

Defining the Wildland-Urban Interface

A Logic-Graphical Interpretation of Population Density

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The Healthy Forests Restoration Act solidified a relationship and responsibility to be shared between federal agencies managing public lands with ignitable vegetation, and the Tribal and County governments where those lands are located. This paper defines an unbiased process of determining where the Wildland-Urban Interface (WUI) exists based on population density as derived from the location of structures.

1.1 Healthy Forests Restoration Act

On December 3, 2003, President Bush signed into law the Healthy Forests Restoration Act of 2003 to reduce the threat of destructive wildfires while upholding environmental standards and encouraging early public input during review and planning processes. The legislation was based on sound science and helped further the President's Healthy Forests Initiative pledge to care for America's forests and rangelands, reduce the risk of catastrophic fire to communities, help save the lives of firefighters and citizens, and protect threatened and endangered species.

Among other things, the Healthy Forests Restoration Act (HFRA):

- Strengthened public participation in developing high priority projects;
- Reduced the complexity of environmental analysis allowing federal land agencies to use the best science available to actively manage land under their protection;
- Created a pre-decisional objections process encouraging early public participation in project planning; and
- Issued clear guidance for court action challenging HFRA projects.

Tribal and County level Wildland-Urban Interface Wildfire Mitigation Plans were developed to adhere to the principles of the HFRA while providing recommendations consistent with the policy document which assisted the federal land management agencies (US Forest Service, Bureau of Indian Affairs, and Bureau of Land Management) with implementing wildfire mitigation projects that incorporated public involvement and the input from a wide spectrum of fire and emergency services providers in the region.

HFRA specified that the responsibility of defining the boundaries of the WUI rests with the Tribal and County Governments and appointed Interface Interagency Committees created by the Tribal Council or the County Commissioners (respectively). In the absence of a defined WUI, the federal agencies were directed to use a fixed buffer distance from defined community centers, or in some instances, around structures. The

federal agencies were directed to use the WUI definition created and approved by the Tribes or the Counties wherever they exist, as appropriate.

1.2 Wildland-Urban Interface; from a wildland fire perspective

1.2.1 People and Structures

A key component in meeting the underlying need is the protection and treatment of fire hazard in the WUI. The WUI refers to areas where wildland vegetation meets urban developments, or where forest fuels meet urban fuels (such as houses). These areas encompass not only the interface (areas immediately adjacent to urban development), but also the continuous slopes and fuels that lead directly to a risk to urban developments. Reducing the fire hazard in the WUI requires the efforts of tribal, federal, state, local agencies, and private individuals. The role of [most] federal agencies in the wildland-urban interface includes wildland fire fighting, hazard fuels reduction, cooperative prevention and education and technical experience. Structural fire protection during a wildfire in the wildland-urban interface is largely the responsibility of Tribal, state, and local governments. Property owners share a responsibility to protect their residences and businesses and minimize fire danger by creating defensible areas around them and taking other measures to minimize the fire risks to their structures. With treatment, a WUI can provide firefighters a defensible area from which to suppress wildland fires or defend communities. In addition, a WUI that is properly thinned will be less likely to sustain a crown fire that enters or originates within it.

By reducing hazardous fuel loads, ladder fuels, and tree densities, and creating new and reinforcing defensible space, landowners would protect the WUI, the biological resources of the management area, and adjacent property owners by:

- minimizing the potential of high-severity surface or crown fires entering or leaving the area;
- reducing the potential for firebrands (embers carried by the wind in front of the wildfire) impacting the WUI. Research indicates that flying sparks and embers (firebrands) from a crown fire can ignite additional wildfires as far as 1¼ miles away during periods of extreme fire weather and fire behavior;
- improving defensible space in the immediate areas for suppression efforts in the event of wildland fire.

Four wildland/urban conditions have been identified for use in the WUI (Federal Register – a part of the Legislation defining HFRA). These include the Interface Condition, Intermix Condition, Occluded Condition, and Rural Condition. Descriptions of each are as follows (Federal Register 66(3), January 4, 2001):

- **Interface Condition** – a situation where structures abut wildland fuels. There is a clear line of demarcation between the structures and the wildland fuels along roads or back-yard fences. The development density for an interface condition is usually up to 3+ structures per acre;

- **Intermix Condition** – a situation where structures are scattered throughout a wildland area. There is no clear line of demarcation, the wildland fuels are continuous outside of and within the developed area. The development density in the intermix ranges from structures very close together to one structure per 40 acres;
- **Occluded Condition** – a situation, normally within a city, where structures abut an island of wildland fuels (park or open space). There is a clear line of demarcation between the structures and the wildland fuels along roads and fences. The development density for an occluded condition is usually similar to that found in the interface condition and the occluded area is usually less than 1,000 acres in size; and
- **Rural Condition** – a situation where the scattered small clusters of structures (ranches, farms, resorts, or summer cabins) are exposed to wildland fuels. There may be miles between these clusters.

In addition to these Federal Register defined WUI categories, Dr. Schlosser, working with over 50 counties and reservations in the west, has identified additional categories to compliment those listed above:

- **High Density Urban** – those areas generally identified by the population density consistent with the location of incorporated cities, however, the boundary is not necessarily set by the location of city boundaries: it is set by very high population densities (more than 20+ structures per acre). Many counties and reservations in the west do not have high density urban areas.
- **Infrastructure WUI** – those locations where critical and identified infrastructure are located outside of populated regions and may include high tension power line corridors, critical escape or primary access corridors, municipal watersheds, areas immediately adjacent to facilities in the wildland such as radio repeater towers or fire lookouts. These are identified by county or reservation level planning committees.
- **Wildland Condition** - a situation where the above definitions do not apply because of a lack of structures in an area or the absence of critical infrastructure crossing these unpopulated regions.

In order to arrive at these definitions, Geographical Information Systems (GIS) processing is useful. The location of structures within a county or reservation are mapped to include structures up to 5 miles beyond the border of the county or reservation. In some locations this involves locating structures from ortho photography, aerial photography, or satellite imagery. Where enhanced 911 services are offered, a rural address database may have been created and will serve as the basis on which to build the WUI GIS layer. The more detailed information is garnered from NAIP digital Imagery at a resolution of 1 meter. For those areas not covered by 1 or 2 meter aerial images, SPOT satellite imagery at a resolution of 2 or 5 meters has been used. These records are augmented with data collected on hand-held GPS receivers to record the location of structures, especially in areas where new housing developments are

encountered that have been built after photography has been taken, or that which is under heavy tree canopies and not seen from above.

All structures are represented by a “dot” on the map. No differentiation is made between a garage and a home or a business and a storage building. Reservations and Counties with a rural addressing map include only the structures with an address assigned, therefore garages and outbuildings are not included in the dataset.

By evaluating this structure density, analysts can define WUI areas on maps by using mathematical formula and population density indexes (within the GIS framework) to define the WUI based on where structures are located. The resulting **population density indexes** create concentric iso-density lines showing high density urban (where they exist), high density WUI areas of Interface and Intermix WUI, as well as Rural WUI (as defined in the Federal Register). This portion of the analysis allows planners to “see” where the highest concentrations of structures are located in reference to high risk landscapes, limiting infrastructure, and other points of concern. These analyses do not buffer at a fixed distance from structures, they represent the density of structures within the county or reservation area and therefore represent unique, logically defined graphical representations of WUI areas based on this density.

1.2.2 Infrastructure

Mitigation Planning Committees augment these population density maps with the identification of critical infrastructure (defined above) and map corridors (power lines, access routes), islands of protection (radio repeaters), and management areas (municipal watersheds) to protect these areas as part of an integrated approach to mitigation.

All Areas have both significant infrastructure and unique ecosystems within their boundaries. Of note for Hazard Mitigation Planning, is the existence of highway routes and the presence of high tension power lines supplying surrounding counties. Many areas are also served by railroads. These resources are considered in the protection of infrastructural resources of the region and the state, not just the local municipality.

Protection of high tension power lines from loss during a natural disaster is paramount in as much as the electrical power they provide serves not only the communities of one area, but also of surrounding areas. The protection of these lines allows for community sustainability, support of the economic viability of each area, and the protection of people who rely on that power. Hazard mitigation under and adjacent to power lines has received considerable attention in forested ecosystems as timber is thinned and heavy accumulations of brush are managed. However, the importance of management of all ecosystems at exposure to risks from a variety of hazards should not be overlooked.

1.3 Tactical WUI Definition

While using GIS housed algorithms, it is possible to create these boundaries of population density. The WUI polygon layers are created from the location of structures in the target area, for example in Benewah County, Idaho, most recently identified from

NAIP 2011 aerial imagery (1 meter resolution, full color). The structures identified do not differentiate between homes, businesses, garages, sheds, farm buildings, or even dog houses. All structures are identified for this analysis. All structures within the jurisdiction were documented in the geographic projection of the NAIP Aerial Imagery (NAD 83 UTM 11N). A buffer around the county was extended into the neighboring jurisdictions to document structure locations in those counties as well within 3 miles of Benewah County's boundary, because the WUI zone is influenced by neighboring structures, as much as they are influenced by those internal to the jurisdiction.

The WUI boundaries are based on the density of the structures within the County. A specific distance between structures, or from structures, is not applied. The distance of a WUI line from the nearest structure is based on the relative density of structures within the jurisdiction. In this manner, the density in the most populated areas shows higher than the density of structures in the low population areas. Structures are used as a proxy for people. This is not a perfect application as an apartment building may house dozens of people, while a rural home may only have 1 to 4 residents, but both structures are represented by one point in the analysis.

The density of structures within the County is generated into a Percent Volume Contour (PVC). Note that a Percent Volume Contour is not the same as the simple contours that are typically produced in tools like ESRI's ArcMAP Spatial Analyst. A PVC represents the boundary of the area that contains x% of the volume of a probability density distribution. A simple contour (like the ones that are produced in Spatial Analyst) represent only the boundary of a specific value of the raster data, and does not in any way relate to probability. For applications like WUI delineation, it is the percent volume contour that is required. The 95% volume contour would therefore on average contain 95% of the points that were used to generate the kernel density estimate.

Figures 1 – 3 show WUI delineations in Benewah County, Idaho, created in 2004, 2010, and 2012 during the administration of WUI Wildfire Mitigation Plans (2004 & 2012), and their FEMA Multi-Jurisdictional Hazard Mitigation Plans (2005 & 2010). The same basic approach was used in each of these WUI definitions although the identification of structures from aerial imagery improved substantially during that time period. Also during this time period the building developments in the County followed a predictable pattern of growth into the lower density Rural Lands making some of the low density Rural lands into Intermix Lands while the Interface Lands grew larger as homes and other buildings were placed adjacent to, but out of their previous boundaries.

Figure 1. Example of WUI defined for Benewah County, Idaho, in 2004.

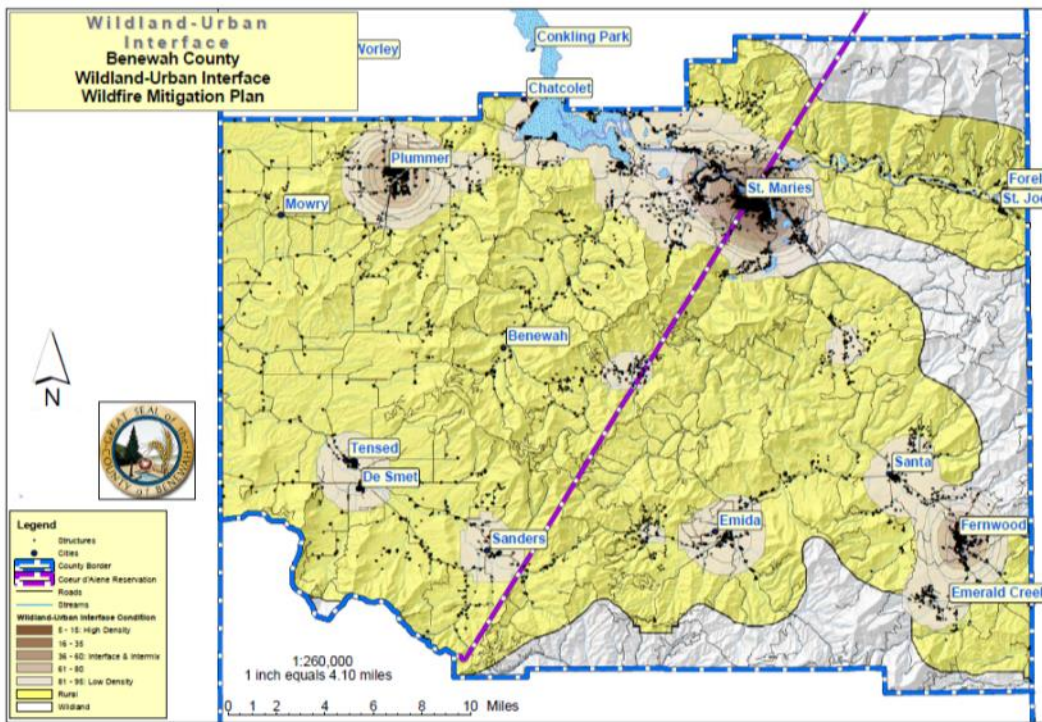


Figure 2. Example of WUI defined for Benewah County, Idaho, in 2010.

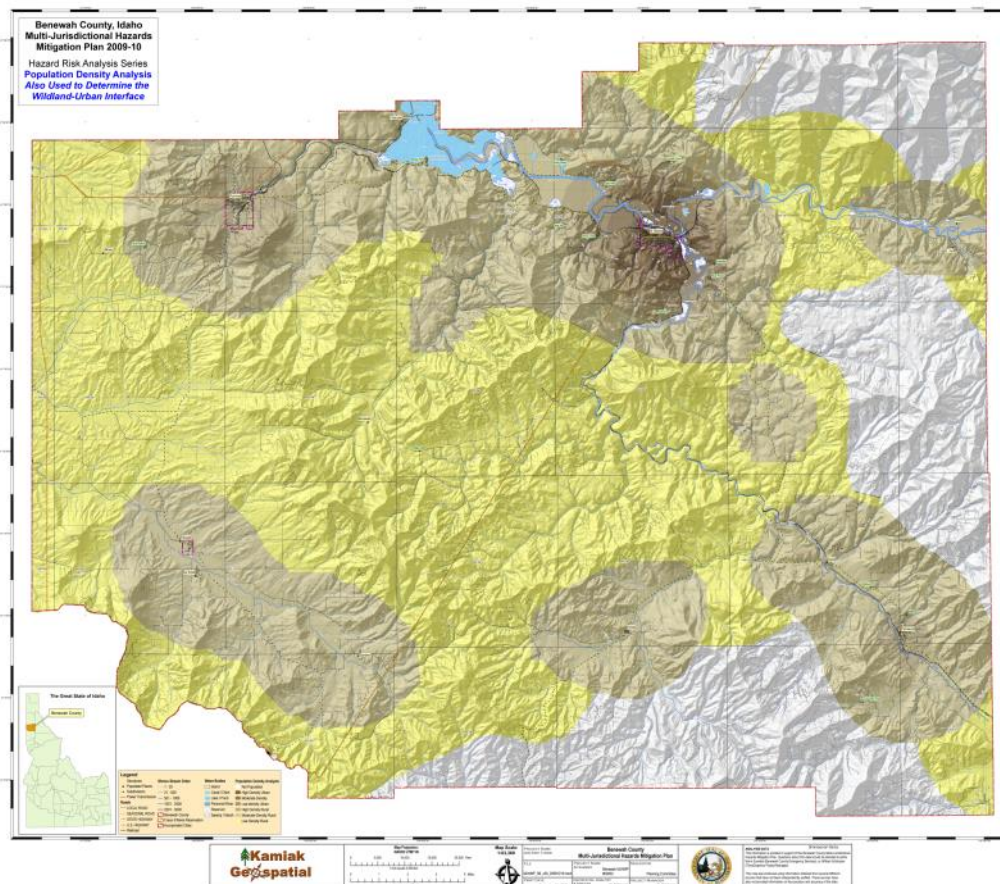
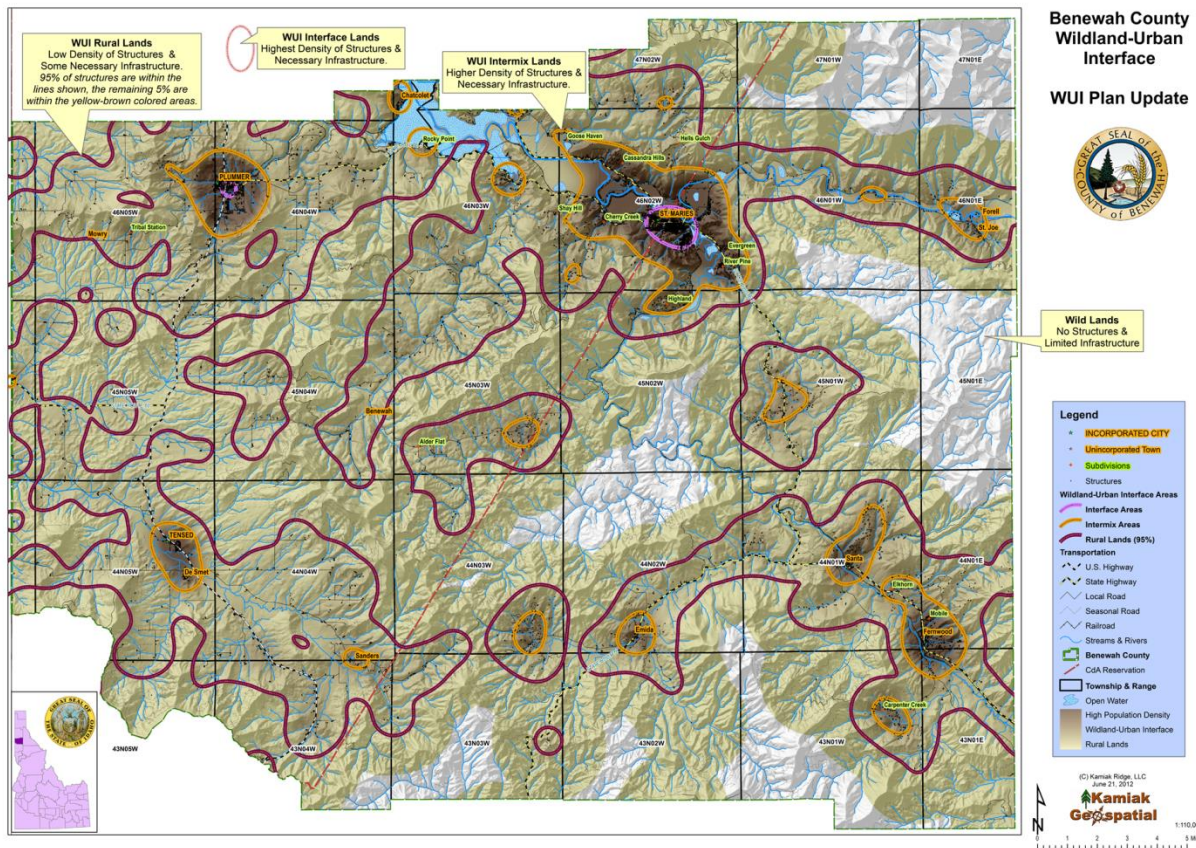


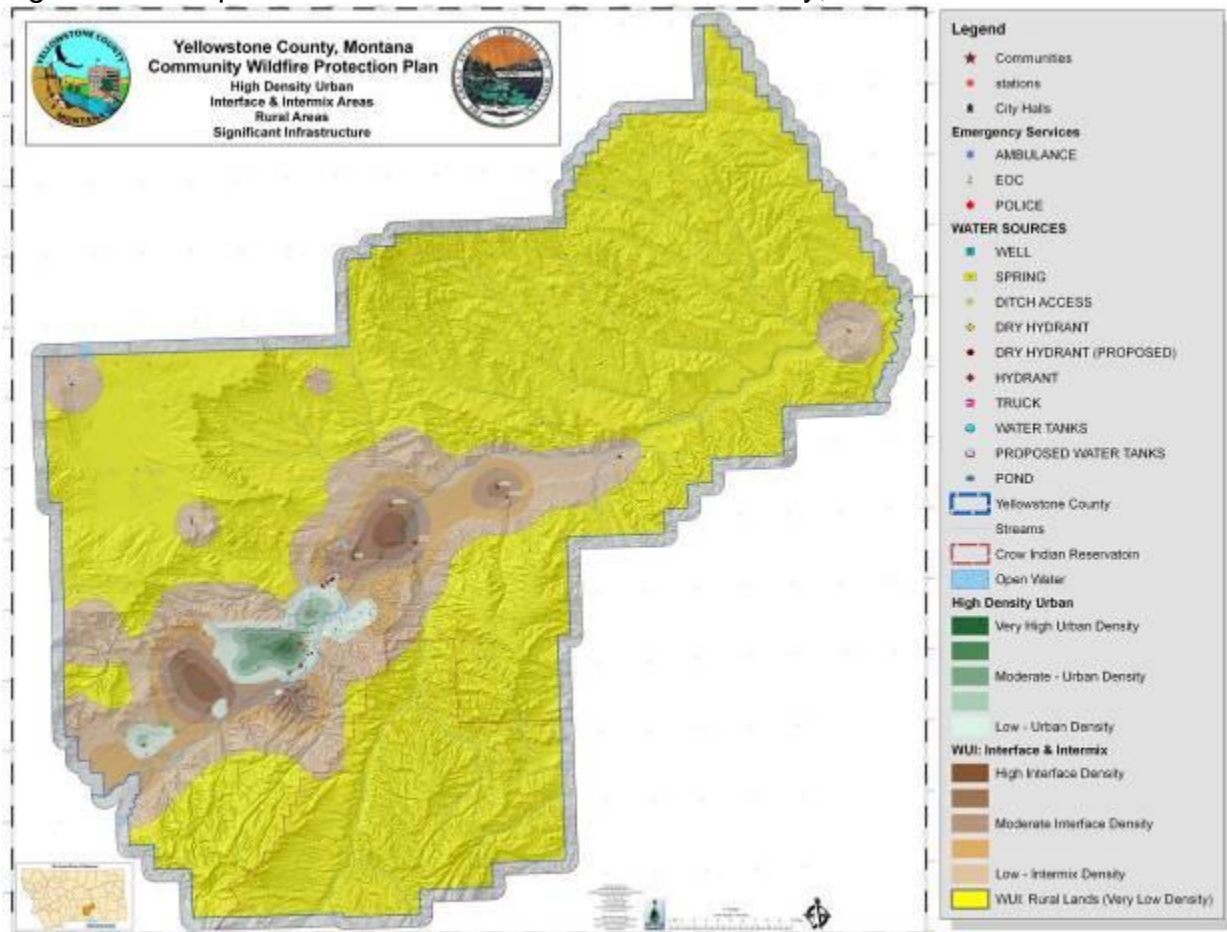
Figure 3. Example of WUI defined for Benewah County, Idaho, 2012.



In Benewah County and the Coeur d’Alene Indian Reservation, there are no High Density Urban areas. The highest densities are consistent with Interface designations and are found in and around the cities of St. Maries, Plummer, and Fernwood. Intermix areas (lighter browns) are found around communities such as Tensed, DeSmet, Sanders, and Emida. Also notice unnamed communities scattered around the county where population densities are consistent with the Intermix designation. By using a structure density definition as opposed to named communities only, the planning committees have been able to locate and identify clusters of structures resulting from the building of subdivisions and other population growth trends. The areas colored in white are the wildlands of Benewah County where few or no structures are located.

This study allows for a comparison of three different time periods. The first analysis was completed in 2004 as part of the Benewah County Wildfire Management Plan when the first WUI designation was made. Using the same analysis procedure, the Population Density Index was created in 2009. The most recent update has been completed in 2012 and shows changes in the population density in response to 1) better aerial imagery allowing more structures to be seen from above, and 2) new structure placement in the County. By looking at these comparisons of the same area with 8 years between assessments, it can be seen where development pressures have been located. Generally, the development pressures are from areas considered Intermix and Interface to expand into rural areas. Look closely at the corridor between DeSmet/Tensed, and Sanders. In 2004 this corridor was considered Rural, in 2009 it became consistent with a population density of Intermix (a higher population density). By 2012 the expansion of ‘Rural Lands’ expanded considerably. The changes happened as a result of new structures built in this area accompanied by higher resolution aerial imagery to document these locations.

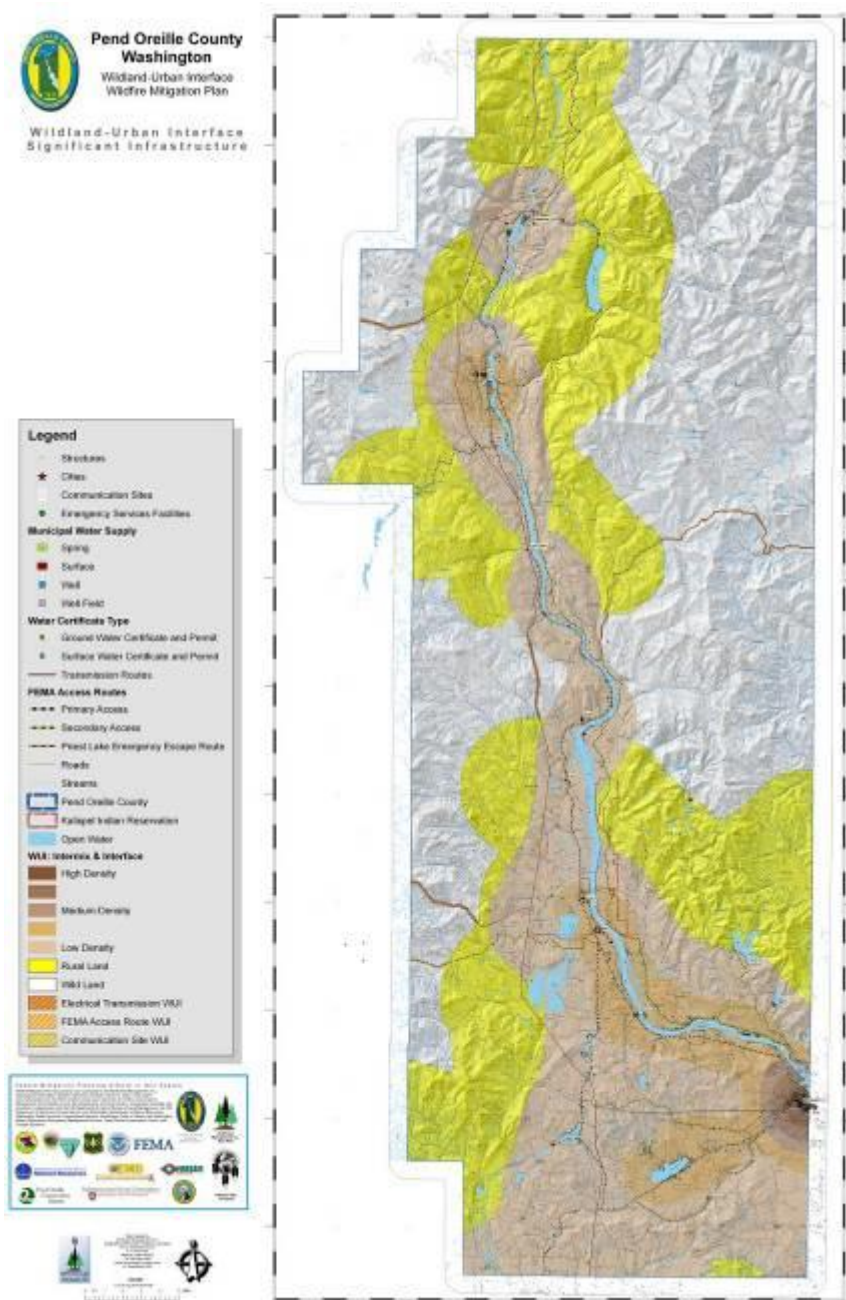
Figure 4. Example of WUI defined for Yellowstone County, Montana.



Notice the greenish polygons in the south central portions of the county; these are the High Density Urban areas of Billings and Laurel. The shades of brown indicate WUI definitions consistent with Interface and Intermix areas with the darker browns indicating higher structure density than lighter brown colored areas. The yellow areas on this map indicate Rural structure densities. Notice there are no wildlands identified in Yellowstone County. Ranches and farm houses are scattered throughout the rural lands. The Crow Indian Reservation is located in the southeast corner of Yellowstone County and continues the rural condition to the east where higher densities are encountered leading to High Interface Density.

Figure 5. Example of WUI defined for Pend Oreille County, Washington.

Pend Oreille County, WA, located in the extreme northeast corner of Washington State has no High Density Urban areas identified. The highest population densities are consistent with Interface Conditions in the city of Newport (southeast region of the county). Most of the houses in the county are located in the southern portions of the county and along the Pend Oreille River (runs north from Newport to Canada border). Most of these populated places have a structure density consistent with an Intermix condition, with higher densities (shown with darker browns) around Usk and lone. The Kalispel Indian Reservation is covered by a combination of Intermix and Rural conditions. Rural population densities surround most of the Intermix and Interface areas and are colored yellow on the map. The white areas are consistent with the wildlands designation. The reader may notice WUI power line corridors crossing the wildlands along the western edge of the county (from lone west and from Usk west). There is also a Priest Lake Emergency Evacuation Route from Ruby (center of map) eastward to the Idaho border which has been designated as part of the Pend Oreille County WUI. Scattered across the wildlands are radio repeater with "Communication Site WUI" areas defined (not visible at this scale). All of these components were identified by the Interface Planning Committee convened to develop the Community Wildfire Protection Plan (CWPP) for Pend Oreille County. This is the WUI adopted by the County for HFRA and NFP purposes.



About the Author:

Dr. William E. Schlosser is a Professional Forester, Natural Resource Economist, Geospatial Analyst, Regional Planner and Environmental Scientist. Dr. Schlosser has worked with Counties and Indian Reservations across the western US to complete hazard mitigation planning consistent with the Healthy Forests Restoration Act, the National Fire Plan, and the Federal Emergency Management Agency (FEMA) for pre-disaster mitigation planning. The analysis defined in this short paper has been published in the Western Forester (Society of American Foresters), within planning documents distributed by Counties, Tribes, States, and FEMA.

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