Technical Guide: Mapping Wildfire Risk to Structures and Other Human Development to Support Implementation of Oregon's 2021 Senate Bill 762

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PURPOSE

This document describes the process used by Oregon State University (OSU) scientists to quantify and map statewide wildfire risk to structures and other human development, as required by Section 7 of 2021 Senate Bill 762 (SB762). It is intended to be a reference for state agencies and partners to aid development of communications products and support planning related to SB762.

The methods, data and figures in this document are updated as of June 24, 2022. Questions about this document or any other data produced by OSU to support SB762 can be directed to osuwildfirerisk@oregonstate.edu.

All of OSU's data products, including the statewide wildfire risk map, will be publicly available on the Oregon Wildfire Risk Explorer (https://oregonexplorer.info/wildfirerisk) by June 30, 2022. The public will be able to access a version of this document at http://osuwildfireriskmap.forestry.oregonstate.edu by June 30, 2022.

BACKGROUND

Under SB762, OSU is responsible for developing three specific data products that will be used to support implementation of SB762 (Figure 1). The three data products include:

1. Development and maintenance of a comprehensive statewide map of wildfire risk (Section 7(1-5)).
2. A map of the wildland urban interface, as defined in ORS 477.015, consistent with national standards (Section 7(7)(c)).
3. A map of the locations of socially and economically vulnerable communities (Section 7(7)(d)).

The purpose of the statewide wildfire risk map is to provide state agencies and the public with a consistent source of information as to where wildfire poses the greatest threat to structures[3] and other human development[4] (hereafter "buildings") across Oregon. Oregon's 2021 Senate Bill (SB762) identifies several specific applications of the statewide wildfire risk map, notably:

[3] A permitted building on a lot that is used as a place where one or more people sleep.
[4] Essential facilities (ORS 455.447) that support community functions, public communication, energy and transportation in excess in size 400 square feet.

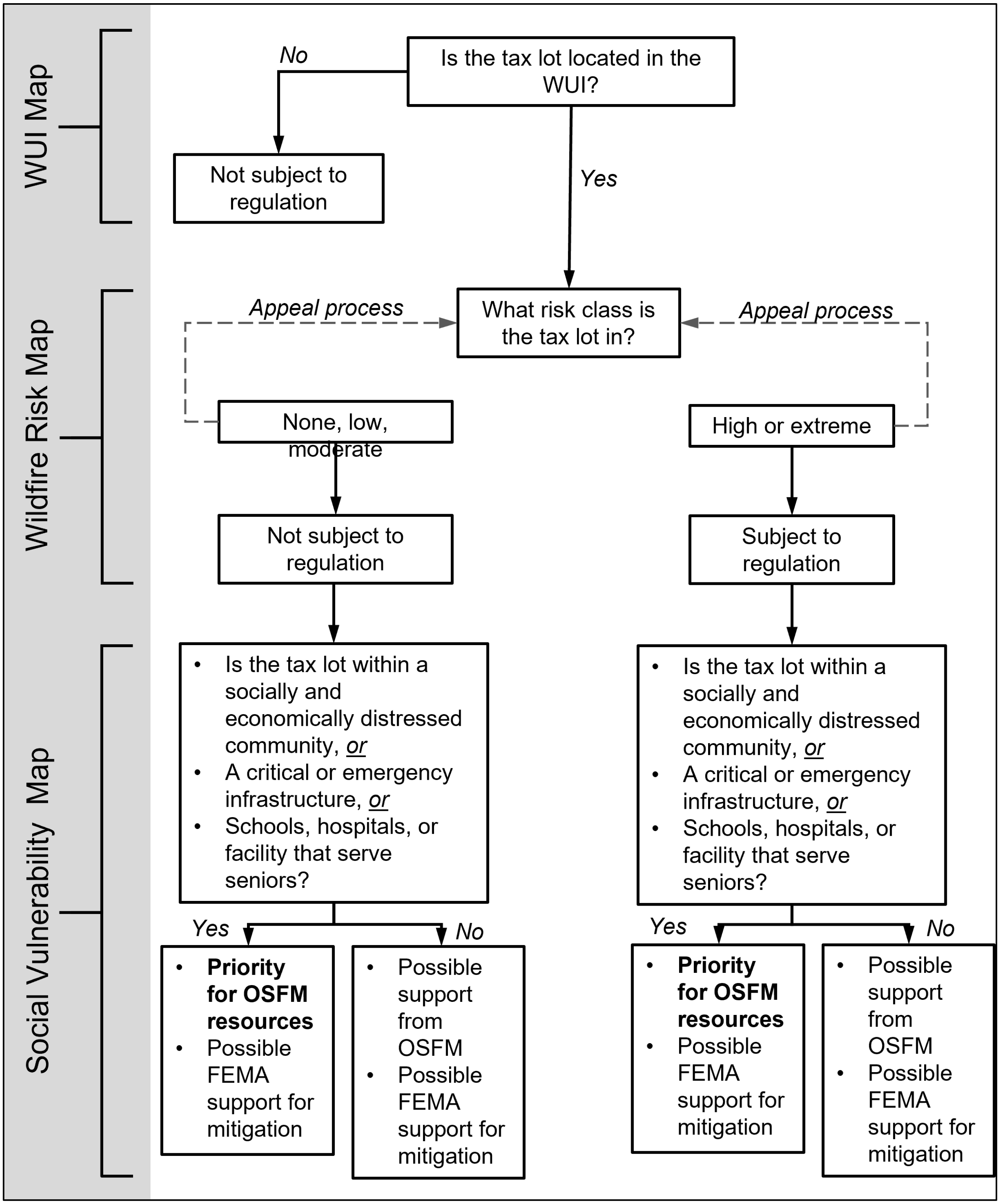

Figure 1. A simplified flowchart of how the three data products developed by OSU will be used together to develop and enforce defensible space rules established under Section 8 of SB762. This is one example of how the three maps will be used in conjunction, but there are other examples from SB762.

- Under Section 8a(1), "The State Fire Marshal shall establish minimum defensible space requirements for wildfire risk reduction on lands in areas identified on the statewide map of wildfire risk described in section 7 of this 2021 Act as within the wildland-urban interface."
- Under Section 11(2), "the Department of Land Conservation and Development shall identify updates to the statewide land use planning program and local comprehensive plans and zoning codes that are needed in order to incorporate wildfire risk maps and minimize wildfire risk, including the appropriate levels of state and local resources necessary for effective implementation."
- Under Section 12(1), "for extreme and high wildfire risk classes in the wildland-urban interface that are identified pursuant to section 7 of this 2021 Act, the Department of Consumer and Business Services shall adopt wildfire hazard mitigation building code standards that apply to new dwellings and the accessory structures of dwellings, as described in section R327 of the 2021 Oregon Residential Specialty Code."

Perhaps the most public application will be to identify properties subject to defensible space and home hardening rules in the WUI, but the map will also be used to inform statewide zoning and land use. This document explains how risk to structures and other human development was calculated at every location in Oregon, regardless of whether or not a structure is currently present. This way, the map can be used in conjunction with the WUI map to guide defensible space and home hardening rules, but can also be used to guide decisions about changes to future land use and zoning rules where structures and other human development may exist in the future.

During more than 60 hours of planning, the Rules Advisory Committee (RAC), comprised of agency personnel OSU scientists and stakeholders, developed science-based guidance for development of the statewide wildfire risk map. We used peer-reviewed methods similar to those applied in state, regional and national risk assessments to create a statewide map of wildfire risk that meets the expectations of the RAC and rules adopted by the Board of Forestry on June 8, 2022 (Dunn et al., 2020; Gilbertson-Day et al., 2018; Oregon State University, 2019; Scott et al., 2013; Thompson et al., 2016; USDA Forest Service, 2021).

The most basic assessment we can make of wildfire risk is the likelihood of fire occurrence. Likelihood is extremely important component of assessing wildfire risk but only using burn probability assumes that all fires will have the same impact on structures and other human development, which we know is not true. For examples, wildfires across the sage-steppe of southeastern Oregon have high rates of spread but are generally lower intensity than those observed in the western Oregon Cascades. With respect to structures and other human development, lower intensity fires typically result in less damage and create more opportunities for control compared to high intensity fires. For those reasons, it's important that the statewide structure risk map reflect all three factors that contribute to wildfire risk (Figure 2; Scott et al., 2013). The result is a map of wildfire risk to structures and other human development that satisfies the needs described in SB762, but which can further be integrated into statewide risk management planning (e.g. Dunn et al., 2020; Scott et al., 2013; Thompson et al., 2016).

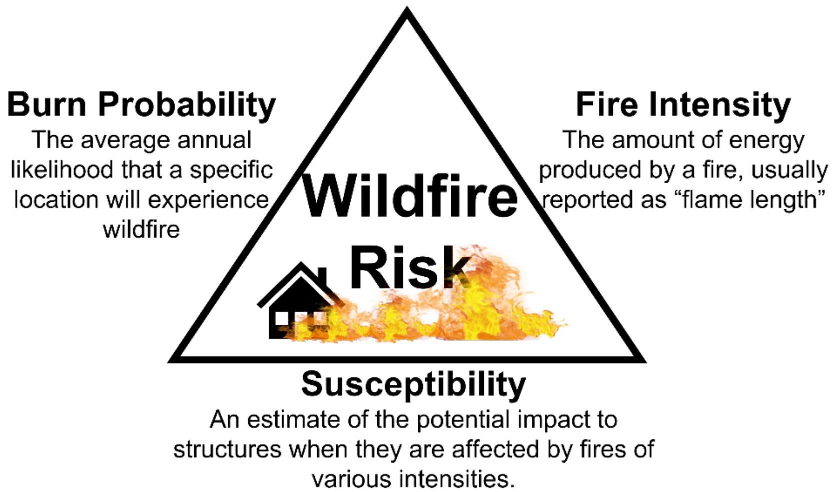

Figure 2. The fire risk triangle includes the three primary components of measuring and quantifying wildfire risk.

Methods for Mapping Statewide Wildfire Risk

We mapped statewide wildfire risk to structures and other human development in four steps:

1. Using fire behavior models to estimate burn probability and fire intensity
2. Determining response functions to reflect susceptibility
3. Quantifying risk
4. Grouping risk into five categories

Modelling Burn Probability and Intensity

Fire modelling was performed by Pyrologix LLC[5], a fire behavior modeling company that has been a leader in wildfire risk analytics for 20 years.

Burn Probability

In the context of SB762 and the statewide risk map, burn probability is the average annual likelihood that a specific location will experience wildfire. In other applications and contexts, burn probability might not refer to an annual estimate, but in this document the term burn probability is always meant as an annual estimate of fire likelihood. Burn probabilities represent long-term averages and are not forecasts or predictions of where fire is going to occur in a specific year. Annual burn probabilities are primarily a reflection of regional climate patterns and vegetation types, but can be affected by land use, ignition patterns and other elements that are within human control.

Burn probabilities are reported as fractions which can be thought of as the percent chance of fire occurring in any given year (Figure 3). For example, a burn probability of 0.01 indicates that a fire is expected once every hundred years on average, or, alternatively, there is 1% chance of a fire occurring in any given year.

For the statewide risk map, we used the large fire simulator, FSim[6], to estimate annual burn probabilities (Finney et al., 2011). FSim has been the foundation of many regional and national wildfire

[5] http://pyrologix.com/
[6] https://www.firelab.org/project/fsim-wildfire-risk-simulation-software

risk applications (e.g. Day, 2020; Gilbertson-Day et al., 2018; U.S. Department of Agriculture, Forest Service, 2022). FSim is a spatially explicit fire behavior model that simulates plausible fires and fire seasons based on local weather records, landscape conditions, and historical patterns of fire occurrence and size. Before running the model, we updated the modeling landscape to reflect fires, other disturbances and fuel treatments that occurred between the release of the base Landfire fuel model data (released as a 2016 landscape) through 2021. In addition, the modelling landscape was adjusted based on feedback from regional wildfire and fuels specialists to reflect fire behavior as observed during fire suppression or prescribed fire operations. Scientists ran over 100,000 simulations across Oregon to account for the wide variability in factors that influence fire occurrence.

Wildfire Intensity

Wildfire intensity is a measurement of the amount of energy produced by a fire, frequently reported as "flame length." Fire intensity is driven by a number of factors including weather, topography, and fuel type. Fire intensity is an important component of risk because varying intensities can lead to different impacts to structures and other human development. For instance, fires with flame lengths less than two feet are less likely to damage structures because they can usually be controlled with hand tools and machinery and are less likely to cast large ember showers. In contrast, fires with flame lengths greater than eight feet are much more likely to damage and destroy structures and other human developments because they can only be engaged with aerial resources when weather conditions allow and are far more likely to cast far-reaching embers that spark new fires.

For the statewide risk map, we used FlamMap[7] to model wildfire intensity (Figure 4). As with burn probabilities, we used an updated landscape reflecting 2022 conditions and ran hundreds of iterations to account for how fire might behave at each location under a full range of plausible weather and fuel conditions (Scott, 2020). By using FlamMap instead of FSim, we simulated fire intensity at a finer spatial resolution and accounted for nuanced interactions between topography and wind which have important impacts on fire behavior.

[7] https://www.firelab.org/project/flammap

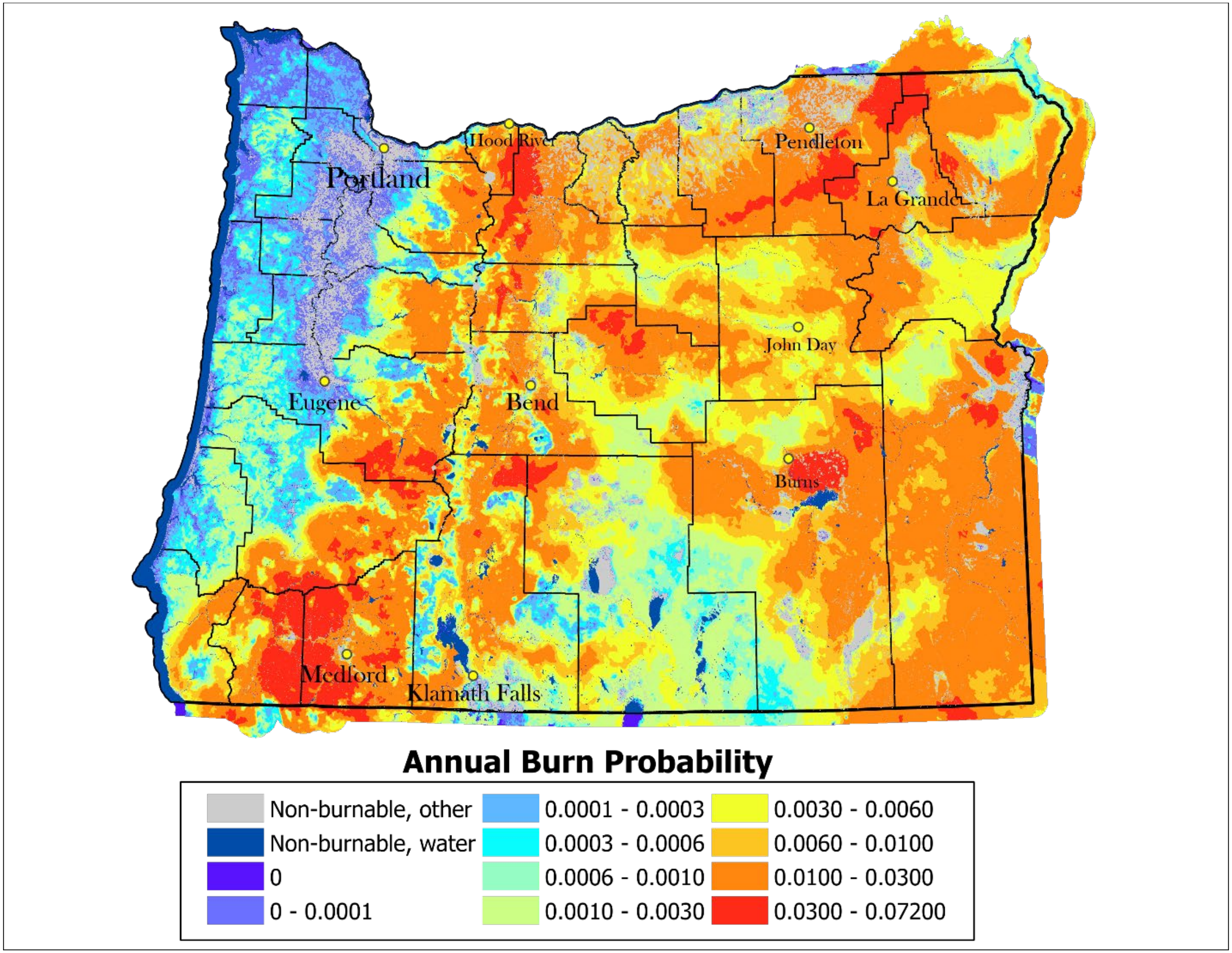

Figure 3. Modeled average burn probability across Oregon. Non-burnable areas include open water, barren ground, urban areas and some types of agricultural land.

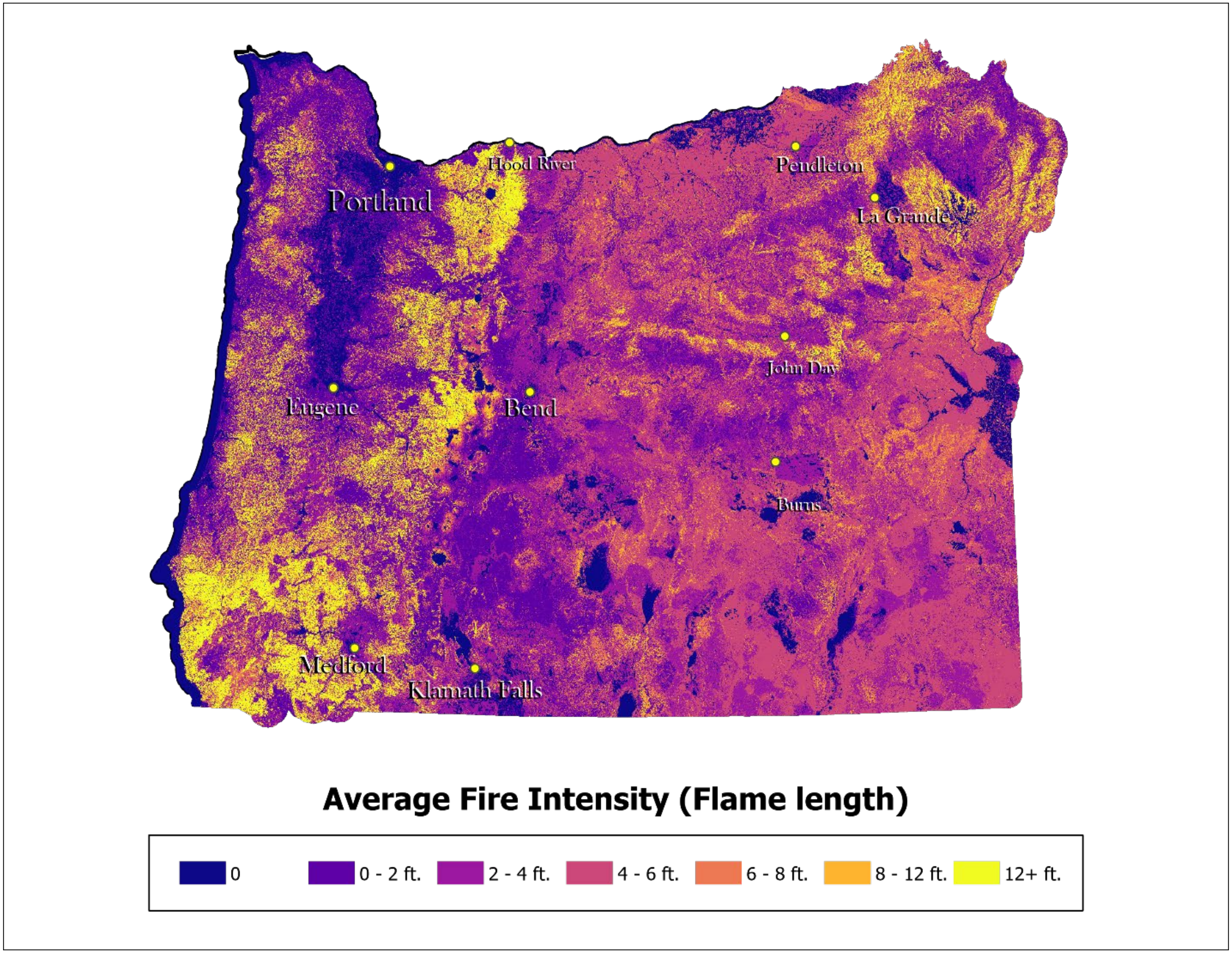

Figure 4. Modeled flame lengths across Oregon. Non-burnable areas include open water, barren ground, urban areas and some types of agricultural land.

Determining Response Functions to Reflect Susceptibility

Susceptibility is a measurement of the impacts to structures and other human development when they are affected by fires of varying intensities. The estimated damage to a structure is directly related to the expected intensity of a wildfire. In other words, the expected damage is a function of the expected flame length (Figure 6). However, the expected damage to structures is also a function to some degree of the kind of vegetation in which the fire is burning. For instance, if a fire is burning in forested vegetation and the flame length at the location of a structure is five feet, the structure is anticipated to suffer a 50% loss in value (Figure 6). The expected loss for each flame length category is called a "response function." In this context when we talk about the change in value it does not mean a change in the monetary value. Instead, the word "value" refers to a generalized, unitless concept of value that allows us to compare relative risk between structures in different locations.

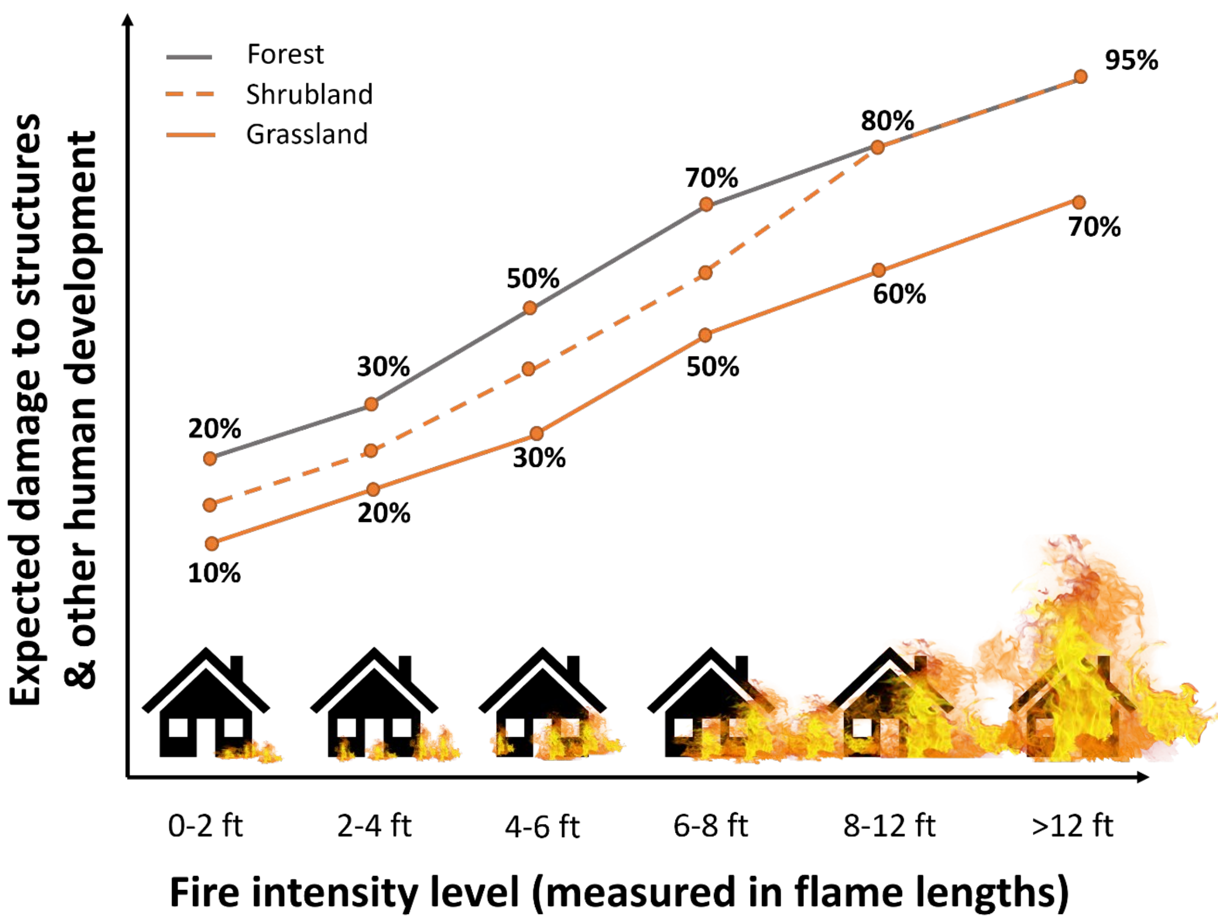

Figure 5. Illustration of generalized susceptibility framework.

Quantifying Risk

The final calculation of risk was performed by multiplying the burn probability by the susceptibility response function associated with the flame length and vegetation type at each location in Oregon (Figure 7). The final risk value, called "expected net value change" (eNVC), tells us the magnitude of the expected annual damage to any structures at that location. We calculated the eNVC at each location in Oregon and then averaged the eNVC within a 90-meter buffer. This last step, taking an average from the surrounding area, helps to account for any uncertainty in the spatial data inputs as well as account for the fact that local risk is to some degree a reflection of the adjacent surroundings on all sides.

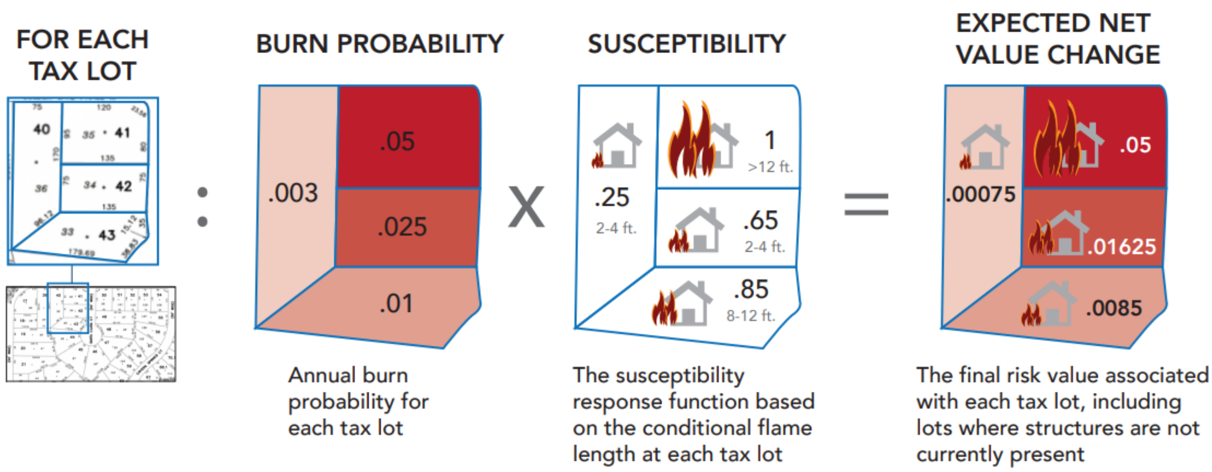

Figure 6. Generalized framework illustrating how burn probability, fire intensity, and susceptibility response functions are used to calculate expected net value change

Annualized eNVC is an abstract value intended to show us where damage is more likely to occur in relative terms; it is not a forecast of what will actually occur in any given year. The statewide risk map illustrates risk to all locations in Oregon, regardless of whether or not there is currently a structure or other human development present.

Grouping Risk into Five Categories

SB762 stipulates that statewide risk will be grouped into five risk categories based on eNVC values: None, Low, Moderate, High and Extreme. During the RAC process we looked at several methods for creating statistically objective thresholds for these classes. Those efforts suggested approximately 25% of the WUI is at high to extreme risk. After going through this process, it became apparent that the final thresholds needed to be accurate and useful within the WUI, but also at a state-wide scale. To define thresholds objectively and accurately at multiple scales, we evaluated a couple scenarios based on this 25% threshold and observed that when approximately 25% of the geographic area of the WUI is in high and extreme risk categories, about 57% of the geographic area of the state is in high or extreme risk categories. In terms of parcels, when approximately 25% of the WUI area is classified as high or extreme, 10% of existing parcels in the WUI end up in the high or extreme risk classes.

- Extreme Wildfire Risk: eNVC value ≥ 0.522288. This range of eNVC values captures 8% of the area of the WUI and includes the 97th and above percentile of buildings in the WUI with the highest risk.

- High Wildfire Risk: eNVC value of 0.137872 - 0.522288. This range of eNVC values captures 15% of the WUI and includes the 90th – 97th percentile of structures in the WUI with the highest risk.
- Moderate Wildfire Risk: eNVC value of 0.001911 - 0.137872. This range of eNVC values captures 40% of the WUI and includes the 60th – 90th percentile of structures in the WUI with the highest risk.
- Low Wildfire Risk: eNVC value of > 0.0 - 0.001911. This range of eNVC values captures 35% of the WUI and includes the 0 – 60th percentile of structures in the WUI with the highest risk.
- No Wildfire Risk: eNVC value of zero. Areas classified as having no risk include two general types of non-burnable areas. The first kind of non-burnable area includes some types of irrigated agriculture, barren areas, snow- and ice-covered areas, and open water. The second type of non-burnable area includes densely developed areas that are not expected to be exposed to potential ember showers.

MAPPING STATEWIDE RISK

The language of SB762[8] is clear that OSU was to create a statewide map of wildfire risk, even though in many instances risk will only be considered in conjunction with the WUI to determine where actions are required (i.e. Section 8a; Figure 8). The statewide map of wildfire risk quantifies risk to buildings at every location in Oregon as if a building were present at all locations (Figure 9). In many locations (i.e. public lands) quantifying the risk to potential structures (structures that are not currently present) is irrelevant because either no structure will ever be present or SB762 does not apply, as is the case with some tribal and federal lands. However, many locations across Oregon do not currently have a structure but could have one in the future. The map in Figure 9 is the statewide map required by SB762 and is a useful planning tool for decisions about future land use and development.

[8] Section 7 (1): "The State Forestry Department shall oversee the development and maintenance of a comprehensive statewide map of wildfire risk that displays the wildfire risk classes described in subsection (4) of this section and populates the Oregon Wildfire Risk Explorer."

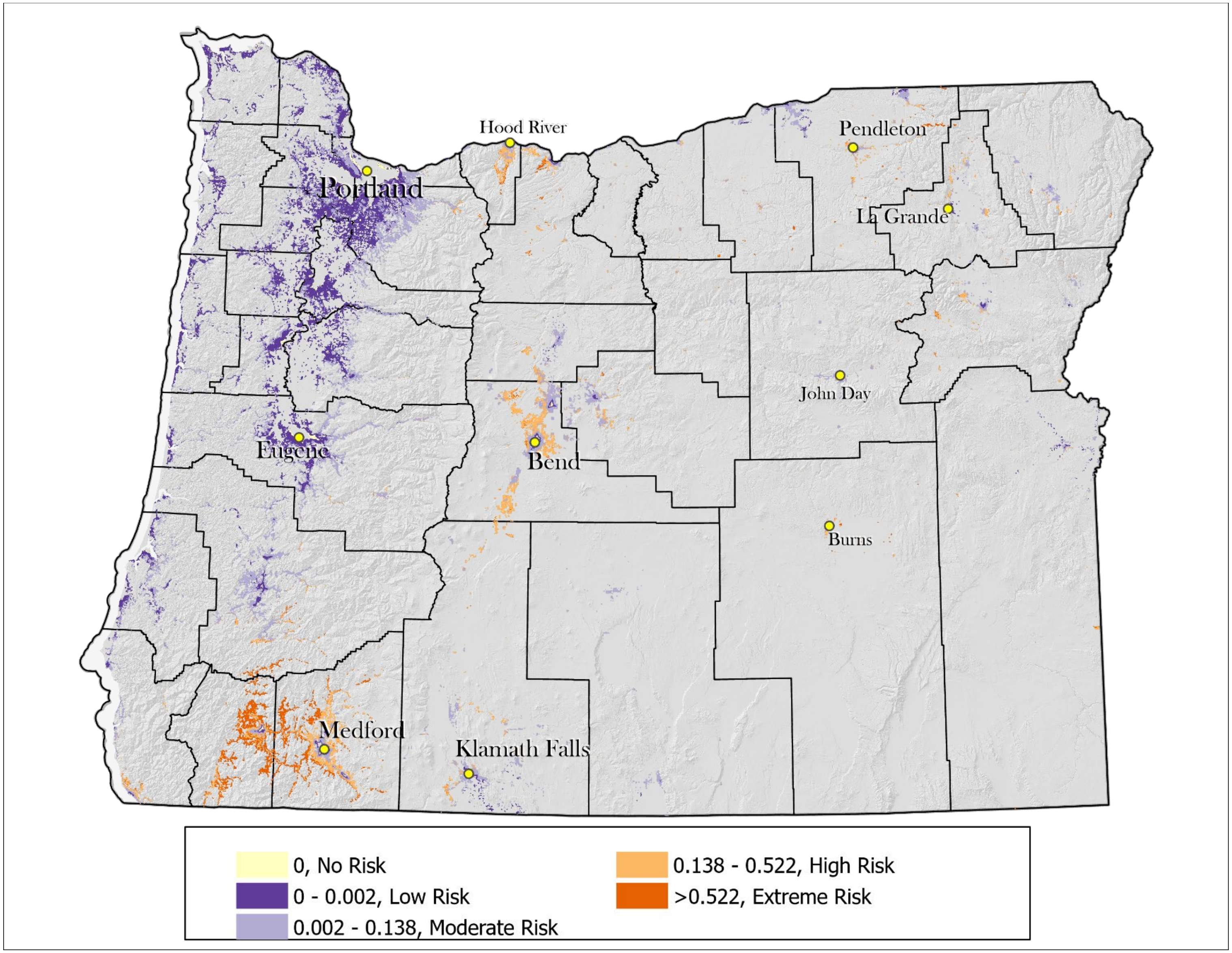

Figure 7. Wildfire risk within the WUI.

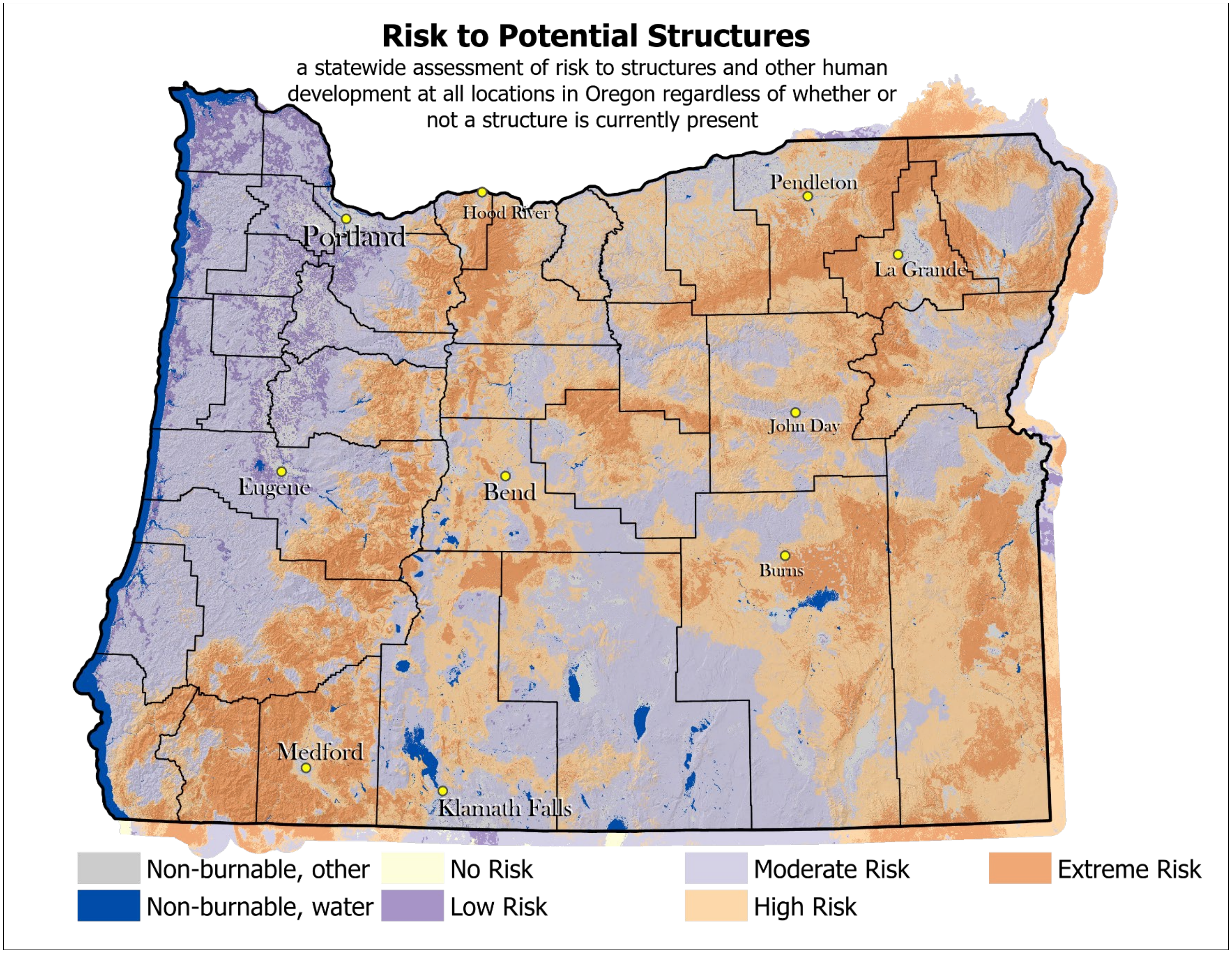

Figure 8. Statewide map of risk within the WUI. This map satisfies the requirement for a statewide assessment of risk to structures and other human development, not just an assessment within the WUI. Risk values in this map assume that a structure is present at every location in Oregon which, of course is not the case. This map could be used to inform land use decisions on lands eligible for future development.

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Frequently Asked Questions

Why is OSU making the wildfire risk map?

Section 7 of Senate Bill 762 directed OSU to coordinate with the Oregon Department of Forestry to develop a statewide risk map for all structures and other human developments.

OSU is a trusted, non-biased source of wildfire risk information. Since 2006, the Oregon Wildfire Risk Explorer, a program of the Institute of Natural resources at OSU, has been a public source of geospatial data and wildfire risk information used in state, regional and local risk management applications. Scientists at OSU have demonstrated leadership in the development and application of wildfire risk science.

What data was used in the fire behavior models?

The fire behavior models operate on three general types of inputs.

- *Fuelscape* - the modeling landscape relies on eight data layers from LANDFIRE that describe topography, canopy fuel characteristics and surface fuel characteristics. LANDFIRE 2.0.0 served as the foundation, but was updated to reflect 2022 conditions based on wildfires and significant disturbances that have occurred since LANDFIRE 2.0.0 was released. In addition, the LANDFIRE data was modified with recommendations from local and regional fuels specialists during a 3-day fuels calibration workshop.
- *Historical fire occurrence* - spatial wildfire ignition records from 1992 - 2020 were used to inform the timing and location of simulated ignitions. The Fire Occurrence Database (FOD; Short, 2021) includes all recorded ignitions from both natural and human causes from 1992 - 2018. The FOD was amended to include spatial fire data from 2019 and 2020 using state, local, and federal records.
- *Historical weather and fuel conditions* – Burn probability was modeled using temperature, precipitation, and relative humidity and data collected from carefully selected Remote Automated Weather Stations (RAWS) Weather records for 2011 - 2021. Wind speed and direction data as collected from the same station but from a longer time period based on the individual stations' records (e.g. 1985 - 2021). Fire intensity was modeled using the same weather variables from gridded weather data available at gridMET (https://www.climatologylab.org/gridmet.html).

Why are developed regions sometimes classified as unburnable?

OSU's task was to evaluate wildfire risk and the potential impacts to structures. The distinction between a wildfire and a structure fire can be unclear, but, in general, when fire begins to be transmitted directly from structure to structure, as happens in more densely developed areas, it becomes a structure fire. Assessing the risk from structure fires requires a different process than the one established in SB762. However, the fire modelling conducted for SB762 did allow fires to grow into developed areas in order to refine estimates of where and how many structures and other human developments might be at risk.

What if another wildfire risk assessment identifies different levels of wildfire risk compared to this assessment?

This map of wildfire risk to structures and other human development serves as the authoritative assessment required by SB762. There are many other wildfire risk assessments representing risk to part or all of Oregon, and they may present different results based on their specific objectives, the methods used to assess wildfire risk, the spatial scale and extent for which wildfire hazard was modeled, and the data that were input to the model. This risk assessment was specifically designed to meet the requirements and needs described in SB762. Other state agencies will refer to this risk assessment when executing their responsibilities in SB762.

How is the SB762 risk map similar or different from the wildfire risk maps that have previously been available from the Oregon Wildfire Risk Explorer?

The Oregon Wildfire Risk Explorer has been a source for a wide range of objective wildfire risk-related maps and data. Most recently, the Oregon Wildfire Risk Explorer has housed many outputs from the 2018 PNW Quantitative Risk Assessment (PNRA) in both the Advanced and Homeowners tools. Although both the 2018 PNRA and the SB762 risk map are quantitative risk assessments, there are some important differences. The three most important differences are:

- The 2018 PNRA was a comprehensive assessment that assessed risk to a wide range of resources and assets including wildlife habitat, infrastructure, drinking water, timber value and others. In contrast, SB762 directed researchers to only assess risk to structures and other human developments.
- The SB762 map quantifies risk at the tax lot level whereas the 2018 PNRA does not.
- The SB762 risk map is based on more contemporary landscape conditions and incorporates recent fires that may significantly alter local patterns of risk.

The public is encouraged to refer to the 2018 PNRA to learn more about how wildfire might affect additional resources and assets, but the SB762 risk map is the authoritative map related to risk to structures and other human developments. The 2018 PNRA map is in the process of being update for both Oregon and Washington and will be available in 2023.

How will a recent wildfire impact wildfire risk values?

Recent wildfires will have variable impacts on property-level risk values according to the proximity of the fire to the property in question, how long ago it occurred, in what kind of vegetation the fire burned and where in the state it occurred. On one hand, a recent wildfire can reduce the amount of fuel available to subsequent fires in the same footprint, thereby reducing intensity. Reduced intensity can lead to a lower risk rating. Similarly, a fire footprint can affect fire spread and may result in fewer fires reaching the property in question, again resulting in a lower modeled risk. On the other hand, as a burned area re-vegetates and recovers it may actually become more flammable and lead to more fires, faster spread, and higher intensity, leading to increased risk.

Importantly, the modeled reduction in fire intensity and fire spread in recently burned areas does not last forever. The risk map will be updated at least every five years, and each time the landscape will be updated to account for changes in vegetation, including vegetation that may have regrown in historic fire footprints.

How is climate change addressed in the wildfire risk assessment process?

The wildfire risk assessment does not include future climate change projections. The fire behavior simulations use observed, historical weather and climate data. However, compared to previous risk assessments, this map is based on more recent climate data and better accounts for emerging trends in temperature and precipitation. The risk assessment is designed to guide decision-making over the next 5 years; the next update will include the latest weather, climate and vegetation data in order to accurately reflect conditions contributing to wildfire risk.

What are the limitations of this risk assessment?

This wildfire risk map is focused on risk to structures and other human development and does not account for risk to additional resources and assets like infrastructure or drinking water. If there are questions concerning overall wildfire risk, please reference the 2018 PNW QWRA which does include these other resources and ecosystem services.

Risk assessments are not a forecast of what will happen in any given year. Even with the best science and analytics, it is impossible to predict when and where a wildfire will occur. Properties classified as moderate and low risk are still exposed to potential wildfire damage.

The landscape used to model wildfire behavior reflected by 2021 conditions, but significant changes in the landscape since then may have altered local risk values. As directed in SB762, risk to structures and other human development will be updated every five years.

Why does wildfire risk class differ between neighboring properties?

The wildfire risk to any one property reflects the surrounding landscape of that property which may or may not differ between neighbors. For instance, neighboring tax lots might be in different risk classes because one tax lot is situated closer to a large swath of flammable vegetation, elevating the burn probability and the fire intensity compared to the other tax lot that abuts largely paved, unburnable land. Additionally, there may be topographic features that could move fire towards one tax lot more often than another.

Did the fire models account for work already performed on properties to reduce wildfire risk?

It is possible that fire model outputs will capture the effect of wildfire risk reduction activities, but not necessarily.

Fuel reduction projects like thinning and prescribed burning might be accounted for depending on how well the activities were documented. The fuel data (LANDFIRE, 2016) used to model fire behavior was updated to account for fuel reduction treatments and disturbances that occurred through the end of 2021 where adequate spatial data was available. Generally, adequate spatial treatment data is only available from federal, state and, occasionally local agencies and organizations. In some cases, spatial treatment data was mapped and collected on private land, but generally that is not the case.

Defensible space activities adjacent to structures are unlikely to be accounted for in the fire models. Spatial descriptions of defensible space activities are generally not available, but even if they were, defensible space activities are usually conducted at too small a scale to be accounted for in the fire models. If a property-owner has already taken steps to reduce their wildfire risk, they may not see the risk level change in the maps. However, the property will be less susceptible from damage from wildfire and the owner is more likely to be in compliance with any of the regulatory elements described in SB762.

Where can questions about the wildfire risk map be directed?

Inquiries can be sent to osuwildfirerisk@oregonstate.edu

Glossary

Wildland Urban Interface

The geographic area where structures and other human development meets or intermingles with wildland or vegetative fuels

Structure

A permitted building on a lot that is used as a place where one or more people sleep.

Other human development

Essential facilities (ORS 455.447) that support community functions, public communication, energy and transportation in excess in size 400 square feet.

Burn probability

The probability that a wildfire will burn a specific location over a specified period of time. The SB762 risk map presents annual burn probability. Burn probability is usually expressed as a value between 0 and 1.

Fire Intensity

The amount of energy produced at the flaming front of a fire. Fire intensity is frequently expressed as flame length, where longer flame lengths indicate greater intensity.

Flame Length

The length of the flame measured at the front of the fire. Flame length is used as a measurement of intensity and is estimated from wildfire behavior models.

Wildfire Risk

The magnitude of expected annual damage to structures and other human developments at a specific location.

Net value change

A unitless value used to quantify wildfire risk in relative terms. Negative numbers for net value change indicate a net loss of value, and the more negative a value is, the greater the expected annual damage.

Susceptibility

The propensity of a structure or other human development to experience damage as a result of burning at a given level of wildfire intensity.

Wildfire intensity

The rate of energy release of a wildfire at a point on a fire perimeter, typically measured as flame length.

Building footprint

A digital representation of a structure or other human development derived from satellite images.