Technical Guide: Mapping Wildfire Hazard and the Wildland-Urban Interface to Support Implementation of Oregon's 2023 Senate Bill 80

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I. PURPOSE

This document describes how scientists at Oregon State University (OSU) mapped the wildland-urban interface (WUI) and wildfire hazard required by Oregon Senate Bill 762 (2021) and Senate Bill 80 (2023). The methods, data and figures in this document are updated as of January 7, 2025.

Sections II – IV provide an in-depth summary of data sources and methods used during development of Oregon's wildfire hazard and WUI maps. Those sections are intended to provide readers with a thorough understanding of the mapping process and will provide a suitable level of detail for most audiences. Detailed geoprocessing methods are included in Appendix A for readers seeking a step-by-step record of data and methods.

Property-level wildfire hazard designations and determinations of WUI status are available on the Oregon Wildfire Risk Explorer (https://tools.oregonexplorer.info/viewer/wildfire). Public datasets are available for download at https://oe.oregonexplorer.info/externalcontent/wildfire/ data/ SB80_Public_Data.zip. Questions about this document or any other wildfire risk and hazard data produced by OSU can be directed to hazardmap@odf.oregon.gov.

II. BACKGROUND

1. Senate Bill 762

Senate Bill 762 (SB 762), enacted in 2021, was an omnibus bill intended to advance a suite of wildfire programs collectively aimed at helping Oregon's communities and landscapes adapt to a changing fire environment. Under SB762, OSU was responsible for developing three specific data products that would help state agencies strategically develop and implement those wildfire programs:

1. **A comprehensive statewide map of wildfire risk** ("statewide risk map"). Senate Bill 762 §7 directed the Department of Forestry (ODF)to consult with Oregon State University on a map that establishes "five statewide wildfire risk classes of extreme, high, moderate, low and no risk" (§7.4). The risk classes were to be "based on weather, climate, topography and vegetation," (§7.4(b)) and the map was to be "sufficiently detailed to allow the assessment of wildfire risk at the property-ownership level" (§7.7(b)). Once complete, the legislation required that the map be "publicly available in electronic form through the Oregon Wildfire Risk Explorer" (§7.5).
2. **A statewide map of the wildland-urban interface** ("WUI"). Senate Bill 762 §7 also requires that the statewide risk map "include the boundaries of the wildland-urban interface, as defined in ORS 477.015, consistent with national standards" (§7.7(c)).
3. **A map of locations of socially and economically vulnerable communities.** Senate Bill 762, §7.7(d) required OSU and ODF to also "include a layer that geospatially displays the locations of socially and economically vulnerable communities" (§7.7(d)). The map of social vulnerability in Oregon uses 15 indicators collected from the 2020 American

Community Survey data summarized at the Census Block Scale. Social vulnerability of each Census block group is represented relative to all other Census block groups.

Oregon State University and ODF developed and released all three map products on June 30, 2022. The statewide risk and WUI maps were received with strong public opposition that led to the withdrawal of the maps in August of 2022 along with a commitment from ODF leadership to review public comments and make changes to the map before re-releasing another version (Profita, 2022). During the initial release and following the withdrawal, OSU and ODF collected and reviewed over 4,000 comments including appeals, written comments and comments made in public meetings.

2. Senate Bill 80

In 2023, the Oregon Legislature passed Senate Bill 80 (SB 80), which carries forward OSU's responsibility for three maps described above, as well as the requirement that all maps be publicly accessible on the Oregon Wildfire Risk Explorer. Changes to the maps themselves were limited to the statewide risk map:

- §1.1 changed the name of map to a statewide wildfire hazard map.
- §1.2 articulates that the purposes of statewide wildfire hazard map are to:
    - §1.2 (a) "Educate Oregon residents and property owners about the residents' and property owners' wildfire exposure by providing transparent and science-based information."
    - §1.2 (b) "Assist in prioritizing fire adaptation and mitigation resources for the most vulnerable locations."
    - §1.2 (c) "Identify where defensible space standards and home hardening codes will apply."
- §1.5 requires that OSU and ODF establish three hazard classes (i.e., low, moderate and high) instead of the five risk classes required by SB 762.

In addition to the mapping-related changes, SB 80 §1.10 required robust community engagement and coordination with local partners including state agencies and counties. Following are highlighted engagements conducted by OSU and ODF following passage of SB 80:

- *(September and October 2023)* Oregon State University, ODF, Oregon State Fire Marshal, the Division of Financial Regulation, and the Building Codes Division all participated in nine meetings around the state with county commissioners and staff.
- *(January 22, 2024)* Oregon State University, ODF, Oregon State Fire Marshal, the Division of Financial Regulation, and the Building Codes Division presented to and took questions from state legislators regarding the wildfire hazard and WUI maps, and related issues.
- *(January 23, 2024)* Oregon State University, ODF, Oregon State Fire Marshal, the Division of Financial Regulation, and the Building Codes Division presented to and took questions from representatives of Oregon Tribes regarding the wildfire hazard and WUI maps, and related issues.
- *(March 7 and 28, and April 18, 2024)* The Oregon Dept. of Forestry hosted a Rulemaking Advisory Committee (RAC) to make recommendations on whether and how to account for irrigated agriculture directly in hazard calculations.

- *(April 26, 2024)* Oregon State University shared draft wildfire hazard and WUI maps, including associated input data, with county planning directors along with a request that counties review the data for potential anomalies and provide spatial data to help address known data gaps.
- *(June 3 – July 1, 2024)* Oregon State University, ODF, Oregon State Fire Marshal, the Division of Financial Regulation, the Building Codes Division and the Wildfire Programs Advisory Council hosted six in-person open house events for the public to learn about updates to the wildfire hazard and WUI maps.
- *(July 18, 2024)* Oregon State University released draft wildfire hazard and WUI maps on the Oregon Wildfire Risk Explorer for the public to review.
- *(July 18 – August 18, 2024)* The Oregon Dept. of Forestry hosted a public comment period for comments regarding the wildfire hazard and WUI maps.
- *(August 26, 2024)* Oregon State University and ODF participated in a meeting for county commissioners from all 36 counties to hear comments regarding the wildfire hazard and WUI maps.

3. How the Maps Will Be Used

The statewide hazard map and the WUI map are intended to be used in conjunction with one another by the Oregon State Fire Marshal and the Department of Consumer and Business Services Building Codes Division during implementation of specific wildfire programs.

- Senate Bill 80 §3 directs the Oregon State Fire Marshal to develop minimum defensible space requirements which will apply to all lands that are both within the WUI *and* classified as high hazard in the statewide hazard map.

- Senate Bill 80 §11 directs the Department of Consumer and Business Services Building Codes Division to adopt wildfire hazard mitigation building code standards that apply to new dwellings located both in the WUI *and* on a property classified as high hazard in the statewide hazard map.

III. WUI MAPPING METHODS

Creating a statewide WUI map involved two general steps (Figure 1). First, we determined which parts of Oregon met the minimum building density requirements to be classified as WUI. Second, for those areas that met the minimum building density threshold, we evaluated the amount and proximity of wildland or vegetative fuels. Following is a summary of data sources and geospatial tasks used to create the WUI map. Detailed geospatial processing steps are described in Appendix A.

1. Develop a potential WUI map of all areas that meet the minimum density of structures and other human development

According to OAR 629-044-1011, the boundary of Oregon's WUI is defined in part as areas with a minimum building density of one building per 40 acres, the same threshold defined in the federal register (Executive Order 13728, 2016), and any area within an Urban Growth Boundary (UGB) regardless of the building density. Step One characterizes all the locations in Oregon that could be considered for inclusion in the WUI based on building density and UGB extent alone ("potential WUI"). The result of Step One was a map of potential WUI which was then further refined into the final WUI map based on proximity to vegetation in Step Two.

A. Compile statewide tax lots.

OSU scientists assembled a comprehensive dataset of Oregon tax lots through two methods. First, seventeen counties host spatial tax lot information online and make it available for public download. OSU accessed public tax lot data for those counties on August 20, 2024. Second, for the remaining counties whose data is not publicly available, OSU obtained access and permission to use the data directly from county assessors or GIS staff. Data were obtained between mid-July and mid-August 2024 for those counties, representing the most up to date tax lot information available at that time.

B. Map all eligible structures and other human development.

OSU scientists mapped structure density in Oregon using the Statewide Building Footprint of Oregon (SBFO) dataset developed by the Oregon Department of Geology and Mineral Industries (Figure 2; Williams, 2021). The statewide building footprint dataset consists of more than 2.1 million building footprints that have been compiled from multiple sources, including remote sensing and municipal/county data. OSU scientists converted the building footprints to point geometry and then excluded all structures less than 400 square feet, OAR 629-044-1005(f). Other human development (OAR 629-044-1005(e))is generally included within the SBFO data since this category typically consists of buildings. In order to be sure that other human development was specifically accounted for in the map, scientists added additional point data that meet the definition of other human development and which were available from Homeland Security (U.S. Department of Homeland Security, 2021).

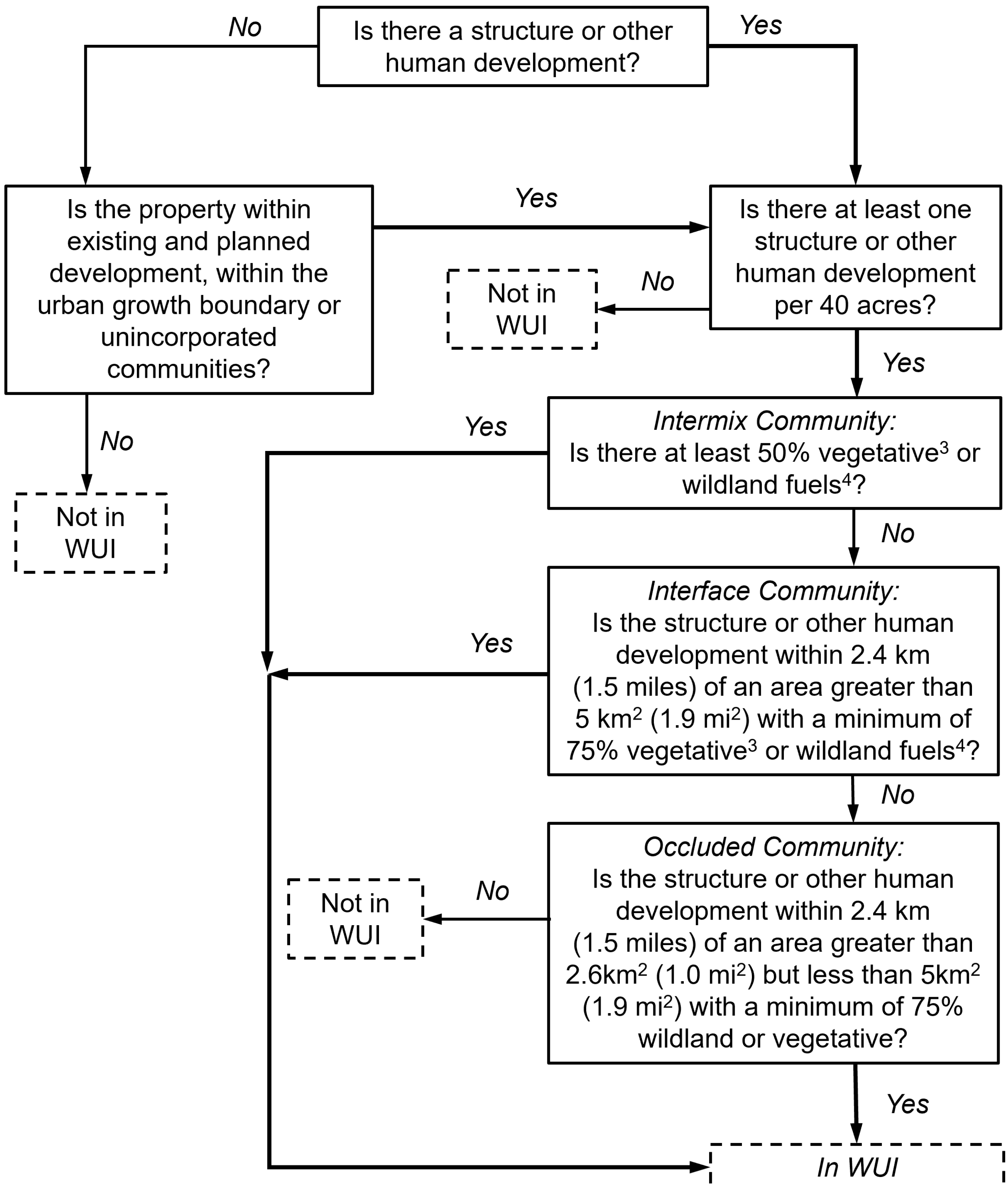

Figure 1. A detailed flowchart illustrating how the WUI is defined for the statewide map, per OAR 629-044-1011.

Figure 2. From Williams, 2021). Examples of how satellite imagery was used to identify and map structures and other human development. Verified buildings included in the final dataset are shown in green; examples of objects removed from the final dataset are circled in red

C. Assign buildings to tax lots and simplify to one building per tax lot.

OSU scientist assigned each building to a tax lot. In compliance with OAR 629-044-1011(3), all the buildings on a single tax lot were simplified down to a single building footprint in an effort to minimize the chance that clusters of non-residential buildings (e.g., barns, storage facilities, etc.) would lead to over-mapping of the WUI, particularly on rural properties.

D. Calculate building density and map potential WUI.

At each location on the landscape, scientists calculated the density of buildings per acre using a search radius of 744.73 ft. A density of 1 building per 40 acres based on this search radius results in a density of 0.025 buildings per acre. To remove isolated properties, researchers assessed building density using a search radius of 746 ft. (1.25 feet wider), which equates to an area just larger than 40 acres (40.14 acres). By doing so, isolated properties had a density of 0.024915 structures per acre which is just below the density threshold. Any structures that did not meet or exceed the density threshold were removed from consideration within the WUI boundary based on building density alone.

After mapping the potential WUI, OSU researchers observed many small, isolated areas of WUI created by two buildings despite being otherwise remote. Upon investigation, these buildings often barely met the density criteria and were sometimes included because of common geospatial rectification errors that occur during assembly of large data sets. Consistent with legislative intent, WUI areas need to have at least three buildings to be considered a geographic area (Figure 3).

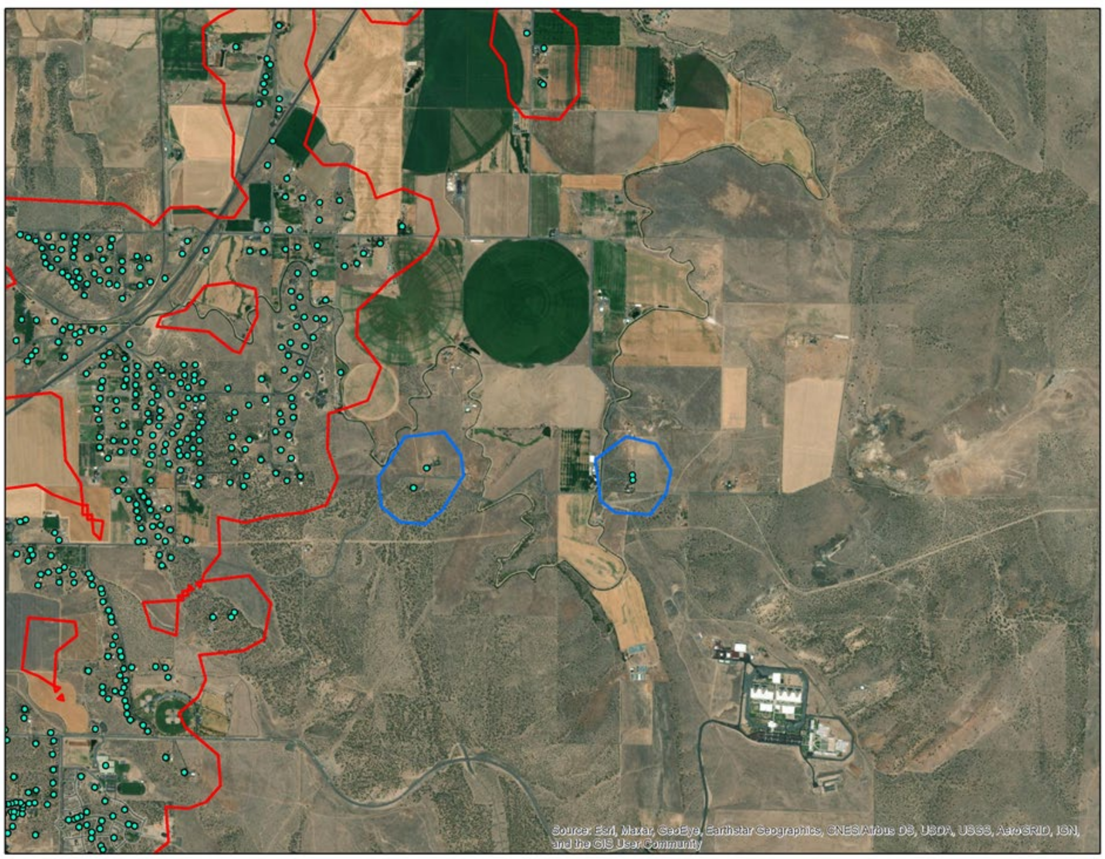

Figure 3. Example of where isolated WUI comprised of just two buildings was removed from the potential WUI map, consistent with legislative intent. Potential WUI are areas that meet the minimum structure density requirements to be included in the WUI, but which may or may not meet the vegetation requirements. The blue circles are areas that met the minimum building density threshold despite including just two buildings. The buildings in blue circles were removed from the potential WUI map leaving only the adjacent are in red within the WUI.

E. Add Urban Growth Boundary to the WUI.

According to OAR 629-044-1011, the WUI also includes all lands within a UGB. Urban growth boundaries are areas within which a city expects to grow over a 20-year period. All cities in Oregon are required to have a UGB. After mapping the potential WUI based on building density, OSU added all UGB polygons (Dept. of Land Conservation and Development, 2022) to the map.

2. Classify the potential WUI map into three types based on the proximity and density of vegetation.

The WUI is also defined by the density and proximity of wildland[3] and vegetative fuels[4] ("fuels"; Figures 1 & 4). By including density and proximity of fuels in the definition of the WUI, the urban core is excluded, and the focus is placed on those areas with sufficient building density *and* sufficient fuels to facilitate a WUI conflagration. Consistent with national standards, OSU scientists further classified the WUI into three general types to inform effective risk management strategies (Figures 4 & 5). A binary version of the WUI map will be used by the State Fire Marshal and Building Codes Division to determine which properties are subject to the standards and codes (Figure 6). The following describes how OSU refined the potential WUI output from step one into the final WUI map.

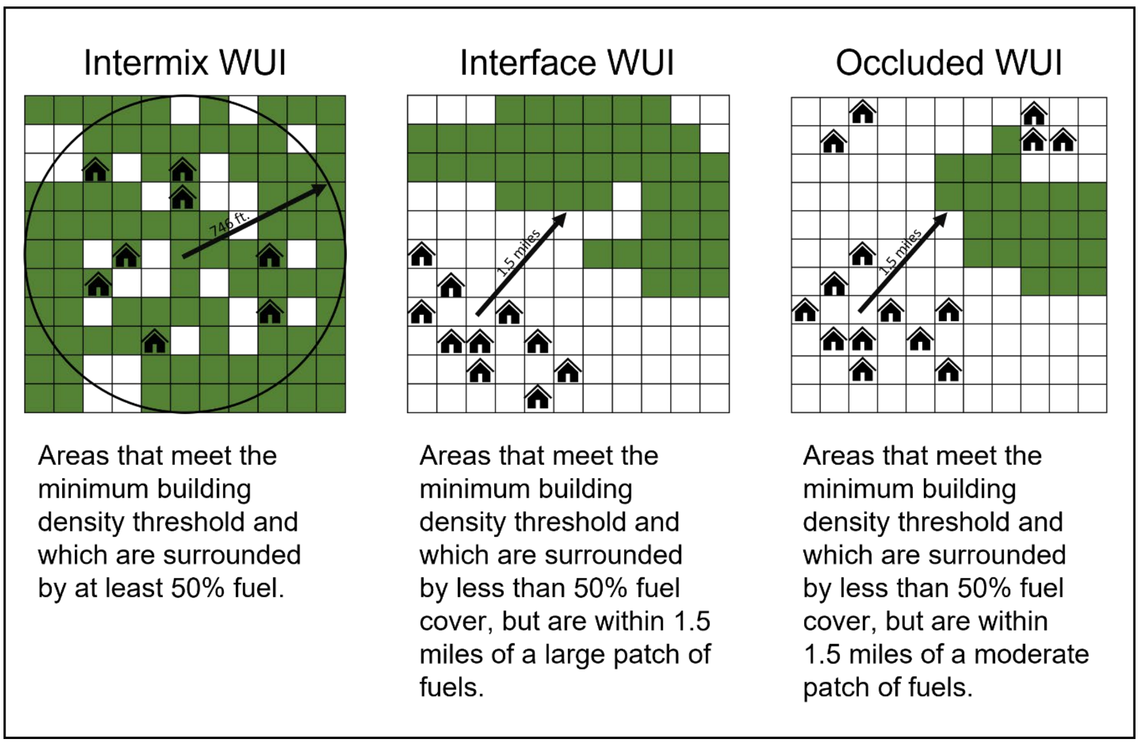

Figure 4. Illustration of the three types of WUI adapted from Bar-Massada (2013). Green squares indicate vegetation.

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[3] 629-044-1005(k): "Wildland fuels" means natural vegetation that occurs in an area where development is essentially non-existent, including grasslands, brushlands, rangelands, woodlands, timberlands, or wilderness. Wildland fuels are a type of vegetative fuels.
[4] 629-044-1005(j): "Vegetative fuels" means plants that constitute a wildfire hazard.

Vegetative and wildland fuels were mapped using LANDFIRE data updated to current conditions (LANDFIRE 2.0, 2019). Fire modeling experts and regional fuel specialists updated and adjusted LANDFIRE fuel models to account for recent disturbance and reflect burnable landscapes across Oregon, creating a burnable landscape that includes all wildland and vegetative fuels and excludes non-burnable areas including barren landscapes, ice and snow, some types of agriculture and much of the urban core.

A. Map the Intermix WUI

Areas that met the minimum building density threshold in Step One *and* which had at least 50% vegetative or wildland fuel cover were classified as Intermix WUI. Intermix WUI is usually small groups of structures in relatively rural settings and on the margins of larger communities. For example, Intermix WUI might include agricultural communities, small and moderate resorts, or rural residential development.

B. Map the Interface WUI

Interface WUI includes areas that met the minimum building density threshold in Step One, *and* which had less than 50% vegetative and/or wildland fuel cover but were within 1.5 miles of a large patch (≥ 1.9 sq. miles) of at least 75% vegetation and/or wildland fuels. In other words, buildings in Interface WUI are not as intermingled with vegetation as Intermix WUI but are nearby to large blocks of vegetation that could result in ember showers exposing this WUI type. Interface WUI is often described as the “rind” around the urban core.

C. Map the Occluded WUI

Occluded WUI includes areas that met the minimum building density threshold in Step One, *and* which had less than 50% vegetative and/or wildland fuel cover but were within 1.5 miles of a moderate patch (1 – 2 sq. miles) of at least 75% vegetation and/or wildland fuels. Similar to Intermix WUI, Occluded areas are not as intermingled with vegetation as Intermix WUI but are nearby to contiguous patches of vegetative and/or wildland fuels that could also result in ember intrusion. However, the patches of nearby vegetation in Occluded areas are smaller than in Interface WUI.

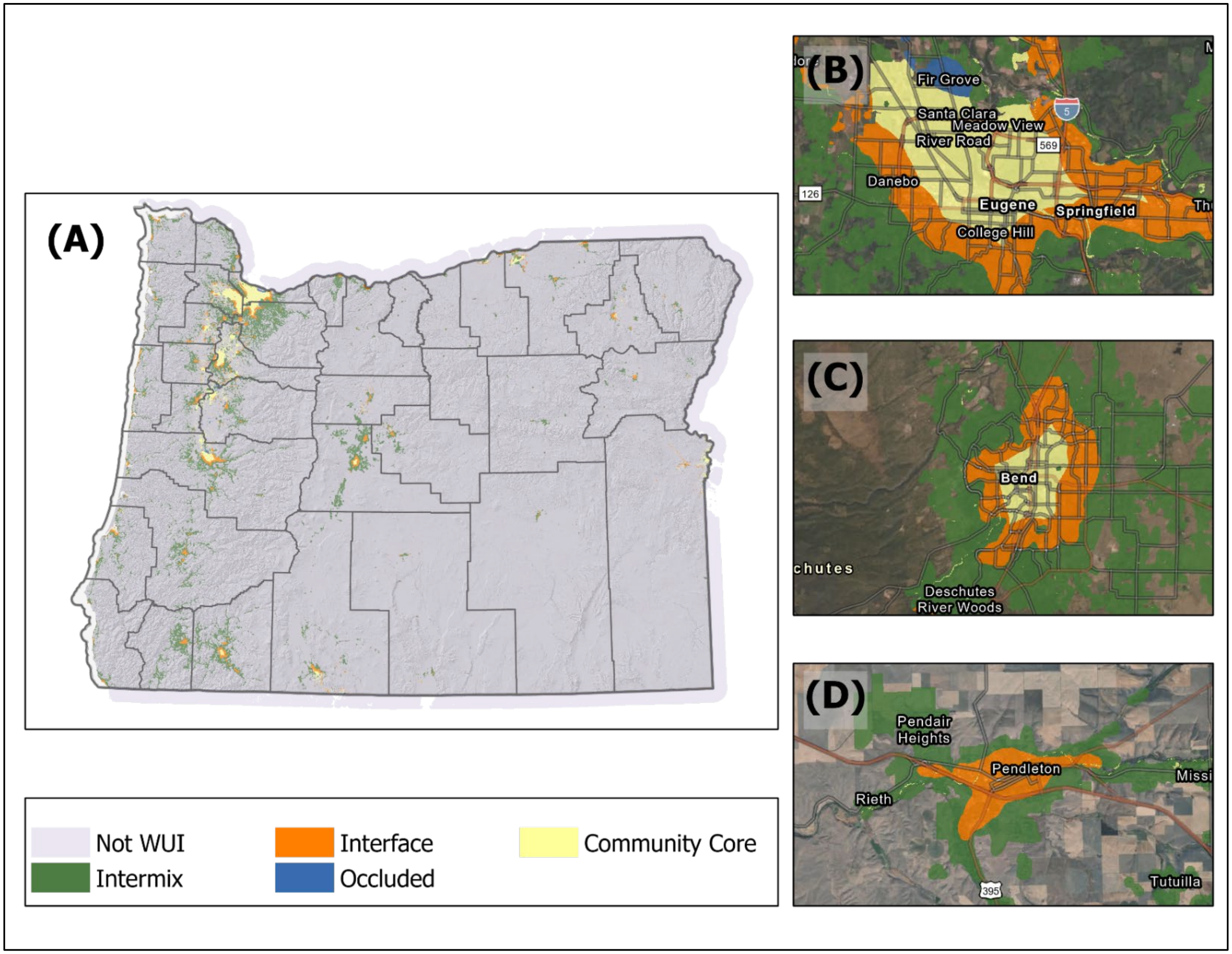

Figure 5. (A) Classified version of the WUI in Oregon. Areas classified as Intermix, Interface and Occluded are within the WUI. (B) WUI around Eugene includes all three classes as well as an urban core (yellow) that is excluded from the WUI. (C) WUI around Bend includes only Intermix and Interface around a community core. (D) In Pendleton, the WUI does not exclude any part of the community because there is enough vegetation to meet the interface criteria (i.e. OAR 629-044-1005(2c)).

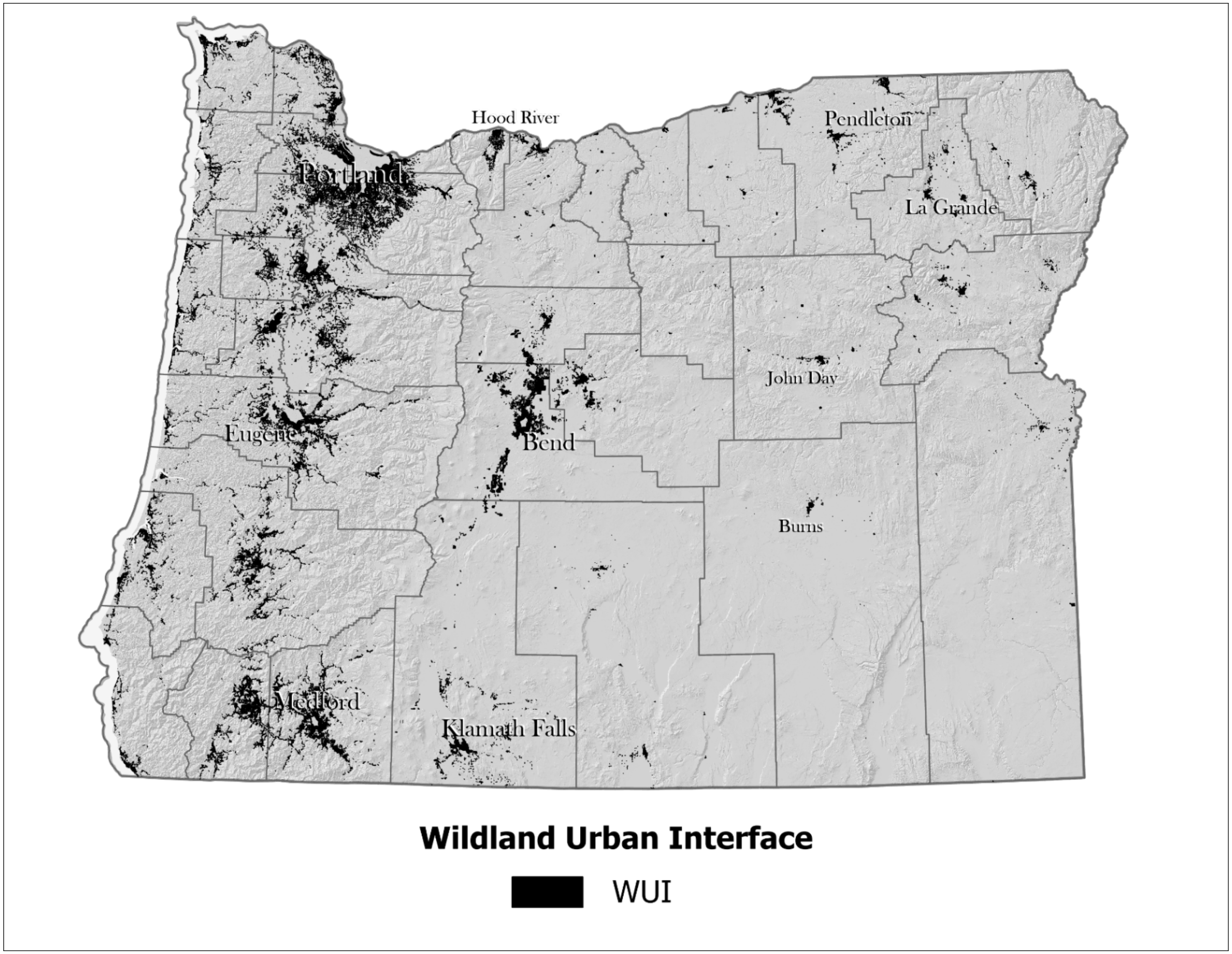

Figure 6. Final Oregon statewide WUI map.

IV. HAZARD MAPPING METHODS

1. Overview

Oregon State University coordinated with Pyrologix LLC, the Oregon Department of Forestry, and fire and fuels subject matter experts from around the state to create the wildfire hazard map described in the following section.

Wildfire hazard is a quantitative, spatial representation of the potential for wildfire to cause social or economic degradation, including injury or death (UNODRR, 2015). Wildfire hazard is a combination of wildfire likelihood ("burn probability") and fire behavior ("fire intensity").

Wildfire likelihood, or burn probability, is the average annual likelihood that a specific location will experience wildfire. Burn probabilities are reported as fractions which, when multiplied by 100, can be thought of as the percent chance of fire occurring for a specific location in any given year. 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. These probabilities represent long-term averages and are not forecasts or predictions of where fire is going to occur in a specific year. When combined with information about fire intensity, burn probabilities help communicate which landscapes are more likely to actually experience the hazard.

Wildfire intensity is a measurement of the amount of energy produced by a fire, frequently reported as "flame length." Fire intensity is driven by several factors including weather, topography, and fuel characteristics. It is an important characteristic of wildfire hazard because varying intensities can lead to different impacts to structures. Sometimes wildfire hazard is expressed only as the condition of wildland fuel (e.g., Hardy, 2005), but this ignores other contributing factors (i.e., climate, weather and topography), and discounts the importance of the likelihood of experiencing a wildfire.

For the purposes of this map, wildfire hazard is defined in OAR 629-044-1005(k) as a numerical value describing the likelihood and intensity of a wildfire, based on specific factors or conditions of weather, climate, topography, and vegetation, as modeled for a given pixel.

Following is a summary of the geospatial data and methods used to develop Oregon's wildfire hazard map. The Modeling Burn Probability and Intensity sub-section describes work that was completed in partnership with Pyrologix LLC., in coordination with researchers at OSU and fire and fuel professionals from around the state. Subsequent sub-sections summarize analyses performed directly by researchers at OSU. Detailed geospatial processing steps are described in Appendix A.

2. Model Burn Probability and Intensity

Fire modelling was performed by Pyrologix LLC (http://pyrologix.com/), a fire behavior modeling company that is a national leader in wildfire risk analytics. The modelling was an iterative process, and intermediate results were reviewed by local fire and fuel professionals from around Oregon. Additional description of the fire modeling process is included in Appendix A.

A. Model Burn Probability[5]

Pyrologix LLC modeled burn probability using the large fire simulator, FSim, developed at the Missoula Fire Lab (Finney et al., 2011). FSim is a comprehensive fire occurrence, growth, behavior, and suppression simulation system that uses locally relevant fuel, weather, topography, and historical fire occurrence information to generate 10,000 simulations of plausible fire seasons. Fire seasons were simulated on a modeling landscape that represented 2022 conditions, including identifiable historical fuel disturbances (e.g. wildfires, some hazardous fuel treatments, etc.) through 2021. (Finney et al., 2011). FSim has been used in a similar way to support other regional and national wildfire risk prioritization strategies (e.g. Day, 2020; Gilbertson-Day et al., 2018; U.S. Department of Agriculture, Forest Service, 2022; U.S. Department of Agriculture, Forest Service, 2022).

Pyrologix simulated a minimum of 10,000 plausible fire seasons at 120-meter resolution. They calculated burn probability by counting the number of times each pixel was intersected by simulated fire and then dividing that count by 10,000. Results were up-sampled to 30-meter resolution to account for non-burnable fuels identifiable at that scale (Figure 7).

B. Model Wildfire Intensity[6]

Pyrologix LLC modeled fire intensity using the Wildfire Exposure Simulation Tool (WildEST). WildEST is a simulation system similar to FSim, but specifically designed to simulate wildfire behavior under a range of weather types (wind speed, wind direction, fuel moisture content). These WildEST results were completed on the 2022 current-condition fuelscape (updated from LANDFIRE as previously described), which reflects fuel conditions for the year 2022 and includes all identifiable historical fuel disturbances through 2021. Pyrologix LLC developed 216 weather scenarios based on unique combinations of wind speed, wind direction and fuel moisture based on empirical weather records collected 2007 – 2021 and summarized within 4km grids.

Pyrologix simulated wildfire behavior (i.e., intensity) under each weather scenario, producing probabilities of various fire intensity levels (represented as flame lengths). WildEST results are expressed as the probability that flame lengths will be within a specific Fire Intensity Level (FIL), given that a fire occurs (Figure 8):

- FIL1: 0-2 ft. flame lengths
- FIL2: 2-4 ft. flame lengths

[5] The original burn probability developed for Oregon by Pyrologix is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> PyrologixHazardDownloads >>CC_2022_burn_probability.tif.

[6] The original average fire itensity developed for Oregon by Pyrologix is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> PyrologixHazardDownloads >> AverageFireIntensity.tif.

- FIL3: 4-6 ft. flame lengths
- FIL4: 6-8 ft. flame lengths
- FIL5: 8-12 ft. flame lengths
- FIL6: > 12 ft. flame lengths

Before calculating wildfire hazard, flame lengths were transformed to fire intensity modifiers[7] (Figure 9). Fire intensity modifiers are a way of expressing fire intensity on a scale 0 – 100 and accounting for differences in hazard resulting from different fuel types (i.e. grass, shrub, timber). At each location, Pyrologix modeled flame lengths, converted flame lengths to fire intensity modifier values, and calculated the probability-weighted average fire intensity modifier value[8].

[7] Fire intensity modifier data are also referred to as conditional risk to potential structures (cRPS).
[8] The original cRPS developed for Oregon by Pyrologix is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> PyrologixHazardDownloads >>CC_2022_Lifeform_cRPS.tif.

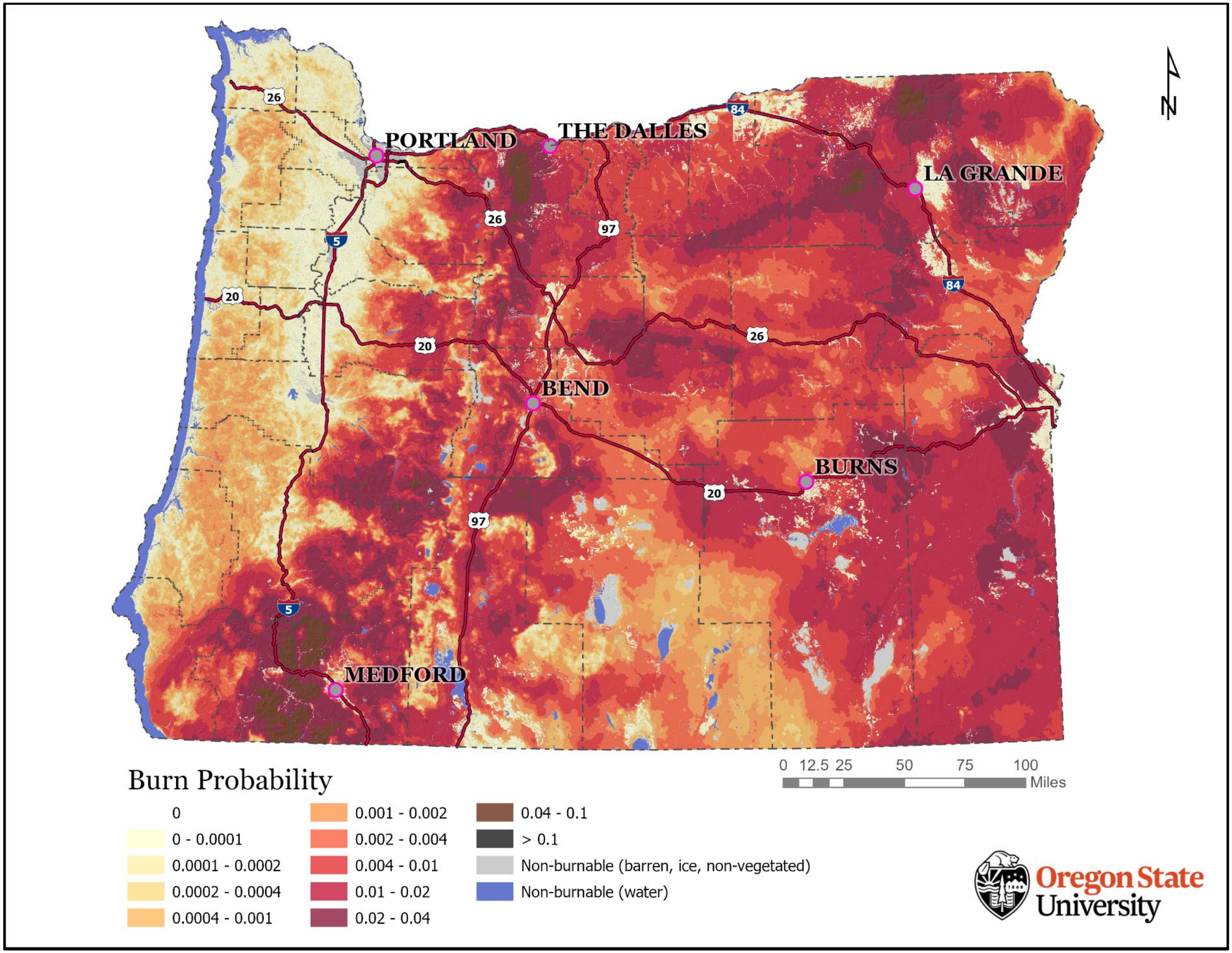

Figure 7. Modeled burn probability across Oregon.

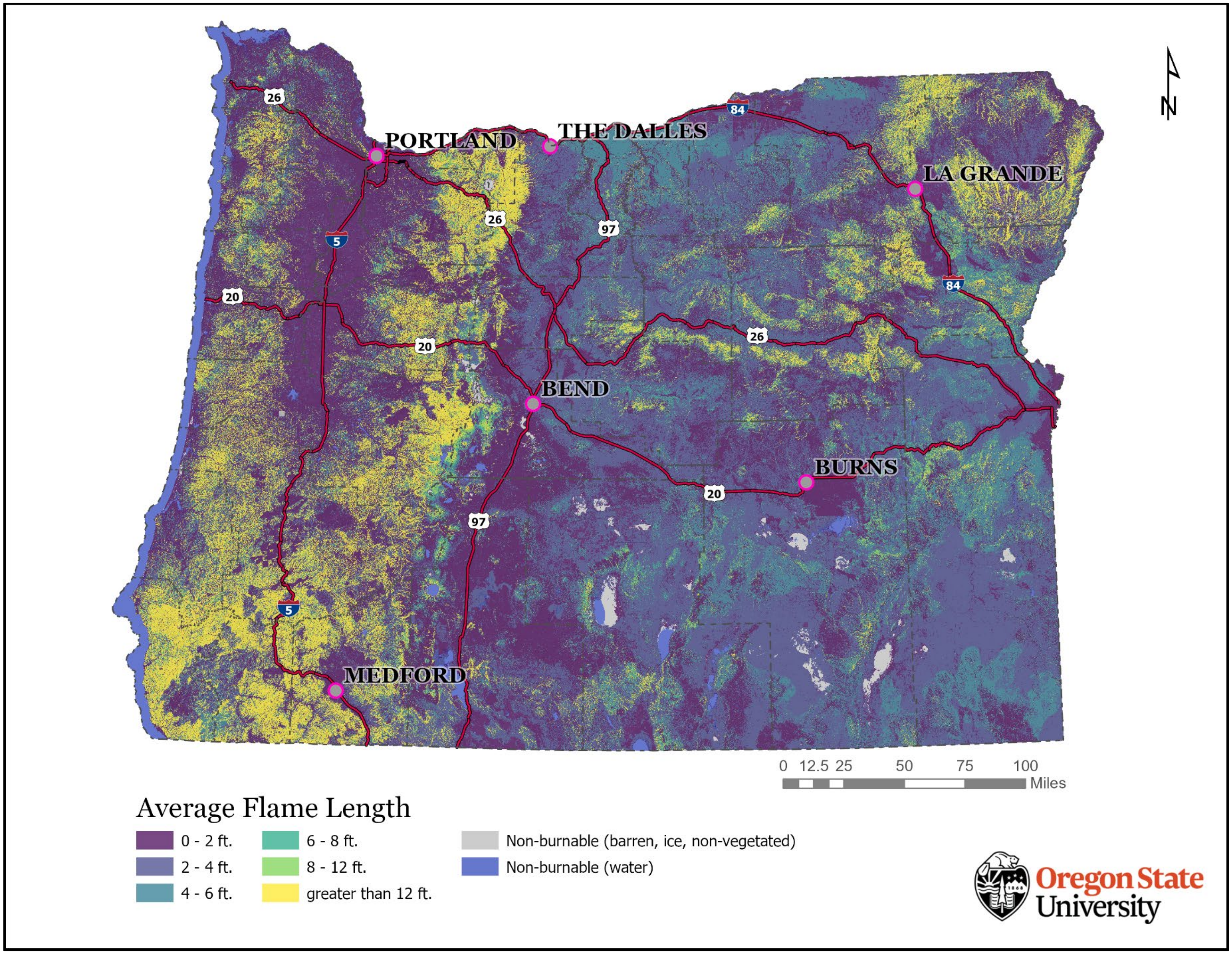

Figure 8. Modeled weighted average flame lengths across Oregon.

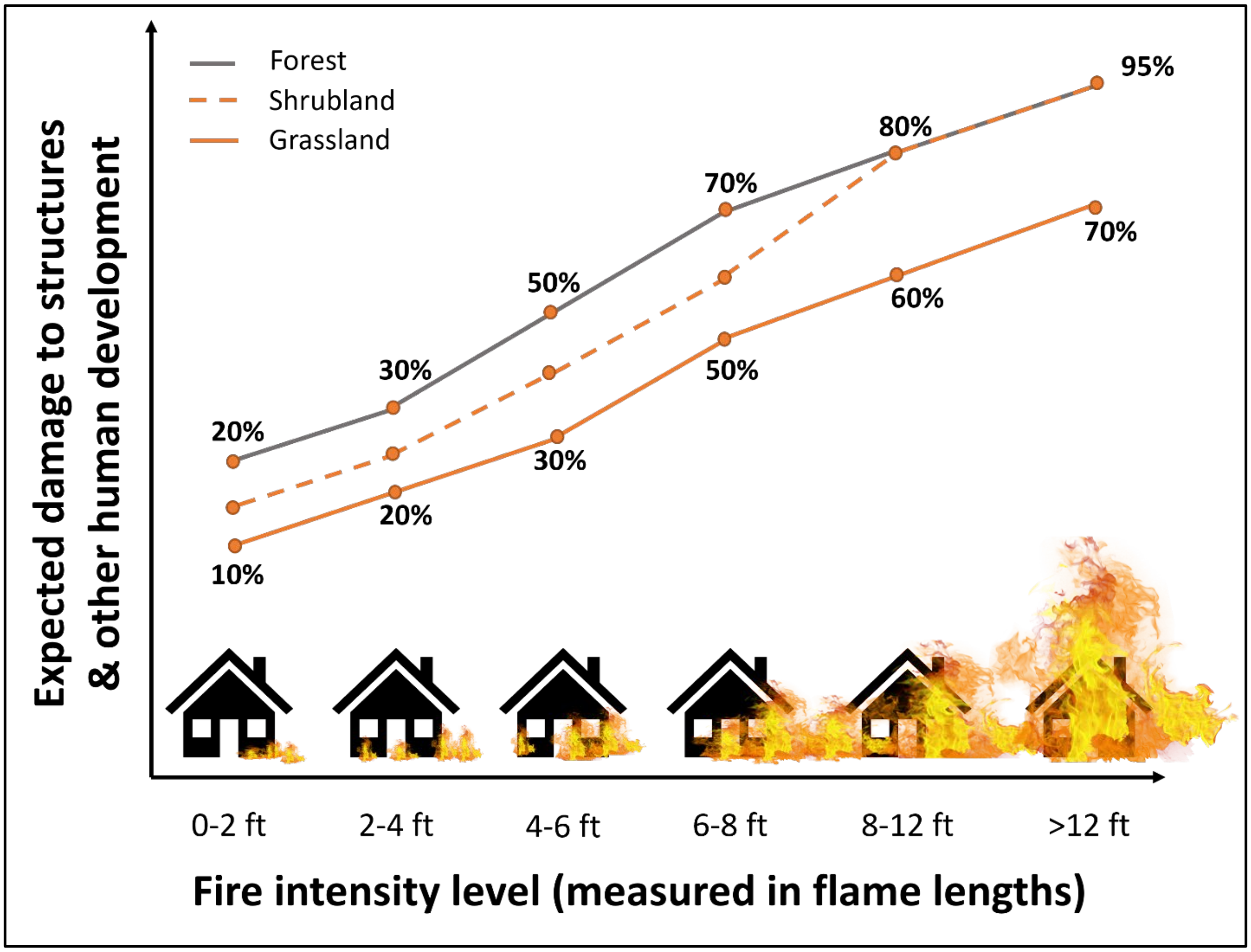

Figure 9. Fire intensity modifiers used to translate flame lengths into a value that is multiplied with burn probability to calculate hazard. The Fire Intensity Modifiers represent the ways in which fire intensity across different fuel types impacts the level of potential damage and opportunities to effectively mitigate (i.e., suppress) the hazard when a fire occurs.

3. Adjust for Irrigated Agriculture

OAR 629-44-1026 requires that wildfire hazard be adjusted in all agricultural areas identified as irrigated in at least one of five representative years.

OSU researchers used IrrMapper (Ketchum et al., 2020) binary data layers from 2017 – 2021 to identify all areas in Oregon that were mapped as irrigated in at least one of those years. Researchers constrained the irrigation data to the spatial extent of mapped agricultural fields using digitized field boundaries produced by the Oregon Water Resources Department in partnership with the Desert Research Institute (OWRD; Bromley et al., 2024).

During review of draft data in spring and summer 2024, county planners (especially from Hood River and Baker County) provided evidence of identifiable data gaps in the irrigation dataset. OSU scientists worked collaboratively with county planners to verify these data gaps and developed corrections applied consistently statewide.

A. Woody Crops

Primarily in Hood River County, feedback received from county planners suggested the majority of woody crops (i.e., orchards) were captured in the irrigation dataset, but that there were persistent errors. These consisted of observable “holes” within the dataset suggesting portions of a field were not irrigated, contrary to common farming practices of orchards. Evaluation by OSU scientists noted these holes were not aligned with observable features that could explain their presence (e.g., recently cleared crops, change in farming practices, etc.). Therefore, the science team adjusted the irrigation data set to include these areas as irrigated. This was accomplished by selecting the agricultural field boundaries from OWRD identified as identified as partially irrigated orchard crops and extended the irrigation extent to the entirety of those digitized field boundaries.

B. Cropped Wetlands

In conversations with Baker County planners, they noted that that the IrrMapper analysis process frequently excluded wetlands, even when the wetlands are identified as irrigated hay fields in the OWRD data. To account for these discrepancies, we intersected freshwater forested/shrub wetlands and freshwater emergent wetlands from the National Wetland Inventory (NWI; U.S. Fish and Wildlife Service, 2023) with the OWRD department digitized field boundaries and included those areas with the extent of irrigated for modifying fire hazard.

The final irrigation layer[9] integrated into Oregon’s wildfire hazard calculations includes:

- All areas within digitized OWRD agricultural field boundaries identified as irrigated in IrrMapper in at least one of five years (2017 – 2021),
- Mapped orchards across the State of Oregon,
- Mapped wetlands used as crops.

OSU scientists adjusted burn probability and fire intensity modifier values at the corresponding locations using this newly created irrigated agricultural dataset. We decreased burn probability to 0.0001 (1 in 10,000 chance) which corresponds with the lowest likelihood in dry landscapes of Oregon and set the fire intensity modifier value to 10 which represents the lowest fire intensity level used in our analyses. All other burn probability and fire intensity modifier values outside the mask were unaffected[10,11].

[9] The final irrigate layer described in this section is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> CompleteIrrigationAdjustmentMask.
[10] The final burn probability layer described in this section is viewable on https://tools.oregonexplorer.info/viewer/wildfire and available for download at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> BurnProbability.
[11] The final cRPS layer described in this section is available for download at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> FireIntensityModifier_cRPS.

4. Estimate Hazard

A. Initial Hazard Estimate

As previously noted, wildfire hazard is an integrated measure of burn probability and fire intensity. To integrate these metrics, we first multiplied burn probability by the spatially coincident fire intensity modifier at the 30 x 30-meter pixel scale. Subsequently, we averaged the resulting hazard values across each tax lot within the State of Oregon as their respective hazard score. Where tax lots were too small or did not include a pixel center, we converted tax lot centroids to points and extracted the underlying hazard value to attribute said tax lot with a hazard score. The result is a feature class with polygon geometry representing property-level hazard values.

B. Hazard Class Thresholds

OAR 629-044-1021 defines the three hazard zones according to specific ranges of hazard values.

- High Wildfire Hazard: hazard value > 0.137872. This range of values represents approximately the 90th percentile and above of tax lot-level hazard values.

- Moderate Wildfire Hazard: hazard value > 0.001911 - ≤0.137872. This range of values represents approximately the 40th – 90th percentile of tax lot-level hazard values.

- Low Wildfire Hazard: hazard value ≤ 0.001911. This range of values represents hazard values at the 40th percentile and below of tax lot-level hazard values.

These thresholds were identified using initial hazard estimates immediately adjacent to structures in the WUI. Researchers multiplied burn probability by the spatially coincident fire intensity modifier at the 30 x 30-meter pixel scale, and then averaged each pixel within a three-cell neighborhood. Then, researchers used all structure points from within the WUI only (n = 792,949) to extract the underlying averaged hazard values. The result was 792,949 hazard values associated with structure locations inside the WUI. Researchers identified the values associated with 90th percentile (i.e. the lower threshold for the high hazard zone), and the 40th percentile (i.e. the lower threshold for moderate hazard zone). These associated suggested thresholds were presented to, and subsequently recommended for adoption by the initial rules advisory committee in February 2022, and formally adopted by the Board of Forestry in June 2022.

C. Final Hazard Zones

Oregon State University released draft property-level wildfire hazard data as described above on the Oregon Wildfire Risk Explorer for a 30-day public comment period beginning July 18, 2024. Significant public comment from this period and dating back to 2022, as well as comment from county commissioners, highlighted concerns about the amount of neighbor-to-neighbor variation ("speckling") in some developed areas at the margins of hazard classes. Consistent with language in OAR 629-044 which refers to hazard "zones," and consistent with

OAR 629-044-1021(2)[12], OSU modified the initial hazard estimates to reduce neighbor-to-neighbor variations in hazard class.

We created final hazard zones that minimize neighbor-to-neighbor differences by converting property-level average hazard scores into pixels at the original modeling scale (30 x 30-meter pixels). We then averaged this hazard layer at a 20-pixel by 20-pixel neighborhood. The 20-pixel neighborhood (10-pixels or 300-meters on either side) is consistent with similar smoothing procedures used by Pyrologix LLC to estimate burn probability and fire intensity in developed areas (Vogler et al., 2021). The result is a raster dataset representing smoothed pixel-level hazard values that account in part of differences in tax lot sizes that influenced the final hazard score. Subsequently, we overlaid our irrigated agriculture layer to ensure small-scale irrigation operations were not lost in this process, while leaving all other updated hazard values unchanged. The result is a smoothed hazard value dataset that includes adjustments for irrigated agriculture[13]. Finally, we averaged hazard values across each tax lot to obtain a final property-level hazard value and assigned each tax lot to their respective hazard zone based on the thresholds described above[14].

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[12] OAR-629-044-1021(2): It is recognized that natural vegetation is highly variable and that the fuel models used in subsection (1) of this rule may not always accurately reflect expected wildfire behavior, due to variations in local species and vegetation conditions. Therefore, consistent with peer reviewed methods, modifications may be made to the hazard rating to ensure accuracy.

[13] The wildfire hazard raster layer described in this section is available for download at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> WildfireHazard.

[14] The final vector wildfire hazard layer described in this section is viewable on https://tools.oregonexplorer.info/viewer/wildfire. It is not available for download because it includes property boundaries, and agreements between the state and counties prohibit sharing of spatial tax lot information.

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VI. APPENDIX A: Developing Oregon's Wildfire Hazard and Wildland-Urban Interface Maps, Detailed Geospatial Processing Methods

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Prepared by: Andy McEvoy

Geoprocessing Environment:

- Geoprocessing was conducted in ArcGIS Pro unless explicitly stated otherwise
- All data projected on the fly in EPSG 2992, NAD_1983_Oregon_Statewide_Lambert_Feet_Intl
- All raster data snapped to and aligned (30-meter cell size) using the burn probability raster produced by Pyrologix LLC, available in SB80PublicData >> FireModelingData >> PyrologixHazardDownloads >> CC_2022_burn_probability.tif

1. Assembling spatial tax lot boundaries

Wildfire hazard was summarized within each individual tax lot in Oregon (n = 1,950,776). Following is a description of how the spatial tax lot data was collected and assembled.

A. Collect Spatial Data from Counties

Spatial tax lot boundary data for all 36 counties was collected by two methods:

1. From online feature services – The following counties (n = 17) maintain publicly accessible, online spatial tax lot datasets. OSU downloaded the datasets on August 20, 2024.
    a. **Benton County** - https://bentoncountygis.maps.arcgis.com/apps/webappviewer/index.html?id=57b2358b418142b2891b3e863c29126a
    b. **Clackamas County** – accessed via Orgon Metro RLIS https://www.arcgis.com/home/item.html?id=9d3c396ffad44649bc7451465aa300f0
    c. **Clatsop County** - https://delta.co.clatsop.or.us/apps/ClatsopCounty/
    d. **Columbia County** - https://gis.columbiacountymaps.com/ColumbiaCountyWebMaps/
    e. **Coos County** - https://www.arcgis.com/home/webmap/viewer.html?webmap=1be7dbc77f8745d78fc5f3e8e85fc05e&extent=-124.8585,42.6536,-122.6914,43.6326
    f. **Crook County** - https://geo.co.crook.or.us/server/rest/services/publicApp/landGroup/MapServer
    g. **Curry County** - https://gateway.maps.rlid.org/maps1/rest/services/Curry/GeneralMap/MapServer

h. **Deschutes County** - https://services1.arcgis.com/znO8Hz1SuVVohYhZ/arcgis/rest/services/Taxlots/FeatureServer
i. **Douglas County** - https://gis.co.douglas.or.us/server/rest/services/Parcel/Parcels/MapServer
j. **Gilliam County** - https://services3.arcgis.com/e3KSI9Py4B7m3xu6/arcgis/rest/services/Gilliam01_TL/FeatureServer
k. **Jackson County** - https://spatial.jacksoncountyor.gov/arcgis/rest/services/OpenData/ReferenceData/MapServer/3/query
l. **Josephine County** - https://www.josephinecounty.gov/departments/geographic_information_systems_(gis)/gis_data_download.php
m. **Klamath County** - https://services.arcgis.com/H6Mh1bySxR4oHx6x/arcgis/rest/services/KC_Taxlots/FeatureServer
n. **Multnomah County** - accessed via Orgon Metro RLIS https://www.arcgis.com/home/item.html?id=9d3c396ffad44649bc7451465aa300f0
o. **Washington County** - accessed via Orgon Metro RLIS https://www.arcgis.com/home/item.html?id=9d3c396ffad44649bc7451465aa300f0
p. **Wheeler County** - https://services3.arcgis.com/e3KSI9Py4B7m3xu6/arcgis/rest/services/Wheeler01_TL/FeatureServer
q. **Union County** - https://unioncountyor.gov/gis-down/
r. **Yamhill County** - https://www.yamhillcountygis.com/server/rest/services/YamhillWebApps/Survey_2023/MapServer

2. For the remaining counties (n = 19), OSU made direct requests to assessors and GIS staff to access spatial tax lot records.
    a. **Baker County** - data received July 22, 2024
    b. **Grant County** – data received July 31, 2024
    c. **Harney County** - data received July 31, 2024
    d. **Hood River County** - data received July 23, 2024
    e. **Jefferson County** - data received August 1, 2024
    f. **Lake County** - data received July 22, 2024
    g. **Lane County** - data received July 24, 2024
    h. **Lincoln County** - data received July 24, 2024
    i. **Linn County** - data received July 19, 2024
    j. **Malheur County** - data received July 22, 2024
    k. **Marion County** - data received July 23, 2024

l. **Morrow County** - data received July 23, 2024
m. **Polk County** - data received July 22, 2024
n. **Sherman County** - data received July 29, 2024
o. **Tillamook County** - data received July 22, 2024
p. **Umatilla County** - data received July 24, 2024
q. **Wallowa County** - data received July 22, 2024
r. **Wasco County** - data received July 29, 2024

B. Assign common identifier to all tax lots and merge tax lot records into single feature class.

1. To each county dataset, added an attribute field named 'CNTY_CODE' and assigned each feature a 2-digit code associated with that county. The two-digit codes correspond to alphabetical order. For example, Bake County is the first county alphabetically, so its two-digit code is '01'; Yamhill County is the last county alphabetically, so its two-digit code is 36.
2. Then, created another attribute field called 'SourceID' and filled it in by concatenating "OSU" with the value in 'CNTY_CODE' and the row FID.
3. Merged the county datasets together and eliminated all fields except for:
    a. SourceID – unique identifier that can be used to connect any feature back to the original associated tax data.
    b. CNTY_CODE – Two-digit code identifying the county with which the tax lot feature is associated.
    c. instName – Name of the county with which the tax lot feature is associated.

2. Map Wildland-Urban Interface

The wildland-urban interface (WUI) combines estimates of structure density and vegetation amount and proximity.

A. Calculate Structure Density and Map Potential WUI

1. Subset structures based on square footage and convert to point geometry
    a. Using the State Building Footprints of Oregon (SBFO; Williams, 2021), removed all buildings less than or equal to 400 square feet (1,948,816 structures remain, or 222,519 removed)
    b. Selected by attribute (SQ FT <= 400)
    c. Deleted attributes (deletes selected features)
    d. Used Feature to Point to convert all building footprint polygons to points (representative centroids). The option "inside" was unchecked.
2. Subset structures to single structure per tax lot[15]
    a. Used Spatial Join to attribute structure points with SourceID (from tax lots generated in Step 1.B.3)

[15] Dataset representing the structure locations used to calculate structure density are publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> WUI_StructureLocationPoints

b. Sort structure point data from largest to smallest so that largest structure on tax lot is the first in the list of points present on an individual tax lot
c. Sorted ascending on SourceID, descending on SQ FT
d. Deleted identical points based on SourceID. Result is a feature class, point geometry, representing structures in Oregon greater than 400 square feet reduced to a single structure per tax lot.
3. Add points representing Other Human Development (OHD), defined as "Essential facilities that support community functions, public communication, energy and transportation in excess in size of 400 sq. ft."
   a. Collected essential facility spatial data from Homeland Infrastructure Foundation-Level Database (Environmental Impact Data Collaborative, 2022) from layers as follows:

Table 1. Layers downloaded from the HIFLD and included in other human development locations used in development of the WUI.

Hospitals	EMS stations
Fire Stations	Colleges and universities
Shelter system	Private schools
Local law enforcement	Wastewater treatment sites
Emergency medical service stations	Emergency operation centers
Public schools	EPA emergency response facility
Electric substations	Port facilities
Power plants	Childcare centers
Solid waste landfill facilities	Oil and natural gas wells
Natural gas processing plants	Natural gas storage facilities
Petroleum ports	LNG import/export terminals
Nursing homes	Public transit centers
Biodiesel plants	Public health departments
Urgent Care facilities	State government buildings

   b. Collected essential facility spatial data from the Interagency Fuel Treatment Decision Support Center US Department of the Interior & US Department of Agriculture, 2024) from layers as follows:
      - Communication towers
      - Electric substations
      - Power plants
   c. All features from Steps 2.A.3a and 2.A.3b were converted to point geometry and merged into a single feature class representing OHD using Merge Layers.
   d. Using Select by Location, selected tax lots from Step 1.B.3 that intersect with the reduced structure locations developed in Step 2.A.2. Exported selected features to a layer representing tax lots that contain a structure from the reduced structure dataset.
   e. Using Select by Location, selected points in the OHD feature (product of Step 2.A.3c) that intersect the tax lot feature developed in Step 2.A.3d and deleted the

selected points. The result is a feature representing reduced OHD points outside of tax lots where structures have already been mapped using SBFO.

   f. Using Spatial Join, joined the reduced OHD points from Step 2.A.3e to tax lot developed in Step 1.B.3 so that the OHD points are attributed with SourceID.
   g. Merged the reduced OHD points (product of Step 2.A.3f) with the reduced SBFO points (product of Step 2.A.2d). The result is a point feature representing all structure locations that will be used to calculate structure density.

4. Calculate structure density using reduced structure location data from Step 2.A.2
   a. Used Point Density with radius of 746 feet. A radius of 746 feet is equivalent to an area of 40.1365 acres and ensures that single structures do not exceed the minimum structure density threshold of 1 structure per forty acres. In other words, a radius of 746 feet ensures that any area of potential WUI includes no less than two structures.
   b. Result is a raster representing structure density
5. Remove locations which do not meet structure density threshold of > 1 structure per 40 acres. On the 30-meter raster from Step 2.A.4, one structure per 40 acres is equivalent to 0.025.
   a. Using Reclassify, reclassified the product of Step 2.A.4 so that all pixels less than or equal to 0.025 (at or below the required density threshold) had a value of 0, and all pixels greater than 0.025 had a value of 1.
   b. Used Extract by Attribute where Value = 1. The result is a raster representing all areas of Oregon that exceed the minimum structure density threshold. This was referred to as "potential WUI."
6. Convert Potential WUI raster to polygon and clean to eliminate instances where structures are only partially surrounded by potential WUI areas, and also instances where potential WUI is mapped between structures but does not include the structures themselves (i.e., overlapping areas of search window in areas where structures are otherwise separated by distances exceeding 746 ft).
   a. Used Raster to Polygon tool
   b. Used Select Layer by Location to select WUI polygons that intersected the reduced structure point locations from Step 2.A.3g. Exported the selected WUI features to a new feature class representing potential WUI (polygon).
   c. Using Select Layer by Location, selected all structures from the reduced structure dataset (product of Step 2.A.3g) that intersect potential WUI from Step 2.A.6b
   d. Using Point Density, calculated the point density using points selected in the previous step and a neighborhood radius of 746 feet.
   e. Using the Reclassify tool, reclassified the product of Step 2.A.6d so that all pixels less than or equal to 0.025 (at or below the required density threshold) had a value of 0, and all pixels greater than 0.025 had a value of 1.
   f. Used Extract by Attribute where Value = 1. The result is a raster representing all areas of Oregon that exceed the minimum structure density threshold, and which represent the cleaned potential WUI.
   g. Using Raster to Polygon, converted the cleaned potential WUI to polygons with the Simplify Polygons option checked.

7. Filter potential WUI to eliminate WUI polygons with less than three structures.
    a. Used Spatial Join to join reduced structure locations (product of Step 2.A.3g) to the cleaned potential WUI polygon feature (product of 2.A.6g), using a one-to-one join and choosing the option 'completely contains.' The result is a feature with an attribute field named 'join count'.
    b. Using Select by Attribute, selected all features where join count was greater than or equal to 3 and exported the selected rows to a new feature. The result is a new feature representing all potential WUI in Oregon containing at least three structures.
8. Add Urban Growth Boundaries[16]
    a. Added field called 'gridcode' to the UGB dataset and used Calculate Field so that gridcode = 1 for all rows.
    b. Used Union tool to add UGB features to Potential WUI features developed in Step 2.A.5.
    c. Dissolved on gridcode using Dissolve to create a single part polygon layer representing potential WUI.

B. Map Vegetation Criteria

1. Estimate the percent vegetation cover for each pixel.
    a. Using the fire behavior fuel model layer[17] developed and used in hazard modeling by Pyrologix LLC., used Reclassify so that all burnable fuel models were set to Value = 1, and all non-burnable fuel models to Value = 0.
    b. Used Focal Statistics on binary raster to calculate mean value. Parameters included a circular neighborhood with 746-foot radius. The result is a raster representing the proportion of pixels that are burnable within the given radius.
    c. Using Raster Calculator, converted the product from Step 2.B.1b to a percentage by multiplying the raster value by 100, and then using the Int function, converted the value to an integer.
2. Based on the percent cover raster from previous step, map Intermix WUI class.
    a. Using Extract by Attribute, extracted all pixels from Step 2.B.1c where Value ≥ 50. Then, using Reclassify, reclassified so that all Values = 1, and converted with Raster to Polygon with the option to simplify polygons checked and the option to create multi-part features unchecked. The result is a feature class with polygon geometry representing all areas in Oregon that meet the vegetation cover requirement for Intermix WUI.
    b. Added field named WUI_TYPE and calculated field as '1'.
3. Based on the percent cover raster from previous step, map Interface WUI class.

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[16] https://geohub.oregon.gov/datasets/oregon-geo::urban-growth-boundaries/about.Dataset representing the urban growth boundaries used to map WUI extent is available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> Urban_Growth_Boundaries

[17] Dataset representing fire behavior fuel models are publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> FireBehaviorFuelModels

a. Using Extract by Attribute, extracted all pixels from Step 2.B.1c where Value ≥ 75. Then, using Reclassify, reclassified so that all Values = 1, and converted with Raster to Polygon. Added a field called 'area' and calculated the area of each polygon in square miles.
b. Using Select by Attribute selected all polygons greater than two square miles and exported a new feature.
c. Buffered the features by 1.5 miles using Buffer. Then, using Erase tool, erased the buffered polygons using the product from Step 2.B.3b.
d. Erased the Intermix WUI (product of Step 2.B.2a) using Erase to create feature representing Interface WUI polygons.
e. Added field named WUI_TYPE and calculated field as '2', using Calculate Field.

4. Based on the percent cover raster from previous step, map Occluded WUI class.
    a. Using Select by Attribute selected all polygons from Step 2.B.3a greater than one square mile and less than two square miles and exported a new feature layer.
    b. Buffered the features by 1.5 miles using Buffer. Then, using Erase tool, erased the buffered polygons using the product from Step 2.B.4a.
    c. Added field named WUI_TYPE and calculated field as '3', using Calculate Field.
5. Using the Erase tool, erased overlap of Occluded, Interface and Intermix WUI types and created unique feature classes for each WUI type.
6. Excluded perennial water, ice and barren land cover types from the Pyrologix LLC fire behavior fuel model datasets and converted raster to polygon.
7. Merged features representing WUI types from Steps 2.B.3, 2.B.4, 2.B.4.
8. Create non-WUI areas based on vegetation
    a. Used the potential WUI feature from Step 2.A.8c to erase a feature representing the boundary of Oregon, using Erase.
    b. Added a field called "WUI_TYPE" and calculated field as '4', using Calculate Field.
9. Merged non-WUI feature class (Step 2.B.8b) with other WUI types (Step 2.B.7) using Merge. The result is a polygon feature class representing areas that meet the criteria for inclusion in the WUI based on the amount and proximity of vegetation.

C. Integrate Potential WUI and Vegetation Criteria to Map Final WUI

1. Converted potential WUI features (Step 2.A.8c) to raster using Feature to Raster
2. Converted WUI types based on vegetation (Step 2.B.9) to raster using Feature to Raster
3. Reclassified raster from 2.C.1 using Reclassify so NoData values were changed to zero values, and all other values were changed to 10. Used the extent of the fuel model raster developed in Step 2.B.6
4. In Raster Calculator, summed the potential WUI raster from Step 2.C.3 with the WUI type raster from Step 2.2.C2 so that:
    - 1 = intermix zone, below density threshold
    - 2 = interface zone, below density threshold
    - 3 = occluded zone, below density threshold
    - 4 = non-vegetated, below density threshold
    - 11 = Intermix WUI
    - 12 = Interface WUI

- 13 = Occluded WUI
- 14 = non-vegetated, above density threshold

5. Reclassified the raster from 2.C.4 so that where Values = 11,12, or 13 the new Value = 1. All other values classified to 0. The result is a raster where Value = 1 representing the final WUI extent.
6. Used Raster to Polygon to convert the WUI raster (Step 2.C.5) to a feature class.[18]

3. Develop Irrigated Agriculture Mask[19]

The irrigated agriculture mask is a raster dataset that identifies all locations in Oregon that meet the definition of irrigated for the purposes of the statewide wildfire hazard map. Within the mask, OSU applied adjustments to wildfire hazard and wildfire hazard input layers in Steps 5.A.1 and 5.A.2.

A. Access IrrMapper Data

IrrMapper (Ketchum et al., 2020) estimates the distribution of irrigation for every year from 1986 to 2021 across all croplands in Oregon. This dataset references 134 different inputs to evaluate existing landcover and determine in each year whether it is irrigated or not, and if its irrigated, whether it represents agricultural land use or non-agricultural uses. The annual evaluation is made at a 30-meter resolution. OSU considers it the best available science for identifying irrigated croplands, particularly at a statewide scale.

1. Using Google Earth Engine, downloaded IrrMapper binary files for each year 2017 – 2021. Binary files represent all identified irrigated agricultural areas with ‘1’ and all other land cover/management types ‘0’.
2. Using Raster Calculator summed the five annual rasters to generate a single raster representing the number of years (0 – 5) that every location in Oregon is verified as irrigated, and extracted all pixels where the value was ≥ 1.
3. Using Pairwise Clip, clipped the raster from the previous step to the extent of all agricultural fields in the field boundary dataset (Bromley et al., 2024) developed by the Oregon Water Resources Department (OWRD) and the Desert Research Institute. The result is a raster representing irrigated agricultural areas within Oregon, that have been verifiably irrigated in at least one of the representative five years.

B. Expand Irrigated Agriculture Footprint

During review of draft wildfire hazard products, county planners identified two specific limitations in the IrrMapper data. First, there were unexplainable holes within persistently irrigated orchards. Second, some wet meadows in central and eastern Oregon were not represented in the IrrMapper

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[18] The final WUI dataset is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> WildlandUrbanInterface

[19] Dataset representing the Irrigate Agriculture Mask is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> CompleteIrrigationAdjustmentMask

data despite being mapped as agricultural fields in the OWRD data and despite evidence of their persistent greenness. Following is a description of how OSU addressed those data gaps.

1. Using the Feature to Raster tool, converted polygons to raster for all features in the OWRD data where the most recent crop data indicates that it was a fruit orchard (i.e. Crop_2021 = 66 – 69, OR Crop_2021 = 77), and reclassified the raster so that all values equaled '1'.
2. Using the Nation Wetlands Inventory (U.S. Fish and Wildlife, 2023), used Select by Attributes and selected 'Freshwater Forested/Shrub Wetland', 'Freshwater Emergent Wetland', and 'Other' from the WETLAND_TYPE attribute and converted the polygon features to raster. Reclassified the raster so that all values equaled '1'.
3. Using Mosaic to New Raster, merged the IrrMapper product from step 3.A.3 above with the two rasters from steps 3.B.1 and 3.B.2 above. The result is a raster representing all areas of Oregon that are considered irrigated agriculture, or persistently green wetlands.

4. Model Wildfire Hazard Components

Wildfire hazard is composed of two elements: burn probability and fire intensity. OSU developed wildfire hazard components in collaboration with the U.S. Forest Service, the Oregon Department of Forestry, Pyrologix LLC., and other partners. Pyrologix LLC was contracted to work with a group of public land management agencies and research scientists to generate spatial representations of wildfire hazard components.

A. Generate Modeling Landscape[20]

The modeling landscape (fuelscape) consists of geospatial raster datasets representing surface fuel model (FBFM40), canopy cover (CC), canopy height (CH), canopy bulk density (CBD), canopy base height (CBH), and topography characteristics (i.e. slope, aspect, elevation). LANDFIRE (LANDFIRE, 2022) was the original source of these rasters. During a calibration workshop in February 2022, more than 50 subject matter experts revised the LANDFIRE data based on their local and professional knowledge of fire and fuels.

Pyrologix LLC incorporated spatial disturbance data representing wildfires and fuel treatments that occurred up through the end of 2021 and modified LANDFIRE FBFM40 data to reflect post-disturbance conditions. Disturbance modifications took into consideration the type of disturbance, the severity, and the time since the disturbance occurred. Fuel treatment records were available from the Forest Activity Tracking System (FACTS) for the USDA Forest Service and the National Fire Plan Operations and Reporting System (NFPORS) for Department of Interior. Oregon Department of Forestry also provided historical fuel treatment data.

The fuelscape developed by Pyrologix LLC and used to model components of Oregon's wildfire hazard map represents structural fuel conditions at the beginning of the 2022 fire season.

[20] Spatial data pertaining to the modeling landscape are publicly available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> FireModelingData >> FireModeling_FuelscapeDetails

B. Model Burn Probability[21]

Pyrologix LLC modeled burn probability using the large-fire simulator, FSim (Finney et al., 2011). FSim is a Monte Carlo model which simulates a full range of plausible fires and fire seasons based on the variability in factors that influence fire occurrence, including ignition location, seasonality, and fire weather conditions. Fire occurrence probability in FSim is a function of a logistic regression between empirical historic large fire ignitions in the study area and the daily Energy Release Component (ERC) at the time of ignition (Cohen and Deeming, 1985). For each day of a simulated fire season, FSim draws from plausible weather scenarios and simulates an ignition if the ERC exceeds the 80th percentile of historic ERC values (Riley et al., 2013). When an ignition is simulated, FSim generates a spatial fire perimeter by computing daily fire spread based on weather and available fuels while estimating the effect of suppression. FSim operates on a daily time step each season and is usually run for at least 10,000 seasons. Burn probability is calculated by adding up the number of instances that a pixel was intersected by simulated fire and dividing the sum by the total number of simulated seasons. Accordingly, burn probability from FSim is an estimate of average annual wildfire likelihood at each pixel.

Pyrologix LLC calibrated FSim to historic fire occurrence and observed fire weather characteristics and simulated 10,000 fire seasons for each of 14 Fire Occurrence Areas (FOAs)[22]. For each FOA, FSim was calibrated to a distribution of fire size and annual number of large fires using spatial fire records from the Fire Occurrence Database (FOD; Short, 2022) which includes fires 1992 – 2020, and records from state and federal agencies for fires that occurred in 2021. For each FOA, the logistic regression between large fire occurrence and ERC was calculated using daily weather records (2007 – 2021) sampled from a representative remote automated weather station (RAWS) within each FOA. Initial modeling was done at 120-meter pixels and then downscaled to account for unburnable portions of the landscape detected at 30 meters.

C. Model Fire Intensity[23]

Model Wildfire Intensity. Pyrologix LLC generated spatial estimates of wildfire intensity using WildEST (Scott, 2020). WildEST is a deterministic wildfire modeling tool that uses a command-line version of FlamMap (Finney, 2006) to simulate 216 deterministic scenarios based on combinations of wind speed, wind direction and fuel moisture content. The 216 scenarios were weighted according to Weather Type Probabilities (WTPs), where more weight was assigned to scenarios associated with higher spread conditions. Pyrologix LLC used 4-Km gridded weather data to develop the 216 scenarios. WildEST simulations were performed at 30-meter resolution.

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[21] The original burn probability developed for Oregon by Pyrologix is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> PyrologixHazardDownloads >>CC_2022_burn_probability.tif.

[22] Fire Occurrence Area spatial data is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >>FireModelingData>>FireOccurrencArea_ModelSpecs >>Oregon_FireOccurrenceAreas.shp

[23]The original cRPS developed for Oregon by Pyrologix is available at: https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> PyrologixHazardDownloads >>CC_2022_Lifeform_cRPS.tif.

WildEST produced spatially explicit flame length probabilities for each of six fire intensity levels (FIL1 – FIL6) required for fire effects analysis. Fire intensity level rasters represent the probability of a fire occurring within the specified flame length range based on heading and non-heading fire types simulated in WildEST.

Using a weighted average from across the six FIL rasters, PyroLogix LLC transformed the average flame length into conditional risk to potential structures (cRPS)[24] values according to the dominant fuel type (Table 2).

Table 2. Estimates of fire intensity were grouped into six fire intensity levels (FILs) based on the conditional probability that if a fire occurs, flame lengths will be within the specified range. Weighted average flame lengths at each location in Oregon were then transformed into the corresponding cRPS value based on the dominant fuel type.

		Dominant Fuel Type		
Fire Intensity Level (FIL)	**Flame Length (feet)**	**Grass**	**Shrub**	**Timber**
		cRPS values		
FIL 1	0 - 2	10	15	20
FIL 2	2 - 4	20	25	30
FIL 3	4 - 6	30	40	50
FIL 4	6 - 8	50	60	70
FIL 5	8 - 12	60	80	80
FIL 6	> 12	70	95	95

5. Calculate Wildfire Hazard

A. Calculate Pixel-Level Hazard

Using burn probability and cRPS rasters developed by Pyrologix LLC and described in Section 4 above, as well as the irrigated agriculture mask described in Section 3 above, researchers calculated wildfire hazard for all pixels in Oregon.

1. Using the Raster Calculator tool, all areas within the irrigated agriculture mask (where the mask is not Null) were set to 0.00001, and all areas outside the mask were set to the corresponding burn probability value in the burn probability raster developed by Pyrologix LLC (see Section 4.B). The result is a statewide burn probability raster that includes adjustments representing irrigated agriculture[25].

[24] Conditional Risk to Structures (cRPS) is also referred to as “fire intensity modifiers” in public-facing documentation.
[25] Dataset representing burn probability including the irrigated agriculture adjustments is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> BurnProbability

2. Using the Raster Calculator tool, all areas within the irrigated agriculture mask (where the mask is not Null) were set to 10, and all areas outside the mask were set to the corresponding cRPS value in the burn probability raster developed by Pyrologix LLC (see Section 4.C). The result is a statewide cRPS raster that includes adjustments representing irrigated agriculture[26].
3. Using the Focal Statistics tool, we averaged the cRPS raster from the previous step using a 3-pixel by 3-pixel window. The result is a smoothed cRPS raster.
4. Using the Raster Calculator tool, multiplied burn probability including the irrigated agriculture adjustment (i.e., product of Step 5.A.1) with the smoothed cRPS raster including adjustments representing irrigated agriculture (i.e., product of Step 5.A.3). The result of this step is a statewide expected risk to potential structures (eRPS) raster representing pixel-level wildfire hazard including adjustments representing irrigated agriculture.

B. Calculate Property-Level Hazard

Using the hazard raster generated in Step 5.A.4 and tax lots generated in Step 1.B.3, researchers summarized wildfire hazard within each property and grouped all tax lots into either low, moderate, or high classes.

1. Using the Zonal Statistics as Table tool, calculated the average pixel-level hazard value (product of Step 5.A.4) within each tax lot (product of Step 1.B.3) using SourceID as the zone field. The table was exported as a .csv file.
2. Researchers joined the zonal statistics table from Step 5.B.1 to the spatial tax lot feature class from Step 1.B.3 using SourceID as the join field. The Zonal Statistics as Table tool sometimes fails to generate statistics for zones which do not cover a pixel center. Researchers identified all tax lots for which no average hazard value had been calculated (n = 456,188) and created a shapefile of all tax lots missing tax lot average hazard values.
3. Using the Feature to Point tool we converted the features included in the product of Step 5.B.2 to points, and then used the Extract Values to Points tool to assign hazard values from the product of Step 5.A.4 (i.e. the pixel-level hazard raster) to the tax lots. The result is shapefile in which tax lots which were skipped by zonal statistics in Step 5.B.1 now have an associated tax lot average hazard value.
4. In RStudio[27], we joined the products of Steps 5.B.2 and 5.B.3 using the left_join function and “SourceID” as the variable on which to join. Researchers then merged the tax lot hazard values from the original zonal statistics outputs and the result of extract values to point using the coalesce function. The result is shapefile that represents tax lot hazard values for all tax lots in Oregon. Manipulating spatial data required sf and tidyverse packages in RStudio.
5. Researchers used the Feature to Raster tool to convert tax lot average hazard values into a raster.

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[26] Dataset representing cRPS including the irrigated agriculture adjustments is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> FireIntensityModifier_cRPS

[27] Researchers processed some steps in RStudio because of personal preferences manipulating attribute tables. All steps can be completed in ArcGIS.

6. Using Focal Statistics, researchers calculated mean values based on a 20-pixel by 20-pixel window.
7. Using Raster Calculator, all pixels within the irrigated agriculture mask (product of Step 3.B.3) were set to 0.0001, and all pixels outside the mask were set to the value generated in Step 4.B.6. The result is a raster that represents 20-pixel smoothed hazard values with the irrigated agriculture mask stamped back in[28].
8. Using Zonal Statistics as Table, researchers calculated the average hazard value in each tax lot, repeating Steps 5.B.1 – 5.B.4 to fill in hazard values for properties for which no zonal statistic was calculated. The result is a feature class representing the final average hazard value for each tax lot in Oregon.
9. In RStudio, researchers used the mutate function to create a new attribute field in the product of Step 5.B.8 named "HAZ" and classified tax lot hazard values into three hazard classes represented as integers (Table 3).

Table 3. Each tax lot was assigned to a hazard class based on the average tax lot hazard value. In the spatial data, hazard classes were represented in the "HAZ" attribute field as integers (i.e. 1, 2, or 3).

Hazard Class	HAZ Attribute Value	Hazard Values
Low	1	0 - <0.001911
Moderate	2	≥ 0.001911 - <0.137872
High	3	≥ 0.137872

10. We created a new attribute field in the product of Step 5.B.9 called "WUI." Using Select by Location we selected all tax lots that intersect the WUI polygon layer. Then, using Calculate Field, we assigned all the selected tax lots a value of 1 and all other tax lots a value of 0. Tax lots for which WUI == 1 are tax lots that are within or adjacent to the WUI.

6. References

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[28] This pixel-level wildfire hazard data representing wildfire hazard immediately prior to summarizing within each tax lot is publicly available at https://oe.oregonexplorer.info/externalcontent/wildfire/data/SB80_Public_Data.zip >> SB80PublicData_WildfireHazard.gdb >> WildfireHazard

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VII. APPENDIX B: Public Data Description

The final and official regulatory maps (i.e. wildfire hazard and wildland-urban interface) required by Oregon Revised Statute (ORS) 477.490 are publicly viewable on the Oregon Wildfire Risk Explorer (https://tools.oregonexplorer.info/viewer/wildfire). There, Oregon property owners and residents can locate their property and access a report which will tell them the hazard zone associated with the property, and whether any part of the property is included within the WUI.

Upon request[29], tax lot level spatial data including hazard and WUI information will be made available to state, local and county governments for planning purposes. However, tax lot level spatial data will not be available for more public download because of data sharing agreements between the state and counties which prohibit the state from distributing spatial tax lot information.

With the exception of tax lot level spatial data, detailed spatial data pertaining to the WUI and hazard maps are available for download at https://oe.oregonexplorer.info/externalcontent/wildfire/data/ SB80_Public_Data.zip. Viewing and analyzing the data requires spatial analysis or Geographic Information System (GIS) software, and knowledge of spatial data. Following is a description of publicly accessible spatial data:

1. Contents

Following is a description of data contained in each sub-folder (Table 1).

Table 4. Summary of sub-folders and contents.

Folder	Contents
FireModelingData	Spatial inputs and model specifications used during burn probability and fire intensity modeling
SB80PublicData_WildfireHazard.gdb	Spatial inputs and outputs related to development of Oregon's statewide wildfire hazard map
SB80PublicData_WildlandUrbanInterface.gdb	Spatial inputs and outputs related to development of Oregon's statewide wildland-urban interface
LayerFiles	ArcGIS Pro v3 layer files for visualizing wildfire hazard and WUI data.

A. Fire Modeling Data

All of the data in this folder was developed by Pyrologix LLC as deliverables in the 2022 Pacific Northwest Risk Assessment.

[29] Requests for tax lot level spatial data can be sent to hazardmap@odf.oregon.gov

FireOccurrenceArea_ModelSpecs

Data in this subfolder were used by Pyrologix during FSim fire modeling.

Foa4XXrXX

There are 14 sub-folders, one for each Fire Occurrence Area (FOA) included in fire hazard modeling. Each FOA is identified by a unique number in the folder name, 4XX (e.g., 423, 401, etc.). Users can refer to 'Oregon_FireOccurrenceAreas.shp' to visualize FOAs.

FOA_4XX_idg.tif – a spatial representation, raster format, of large fire ignition relative likelihood. Used in FSim fire modeling.

Foa4XX_SeasonERC.csv – a tabular summary of daily Energy Release Component (ERC) values for each 4km grid in the FOA. Used in FSim fire modeling.

Oregon_FireOccurrenceAreas.shp – a spatial representation, polygon geometry, of FOAs used in FSim modeling.

PyrologixHazardDownloads

CC_2022_burn_probability.tif – raster file representing average annual wildfire likelihood (i.e. burn probability) developed by Pyrologix

Burn probability.lyr – ArcGIS Pro 3.0 layer file for visualizing 'CC_2022_burn_probability.tif'

CC_2022_Lifeform_cRPS.tif– raster file representing average conditional risk to potential structures (i.e. fire intensity) developed by Pyrologix

Lifeform Conditional Risk to potential Structures.lyr – ArcGIS Pro 3.0 layer file for visualizing 'CC_2022_Lifeform_cRPS.tif'

FireModeling_FuelscapeData.gdb

An ESRI file geodatabase containing eight raster files used to represent vegetation and topography in burn probability and fire intensity modeling conducted by Pyrologix.

PNRA2022_ASP_30m_OR – 30-meter resolution raster representing aspect.

PNRA2022_CBD_30m_OR - 30-meter resolution raster representing canopy bulk density

PNRA2022_CBH_30m_OR - 30-meter resolution raster representing canopy base height

PNRA2022_CC_30m_OR - 30-meter resolution raster representing canopy cover

PNRA2022_CH_30m_OR - 30-meter resolution raster representing canopy height

PNRA2022_ELEV_30m_OR - 30-meter resolution raster representing elevation

PNRA2022_FM40_30m_OR - 30-meter resolution raster representing fire behavior fuel models

PNRA2022_SLP_30m_OR - 30-meter resolution raster representing slope

B. SB80PublicData_WildfireHazard.gdb

Includes five raster layers representing intermediate products from the wildfire hazard map development process. All rasters are represented in 30-meter resolution. Brief descriptions provided below, and more detailed descriptions available in associated metadata.

AverageFireIntensity – Average fire intensity represented as flame lengths. The average fire intensity represented here was not used in when calculating hazard for Oregon's statewide wildfire hazard map. The original FIL rasters were transformed into fire intensity modifiers (also known as conditional risk to potential structures or cRPS) before calculating hazard. Instead, average fire intensity values represented here are a useful reference for understanding variability in fire intensity. These data do not include adjustments for irrigated agriculture.

BurnProbability - Burn probability is an estimate of the average annual likelihood that a fire will impact a given location. These data include specific adjustments to reflect the hazard mitigating characteristics of irrigated agriculture. Using the Complete Irrigated Agriculture Mask, burn probability values were adjusted to 0.00001 where the Complete Irrigated Agriculture Mask was not Null (i.e. areas that meet irrigated agriculture definitions).

CompleteIrrigationAdjustmentMask - The irrigated agriculture mask is a raster dataset that identifies all locations in Oregon that meet the definition of irrigated for the purposes of the statewide wildfire hazard map. Within the mask, we applied adjustments to wildfire hazard and wildfire hazard input layers in subsequent steps. All pixels where Value = 1 are considered irrigated for the purposes of developing the statewide wildfire hazard map. Where Value = 1 in this raster dataset, burn probability and conditional risk to potential structures were both adjusted to reflect reduced likelihood and intensity as a result of irrigation.

FireIntensityModifier_cRPS - Fire intensity modifiers are the values multiplied by the burn probability raster to calculate initial hazard estimates. These data include specific adjustments to reflect the hazard mitigating characteristics of irrigated agriculture. Before calculating hazard, we applied a fire intensity modifier to the fire intensity (i.e. flame length) dataset. The purpose of the fire intensity modifiers is to place fire intensity on a simplified scale and to capture variation in hazard across dominant fuel types (i.e. grass, shrub, and timber). For each pixel in the fire intensity raster, based on the dominant fuel type and on which Fire Intensity Level (FIL) the weighted average flame length was in, we substituted the following fire intensity modifiers:

- Grass: (FIL1) 10; (FIL2) 20; (FIL3) 30; (FIL4) 50; (FIL5) 60; (FIL6) 70
- Shrub: (FIL1) 15; (FIL2) 25; (FIL3) 40; (FIL4) 60; (FIL5) 80; (FIL6) 95
- Timber: (FIL1) 20; (FIL2) 30; (FIL3) 50; (FIL4) 70; (FIL5) 80; (FIL6) 95

WildfireHazard - These data represent pixel-level wildfire hazard values based on burn probability and fire intensity, and which were averaged within tax lots to estimate final tax lot level hazard values available on the Oregon Wildfire Risk Explorer.

C. SB80PublicData_WildlandUrbanInterface.gdb

Includes four data layers representing intermediate and final products from the wildland-urban interface map development process. Brief descriptions provided below, and more detailed descriptions available in associated metadata.

FireBehaviorFuelModels **–** 30-meter resolution raster representing fire behavior fuel models developed by Pyrologix for fire modeling. Used during development of the WUI to evaluate the proportion and proximity of vegetation per OAR 629-044-1005 and delineate WUI classes.

Urban_Growth_Boundaries - A vector dataset (polygon geometry) representing urban growth boundaries (UGBs) in the state of Oregon. Used per OAR 629-044-1005 to delineate the WUI

WildlandUrbanInterface **–** A vector dataset (polygon geometry) representing the final WUI boundary.

WUI_StructureLocationPoints - A vector dataset (point geometry) representing structure locations used to identify all areas of Oregon that meet the structure density criteria (i.e. greater than one structure per 40 acres) defined in OAR 629-044-1005.

D. LayerFiles

ArcGIS Pro v3 layer files for visualizing data included in sub-folders above.