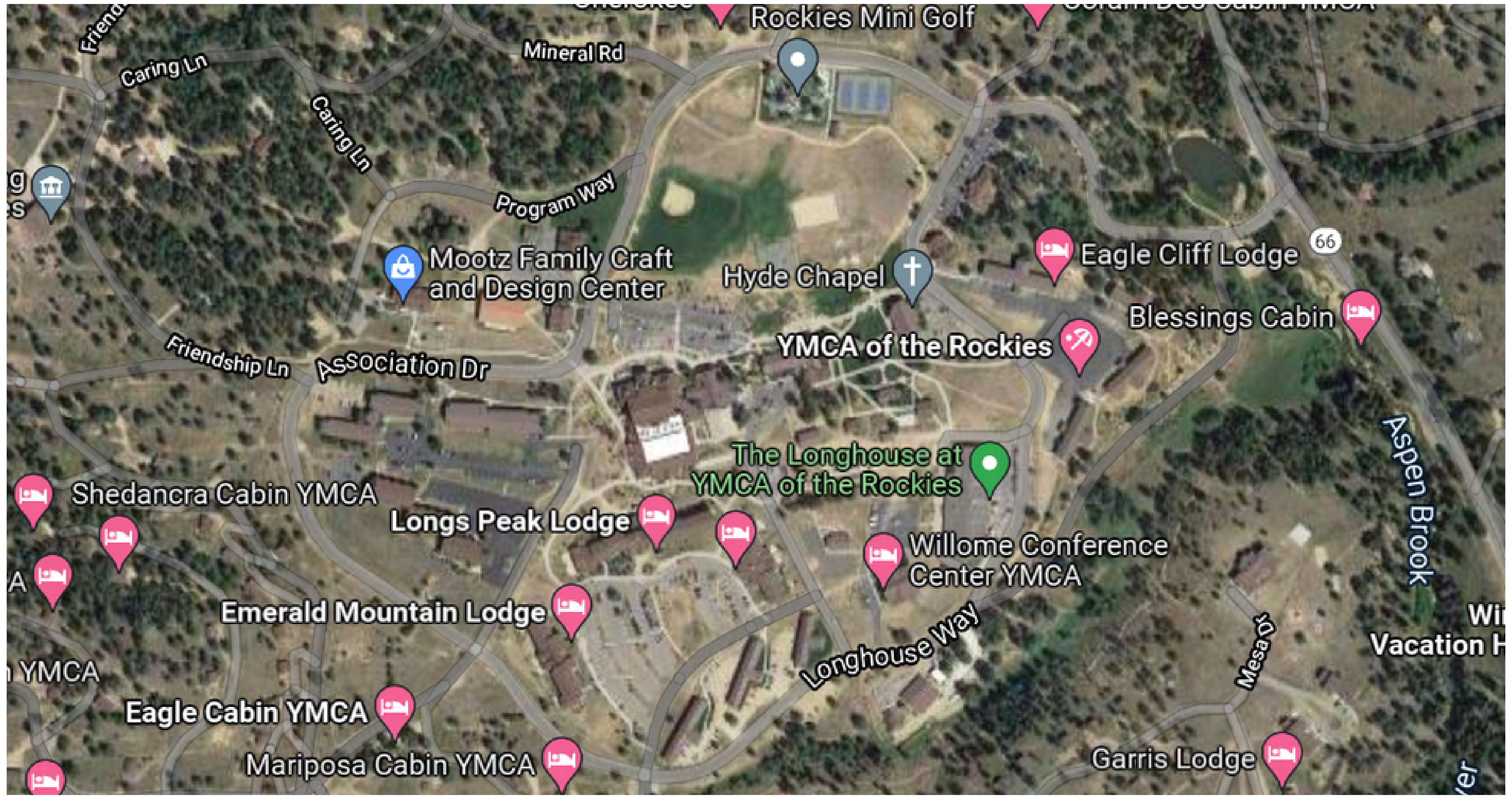
Small-scale mitigation involves looking at the building itself. The structure’s material composition, roof creation, and ventilation all contribute to the building’s safety. The main strategy for increasing roof integrity in dry climates consists of adding a layer of ceramic tiles on the roof to allow the structure to have protection for up to an hour of fire exposure. Exposed wood surfaces can be treated with flame retardant substances, such as varnish. In terms of the ventilation of the building, any external openings must be sealed to prevent fire or embers from an easy entrance to the building. Finally, regularly cleaning the roof of a building prevents a fuel buildup of natural, flammable debris (Arruda et al., 2021). During this general cleaning, it is vital to focus on areas where fuels pile up such as in gutters, under decks, and in corners and crevasses around buildings.

Implementing wildfire-resistant changes is often determined by cost. According to a report compiled by Headwaters Economics, a non-profit independent research group dedicated to improving land management and community development decisions, the cost of retrofitting often depends more on demolition and waste removal than it does on reconstruction. When comparing three different wildfire-resistant building codes, authors Dr. Stephen L. Quarles and Kelly Pohl found that while it is slightly more cost effective to construct homes using the suggested wildfire prevention strategies than not due to the cheaper costs of the proposed materials (an average total savings of $1,910), retrofitting is often more expensive due to demolition and removal costs of current features. The authors claim that the cost of retrofitting an existing roof completely to be around $22,000, and the siding of a house $40,350, both exceeding the costs of new construction. However, the upkeep of these fire-resistant structures would be less time consuming and expensive, since they would be made of more durable materials. Also, retrofitting roofs and exteriors can be done based on the priorities of the current structure, meaning a complete overhaul may not be necessary to keep the structure safe. For example, instead of replacing the siding on the entire building, only the areas more vulnerable to radiant heat exposure such as walls facing other buildings, slopes, or high wind areas would need replacing with fire-resistant materials (Quarles & Pohl, 2018). It could also be more cost effective to perform these changes on multiple buildings at once, cutting down costs by buying materials in bulk for the similarly-constructed cabins.

An example of these strategies being implemented in a neighborhood-like setting occurs in Estes Park, Colorado. In Estes, fire inspectors that work within the Estes Valley Fire District survey specific neighborhoods and areas upon request. They work closely with homeowners and Homeowners Associations to teach them about vulnerable areas of their homes to fire and how to best modify their homes and surroundings to make them safer, using a good, better, best approach for said suggestions. This model provides several options for homeowners to choose from for how to help protect their property, the levels of protection increasing as the levels increase. We decided to use this framework when making our recommendations to the YMCA, so the staff could choose which methods would work best for the campus.



Figures 6: A distanced map of the YMCA of the Rockies main campus (Google, 2022).



Figures 7: A close-up map of the YMCA of the Rockies main campus (Google, 2022).

2.4 Fire Risk to the Town of Estes Park and the YMCA

The YMCA of the Rockies, the sponsor of this project, operates an 860 acre campus in Estes Park, Colorado, bordering the Rocky Mountain National Park on the western half of its perimeter. The Estes Park Center provides 232 cabins, as well as a cluster of administrative buildings around the center of their campus: a dining hall, a chapel, employee lodging, conference centers, and a number of large lodges. The proximity of the YMCA to Rocky Mountain National Park makes the campus susceptible to wildfires because the area becomes quite dry and warm in the summer months. While most of Colorado is dry and warm, it is the addition of excess fuels thanks to the vast forests of the RMNP that increases the risk of fire. The combination of a dry, warm climate and fuel availability create optimal fire conditions. With no barriers between this forest and the YMCA, fires can travel to the campus with ease (National Park Service, 2021).

The YMCA's Exposure to Fire Over the Past Years

A few major fires have threatened the YMCA, including the East Troublesome Fire (2020), and the Kruger Rock Fire (2021). While no wildfire has ever reached the property, these fires came close, with the East Troublesome Fire even forcing the YMCA to evacuate.

The East Troublesome Fire began on October 14, 2020, and spread extremely fast due to high winds, eventually burning 6,000 acres per hour. Other exacerbating factors included terrain, weather, and the Lodgepole pines killed by beetles. One important note is that the fire reached 9000 ft. in elevation at one point, which prior to climate change the temperatures at this elevation would have been too low to sustain a fire like East Troublesome (Encyclopedia Staff, 2021). From October 20-23rd, the total acreage burned increased from 18,000 to 87,000. The fire crossed the Continental Divide and touched the edges of the town of Estes Park during this time. The Continental Divide has served as a natural fire break up until this point. Mountains help control fires because although fire spreads faster uphill, once the peak is reached the flames are usually bent backward due to winds coming from the opposite direction. The declining slope on the other side of the peak also discourages fire, as the heat transfer and wind are no longer prefacing the path of the fire as it does on an incline (Topography, n.d.). Due to the factors described above, the fire was strong enough to jump the Continental Divide and head directly towards the YMCA. A snowstorm blew in on October 24th, which saved the YMCA from the fire. It was officially deemed contained on November 30th (East Troublesome Fire Information, n.d.). Below is a photo illustrating the area burned by the East Troublesome Fire. The main campus of the YMCA is marked with a black star, so it is visible how close this fire came to reaching it.

The Kruger Rock Fire was the smallest, most recent, fire of the two. It began on November 16, 2021 and was considered controlled on November 29, 2021. It burned a total of 147 acres, and it was located just 2 miles southeast of the town of Estes Park (Kruger Rock Fire Information, n.d.). This fire is important to note because of its proximity not only to the YMCA but also to the town. It began with a tree that fell onto a power line and spread due to low humidity and high winds. This fire led to evacuations in the town of Estes Park,. The fire was contained by 150 firefighters; it posed a threat that was dissipated in the few weeks of work put in to stop it (Zialcita, P., Otárola, M., & Wertz, J., 2021).

Even during the 7-week period of the IQP from March to May 2022, a total of five wildfires occurred in Larimer county, with two of them sparking right in Estes Park. While the fires were considered small, the fact that so many fires occurred outside of what is considered “wildfire season” is all the more reason to be concerned for the YMCA’s safety.

The YMCA’s Current Mitigation Strategies

In terms of current mitigation strategies, the YMCA has made many small-scale efforts that have improved its safety, such as forest thinning and controlled burns on collected ladder fuels and brush. The organization’s groundskeepers and supervisors are responsible for fire safety. Much of their work has been to slowly clear out the beetle-ravaged spruce trees from the forest floor. Forest thinning is done to reduce the chance of fire spreading quickly and takes place in the summer with a larger crew and after the snow has melted. The group also monitors and clears low-lying branches that could spread fire up a tree and consume it. While the YMCA will continue to thin trees in adjoining patches of forest, the organization at this moment wants to better assess fire risk to its cabins, many of which are located in the forest perimeter of the campus.

The YMCA was curious to see if their mitigation strategies have been sufficient in protecting the campus from any future wildfires. In order to complement the work of the YMCA’s Buildings and Grounds department, the Y wanted an assessment on wildfire risk on campus to be carried out, helping to direct the Buildings and Grounds teams towards the most vulnerable areas and apply more effective strategies.

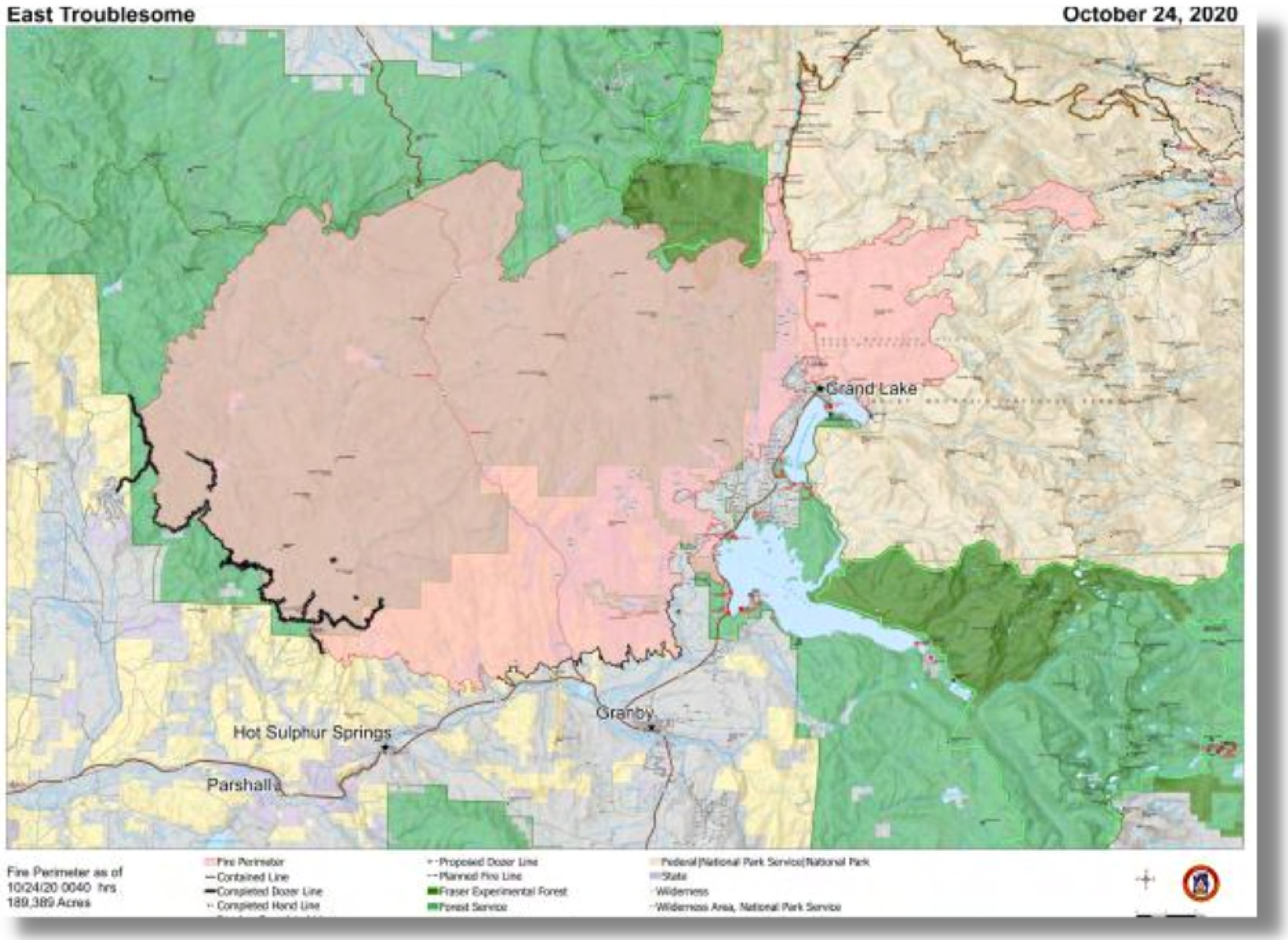


Figure 8: A map of the total area burned during the peak of the East Troublesome Fire. The YMCA is signified with a star (East Troublesome Fire Information, 2020).

CHAPTER 3: APPROACH

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3.0 Approach

The goal of this project was to identify cost effective measures to help the YMCA better protect its cabins from wildfires. To achieve our goal we identified the following objectives:

- Obtain local perspectives of fire risk at the YMCA through coding key-informant interviews
- Assess the cabins' current fire vulnerabilities to wildfire through photo documentation, blueprint analysis, and in-depth data collection during an assessment tour
- Create an interactive map that will allow the YMCA staff to analyze data regarding their cabins and make retrofitting and maintenance decisions based off of it.
- Conduct a cost analysis of potential retrofitting modifications to the cabins

Surveying the land around each cabin for fire risks, as well as the attributes of the cabins, can enable the YMCA to make decisions about improvement to reduce wildfire risk at a fine scale.

3.1 Assessing the vulnerability of cabins to wildfire

On the YMCA campus in Estes Park there are a total of 232 cabins and 9 lodge buildings. To assess the potential fire hazards and openings for embers in and on the structures, we took a three-pronged approach: 1) reviewing blueprints of building plans; 2) interviews with the building managers on campus and other YMCA staff, and; 3) conducting a building assessment in the field (worksheet construction is discussed further in Section 2.3).

Key Informant Interviews

We gathered information on the current state of the cabins and on the best assessment practices by conducting interviews with a series of key informants, including YMCA staff, professors with the Fire Protection Engineering Department at WPI, and local fire experts such as the Chief Fire Inspector and a volunteer fire education expert with the Estes Valley Fire District. The purpose of these interviews was to learn about fires and how they interact with cabins.

To better understand what areas of buildings are most vulnerable and how house-like structures ignite, our team conducted an interview with Professor James Urban of WPI's Fire Protection Engineering Department. Professor Urban studies how wildland and manufactured materials ignite and other combustion phenomena. We held a key informant interview with Kelly Wilkerson, the head groundskeeper of the YMCA of the Rockies who is in charge of clearing the forests of any ladder fuels and other potential fire hazards from the Y's properties, as well as keeping outdoor areas and structures clean and well maintained. We met with Troy Husler, of the Y's buildings and maintenance department, to better understand the materials used to construct the cabins and the costs of cabin retrofitting, as well as how the YMCA's yearly budget is developed. Finally, to learn about how local residents retrofit their homes or create defensible spaces around their properties, as well as what the local fire department recommends as best practices, our team interviewed Senior Fire Inspector Raina Eshleman. This interview followed a semi-structured interview style, and notes were taken during the meeting. Our team also visited the Estes Valley Fire Station, where Captain Eshleman walked our team through how the fire department conducts wildfire home assessments.

After each key informant interview, the field notes taken by the designated note taker were transferred into a shared document online using Google Drive. No interviews had audio recordings due to them all taking place in the field instead of in an enclosed area where audio could be easily recorded.

Building Plans and Documentation Research

To understand the cabins' construction materials and learn how fireproof the structures were upon arrival, we gathered floor plans of each cabin type that were available from the YMCA's Head of Buildings and Maintenance. We specifically focused on what external features each cabin type had (such as porches or decks), what materials the siding and roofing were made of, the types of windows installed, and if any modifications had been made to the structures since they were built.

Figure 9: Teammate Mason Thyng analyzing 2 bedroom cabin building plans.

We had thought initially to analyze maintenance logs for the cabins, but due to being able to visually inspect the physical state of each cabin we deemed the logs irrelevant to our goal and thus the idea fell through.

In addition to reviewing building plans, we photographed the cabin exteriors. Many of the cabins on campus had the same layout, with ten different cabin layouts spread across the YMCA campus. We took photographs of each cabin style, as well as especially problematic areas surrounding the cabins, such as cabins with flammable trees or shrubs close to the structures, areas of extreme vegetative buildup and debris, vents or eaves that were missing ember-protective gratings, and roofs that were missing sections of tiling.

Cabin Assessment

To construct a wildfire protection cabin assessment, we collected information from a wildfire home assessment checklist created by the Insurance Institute for Business, Home and Safety. The document discussed specifically how house-like structures in wooded areas are vulnerable to fire, and how to modify those structures to better protect them. Items from the document we chose to include in our initial assessment were if gutter covers, enclosed eaves, plants and whether debris existed within five feet of the building's walls, and overhanging limbs were present. We also included the siding and decking materials (Wildfire home & safety checklist, 2022).

Figure 10: Mason F., Mason T., and Jillian on the nature hike with sponsor Donovan Colegrove, analyzing a blue spruce tree.

Our team decided to use Google Forms to record and compile assessments in the field. By using Google Forms, our team was able to fill out the survey on cellular devices as we assessed cabins. Google Surveys worked well because it allowed us to submit multiple responses and compile them within a Google Sheets document. Using this software also allowed us to directly link our database responses into the mapping software (Google Reports).

In assessing cabins close to the main campus to troubleshoot the survey, we found that there were aspects of the survey that were lacking. We revised our individual cabin assessment to focus more on what vegetation surrounds the cabins and if there are any glaring maintenance problems nearby that required the grounds team's attention, such as overhanging tree limbs too close to the roofs and power lines that touch vegetation. The revised assessment also included a section where we listed all of the trees and shrubs within the cabin's defensible space (30 ft from the outer walls), including the plant type and how many were present. The final individual cabin assessment is included in the appendix section of this document (Appendix B).

Figure 11: A map of the YMCA campus marked with every structure we assessed.

We inspected each cabin to document siding materials, decks or porches, and non-plant items of concern like deck chairs or swings. Additionally, we inspected the immediate surroundings including the density of cabins in the area, the amount and types of woody or herbaceous plants in each defensible zone (area between a structure and flammable vegetation), whether or not any flora was in direct contact with the house and the types, and if any branches were above the roof. We also looked at the terrain, such as the elevation of the cabin compared to the surrounding wilderness. As fire tends to spread upwards, a group of cabins on a hill overlooking a dry forest, for example, would always be noteworthy.

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To analyze the cabins, our group split into two teams when conducting assessments. Each team had one member filling out the Google Forms cabin assessment, while the other walked around the cabin, looking for debris, tree overhangs, and flammable vegetation.

Once the cabins had all been assessed, the assessment form was streamlined for the ease of the YMCA staff who could use it to assess future cabins. All answer fields were changed to a multiple-choice format based on the data we had collected. This was so the code for the vulnerability score we assigned each building could recognize keywords to calculate the scoring for each cabin. This scoring system is discussed further in the section titled “Creating a Scoring System for Cabins” within section 3.2.

Figure 12: Mason and Katherine on cabin assessment tour (left) and Mason Thyng, Mason Figler, and Jillian Wright out assessing cabins (right)

Figure 13: Sample screenshot of completed database. For more, see Appendix G.

Timestamp	Cabin Name	Cabin Coords
3/28/2022 13:37:03	A Third Way	40.33669, -105.56899
4/7/2022 11:51:50	Aerie	40.33033, -105.56325
4/7/2022 11:13:24	Aftermath	40.33035, -105.56556
4/4/2022 10:47:15	Agate	40.3446124, -105.5741816
3/22/2022 14:22:39	Alleluia	40.33755, -105.57917
3/28/2022 13:37:36	Aloha	40.33984, -105.57897
3/28/2022 10:48:08	Alpenglow	40.33474, -105.57771
3/28/2022 10:50:30	Alplily	40.33423, -105.58029
3/25/2022 16:19:30	Anasazi	40.34428, -105.5698

3.2 Creating a Database and Interactive Map

Our team created a database from the assessment we completed of each cabin (Appendix G). This data was linked to a map showing the location of the cabins and was stored using Google Sheets. The idea for the database is for the YMCA to easily interact with the platform, edit it, and change different aspects for each datapoint. The information in the database can be referenced by members of the maintenance staff, allowing them to better prioritize assignments that mitigate the risk of spreading wildfires.

Creating a Spatial Component of the Database

The database was linked to a digital map of the YMCA campus and the cabins through Google Reports, where clicking on a cabin would open a window that displays the data from the cabin assessment. Google Reports allows data to be displayed in different ways, with a map being its primary purpose. We chose this platform because of its user-friendly interface and legibility. There is a feature to add heat readings onto the map, which was particularly useful to our project. A heat map takes into account a numerical value associated with a location, and depending on where that value falls on a predefined scale its given a color. Typically, cooler colors such as blue and green are for the lower end of the scale, while hotter colors such as red and orange are for the higher end. These colors are then blended together depending on their vicinity (for example, see figure 27 in section 4.3). The excel sheet data could also be included in the Google Report to allow the user to view the full data.

Another platform we considered was Google MyMaps. This is a similar software to Google Reports, but it does not automatically update, whereas Google Reports does. There were also issues we encountered with the base map for Google MyMaps, as there were default points that were not able to be removed and interfered with our data. Google Reports was overall a more straightforward and robust platform for our project. On top of the map showing the location of each cabin, we added a pop-up text box, accessed by hovering the cursor over a point, that contains more information relating to the cabins' risk (Appendix C). The interactive map aspect of the database gives the staff at the YMCA more ease of use when viewing the database. Seeing the cabins on a map will allow them to access information quicker, and it is much more robust than just an Excel sheet. In terms of applying the zoning layer of the map, a visual representation makes it easier to summarize data and access areas of concern.

Creating a Scoring System for Cabins

In order to identify at-risk properties at the Y, an aggregate vulnerability score was assigned to each cabin. This score was based on the data collected during the assessment process. Each attribute in the survey was given a number value that reflected its risk. To construct this scoring system, we split the types of fire hazards into sections and then ranked them from most to least dangerous based on previous studies from the Colorado State Forest Service (CSFS) and the Insurance Institute for Business and Home Safety (IBHS).

To rate each fire risk parameter, we grouped the parameters from our cabin assessment questions into several categories: siding material, decking material, decking aspects, landscaping hazards outside of 5 feet from the cabin, landscaping hazards within 5 feet of the cabin, and structural hazards. Once categorized, we organized the parameters under these categories in order from most to least hazardous based on the information from the IBHS and CSFS studies. A score of 1-10 points was applied to each hazard within the categories.

When it came to scoring the building materials, the base points score was based on the material's Flame Spread Index (FSI). The FSI is used to describe the surface burning characteristics of building materials, and is the most often used number when evaluating materials for fire safety. These values are determined using the American Society for Testing Materials (ASTM) E-84 test, also known as the tunnel test. This test is performed by placing a piece of the material inside of a test chamber and exposing one end to a gas flame. The test measures how far and fast a flame can spread across the sample's surface and the material is given a score from 0 to 100 called the Flame Spread Index, the lower end of the scale being less likely to burn and the upper end being more likely.

For hazards that increased in danger depending on contact with different building materials, a multiplier was devised for each building material identified. These multipliers were applied to landscaping and structural hazards that involve siding and decking materials, since the risk of these hazards increases depending on the building material they come in contact with. The materials with the highest FSI value, wooden plywood boards and wooden decking, would double the danger of involved hazards, thus they would multiply the point value of said hazards by 2. The middling materials multiplied the hazard scores by 1.5, while the most safe materials multiplied the hazard scores by either 1 or 0. The hazards these multipliers were applied to were roofs and/or sidings in poor condition, a porch built on a slope, plants growing against siding, and plants found underneath porches. An example of how these multipliers can be seen in Figure 13. The image highlights an area on a cabin where the wooden board siding was in poor condition, and shows how the multiplier for wooden boards was applied to the "roof/siding in poor condition" parameter.

Figure 14: Photograph of ASTM E84 tunnel test for flame spread index value. (ICC NTA, 2022)

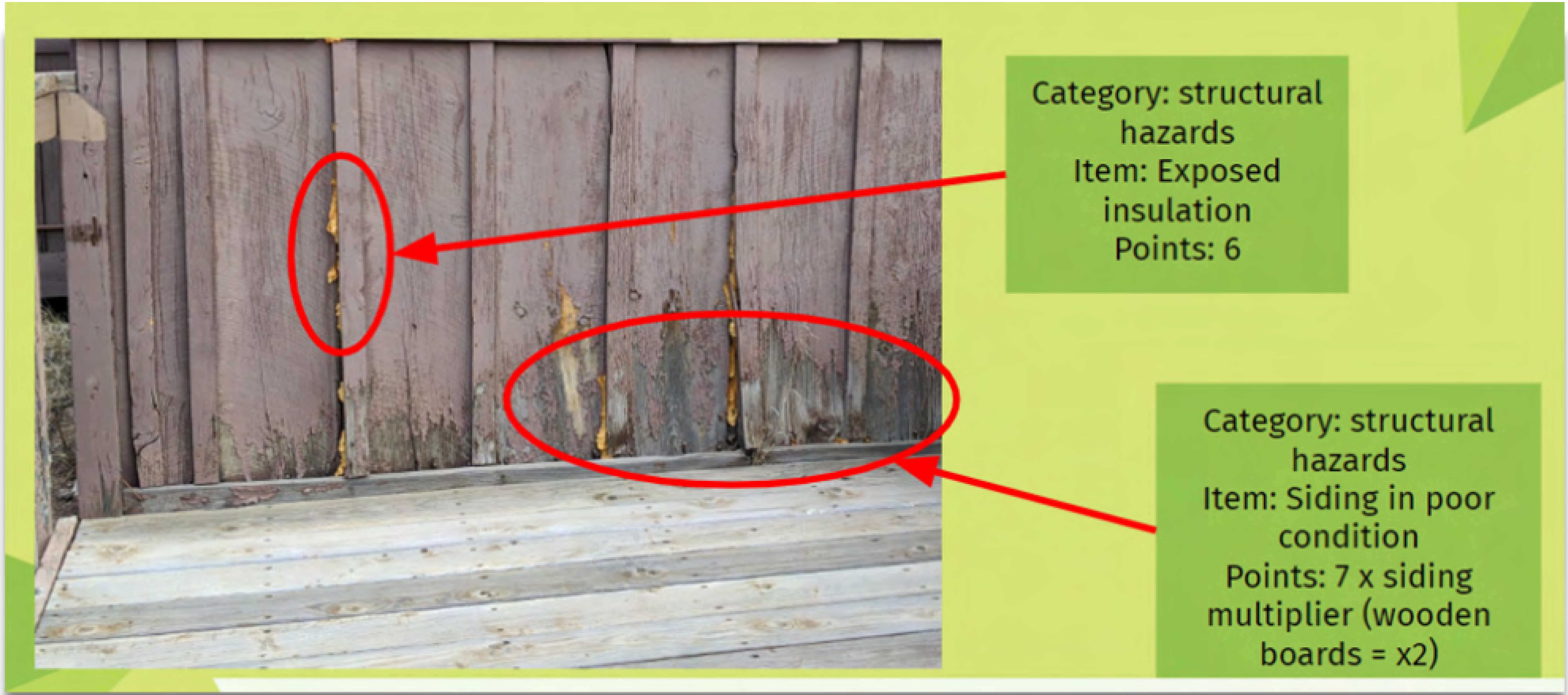

Figure 15: Structural hazards on a cabin and how the vulnerability scoring system was applied to said cabin.

A full breakdown of the hazard categories, the individual hazards within their categories, and the points assigned to each hazard is displayed in Appendix F. The number of other cabins within 100 ft was also calculated into the score. For individual building entries, the total points for each parameter that applied to that building were added up in the database, with the final sum representing the vulnerability score. To ensure our scoring system accounted for relevant wildfire vulnerabilities of structures, we consulted Professor Urban of the WPI Fire Protection Engineering Department, as well as Captain Eshleman of the Estes Valley Fire District.

Refining the Database Through User Testing

During the development of our map, we periodically shared our progress with our sponsors. After the completion of our database and map, we created a user guide that lists out all of the ways to utilize the map to its fullest. We included a section that outlines how we completed the assessments, so if the staff at the YMCA wants to redo the assessment years down the line, they would be able to complete them in a way that lines up with the database. An in-depth user manual was constructed for the YMCA staff so seasonal staff could learn how to use the database without extensive training (Appendix H).

3.3 Identifying Cost-Effective Measures to Reduce Wildfire Risk to Cabins

Following our assessment, we developed a retrofit cost analysis to upgrade YMCA cabins in order to make them less susceptible to wildfire. The costs for upgrades were determined based on input from the YMCA's facility crew, the YMCA of the Rockies' Building and Maintenance Supervisor Troy Husler, and the Estes Valley Fire District's Senior Fire Inspector Raina Eshleman via interviews.

We also consulted the Headwater Economics' Building a Wildfire-Resistant Home: Codes and Costs (Appendix D). The study examines the cost difference between fireproof and non-fireproof materials for building structures. Overall, this cost analysis within the database allowed the YMCA to determine where to apply its mitigation efforts and budget for retrofitting in a cost-effective manner.

Preliminary Research on Materials and Components

To help decide what recommendations for building materials to make for the YMCA, a cost analysis was performed on different potential materials. Our team decided to focus on four different external areas of a building to research: roofs, siding, decking, and attachments. Additional attachments were researched as suggested by the Estes Park Fire Department, which included gutter covers and eave enclosures. For each material for the roof we compared fire resistance, pricing and lifespan. To find information on siding and decking material, we were provided access to the YMCA's invoice system. We were also given a guide for each of the 7 cabins built or remodeled in 2021, which detailed the invoices relating to that cabin, including the company whose services were provided and the number for that invoice. We were told that all of the materials came from Estes Park Lumber, so we looked into further detail about invoices from them and pulled out the following information for materials of the siding and decking:

- Units used
- Amount bought
- Price per unit
- Total price
- Cabin the invoice is for
- Invoice number the information was retrieved from

Numerical Calculations for Cost Analysis

Invoices for the roof shingles of the cabins were not included in the provided documents. To rectify this research gap, we reached out to Husler to get the specific brand of shingles used on the cabin roofs. We then used the provided information to research average costs of the shingles through several internet sources. As a potential comparison, we also found the average cost of aluminum metal roofing per linear foot. This was to determine if metal roofing was a potential option for the YMCA to implement. For the siding material cost analysis, our team collected all of the pricing data for siding of all 7 cabin invoice documents and averaged the total cost for each siding material recently used (pine logs and fiber cement panels). For decking materials, we compared the average costs of boards to the cost of alternative decking companies within the area. We were also able to find the average cost of adding gutter covers and eave enclosures to cabins by getting approximate dimensions from building plans and researching the average cost of the attachments.

CHAPTER 4: FINDINGS

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4.0 Findings

4.1 Getting the Pulse on Wildfire Mitigation at the YMCA

Current YMCA Mitigation Practices Are Not Sufficient for Clearing Vegetation Near Cabins

Through multiple interviews with YMCA employees and staff, specifically those who work in the Buildings and Grounds department, it was revealed that almost all mitigation practices performed are in terms of landscaping. The Grounds Superintendent interview informed us that they limb up trees and remove ladder fuels when possible, and perform prescribed burns during the colder months. However with only four people on the ground during the off-season at the Y, and due to relying heavily on seasonal staff during the busy seasons, there is only so much ground that they can cover in a year before more fuels accumulate. This means that there is a large amount of excess vegetative debris around the cabins that has not been accounted for and needs to be cleared. When a fire reaches the YMCA campus, if there are fuels such as brush and tree limbs touching the cabin walls, that cabin will very easily go up in flames. Thus, our cabin assessment data and vulnerability score took into account not just the building materials of the cabin, but the plant life surrounding them within their defensible space, as well.

Wildfire Mitigation Decisions are Influenced by Cost Considerations

There are many constraints when it comes to making the YMCA Estes Park Center cabins more fire-resistant, most of which are related to budget limits. In response to the question of what the Y would want if there were no monetary limits, Tom Husler said that he would "love to" replace all of the buildings' asphalt shingle roofs with metal ones. "It depends on the cost of labor" metal roofs are beneficial to structures in the area not just for their fire resistance, but also because they would have a much longer lifespan than the asphalt shingles However, the initial price could prove too expensive for the YMCA to cover for one building, let alone many cabins. To install a solid metal roof would cost around $10.50 to $17.50 per square foot for standing seam aluminum roofs, while architectural grade asphalt shingles on average cost around $4.76 per square foot and are much cheaper to install (retrofitting costs are discussed further in section 4.3). When asked if the YMCA would be willing to build solely with fire-safe materials like fiber cement siding and composite board decks, Husler confirmed that the YMCA would be more than willing to do so. Because of the rising costs of natural materials like wood, and the long-term durability of these alternative materials, it is becoming more cost-effective to build using manufactured construction materials, such as asphalt shingles rather than wood.

To determine what material changes and future projects fit within the YMCA's constraints, the Y's budgeting system first had to be considered. The YMCA budget is split into three subsections: operations, capital projects, and philanthropy. The operations budget covers day-to-day expenses to keep the YMCA campus running and covers costs for housekeeping, dining, and general maintenance of the buildings and grounds. The budget for capital projects funds projects that the YMCA administration deems important, but cannot be covered by operations. These projects are identified by each department and brought forward to the YMCA executives during September when the budget for the next year is approved. Projects approved by the board are typically allocated a budget of $10,000-$30,000. The final budget subsection is philanthropy, where donors to the YMCA fund projects that are too large to be covered by the capital projects budget. According to one of our interviewees, “the philanthropy team is willing to go to donors and ask for more money for specific projects if those projects do not yet fall under the philanthropy budget.”

Wildfire Mitigation Decisions are Influenced by the Cabin Adoption Program

Another limitation the Y faces when attempting to address wildfire mitigation on campus involves the cabin adoption program. The cabin adoption program is where donors can pay to renovate a cabin, normally costing at least $30,000, and for the next 30 years get priority for booking time at that cabin. However, there are 54 cabins that are lifetime donations, meaning that the cabin belongs to a donor until they pass. Even then, their family gets priority to readopt the cabin. Many of these lifetime cabins are not updated for decades because many of the donors are elderly and are not in a position to provide additional support, financially or otherwise, to re-side the cabin or replace its decking, and due to this some of the cabins haven’t been renovated in over 50 years.

Even for the cabins that are not considered lifetime donations, it is unclear how often the YMCA could carry out wildfire mitigation retrofitting projects. Construction season at the Y takes place when the campus is the least busy, that is, between the end of its winter season and before the summer when visitors arrive en masse. Due to this time constraint, only three or four cabins are remodeled each year, with one or two new cabins started, making retrofitting for fire mitigation a long-term project that could take decades to complete.

Trade-offs Between Safety and Aesthetics

One of the final constraints we need to consider when making recommendations is that the YMCA is a business that relies heavily on the satisfaction of its guests to continue operation. Because of this, the cabins need to remain attractive and maintain the woodsy, mountainous aesthetic that they currently have. This can run counter to best practices in relation to defensible space around structures as we noted earlier. Y staff were concerned that if the cabins had almost all vegetation within five feet removed, then the beauty and appeal of the cabins, and therefore of the campus itself, would suffer.
Thus, any changes that we would suggest should balance the character of the campus with safety considerations.

4.2 How Vulnerable are the YMCA’s Cabins to Wildfire

How Does Surrounding Vegetation Contribute to Cabin Wildfire Risk?

From our analysis, we found that plant proximity, debris presence, and non-organic items of concern were the largest contributors to the vulnerability of cabins. Plant proximity involved the types of trees and shrubs that were near the cabin. We calculated averages based on the number of trees within 30 feet, the intermediate-risk zone, of each cabin. On average, cabins had 4 ponderosa pines and less than 1 blue spruce, Douglas fir, and aspen within 30 feet. The risk level varied based on the types of plants; a highly flammable juniper plant in close proximity was more concerning than a hardy ponderosa pine.

In terms of cabin surroundings, the ratio of tree averages was important to note. The fact that ponderosas were the most common was ideal, as they are the most fire-resistant. The second most common type of tree was the aspen. While nearly 90% of the cabins surveyed had no aspen within 30ft, aspens grow in clusters, where the average tree count when looking only at locations with aspen was about 5.8 trees.

The reason why the average number of blue spruce near cabins was so low was because blue spruce trees could only grow healthily near a water source. This helped explain why so many of the blue spruce trees we saw were sickly looking or dead. Because they were planted for ornamental value, they were often planted in areas that did not have a proper water source, causing them to deteriorate. There was a regular distribution of Douglas fir across campus, with most scattered evenly amongst the campus; this revealed to us that these trees grew transiently with few requirements to thrive. Overall, the health of the trees proved to be relatively ideal on campus, with very few trees dying due to lack of sunlight or resources (with the exception of the blue spruce trees). The main problem was their proximity to the cabins themselves, sometimes being right up against the wall of a cabin, and the overhang that the trees caused.

Juniper was considered and examined separately from the other tree data collected because of its natural combustibility and tendency to explode when ignited. We identified 53 juniper plants within 30 feet of the cabins. Ideally, the number of junipers present should be reduced. Many of the plants we observed were small, so removal would not take much time or labor.

Over Half of the Cabins had Branches Hanging Over Their Roofs

We found that 56% of the cabins had some form of overhang. Overhanging limbs mean that they are directly above the roof. Figure 16 consists of a bar chart displaying the rating that was given for any cabins with overhang present. When overhang was present, we rated it on a scale from 1-10 based on what percentage of the roof was covered. A rating of 1 would indicate 10% coverage, while a 10 would mean there were branches above the entire roof (100%).

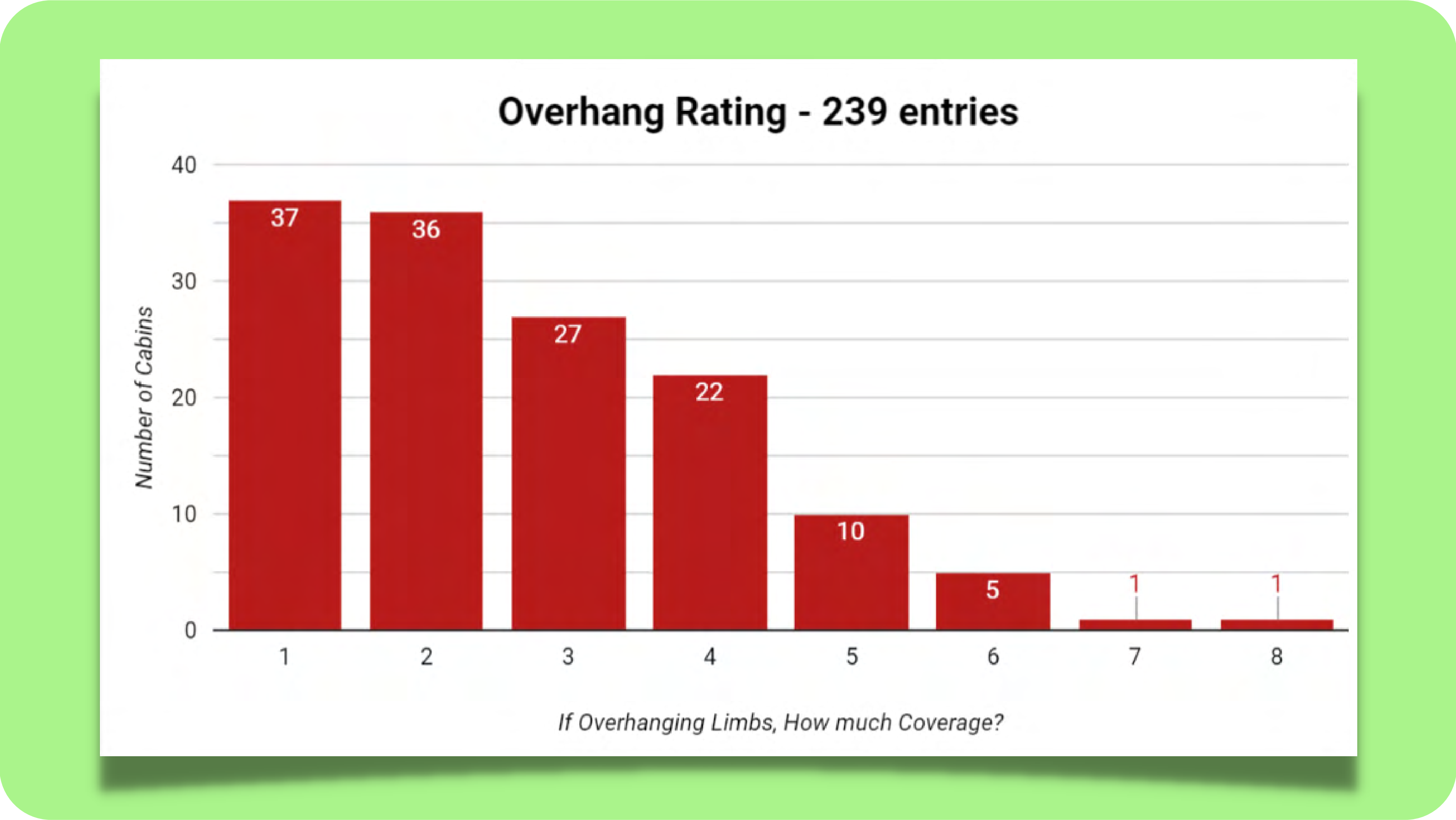

Figure 16: Bar chart of Overhang Rating of the 239 cabins assessed.

Overhang can be dangerous because it can increase the risk of flames from tree canopies spreading to buildings. When tree overhang is present, the branch above a roof provides a ladder-like bridge for the flames to spread to the building, providing an entirely new fuel source for the fire to burn. We rated the majority of overhang situations as either a 1, 2, or 3, which means that 10-30% of the roof was covered by trees. Examples of what we rated a 1, 3, and 7 can be found in figure 17 (see page 29).

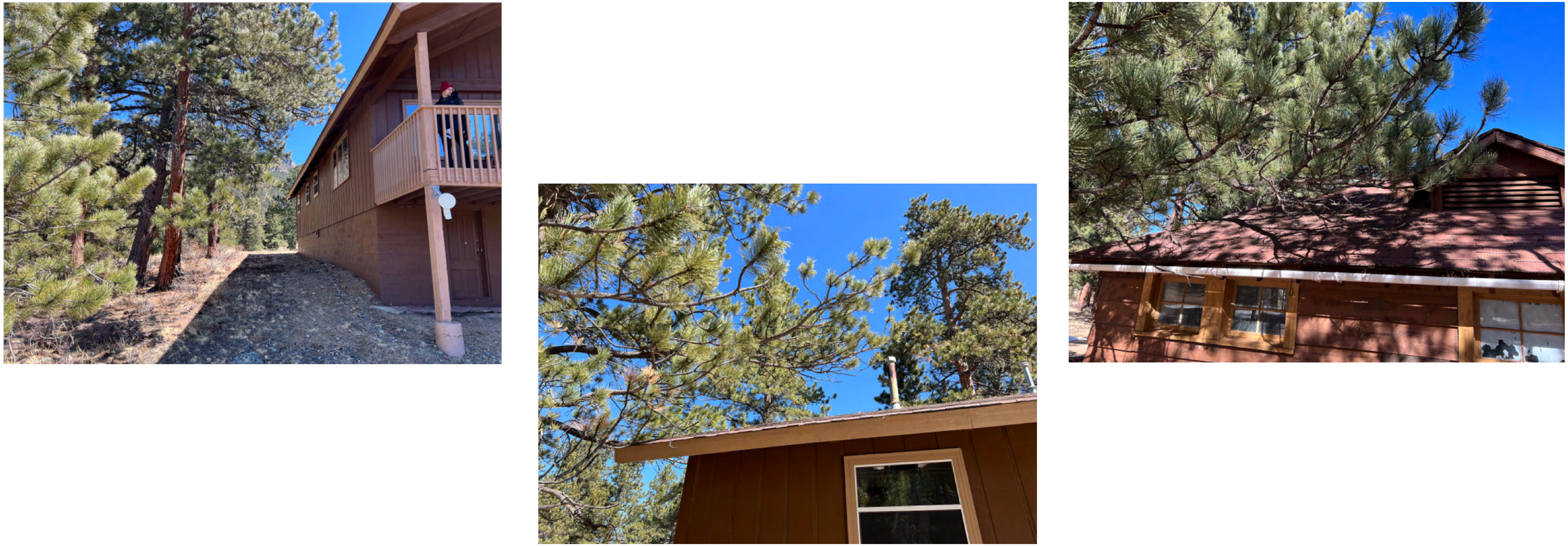

Figure 17: Examples of assessed Overhang Ratings of 1 (Left), 3 (Middle), and 7 (Right).

Figure 18: Image of a tree in direct contact with the cabin.

Although a large majority of the overhang was not extreme, the 17% of cabins with an overhang score of 4 or higher should not be overlooked. These cabins typically had branches touching the roofs in multiple places or had multiple trees with large overhanging limbs. Also, through our cabin assessment, we found multiple instances where the tree trunk was in direct contact with the cabin's siding or roof as seen in Figure 18.

Debris

Another source of wildfire fuels comes from debris, or clusters of leaf litter, pinecones, and dead vegetation that have fallen to the forest floor. We found a wide array of debris across the campus such as logs, branches, dead standing trees, and various organic brush. About 34% of the cabins had some form of debris around them. The most common types of debris were duff, pinecones and fallen branches. This was to be expected, as our surveys were conducted during the winter thaw, the groundskeeping team have not cleared the branches that accumulated during the winter. The cabins with more trees had many more dried pine needles and pine cones. Examples of the debris types we analyzed are shown in Figure 19 (see page 31).

Proximity of Vegetation to Cabins

Nearly half of the cabins surveyed (46%) had bushes or trees growing within 5 feet of the structure. In a wildfire, this vegetation could expose the cabin siding to direct flame, leading to a much higher likelihood of the cabin igniting. 25% of the cabins with close vegetation, 11% of all assessed cabins, had thicker bushes growing not only against the sides of the cabin, but underneath the porches as well. This is especially dangerous, as a fire burning below a wooden structure has a much higher chance to ignite than a fire burning above or even next to a structure.

Figure 19: Different forms of debris around cabins. Branches (Left), dead standing tree (Middle), and a log (Right).

Additional Man-Made Items

Non-organic items that added to the cabin's wildfire risk included gas grills, wooden Adirondack chairs, wooden picnic tables, fences, and wooden swings. Some 63% of the cabins had wooden chairs on porches, while some had composite chairs which are less likely to combust. Large wooden structures such as swings and tables on porches were also a common sight, while wooden fences were more of a rarity. With over 72% of the cabins having some kind of flammable construct close by, the campus has much more fuel if a wildfire were to spread.

4.3 How Do Cabin Materials Contribute to Wildfire Risks at the YMCA?

Roofing

All of the cabins at the YMCA used asphalt shingles for roofing. These composite shingles found across campus have a high fire-resistive rating, with asphalt composite

Figure 20: Two wooden tables in close proximity to a cabin.

Figure 21: Image of Architectural Asphalt Shingles at the YMCA.

shingles having a Class A Fire Rating. This meant that they are among the most fire-resistant materials and are approved by the fire code for structure ignition reduction in wildland areas, NFPA 1144 (2018). This high roof rating allowed for the cabins to have even greater wildfire protection.

Siding

The three types of siding used throughout the campus are pine logs, wooden planks, and fiber cement panels. Figure 20 shows these different types of siding in order of fiber cement, wooden planks, and pine logs from left to right.

Figure 23 (see page 36) shows that 26.4% of the cabin sidings were constructed of fire-resistant fiber-cement boards, which have a Class A Fire rating according to the Flame Spread Index. The 33.1% of cabins with eastern white pine log siding are less fire-resistant, with a Class B Fire rating, while the other 39.7% of cabins have plank plywood siding with a Class C Fire rating. This means that only around a quarter of the cabins on campus are as well protected as they can be in terms of fire-resistant siding.

Figure 22: Cabins with fiber cement (left), wooden plank (Middle), and pine log (Right) sidings

The other siding materials used were stone and plastic, but they were only used on non-residential buildings like the Jellison Youth Center and the Wind River Water Treatment Plant on Rainbow Road. According to the FSI, stone siding has a Class A Fire rating, while plastic sidings such as vinyl have a fire rating of around Class A or B, depending on the components of the plastic.

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According to Husler, when cabins are remodeled the cabin donor has the option to pay for new fiber cement siding or not. If they chose to not pay for fiber cement boards, the YMCA re-sides the cabin using the pine log veneers. Figure 22 shows a satellite map of the YMCA cabin locations color-coded by siding material. The blue dots on the map are cabins with wooden board siding, green are fiber cement, teal are pine logs, and orange are stone. According to the map, there are no areas with high vegetation levels where more hazardous sidings are specifically used, nor are there large sections of campus with only one siding type. Thus, there was no correlation between areas with high vulnerability and the types of sidings used in that area.

Porches and Decks

Almost every cabin had some type of porch attachment, including front, back, wraparound, and second story. Some were slightly elevated off the ground, while others were located around the second or third floor. The porches were either made of composite lumber consisting of wood fiber, plastic, and a binding agent or constructed out of pine planks.

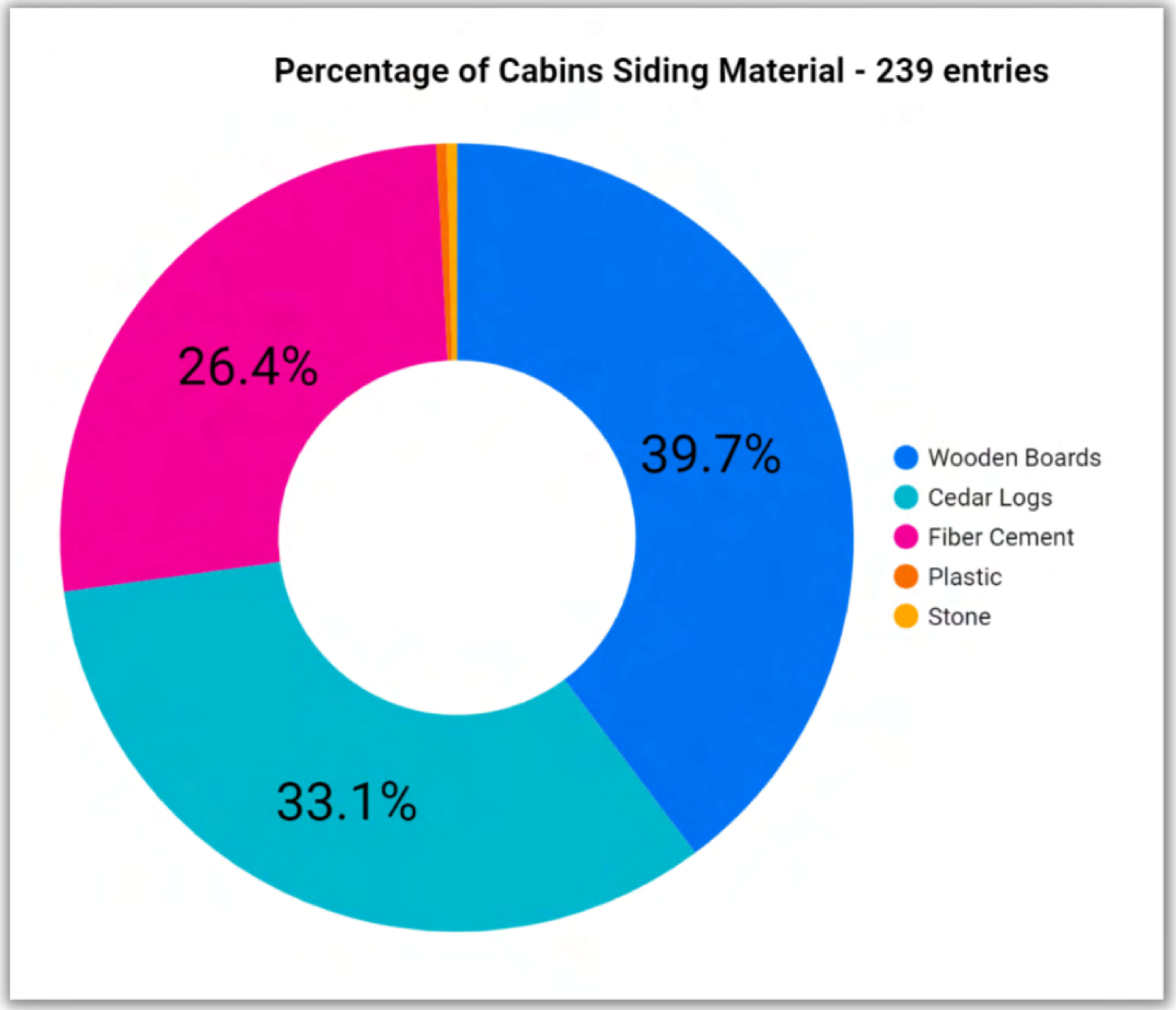


Figure 23: Siding materials on the 239 assessed buildings on the YMCA campus.

Figure 24: Map of assessed buildings depending on siding material. Blue dots indicate wooden board siding, teal dots are pine logs, green dots are fiber cement, orange is plastic, and red is stone siding.

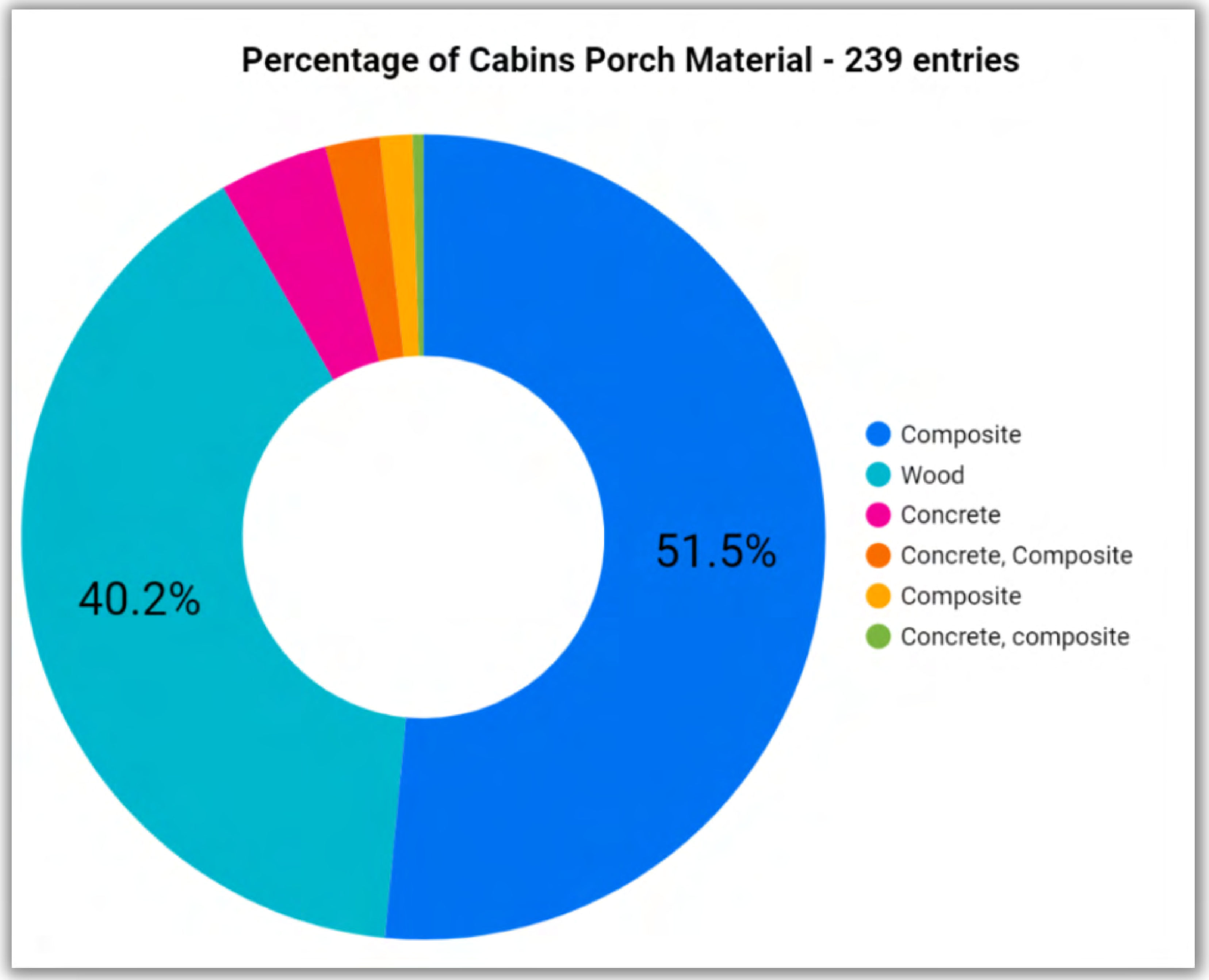


Figure 25: Pie chart of porch materials on the 239 assessed buildings on the YMCA campus.

Figure 25 shows a pie chart of the different porch materials and types of the 239 campus buildings assessed. This included 232 cabins and a few miscellaneous lodges and buildings. Of the 239 buildings, over half (54.9%) of them had a porch/deck made of composite decking, while more than a third (37.7%) were constructed out of wood. The remainder were made of combinations of different materials, such as cement decks with composite railings among others.

Some of the cabins had elevated porches, and we noticed plants were growing under them. This vegetation could be set alight by firebrands or embers.

Many cabins had a combination of wood siding and composite porches, which suggests that updates to the porches were more common than siding updates.

Vulnerability Score Analysis

Thanks to the scoring system we developed in tandem with the database, we could assess how vulnerable the cabins on the YMCA campus are to wildfire taking into account the following parameters: siding material, decking material, decking aspects (if the porch wraps around more than one side of the building and if the porch has multiple stories), landscaping hazards 5-30 feet away from the cabin (ladder fuels, all types of trees identified on campus, surface fuels/debris, and grasses such as sagebrush), landscaping hazards 0-5 feet away from the cabin (plants against the cabin's siding, limb overhang, limb presence over chimneys or through power lines, gutter debris, plants under porches, and sapling patches), and structural hazards (roof and/or siding in poor condition, exposed insulation, holes in cabin siding, exposed/open eaves, porches built on a slope, combustible furniture, and combustible personal items). These parameters were determined through combustion and fire risk studies performed by the IBHS and the Colorado State Forest Service. The risk levels of siding and decking materials were determined through Flame Spread Index values assigned to the construction materials after being tested using the ASTM E84 standard, which is the testing method for surface burning characteristics of building materials. Explicit point assignments are displayed in Appendix F.

As described in Chapter 3.2, the point values for each parameter that applied to a building entry were added together to get a total vulnerability score for that entry. The purpose of these scores were to help determine which cabins are currently at the most risk for wildfires. The buildings with the highest scores are the most vulnerable, while the ones with the lowest scores are least vulnerable. Figure 27 shows the statistical analysis of the scores, including mean, median, mode, minimum, and maximum cabin score.

The mean, median, and mode in Figure 27 were calculated to determine just how vulnerable the average cabin on the campus was. Many of the factors that contributed to these middling scores were power line and chimney overhang, gutter clutter, vegetation underneath porches, pine log siding, wooden decking, combustible deck furniture, and large amounts of ponderosa pines.

To spatially analyze the overall most vulnerable areas on campus, we applied the database scores with their area markers to create a heat map, which can be seen in Figure 27. This map shows where the largest clusters of high-risk cabins are, so the YMCA may determine where to first apply mitigation tactics. On the map, the areas highlighted in red are the places with the most high-risk cabins, the yellow areas with the cabins at medium risk, and the blue areas are the places with lowest risk cabins. Based on this map, we determined the most at risk areas of campus to be the very top of Mountainside Dr., The Summit, Samson Ct., and Friendship Ln.

In terms of individual scores, the most at risk cabin was Bison with 114 points, located on Mountainside Drive near the Mountainside Lodge. The cabins in this location were in extremely poor condition to the point where they have not been open for booking for several years. This cabin had wooden plank siding, a wooden deck, no foundation, siding, and roofing in poor condition, and a total of 22 lodgepole pine trees, several of which were within 5 feet of the cabin walls. Our team determined all of these factors to be significant contributions to how vulnerable a structure was.

The maximum score overall was actually 124, but since this score was assigned to the Mountainside Lodge building our team considers Bison to still be the highest scored cabin.

The minimum score belonged to Ponderosa, which was one of the newest constructed cabins. What made Ponderosa's score so low was due to many factors; the cabin had no trees or vegetation near it for at least 30 feet, no debris either around the grounds or in the gutters, and no combustible deck furniture. Ponderosa had fiber cement siding, a siding material that has a score of zero on the FSI, and also was one of the few cabins built with a concrete deck, a material which when it comes in contact with fire would not combust. Figure 29 consists of several images of what we determined to be a low-risk cabin. This cabin was Black Bear, which had a score of 11.

Minimum	Maximum	Mean	Median	Mode
5	114	36.3	34	22

Figure 26: Table of wildfire vulnerability score statistics from cabin assessment database

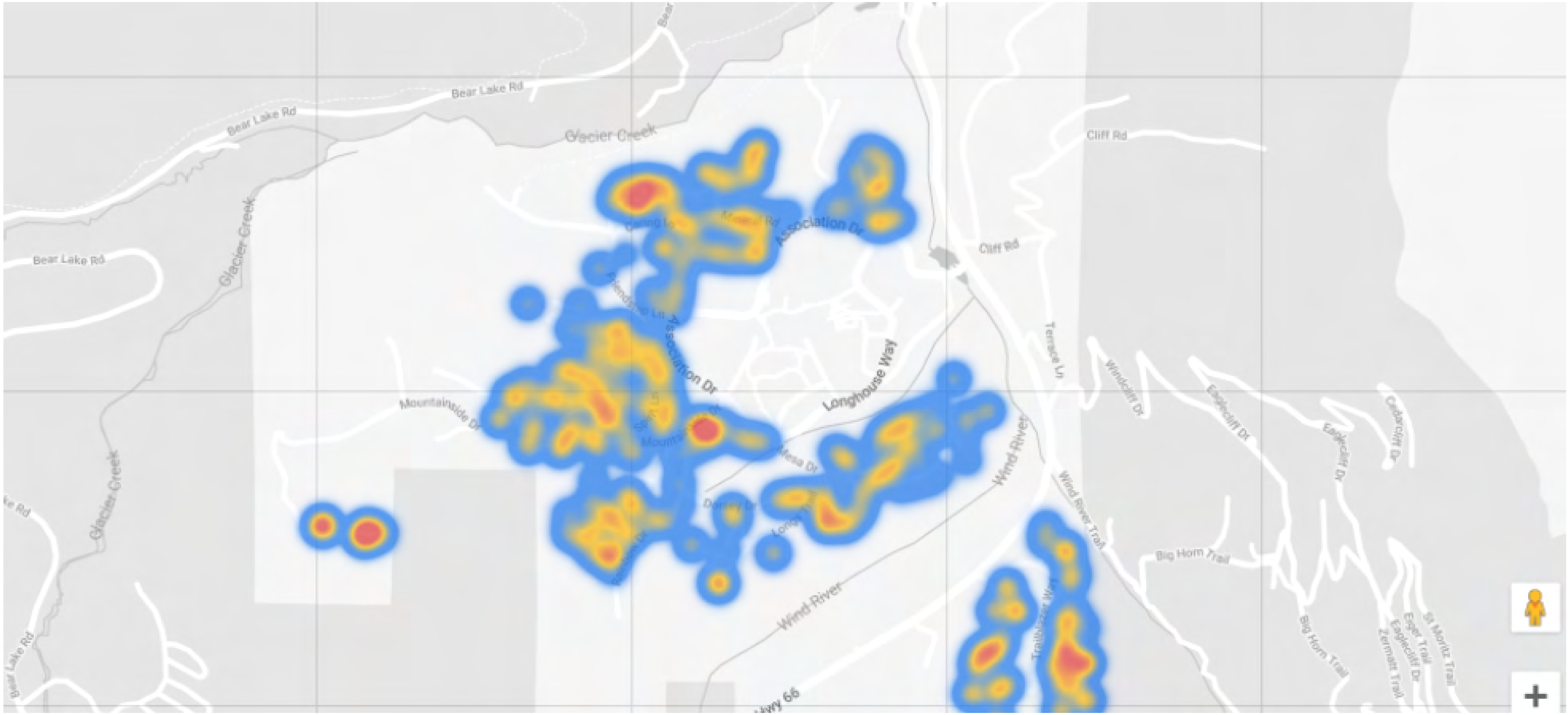


Figure 27: Heat map displaying areas with highest risk cabins.

Figure 28: Images of Black Bear, a low risk cabin. Note how there is no vegetation surrounding the cabin within 5 feet, no gutter debris, and no overhang.

While we can confidently say the scoring system assessed the form results well, it was not perfect. One factor that the system did not take into consideration was how healthy the blue spruce trees were if any were present within 30 feet of the structure. As stated above, most of the blue spruce trees found were either sick or dying due to a lack of water access, but some were in healthy condition. The blue spruce trees that were dried out are far more hazardous to built structures than the healthy trees, but since we did not specify which blue spruces were healthy and which were unhealthy, it was not factored into the score and thus blue spruces were assigned a lower point value to correspond with live trees.

Another limiting factor was the foundation of the buildings. Some of the cabins we assessed did not have a standard cement foundation, and instead were built above ground on stilts. While this is a fire risk, it was not discussed in any fire risk studies, and thus was not taken into account when applying the scoring system.

4.4 Interactive Map

User Testing

In order to establish the robustness of our map system, we completed user testing on Troy Husler and Kelly Wilkerson. This provided us with feedback from those who would be utilizing the map the most, and it gave us an idea of different improvements to implement. The recommendations we received involved creating data summaries geared towards the staff of the Buildings and Grounds Department that would aggregate the data into two vulnerability scores, one taking into account structural aspects and the other taking into account landscaping aspects of our assessments.

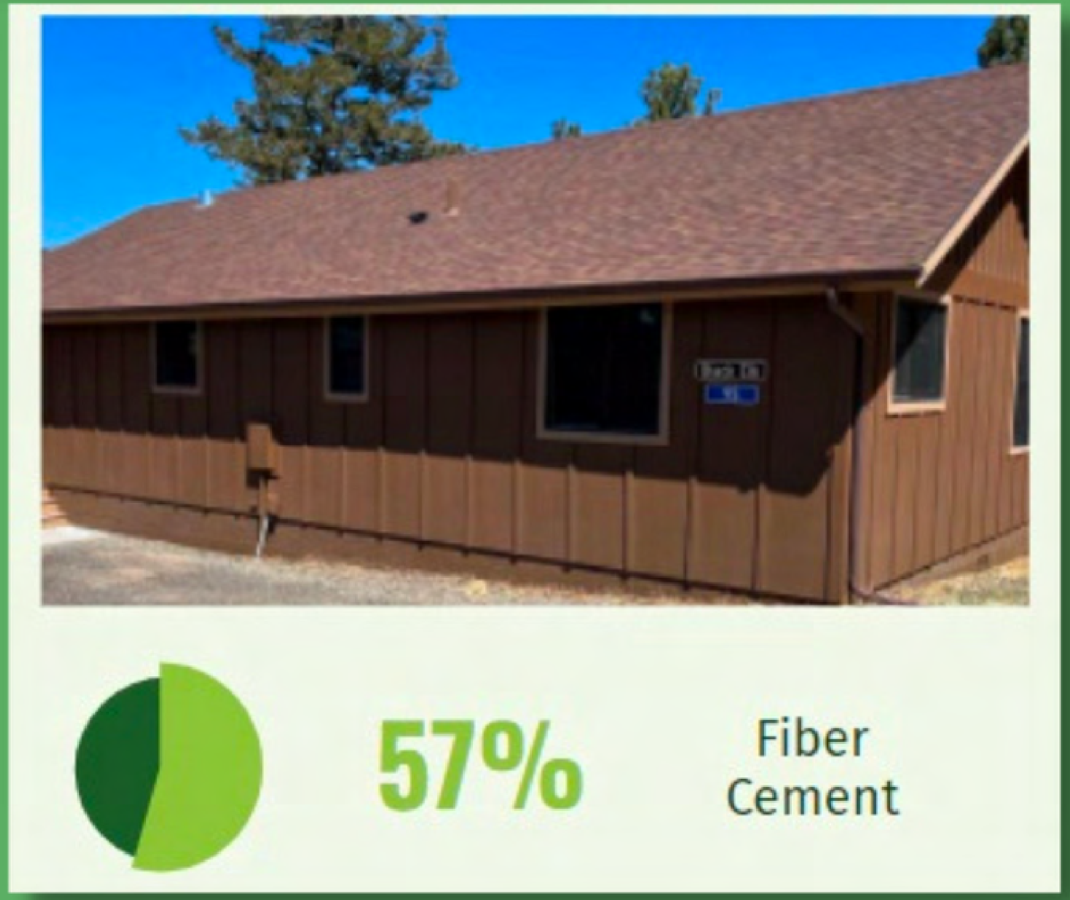
4.5 What are the likely costs for cabin retrofitting?

Siding: Pine Logs vs. Fiber Cement

There were many aspects to consider when it came to choosing materials to retrofit cabins. As mentioned in section 4.1, some materials may cost more initially, but over time they end up being the more cost-effective option due to durability and less need for maintenance. During our research, we found that while materials such as fiber cement siding cost more to install because of specialized installation requirements, it can be cheaper in the long run when compared to wood siding because it can last far longer with less upkeep. The YMCA pays on average $2000 more for fiber cement siding than they do for pine log siding per cabin (excluding reunion cabins). Figure 30 below displays the cost data from our analysis of invoices related to building work at the YMCA.

	Price
Average cost of using cedar logs	$1,430.94
Average cost of using fiber cement	$3,587.90
Difference	$2,156.96 (250.73% increase)

Figure 29: Table of average price comparison between fiber cement and pine log siding per cabin (non-reunion), data collected from YMCA invoices of 7 cabins built in 2021. Prices from these cabin invoices were averaged together to get the price values.



While the additional cost for fiber cement siding appears steep, fiber cement siding not only is less ignitable than wood siding--fiber cement siding has a Class A Fire rating while pine logs have a Class C Fire rating--but it also lasts longer, surviving in good condition for over 50 years before it needs to be replaced (Taylor, Bernstein & Vila, 2021). In comparison, wooden siding, both planks, and logs require replacement every 20 years or so, not including any maintenance such as filling gaps and cracks as they develop, and the need to repaint or reseal wooden sidings every 6 to 10 years (Colorado Siding Repair, 2022). The lifespan of fiber cement siding would provide cabins not only with decades of fire protection but also decades of use as attractive siding without the need for frequent repairs or replacements. Another benefit to using fiber cement siding is that fiber cement, unlike organic sidings like wood, is termite-proof. While this may not be a current issue in the mountainous regions of the United States, it is still a benefit to consider.

Roofing: Asphalt Architectural Shingles vs. Aluminum Standing Seams

The YMCA has discussed the possibility of installing metal roofs on cabins when they are retrofitted. Figure 31 shows the pricing for two different roofing materials: asphalt architectural shingles, which the YMCA used to construct most if not all of the cabin roofs, and aluminum standing seams, a fire-proof metal roofing alternative (Eddy, 2022; Ragan, 2021).

While asphalt architectural shingles are cheaper in terms of the price of materials, it has half the lifespan that an aluminum standing seam metal roof would provide. However, both roof types, if installed correctly, provide the same level of fire protection according to the ASTM E108 test, the roof covering fire test equivalent to the ASTM E84 test which helped us develop our vulnerability scoring system. While asphalt tiles contain combustible materials, they also contain noncombustible materials. The addition of the noncombustible materials prevents the asphalt from igniting, providing the roofing material with Class A fire resistance.

Adding Eaves and Gutter Covers

Eave soffits are important for wildfire safety because they prevent embers from entering any small gaps that may exist underneath the open area where a building's roof extends past the edge of the walls. Gutter covers provide similar protection by preventing plant debris from building up in the gutters, which a stray ember could ignite. Since the YMCA does not add eaves and/or gutter covers to their cabins, we gathered data from internet sources to determine how much they cost. Figure 32 shows the cost of each item per linear foot the material for a typical 2-bedroom cabin at the Y.

Metal mesh eave soffits cost around $1 to $3 per linear foot, while metal mesh gutter covers cost around $1.50 to $3.50 per linear foot. When multiplied by the roof perimeter of an average cabin (2-bedroom), the final price for eave soffits resulted in a range of $147 to $441 per cabin for materials, and gutter covers with $220.50 to $514.50 per cabin. Because these prices were applied to an average roof perimeter, these values do not reflect how much it would cost to install the materials to every cabin type. Cabins with multiple levels, we found, have a similar roof perimeter to their single-story counterparts. Figure 33 shows a photograph of a cabin with gutters filled with leaf litter and debris. This situation is the reason why we looked into gutter covers.

	Asphalt Architectural Shingles	Aluminum Standing Seams
Cost (per square foot)	$4.76	$10.50 - $17.50
Fire Resistance Class	Class A	Class A
Life Span	20-30 years	50-60 years

Figure 30: Cost, fire resistance class, and life span data on AAS and ASS roofing materials.

	Cost (per linear ft)	Average cabin roof perimeter*	Cost per Cabin
Eaves	$1-$3	147 ft	$147-$441
Gutter Covers	$1.50-$3.50	147 ft	$220.50-$514.50

*Figure 31: Table of eave and gutter cover cost analysis (*roof perimeter was taken from building plans for 2 bedroom cabin)*

4.6 Limitations

There were a number of limitations that we came across in the midst of our project work. First, in terms of our aggregate scoring, we chose to score each cabin individually in terms of vulnerability. This required a higher level of expertise than assessing cabins across areas; there was a level of preciseness that we attempted to achieve but may have room for error. Another limitation fell within the cost analysis we provided, which was accurate based on the current market. However, changes in supply and demand can alter these costs throughout time. Labor costs are also very volatile and difficult to predict, so these were not accounted for. There was the issue of the availability of potential contacts during our stay at the project site. We had initially planned on interviewing the YMCA's main contractor for example, but when we arrived was one of the busiest times for him here at the YMCA campus, he was very busy with his projects and thus did not have time to provide us with an interview. Finally, we did not have the time or access to the interiors of the cabins readily available to us, so we did not perform an assessment in terms of making this aspect more fire-resistant.

Figure 32: Photograph of cabin with filled gutters

CHAPTER 5: RECOMMENDATIONS

Table of Contents

5.0 Recommendations

Overall, the purpose of our vulnerability scoring scheme is to identify those cabins that need the most attention and priority. When tackling each of these recommendations below the YMCA should focus on the buildings identified with the highest scores. The problems and solutions fall into three categories: vegetation/landscaping improvements, alterations to existing cabins, and building options for new cabins.

5.1 Vegetation Surroundings

For each improvement we consider three options: Good, Better, and Best. “Good” is generally the easiest and least expensive but provides the least protection, while “Best” is generally the most labor-intensive and provides the best protection. “Better” covers the in-between options, providing a middle ground between labor and protection. All of the “Good” and “Better” recommendations can be funded through the Building and Grounds operating budget due to the lack of materials needed and minimal labor costs. However, the “Best” recommendations, due to its extensive nature, may require a capital project budget due to the amount of labor they would require and the addition of potential materials such as large stone gravel. The chart below outlines our Good, Better, Best suggestions by putting them in comparison to each other.

What Budgets Cover the Good, Better, Best Recommendations

Most of the landscaping recommendations we made involve physical labor. For situations like those, we did not feel at liberty to determine what budget we should recommend due to it being, most likely, a salary issue. Since the YMCA burns all its own brush through prescribed burns, there is no additional cost for debris removal.

	Good	Better	Best
Overhang	- Remove overhang branches in direct contact of roof and siding	- Remove any branches hanging over roof up by 5 feet	- Remove any branches hanging over roof up by 10 feet
Vegetation	- Parts of plants growing directly against building walls should be removed	- All small plants within 5 feet of building should be removed - Trees growing within 5 feet should have limbs touching the building removed	- All small plants within 30 feet of building should be removed - Trees growing within 5 feet should be cut down completely - Remove sickly looking trees
Debris	- Remove leaf litter and pinecone buildup (duff) underneath trees and bushes	- Remove large debris from underneath trees and bushes - Rake up all leaf litter and pinecones (duff) within 5 feet of building - Remove large debris in the 30 ft zone around the cabin	- Remove large debris from underneath trees and bushes - Rake up all leaf litter and pinecones (duff) within 30 feet of building - Remove vegetation underneath porches - Mow grass down 5 ft around the cabin
Tree Limbing	- Remove dead limbs of trees within 30 ft of cabin walls	- Remove dead limbs of trees within 30 ft of cabin walls - Remove branches of trees within 30 ft of the cabin up to 5 feet off the ground	- Remove dead limbs of trees within 30 ft of cabin walls - Remove branches of trees within 30 ft of the cabin up to 10 feet off the ground
Additional Items		- Remove all branches resting in power lines or over chimneys	- Remove all branches resting in power lines or over chimneys - Add metal trays underneath grills - Put large stone gravel under porches to prevent future plant growth

Figure 33: Good, Better, Best recommendations chart

Other recommendations that require materials, such as adding large stone gravel to the 5 feet around a cabin or placing metal trays underneath grills, should be treated as a capital project and be applied for as one during the next YMCA budget planning cycle.

5.2 Building Retrofitting

In terms of existing cabins, the two most important factors are siding and porch material. The most fire protective siding is fiber cement. Ideally, all future building projects would be built using fiber cement for the siding material. The best porch material for fire safety is fire class A composite, so using decking material such as the TimerTech Vintage Collection would reduce the fire risk for the cabin.

We do not recommend the YMCA replace asphalt tile roofs with standing seam aluminum roofs since the aluminum would provide minimal additional fire protection for an extreme price increase. Also, asphalt shingle roofs can be patched if a shingle is damaged, whereas metal roofs, if damaged, are difficult to repair.

The smaller-scale factors to consider mainly consist of maintenance tasks. Any gutters that are filled with debris should be cleared. Maintenance tasks to reduce fire risk involving cabin structures themselves should focus on filling holes in siding, exposed insulation, small cubby doors damaged or open, and miscellaneous surrounding items such as moving porch swings and grills. Holes in siding and any other damages should be repaired as soon as possible, especially when insulation is exposed. Almost every cabin had windows or small cubbies that lead under the structure in the back; many of these are open, broken, or had holes that need repairing. Firebrands or embers can enter small holes like these and endanger the entire structure. Wooden chairs should be replaced with chairs constructed using composite materials like Trex, similarly to tables and swings to eliminate fuel sources near the cabins. Until these items have been replaced, they should be moved 30 feet away from the building. Metal trays should be added below grills to catch excess hot oil that may drip out to avoid the start of a fire. Wooden fences should be replaced with metal, composite, or removed completely based on their purpose. Fire can travel along a wooden fence to ignite a cabin. Fire pits should not be within 30 ft of any structure in case of stray embers or firebrands reaching the building.

All of these recommendations except for gutter cover and eave soffit installation could be funded through the Building and Grounds operating budget, since they are smaller scale. Eave soffits and gutter covers, due to their material costs and the amount of labor required for installation, should become a proposed capital project. The capital/philanthropic budget could be considered for these modifications if many changes are done at once across a variety of cabins. With an estimated cost of remodeling a cabin being around $30,000, increasing the quality of the decking material and adding gutter covers and eave enclosures would increase this cost to around $32,178.62, or about a 7.25% increase.

5.3 Which Cabins to Focus On

According to the vulnerability scores assigned to the cabins within the building database, the buildings in most need of retrofitting and require immediate attention are Bison, Mountainside Lodge, and Coleman. Bison and Mountainside Lodge are located out on the very edge of Mountainside Drive, about 0.5 miles past where the property map ends. These buildings are at highest risk of burning if exposed to wildfire because they are on the very edge of the property in an area with large amounts of lodgepole pines. Bison and Mountainside Lodge are both completely constructed out of wood, and have some structural damages that could become entrance points for embers and firebrands.

We strongly suggest Coleman also be updated as soon as possible. Coleman cabin, located on Coleman Road, is currently the oldest cabin on campus, and thus one of the most vulnerable. Like Bison and Mountainside Lodge, Coleman is constructed completely out of wooden materials. Although Coleman does not have a high score, it is built on stone stilts and thus has no foundation, a factor that was not taken into account when developing our vulnerability scoring system. We highly suggest the YMCA focus their attention on any cabin that has this issue, such as the 2-bedroom cabins on Samson Ct (Eagle, Blue Bird, Blue Bell, Oriole, and Wren's Nest).

Other than those specific cabins, we suggest the YMCA focus any remaining efforts on cabins that have a vulnerability score above 50, of which there are 53 total buildings.

5.4 Options for New Buildings

The best material for fireproofing is fiber cement, so any new buildings should utilize this siding. Porches should be made of composite railing and cement flooring, as wood is much more flammable. Porches that can't be made from cement due to structural limitations should be made out of a composite material with a higher fire class rating, e.g. the TimerTech Vintage Collection. Gutter covers should be implemented as well as eave soffit covers, both of which prevent firebrands and embers from causing harm to the structure. Switching the porch material and adding covers for gutters and eaves would increase the cost to the donor by around 8% to 10% of the estimated renovation cost which is $30,000. Regarding location, building at the top of an incline should be avoided; fire travels much faster uphill. If an incline cannot be avoided, then the YMCA should make sure that the new structure is not built on a westward-facing incline, since the prevailing winds are one of the main causes of strengthening wildfires in the area blow west to east. Locations surrounded by dense forests or a large number of trees should be avoided. These forests increase the surrounding wildfire fuel and any tree within 10ft will cause an overhang. Any plants within 5 ft of the structure will increase the risk of fire due to firebrands/embers.

CHAPTER 6: CONCLUSION

6.0 Conclusion

Most of the improvements we have identified are small, specific tasks that the YMCA could introduce to its operations in the next few years; they mainly focus on the vegetation surrounding cabins. Using our database and interactive map, the YMCA can focus its efforts on retrofitting the most vulnerable cabins to reduce the level of risk across the campus. The increase in wildfire due to climate change has threatened the West more each coming year. Just in the time we have been in Colorado there have been four wildfires around our general area. The WUI has been actively expanding in this area, which means that there is a more critical need for retrofitting and landscaping residences and homes. This means that the YMCA is becoming more vulnerable to fire exposure; our work has aimed to provide options in order to achieve a higher level of safety.

While we focused on enhancing the protection of the built environment of the YMCA, future projects could assess cabin interiors in terms of fire risk, or evacuation practices in the event of a wildfire. When the property is evacuated, gas lines are shut off to prevent combustion. The water lines are also turned off due to the lack of gas heating in order to prevent burst pipes. We have learned there is no system other than map marking to ensure all lines are shut off, which has caused building damage in the past due to missed lines, so this process could be organized as a part of a future project as well. Our assessments and recommendations would also benefit from a reevaluation in 5-10 years. Through landscaping, altering existing cabins, and building more resistant cabins, the YMCA of the Rockies has an opportunity to safeguard its campus.

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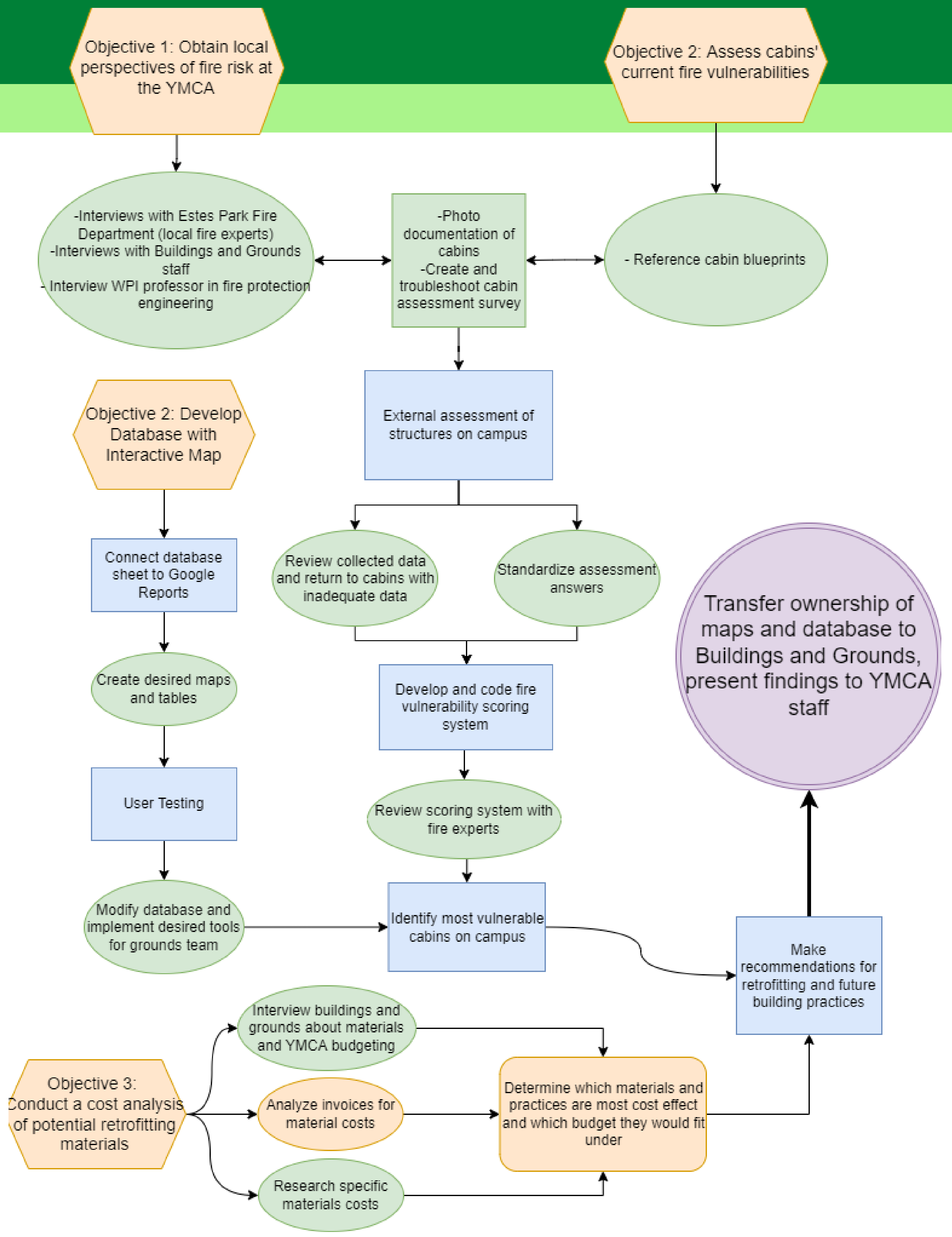
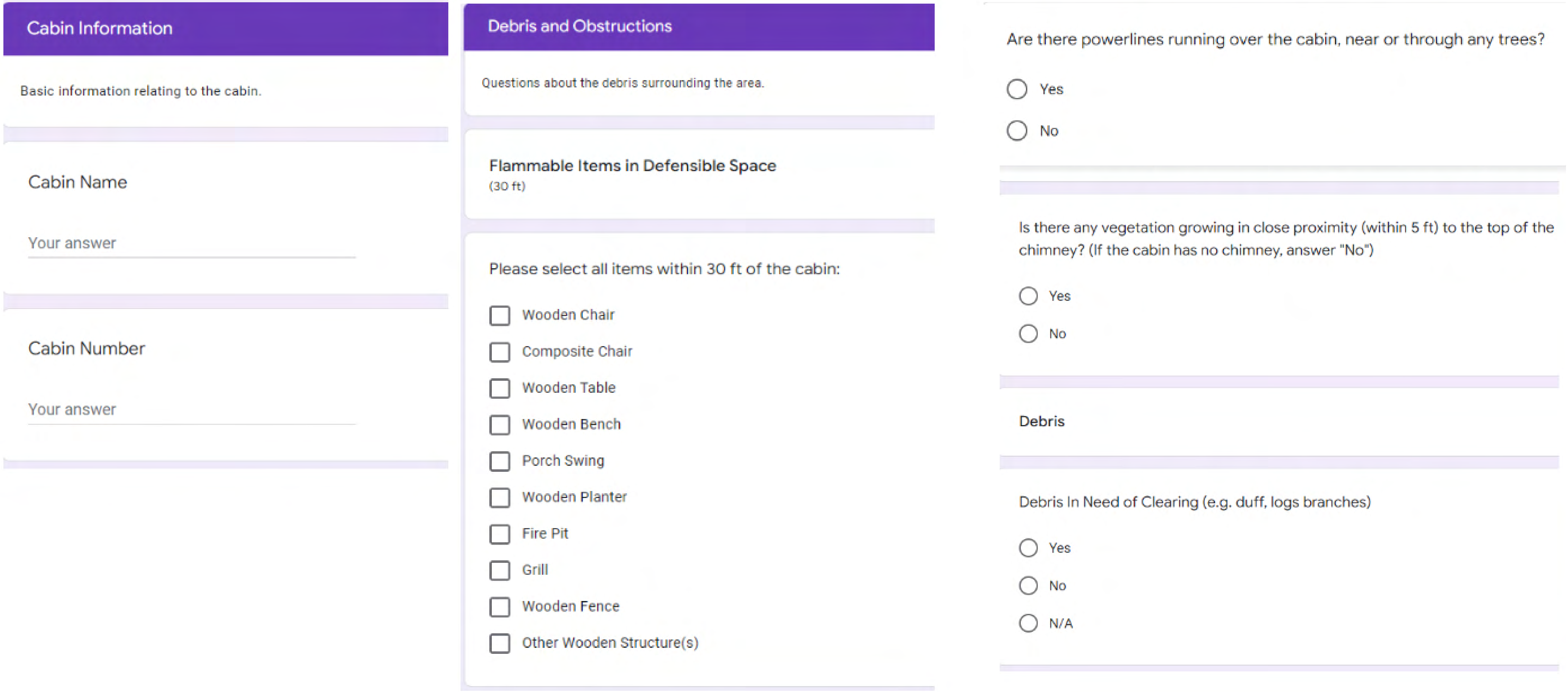
Appendix A: Flowchart

This flowchart provides a basic outline for the methodology we followed while completing our project at the YMCA of the Rockies



Appendix B: Preliminary Cabin Assessment

This Google Form assessment survey was created from a combination of our own research and a previously existing survey used by the Colorado State Forest Service (CSFS) and the Insurance Institute for Business and Home Safety (IBHS). This formed is linked to Google Sheet to collect all of the data.


Cabin Information

Basic information relating to the cabin.

Cabin Name

Your answer

Cabin Number

Your answer

Debris and Obstructions

Questions about the debris surrounding the area.

Flammable Items in Defensible Space
(30 ft)

Please select all items within 30 ft of the cabin:

- Wooden Chair
- Composite Chair
- Wooden Table
- Wooden Bench
- Porch Swing
- Wooden Planter
- Fire Pit
- Grill
- Wooden Fence
- Other Wooden Structure(s)

Are there powerlines running over the cabin, near or through any trees?

- Yes
- No

Is there any vegetation growing in close proximity (within 5 ft) to the top of the chimney? (If the cabin has no chimney, answer "No")

- Yes
- No

Debris

Debris In Need of Clearing (e.g. duff, logs branches)

- Yes
- No
- N/A

Appendix B: Preliminary Cabin Assessment (Cont.)

Debris (Continued)

Select an option based on the type of debris in the area.

Please select all below that are part of the debris.

- [ ] General
- [ ] Branches
- [ ] Logs
- [ ] Brush Pile
- [ ] Dead Tree(s) (standing or fallen)

Porch Questions

Specific questions about the porch.

What material is the porch is made of?

- [ ] Wood
- [ ] Composite
- [ ] Concrete

Does the porch wraparound two or more sides of the cabin and/or is there more than than one porch?

- ◯ Yes
- ◯ No

Does the porch have multiple stories? Or is heigh enough off the ground for a grown human to fit under?

- ◯ Yes
- ◯ No

Is there notable vegetation (e.g. bitterbrush or trees) growing under or through the porch?

- ◯ Yes
- ◯ No

Vegetation

Over Hanging Limbs?

- ◯ Yes
- ◯ No

If Overhanging Limbs, How much Coverage?

	0	1	2	3	4	5	6	7	8	9	10	
1 or 2 Small Limbs	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Completely Covered

Vegetation Count

Please provide the amount of each plant withing 30 ft of the cabin. If none, type "0". Please provide number answers only, no letters.

Is there at least one patch of multiple tree saplings? If so, mark "Yes" here and exclude them from your count for the next question.

- ◯ Yes
- ◯ No

Amount of Ponderosa Pine

Your answer

Appendix B: Preliminary Cabin Assessment (Cont.)

Amount of Blue Spruce

Your answer

Amount of Douglas Fur

Your answer

Amount of Aspen

Your answer

Amount of Juniper

Your answer

Amount of Cottonwood

Your answer

Amount of Lodgepole Pine

Your answer

Cabin Structure

Questions revolving around the structure/materials of the cabin.

Is the cabin built on a non-negligible incline?

- ◯ Yes
- ◯ No

What is the siding of the cabin made of?

- ◯ Wooden Boards
- ◯ Fiber Cement
- ◯ Stone/brick
- ◯ Cedar Logs
- ◯ Plastic

Is the siding or roof in a noticeably poor condition due to age or wear?

- ◯ Yes
- ◯ No

Is there any exposed insulation?

- ◯ Yes
- ◯ No

Are there any unintended holes in the siding or windows that lead into the cabin?

- ◯ Yes
- ◯ No

Is the gutter free of debris?

- ◯ Yes
- ◯ No

Does the cabin have a porch?

- ◯ Yes
- ◯ No

Appendix B: Preliminary Cabin Assessment (Cont.)

Are any of the trees or brush growing within 5 ft of the cabin?

- Yes
- No

Is Bitterbrush present within 30 ft?

- Yes
- No

Is Sage bush present within 30 ft?

- Yes
- No

Back | Next

Other Questions

(Didn't really fit anywhere else)

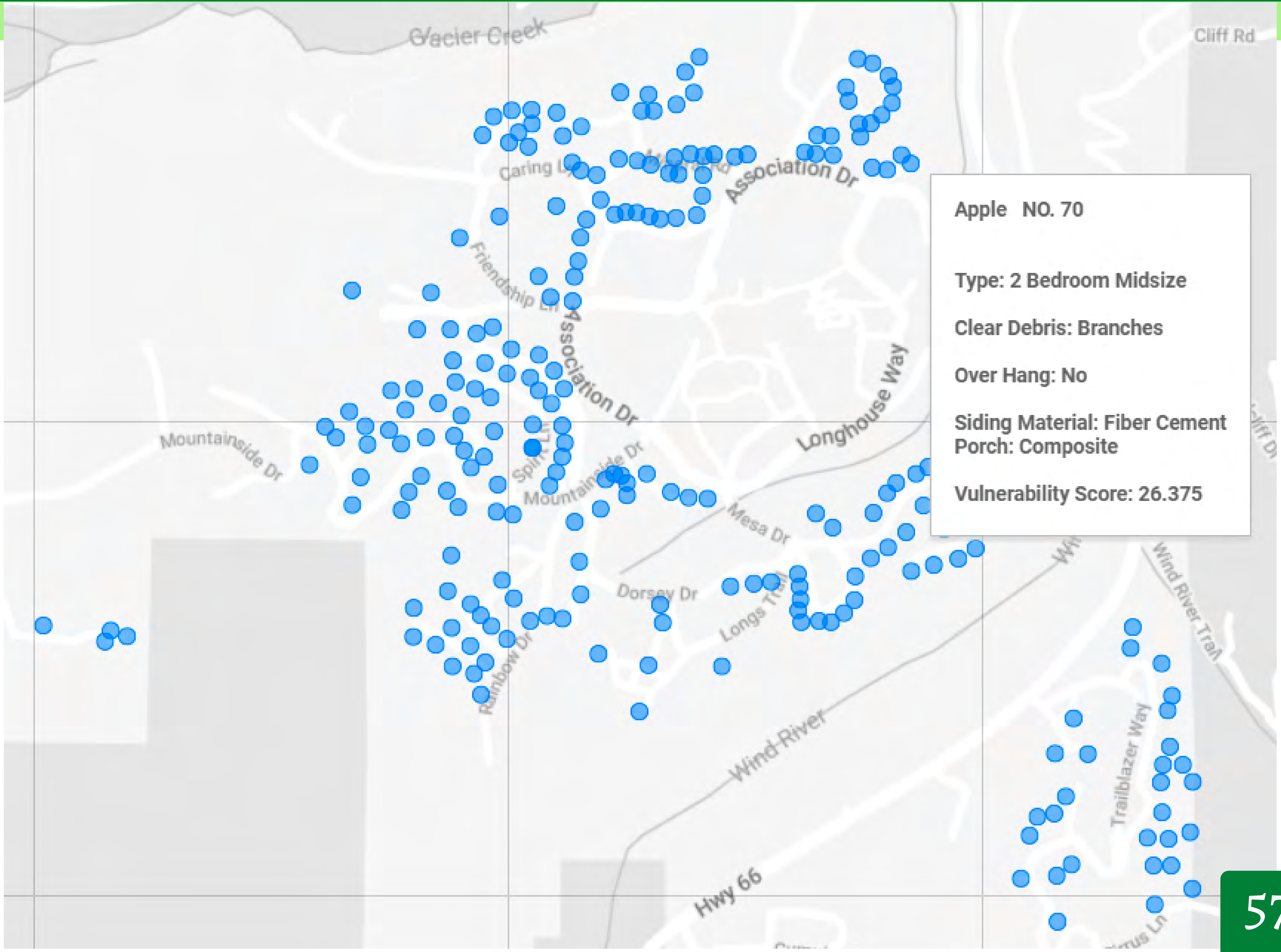
Any Additional Notes Specific for this Cabin?

Your answer

Back | Submit

Appendix C: User Interface Mockup of Map

This image is a screenshot of the cabin map connected to the cabin assessment database, both of which were given to the YMCA of the Rockies' Buildings and Grounds team. Each dot indicates a building assessed.



Appendix D: Cost Analysis from Headwaters Economics

This appendix contains the framework we used for our team's cost analysis on building materials.

	Typical	Wildfire-Resistant	Difference	
Roof				
Roofing	14,870	16,380	1,510	10%
Vents	930	1,560	630	68%
Soffit & Fascia	5,080	6,970	1,890	37%
Gutters	930	2,760	1,830	197%
Subtotal	**$21,810**	**$27,670**	**$5,860**	**27%**
Exterior Walls				
Siding	29,930	12,360	(17,570)	-58%
Sheathing	3,810	4,180	370	10%
Doors	6,170	8,120	1,950	32%
Windows	8,470	11,530	3,060	36%
Subtotal	**$48,380**	**$36,190**	**-$12,190**	**-25%**
Deck				
Decking surface	8,230	9,430	1,200	15%
Framing	930	1,230	300	32%
Fascia	570	920	350	61%
Subtotal	**$9,730**	**$11,580**	**$1,850**	**19%**
Near-Home Landscaping				
Mulch (bark vs. rock)	1,220	3,250	2030	166%
Landscape Fabric	0	540	540	-
Subtotal	**$1,220**	**$3,790**	**$2,570**	**211%**
All Components				
Total	**$81,140**	**$79,230**	**-$1,910**	**-2%**

Appendix E: List of Vegetation by Flammability

Appendix E contains the list of flammable plants that are most hazardous in the WUI. Of the plants on the list, the ones present on campus are Douglas fir, Juniper, Pine, Bitterbrush, Oregon grape (not seen near any cabins), and Sagebrush.

Highly Flammable Plant List:

PLANTS THAT WILL IGNITE QUICKLY AND BURN READILY

When living in a Wildfire Hazard Zone, it is recommended that these plants NOT be used within 30 ft of any structures, fenced outbuildings or decks. This list is NOT all-inclusive as other plants with similar characteristic, such as: low moisture, dry limbs and needles and abundant oils are potentially hazardous. Plant smart and use fire-resistant vegetation to create defensible space around all structures.

TREES

Acacia	*(Acacia sp.)*
Arborvitae	*(Thuja sp.)*
Cedar	*(Cedrus sp.)*
Cedar/Cypress	*(Chamaecyparis sp.)*
Cypress	*(Cupressus sp.)*
Douglas fir	*(Pseudotsuga menziesi)*
Fir	*(Abies sp.)*
Hemlock	*(Tsuga sp.)*
Juniper	*(Juniperus sp.)*
Pine	*(Pinus sp.)*
Sequoia	*(Sequoia sp.)*
Spruce	*(Picea sp.)*
Yew	*(Taxus sp.)*

SHRUBS

Blackberry	*(Rubus armeniacus)*
Bitterbrush	*(Purshia tridentata)*
Juniper	*(Juniperus sp.)*
Laurel sumac	*(Malosma laurina)*
Manzanita*	*(Arctostaphylos sp.) *except for Kinnikinnick*
Oregon grape*	*(Mahonia aquifolium) *except for 'Compacta'*
Rosemary*	*(Rosmarinus sp.) *except for 'Prostratus'*
Sagebrush	*(Artemisia sp.)*
Scotch broom	*(Cytisus scoparius)*
Scrub oak	*(Quercus sp.)*
Wild Lilac	*(Ceanothus sp.)*

GRASSES AND GROUND COVER

Dry annual grasses	
Large bark mulch	
Pampas grass	*(Cortaderia selloana)*

Appendix F: Vulnerability Scoring System Weights and Application

This appendix is a compendium of the different hazards that can be applied to the cabins and buildings surveyed on the YMCA campus. The hazards were broken down into sections, and then assigned point values based on how much more vulnerable each hazard makes a building to wildfire. All of these weightings correspond with questions from our cabin assessment within the answer collection Google Sheet, and were applied to the data through coding. These values, while relative, are based upon research documents from the CSFS's "Protecting Your Home from Wildfire: Creating Wildfire-Defensible Zones" fact sheet and IBHS's "Wildfire Retrofit Guite: Rocky Mountain Edition." Citations for these documents are provided at the end of this appendix. FSI values were gathered from the Louisiana Department of Safety and Corrections, as well as several ASTM E-84 test result documents.

Siding Ignitability:

1. Wooden boards: base points = 6 (material multiplier = x2)
2. Wooden logs: base points = 3 material multiplier = (x1.5)
3. Fiber cement: base points = 0 (material multiplier = x1)
4. Stone: base points = 0 (material multiplier = x1)

Decking Ignitability:

1. Wood: base points = 5 (material multiplier = x2)
2. Composite: base points = 3 (material multiplier = x1.25)
3. cement : base points = 0 (material multiplier = x0)

Decking aspects:

1. Wraparound (x1.5 to deck material base points)
2. Multiple stories (x1.5 to deck material base points)

Landscaping Hazards (outside of 5 ft from cabin):

1. Ladder fuels (bitterbrush, juniper, branches w/in 10 ft of forest floor for conifer trees)
   a. Blue Spruce (3 points per tree)
   b. Presence of bitter brush (3 points per tree)
   c. Lodgepole (2 points per tree)
   d. Juniper (2 points per tree)
   e. Ponderosa (1 point per tree)
   f. Fir (1 point per tree)
   g. Aspen (0.5 points per tree
   h. Cottonwood (0.5 points per tree)

3. Surface fuels: debris (1 point per debris type listed)
4. Grasses: presence of sagebrush (1 point)

Landscaping Hazards (within 5 feet of cabin):

1. Plants against building siding (8 points x siding material multiplier)
2. Limb overhang near roof of building (overhang score as recorded through assessment, score number applied as points value)
   a. Add +3 points to score if overhang is over chimney or through power lines
1. Debris buildup in gutters (5 points)
2. Plants under decking (4 points x porch material multiplier)

Structural Hazards:

1. Roof and/or siding in poor condition (7 points x siding material multiplier)
2. Exposed insulation (6 points)
3. Unintended holes (3 points)
4. Exposed/open eaves (3 points)
5. Deck built on a slope (2 points x porch material multiplier)
   a. Add +1 point for each recorded piece of combustible furniture (i.e. wooden chairs,

grills, wooden tables)

   a. If deck furniture is composite, add no points to score

6. Combustible personal items (such as playgrounds, firewood piles, etc.) within 30 feet
of cabin (1 point for each item listed)

Appendix G: Database Sample

Appendix G contains sample answers for all fields within the cabin assessment database created.

	Timestamp	Cabin Name	Cabin Coords	Cabin Number	Cabin Type	Debris In Need of Clearing (e.g. duff, logs branches)	Please select all below that are part of the debris.
2	3/28/2022 13:37:03	A Third Way	40.33669, -105.56899	41	3 Bedroom Plus	Yes	Dead Tree(s) (standing or fallen)
3	4/7/2022 11:51:50	Aerie	40.33033, -105.56325	529	3 Bedroom w/ Fireplace	Yes	Logs
4	4/7/2022 11:13:24	Aftermath	40.33035, -105.56556	103	4 Bedroom Plus	Yes	Logs
5	4/4/2022 10:47:15	Agate	40.3446124, -105.5741816	125	2 Bedroom Basic	Yes	General
6	3/22/2022 14:22:39	Alleluia	40.33755, -105.57917	106	3 Bedroom w/ Fireplace	No	
7	3/28/2022 13:37:36	Aloha	40.33984, -105.57897	58	2 Bedroom w/ Fireplace	Yes	Branches
8	3/28/2022 10:48:08	Alpenglow	40.33474, -105.57771	528	3 Bedroom w/ Fireplace	No	
9	3/28/2022 10:50:30	Alplily	40.33423, -105.58029	104	3 Bedroom w/ Fireplace	Yes	Logs
10	3/25/2022 16:19:30	Anasazi	40.34428, -105.5698	191	2 Bedroom w/ Fireplace	No	

Over Hanging Limbs?	If Overhanging Limbs, How much Coverage?	Amount of Ponderosa Pine	Amount of Blue Spruce	Amount of Douglas Fir	Amount of Aspen	Amount of Juniper	Amount of Cottonwood	Amount of Lodgepole Pine
No	0	3	0	0	0	0	0	0
No	0	0	0	1	0	0	0	0
No	0	8	0	0	5	4	0	0
Yes	3	9	0	0	0	2	0	0
No	0	6	0	0	0	1	0	0
No	0	2	0	0	0	0	0	0
Yes	4	8	0	0	0	0	0	0
No	0	5	0	0	0	0	0	0
Yes	2	1	0	0	0	0	0	0

Appendix G: Database Sample (Cont.)

Any Additional Notes Specific for this Cabin?	Cabin-specific images	Please select all items within 30 ft of the cabin:	Are there powerlines running over the cabin, near or through any trees?	Is there any vegetation growing in close proximity (within 5 ft) to the top of the chimney? (If the cabin has no chimney, answer "No")	Is the cabin built on a non-negligible incline?	What is the siding of the cabin made of?	Is the siding or roof in a noticeably poor condition due to age or wear?	Is there any exposed insulation?
	https://drive.google.com/	Wooden Chair	No	No	No	Fiber Cement	No	No
		Wooden Chair	No	No	No	Wooden Boards	No	No
		Wooden Chair, Wooden Table	No	No	No	Wooden Boards	No	No
			No	No	No	Wooden Boards	No	No
			No	No	Yes	Fiber Cement	No	No
		Wooden Chair	No	No	No	Wooden Boards	No	No
	https://drive.google.com/		No	No	No	Cedar Logs	No	No
		Wooden Chair	No	No	No	Wooden Boards	No	No
			No	No	No	Cedar Logs	No	No

Are there any unintended holes in the siding or windows that lead into the cabin?	Is the gutter free of debris?	Does the cabin have a porch?	What material is the porch is made of?	Does the porch wraparound two or more sides of the cabin and/or is there more than than one porch?	Does the porch have multiple stories? Or is heigh enough off the ground for a grown human t fit under?	Is there notable vegetation (e.g. bitterbrush or trees) growing under or through the porch?	Is Bitterbrush present within 30 ft?
No	Yes	Yes	Composite	Yes	Yes	Yes	No
No	Yes	Yes	Wood	No	No	Yes	Yes
No	Yes	Yes	Wood	No	Yes	No	Yes
No	Yes	Yes	Composite	Yes	No	No	Yes
No	Yes	Yes	Wood	No	Yes	No	Yes
No	Yes	Yes	Wood	Yes	Yes	No	Yes
No	Yes	Yes	Composite	No	No	No	Yes
No	Yes	Yes	Wood	Yes	No	No	Yes
No	Yes	Yes	Composite	Yes	No	No	Yes
						No	Yes

Appendix G: Database Sample (Cont.)

Is Sage bush present within 30 ft?	Are any of the trees or brush growing within 5 ft of the cabin?	Is there at least one patch of multiple tree saplings? If so, mark "Yes" here and exclude them from your count for the next question.	Closest Cabin	Number of Cabins in 100 ft	Vulnerability Score	Image URL
Yes	No	No	Four Sisters	0	54.75	https://drive.google.com/
Yes	Yes	No	Ohana	0	50	
No	No	No	Brady	0	50.5	
Yes	Yes	No	Onyx	0	60.875	
Yes	No	No	Rams Horn	0	30	
No	Yes	No	Twin Pines	0	52	
No	Yes	No	Wapiti	0	38	https://drive.google.com/
Yes	Yes	No	Tyndal	0	49	
Yes	Yes	No	Arapahoe	1	31.875	

Appendix H: User Manual: Building Assessment Database

The following pages contain the user manual created for the Buildings and Grounds team so they can easily learn to use and operate the database, assessment survey, and maps we created during our project. These pages are formatted differently from the rest of this report in order to make it readily available to anyone who desires to print off the user manual seperately.

Appendix H: Database and Maps User Manual

User Manual: Building Assessment Database

By: YMCA Wildfire - WPI

Authors:
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Advisors:
Robert Hersh, Despoina Giapoudzi

Sponsor:
The Young Men’s Christian Association (YMCA) of the Rockies

I. Table of Contents

1. Initial Steps

First, you want to log into the allocated Gmail account given.

Username: ************

Temporary Password: ***********

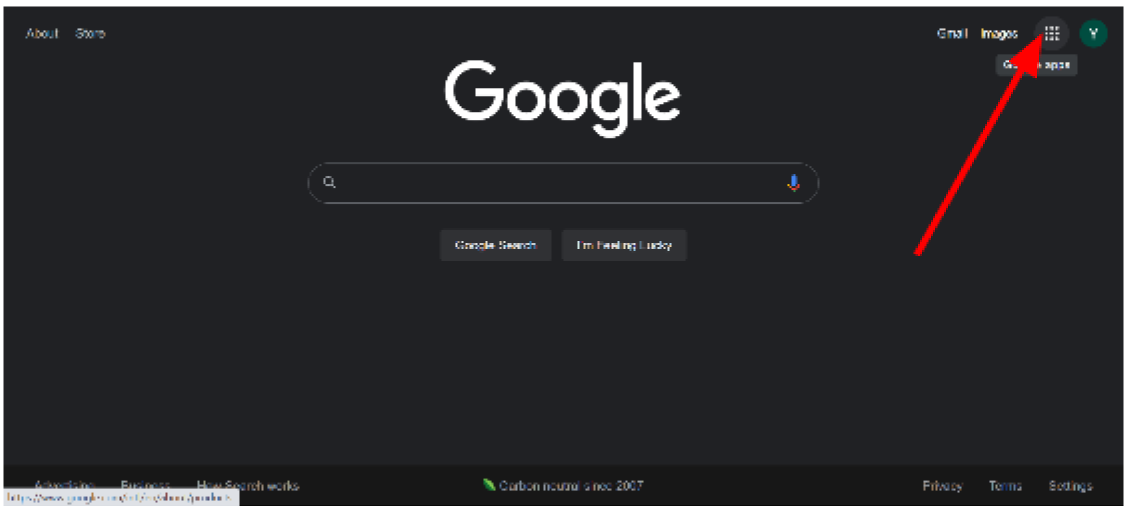
(If you wish to change the password please do so)

If you are wishing to fill out a form, click this link

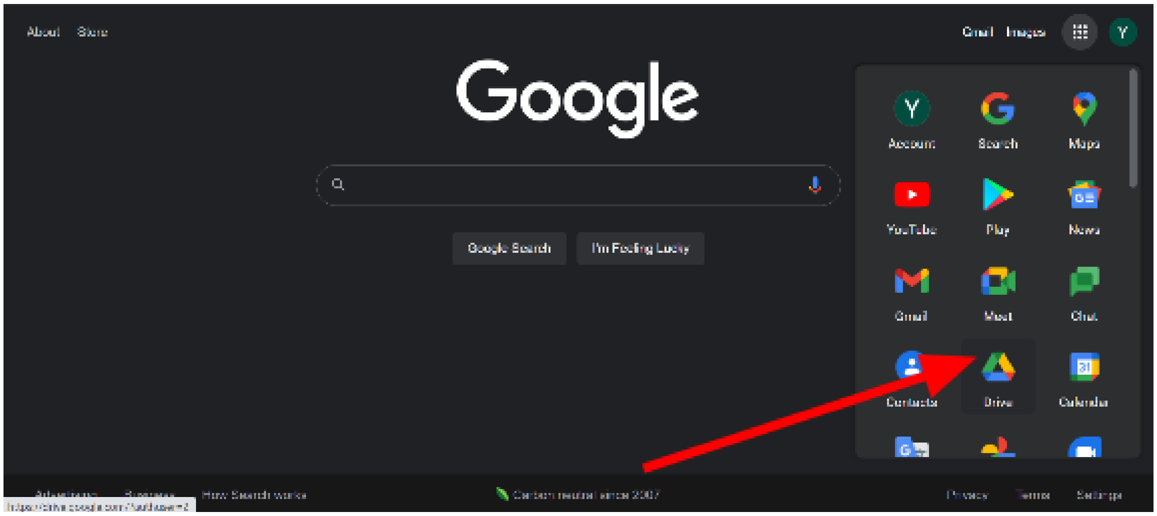
https://forms.gle/J5r6hdTAD8hpcMPR9

If you want to navigate to the data, follow these steps:

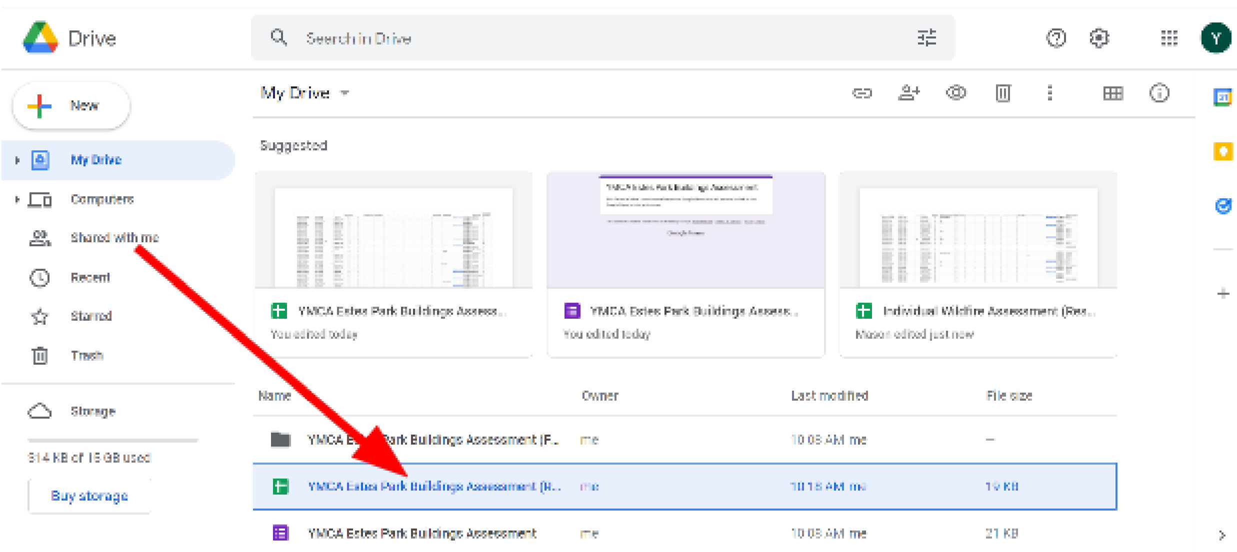
1. After logging into Gmail, you will see a Y in the upper right corner of the screen. Select the square Google Apps icon in the upper right corner of the Google Home Page.



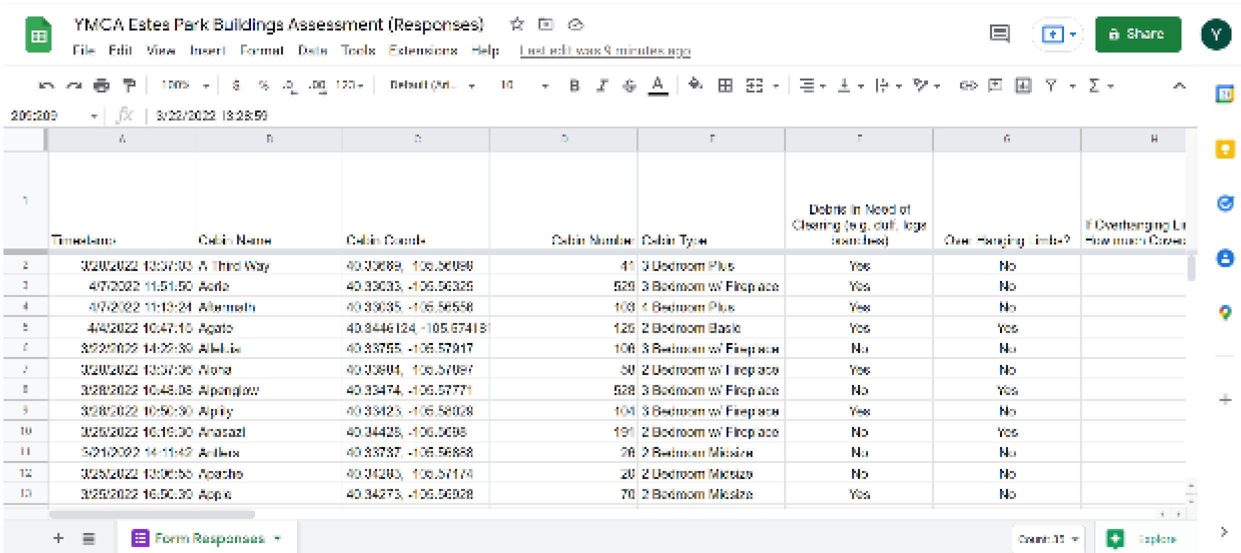
2. From the Google Apps menu, select Drive.



3. You will be brought to your Google Drive which stores the Excel Sheet of data. You can click on the sheet to view the data.



4. This is what the spreadsheet shows, the cabins in alphabetical order by name.



2. Updating Data

If you want to update data for a cabin that has already been added to the database, you must access the excel sheet. To locate the building's associated data row, you should press ctrl+F and type in the building name to find its appropriate row. Below is an example highlighting the cabin Agate. When you search for a cabin by name, it will become highlighted in green like below in the column outlined in red.

Timestamp	Cabin Name	Cabin Coords	Cabin Number	Cabin Type	Debris In Need of Clearing (e.g. duff, logs branches)
3/28/2022 13:37:03	A Third Way	40.33669, -105.56899	41	3 Bedroom Plus	Yes
4/7/2022 11:51:50	Aerie	40.33033, -105.56325	529	3 Bedroom w/ Fireplace	Yes
4/7/2022 11:13:24	Aftermath	40.33035, -105.56556	103	4 Bedroom Plus	Yes
4/4/2022 10:47:15	Agate	40.3446124, -105.5741816	125	2 Bedroom Basic	Yes
3/22/2022 14:22:39	Alleluia	40.33755, -105.57917	106	3 Bedroom w/ Fireplace	No
3/28/2022 13:37:36	Aloha	40.33984, -105.57897	58	2 Bedroom w/ Fireplace	Yes
3/28/2022 10:48:08	Alpenglow	40.33474, -105.57771	528	3 Bedroom w/ Fireplace	No
3/28/2022 10:50:30	Alplily	40.33423, -105.58029	104	3 Bedroom w/ Fireplace	Yes
3/25/2022 16:19:30	Anasazi	40.34428, -105.5698	191	2 Bedroom w/ Fireplace	No
3/21/2022 14:11:42	Antlers	40.33737, -105.56888	26	2 Bedroom Midsize	No
3/25/2022 13:06:55	Apache	40.34293, -105.57174	20	2 Bedroom Midsize	No
3/25/2022 16:50:39	Apple	40.34273, -105.56928	70	2 Bedroom Midsize	Yes
3/25/2022 16:21:07	Arapahoe	40.34409, -105.56969	203	2 Bedroom w/ Fireplace	No

If you want to edit the data, keep in mind that each column associates with a different question in the form. You must then locate the appropriate column associated with the changed data and edit it accordingly. It is critical that capitalization, spelling, and naming conventions remain consistent across the board, especially for multiple-choice questions. These naming conventions will follow the questions and answers from the Google Form. If you need to enter multiple entries in a single cell, separate the entries by commas like below:

S	T	U
Please select all items within 30 ft of the cabin:	Are there powerlines running over the cabin, near or through any trees?	Is there any vegetation growing in close proximity (within 5 ft) to the top of the chimney? (If the cabin has no chimney, answer "No")
Wooden Chair	No	No
Wooden Chair	No	No
Wooden Chair	No	No
Wooden Chair	No	No
	No	No
Wooden Chair, Wooden Table	Yes	No
Wooden Chair	No	No
Wooden Chair	No	No
Fire Pit, Wooden Chair, Grill	No	No
Wooden Chair, Wooden Table	No	No
Grill, Porch Swing, Wooden Chair	No	No

This will keep the interactive map functioning properly along with the displayed charts of the data on Google Reports. Alternatively, you can delete the entry by deleting the row and filling out an entirely new entry for the structure.

3. Uploading New Building Data

If a new cabin/building were to be built that you want to add to the database, then you must fill out the Google Form that is linked to the editable Google Sheet containing the rest of the building data. Once completed an additional row will be added to the end of the Sheet with the completed information. If you want the data to properly display on the interactive map, then you must obtain the coordinate associated with the building. It is critical that a new cabin has its coordinates inputted manually into the spreadsheet, or else it will not be displayed on the map. This can be done using Google Maps, and clicking on a location on the map. Once clicked, the associate coordinates should display at the bottom of the screen. This information should be copied and pasted into the column labeled "Cabin Coords" in the Google Sheet where the data entry is. It might be beneficial to change the Google Maps layer to “Satellite” for a better visual of the building.

Another option is using an application on a mobile device that uses satellite data to tell you your exact coordinates. If you are standing next to or near the cabin location, you can also manually input that data into the spreadsheet.

4. How to Use the Form

If you were to create a new data point, the Google Form is very extensive and detail-oriented to collect the most valuable data. After opening the Google Form link, you are promoted to the title page displaying the description of the form. Once the text is read, you can select the “Next” button to continue. This can be seen in Figure 1.

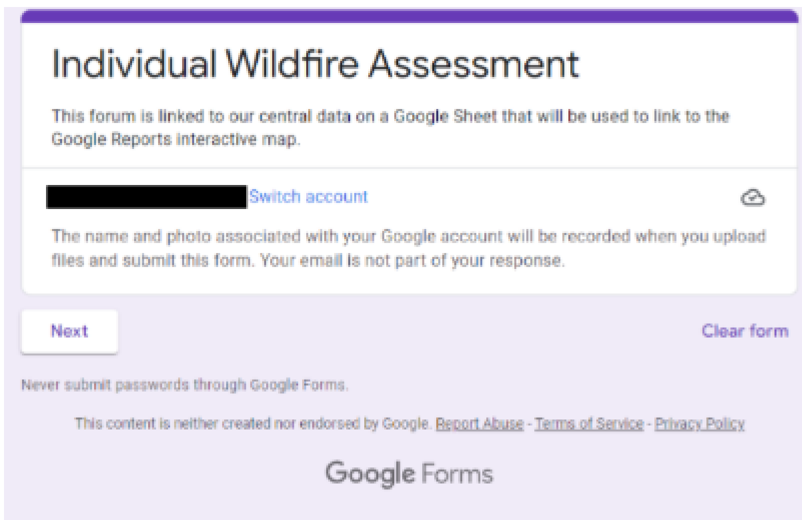


Figure 1: The Google Form Title Page

You are then taken to the next page to gather basic building data including name, number, and type. Once complete you can press the “Next” button at the bottom of the form to continue. This page can be seen in Figure 2.

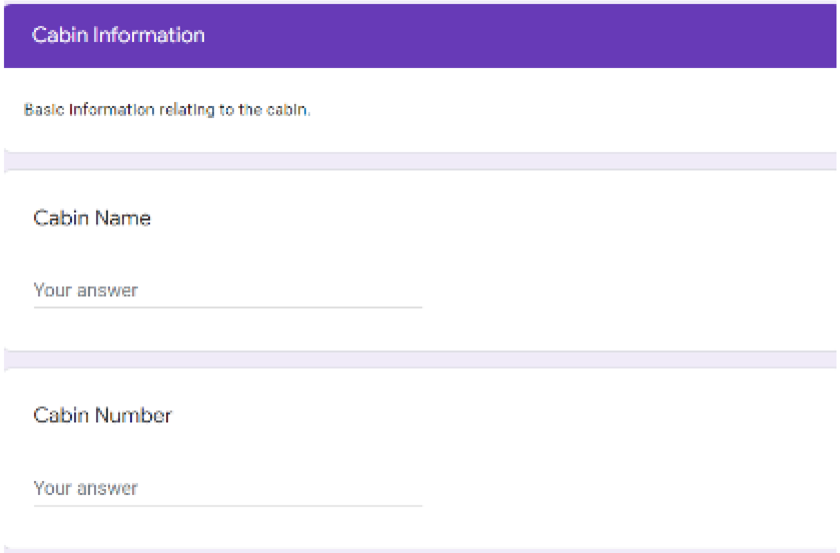


Figure 2: Building Information Page

Afterward, the next page is used to gather data regarding debris and obstructions surrounding the building. This section focuses on any susceptible items within 30 feet of the building. This includes wooden chairs, wood tables, grills, fences, etc. This complete list can be seen in Figure 3.

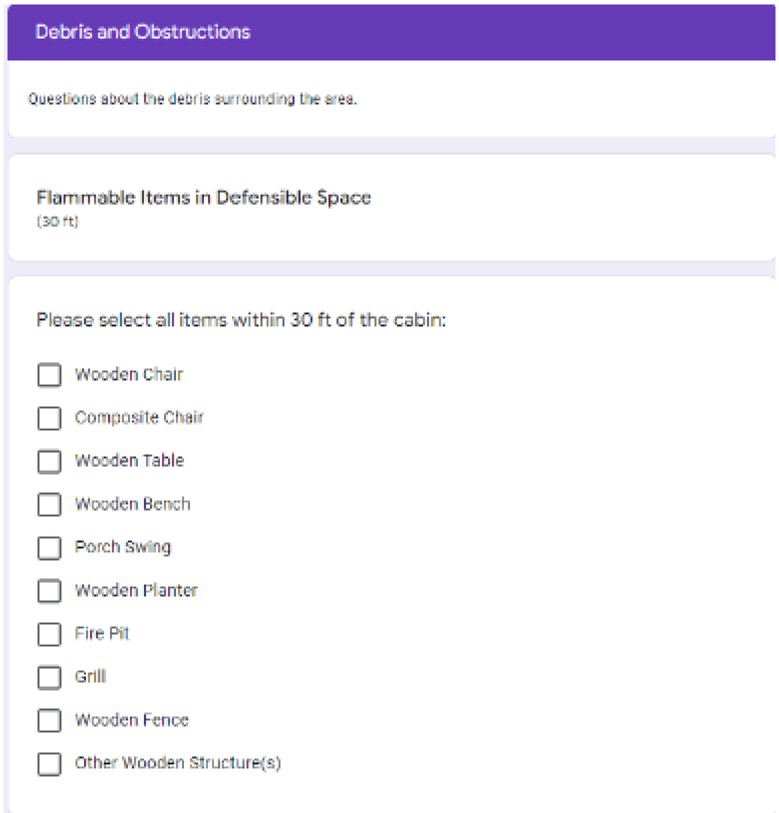
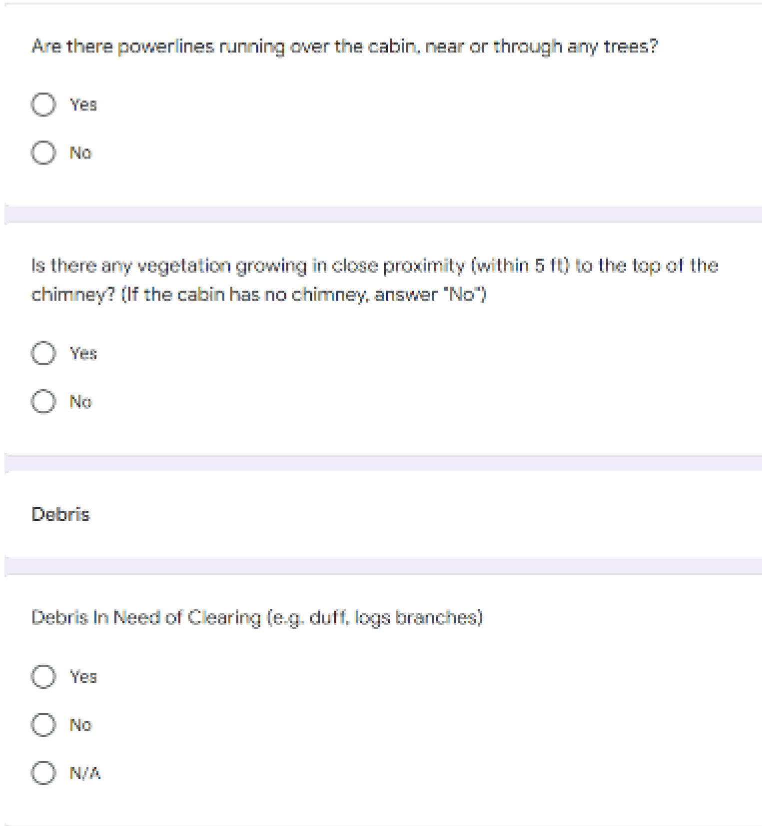


Figure 3: The Beginning of the Debris and Obstructions Page

Afterward, you must look around the building to answer the prompted questions including power line presence, branch proximity to the chimney, and debris presence. This can be found in Figure 4. If the debris question is selected as "Yes", you will be moved to the next page to answer the type of debris found. If "No" or "N/A" is selected, then the debris page is skipped and continues to the one after it. Once this page is complete, you can select "Next" at the bottom of the page to continue.


Are there powerlines running over the cabin, near or through any trees?

- ◯ Yes
- ◯ No

Is there any vegetation growing in close proximity (within 5 ft) to the top of the chimney? (If the cabin has no chimney, answer "No")

- ◯ Yes
- ◯ No

Debris

Debris In Need of Clearing (e.g. duff, logs branches)

- ◯ Yes
- ◯ No
- ◯ N/A

Figure 4: End of the Debris and Obstructions Page

If the debris is selected as "Yes", you will then be moved to the page shown in Figure 5. This asks for the type of debris that is located around the building. Multiple choices can be selected if there is more than one type of debris. Once completed, you can select the "Next" button at the bottom of the page to continue.

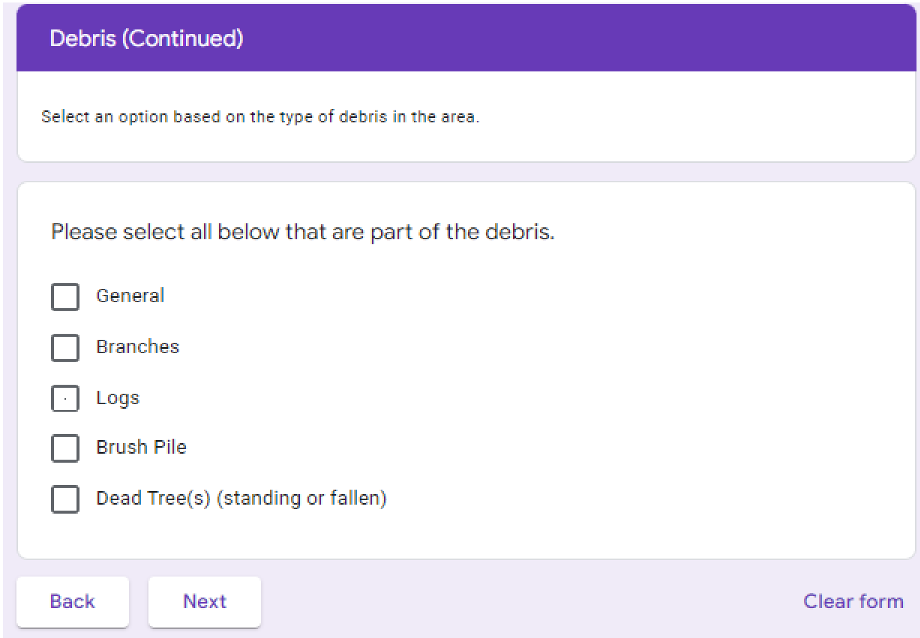


Figure 5: Debris Infromation Page

If the debris is selected as “No” or “N/A”, you will be taken directly to the next page asking for information regarding the building’s structure. In this section, you will answer questions including incline presence, siding material, building condition, insulation exposure, unintentional holes, gutter condition, and porch presence. This can be seen in Figure 6. If the porch question is “Yes”, then you will be taken to a separate page to answer porch-specific questions. If “No” is selected, then you will skip the porch page. Once completed, you can select the “Next” button at the bottom of the page to continue.

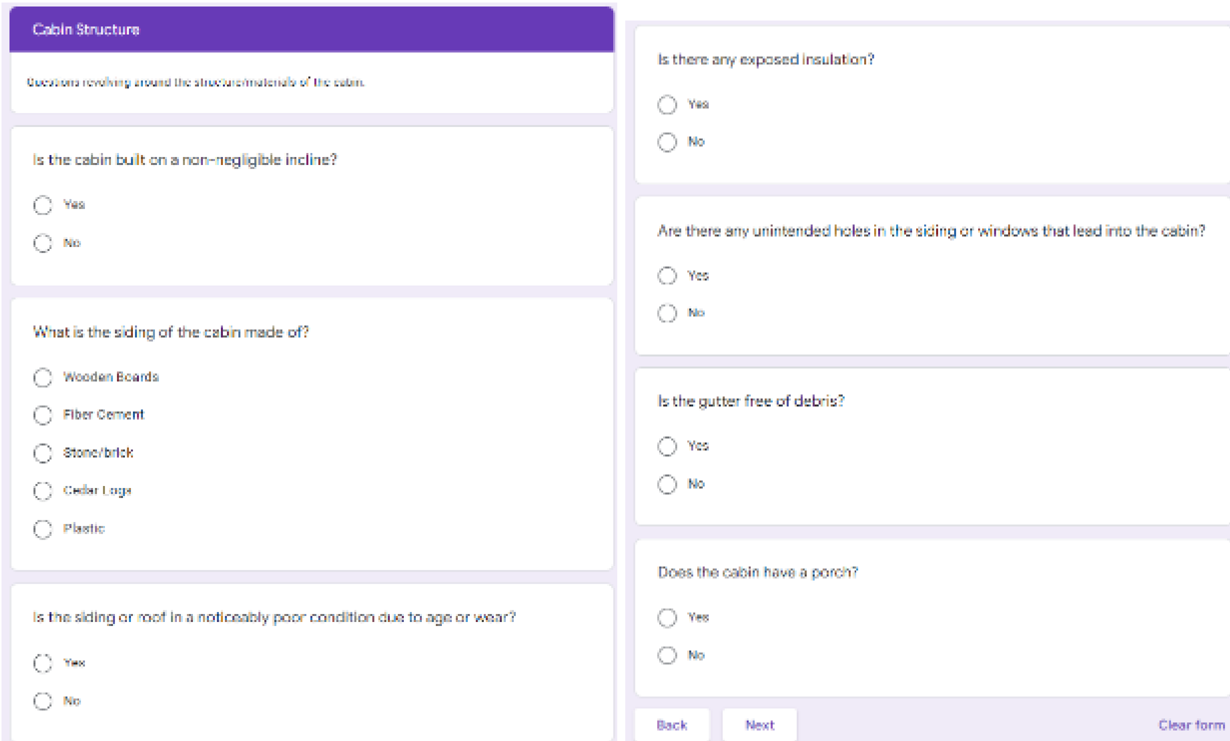
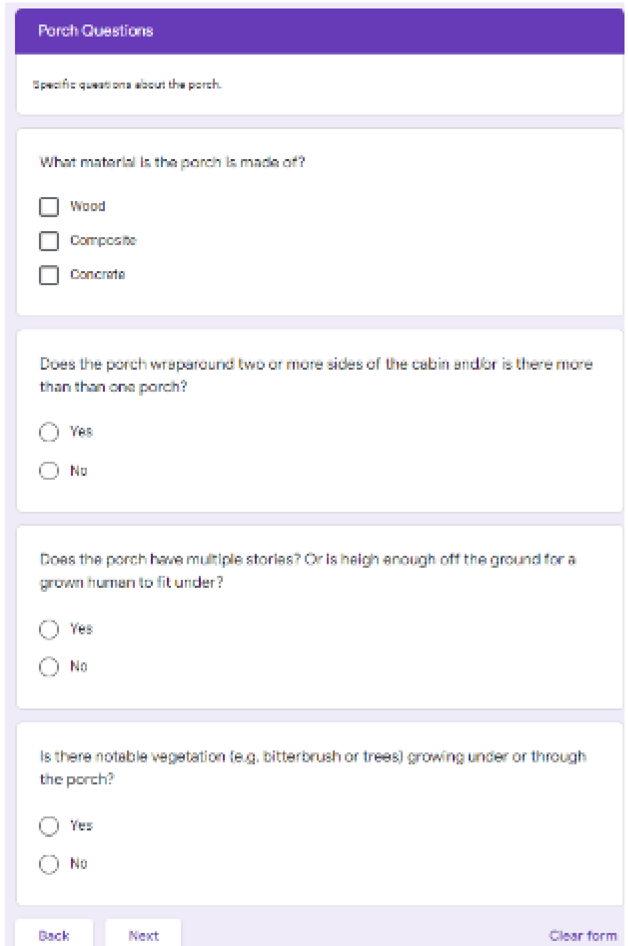


Figure 6: Building Structure Page

If "Yes" is selected, then you will be taken to the next page to answer porch questions. This will include questions about porch material, porch type, porch height, and vegetation presence under it. This can be seen in Figure 7. Once complete, you can select the "Next: button at the bottom of the page to continue.


Porch Questions

Specific questions about the porch.

What material is the porch is made of?

- [ ] Wood
- [ ] Composite
- [ ] Concrete

Does the porch wraparound two or more sides of the cabin and/or is there more than than one porch?

- ( ) Yes
- ( ) No

Does the porch have multiple stories? Or is heigh enough off the ground for a grown human to fit under?

- ( ) Yes
- ( ) No

Is there notable vegetation (e.g. bitterbrush or trees) growing under or through the porch?

- ( ) Yes
- ( ) No

Back Next Clear form

Figure 7: Porch Question Page

If the porch is selected as “No”, you will then be taken directly to the next page to answer questions regarding the vegetation around the building. This can be seen in Figure 8. This page will include questions about tree overhang and scale, sapling patch presence, the number of trees/brushes based on type, vegetation proximity, and Bitterbrush and Sage presence. For the overhand scale of the building, it ranges from 0 to 10 with 0 being no overhang and 10 being completely covered. Once complete, you can select the “Next” button at the bottom of the page to continue.

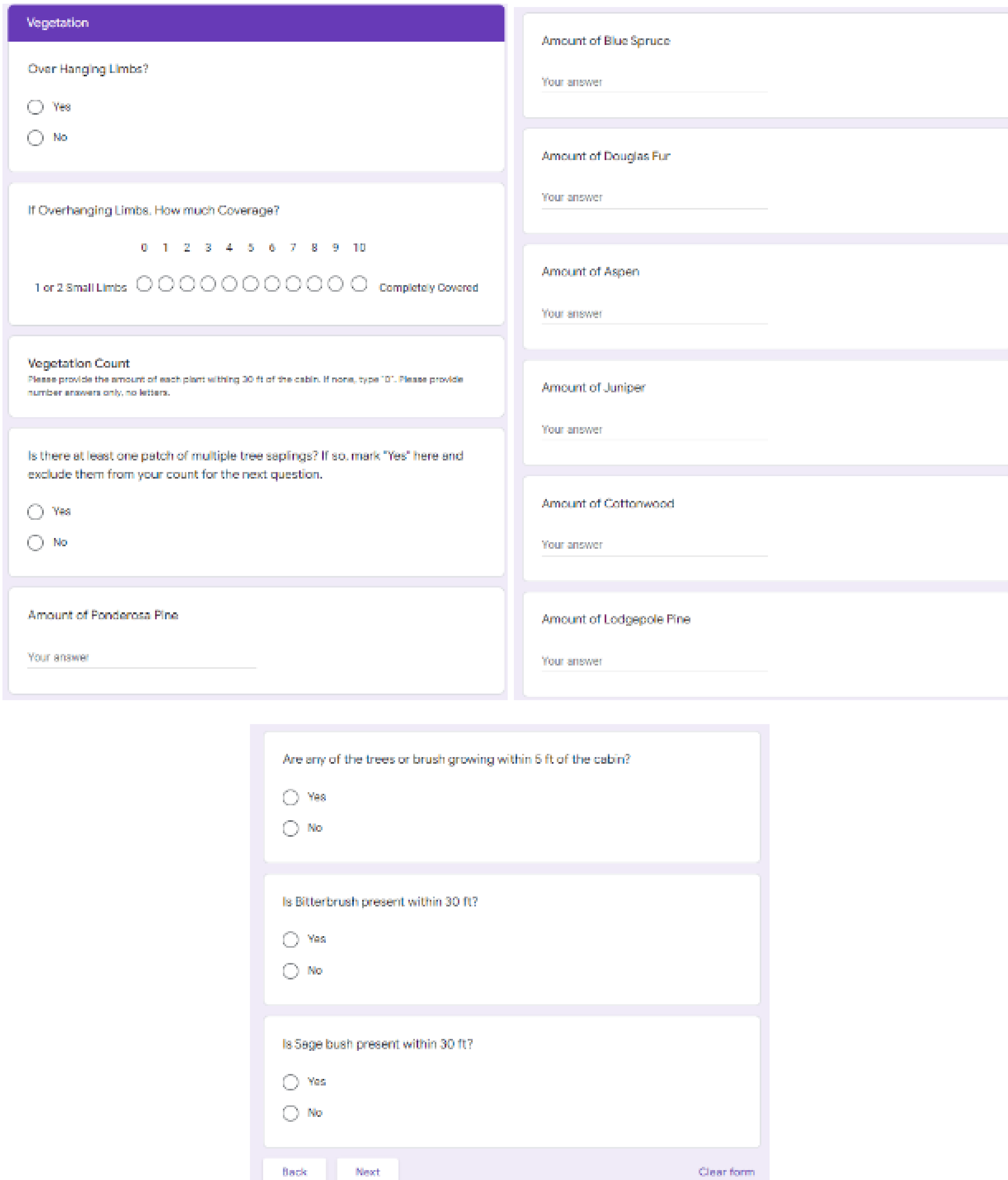


Figure 8: Vegetation Information Page

Finally, you are taken to the final page of the form to answer additional notes that you want to add to that did not fit in the form. This can include information regarding noticeable building damage and/or any unusual vegetation around the building. This can be seen in Figure 9. Once completed, you can select the "Submit" button to finish the form and the data will be added to the linked Google Sheet. In order for the data to be incorporated and displayed on the Google Reports see the section: Uploading New Building Data.

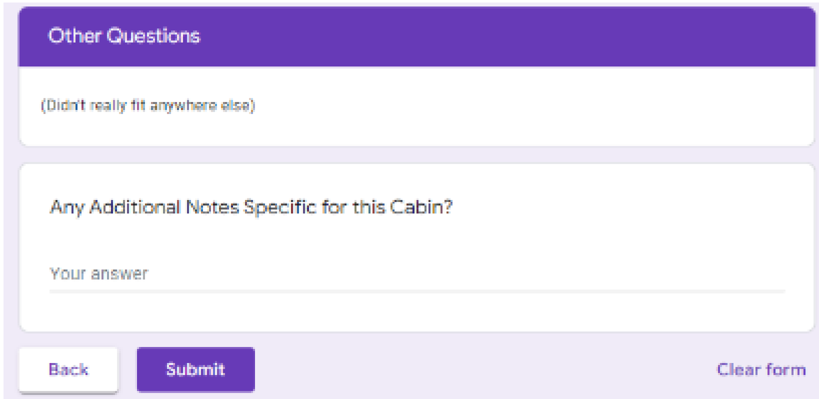


Figure 9: Other Questions Page

5. Google Reports

To access the data collected in the Google Sheet, you must navigate to the Google Reports page connected to the Sheet. Below is the link to access the Google Report.

https://datastudio.google.com/reporting/ca07a9bf-6de1-498b-8af7-5d7308cc435f

If there is an error in the data, e.g. tables or charts are not displaying, follow the steps below until the problem is resolved:

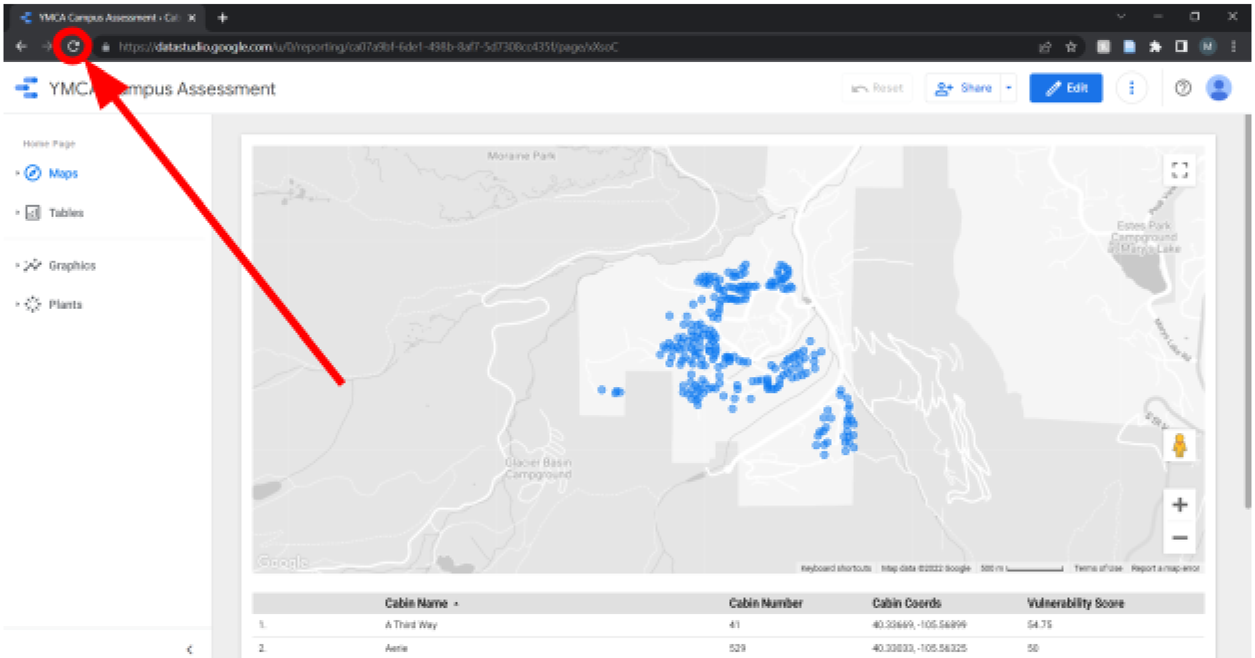
1. Check network connection
2. Refresh the page
3. Refresh the fields
4. Contact support

Check Network Connection

If your device is not connected to the internet, Google Data Studio may not be able to retrieve the data from the spread sheet. Please obtain internet access before continuing.

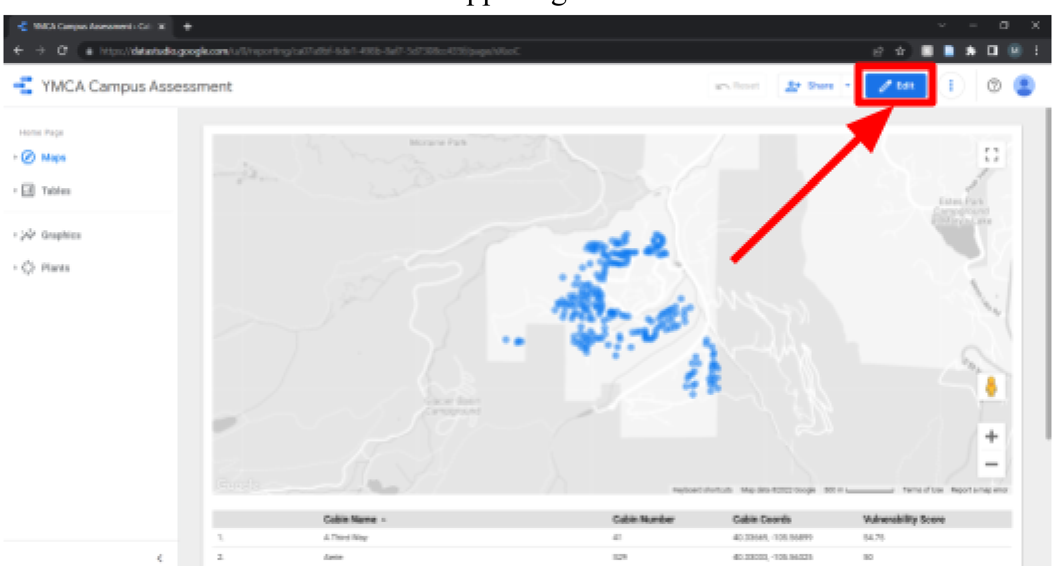
Refresh the Page

Click the button in the upper left hand corner of the screen

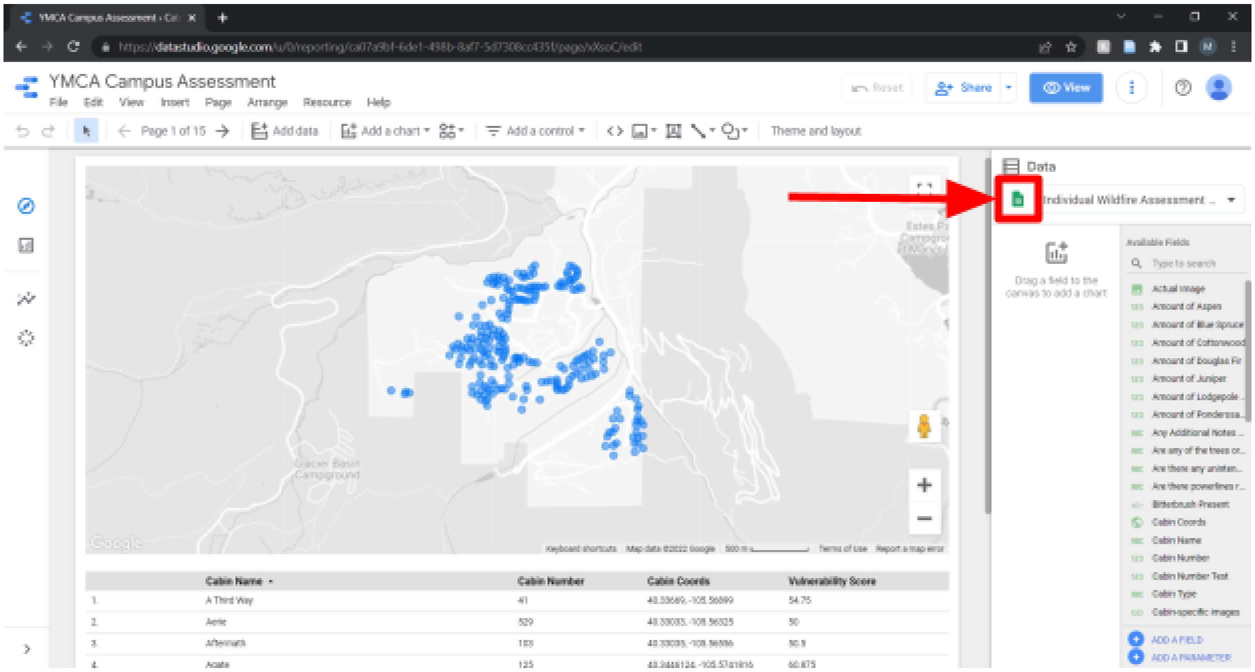


Refresh Fields

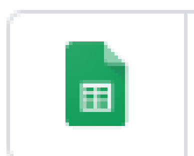
1. Click the Edit button in the upper right hand coner



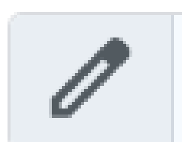
2. Click on the following button located on the right side of the screen:



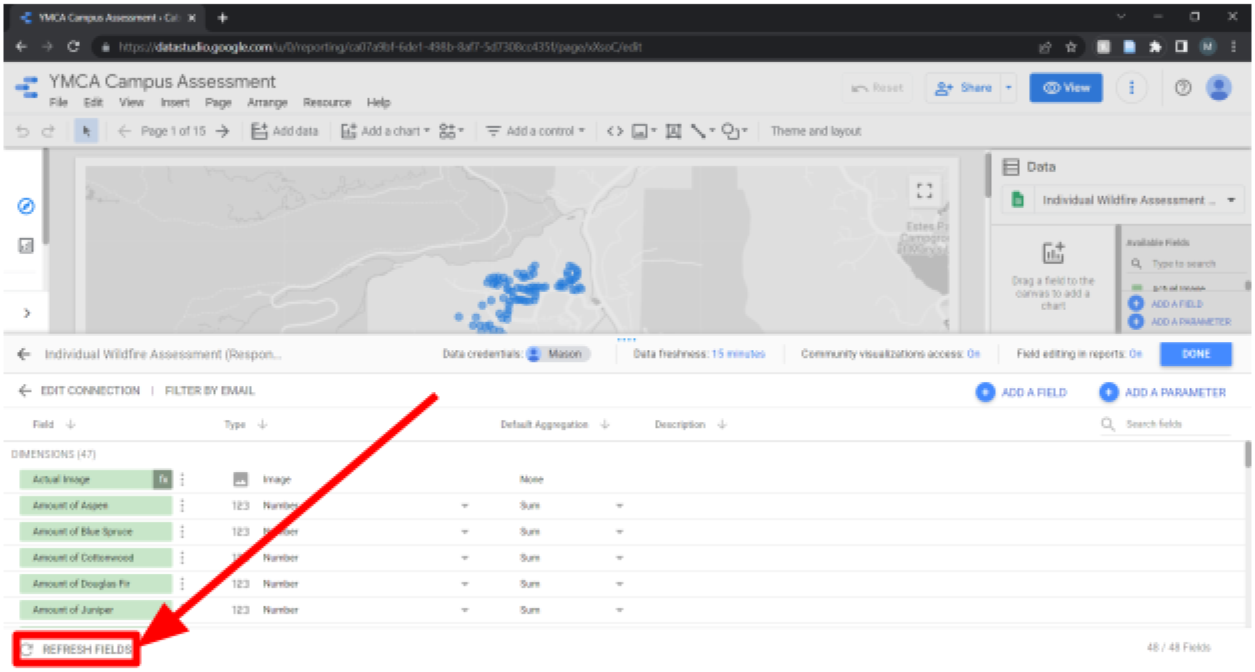
It will initially look like the following symbol:



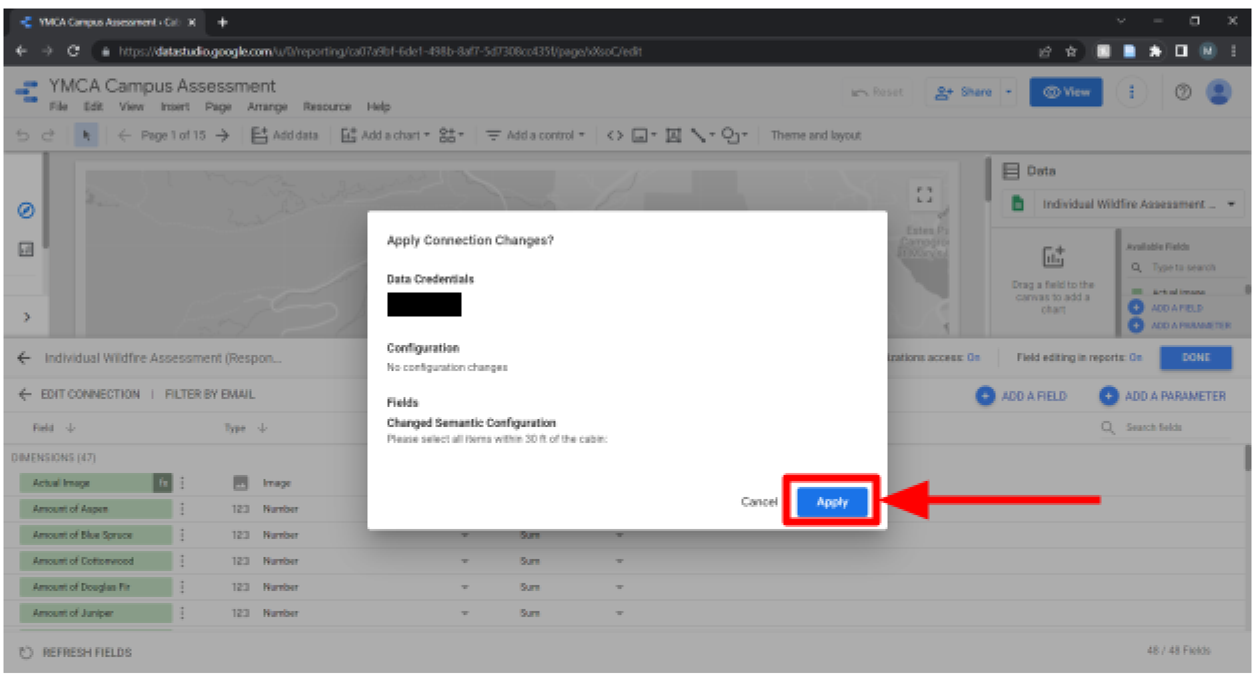
But will change to the following symbol when hovered over:



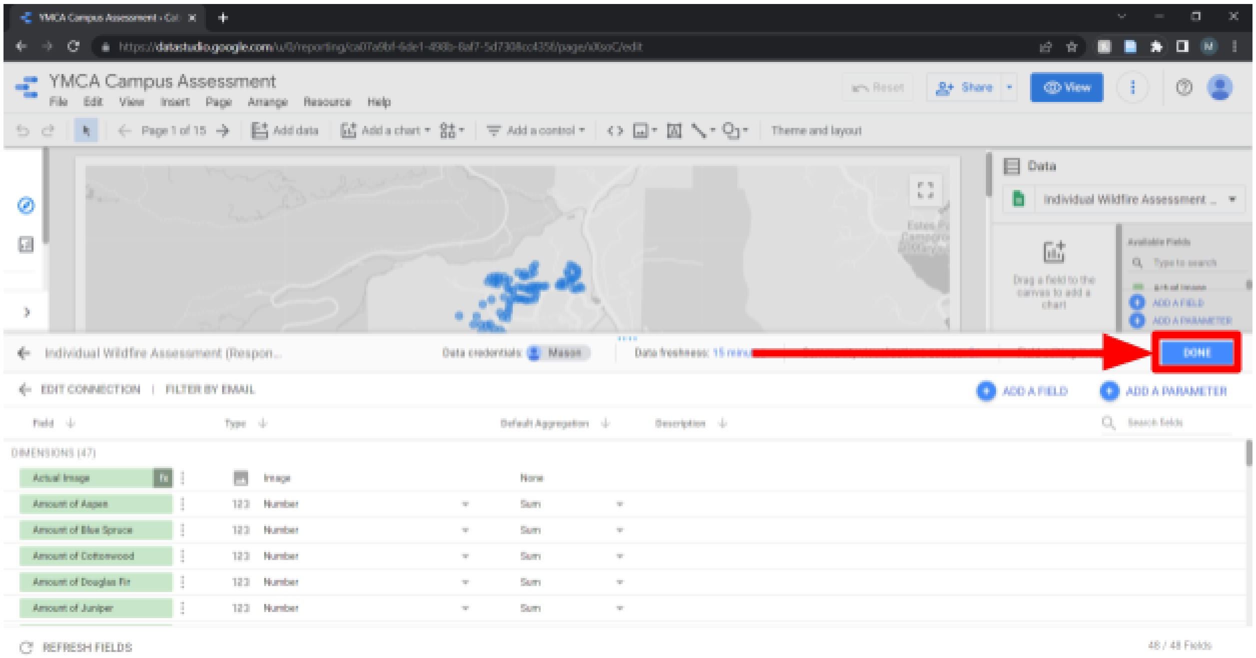
3. Click Refresh Fields on the new screen:



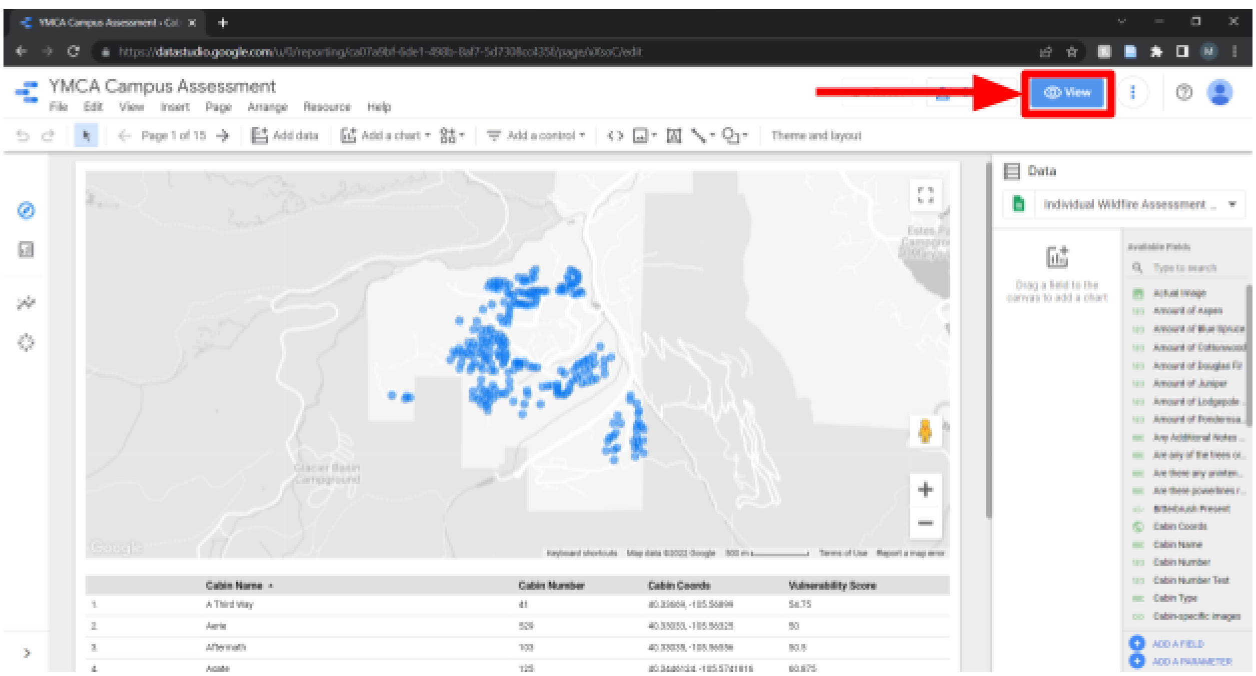
4. Click Apply on the pop-up window



5. Click Done button



6. Click View to exit edit mode



Contact Support

If problems still persist, please contact gr-rm_d22_ymcawild@wpi.edu for support.