City of Ashland

2020 Mortality Monitoring Results and Analysis

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May 2020

Acknowledgements

The authors wish to acknowledge the contributions of three key individuals that helped in creating this report. Many thanks to Max Bennett, Oregon State University Extension Service Forester, for his ongoing commitment to this topic and his thorough review of this report and many concrete suggestions for improvement. Also, to Bill Schaupp, retired US Forest Service Forest Entomologist who tirelessly studied the Douglas-fir/flatheaded fir borer relationships and helped create the beginnings of a solid science on the topic where little existed before. Finally, thanks also to Chris Chambers, Forest Division Chief, Ashland Fire and Rescue for his careful review and important input into the final document.

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Introduction

Active management of City owned forestlands was initiated in 1995 with three primary objectives (Ashland Forest Plan, 2016):

- Protection and promotion of the City's water supply
- Maintenance and promotion of forest health
- Reduction in the fire-prone nature of the forestland through active management of vegetation and fuels

In the past 25 years, ongoing tree mortality from insect and disease related agents has challenged accomplishment of those objectives. Subsequent attempts to implement effective management activities, is very complex and rapidly changing in a world with forests under increasing stressors, including from droughts and climate change. Amidst this complexity and uncertainty, the City has employed various management practices and silvicultural strategies over the past 25 years. This paper describes both qualitative and quantitative approaches, results and analyses of management activities to date to help inform current and future management strategies on the City ownership. To that end, Small Woodland Services, Inc. conducted field inventories in March of 2020 to identify and map standing tree mortality in the lower watershed portion of the City of Ashland ownership. The following objectives guided this work:

1. Establish a spatially explicit mapping of standing tree mortality (~8"+ dbh) on the lower watershed portion of City-owned forestlands to be used as a baseline for future reference. Analyze resulting landscape-level spatial patterns to help understand where and why tree mortality may be occurring on City lands.
2. Combine spatial data with qualitative assessments derived over 25 years to make suggestions about future management potentials given expected increased stressors from drought, climate change and other factors.
3. Determine the potential for utilizing the surveyed existing snags, in association with other low-vigor conifers, to support a future helicopter thinning operation designed to improve stand conditions and/or otherwise meet City goals and objectives.
4. While conducting the survey, identify and map potential non-commercial thinning opportunities and occurrence of invasive plants.

This paper uses published science and other professional publications to help validate results presented but is by no means an exhaustive compilation of the available science. In fact, for many of the management-related questions discussed in this paper, published science-based information is lacking, especially for the insect that has contributed to the most significant mortality on the City ownership, the flatheaded fir borer *Phaenops drummondi*. The science cited is used to provide insight to, and support, some of the more complex analyses that are required when multiple objectives are desired in the management of a complex landscape in an era of rapidly changing conditions.

Methods

To accomplish the multiple objectives, the entire 485 acre City-owned lower watershed area was visited and surveyed (see Maps 1a,b,c,d), with several exceptions: 1) Unit LW-T; 2) the upper half of Unit LW-U; 3) several non-forest areas (e.g. quarries). Although this area is only a portion of the 1100 acres addressed in the Ashland Forest Plan, which includes numerous areas managed by Ashland Parks and Recreation, the survey and subsequent results presented herein are intended to be able to inform management possibilities throughout the entire City and Parks forerstland ownership, as well as on other similar adjacent non-municipal lands.

Areas were generally traversed on the contour, looking both uphill and downhill for dead conifers ~8" dbh and larger. Individual tree mortality was common in much of the area surveyed, but recording individual snags was beyond the scope of this project. Generally, recording of snags was limited to groups of four or more dead conifers in close proximity, generally within 1/10 acre. Occasional noteworthy individual trees were recorded, such as recently dead pine and large diameter snags (>25" DBH). Locations were identified with a waypoint using Avenza mapping software. For larger areas with more extensive and contiguous mortality (i.e. generally greater than 1/2 acre in size and including at least 30+/- dead trees), polygons were GPS'ed in the field.

Mortality was recorded primarily for coniferous species- Douglas-fir, ponderosa pine and the occasional sugar pine. Incense cedar was also present but in small numbers with little evident mortality at this time. Dead hardwoods were not included, except in the B3-E1-B4 prescribed burn unit (2018), where extensive post-fire mortality of Pacific madrone occurred.

At each waypoint/polygon, the following information was recorded: tree species, estimated number of snags, approximate range of DBH's, estimated time since initial mortality, and current snag merchantability and subsequent potential for helicopter thinning. In the larger polygons, an estimated percent of total standing trees killed by species was also recorded. Standard merchantability rules were applied such as size, time since initial mortality (e.g. red needles still present?), amount of defect, bark slippage and subsequent exposed and cracking inner wood, etc. Any other important notes or points of interest were also recorded.

Although snags are critically important values from a wildlife habitat perspective, most of the snags surveyed were 8-16" dbh and less valuable from this perspective. More valuable larger snags 17"+ dbh were uncommon in this survey, but tend to be more persistent than the smaller snags.

Ongoing snag development on the lower watershed parcel has been in a constant state of flux over the past 25 years with low levels of more endemic ongoing mortality, punctuated with waves of higher intensity outbreak levels of mortality often associated with drought. In that process, both inputs and reductions of snags (e.g. falldown, removal in commercial activities) have occurred, but have varied both in time and by location .The subsequent falldown of a snag within 3-10 years after initiation has resulted in ongoing accumulations of both subsequent large woody debris and fuels in that same time frame.

A small percentage of the snags (i.e. estimated 5%+/-) recorded in this survey were newer than 3 years since mortality- not surprising given the last drought-related major pulse of mortality in 2015-16. Most of these 1-2 year old snags were considered merchantable, especially those that had recently died and/or were of a larger size. Larger Douglas-fir snags can retain some merchantability into the second year, although decay processes begin to reduce their merchantability.

When invasive plants were identified, a waypoint was recorded and the species was identified. These waypoints were combined with invasive plant locations that were identified in the 2017 property-wide inventory to create a map (see Map 3) with all identified invasive plant locations and species.

Possibilities for needed non-commercial thinning were also recorded with the results presented in a separate report ("City of Ashland Lower Watershed Ownership- 2020 Non-Commercial Thinning Possibilities Summary", Small Woodland Services, Inc., April 2020).

Results

<u>Snag Survey Results</u>

Almost all units on the lower City ownership had some tree mortality and existing individual snags, although the total amount by unit varied widely. In this survey which only recorded at least 4 snags ~8" dbh and larger in close proximity, unit level totals ranged from 0 to 9.7 snags per acre (see Table 1). Only four units had no 8"+ snags other than individual or small clumps of snags (i.e. 3 or less): LW-G, LW-J, LW-Q and LW-W1.

Douglas-fir was by far the most abundant conifer snag 8"+ dbh (883total) identified in this survey, with considerably fewer ponderosa pine (64) and a rare sugar pine (3). This was due at least in part because Douglas-fir is the most common conifer on the lower City ownership, comprising close to 86% of the conifers 8"+ dbh in the 2017 inventory. There were no 8"+ dbh incense cedar snags found in the survey.

While the number and size of snags varied throughout the groups of dead trees recorded in this survey, groups of 5-10 Douglas-fir snags in the 8-16” DBH classes were very common. Snags 18"dbh or greater were uncommon, particularly at lower elevations in the ownership while increasing at elevations above 2800'(+/-) where site productivities improve. These larger snags (primarily 18-24" dbh) were almost all 3 or more years since initial mortality and largely unmerchantable. However, these larger size classes of snags did provide important wildlife habitat values in most cases.

Unit LW-B experienced the most mortality with 487 snags total in this survey (see Appendix: Table 1). This total was strongly influenced by extensive mortality in Polygons 1 and 2 in subunit LW-B2 where slightly less than 200 snags were found (see Appendix: Table 6). Units LW-A (122), LW-E (105), LW-K (81) and LW-R (46) also contained high numbers of snags. All of the other units contained 22 or fewer total snags.

On a per acre basis, the above 4 units, along with Units F and H, all contained greater than 2.6 8"+dbh snags per acre, ranging up to 9.7 per acre in Unit A. All of the other units contained 1.5 or fewer snags per acre (see Appendix Table 1; Map 6- "Surveyed Units with Limited Douglas-fir Mortality").

The most extensive within-stand mortality of Douglas-fir occurred in one general location in the lower City ownership- Polygons 1, 2 and 3 in Units A, B1 and B2 (see Maps 1a,b; Appendix: Table 6). Polygon 1 in Unit B2 (known as "Barranca") had almost complete mortality (90+%; see Table 6), most of which had been dead for many years. This represented a considerable fire hazard in close proximity to residences in the City of Ashland and as a result, a recent contract was completed falling existing snags and piling downed fuels in this area, with burning of this material to be completed in winter 2020-2021. In adjacent Polygons 2 and 3, close to 2/3 of the still standing Douglas-fir were dead, with resulting standing and downed dead fuels yet to be treated.

Ponderosa pine snags were only found in 3 units on the ownership- LW-E, LW-K and LW-M. All of these units are located on more southerly/southwesterly aspects as is common for distribution of ponderosa pine. The low prevalence of ponderosa pine snags is explained at least in part by the general lack of more southerly and westerly aspects on the lower City ownership. Pine has also declined in abundance in the denser forests that have resulted in the absence of more frequent fire in the last century. Ponderosa pine regeneration is rare in the shady forests that have developed in the absence of fire.

However, ponderosa pine snags were abnormally high in Polygons 4 and 5a in Units LW-E1 and LW-B4 These polygons were located in an area underburned in 2018 and the mortality was likely due to the effects of prescribed underburning and associated post-burn bark-beetle related mortality. Unit LW-M also had a higher number of ponderosa pine snags (and very few Douglas-fir snags) including several larger, older trees that had recently died within the last year.

Douglas-fir mortality was strongly related to elevation (see Appendix: Table 4). The lower elevation units below ~2800' averaged around four 8"+ dbh snags per acre, while DF snags above that elevation averaged only about 0.5/acre. One unit, LW-B has a series of subunits from LW-B2 through LW-B7 that are topographically similar but slowly ascending approximately 300' in elevation, with a corresponding general decrease in DF mortality (see Appendix: Table 5)

Douglas-fir mortality was also related to topographical slope position (see Appendix: Table 2). In those areas in the approximate upper third slope position and/or along lateral ridgelines, DF mortality averaged slightly over 7/acre; in mid-slope positions, 3.5; and in lower third slope positions slightly less than 1/acre.

Since 1995 and the initiation of active management of the City of Ashland forestlands, DF mortality has been observed most commonly occurring first around edges of stands, as has been observed throughout southern Oregon. In some cases, additional mortality failed to advance appreciably farther into the stand (Subunits LW-B1, LW-B4; Unit LW-J) while elsewhere mortality advanced into the stand, usually in pulses associated with drought. In some cases, mortality of Douglas-fir was rapid and relatively complete (e.g. Polygons 1, 2 and 3- Map 1a,b; Appendix Table 6), while in other areas mortality occurred more slowly over time, some of which is still ongoing. It was also observed that individual larger and/or taller Douglas-fir were often first attacked in the middle interior of an otherwise unattacked stand.

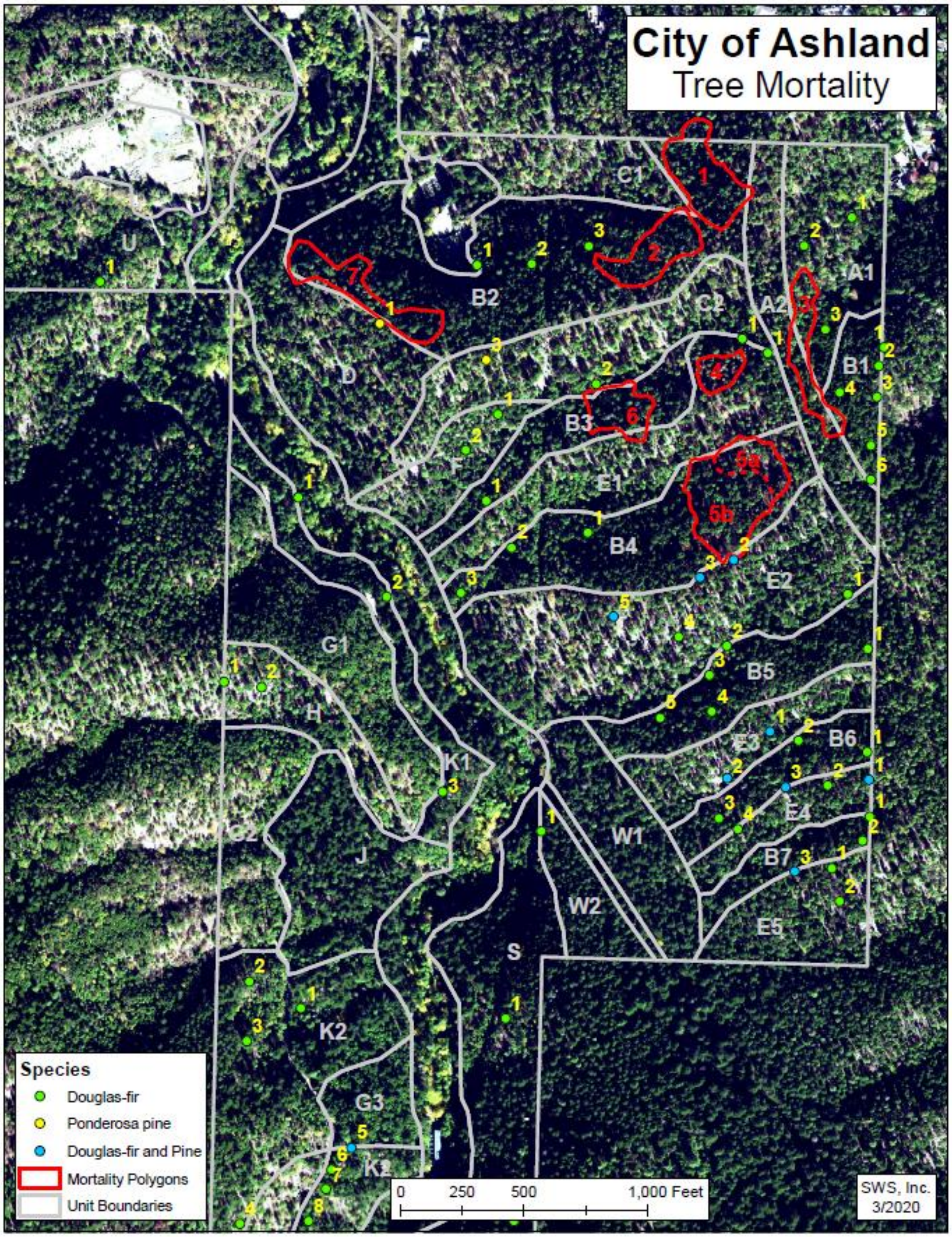
<u>Results of burn severity/tree mortality relationships in the 2018 prescribed underburn in Unit B3-E1-B4</u>

The Composite Burn Index (CBI) burn severity assessment (Key and Benson 2006) is a method of monitoring burned landscapes to determine first order fire effects. It is based on a scale of 0-3, with severity categories of minimal (0-0.5), low (0.5-1.5), moderate (1.5-2.5) and high (2.5-3). CBI monitoring results have been determined for most of the prescribed underburning units on the City ownership in the last 7 years. CBI results for the prescribed underburn in May 2018 in Unit B3-E1-B4 (1.52) were the highest for any unit underburned on the City ownership to date, although portions of other units burned have reached similar levels of severity.

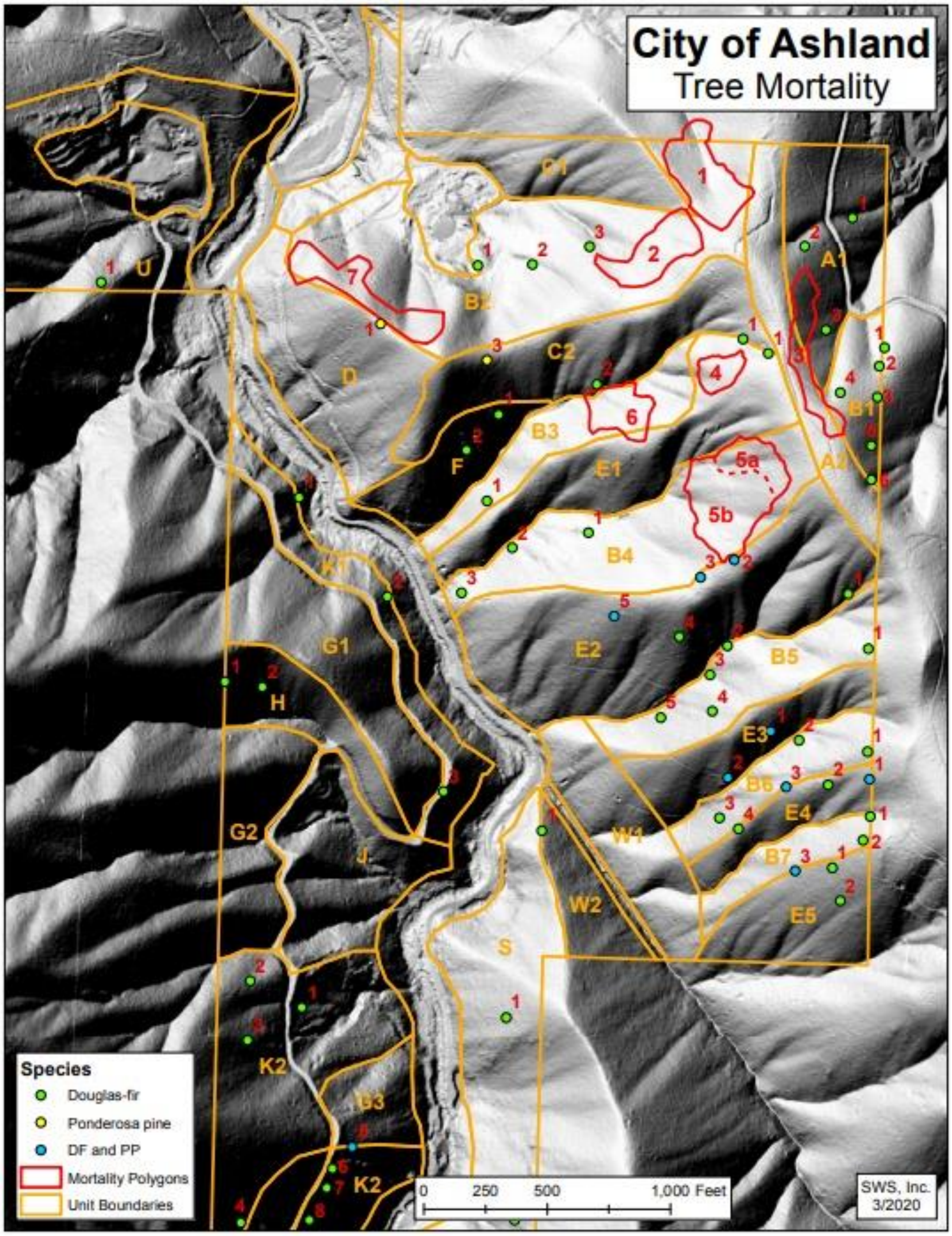
Levels of tree (>8"dbh) mortality were also recorded 5 months after the May 2018 underburn on 6 permanent plots. Results showed 7% mortality, all of one species- Pacific madrone, although there was also significant decline in Douglas-fir and ponderosa pine as measured by bole scorch and crown consumption. The plots were monitored again in March 2020 and additional mortality had occurred (almost all Pacific Madrone), bringing the overall total to 20% over 22 months. This result of ongoing post-burn decline and mortality of Pacific madrone over time (up to three years or more) has been found elsewhere on the City ownership in similar situations. However, only one ponderosa pine and no Douglas-fir had died in the 6 plots re-measured in 2020, although both species had notable mortality within the underburned unit as a whole. The permanent plots did not accurately capture the mortality that occurred in two primary locations in the underburned unit- 0.5 acre Polygon 4 and 0.9 acre Polygon 5a (see Map 1a,b).

Most of the Douglas-fir mortality in the underburned unit appeared to be directly related to the burn itself although evidence of additional flatheaded fir borer attack appeared to be continuing. Few of the ponderosa pine appeared to be killed outright by the prescribed burn, but dynamics associated with post-fire decreased tree vigor contributed to eventual bark beetle related mortality from western pine beetle and the pine engraver beetle. This patchy mortality of ponderosa pine in the underburned unit was not found anywhere else on the lower watershed parcel in this survey, strongly suggesting a relationship between the underburn and eventual pine mortality. In addition, post-burn increased mortality from bark beetles following prescribed underburning has not been found on City ownership in other underburned units to date, suggesting that a relationship may exist between post-burn mortality and the higher burn severity (CBI 1.52) than in other underburns on City ownership. However, the CBI score of 1.52 is barely into the moderate range of burn severity which is often considered acceptable in most prescribed underburning outcomes. The somewhat more severe outcomes in this burn/unit were likely also influenced by other variables as well such as topographical influences (e.g. very steep with increased heating and damage of crowns), droughty conditions pre-dating the burn, low site productivities in these upper third slope locations, inherently reduced pre-burn tree vigor, and perhaps others.

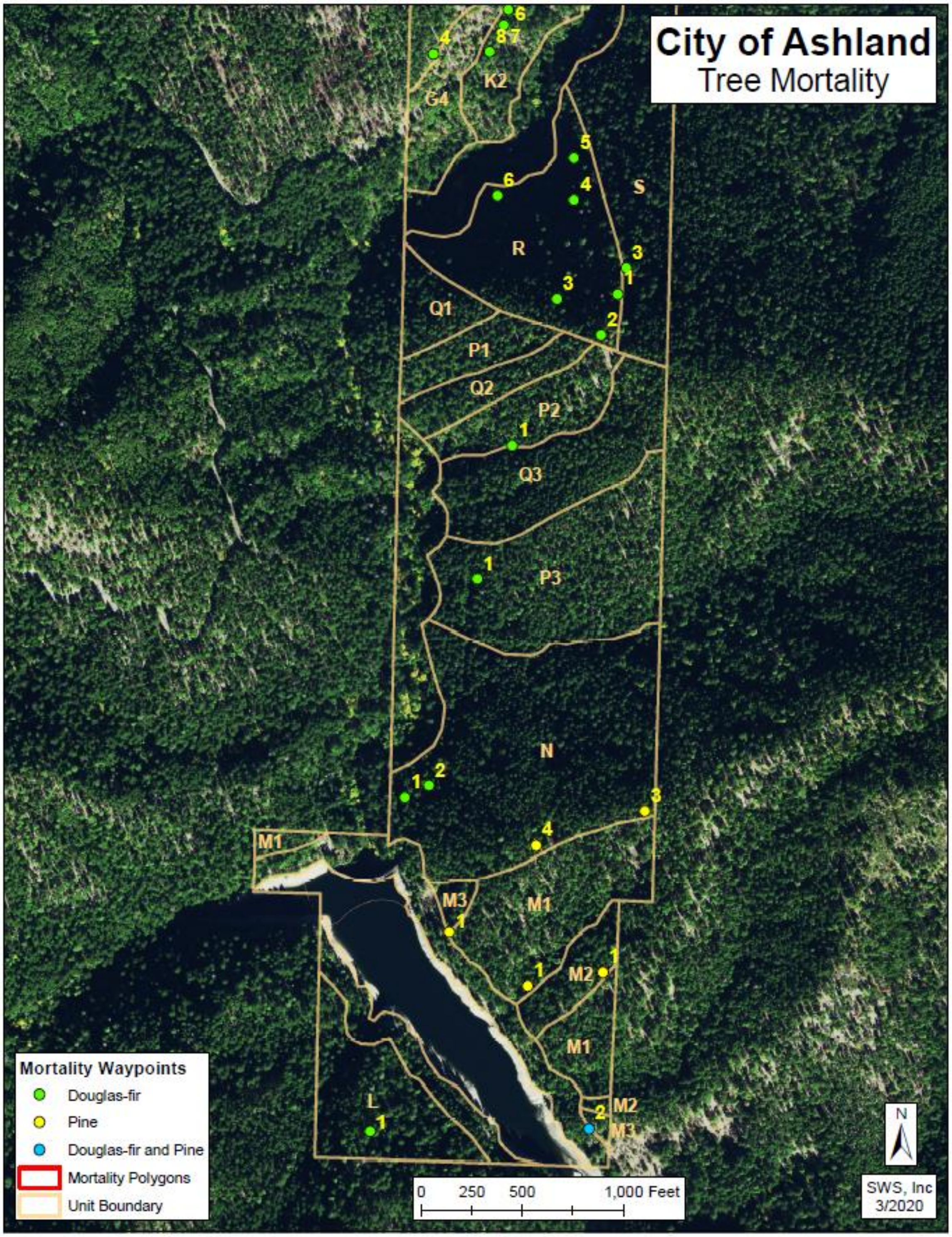
Map 1a


City of Ashland
Tree Mortality
Species
Douglas-fir
Ponderosa pine
Douglas-fir and Pine
Mortality Polygons
Unit Boundaries
0
250
500
1,000 Feet
SWS, Inc.
3/2020

Map 1b


City of Ashland
Tree Mortality
Species
Douglas-fir
Ponderosa pine
DF and PP
Mortality Polygons
Unit Boundaries
0 250 500 1,000 Feet
SWS, Inc.
3/2020

Map 2a


City of Ashland
Tree Mortality
Mortality Waypoints
Douglas-fir
Pine
Douglas-fir and Pine
Mortality Polygons
Unit Boundary
0 250 500 1,000 Feet
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SWS, Inc
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G4
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Q1
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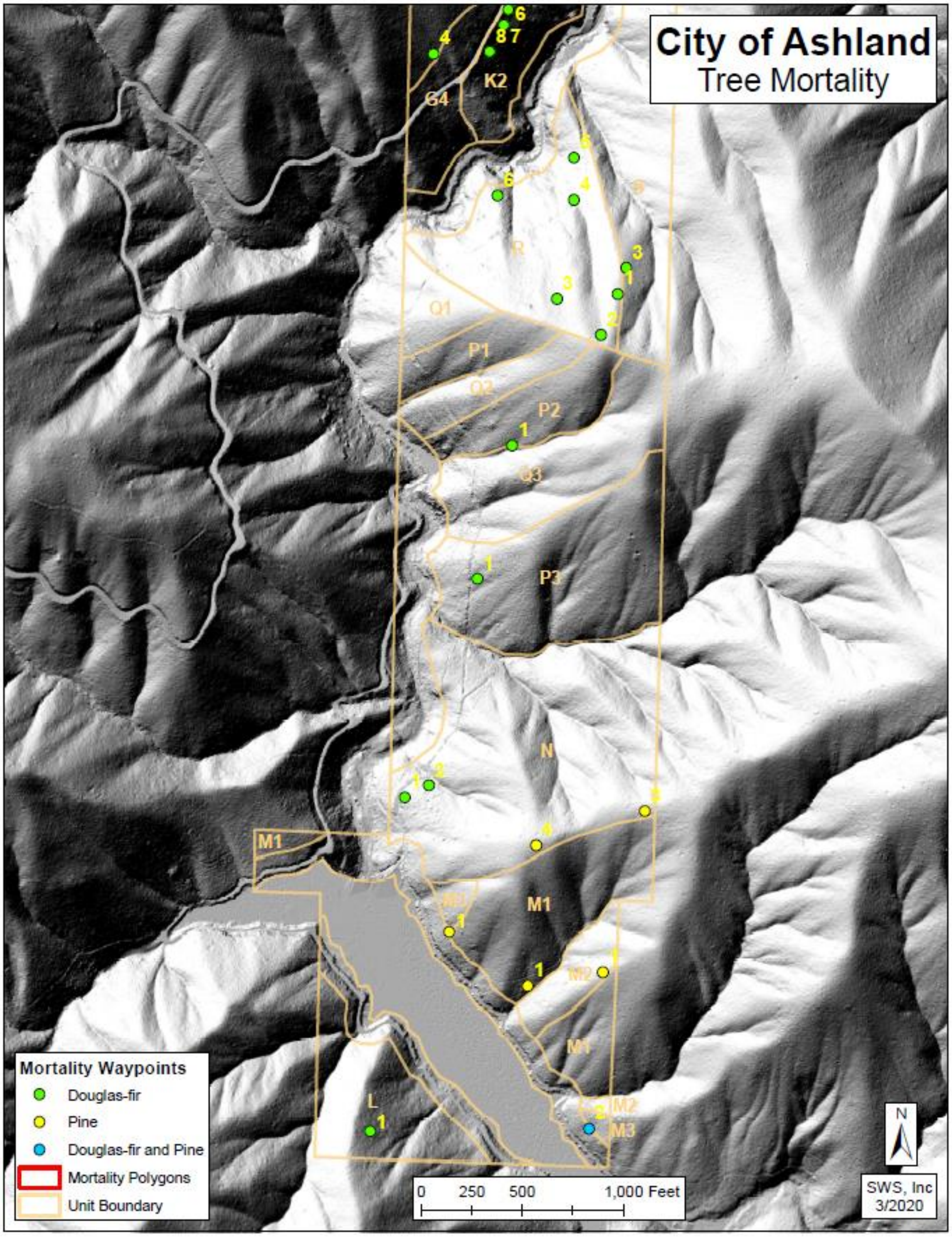
Map 2b


City of Ashland
Tree Mortality
Mortality Waypoints
Douglas-fir
Pine
Douglas-fir and Pine
Mortality Polygons
Unit Boundary
0 250 500 1,000 Feet
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SWS, Inc
3/2020
K2
G4
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Q1
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P2
Q3
P3
N
M1
M2
M3
L

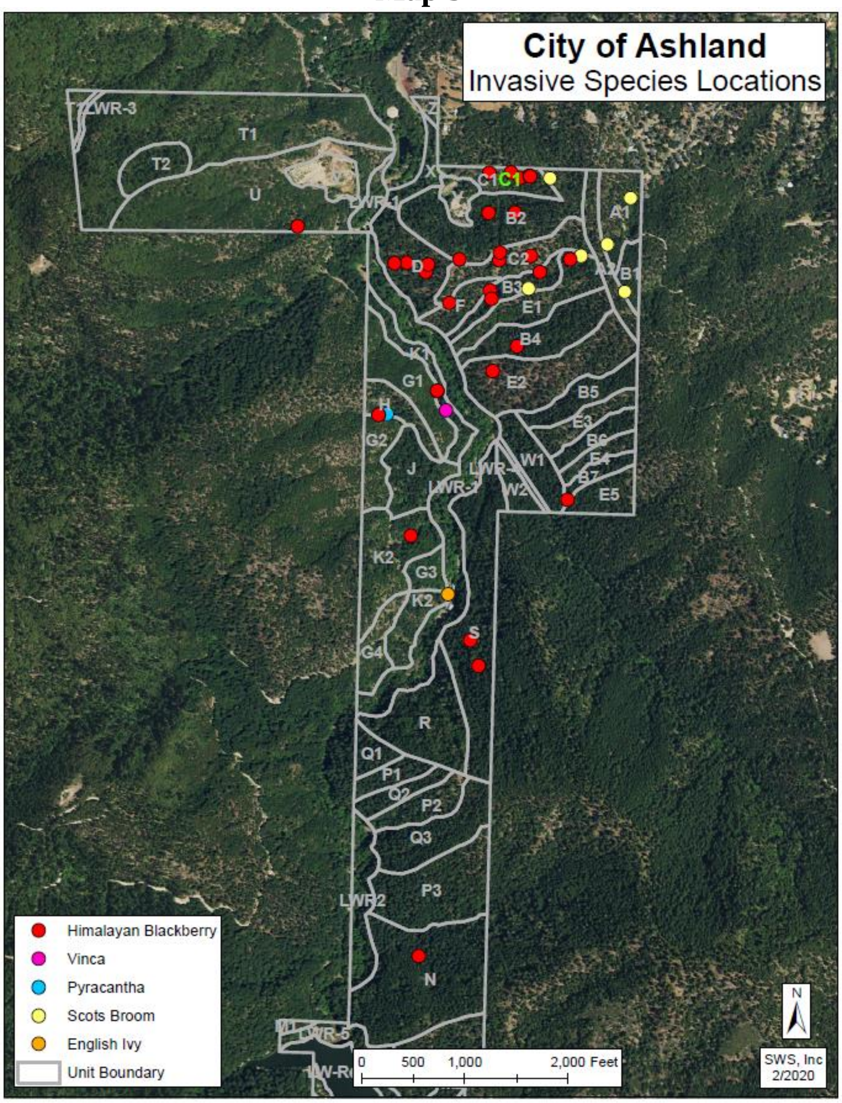
Current potential for helicopter harvest of dead merchantable conifers

The vast majority of the surveyed snags were beyond merchantability, having died 3 or more years ago. Recently dead trees that had current merchantability comprised only about 5+/-% of the total snags surveyed, and were widely scattered and rarely in close proximity that would allow for full payload in a turn of logs in a helicopter logging project. This makes economic retrieval of them unrealistic at this time due to the low total volume, the small piece size and the very scattered nature of that volume, particularly given that the only way to retrieve them is through very expensive helicopter logging. The only way that current merchantable conifer snags could realistically be retrieved would be if they were incorporated into a needed stand level thinning that generated more consistent and larger amounts of merchantable volume.

Occurrence of Invasive Plant Species

The occurrence of invasive plant species was recorded in the field using Avenza technology (see Map 3). A portion of these locations were then re-visited and the invasive plants removed, including all of the Scots broom.

Map 3



Discussion

Tree mortality generally occurs as the final outcome of a combination of assorted cumulative stressors which combine to produce physiological changes from which a tree cannot recover. These stressors can include excessive stand densities, drought and other weather-related phenomena, impacts from fire or other physical damage, low site productivities, soils impacts such as soil compaction, impacts from insects and diseases and others. These cumulative stressors typically combine to limit the available moisture to the tree. The Mediterranean climate of southern Oregon, with extended hot and dry summer seasons, exacerbates the role of moisture influencing tree mortality, particularly at lower to mid elevations like those of the lower City ownership.

Although moisture limitations alone are enough to cause tree mortality, it more commonly occurs when native insects respond to increasing tree and stand level stress and are more successful at overcoming natural tree defenses. This dynamic occurs with a cadre of insects that are host-specific for any given tree species, with a corresponding biology unique to the insect/tree. Understanding these relationships is key for land managers to be able to conduct stand management to meet long-term objectives, as outcomes can range from mortality of a small number of scattered individual trees to mortality of all trees of a given species from large areas in a high severity disturbance. This report explores ways to avoid these type of high severity disturbances from insect-related mortality while perhaps accepting some smaller scale, low to moderate severity levels of mortality from insects, disease and/or low severity prescribed fire. Management that helps increase the likelihood for these types of disturbances are much preferred over the type of high severity disturbance that is often associated to varying degrees with wildfire which would NOT be desirable for achieving objectives for City forestlands.

Douglas-fir insect-related mortality from flatheaded fir borer

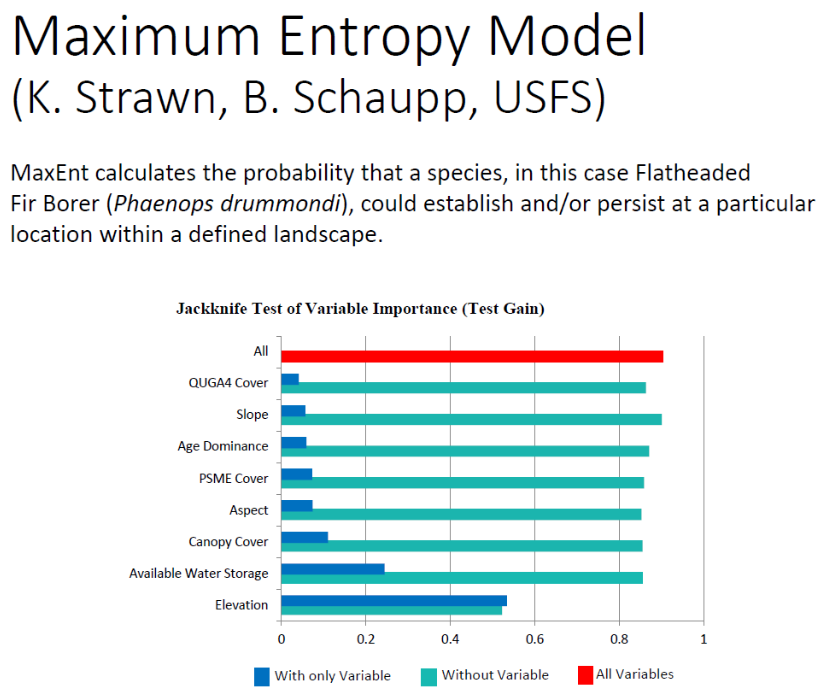
Douglas-fir is the most common tree species on the lower City ownership currently and its abundance on these sites is thought to be outside of historical norms (Metlen et. al 2012; Ashland Forest Plan 2016). Elevated densities on these moisture-limited sites has resulted in a high level of cumulative stress of Douglas-fir. A number of biotic and abiotic agents can contribute to eventual tree mortality, including site and weather factors such as described above. In addition, there are a host of other biotic agents that may be contributing to Douglas-fir decline such as Douglas fir engraver *Scolytus unispinosus*, Douglas-fir pole beetle *Psuedohylesinus nebulosus*, Douglas-fir twig weevil *Cylindrocopturus furnissi*, Douglas-fir beetle *Dendroctonus preudotsugae*, Phomopsis canker *Phomopsis lokoyae*, Armillaria root disease *Armillaria ostoyae*, Laminated root disease *Phellinus weirii* and likely others.

However, on a broad scale, the primary causative biotic mortality factor affecting Douglas-fir on the City ownership in recent years has been the flatheaded fir borer (FFB) *Phaenops drummondi*. This insect prefers dying, burned or recently downed hosts and is generally regarded as part of the "clean-up crew" that begins the process of decay of downed wood, as do most wood-boring insects. They typically have a one year life cycle, but can have an extended life cycle of up to 4 years (or perhaps more) depending on host quality. In southern Oregon, they have become well-established agents of mortality of Douglas-fir, with host-finding mediated by the trees broadcasting a chemical message of degraded tissue (Schaupp 2017, 2018).

Historically, there has been little research, few publications and only episodic attention given to the species (Schaupp 2017), at least until recently when (now retired) USFS Forest Entomolgist Bill Schaupp devoted considerable time, energy and expertise to understanding and monitoring this species, even though the insect is acknowledged to be difficult to detect in the field. A major symposium in April 2017 ("The Flatheaded Fir Borer and Management of Low Elevation Douglas-fir in the Klamath Mountains Ecoregion: Knowns, Unknowns, and Best Practices", Oregon State University Extension) summarized knowledge about the insect and its occurrence. In that symposium, Schaupp presented a working hypothesis: "that these FFB-attacked Douglas-fir are at the lower end of their ecological amplitude, growing on marginal sites. Available moisture could be a key factor in this. It is suspected that a more frequent fire return interval would result in far fewer Douglas-fir occupying such warm, dry sites."

Schaupp also presented a Maximum Entropy model (Strawn and Schaupp, 2017) that found two variables that offered significant contributions to model gain: elevation and available water.

Graph 1



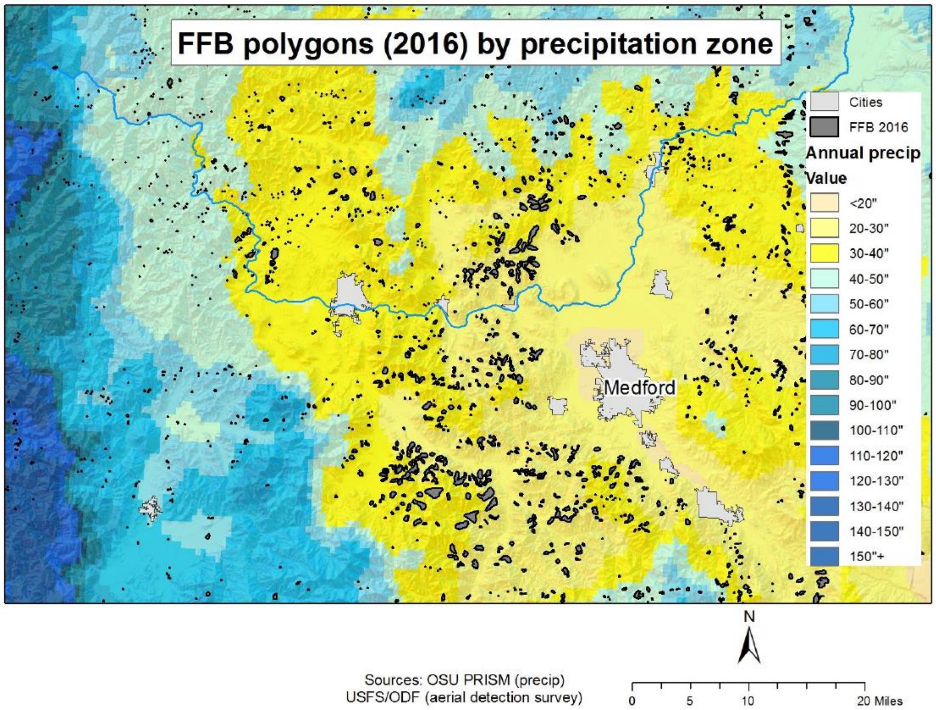
Schaupp also produced the following list of risk factors (***most important risk factors; *moderately important risk factors):

- *** Elevation less than 3,500 feet
- *** Low water availability
- ** Pine-oak forest type
- ** Hot, dry sites
- * Fire recently or long time absent
- * Sparse crown, poor growth

In the same symposium, Max Bennett (OSU Extension Forester) offered 3 primary environmental variables associated with flatheaded fir borers in a GIS analysis- precipitation (see Map 4; Graph 2), elevation, and soil water. Other factors that seemed important included:

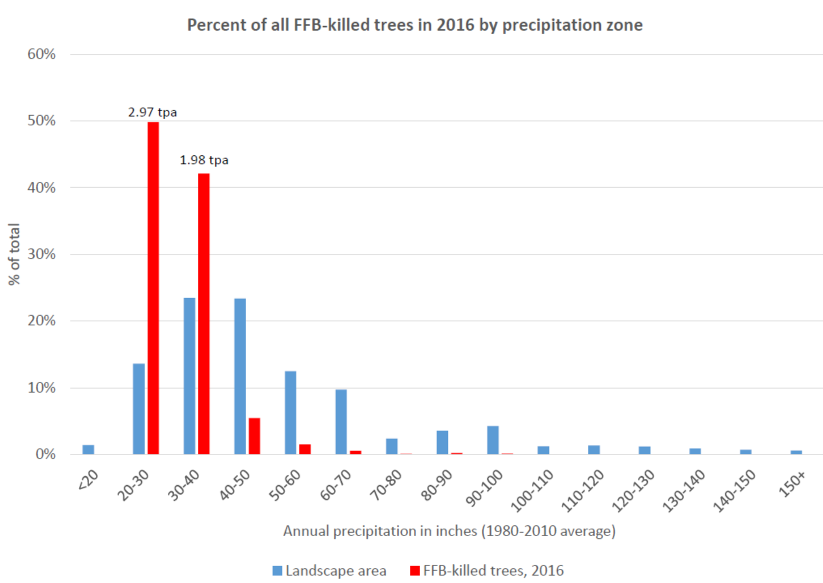
- •DF growing in or on margins of stands with Oregon white oak
- •Local topography, e.g., concave vs. convex slopes
- •Patch edges vs. interiors
- •Low vigor DF in the 80-120 year age class growing on marginal sites for DF

Map 4



Source: Bennett 2017

Graph 2

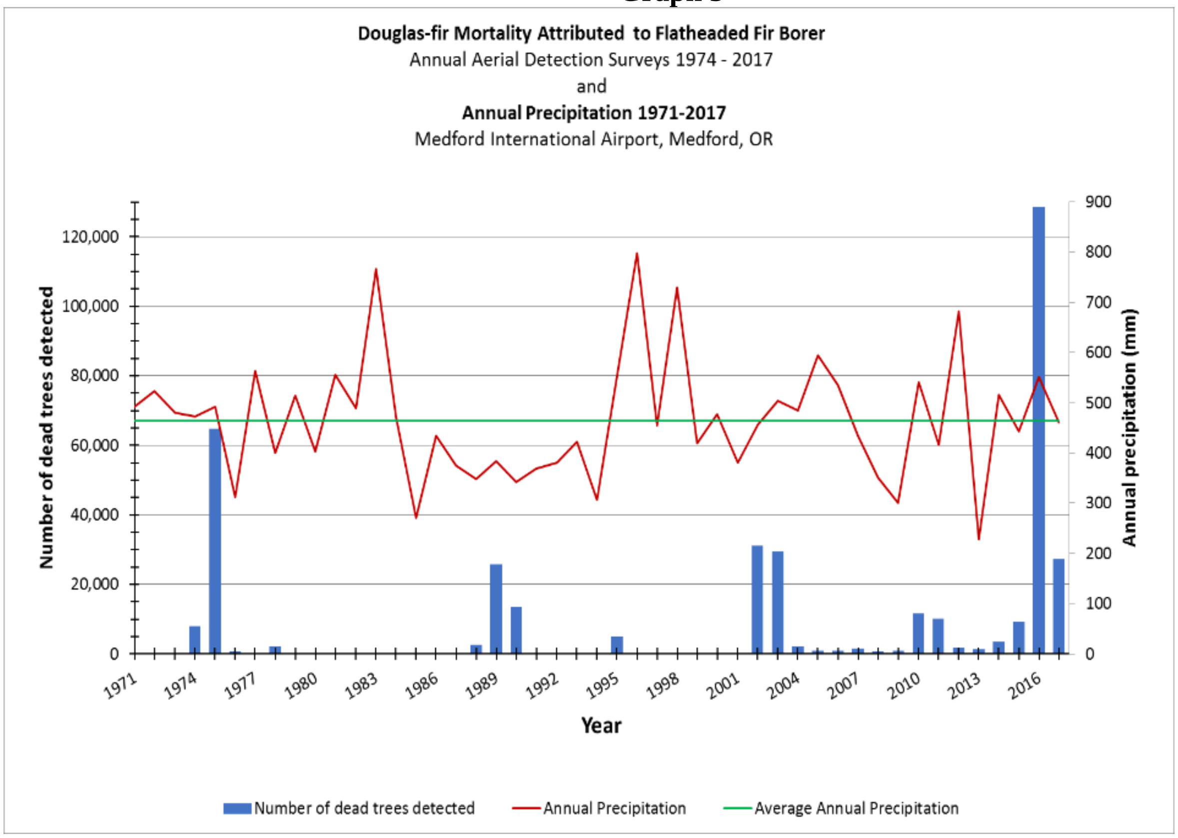


Mean annual precipitation 2016 FFB polygons 29.4”

Source: Bennett 2017

Bill Schaupp also presented a graph (see Graph 3 below) establishing a relationship between low annual precipitation and increased FFB activity. The years in which increased FFB activity occurred correspond nicely with years of high Douglas-fir mortality in the Ashland WUI back to the first major pulse of FFB related mortality in the Lithia Park hillside in 1989-90.

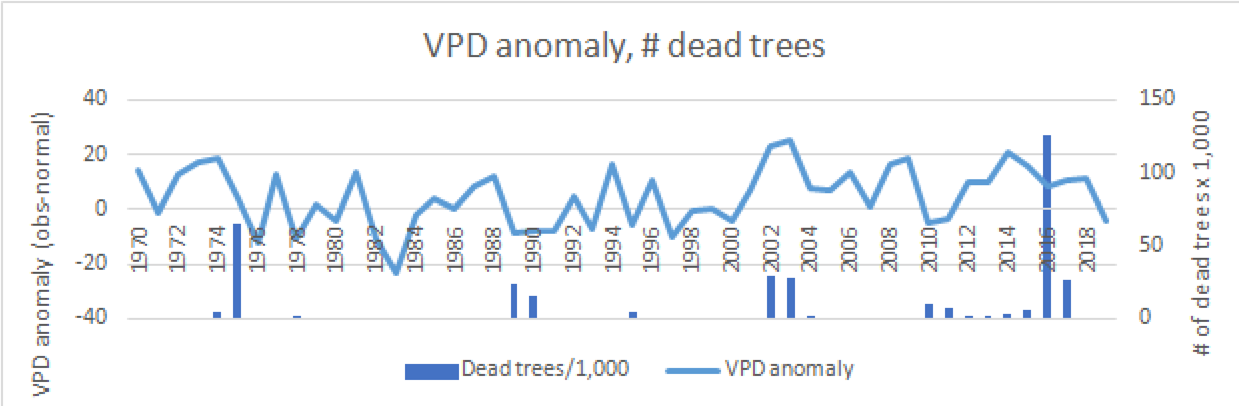
Graph 3



Source: Schaupp 2017

Max Bennett has recently added to this understanding, and proposed the concept of the deleterious effects of "hot drought" in the summer season when vapor pressure deficits (VPD) produce abnormal stress on trees. “Hot drought” is a combination of dry conditions and hotter than normal temperatures that causes trees to become more vulnerable to insects pests, pathogens, and abiotic damage. As VPD goes up, the atmospheric “pull” on trees to supply water from their roots increases. If the pull increases beyond a critical level, portions of the water columns within the root-tree transport network may fill with air bubbles (cavitation), resulting in a loss of water transport capability in that location and death of plant tissue supplied by the water column. Alternatively, the tree may close stomata, reducing water loss but also reducing photosynthesis. VPD is not a direct measure of tree moisture stress, since we don’t know from VPD the level of available soil water storage and the ability of a given tree to access that moisture, but all other things equal, we should expect relative tree moisture stress to increase as VPD increases (Bennett, unpublished, 2020; Grossiord et. al 2020).

Graph 4



Source: Bennett (2020)

In Graph 4, peaks in vapor pressure deficit (VPD) correlates well with corresponding increases in dead trees in southern Oregon (which are counted in the annual aerial insect survey that is usually in the late spring or summer of the year after the main damage occurs) at the time of or in the year immediately following a high VPD. In other words, the peak of this index matches very well with the peak of mortality. The peaks also correlate with flatheaded fir borer related mortality events in the Ashland wildland interface area in 1989-90, 1994-96, 2002-03, 2009-10 and more recently in 2014-16.

In summary, Schaupp (2018) concluded that when there is not enough water:

- Water-conducting cells blocked by air bubbles
- Water conducting cells collapse
- Close stomata (openings in leaves) for too long, reduce amount of food produced (carbon starvation)
- Less food available for growth, defense, and repair
- Fewer defensive mechanisms or compounds makes tree more vulnerable to insects and pathogens
- Overheats, proteins denature, volatiles emitted
- Wilting
- Cells and features formed are small with resulting stunting, dieback, disease, insect attack and death.

The potential for rapid and massive upswing in mortality related to drought (such as the 2001 drought event) is captured in Table A:

Table A

Annual Cooperative Aerial Mortality Survey- Number of Dead Trees, Rogue/Illinois Valleys, Siskiyou Foothills, Umpqua Interior Foothills, and Inland Siskiyou Bioregions

Species	2000	2001	2002
Sugar Pine	112	144	699
Ponderosa Pine	249	417	20,986
Douglas-fir	413	321	32,148

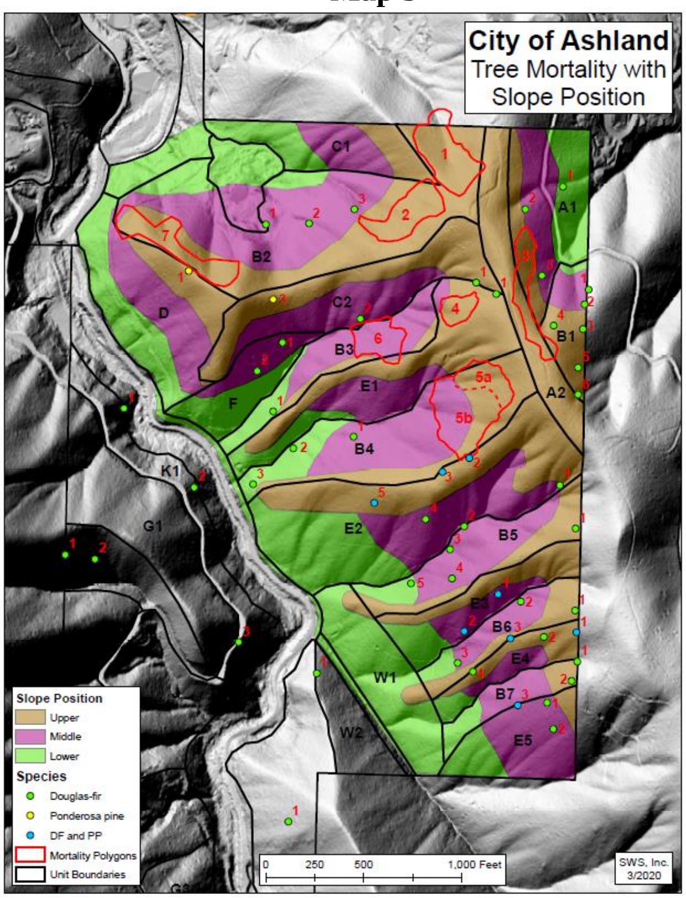
Source: Southwest Oregon Forest Insect and Disease Service Center

The spatially explicit data presented as results in this report tends to agree with the findings above, and validate some of the qualitative assessments that have guided forest management on City lands over the past 25 years. Analysis of the data in this report suggests the following conclusions:

1. Mortality of Douglas-fir is related to elevation on the City ownership (see Maps 1a,b,c,d) ; Table 4) with a noticeable elevational transition in mortality currently at around 2800'+/- in this north-trending watershed , with some variation depending on other site factors. This was recognized qualitatively on City lands and presented as early as 2006 (Main 2006). The elevational gradient for annual precipitation is quite steep on the City ownership, varying from 23 to 27 inches annually in just 1.6 miles between the lowest elevation sites (2300') and Unit LW-M at Reeder Reservoir (3200'). In addition, with the ~900' elevation change, a 2-3 degree Fahrenheit reduction in average temperature and associated decrease in VPD occurs with this increasing elevation.

2. Topographic slope position also is a factor as spatially presented (see Map 5; Appendix Table 2). The upper third slope locations typically have shallower and/or rockier soils with less available waterholding capacity than elsewhere on the landscape. Conversely, lower slope positions tend to have deeper soils and more waterholding capacity, as well as benefitting from cooler temperatures, higher humidities and reduced VPD, especially when closer to more significant aquatic/riparian habitats of Ashland Creek. Mid-slopes are intermediate, and the spatially explicit data in this analysis clearly shows these distinctions. These kind of topographic variables are important for retaining climate and disturbance refugia where trees are less stressed and more likely to avoid higher levels of mortality found elsewhere on the landscape, an important element for biodiversity conservation (Downing et.al 2020).

Map 5



3. Aspect in droughty low elevation sites also appears to be important on this microsite scale of analysis, although perhaps not to the same degree as the first two variables. In this analysis, almost all of the polygons of high severity mortality were located on west or northwest aspects, or on ridgelines with a small amount of spillover downslope. This result is suspected to be an integration of two factors: 1) these are dry sites with shallower, rockier soils, moreso than associated northerly/northeasterly aspects; 2) there is a higher abundance and densities of Douglas-fir, particularly as compared to more southerly aspects, and subsequent potential for FFB habitat. However, in a number of low elevation sites in the Ashland Wildland Urban Interface (WUI) area and elsewhere in southern Oregon, northerly and northeasterly aspects with similar stand types, elevations and topography appear to retain improved long-term survival and growth of Douglas-fir , as well as more successfully responding to stand density reduction treatments and avoiding severe flatheaded fir borer related mortality. Northerly and northeasterly aspects in general are cooler and shadier, but they also tend to be steeper (+5-15%) in the decomposed granitic landforms of the Ashland batholith, resulting in even more shading, less solar heat input, and reduced VPD for longer periods of time during the year. For example, Unit LW-B1 is close to many of the high severity polygons (see Maps 1a, 1b, 5) but is located on more northeasterly aspects and has maintained stand integrity with reduced interior stand mortality (mortality has occurred on the transitional edges with other aspects, particularly to the east), even though it has never been treated. Similarly, nearby 44 acre AFR Unit 2d on US Forest Service ownership to the west is an excellent example of a low elevation Douglas-fir dominated, multi-layered old-growth forest habitat with minimal insect-related mortality largely because of its favorable microsite on steep more northerly aspects. Importantly, it was one of the few areas that burned as an understory fire in the otherwise high severity 1959 wildfire, attesting to the effectiveness of such sites and stand conditions in mitigating the potential for wildfire.

4. As elsewhere in southern Oregon, flatheaded fir borer related mortality often occurs first on the edges of stands in the City ownership, as well as attacking the largest, tallest interior trees first (Main 2006, 2010; Schaupp 2016, Bennett 2017). It has been theorized that higher bole temperatures in direct sun in these more open conditions may produce chemical signals that act as attractants to flatheaded fir borers. If the insects are responding to temperature signals in the boles, then increasing temperature with "hot droughts" and/or climate change could continue to elevate flatheaded fir borer related mortality in southern Oregon. This could also help explain why some thinned stands may actually produce an increase in flatheaded fir borer activity. Stand edges may also be susceptible to increasing competition for resources as neighboring vegetation in the adjacent openings matures.

5. Size of interior habitat also appears to have some influence on the potential for successful attack by flatheaded fir borers. These larger sized units produce more shading, decreased temperatures, and maintenance of elevated humidities, thereby avoiding bole heating, high VPD's and effects from "hot droughts". Smaller and/or more narrow unit configurations such as subunits LW-B2 "Barranca" (see Polygon 1 in Map 1a,b) and LW-B3 (see Polygon 3 in Maps 1a,b,) with more edge effect and less interior habitat, have had greater levels of Douglas-fir mortality than other adjacent stands (e.g. portions of Unit LW-B2 in the lower third slope positions; Unit LW-B4; and Unit LW-J all have larger interior habitat and have retained their stand integrity for longer times than elsewhere in the same vicinity). Mortality has also been minimal in the previously described USFS Unit 2d that support old-growth forest conditions in this large 44 acre unit with abundant interior habitat.

6. Flatheaded fir borer related mortality has been most abundant in southern Oregon on low productive sites with 80-120 year old even-aged stands dominated by extremely dense, suppressed and stagnant Douglas-fir. The low productivity of these sites is usually related to soils conditions with reduced water-holding capacity. The vegetation reflects those conditions with very drought tolerant species present or in close proximity, most notably Oregon white oak, whiteleaf amnzanita, mountain mahogany and others. The stands on these sites that are preferentially attacked by FFB tend to have extremely high stand densities (often at or even above theoretical maximums for Douglas-fir), highly stressed trees and are easy targets for

rapid expansion of FFB populations. These even-aged Douglas-fir dominated stands were established after a change from the historic more frequent, low severity disturbance regimes to the more infrequent high severity disturbances that became more common in the 20th century. They typically have had little stand differentiation over time but rather retain a homogenous tree and stand structure characterized by trees with small crowns, low radial growths and high to extreme stand densities of primarily smaller diameter Douglas-fir. Unlike more ongoing endemic levels of thinning that remove less vigorous individuals more slowly over time, these older extremely dense stands (some have been measured to exceed the theoretical maximum; see Appendix, Table 9) are characterized by stand development with limited mortality to very high densities, often with outbreak levels of FFB as the final agent of stand level mortality which can occur in a rapid pulse often associated with drought. These stands, and subsequent stand level mortality, has been a common occurrence over the past 30 years in the Ashland WUI, on the lower City ownership and elsewhere on similar sites in southern Oregon. In 1998 prior to active management on the City of Ashland forestlands, high to extreme stand densities were measured in 18 out of 22 units (see Appendix: Table 9).

Each of the six above-listed variables have strong relationships with temperature and water stress, factors which have been long understood to influence host tree vigor in tree/insect dynamics (Powell and Logan 2005, Berg et al.2006). This reality is amplified by the Mediterranean climate of southern Oregon with inherent seasonal water shortages in the dry summer season.

Water availability for plants is also strongly associated with site productivity on the City ownership, with deeper more productive soils able to store greater amounts of water that translates generally into higher stocking levels of larger and more vigorous trees than on sites of lower productivity. Site productivity also is related to the six factors described above- it tends to increase with elevation, more favorable slope positions, on more northerly aspects and in stand development patterns where trees more rapidly differentiate and thus avoiding the development of the extremely dense, stagnant, suppressed and relatively homogenous stands of 80-120 year old Douglas-fir where flatheaded fir borer related mortality has been the most pronounced.

An abundance of suitable host trees of susceptible vigor, age and density are required for large scale insect outbreaks to occur (Fettig et. al 2007). In association with drought and water stress (see Table A; Graphs 2,3,4), this is what has happened in the following larger scale FFB-related mortality events on City lands:

- Lithia Park in the 1989-1993 drought cycle;
- Units A and D1 following the extended 1987-1994 drought
- Unit B2 "Barranca" initiated at the same time and amplified in the 2001 drought event;
- Douglas-fir mortality throughout the northern half of the lower watershed area following the 2001 drought event which resulted in the 2004 helicopter timber sale;
- A less noticeable mortality event following the 2008-09 drought cycle (see Main 2010)
- Increased Douglas-fir mortality following the 2013-14 drought cycle which resulted in many of the 3+ year old snags found in this survey that were initiated in 2015-16.

<u>Risk Rating of the Potential for Tree Mortality</u>

This very nuanced analysis with 6 determinate characteristics varying on a microsite level is displayed in a simple table format that can improve understanding about the complexity of the cumulative stressors that inherently elevate the risk of Douglas-fir mortality (see below and in Appendix, Table 7. Simple Risk Rating for Douglas-fir Mortality on the lower City of Ashland Ownership). This table combines both qualitative and quantitative assessments in order to predict imminent risk of stand level decline/mortality, the potential for effective treatments to reduce that risk and in general assist in making management decisions in situations where conditions can be rapidly changing. The table clearly shows the extreme risk of mortality (scores of +6 to +7) in sites/stands where extensive mortality has already occurred- the seven spatially explicit polygons of mortality exhibited on Maps 1a,b.

In contrast, the table also exhibits the reduced risk of mortality in units that currently have low levels of tree mortality. (i.e. a score of -1 to -3 in Units LW-J, LW-P, LW-Q and LW-N). One example unit, Unit LWK-1, is shown that currently is rated as a high risk, but currently with a moderate level of mortality (i.e. an overall score of 0 in Table 7).

Table 7: Simple risk rating for Douglas-fir mortality in the lower City of Ashland ownership[1]
(Positive numbers indicate increased likelihood of mortality, lower numbers indicate decreased likelihood of mortality; Scale is from +2 to -2).

Variable	Polygons[2]						Example Units				
	1	2	3	5[3]	6	7	K1[4]	N	P	Q	J[4]
Elevation	+2	+2	+2	+1	+1	+2	+2	-2	-1	-1	+2
Topographical position	+2	+2	+2	+2	+1	+2	-2	0	0	0	-2
Aspect	-1	+1	-1	+1	+1	0	-2	-1	+1	-1	0
Stand edge/interior habitat	+2	-1	+2	+1	+2	+1	+1	-2	-1	-1	-1
Excessive stand density[5]	+2	+2	+2	+1	+2	+1	+1	+2	0	+1	-1
Total	**+7**	**+6**	**+7**	**+6**	**+7**	**+6**	**0**	**-3**	**-1**	**-2**	**-2**

[1]This table is provided as a conceptual framework for assessment to help understand how multiple variables can be assessed to provide a rating for any individual site/stand. The variables should also probably be weighted in importance although a much more elaborate analysis (e.g.. multivariate analysis) would be needed to provide this type of information and is well outside the scope of this paper. The influence of each variable presented varies greatly between sites but all have various levels of relationships with moisture availability.
[2]Polygon 4 was excluded because it was in a portion of the prescribed underburn that had no Douglas-fir mortality.
[3]The 2018 prescribed burn was an additional influence on mortality in Polygon 5.
[4]Close proximity to riparian areas and more favorable microclimate conditions wereanother influence on the low levels of mortality in Units K1 and J.
[5]Generally in even-aged 80-120 year old stands with much reduced stand differentiation; in these situations, stand level dynamics seem to have greater influence (i.e. they tend to act as a single unit with reduced potential for individual tree release) and adjustments through thinning can be more problematic..

Table 7 can be used to help quantitatively assign the risk of current or future mortality in other units on the lower City ownership, as well as on other City or Parks-owned lands if desired. With the survey results in this project and the table as a guide, four general categories of risk are defined for the Lower City ownership:

1) Extreme risk sites that have already gone through significant stand level decline/mortality;
2) High risk sites/stands, moderate levels of mortality
3) Moderate risk sites/stands, low current mortality
4) Low risk sites/stands, low current mortality,

<u>1. Extreme risk sites that have already gone through significant stand level mortality</u>

Extreme risk sites are primarily sites of lower productivity at lower elevations in the northern half of the lower City ownership. Many of these stands on these sites have already gone through the bulk of the phase of Douglas-fir removal from FFB-related mortality (see Polygons 1-7, Map 1a, 1b). As a result, these stands currently have much reduced levels of Douglas-fir and available FFB habitat and thus are also included in the section on low risk sites, low levels of currently mortality (see below). However, the site and stand conditions that produced this outcome, and the processes associated, are important to understand. One outcome is a much elevated amount of snags and subsequent downed fuels exists amidst developing fire-prone early successional vegetation, significantly compromising fire management goals and objectives on the lower City ownership. These current high fuel loadings are located close to City homes and infrastructure (see Polygons 1-7; Maps 1a,b).

2. High risk sites/stands, moderate levels of mortality (Units LWB, LWE3-5, LWG-4, LWK-1,2).

These high risk sites/stands have a range of pre-existing conditions, are the most difficult to assess and categorize, and subsequent outcomes from stand density reduction more difficult to predict. Many of these stands have continued on a path in recent years of frequent, low to moderate level snag development that more closely emulates endemic ongoing types of mortality. However, they are often adjacent or in close proximity to extreme risk sites/stands that have already undergone stand level mortality events. Although these sites/stands have avoided that outcome to date, it is suggested that they are not far from developing a stand level mortality outbreak. Site/stand characteristics are often only slightly different than the extreme risk sites/stands and the potential for successful treatment to build increasing stand level resilience is much more time sensitive, with each ensuing year further decreasing the likelihood of a more desired favorable response to thinning. Conducting stand density reduction in the middle of an outbreak is usually far less successful than prior to outbreak level conditions.

3. Moderate risk sites/stands, low current mortality (Units LW-L, M, N, P, Q, S, and W)

Sites/stands with a low amount of current mortality but a moderate risk of increased mortality in the near future are primarily located above 2800' elevation in the southern half of the lower City ownership. The increased elevation, more moisture availability and improved site productivity has allowed post-thinning retention of more vigorous trees than has occurred post-thinning on sites at lower elevations with reduced productivity. In comparison, however, the units are at relatively high densities currently (see Appendix- Table 8) although nowhere near the densities of those that existed pre-treatment lower in the lower City ownership (see Appendix-Table 9).

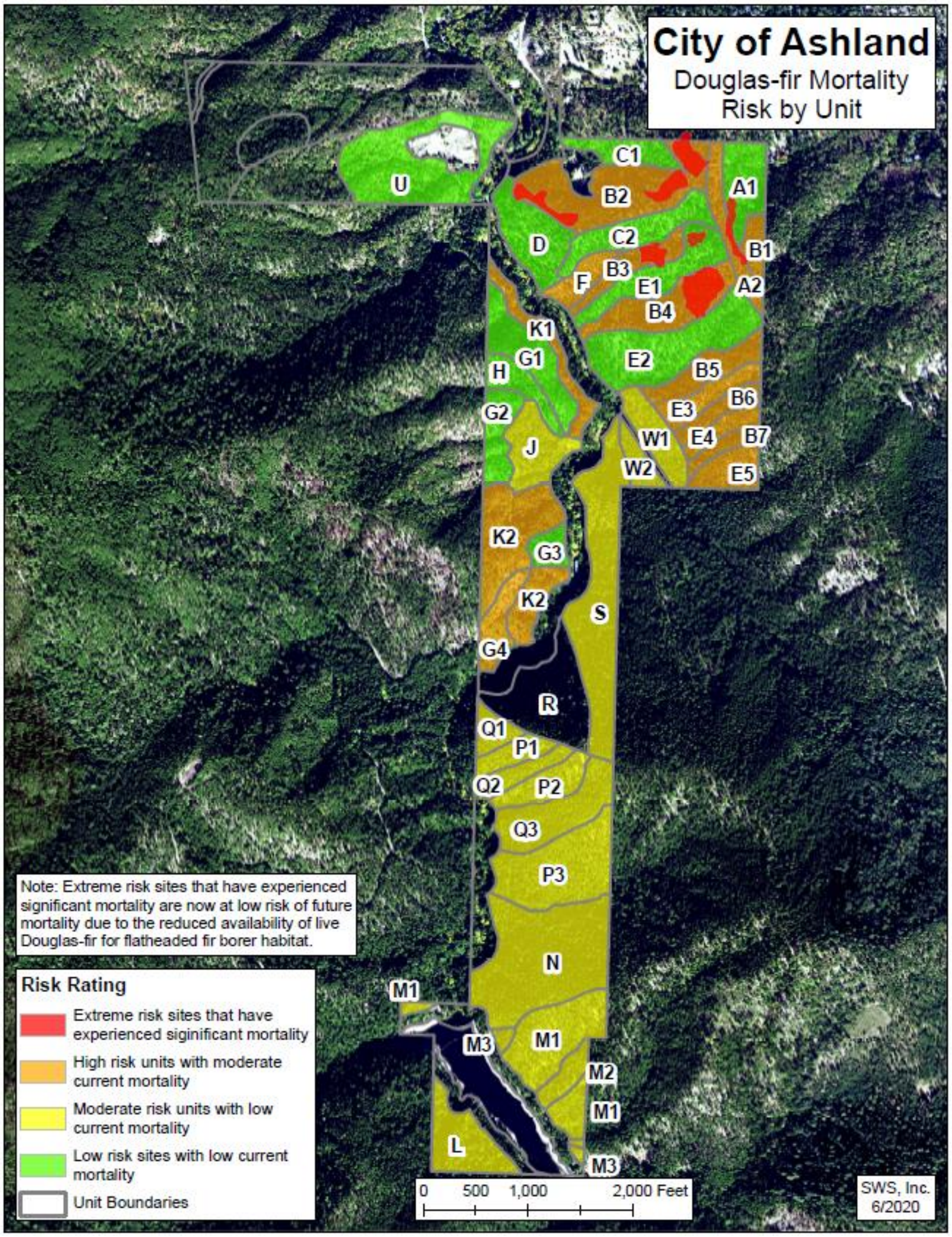
4. Low risk sites/stands, low current mortality

Sites with a low amount current Douglas-fir mortality and a reduced risk for additional mortality occur primarily in the lower elevations in the northern half of the lower City ownership. There are located in 3 types of site/stand conditions:

1) areas of very low site productivity that have already been through a significant wave of mortality that reduced the abundance of Douglas-fir and available habitat for FFB. These include the high mortality polygons as shown in in Maps 1a, 1b in Units LW-A1,2; B2-portions; B3-portions; D);
2) units on more southerly aspects that have had a reduced abundance of larger Douglas-fir (typically < 30/acre that are greater than 8" dbh) that currently make unlikely FFB habitat. These include Units LW-C1,2 and E1,2 that are currently at relatively low density (see Appendix; Table 8) and being managed to increase the percentage of pines;
3) younger units established after the 1959 wildfire (i.e. Units U,G) that are currently dominated by younger stands of mixed hardwoods and conifers initiated after that fire and lacking any continuous stocking of 8"+ dbh Douglas-fir.

It is important to note that the scale and intensity of the waves of Douglas-fir mortality following droughts appears to be decreasing in the lower City ownership, particularly after the more severe outbreaks that occurred beginning in 1989, 1995-96 and 2002-03. It is suspected that this has been due largely to the decreasing amount of available habitat for flatheaded fir borers given ongoing reductions in Douglas-fir on the sites of lowest productivity- both through active management (both commercial and non-commercial) and ongoing insect-related mortality throughout the area. Average basal areas for the lower City ownership have dropped approximately 25% from 1998 to 2017 (from 211 to 158 ft^2/acre), even with considerable ingrowth, and occurring at a wide range across a combination of both treated and untreated units. Eighteen out of 22 units were above a relative density index of 0.65 in 1998 (Main 1998), generally regarded the point where competition related mortality begins to occur. In contrast, the 2017 City inventory revealed that only 4 out of 21 units were above that density threshold. It is possible, if not likely that the more frequent disturbance regime instituted through repeated light silvicultural "stand improvement" types of thinning has contributed to both increased stand level vigor as well as decreased abundance of retained Douglas-fir, resulting in less opportunity for development of outbreaks of FFB related mortality like had been experienced prior to active management. Current intensities of mortality of Douglas-fir appears to be more of an ongoing endemic nature since the last major pulse in 2002-03 that predated the helicopter thinning in 2004. However, it is also certainly possible that elevated amounts of mortality may occur in the near future in other areas that have had less mortality over time to date. This years serious drought may be a precursor to exactly that possibility. The use of the maps of snags generated in this report (Maps 1a, 1b, 2a, 2b) should be able to serve as a baseline with which to analyze future changes over time.

Map 6



Management Strategies to Reduce Risk of Mortality of Douglas-fir

Adjustments in the density, species composition and stand structures through vegetation manipulation is a principal method by which ownership goals and objectives can be shaped in forest and resource management. Commonly known as stand density reduction, this is a well-established method for encouraging development of more resilient stands of increasing resistance to insect-related mortality (Fettig et.al 2007, Jain et.al 2012). However, each tree species and its associated cadre of insects that interact with it, has its own unique biology. The relationships between Douglas-fir and flatheaded fir borers is very complicated and has been little studied. The analyses offered here attempt to integrate 25 years of experience on the lower City ownership with existing science about tree/insect biology in general and emerging science about Douglas-fir/flatheaded fir borer in particular. It is offered to help guide the City in current and future decisionmaking in the management of their lands on the lower City ownership. However, it is only a guide and it is hoped that much additional adaptive learning can improve knowledge and understanding about this topic. In this location so close to town, in a municipal watershed and amidst a rapidly changing climate, it is essential that this learning occur.

In historic forests, stand density reduction commonly occurred through regular disturbance processes, including fire that occurred on a 7-12 year frequency in southern Oregon prior to the forced removal of native American influences on the landscape (Metlen et.al . 2018) Today, three of those disturbance agents- fire, insects and forest diseases- still occur, although they have moved from more frequent lower severity events to more infrequent, higher severity disturbance events, such as wildfire or the complete stand removals as a result of flatheaded fir borers as previously described. Restoring a more frequent, lower severity disturbance regime through repeated staged more conservative thinnings that more closely emulates historical disturbance regimes has been a common management theme on the lower City ownership.

Determining the effectiveness of stand management practices at producing desired changes on the low productivity sites in the lower City ownership depends on consideration of the following important variables:

1) an accurate assessment of sites/units based on existing environmental conditions such as aspect, topography, soils, etc.

2) an understanding of historical disturbance regimes, the possibility of more closely emulating those disturbance regimes, and the subtle and complex changes that have occurred with the change in disturbance

2) an in-depth identification of current stand condition and the potential for individual trees/vegetation of desired species to respond and release following various treatments;

3) the opportunity to prescribe and implement various types, frequencies, intensities and scale of silvicultural treatments over time depending of current and evolving City objectives;

4) the ability to predict responses to existing trees and vegetation to various treatments, and combinations of treatments with the intent of improving and/or optimizing tree and stand level vigor as a key element of resilience given future changing climate and likely future drought events;

5) constant monitoring to assess year to year changes in climate and the corresponding stand/tree/site vegetation response to thinning, prescribed underburning or other silvicultural treatments; and

6) rapid adjustment if necessary through principles and practices of adaptive management with a desired outcome of applying lessons learned directly onto the ground.

Insect-related mortality on the lower City ownership over the past 30 years has occurred in two primary types of disturbance: 1) endemic levels of mortality that is frequent, ongoing and generally of lower severity; and 2) infrequent higher levels of mortality produced under outbreak conditions in which larger stand level mortality occurs, usually in association with drought conditions. Both of these have been largely "unplanned disturbance events" that can vary considerably in terms of size, intensity, duration and scope. They can occur in ways that are outside of what is optimal given the City's objectives (e.g. loss of desirable species such as ponderosa or sugar pine; significant patches of mortality that results in a much greater fire hazard in the future when snags fall to the ground; occurring on slopes prone to failure with loss of root strength aggravating that potential, etc). However, ongoing, smaller scale, endemic levels of mortality is much more apt to occur in ways that more closely allow for achieving City objectives. In both types of disturbances, however, key to achieving City designated fire management objectives depends on effective treatment of developing slash that occurs as snags fall to the ground, fuels accumulate and more fire prone early successional vegetation develops in the resulting openings.

Planning for using endemic levels of insect-related disturbance events to achieve City objectives is much more problematic for a host of reasons, however, not the least of which is how quickly that it can change into a high severity event in stressful weather or climate conditions. On the other hand, planned silvicultural activities can be disturbance events designed to accomplish City goals and objectives without the wider range of potential outcomes that occurs with unplanned, weather dependent forms of disturbance.

There are two primary silvicultural practices that reduce stand densities to achieve specified objectives: 1) prescriptive thinning (either commercial or non-commercial) which has long been studied and well understood to be an effective tool for minimizing potential outbreaks of insect-related mortality (Fettig et. al 2007) ; 2) the use of prescribed underburning, which is less precise in outcome but more closely reflects historic disturbance regimes and primarily focuses on removal of excess surface and ladder fuels. Active management to achieve City objectives has primarily used one or both of these silvicultural practices to manipulate vegetation to more desirable conditions. In many cases, the use of both in any one stand or unit provides the best long-term outcome for individual stands from a fire management perspective (Stephens and Moghaddas 2005, Stephens et.al 2009, Fule et.al 2012). However, treatment response and management outcomes have been variable depending on the type of factors described above. A careful analysis of treatment responses over the past 25 years on the lower City ownership should be able to help inform decisions on how to proceed currently and into the future.

As outlined in the previous section, the units and stands on the lower City ownership are at various levels of risk of developing additional significant levels of tree mortality currently and in the future, while others have already gone through that phase and have large amounts of snags, downed trees and fuels and dense, incoming shrubs, small trees and other vegetation- all of which contribute to a significant fire hazard as well as developing tree and stand level stress . Generally speaking, it is in the City's best interests to avoid this outcome on most of its ownership, but rather help build healthy more vigorous stands that continue development towards older and often more open forest conditions whenever possible.

In extreme risk sites, thinning in these types of stands to produce desired outcomes can be very challenging and problematic, and does not necessarily prevent flatheaded borer related mortality and may actually aggravate it in some situations. Stands on these sites often lack of stand differentiation, the associated lack of vigorous individual trees and the increased likelihood that individual trees will not respond to stand density reduction. This condition suggests that system (or stand) level dynamics and processes may more important than individual tree dynamics with the entire system remaining close to a tipping point for extended periods of time. Even relatively slight changes may increase cumulative stand level stress resulting in a cascading threshhold of stand level mortality, often in association with drought.

Negative impacts associated with thinning that suddenly opens these types of stands include 1) sudden exposure of foliage that has long been composed of shade needles, 2) increased VPD 3) bole heating, which has been thought to provide a chemical signal that acts as an attractant to FFB 4) disruption of finely tuned below-ground processes (e.g. new stumps are in essence injuries in which limited resources are utilized to heal these wounds; mechanisms of water uptake such as hydraulic re-distribution developed over 80-120 years are impacted: etc.) 5) and likely numerous other complex relationships that may contribute to stand level decline rather than individual tree release. More aggressive thinning in these stagnant stands would likely have increased potential FFB-related mortality as Schaupp (2017) reported with heavy thinning in these types of stands during and right after drought.

However, given their frequent occurrence at low elevation sites in the lower City ownership, their location close to homes and infrastructure and their favorable stand structure particularly from a fire management perspective (dense canopies with high height-to-crown base, limited surface fuels and understory/ladder fuel development, closed canopies that continue to retard understory development, etc.), their functionality and retention in place can be important. This is in contrast to stand level decline and mortality, subsequent rapid increases in snags and downed fuels and emerging more fire-prone early successional vegetation that make these stand development trends in untreated stands, and associated extreme fire hazard, highly undesirable.

Unfortunately, these older stands, long at excessive densities on less than optimal sites and with low individual tree and stand level vigor, may not release and respond to thinning for some time, if at all. Main (2006) found an average decline of 15-30% in DF radial growth on lower City ownership in 2006 following considerable stand density reduction in the previous 4 years, with the greatest reduction in radial growth on the less productive sites. Simultaneously, there was a 61-89% increase in effective ground cover on these same sites, suggesting that the stand density reduction released the vegetation most likely to benefit from the treatment on these lower productive sites- the more aggressive understory grasses, herbaceous vegetation and native shrubs that are well-suited to these site conditions.. This understory development further challenged vigor and growth of the retained overstory trees, especially Douglas-fir. Ponderosa pine radial growth fared better in this same situation with an average decline of only 8.1% in comparison.

However, individual trees with better pre-treatment vigor were also much more likely to benefit from thinning by maintaining or improving vigor, increasing likelihood of long term retention in future stands. On the sites previously discussed, Main (2006) found that Douglas-fir with crown ratios of 40%+ , although still declining in radial growth, grew in radial growth 34.6% better than those with crown ratios <40%. In a species comparison, ponderosa pine with 40+% crown ratios also fared better with a positive radial growth increase (5.9%) as compared with a 27.5% radial growth decline in pines with less than 40% crown ratios. Unfortunately, in those stands that had more significant stand level mortality (see Polygons 1-7 in Maps 1a,1b), there were few, if any of these more vigorous tress as little stand differentiation had occurred over the 100-120 year time frame since initiation. Understanding how various levels and timing of treatments affects future stand development is critical in these situations.

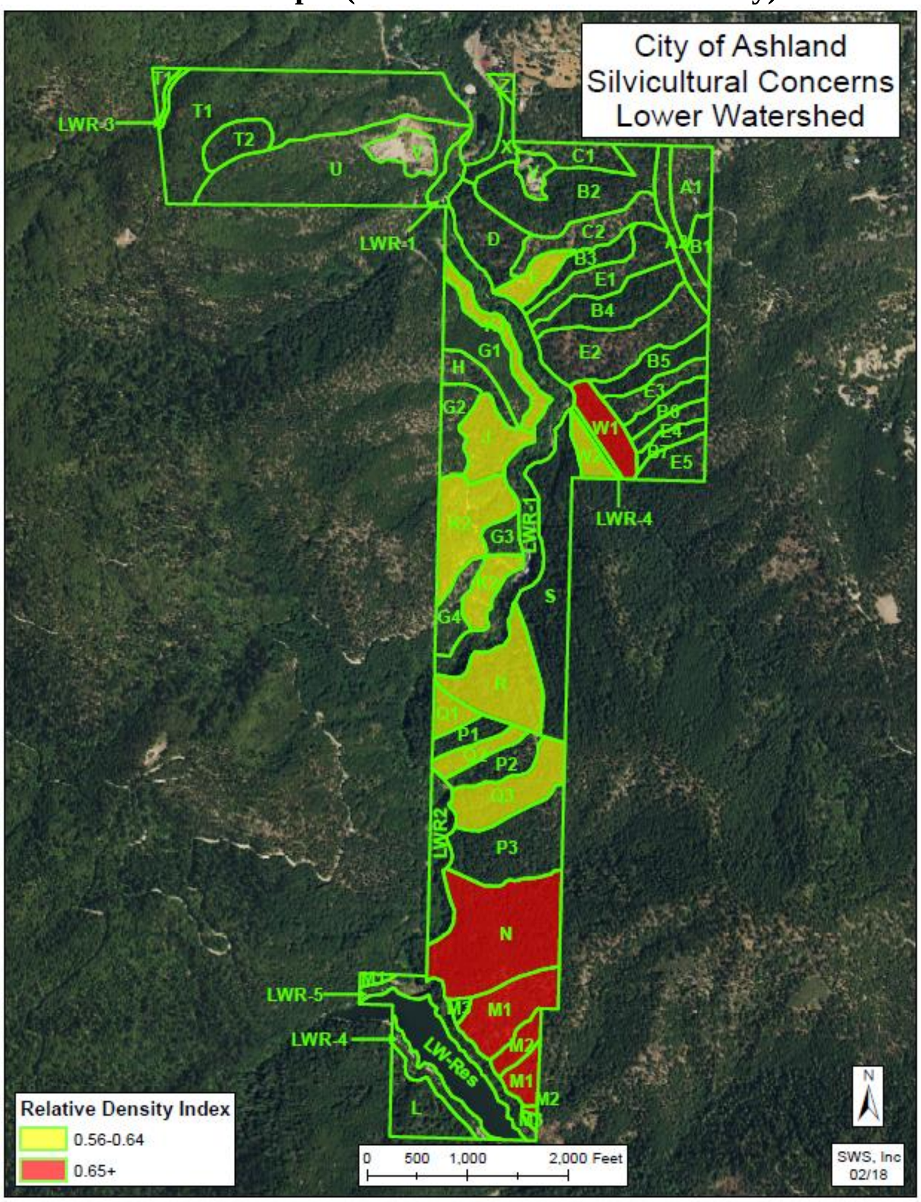
In response to this need, frequent light thinnings have been used with some success on the lower City ownership in these types of stands to more slowly alter the system to more favorable stand densities while dispersing mortality over time rather than the complete stand mortality that has commonly occurred in untreated stand conditions. Although ongoing mortality may not be able to be avoided, multiple conservative interventions do more closely replicate the historic more frequent, low severity disturbance regime even though it is likely that the historic landscape contained few of these even-aged dense suppressed Douglas-fir dominated stand structures. In the process, it has been found possible to extend the life of Douglas-fir in the stand composition.

This same strategy of multiple conservative interventions can also apply to high risk sites/stands with current moderate levels of mortality. Stand density reduction can be chosen as a planned (manual thinning, either non-commercial or commercial depending on stand conditions) or unplanned (endemic low levels of mortality spread out over time) event. Both types of stand density reduction can emulate the more frequent, low severity disturbance regimes that characterized stand development in the era of more frequent, low severity fire. Of course, it is unknown if the second type- endemic ongoing low-levels of mortality- will occur continually over time, given the vagaries of future weather and climate, site nuances, and professional judgment. Both methods of stand density reduction come with risks of a stand level response of significant mortality as previously described for extreme high risk sites, particularly as stand continue to grow and the frequency of warmer and drier conditions increases. Most importantly, decisions of how to proceed should always be made amidst the overarching backdrop of ownership objectives (e.g. how to proceed in Unit LW-K1 given the very steep slopes immediately above Ashland Creek with elevated potentials for slope failure and downstream impacts; accessibility and the associated costs for stand density reduction, especially commercially; etc.).

Moderate risk sites/stands with low levels of current mortality are good candidates for additional stand density reduction once again to improve tree and stand vigor and prepare the stands for more challenging conditions in the next drought event and/or with future warmer and/or drier conditions. These sites/stands are primarily located on better sites and higher elevations in the south half of the lower City ownership and subsequently have reduced moisture stress, even though they are currently at higher stand densities than elsewhere on the ownership. These higher densities, better sites and overall improved tree and stand vigor suggest that these stands/sites would respond nicely to stand improvement thinnings and continue on a track of development towards older forest conditions as desired by the City (Ashland Forest Plan 2016). Thinning well-ahead of future stress events such as drought is always more successful than during the actual event (Six and Skov 2009). The larger tree size and improved tree vigor in these stands currently, likely additionally improved in a future stand density reduction, would also allow more resistance to retained overstory tree damage and subsequently greater flexibility and success in any prescribed underburning operation.

In the previous section, there are 3 types of stands that currently have low risk of developing Douglas-fir mortality to any extent and also have low levels of snags currently. All three situations will require continued young stand management to keep stand densities at desired levels in order for these stands to develop into older forest conditions without significant future mortality from insects, disease or fire. With generally reduced site productivity, these stands will also take longer to develop into older forest conditions than on the more productive sites in the southern half of the lower City ownership. In some cases, downed fuels from stands that have already gone through FFP-related stand level reductions in Douglas-fir can be an issue if it has not been previously treated (e.g. treatment of downed fuels in Polygons 1 and 2 in portions of Unit LWB-2 are currently under contract for completion this year (see Maps 1a,1b). Planned or unplanned stand density reduction elsewhere in these types will also require continued slash treatment to maintain more fire management effectiveness, including use of prescribed fire when possible. Failure to actively manage these younger stands as they develop will, in the long-term, begin to compromise City objectives (e,g, develop excessive stand densities and subsequently low tree and stand level vigor; become a fire hazard; development of a less desirable species composition, etc).

Map 7 (from results of 2017 inventory)



This is a far more nuanced approach to thinning than occurs on most forest ownerships but is important when trying to achieve the multiple values and objectives in the complex and diverse environmental setting of the lower City ownership. A careful analysis of treatment responses over the past 25 years on the lower City ownership should be able to help inform decisions on how to proceed currently and into the future. For example, the effects and outcomes of various treatments/no treatment in stands/units that largely began in 1995 in similar stands with similar stand conditions, aspects and topographic locations can be observed and analyzed in the seven LW-B subunits. These were all 100-120 year old dense stagnant Douglas-fir dominated stands when silvicultural prescriptions were first developed (Main 1996, 1998) and implementation of active management of the City forestlands was begun. These subunits are largely located on northwesterly aspects in topographical locations trending from ridgelines to Ashland Creek (an exception is subunit B1 on northerly to northeasterly aspects in primarily mid to upper third slope positions only). Stand densities in 1995 were uniformly high to extreme, averaging 700-800 trees per acre of primarily Douglas-fir poles 6-14" dbh (average quadratic mean diameter of 8-9"), basal areas averaging 250-300 ft^2/acre and relative density indices averaging 0.9-1.0 and occasionally higher (i.e. at or very near the theoretical maximum relative stand density of 1.0). Flatheaded fir borer related mortality of Douglas-fir had been occurring, successfully removing Douglas-fir from Lithia Park in 1989-1990 and beginning to occur at a similar level in COA Units LW-A, LW-B2 "Barranca" and LW-D. These were largely extreme risk sites in the current rating system (see Table 7) and the polygons of mortality on Maps 1a,b had already occurred prior to active management of these sites

Since that inauspicious beginning. the following range of treatments/no treatment have occurred in this one unit (LWB) with 7 very similar subunits, providing the City the opportunity to observe management-related outcomes influenced by differences in treatments across a number of very similar sites/stands- a fine example of situational learning and adaptive management on extreme and high risk sites/stands.

1. In the "Barranca" portion of subunit LW-B2 (Polygon 1, Map 1a,b), over 95% of the original DF trees in this unthinned area have died, and most of this mortality occurred in two major pulses occurring between 1995-2003. The only treatment in this area to date has been falling some of the dead snags (especially near trails), followed by piling and burning resulting slash. Planting conifers, especially ponderosa pine, has also occurred as a follow-up treatment.

2. In a similar site and stand condition, harvesting to remove merchantable dead and dying Douglas-fir was conducted in Unit LW-D in 1996 and in Unit LW-A in 1995 and 2003 in order to remove this excessive fuel loading located adjacent City of Ashland houses and infrastructure while it was still merchantable. Accessibility to these units allowed for ground-based systems to be utilized, with a more favorable economic outcome. An estimated 2/3 to 3/4 of the merchantable sized Douglas-fir was removed. Both units have since received additional treatments, including prescribed underburning, and are much more advantageous currently from both a fire management and forest health perspectives.

3. In an adjacent stand in subunit LW-B2 (Polygon2, Maps 1a,b), three light thinnings (2 non-commercial and one commercial) and one understory release treatment have occurred in an attempt to slowly "release" the stand from severe stagnation. Today, the stand is comprised of a relatively low stocking of green Douglas-fir (currently, an estimated 60% of the Douglas-Fir >8" dbh are snags; see Appendix: Table 6). Mortality of Douglas-fir has occurred more slowly over time, avoiding the major pulses and resulting almost complete mortality that has occurred in the adjacent "Barranca" subunit. In essence, the repeated light thinnings appear to have allowed Douglas-fir mortality to spread out over time, perhaps 10-15 years longer than in the Barranca. In the process, this extended time frame of ongoing mortality was not only more socially acceptable as a form of stand management in a highly visible area, but also avoided significant increases in fuels and associated fire management concerns as well as maintaining future options for stand management and allowing evolving silvicultural strategies to develop in an adaptive management framework. On other sites where slope stability is more of an issue, post mortality ingrowth of tree and vegetation spread out over time can minimize the effects of a more sudden loss of root strength associated with a more major pulse of mortality. It remains to be seen if this slower process of

lighter, but more ongoing tree mortality will allow eventual greater long-term retention of some level of Douglas-fir in the overstory. However, this strategy has been used elsewhere on private holdings in the Ashland WUI with success and remains a possible strategy to consider for thinning in extremely dense older stagnant stands on low productivity sites.

4. In contrast, subunit LW-B4 has been thinned twice (one commercial and one non-commercial) and had one follow-up understory release treatment and mostly retains a fully stocked stand of live overstory Douglas-fir although some mortality has occurred on the edges and in the 2018 prescribed burn unit. It is suspected that the retention of the larger interior habitat has contributed to this outcome, particularly given that the same treatment has resulted in a greater level of stand mortality in nearby subunit LW-B3 where the much smaller, narrower unit configuration and lack of interior habitat produced significant "edges" - ideal habitat for flatheaded fir borers.

5. Subunits LWB-4 through 7 also have been thinned twice and have generally lower Douglas-fir mortality than the lower elevation Subunits LWB-1 through 3 (see Table 6), with the exception of the larger interior habitat of the bottom third slope locations in subunit LW-B2 (both favorable conditions for Douglas-fir tree vigor). They also tend to be less exposed in their topographical positions and have more riparian influence at lower slope positions.

6. Subunit LWB-1 which has never been treated due to slope instability issues also has yet to receive extensive mortality except around the edges. This may be due to its more favorable aspect (N-NE) with a block of midslope interior habitat along a cooler steep topographical draw with more favorable site productivity. Adjacent untreated stands on more easterly aspects on the neighboring ownership have had extensive Douglas-fir mortality, just as occurred in adjacent Unit A in the mid 1990's.

7. The varied effects of prescribed underburning in the various units will continue to be closely monitored in all of these units as it is implemented. For example, one outcome of that monitoring is described in the following section that analyzes the effects of prescribed underburning of various intensities on ponderosa pine.

Although there has been considerable mortality of Douglas-fir over the last 30 years on these gradationally low productive sites, it is incorrect to infer these sites "are not Douglas-fir sites". It is likely that in the historical landscape, older drought and fire resistant Douglas-fir were generally larger and more scattered in distribution in the more open forests that were maintained in the more frequent, low to moderate severity disturbance regime. Douglas-fir is a species well-adapted to survive frequent, low severity fire, particularly as it gets older with thicker bark and more elevated foliage. Douglas-fir were also more likely to grow larger and/or more abundant at lower elevations in natural refugia locations such as on more northerly aspects in lower third slope positions closer to the moderating influence of streams. With a landscape dominated by these historical stand conditions, it is likely that there was very little insect-related mortality of Douglas-fir from flatheaded fir borer.

However, it is appropriate to say that in the long term, these sites cannot support dense stagnant, suppressed, older stands of Douglas-fir with minimal crowns and poor radial growths under an infrequent disturbance regime. These types of stands are highly susceptible to attack from flatheaded fir borer, particularly if they occur with any regularity on the landscape. Flatheaded fir borer populations can expand significantly and rapidly if enough landscape level habitat exists,, such as occurred in several major pulses in the 15 years from 1989 to 2004, and more recently in places like Ferris Gulch in the Applegate.

As a result of these more landscape level events over the past 30 years, Douglas-fir on these marginal sites has decreased in abundance and with it, a subsequent decrease in available habitat for flatheaded fir borer on those same sites. The smaller pulses of mortality that have continued to occur in the last 15 years are beginning to more closely emulate suspected endemic levels of mortality. However, it is also plausible, if not likely, that additional expansion of flatheaded fir borer related mortality could be expected with ongoing growth and densification of Douglas-fir at slightly higher elevations, lower topographical locations, more favorable aspects, and/or in stands already at higher densities, especially if coupled with a warming and drying climate and/or punctuated by severe droughts.

Additional stand density reductions, either commercial or non-commercial, and ideally well-ahead of drought events, can maintain stand densities below the threshholds where the likelihood for major pulses of mortality are reduced, avoiding the associated undesirable pulse accumulations of downed fuels and subsequent increase in wildfire potential. A key threshold to be continually working with is the maintenance of enough tree cover with which to retard understory development to acceptable levels from a fire perspective while decreasing stand densities such that improved vigor provides resistance not only to damage only from insects, disease and fire as forms of disturbance, but also to expected increased stressors from climate change. This will likely be a continually moving target requiring careful observation on a microsite level and both quantitative and qualitative information to help understand future stand development and possibilities for implementation of various types of silvicutural activities. Although this is a good overall ongoing objective for stand management in most situations, it is also possible to retain excess canopy and increased crown bulk density that can result in increased potentials for fire spread through the crowns in the most severe fire behavior. Discontinuous crowns, maintenance/development of crown openings and more discontinuous canopy fuels in uneven aged management are also part of mitigating wildfire potential through stand management. It is important to start to incorporate areas of larger horizontal fuel reductions in the Ashland watershed to offer opportunities to stop fire spread in the most severe types of fire behavior.

Ponderosa pine insect-related related mortality from fire and bark beetles

Mortality of ponderosa pine has long been an issue throughout its range, extending from southern California into British Columbia, and eastward into Montana. It was intensively studied with results published in a seminal work by Miller and Keen (1960). More recently, mortality of ponderosa pine was extensive in the Ashland Watershed in the extended drought period of 1987-1994 when many large older trees died. However, mortality of ponderosa pine has historically been much less of an issue on the lower City ownership to date, at least in part due to the low abundance of the species in general- an average of only about 18 trees per acre in the Lower watershed currently and primarily on the much less common more southerly aspects. In this survey, pine snags 8"+ dbh were also much less abundant and only recorded in 6 units.

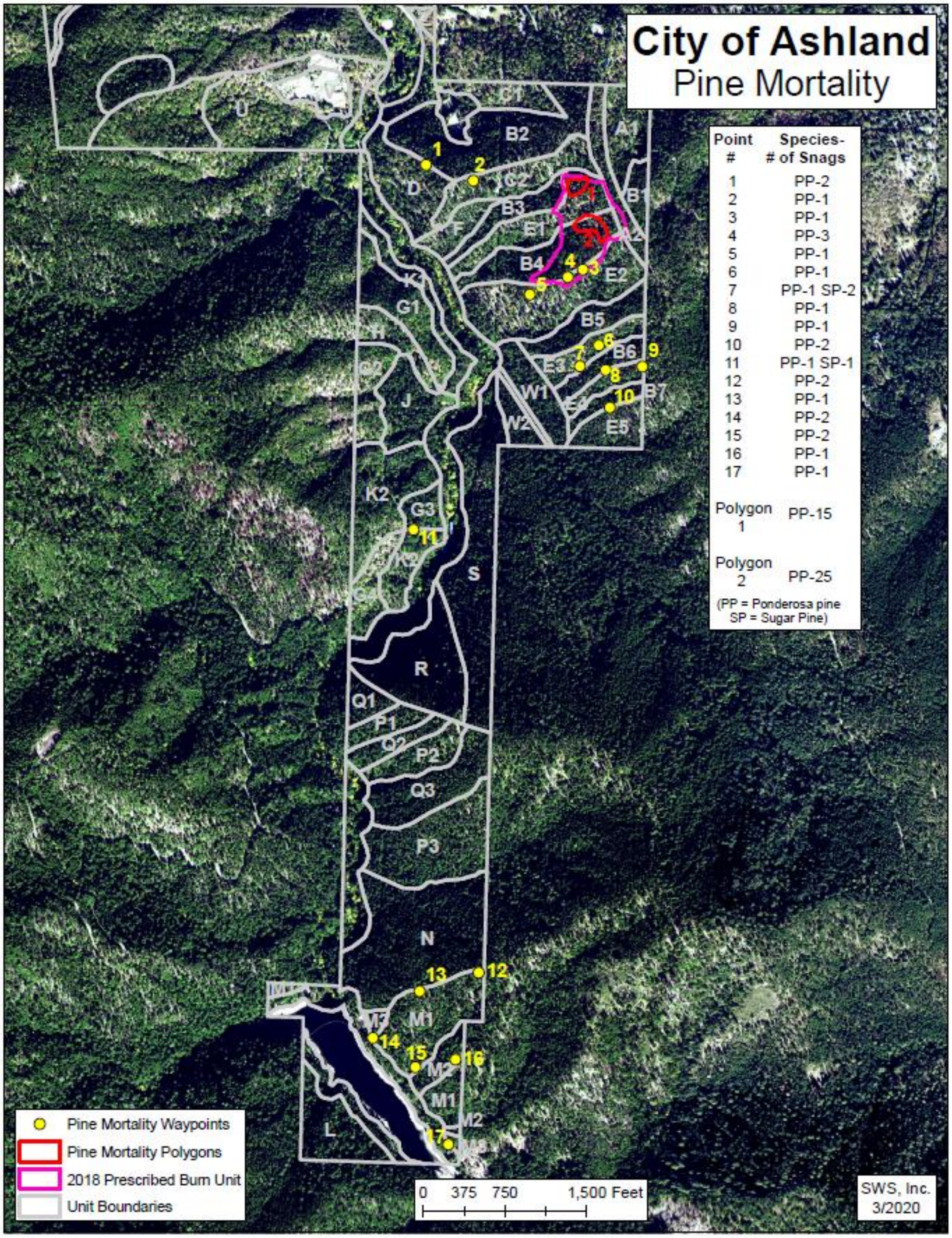
Retention and promotion of ponderosa pine is especially important on the City ownership, and elsewhere, because:

1) it was far more common historically[1]
2) it is well selected for growth and vigor on drier, droughtier sites
3) it is generally resistant to damage from fire in more frequent fire regimes
4) it is the native tree species most likely to adapt well with projected climate change and warmer, drier conditions.

[1]John Leiberg in 1900 measured basal areas (4"+ dbh) by species for the Township and Range in which the lower City ownership exists. He found 60% ponderosa pine, 15% sugar pine, 25% Douglas-fir and 5% oak/madrone. 2017 City of Ashland inventory results found 7.6% ponderosa pine, 0.5% sugar pine, 64.6% Douglas-fir and 25.1% oak/madrone.

As with flatheaded borer in Douglas-fir, insect-related mortality of pines has also long been associated with a similar array of cumulative stress from a variety of sources including excessive stand density, drought, fire, root disease, soil compaction, mechanical damage and other stressors. Several insects are involved in attacking ponderosa pine- *Dendroctonus brevicomis* the western pine beetle, *Ips paraconfusus* the pine engraver beetle and *Dendroctonus valens* the red turpentine beetle. The red turpentine beetle focuses in the first 6-8 feet of a tree and generally does not kill the tree, but can contribute to cumulative stress and pre-dispose the tree to attack from other beetles. The pine engraver beetle generally attacks tops and smaller second growth trees, while the western

Map 8


City of Ashland
Pine Mortality
Point #
Species- # of Snags
1 PP-2
2 PP-1
3 PP-1
4 PP-3
5 PP-1
6 PP-1
7 PP-1 SP-2
8 PP-1
9 PP-1
10 PP-2
11 PP-1 SP-1
12 PP-2
13 PP-1
14 PP-2
15 PP-2
16 PP-1
17 PP-1
Polygon 1 PP-15
Polygon 2 PP-25
(PP = Ponderosa pine SP = Sugar Pine)
Pine Mortality Waypoints
Pine Mortality Polygons
2018 Prescribed Burn Unit
Unit Boundaries
0 375 750 1,500 Feet
SWS, Inc.
3/2020

pine beetle attacks two general types of trees/stands: 1) dying old growth trees scattered within a stand, and 2) clumped mortality of second-growth ponderosa pine in overstocked stands. Western pine beetle attacks >6" dbh trees along the bole, but not in branches (ODF 2017).

In the last several years, recent upswings in pine mortality locally has generally been attributed to increased populations of the western pine beetle. It has been particularly noticeable at lower elevations in and around the Ashland wildland urban interface including sites like Siskiyou Mountain Park and in this last year, the Lithia Park hillside. This survey revealed that several large old growth ponderosa pine recently died at 3200' elevation in Unit M.

Map 7 reveals that ponderosa pine mortality is restricted to several primary units currently and is otherwise more scattered and localized. However, the recent increased mortality trends at lower elevations in the near vicinity suggest the need to more carefully manage pines to improve tree vigor largely through stand density reduction- both in their immediate vicinity and on a stand level as well. Stands retaining 80-120 ft^2/acre, and occasionally as high as 150 ft^2/acre have long been successful at maintaining high vigor of pines and most of the southerly aspects on the lower watershed are at or below those numbers (COA 2017 inventory), with the exception of southerly aspects in Unit LW-M. However, predicting individual trees that may be at risk of bark beetle related mortality has proved to be very challenging on the very droughty, low elevation sites in the Ashland WUI area.

A bark-beetle related clumped mortality of second growth ponderosa pine has occurred in the recently (2018) underburned Unit B3-E1-B4 in two polygons comprising a current total of 1.4 acres, and appearing to expand this year. This type of clumped mortality of second growth ponderosa pine(see Map 1a,b,c,d ; Polygon 4,5a) has occurred nowhere else to date on the Lower City ownership suggesting a relationship between that pine mortality and effects from the 2018 underburn likely contributing to cumulative stress and subsequent pine beetle attack involving all three insect species. This potential outcome has been well-established in the published science (, Cluck and Lee 2017, ODF 2017, Schaupp 2017, Six and Skov 2014)). Endemic, non-outbreak beetle populations can cause additional mortality than what might have occurred by burning alone (Negron and Popp 2004, Fettig et. al. 2010).

The 2018 prescribed burn was the hottest of any of the burns on City ownership, with a cumulative Composite Burn Index (CBI) score of 1.52 (on a scale of 0-3). In a similar and adjacent topographic setting in the adjacent upper half of Unit LW-E2, a prescribed underburn in 2013 produced CBI rating of 0.90 and resulted in no mortality of ponderosa pine either from the fire or from following insect-related mortality as sampled 26 months later. It is reasonable to assume that minimizing fireline intensity during underburn operations (i.e. "cooler" burns) may have an additional benefit of minimizing additional post-burn beetle related pine mortality in the future. Hood et. al. (2017) describes methods of induced defense of pines that exist in systems with more frequent fire. In these more frequent fire regimes, non-lethal low severity fire induces resin duct defense in ponderosa pine while lack of fire relaxes resin duct production in forests dependent on low severity fire. They found that trees killed by bark beetles invested less in resin ducts relative to trees that survived attack. Normal advantages attributed to ponderosa pine as a fire species may not be as pronounced, or even evident, in long-unburned pine forests.

The City has embarked on an ambitious program of underburning previously thinned units throughout the lower City ownership, completing 134 acres in 12 units since 2007. This thinning and underburning strategy is well-established in the published science to be the "gold standard" for sustaining low level crown fire potential (Stephens and Moghaddas 2005, Stephens et.al 2009, Fule et.al 2012). It is described as superior to "thin only" treatments for 3 reasons (Crotteau et.al. 2018):

1) it treats both surface fuels by burning and canopy fuels by silvicultural thinning;

2) applying prescribed underburning kills advanced regeneration and developing shrubs and hardwoods and resets the understory stand development phase, thereby lengthening the duration of overall treatment effectiveness:

3) it has reduced mortality compared to untreated or burn only treatments but may have slightly greater mortality than thin only treatments.

Unfortunately, this potential increase in mortality in pines post-burn is likely what happed in the recent underburn. However, this outcome may be one that can be accepted as part of a larger benefit, particularly if it can be kept to a minimum. Site related factors may make it difficult to achieve low severity underburns in all cases. For example, several factors in the 2018 underburn in Unit B3-E1-B4 made it difficult to burn "cooler" and in such a way as to minimize excessive cumulative stress on pines:

1. it was a very steep unit, which made fire related site impacts to overstory trees much more difficult to control ;
2. it was in an upper third slope location at relatively low elevations- both factors that suggest a very moisture limiting site with trees likely stressed even before the fire. The vegetation reflected those site conditions with low basal area of conifers dominated by greater levels of ponderosa pine and whiteleaf manzanita, a drought-tolerant shrub;
3. the date of the burn was within an extended droughty period with lower than average precipitation during the 12 months preceeding the burn.

It is also likely that historically this low productive site was a very open forest type in a more frequent, low severity fire regime, contributing to a significant reduction in the potentials for landscape level wildfire. Although the stand or unit level objectives at this point in time (such as retention of ponderosa pine) may have been less than optimal following the burn, particularly given ongoing pine mortality as an outcome, it may still be an acceptable outcome on a landscape level where pockets of moderate severity fire are even desirable in order to break up landscape level fuel continuity. The 2 current polygon sizes of 0.5 and 3.1 acres are smaller than the maximum openings theorized in more open stand conditions in historical forests, and the retention of other tree species that survived the fire within these polygons present a much more complex stand structure than simple openings devoid of vegetation. In addition, the resulting more open post-burn conditions that resulted provided an opportunity to encourage more pine establishment (a common practice in the last 25 years on City ownership following various treatments), and 300 sugar pine were planted in the underburned unit the following spring.

In the long-term restoration focus of the City, however, the notion that pine as a species are somehow free from fire-induced damage/mortality and that they will preferentially survive and thrive in a world of more frequent fire should be re-considered based on the results found here, and elsewhere by the author. It is believed that ecological processes that functioned in the more frequent low severity fire regimes, and resulted in more ponderosa pine on the landscape, are not the same as those that have occurred in this new more infrequent fire regime of the past 100+/- years. Unlike pines in the frequent, low severity fire regime of previous systems, these second growth ponderosa pine have initiated and grown in now long-unburned conditions. Given pines long-term importance as a species on the lower City ownership, it is advised that fire behavior in initial underburns be kept at low severity whenever possible to restore the pattern of increased resin duct defense against future damage from bark beetles or future low to moderate severity fires, planned or unplanned. Regardless, in a world of more frequent fire, ponderosa pine is still a species well-adapted to survive and thrive.

Opportunites for commercial thinning

There is little opportunity to solely retrieve existing merchantable snags via helicopter harvest systems on the lower City ownership at this time. They are far too scattered to be economically retrievable. However, the ownership should be carefully monitored in the future to try to predict if and when another major outbreak-level pulse in mortality occurs, such as happened with Douglas-fir in 2002-2003 that resulted in 2004 helicopter harvest. This 2002-03 mortality pulse was a landscape level event that occurred primarily below 2800'. This sizable amount of merchantable snags which comprised about 1/3 of the total volume in the harvest was able to be incorporated with commercial thinning in stands to improve overall conditions while resulting in enough merchantable volume to economically pay for the use of a helicopter to accomplish City objectives.

Future impacts on tree vigor from droughts and/or climate change will likely increase that possibility for more landscape level mortality of Douglas-fir, perhaps moving up in elevation into areas above 2800' where snags are currently the fewest (see Map 6). These in general are more productive sites with less moisture stress and more stand resiliency currently than those at lower elevation on the Lower City ownership. Average basal areas in these units are 194 ft^2/acre compared with 131 ft^2/acre in the lower portions of the ownership where site productivity is reduced, thinning has been more frequent and mortality has been much more pronounced. Largely through active management alone, basal areas in the upper elevation units have decreased about 20% from 1998 to 2017 even with considerable ingrowth. On the lower portion of the ownership, both ongoing mortality and active management have combined to reduce basal areas close to 29% from original amounts (1998), even with ingrowth.

Vigor in many of these areas could be improved through thinning currently in hopes of avoiding the type of stand-level decline that encouraged Douglas-fir mortality at lower elevations in the first place. However, thinning prior to outbreak levels of insect-related mortality is far more effective than during an outbreak (Fettig et. al 2014, Hood et.al 2016). Non-commercial thinning is mostly much less likely to be able to be used as a treatment of choice as it already has been implemented and no longer is contributing as significantly to excessive stand densities. Commercial thinning could be used however to reach more desirable stand densities. However, these areas above 2800' also have the longest helicopter flight distances to possible landings (e.g. the granite quarry used in the 2004 helicopter thinning) with the subsequent high cost for retrieval, probably well in excess of potential log value even under the most favorable of market conditions.

There may be possibilities for small ground-based and/or modified cable systems (e.g. tong-thrower, Yoder) in the few small locations that have road access on the City ownership. This type of operation was completed in both Units LW-A and LW-D in the late 1990's, both of which had access for ground-based systems that allowed for economically viable retrieval of dead merchantable trees (i.e. large diameter fuels that would have been much more expensive if their removal had to be done by hand through piling and burning, if it could have been done at all). Several current opportunities for a similar approach are: 1) Unit LW-K1/K2/G4 below the 2060 Road; 2) Unit LW-A2.

Units LW-K1/K2/G4 below the 2060 Road currently have small pockets of conifer mortality that may allow for economic retrieval although there is likely not enough total volume of recently dead but still merchantable trees to pay for logging equipment move-in costs. These units are currently at relatively high risk of future FFB infestation, although to date the mortality has remained largely at endemic levels in low amounts scattered throughout the units. If this continues, a slow "natural" density reduction might occur that could possibly meet long-term City goals for the stands, providing a steady influx of a range of snags of multiple species and size classes which would offer important wildlife habitat values as well as keep soil-holding tree roots in place and limit the potential for slope failure directly into Ashland Creek on these very steep, failure-prone slopes. The key to achieving City goals in this situation is the continuation of light, ongoing, more endemic FFB related mortality spread out over time on this site as opposed to a more sudden and drastic mortality pulses that have occurred in the past on the lower City ownership in nearby areas . The results of this analysis suggest more endemic mortality spread out over longer time frames may be possible given this units location on more easterly aspects in lower third slope positions adjacent Ashland Creek where moisture stress is less pronounced (see Table 7). However, the effects of future hot droughts and/or other effects of climate change could easily shift that tipping point towards a major outbreak-level pulse of mortality pulse event in ways that are not totally understood or able to be predicted at this time. This type of outbreak level mortality would be less desirable, with subsequent major fuels accumulations and increased potential for slope failure. In either case, continued mortality spread out over time (whether in ongoing endemic levels or emulated by thinning) or in larger single insect-related pulses, will result in high accumulations of downed fuels and present a less than desirable fire management concern. High severity wildfire in this location could significantly increase the likelihood of slope failure immediate above Ashland Creek, with subsequent increased potential for associated downstream impacts similar to what happened in 1997. Thinning, whether commercial or non-commercial in these units, could emulate more endemic levels of mortality, spaced out over place and time in ways that may reduce the likelihood of slope failure. The thinnings could also be conducted on carefully mapped locations where slope failure is least likely. (see "City of Ashland Lower Watershed Ownership- 2020 Non-Commercial Thinning Possibilities Summary", Small Woodland Services, Inc., April 2020). In all scenarios, including endemic levels of mortality, resulting slash should have to be piled and burned in order to not aggravate fire behavior potentials. It is suspected that these treatments would likely provide a minimal positive effect on fire management potentials due to their small and scattered locations on steep sites. However, they would tend to begin to break up fuel continuity in both horizontal and vertical directions- a fire management benefit- as well as begin to restore lower stand densities, improved tree vigor and more resilient stand conditions, with benefits from slope stability, forest health and long-term fire resiliency perspectives, particularly given future climate change. A serious drought in the near future could significantly decrease the likelihood of ongoing more endemic mortality and increase the likelihood of a major pulse of mortality in these units. Although this would allow for a more favorable likelihood of an economically viable retrieval of merchantable trees (if conducted quickly as in 2004), it would also result in negative consequences from fire management, forest health and slope stability perspectives.

The only other place where access may allow ground based systems to be used to economically retrieve merchantable timber is a small area in Unit LW-A2 along the ridgeline with access from the Ashland Loop Road (permission from a private landowner would be needed). Mortality of conifers has been both ongoing and in major pulses over time (see Polygon 3 on Maps 1a, 1b) in this location which is particularly undesirable on a landscape level because this in a primary fuel reduction zone on the lower City ownership, separating the Ashland Creek watershed from other smaller watersheds to the east and down into the urban environment of the City of Ashland. This area needs continuing maintenance to maintain both its fire management effectiveness and its aesthetically pleasing nature from a recreational perspectives. Ongoing mortality and hazardous snags can easily compromise both fire and recreational objectives. With ground-based systems and low move-in costs, it is suspected that this area could possibly be done with reduced City expenditures. The use of a tong-thrower in this location would expand the area of influence partially down slopes and improve the effectiveness of treatments. Public buy-in in this heavily used area would be essential.

It is unlikely that ponderosa pine will be economically feasible to be removed as logs in the near future given its historic low value in the southern Oregon marketplace over the past 10 years.

There has been somewhat extreme volatility in log markets in response to the Covid-19 pandemic. Log markets virtually disappeared within several days with the initial pandemic-related shutdown. However, they have recently re-opened with favorable log prices depending on species. Where the market is heading, and for how long it will exist, is very hard to predict in these uncertain times. Nonetheless, the ability to closely watch markets and respond quickly to favorable log markets will likely be of increasing importance in the near future in determining the economic viability of any project involving merchantable timber.

The Potential Effects of Climate Change on Future Mortality

There are potential direct and indirect impacts of climate change on multiple aspects of host trees, and bark beetle community ecology and population dynamics (Bentz et.al. 2010). Climate-change induced shifts in bark beetle outbreak frequency and intensity may indirectly affect patterns and severity of wildfire, although the relationships are poorly understood, highly complex, and temporally and spatially dynamic (Jenkins et.al. 2008)

The effects of climate change on City-owned forests has long been a concern. Main (2006) refers to importance of the effects climate change in these emerging stand management dynamics on City ownership. The Ashland Forest Plan (2016) dedicated an entire chapter to the topic, with the following recommended management objectives:

- reducing the likelihood of high-severity fire through strategically placed fuel treatments and subsequent implementation of prescribed underburning to maintain reduced fuels and less fire-prone conditions

- managing for both development and maintenance of older forests that may sequester and retain large amounts of carbon over time;
- focusing on protection and restoration of diverse forest structures, plant communities and associated genetic resources which are important mechanisms of resilience;
- emphasizng multiple species management including species well selected to thrive in future warmer and drier conditions such as pines, hardwoods and shrub species (within prescribed spatial considerations for their potential to aggravate fire potential and hazard; and
- monitoring and control of invasive species that are prone to establishment and/or expansion in changing climates.

These survey results and analyses have important relevance for future management given evolving understandings and concern about climate change and its impacts on forest ecosystems. In addition, the somewhat subtle changes in the last 25 years on City forestlands have been well documented, both qualitatively and quantitatively (City of Ashland inventories (2000, 2007, 2017); Main 2006; Main 2010: City of Ashland Forest Plan 2016). For instance, FFB stand replacement levels of mortality in DF started at 2000' elevation in 1989-90 and proceeded to 2200-2700' in Units LW-A, LW-B ("Barranca") and LW-D in 1995-96. More landscape level mortality occurred up to about 2800' in the drought event of 2001-02. Anecdotally, FFB occurrence was observed by the lead author at a maximum of 2800' elevation in 1995, 4200' in 2013.

Although the increase in insect-related mortality on the lower City ownership is influenced by many factors, including various site factors and increasing stand densities over time, it is also likely that this upward advancement in mortality is related to warmer and drier "hot drought" conditions that have been increasing as a result of climate change. Bark beetle outbreaks driven by climate change may result in trajectories beyond the historical resilience boundaries of some forest ecosystems, causing irreversible ecosystem regime shifts (Bentz et. all. 2010). Perhaps some of the insect-related mortality surveyed and discussed in this report are either the results of such shifts and/or contributing to "trajectories beyond the historical resilience boundaries" of our local ecosystems. Given that possibility, it would be prudent to continue appropriate management level responses, especially reductions in stand density through various silvicultural treatments with subsequent improvement of tree and stand vigor well ahead of future drought conditions. This is probably the single most important thing that can be done to prepare for future impending increasing forest stressors associated with climate change.

Given the inventory data set and a well recorded history of management activities, the City is in an excellent position to further explore and study the potential impacts of climate change on changing forest conditions.

Summary

Analysis of the data in this report suggests that the management level responses suggested for the same general area in Main (2010) are still appropriate:

- encourage the retention of the most vigorous Douglas-fir possible
- maintain stand integrity in the largest patch sizes possible (avoid artificially creating stringers of small patches of Douglas-fir)
- reducing densities of developing hardwoods and shrubs on the edges of existing stands of Douglas-fir
- utilize prescribed underburning to minimize understory development
- continue to emphasize increasing tree species diversity through retention and promotion of pines, incense cedar and hardwoods (especially California oak) in thinning regimes
- balance hardwood retention within the vicinity of preferred conifers given the increased competition they offer for moisture and site resources
- plant a mixture of ponderosa pine, sugar pine (blister rust resistant) and incense cedar in openings where appropriate.

However, the survey of snags and spatial representation of that data in this report has allowed a more in-depth analysis of the issues around site, species and stand level differences in effects on mortality, as well as projections of the influence of various management practices on the lower City ownership over the past 25 years. These analyses make it clear that achieving specific ownership objectives required a much more nuanced and balanced approach to management than can be achieved through uniformly applied regional guidelines to encourage any singular management objective (e.g. timber volume, wildlife habitat, fire resistant landscapes, more open forests, etc.). This is particularly important in the extremely diverse, botanically rich, geologically unique Klamath/Siskiyou bioregion where microsite-level changes occur with regularity and over short distances. Accomplishing implementation of planned disturbance regimes that emulate the historic 7-12 year periodicity is equally challenging. The use of both qualitative assessment gathered over 25 years, as well as quantitative information obtained through permanent plot inventories, were essential in continuing to interact with this complex landscape in meaningful ways. The continued use of both methodologies incorporated into a framework of rapidly evolving adaptive management will require a similar level of nuance in application over space and time in the future, particularly given future projected climate changes punctuated by periodic droughts.

The City of Ashland has a good opportunity to continue monitoring for developing trends for future individual tree, stand and landscape level mortality on their ownership given:

1) an excellent existing inventory of site, stand and tree level data measured three times (2000, 2007, 2017) on 137 plots on the lower watershed parcel;
2) a careful and complete chronology of silvicultural treatments performed over time on a unit/subunit basis;
3) a steep environmental gradient of elevation, precipitation and temperature within the City ownership that allows for differences in outcomes in relatively short distances;
4) over 25 years of qualitative observation and experience in the above landscape;
5) the results of this survey to be used as a baseline for future reference.

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Appendix

Table 1: Estimated number of surveyed conifer snags 8"+ DBH by unit

Unit	Acres	DF	DF/Acre	Pine	Pine/Acre	Total	Total/Acre[1]
A[2]	12.6	122	9.7	0	0	122	9.7
B[2]	50.8	462	9.1	25	0.5	487	9.6
C	14.1	13	0.9	1	0.1	14	1.0
D	9.9	0	0.0	2	0.2	2	0.2
E	39.9	77	1.9	28	0.7	105	2.6
F	3.8	10	2.6	0	0	10	2.6
G	23.3	0	0.0	0	0	0	0
H	4.5	14	3.1	0	0	14	3.1
J	8.1	0	0.0	0	0	0	0
K	23.4	79	3.4	2	0.1	81	3.5
L	9.0	3	0.3	0	0	3	0.3
M	21.0	1	0.0	9	0.4	10	0.5
N	27.4	16	0.6	0	0	16	0.6
P	25.5	10	0.4	0	0	10	0.4
Q	17.9	0	0.0	0	0	0	0
R	14.6	46	3.2	0	0	46	3.2
S	23.6	22	0.9	0	0	22	0.9
U[3]	19.2	5	0.3	0	0	5	0.26
W1	6.3	0	0.0	0	0	0	0
W2	3	3	1.0	0	0	3	1.0
Total	**357.9**	**883**	**2.5**	**67**	**0.2**	**950**	**2.7**

[1]Pacific madrone snags were recorded for the polygons in the B3-E1-B4 prescribed burn unit.
Unit B contained 40 madrone snags and Unit E contained 15 madrone snags, all in the prescribed burn unit.
[2]Snags recently felled in 2018 for trail safety were included in the data for Units A and B.
[3]Unit U was only surveyed in the portions of the Unit that were prescribed burned or pre-commercially thinned, piled, and burned.

Table 2: Estimated conifer snags 8"+ DBH by slope position, Units A-F, W1

Slope Position	Acres	Douglas-fir	Pine	Total	Snags/Acre
Upper	60.2	429	10	439	7.3
Middle	51.4	175	6	181	3.5
Lower	37.6	35	0	35	0.9

*Snags located in the polygons in the prescribed burn unit were not included in this analysis.

Table 3. Percentage conifer mortality by species for trees 8"+ DBH

Species	% Dead[1]
Douglas-fir	3.8%
Ponderosa pine	2.1%
Sugar pine	2.1%

[1]Percent dead was calculated by dividing the approximate number of snags from the 2020 survey by the number of living trees recorded in the 2017 inventory of the lower watershed

Table 4: Estimated number of surveyed conifer snags 8”+ by unit: Lower elevation sites vs. higher elevation sites

Group[1]	Unit[2]	Acres	DF	DF/Acre	Pine	Pine/Acre	Total	Total/Acre
Lower Elevation	A	12.6	122	9.7	0	0	122	9.7
	B[3]	47.7	417	8.7	0	0	417	8.7
	C	14.1	13	0.9	1	0.1	14	1.0
	D	9.9	0	0.0	2	0.2	2	0.2
	E[3]	39.4	77	2.0	13	0.3	90	2.3
	F	3.8	10	2.6	0	0	10	2.6
	H	4.5	14	3.1	0	0	14	3.1
	K	23.4	79	3.4	2	0.1	81	3.5
	U[4]	19.2	5	0.3	0	0	5	0.3
	W1	6.3	0	0.0	0	0	0	0.0
	W2	3	3	1.0	0	0	3	1.0
	Total	**183.9**	**740**	**4.0**	**18**	**0.1**	**758**	**4.1**
Higher Elevation	L	9	3	0.3	0	0	3	0.3
	M	21.0	1	0.0	9	0.4	10	0.5
	N	27.4	16	0.6	0	0	16	0.6
	P	25.5	10	0.4	0	0	10	0.4
	Q	17.9	0	0.0	0	0	0	0
	S	23.6	22	0.9	0	0	22	0.9
	Total	**124.4**	**52**	**0.4**	**9**	**0.1**	**61**	**0.5**

[1]The break-off between lower and higher elevation units is approximately 2800’ average unit elevation.
[2]Units G, J and R are anomalies and were not included in this analysis. Unit T was not surveyed.
[3]The areas containing trees killed within the B3-E1-B4 polygons were excluded, as the mortality in that area was associated with the prescribed burn, rather than elevation.
[4]Unit U was only surveyed in the portions of the Unit that were prescribed burned or pre-commercially thinned, piled, and burned.

Table 5: Douglas-fir snags 8”+ DBH in B subunits

Subunit	Acres	Snags	Snags/Acre
B1	2.6	39	15.0
B2[1]	19.7	238	12.1
B3	4.9	36	7.3
B4[2]	7.9	24	3.0
B5	6.4	39	6.1
B6	3.7	28	7.6
B7	2.5	13	5.2

[1]Snags/acre much higher in upper third slope locations; much lower in lower thirds
[2]Douglas-fir snags in the B3-E1-B4 prescribed burn unit are not included

Table 6: Polygon Summary Data

Polygon #		Unit	Acres	Species[1]	DBH	Approximate # of Snags[2]	% Species Killed	Snags/ Acre
1		B2	1.8	DF	8-18	125+/-	90	69.4
2		B2	1.4	DF	8-18	50+/-	60	35.7
3		A1/A2	1.2	DF	8-18	100+/-	65	83.3
4[3]		E1	0.5	PP	6-14	15	70	30.0
				MA	2-8	15	20	30.0
5[3,4]	5a	B4	0.9	PP	8-14	25	60	27.8
	5b		2.2	DF	6-20	45	35	20.5
				MA	4-12	40	35	18.2
6		B3	1.0	DF	12-18	30	40-50	30.0
7		B2	1.6	DF	8-16	40	25-50	25.0

[1]Pacific madrone was only recorded for polygons 4 and 5 due to extensive mortality in the prescribed burn unit. Other polygons may include madrone mortality, but it was not recorded.
[2]The approximate # of snags was estimated for polygons with 50 or more snags. Polygons 1, 2, 3, 6, and 7 do not include snags that have fallen to the ground or those that were removed in the helicopter logging in 2004. Snags that were felled for trail safety in polygons 1 and 3 were included.
[3]Polygons 4 and 5 were completely within the B3-E1-B4 prescribed burn unit.
[4]Overlap of species mortality exists in 5a and 5b.

Table 7: Simple risk rating for Douglas-fir mortality in the lower City of Ashland ownership[1]

(Positive numbers indicate increased likelihood of mortality, lower numbers indicate decreased likelihood of mortality; Scale is from +2 to -2).

Variable	Polygons[2]						Example Units				
	1	2	3	5[3]	6	7	K1[4]	N	P	Q	J[4]
Elevation	+2	+2	+2	+1	+1	+2	+2	-2	-2	-2	+2
Topographical position	+2	+2	+2	+2	+1	+2	-2	0	0	0	-2
Aspect	-1	+1	-1	+1	+1	0	-2	-1	+1	-1	0
Stand edge/interior habitat	+2	-1	+2	+1	+2	+1	+1	-2	-1	-1	-1
Excessive stand density[5]	+2	+2	+2	+1	+2	+1	+1	+1	0	+1	-1
Total	**+7**	**+6**	**+7**	**+6**	**+7**	**+6**	**0**	**-4**	**-2**	**-3**	**-2**

[1]This table is provided as a conceptual framework for assessment to help understand how multiple variables can be assessed to provide a rating for any individual site/stand. The variables should also probably be weighted in importance although a much more elaborate analysis (e.g.. multivariate analysis) would be needed to provide this type of information and is well outside the scope of this paper. The influence of each variable presented varies greatly between sites but all have various levels of relationships with moisture availability.
[2]Polygon 4 was excluded because it was in a portion of the prescribed underburn that had no Douglas-fir mortality.
[3]The 2018 prescribed burn was an additional influence on mortality in Polygon 5.
[4]Close proximity to riparian areas and more favorable microclimate conditions wereanother influence on the low levels of mortality in Units K1 and J.
[5]Generally in even-aged 80-120 year old stands with much reduced stand differentiation; in these situations, stand level dynamics seem to have greater influence (i.e. they tend to act as a single unit with reduced potential for individual tree release) and adjustments through thinning can be more problematic..

Waypoints

Unit	Point #	Species-estimated snags
A1	1	DF-7
A1	2	DF-8
A1	3	DF-7
B1	1	DF-6
B1	2	DF-8
B1	3	DF-6
B1	4	DF-6
B1	5	DF-6
B1	6	DF-7
B2	1	DF-4
B2	2	DF-9
B2	3	DF-10
B3	1	DF-6
B4	1	DF-8
B4	2	DF-10
B4	3	DF-6
B5	1	DF-10
B5	2	DF-6
B5	3	DF-10
B5	4	DF-7
B5	5	DF-6
B6	1	DF-10
B6	2	DF-10
B6	3	DF-8
B7	1	DF-6
B7	2	DF-7
C2	1	DF-8
C2	2	DF-5
C2	3	PP-1
D	1	PP-2
E1	1	DF-5
E2	1	DF-8
E2	2	DF-3 PP-1
E2	3	DF-2 PP-3
E2	4	DF-5
E2	5	DF-3 PP-1
E3	1	DF-5 PP-1
E3	2	DF-7 PP-1 SP-2
E4	1	DF-6 PP-1
E4	2	DF-8
E4	3	DF-3 PP-1

Waypoints

Unit	Point #	Species-estimated snags
E4	4	DF-10
E5	1	DF-5
E5	2	DF-3
E5	3	DF-4 PP-2
F	1	DF-5
F	2	DF-5
H	1	DF-7
H	2	DF-7
K1	1	DF-6
K1	2	DF-6
K1	3	DF-4
K2	1	DF-10
K2	2	DF-12
K2	3	DF-4
K2	4	DF-7
K2	5	DF-7 PP-1 SP-1
K2	6	DF-5
K2	7	DF-5
K2	8	DF-13
L	1	DF-3
M1	1	PP-2
M1	2	PP-1
M1	3	PP-2
M2	1	PP-1
M3	1	PP-2
M3	2	DF-1 PP-1
N	1	DF-10
N	2	DF-6
P2	1	DF-6
P3	1	DF-4
R	1	DF-4
R	2	DF-15
R	3	DF-5
R	4	DF-6
R	5	DF-9
R	6	DF-7
S	1	DF-10
S	2	DF-5
S	3	DF-7
U	1	DF-5
W2	1	DF-3

Table 8: 2017 Lower watershed live tree summary

Unit	Acreage	# of Plots	TPA	BA	QMD	SDI	RDI**	Crown Closure (%)
A1	5.01	3	319	110	7.9	220	0.47	58
B	51.73	14	574	124	6.3	272	0.50	68
C	12.16	5	139	79	10.2	143	0.29	43
D	9.94	2	122	104	12.5	175	0.32	44
E	33.03	9	173	88	9.7	164	0.30	49
F	4.34	2	522	139	7.0	294	0.57	72
G	18.17	15	719	131	5.8	299	0.54	86
H	4.51	4	266	122	9.2	232	0.41	58
J	6.97	5	381	182	9.4	343	0.59	81
K	24.69	14	587	166	7.2	347	0.61	86
L	8.97	6	394	154	8.5	302	0.53	84
M1	14.20	4	308	206	11.1	362	0.69	73
M2	3.65	3	410	250	10.6	449	0.77	87
N	31.44	8	300	234	12.0	399	0.69	88
P	23.04	11	177	161	12.9	267	0.50	75
Q	16.50	6	256	220	12.6	369	0.62	82
R	18.52	5	421	178	8.8	342	0.61	86
S	16.09	6	312	142	9.1	270	0.46	84
W1	8.00	3	899	170	5.9	384	0.72	82
W2	4.63	4	476	197	8.7	382	0.62	86
Total*	315.59	129	390	154	9.2	293	0.55***	73

*Totals were weighted by unit acreages

**RDI values were derived from spreadsheets developed by Guenther Castillon (former USFS silviculturist) that were used in Ashland Forest Resiliency (AFR) projects

***RDI total was estimated

Table 9: 1998 Silvicultural Indices by Unit (Main 1998)

STAND DATA —ORGANON OUTPUTS

Unit/ Subunit	Plot Type	Number of Plots	Total # of Trees	Basal Area (sq. ft. per acre)	TPQ (trees per acre)	Quadratic Mean Diameter (inches)	Relative Density Index (RD)	Notes (SDR = Stand Density Reduction)
A1	2	4	34	170	371	9.2	.61	Initial commercial & non-commercial SDR completed.
A2	2	4	35	180	397	9.1	.65	Initial non-commercial SDR completed
B1	2	5	77	308	866	8.1	1.16[2]	Unthinned headwall
B2	2	5	71	284	769	8.2	1.06[2]	Unthinned headwall area along northern property line
B2,3,4	1,2	15	139	199	417	9.3	.70	Initial non-commercial SDR completed
B5,6	2	5	52	245	565	8.9	.89[2]	Initial non-commercial SDR completed
D1	2	4	38	190	358	9.5	.67	Initial commercial and non-commercial SDR completed
E1,2,3	2	13	106	163	247	11.0	.56	Initial non-commercial SDR completed
F	2	5	69	276	511	10.0	.96[2]	
G1	2	3	33	110	572	5.9	.47	38-year-old stands initiated after 1959 wildfire
H	1	4	25	120	146	12.3	.38	
J	2	5	58	232	432	9.9	.80[1]	
K1,2	2	8	81	202	391	9.7	.71[1]	
K3	2	3	35	233	290	12.1	.75[1]	
L								Structurally very diverse stand
M2	1	4	45	187	548	7.9	.71[1]	
M3	1	3	39	241	505	9.3	.85[2]	
N	1	4	58	275	441	10.7	.93[2]	
P3	1	4	58	208	345	10.5	.70	
P1,2	2	4	41	205	324	10.8	.69	
Q1,2,3	2	6	89	297	689	8.9	1.07[2]	
R1	2	4	42	210	339	10.7	.71[1]	
S	2	6	74	247	460	9.9	.86[2]	

[1] Stand density very high; RD's 0.7-0.8; within-stand mortality occurring.
[2] Stand density extreme; RD's greater than 0.8; extensive within-stand mortality to be expected.

Plot Type
1 - Permanent ORGANON growth and yield plots installed and data collected.
2 - Stand density plots only—data collected was diameter by species for 20 basal area factor variable plots.