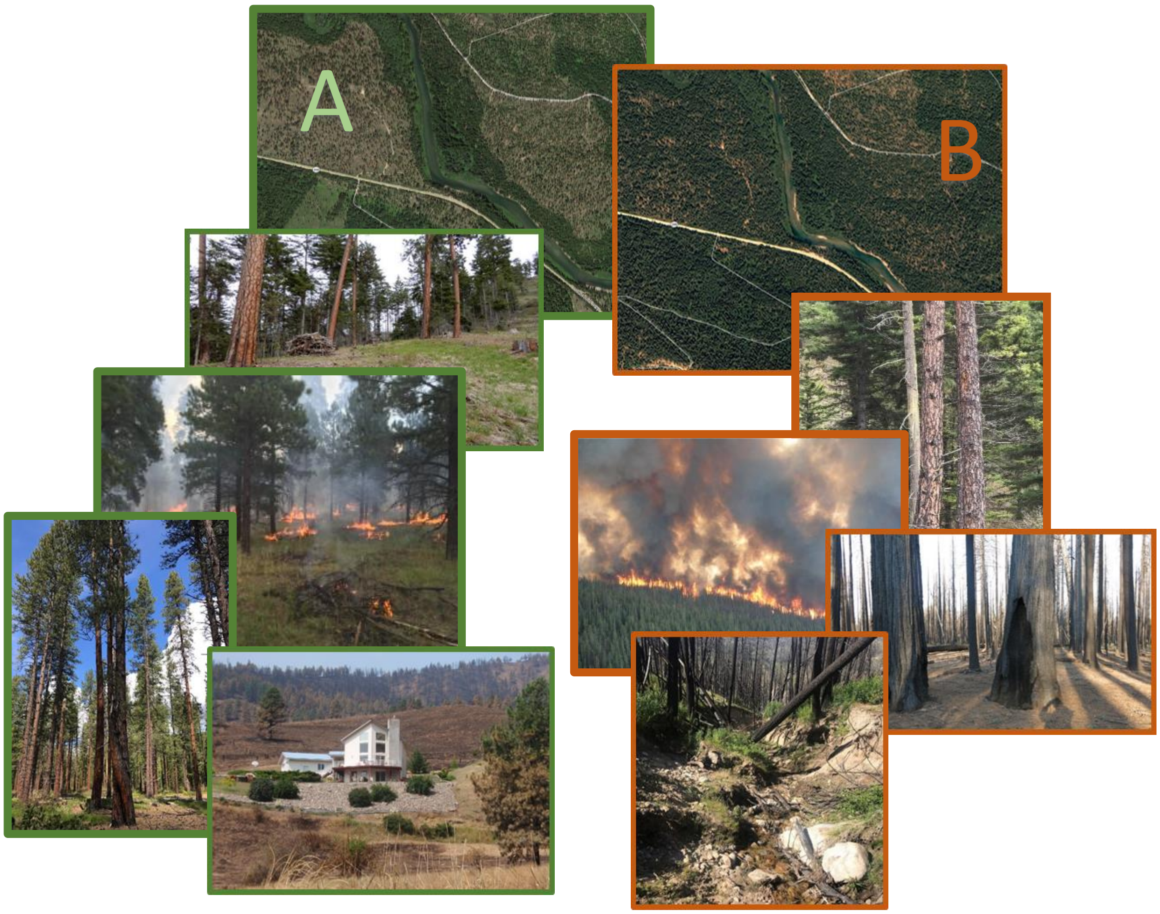
Floods Risks following Wildland Fires

A Case Study: Plain, Washington



Institute for
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Resilient and Safe Communities

Cover: Counter clockwise from the 2017 Google map image A near Plain WA illustrates a probable managed forest scenario. Clockwise from the 2006 image of the same area, B offers an unmanaged scenario. The low intensity prescribed burn picture was taken off the sanjuanheadwaters.org web page. The high intensity fire picture is of the 2006 Tripod Fire Complex taken off the Inciweb.org web site. See report for other picture sources.

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Introduction/Executive Summary

This study looks at probable changes in the wildland fire and flood risks over the long term for the Chelan County community of Plain, Washington. The objective of the research is to determine if the approaches to risk reduction can be improved by taking into account long-term expected changes.

The key finding is that preserving what Plain stakeholders value and reducing future risks are not solely dependent on surviving high /low intensity[1] , large, and severe wildland fires and associated flooding, but in preserving the forest soil. Forest regeneration depends on reducing the mobilization of forest sediment and preventing high intensity fires which make soils unproductive.

Conserving current values can only be achieved if Plain remains safe from wildland fires and residents embrace Fire Adaptive Communities (FAC) and FireWise practices thereby allowing attention to be diverted from protecting human settlements to protecting forests and the ecosystem services these forests provide.

Research Approach

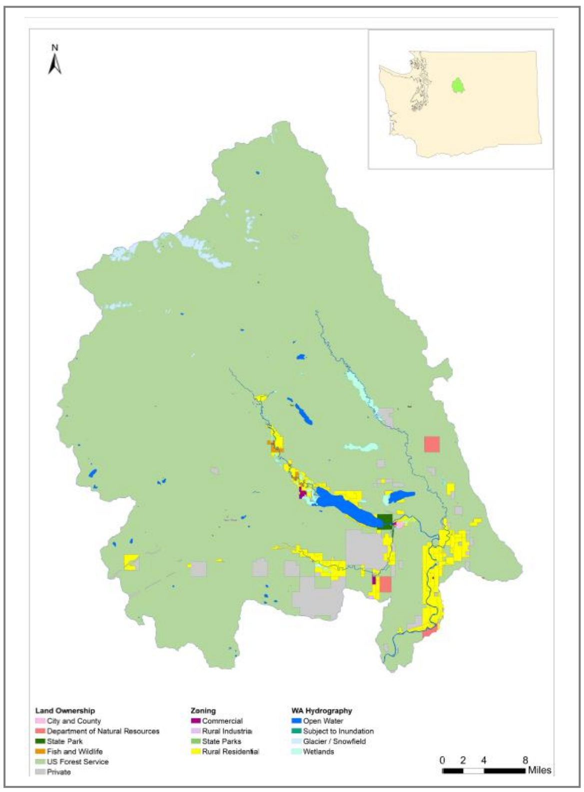

Figure 1: Study area: Community of Plain, WA

The approach used applied an appreciative-inquiry scenario processed to a case-study community. Plain, Washington (Figure 1) was selected as the study site based on its unique characteristics. This unincorporated community of about 2,500 residents is located within a forested landscape near Lake Wenatchee and is at risk from wildfires and severe flooding of property.

The wildfire risk and flooding was assessed based on four scenarios. The scenarios include three different time frames, 2020, 2040 and 2080.[2]

In this paper, we discuss the results of our analysis, suggest risk reduction measures, and translate them into guidelines (tools) that can be used to mitigate wildfire and flooding risk in four different scenarios (described late in the report).

The resulting research proposes mutual risk reduction measures between the scenarios explored as well as recognition of path dependencies. The measures were assessed based on the values reported by the Plain community stakeholders during the workshop.

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[1] Fire line Intensity - The rate of heat energy release per unit time per unit length of fire front. High intensity fires can cause major negative impacts on soil including erosion, productivity and hydrophobicity.

[2] Increases reflect temperature of 1.1˚C (2.0˚F), 1.8˚C (3.2˚F), (3.0˚C) 5.3˚F, respectively, for the Pacific Northwest. Based on University of Washington Climate Impact Group research.

A community workshop was held in Plain, Washington. The event followed a storytelling format in which stakeholders identified values at risk along with the capital that supported these values. In addition, by placing the stakeholders into groups and associating them with a given scenario, where they were told to be true to their perspective scenarios, risk mitigation measures were developed along with opportunities to advance community values.

The results of these team efforts were discussed and researched following the workshop. This report is the result of this community value-driven material.

The leading theme that emerged from this research was that reducing risks are not solely dependent on the community surviving large, severe, and high intensity wildland fires and associated flooding, but also on preventing soil degradation and forest restoration. Healthy soils are an important component of resilient forest; they store moisture, provide nutrients, and anchor trees. Consequently, risk reduction and community resilience depends on soil stability, vegetative cover, and maintaining healthy soils composed of organic matter and microorganisms, which can enable forest regeneration.

Forest Stresses and Resilience

Forests with unproductive soils have the potential to hinder regeneration. Sediment mobilization and landslides have always posed a threat, however, with our changing climate; winters are becoming shorter and wetter, with less snow, while summers are becoming drier and longer. The generation of flashy fuels, uncharacteristically denser forests, and increases in fire risk are stressing normal regenerative processes.

Forests are becoming increasingly stressed from high intensity fires and resulting soil mobilization and degradation. This is causing a reduction in forest ecosystem services and is limiting forest related values presented within each of the alternative future scenarios discussed at the Plain workshop. These futures would stress natural features along with straining supporting infrastructure. The community would be less safe from wildland fires and flooding risks. The desired rural character would be less attractive and the rate of recreational opportunities would be limited.

Forests are becoming less resilient[3]. Exceedingly intense and high severity forests hinder regeneration. Regenerative tipping points are crossed[4]. In order for fires to be less intense and provide some ecosystem benefits, forest composition and structures, similar to historical forest conditions, need to be restored by using a variety of management practices such as harvesting, thinning, prescribed fires, etc. Forest managers, urban planners, and communities must work together to maintain a healthy forest for the future while safely developing urban areas to reduce threats to the ecosystem.

Without such an emphasis on forest health, high-severity fires have the potential to permanently devastate forest resources and ecosystem services. If biological legacies, remain, ecological function and resources could be restored. These biological legacies[5] will become extremely valuable as a potential for seed source, microorganisms, and wildlife habitat in these disturbed ecosystems. Consequently, they will require protection from future anthropogenic effects and or wildfires.

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[3] The concept of resilience introduced here is adapted from Holling 2001, and Walker and Salt 2011. Resilience is further discussed within the context of the adaptive cycle p20-21

[4] **Tipping Point.** This is a point at which a relatively small change in external conditions causes a rapid change. There are numerous thresholds involving regeneration.

[5] **Biological Legacies**: Living organisms that survive a catastrophe and have a role in ecosystem functioning, such as living trees, microorganisms, seed bank, etc. The processes involved with these legacies are also referred to "remembering" withinin the context of social ecology.

As for burnt forests, they can exploit natural biogeophysical feedbacks as with fire activated seeds. High intensity fires however, can destroy such feedback mechanisms. When such thresholds are crossed efforts must be taken to monitor restoration[6], to reduce vulnerable conditions and remove stresses that limit forest regeneration and future sustainability. This includes limiting the grazing of cattle, controlling wildlife such as elk and deer, establishing vegetation that transforms the ecosystem, is better adapted to a changing environment[7], and preventing revolt such as the establishment of invasive species[8].

As for the built environment, forest management in the wildland urban interface (WUI) can be benefited by applying a coupled human-natural ecosystem approach. Coupled human and natural ecosystems are integrated systems where people and nature interact reciprocally and create feedback loops (Liu et al., 2007). They are not separate systems but a coupled human-natural ecosystem that must be studied to anticipate how environmental changes will affect urban form (Alberti 2008). Humans are major actors in influencing the natural ecosystem in favor of human well-being and to the detriment to natural systems (Millennium Ecosystem Assessment 2005). Through human governance and regulation of systems, we can better manage an integrated ecosystem to become more resilient to disruptive events.

Creating fire-adaptive communities can allow us to redirect our emphasis to enabling the regeneration of our forests – keeping soil on our forested slopes.

This report examines coupled human-natural systems in Plain, Washington, and the ways in which the community can adapt to fire and flooding threats to assure the resilience of human settlements along with that of surrounding forests. We utilize scenario-planning methods to develop four plausible alternative futures (also referred to as scenarios) with fire, floods, and population as drivers of change.

Scenarios

The four scenarios representing four uncertain futures and applying wildland fire, flood, and population are:

- **Local Renewal:** population decreases following major fires and flooding events;
- **Community Transformation:** population increases despite major fires and flooding events;
- **Local Reorganization:** population decreases (due to outside forces) as fire and flooding threats increase, but no major events occur; and,
- **Reactive Management:** population increases as fire and flooding threats increase, but no major events occur.

[6] **Feedback.** Resilient communities have self-organizing feedback mechanisms. Our management practices need augment natural feedback mechanisms.
[7] **Transformability:** This is the capacity to create a fundamentally new system when conditions make the existing system untenable—where organizations are capable of exploiting new opportunities.
[8] **Revolt.** This occurs when forces or events overwhelm recovery such as the establishing of invasive species.

Four scenarios were created by applying three drivers to two axes (Figure 2). The horizontal axis represents population ranges from year 2000 to 2080. The wildland fires and flooding follow similar trajectories and therefore the vertical axis reflects both fire and flooding events.

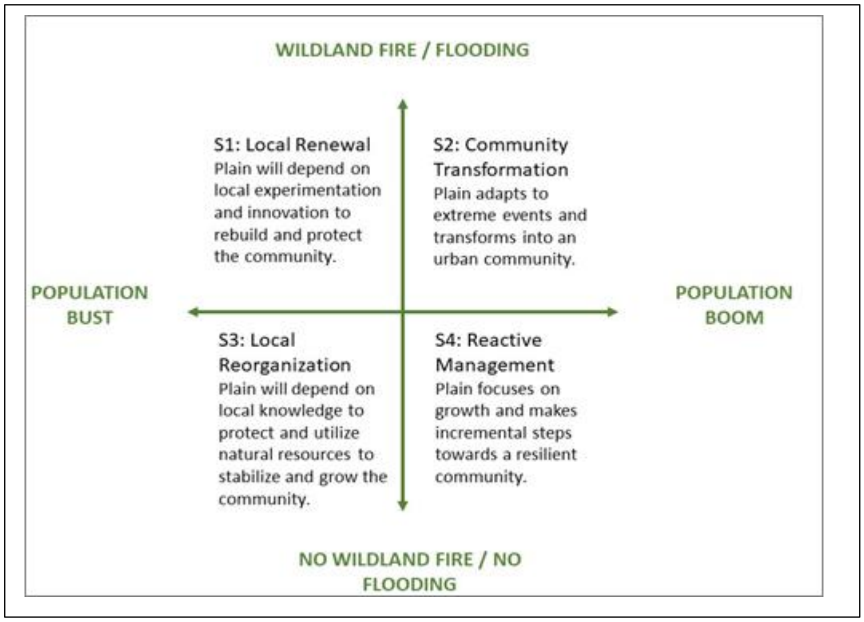


Figure 2. Four Scenarios.
X-axis: population increase or decrease, Y axis: lack of wildfires/floods or increase in wildfires/ floods

We used appreciative inquiry storytelling methods at a community workshop to identify community values along with the associated capital (social, natural, and built) responsible for providing the identified values. This exercise was performed before introducing the scenarios. This method “de-emphasizes the specific risk scenario itself” and allows the community to focus on linking community planning goals and values to migration and recovery strategies (Freitag et al., 2014).

Risk Reduction and Uncertainty

At the Plain workshop, participants’ stories described a close-knit community, with natural features of the forest, a rural character, having year-around recreation, and adequate built infrastructure as values they wanted to maintain. The participants noted that forests can be resilient and we can support these adaptive cycle processes. There are measures that will reduce risk for each of these probable future scenarios there by reducing the uncertainties in determining the appropriate actions.

In collaboration with researchers, the community devised a list of adaptation measures based on community values and objectives within the context of four plausible futures. Each measure was evaluated to see if it would reduce the likelihood of future actions (path dependencies). Policy makers would be able to test out various strategies to see which will best the suit the community needs

These measures would reduce risks whether Plain grows or loses population, whether the surrounding forests survive through 2080 with limited high intensity and severe fires or whether very high-severity fires consume much of the forest landscape. The measures focus on:

- Protecting our settlements
- Adopting proactive codes
- Not increasing the risk
- Eliminating the possibility of high intensity and severe fires
- Directing suppression efforts to protecting forest loss
- Applying extensive forest restoration and post fire rehabilitation efforts
- Experimenting with new approaches.
- Monitor practices

This research was undertaken by The University of Washington Institute for Hazards Mitigation Planning and Research through a Cooperating Technical Partners (CTP) grant from the Federal Emergency

Management Agency (FEMA) to develop risk reduction measures based on long-range Wildland/Flood predictions. The Institute partnered with the School of Environmental and Forest Sciences.

Background

Fire is an integral and complex component of forested ecosystem, helping to maintain forest health, structure, diversity, and function (Agee, 1993). Unfortunately, changes in land use, coupled with fire exclusion, have minimized the benefits the fires provide, while accelerating the decline of forest health. Topography, climate, and vegetation control the dynamic nature of wildfires (Figure 3) (Falk et al 2007, Collins and Stephens, 2010); as such, alteration to one of these elements can exacerbate fire effects upon the landscape.

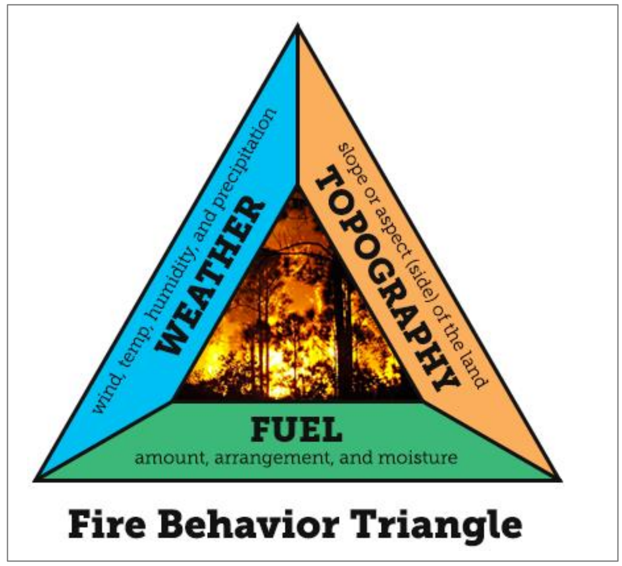


Figure 3: Fire behavior triangle

Wildfires are described in terms of fire regime[9], frequency[10], extent[11], and severity[12]. Fire severity is an important component that will be analyzed per this report; we will distinguish between vegetation burn severity[13] and or soil burn severity[14] respectively (Table 1&2) (FRCC Guidebook 2010)

[9] **Fire regime[5]** is a term that describes fire occurrence in terms of frequency, extent, severity, seasonality, and synergy with other disturbance agents.

[10] **Fire frequency[6]** is defined as the number of times a fire occurs within a specific area.

[11] **Fire extent[7]** is the total area burned by a single wildfire.

[12] **Fire severity[8]** the effects upon the landscape. Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time

[13] **Vegetation burn severity[10]**: The effects of fire on the vegetation, composed of four classification, unburn, low, moderate (mix), and high severity.

[14] **Soil burn severity[11]:** The effects of fire on the soil, composed of four classifications, unburnt, low, moderate (mix), and high severity.

Table 2. Soil burn severity 1997ssification and characteristics.

Group	Frequency	Severity	Severity Description
I	0-35	Low/Mix	Generally low-severity fires, replacing <25% of the dominant overstory vegetation; can include mixed-severity fires that replace up to 75% of the overstory
II	0-35	Replacement	High severity fires replacing greater than 75% of the dominant overstory vegetation
III	35-200	Mixed/Low	Generally mixed-severity; can also include low-severity type in this frequency range
IV	35-200	Replacement	High-severity fires
V	200+	Replacement/any severity	Generally replacement severity; can include any severity type in this frequency range

Table 1: Regime groups (Vegetation Burn Severity)

Soil and litter parameter	Low-2	Moderate-3	High-4
Litter	Scorched, charred, consumed	Consumed	Consumed
Duff	Intact, surface char	Deep char, consumed	Consumed
Woody Debris-Small	Party consumed, charred	Consumed	Consumed
Woody Debris-Logs	Charred	Charred	Consumed, deeply charred
Mineral soil	Not changed	Not changed	Altered structure, porosity, etc.
Soil Temp at 0.4 in (10mm)	<120F(<50C)	210-390F (100-200C)	>480F (>250C)
Soil Organism Lethal Temp	To 0.4 in (10mm)	To 2 in (50mm)	To 6 in (160 mm)

Based on post fire appearance of litter and soil (Hungerford 1996, DeBano et al., 1998

Although fire imposes a spectrum of changes on the ecosystem, high-severity fires–that is, those which cause high tree mortality of 75% (FRCC Guidebook 2010) or 80% (MTBS) or almost full removal of soil litter and duff (DeBano et al. 1998)–are of particular concern because of their potentially long-lasting effects and immediate high impact on runoff and soil sediment production. The consumption of organic matter denudates the landscape, damages timber resources, impacts wildlife habitat, and alters the soil's physical and chemical composition, affecting watersheds and natural forest regeneration (Cram et al. 2006; Anderson et al. 1976, Swank and Crossley 1988, and Neary and Hornbeck 1994) –all effects that have the potential to affect human lives and property.

Fire Regimes

Decades of fire exclusion coupled with changes in forest management techniques have altered species composition (Weaver 1959; Everett et al. 1996) and the fire regimes (Keane et al. 2002) of forests in the Western United States. Historically, forests such as Ponderosa pine forests experienced frequent, low-severity wildfires (Hessburg et al. 2005, Perry et al. 2011, Hardy et al. 1998), which removed surface and ladder fuels and created a park-like landscape (Agee 1998). In contrast, forests at higher elevations generally experienced infrequent high-severity, stand-replacing wildfires that occurred in the order of

200 years or more. However, in the western US, this is no longer the case, particularly in the Interior Columbia River Basin (Hessburg et al. 2000, 2004).

The suppression of wildfires increased the buildup of understory vegetation and increased forest density. These dense and structurally simplified stands have exacerbated the scale of forest disturbances, including wildfires, pests and pathogen outbreaks (Agee 1993, Hessburg et al. 1994) and has increased forest flammability to hazardous levels. These alterations, coupled with longer fire seasons and hotter and drier summers, have increased the area burned and the area burned at high severity (Westerling et al. 2006). For example, approximately 30% of fires over 100,000 acres in the United States have occurred in the last five years (NIFC).

In the state of Washington, since 2000, the number of fires over 1,000 acres has increased from a couple early in the first years of the century and reached 36 and 25 in 2015 and 2016, respectively. Large fires, those that burn over 1,000 acres, are no longer an anomaly. Since 2006, Washington State has experienced an increase in large fires, mainly in north-central Washington. In 2006, the Tripod Complex Fire burned over 180,000 acres, followed by the largest wildfire in the state to date, the Carlton Complex fire (256,108 acres), and just this summer (2017), the Diamond Creek Fire burned 128, 272 acres (Figure 4). Current climate change scenarios, coupled with the current fuels and vegetation status of the forest, suggest that these types of fires will continue to degrade the landscape unless proper management policies are implemented.

Effects of Climate Change on Northwest Forests

The effects of global climate change will alter weather patterns in Northwest forests, resulting in a suite of ecosystem responses. There is a consensus among regional climate change models that the Northwestern United States is likely to become noticeably warmer (Mote and Salathe 2010), and temperature extremes are likely to become increasingly frequent in the region (Easterling et al. 2000). The effects of climate change on overall precipitation levels are more uncertain, and there are differences among regional climate change models (Mote and Salathe 2010). There is likewise a high level of uncertainty regarding the future occurrence of extreme precipitation events. Models described by Leung et al. (2004) show large increases in wintertime extreme rainfall events in the Cascades. In contrast, Rosenberg et al. (2010) did not find statistically significant differences in the predicted extreme precipitation events in Washington State. Various other climatic changes are also expected in Northwest forests including changes to wind patterns (Sailor et al. 2010, Zwiers et al. 1998), increases in drought severity and duration (Dale et al. 2001), and increases in atmospheric humidity levels (Flannigan et al. 2009). These deviations from climatic normal

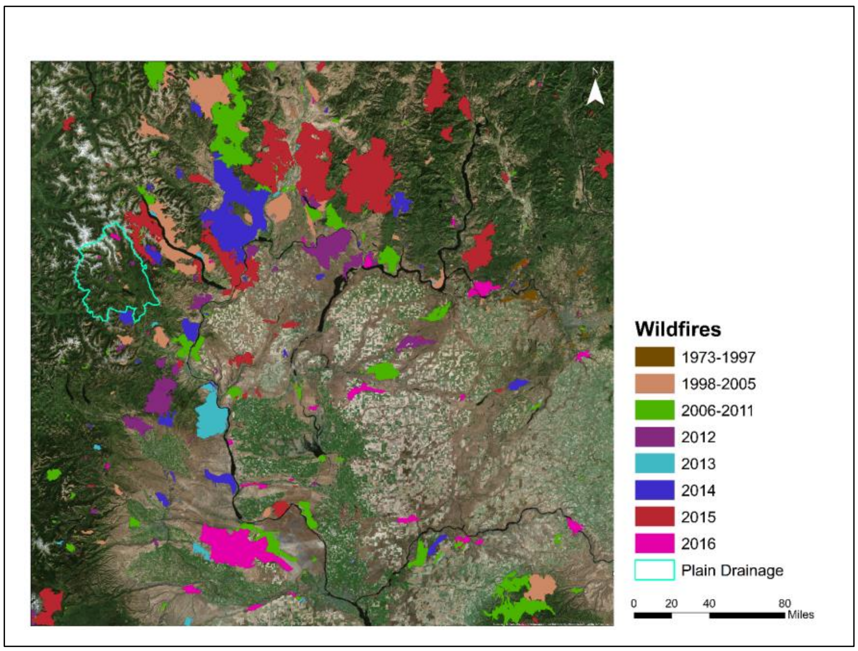


Figure 4: Large fires in Washington State from 2000-2016. (Source (Northwest Interagency Coordination Center)

can result in a variety of ecosystem responses in Northwest forests, such as hydrological, ecological, and fire-related changes.

For example, increased temperature levels will alter hydrological processes by reducing the reserves of snowpack in the mountains, which are a primary source of water in the western United States (Cayan 1996). This hydrological change can shift historically snow-fed streams to precipitation-based ones (Hamlet et al. 2013), which will cause changes in the timing and quantity of water (Mote et al. 2005). Forest disturbances can be altered by the hydrological changes. For instance, increased flooding and extreme precipitation can result in increased frequency and extent of landslide events (Dale et al. 2001). These changes in the timing and intensity of hydrological processes can also cause changes to the intra-annual patterns of fuel and soil moisture level (Gergel et al. 2017), which can influence forest processes by weakening and killing tree species through cavitation of xylem water columns (Allen et al. 2010), and increasing fire flammability and risk (Flannigan et al. 2009).

Ecological functions of the forest can also be influenced by climate change. Increased temperatures can create environments more suitable to forest pests (Allen et al. 2010). Of particular concern are pine bark beetles, which are able to survive the increasingly mild winters in the western United States, and find hosts in the increasingly heat, drought stressed, and overcrowded trees, (Bentz et al. 2010). Climatic changes have also created conditions that mediate the range flora and fauna (Littel et al. 2010), most notably flammable cheatgrass (*Bromus tectorum)* grasses (Bradley et al. 2016), which can influence woody biomass levels by exacerbating fire spread (Balch et al. 2013). Similarly, large, catastrophic fires may also cause local extinctions of plant and animal species. In particular, small and isolated populations of salmon), such as salmonids, have become extinct following large, high-severity fires (Rieman et al. 1997).

Figure 5: Post fire soil erosion on a high severity fire, 2014 Carlton Complex Fire.
(Source: E. Alvarado)

Changes in the forest meteorology, hydrology, and biology can interact to alter the future fire risk in Northwest forests. For instance, decreased fuel and soil moisture will increase flammability of the landscape (Gergel et al. 2017), as will beetle- and drought-killed trees (Allen et al. 2010). In parallel, with changes in fuel moisture, dry lightning frequencies are likely to increase subsequently increasing ignition frequency (Price and Rind 1994, Flannigan 2000). The increased temperatures and reduction of periods with snowcould result in a lengthening of the fire season, with an increasing number of large fires occurring during the shoulder seasons (Westerling et al. 2006). In forest ecosystems, precipitations can alter the flammability of already abundant fuels, while in rangeland systems, precipitation can control the biomass levels of often-flammable fuels (Meyn et al. 2007). The changes in fire regimes can also interact with hydrological and biological processes of forest systems.

Fire Effects on the Ecosystem

The extent to which fire affects an ecosystem is far-reaching, from above-ground effects on vegetation to below-ground effects on the chemical, physical, and biological components of the soil. Fire impacts on the soil result from the direct effects of the fire, including the consumption of the organic soil layer and the amount of heat transferred into the soil column. Consequently, high-severity, slow-moving, and smoldering fires pose the highest threat to the soil environment (Figure 5). Physically, the heating of the soil increases the pH, and bulk density (Neil et al. 2007) and creates water-repellent soils (Debano 1981). Soil-chemical alterations result via nutrient volatilization (nutrient loss to the atmosphere), as in the case of nitrogen, organic phosphorus, and sulfur (Debano et al. 1998 and Klopatek 1987). Due to the temperature sensitivity of the biological factors of the soil, microorganisms such as bacteria and fungi are removed from the soil when temperatures reach the 50-121˚C range via heat-induced mortality (Neary et al. 1999). Subsequently, post fire, indirect effects upon the soil continue due to the lack of vegetation and canopy cover to protect the soil from environmental impacts, such as solar radiation, wind, and precipitation. Nutrient loss, in the post-fire denuded environment, results from runoff, leaching, and soil erosion (Arocena and Opio 2003, Wanthongchai et al. 2008), while microbial loss can continue due to increased soil temperatures and the lack of organic matter.

Figure 6: 2014 King Fire, High severity burnt area (both vegetation and soil).
Removal of soil organic matter left the soil denuded and increases potential for soil erosion. (Source: Colton Miller 2016)

The physical alterations to the soil have other indirect effects that can severely alter the hydrological response of the watershed. The creation of water-repellent soils (Neary et al., 2005 updated 2008) leads to decreased infiltration and increased runoff and erosion (Figure 6, Certini 2005 and Robichaud et al. 2000), which lead to other cumulative effects, such as increased runoff, peak flow, and surface erosion. With the compound effects of all the alterations that fire has on the landscape, sediment delivery to channels, channel bank erosion, and increase turbidity flows (Swanson 1981, Martin and Moody 2001) can also increase. All these effects are of major concern to downstream water quality because of their ability to contaminate the waters with nutrients, metals, and organic pollutants (Elliot et al. 2005).

A recent concern of high-severity wildfires is the lack of successful natural regeneration. The post-fire landscape is composed of large high-severity patches, where distance to seed source has surpassed the dispersal ability of conifers and where slow-moving, high-severity wildfires destroy the seed bank. In instances where the source is present, secondary effects to the microhabitat (soil, nutrients, water, shade, and biological requirements) can prevent successful seedling establishment and survival. Drastic reduction of canopy cover increases solar radiation and temperatures, both in the atmosphere and in the soil, which results in unfavorable germination conditions, further hindering establishment and survivorship of the seedlings (Stein and Kimberling 2003, and Petrie et al., 2016). Consequently, the interior of these patches may lack conifer regeneration for decades (Savage and Mast 2005, Haire and McGarigal 2010, Roccaforte et al. 2012), potentially decreasing the ecosystem services and economic value of these forest.

Fuel Management

Decline in forest health, increases of forest flammability, and climate change have resulted in larger wildfires in Washington in the last few years. Due to the lack of natural disturbances, such as wildfires, approximately 41 percent of all coniferous forests in Eastern Washington are in the mid-closed canopy class (Haugo et al. 2015). This continuous overlap of tree crowns and dense understories significantly increases the possibility of large wildfires burning at high severity, threatening communities nearby. One of these towns of high concern is Plain, WA and its surroundings. This area has not experienced a significant large wildfire in over a century. The most recent fire was in 2005 when the Dirty Face Fire burned 1,150 acres near Lake Wenatchee (Figure 7). Consequently, preventative measures, such as forest fuel and silvicultural treatments, are required in order to modify the severity of potential future wildfires and to create ecologically resilient forest. Ecological resilience includes the ability of forest to persist and re-organize after a disturbance and adapt to climate changes while maintaining its structure and function (Walker et al. 2004).

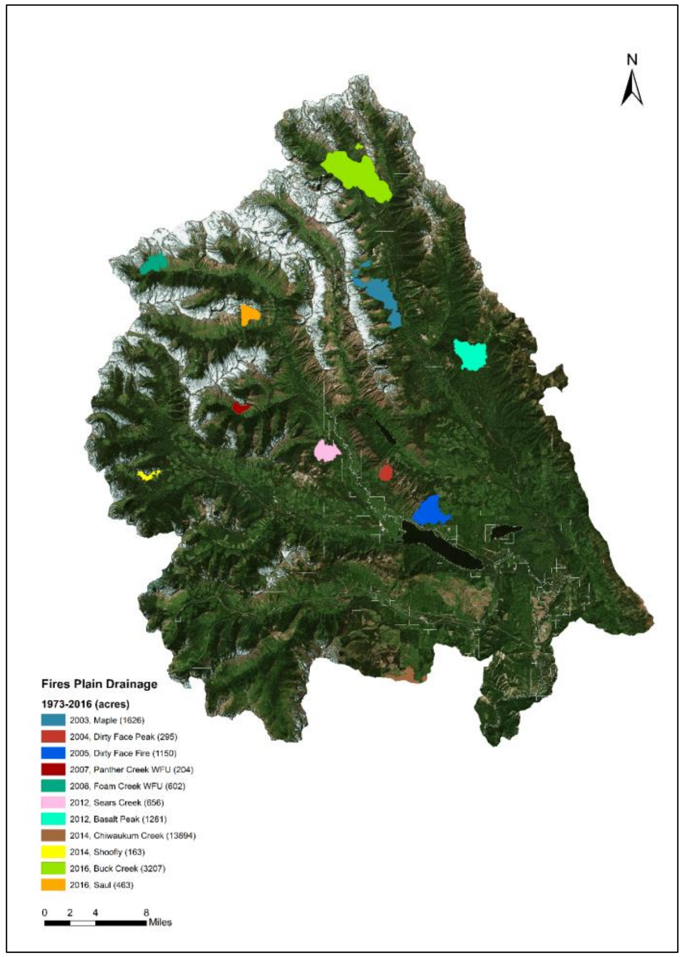


Figure 7: Wildfires over 100 acres, within the plain community from 1973-2016 (DNR)

Managing these unhealthy and highly flammable fragmented dry-forests, to a stage where we can mitigate wildfire severity while increasing forests resiliency is difficult. Management strategies are site dependent, but research has shown that dual treatments, mechanical thinning, and prescribed burns are the most effective strategies for the creation of resilient forests (Allen et al. 2002; Franklin et al. 2008; Hessburg et al. 2005). Mechanical treatments remove ladder fuels and increase distance to base of tree crowns and spacing between crowns (Agee and Skinner 2005), while continuous intervals of prescribed burning maintains the openness of the treated landscape. Hence, in the face of wildfires, the fires lack the ability to move into the canopy and remain grounded, which decreases tree mortality from fire and surface

Figure 8: Effect of fuel treatments on wildfire. Left to right: no treatment (2015 North Star Fire), thin and prescribed burn (2014 Carlton Complex Fire), and thin only (2006 Tripod Complex Fire). Dual treatment minimizes tree mortality and increased tree survivorship.

damage (Stephens et al., 2012), thus leaving behind a landscape of large-diameter, fire-resistant trees (Agee and Skinner 2005).

Fuel treatments recommended to create safe forest and reduce fire-hazards, follow four principles (Agee and Skinner 2005): Treatments reduce:

1. Surface fuels. Reduces potential flame length.
2. Flame length and decrease torching potential.
3. Risk of crown fires.
4. Tree mortality.

More recently, Hessburg et al. (2015) proposed seven core principles to guide landscape restoration of landscapes in the inland Pacific Northwest:

- **Principle 1**: Regional landscapes function as multi-level, cross-connected, patchwork hierarchies.
- **Principle 2**: Topography provides a natural template for vegetation and disturbance patterns at local landscape, successional patch, and tree neighborhood scales.
- **Principle 3**: Disturbance and succession drive ecosystem change.
- **Principle 4:** Predictable patch-size distributions historically emerged from linked climate-disturbance-topography-vegetation interactions.
- **Principle 5:** Successional patches are ‘‘landscapes within landscapes.’’
- **Principle 6**: Widely distributed, large, old trees provide a critical backbone to dry pine and dry-to-mesic, mixed-conifer forest landscapes.
- **Principle 7:** Land ownership, allocation, management, and access patterns disrupt landscape and ecosystem patterns.

Post-fire Rehabilitation

During the past two decades, the size of the population living in the Wildland Urban Interface (WUI) has dramatically increased, as has the size and severity of wildfires (Stewart et al., 2003). Consequently, maintaining public safety not only requires rapid-fire suppression, but also requires mitigating post-fire hazards through rehabilitation/restoration treatments. These treatments can include a diverse array of practices including soil erosion control, flood control, water quality assessment, maintenance and reforestation strategies.

Soil Immobilization Treatments

Hillslope stabilization is the first line of defense to prevent the mobilization of sediment, which poses a threat to the wellbeing of humans and the forest. Hillslope treatments include reestablishing plant cover, contour felled logs, and mulching. Although each technique has its benefits, various studies have determined that broadcast seeding with perennial grasses, and/or a mixture of grasses and legumes, is the most effective and economical treatment (Miles et al. 1989, Agee 1993) both to minimize soil erosion and to increase ground cover immediately after a wildfire.

Figure 9: Slope Stabilization. Contour felled log, straw and silt fence to stabilize the slopes to prevent soil erosion and runoff (Source New Mexico State Forestry)

Straw mulching is another technique that is sometimes used along with seeding. Mulching is an effective treatment used to minimize raindrop impacts and overland flow, aids in infiltration, and reduces soil erosion (Robichaud et al. 2005). Due to their high cost, mulching treatments are only used in gentle slope areas and areas where wind is of little or no concern, such as above or below roads, above streams, or below ridge tops (Robichaud et al. 2005).

Contour Log Structures are an effective method of reducing water velocity, breaking up concentrated flows and storing sediment in areas where high precipitation events are not a problem. These type of treatments involve felling logs along the contour of hillsides in order to minimize sediment flow, which in turn can prevent potential landslides (Figure 9) (Robichaud et al. 2005). Various other treatments can be used to minimize soil mobilization and increase infiltration, including straw wattles, contour trenching/terraces, and scarification/ripping. All treatments are effective but the application depends on the site and cost available for restoration of given areas.

Channel Treatments

Channel treatments are implemented in order to prevent debris movement downstream by minimizing sediment and water movement in ephemeral and small channels (Robichaud et al. 2000). Treatments include a variation of dams; some are temporary, as in the case of straw-bale-check dams and log-check dams, and others are semi-permanent, such as rock dams (Miles et al. 1989). Other channel treatments include channel stabilization treatments used to stabilize the channel gradient, such as log-grade stabilizers and rock-grade stabilizers.

Streambank Protection

Streambank and channel protection are treatments used to prevent erosion of channel backs and bottoms during storm surges and runoff events (Robichaud et al. 2005). Such treatments include in-channel felling and debris basins. The type of protection used is dependent on the stream affected. For example, debris basins are usually used in streams that already carry a high sediment load; therefore, it requires additional treatments in order to reduce deterioration of water quality and threats to human life.

Reforestation

In the areas burned at high severity, reforestation might be required in order to guarantee or accelerate the recovery of tree cover**.** Reforestation must ensure a healthy forest composition by overseeing the long-term restoration of a proper forest structure via establishment of reference species composition, natural variability of canopy densities, and proper spatial arrangement of trees, so that natural openings are maintained (Roccaforte 2014). In the face of climate change, it is also important to consider the potential for assisted species migration, i.e., the physical movement of tree species beyond their native range, where deemed necessary.

Adaptive cycle

While researching how to reduce the adverse impacts of Spruce Bark Beetles to forests in British Columbia, Canada, C.S. Holling concluded that the change he was studying was natural and was reflective of a larger natural cycle. This cycle was labeled "Panarchy" and is thought by many to describe a phenomenon characteristic of all living communities. (Holling 2001)

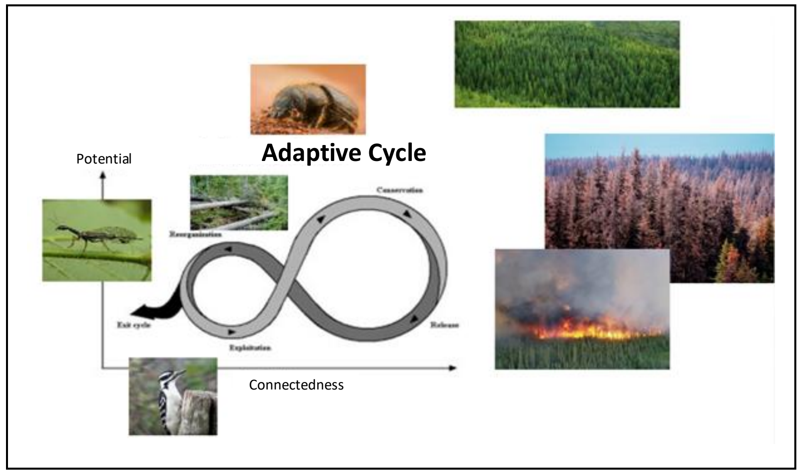


Figure 10: Adaptive fire cycle (Adapted from Holling 2001)

This adaptive cycle helps explain the overarching concept of resilience.

For example, a spruce forest may grow and mature along with a beetle population. Both populations enter a phase Holling refers to as “conservation." At some point, however, a threshold is crossed and the community of trees is overcome by the community of beetles. As a result of this crossed tipping point, trees die; the stressed spruce forest may at some point catche fire. These fires can build soils and, in being frequent without being fueled by extensive forest debris, are typically not sufficiently high intensity to render soils unproductive and extensively mobilize forest soils. Following such fires, both communities of trees and beetles may enter a “release” phase (Figure 10).

This release phase is critical and demonstrates that competition is important to the understanding of resilience. The resilience of one population may contribute to the collapse of another population. Competition helps to define resilience.

However, in our illustration, if both populations have found refuge in isolated areas of sanctuary where both communities can survive. These communities may enter a reorganizing phase. This phase determines whether either the spruce or the beetle community survives and the other collapses

Survival as we have already stated is benefited by biological legacies or remembering, and there being a surviving community population of sufficient size to enable regeneration. Yet, survival also depends on that population’s ability to transform to what may be a new post-burn environment, and that no other communities are available to replace the original niche. This latter facet is referred to as revolt. Revolt is a very familiar process to any Northwest farmer or gardener battling morning glory or similar invasive species.

This adaptive cycle has been defining Northwest forests since the glacier receded about 13,000 years ago. Trees grew and forests matured. Beetle populations invaded and were largely controlled by birds and other predators being able to hunt beetles within these emerging forests. As forest matured, beetles gained protection. When predators could not control beetle populations, a tipping point was crossed and forests died. Fire consumed the forest, but sufficient seed stock survived, “remembering” and new spruce forest emerged to exploit the environment, and the conservation cycle began anew.

However, human populations and a changing climate are altering this cycle. Our settlements are now encroaching on the Wildland Urban Interface (WUI), which has resulted in limiting the frequency of lower-intensity, fuel-removing fires; these settlements have diverted wildland fire-suppression efforts away from protecting the forest to protecting structures.

Making this situation worse is the fact that our changing climate is causing shorter, warmer, wetter winters and longer, drier summers, leading to the build-up of flashy fuels and more frequent summer fires. Additionally, it appears that the conditions that brought the pollinators and seed-distributing birds and insects to the forests are becoming increasingly out of sync with historical processes. Transformation will happen, but it took many thousands of years for the current forests to evolve naturally. This time, we will have to assist with species evolution and migration.

Study Area

A group of Chelan County stakeholders selected Plain, Washington as the case-study community[15]. Plain provides an excellent case study because it is a community that is growing in population, attracting more recreational seekers, and is situated within an at-fire-risk forested landscape. The town is located downstream at the confluence of the Wenatchee River and stream channels that originate on the Eastern Cascades slopes. As such, the Plain watershed was defined by the topographic divides and the areas where surface-water runoff drains into the Wenatchee River. Furthermore, the Plain watershed is one of the few sections within the Eastern Cascades ecoregion that has not experience a major wildfire in the last century (Figure 11.)

This section reviews Plain's community planning and hazard-mitigation efforts by the local community and county.

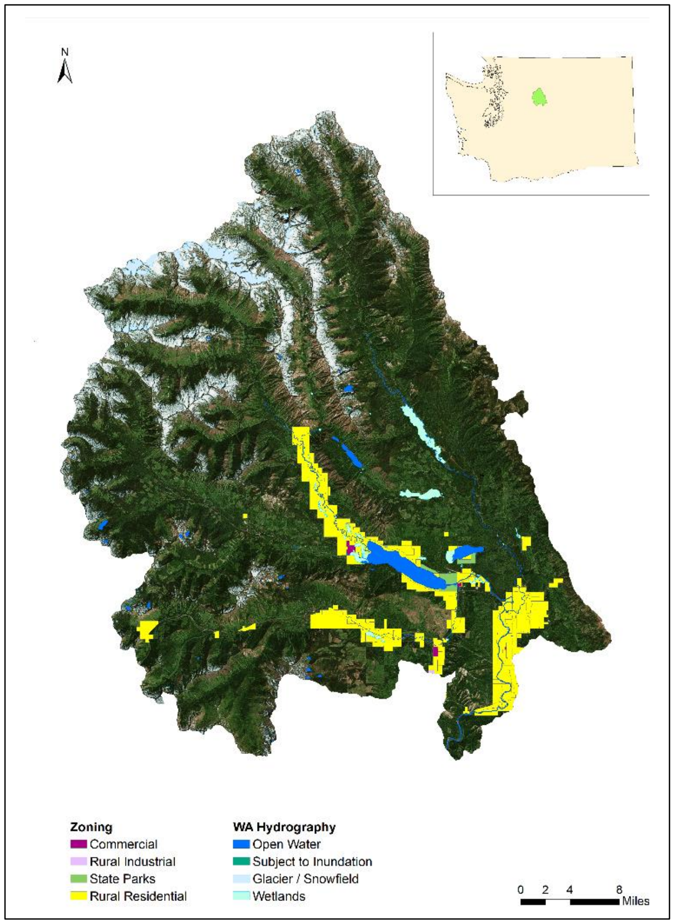


Figure 11: Study area (Plain drainage) near Plain Washington, and the Wenatchee River

Policy Framework

Chelan County Comprehensive Plan

The Chelan County Comprehensive Plan is based on the community's goals and aspirations in regard to community planning. It outlines public policy for land use, housing, utilities, transportation, and recreation. The "plan seeks to provide [an] opportunity for growth, while preserving the positive attributes that make the County so desirable" (pg. 4). This section provides background on Plain based on the Plan and serves a reference point when exploring alternative futures.

The community of Plain is located at the foothills of the Eastern Cascade Mountains, in unincorporated west-central Chelan County, Washington. The area is mainly comprised of lands owned and managed by the United States Forest Service, including the Glacier Peak Wilderness. Private and state lands are situated around Lake Wenatchee, Fish Lake, and the Stevens Pass Corridor. People who live in and visit the area are attracted to the natural landscapes and rural setting.

The geological landscape of steep and unstable slopes, floodways, wetlands, and other areas make it unsuitable for development. In addition, three out of the 30 different soil types (Brief, Burch, and Chiwawa) are most suitable for development due to septic-tank absorption capabilities. The other 27 soil types have septic-tank absorption limitations.

[15] Meeting held at Chelan County offices January 13, 2017; 10:30 AM – 12:30 PM .

There are dozens of alpine lakes with Lake Wenatchee and Fish Lake being the largest and most significant. There are also many rivers and creeks that flow into the Columbia River including Wenatchee River, Chiwawa River, Nason Creek, Little Wenatchee River, White River, Napeequa River, Phelps Creek, and Whitepine Creek.

The community has a commercial area that supports rural functions, an elementary school, county sheriff services, and fire stations served by volunteers. Current zoning for the study area requires development to support and maintain the rural character of the community. Development will be compatible with rural living clustered in a form that limits road cuts and obstruction of viewscapes, preserves open space, is environmentally friendly, and encourages recreational activities. Development is concentrated near and around Lake Wenatchee, Fish Lake, rivers, and transportation routes. More information about population and housing is described later in the report.

Across Washington State, people express growing interest in affordable physical activities. The top five are walking/hiking, outdoor team and individual sports, nature activities, sightseeing, and bicycle riding. This is consistent with the goals outlined in the Chelan County Parks and Recreation Plan. Out of ten projects identified by the community, developing a Comprehensive Trails Plan ranked first. The plan would "determine the linkages the trails will provide, exploring alignment, design cost, phasing and relative priority" (pg. PR-24).

A mix of public (state and federal), private, and individual water systems services the Plain community. The largest providers of water are the Alpine Water District, Chiwawa Community Association, Ponderosa Community Club Inc., and Thousand Trails Water Systems. The Wenatchee-Chiwawa Irrigation District services 1300 acres for approximately 300 customers.

Wastewater near Lake Wenatchee is collected and treated by the Clean County Public Utility District (PUD) Water System. Septic-tank effluent pumping systems are operated and maintained by the PUD. Solids are pumped out and treated at a treatment facility, which is designed to add capacity. Some areas around Lake Wenatchee are connected to the treatment facility system while other subdivisions utilize septic systems. Due to low population, a public wastewater system is not feasible.

The County's storm drain systems primarily consists of roadside ditches with culver pipes that divert water under the roads and driveways. The water drains to a natural drainage course. Pipe drain systems are located only in limited urban areas and they do not include Plain.

Regarding utilities, the community has no cable television; receives telephone and cellular service through GTE Northwest, Air Touch Cellular, and Cellular One; natural gas through Cascade Natural Gas; and electrical utilities provided by the Chelan County Public Utility District.

The largest employment sector in Chelan County is agriculture, forestry, and fishing, followed by services, retail trade, and government. The government and service sectors have the highest wages, respectively, followed by agriculture, forestry, fishing, and retail trade. The agriculture sector has seen a decline in employees, the number of irrigated farms has decreased, and the average farm size has grown while the number of farms with less than 500 acres has decreased. If the County continues to lose farms of less than 500 acres due to globalization, increasing operational costs, climate change, or other factors, the local economy will be impacted.

The comprehensive plan is based on the assumption of growth, which can accommodate population increase and economic expansion. This method is good for positive linear planning, but what if there is an economic downturn or a disastrous event that drives people away from the community? Comprehensive plans do not typically account for reduction in population, infrastructure, or services.

Chelan County Multi-Jurisdiction Natural Hazard Mitigation Plan

The Federal Disaster Mitigation Act of 2000 requires local, state, and tribal governments to develop a hazard mitigation plan before receiving mitigation grant assistance. Hazard mitigation planning aims to reduce the loss of life and property by reducing the impact of disasters. Chelan County developed a multi-jurisdiction plan in 2004 and updated it in 2011. The mission of the plan is "*to promote sound public policy to protect citizens, critical facilities, infrastructure, private property and the environment from natural hazards by increasing public awareness, documenting the resources for risk reduction and loss-prevention, and identifying activities to guide Chelan County towards building a safer, more sustainable community*" (Chelan County 2011, 3). Eight natural hazards have been identified in Chelan County, two of which are the focus of this report: wildfire and flooding (Chelan County 2011).

Flooding:

The two common flooding types in the county are flash and riverine. Flash flooding is most likely to occur during the summer months and is associated with cloudburst-type rainstorms, ice, or debris dams. Flash floods have caused deaths within the region and, due to human settlement locations at the base of steep slopes in the 100- and 500-year floodplain, the threat of deaths remains high. Riverine flooding occurs during early winter to late spring and during periods of heavy rain. No deaths have been reported due to riverine flooding, but public and private properties have been lost (Chelan County 2011).

Recommended mitigation actions in the plan for flooding include:

1. Analyze repetitive flood properties for removal or mitigation adaptation
2. Development restrictions in the floodplain
3. Community education on hazard
4. Protect and manage strategies to preserve open space
5. Enhance data and mapping of floodplains
6. Improve warning system
7. Establish a framework for surface water management

Chelan County participates in the National Flood Insurance Program (NFIP) (Chelan County 2011). The program provides affordable flood insurance for property owners and encourages communities to reduce risk in floodplains (FEMA 2017). No cities or towns, including the County, participate in the Community Rating System (CRS), a system that significantly reduces flood insurance costs if the community exceeds minimum NFIP requirements. Communities that do participate in CRS can reduce their flood insurance costs by 45%. CRS grants "credits" to communities that engage in 19 different activities in four categories: 1) public information: educate the public about flood insurance and damages; 2) mapping and regulations: update flood maps for protection to new development; 3) flood damage reduction: reduce flood risk to existing buildings; and 4) flood preparedness: enhance and maintain safe flood warning and infrastructure (FEMA 2015).

Wildfire:

Fire behavior is largely influenced by three factors: fuel, weather, and topography. The County has large quantities of snags and hazard trees in the forest, longer and drier summers, and complex terrain that can make efficient firefighting challenging. These elements add up to a serious threat to the County (Chelan County 2011), especially because in this region, fire ignitions are the result of both lightning strikes and humans' actions.

Recommended mitigation actions in the plan for fire include:

1. Implement wildfire prevention and mitigation activities,
2. Evaluate building and construction techniques to prevent wildfire damage,

3. Public education, and
4. Encourage and develop fire-risk maps for the public.

The County's hazard mitigation plan focuses on protecting life and property through risk reduction awareness and activities. This a good goal; however, it is unclear what the community values protecting. Moreover, the plan focuses on local capabilities of County agencies, non-governmental organizations, and private property owners to reduce risk to hazards. It does not recognize that federal and state forest agencies are the largest landowners in the County and successful mitigation efforts must also include participation, collaboration, and coordination of all community stakeholders. This idea is the basis of Fire Adapted Communities (FAC), a coalition that helps people live in the wildland urban interface (WUI).

Fire Adapted Communities (FAC)

Everyone is responsible for wildfire safety. As more people move and recreate in the forest, the people in communities like Plain need to work together to adapt to life in the WUI. Plain has launched a FAC coalition comprised of federal, state, and local public agencies working in collaboration with the businesses, non-profits, and community-based organizations to help people reduce fire risk. The Plain FAC follows the experience of the neighboring Chumstick FAC, which is one of the most consolidated FACs in the state. Protection of the wildland urban interface includes people, buildings, infrastructure, nature, and cultural resources. The seven major components of FAC are being implemented in Plain. Each component and associated work in Plain is as follows:

Firewise Communities Neighbor to Neighbor

A community with wildfire risk is all connected, therefore everyone needs to participate in risk reduction efforts. Community members can help each other out by trading skills[16] to make everyday connections and reduce risk. A community that helps each other before a disastrous event occurs is more likely to help each other recover from an event (Cretney and Bond 2014).

Figure 12. Defensible space. *Naneum Canyon in 2010 near Yakima. Source: E. Alvarado, (2015)*

Plain is a recognized community, and members are actively educating the public on how to protect people, buildings, and property. In September 2017, the community hosted a FAC training funded by FEMA. Continuing education and training to increase awareness among people who live in the area and added effort need to be made to engage absentee homeowners who rent their properties. Individuals can protect their families and homes by creating "defensible space" around their homes by using simple landscaping techniques such as mowing the lawn, watering vegetation regularly or xeriscape, and removing dry vegetation within 30 feet from the home. Around 100 feet of the home, it is recommended that minimal and well-maintained grass, shrubs and trees be planted (Figure 12). Moreover, people can prepare for an event by being aware of the fire risks, creating an evacuation plan,

[16] Time banking is a voluntary neighborhood based system where services can be offered and received for free. Members providing a service receive time credits and can spend them on services they want. All skills are treated equal and time providing the service is banked.

and be ready to leave when asked to do so by emergency management professionals. Community outreach and education is ongoing in Plain.

Community Wildfire Protection Plan

The Cascadia Conservation District is in charge of developing the Community Wildfire Protection Plans (CWPP) for Chelan County. The Lake Wenatchee/Plain and Ponderosa CWPPs cover the study area and were finalized in July 2007. The plans include an assessment of current conditions, evaluation of risk, and current activities to address threats to the community.

Codes and Standards

Building codes and standards can reduce fire risk at the beginning of the development phase. Chelan County's building code 15.40.050 requires development projects in the wildland urban interface to use Class A roofing/noncombustible roof covering. The fire marshal may reference other guidelines such as the Urban Wildland Interface by the International Fire Code Institute or NFPA 299, Standard for Protection of Life and Property from Wildfire prepared by National Fire Protection Association Technical Committee on Forest and Rural Fire Protection (Res. 2000-127 [part], 10/17/00) before issuing a permit, but is not required to enforce strict building codes outlined in these guidelines.

The Plain community has a FAC coalition that is committed to building support for fire prevention, mitigation, response, and recovery efforts. They are working to gain more support from all community members and establish a culture of sustainable living in the forest.

Scenario Planning

We applied scenario-planning methods to develop four alternative futures and used them to discuss resource management strategies in order to examine how the community of Plain can become resilient to fire and flooding hazards. The most important and uncertain drivers of change in the community are wildfire, flooding, and population. The parameter of each driver was calculated using predictive modeling techniques based on past events and possible future conditions. The next sections will discuss how the parameters of each driver were established.

This approach embraces the understanding that human and natural ecosystems have co-evolved over time and must be studied as a coupled human-natural system to anticipate how environmental changes will affect urban form (Alberti 2008). An integrated system like this, where people and nature interact reciprocally, creates feedback loops (Liu et al. 2007). For example, as more people move and visit Plain, more housing, businesses, and recreational activities will be developed. Natural land cover will be replaced with paved surfaces. The soil will lose the ability to infiltrate rainwater and recharge groundwater. Roadside ditches or stormwater drains are built to move water away and therefore alter natural systems. People are attracted to the natural features of the forest and diminish it through occupancy of the space.

Rural communities that rely on natural resources for their economic and cultural livelihoods must take a coupled human-natural ecosystems management approach for their resilience (Jacobs and Cramer 2017). Resilience is "the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions" (IPCC 2012, 563).

Scenario Futures

Using the data generated by wildfire-risk statistical modeling and flooding calculations, scenarios were mapped so as to illustrate future conditions. Each scenario is the product of wildland fire, flood, and population drivers and associated impacts through 2020, 2040, and 2080, respectively. The flood driver assumed two conditions: increased run-off and sediment blockage within the Wenatchee River.

Wildfire

Fire impacts were described by the amount of area burned at high severity, assuming an individual fire was a high intensity event if it were large and killed a large proportion of the above-ground vegetation. The effects of climate change on high-impact events were predicted by fitting two statistical models to 13 climate models. The statistical models were fit using data from the Monitoring Trends in Burn Severity (MTBS) program and described two independent fire characteristics: the area burned and the percentage of area burned at high severity. These models were applied to 13 climate models and averaged to forecast future fire impacts in 2020, 2040, and 2080. The effects of pest populations on wildfire activity was not explicitly included within any of the models.

The wildfires described within the scenarios are based on pixel classification, within each scenario. The model classified the pixels with the highest possibility of burning the largest area at high-severity from 1-6. Based on these rankings, the pixels were selected as probable locations for a wildfire, assuming that no management techniques were implemented within the areas. As such, the fire spread and area burned followed the natural terrain of the landscape. The watersheds were used as a proxy for the area burned as it too, follows the natural terrain, which serves as a natural barrier for fire spread. Consequently, the wildfire names are based on one of the watersheds burned within a given fire. For example, in scenario year 2040 we ignited fires, Beaver Creek and Rain Creek that engulf three watersheds. The fires burned a total of 50, 071.16 acres. In scenario year 2080, we ignite four more fires which engulf seven watersheds and burn a total of 140, 333.16 acres. Table 3 lists the details of each fire.

Table 3.Wildfires ignited under each scenario year

<table>
<tr><th>Scenario Year</th><th>Wildfires</th><th>Area (Acres)</th><th>Watersheds Burned</th><th>Area Burned</th><th>Total Area Burned</th></tr>
<tr><td rowspan="3">2040</td><td>Beaver Creek</td><td>28543.03</td><td>Beaver Creek-Wenatchee River</td><td>28543.03</td><td rowspan="3">50071.69</td></tr>
<tr><td rowspan="2">Rainy Creek</td><td>10664.78</td><td>Lake Creek</td><td rowspan="2">21528.66</td></tr>
<tr><td>10863.88</td><td>Rainy Creek</td></tr>
<tr><td rowspan="9">2080</td><td rowspan="2">Phelps Creek</td><td>10204.79</td><td>Phelps Creek</td><td rowspan="2">23895.63</td><td rowspan="9">140333.16</td></tr>
<tr><td>13690.84</td><td>Rock Creek</td></tr>
<tr><td>Lower Chiwawa</td><td>25087.91</td><td>Lower Chiwawa River</td><td>25087.91</td></tr>
<tr><td>Chikamin Creek</td><td>14014.8</td><td>Chikamin Creek</td><td>14014.8</td></tr>
<tr><td rowspan="5">Nason Creek</td><td>22339.12</td><td>Upper Nason Creek</td><td rowspan="5">77334.82</td></tr>
<tr><td>11993.37</td><td>Panther Creek</td></tr>
<tr><td>21759.51</td><td>Upper Little Wenatchee River</td></tr>
<tr><td>8856.68</td><td>Middle Little Wenatchee River</td></tr>
<tr><td>12386.14</td><td>Lower Little Wenatchee River</td></tr>
</table>

Each resulting map describes the future fire impacts in the Plain watershed in 2020, 2040, and 2080. Specifically, the color of each grid represents the amount of area that is predicted to burn at high severity if a fire occurred at that location. The predictions are averages of both model components – fire size and percent burned at high severity – across the year and climate models.

Flooding

Under natural condition, moving water moves sediment downstream, replenishing groundwater, and makes the soils more fertile. Unfortunately, it also has the potential to lead to damaging floods, which can affect the surrounding communities. Although flooding is a natural occurring event, it submerges normally high land with water, especially the areas within the floodplain[17]. As more people move into floodplain areas and with the alterations to climate, it is likely that floods will become more prevalent and disastrous, both for human life and for property.

Typically, dams and levees are built to control and contain streams and rivers to protect human settlements; however, they can fail or become overwhelmed. As a result, people, animals, roads, bridges, and infrastructure in human and natural habitats can be lost.

Flood Insurance Rate Maps (FIRM) have been developed to help identify flood risks and are used to administer the National Flood Insurance Program (NFIP) however flooding is not limited to only areas identified on the FIRM maps.

As stated earlier, Chelan County is under regular threat of flash and riverine flooding due to the topography and climate. The County also has a history of post-fire flooding. After wildfires, vegetation and soil are damaged or destroyed, which means that water cannot infiltrate (be absorbed) and runs downhill causing floods.

Flood risk mapping

To assess flooding risks and estimate damage in Plain, we used HAZUS-MH. HAZUS-MH is a geospatial software modeling program developed by FEMA that is used to assess risk for different natural disaster scenarios, including flood, earthquake, hurricanes, and tsunami. To estimate the damages caused by flooding to a particular community, HAZUS-MH needs three layers/variables: the buildings in the community, a layer showing the depths of the floodwater in the community, and formulas that apply the depth of the water to the types of buildings found in the community.

The building layer, or general building stock, for Plain, WA and the surrounding environment was created using Chelan County tax assessor data and loaded into the HAZUS-MH model. Using up-to-date tax assessor data allows HAZUS-MH to have the most accurate account of buildings in the area, which helps when estimating flood damages.

The flood layer affecting Plain was generated using the HAZUS-MH Flood module Hydrology and Hydraulics process. This process uses the local topography of the area and then estimates flood depths based on the amount of water flowing in the local rivers and streams, or discharges. The discharge input into the HAZUS-MH model was calculated by the University of Washington Institute for Hazard Mitigation Planning and Research. These discharges took into account the regular flood risk, but also the estimated increased risk posed by excessive wildfires in the Plain region in the near future. The final product is called a flood-depth grid. A total of five depth grids were created for this project to account for the different flood-following-fire scenarios in 2020, 2040, and 2080.

HAZUS-MH has formulas built into the software called depth-damage curves that take the depth of floodwaters and then apply it to different types of buildings to estimate structure and content damages, as well as an estimate of displaced people and amount of short-term sheltering needed. By combining the general building stock, flood-depth grids, and depth-damage curves, HAZUS-MH was used to estimate present and future risk of flooding following wildfire in Plain, Washington.

Determination of discharge

The potential post-fire sediments for the Plain fire scenarios were estimated using data from a similar watershed that burned 100% in 1970 in the Entiat Fire (Woodsmith et al. 2004). Average fire-severity

[17] A floodplain is land next to streams or rivers that is subject to flooding.

estimates were compiled for large fires in the East Cascades ecoregion from 1985 through 2014. The 100-year return period for peak discharges (cfs) used were estimated as 27,825 cfs for a Log-Pearson III distribution adjusted for the USGS Site Number 12457000 (Wenatchee River at Plain, WA) (work done by Cheng et al. 2017).

The Entiat watershed is one of the three known in the world that has been monitored before and after a highly severe natural wildfire. The Entiat experiment is located in the Okanogan-Wenatchee NF, near Plain WA. It was established a permanent monitoring site to study the effect of timber harvesting on soil erosion and sediment deposition in streams (Helvey et al. 1976). The watershed extends to 120,100 acres and it is located in a snow dominated forest catchment. Three of the sub-watersheds burned completely in the 1970 fire, McCree, Burns and Fox Creeks, each having approximately 1,236 acres. These 3 watersheds had a total increase of 272 cfs for the approximately 3,707 acres. The runoff and sediment production was measured nine years before the fire and seven years after the event. Runoff at least double from the pre-fire values. Soil sediment mobilization increases dramatically shortly after the fire and decreases after the vegetation stabilizes. The erosion rate and lasting effects depend on the climate, topography, soil properties, and amount of surface cover, which may include unburned duff and needle cast from the scorched trees.

For forests that regenerate rapidly and experienced a low-severity fire, the risk of erosion decreases at a rate of almost 90 percent each year. By the third year erosion may be negligible. Some of the erosion models, such as WATSED, the sediment delivery is reduced over a 15-year period following a fire before the impact is assumed to be zero. (Neary 2005).

The Entiat watershed did not have evidences of a large wildfire for at least 200 years before the 1970 fire. Helvey (Helvey et al. 1976) reports an increase of 50% on year 1 and increase of 150% median runoff years 1-6. Seiber et al. (2010) estimated that based on average peak flows increased 120% on the first few years. More recently, Gartner (1984, cited by Neary et al 2008) estimated (1984) that the Entiat watersheds produced 1,355 yd^3/mi^2 for a rainfall event of 14 inches.

Fire severity was estimated from summarizing the wildfires over 1000 acres that have occurred from 1984 through 2014 on the Eastern Cascades ecoregion. These fires burnt an area that spans from 1007 to 27,6089 acres, with a high-severity range from 0% to 66%, an average of 27% and a median of 25%. The 27% average was used as the expected high severity for the fires predicted for the Plain project in 2040 and 2080.

These are similar forest and fire conditions as the forest within the Plain project. The impact on vegetation, runoff, and soil-sediment production could be similar if the predicted fires for the Plain project area burn under similar weather conditions as those that caused the large fires in recent years. In summary, the calculations used the average high-severity for large fires in the Eastern Cascades ecoregion, the peak flows from the Entiat Experimental Forest, and the peak discharges for the 100–year floods in the USGS Plain Station.

There are a several limitations on these calculations. The model for area-burnt prediction that was used for this work does not produce fire severity. However, soil erosion and sediment production depend on loss of ground cover, which include duff, litter, and vegetation cover. The fire severity from the MTBS data is based on tree severity and not on soil severity as defined by Wells et al. (1979) and DeBano et al. (1998), a measure that will be more related to soil-sediment production. Fire severity for future fires is also assumed to be the same in the future, which may not hold true due to higher temperatures, continued accumulation of dead biomass in the forest due to natural mortality, increased insect outbreaks, and increased stress of forest vegetation. Not included on this assessment are the predictions that timing of flooding may shift due to climate change and decrease of snow depth that will create early water runoff when the soil may still be frozen and cause higher soil sediment and debris production.

Table 4. Calculations:

Total Area in the Plain Project: 394,055 acres. Peak flow in a high severity fire, 12,605 cfs. 100-event, 27,825

A. Prediction Year	B. Total Area Burned in Watershed, acres	C. Area Burned under High Severity, acres (B*0.27)	D. Percent of Plain Project (C/394,055*100)	E. Additional cfs to Peak Flow, cfs (12,605*D)	F. Additional cfs to 100-year event 27,825*D
2040	50,071.69	13,519.36	3.43%	432.35	954.3975
2080	140,333.16	37,889.95	9.62%	1,212	2,675

These discharges took into account the regular flood risk and also the estimated increased risk posed by excessive wildfires in the near future within the Plain watershed. The final product is called a flood-depth grid. A total of five depth grids were created for this project to account for the different flood-following-fire scenarios in 2020, 2040, and 2080.

Finally, HAZUS-MH software has formulas built into the software called depth-damage curves that take the depth of floodwaters and then apply it to different types of buildings to estimate structure and content damages as well as an estimate of displaced people and amount of short-term sheltering needed. By combining the general building stock, flood depth grids and depth damage curves, HAZUS-MH was used to estimate present and future risk of flooding following wildfire.

Population

The third driver of change was population. The number of people in the area affects the wildland fire and risks. Human settlement alters land cover and land use as well as resources available to reduce risks and exploit opportunities. In addition, associated recreational activities will contribute to a change in the forest. We also looked at community stewardship as dimensions of population.

The study area is located in Census Tract 9602 Block Groups 1 and 3. Since Plain is an incorporated community, it does not have official boundaries as a city does. Therefore, we used these block groups to estimate population in this area (see Table 5).

To project population size and number of housing units in 2020, 2040, and 2080, we calculated the rate of change from 2000 to 2010 and applied the rate of change for subsequent decades. During this ten-year period, the population grew by 12.5 percent while the number of housing units grew by 46 percent. Based on the actual numbers in 2000 and projected 2080 numbers, we established endpoints, which is a range to study for population and housing units. The endpoints for the lower population-bust scenario is 2,238 and population-boom scenario is 5,747. The end points for housing units are 2,207 and 47,498, respectively (Table 4).

Table 5. Actual and Projected Population, Housing Units, and Housing Units Occupied

	Year	Population	Housing Units	Housing Units Occupied by Owner or Renter	Percent of Housing Units Occupied by Owner or Renter
Actual	2000	2238	2207	903	41%
	2010	2518	3239	1101	34%
Projections	2020	2833	4754	1343	28%
	2040	3586	10239	1638	16%
	2080	5747	47498	1999	4%

Source: U.S Census Bureau, 2000 and 2010. Prepared by Social Explorer.

It is important to note that in 2000, the owner or renter occupied only 41 percent of housing units, with 59 percent vacant. According to the Census, vacant means the units are either for rent, for sale only, or otherwise vacant. The actual occupancy numbers from 2000 to 2010 increased by 22 percent; however, with the projected increase in housing units, the occupancy rates by owner or renter fall over time. We assume that projected housing units occupied by owner or renter will increase as population and housing units increase. In other words, a tourist town turns into a place where a diverse set of businesses exist and residents that are more permanent reside in the area. Based on community knowledge, many of the current vacant units are secondary homes and rented out to vacationers.

The current zoning regulations would allow for approximately 6,066 units to be built in the area (Chelan County Community Development, 2016). This was calculated using current zoning regulations for allowable housing units per acre. Parcels owned by the government were removed from the analysis because we assume that the government will not sell of parcels for development. Housing units for parcels zoned Commercial Minerals Lands (MC), Rural Commercial (RC), Rural Industrial (RI), and Rural Public (RP) are not allowed there and so these zones are not in Table 5.

Table 6. Maximum Number of Units Allowable Under Current Zoning Codes, 2016.

Zoning*	Zoning Code	Acres per Housing Unit	Maximum # of Units
Commercial Forest Lands	FC	20	1358.7731
Rural Residential/Resource 10	RR10	10	436.077
Rural Residential/Resource 2.5	RR2.5	2.5	597.7416
Rural Residential/Resource 20	RR20	20	256.85725
Rural Residential/Resource 5	RR5	5	1562.521
Rural Residential/Residential	RRR**	1	764.025
Rural Village	RV***	2.5	17.684
Rural Waterfront	RW****	1	1073.31
Total			6066.98895
* The research assumes that government property will not be sold off for residential development. Therefore, government property was removed from the analysis.			

Zoning*	Zoning Code	Acres per Housing Unit	Maximum # of Units
** The zoning allows for one unit on less than 1 acre. This means there can be multiple units on 1 acre. For the purpose of this research, the Acres Per Unit is held at 1.			
*** The zoning allows for one unit on less than 1 acre. This means there can be multiple units on 2.5 acres. For the purpose of this research, the Acres Per Unit is held at 2.5 acres.			
**** The zoning allows for one unit on less than 1 acre. This means there can be multiple units on 1 acre. For the purpose of this research, the Acres Per Unit is held at 1.			

(Source: Chelan County Community Development, 2016)

Finally, we examined community stewardship programs as they are critical to the success of planning and management of natural resources. Plain community stewards include volunteer firefighters and members of FAC and Firewise. Resource management agencies should not view stewards as low-cost service providers or groups to consult with but as community partners who have the agency to influence decisions on management practices.

The population range in a bust and boom scenario is therefore set between actual population in 2000 to projected population in 2080. In scenarios where population increases, zoning codes will need to change to accommodate more people and meet housing demands. When population is low, community-steward programs are driven by tight-knit community members. Programs when population is high are driven by the community and governmental agencies.

Scenario Futures

Using the data generated by wildfire risk statistical modeling and flooding calculations, scenarios were mapped as to illustrate future conditions (Figure 13). Each map describes the future wildfire impacts in the Plain watershed in 2020, 2040, and 2080. The color of each grid represents the amount of area that is predicted to burn at high severity if a fire occurred at that location. The predictions are averages of both model components – fire size and percent burned at high severity – across the year and climate models. Six ignition points are located in watersheds with the highest risk and labeled from highest to lowest.

Scenarios one and two have flooding risk following significant burns. These maps illustrate flooding risks due to increases in discharge and sediment blockage within the Wenatchee River Channel. The number and percent of buildings with substantial damage is shown.

Current zoning has been included on all the maps and we have assumed that these designations do not change over time. Rural residential classifications were consolidated into a single category labeled Rural Residential. It includes all Rural Residential, Rural Waterfront, and Rural Village zones (see Comprehensive Plan, 2016).

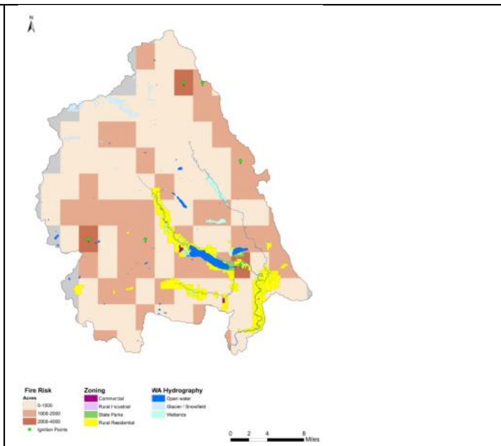
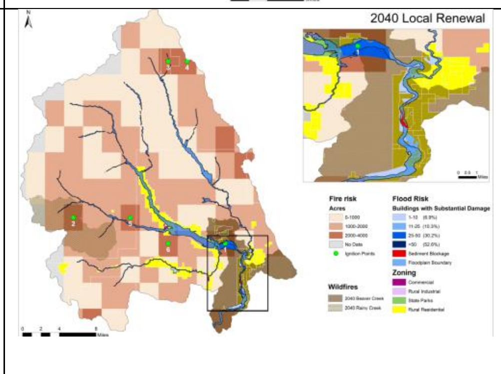
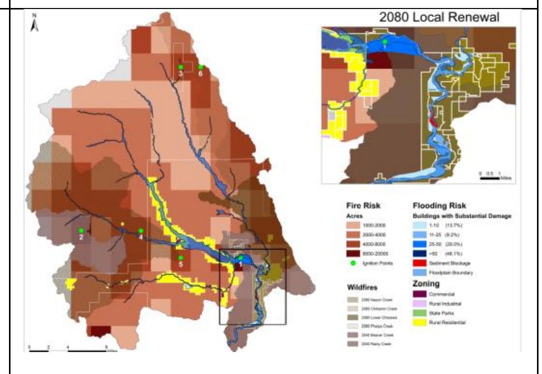
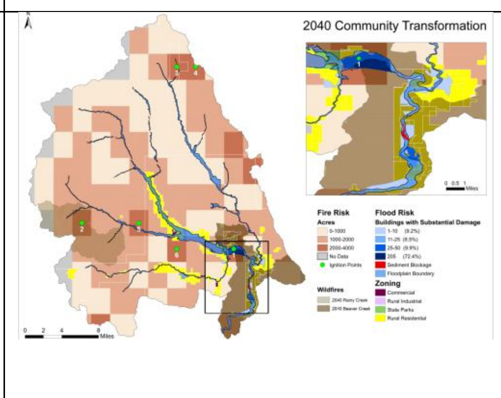
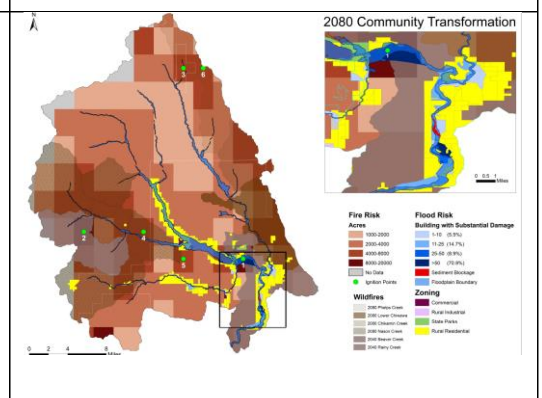
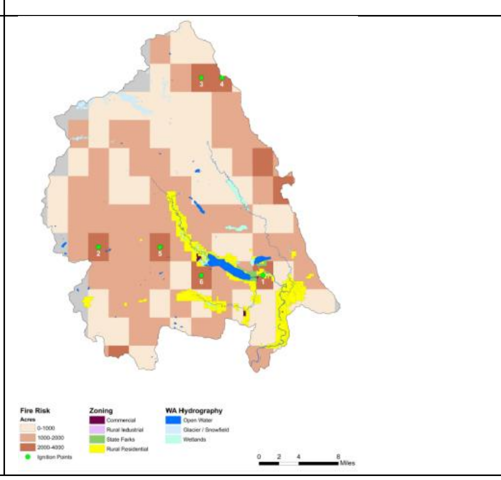
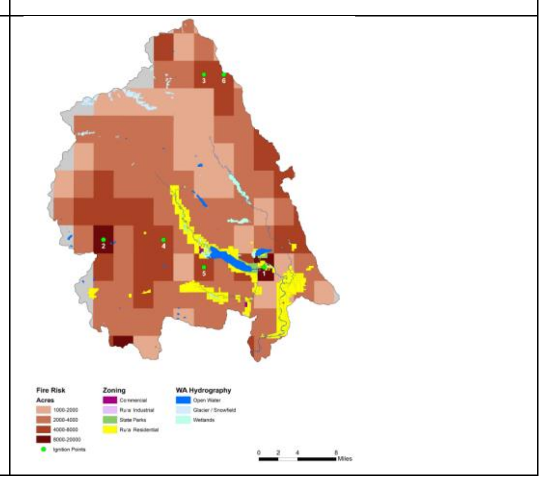
Baseline 2020		
S1 Local Renewal		
S2 Community Transforma-tion		
S3 Local-Reorganization / S4 Reactive-Management 2040/2080		

Figure 13: Scenario Maps.

Public Process

The public process included introductory conference calls between FEMA, the University of Washington, and Chelan County Public Works Department to develop the scope of the project and identify steering committee members who would guide the process. There were two steering committee meetings and one community-wide workshop. Information gathered from the workshop was analyzed, and a draft report was sent to participants to review and comment on before finalizing the report.

On January 13, 2017, the Chelan County Public Works Department convened a meeting of regional fire and flooding subject matter experts along with the University of Washington to identify a study area (see Appendix A). Committee members reviewed the scope of the grant and identified two potential study areas. The City of Wenatchee in the Mission Ridge and Squilchuck Canyons and the unincorporated Plain community, located north of the City of Leavenworth. The committee selected Plain. The community was growing, had a fire and flooding risk, and an active community interested in risk reduction. The UW Institute Team reviewed FEMA FIRM flood maps, historical fires, and current forest fuels; conducted a site survey confirming the committee's perception of risk in Plain; and the community was selected as the study area.

On April 28, 2017, the Lake Wenatchee Fire and Rescue District located in Plain hosted the second Steering Committee meeting with Plain community members (Appendix B). The purpose of the meeting was to learn more about the Plain community and hazard risks, and get buy in from key stakeholders on the project. Having achieved those results during the meeting, the community workshop date was scheduled for June 2, 2017.

Following the workshop, the University Team evaluated resulting information and prepared distributed extensive notes (Appendix F) of the workshop, highlighting key points and tentative conclusions to all those invited to the workshop, including those who could not attend. These mailings were followed up with a call. A questionnaire was prepared to clarify emerging direction. A draft of this report was distributed to all invitees before the final report was prepared.

Workshop

The Lake Wenatchee Fire and Rescue District invited key stakeholders to the workshop by sending letters and calling representatives. A total of fourteen stakeholders along with six presenters and note takers from the University of Washington (Appendix C) attended the six-hour workshop.

The objective of the workshop was to have participants identify key community values and measures that would reduce the risks to these values for four futures.

Four to five stakeholders and at least one note taker sat at three different tables. Each of three tables was assigned one scenario to discuss using an appreciative-inquiry storytelling method. No participants were assigned to Scenario 4 (S4), Local Reorganization: population decreases (due to outside forces) as fire and flooding threats increase but no major events occur. This was the least probable scenario and the Institute Team felt that the exercise would be better served if the other three scenarios had greater representation.

The workshop followed an asset-based Appreciative Inquiry (AI) approach through storytelling. AI encourages participants to look at a "positive core" of strengths, assets, and values, while more traditional mitigation planning often begins with an assessment of hazards and risks. Focusing on values through storytelling and not on dysfunctions would encourage broader discussion resulting in more creative and achievable solutions. Our story format had three elements, each discussed within one of three rounds of discussion.

- Round 1: Describe your community; determine your values and identifying the capital responsible. In story language, these translated into the determining the story characters, setting and plot. The AI process proved the framework for the identification of values. By adhering to an AI process, the focus of discussion was on determining what participants valued. Why the participants lived/worked/recreated within Plain. Participants then identified the social, built, and natural “capitals” that support these values. Capitals were discussed as ”things” that support values and included community organizations (social capital), good bridges (built capital), and shoreline protection and access (natural capital). Participants were asked to begin their stories with “Once upon a time there was a community called Plain.”
- Round 2: Introduce shocks to compromise/stress the capital responsible for values. All stories about change include conflict. Here, conflicts were offered as probable alternative futures based on three drivers – wildland fire, post-fire flooding, and population growth. Teams were asked to be true to their scenario.
- Round 3: Develop strategies that reduce the risks and exploit opportunities arising from the introduced scenario. Stories have a resolution, and, here, resolutions are the approaches and tools required to assure the maintenance of the listed community values following an introduced change. If a capital was compromised and was not available to support a community value, participants were encouraged to identify different, alternative capitals.

The community workshop used a World Café format to broaden the AI storytelling process. The results of the workshop guided subsequent research by the University of Washington Institute Team.

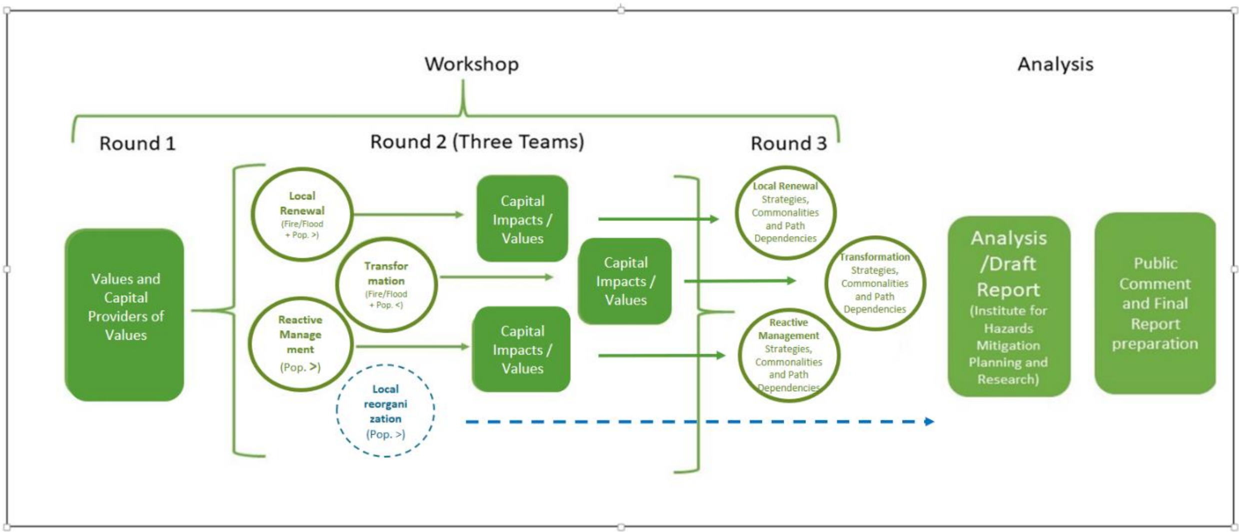


Figure 14: Workshop and Analysis Process

Round 1: Community Values and Direction

Values

Workshop participants were asked to identify what they valued in Plain and what things (social, built, and natural capitals) it provided them. They value a close-knit and safe community, natural features of the forest, rural character, year-around recreational activities, and the built infrastructure. They shared stories of why they valued these things and the people, places, and things that provide them. Their values included:

1. **Close-knit and safe community:** Residents, businesses, and government agencies know each other and value their relationships. They interact and strengthen their community by participating

in events and frequenting local establishments. Some of these include the Beaver Valley Schools, Plain Community Church and Pantry, Plain Hardware, FIREWISE and Fire Adapted Communities (FAC), Thursday dinners, and yard sales.

2. **Natural features**: Located in the Eastern Cascade Mountains in central Washington, the rural community of Plain offers beautiful viewscapes that attract many people to the area. The forest ecosystem provides animal and plant life, trees, streams, glaciers, and trails.
3. **Rural character:** Large land lots and low population give the community a rural character. Local businesses provide services to people who seek enjoyment of natural features. Most of the land is designated as National Forest. Development is primarily along Lake Wenatchee, Fisk Lake, and transportation routes.
4. **Infrastructure:** The built and natural capitals that connects people and the environment are valued. Some important infrastructure includes fiber communication and forest trails.
5. **Year-around recreation:** The natural features of Plain provide opportunities for year-round recreational activity. Residents and visitors alike go hunting, fishing, skiing, kayaking, horseback riding, snowmobiling, zip lining, hiking, and more. Adventurers can do these activities in and around Lake Wenatchee, Fish Lake, and two state parks.

Goals

Five community goals were developed based on community values. These goals are aligned with mitigation approaches and tools. The goals are as follows.

1. Maintain a **close-knit community** through informal and formal community engagement activities at local establishments.
2. Preserve **natural features** by conserving open space and promoting environmentally friendly policies.
3. Sustain **rural character** of the community.
4. Maintain and increase **infrastructure** systems (built capitals) to enhance human well-being and safety.
5. Increase and enhance **year-round recreation** opportunities that are consistent with rural activities but that also increase economic opportunities.

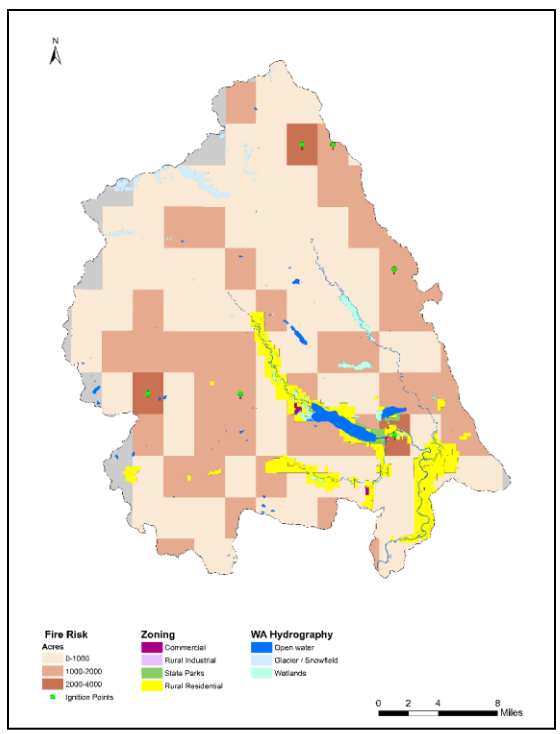


Figure 15: Baseline Map, 2020.

Round 2: Future Conditions (Four Scenarios)

Discussions

To address uncertainty, four alternative futures were presented at the June 2nd workshop. Teams were asked to come up with ways to reduce risks to the community values identified in round 1. Participants were asked to be consistent with their scenario. Participants could refine and clarify their scenarios and, in addition, all participants were encouraged to have fun with the scenarios and to put their discussions and reporting into a story context.

Risk-reduction strategies were developed for each alterative future. Strategies were defined as a collection of approaches and tools to achieve an objective. Approaches and tools are needed to implement an objective. For example, if the objective is to improve forest management, an approach may be to prevent homes from catching fire thereby diverting resources away from protecting forest ecosystem services. A supporting approach may be to require the use of fire-resistant materials. Tools are the means to achieve the approach. In the above example, a community could adopt a building code that requires homes to be built with fire-resistant materials. Example strategies include Plain enhancing forest management practices through reducing the fire risk to homes by requiring all new or substantially improved homes to be built with fire-resistant materials.

The overarching objectives driving this analysis were developed from values offered and discussed by Plain stakeholders attending the June workshop:

1. Preserve healthy forest.
2. Reduce fire risk to life and property.
3. Reduce post-fire hazards to life and property.
4. Reestablish healthy forests in burnt areas.

The following are the results from the four-team discussions. These results were the product of research undertaken by the Institute project team from value-driven material gathered from workshop notes and recordings of workshop presentations.

Scenario 1: Local Renewal

Figure 16: Thinned forest.
(Source: Fabiola Pulido, 2017)

Plain the Community:

Within this scenario, Plain’s population remains stable through 2040 and decreases after each fire and flooding event. Non-owner-occupied homes and businesses that suffered significant or total damage are not restored, reducing the number of tourists. Homeowners whose primary residence is in Plain rebuild. Moreover, without natural resources, many people feel that the area no longer provides the values that caused them to come to Plain in the first place. The remaining residents and business owners become a more close-knit community. Government agencies responsible for forest and floodplain management have limited funds to make improvements due to lower tax revenues and increased firefighting costs.

Community members are determined to work collaboratively with non-profits and government agencies to rapidly test out new approaches to sustainable living in the wildland urban interface. They rely on local knowledge to develop novel combinations for forest management. Their ability to be flexible and willingness to experiment help to rebuild and protect the community.

The Forests:

Shorter, warmer winters with fewer freezing days coupled with drier, longer, and warmer summers has contributed to wildland fire consuming three watersheds in 2040. Additional fires in 2080 consumed the forest and population centers in southeastern Plain.

There are biological legacies left, but they are stressed. For the most part, the watershed forest has not recovered. Grasses and shrubs appear each spring, but these dry quickly each year (Figure 17) Traditional forests that begin to reestablish have a difficult time adjusting to climate-induced changes. Rain has also washed away soil.

Figure 17: Flashy fuels
2014 Carlton Complex Fire, accumulation of flashy fuels from regeneration of, annual plants and grasses. (Source F.Pulido)

The Change/Hazard:

In this scenario there are increases in fuel levels result in higher risk within the Plain drainage, while associated fire risk remains in isolated locations and along river valleys. Biological legacies and associated fire risk remain in isolated locations and along river valleys.

HAZUS estimates that, for Scenario 1, about 316 buildings will be at least moderately damaged. This is over 27% of the total number of buildings in the scenario. There are an estimated 144 buildings that will be completely destroyed. This is only slightly larger than might be expected if a 100-year flood occurred today.

Table 7. Expected Building Damage by Occupancy, Local Renewal. 2080

Expected Building Damage by Occupancy		
Damage level	2020 Normal Population 100 year Flood Damage	2080 Scenario 1
Damage Level 1-10	16	12
Damage Level 11-20	49	40
Damage Level 21-30	32	35
Damage Level 31-40	36	38
Damage Level 41-50	43	47
Substantially	120	144
Total:	296	316

Flooding becomes the greater risk. Floods can result from water rushing down valleys or from water backing up river channels because of sediment blockages. In this scenario, sediment blockages occurring in the Wenatchee River damage buildings in and near the floodplain.

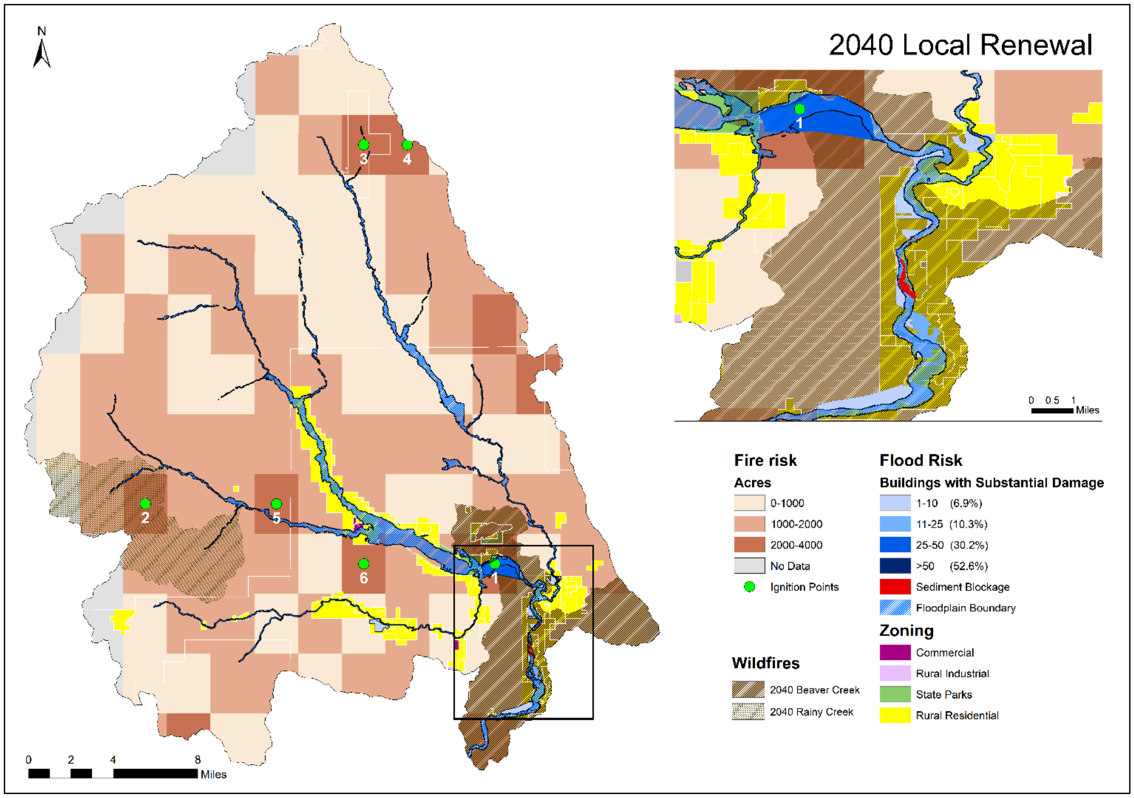


Figure 19: 2040 Local Renewal Scenario Map

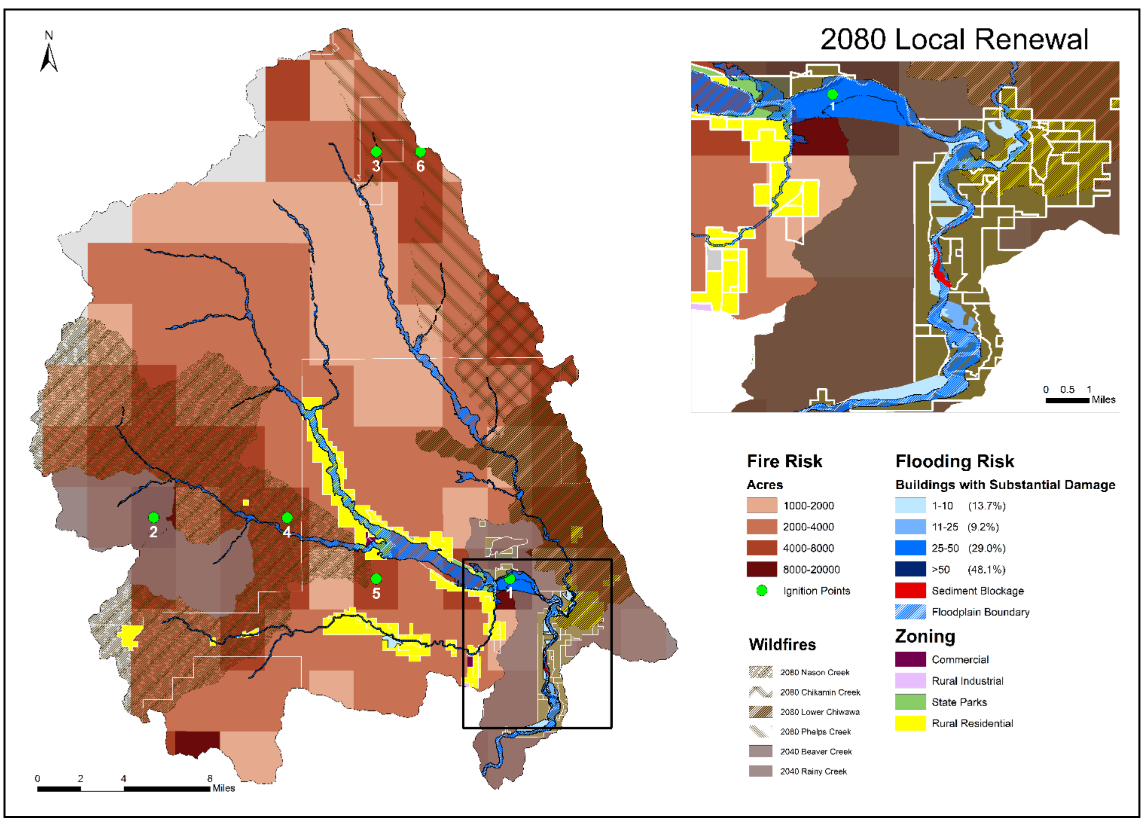


Figure 18: 2080 Local Renewal Scenario

Impacted Values:

The natural environment has changed, but there are some unburned areas (biological legacies) that can still be utilized for recreation. Recreational activities change over time to adapt to the new landscape and climate conditions. For example, more game species are attracted to grasslands, and hunting interests will increase. Although small and isolated populations of salmon may be negatively affected by the fire, resident fish species that can live in warmer waters will thrive and attract fishermen. Fires and flooding have damaged infrastructure and government agencies have been slow to address these issues. Since there is no pressure to develop, the rural character remains intact. The remaining residents become closer as they experiment with new forest management techniques.

Reduce Risk/Enhance Opportunities:

Based on community values, researchers and workshop participants developed approaches and tools for each objective within the scenario to reduce risk in the wildland urban interface.

OBJECTIVE 1: PRESERVE EXISTING FOREST		
VALUES	**APPROACHES**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Volunteer forest stewards manage remaining ecological high priority areas, including areas managed for "remembering." Fire risk reduction techniques may selectively be applied to protect some regions.
2	Increase water storage	Agricultural interests encouraged to build on-site water retention facilities. Funding may be available through the Conservation Reserve Enhancement Program (CREP)
		Volunteer forest stewards could help construct small retention/detention facilities.
2	Remove hazardous fuels	Community base organizations could collaborate with federal, state, and local agencies to gather support for prescribed burn efforts.
		Consider fuel reduction and prescribed burn efforts with state and federal funds. Need for management action. May be lower if large, high severity fire.
		State government agencies apply more resources to remove ladder fuels within high-risk areas.
		Acquire equipment needed for small scale harvesting and remove of ladder fuels. Community groups could utilize these tools.
2, 5	Limit access to high fire severity risk areas	Government agencies could regulate, monitor, and enforce limited access to high risk areas.
		Private land owners could monitor activities on their lands.
		Volunteer guides could help control access to high-risk areas.
		Restrict motorized vehicular access to high-risk areas.
5	Improve risk awareness	Tours or interpretative signage can be establish near burn areas in State Park lands and managed by volunteers.
		State Park can update the interpretive trail with new information about water storage, thinning, and limited access projects and initiatives to educate the public.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	APPROACHES	TOOLS
1, 4	Encourage the construction and maintenance of resilient properties	Provide property owners FireWise information and establish community tool lending libraries (e.g. chipper) for remodels and property maintenance.
		Establish a time bank program where residents can provide and receive resources.
1, 4	Improve fire risk awareness	Chelan County OEM and Fire Department could strengthen FAC programs.
		Neighborhood based groups could meet on regularly to share risk information as well as preparedness, mitigation, and response approaches.
		The Fire Department could provide risk information and maps through public meetings, mailers, electronic communication platforms, or signage.
1, 4	Improve response planning and capability	Government agencies could plan, train, and exercise response plans.
		Institute capital improvements to provide evacuation route alternatives.
		Volunteers could partner with government agencies to identify evacuation routes then plan, train, and exercise evacuation procedures.
3, 4	Limit development in high risk areas	Develop a strategic plan for removal of high risk properties and property reuse for risk mitigation. HMGP grants may be available to buy out properties.
		Restrict new development in high risk areas.

OBJECTIVE 3: REDUCE POST-FIRE HAZARDS TO LIFE AND PROPERTY		
VALUES	APPROACHES	TOOLS
2	Direct suppression resources to prioritize the protection of vulnerable areas.	Develop a plan that identifies vulnerable drainages and appropriate response.
		Federal, state, and local government agencies enter into an agreement with private property owners to facilitate rapid suppression responses on private property.
3, 4	Encourage the construction of resilient properties	Government requires flood proofing to higher standards for new and substantially improved structures. Less effective if large population exodus.
		Local volunteer groups could distribute information on the importance of floodproofing homes through retrofitting. The County Planning Department or Fire Department could provide materials. Less effective as response to fire event and should be thought of as preventative.
4	Improve flood risk awareness	Field trips to burnt, unburnt and biological legacies to demonstrate mitigation measures that can be applied to private property. This could provide a business opportunity for local residents.
		Utilize FEMA's Community Rating System Plan to develop and implement an emerging flood risk plan.
4	Limit development in high risk areas	Identify high flood risk areas before and after a fire; especially where flash flooding and back up from sediment laden streams can occur. Develop codes to limit development in these areas.
		Remove and/or restrict services to higher flood risk areas. Limit infrastructure improvements such as roads and utilities.
		Revise sub-division ordinance occupancy permit conditions commensurate with current and future flood risks to life and property (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).
2	Reduce water discharge in burnt areas	Volunteers place fallen trees perpendicular to the slope, leave remnant trees, create water retention ponds, etc.

OBJECTIVE 4: REESTABLISH FOREST IN BURNT AREAS		
VALUES	**APPROACH**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Government agencies and private property owners enter into an agreement to facilitate revegetation. Subsidies are a bargaining tool given sufficient tax base.
		Reestablish priority areas with volunteer support.

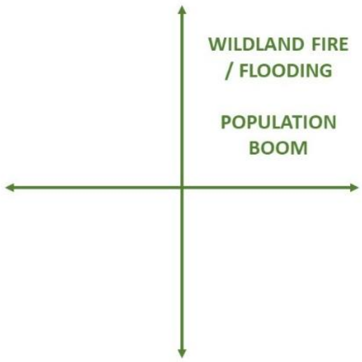


Figure 20: Carlton complex fire 2014 picture taken three years post fire.
(Source Fabiola Pulido-Chavez)

<u>Plain the Community:</u>

Despite fire and flooding events throughout the years, the population continues to increase. The population sees the decreased fire risk resulting from past burns as a benefit and more people move to the community. Chelan County is forced to update zoning codes to meet growth demands. The local economy has adapted to new climate conditions, and tax revenue is at an all-time high. Government agencies have tax revenue to spend on community stewardship programs as well as professionally driven forest and floodplain management programs. The community becomes more urbanized with more infrastructure, professional fire services, and other governmental services located in Plain. Innovative forest and floodplain management techniques have been developed to recover and adapt to hazardous threats. The community has successfully stabilized, become more connected, and transformed into something new.

<u>The Forests:</u>

Shorter, warmer winters with fewer freezing days coupled with drier, longer, and warmer summers has contributed to wildland fire consuming Beaver Creek and Rainy Creek watersheds in 2040. Nearly 51,000 acres of forest and population centers in southeastern Plain were burned. In 2080, additional fires in Rock Creek, Lower Chiwawa, Nason Creek, and Chima Creek watersheds burned over 190,000 acres.

There are biological legacies left but they are stressed. For the most part. the drainage has not recovered. Grasses and shrubs appear each spring, but these dry quickly each year and easily burn. Traditional forests that begin to reestablish have a difficult time adjusting to climate-induced changes in timing and increased rain events have led to increased soil erosion.

<u>The Hazard/Change:</u>

Spring and summer fire risks remain due to increase flashy fuels. Biological legacies and associated fire risk remain in isolated locations and along river valleys.

Flooding becomes the greater risk due to the wildfires that have occurred within the Plain watershed, and the increased sediment flow has caused sediment blockages within the Wenatchee River and its estuaries, increasing flooding in the surrounding areas and damaging buildings.

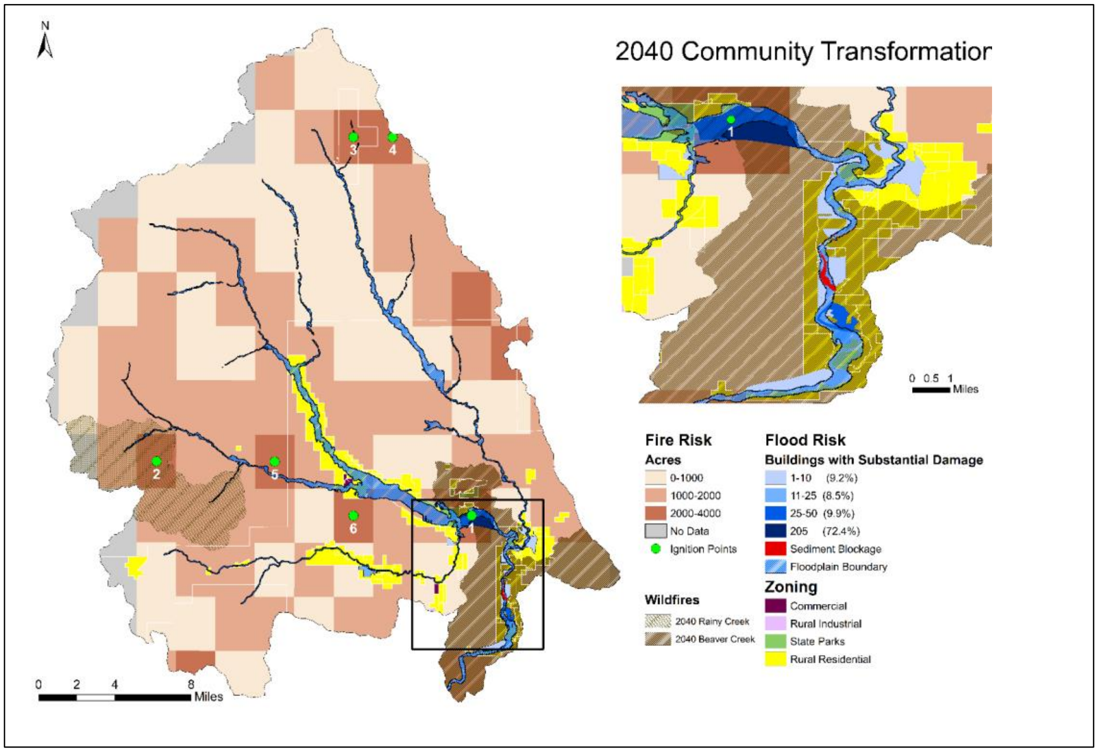


Figure 21: 2040 Community Transformation Scenario Map

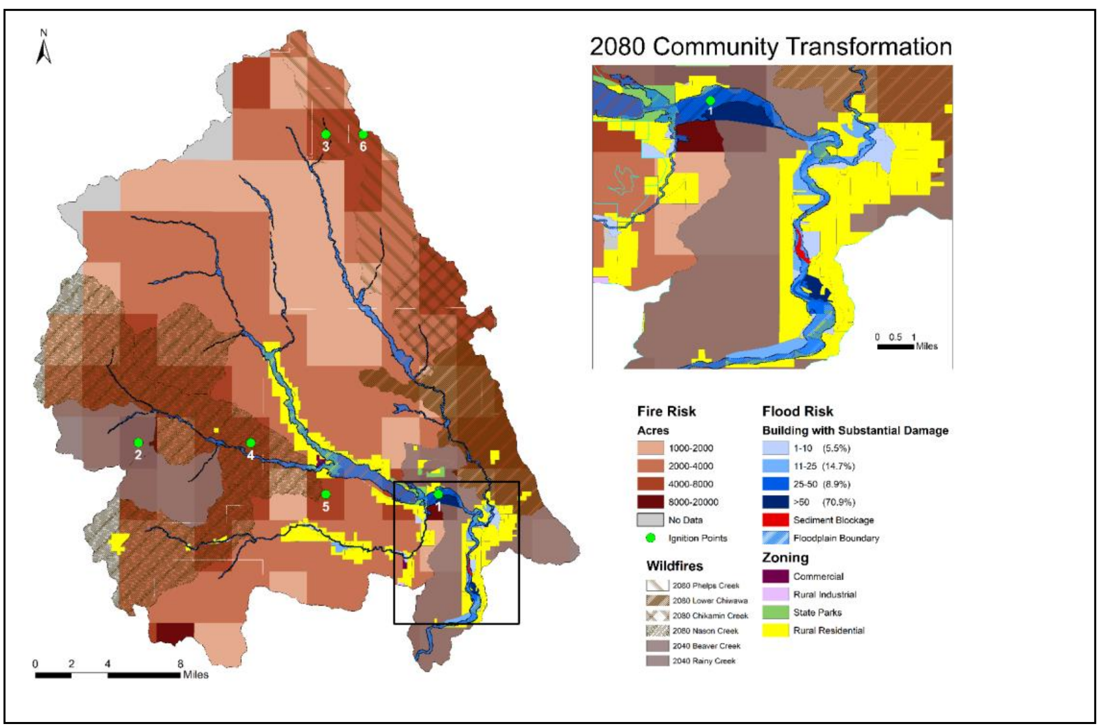


Figure 22: 2080 Community Transformation Scenario Map

Impacted Values:

The natural environment has changed, but there are biological legacies to be remembered and enjoyed, and trails to explore. Hunting has changed, with more game species such as deer that prefer grasslands, and resident fish species include those that can live in warmer waters. Some salmon populations may be susceptible to extinction in large, high-severity fires.

Rural character is diminished by population growth. Close-knit community connections are still driven by residents but assisted by government steward programs as well. More stable and connected infrastructure is developed to accommodate more residents, economic development, and visitors.

HAZUS estimates that if a 100-year flood occurred today, about 296 buildings will be at least moderately damaged. This is over 31% of the total number of buildings in the scenario. There are an estimated 120 buildings that will be destroyed. The 2080 building-related economic loss will total about 24 million dollars.

For this high-growth, extensive-burn scenario, about 1,749 buildings will be at least moderately damaged from a 100-year flooding event or a blockage within along the Wenatchee River channel. This is over 28% of the total number of buildings in the scenario. There are an estimated 760 buildings that will be completely destroyed. Economic losses may exceed $212 million.

Table 8. Expected Building Damage by Occupancy, Community Transformation, 2080

Expected Building Damage by Occupancy			
Damage Level	2020 Normal Population – 100 Year Flood Damage	2080 Scenario 2- 100 Year Flood Damage	2080 Scenario 2 – Flood Damage by River Blockage
Damage Level 1-10	16	90	100
Damage Level 11-20	49	228	231
Damage Level 21-30	32	198	199
Damage Level 31-40	36	223	218
Damage Level 41-50	43	250	250
Substantially	120	760	761
Total:	296	1749	1759

Table 9. Building-Related Economic Losses by Occupancy Types, Community Transformation, 2080

Building-Related Economic Losses by Occupancy Type ($M)			
Land Use	2020 Normal Population 100 Year Flood Damage	2080 Scenario 2 – 100 Year Flood Damage	2080 Scenario 2 – Flood Damage by River Blockage
Residential	43	198	198
Commercial	4	15	15
Industrial	0	0	0
Other	0	1	1
Total	47	212	214

Scenario 2 was thought the most likely to occur by those attending the Plain workshop.

Reduce Risk/Exploited Opportunities

Based on community values, researchers and workshop participants developed approaches and tools for each objective within the scenario to reduce risk in the wildland urban interface.

OBJECTIVE 1: PRESERVE EXISTING FOREST		
VALUES	APPROACHES	TOOLS

2	Employ approaches that support natural regeneration / explore assisted migration measures.	Local volunteer or paid forest stewards manage ecological high priority areas, including areas managed for "remembering". Fire risk reduction techniques may selectively be applied to protect some regions.
2	Increase water storage	Agricultural interests encouraged to build on-site water retention facilities. Funding may be available through the Conservation Reserve Enhancement Program (CREP) or possibly local funds. May be ineffective in absence of large, high-severity fire.
		Community-based volunteer and paid forest stewards could help construct small retention/detention facilities.
		Local funds could be used to support actions. (general revenue, Local Improvement Districts, special assessment district, a form of tax increment financing could be used to finance such activities.)
2	Removal of hazardous fuels	Community base organizations could partner with federal, state, and local agencies to gather support for prescribed burn efforts.
		Develop and execute fuel reduction and prescribed burn efforts with local, state, and federal funds.
		Acquire equipment needed for small scale harvesting and remove of ladder fuels. Tools could be utilized by community groups.
		Local government develop a revenue strategy to increase the removal of ladder fuels within high risk areas. (e.g. General revenue, creation of a taxing district, etc.)
		State governments apply more resources to remove ladder fuels within high risk areas.
2, 5	Limit access to high fire severity risk areas	Government agencies could regulate, monitor and enforce limited access to high risk areas.
		Private land owners could monitor activities on their lands.
		Volunteer guides could help control access to high risk areas.
		Restrict motorized vehicular access to high risk areas.
5	Improve risk awareness	Tours or interpretative signage can be establish near burn areas in State Park lands and managed by volunteers.
		State Park can update the interpretive trail with new information about water storage, thinning, and limited access projects and initiatives to educate the public.

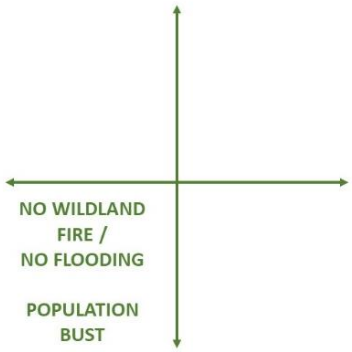
OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
1, 4	Encourage the construction and maintenance of resilient properties	Adopt higher building and subdivision codes to address new and substantially improved construction.
		Provide property owners FireWise information and community tool lending libraries (e.g. chipper) for remodels and property maintenance.
		Establish a time bank program where residents can provide and receive resources.
		Adopt green infrastructure development to increase water absorption in place.
1, 4	Improve fire risk awareness	Chelan County Office of Emergency Management and Fire Department could strengthen FAC programs.
		Neighborhood based groups could meet regularly to share risk information as well as preparedness and response approaches.
		The Fire Department could provide risk information maps of risk areas, signage, written, email or through public meeting.
1, 4	Improve response planning and capability	Government agencies could plan, train, and exercise response plans.
		Institute capital improvements to provide evacuation route alternatives.
		Government agencies will identify evacuation routes then plan, train, and exercise evacuation procedures with responding agencies and community.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
3, 4	Limit development in high risk areas	Develop a strategic plan for removal of high risk properties and property reuse for risk mitigation. HMGP grants, general funds, and tax increment financing are all potential options.
		Revise sub-division ordinance commensurate with current and future wildland fire risks (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).

OBJECTIVE 3: REDUCE POST-FIRE HAZARDS TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
2	Direct suppression resources to prioritize the protection of vulnerable areas.	Develop a plan that identifies vulnerable drainages and appropriate response.
		Federal, state, and local government agencies enter into an agreement with private property owners to facilitate rapid suppression responses on private property.
3, 4	Encourage the construction of resilient properties	Government requires flood proofing to higher standards for new and substantially improved structures.
		Local volunteer groups could distribute information on the importance of floodproofing homes through retrofitting. The County Planning Department or Fire Department could provide materials.
4	Improve flood risk awareness	Field trips to burnt, unburnt and biological legacies to demonstrate mitigation measures that can be applied to private property. This could provide a business opportunity for local residents.
		Utilize the Community Rating System Plan to develop and implement an emerging flood risk plan.
4	Limit development in high risk areas	Identify high flood risk areas before and after a fire; especially where flash flooding and back up from sediment laden streams can occur. Develop codes to limit development in these areas.
		Remove and/or restrict services to higher flood risk areas. Limit infrastructure improvements such as roads and utilities.
		Revise sub-division ordinance occupancy permit conditions commensurate with current and future flood risks to life and property (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).
2	Reduce water discharge in burnt areas	Federal and state agencies support mitigation actions (e.g. place fallen trees perpendicular to the slope, leave remnant trees, etc.)

OBJECTIVE 4: REESTABLISH FOREST IN BURNT AREAS		
VALUES	**APPROACH**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Establish local tax base to finance high priority areas.
		Reestablish priority areas with federal and state agencies along with volunteer support

Scenario 3: Local Reorganization



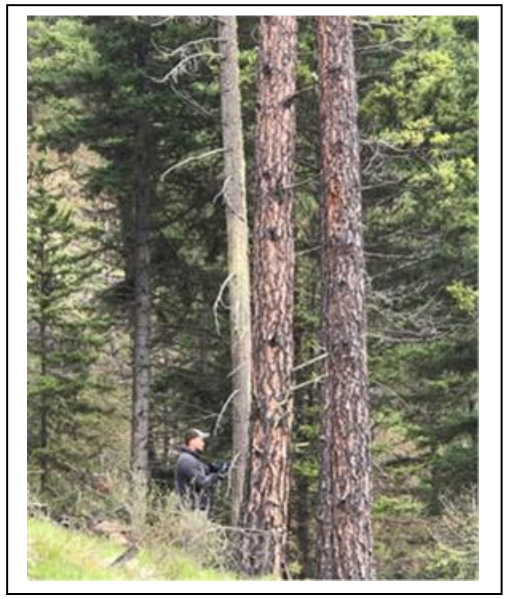


Figure 23. Over-grown ponderosa pine with mixed conifers in the understory near Liberty, WA. *(Source E. Alvarado)*

<u>Plain the Community</u>

This scenario was determined by those attending the workshop to be the least probable and in order increase participation at the more likely table discussions, participants were not assigned to develop the scenario. After the workshop the University Institute Team role played the scenario.

This scenario assumed that outside forces, supported by an increase in fire risk, result in a decrease in the population of the study area. The scenario assumes that there have been no fires within the larger Plain area through 2040 and 2080. The buildup of fuels and climate-change impacts (drier and warmer summers with an ensuing increase in insect infestation) has resulted in an extreme wildland fire risk.

Because of an awareness of the fire and associated flood risks, residents and businesses leave the area. The remaining residents become very close-knit, and there is an increased community stewardship to maintain safe properties and limit wildland fire threats. Local governmental agencies responsible for forest and floodplain management have limited funds to make improvements or direct funds to forest management due to lower tax revenue while federal and state funding for fire risk-reduction is sporadic.

Changes in population were unpredictable, but the community reorganizes its resources to improve safety in the wildland urban interface. They seek to rapidly exploit natural features of the forest to attract people back to the area and accumulate economic and social capital to retain a sustainable population.

<u>The Forests:</u>

As if a miracle, there have been no major wildland fires. The mature forests have been able to withstand changes in climate. However, with lengthening in the growing season and the lack of severe wildland fires, these forests are thick with ladder fuels and contain numerous stands of insect-infested dying or dead trees.

<u>The Hazard / Change</u>:

The risk of damaging fires is extreme. Ladder fuels have increased by 10 percent from 2020 to 2040 and from 2040 to 2080. Mechanical thinning and prescribed burning programs do not do enough to reduce fuel accumulation.

Flooding risks have not increased because of changes in post-fire-related runoff or sediment mobilization. The forests provide considerable ground cover, tempering rain intensity, stabilizing soils, and enabling greater evapotranspiration. Some increases in flooding will result from escalations in rain frequency and magnitude along with little moisture being stored as snow.

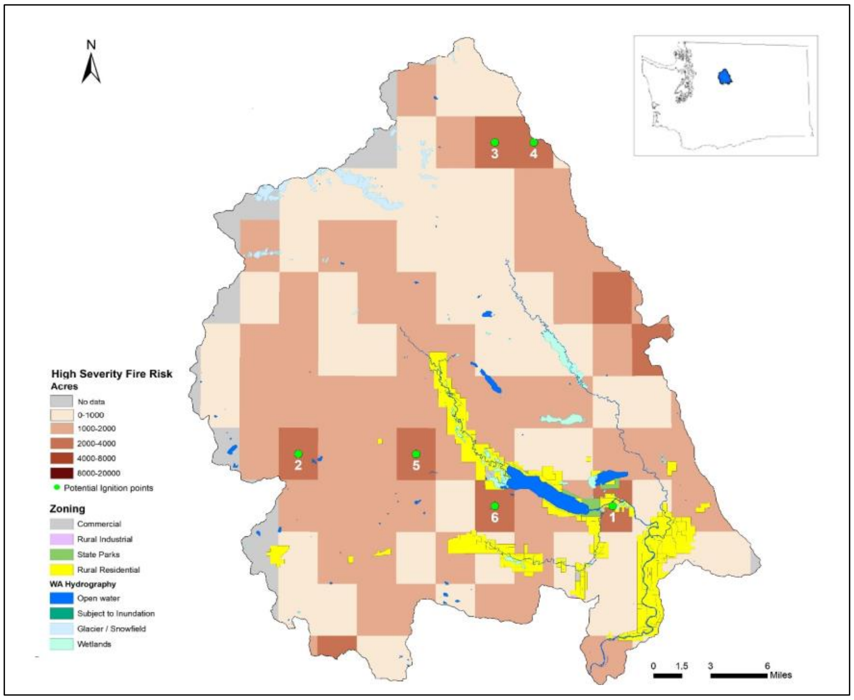


Figure 24: 2040 Increase fuels, no wildland fire, and no flooding scenario map.

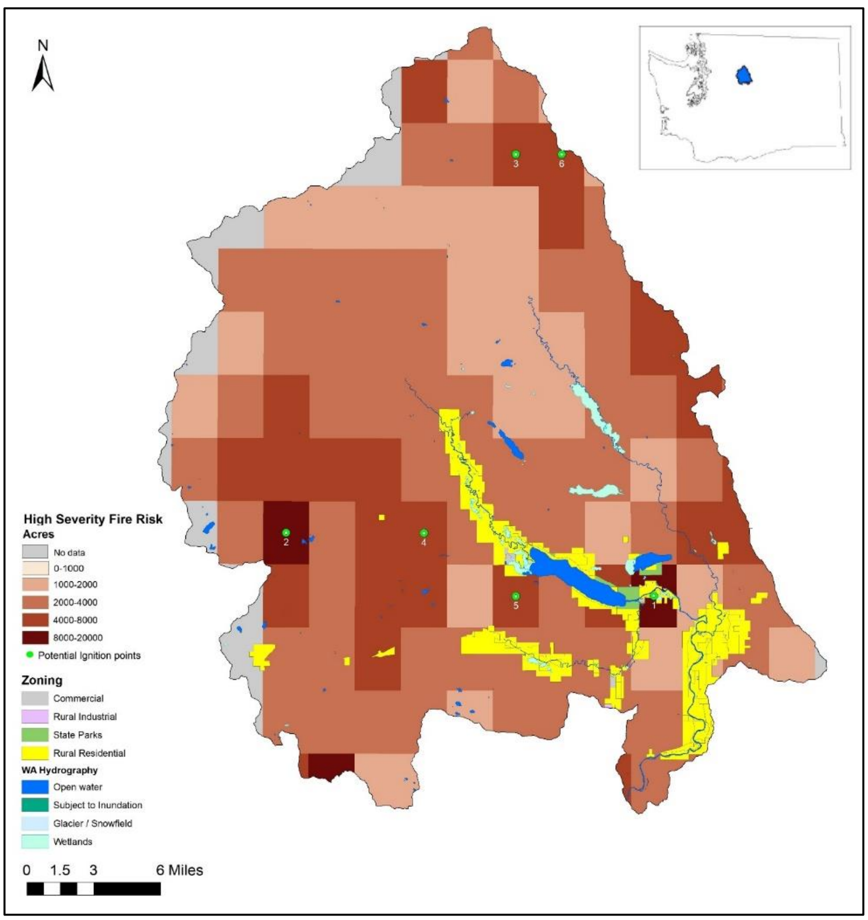


Figure 25: 2080 Increase fuels, no wildland fire, and no flooding scenario map.

Impacted value

The natural environment has not substantially changed. Forests are denser and the risk of high intensity fires is huge. There are many trails to explore. Hunting and fishing has not been drastically influenced by wildland fire, although some grassland game species may become less abundant. Community connections erode as people move away and groups need to rebuild their social networks. There might be insufficient numbers of people who have the ability and willingness to take on leadership or membership roles in community-stewardship programs. Endanger species such as the spotted owl have drastic consequence to what kind of land management actions can be implemented. The presence of the owl severely restricts what can be done.

Reduce Risk/Exploit Opportunities:

Based on community values, researchers and workshops participants developed approaches and tools for each objective within the scenario to reduce risk in the wildland urban interface.

OBJECTIVE 1: PRESERVE EXISTING FOREST		
VALUES	**APPROACHES**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Local volunteer or paid forest stewards manage remaining ecological high priority areas, including areas managed for "remembering". Fire risk reduction techniques may selectively be applied to protect some regions.
2	Increase water storage	Agricultural interests encouraged to build on-site water retention facilities. Funding may be available through the Conservation Reserve Enhancement Program (CREP) or possibly local funds.
		Volunteer and paid forest stewards could help construct small retention/detention facilities.
2	Removal of hazardous fuels	Community base organizations could partner with federal, state, and local agencies to gather support for prescribed burn efforts.
		Develop and execute fuel reduction and prescribed burn efforts with local, state, and federal funds. Need for management action may be lower if large, high severity fire.
		Establish a small diameter saw mill through a public private partnership for small scale harvesting and remove of ladder fuels. This will also generate new jobs.
		Local government develop a revenue strategy to increase the removal of ladder fuels within high risk areas. (e.g. General revenue, creation of a taxing district, etc)
		State government agencies apply more resources to remove ladder fuels within high risk areas.
2, 5	Limit access to high fire severity risk areas	Government agencies could regulate, monitor and enforce access to high risk areas.
		Private land owners could monitor activities on their lands.
		Volunteer or paid guides could help control access to high risk areas.
		Restrict motorized vehicular access to high risk areas.
5	Improve risk awareness	Tours or interpretative signage, can be establish near burn areas in State Park lands and managed by volunteers.
		State Park can update the interpretive trail with new information about water storage, thinning, and limited access projects and initiatives to educate the public.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
1,4	Encourage the construction and maintenance of resilient properties	Adopt higher building and subdivision codes to address new and substantially improved construction.
		Provide property owners FireWise information and community tool lending libraries (e.g. chipper) for remodels and property maintenance.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
		Establish a time bank program where residents can provide and receive resources.
1, 4	Improve fire risk awareness	Chelan County OEM and Fire Department could strengthen FAC programs.
		Neighborhood based groups could meet regularly to share risk information as well as preparedness and response approaches.
		The Fire Department could provide risk information and maps through public meetings, mailers, electronic communication platforms, or signage.
	Improve response planning and capability	Government agencies could plan, train, and exercise response plans.
		Institute capital improvements to provide evacuation route alternatives.
		Volunteers will partner, possibly with professional support, with government agencies to identify evacuation routes then plan, train, and exercise evacuation procedures.
1, 4	Limit development in high risk areas	Develop a strategic plan for removal of high risk properties and property reuse for risk mitigation. HMGP grants, general funds, and tax increment financing are all potential options.
		Revise sub-division ordinance commensurate with current and future wildland fire risks (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).
		Restrict subdivision of property within remaining higher risk areas at WUI.

OBJECTIVE 3: REDUCE POST-FIRE HAZARDS TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
2	Direct suppression resources to prioritize the protection of vulnerable areas.	Develop a plan that identifies vulnerable drainages and appropriate response.
		Federal, state, and local government agencies enter into an agreement with private property owners to facilitate rapid suppression responses on private property.
3, 4	Encourage the construction of resilient properties	Government requires flood proofing to higher standards for new and substantially improved structures.
		Local volunteer groups could distribute information on the importance of floodproofing homes through retrofitting. The County Planning Department or Fire Department could provide materials. Less effective as response to fire event and should be thought of as preventative.
4	Improve flood risk awareness	Field trips to burnt, unburnt and biological legaciess to demonstrate mitigation measures that can be applied to private property. This could provide a business opportunity for local residents.
		Utilize the Community Rating System Plan to develop and implement an emerging flood risk plan.
4	Limit development in high risk areas	Identify high flood risk areas before and after a fire; especially where flash flooding and back up from sediment laden streams can occur. Develop codes to limit development in these areas.
		Remove and/or restrict services to higher flood risk areas. Limit infrastructure improvements such as roads and utilities.
		Revise sub-division ordinance occupancy permit conditions commensurate with current and future flood risks to life and property (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).
2	Reduce water discharge in burnt areas	Federal and state agencies support mitigation actions (e.g. place fallen trees perpendicular to the slope, leave remnant trees, etc.)
		Volunteers or paid stewards support actions (e.g. place fallen trees perpendicular to the slope, leave remnant trees, etc.)

OBJECTIVE 4: REESTABLISH FOREST IN BURNT AREAS		
VALUES	**APPROACH**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Government agencies and private property owners enter into an agreement to facilitate revegetation. Subsidies are a bargaining tool given sufficient tax base.
		Reestablish priority areas with volunteer support

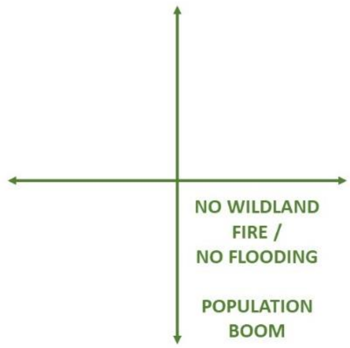


Figure 26: Prescribed burns in Winthrop. *(Source Fabiola Pulido)*

<u>Plain the Community:</u>

This scenario assumes forest fuels increase by 10 percent from year 2020 to 2040 and again from 2040 to 2080. The community may have been fortunate that there have been no burns through 2080. *However, the fire risk is significant.* The climate has changed bringing warmer, drier, and longer summers. There have been few cold periods of sufficient duration to kill insect populations. There are large stands of dead and dying trees surrounded by dry ground cover.

The community has adapted to changing climate conditions and continues to grow. They find ways to exploit natural features of the forest and attract new businesses. By 2040, the community begins to lose its rural character and, by 2080, the community has shifted from a rural to an urban character, with more infrastructure, professional fire services, and other governmental services located in Plain. Without any major events, the local government is focused on growing the economy, updating zoning codes to accommodate development, and implementing reactive forest-management policies.

Local government is focused on emergency preparedness and response, and less on forest management adaptation. Where fire risks have been reduced, it is largely because human development has removed vegetation (combustible fuels) and replaced these fuels with less volatile materials (buildings and infrastructure). Wildland interface development has increased, and the value of isolated, large lot parcels are more prized despite the fire danger. At the same time, there is a desire to protect the rural character by allowing development to extend further into the forest. The community is stable and connected, but vulnerable to external shocks such as wildland fire and flooding.

<u>The Forests:</u>

As if a miracle, there have been no major wildland fires. The mature forests have been able to withstand changes in climate. However, with lengthening in the growing season and the lack of severe wildland fires, these forests are thick with ladder fuels and contain numerous stands of insect invested dying or dead trees.

The hazard/change

The risk of damaging fires is extreme. Forest biomass increases have increased by 10 percent from 2020 to 2040 and from 2040 to 2080. Mechanical thinning and prescribed burning programs do not do enough to reduce fuel accumulation.

Flooding risks have not increased because of changes in post-fire-related runoff or sediment mobilization. The forests provide considerable ground cover, tempering rain intensity, stabilizing soils, and enabling greater evapotranspiration. Some increases in flooding will result from escalations in rain frequency and magnitude along with little moisture being stored as snow.

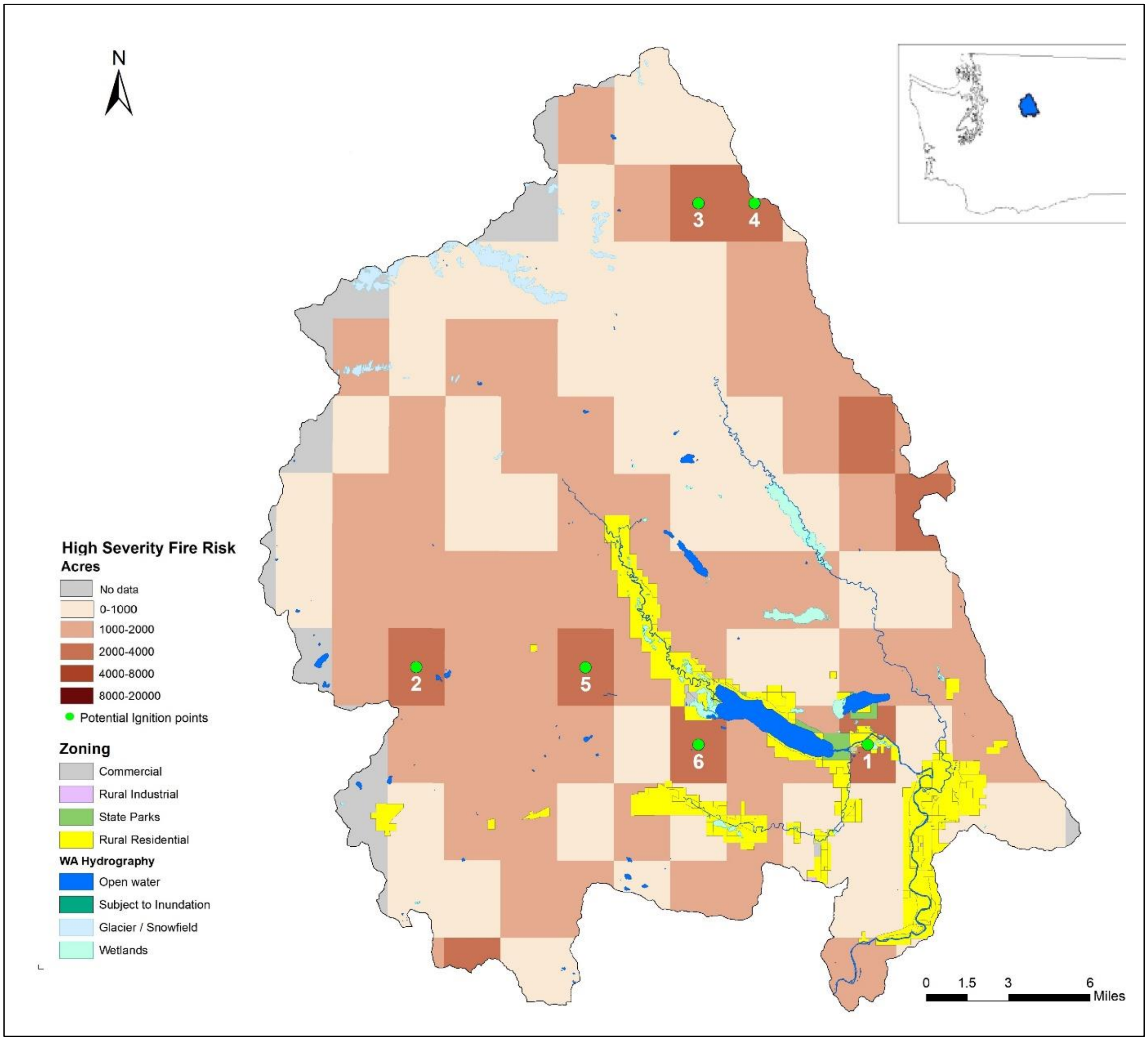


Figure 27: 2040 Increase fuels, no wildland fire, and no flooding scenario map

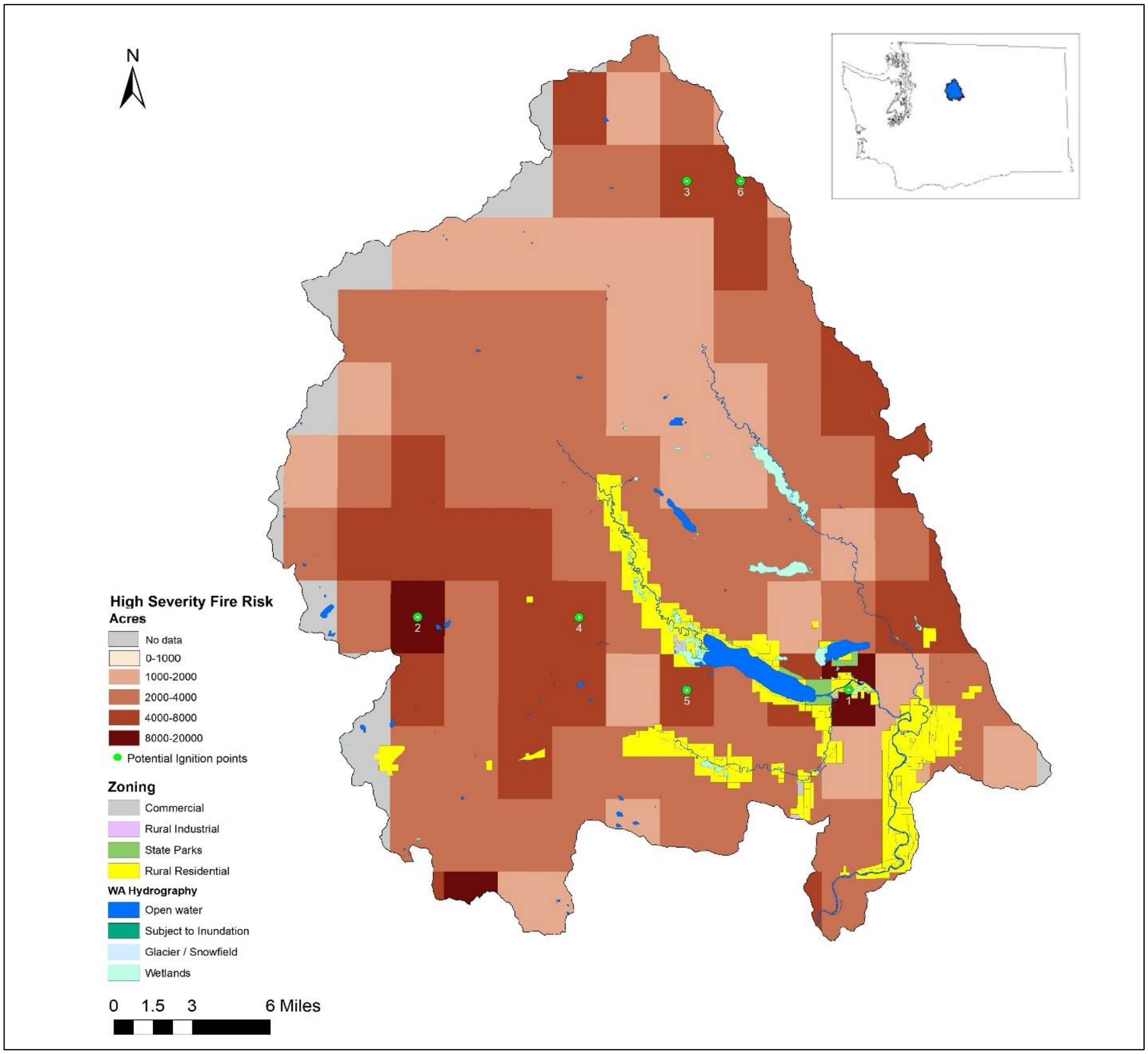


Figure 28: 2080 Increase fuels, no wildland fire, and no flooding scenario map

The natural environment has been significantly altered due to the increase in fuels. Consequently, the Plain watershed is at risk of severe wildfires.

Hunting and fishing is largely uninfluenced by wildland fire with the exception of slight reductions in some game species that favor grassland habitat.

The rural character of the community has been diminished by the population growth. Close-knit community connections are still driven by residents but are assisted by government-steward programs. More stable and connected infrastructure is developed to accommodate the increase in population, visitors, and economic development.

Reduce Risk/Exploit Opportunities:

Based on community values, researchers and workshops participants developed approaches and tools for each objective within the scenario to reduce risk in the wildland urban interface.

OBJECTIVE 1: PRESERVE EXISTING FOREST		
VALUES	**APPROACHES**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Local volunteer forest stewards manage ecological high priority areas, including areas managed for "remembering Fire risk reduction techniques may selectively be applied to protect some regions.
2	Increase water storage	Agricultural interests encouraged to build on-site water retention facilities. Funding may be available through the Conservation reserve Enhancement Program (CREP), but may be ineffective in absence of large, high-severity fire.
		Community-based volunteer forest stewards could help construct small retention/detention facilities. These management strategies may be unnecessary in absence of large, high-severity fire.
		Local funds could be used to support actions. (general Revenue, Local Improvement Districts, special assessment district, a form of tax increment financing could be used to finance such activities.)
		Update codes to require green infrastructure implementation to retain water in place. This is effective when natural landscapes are removed for development.
		Update codes to require green infrastructure implementation to retain water in place. This is effective when natural landscapes are removed for development.
2	Remove hazardous fuels	Community base organizations could collaborate with federal, state, and local agencies to gather support for prescribed burn efforts.
		Develop and execute fuel reduction and prescribed burn efforts with state and federal funds.
		Establish a small diameter saw mill through a public private partnership for small scale harvesting and remove of ladder fuels. This will also generate new jobs.
		Local government develops a revenue strategy to increase the removal of ladder fuels within high risk areas (i.e. General revenue, creation of a taxing district, etc.)
		State government agencies apply more resources to remove ladder fuels within high-risk areas.
2, 5	Limit access to high fire severity risk areas	Local and State government could regulate, monitor and enforce access to high-risk areas.
		Private land owners could monitor activities on their lands.
		Volunteer guides could help control access to high-risk areas.
5	Improve risk awareness	Tours or interpretative signage can be establish near burn areas in State Park lands and managed by volunteers.
		State Park can update the interpretive trail with new information about water storage, thinning, and limited access projects and initiatives to educate the public.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
1, 4	Encourage the construction and maintenance of resilient properties	Adopt higher building and subdivision codes to address new and substantially improved construction.
		Provide property owners FireWise information and community tool lending libraries (e.g. chipper) for remodels and property maintenance
		Establish a time bank program where residents can provide and receive resources.
		Adopt green infrastructure development to increase water absorption in place.
1, 4	Improve fire risk awareness	Chelan County OEM and Fire Department could strengthen FAC programs.
		Neighborhood based groups could meet regularly to share risk information as well as preparedness and response approaches.

OBJECTIVE 2: REDUCE FIRE RISK TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
		The Fire Department could provide risk information and maps through public meetings, mailers, electronic communication platforms, or signage.
1, 4	Improve response planning and capability	Government agencies could identify evacuation routes then plan, train, and exercise evacuation procedures with community.
		Government agencies could plan, train, and exercise response plans.
		Institute capital improvements to provide evacuation route alternatives.
3, 4	Limit development in high risk areas	Develop a strategic plan for removal of high-risk properties and property reuse for risk mitigation. HMGP grants may be available to buy out properties.
		Revise sub-division ordinance commensurate with current and future wildland fire risks (consider increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).
4	Remove hazardous fuels	Restrict subdivision of property within WUI.

OBJECTIVE 3: REDUCE POST-FIRE HAZARDS TO LIFE AND PROPERTY		
VALUES	**APPROACHES**	**TOOLS**
2	Direct suppression resources to prioritize the protection of vulnerable areas.	Develop a plan that identifies vulnerable drainages and appropriate response.
		Federal, state, and local government agencies enter into an agreement with private property owners to facilitate rapid suppression responses on private property.
3, 4	Encourage the construction of resilient properties	Government requires flood proofing to higher standards for new and substantially improved structures.
		Local volunteer groups could distribute information on the importance of floodproofing homes through retrofitting. The County Planning Department or Fire Department could provide materials.
4	Improve flood risk awareness	Field trips to burnt, unburnt and biological legacies to demonstrate mitigation measures that can be applied to private property. This could provide a business opportunity for local residents.
		Utilize the Community Rating System Plan to develop and implement an emerging flood risk plan.
4	Limit development in high risk areas	Identify high flood risk areas before and after a fire; especially where flash flooding and back up from sediment-laden streams can occur. Develop codes to limit development in these areas.
		Remove and/or restrict services to higher flood risk areas. Limit infrastructure improvements such as roads and utilities. This tool can be Less effective if large population exodus.
		Revise sub-division ordinance occupancy permit conditions commensurate with current and future flood risks to life and property (consider: increasing minimum size of eligible parcels, decreasing density and allowing used commensurate reducing wildland stresses to the resource).

OBJECTIVE 4: REESTABLISH FOREST IN BURNT AREAS		
VALUES	**APPROACH**	**TOOLS**
2	Employ approaches that support natural regeneration / explore assisted migration measures.	Establish local tax base to finance high priority areas.
		Reestablish priority areas with federal and state agencies along with volunteer support

Community Review and Comment Process

One month after the workshop, a draft report was sent to the community for review and comment. Workshop participants were given one month to review the draft report and send back comments. In addition, participants were sent a survey to flush out conflicting values and future scenario predictions as well as to rank approaches and tools. The comments were reviewed by researchers and incorporated where appropriate.

Round 3: Strategies

Commonalities apparent from all scenarios

Emerging Forest Fire Cycle:

1. Forests will produce hazardous fuels.
2. Small forest fires will be suppressed, contributing to ladder fuel concentrations.
3. Forest fires will increase in severity, reducing post-fire regenerative processes.
4. These regenerative processes will be further stressed by expected changes in climate:
    a. Warmer, wetter winters
        i. Insect populations survival increased
        ii. Water storage reduced with reduced snow pack
        iii. Greater water velocity in drainages – increases in soil and nutrient mobilization
    a. Earlier spring
        i. Timing if natural processes changed – sprouting of new growth, arrival of germinators
    b. Longer, drier summers
2. Succession processes not progressing beyond grasses and shrubs (this cycle and resulting change in the risk profile was not fully realized at the time of the workshop):
    a. Wetter, warmer winters will increase production of first successional generation plants.
    b. Long, hot summers will dry these fuels resulting in increases in flashing fuel fires.
    c. Because of this the change in the fire regenerative cycle forests will have difficulty reestablishing.
3. This cycle will be further compromised as it is washed way, and is not being rebuilt or replaced.

Major Themes

When assessing all scenarios, several themes emerged that were common to each of the four scenarios.

1. Increases in wildland fire risks can be expected (without significant human intervention) and risks will continue over the long term (2080). The risk for wildfires will still be present after significant burns. This is because climate change will most likely result in wetter, shorter, and warmer winters leading to the grown of flashy fuels (greases and shrubs). The longer and drier summers increase the likelihood of fires and more frequent flashy wildland fire events.
2. Burnt forests will not regenerate as has occurred historically. Without extensive human intervention, soil will be mobilized following high intensity fires, and with high-severity soil burns, as previously mentioned, the establishment of more traditional forests will be difficult.
3. Post high intensity fires will remove seed sources and nutrients including beneficial microorganisms. Forests experiencing these stresses coupled with future climate conditions have experienced reduced forest regenerative capabilities. Such a reduction has led to extensive soil mobilization. And for many forested areas these will be permanent.

Reducing both the potential for high intensify and high-severity wildfires and the lack of post-fire regeneration is possible, but it will require significant resources. Consequently, it might require redirecting resources from protecting human settlement to protecting ecosystem services. One solution is implementation of fire-adaptive practices within the settlement.

Risk Reduction Approaches Common to All Scenarios

Preserve healthy forest

Institutionalizing proactive and sustainable ecosystem management practices is critical for preserving healthy forests. To protect vulnerable critical forests and forest segments, governmental agencies could employ mechanical and prescribed burns to thin or harvest dense forests in and around WUI. This would also enhance defensible space and overall community safety. Governmental agencies could also enter into a public-private partnership to start a new small-diameter mill to increase jobs for local people and harvesting of ladder fuels.

Harvesting the dense forest means that if a fire occurs, the WUI community is safe, and wildfire suppression can be strategically redirected to vulnerable forested areas and its surroundings. Vulnerable critical resources would include critical watershed, biological legacies, and erodible soils within critical drainage. Post-fire forest rehabilitation for soil erosion and flood control are important in reducing subsequent risks. Implementing hill and channel treatments by volunteers or professional staff would reduce these risks of landslides and mudflows downslope.

The biological legacies are significantly important for forest regeneration, wildlife maintenance, and health, and recreational purposes. Unfortunately, anthropogenic fires are a significant source of concern. Consequently, recreational limitations within these biological legacies must be implemented to reduce fire risk. Government agencies could limit access to high-risk fire areas during dry summer months, until the risk decreases. Prohibiting motorized vehicles within the remnant forest and preventing the development of new trails can limit the number of visitors, while signage on present trails can help educate the visitors about fire dangers.

Reducing fire risk to life and property

Supporting strong, sustainable local-community capacity and capabilities can reduce fire-damage costs (Fire Adaptive Community practices). More importantly, it is vital for the maintenance of the values expressed by those attending the Plain workshop to have resilient forests, and this is only possible if resources can be diverted away from our built environment to removing the stresses to our natural environments.

Below are some tools to help enable a more fire adaptive and flood tolerant community.

1. **Develop higher codes and ordinances:** can have a great impact where growth is occurring. These tools can**:**
    - Facilitate ignition-resistant construction, defensible space, adequate access/egress, etc.).
    - Restrict land subdivision to protectable areas as a condition of land division that do not stress ecosystem services.
    - Provide higher flood protection standards than are normally required by the National Flood Insurance Program (NFIP).
2. **Provide retrofitting incentives:** can promote Firewise standards where there is little growth and police powers are not generally effective. These can include:
    - Government-subsidized loans through public-private partnerships.
    - Provide technical support.
    - Provide incentives to retrofit structures to Firewise standards or higher NFIP regulations.

3. **Increase local capacity:** train volunteers in Firewise and Fire Adapted Communities Programs, wildland fire-response capabilities, Ready, Set, Go! Programs, etc. Volunteer stewards could:
    - Create defensible space/Home ignition zones for neighbors.
    - Trim trees and remove ladder fuels around critical landscapes and built facilities**.**
4. **Devise evacuation routes** to facilitate the rapid and orderly evacuation of residents in the event of a wildland fire incident.
5. **Identify and maintain fire and flood safety zones** within predesignated locations, adjacent to the community where residents can safely assemble in the event of a wildland fire incident.
6. **Collaborative partnerships:** as needed to initiate and sustain a Fire Adaptive Community (FAC) initiative within the community.

Pathways that would reduce choices of future actions

There are actions that have little lasting impact. A small isolated fire, the burning of an insured home where the occupants found safe refuge, the construction and subsequent restoration of a logging road, and an isolated beaver-dam break are examples of events that can have little lasting impact. But some actions make permanent change and can lead to lasting and irreversible adverse impacts. Below are those identified directly within the context of the four alternative futures discussion or from research emanating from such discussions.

1. **Increase the fire risk to life and property**
    - <u>Subdivide high-risk properties</u>: Once land has been legally subdivided, it sets the stage for development, which is very difficult to reverse. Fragmented properties, land at the tops of slopes, within forested areas, along natural wind corridors, within areas without reliable water sources or access, lacking the availability of professional, paid suppression capability, poor accessibility for large fire trucks, homes without a defensible space, dead forest caused by beetles or drought, near powerlines—these are particularly difficult to defend.
    - <u>Improved and maintenance of access to at-risk forests</u>. Roads (and other services) providing access to vulnerable forests, especially those that are publicly owned and maintained, can encourage WUI development.
2. **Increase the flood risk to life and property**
    - <u>Subdivide at-risk areas.</u> Legal subdivisions lead to development. This is the intent of subdividing the land. It is to set the stage for development but, as mentioned above, once platted, the use becomes very static, and the assemblage of platted land and the removal of development becomes very expensive. At-risk areas change and do not recognize plat maps. Chelan County is participating in the National Flood Insurance Program and accordingly requires sub-divisions of land to recognize flood hazards and the development within these subdivisions to construct flood resistance structures. However the regulating document is the FEMA Flood Insurance Rate Maps (FIRM), which does not reflect future conditions. Post-fire flood risk will change the flood hazard dramatically regardless of the location of platted parcels. There are opportunities for homes to be retrofitted to accommodate the new risk, once the risk has been identified, but this, too, is expensive and may not be possible if the nature of the risk does allow for on-site alterations as would be caused by avulsions, high-water velocities, and extensive large debris.
    - <u>Improved at-risk properties</u>. As set above, the platting of land stabilizes the land uses, but also, once a property has been improved, it is very expensive to alter or remove the improvement. If a flood risk area is developed and equity is reduced, it is difficult for owners to assemble the capital required to abandon and raze at-risk development
3. **Stress forest health**

- Occurrence of large high-severity fires. Once a large fire occurs, the forest is altered on the long term. This sets the stage for a new adaptive cycle that may not ever (or at least within the lifetime of existing stakeholders) recover, especially under a climate-change scenario.
- Suppression efforts not directed to the protection of vulnerable resources. Vulnerable at-risk ecosystem services could include watersheds vital to a community water supply, landslide risk areas, slopes with erodible soils, and forests vital to endangered populations.

4. **Inhibit sustainable forest regeneration within burnt areas**
   - Allowing sediment to be mobilized.
   - Allowing significant increases in deer, elk, and cattle. These grazers can prevent the successional processes.

Survey

In July we sent extensive notes describing what we had gleaned from the workshop. These notes included issues mentioned directly or inferred from our workshop notes. Only two attendees responded, both favorably. We followed with individual emails and phone calls when agreed.

With this feedback, we were fairly confident that issues of concern were being addressed.

To make certain, however, and after taking to a local representative, we thought it best that we send a short questionnaire to all those invited to the Plain workshop.

Twenty questionnaires were sent and six responses were received. All returned questionnaires were from those that had attended the workshop. Four of the six respondents lived or owned a business in Plain. This response represented a little less than one-half of the attendees. However, the results were in line with the strategies being considered addressed their values.

Questions:

1. Values may conflict with population growth – There was an acceptance of the benefit of increased regulation.
2. Confine growth - All but one respondent would confine growth to protectable areas (where police, fire, and public services can get to easily) or allow for large lots to be divided into smaller lots and adopt strong building codes to reduce fire risk (e.g., use fire-resistant building materials, require on-site water sources, adopt Firewise approaches, etc.)
3. Recreation opportunities involve access to the forest – With increasing fire risk, respondents saw a need to control access to vulnerable forests.
4. Managed access - Four respondents would prevent or control hikers, hunters, and recreational seekers from entering high fire-risk forest areas. Access could be resumed after fire risks are lowered (i.e., communities can lower fire risk through controlled burning, manual thinning of trees, and constructing water ponds, etc.)
5. Flood risks will greatly increase following fires – Having better flood-risk maps was seen as important and most all felt that these maps should reflect future conditions, although several respondents felt that these maps should only be advisory and not keyed to increased regulation.
6. Building codes reduce fire risk – All felt the need for stricter fire reduction codes; however, about one-half of these respondents did not feel the codes should be triggered by the passage of time. All felt there was a need for local public funding to help offset the costs of complying with higher codes and approved of public support for individual self-help, home retrofitting efforts.

Conclusions

Plain can preserve, and even enhance, their community values despite the uncertainties involved. There are actions that would achieve benefits for a variety of futures. And there are paths Plain can take that would increase their options to address change. They have the capability.

The main challenges are to construct a built environment that would enable the protection of the forest landscape and to prevent and or limit soil erosion. To accomplish this, more resources must be diverted from protecting human settlement to protecting, maintaining, and regenerating healthy forests. This will only be possible if residents greatly reduce their vulnerability to built-capital and implementing proven Firewise and Community Fire Adaptive (CFA) measures.

Uncertainties

The community of Plain may grow or lose population.

The surrounding forests may survive through 2080 with limited high intensity fires and minimal flooding, and minimal soil loss. This alternative future, with few wildland fires, seems beneficial, but the lack of fires without any forest management will only worsen the severity of future fires and the area burned. Consequently, the effects on the landscape can be permanent and we increase the risk of reverting from a forested landscape to a grassland and/or shrubland with long lasting consequences on soil and hydrology.

This study examined four alternative futures, driven by three trajectories – wildland fire, flooding, and changes in population growth.

1. **Local Renewal:** population decreases following major fires and flooding events;
2. **Community Transformation**: population increases despite major fires and flooding events;
3. **Local Reorganization:** population decreases (due to outside forces) as fire and flooding threats increase, but no major events occur; and,
4. **Reactive Management:** population increases as fire and flooding threats increase, but no major events occur.

These alternatives assumed little corrective human intervention and described futures that would compromise strongly held community values. Natural processes would be stressed, along with straining supporting infrastructure. These scenarios reflected a Plain community that would be less safe from wildland fires and flooding risks. The desired rural character would be less attractive and the rate of recreational opportunities would be limited.

Addressing Uncertain Futures

Enhancing or at least maintaining community values regardless of the future was the challenge of this research. Each future discussed presents different challenges to the values expressed by community stakeholders. However, there are approaches that would help enhance and maintain these values regardless of the specific future realized. Below are the main approaches offered.

1. **Protect our settlements:** First and foremost, Plain must create a fire-adaptive community. This means that the community must embrace tried and true risk-reduction measures. Not to institute these measures would not only place landowners at risk, it would cause suppression and rehabilitative resources to be diverted from protecting the forest and related ecosystem services. It would be denying future generations the opportunity to enjoy the forest and appreciate the values current stakeholders currently enjoy.

2. **Adopting proactive codes**: Structures within the current floodplain will remain flood prone under each of the explored four futures. However, flooding will likely be more frequent and flood-prone lands will be more extensive. Floodplain maps can be prepared that reflect and regulate these future conditions without adding extensive costs to new homes. This is true for post-fire Scenarios 1 and 2. Scenarios 3 and 4 describe pre-wildfire/flood conditions where extensive storage is available. However, less water will be stored as snow and ice as the climate warms and the risks of extremely high intensity fires are huge.
3. **Not increasing the risk**: There are actions that not only increase the current risks, but limit the choice of applicable future risk-reduction actions. The community can offset these risks by implementing soil erosion techniques, decreasing access to vulnerable areas, and restricting the approval of unprotectable subdivisions of land and occupancy in vulnerable areas.
4. **Eliminating the possibility of high intensity, severe fires:** Fires are a part of natural fire regime, but extremely high intensity fires significantly alter the land, inhibit regeneration, and contribute to a permanent forest loss. This report discusses a variety of approaches to help mitigate the potential for high intensity and high-severity fires, such as mechanical thinning and prescribed burning, and direct fire-suppression efforts in protected forested areas.
5. **Directing suppression efforts to protecting forest health**: Diversion of resources from built communities can increase suppression efforts of vulnerable forested landscapes, such as vulnerable hillsides, rivers, and estuaries.
6. **Applying extensive post-fire rehabilitation efforts:** Soil must be kept in the forest. Post-fire rehabilitation approaches include soil immobilization treatments such as hillslope stabilization techniques, including straw mulching and applying contour log structures. Channel treatments are also required to protect water quality and wildlife; such treatments include streambank and channel protection
7. **Experiment with new approaches:** We are entering a new normal with historical references offering insufficient guidance. Experimentation is needed. As an example, reforestation practices need to consider the potential for assisted species migration, the physical movement of tree species beyond their range, where deemed necessary.
8. **Monitor practices:** With a changing climate, we are entering uncharted terrain; as such, monitoring, research, and assessment are vital elements of being resilient.

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Appendix A: First Steering Committee Meeting Participant List

First Steering Committee Meeting
Location: Chelan County Public Works Department
Date and Time: January 13, 2017; 10:30 AM – 12:30 PM

NAME	ORGANIZATION	POSITION/ROLE
Mike Cushman	Cascadia Conservation	
Katherine Rowden	NWS	
Jason Detamore	Chelan County Public Works	Director
Annie Schmidt	Washington FAC	
Joe Lange	USDA Natural Resources Conservation Services (NRCS)	
Bob Freitag	University of Washington	Co-Principal Investigator
Ernesto Alvarado	University of Washington	Co-Principal Investigator
Lan Nguyen	University of Washington	Research Assistant

Appendix B: Second Steering Committee Meeting Participant List

Second Steering Committee Meting
Location: Lake Wenatchee Fire District #9, Station #91, 2196 Lake Wenatchee Highway
Date and Time: April 28, 2017; 11:00 AM - 12:30 PM

NAME	ORGANIZATION	POSITION/ROLE
COMMUNITY MEMBERS		
Deb Newell	Firewise Plain	Community Leader, Business Owner, Resident
Doug Pedeleton	Ponderosa Community Club	Community Leader, Resident
GOVERNMENT/NON-PROFIT ORGANIZATON		
Jason Detamore	Chelan County Public Works	Director
Mick Lamar	Lake Wenatchee Fire and Rescue	Fire Chief, Resident
Patrick Haggerty	Cascadia Conservation District	
Annie Schmidt	Washington FAC	
FEMA CONTRACTORS/RESEARCHERS		
Ernesto Alvarado	University of Washington	Co-Principal Investigator
Bob Freitag	University of Washington	Co-Principal Investigator
Lan Nguyen	University of Washington	Research Assistant
Harry Podschwit	University of Washington	Research Assistant
Fabiola Pulido	University of Washington	Research Assistant

Appendix C: Workshop Participant List

Workshop
Location: Lake Wenatchee Fire District #9, Station #91, 2196 Lake Wenatchee Highway
Date and Time: 9:00 AM – 3:00 PM

NAME	ORGANIZATION	POSITION/ROLE
COMMUNITY MEMBERS		
Bob Jennings	FAC	Community leader
Mary Long	Homeowner	Resident
Deb Newell	Firewise/FAC Plain	Community leader, Business Owner, Resident
GOVERNMENT/NON-PROFIT ORGANIZATON		
Diane Blake	Cascade Medical	
Nolan Brewer	Department of Natural Resources	
Jason Detamore	Chelan County Public Works	Director
Rick Halstead	WA State Parks	Resident
Patrick Hagerty	Cascadia Conservation District	
Mick Lamar	Lake Wenatchee Fire and Rescue	Fire Chief
Nancy Smith	Leavenworth Chamber	Director
Bill Moffat	Lake Wenatchee Fire and Rescue	Firefighter, Resident
Dave Saugen	Tall Timber	
Annie Schmidt	Washington FAC	
FEMA CONTRACTORS/RESEARCHERS		
Ernesto Alvarado	University of Washington	Co-Principal Investigator
Bob Freitag	University of Washington	Co-Principal Investigator
Wendy Freitag	University of Washington	Assistant
Lan Nguyen	University of Washington	Researcher
Harry Podschwit	University of Washington	Researcher
Fabiola Pulido	University of Washington	Researcher

Appendix D: Wildfires as Drivers

Data

Given the importance of burn area and severity to environmental impacts, two ecosystem models were constructed for each fire characteristic. The Monitoring Trends in Burn Area Severity (MTBS) databases (https://www.mtbs.gov) were used to calculate the total burn area and percentage burned severely, hereafter PBS. The events were filtered to include named large (>1000 acres) wildfire events occurring in the Okanogan-Wenatchee National Forest, between 1984-2010, resulting in dataset of 40 large wildfire events. A set of ten independent variables was used in the model selection process that included six weather variables, three temporally invariant variables, and a fuel quantity variable. The six weather variables included specific humidity, wind speed at 10 m, seasonality, departure from normal, annual precipitation totals, and bi-annual precipitation totals. Seasonality measured intra-annual temperature patterns, being negative in the winter months and positive in the summer. Seasonality was calculated as a temperature anomaly referenced by historical measurements from all months at a particular location. In addition to seasonality, temperature was also measured using departure from normal. Departure from normal was simply temperature anomaly referenced by temperature measurements specific to the month of the observed data. Departure from normal was then negative when a given month was particularly cold and was positive when it was warmer than average. Precipitation totals were calculated at 12- and 24-month durations. All weather data were at a monthly time scale and came from the University of Idaho MetData program (https://climate.northwestknowledge.net/METDATA/). The temporally invariant variables included elevation, latitude, and longitude. Fuel levels were described using zonal statistics of median forest biomass measurements over the same grid as the weather data (Blackard et al. 2008).

Model fitting and selection

Two ecosystem models were developed for both the final burn area and PBS fire characteristics. Models were fit in a generalized linear model framework, where the logged and thresholded burn area data was modeled using a log-link and gamma response, and the PBS with a logit-link and beta response. Using the set of 10 independent variables an initial set of 32 potential models was considered. The 32 models contained all linear combinations of the weather variables constrained such that it included at least one temperature variable, 1 precipitation total, and the biomass variable. The model was further constrained so that no more than 5 variables are used to prevent overfitting. These constraints generated a model that predicted increased fire risk in response to changes to temperature precipitation, and fuel levels.
Model selection was performed using Monte-Carlo Cross-validation (Xu and Liang 2001). The performance of each of the 32 models was determined by repeatedly splitting the dataset into equal sized training and testing set. The testing set was used to fit the model and the testing set was used to test the performance. The burn area models were selected to minimize the average multiplicative loss,

$$\boldsymbol{s}_{BA} = \sum \ln(\boldsymbol{x_{obs}}/\boldsymbol{x_{pred}})^{\mathbf{2}}$$

and the PBS models were selected to minimize the average log-log loss.

$$\boldsymbol{s}_{PBS} = \sum \mathbf{log}\,(\log_{x_{obs}}(x_{pred}))^{\mathbf{2}}$$

The resulting model responded to climactic changes in an intuitive manner. Burn area was predicted to increase when 12-month precipitation totals were low, temperatures were unusually warm, and forest biomass was high. Similarly, PBS was predicted to increase when 24-month precipitation totals were low, temperatures were unusually warm, in high-biomass, and high-elevation forests. All statistical calculations were performed in the R programming environment (Harry Podschwit MS Thesis)

Climate change and large, high severity fires

Both ecosystem models were used to estimate the effect of climate change on both fire characteristics. This was done by directly applying the ecosystem models to regional downscaled weather data generated from 13 GCM models: bcc-csm1-1-m, BNU-ESM,CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-ESM2M, HadGEM2-ES365, inmcm4, IPSL-CM5A-MR, MIROC5, MRI-CGCM3, NorESM1-M . Final burn area and PBS estimates were then calculated along three factors: time, emission scenario, management scenario. The time factor included three levels corresponding to the years 2020, 2040 and 2080. The carbon scenario factor included two levels, one for the RCP45 scenario, and another for the RCP85 scenario. Lastly, the forest management scenario included three levels, one with present day fuel levels, one with a 10% increase in forest biomass, and another with a 10% decrease in forest biomass. Fire risk was quantified by calculating the area burned severely, where (ABS=PBS*BA). The quantity was calculated across all factors and the total risk was measured by averaging across climate models and months by taking the multi-model annual average.

References:

Blackard, J.A., M.V. Finco, E.H. Helmer, G.R. Holden, M.L. Hoppus, D.M. Jacobs, A.J. Lister, G.G. Moisen, M.D. Nelson, R. Riemann, B. Ruefenacht, D. Salajanu, D.L Weyermann, K.C. Winterberger, T.J. Brandeis, R.L. Czaplewski, R.E. McRoberts, P.L. Patterson, R.P. Tymcio (2008) Mapping U.S. forest biomass using nationwide forest inventory data and moderate resolution information. Remote Sensing of Environment

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R Development Core Team (2008) R: A Language and Environment for Statistical Computing. Available at: http://www.R-project.org

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Appendix E: Projecting Post-Wildfire Flooding Exposure & Vulnerability

Plain, WA

HAZUS-MH 3.2

Non-technical Description:

HAZUS-MH is a geospatial software modeling program developed by FEMA that is used to assess risk for different natural disaster scenarios, including flood, earthquake, hurricanes, and tsunami. To estimate the damages caused by flooding to a particular community, HAZUS-MH needs three layers/ variables: the buildings in the community, a layer showing the depths of the floodwater in the community, and formulas that apply the depth of the water to the types of buildings found in the community.

The building layer, or general building stock, for Plain, WA and the surrounding environment was created using Chelan County tax assessor data and loaded into the HAZUS-MH model. Using up-to-date tax assessor data allows HAZUS-MH to have the most accurate account of buildings in the area, which helps when estimating flood damages.

The flood layer affecting Plain was generated using the HAZUS-MH Flood module Hydrology and Hydraulics process. This process uses the local topography of the area and then estimates flood depths based on the amount of water flowing in the local rivers and streams, or discharges. The discharge input into the HAZUS-MH model was calculated by the University of Washington Institute for Hazard Mitigation Planning and Research. These discharges took into account the regular flood risk but also the estimated increased risk posed by excessive wildfires in the Plain region in the near future. The final product is called a flood-depth grid. A total of five depth grids were created for this project to account for the different flood–following-fire scenarios in 2020, 2040, and 2080.

HAZUS-MH has formulas built into the software called depth-damage curves that take the depth of floodwaters and then apply it to different types of buildings to estimate structure and content damages, as well as an estimate of displaced people and amount of short-term sheltering needed. By combining the general building stock, flood-depth grids and depth-damage curves, HAZUS-MH was used to estimate present and future risk of flooding following wildfire in Plain, Washington.

Technical Description / Methodology:

1. Generating Discharge Numbers to input for HAZUS-MH
    a. Initial 100-Year Discharge numbers taken from most recent effective Flood Insurance Study for Chelan County: 530015V000B Effective 9/30/2004. Base 100-year discharge numbers were taken for the Wenatchee River at the Plain Gage (34,100 peak cfs, 591 sq miles of drainage area).
    b. 2040 and 2080 100-year discharges were calculated by adding additional flows from wildfire burned areas calculated by University of Washington Institute for Hazard Mitigation Planning and Research. These discharges were calculated into year-equivalents using a logarithmic scale based on 10-, 50-, 100-, and 500-year flows for the Wenatchee River at Plain, WA for easier HAZUSs input. The combined discharges for the 2040 depth grid were equivalent to a 120-year flood, and the 2080 depths grids are equivalent to a 160-year flood.
2. Updating CDMS with General Building Stock
    a. Generate General Building Stock for Study Region
        i. This process was already completed through previous work for Chelan County. It involves matching tax assessor data with parcel data and then using building footprints, address points, and parcel centroids to create a GIS layer of every structure in the study area with best available building characteristic data formatted into HAZUS-ready input. Where no data were available, HAZUS defaults were used (Slab on Grade foundation, .67 feet FFE, etc.).
        ii. Three different building stocks were generated based on population growth of the scenarios: base year/low growth was current building stock. High-growth building stocks in 2040 and 2080 were doubled to match population projections. The maximum population growth in 2080 was used to create the maximum building stock, using quadruple the base-year building stock, to match projections.
    b. Import into CDMS
        i. Using the pre-formatted study region building-stock data, use the CDMS tool to import aggregate building data based on which kind of population scenario you will be running. This is accomplished by matching relevant fields in CDMS tool – building cost, flood-structure type, first floor elevation, etc.
3. Running the HAZUS-MH Model
    a. Creating study region
        i. Generate study region using census-tract level of aggregation that matches watershed boundaries for Plain, WA. The watershed boundary level of HAZUS is too large, and the census tracts follow the predetermined study region for the most part.
        ii. Check in the aggregated building inventory menu to see if the import data properly reflects that population scenario being run.
    b. Generating Depth Grids
        i. Create DEM mosaic that will be used for H&H model.

        1. HAZUS first needs a DEM of the local topography to create a flood model. In this case, speed is of the essence. Trial runs with 10-meter and 30-meter resolutions for the whole study region concluded in the USGS NED 30m dataset being used. While not ideal for site-specific analysis, the 30-meter data will generate a depth-grid good enough for preliminary analysis.
        2. To minimize artifact errors, download the 30M NED data directly from the USGS website, use GIS process mosaic to new raster to create one raster file of the correct projection (generally NAD 83 UTM) and resolution. HAZUS cannot do this on its own. The fewer artifacts when stitching together the DEM, the better the resulting flood-depth grid.
    ii. Use the HAZUS H&H module to generate a stream network for the study region.
        1. I used a stream network drainage area of 10 sq.miles: that level of sensitivity generated reaches for all the main streams and tributaries in the Plain region.
    iii. Using the previously calculated discharge numbers/year intervals, use the HAZUS H&H algorithm to generate depth grids for the study region. Sometimes the H&H can "act a little crazy" using flat-return periods if the stream doesn't have proper discharge numbers from the NHD built into the program. Using the generated stream network, there were a couple streams that generated results "flowing up the mountain" in absurd depths; fortunately, they were pretty isolated.
        1. Using ArcGIS, it was easier to edit the depth-grid polygon boundary to the "realistic" flooding areas around each stream, then clip the output rasters to match those, resulting in better depth grids.
        2. To ensure conformity across scenarios, use mosaic to new raster and the "MAXIMUM" blend setting to ensure the 2040 depth grid is always at least equal to or higher than the Base year flood, and that the 2080 scenario is at least equal to or higher than the 2040 depth grid.
    iv. For blockage scenarios, add the water depths to the appropriate depth grids. All the depth grids generated by HAZUS generally covered with higher depths all the blockage rasters, so while this process isn't ideal (using flow regulators or altering the DEM would be better, but time consuming), it will suffice for preliminary analysis.
  c. Using Depth Grids for Scenarios
    i. Based on the population scenario and year, import the proper depth grid into the study region created by HAZUS.
4. Output Results
  a. Export results from HAZUS into Crystal Reports – Global Summary for submission to UW.
  b. Backup scenario file .hprs.
5. Areas for improvement:
  a. Generate discharge changes for each stream reach instead of stream as a whole.
  b. Generate depth grids using higher resolution DEM.
  c. Add blockage scenarios using flow regular or modified DEM.
  d. Update general building stock to reflect future land use and zoning changes.

e. Instead of general building stock, use User-Defined Facilities analysis, so each structure is analyzed instead of the aggregate at the census block level.

Appendix F: Workshop Meeting Notes

Plain Fire / Flooding Workshop Meeting Notes

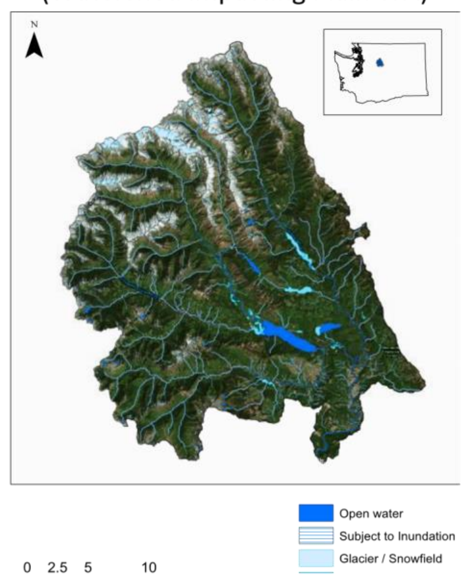
(For those who attended the June 2nd workshop as well as interested parties, please review and send comments to Michael Godfried: Godfried@uw.edu)

Request: We are encouraging you to comment on the following document.

Workshop Description

On Friday, June 2, the University of Washington Institute for Hazards Mitigation project team conducted a workshop at the Lake Wenatchee Fire and Rescue District Office in Plain, Washington. The workshop was funded by the Federal Emergency Management Agency (FEMA).

Project Area
(Watershed impacting Plain WA)



Plain was selected as the project area because it is growing, has an existing fire risk, and will be impacted by flooding following a forest fire event. The workshop intent was to determine wildland fire and flooding impacts and long-term adaptation measures.

The workshop used storytelling to help participants to come up with fire and flood risk reduction measures for alternative future scenarios. These future conditions included two time horizons, 2040 and 2080. Participants identified community values, objectives, and adaptation measures that could be successful for these scenarios.

They also identified processes that would reduce the likelihood of future actions (path dependencies).

Alternative Futures

Four scenarios were presented at the workshop. Plain's future is uncertain. To address this uncertainty, the Institute project team identified two drivers that could have significant future impacts. The drivers outside the community include wildland fire and the ensuing flooding. The drivers inside the community include population growth. The resulting four alternative scenarios for the future include:

1. **Local Renewal:** population decreases following fires and flooding events.
2. **Community Transformation:** population increases despite major fires and flooding events.
3. **Reactive Management:** population increases as fire and flooding threats increase but no major fire events occur.

4. **Local Reorganization:** population decreases (due to outside forces) as fire and flooding threats increase but no major fire events occur.

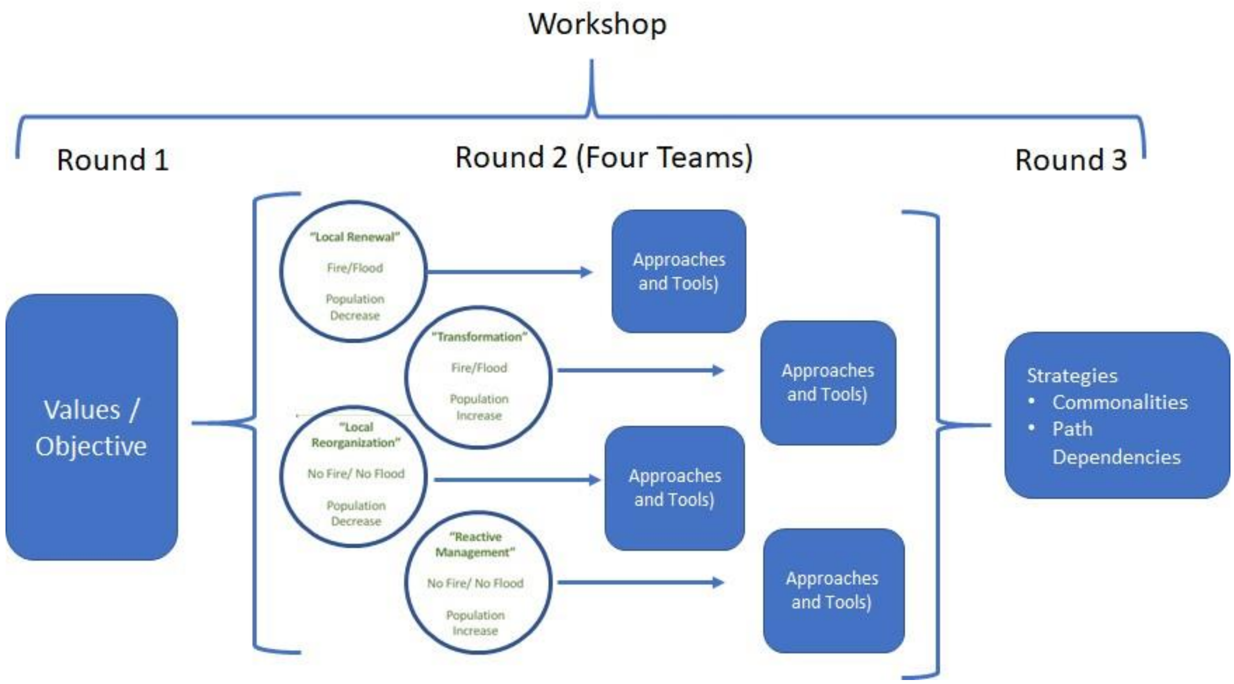
Rounds of Play:

The workshop consisted of three rounds of activities:

Round 1 - Participants defined what they valued, and what goals and objectives supported their values. These were used to assess the merits of all subsequent activities.

Round 2 - Participants worked in one of four teams. Each team worked on a future scenario and suggested approaches and tools that support community values. Within this round of play, teams rotated in a "World Café" fashion. This allowed the other teams to comment on all the scenarios.

Round 3 - Teams identified risk reduction recommendations common to the scenarios and identified path dependencies.



Round 1: Community Values and Direction

During Round 1, participants, as a group, were asked to identify what they valued in Plain and what things were responsible for these values. They were also asked what could be improved and to offer future objectives that would support these values and correct deficits.

Values include their close-knit sense of community. The community is strong because they get together at many events and local establishments. They also valued being out in nature – the mountains, forests, rural character, trails, hunting, and fishing that provide year-round recreation. They enjoyed sharing this way of life with family and friends.

Improvements include the need for better forest management practices, principally fuel reduction. There was a desire for more full-time owner occupied residents, and several people mentioned the need for affordable housing. The community could also benefit from greater employment opportunities. Plain could use more trails, including a dedicated bike lane to Leavenworth. Needed road improvements would provide better emergency response. Participants also want more support for local businesses. Lastly, there is a need for a greater awareness of the risks from fires and flooding.

Objectives that support these values and improvements are:

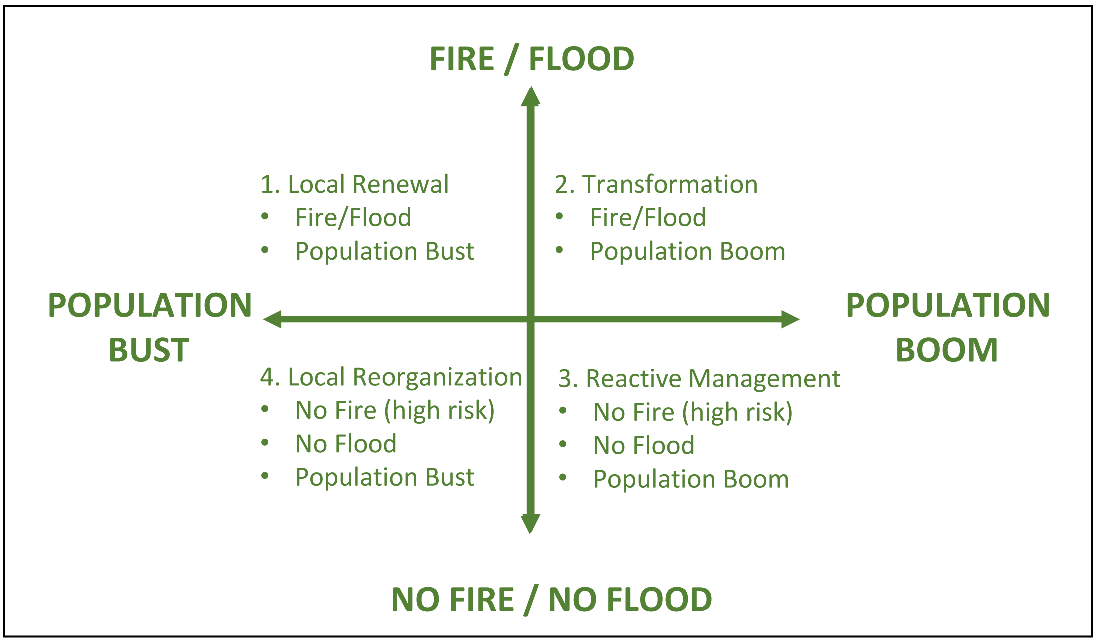
1. Encourage more full-time residents and affordable housing.
2. Support local business (conflict – most services support tourism).
3. Improve employment opportunities.
4. Increase local/county awareness of flood risks.
5. Better forest management and restoration of natural hydrology.
6. Limit wildland interface development to mitigate flood and fire risk.
7. Maintain rural character with large lots.

8. Prepare and exercise wildland fire response plans.

Round 2: Develop Strategies for Four Alternative Futures

The objective of Round 2 was for participants to suggest ways their community values could be maintained within the context of a given future scenario. Participants were encouraged to create a story of the future that was consistent with the assigned scenario and to also have fun.

At the start of Round 2, participants were assigned to one of four scenario teams for each alternative future condition (Local Renewal, Community Transformation, Reactive Management, and Local Reorganization). Each scenario was the result of two drivers. One driver is population growth with the associated changes to rural character. The other driver is risks from fire and the ensuing floods.



Growth and Corresponding Changes in Community Character

As reflected by the current Census, Plain is as follows:

- Population (2,833)
- Housing Units (2,452)
- Land capacity (6,317 housing units)
- Rural character

Scenario 1 (Local Renewal) and **Scenario 4** (Local Reorganization): Plain characteristics change to reflect the following by <u>2040</u> with the trend increasing further by <u>2080</u>:

- Population decreases
- Housing units decrease
- Land capacity exceeds demand

- Rural character

Scenario 2 (Transformation) and **Scenario 3** (Reactive Management): Plain characteristics change by 2040 to reflect the following (the model used will be described in the final report):

- Population increase to (3,586)
- Housing Units (4,948)
- Land capacity based (6,317 housing units)
- Rural character

Scenario 2 (Transformation) and **Scenario 3** (Reactive Management) Plain characteristics change by 2080 to reflect:

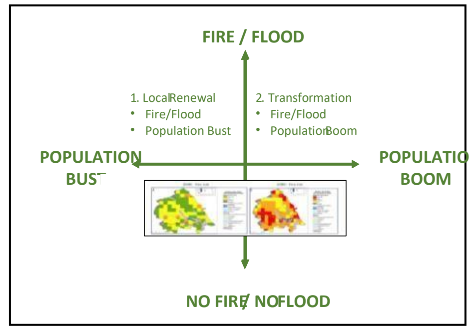
- Population (5,108)
- Housing Units (20,151)
- Zoning changes to meet housing demand
- Urban character (change from rural)

Fire and Flood Risks

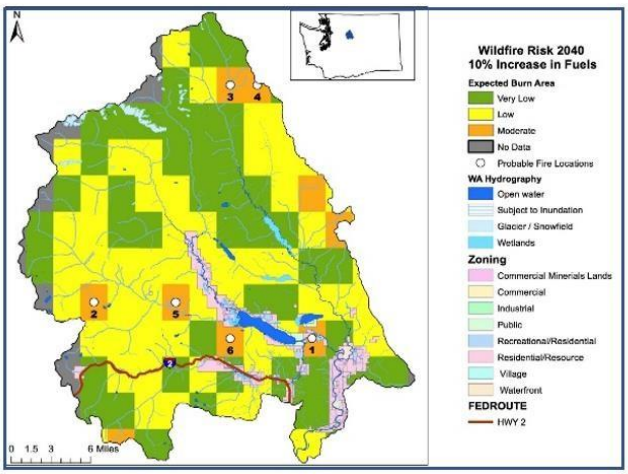
The fire driver required the development of estimates of future fire conditions. (The model used will be described in the final report.) Given fuel accumulations, changes in climate, and insect infestation, the following fire projections were developed for 2040 and 2080. These projections were used to drive discussion of **scenario 3** and **scenario 4**. They reflect a pre-wildland fire-event condition where the wildland fire risk is high by 2040 and extreme by 2080. There are no related flood risks because the land cover remains as forest. Therefore, surface water discharge and sediment mobilization rates have not changed.

Futures Reflecting a Pre-burn Condition - Scenarios 3 (Reactive Management) and 4 (Local Reorganization).

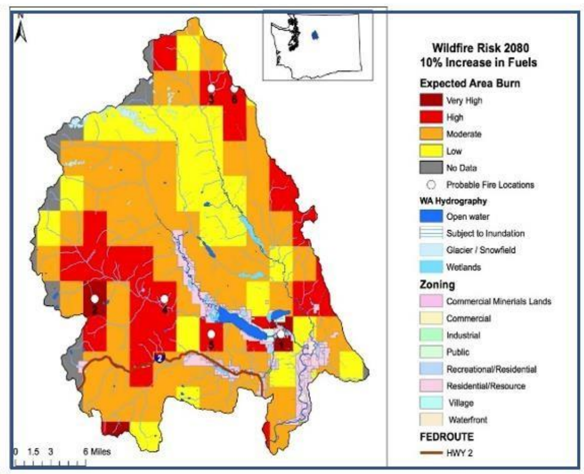
Scenario 3 (Reactive Management) and **Scenario 4** (Local Reorganization) reflect burnt conditions. Both scenarios assumed that a fire has occurred within the higher-risk areas. Some of the areas burnt by 2040 and more by 2080. It also assumes that the areas burnt in 2040 have not substantially recovered by 2080.



2040: Fire risk



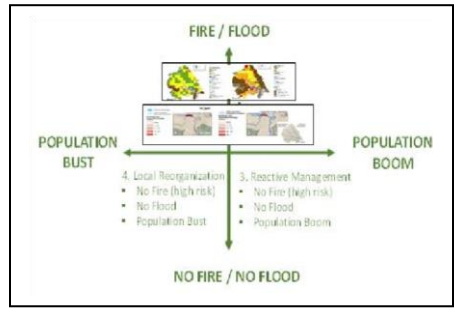
2080: Fire risk

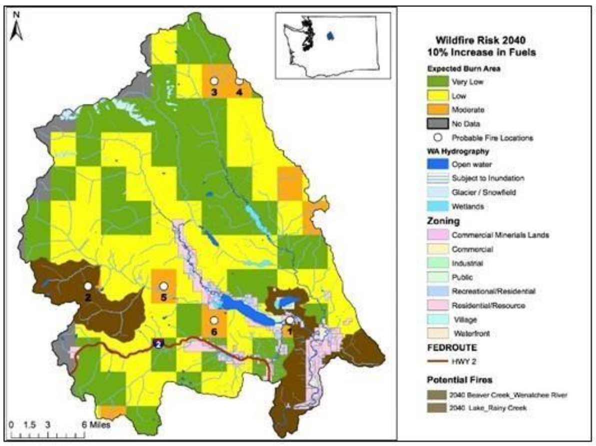


Maps reflect high risk areas along with areas that have the high probability of burning before for 2040 and 2080

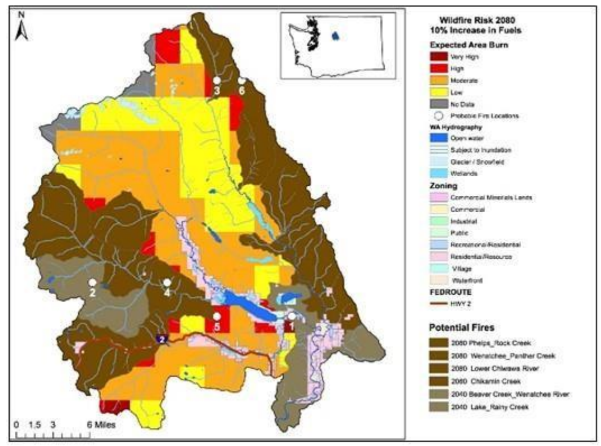
Futures reflecting a <u>Post-burn</u> condition - Scenarios 1 (Local Renewal) and 2 (Transformation).

Scenario 1 and **scenario 2** are more complex. Both assume fire has occurred in the higher-risk areas.





2040 - Fire Risk and Areas Burnt



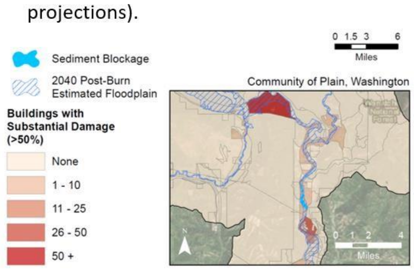
2080 Fire Risk and Areas Burnt

Maps reflect high risk areas and areas that would have most like burnt before for 2040 and 2080

Scenario 1 (Local Renewal) and **Scenario 2** (Transformation) also reflect flood areas. Floods follow fire as surface-water discharges increase and sediment collects in streams and rivers. The following identifies probable flooding areas. The flooding is caused by water running off the surrounding slopes caused by sediment blocking the Wenatchee River.

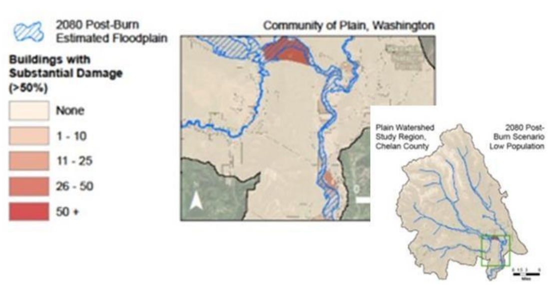
Flood from Blockage

Areas flooded from sediment blocking channel. In 2080 it estimated that about 750 homes will be flooded. (Estimate includes 2080 growth projections).



Flooding from a 100yr Storm

Areas flooded from increased discharges. In 2080 about 350 homes could be flooded from a 1% flood. (Estimated include 2080 growth projections.



Round 2: Future Conditions (Four Scenario) Discussions

To address uncertainty, four alternative futures were presented at the June 2nd workshops. Teams were created to come up with ways to reduce risks to the community values identified in round 1. Participants were asked to be consistent with their scenario. Participants could refine and clarify their scenarios. Participants were encouraged to have fun with the scenarios and to put their discussions and reporting into a story context. Strategies were developed from notes gathered at the workshop. These strategies were assessed through a SWOT analysis. The following are the results from the four team discussions.

Strategies

Risk Reduction strategies were developed for each alterative future. **Strategies** were defined as a collection of **approaches and tools** to achieve an objective.

Approaches and tools are needed to implement an objective. For example, if the objective is to prevent homes from catching fire, one approach may be to require the use of fire-resistant materials. Tools are the means to achieve the approach. In the above example, a community could adopt a building code that requires homes to be built with fire-resistant materials.

The **strategy** in the above example could be: Plain will reduce the fire risk to homes by requiring all new or substantially improved homes to be built with fire resistant materials.

SWOT Analysis

Strategies were developed for the approaches and tools offered for each alternative future. The Institute project team evaluated each strategy for **s**trengths, **w**eaknesses, **o**pportunities, and **t**hreats. This is referred to as SWOT analysis.

SWOT analysis helps to identify internal factors (inside the community) and external factors (outside the community). These factors can have a positive or negative impact on the proposed strategy.

- **Strengths** (internal): characteristics of the strategy that give it an advantage over others
- **Weaknesses** (internal): characteristics that place the business or project at a disadvantage relative to others
- **Opportunities** (external): elements in the environment that the strategy could exploit to its advantage
- **Threats** (external): elements in the environment that could cause trouble for the strategy

The identification of SWOT items are important and can help evaluate a strategy. First, decision-makers should consider whether the strategy is achievable given the SWOT analysis. If the strategy is ***not*** achievable, different objectives, approaches, or tools may be needed.

Users of SWOT analyses must ask and answer questions that generate meaningful information for each category (strengths, weaknesses, opportunities, and threats). Doing so makes the analysis useful and helps users to find what strategies work best.

Four Alternative Future Scenarios

<u>Scenario 1:</u> Local Renewal - Population decreases following fire and flooding events.

The **"Local Renewal"** scenario assumed extensive fuel accumulation and increases in average temperature due to longer, warmer, and drier summers. There would be major fires before 2040 and again before 2080. Flooding would also result from sediment blocking rivers and streams and increased discharges. These threats would cause many current residents to leave the area and Plain's population would decrease by 2040 and further in 2080.

Workshop participants expanded their **"Local Renewal"** story with the following:

- Following each fire, people and businesses leave the area for safer locations. Without natural resources, many people felt that the area no longer provided the values that caused them to come to the Plain in the first place.
- The remaining residents would become a more close-knit community with an increased feeling of stewardship and willingness to maintain what remained of the natural environment.
- Government agencies responsible for forest and floodplain management have limited funds to make improvements due to lower tax revenues and increased firefighting costs.

Strategy: The objective is to maintain a close-knit, rural community with opportunities to enjoy nature and to maintain a place where family members enjoy visiting. The following is needed:

- <u>Moderate emphasis on emergency-response plan when entering remaining high-risk areas or when these areas burn:</u> This acknowledges that many of the higher-risk areas have burnt and no longer represent a similar severe risk. Safety will rely on community-initiated preparedness (mostly through enhanced warning).
- <u>Maintain remaining natural resources:</u> Resources would not be available for larger-scale mitigation efforts. Residents would have to lobby for approaches that increase resiliency in the remaining forests. Rehabilitation would have gains outside of those remaining in Plain.

- <u>Lobby for government action:</u> A smaller population might reduce the political power of the remaining residents. However, an argument can be made that the whole state benefits from protecting Plain's remaining residents and forests.

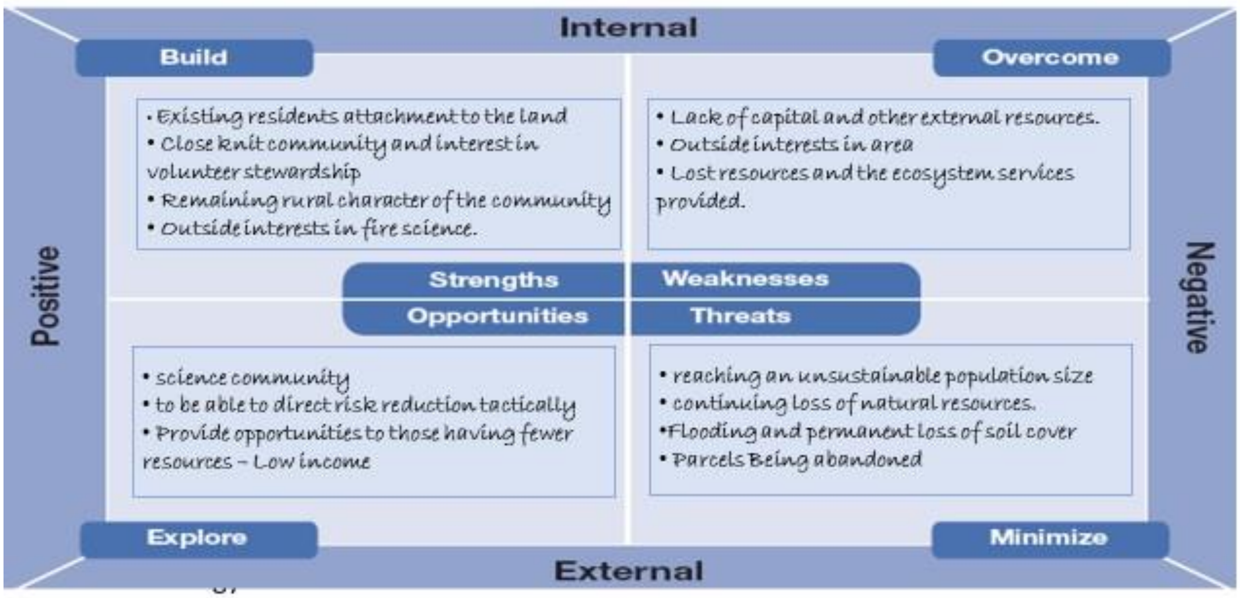
Approaches and tools mentioned at the workshop. The suggestions offered below were discussed by workshop attendees. The following items, along with related measures, address the community values and are being further researched:

- **Wildland fire risk reduction discussion**. (The risk of future wildland fires is greatly reduced within scorched areas):
    - <u>Targeted risk reduction</u>*:* Fire-adaptive management, because of limited funds, will be performed on a tactical basis. For example, residents perform thinning of ladder fuels on a time-available basis.
    - <u>Volunteer support:</u> Longer-term mitigation measures are the responsibility of volunteer resident teams created to perform specific risk-reduction tasks. These tasks include implementing emergency-response plans and manually reducing ladder fuels for specific targets.
    - <u>Residents remaining:</u> Many residents who lived within the larger Plain community (now incorporating large burn areas) left because the area no longer provides the valued natural amenities. Homesteads may be abandoned.
    - <u>Volunteer retrofits:</u> Those living in interface areas continue to remain within these high-risk areas. These resident volunteers improve or retrofit their sites and apply Firewise approaches.

- **Flood** (flood risk increasing):
    - <u>Warning and Response</u>*:* Flood-risk reduction for this scenario is pretty much restricted to warning and response. Residents keep alert for signs of flooding.
    - <u>Flood proofing:</u> Some residents within higher flood-risk areas retrofit their home, but most will have to wait for a government buyout.
    - <u>Increasing flood protection standards has little impact:</u> Increasing NFIP requirement would have little effect where new development or substantial improvements are not occurring.

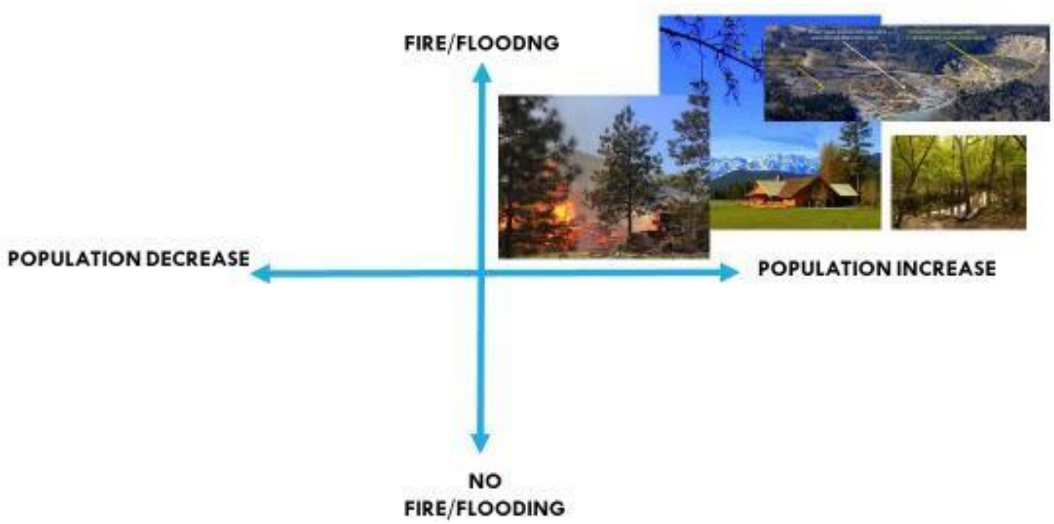
Assessment: The above strategy was assessed as to their strengths, weakness, opportunities, and threats (SWOT). A SWOT analysis for this strategy indicated that the lack of market-based incentives, reduced capital, and minimal roll-out of risk-reduction measures limit comprehensive approaches:

Local Renewal (more individualistic interests)



<u>Scenario 2</u>: Community Transformation: Population increases despite fires and flooding events.

Those attending the workshop overwhelmingly thought that this was the most probable future.



The **"Community Transformation"** scenario assumed that there had been major burns before 2040 and again before 2080. Areas burnt are not recovering and the fire risk remains low in the burnt areas. Flooding risks are high. As soil permeability has decreased, flooding risk is increasing. Sediment has blocked the river at two locations causing additional flood risks. In **scenario 2** the population has increased despite past fires and increased flood risk.

Workshop participants expanded on the scenario by offering the following:

- The population sees the decreased fire risk resulting from past burns as a benefit.
- The local economy is adapting to climate changes and tax revenues are at an all-time high.
- Government agencies have funds to spend on community stewardship programs as well as more professionally driven forest and floodplain management programs.
- Innovative management techniques have been developed to support response and recovery, and to adapt to the remaining threats. These include:
    - Forest harvesting techniques that remove ladder fuels that are revenue neutral or even turn a profit, thereby reducing the fire threat in remaining forest segments.
    - Flood risks within the existing burn areas have been reduced through a series of human intervention approaches (i.e., providing check dams, small detention areas, falling selected trees horizontal to existing slopes, and even re-introducing beavers). The community has successfully transformed into something new.
- However, the new population may not support using additional tax revenues (from population growth) to improve forest health.
- The sheer population increases has compromised the rural character.
- Attempts to maintain the large lot rural character results in more wildland interface development. This, in turn, puts further stress on natural amenities.

Strategy: The community objective is to maintain a close-knit, rural community with opportunities to nature and maintain a place where family members enjoy visiting. "Growth" in and of itself could represent a threat to these values.

The team working on scenario 2 benefited from having been involved with recent wildland fire events. This team felt the need for a more comprehensive planning approach. The approaches and tools listed below were taken from participant discussions:

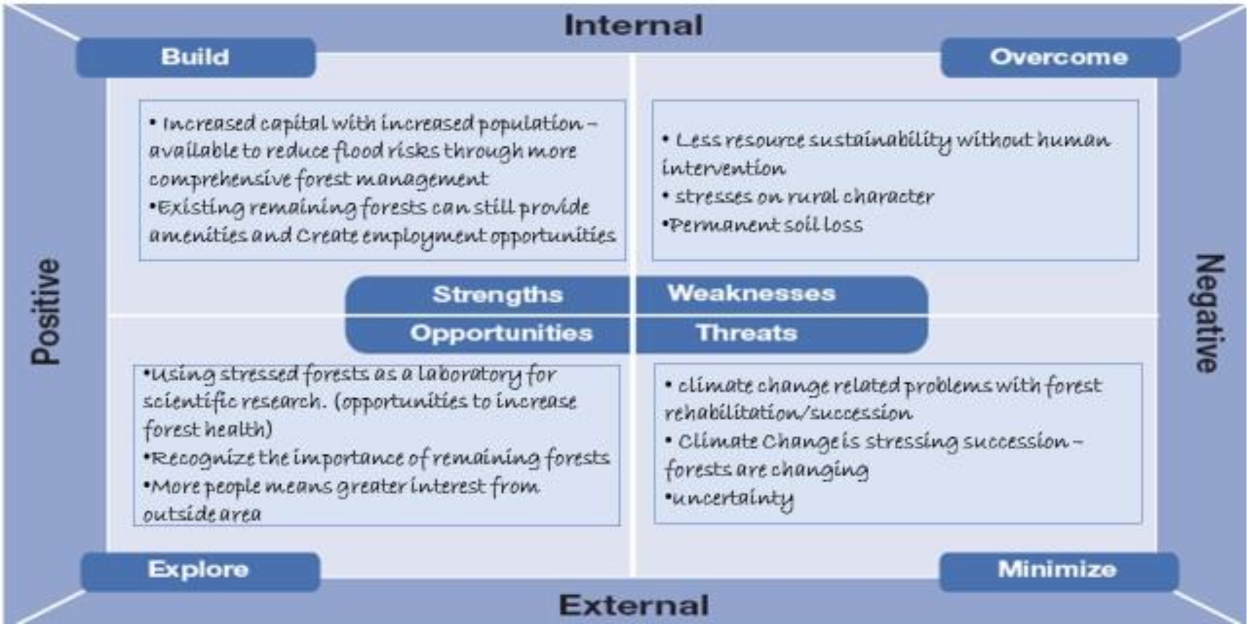
- **Fire risk reduction measures** (Scenario 2 has a reduced wildland fire risk within the project area because of the burns):
    - Forest management: Reduce the overall fire risk from the more extreme and very high intensity fires within the remaining forest segments:
        - Manage remaining forests and capture income from selective harvesting. With fewer forested acres there are fewer areas to protect. A combination of thinning and prescribed burns may prove effective.
        - Create new technologies such as the development of small mobile self-contained harvesting machinery that makes the harvesting of ladder fuel revenue neutral or event profitable.
        - Institute aggressive forest rehabilitation measures.

- Planting
- Reduced harvesting of burnt trees
- Restricted access to vulnerable stands
    - Reduce the impacts of wildland fires:
        - Require Firewise practices: These can be required as a condition of building and subdivision permits. Planning related ”police powers” are effective at controlling development when a community is changing.
    - Restrict development in remaining forests: With a new recognition of the values of lost forest ecosystem services, interface development is not allowed in remaining forests. Transfer or Purchase of Development Rights (TDRs/PDRs) could prove helpful to relocate interface homes from recovering burnt areas.
    - Emergency Response Plan: An Emergency Response Plan will be needed for this scenario. Risk is usually viewed as a function of frequency multiplied by impact. Although the frequency of wildland fires has been reduced as a result of previous burns, the impact is large due to an increase in population. This planning effort could include better access for firefighters, fire breaks, and areas were water would be made available.

- Flood (flood risk will increase – discharges will increase and sediment will be mobilized):
    - Limit soil mobilization through:
        - Limit/manage harvesting of burnt trees.
        - Increase engineered detention/retention structures to provide storage and reduce discharge; build check dams; build beaver type ponds.
        - Fall trees perpendicular to slopes.
    - Adopt higher National Flood Insurance (NFIP) standards such as defining the .2 flood (500-year) as the base flood, increase freeboard, and enforce set back riparian buffer requirement. Because Scenario 2 assumes growth, police powers will be more effective.

Assessment: Following is an assessment of the above strategy as to its strengths, weakness, opportunities and threats (SWOT):

Transformation:



<u>Scenario 3:</u> Reactive Management - Population increases, fire and flooding threats increase, no major events occur.

The **"Reactive Management"** scenario assumes forest fuels increase by 10 percent from year 2020 to 2040 and again from 2040 to 2080. The community may have been fortunate that there have been no burns through 2080. *However the fire risk is huge.* The climate has changed, bringing warmer, drier, and longer summers. There have been few cold periods of sufficient duration to kill insect populations. There are large stands of dead and dying trees surrounded by dry ground cover. Also, by 2040 the community was losing its rural character. By 2080, the community has shifted from a rural to an urban character.

<u>Workshop participants offered the following additions to the scenario:</u>

- Government agencies are focused on population growth, changing zoning codes to accommodate development, and implementing reactive forest management policies.
- Where fire risks have been reduced, it is largely because human development has removed vegetation (combustible fuels) and replaced these fuels with less volatile materials.
- Wildland interface development has increased. The value of isolated, large lot rural character parcels are more prized despite the fire danger.
- The focus is on preparedness and response and not forest management adaptation.
- Mitigation actions may follow burns, but Scenario 3 assumes there have been few major burns to recover from.
- There are extensive forests remaining. Development pressure grows despite the risks. At the same time, there is a desire to protect the rural character by allowing development to extend further into the forest.
- There has been a buildup of forest fuels. It can be assumed that minimal attention has been given to fuel-load reduction.

Strategy:

Similar to Scenario 2, the Reactive Management Scenario 3 assumes growth. Growth in and of itself challenges the community objective of maintaining a close-knit, rural community connected to nature.

Like Scenario 2, the Reactive Management scenario assumes population growth and infrastructure development. Growth may conflict with community values, including allowing large-lot development at the wildland interface. However, unlike Scenario 2, the community has escaped major wildland fires. More people have come to the area and are taking advantage of the forest and all the associated activities.

Strategy: To maintain a close-knit, rural community with opportunities to enjoy the nature will require more financial capital (from increases in tax revenue) and full-time paid staff to:

- <u>Devote extensive resources to planning, training, exercising and implementing</u> comprehensive fire preparedness, mitigation, response and recovery plan.
- <u>Provide capital to facilities</u> that enhance preparedness, mitigation and response measures including warning instruments, firebreaks and decentralized water supply.
- <u>Adopt very stringent fire prevention risk reduction</u> codes and ordinances regulating new and substantial improvements to existing structures.
- <u>Direct resources tactically to forest management and fuel reduction</u>. Because the forests have largely been ignored, fuel loading is high. Prescriptive burning would be extremely dangerous. Forest risk reducing management practices would have to be directed to the more vulnerable and probably more opportunistic areas.

<u>Workshop participants offered the following approaches and tools:</u>

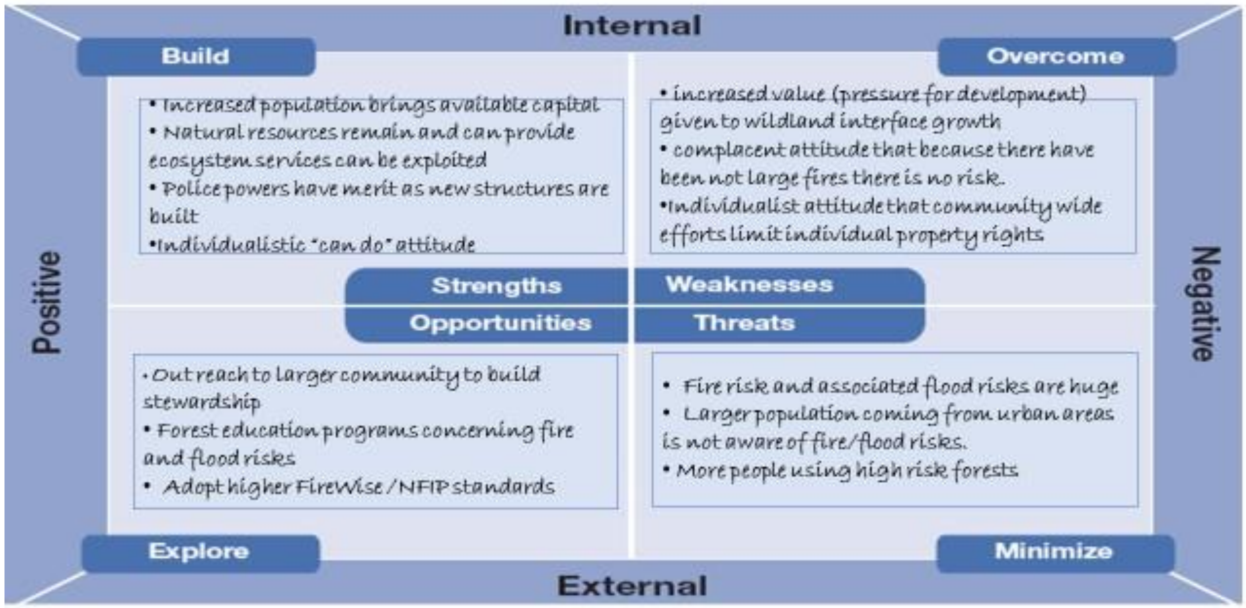
- **Fire** (the overall fire risk is high):

- Increase the forest health.
    - There are funds to apply to forest management. But because of the lack of past fire events there will be less leverage to get funds.
- Response and evacuation plans become crucial. Capital improvements may be constructed to support response efforts, including:
    - Improving existing routes such as River Road, Camp 12, and KAHLER Road; will ensure safer routes for all.
    - A full-service fire department along with sufficient water supply for firefighting.
    - Fire breaks and safe havens for wildland firefighters.
    - Automatic warning and notification procedures.
- Adopt Wildland Urban Interface codes and limit development, especially rental development to low fire-risk areas.
- Fire Adaptive Communities (FAC) requirements may be codified and strictly enforced. Create a public-private logging industry to thin out small diameter logs and repurpose extracted timber. This will reduce forest fuel and create new jobs that are consistent with the rural character of the area. Startup funds could come from Community Development Block Grants (CDBG).

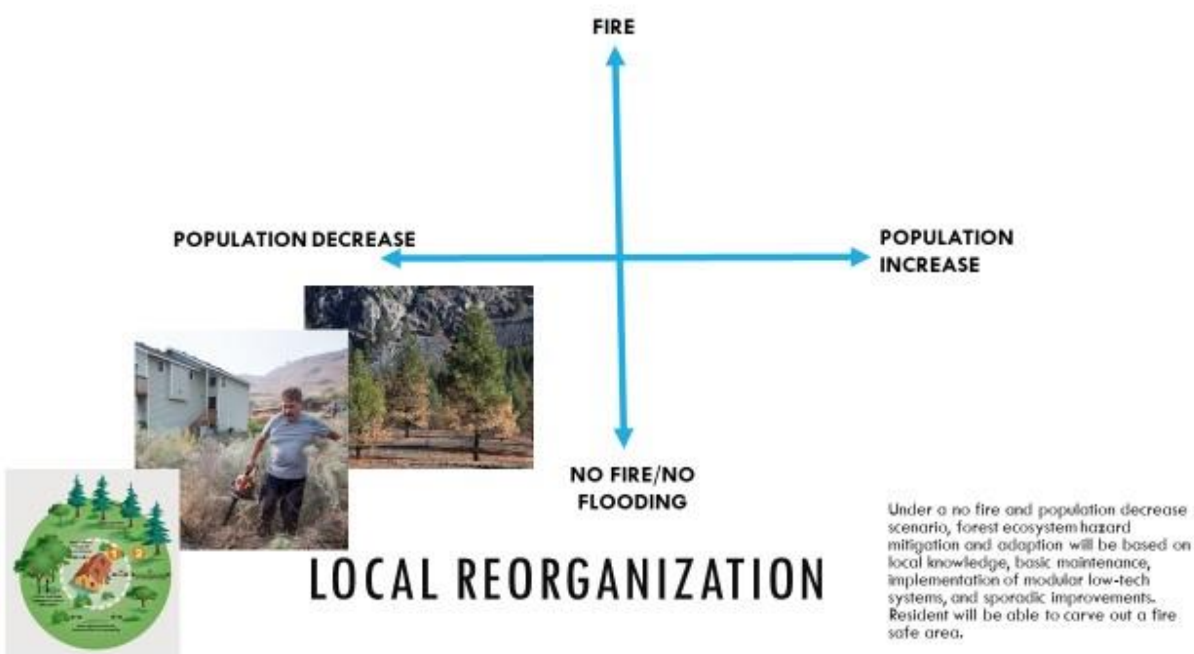
- **Flood Risk.**
- There is no current flood risk because of the forest remains intact. However, with increased professional capability, post-fire flood risks can be anticipated and addressed in planning. Also, such plans can include capital improvements.
    - Engineer retention areas to support response as well as support post-burn detention in holding runoff and aiding forest regeneration.
    - Adopt higher National Flood Insurance Program Standards.

Assessment: Following is an assessment of the above strategy as to its strengths, weakness, opportunities and threats (SWOT).

Reactive Management



<u>Scenario 4:</u> Local Reorganization - Outside forces stimulate a population decrease, fire and flooding threats increase, no major events occur.



The **"Local Reorganization"** scenario assumed that outside forces, supported by an increase in fire risk, result in a decrease in the population of the study area. The scenario assumes that there have been no fires within the larger Plain area through 2040 and 2080. The buildup of fuels and climate-change impacts (drier and warmer summers with an ensuing increase in insect infestation) has resulted in an extreme wildland fire risk.

Workshop participants added to the scenario description with the following:

- Because of an awareness of the fire and associated flood risks, residents and businesses leave the area.
- The remaining residents become very close-knit and there is an increased community stewardship to maintain safe properties and limit wildland fire threats.
- Local governmental agencies responsible for forest and floodplain management have limited funds to make improvements or direct funds to forest management due to lower tax revenue.
  - Federal and State funding for fire-risk reduction is sporadic.

Strategy: The objective is to maintain a close-knit, rural community with opportunities to enjoy nature and a place where family members enjoy visiting. The following is needed:

- Awareness of the day-to-day risk conditions
- Dependence on local community volunteer support for response planning and targeted forest management that is directed to high risk vulnerabilities.

Approaches and tools offered at the workshop:

Fire (the overall risk is huge, and resources are limited. However, because there are fewer residents the overall risk is lower than scenario 3):

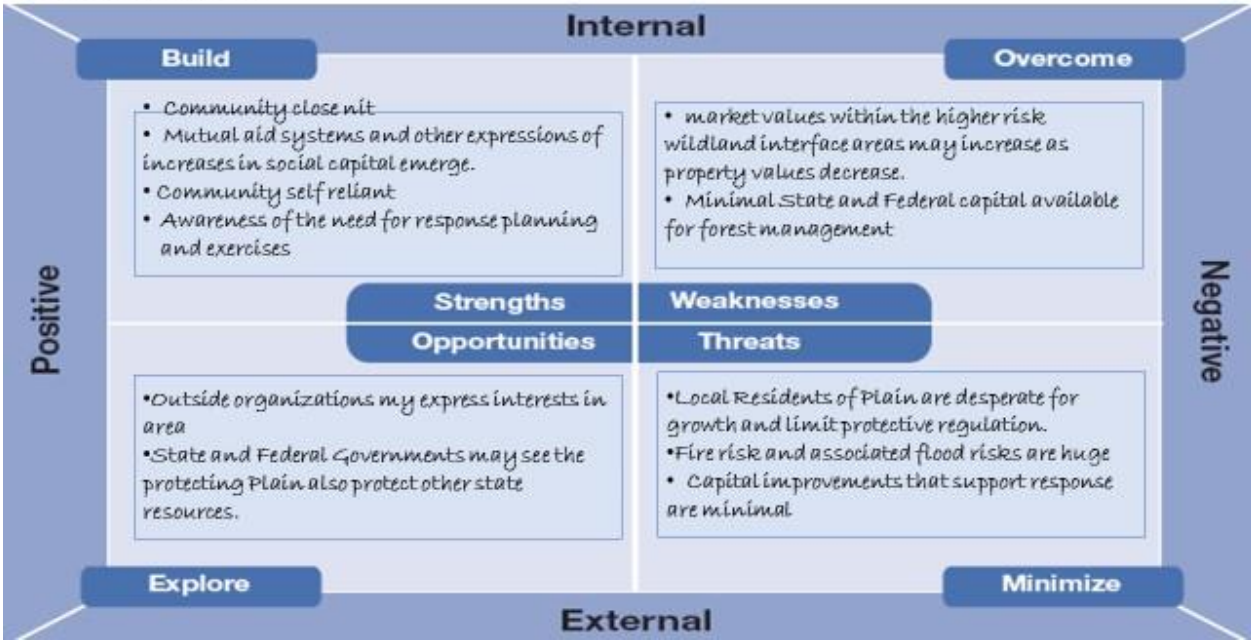
- Increased stewardship: Volunteers can target the most vulnerable resources to help manage and increase the forest health.
- Implement Firewise approaches on a volunteer basis. Planning and zoning police powers have little impact on communities that are not changing.
- Create a group of dedicated volunteers to develop, exercise and implement fire preparedness and response plan. The community group meets on a regular basis to refine and exercise their fire response plan.

Flood (there is little current wildland fire-associated flooding risks.):

- There is little awareness of the associated flooding dangers. Outside of the NFIP requirements, few measures are implemented. The NFIP has little impact because few new structures are being built or substantially improved.

Assessment: Following is an assessment of the above strategy as to its strengths, weakness, opportunities, and threats (SWOT).

Local Reorganization



Round 3: Search for Path Dependencies and Common Strategies
During Round 3, participants of each scenario were asked to present the approaches and tools that would reduce risks from fire and flooding and suggest measures that may be common to all. Participants were also asked to identify actions that my limit these risk reduction measures, or path dependencies.

The following findings were taken from meeting notes and are being researched by the Institute project team. Positive items support community values identified by the participants. Negative path dependencies detract from these values.

Path dependence. Items mentioned in the team discussions include the following:

- **Built capital:**
    - I<u>nfrastructure</u>, primarily roads that provide access: Roads, and forest locations with public infrastructure, can support fire suppression. They also often lead to development and subdivision of the land. Development often begins with large lot subdivisions but often leads to smaller lots through “short platting. The end result is seldom, if ever, reversed.
    - <u>Wildland Urban Interface</u> development leads to continued development.
    - <u>Occupancy of interface areas</u> can lead to more stewardship or a reduction of forest lands.

- <u>Once access is provided</u> and areas developed, going back to reforestation is difficult and expensive.

- Harvesting timber removes nutrient from the land. This process increases the time required for restoration and increases costs. With each logging, the new forest is less productive than the previous forest.

- **Natural Capital:**
  - Forest fires can remove ladder fuels, provide nutrients and are part of a natural forest cycle. These types of fires often suppress land values as cited by workshop participants. However, the impact is usually small and short term and may be required to assure forest health. Major fires (crown fires, class 4) may kill the forest, beginning a new successional process that will be very long-term. The Institute project team is also researching indications that forests are not recovering due to climate change. The sequence of natural processes associated with forest regeneration (flowering, seed generation, seed dispersal, etc.) has changed.
  - Flooding often accompanies major burns. Soil becomes hydrophobic and less permeable. This can lead to the runoff of the soil and the ground cover. This sediment can block streams and cause flooding as the increased discharge backs up in the channel. More importantly, the loss of soil reduces the possibility of future forests being established. Forests will never recover.

- **Social Capital:**
  - Compromising the resource. Exploiting any single resource at the expense of the larger interrelated system can destroy the resource forever. This, in turn, undermines the values deemed important by workshop participants.

Recommendations

The University of Washington Institute project team is assessing the group discussions in order to determine what paths would be appropriate for a variety of alternative futures. The Institute team is also studying what are the path dependencies and triggers that challenge community values and objectives.

To make this assessment, we need to know if we are on the right track. This is why we are asking you to comment on the assumptions and process described within this document.

We want to thank you for your continued participation.

Again, please forward your comments to Michael Godfried at Godfried@uw.edu.

Appendix G: Survey

Plain Fire and Flooding Workshop
Follow up Questionnaire

Plain's future risks from large, severe wildland fires and flooding focuses on soil - keeping it healthy and in place. Soil stores moisture, provides nutrients, and anchors trees. Risk reduction and community resilience depend on soil staying on the slopes and having vegetation cover and organic material to enable forest regeneration. This means that wildland fires cannot be exceedingly high intensity or severe.

FEMA awarded a grant to the University of Washington Institute for Hazards Mitigation Planning and Research to study the problem, identify risk reduction measures, and implications of these measures if implemented. To do this, we utilize scenario-planning methods to develop four plausible alternative futures (also referred to as scenarios) with fire, floods, and population as drivers of change (see Figure below). In summary, the four scenarios that were developed are:

Scenario 1 (S1). Local Renewal: population decreases following major fires and flooding events;
Scenario 2 (S2). Community Transformation: population increases despite major fires and flooding events;
Scenario 3 (S3). Local Reorganization: population decreases (due to outside forces) as fire and flooding threats increase but no major events occur; and,
Scenario 4 (S4). Reactive Management: population increases as fire and flooding threats increase but no major events occur.

These scenarios were presented at a community workshop in Plain on June 2, 2017. Participants were asked what they valued about their community and what objectives and strategies they thought were important at reducing risk given the scenario. To further develop the recommendations for the report, we would like more input from the community.

We kindly ask that you please take the short survey below and **return it by Tuesday, November 7, 2017 to Lan Nguyen at** lan8@uw.edu.

Highlight or **bold** your responses. Thank you!

1. Did you attend the workshop held on June 2, 2017?

   (Select one.)

IIIII	a. Yes
	b. No
I	c. Invited, but could not attend.

2. What is your interest in Plain Washington.

   (Select all that apply.)

III	a. Owner of residence (primary residence)
	b. Owner of residence (secondary residence)
I	c. Owner/Representative of Business
II	d. Work in Plain
	e. Rent a home in Plain
IIII	f. Recreate in the larger community
III	g. Work for local (County/city) government
I	h. Work for State Government
	i. Work for Federal government
I	j. Provide an information / management / regulatory forest function
III	k. Other Coordinator for Firewise Program in Lake Wenatchee/Plain area Volunteer fire fighter/leadership committee for FAC Primary resident – not owner

3. Values may conflict with population growth. Workshop participants said they value Plain's rural character. As the population increases over time, development of housing, roads, businesses, and other infrastructure will grow as well. To reduce fire and flooding risk with increasing population and development, which of the following do you support?

   (Select all that you support. If you have a clear first choice place an "X" through the letter. If you have other ideas, please comment in the space below.)

IIIII	a. Confine growth to protectable areas (where police, fire, and public services can get to easily).
II XX	b. Allow for large lots to be divided into smaller lots and adopt strong building codes to reduce fire risk (e.g. use fire resistant building materials, require on-site water sources, adopt Firewise approaches, etc.)
I	c. Allow for large lot to be divided into smaller lots if a taxing district is created to support additional police, fire, and forest management services needed to support more property and people.
I	d. Something else. Disallow further building in the WUI.

Comments:

4. Recreation opportunities involve access to the forest. Access also brings more people into the forest and most fires are started by people. Which of the following would you support?

   (Select all that you support. If you have a clear first choice place an “X” through the letter. If you have other ideas, please comment in the space below.)

III X	a. Prevent or control hikers, hunters, and recreational seekers from entering high fire risk forest areas. Access could be resumed after fire risks are lowered (i.e. communities can lower fire risk through controlled burning, manual thinning of trees, constructing water ponds, etc.)
I	b. Allowing access to the forest for people who have received certified training on fire safety and consequences to life and property.
	c. Allowing recreation seekers to enter vulnerable forests if they are accompanied by a trained local forest guide.
I	d. Something else. Implement a social marketing campaign that brings forest users in because of their interest in the forest but is embedded with educational materials to help forest users recreate in a safe manner.

Comments

Support A, with the text added in red.

a. Prevent or control hikers, hunters, and recreational seekers from entering high fire risk forest areas during periods of high fire risk. Access could be resumed after fire risks are lowered (i.e., communities can lower fire risk through controlled burning, manual thinning of trees, constructing water ponds, etc. or when weather and fuel conditions reduce the risk [e.g., fall, winter, spring, moderate summer-time])

b. Forests east of the Cascade crest below a certain elevation; all reach a very high fire risk- most summers. It is hard to imagine preventing entry is a viable option. Some degree of control – perhaps, in areas of highest risk, or limited closures in highest fire risk areas during extreme periods . . . maybe?

   A fire risk certification for users, like boating safety training . . . enforcement would be next to impossible on any significant level. However, greatly increasing educational opportunities through outdoor recreation service providers, retailers, and organizations (Mountaineers, WTA, Team Naturaleza, El Sendero, Leavenworth Mountain Organization), websites such as alltrails.com, routesrated.com, etc. etc. is a start. Also, much increased signing and displays at access points to public forests that increase awareness of potential sources of accidental ignition, campfire safety, bans.

Petitioning the federal government to increase funding for these efforts and additional USFS personnel who can provide education and enforcement.

5. Flood risks will greatly increase following fires. The three main strategies for floodproofing properties are protect, retreat, and accommodate. Protecting properties could include digging ditches to divert water flow away from buildings or digging ponds to store rainfall. Retreating strategies include phasing out development or buying out property in high-risk areas. Accommodating strategies include raising the first floor of buildings to expected flood levels or creating rain catchment systems in developed areas. Regulations that require floodproofing are driven by FEMA flood maps; however, these maps calculate current risk not future risks. Which of the following would you support?

   (Select all that you support. If you have a clear first choice place an "X" through the letter)

II X		a. Having the County remap the floodplain to include this future risk thereby expanding the area of mandatory regulation.
III		b. Having the County remap the regulatory floodplain but do not require enforcement of these additional hazardous land. This would increase flooding awareness.
II		c. Not mapping the area until the fire has occurred and flooding is credible
		d. Something else. ___________________________________

Comments: Concern about agency overreach.

6. Building codes reduce fire risk. Constructing buildings with fire-resistant materials has been proven to reduce fire risk. Which of the following would you support?

   (Select all that you support. If you have a clear first choice place an "X" through the letter. If you have other ideas, please comment in the space below.)

IIIII X		a. Adopt stricter building codes for new construction and substantial remodels.*
III		b. Enact stricter building codes that are triggered by the passage of time. For example, all roofs must be metal within 5 years.
IIIIII		c. Provide local public funding to help offset the costs of complying with higher codes. This could be in the form of grants, loans, or tax incentives.
IIIII		d. Provide local support of individual self-help home retrofitting efforts. Such support could include

		creation of lend tool libraries, providing free or reduced permits, or holding classes prove skills.
I	e.	Something else. Disallow future building in the WUI

Comments:

*In identified zones where risk is higher.

7. Prescribed burns and mechanical treatment of fuels have been proven to be very effective in reducing fuels and limiting the risk from catastrophic fires but produce smoke. Such fires pose a risk in and of themselves should they become uncontrolled, can be very disruptive to a community and the forest resources, and have a significant impact on air quality and community health. The “prescription window” for conducting a prescribed burn under the right weather and fire conditions can be small and with little notice. Would you accept:

   (Select all that you accept, If you have a clear first choice place an “X” through the letter)

II	a.	A community could determine a prescribed burn “watch” period for burns for the entire season and a few days of notice or so when the time and place a specific prescribed burn might be initiated.
II	b.	A prescribed burn if I know several months in advance of when a week or less burn was expected.
II	c.	The identification of two or three week period when a prescribed burn might be initiated, but that the tentative period would rotate every three to five years as needed.
IIIIII	d.	Support of thinning and slash disposal through prescribed fires or other mechanical means.
I	e.	Something else. Changes in prescribed burn regulations to allow larger "windows" to conduct burns.
I		Something else. Enhanced public notification systems for prescribed burning.

Comments:

Item “A” would/should still apply.

RESULTS

The Plain survey was developed to gain additional insights on mitigation strategies. The survey was emailed to people who were invited to the workshop. Seven of those who answered the survey attended the workshop. These people represent residents (4), business owners (1), workers (6), community leaders (2), and recreationists (4). The following is a summary of the results.

During the workshop, participants identified rural character as a value. To protect that value for scenarios where population growth is projected, most people want to confine growth to protectable areas where police, fire, and public services can get to easily (6 votes). People also strongly support large lots to be subdivided into smaller lots and adopting strong building codes to reduce fire risk (e.g., use fire-resistant building materials, require on-site water sources, adopt Firewise approaches, etc.) (2 votes, 2 clear choice votes). One person supported subdivision of large lots and creating of taxing district to support governmental protection and mitigation services. One person expressed a desire to stop development in the WUI.

Plain attracts people to recreate in the forest; however, this increases fire risk because most fires are started by people. Most survey takers supported preventing or controlling access to high fire-risk forest areas when fire risks have been lowered through fuel reduction, construction of water retention ponds, or when the fire risk is not high (e.g., winter, spring) (3 votes, 1 clear choice vote). One person supported the idea that visitors should receive certification training on fire safety before entering the forest and no one supported the idea of visitors being accompanied by a trained local forest guide. Others suggested educating the public about fire risks through social media, outdoor recreation service providers, retailers, and organizations. Another person recommended increasing signage and displays at access points about accidental ignition, campfire safety, and bans. Community members could lobby the federal government to pay for these efforts and provide education and enforcement.

Support for flood-risk reduction measures was weak and were split almost evenly for the three recommendations with no additional suggestions. The recommendations included: remapping the floodplain with future risks thereby expanding the area of mandatory regulation (3 votes); remapping the regulatory floodplain but do not require enforcement of these additional hazardous land to increase flooding awareness (3 votes); and not mapping the area until the fire has occurred and flooding is credible (2 votes). One person expressed a concern about agency overreach.

There was strong support for fire mitigation measures in the WUI. Adopting stricter building codes for new construction and substantial remodels (5 votes, 1 clear choice vote) and providing local public funding to offset costs for compliance (6 votes) ranked the highest. Other mitigation measures include providing local support for individual retrofitting (5 votes), enacting stricter building codes that are triggered by the passage of time (3 votes), and not building in the WUI (1 vote).

Prescribed burns and mechanical treatment of fuels have been proven to be very effective in reducing fuels and limiting the risk from catastrophic fires but produce smoke. There was strong support for thinning and slash disposal (6 votes) and weak support for when and where they take place as well as notification procedures.

Appendix H: Improvement

Improvements

The community also considered things that would make the area a better place to live, work, and play. They shared stories of what they would like to see in the future. These statements were not used directly but helped define the goals.

1. **More full-time residents.** Non-owner occupied homes outnumber owner occupied homes in the area. This means, part-time residents rent out their homes when they are not there. Visitors do not always exhibit good behavior and respect the natural environment and quality of life of full-time residents. Moreover, part-time residents are difficult to engage in Firewise property management techniques to reduce fire risks.
2. **Fewer mosquitos.** Mosquitos are a pest to humans and reduce our ability to enjoy the outdoors. Reducing the number of mosquitos would benefit the human population by reducing bites and infection while possibly increasing the number of visitors.
3. **Affordable housing.** As the area becomes more popular, the community wants to see more affordable housing built to accommodate young families and service sector workers.
4. **Trail and road maintenance.** Well maintained trails and roads make the community attractive and accessible. They are critical public infrastructure that not only help the community thrive but they are also vital for emergency operations. It is important to keep maintain trails and roads.
5. **Bike trail to Leavenworth, WA.** The City of Leavenworth is approximately 14 miles away from Plain. The City was redeveloped into a Bavarian style village in the 1960s to revitalize the town and attract tourists. Festivals and events are held throughout the year to attract visitors who want the Bavarian and outdoor experience. Developing a bike trail that links the City and Plain would be mutually beneficial.
6. **Forest management.** The National Forest makes up most of the study area and surrounds the community of Plain. The community would like to see the United States Forest Service (USFS) to increase forest management to reduce wildfire risk and maintain a stable forest ecosystem.
7. **Jobs.** One of the key components of keeping and attracting young people and families to the area are jobs. Creating new jobs that are consistent with the rural character of the community could achieve this goal.