Fire ecology report
Woodbury Fire
June 8th – July 15th, 2019

Tonto National Forest

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Conditions prior to the Woodbury Fire

From October 2018 through June 2019, the Tonto Basin and Globe RAWSs recorded close to average, or below average precipitation for all but three months. October precipitation was over twice as high as the average. The moisture effects of fall precipitation can last longer than spring or summer precipitation, because temperature is lower, relative humidity is higher, and plants are not growing as actively (decreased evapotranspiration). Precipitation in February broke records across Arizona, with the Tonto Basin RAWS once again recording over twice the average precipitation and the Globe RAWS recording almost three and a half times the average monthly average (Figure 1). There are no gauges or methods in place to measure precipitation in or near the Superstition Wilderness, but the record-breaking snowfall in February produced up to ½ inch of snow as low as 2,300 feet, and 1 – 2 inches across broad areas of the Sonoran Desert (Figure 2).

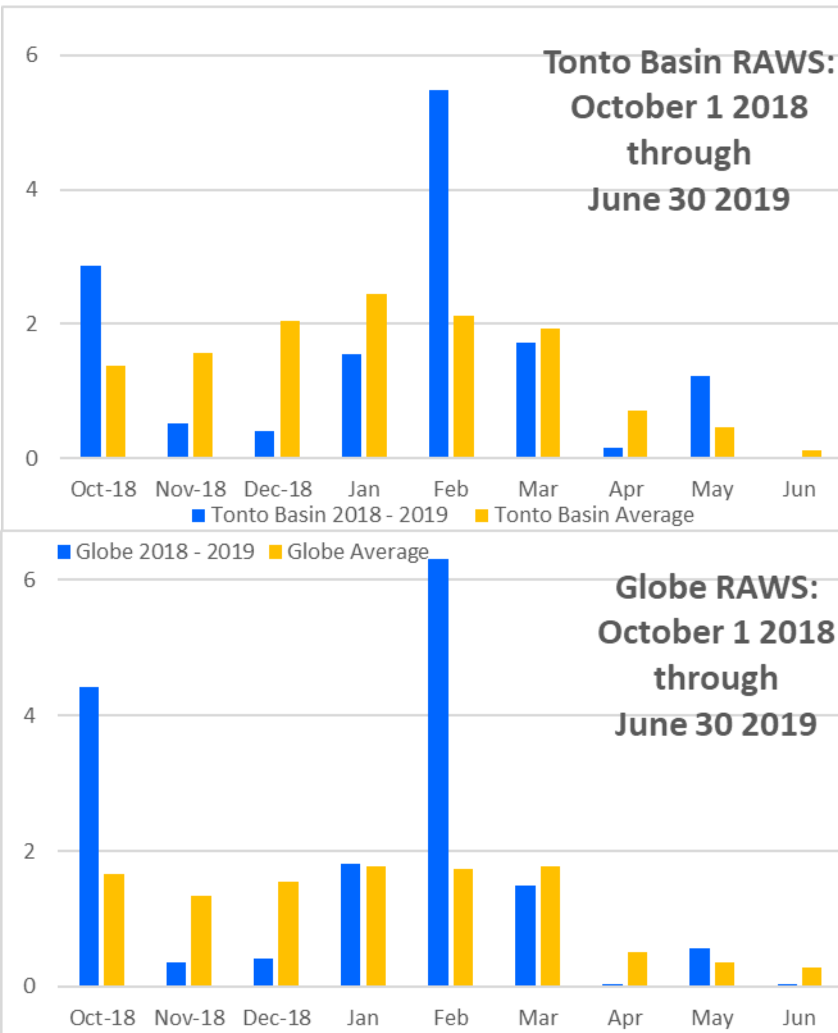

Figure 1. Precipitation at two of the RAWS closest to the Woodbury Fire.

Unlike the precipitation that typically falls at lower elevations in the southwest, snowmelt infiltrates slowly into the soil as it melts instead of flowing downhill into a stream as rainfall often does. This recharges the deeper soil moisture that is used by deeper rooted species, including large and old trees, and many desert and chaparral species. Deep soil moisture can keep live fuel moisture levels high in the foliage and wood of deep rooted species, even if soil at the surface is dry and shallow rooted species and annuals are fully cured.

Figure 2. Figure 2. Snow in Fountain Hills in February 2019 (photo credit msn.com).

In the Sonoran desert, vegetation generally grows in clumps, with insufficient vegetation/fuel between to carry fire far or fast. In wet years, such as 2019, the seeds of invasive, exotic grasses that usually lie dormant in the surface layer of the soil germinate and thrive. Precipitation in February was sufficient to produce a bumper crop of invasive annual grasses in the Sonoran Desert, and the ecosystems that interface with it, particularly riparian areas and the lower levels of Semi-Desert Grasslands.

Prior to the Woodbury fire, there had been little rain for about a month, and the exotic, invasive grasses that infest the southwest desert were cured and ready to burn. In the area that burned in the Woodbury Fire, Red Brome (*Bromus rubens*) and Mediterranean grass (*Schismus spp.*) were particularly pervasive (Figure 3, Figure 4). Fuel moistures in Tonto Basin and Globe were still on the high side for shrubs in the desert, chaparral, and grasslands to burn well, with manzanita (*Arctostaphylos pungens*) at 85 – 96% and Sonoran Scrub Oak (*Quercus turbinella*) at 80 – 96%.

The fire history and ecology in the Woodbury Fire area

Fire is a key disturbance process for the upper elevation ecosystems in the footprint of the Woodbury Fire, but its effects are mostly destructive in the Sonoran Desert. Vegetation types above the Sonoran desert are all fire-adapted, albeit with a variety of fire regimes. The fire ecology of the vegetation types that occur there, the temporal and spatial lightning patterns, and tree ring evidence from multiple locations within 30 miles (Pinal Mountains, Mount Ord, Webber Creek, the Sierra Anchas, and various locations on the San Carlos Reservation) all document fire adapted ecosystems at similar elevations. These studies show significant spatial and temporal variability of historic fire regimes in ponderosa pine and adjacent ecosystems, with fire return intervals ranging from 1 – 41 years, and average return intervals of 1 – 11 years for fine to broad range fires, with the majority occurring from April through July (Kaib 2001b, Kaib 2001a).

Figure 3. Typical Red Brome (exotic, invasive) cover near where Woodbury started.

Figure 4. Mediterranean grass (*Shismus spp.*) cover two days before it burned.

There are no site specific data on fire history in the Superstition Wilderness prior to 1970 (Figure 5), but lightning patterns in the Superstitions and the surrounding area show more lighting strikes at upper elevations where more ecosystems are fire adapted (Figure 6). It is likely there that many fires have gone unreported because of the remoteness of the landscape. Since 1970 there have been 242 fires reported in the footprint of the Woodbury Fire, 83% of which occurred from May through September. For that same period, there were 160 lightning caused fires from May through October, almost half of which were 10 acres or less. Forty-three (27%) of the lightning fires were in frequent fire ecosystems.

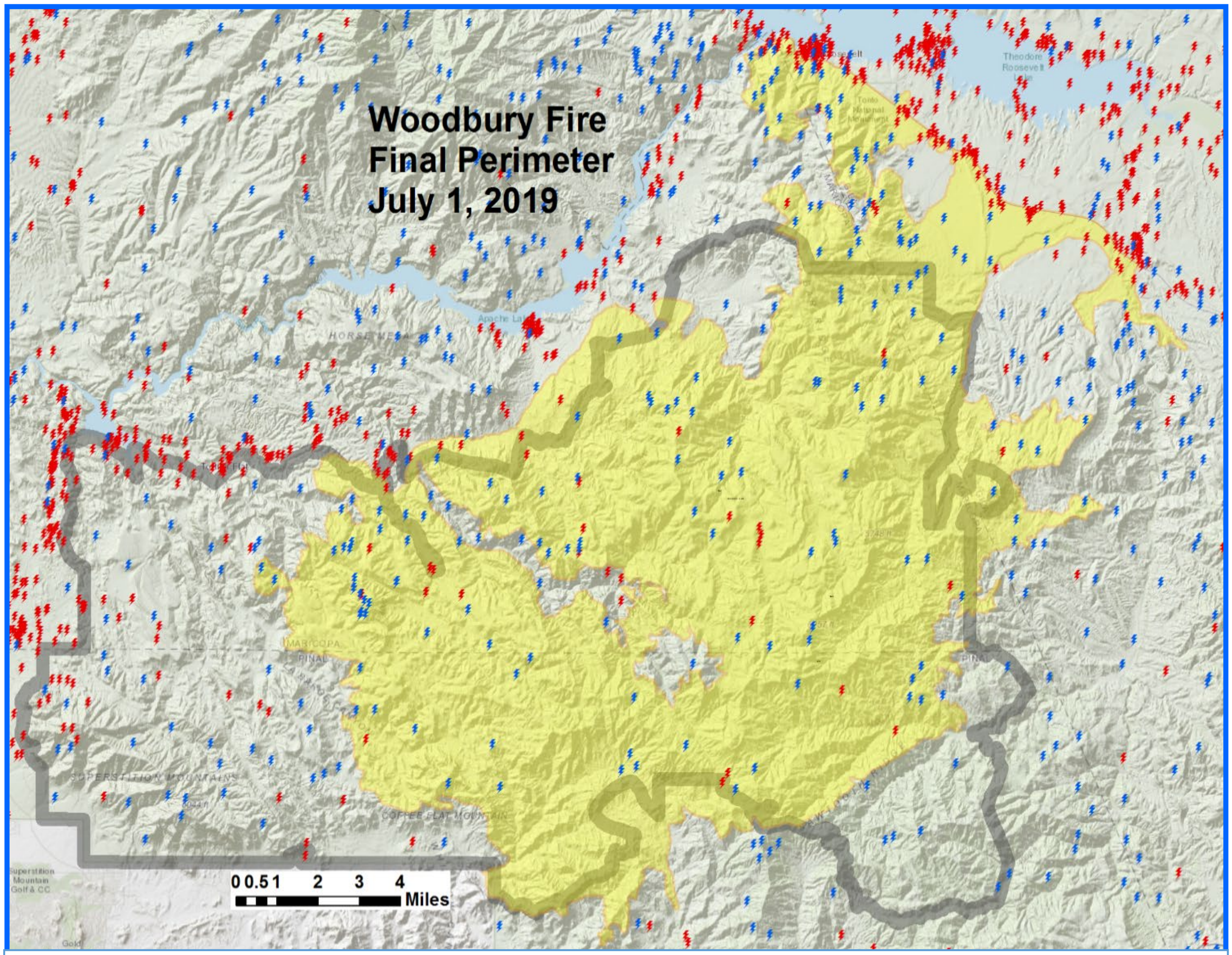

Figure 5. Fires reported from 1970 to 2017. The final footprint of the Woodbury Fire is in yellow. Red bolts = human start; blue bolts = lightning start. The grey line is the boundary of the Superstition Wilderness.

Active fire suppression in the Superstition Wilderness as recently as the 2000s kept most fires small, with 40% of the fires less than an acre, and 86% less than 50 acres. Additionally, current and past effects of grazing, and occasional drought are likely responsible for the lack of sufficient grass in many areas. Grass is the primary surface fuel for frequent fire systems and, for fire to play its natural role, there must be sufficient grass density and continuity for it to burn with sufficient intensity to kill or topkill shrubs and seedlings, and to maintain a healthy canopy base height.

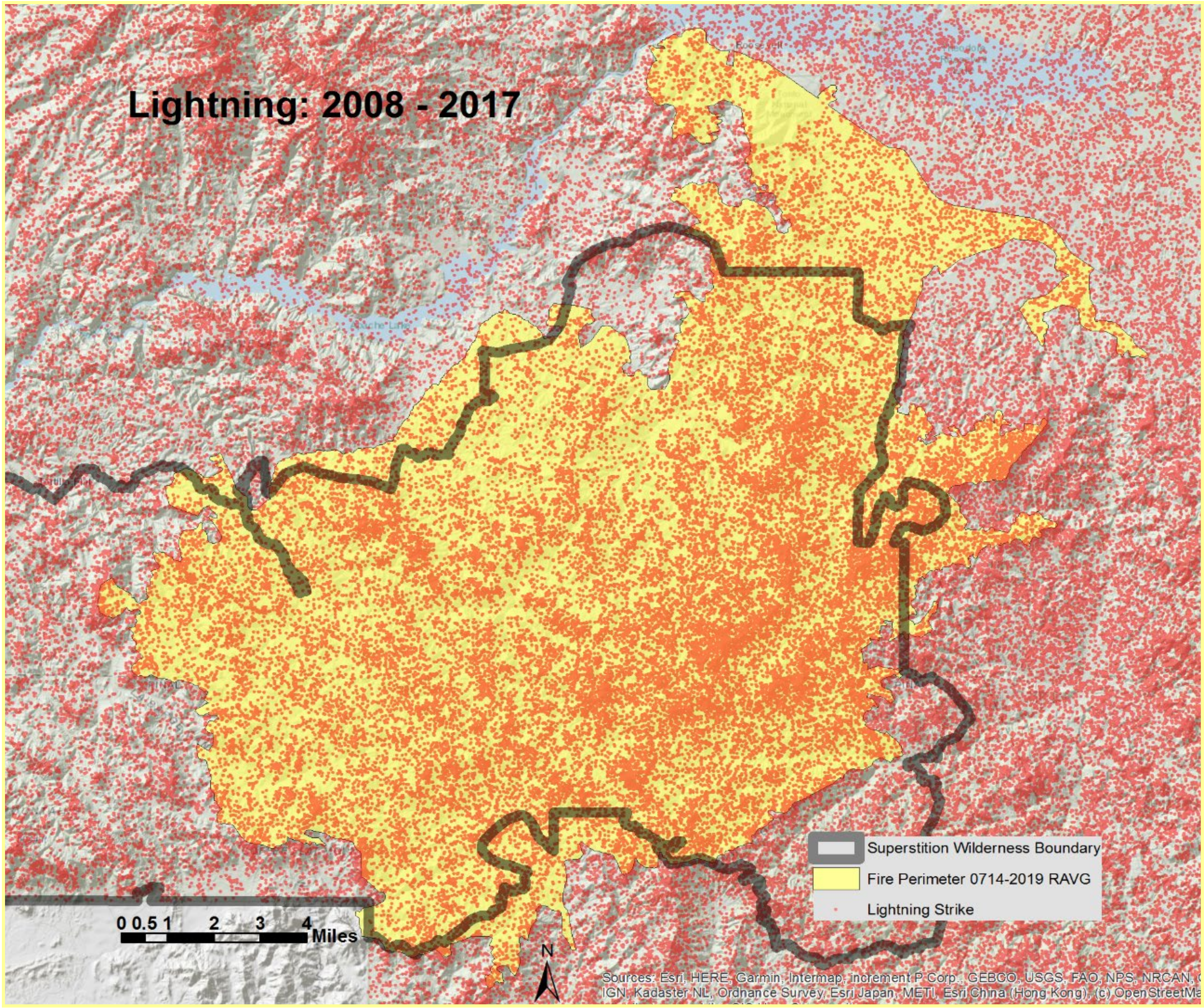

Figure 6. Lightning strikes in the vicinity of the Woodbury Fire from 2008 - 2017.

Vegetation / fuel structure

The vegetation and topography of the Superstition Wilderness and the surrounding area are diverse, encompassing the Superstition Mountains, including Superstition Mountain at 6,299 feet. The topography is extreme, and supports a complex mosaic of vegetation types, which vary with aspect, slope, elevation, moisture, and substrate. The highest elevations, mostly above ~5,500 feet, include stands of ponderosa pine, intermixed in a mosaic with juniper/oak savannas, grasslands, pinyon/juniper, and chaparral. Chaparral occupies steep slopes and, at the upper end of its range, is integrated in with ponderosa pine, and pinyon/juniper. Lower down, chaparral occurs mostly on steep, north slopes, and in pockets and drainages where there are north aspects in the semi-desert grasslands. Sonoran Desert and desert riparian vegetation occupy the lowest elevations. Riparian vegetation snakes through all of these types, mostly in steep sided, deep, winding canyons, but sometimes in wider valleys with more gentle slopes, such as the Reavis Valley.

In addition to being a designated Wilderness, most of the area is extremely remote and rugged so, with the exception of grazing, some trail work and, up until the last decade fire suppression, active vegetation management has been rare.

Within the Woodbury Fire footprint, ponderosa pine occurs only in the upper elevations, and is a good indicator of a frequent, mostly low severity fire regime. Many of the vegetation types that interface with it, woodlands and grasslands, are also adapted to frequent fire. Others, such as chaparral, are also adapted to fire, but to less frequent, higher severity fire. Frequent fire ecosystems that have missed multiple fire cycles and/or have not been thinned increasingly support high severity / high intensity fire as time-since-fire increases. In the absence of fire, in woodlands and open forests, canopies close up, ladder fuels develop and increase, trees become dense and unhealthy, surface litter accumulates. The herbaceous surface cover decreases, and the composition shifts away from fire adapted and shade intolerant species.

Ecological Response Units (ERUs) and Mid-scale Vegetation classifications

This analysis uses Ecological Response Units (ERUs) to evaluate the ecological effects of the Woodbury Fire (Wahlberg et al. 2017 (in draft)). ERUs are classified by the response of vegetative associations to disturbance, vegetative structure, seral state distribution, and numerous other attributes. As currently mapped, it is a relatively coarse spatial classification in which ponderosa pine in the Superstitions does not show up. In order to address that, areas where the Mid-Scale Vegetation Classification is ponderosa pine, were re-classified as Ponderosa Pine / Evergreen Oak (PPE) (Figure 8, Figure 7). There are additional vegetation types that can be seen a finer scale in on aerial photos but, with the exception of PPE, this analysis uses only the ERUS as they are mapped. ERUs mapped within the RAVG perimeter (see section on BARC vs. RAVG) of the Woodbury Fire are shown below in **Table 1**. Mojave-Sonoran Desert Scrub comprises 40% of the

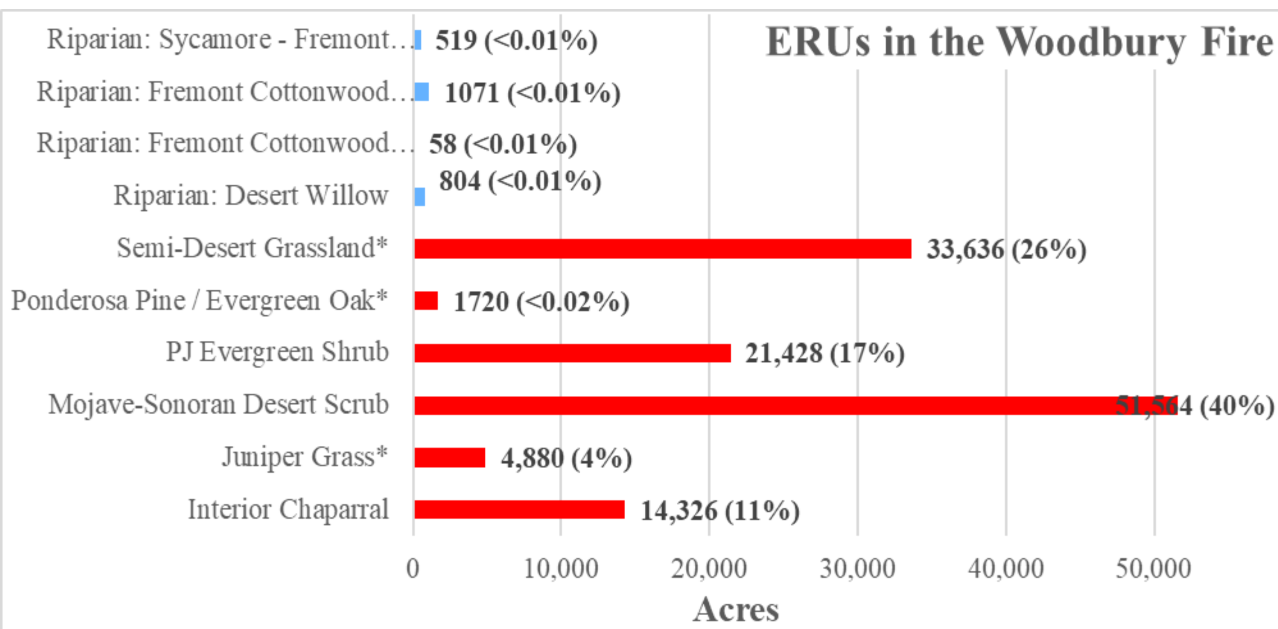

Figure 7. Ecological Response Units within the Woodbury Fire footprint. '*' = frequent fire ERU.

area within the fire perimeter, while fire adapted ecosystesm comprise about 60%. Riparian areas, some of which are adapted to occasional fire, some of which aren't, comprise about 2% of the area (about 2,500 acres). **Table 1**, Figure 8 and Figure 7.

Table 1. Vegetation Types (ERUs) within the fire perimeter.

Vegetation type (ERU)	Average fire severity	Historic Fire Return Interval (range / average)	Patch size
Mojave-Sonoran Desert Scrub	Mixed severity	35 – 1500 / 450	4,200 – 8,100
Interior Chaparral	High severity	30 – 100 / 50	930 – 2,100
Juniper Grass	Low severity	1 – 30 / 15	
Ponderosa Pine - Evergreen Oak*	Mostly low severity; some mixed severity	1 – 60 / 5	Avg < 0.2 acre, but up to 50
Pinyon Juniper Evergreen Shrub	High severity	35 – 200 / 100	50 – 200
Semi-Desert Grassland	High severity	2-30 / 10	Up to the size of the ERU
Riparian: Desert Willow	Mixed severity	It depends on adjacent fire regimes and geometry of this ERU.	Unknown
Riparian: Fremont Cottonwood/Conifer	Mixed severity		Unknown
Riparian: Fremont Cottonwood/Shrub	Mixed severity		Unknown
Riparian: Fremont Cottonwood/Oak	Mixed severity		Unknown
Riparian: Sycamore/Fremont Cottonwood	Mixed severity		Unknown

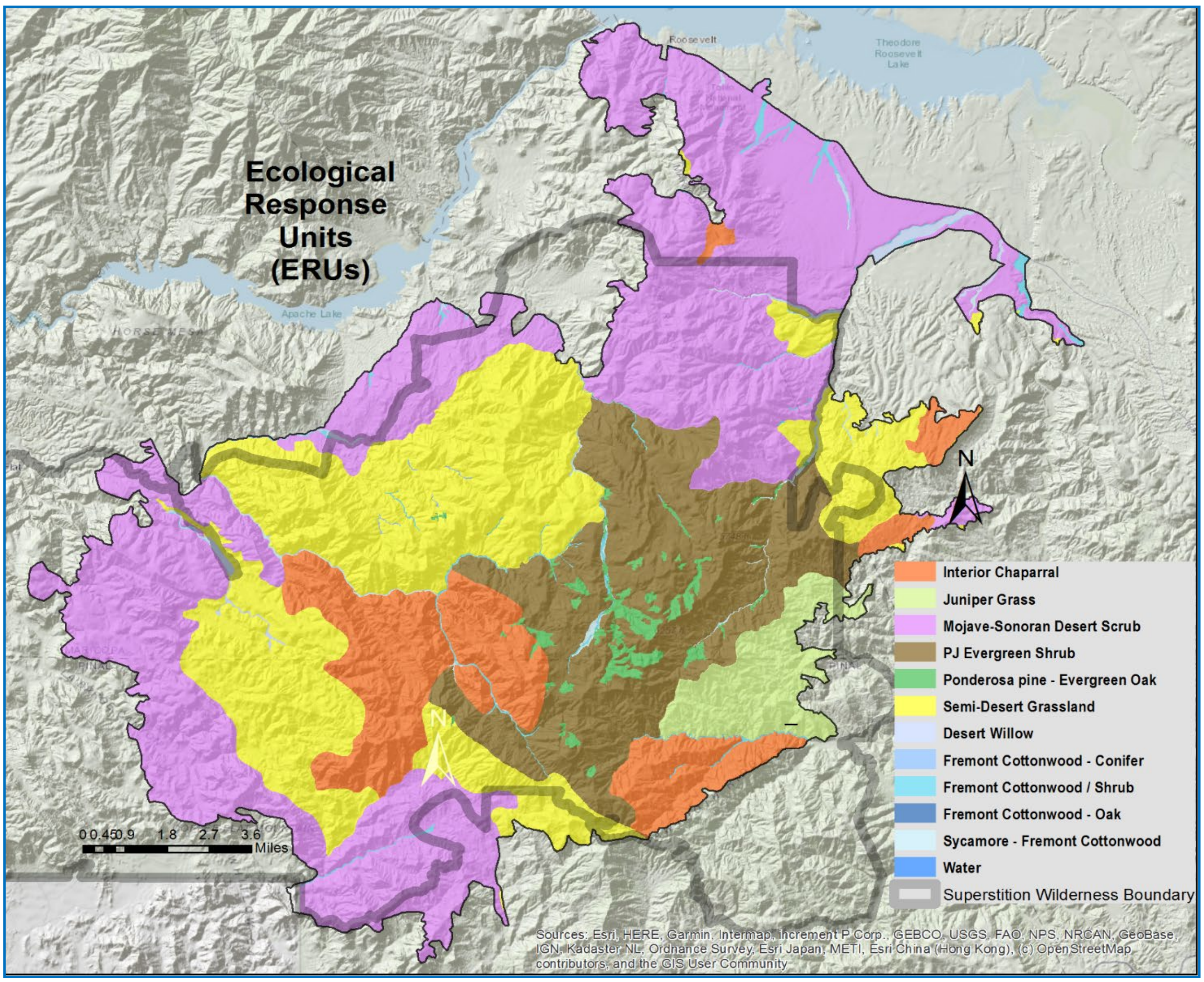

Figure 8. ERUs in the Woodbury Fire footprint.

Potential wildfire Operational Delineations (PODs)

The Tonto NF uses Potential wildfire Operational Delineations (PODs) to inform decisions on the management of wildfires. However, the current PODs, though updated in spring of 2019, were developed with data from years that are more typical in regards to precipitation. The exceptionally high winter/spring precipitation in 2019 resulted in a fuel load, and the associated fire behavior, that only occurs in wet years. Work on an El Niño version of PODs had begun 3-4 days before the Woodbury Fire started. As such, in the desert, and the lower desert grassland areas, existing POD boundaries were not necessarily functional places to engage fire.

Fire Progression Summary

The first smoke from the Woodbury Fire was reported to the Phoenix Interagency Fire Center around 1330 on June 8th. An hour later, a recon flight reported the fire was about 50 acres, active on all sides, and running in grass and brush. It was burning at about 3,500’ in a remote location, about 10 miles north of Highway 60: about ½ mile from the Superstition Wilderness to the northeast and to the southwest (Figure 9).

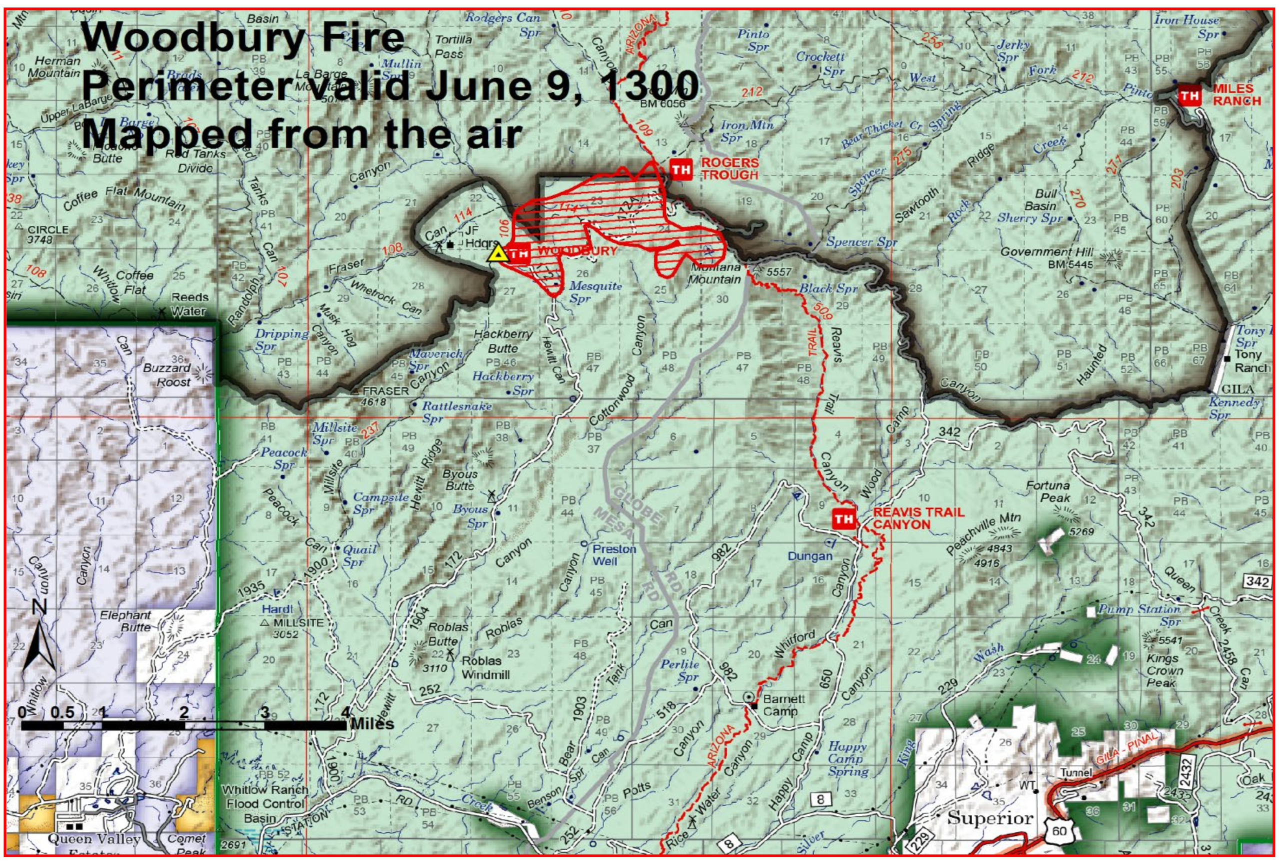

Figure 9 shows the origin as the yellow triangle. This perimeter was mapped around 1300 on June 9th.

Firefighters reached the fire around 1445. By 1645, the fire was estimated at about 150 acres. Around 1730, a more detailed size up reported that spread potential was high, and the fire was burning in hazardous terrain, 40 – 60% slopes with poor access and mostly light, flashy fuels interspersed with patchy shrubs. It had grown to 300 - 400 acres, and had reached the Superstition Wilderness (WILDCAD 2019). Flame lengths were reported at 20 feet in the grass. By the next morning, it had grown to over 1,600 acres.

The fire continued to spread, and was active all night, with 20-30’ flame lengths where there was dense, cured grass under shrubs. Fires often ‘lay down’ just before dawn, when temperatures are the coolest and relative humidities at the highest, but the Woodbury Fire didn’t (Figure 10).

Figure 10. The Woodbury Fire at about 0500 on June 10th (Photo by Mark Sando).

By the end of the day on the 10^{th} it was over 4,400 acres. It continued to move to the southwest, through Sonoran Desert. To the northwest, it burned up into a large area of semi-desert grassland.

On the 11th, the fire was transferred to an IMT3, but updated reports of fire behavior resulted in a re-assessment of the fire potential, and the fire was transferred to an IMT1 on the 12th.

Overnight on the 13-14th, a rare wind event occurred, and the fire moved about four miles to the northwest past where it had been at sunset on the 13th, reaching SR88, and adding about 12,000 acres. The majority of these acres were in grasslands and Sonoran Desert. In 2019, the Sonoran Desert was functioned as grassland system in regards to fire behavior, with high rates of spread.

As the fire continued to spread in the desert areas to the northwest, it moved further into the Superstition Wilderness, burning through Sonoran desert as well fire adapted ecosystems. The lack of access and the behavior of the fire left few options for management actions. Burning out fuels in advance of the expected path of a fire is a tried and true tactic, but fire managers knew that the effects would be destructive in the Sonoran Desert. Nonetheless, there were few options. Retardant and water drops were used heavily in places, with mixed results. In some places it stopped or slowed the fire, and in other places the fire burned through or around it. Aerial ignitions were used minimize fire intensity and severity in the ponderosa pine in the Log Trough PAC (more details on page 42), and in the Reavis Valley.

For a few days after the 16th, the wind pushed the fire around in the upper elevations, and the fire responded to burnout operations around the Reavis School. Tables 2 and 3 show weather recorded at the lowest elevation RAWS within 15 miles of the fire (Goldfield) and the Fish Creek RAWS, which was installed on June 17th and remained up while the fire was active. The Fish Creek RAWS picked up the strong, gusty winds that occurred, particularly at mid and upper elevations (Table 2, Table 3). Burnout operations, combined with strong, gusty winds, pushed the fire to increase by 14,000 – 16,000 acres a day between the 20th and the 23rd. During that time, the Fish Creek RAWS recorded 20 foot wind speeds of 16 – 20 mph with gusts of 27 – 38 mph.

Table 2. Weather data are from the Goldfield RAWS, about 10 miles northwest of the fire (elev 1,397 ft). The yellow row is the day the fire started. Wind direction is an estimate for the periods with the highest wind speed.

Date	Mx temp (F°)	Min RH	Hours with WS > 10	Hours with WG > 20	Max Wind speed/Gust	Wind Direction	Fire Growth (acres)
6/8	100	7	1	1	10/28	SW > WNW	~750
6/9	107	7	0	0	8/14	SW	615
6/10	108	12	2	3	12/22	SE > SSW	3,045
6/11	107	9	0	0	9/19	SW	3,009
6/12	111	6	0	0	8/18	SW	699
6/13	107	9	0	0	7/14	SSW > SW	4,841
6/14	105	6	3	3	11/25	SSW > SW	12,755
6/15	103	9	0	0	7/15	SW	10,634
6/16	105	8	0	0	8/16	SW > WSW	1,267
6/17	104	7	2	2	10/22	SSE > SW	2,786
6/18	103	6	0	2	8/20	SW	3,904
6/19	104	6	0	1	8/27	SSW > SW	6,128
6/20	102	5	0	3	9/21	SSE > SW	15,413
6/21	103	8	4	7	12/27	SSW >	14,021
6/22	99	12	0	3	9/22	SW > WSW	16,355
6/23	100	8	0	0	7/19	SW	16,459

6/24	104	6	0	1	8/20	SW > WNW	6,918
6/25	106	7	0	0	9/17	SW > WSW	3,663
6/26	102	14	0	0	9/19	SW	141
6/27	105	6	0	0	8/18	SW	3,993
6/28	111	9	0	1	8/23	SSW >	237
6/29	112	9	1	0	10/19	SW > WSW	48

Table 3. Weather data are from the Fish Creek temporary RAWS installed on June 17th about 2 miles northwest of the fire (elev 2,900 ft). Wind direction is an estimate for the periods with the highest wind speed.

Date	Mx temp (F°)	Min RH	Hours with WS > 10	Hours with WG > 20	Max Wind speed/Gust	Wind Direction	Fire Growth (acres)
6/17	96	6	3	5	14/25	S > W	2,786
6/18	95	6	10	8	15/30	SSW >	3,904
6/19	95	7	10	6	15/28	SW > WNW	6,128
6/20	94	6	9	6	19/29	SSE > WNW	15,413
6/21	93	10	16	15	20/38	S > SW	14,021
6/22	91	14	9	11	16/30	SW > W	16,355
6/23	90	10	7	5	17/27	SW > WNW	16,459
6/24	95	6	9	5	13/25	SW > WNW	6,918
6/25	96	8	12	5	15/26	S > W	3,663
6/26	94	13	6	5	14/29	ESE > W	141
6/27	97	9	8	5	17/28	SSE > WNW	3,993
6/28	104	9	10	8	14/26	SSE > WNW	237
6/29	104	11	8	5	15/23	SW > WSW	48

On the 23rd, the fire was rapidly moving towards SR88, and air resources were committed elsewhere on the fire, so the last area to be burned out was along SR88. After that, fire activity slowed down significantly, with most of the additional acres resulted from interior areas burning out, or cleaning up the perimeter. The last day of any significant growth was the 27th, and the fire was declared contained on July 15th.

Incident Objectives

The Incident Objectives in the WFDSS Decision are in italics and are evaluated below.

Social / Political Objectives

1) *Continue to maintain timely communications with all agencies and landowners involved (Az State Forestry and Fire Management, BLM, USFS, private landowners, county officials, ADOT, law enforcement, agency PIOs/PAOs, ADEQ, and other stakeholders) to ensure they are aware of the fire status.*

   This objective was met.

   Throughout the fire, daily calls and/or meetings were held with the cooperators listed above, as well as mine owners/operators, SRP, and permittees. Daily updates were posted on Inciweb and social media, and sent out to emailing lists. Reporters were given access (accompanied) to portions of the fireline, and daily reports were sent to employees.

2) *Ensure firefighter, aviation, and public safety through clear, concise leader's intent, work*

prioritization, and implementation of fundamental firefighter principles with thorough risk informed decisions.

This objective was met.

This includes consideration of exposure for fire responders, as well as strategies and tactics that were likely to succeed. Throughout the fire's interior, there are virtually no roads, few trails, and much of the interior, particularly on the northwestern portion near Fish Creek, is extremely rugged and inaccessible county. Chaparral and Pinyon/Juniper-Evergreen shrub covered large portions of the mid-elevational areas on the fire and is difficult, at best, to walk through. Most of the roads that run close to the wilderness are rough, requiring 4WD. A UTV or a Jeep were often the only means of motorized access for some roads.

The size of the fire, and the large Wilderness area within it meant that to get from one side of the fire to the other took 1 ½ hours – up to 3 ½ hours to drive all the way around. In addition, State Route 88 is a dangerous road, and minimizing the frequency with which crews and other fire traffic had to use it was an effective safety measure, as was a closure of this highway to the public. A spike camp was set up at Windy Point, and for several days, when the fire was active on the west and northwest sides, and crews were prepping the southeast side of the fire near Top of the World, a second spike camp was set up. This minimized the time spent driving and avoided unnecessary exposure from driving, and allowed crews to spend their time more productively, on the fire or in camp. Roads in strategic locations were widened and prepped for use during burnouts, primarily by mechanically removing/chipping/piling fuels (Figure 11). This kind of prep combined with burnout operations did not require crews to work in the interior of the fire area.

Figure 11. SR88 where it was prepped prior to a burnout.

3) *Minimize adverse effects from fire and suppression activities to range infrastructure.*

This objective was met.

Management actions taken on the fire were designed to minimize damage to range infrastructure as much as possible, while maximizing the likelihood that those actions would stop the fire. With multiple VARs, and a large, complex, often fast-moving fire, it was inevitable that range infrastructure would be damaged.

Infrastructure / WUI Protection Objectives

1. *Continue to assess the fires impact to values at risk including, power lines, recreational sites, roads and trails, county and municipal structures, the Roosevelt Dam, and multiple communities.*

   This objective was met.

   The potential for fire to impact Values At Risk (VARs) was continuously monitored and evaluated by frequent recon from the ground and air, local and team knowledge and expertise, and fire modeling. Fire managers created Management Action Points (MAPs) to address concerns about specific VARs, and the subsequent actions that would be taken if fire infringed on the MAPs. Strategies and additional MAPs were added as the fire grew and threats shifted spatially, temporally, and in magnitude.

   Structures within the perimeter of the Woodbury Fire were of widely varied jurisdiction. Most were private lands, mostly ranches, but also the Reavis School and an acre or two of DOT land along SR88. There were no FS structures within the footprint of the fire, though there were signs and maps at trailheads. These were successfully prepped and protected, and were not damaged by the Woodbury Fire. In the interior of the fire, roads, trails, and the associated signage will need to be assessed for safety and condition. The only documented damage, outside of range infrastructure, was temporary structures at the Reavis School. Given the extreme fuel loading in and around that property, and the lengths that firefighters went to in order to protect it, the damage to those structures was less than many expected.

Natural / Cultural Resource Objectives

1. *Continue to limit uncharacteristically high severity fire and high impact suppression activities to T&E critical habitat areas to reduce habitat disturbance and assess the impacts caused by suppression activity.*

   TES habitat is discussed below in #3.

2. *Minimize adverse effects from fire and suppression activities to the Sonoran Desert ecosystem. The Sonoran Desert ecosystem is fragile, and is not fire adapted. Non-native grasses are abundant this year. This puts the Sonoran Desert at a very high risk of damage from uncharacteristic fire effects, and management actions associated with suppression efforts.*

   This objective was met to the degree adverse effects ***could*** be minimized.

   The effects of the Woodbury Fire on the Sonoran Desert are described below.

3. *Protect and minimize suppression impacts to natural and cultural resources, threatened and endangered species habitat, livestock forage, archaeological sites, historic sites, wildlife*

habitat, and scenic values.

'Natural Resources' is a broad term that includes the ecology of the area affected by the Woodbury Fire. This is discussed below by Ecological Response Units (ERUs).

BARC vs. RAVG

Fire effects on the ERUs were evaluated based on fire effects to soil and fire effects to vegetation using the following data.

Burned Area Reflectance Classification (BARC) data provide a first look at the severity of a fire's effects to soil, but not to vegetation. Rapid Assessment of Vegetation Conditions (RAVG) data evaluate the severity of a fire's effects on vegetation, but are not available for a few weeks after the fire stops burning. That's partly because scorched foliage needs time to turn brown, so it shows up better in remote imagery. **Where there is high soil burn severity, there will be high severity effects to vegetation, but high severity effects on vegetation does not indicate high, or even moderate severity effects on soil. Thus, 'fire severity' (fire effects to vegetation) is always higher than burn severity.**

Perimeter

Perimeter mapping is not an exact science, and the mapped size of a fire depends on the source. The difference in total acres as mapped by the Incident Management Team, BARC, and RAVG was about 6,300 acres (Table 4).

Table 4. Total acres within perimeter from different sources.

	BARC	RAVG*	IMT mapping
Final acres within perimeter	122,805	129,121	123,875

*Acres used for this analysis unless otherwise stated

BARC datasets may not always cover the entire area within the final perimeter of a fire. In order to begin evaluating hazards in and around burned areas quickly, BAER teams may begin to evaluate initial data while the fire is still burning. Subsequent BARC datasets are more likely to be complete, but still may not include every acre, because the fire may still be burning in areas that would be low post-fire hazard.

Incident Management Teams need updated perimeters on an almost daily basis for fire modeling to be relevant, to develop strategies and tactics, and for public information. During a large fire, and/or a fire such as Woodbury where much of the area is difficult to access, most of the perimeter mapping is done from the air. The final perimeter of the Woodbury Fire was over 150 miles, mostly in very rugged terrain. To accurately map it in a helicopter would require 6-7 hours and multiple flights, which cannot be done frequently. As a result, aerially mapped perimeters are smoothed out versions of the actual perimeter.

RAVG data are collected based on satellite imagery collected well after the fire is done burning, but includes all of the area within previously mapped perimeters, whether that area all burned or not. As a result, RAVG data may over-count acres because all of the area mapped by the IMT will be included, as well as acres that burned after the IMT was done mapping.

Fire Retardant

Fire retardant can be a highly effective tactic for stopping or slowing a fire and, depending on environmental conditions (vegetation, precipitation, soil type, rate of application, ecosystem type, etc.), it can have minimal negative effects. In Sonoran Desert, in particular, the effects of using retardant are likely to be minimal compared with the effects of fire. Retardant was used in many places on the Woodbury Fire with variable effectiveness. In some places, such as Sawmill Ridge, it was one of the tactics that kept fire from moving further to the east and southeast. In other areas, such as where the fire started, it was relatively ineffective, and the fire burned though and/or around it.

Where retardant was used, it may be visible for a few years, though the visual effects of seeing retardant are of much shorter duration than the visual effects of seeing dead/dying saguaro and other burned over desert vegetation. From an ecological perspective, there is little doubt that where retardant was used successfully in the Sonoran desert, the effects were far less detrimental than the effects of unchecked fire would have been.

Phos-chek was the retardant used. Where it did not burn, and depending on how long it was on a plant prior to precipitation, it could dehydrate plants, causing the foliage to burn brown and the plant to wither, at least temporarily. Rain washes off most of the retardant, and plants can recover. The effects of Phos-chek are often like fertilizer, and growth may be enhanced after rain. There is relatively low acute toxicity to aquatic organisms. Some aquatic organisms, including fish, can be sensitive to even minor changes in water temperature (such as may result when a fire burns consumes vegetation shading a stream), and from ash and other debris entrained in overland flow, so it can be difficult to attribute any resulting mortality to one variable.

Near the west fork of Pinto Creek, there was a ~1 mile stretch where retardant was dropped in a retardant avoidance area. The district biologist is consulting with the Fish and Wildlife Service to evaluate the effects.

Fire effects to ERUs

Fire effects to individual species and plants were often within the Historic Range of Variation (HRV). For example, individual shrubs and/or groups of shrubs had become decadent, and were ready to burn. They benefited from the fire, as it consumed the dead wood and allowed the energy from the roots to be routed into growing fresh sprouts. However, effects to the ERU as a whole were often out of whack because of overly large patches of high severity.

Interior Chaparral (IC)

Transitioning from low-elevation deserts, and sometimes intergrading with semi-desert grasslands, Interior Chaparral consists of mostly of woody evergreen shrubs. Sparse tree cover is also typical of this ERU and, in the upper elevational ranges, there can be some pinyon, juniper, or ponderosa pine. The fire return interval for chaparral varies widely (**Table 1**, page 9), and it recovers quickly from fire.

Research on the Tonto NF has shown that 80 years without fire in chaparral vegetation resulted in an 86% increase in woody cover (Sankey, Leonard and Moore 2019). Of the 17,253 acres of IC within the Woodbury perimeter, records show less than 250 acres had burned in the last 50 years. So, when the Woodbury Fire burned, there were about 17,000 acres with elevated levels of woody cover/fuels that were ripe for burning.

Soil Burn Severity: BARC data show soil burn severity is within the Historic Range of Variability (HRV) for IC, with only two patches of high burn severity as big as 10 acres. There are extensive areas of moderate burn severity (>1,000 acres) in IC, mostly in the upper reaches of Spencer Spring and Bear Thicket, but moderate soil burn severity is not really a concern IC (Table 5).

Table 5. Fire severity and burn severity in Interior Chaparral.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Interior Chaparral	High	18	<1%	7,342	43%	17,253	13%
	Moderate	5,469	45%	4,848	28%		
	Low	4,944	41%	2,061	12%		
	Unburned/Very Low	1,762	14%	2,577	15%		
	Cloud Cover, no data			424	3%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

Fire Severity (vegetation): RAVG data show extensive areas of high severity. IC is adapted to infrequent, mostly high severity fire, and needs fire to periodically to consume decadent wood, scarify seeds, and rejuvenate chaparral vegetation. Ideally patch size, would be less than 2,100 acres most of the time. Fire severity is high over about 71% of the IC (7,342 acres), and the high severity patch size exceeds 2,100 acres in one large high severity patch near Bear Thicket Creek and Spencer Spring Creek, which feed into Pinto Creek (Table 5).

Most of the chaparral would have had a significant dead component because the absence of fire for so long produced elevated levels of woody cover (Sankey et al. 2019), increasing its flammability. Historically, it takes 3-4 weeks for chaparral to go from peak greenup to becoming full available. In early June, foliar moisture as measured in Globe and Tonto Basin was just dipping into the 'available' range, with manzanita and turbinella oak ranging from 80 – 96%. The fire started at an elevation on the higher area of the Sonoran Desert where the desert intergrades with semi-desert grassland. There was a significant grass component, and there was chaparral-like vegetation on north slopes and some drainages. Over the next few days, the fire moved up into areas where north slopes were increasingly dominated by chaparral (Figure 12, Figure 13). On June 14th, the fire began to burn well in chaparral when slope aligned (Figure 14). As the shrub foliage continued to dry out over the next few days, there were notable increases in its flammability and intensity. Parts of the IC burned in a mosaic of mostly moderate severity, but most of it burned in large patches of high severity or high severity mixed with moderate severity. **High fire severity in chaparral is within the HRV, however, the patch size is mostly on the upper end, close to 2,100 acres. The majority of the IC burned, leaving a deficit of the mature closed state, which should represent over 90% of IC.** The chaparral will not burn again for several years, providing options for the management of future wildfires in adjacent areas.

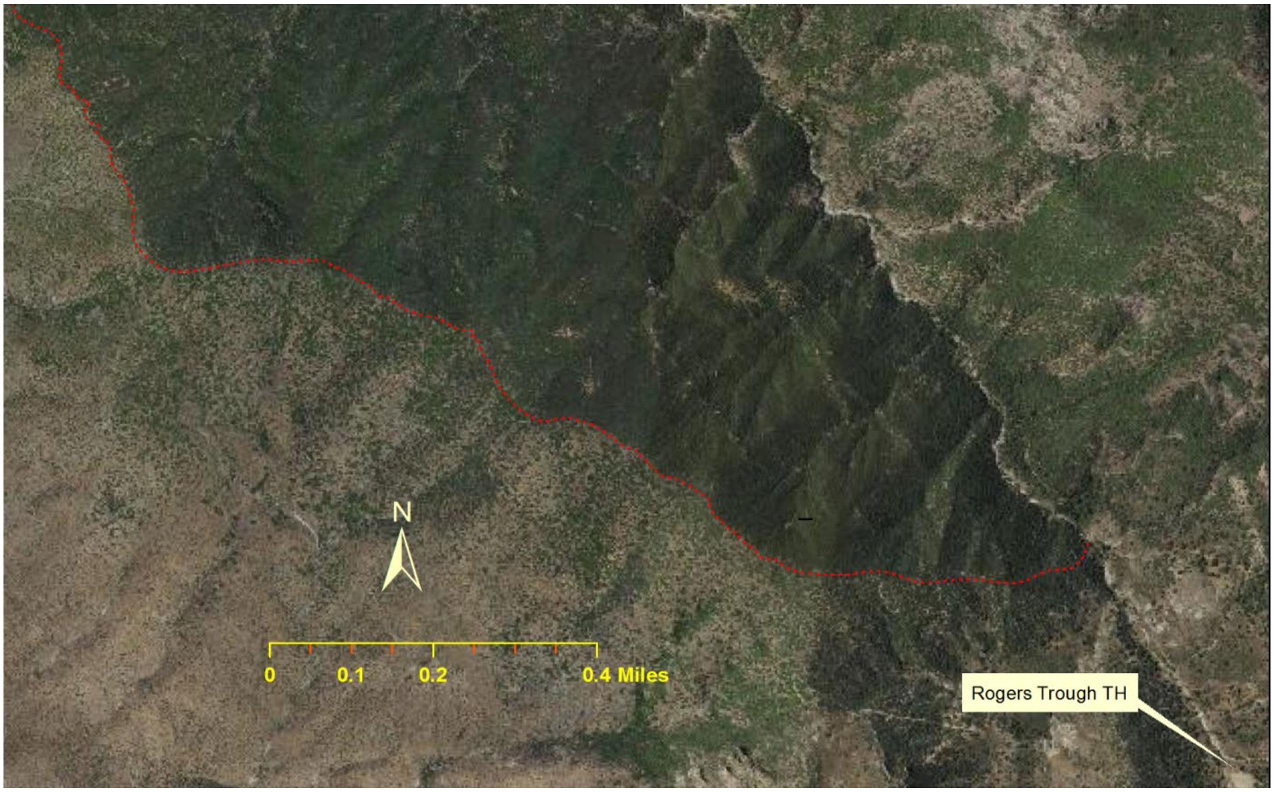

Figure 12. Red line shows the north/south ridge. In this 2017 image, chaparral is dark green on the north slope.

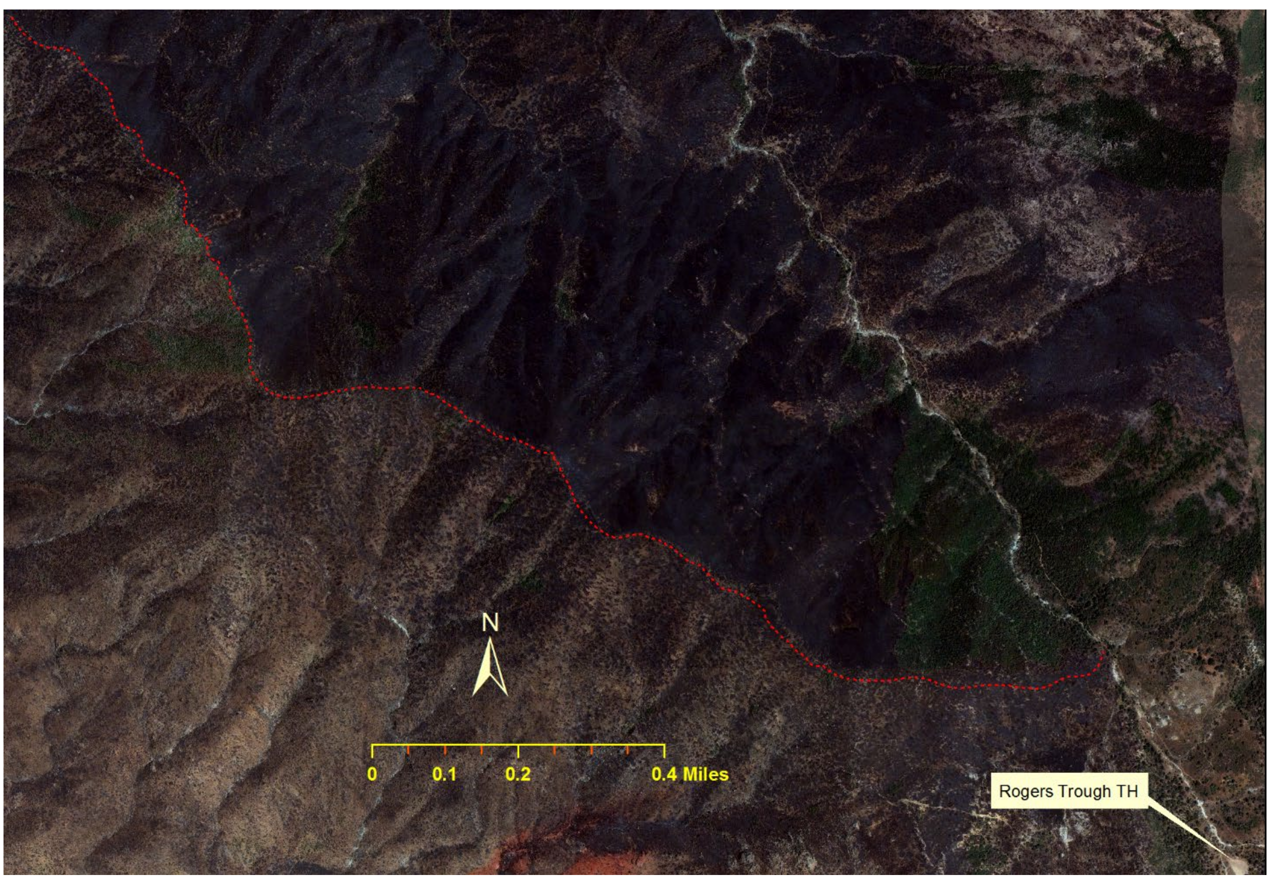

Figure 13. Red line shows the north/south ridge. In this post-fire image, the high severity effects typical of chaparral are apparent.

Figure 14. Chaparral burning in Rogers Canyon on June 14th. View is from the south; fire is moving up the slope from the north.

Juniper Grass (JUG):

Juniper Grass (JUG) is a savanna system, with a high frequency/mostly low severity fire regime. About 10% of the trees can be in a closed condition, which represents areas where fire effects would be mixed or high severity. Typically, the herbaceous surface fuel is composed of native perennial grasses, while forbs consist of both annuals and perennials. Shrubs should be absent or scattered in this ERU. Figure 15 shows some unburned and burned areas of JUG. In the unburned area, shrubs and immature juniper are visible. All of the mapped JUG in the Woodbury footprint was in one contiguous area northwest of the Miles Ranch on the east side of the fire. Historically, fire would have burned on average about every 20 years, often more frequently, and rarely going longer than about 35 years. In the last 50 years, only 374 acres of the 4,884 acres of JUG within the Woodbury Fire perimeter have burned, allowing woody encroachment that set the area up for uncharacteristically high severity fire (Figure 15).

Soil Burn Severity: Overall soil burn severity in the Juniper Grass (JUG) was a higher than desired, with moderate soil burn severity across 68% of the ERU (Table 6). The effects of moderate burn severity depend a lot on conditions following a fire. Moderate severity on steep slopes can be sufficient to allow topsoil and much of the seedbank to wash away if there are heavy rains. If there is only moderate rain in the few months post-fire, ground cover may start to recover as grasses resprout, increasing surface roughness sufficiently to slow down water and sediment. In some places, moderate soil burn severity could have been sufficient to damage grasses and forbs so that ground cover recovery is slow.

Fire Severity (vegetation): Fire severity was much higher than is desirable, with 70% of the vegetation burning with high severity (Table 6).

Figure 15. Area mapped as Juniper Grass (JUG). Woody encroachment is visible in the unburned area.

High severity patches of up to 30 acres are considered to be within HRV for this ERU, but there are few patches that small in the JUG in the Woodbury Fire. One patch is close to 1,000 acres, and many areas are 2-300 acres of high severity, with only small areas of low and mixed severity. The primary cover in this ERU is grass, and healthy grass can come back if post-fire soil erosion isn't too bad and it is rested from grazing. It is the mid- and old age classes of the junipers that will be missing from this area for several decades and a century or more before the full structure will recover, regardless of management. As with most places, the speed of recovery depends, in part, on the proximity of a seed bank for species of juniper that don't sprout. On the Tonto NF, Alligator Juniper is the only native juniper that sprouts.

Table 6. Fire severity and burn severity in Juniper Grass.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Juniper Grass	High	10	<1%	3,435	70%	4,884	4%
	Moderate	3,303	68%	725	15%		
	Low	987	21%	328	7%		
	Unburned/Very Low	526	11%	260	5%		
	Cloud Cover, no data			130	3%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

Mojave-Sonoran Desert Scrub (MSDS)

The Sonoran Desert is a special place to Arizonans, yet it is fragile, and poorly adapted to fire or mechanical disturbance (wheels, hooves, or anything else that displaces soil). As such, it is often singled out when objectives are written for fires because, unlike almost all of the other ERUs on the TNF, fire effects in the desert are almost always detrimental. Mojave-Sonoran Desert Scrub (MSDS) is highly variable, with 'normal' conditions ranging from areas of barren rocky substrates with less than 1% plant cover, to areas with deep, well-developed soils that support dense populations of succulents, native grasses, perennial shrubs, and herbaceous ephemerals that emerge during infrequent wet periods (such as spring of 2019). As was described earlier in this report, winter and spring precipitation in 2018-2019 produced a bumper crop of invasive grasses that changed the potential fire behavior and effects in the desert, leaving it highly flammable and vulnerable to fire effects that are likely to change the composition and appearance for a century (Abella 2010).

Soil Burn Severity: As is indicated by the data (Table 7), fuel loads in deserts are not sufficient to produce residence times or temperatures that can severely damage soil; there was no high soil burn severity. Where there was moderate soil burn severity, post-fire disturbance such as monsoon rains, herbivory, hoof action, and/or wheels, will have a significant effect on the response of desert soils and, therefore, the response/recovery of desert vegetation.

Table 7. Fire severity and burn severity in Mojave-Sonoran Desert Scrub.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Mojave-Sonoran Desert Scrub	High	0	0	13,768	27%	51,564	40%
	Moderate	2,894	6%	21,411	42%		
	Low	31,050	63%	8,176	16%		
	Unburned/Very Low	15,427	31%	7,803	15%		
	Cloud Cover, no data			390	<1%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

<u>Fire Severity (vegetation)</u>: In general, MSDS is not adapted to fire, though some species are more vulnerable than others. Two of the most iconic Sonoran desert species, saguaro and palo verde, are highly vulnerable to fire ((Alford, Brock and Gottfried 2004)). Even low intensity fire (short flame lengths) can produce mixed or high severity that significantly changes the composition of desert plant communities. Cactii and some woody species have green skin or bark. The green indicates the presence of chlorophyll, and photosynthetically active tissue – that's how the plant makes food for itself. For some species, such as palo verde, the bark is very, very thin, and it can be girdled or lethally scorched by even a very cool fire (Figure 16).

The scorched skin of a cactus (or leaves or needles or bark) results from cells that burst when the water inside is heated and swells; we see that as scorch when the green turns brown or yellow. On a saguaro, the scorched skin turns brown and never heals; it will have a scar for the rest of its life. Its survival depends on how much is scorched, and post-fire environmental conditions and threats, with long term mortality as high as 80% (Wilson et al. 1996). This is true for all cactii, with the scorched skin representing decreased ability to photosynthesize. Other desert species can sprout prolifically and, though they will be smaller, less mature plants, their sprouting will provide some of the first nurse plants for saguaro and other species that need some protection for immature plants to thrive and mature. Even if there is no more fire in the burned areas, mature plants take decades to mature. In areas with high, moderate, and some low severity, there will be an overall shift in species composition towards sprouting species, mostly shrubs, and grasses. The grasses will be mostly invasive exotic species, particularly at the lowest elevations.

Figure 16. Palo verde branches 3-4 days post-fire. The brown is scorched bark where the heat from a not-very-hot fire burned below the tree.

The prevalence of invasive grasses in the desert in wet years, and their ability to support large, fast-moving fires will continue. The invasive grasses may decrease in density for 2-4 years, but it is highly unlikely that they will ever go away. Post-fire ground disturbance can lead to soil compaction and loss (as little as 5-10 cm at soil surface), hindering recovery, and potentially eliminating long-lived dominates such as creosote, and shifting dominance to short-lived disturbance adapted species (including natives and exotics).

MSDS occupies about 40% of the area within the perimeter of the Woodbury fire, and is the only ERU along the edge of the Woodbury Fire footprint (except for some riparian areas). While there were a lot of adverse effects from this fire, it is unfortunate that the ecosystem that was the most damaged is also the only one that is easily visible to most people. Fire behavior in MSDS was, unfortunately, typical for a wet year when it burns like a grass/shrub system (Figure 17). Figure 17 shows extreme fire behavior from a headfire moving uphill in MSDS with Red Brome in what would be sparsely vegetated or bare interspaces between clumps of vegetation in a typical year.

Fire effects are influenced by past fire severity, fire frequency, and species composition, structure, and the presence of exotics. Invasive species encroachment along with altered vegetation structure (for example, increased shrub density) are influencing uncharacteristic fire in MSDS, and that is likely to continue, particularly when winter/spring precipitation produces a bumper crop of invasive, exotic grass to fuel fast-moving fires.


Figure 17. Fire behavior in MSDS in a burnout operation along SR88. (Photo credit William Dudley)

Pinyon – Juniper / Evergreen Shrub (PJC)

This ecological response unit is generally found above and adjacent to chaparral at lower elevations and in montane forests at higher elevations. PJC normally occurs as a mix of trees and shrubs with sparse herbaceous cover, but includes vegetation states that are herbaceous, shrub, or tree-dominated, depending on time since disturbance. Information on HRV is sparse, but it is assumed that less than 5% of the area should be in a recently disturbed state, with patch size generally from 50 to 200 acres (United States Department of Agriculture 2017). Infrequent fire with mixed to high severity typifies this ERU, though the severity varies a bit, depending on the species composition. Areas where the understory is manzanita are more likely to burn with higher severity and less frequent fire than where oak dominates the understory. Time since disturbance affects tree cover, which should be less than 10% tree cover where the vegetation is the most mature, as well as the density of the shrub understory. Perennial native grasses and both annuals and perennial forbs comprise the remainder of the inter-canopy interspaces.

PJC should have an average fire return interval of less than 100 years, with some areas burning more frequently. Over the last 50 years, only 6 acres of PJC within the footprint of the Woodbury fire have burned. While that is not outside of its HRV, it affects the patchiness of the system by increasing patch size, increasing the continuity of decadent fuel loading, and increasing the chances that fires that burn would be large and produce high severity effects. That is what happened with the Woodbury Fire.

Soil Burn Severity: Some high soil burn severity is probably natural when this system burns, though there are no data that specify that. Two percent of this ERU had high soil burn severity, mostly in one of two areas (Table 8). One is the upper watershed above the west fork of Pinto Creek, and an area in the upper watershed above Rogers Canyon. Moderate soil burn severity probably should be common in mature areas of PJC that burn, though greater patchiness would be healthier and more sustainable for the ERU and other adjacent/affected ERUs. Most likely, high severity would be in small patches related to the size of tree groups that burned, less than 10 acres and probably closer to 1 acre (Wahlberg et al. 2017 (in draft)).

Fire Severity (vegetation): Most of this ERU (68%) burned with high severity (Table 8). Some high severity would be natural in PJC, particularly where the understory is mostly manzanita. Patch size, under the most generous references available, should rarely exceed 200 acres, and that should be uncommon. The 38% (14,000+ acres) of high severity in PJC is mostly in large contiguous patches: one exceeds 5,000 acres, with just a few small areas of mixed severity, two are close to 2,000 acres, one is around 1,500, and some over 500 acres. Additionally, reference conditions suggest that only 5% of the area should be in a recently disturbed state.

Table 8. Fire severity and burn severity in PJ Evergreen Shrub.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
PJ Evergreen Shrub	High	468	2%	14,464	68%	21,428	16%
	Moderate	13,935	65%	1,803	8%		
	Low	2,609	12%	1,341	6%		
	Unburned/Very Low	4,343	20%	3,366	16%		
	Cloud cover / no data			454	2%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

The high severity areas surround Campaign Creek, including the upper watershed, Reavis Valley Creek, and a large patch west of Iron Mountain along Rogers Canyon.

Ponderosa Pine – Evergreen Oak (PPE):

Available spatial data show 1,721 acres of Ponderosa Pine / Evergreen Oak (PPE) within the perimeter of the Woodbury Fire. The dynamics of this ERU are not as straightforward as other ponderosa pine ERUs, or as PPE is in other locations on the Tonto NF. To account for the variability in this system, there are subclasses with different fire regimes and different vegetation and fuel structure. In the Superstition, many patches of PPE are long and narrow because it is at the lower elevations of its range, and most often occurs in cool air drainages and on north aspects. As described briefly earlier, ERUs are mapped at a scale that is too coarse to include any of the ponderosa pine in the Superstition Mountains. For this analysis, what is mapped as ponderosa pine in the Midscale Vegetation Data for the Tonto NF was reclassified as PPE. Even so, it is poorly mapped in the Superstitions, so there are areas of mature ponderosa pine that are not mapped at all, and other areas mapped as ponderosa pine that clearly haven't had ponderosa pine for decades, if ever (Figure 18).

Some of the PPE would almost certainly be a subclass called 'Evergreen Shrub Subclass', in which ponderosa pine is less dominant, and shrub cover is higher, with many of the same shrub species found in the chaparral. This vegetation type favors slightly longer fire return intervals and higher fire severity. In the Superstition Mountains, PPE probably includes this Shrub Subclass, but it is not mapped. In other places where it probably occurs, the shift from PPE to IC occurs in patches, and/or as a gradient, with the Shrub Subclass functioning like an ecotone between the chaparral and PPE, as well as the associated fire regime. Most of the PPE in the Superstitions is surrounded by, and interfaces with, Pinyon-Juniper Evergreen Shrub (PJC). There is not usually a clean line between them, but a slow shift in the dominance of the pine.

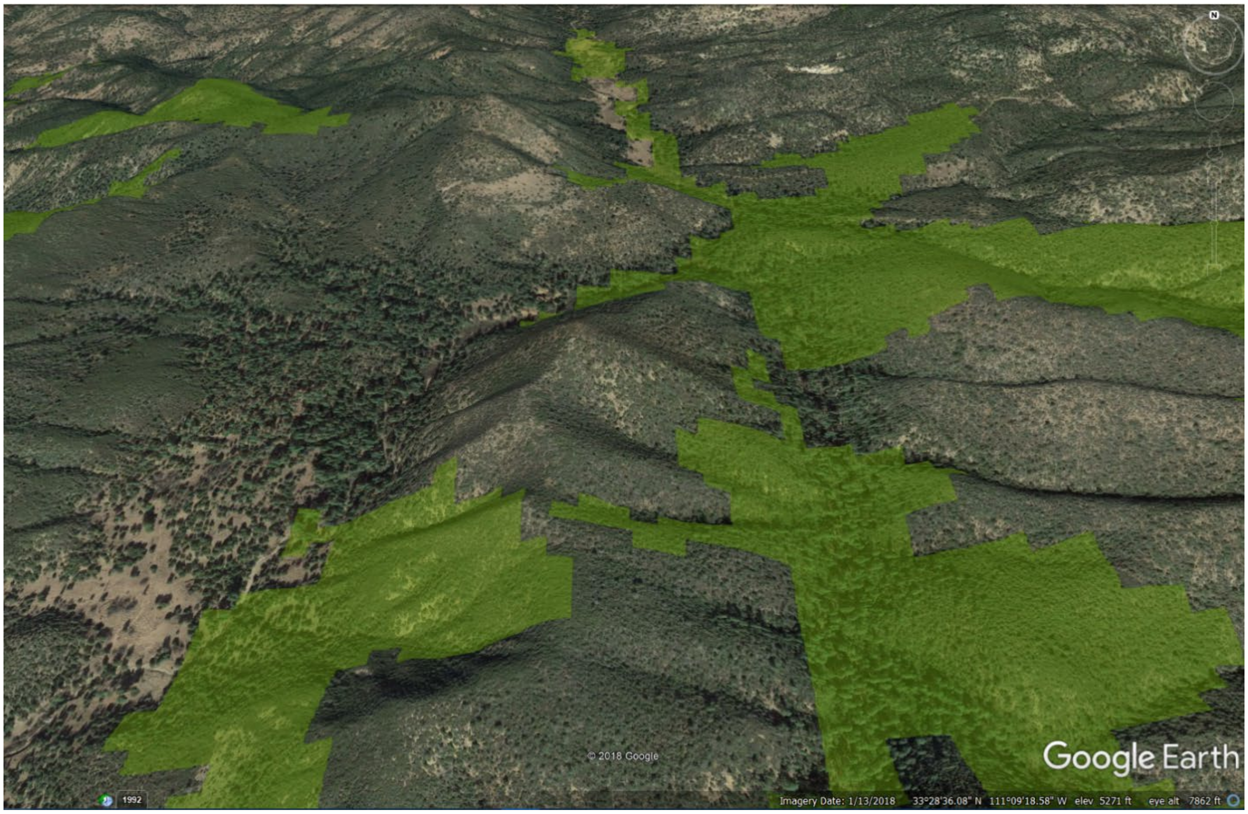

Figure 18. Google Earth image from 2018 showing areas currently mapped as ponderosa pine in green.

There is no record of any fire in the ponderosa pine in the Superstition Mountains for the last 50 years, though it is unlikely there would be ponderosa pine if there was no fire. As in the majority of the PPE on the TNF, the lack of fire has allowed sprouting shrub species to become established underneath ponderosa pine at densities that are not sustainable with a fire regime that can support ponderosa pine (Figure 19). Historically, fire would have killed/topkilled the understory and consumed most of the litter in the pine where there grass or ponderosa pine needles can facilitate frequent, low intensity and mostly low severity fire. Where PPE interfaces with the chaparral, needle drape on shrubs, pine litter on the ground, and a grass-dominated understory would have maintained an ecotone in which fire would kill / topkill most of the chaparral shrubs encroaching in to the pine. A lack of continuous surface fuel would have minimized the ability of low severity fire to burn in chaparral so, when it did occasionally burn, it would kill ponderosa pine that was encroaching into the chaparral or PJC.

The effects of missing fire cycles will have created a broader ecotone between the ERUs where there are a mix of dense shrubs and relatively young ponderosa pine. This arrangement would be more likely to favor the shrubby vegetation which would benefit from high severity fire that would kill the ponderosa pine. Increased canopy cover decreases light and precipitation to the surface which, in turn, decreases the light flashy fuels (grass-dominated) at the surface.

In addition to decreased diversity, and a shift to more shade-tolerant species, the fire behavior associated with increasing fuel loads of dense pine litter and heavy fuels, combined with increased ladder fuels, supports high intensity fire which could also produce high soil burn severity. That favors ERUs with sprouting shrubs, particularly IC and PJC.

Figure 19. PPE from the Arizona Trail in the Reavis Valley in April of 2019. (Photo credit Rand Snyder)

<u>Soil Burn Severity</u>: In a healthy PPE fire regime, high soil burn severity would be unusual, and would only occur where there are jackpots of heavy fuels. There are no data that specifically evaluate the historic amount of high soil burn severity, but 3% is likely to be on the high side, though it may not unreasonable for a first-entry burn in PPE.

In the PPE there were 42 acres (3%) with high soil burn severity, and 892 acres (53%) with moderate burn severity (

Table 9). The largest area of high burn severity mapped in the PPE was about 25 acres.

Table 9. Fire severity and burn severity in Ponderosa Pine / Evergreen Oak.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Ponderosa Pine / Evergreen Oak	High	42	3%	762	44%	1,721	<0.02%
	Moderate	892	53%	262	15%		
	Low	341	20%	307	18%		
	Unburned/Very Low	419	25%	334	19%		
	Cloud Cover, no data			57	3%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

<u>Fire Severity (vegetation)</u>: Aerial photos show that ponderosa pine in the Superstitions exists in small patches, some of which were connected and some of which were not. Recent research suggests that small refugia (healthy patches of ponderosa pine within larger areas where there was high severity fire) have a significant value in maintaining the resilience of the entire area (Coop et al. 2019). In some areas, post-fire images show patches in the valleys that are likely to contribute to regeneration in future years if weather cooperates. With high severity over 44% of the PPE, an evaluation of the available data, including pictures, Google Earth, and mapped severity, it is clear there are stands of ponderosa pine that are unlikely to recover (Figure 20).

Figure 20. High severity effects in a stand of PPE.

The establishment of sprouting shrubs in the PPE has been facilitated by a lack of fire. This increased shrub cover supports a fuel structure that produces more high severity fire than this ERU is adapted to. It is very difficult to reduce sprouting shrub cover once established (other than top-killing). Ponderosa Pine/Evergreen Oak needs fire more often than the ponderosa pine ecosystems that are more common across the western US because of the prevalence of sprouting shrubby species that can burn with high intensity and serve as ladder fuels. **Without a fuel structure that**

supports the type/s of fire PPE is adapted to, it is likely that some areas of high severity in the PPE may never recover. However, in the 900 or so acres where the fire effects were beneficial (low and some moderate severity) the effects of the Woodbury Fire will also be beneficial.

Semi-Desert Grasslands (SDG):

Semi-Desert Grasslands (SDG) are an ERU for which high soil burn severity is bad, and high fire severity is desirable. There should be less than 10% tree cover and, though there could be more than 10% shrub cover, it would be patchy and not dominate. Only about 9% (3,016 acres) of the grasslands within the footprint of the Woodbury Fire have burned within the last 50 years and, as a result, large areas have significant encroachment from woody species.

The only time grasslands aren't flammable is when they're too green (just 2-3 months of most years), wet, heavily grazed, or recently burned. If they don't burn frequently enough, shrubs begin to encroach, increasing potential fire behavior and, therefore, also increasing the difficulty and complexity of managing fire in those areas. Grazing is often suggested as a proxy for fire in grass, but that tends to exacerbate the encroachment of woody species, and promotes cacti, yucca, acacia, mesquite, and other species that are not generally palatable to, or desirable for, livestock and are useful for different suite of wildlife than are healthy grassland vegetative associations.

<u>Soil Burn Severity</u>: It is practically impossible for fire to produce high soil burn severity in areas that truly are grasslands, because it requires long residence times and/or heavy fuel loading to provide sufficient soil heating. That is reflected in the BARC data which show less than one acre of high burn severity, and about 2,600 acres of moderate burn severity (Table 10).

Table 10. Fire severity and burn severity in Semi-desert Grasslands.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Semi-Desert Grassland	High	<1	<0.03%	18,018	54%	33,783	26%
	Moderate	2,619	8%	9,820	29%		
	Low	25,001	78%	2,875	9%		
	Unburned/Very Low	4,544	14%	2,675	19%		
	Cloud Cover, no data			245	<1%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

<u>Fire Severity (vegetation)</u>: High severity fire is desirable in grasslands, and is the primary means of keeping woody species in check, and rejuvenating decadent grasses, forbs, and that portion of the existing shrub population that is beneficial and natural.

Red Brome has invaded SDG to a significant degree; up to 70% cover in transects put in adjacent to the burned area, and is affecting the diversity and potential fire behavior and effects in SDG. It has displaced native species, and provides what may be a more contiguous fuel load at the height of the seedhead than native grasses would because of the morphology of the plant and the density of the individual plants. In years like this one, the seed head is particularly robust/dense (Figure 22) so, when fully cured (Figure 3), it can produce surprisingly high fire intensity (long flame lengths). The density of Red Brome should be lower for a few years where it burned, but there is no reason to think it will decrease in the long term.

Figure 21. This area is mapped as SDG; note the woody cover and the dominance of Red Brome.

There are over 33,000 acres of this ERU within the area burned by the Woodbury fire. **Fire effects on Semi-Desert Grasslands (SDG) were beneficial, decreasing woody cover, recycling nutrients, and scarifying species that may germinate better with fire. Post fire management, however, will be important in the response of the grasslands, particularly where they were in poor shape prior to the fire.**

Figure 22. Red Brome seed heads curing in May (left) and still developing in April (right).

Riparian

Riparian areas are not a significant proportion of landscapes in the southwest, but they provide an outsized ecosystem service in the form of habitat and water movement in and across the landscape. There are six different riparian types within the perimeter of the Woodbury Fire, though there is less than an acre of Fremont Cottonwood – Oak, so it was not evaluated. There are little to no data available for fire effects on these riparian types, so extrapolations are made here based on the known fire ecology of the dominant species, as well as the influence of adjacent fire regimes.

Many species that grow in the riparian areas will sprout following a fire (velvet mesquite, sycamore, box elder, netleaf hackberry, desert willow, and others). However, not all riparian species will sprout and, even when they do, sprouts do not provide the same structural components for habitat and ecology. That said, particularly in upper elevation riparian areas, fire will often act as a janitor, cleaning up excessive debris jams, and rejuvenating some species in the riparian corridor. The frequency and species composition of adjacent ecosystems has a significant effect on the fire ecology of a riparian area. Those types adjacent to frequent fire regimes could burn almost as often as every few years, though the burns would likely be patchy and discontinuous. Other types, such as Fremont Cottonwood – Sycamore, would have rarely burned, particularly when adjacent to Sonoran Desert. About 200 acres of the mapped riparian areas within the Woodbury Fire footprint have burned in the last 50 years.

<u>Soil Burn Severity</u>: There were no acres of high burn severity (Table 11). The 321 acres of moderate burn severity, represent 26% of the mapped riparian areas within the fire perimeter. Moderate soil burn severity occurred within, and adjacent to about a mile of the riparian corridor of the upper West Fork watershed of Pinto Creek, as well as several springs in the area, and over a mile of Rogers Canyon northwest of Rogers Trough Trailhead.

<u>Fire Severity (vegetation)</u>: High severity in riparian areas was mostly patchy, with high severity along some stretches of riparian corridors and the upper watersheds affecting them, and about 80% of riparian areas with moderate or lower severity.

In Fremont Cottonwood-Shrub, there was high severity:

- Along a ~3 mile stretch of Fremont Cottonwood- Shrub in the upper stretch of Rogers Canyon south of Plow Saddle, that includes several smaller drainages and watersheds that burned with mostly high and some moderate severity.
- Along 1 ½ miles of the west fork of Pinto Creek there was also high severity in this riparian type.
- In Rogers Canyon NW of Rogers Trough Trailhead, there was almost 2 miles of high severity in this riparian type.

Most of the species found in this riparian type will sprout, though the response will depend on the intensity of the fire and soil burn severity.

In Desert Willow, there was high severity just south of the Tortilla trailhead. Although it will be a while before the vegetation structure recovers, Desert Willow will sprout back from the root collar, as will some of the other species often found in this type, such as Velvet Mesquite and Netleaf Hackberry.

In Sycamore / Fremont Cottonwood, there is patchy high severity along Campaign Creek, and large areas of mostly high with some moderate severity in much of the upper watershed. Older Fremont Cottonwood will usually sprout from the base, though saplings and seedlings are likely to be killed.

Table 11. Fire severity and burn severity in Riparian ERUs.

Severity (acres and % of ERU burned at the given severity)		**Soil***		**Vegetation**		**Acres and % of area within fire perimeter of each ERU**	
		acres	**%**	**acres**	**%**	**acres**	**%**
Riparian: Desert Willow	High	0	0%	128	16%	804	<0.01%
	Moderate	62	8%	246	31%		
	Low	293	35%	244	30%		
	Unburned/Very Low	460	57%	178	22%		
	Cloud Cover, no data			8	1%		
Riparian: Fremont Cottonwood - Conifer	High	0	0%	31	54%	58	<0.01%
	Moderate	16	28%	6	11%		
	Low	22	39%	8	14%		
	Unburned/Very Low	19	4%	12	21%		
Riparian: Fremont Cottonwood / Shrub	High	0	0%	2.8	19%	1,071	<0.01%
	Moderate	169	18%	266	25%		
	Low	333	36%	261	34%		
	Unburned/Very Low	431	46%	229	21%		
	Cloud Cover, no data			7	<1%		
Riparian: Sycamore - Fremont Cottonwood	High	0	0%	115	22%	519	<0.01%
	Moderate	92	23%	113	22%		
	Low	163	41%	110	21%		
	Unburned/Very Low	140	35%	182	35%		
All Riparian	High	0	0%	481	20%	2,188	1.9%
	Moderate	800	37%	631	26%		
	Low	339	16%	722	29%		
	Unburned/Very Low	1,049	48%	602	24%		
	Cloud Cover, no data			16	1%		

***acres and % of soil severity are based on BARC data, which total about 122,000 acres**

Riparian areas can be particularly vulnerable to high severity fire effects above them, adjacent, upslope, or even miles upstream. There are many areas, particularly upper watersheds, in which there are large, contiguous areas of high severity. These will produce elevated levels of overland flow and debris for as long as a few years, though the magnitude will depend on the intensity and amount of rainfall that comes down, and how well and fast the surface vegetation recovers. Where there was extensive high severity above riparian areas, recovery can be expected to take well over 30 years (Leonard et al. 2017).

Summary of Fire Effects to all ERUs

Within the perimeter of the Woodbury Fire, there are a mix of ERUs and fire regimes (

Table 12). Some ERUs will have benefitted from the Woodbury fire, though most will have adverse effects at some level, some significantly so.

Table 12. Distribution of Mapped ERU Fire Regimes within the Woodbury Fire perimeter, showing about 58% of the acres are fire-adapted ERUs.

Fire Regime	ERUs	acres	%
Frequent fire	Semi-Desert Grassland, Ponderosa Pine / Evergreen Oak, Juniper Grass	40,235	31%
Infrequent fire	Interior Chaparral, Pinyon-Juniper Evergreen Shrub	35,754	28%
Riparian	Sycamore-Fremont Cottonwood, Fremont Cottonwood – Shrub, Fremont Cottonwood – Oak, Fremont Cottonwood – Conifer, Desert Willow	2,452	1.9%
Desert	Mojave-Sonoran Desert Scrub	51,564	40%
All fire adapted	Frequent Fire + Infrequent Fire ERUs	75,989	58%

Soil Burn Severity: While high Fire Severity effects to vegetation is beneficial in some cases, high soil burn severity is not for the ERUs in the Woodbury Fire; at least not in any quantity. However, there was very little high soil burn severity across the fire; only 538 acres, and 76% of the area had very low/unburned to low severity (Table 13). The effects of moderate soil burn severity will depend largely on exactly where it is (steep slopes, adjacent to a stream, etc.), the vegetation type it is in (how fast it can recover and/or how fast ground cover recovers), and the patch size.

Table 13. Soil Burn Severity across the BARC data footprint of the Woodbury Fire.

	Soil Burn Severity	
	acres	%
Very Low Severity/ Unburned	28,072	23%
Low Severity	65,733	53%
Moderate Severity	29,452	24%
High Severity	538	<0.1%

Most of the high soil burn severity was in Pinyon-Juniper Evergreen Shrub in the upper elevations of the Superstitions (Figure 23).

Fire Severity (vegetation): With the exception of Semi-desert grasslands, for which large areas of high severity are beneficial, uncharacteristically large patch size is the most significant cause of the majority of the detrimental fire effects in the Woodbury Fire, and large areas of high severity can be seen in Figure 24.

The cause can be traced largely back to the interruption of the fire regime, long documented as resulting mostly from grazing and fire suppression. Fuel loads become uncharacteristic in amount, density, continuity, and arrangement, resulting in uncharacteristic fire behavior which produces uncharacteristic fire effects.

Infrequent fire ERUs are adapted to mixed and/or high severity, but patch size is an important variable. With the exception of Semi-desert grasslands, the size of high severity patches exceeds HRV for all of the ERUs. Excessively large patch size results in:

- Seed sources historically part of the response to fire may be too far away to reach the interior areas of the high severity patches.
- Seed sources at or near the surface (in the litter, seedheads, on or very close to the surface) may have been incinerated, leaving large areas dependent on seed sources in adjacent areas (see bullet #1).

- When there is a deficit of vegetation for too long, the chances of an area being occupied by invasive/exotic species increases.
- Erosion, particularly on steep slopes, will be accelerated over larger areas than is typical, because there is a larger area with little/no ground cover that is a source for overland flow.
- It can set the area up for similar fire sizes in the future because there are large areas with similar fuel structure/stand age.
- Interactions with key fauna may be disrupted if habitat components are missing, such as hiding cover, thermal cover, pollination dependent species, or food sources

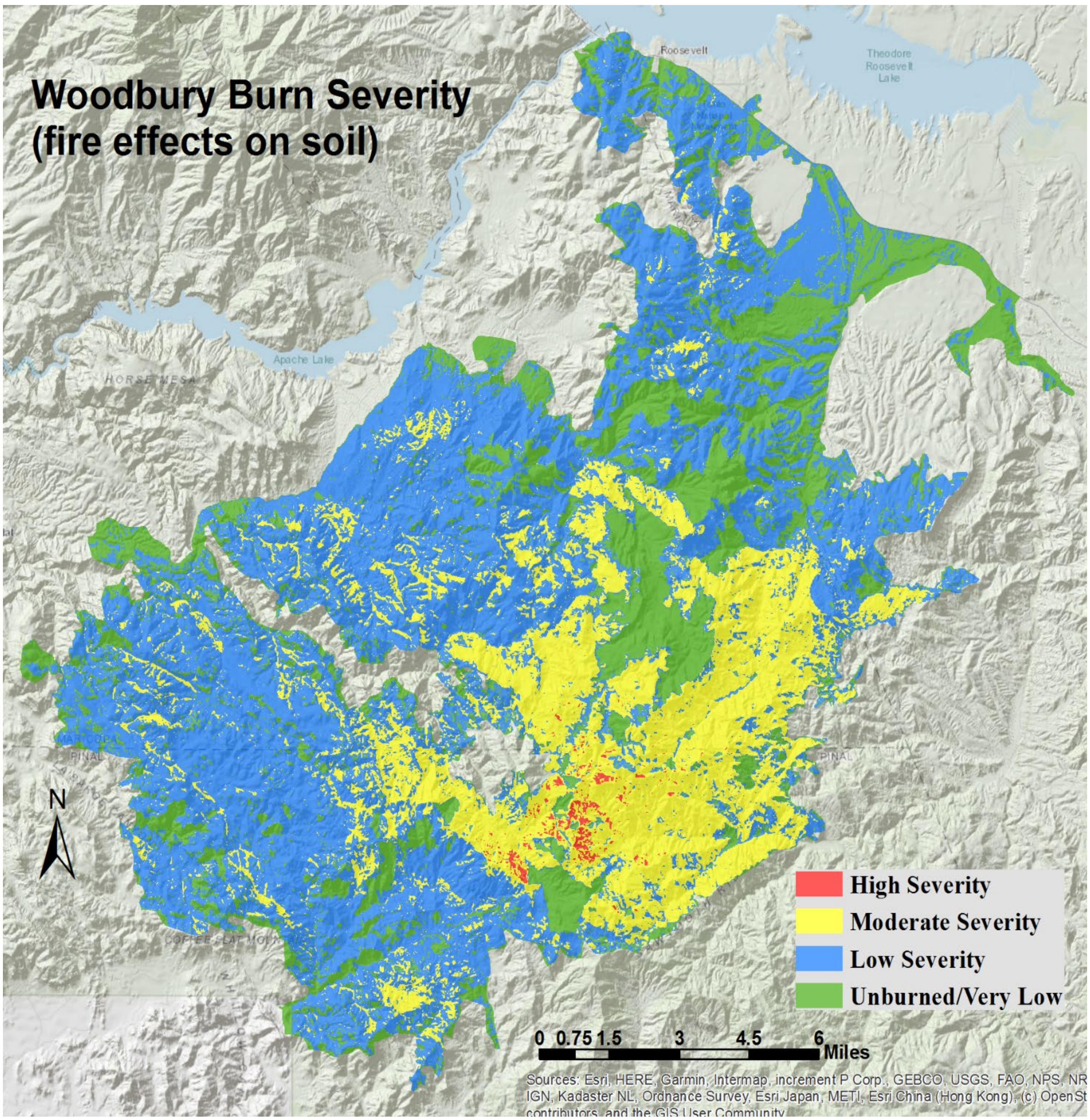

Figure 23. Soil Burn Severity in the footprint of the BARC data.

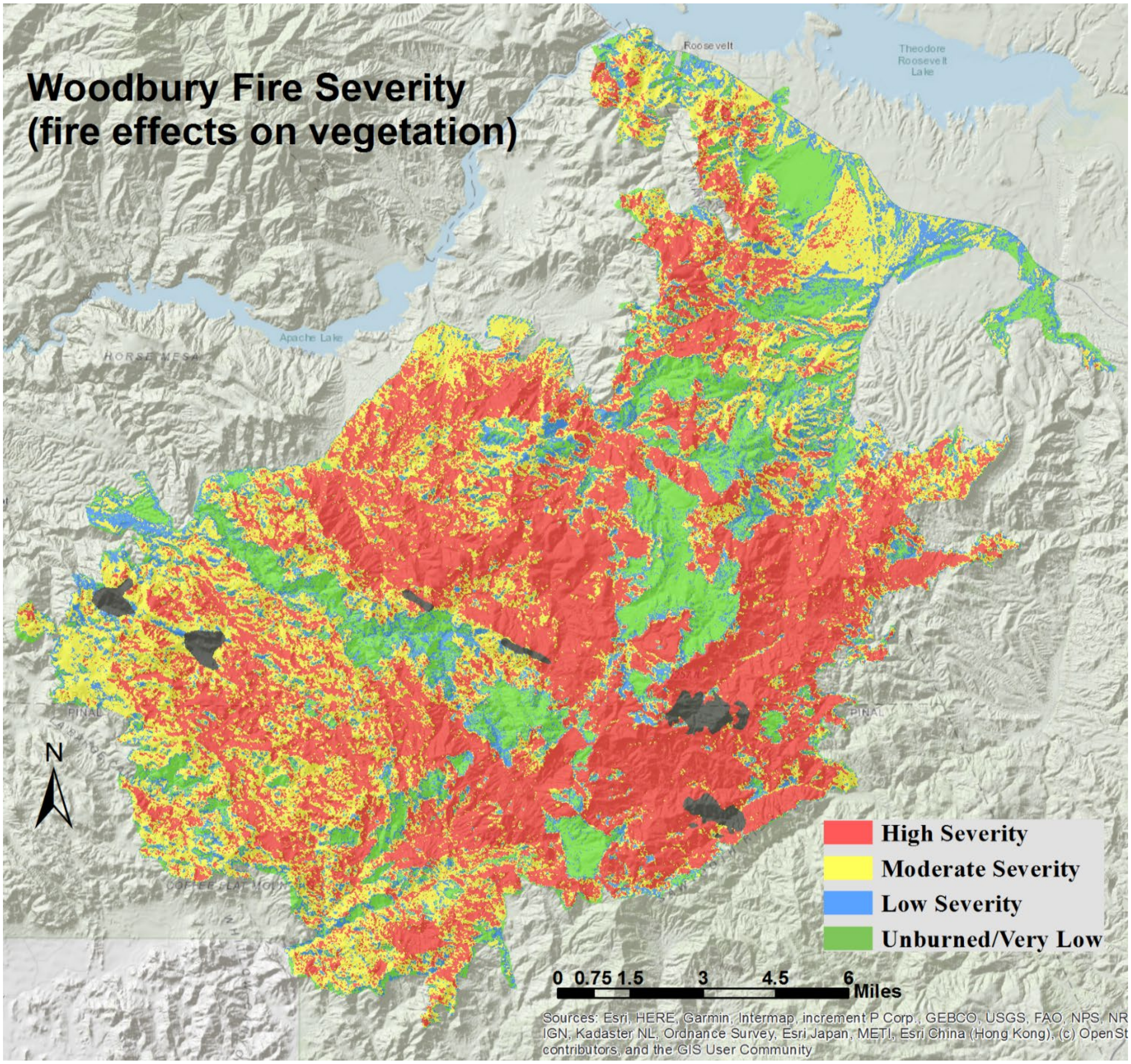

Figure 24. Fire Severity (vegetation) across the RAVG data footprint.

The largest area is on the east and southeast side, mostly in Juniper Grass, Interior Chaparral, Pinyon-Juniper Evergreen Shrub. This area has a few small patches of low/very low, but is well over 10,000 acres, in additional to large high severity patches nearby that have higher patchiness (Figure 24, Figure 25). This is a larger contiguous area of high severity than occurred in the Wallow Fire, and will be evaluated further in the future.

The short monsoon may prove to have been a boon to some of that area, because less rain would produce less erosion, and topkilled species will sprout, increasing the surface roughness and slowing down overland flow. Additionally, where there was low to moderate severity, there is time for scorched leaves and needles to fall, improving ground cover prior to more heavy rain.

Although the fire severity map (vegetation effects) is alarming, high severity is healthy for the

33,000 acres that are Semi-desert grassland, as well as where the high severity is patchy in Pinyon/Juniper Evergreen Shrub, and Interior Chaparral.

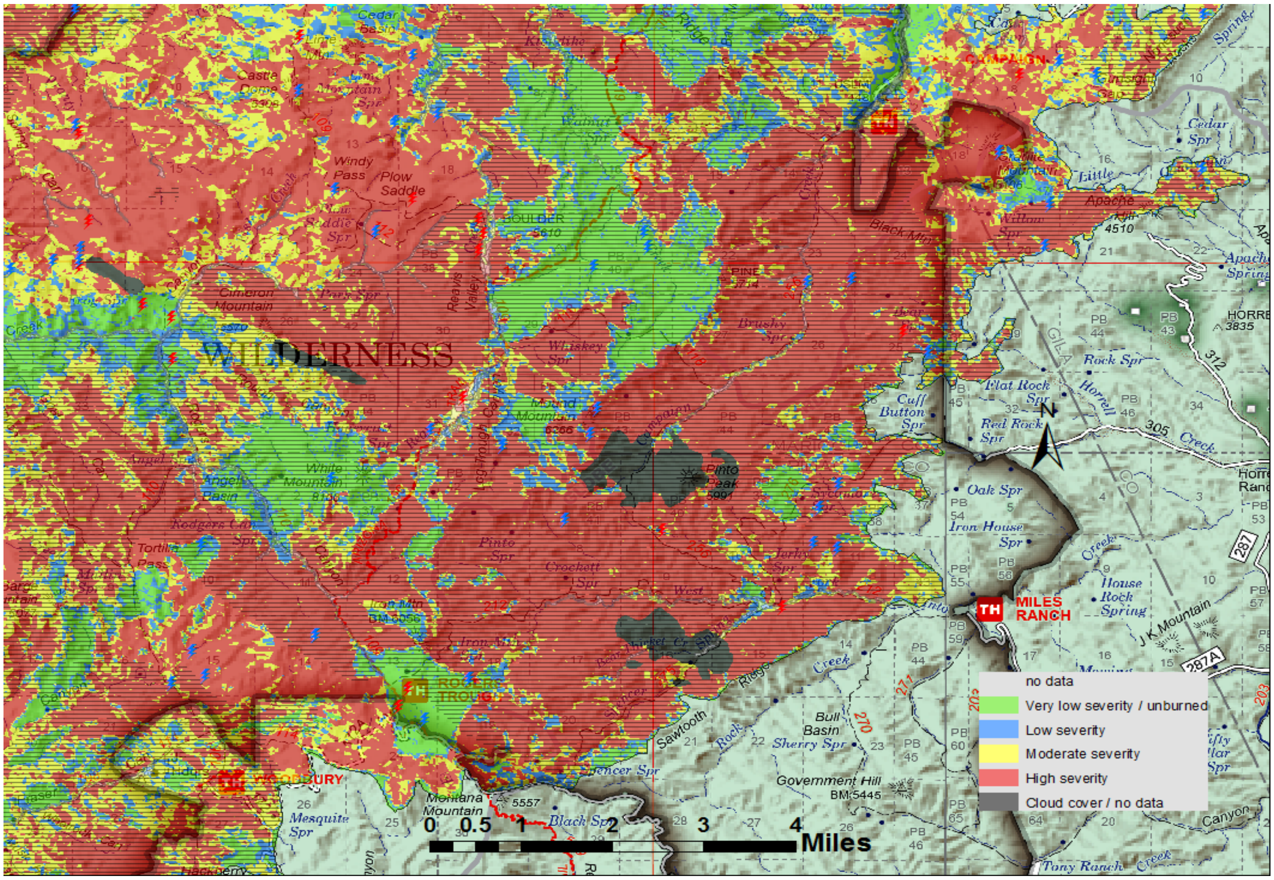

Figure 25. Lined/hatched areas represent ERUs other than grasslands for which the size of high severity patches mostly exceeds the maximum described for these ERUs.

The immediate response of the ERUs to the fire depends on post-fire variables, such as precipitation, temperature, disturbance (wheels, grazing [native and non-native], bugs (mostly in ponderosa pine), invasive species, and other post-fire conditions that affect watersheds (hydrology and soil), flora and fauna growth, and future fires. Some depend on management decisions, some do not. Reintroducing fire to frequent fire adapted ERUs from which fire has long been absent is best managed in multiple entries.

Overall, ***not taking into account patch size – which is an important component of a fire regime***, an estimate of the effects of the Woodbury fire suggests that fire effects may have been beneficial on 37 - 41% of the area burned (47,588 - 53,385 acres), and that fire effects may have been damaging on 19 – 42% of the area burned (63,092 – 67,727 acres) (Table 14). Those numbers assume that:

For the *maximum* numbers of *beneficial* effects:

- ¾ of high severity, and all other severities were beneficial to infrequent fire ERUs (Pinyon-Juniper / Evergreen Shrub and Interior Chaparral). Recognizing that a fair amount of the high severity was in unnaturally large patches
- Moderate severity and lower was beneficial for Juniper Grass and Ponderosa Pine /

Evergreen Oak
- All fire was beneficial for Semi-desert grasslands
- Moderate severity and lower was beneficial to riparian areas
- No fire was beneficial to the Sonoran Desert

For the *minimum* numbers of *beneficial* effects:

- ½ of high severity, and all other severities were beneficial to infrequent fire ERUs (Pinyon-Juniper / Evergreen Shrub and Interior Chaparral). Recognizing that a fair amount of the high severity was in unnaturally large patches
- Moderate severity and lower was beneficial for Juniper Grass and Ponderosa Pine / Evergreen Oak
- All fire was beneficial for Semi-desert grasslands
- Low and very low / unburned was beneficial for riparian areas
- No fire was beneficial for Sonoran Desert

For the *maximum* numbers of *damaging* effects:

- ¾ of the high severity was damaging (assuming patch size is too large) in infrequent fire ERUs (Pinyon-Juniper / Evergreen Shrub and Interior Chaparral)
- Moderate severity and higher was damaging to Juniper Grass and Ponderosa Pine / Evergreen Oak
- All fire was beneficial for Semi-desert grasslands, so no acres
- Moderate and high severity was damaging to riparian areas
- All fire was damaging for Sonoran Desert

For the *minimum* numbers of *damaging* effects:

- 1/3 of the high severity was damaging (assuming patch size is too large) in infrequent fire ERUs (Pinyon-Juniper / Evergreen Shrub and Interior Chaparral)
- High severity damaging to Juniper Grass and Ponderosa Pine / Evergreen Oak
- All fire was beneficial for Semi-desert grasslands, so no acres
- High severity was damaging to riparian areas
- All fire was damaging for Sonoran Desert

Table 14. Rough estimate, not counting patch size, of the beneficial and damaging fire effects.

	min		**max**	
	acres	**%**	**acres**	**%**
'Good' acres	53,385	41%	47,558	37%
'Bad' acres	67,727	52%	63,092	49%

Cultural Resources

Damage to cultural and historic sites will need to be evaluated and documented by forest/district specialists. However, initial assessments indicate that there was likely little damage to known archaeological sites, and only minor damage to the Reavis Ranch orchard and surrounding areas.

Archaeological Sites

There are many archaeological sites within the footprint of the Woodbury Fire. Prior to the fire, some were known, and many previously unrecorded sites were revealed where the vegetation was consumed by the fire (Figure 26).

Figure 26. A previously unmapped archeological site revealed by the fire.

Reavis Ranch

‘Reavis Ranch’ was a working ranch in the late 1800s which has since become an historic site high in the Superstition Mountains. It is a destination for hikers, and includes flat areas on which row crops were once planted that are currently covered primarily with Weeping Lovegrass (an invasive, exotic bunchgrass). There is an orchard which still produces apples, and miscellaneous remains of buildings and equipment (Figure 26).

Figure 27. Reavis Ranch orchard a few years prior to the fire. (Photo credit Mark Taylor)

Figure 28. The orchard at the Reavis Ranch is in the left and center of this post-fire image.

The Reavis Ranch is in the Reavis Valley, in the midst of ponderosa pine and riparian vegetation, with Pinyon-Juniper-evergreen shrub on the surrounding hills. That means the ranch is in an area with a low severity fire regime that intergrades with mixed and high severity fire regimes on all sides. When it was clear the fire would be burning through this area, management took actions to try to minimize the fire severity/intensity in the area with aerial ignitions. Management actions were mostly successful. The fire burned through some of the orchard, but left most of the ranch area unburned, or with low severity (Figure 27,).

Medusa

'Medusa' is a name that has been given to an ancient alligator juniper not far from the Reavis Ranch. Its estimated age is between 600 and 1,000 years. Despite many people's familiarity with it, and multiple queries from the public during the fire, it was less than a day before the fire was expected to burn it over that the team was able to find coordinates in order to pinpoint the location. In the end, it was badly scorched, though not actually burned. Whether or not it survived is unknown at this time (Figure 29).

TES and Wildlife Habitat

The description below includes the evaluation of Objective #1 in 'Natural / Cultural Resource Objectives' above.

A wildlife biologist will need to identify if and how which species have been affected. Much habitat has changed significantly but, as of one month post-fire, there is a lot of wildlife in the burned area. Arizona Game and Fish have favorably assessed the effects to wildlife in the burned area, spotting desert bighorn, white-tailed deer, and black bear in the burned area, but long-term effects remain to be evaluated.


Figure 29. Medusa pre-fire (left) and post fire (right). Pre-fire photo by Mark Taylor.

Figure 30. Black bear within the burned area. (Photo credit: Arizona Game & Fish).

Arizona Hedgehog Cactus (AHC)

Arizona Hedgehog Cactus (AHC) is a federally listed species. Cacti are generally slow-growing species, and AHC seedlings are rare (Taylor 2016). As documented in the Woodbury Fire BAER Wildlife and Botany Specialist Report (Madera, 2019), impacts on AHC were isolated to an estimated 1,106 acres of current and suitable habitat within the footprint of the fire perimeter just north and northeast of Sawtooth Ridge, and one occurrence near Spencer Spring, about 1 mile northeast of the 172A road.

About 150 aces of the area near Spencer Spring had previously burned in 2011 in the 650 Fire. While soil burn severity in the area mapped as AHC Suitable Habitat was mostly very low severity, and low severity with some moderate severity, RAVG data (fire severity on vegetation) included over 700 acres of high severity in that area mapped as AHC suitable habitat,

Sawmill Ridge is the edge of the fire in this area, in large part because of retardant drops, which were successfully used to stop the fire. However, the proximity of the retardant is such that it could easily reach AHC. At this time, there is no data on the effects of fire retardant on hedgehog cactus of any kind (Madera, 2019, personal communication).

Gila topminnow

There are five areas in the Woodbury Fire footprint with Gila topminnow habitat. Two are along Campaign Creek. One starts at the Reavis School, and continues upstream for a little over a mile. The second location is also on Campaign Creek, about 2 miles north/downstream from the school. The upper watershed of Campaign Creek burned with low and moderate soil burn severity, but with moistly high and a little moderate fire severity (vegetation effects).

A second location is along Cottonwood Creek on the northwest part of the fire, near the edge of the fire. The mapped perimeter shows the fire having burned all the way down to the south bank of cottonwood creek in this area. Aerial images and the BARC data show the fire edge to be .01 - .25 mile from the stream for that part of the stream showing as habitat. The fire edge on the north side is from 0.22 to about 0.4 miles from the stream. Soil burn severity in this area was mostly low to very low, with a few patches of moderate up the drainage. Fire severity was mostly high severity in the area, but the areas adjacent to the mapped habitat were low to very low or unburned. Most of this area is Sonoran Desert, with a small patch of chaparral a mile upstream.

A forth location is along the West Fork of Pinto Creek, downhill, downstream, or within an area that burned with high severity (vegetation), and will probably be lost from the effects of ash and sediment into the creek.

The fifth location is along Tortilla Creek on the west northwestern area of the fire. This area burned mostly with low to moderate severity, so adverse effects to the minnow may be only minor.

Effects on topminnow habitat will depend on the intensity and duration of future precipitation events in the high and moderate severity adjacent to, and upslope from the habitat. Wildlife biologist will work with FWS to evaluate the long-term impacts to the Gila Topminnow.

Mexican Spotted owl (MSO) Habitat

The Log Trough PAC was the only PAC within the perimeter of the Woodbury fire.

MSO habitat in forested areas, particularly core areas, often has a denser vegetative structure than surrounding areas. This produces increased potential for extreme fire behavior and higher severity fire effects than the areas surrounding them, and at or exceeding the upper end of HRV. Log

Trough PAC is in the middle of the Superstition Wilderness, so the designation as a PAC would not have affected the management of the vegetation, except for fire suppression. Additionally, portions of the PAC are Pinyon-Juniper Evergreen Shrub, for which the natural fire regime is high severity/low frequency. In the PAC, this interfaces with Ponderosa Pine /Evergreen Oak, for which the fire regime is high frequency and low/moderate severity (Figure 31).

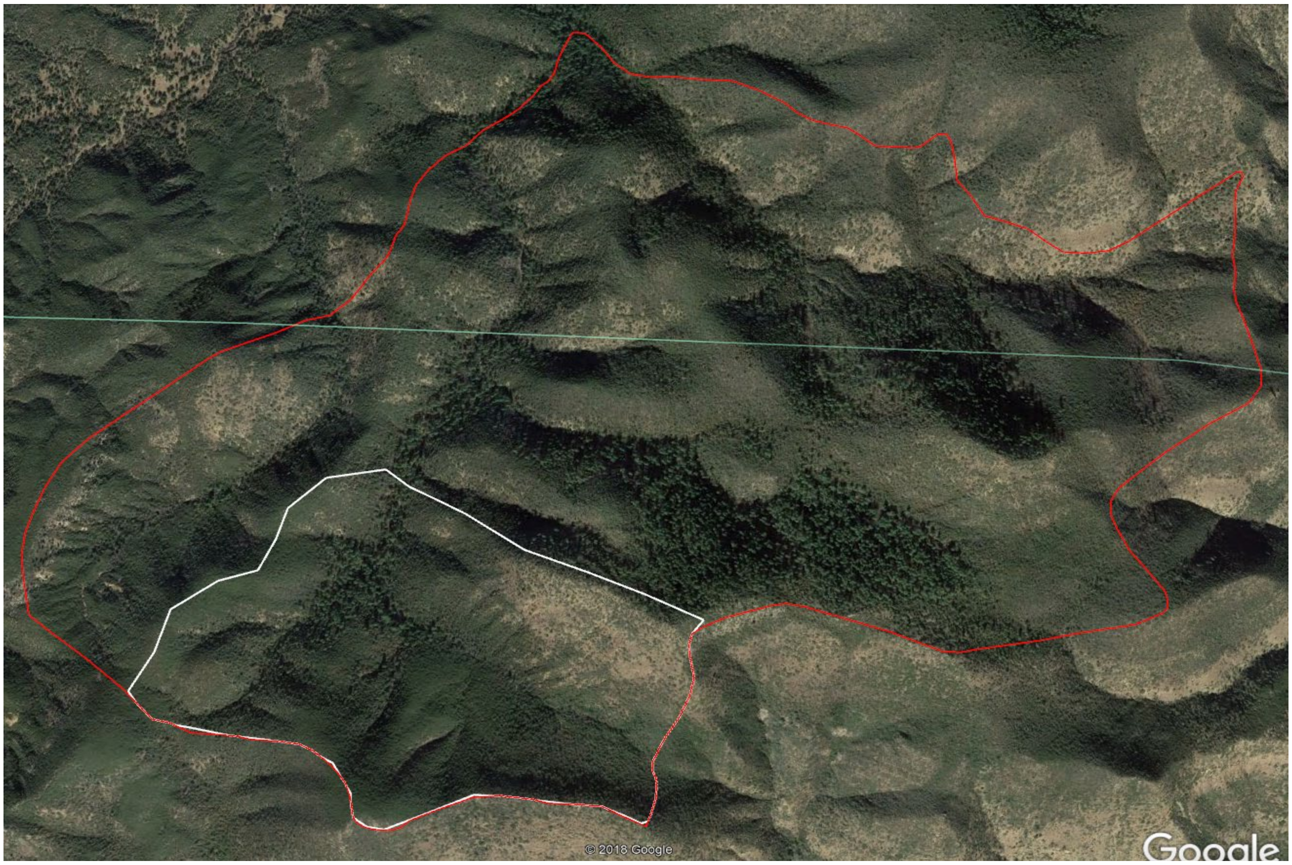

Figure 31. Log Trough PAC, before it burned in the Woodbury Fire showing a mosaic of vegetation types.

Aerial imagery shows a mosaic that, on a finer scale than Ecological Response Units (ERUs) are mapped, includes what appears to be grassland, savanna, and/or chaparral (Figure 31). At the ERU scale, only Pinyon/Juniper Evergreen Shrub was mapped prior to reassigning Ponderosa Pine /Evergreen Oak where the Midscale Vegetation layer mapped ponderosa pine. At the scale of the PAC and the surrounding area, there is clearly more variability in the vegetation than is mapped in the ERU layer. Throughout the PAC (and the Superstitions), frequent fire regimes are interspersed with infrequent fire regimes which, in the southwest, are vegetation types which have a relatively low burn window each year, only burning when fuel moisture is below a certain level. When those fuels are not available, low intensity fires that do burn in the frequent fire regimes would stop where the vegetation became dominantly Pinyon/Juniper Evergreen Shrub or Interior Chaparral. Figure 31 shows a clear difference in vegetation by aspect in the PAC area, and in the drainages. There are records of just 3 fires in or near the PAC since 1970, the largest of which was only 5 acres.

When it was clear that the fire was likely to burn though the PAC, probably with high severity in the Ponderosa Pine / Evergreen Oak, a strategy was implemented to modify fire behavior and effects using aerial ignitions. The plan was to implement ignitions as early in the day as possible, right before sunrise when the temperature and humidity were as favorable for lower severity fire effects and desirable fire behavior as they would be throughout the day. Despite a late start due to technical difficulties with the aircraft, fire severity patterns suggest that the aerial ignitions did help to moderate the fire behavior in some of the Ponderosa Pine /Evergreen Oak as PSD ignited the southeast boundary of the PAC.

Soil Burn Severity: Only 8% of the PAC had high soil burn severity, but 64% had moderate soil burn severity (Table 15, Figure 32). The high and moderate soil burn severity occurred in both ERUs. About half of the 57 acres of high soil burn severity occurs in a contiguous patch on steep and moderate slopes. There is likely to be accelerated erosion in that area, and the amount of topsoil lost, particularly in the Ponderosa Pine /Evergreen Oak, will have a significant effect on the potential recovery. There will be a deficit of ground cover and herbaceous surface vegetation for at least a few years.

Table 15. Fire severity (vegetation) and burn severity (soil) in the Log Trough PAC by ERU

Log Trough PAC (736 acres)	**Vegetation**		**Soil**		
	acres	**%**	**acres**	**%**	
PJ Evergreen Shrub (acres/% of PAC)	**395**	**54%**			
Unburned / Very Low Severity	24	6%	29	7%	acres/ % of this ERU within the PAC
Low Severity	35	9%	45	11%	
Moderate Severity	31	9%	278	70%	
High Severity	305	76%	43	11%	
Ponderosa Pine / Evergreen Oak(acres/% of PAC)	**341**	**46%**			
Unburned / Very Low Severity	20	6%	39	11%	acres/ % of this ERU within the PAC
Low Severity	97	28%	95	28%	
Moderate Severity	57	17%	193	57%	
High Severity	167	49%	13	4%	
Cloud Cover, no data	<1	<1			
Overall Severity (acres/% of PAC)					
Unburned / Very Low Severity	43	6%	68	9%	acres/ % of entire PAC, all ERUs
Low Severity	132	18%	140	19%	
Moderate Severity	89	12%	471	64%	
High Severity	472	64%	57	8%	
Cloud Cover, no data	<1	<1			

Fire Severity (vegetation): the ERU map shows high severity in almost 50% of the Ponderosa Pine / Evergreen Oak (Figure 32). The area of Ponderosa Pine / Evergreen Oak adjacent to the PSD drops burned with low severity. The amount, and the configuration, of the high severity in Ponderosa Pine / Evergreen Oak was outside of the HRV. Recovery in the large areas of high severity will depend in large part on the weather, fire, and proximity of seed sources. Where fire severity was low, very low, or moderate in the Ponderosa Pine / Evergreen Oak, the effects of the Woodbury Fire will be beneficial, decreasing the potential for high severity fire effects from future fires.

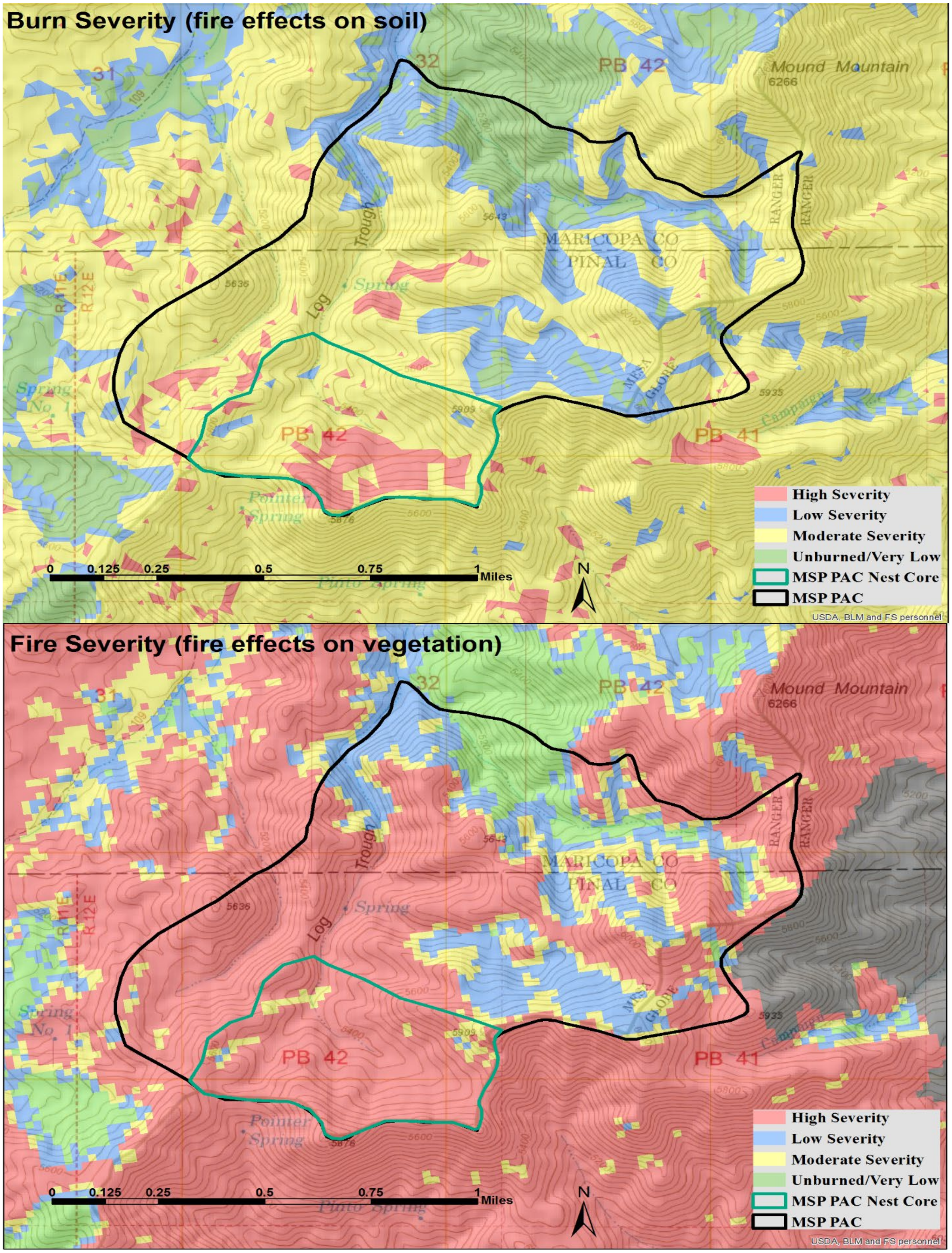

Figure 32. Fire effects in the Log Trough PAC.

This is also true for much of the moderate fire severity, though there is more variability in both long and short term effects, which depend largely on the weather and the responses of adjacent areas. Where there was high fire severity in ponderosa pine, the fire may have pushed the vegetation over a threshold, because the pine will have a hard time regenerating, while the oaks and most other shrubs will sprout. Some of this area can be expected to shift to a shrubland system similar to chaparral, for at least several decades (Barton 1999, Savage and Mast 2005, Leonard and Tecle 2015).

Coarse Woody Debris (CWD) provides important habitat for MSO prey, so it is worth noting that, although aerial photos show little remaining where there was high severity fire, there are at least two contiguous areas where fire effects in the PPE were beneficial. In these areas, and in the areas of moderate severity, new CWD will be created from trees weakened or killed by the fire.

Some of the effects on MSO habitat are summarized above, but the effects to MSO will need to be further evaluated by a wildlife biologist.

Livestock Forage

This was evaluated above with Social/Political Objective #3. Of the 9 allotments within the Woodbury fire perimeter, 5 were active. Range staff and ranchers are working together on site specific needs to determine needed repairs and what vegetation condition should be prior to the resumption of grazing.

Management Implications and Conclusions

The Woodbury Fire (~129,000 acres) was the 5th largest fire in Arizona history, with over 150 miles of perimeter. Over 78% (101,000 acres) of the fire was in the Superstition Wilderness. There are no roads through the wilderness, and fire behavior and access were such that there were few safe and effective options for putting crews on the ground within it. Aerial ignitions, water and retardant drops, and large burnouts were the only options.

The absence of fire in fire adapted ecosystems not only allows live and dead woody fuel to increase, but the fuels also become more contiguous. This results in higher intensity and higher severity, and increases the potential patch size of high severity effects.

Fire adapted ERUs cannot be maintained with just mechanical treatments, even if that was an option in the Superstition Wilderness, because of the many functions of fire. There were about 36,000 acres of infrequent fire ERUs which when mature, as these were, burn with fairly extreme fire behavior. These areas would be difficult and complex to treat with prescribed fire, even if they weren't in a Wilderness and if access was good and there were functional firelines.

The vegetation types above the Sonoran desert are all fire adapted, but the timing of this fire was particularly unfortunate. Seasonally, because it was fairly predictable that there would be hot, dry weather for the next month. The year was also an unfortunate one for fire in this area because the invasive grasses in the desert converted hundreds of thousands of acres of vegetation that rarely burns (the Sonoran Desert) into a highly flammable, flashy grass/shrub fuel model that could burn fast and hot.

Across much of the Tonto NF, getting fire back into areas that badly need it will require managers to accept higher levels of severity than is typical for a given ERU. Determining what levels of high severity to accept is a difficult question. Fire is unavoidable, and will continue to be in the future as the Tonto NF strategizes on how to manage 2 million acres of fire adapted ecosystems. Options remain limited for using anything other than wildfire to manage vegetation in the Superstition Mountains and Wilderness and the adjacent fire adapted ERUs. Funding, competing priorities, and the complexities of fire in Wilderness area mean this area will continue to be particularly difficult to maintain as, or restore to (depending on the ERU), a healthy, resilient condition.

Many of the undesirable fire effects that did occur, did so not because of decisions made in the last few months, or even years, but because of the culmination of human impacts over the last century or so. In particular, in the fire adapted ERUs there were areas of contiguous fuel loading that resulted from a lack of fire. The patchiness of the fuels that should have been part of the upper elevation ERUs was mostly missing, so the fire was able to burn through large contiguous areas of decadent Pinyon-Juniper / Evergreen Shrub and decadent Interior Chaparral. The lack of a mosaic of fuel loading/arrangement on the landscape will promote more of the same as similar areas recover at similar rates. There are also significant areas that did and still do maintain the patchiness that is healthy for these systems. Overall, there may be about 40% of the burned area for which effects were beneficial, and about 50% for which they were not.

The effects of the Woodbury Fire and the management actions associated with it will make it easier to get fire into even the more remote areas of the Superstitions for some years to come. For the next few years, there should be more options for line officers and fire managers making decisions on the management of wildland fire in the Superstition Mountains and Wilderness.

Sonoran Desert Management in Wet Years

The Tonto National Forest will need to make some difficult decisions on how to manage the Sonoran Desert in years such as this one when the desert is functionally a grass / shrub system in which fire is frequent rather than a desert ecosystem in which fire is rare. There are multiple options, though there are tradeoffs for all of them. These include, but are not limited to:

- Selective Grazing: In years when there is sufficient moisture to produce a grass crop such as occurred this year, and ONLY in such years, graze strategic areas hard in February/March, when the grasses are palatable to provide fire breaks. This would also decrease the seed source in those areas, but would require additional fencing and intensive livestock management. It is also likely to have a significant adverse effect on ephemeral desert species which only come up in such years, are short lived when they do, and are dependent for their survival on the seeds they produce during that short period.
- Selective low severity / low intensity prescribed fire: In years when there is sufficient moisture to produce a grass crop such as occurred this year, use prescribed fire in strategic locations to burn the grass as soon as it will burn, before the seeds are viable, and with as cool a fire as can be managed. This would also be likely to have adverse effects on some of the native species, particularly ephemerals, but would prevent or minimize the size of more devastating fires that could occur later in the season. This option would not require additional fencing or intensive livestock management.
- Create and maintain fire breaks in strategic locations. They would be unsightly to many, but

could potentially protect large areas of Sonoran Desert. They would also be likely to attract OHV users, and could provide a foothold for invasive species.

- Use options from above to protect specific areas that are deemed to be more intact and ecologically valuable instead of strategically working out how to protect the larger landscape.

As has been discussed on this and other forests in the southwest, business as usual (chopping areas up into burn units), even if it was feasible on the landscape the Woodbury Fire burned in, merely continues the challenge of trying to get the landscape treated before a truly devastating wildfire occurs. In the case of the Woodbury Fire, this resulted in adverse effects on about half of the burned area. Balancing burn windows with opportunities to burn on a scale that will improve the condition of the landscape over time is the challenge for land managers on the Tonto National Forest. Fuels will continue to build up, and the results of past and current management, mostly fire and grazing, will continue to affect the condition of the landscape within and surrounding the area burned in the Woodbury Fire.

In the case of the Woodbury Fire and the Superstition Wilderness, it was unlikely that any prescribed fire or mechanical treatments could be implemented in the next decade or so, and wildfire was, and remains, the only likely treatment for this area for the foreseeable future.

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