PROTECTING FRONT RANGE FOREST WATERSHEDS FROM HIGH-SEVERITY WILDFIRES

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The threat of high-severity wildfires to Colorado Front Range communities and their water supplies is real and unprecedented. One cause is decades of a fire exclusion policy that allowed the forest understory to fill in, increasing forest density as well as providing "fuel ladders" that carry ground fires into tree crowns. Once a fire moves into the crowns of trees it can be quickly transformed from a low-intensity, ground-clearing occurrence into a high-severity, stand-replacing event. An extreme example of the latter is the 2002 Hayman Fire, which burned 138,000 acres of forest and destroyed 133 homes and 466 outbuildings at an estimated total cost of $238 million.

When forests burn, the watersheds of which they are a part are affected. In the case of high-severity wildfires, watersheds are substantially altered.[1] The short-term impacts of high-severity wildfires are well known: destruction of timber, forage, wildlife habitat, scenic vistas, and water supplies. Somewhat less familiar are the impacts of soil erosion and sediment, and organic debris flows in the immediate post-fire period, which can impose a heavy and costly toll on water infrastructure, such as conveyances and storage reservoirs.

For example, the residual effects of the Hayman fire on Denver's water supply are still problematic. A November 2006 *Denver Post* article reported:

> More than four years after the Hayman fire roared over the land surrounding Denver Water's 101 year-old Cheesman reservoir, mud, ash, and decomposed granite continue to pour into it following rainstorm events. Denver Water has spent $7.8 million in the last four years on activities such as removing debris, replacing culverts, building sediment dams, and seeding slopes, officials say. There is still $20 million worth of work that remains to remove an estimated 1 million cubic yards of fire-related debris from Strontia Springs Reservoir, downstream of Cheesman (Reservoir) (Meyer).

The same article reported that roughly 56 percent of the area burned by the Hayman Fire drains directly into the Cheesman Reservoir, which stores approximately 12 percent of the Denver metro area's water supply (Denver Water). To reduce sediment and organic debris from entering the reservoir, extensive rehabilitation efforts were implemented around the reservoir and two upstream dams were built to capture sediment and organic debris. It has cost approximately $300,000 annually to clear the two dams and keep them operational (Meyer).

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[1] "Fire severity" refers to the degree to which a forest has been altered or disrupted by fire. It is determined by fire intensity, fuel consumption, and time (Helms). A "high-severity" wildfire is a forest replacement event with high canopy mortality. A "low-severity" wildfire is a surface or ground fire, involving no canopy mortality. A "mixed-severity" wildfire results in moderate canopy mortality with parts of the forest having low-severity surface fires and other parts, high-severity crown fires.

Mechanical treatments, including thinning and prescribed fire, are proposed to reduce fire hazard on the Front Range by reducing the buildup of forest fuels that has occurred as a result of fire exclusion. Reduction of hazardous fuel loads would reduce the threat of high-severity wildfires to critical watersheds and water infrastructure, and human life and property. Under certain conditions, it would also restore the historic fire regime of the lower montane, which includes variable-severity fires that tend to low-severity surface fires, promoting the sustainability of lower montane forests.

WILDFIRE TRENDS

The threat of high-severity wildfires to Colorado Front Range communities is very serious, but not unique. It exists throughout much of the western United States. While the average annual number of wildfires has declined nationally, the average number of acres burned annually has increased, as shown in Table 1. Hence, the average size of the wildfires has increased. A relationship exists between fire size, intensity, and severity. Larger wildfires tend to be hotter (more intense), and the impacts of hotter wildfires tend to be more destructive or severe.

TABLE 1
AVERAGE ANNUAL NUMBER OF WILDFIRES IN THE UNITED STATES AND AVERAGE ANNUAL ACRES BURNED
1960-2006

Decade	Average Annual Number of Wildfires	Average Annual Acres Burned (in thousands of acres)
1960-1969	119,972	4,572
1970-1979	155,112	3,194
1980-1989	163,329	4,236
1990-1999	106,393	3,786
2000-2006	77,431	6,967

SOURCE: National Interagency Coordination Center

The situation in Colorado is somewhat different. The annual number of wildfires has increased from an average of 457 fires per year in the 1960s to an average of 2,575 fires per year in the 2000s, as shown in Table 2. The average number of acres burned annually has also increased from an average of 8,170 acres per year in the 1960s to an average of 88,737 acres in the 2000s. This number is skewed, of course, by the Hayman Fire. Still, there is no question that the average number of acres burned annually has increased.

Wildfires are expensive. As might be expected with the increasing number of acres burned annually, wildfire suppression costs for federal agencies have increased, as have average suppression costs per fire. For example, cost data for the twelve-year period 1994-2006 show average annual wildfire suppression costs for federal agencies for the period 1994 through 1999 were $495,412,000, and the average annual wildfire suppression costs for federal agencies for the period 2001 through 2006 were more than $1,219,224,000. Since the average number of wildfires has declined, as shown in Table 1, it follows that average suppression costs per fire have increased.

TABLE 2
NUMBER OF WILDFIRES AND ACRES BURNED IN COLORADO
1960-2006

Year	No. of Fires	Acres Burned	Year	No. of Fires	Acres Burned
1960	427	9395	1990	1475	9825
1961	199	5500	1991	1449	6576
1962	578	17243	1992	1048	4158
1963	440	7480	1993	1267	3526
1964	344	7137	1994	3158	52125
1965	182	964	1995	2224	49498
1966	673	7361	1996	2499	49498
1967	434	2635	1997	1605	16703
1968	795	15449	1998	1349	10181
1969	499	8534	1999	1987	33256
1960-69	*Avg. = 457*	*Avg. = 8170*	*1990-99*	*Avg. = 1806*	*Avg. = 21796*
1970	575	8430	2000	2043	76288
1971	1049	14798	2001	2966	45816
1972	553	5000	2002	3409	244252
1973	560	2169	2003	2471	23308
1974	1086	5166	2004	1826	15239
1975	984	3746	2005	2014	14446
1976	572	4520	2006	3294	201809
1977	730	6483	2000-06	*Avg. = 2575*	*Avg. = 88737*
1978	362	13085			
1979	869	3139			
1970-79	*Avg. = 734*	*Avg. = 6554*			
1980	1724	18828			
1981	1537	9835			
1982	1127	10184			
1983	831	11752			
1984	631	12913			
1985	985	25343			
1986	1337	30247			
1987	1194	24208			
1988	1722	33037			
1989	1767	56732			
1980-89	*Avg. = 1286*	*Avg. = 23308*			

SOURCE: Colorado State Forest Service

HUMAN POPULATION TRENDS IN COLORADO

Colorado had the third largest percentage increase in population of the fifty states during the period 1990 to 2000: 30.6 percent (Seidl *et al.*). It has continued to grow: from 4.3 million in 2000 to an estimated 4.7 million in 2005. Population is not evenly distributed. The fastest growing counties are generally east of the continental divide along the Front Range with major cities — from north to south — being Fort Collins, Boulder, Denver, Colorado Springs, and Pueblo (Net Population Growth). Ten of the eleven counties with populations over 100,000 are contiguous. The exception is Mesa County, which is located on the Western Slope and borders Utah. Grand Junction is the major population center in Mesa County. The ten contiguous counties of Adams, Arapahoe, Boulder, Denver, Douglas, El Paso, Jefferson, Larimer, Pueblo, and Weld contain 81 percent of Colorado's human population. This report focuses on five of these counties — Boulder, Douglas, El Paso, Jefferson, and Larimer — *plus* Clear Creek, Gilpin, Grand, Park, and Teller counties. These will be subsequently referred to as the "ten Front Range counties."

Population growth in Colorado is driven by three factors: (1) a highly educated workforce, which has resulted in development and growth in the following industries (listed in order of number of employees): manufacturing (166,495), transportation (61,834), computer software and data storage (53,200), telecommunications (49,446), aerospace (40,000), agriculture and food processing (39,969); (2) construction and ownership of second homes in resort communities; and (3) retirees locating in Colorado (Colorado Office of Economic Development & International Trade; Seidl *et al*.). In 2000, Colorado was listed as the second most educated state in the United States and the fifth wealthiest (Seidl *et al*). Nevertheless, the distribution of both wealth and income is very uneven. Colorado's population is expected to increase from by 35 percent — to 5.8 million people — by 2030 (Negative Population Growth).

Home construction follows population growth, especially when the population is wealthy, and Colorado is no exception. For example, 15 percent of existing housing units were built during the five-year period 1995 to March 2000. The average for the United States as a whole was 9.7 percent. Growth in home construction continued during the succeeding five years and a strong market is projected for the foreseeable future (National Association of Home Builders). As would be expected, home construction occurs at or near population centers, which in Colorado is east of and along the Front Range.

The important point for the purposes here is that human population in Colorado is growing, particularly vicinity of the Front Range; the people tend to be both comparatively wealthy and educated, and home construction has followed virtually throughout the length of the Front Range and has extended throughout the lower montane into higher elevation forests. There has also been a strong market in second homes located in resort communities, and these tend also to be located in and around the high elevation forests. Indeed, an unfortunate result of the strong, robust economy in and around the Front Range is a growing number of flammable structures surrounded by hazardous forest fuels.

FRONT RANGE WATER SUPPLIES

New residences require infrastructure, including roads, power and telecommunications lines, sewer or septic systems, and water lines. Front Range metropolitan areas are net importers of water. Indeed, the area east of the Front Range consists of semi-arid, short-grass prairie with an average annual rainfall of about 14 inches. Virtually all drinking water comes from mountain snowmelt, primarily from west of the continental divide. Primary water sources for Denver Water come from the South Platte River, which is east of the continental divide, and the Blue and Fraser Rivers, which are west of the continental divide. Four major reservoirs are located in the South Platte Collection System: Antero, Cheesman, Eleven Mile Canyon, and Strontia Springs. These four reservoirs provide 30 percent of Denver Water's total water storage capacity.

The Blue River and the Dillon Reservoir are part of the Roberts Tunnel Collection System, which transports water across the continental divide into the North Fork of the South Platte River to Strontia Springs Reservoir. The Moffat Collection System transports water from the Fraser River through the Moffat Tunnel into South Boulder Creek and then into the Gross and Ralston Reservoirs. Denver Water has three treatment plants: Marston, Moffat, and Foothills. It provides water to 1,115,000 people in the Denver Metro area.

The largest water provider north of Denver is the Northern Colorado Water Conservancy District (NCWCD), which conveys Colorado River water pumped to Shadow Mountain Reservoir and channeled to Grand Lake and the west portal of the Adams Tunnel. The Adams Tunnel transports the water beneath the continental divide to Mary's Lake, then to Lake Estes and the Flatiron Reservoir. From there, it is distributed, among other places, to Horsetooth Reservoir, which provides drinking water to the city of Fort Collins, and to Boulder Reservoir, which supplies drinking water to the city of Boulder. NCWCD delivers an average of 310,000 acre-feet of water annually to 100 ditch, reservoir, and irrigation companies, and 32 communities.

The largest water provider south of Denver is Colorado Springs Utilities, which takes water from four watersheds in the Pike National Forest, as well as (1) Homestake Reservoir in Eagle County west of the continental divide through Homestake Tunnel to Twin Lakes Reservoir and the Homestake Pipeline to Rampart Reservoir, and (2) the Blue River in Summit County to the Blue River Pipeline to North Catamount Lake. Colorado Springs Utilities owns water rights entitling it to 220,900 acre-feet of water per year, which it stores in 25 reservoirs.

The seven largest Front Range water providers are shown in Table 3. Note that in 2006, six of them —Aurora, Boulder, Colorado Springs Utilities, Denver Water, Fort Collins, and NCWCD — were identified as providing water to "about 63% of Colorado's population of about 4.3 million people, either directly or through contracts or shares" (Ray and Lowrey). If Westminster is added, the ratio increases to 65 percent. All but one of the seven (Westminster) take water from west of the continental divide and deliver it east to their customers via a complex system of pumps, conveyances, and storage reservoirs.

TABLE 3
MAJOR FRONT RANGE WATER PROVIDERS

Name	Water Sources	Water Rights
Aurora (Pop. 297,235)	Has multiple sources of water in three separate basins: the Colorado, Arkansas, and South Platte River. Water is transported from as far away as 180 miles.	Twelve reservoirs and lakes provide Aurora with more than 155,466 acre-feet of storage capacity.
Boulder (Pop. 91,685)	(1) Barker Reservoir on Middle Boulder Creek (40 %); (2) Silver Lake/Lakewood Watershed on North Boulder Creek (40 %); (3) Boulder Reservoir (20 %), which comes from the CBT and Windy Gap Projects	Delivers approximately 20,000 acre-feet of water annually to customers.
Colorado Springs (Pop. 369,815)	Colorado Springs Utilities water comes from multiple sources and is stored in 25 reservoirs. Four watersheds are in the Pike National Forest. Water also comes west of the continental divide in Eagle County through the Homestake Tunnel to the Homestake Pipeline and the Rampart Reservoir. Another source of water is the Blue River in Summit County where water is taken by the Blue River Pipeline into North Catamount Lake.	Owns the rights to 220,900 acre-feet per year of water. Has the ability to transport more than 110,000 acre-feet per year of water to Colorado springs from as far away as 200 miles.
Denver Water (Serves approximately 1.1 million people, including Denver, pop. 557,917)	Blue, Fraser, and South Platte Rivers. Other water sources: Williams Fork River, South Boulder Creek, Ralston Creek, and Bear Creek. Main Reservoirs: Dillon, Eleven Mile, Cheesman, Gross, and Antero	Has 673,110 acre-feet of water storage capacity spread among 10 reservoirs. Uses 234,000 acre-feet of treated water annually, which is one-third of Colorado's treated water supply
Fort Collins (Pop. 128,026)	(1) The Colorado-Big Thompson (CBT) project; (2) the Cache la Poudre River basin; (3) transmountain water from the Michigan River basin.	Delivers an average of 28,000 acre-feet of water annually to customers.
Northern Colorado Water Conservancy District (NCWCD)	NCWCD is a public agency created in 1937 for the construction of the Colorado-Big Thompson (CBT) Project. Takes water from the Colorado River vicinity Lake Granby and transports it through the Adams Tunnel beneath the continental divide to Lake Estes for subsequent distribution.	Delivers an average of 310,000 acre-feet of water annually to more than 100 ditch, reservoir, and irrigation companies and 32 communities, including Boulder, Estes Park, Ft. Collins, Greeley, Loveland, and Longmont.
Westminster (105,084)	Water supply originates at the continental divide near Loveland Pass and Berthoud Pass in the Clear Creek watershed. The water is stored in Standley Lake until it is withdrawn for treatment	Holds some of the most senior water rights on Clear Creek

CRITICAL WATERSHEDS

The seven major water providers in the ten Front Range counties draw water from watersheds listed alphabetically in Table 4, which contains a watershed name (developed for exposition purposes here), its unique eight-digit HUC number, the county or counties in which it is primarily located, and major water providers with water rights in the watershed. With one exception — South Park — the name of the watershed is taken from the name of the principal water course in the watershed. The unique eight-digit HUC numbers are used by the U.S. Geological Survey. Three of the watersheds — Blue River (14010002), Eagle River (14010003), and Upper Arkansas (11020001) — are outside the ten Front Range counties. Hence, their rows are shaded in the table.

One small additional watershed — Black Squirrel, 11020003) — is located largely in El Paso County. Black Squirrel Creek rises in north El Paso County, flows south to the Arkansas River and lies in the lower ecotone and plains grassland vegetation zones. Its surface water flow is low and intermittent. Hence, it is an anomaly compared to the other watersheds, and it is also shaded in Table 4.

The remaining eight watersheds constitute “critical watersheds” in the ten Front Range counties. Boundaries of these critical watersheds are shown in subsequent maps.

TABLE 4
CRITICAL FRONT RANGE WATERSHEDS

Watershed	Principal Water Courses	County	Water Provider
Big Thompson 10190006[1]	Big Thompson River, Little Thompson River	Larimer	Greeley, NCWCD[2]
Black Squirrel 11020001[1]	Black Squirrel Creek	El Paso	None
Blue River 14010001[1]	Blue River	Summit	Denver Water, Colorado Springs
Cache la Poudre 10190007[1]	Cache la Poudre River, Fossil Creek, Spring Creek, North Fork Cache la Poudre River	Larimer	Greeley, Fort Collins
Clear Creek 10190004[1]	Clear Creek, Ralston Creek	Clear Creek, Jefferson	Denver Water, Golden, Westminster
Eagle River 14010002[1]	Eagle River, Homestake Creek	Eagle	Colorado Springs
Fountain 11020003[1]	Fountain Creek, Monument Creek	El Paso	Colorado Springs
St. Vrain 10190005[1]	St. Vrain Creek, Boulder Creek	Boulder	Boulder, Denver Water, Longmont
South Park 10190001[1]	Middle Fork South Platte River, Plum Creek, Tarryall Creek, South Fork South Platte River	Park, Teller	Aurora, Denver Water, Thornton
Upper Arkansas 11020001[1]	Arkansas River, Chalk Creek, Clear Creek, Cottonwood Creek, Lake Creek	Lake, Chafee, Fremont, El Paso	Aurora, Colorado Springs
Upper Colorado River 14010001[1]	Colorado River, Fraser River, Williams Fork River Willow Creek	Grand	Aurora, Denver Water, Greeley, NCWCD[2]
Upper South Platte 10190002[1]	Bear Creek, North Fork South Platte River, Trout Creek	Park, Jefferson, Douglas	Aurora, Denver Water, Thornton

[1]Eight-digit Hydrologic Unit Code (HUC), U.S. Geological Survey
[2]Northern Colorado Water Conservancy District

FRONT RANGE FORESTS

Map 1 shows Front Range forest types. The colors pertaining to ponderosa pine, lodgepole pine, and spruce-fir forest types dominate the map. Generally, these forest types occur at overlapping elevations with ponderosa pine at lower elevations (6,300 to 9,500 feet), lodgepole pine at higher (7,500 to 10,000 feet), and spruce/fir (Engelmann spruce and subalpine fir) in the subalpine level (9,000 to 11,500 feet). Critical watershed boundaries are shown in light blue. The boundaries of the ten Front Range counties are shown in black.

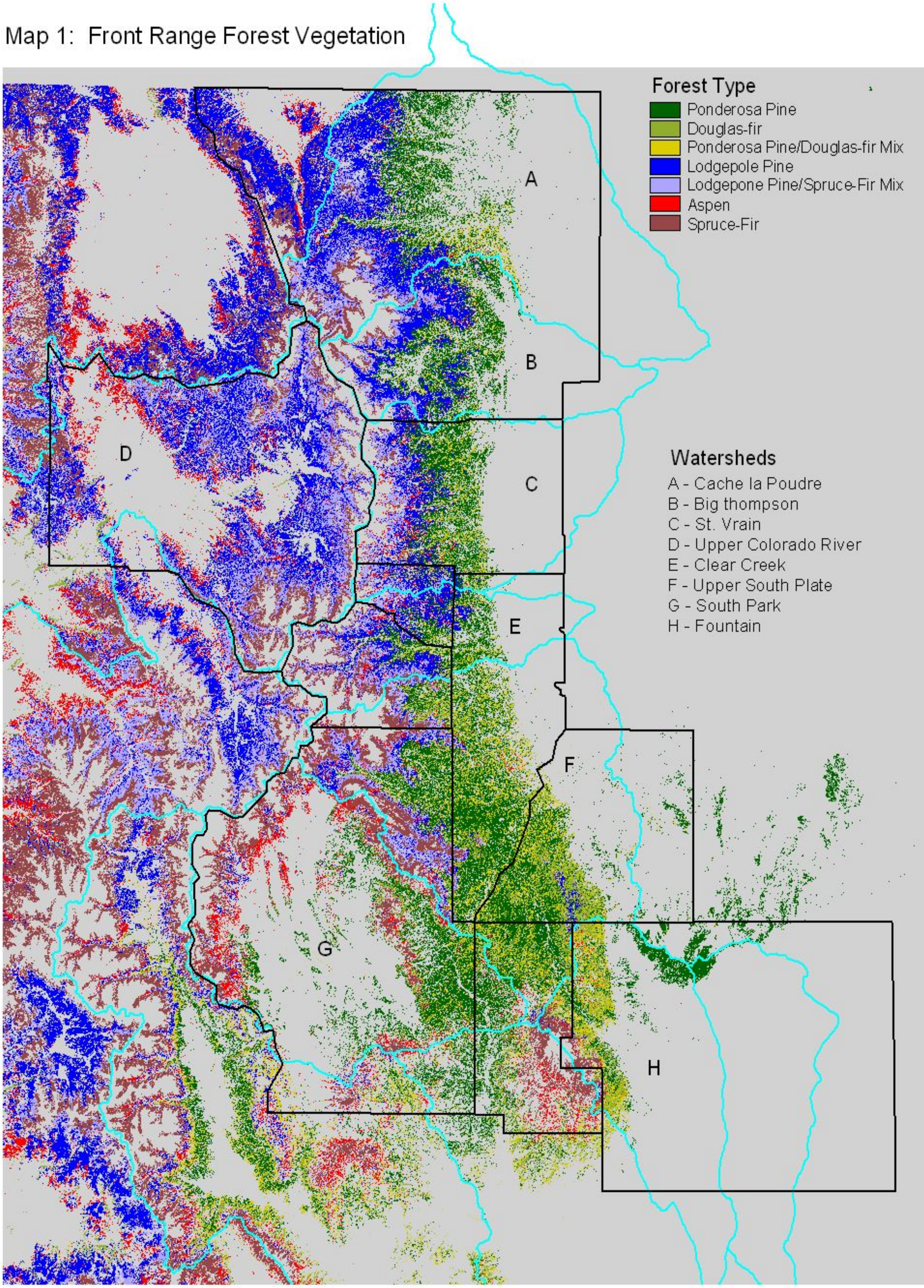
Map 2 shows the six Front Range vegetation zones, ranging from plains grassland to lower montane to alpine. Elevations that apply to these zones are provided in Table 5. Note that a given zone appears at lower elevations in the north than in the south. Following Map 1, ponderosa pine occurs in the lower ecotone, and both ponderosa pine and Douglas-fir occur in the lower montane. Mesic ponderosa pine and mixed conifer forests — combinations of ponderosa pine, Douglas-fir, aspen, blue spruce, limber pine, Engelmann spruce, and subalpine fir — are located in the upper montane. Lodgepole pine and the spruce/fir are located in the subalpine zone. Aspen groves or aspen mixed with other species actually occur in three zones — lower montane, upper montane, and subalpine — typically where there is abundant sunlight and moisture. Boundaries of the ten Front Range counties are shown in Map 2 in black. Critical watershed boundaries are shown in red.

TABLE 5
ELEVATIONS OF FRONT RANGE FOREST VEGETATION ZONES
(IN FEET)

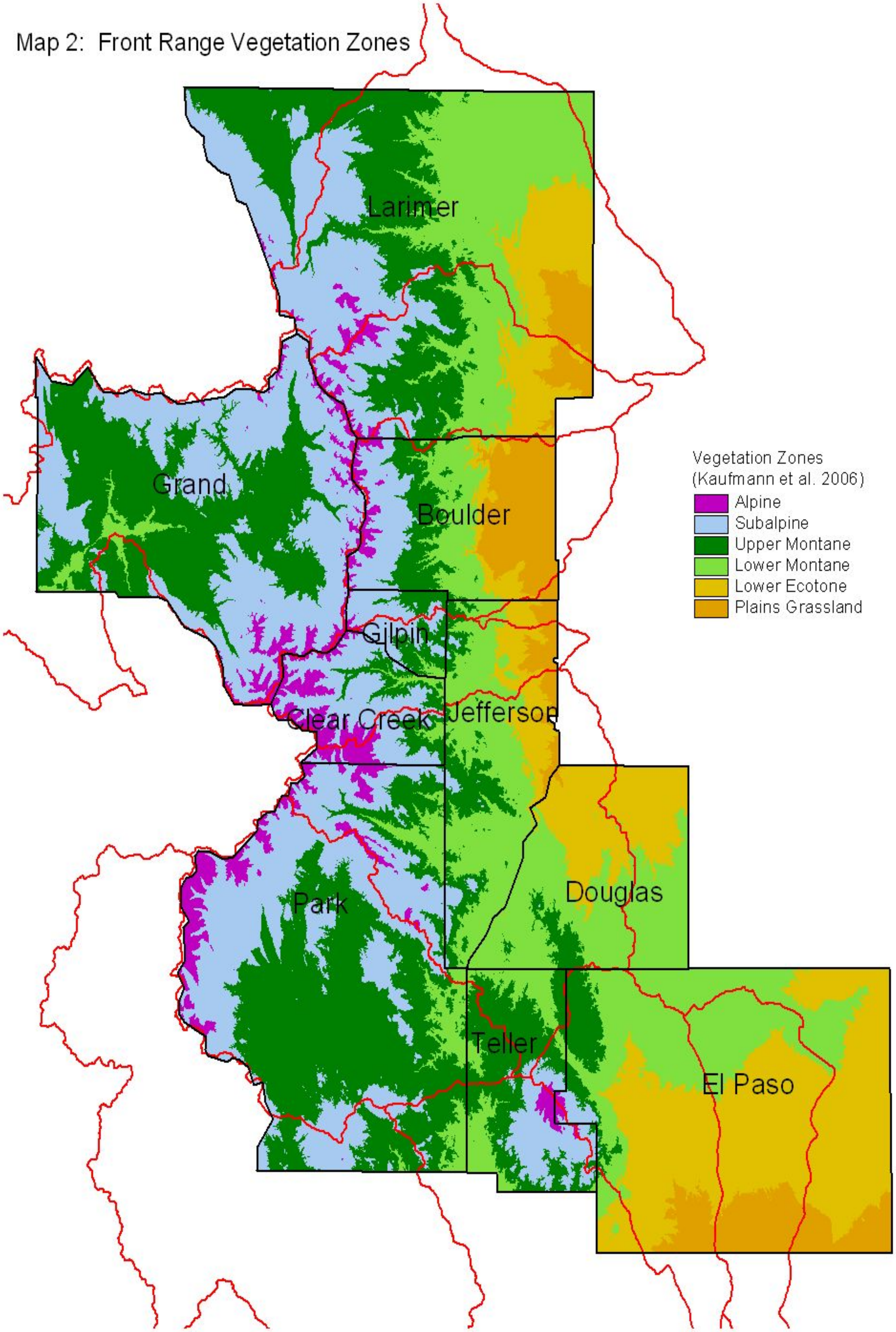
Vegetation Zone	Southern	Central	Northern
Plains Grassland	<5500	<5500	<5000
Lower Ecotone	5500-6500	5500-6000	5000-5500
Lower Montane	6500-8500	6000-8000	5500-7500
Upper Montane	8500-9500	8000-9000	7500-9000
Subalpine	9500-11500	9000-11500	9000-11500
Alpine	>11500	>11500	>11500

SOURCE: Kauffman, M.R., T. T. Veblen, and W. H. Romme. 2006. "Historical Fire Regimes in Ponderosa Pine Forests of the Colorado Front Range, and Recommendations for Ecological Restoration and Fuels Management." Front Range Fuels Treatment Partnership Roundtable, findings of the Ecology Workgroup. www.frftr.org/roundtable/pipo.pdf

Map 1: Front Range Forest Vegetation



Map 2: Front Range Vegetation Zones



The forested area of Front Range vegetation zones is shown in Table 6; the subalpine zone is the largest (1,525 thousand acres) followed by the upper montane (1,122 thousand acres). The lower montane is the third largest with 721 thousand acres. The forests of the lower montane are unnaturally dense and well outside their historical range of variability, resulting in an abnormal accumulation of forest fuels (Kauffman *et al.*). The risk of fire ignition and spread is high because several months of hot, dry weather occur almost annually, which can leave fuels sufficiently desiccated for extensive fires to occur. Indeed, virtually all the large fires in recent years in the Front Range have been in the lower montane (Kauffman *et al.*).

The upper montane is a very complex ecosystem that is not well understood. Hence, it is difficult to judge whether it is outside its historical range of variability. The risk of fire ignition and spread is less significant than in the lower montane because higher elevations retain more moisture than lower elevations. The subalpine zone is well understood, and probably is not outside its historic range of variability. While the risk of fire ignition and spread is usually low in the subalpine zone because of its generally cool, moist climate, when fires do occur, they tend to be high-severity fires.

As should be apparent from the above, fire plays a part in the ecology of all three vegetation zones, which is common in forests of the Interior West. Fire is a naturally occurring event and will happen regardless of human efforts to the contrary.

TABLE 6
FORESTED AREAS OF FRONT RANGE VEGETATION ZONES BY COUNTY (ACRES)

County	Forest Vegetation Zone						
	Alpine	Subalpine	Upper Montane	Lower Montane	Lower Ecotone	Plains Grassland	Total Area
Southern							
Douglas		118	27403	134185	8404	18	170128
El Paso		11671	58767	83563	2520	1	156522
Park	11391	369175	213252	64946			658764
Teller	1324	69812	144234	52865			268235
Central							
Clear Creek	6256	122893	35426	7787			172362
Gilpin	127	49934	31867	2483			84411
Jefferson	5	15655	73399	168948	477	42	258526
Northern							
Boulder	357	64812	70809	72427	1205	11	209621
Grand	2097	475658	160461	955			639171
Larimer	131	345509	306480	133092	593	3	785808
Total Area	21688	1525237	1122098	721251	13199	75	3403549

Fire Regimes and Return Intervals

Fire regime refers to the characteristic frequency, extent, intensity, severity, and seasonality of fires within a forest ecosystem (Helms). Tables 7 and 8 provide data on Front Range fire regimes, first by vegetation zone, second by forest type. The redundancy is intentional because it underscores the connection between forest zones and forest types.

Table 7
Historical Fire Regimes of Front Range Forest Vegetation Zones

Zone	Fire Interval	Fire Regime
Lower ecotone: transition to ponderosa pine	0 to 35 years[1]; 2 to 30 years[2]; 30 to 70 years[3]	Variable severity that tends toward frequent, low-severity surface fires
Lower montane: dry ponderosa pine; dry Douglas-fir	0 to 35 years[1]; 2-30 years for ponderosa pine, 25-100 years for Douglas-fir[2]; 30 to 70 years[3]	Variable severity that tends toward frequent, low-severity surface fires
Upper montane: mesic ponderosa pine; mesic mixed conifer[4]	35-200 years[1]	Variable severity that includes low-severity, mixed-severity, and high-severity (stand replacement) crown fires
Subalpine: lodgepole pine; spruce/fir	200+ years[1]; 25-340 years for lodgepole pine, 35 to >200 years for Englemann spruce-subalpine fir[2]; 200 to 400 years[3]	High-severity (stand-replacement) crown fires
Alpine: no trees	>100-500 years[2]	n.a.

[1]Interagency Fire Regime Condition Class Handbook
[2]Fire Regime Table, http://www.fs.fed.us/database/feis/fire_regime_tale/fire_ecology.html
[3]Front Range Fuels Treatment Partnership Roundtable, pp. 26-28
[4]Combinations of mesic ponderosa pine, Douglas-fir (up to ~8000 feet), aspen, blue spruce, limber pine, Engelmann spruce, and subalpine fir

The lower ecotone of the Front Range, which is the transition zone of prairie grassland to ponderosa pine, has a historical fire return interval of 0 to 35 years. Its fire regime is variable severity that tends toward frequent, low-severity surface fires. The same interval and fire regime applies to the lower montane.

The upper montane, as noted above, is a very complex ecosystem, and it has a historical fire return interval of 35 to 200 years, which is longer than that of the lower montane but generally shorter than that of the subalpine zone. The fire regime is variable severity, including low-severity surface fires, mixed-severity fires, and high-severity (stand replacement) crown fires.

The fire-return interval for the subalpine zone is longer than those of the lower and upper montane zones, 200 to 400 years. The fire regime is high-severity (stand replacement) crown fires.

The respective forest types in Table 8 correspond to the forest zones noted above: dry ponderosa pine to the lower ecotone; dry ponderosa pine and dry Douglas-fir to the lower montane; mesic ponderosa pine and mixed conifer forest — combinations of mesic ponderosa pine, Douglas-fir (up to ~8000 feet), aspen, blue spruce, limber pine, Engelmann spruce, and subalpine fir — to the upper montane; and lodgepole pine and spruce/fir to the subalpine zone. Accordingly, the historical fire-return intervals and fire regimes are comparable.

Again, the fire regimes are historical: those which *were*, not necessarily those which *are*. Certainly the present fire regime of the lower montane is different from its historical counterpart because of the fire exclusion policy that resulted in the filling-in of the forest understory. Uncontrolled early logging exacerbated the trend because it focused on removal of large trees without subsequent thinning of young ponderosa pine and Douglas-fir trees that grew in their place. Hence, the present fire regime of the lower montane is of variable severity, but the incidence of high-severity fires, such as the Hayman Fire, has increased while the incidence of low-severity fires has declined.

Whether the present fire regime of the upper montane is significantly different from its historical counterpart is questionable because it is equally questionable whether the upper montane zone is outside its range of natural variability. In contrast, the subalpine zone is within its historical range of natural variability. Hence, its present fire regime is consistent with its historical counterpart.

High-severity fires now account for perhaps twice as much area in the West as they did historically, largely because of fuels buildup in forest areas of low- and mixed-severity fire regimes resulting from the fire exclusion policy. Other things being equal, high-severity fires can be reduced in the West by restoring forests with low- and mixed-severity fire regimes. This would be difficult, however, in the spruce/fir and lodgepole pine forests on the Front Range because stand-replacing fires are normal, as is the current frequency of wildfire. Further, the cost of reducing the stand density of these forests through thinning at a landscape scale would be prohibitive.

For example, the cost of treating the 1.5 million-acre Front Range subalpine zone (see Table 6) would be $611 million, assuming a cost of $401 per acre, the average treatment cost used by the FRFTP Roundtable in its report *Living with Fire*. . . Reducing the incidence of high-severity fires in the upper montane of the Front Range would also be a challenge because it is questionable whether the upper montane is outside its historical range of natural variation and, further, the consequences of a landscape-level density reduction are unknown. Of course, the costs would be substantial, an estimated $450 million. Indeed, the unnatural fuels buildup on the Front Range occurs in the lower montane. It is here that the incidence of high-severity fires is abnormal, where hazardous fuels reduction at the landscape level could be successful and where ecological restoration is warranted.

TABLE 8
HISTORICAL FIRE REGIMES OF FRONT RANGE FOREST TYPES[1]

Forest Type	Fire Return Interval Range[2] (years)	Historical Fire Regime[3]		
		Low-Severity (Understory) 1-30	Mixed-Severity[4] 30-100	High-Severity (Stand Replacement) 100-400
Ponderosa pine, east of continental divide	2-30[5]	m	M	m
Ponderosa pine, west of continental divide	2-30[5]	M	m	
Douglas-fir	25-100[5]	m	M	
Mixed conifer[6]	25-100[5]	m	M	m
Aspen	7-120	m	M	
Lodgepole pine	25-340[5]		M	M
Lodgepole pine/Spruce-Fir mix	n.a.		M	M
Spruce-fir	35 to ≥200		m	M

[1]Arno, S. F., and C. E. Fiedler. Mimicking Nature's Fire: Restoring Fire-Prone Forests in the West. Washington: Island Press, 2005. Table 3.1, p. 17
[2]Fire Regime Table http://www.fs.fed.us/database/feis/fire_regime_table/fire_ecology.html
[3]"M" indicates a major part of the forest type; "m" indicates a small representation
[4]"Thus, in all of the vegetation zones of the Colorado Front Range, the historical fire regime would best be characterized as mixed severity or variable severity." (Kaufmann et al., p. 3.)
[5]Fire return interval varies widely
[6]Combinations of mesic ponderosa pine, Douglas-fir (up to ~8000 feet), aspen, blue spruce, limber pine, Engelmann spruce, and subalpine fir

MOUNTAIN PINE BEETLE INFESTATION

While other insect infestations exist in Colorado, the most serious is the decade-long infestation of the mountain pine beetle in northern Colorado's lodgepole pine forests. Climate is a major factor in controlling bark beetle outbreaks, and the current warming trend together with the drought of the past decade have stressed lodgepole pine and made it more susceptible to bark beetles. Colorado has approximately 1.5 million acres of lodgepole pine, and approximately 43 percent of it — at the time of writing — is or has been infested. Lodgepole pine in Grand County is particularly impacted, and a widely held belief exists that insect outbreaks set the stage for severe forest fires.

Scientific support for this belief is ambiguous, however. Romme et al. state: "(T)he assumed link between insect outbreaks and subsequent forest fire (events) . . . may in fact be incorrect or so small an effect as to be in consequential . . ." (Romme *et al.*). On the other hand, Lynch *et al.* (2006) studied the influence of previous pine beetle activity on the 1988 Yellowstone fires. They found beetle-affected areas had an 11 percent higher probability of burning than areas unaffected by beetles. Turner *et al.* (1999) also studied the influence of previous beetle activity on the Yellowstone fires and found the likelihood of crown fire was increased "somewhat" in lodgepole pine forests where beetle-caused tree mortality was high. The theoretical connection is that after the dead trees fall to the ground, they can fuel an intense surface fire with heat and flame lengths that can reach into the crowns of live trees that have survived the beetle infestation. Wildfires fueled by extensive downed timber can also severely damage forest soils.

A potentially similar situation exists in the lodgepole pine forests of northern Colorado where literally hundreds of thousands of acres are or have been pine-beetle infested resulting in millions of dead lodgepole pine trees. Grand County contains approximately 253.5 thousand acres of lodgepole pine, 62.7 percent in the national forests of the county, 9.6 percent on BLM land, and 20.3 percent on private land. About 75 percent of the mature lodgepole pine acreage is or has been infested. The protocol for treatment of infested lodgepole stands is removal of the dead trees (salvage), infested green trees (sanitation), and susceptible host material (thinning or clearcutting) (Colorado State Forest Service). Spraying high-value trees with a preventive insecticide is recommended only on a very limited, site-specific basis, such as near a residence or an individual campground. Costs prohibit broader application.

The Arapaho National Forest is implementing a silvicultural prescription whereby dead lodgepole pine is harvested through clearcutting (leaving green trees of other species where they occur), thereby reducing the canopy bulk density, making it difficult for fires to spread into the crowns. This treatment also reduces the potential for severe surface fires that would result if ignition were to occur in trees that had fallen to the ground.

Broadcast burning after dead timber is harvested reduces fine fuels that contribute to ignition and fire spread and, importantly, releases soil nutrients. Pile burning has a comparable effect. Creative use of prescribed fire can produce irregular swathes and soften the geometrical shapes of clear cuts. Application of fire in this context is consistent with the physiology of the serotinous cones of the lodgepole pine in the region, where an estimated 50 percent of the cones are of this kind.

Key to regeneration success is to maintain low surface heat. The resinous bond of lodgepole pine cones breaks at temperatures between 45^o and 60^o C (113^o-140^o F) thereby releasing the seeds (Perry and Lotan). Seeds heated to 76^{o} - 80^o C (169^o-176^o F) and higher show significant and accelerating decrease in germination (Knapp and Anderson). For purposes of comparison, DeBano found temperatures at the soil surface can reach 900^o C (1652^o F) during a high-severity wildfire event with higher temperatures reaching 1100^o C (2012^o F) or more in the burning canopy (1981). The litter layer, including cones and seeds, is completely consumed during such extreme fires and the organic material is mineralized and volatilized during oxidation.

It should be noted that the combined treatments of clearcutting and broadcast burning on mature lodgepole pine forests "roughly mimic effects of natural, stand-replacement fires" (Hardy *et al.*).

Such a general prescription on public lands would have to be complemented with prescriptions to protect private lands and communities from the risk of high-severity wildfires. Part of this effort would involve an assessment of local risks, such as those identified through the development of a Community Wildfire Protection Plan, provided for in the 2003 Healthy Forests Restoration Act.

Treatment of areas with highly erodible soils, whether on private or public land, must be a priority to insure that the risk of high-severity wildfire is minimized, thereby avoiding the impacts of post-fire flooding, landslides, organic debris flows, and sedimentation.

FRONT RANGE FOREST OWNERSHIP

Ownership of the Front Range forest vegetation zones is shown in Map 3 and numerically summarized in Table 7. By far the largest owners as a whole are the U.S. Forest Service (60.1 percent) and the private sector (27.1 percent). As for the three largest forest vegetation zones — subalpine, upper montane, and lower montane — the Forest Service has 74.8 percent, 51.1 percent, and 43.1 percent, respectively, while the private sector has 11.5 percent, 37.3 percent, and 44.0 percent. While addressing potential hazards of high-severity wildfire on the Front Range will require participation, collaboration, and cooperation among all levels of government, the Forest Service and private landowners are essential due to the relative size of their ownerships.

Map 3: Public and Private Land Ownership in Front Range Counties

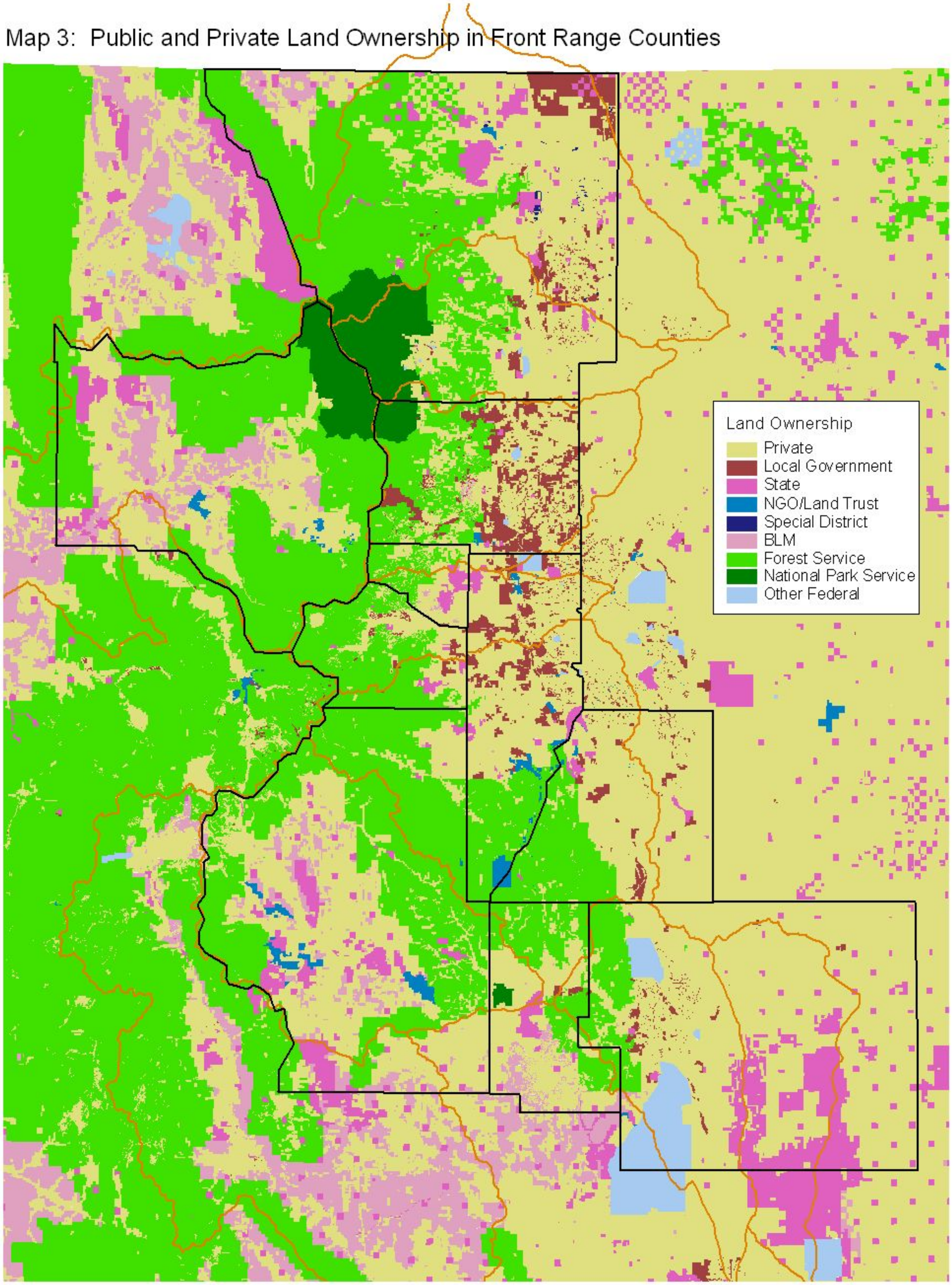


TABLE 7
FRONT RANGE FOREST VEGETATION ZONES BY OWNERSHIP

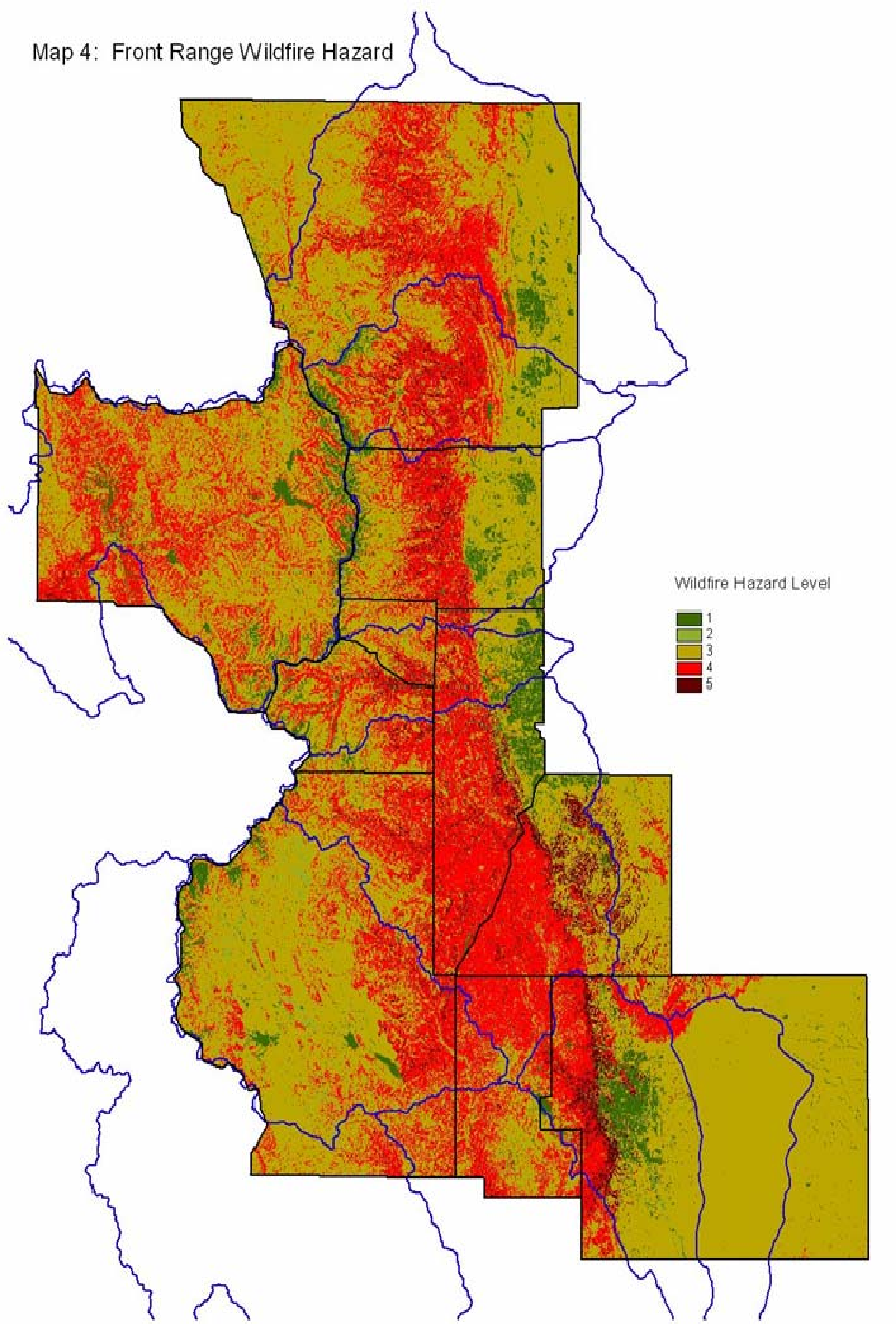
	Alpine	Subalpine	Upper Montane	Lower Montane	Lower Ecotone	Plains Grassland	Total
Private	1660 (7.5)	174882 (11.5)	**418639**[1] **(37.3)**	**317705**[1] **(44.0)**	9429 (71.4)	16 (21.3)	922322 (27.1)
Local Government	54 (0.2)	10489 (0.7)	12798 (1.1)	45346 (6.3)	1592 (12.1)	9 (12.0)	70287 (2.1)
State Government	0 (0.0)	25483 (1.7)	44414 (4.0)	17873 (2.5)	360 (2.7)	50 (66.7)	88180 (2.6)
NGO/Land Trust	0 (0.0)	836 (0.0)	2842 (0.3)	13261 (1.8)	226 (1.7)	0 (0.0)	17165 (0.5)
Special District	0 (0.0)	0 (0.0)	0 (0.0)	60 (0.0)	9 (0.0)	0 (0.0)	69 (0.0)
BLM	0 (0.0)	45011 (3.0)	42325 (3.8)	10147 (1.4)	7 (0.0)	0 (0.0)	97489 (2.9)
Forest Service	20144 (91.0)	**1141580**[1] **(74.8)**	**573425**[1] **(51.1)**	**311218**[1] **(43.1)**	683 (5.2)	0 (0.0)	2047051 (60.1)
Nat'l Park Service	284 (1.2)	126955 (8.3)	27486 (2.4)	1171 (0.2)	0 (0.0)	0 (0.0)	155896 (4.6)
Other Federal	0 (0.0)	0 (0.0)	113 (0.0)	4470 (0.6)	894 (6.8)	0 (0.0)	5477 (0.2)
Total Area	22142 (99.9)	1525237 (100.0)	1122042 (100.0)	721250 (99.9)	13199 (99.9)	75 (100.0)	3403946 (100.1)

[1]Numbers are boldfaced to emphasize relative importance of landowner.

FRONT RANGE WILDFIRE HAZARD

Wildfire hazard levels for the ten Front Range counties are schematically shown in Map 4; green represents the lowest hazard level and red and maroon represent the highest levels. Wildfire hazard is given by [Fuel Hazard]*0.40 + [Disturbance Regime]*0.35 + [Aspect]*0.10 + [Slope]*0.15 (Colorado State Forest Service 2002). Watershed boundaries are shown in blue; county boundaries in black.

The extent of the red, indicting a high wildfire hazard level, is compelling, making clear the need for expedient corrective action.


Map 4: Front Range Wildfire Hazard
Wildfire Hazard Level
1
2
3
4
5

SOIL ERODIBILITY ON THE FRONT RANGE

Depending on intensity and duration, wildfire can change the soils of a watershed (1) by consuming the litter layer at the surface of the soil, and (2) by destroying binding organic matter in the soil itself (Neary). A water-repellent zone or layer forms when hydrophobic organic compounds coat soil aggregates or minerals at or parallel to the surface. This hydrophobic layer prevents water from wetting soil aggregates. It effectively seals off the soil during rainfall events, accelerating surface runoff and sediment transport and deposition. This phenomenon does not require extreme soil temperatures in order to occur: 176^{o}-288^{o} C (349^{o}-550^{o} F) (DeBano).

The predominant effect of wildfire as it relates to flooding and soil erosion is to divert water from movement into the soil to overland flow, causing soil erosion — first sheet, then rill and gully — as well as movement of large volumes of organic debris (Ice). The adverse impacts continue when the water, sediment, and debris pour off slopes into receiving channels, scouring banks and bottoms, often overwhelming them and causing flooding, sometimes miles away from the precipitating wildfire event. Sediment and organic debris can dramatically alter water courses.

An example is the Buffalo Creek fire of 18 May 1996, which burned 11,900 acres of the Pike National Forest and surrounding private lands, and destroyed 10 dwellings. Less than two months later, on 12 July 1996, a thunderstorm discharged approximately 2.5 inches of rain on the fire-ravaged watershed, causing severe flooding. In addition to washing out roads, destroying the City of Buffalo Creek's potable water supply and telephone facilities, and taking the lives of two Buffalo Creek residents, hundreds of thousands of tons of sediment and organic debris were deposited in Strontia Springs Reservoir. According to Denver Water, water quality and fire rehabilitation costs are approximately $28 million. Pristine riparian habitat along Buffalo and Spring Creeks were also lost for years to come.

A principal determinant of the extent of post-fire effects of water-repellent soil conditions, surface runoff, and soil erosion is soil erodibility, which is a function of several factors, including soil texture, organic matter content, and permeability. Soil erodibility is a recognized soil metric and a component of the Revised Universal Soil Loss Equation (RUSLE),

$$A = R * K * LS * C * P$$

where:

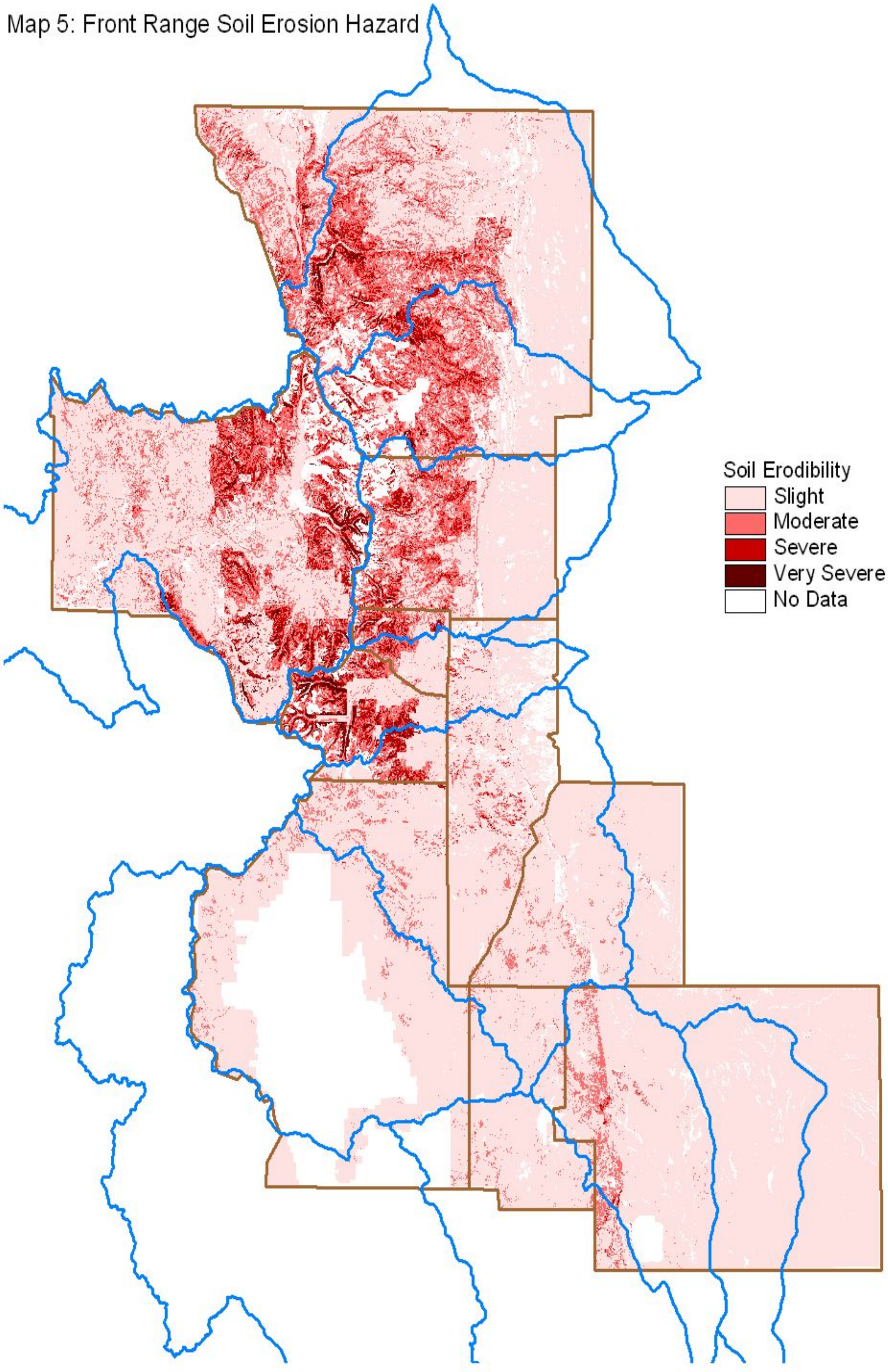
A = estimated average soil loss in tons per acre per year,
R = R rainfall-runoff erosivity factor,
K = soil erodibility factor,
L = slope length factor,
S = slope steepness factor,
C = cover-management factor, and
P = support practice factor

K is of concern for the purposes here. It is a measure of the inherent susceptibility to erosion of a given soil and ranges from near zero to 0.6, where low values represent low soil erodibility and high values reflect high soil erodibility. An attempt was made to gather K factor values for all soils in the ten Front Range counties.

Once K factor values were gathered, they were multiplied by slope angle categories to develop erosion hazard ratings (MacDonald *et al.*), which are shown for the ten-county area in Map 5 for which some parts are missing. An examination of Map 5 indicates severe soil erodibility in western Larimer, Boulder, Gilpin, and Clear Creek Counties, and eastern Grand County. Expert opinion indicates that K factor values significantly understate soil erodibility in the Upper South Platte and South Park watersheds in the four-county area of Park, Jefferson, Douglas, and Teller counties (Wright).

Such opinion is substantiated in *Landscape Assessment: Upper South Platte Watershed*, a 1999 study of 13 6^{th} level contiguous watersheds southwest of Denver in the Upper South Platte. This area is largely within the Pike National Forest, totals 645,672 acres, and runs generally 36 miles northwest of the town of Woodland Park. Virtually in the middle of the area, and among the 13 contiguous watersheds, is Buffalo Creek, mentioned above. The purpose of this study was to prioritize the 13 watersheds in terms of restoration needs, as well as the kinds of restoration treatments necessary to re-create conditions comparable to those that existed prior to European settlement.

One of the principal findings of the 1999 study indicates that there are "highly erodible soils throughout the area." Indeed, 50 percent of the acres involved were rated "very high" or "extreme" in terms of soil erosion potential. If those acres ranked "high" were added, the ratio is 65 percent. Due to lack of data at the requisite scale, the comparable area in Map 5 does not reflect this degree of soil erodibility.


Map 5: Front Range Soil Erosion Hazard
Soil Erodibility
Slight
Moderate
Severe
Very Severe
No Data

WATER INFRASTRUCTURE

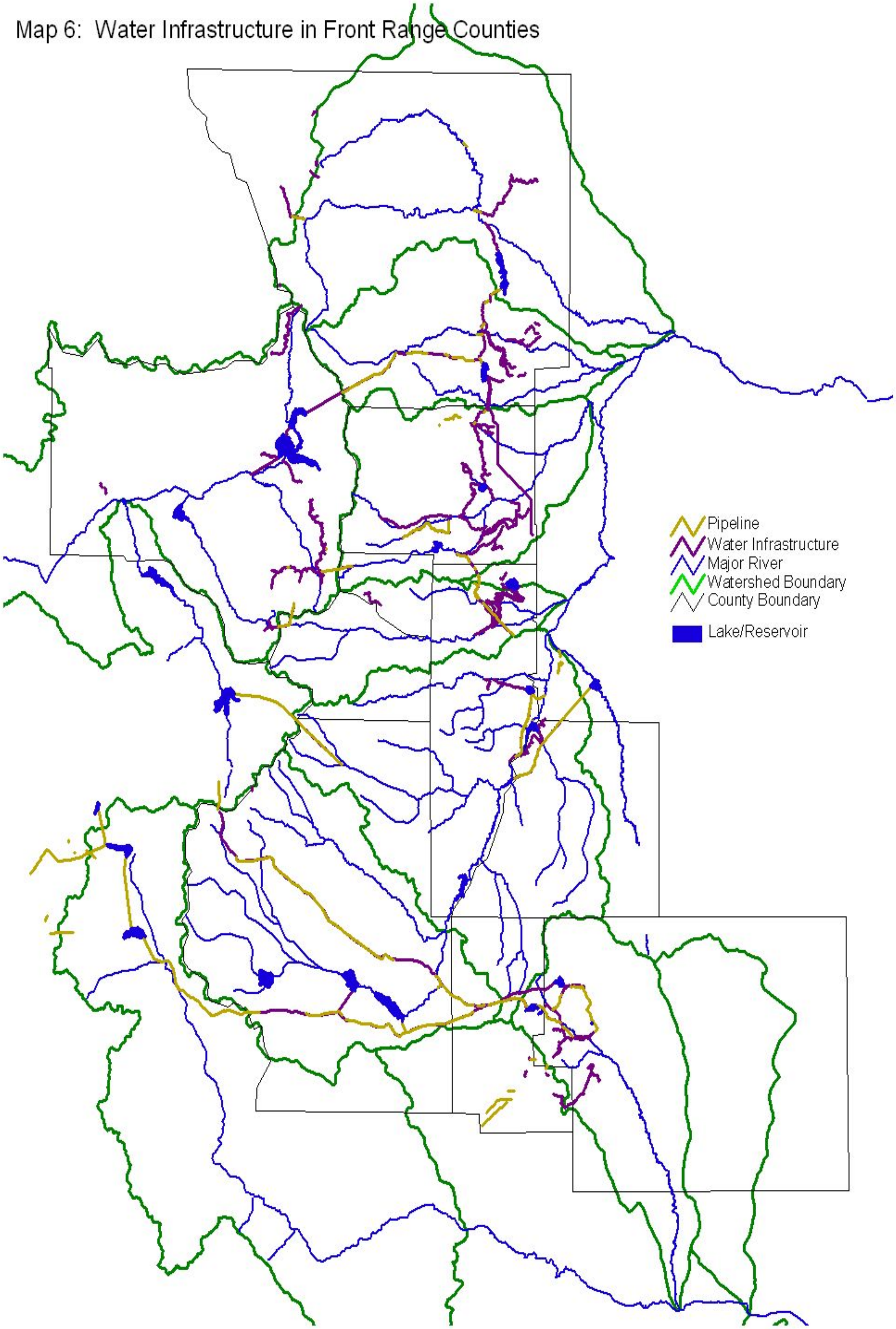
As noted above, the seven major providers serving Front Range communities get their water from eleven watersheds, and eight have been designated as critical because they are mostly or wholly contained in the ten Front Range counties. The major providers deliver water through nine conveyances, which include pipelines, canals, tunnels, aqueducts, and ditches, as well as existing channels of streams and rivers. Six of the seven water providers — Westminster being the exception — get some or all of their water from west of the continental divide. Substantial distances are involved. Colorado Springs reportedly brings water from one source located 200 miles away. On its journey from west to east, water is stored in multiple reservoirs of various kinds and sizes.

Map 6 shows the major water conveyance infrastructure for the seven water providers, major rivers, and reservoirs. Watershed boundaries are shown in green.

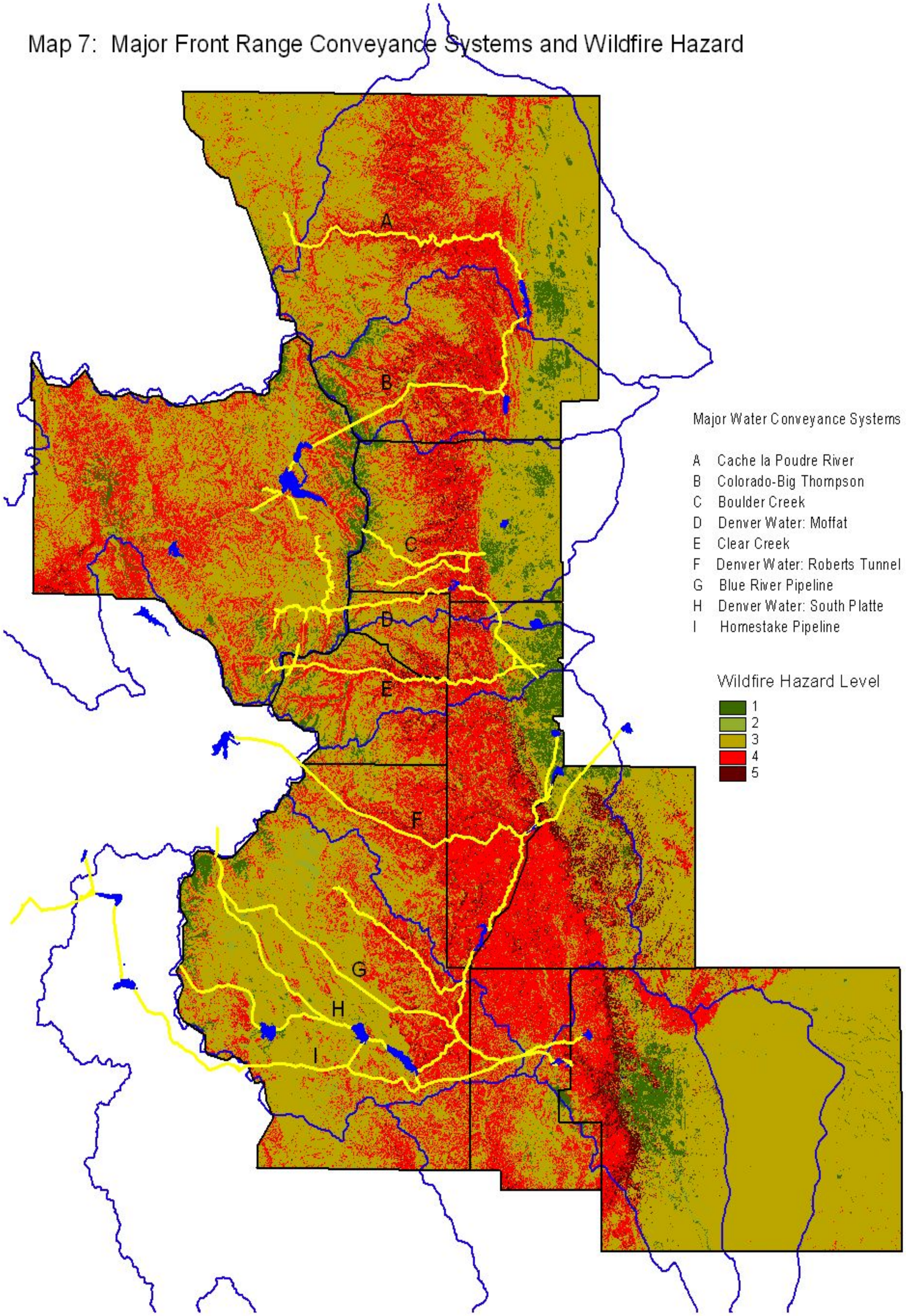
Most of the conveyances flow through forests at some point and for extended distances. Similarly many of the reservoirs are surrounded by forests. High-severity wildfires can have a catastrophic impact on watershed values, water conveyances, and reservoirs. As noted earlier, sediment from post-fire flooding, landslides, and organic debris flow can put water conveyances and reservoirs out of operation. Rehabilitation, which often requires construction of physical structures such as sediment dams, involves large expenditures of money, time, and effort.

The wildfire hazard map is shown in Map 7 with major Front Range water conveyance systems overlaid. The resulting image shows well the extent to which these systems flow through areas that are of a high fire hazard, are vulnerable to wildfire.

Map 6: Water Infrastructure in Front Range Counties



Map 7: Major Front Range Conveyance Systems and Wildfire Hazard



PROBLEM SUMMATION

The lower montane forests of the Front Range are unnaturally dense and have an abnormal accumulation of forest fuels making them susceptible to high-severity wildfires. At the same time, a prolonged infestation of mountain pine beetle has occurred in lodgepole pine forests of northern Colorado, killing millions of trees. The situation in Grand County, which contains 253.5 thousand acres of lodgepole pine, is particularly problematic since more than 76 percent of the mature lodgepole pine is infested. The resulting forests of dead and dying trees are susceptible to wildfires.

Approximately 4.7 million people are concentrated along Colorado's Front Range. It is a rapidly growing state, the third fastest in the United States during the period 1900-2000, and projections for the next 20 years indicate that rapid growth will continue. Front Range counties are semi-arid, receiving about 14 inches of rain annually. Most of the drinking water for the Front Range comes from snow melt both east and west of the continental divide that flows in eight critical watersheds in the ten Front Range counties.

Due to the accumulation of forest fuels, these watersheds are threatened with high-severity wildfires that could destroy them as sources of drinking water for the foreseeable future. Not only are wildfires a threat to drinking water supplies, sometimes the sediment and organic debris flows caused by water-repellant soils and overland water flows that follow wildfires are even more problematic. If not mitigated by costly catch basins and other mitigating structures requiring annual maintenance, sediment and organic debris can destroy reservoirs as a functional part of a drinking water supply system.

The threat of high-severity wildfire to critical Front Range watersheds and the drinking water of Front Range communities is unprecedented. If the threat materializes, it could adversely affect human health and safety, and seriously impact the Front Range economy.

GLOBAL CLIMATE CHANGE AND WILDFIRE

Global warming is generally recognized by climatologists, in particular, and the scientific community in general. Since 1880, average temperatures have increased 0.8 ^{0} C (1.4 ^{0} F) around the world, much of this in recent decades (National Geographic News 2007). The last two decades of the 20th century were the hottest in 400 years and possibly the warmest for several millennia. The Intergovernmental Panel on Climate Change (IPCC), which is overseen by the United Nations and the World Meteorological Organization, reports that 11 of the past 12 years were among the warmest since 1850.

Human activity "very likely" has caused all or most of the current planetary warming, according to a recent report of the IPCC, whose work is based on the efforts of some 2,500 scientists from more than 130 countries. "Very likely" translates to a 90-percent probability. Industrialization, deforestation, and pollution have greatly increased atmospheric concentrations of greenhouse gasses that tend to trap heat near the surface of the earth. Such gasses include water vapor, carbon dioxide, methane, and nitrous oxide.

Even if greenhouse-gas emissions are stabilized, global warming will continue, although at a reduced rate. There is no quick fix because, aside from water vapor near the surface, greenhouse gases take a long time to leave the atmosphere. In other words, global warming will continue for centuries.

In terms of wildfire, the implications of global warming for the western United States are generally negative. The effect of warming on snowpack is key because the hydrology of the western United States is dominated by snow. Global warming will result in higher temperatures, which will cause snowpack to melt earlier. An estimated 75 percent of annual stream flow in the West comes from snowpack (Running 2006). Earlier snowmelt will lead to an earlier, longer fire season, thus increasing opportunities for fire ignition and larger fires because of extended drying of soils and vegetation. Earlier snowmelt will also expand the area vulnerable to wildfires to parts of high-elevation forests, which were less vulnerable when snowmelt occurred later.

Westerling *et al.* (2006) analyzed the geographic location, seasonal timing, and regional climatology of 1,166 recorded wildfires in the western United States that were larger than 400 acres. Since 1986, “wildfire frequency was nearly four times the average of 1970 to 1986, and the total area burned by these fires was more than six and a half times its previous level.” They also found that increases in spring and summer temperatures beginning in the mid-1980s, which induced an earlier snowmelt, increased the duration of the wildfire season by 78 days, and increased the average burn duration of large wildfires from 7.5 days to 37.1 days. Although they did not look at the cause of these changes — global warming or an unusual natural fluctuation — Westerling *et al.* observed that “virtually all climate-model projections indicate that warmer springs and summers will occur in the region in coming decades.” They concluded that “These trends will reinforce the tendency toward early spring snowmelt and longer fire seasons. This will accentuate conditions favorable to the occurrence of large wildfires, amplifying the vulnerability the region has experienced since the mid-1980s.”

Fried *et al.* (2004) estimated the impact of climate change on wildland fire and suppression effectiveness in northern California. They found the warmer and windier conditions produced fires that burned more intensely and spread faster in most locations. They predicted a doubling of fire escapes (114 annually) and a 50 percent increase in acres burned (an additional 5,000 acres) by contained fires.

Global warming *exacerbates* the threat of high-severity wildfire to critical Front Range watersheds. It does this by causing earlier and longer fire seasons, increasing the opportunities for ignition and larger, more intense burns, by drying of soils and vegetation and expanding areas vulnerable to wildfire. Global warming also adversely affects western forests to the extent it promotes population growth of inspect pests, such as the mountain pine beetle.

EVALUATION CRITERIA

Prior to systematic consideration of courses of action to reduce the risk of high intensity wildfires to Colorado Front Range watersheds, agreement is necessary on criteria for their evaluation. Four criteria are given here.

First, the protective treatments should effectively reduce the risk of wildfire to watersheds and water infrastructure such as reservoirs and conveyances. In other words, the protective treatments should do what they are said to do.

Second, the protective treatments should have public support because a substantial expenditure of public funds will be involved, and the benefits of the expenditure will accrue. Furthermore, the protective measures are likely to be applied to both private and public forest land. For these reasons, the public must understand what is being done to forests and why it is necessary.

Third, the protective treatments should be administratively practicable or feasible. If the treatment requires physical access, such access is available. It is not precluded by federal, state, or local law or administrative regulation. Similarly, if the treatment requires a particular action, like prescribed burning, such action is not precluded by law or administrative regulation.

Fourth, the protective treatments for reducing the threat of high intensity wildfires to watersheds and water infrastructure should be consistent with, compatible with, similar treatments for protecting communities from the risk of high intensity wildfires. The treatments should not work against each other.

ALTERNATIVE TREATMENTS

Treatment of Front Range forests to decrease the risk of high-severity wildfires to critical watersheds involves reducing the accumulation of hazardous fuels. Mechanical treatments and prescribed fire are two basic types of treatments (Bureau of Land Management). Mechanical treatments involve machines, e.g., chain saws, feller bunchers, skidders, skyline cable yarders, in-woods chippers, masticators, etc., to reduce stand density and remove lower tree limbs to reduce ladder fuels. Prescribed fire is the intentional ignition of fire under certain predetermined conditions to meet specific hazardous fuel reduction objectives. Mechanical and prescribed fire treatments are often used together, usually in succession; prescribed fire follows mechanical treatments.

Prescribed fire is less costly than mechanical treatments, but it has significant constraints, even when used in conjunction with mechanical treatments. For one, prescribed burning is highly regulated to mitigate air pollutant emissions that affect air quality and visibility. Prescribed fire can only be ignited within a “window” of very specific conditions involving wind, temperature, and humidity. For another, prescribed burning involves some risk in that it can get out of control, which has happened on occasion. A well known example was the Cerro Grande Prescribed Fire in New Mexico, which was ignited at the Bandelier National Monument on 4 May 2000 by National Park Service fire personnel. Personnel lost control of the fire on 7 May 2000, and the fire ultimately burned 47,650 acres and 235 homes, and caused the evacuation of 18,000 residents in the towns of Los Alamos and White Rock. The fire was declared contained on 6 June 2000. Although prescribed fire use by federal agencies is done with detailed planning and serious concern for public safety, its use in human-populated areas, such as the wildland-urban interface, is seriously limited.

RECENT TREATMENT RECOMMENDATIONS

The Front Range Fuels Treatment Partnership (FRFTP) is an alliance of federal, state, and local governments; land management agencies; private landowners; conservation organizations; and other stakeholders, committed to reducing wildland fire risk through sustained fuels treatment. FRFTP has recommended treating 510,000 acres of wildland-urban interface along the Front Range over ten years. Eighty-five percent of these treatments would occur on public land and would cost approximately $24 million each year, far above current annual funding levels of $6 million (FRFTP Roundtable, p. 11).

The Front Range Fuels Treatment Partnership Roundtable (FRFTP Roundtable) is an offshoot of the FRFTP and describes itself as "a coalition of individuals from state and federal agencies, local governments, environmental and conservation organizations, the academic and scientific communities, and industry and user groups . . . (committed) to forest health and fire risk mitigation along Colorado's Front Range" (FRFTP Roundtable). It recommends treating 1,538,463 acres over a 40-year period at an annual cost of $15.4 million per year (FRFTP Roundtable, pp. 8, 31). Of the total acreage, 809,110 acres would be treated for fire risk mitigation, 387,489 acres for ecological restoration, and 341,864 acres would be treated for both ecological restoration and fire risk mitigation (FRFTP Roundtable, p. 8). Sixty percent of the total acreage in need of treatment is on private land.

To appreciate the scope of the treatment and using the acreage numbers published in *Living with Fire. . .* , there are 758 thousand acres in the lower montane, not including Grand County, 979 thousand acres in the upper montane, again not including Grand County. If the acreage for Grand County in Table 6 is added, the foregoing numbers would increase to 759 thousand acres and 1,139 thousand acres, respectively, a total of 1,898 thousand acres. Hence, the FRFTP Roundtable is recommending treating virtually all (96 percent) of the lower montane —729 thousand acres — and the equivalent of about 71 percent of the upper montane.[2] The latter treatments would address fire risk mitigation applied on a site-scale basis, and while they could be applied on the lower ecotone and subalpine zones, the acreages treated would be comparatively modest. The loci of most of the treatments would be in the lower montane first, and the upper montane second.

RECOMMENDATION

This treatment makes sense for the lower montane forests with a short fire-return interval (0 to 35 years) and a variable-severity fire regime that historically tends to low-severity surface fires. It also makes sense for upper montane forests with an intermediate fire-return interval (35 to 200 years) and a variable-severity fire regime that historically tends to a combination of low-, mixed- and high-severity fires when the purpose is fire risk mitigation.

Forests with an infrequent fire return interval (more than 200) years and high-severity (stand replacement) fire regime are another matter, however, particularly when they are even-age and extend across the landscape. The large, even-age lodgepole pine forests in Grand County are an example. They are currently at risk for a very large conflagration, in great part because of the dead and dying trees from the current mountain pine beetle infestation.

But after the inevitable wildfire occurs, and when lodgepole pine forests have re-established themselves, they will once again become large, even-age forests, susceptible to future mountain pine beetle infestations and again at risk for large, high-severity wildfires. The occurrence of such large fires, either now or in the future, is not socially acceptable for the Front Range for reasons of both community and critical watershed protection.

[2] 759,000 x .96 = 728,640. 1,538,463 – 728,640 = 809,823. 809,823/1,139,000 = .71.

The solution must go beyond thinning and prescribed fire; its scope must be broader than individual stands and extend to the landscape level. Indeed, *large, even-age lodgepole pine forests in the subalpine zone must be broken up into a mosaic of age classes and an enhanced mixture of native tree species through artful use of fuel breaks and application of variety of silvicultural tools*, including thinning, restoration forestry, timber harvesting, and seeding and planting, to mitigate fire risk. Accessibility will be a problem, at some point. For example, much of the Arapaho National Forest is administratively designated as roadless, meaning no roads can be constructed in these areas. Still, lodgepole pine forests in roadless areas must be part of the picture when developing an overall strategy to reduce the risk of large high-severity wildfires. When application of silvicultural tools is appropriate, personnel applying them can be airlifted into and out of the roadless areas or they can pack in. Note that ownership of the subalpine zone is predominantly federal. The Forest Service (74.8 percent), BLM (3.0 percent), and the National Park Service (8.3 percent) own the majority: 86.1 percent (see Table 7).

The foregoing treatment is not standard protocol. It is an adaptation of possible remedies to meet the current exigent conditions in the subalpine zone of the Front Range, to reduce the current threat of high-severity wildfires to critical watersheds of the Front Range. Remedial action is called for. And the foregoing treatment makes sense.

Virtually as important, is that the action be done in a timely way. Treatments must be balanced with biomass utilization. The FRFTP proposes a *ten-year time frame* for its proposed treatment of federal lands. The FRFTP Roundtable proposes a *forty-year time frame* for its proposed treatment of both federal and private land. Ten years is not enough time to get the requisite plants up and operating. It also falls short for full depreciation of plant and equipment for tax purposes. On the other hand, forty years is too long to sustain a program of the scope envisioned.

A *twenty-year time frame* is realistic. It would allow time for private investors to gather capital and get plants utilizing woody biomass on-line. It would also allow time for full depreciation of plants and equipment.

To summarize, it is proposed here that *all areas in critical watersheds with a level 4 or 5 wildfire hazard (see Map 4) be treated over a twenty-year period* to reduce the risk of high-severity wildfires. *Mechanical treatments and prescribed fire* would generally be applied in the lower montane forests with short fire-return intervals (0 to 35 years) and a variable-severity fire regime that historically tends to low-severity surface fires, and in the upper montane to forests with an intermediate fire-return interval (35 to 40 years) and variable-severity fire regime that historically tends to a combination of low-, mixed-, and high-severity fires, on a site-specific basis and solely for the purpose of fire risk mitigation. *Artful development of fuel breaks and a mosaic of age classes and enhanced mixtures of native tree species* would be applied in the subalpine zone in lodgepole pine forests and other forest types characterized by an infrequent fire-return interval and a high-severity fire regime, where and when high risk of wildfire is evident. This treatment would be achieved through application of a variety of silvicultural tools including thinning, restoration forestry, timber harvesting, and seeding and planting.

PROJECTED COST OF IMPLEMENTATION

The data in Table 10 indicates the acreages involved. Treatment costs average $125 per acre for prescribed burning, and $400 to $800 per acre for mechanical treatments (FRFTP Roundtable, p. 17). In footnotes 19 and 20 of *Living with Fire . . .* , treatment costs, based on local 2004 U.S. Forest Service data, ranged from $114 to $786 per acre, with an average treatment cost of $401 per acre (FRFTP Roundtable, 2006, pp. 30-31). Using the foregoing average treatment cost per acre, the total cost for treatment of the lower and upper montane would be $682,827,612, alternatively expressed: $34,141,381 each year for 20 years. Some skepticism exists about these cost estimates. Recent correspondence with an official of the Arapaho and Roosevelt National Forests stated "a more accurate range of costs is probably $250 to more than $1500 per acre" (Hamilton). Half the difference of this range would yield an average cost estimate of $875 per acre. If correct, the cost of treatment could be about twice the earlier amount, $1,489,960,500 or $74,498,025 per year for 20 years.

For lack of data, the same cost estimates are applied to creating fuel breaks and a mosaic of age classes in the subalpine zone, particularly in lodgepole pine forests. The total cost of treating this area would be $163,985,341, or alternatively, $8,199,267 per year for 20 years. If the higher cost estimate is used — $875 per acre — the cost of treatment would be $357,823,375 or $17,891,169 per year for 20 years. These numbers and the comparable numbers in the paragraph above are summarized in Table 11.

It should be recognized that a very large overlap exists between treating Front Range forests for ecological restoration and fire risk mitigation, as proposed by the FRFTP Roundtable, and treating these same forests to reduce the risk of high-severity wildfire to critical watersheds. The prescribed treatments for the lower and upper montane are virtually the same, as are most of the acreages in these zones. The main difference is the treatment of lodgepole pine forests in the subalpine zone. Indeed, the incremental cost of protecting critical watersheds is 37 percent over that proposed by the FRFTP Roundtable.

In conclusion, there are two alternatives for Front Range forests with a high wildfire hazard level. One is a comprehensive program of mechanical treatments and prescribed fire for the lower and upper montane, and development of artful fuel breaks and a mosaic of age classes for lodgepole pine forests in the subalpine zone. The other alternative, of course, would be to take no action; let nature take its course.

TABLE 10
WILDFIRE HAZARD TREATMENT AREAS BY WATERSHED AND VEGETATION ZONE
(ACRES)

Watershed	Mechanical Treatments and Prescribed Fire	Fuel Breaks and a Mosaic of Age Classes
Cache la Poudre, 1019007		
Lower montane	129,045	
Upper montane	110.455	
Subalpine		29,907
Big Thompson, 10190006		
Lower montane	95,575	
Upper montane	78,358	
Subalpine		28,989
St. Vrain, 10190005		
Lower montane	86,317	
Upper montane	54,217	
Subalpine		22,521
Clear Creek, 10190004		
Lower montane	40,069	
Upper montane	36,687	
Subalpine		45,718
Upper South Platte, 10190002		
Lower montane	368,793	
Upper montane	183,610	
Subalpine		66,530
South Park, 10190001		
Lower montane	31,894	
Upper montane	126,023	
Subalpine		66,458
Fountain, 11020003		
Lower montane	90,511	
Upper montane	56,320	
Subalpine		10,930
Upper Colorado River, 11020004		
Lower montane	13,108	
Upper montane	201,830	
Subalpine		137,988
All Watersheds		
Lower montane	862,031	
Upper montane	847,500	
Subalpine		408,941
Total	**1,702,812**	**408,941**

TABLE 11
TREATMENT COSTS
(MILLIONS OF DOLLARS)

Treatment	Lower and Upper Montane		Subalpine		All Three Zones	
	Total	Annual[1]	Total	Annual[1]	Total	Annual[1]
Mechanical Treatments & Prescribed Fire	682.8 to 1,490.0	34.1 to 74.5				
Fuel Breaks & Mosaic of Age Classes			164.0 to 357.8	8.2 to 17.9		
All Treatments					846.8 to 1,847.8	42.3 to 92.4

[1]Annual cost is given by total cost divided by 20 years.

BIOMASS UTILIZATION

The challenge of reducing the risk of high-severity wildfire to critical Front Range watersheds goes beyond reducing the level of hazardous fuels. It must also deal with the biomass removed from treated forests. Forest biomass can be burned, scattered, or used in some way. Burning is problematic because of the air pollutants emitted and possible impacts on visibility. Chipping and scattering done on any significant scale could become problematic because of possible aesthetic and ecological concerns. Commercial utilization of sawlogs, posts, and poles is quite feasible, but they comprise a minority component of the biomass removed from the forest, an estimated 40 to 30 percent. At issue is the remainder, an estimated 60 to 70 percent of the remaining woody biomass, defined as woody material that is less than 7 inches in diameter.

PROJECTED BIOMASS YIELD ALONG THE FRONT RANGE

Two recent efforts have been made to estimate the amount of woody biomass that would be generated by treatments to reduce hazardous fuels and suggest strategies for their use. The FRFTP Roundtable estimated these treatments could yield approximately 195,000 green tons (gT) of woody biomass per year, or roughly 5.1 gT per acre, as shown Table 12.

Mater Engineering, Ltd., conducted what it identified as the Coordinated Resource Offering Protocol (CROP) analysis on removal projections of woody material from national forest, BLM, and selected county lands on the Front Range for the period 2006 - 2010 (2006). Woody material was grouped in three categories: logs ≥12 inches; small logs ≥7 inches but <12 inches; and woody biomass, biomass < 7 inches. The analysis determined that approximately 111,698 gT of woody biomass plus half of the logs ≥7 inches but <12 inches, are intended to be offered annually during the period 2006 through 2010. These materials will be offered from an estimated 30,400 acres of national forest and BLM lands each year, which is less than the annual treated acres goal established by the FRFTP Roundtable (38,462 acres).

EXISTING BIOMASS MARKETS

According to the CROP analysis, an estimated 60 million board feet (MMBF) of sawlogs could be used to produce lumber, house logs, and utility poles and pilings. Another 78 MMBF of smaller logs (≥7 inches but <12 inches) could be used to produce rough sawn lumber, posts, and poles, landscaping ties, and mine props. Markets for these products currently exist. They are already sold in Colorado**,** but most of the supply comes from out of state. Approximately 90 to 100 percent of the wood products currently exchanged in markets in Colorado are imported (Lynch and Mackes 2001).

TABLE 12
FRONT RANGE BIOMASS YIELDS

Estimate Source	No. of Acres Treated/Yr.	Total Biomass Yielded /Yr. (gT)	Total Biomass Yielded/Ac. /Yr. (tons)	Woody Biomass[1] Yielded/Yr. (gT)	Woody Biomass[1] Yielded/Ac./Yr. (gT)
FRFTP Roundtable	38,462[2]	300,000[3]	7.8[4]	195,000[5]	5.1[6]
Mater Eng. Ltd.[7]	30,400	248,331	8.2	111,698[8]	3.7

[1]Woody material < 7 inches in diameter
[2]Table in fn. 20 on page 31 of FRFTP Roundtable, 2006
[3]Table in fn. 25 on page 33 of FRFTP Roundtable, 2006
[4]300,000/38,462 = 7.8
[5](60 + 70)/2 X 300,000 = 195,000
[6]195,000 gT/38,462 acres = 5.07 gT/Ac
[7]Includes estimates from national forest and BLM lands only
[8]Includes all biomass materials <7" diameter and ½ the volume of logs ≥7" and ≤12"

EMERGING OR POTENTIAL MARKETS

Undeveloped markets exist on the Front Range for woody biomass (again, biomass < 7 inches in diameter), and the volumes are substantial. The CROP analysis estimated over 111,000 gT of woody biomass would be offered annually from public lands during the period 2006 - 2010. Extrapolating from data in footnotes 20 and 25 in the FRFTP Roundtable report, approximately 195,000 gT per year of woody biomass would be yielded if the FRFTP Roundtable proposal were implemented. If what is proposed in this paper were adopted, still more woody biomass would be offered because of the larger number of acres treated annually, an estimated 105,588 acres. Hence, if 5.1 gT of woody biomass are yielded per acre per year as shown in Table 12, then an estimated 538,499 gT of woody biomass would be yielded annually under the current proposal.

Several uses of woody biomass have the potential to significantly offset the costs of fuels treatments. They include:

- *Bioheating* (using woody biomass to heat large buildings). For example, three hundred new public schools are anticipated along the Front Range and more than 500 existing schools will need replacement boilers over the next 25 years. It is estimated that each of these will require approximately 300 gT/year of woody biomass. The FRFTP Roundtable suggests bioheating offers the greatest potential for near-term use of woody biomass, pointing out that this proven technology has the potential to help cut fuels treatment costs by more than 40 percent (FRFTP Roundtable, p. 13).
- *Combined Heat and Power (CHP)* (using woody biomass to produce both thermal and electrical energy to office complexes, medical facilities, and large industrial buildings through cogeneration plants). While there currently are no CHP facilities located on the Front Range, investors have expressed interest in locating in Colorado if consistent supplies of woody biomass are available. An estimated 88,000 gT/year would be needed to supply a 5 MW CHP facility.
- *Co-fired Power* (combining woody biomass with coal to produce electricity). For example, Aquila Inc.'s W.N. Clark Power Plant in Cañon City, Colorado, burns 400 to 500 short tons of coal per day and is permitted to burn a maximum of 20 to 25 gT of wood per day. The facility can currently handle woody material up to 2 inches in diameter and use 4 to 5 gT per day (McNeil Technologies 2003).
- *Bioenergy* (using woody biomass for the production of electrical power from small, efficient generating plants). No bioenergy facilities are currently located on the Front Range, but they could be, and their electrical output could be designed to fit the supply of woody biomass available, by producing 20, 18, 10, or even 5 MW of energy (see Table 13). Renewable power generation facilities such as the Fairhaven Power Company in Eureka, California, produces 18 MW of electricity from 260,000 gT/year of wood waste in the form of bark, sawdust, wood chips, and wood shavings (DG Energy). The capital outlay for a plant of this kind is approximately $30 million.
- *Wood pellets* (using woody biomass to produce wood pellets for home heating). Lynch and Mackes (2002) reported that 60,000 tons of wood pellets were consumed in Colorado, all of which were imported. There currently is interest in opening a wood-pelletizing plant in Colorado. If this occurs, the effect on supply of woody biomass could be substantial. Forest Energy Systems — a company specializing in biomass solutions for commercial and industrial applications — uses approximately150,000 gT per year of woody biomass to produce 65,000 tons of biomass fuel pellets at their Show Low, Arkansas plant (House Committee on Resources).
- *Oriented Strand Board (OSB)*(using woody biomass to produce wood-based composite panels). Fuel reduction treatments removing small-diameter aspen, true firs, lodgepole pine, and ponderosa pine could be used to provide raw material for OSB production. Unfortunately, an OSB plant in Olathe, Colorado closed in 2002 because of wood supply problems, high raw material transportation costs to its western Colorado location, and a depressed product market (Lynch and Mackes 2001). Lynch and Mackes (2001) reported that Colorado could likely support as many as two OSB plants if centrally located along the Front Range.

TABLE 13
BIOMASS REQUIREMENTS FOR POWER GENERATION FACILITIES

MW	Annual Biomass Requirements (gT/yr)	Capital Requirements ($million)
18	260,000	$30
13	188,000	$22
10	143,000	$17
8	114,400	$13
5	87,600	$12[1]

[1]McNeil Technologies 2005

IMPORTANCE OF CONTINUITY OF SUPPLY

The Forest Service is the largest land owner on the Front Range with 60 percent of the forest acreage. The agency owns 43 percent of the forest land in the lower montane. Declining timber sales from national forests have contributed to many firms going out of business (Lynch and Mackes 2002). For many potential investors in woody biomass utilization facilities, the key question is whether long-term supply agreements—10 years or more—can be made. When these are possible, investors are much more willing to put forth the investment dollars needed for construction of bioheating, CHP, co-fired energy, bioenergy, wood-pelletizing, or OSB facilities.

For the Forest Service, the cost of accomplishing fuel hazard reduction treatments under long-term stewardship contracts would be based on several factors. Internal costs such as NEPA analysis and other aspects of preparing and administering long-term contracts would be considered in addition to external contracting costs (Sample 2007). A further challenge is that agency funding gets swept into a reserve to cover the increasing costs of wildfire suppression, as it is for all national forest management programs. So funding a systematic fuel hazard reduction program will be a challenge even though it would serve to reduce future fire suppression costs (Lenart 2006).

Transportation costs significantly affect the supply of woody biomass because of its low value per unit of weight. Transporting woody biomass distances that exceed 65 miles can quickly make investments in renewable energy facilities economically unfeasible (Fuffatto). The use of concentration yards can extend this distance by minimizing the number of trips needed and making raw material more uniform in quality because of economies of scale. Hence, establishing and operating concentration yards at strategic locations should be considered and is probably desirable.

Woody biomass utilization is a critical factor in any program aimed at reducing the threat of high-severity wildfires to critical watersheds along the Front Range because it can significantly lower treatment costs. As noted above, the FRFTP Roundtable suggests that hazardous fuels treatment costs can be reduced by 40 percent. In fuels treatments conducted under the White Mountain Stewardship Contract on the Apache-Sitgreaves National Forest in Arizona: "Economics of scale and the increasing value of wood-based energy contributed to reducing the cost of mechanical treatments . . . *by half* (emphasis added), from an average of $500-600 per acre to an average of $250-300 per acre" (Sample, 2007). Many opportunities are available for woody biomass utilization on the Front Range, but there is no "silver bullet." Instead, several opportunities exist, and they would probably involve one or more concentration and sorting facilities to reduce transportation costs and achieve efficiencies associated with raw material quality and uniformity. But the biggest hurdle to overcome is continuity of supply, which must be assured if investors are going to make the necessary investments in plant and equipment.

STRATEGY FOR WILDFIRE HAZARD REDUCTION

The FRFTP Roundtable developed a ten-part strategy for fire risk mitigation and ecological restoration along the Front Range (see Appendix A), which fully recognizes that a change in public policy of this scope requires a concerted, comprehensive, and sustained effort.

Protecting critical Front Range watersheds from high-severity wildfires can be one component of this larger effort, as the commonalities in watershed and community protection are substantial in terms of what is required and how it should be accomplished. Hence, efforts to protect critical watersheds and communities from wildfire should be joined. When and where they are consistent with ecological restoration, all three should be joined.

Water is both essential and scarce along the Front Range, and the threat of high-severity wildfire to its supply is direct and real. The high degree of public awareness of this threat, combined with the relatively small number of water providers, offer a unique opportunity to implement public policy to reduce the threat of high-severity wildfires.

Water providers should consider preparation of *critical watershed wildfire protection plans* for each critical watershed in which they have an interest. They would be comparable to the Community Wildfire Protection Plans provided for in the Healthy Forests Restoration Act of 2003. Where two or more water providers have an interest in a given watershed, plans should be prepared collaboratively. The plan should include several features such as:

- Engagement of concerned federal, state, and local government agencies;
- Open participation of all interested parties;
- Preparation of a base map of the watershed that includes:
  - ✓ Major terrain features
  - ✓ Forest and range vegetation types
  - ✓ Local communities,
  - ✓ Roads, major power and communication lines, and
  - ✓ Water supply structures and conveyances.
- An assessment of
  - ✓ Vegetative fuel hazard,
  - ✓ Risk of wildfire occurrence,
  - ✓ Potential impacts on water supply and infrastructure, communities, and other human values.
- A fuel hazard reduction program including:
  - ✓ Priorities,
  - ✓ Treatments,
  - ✓ Roles and responsibilities,
  - ✓ Specific timetables,
  - ✓ Funding needs,
- A monitoring program to assess implementation of the fuel hazard reduction program.

Completed *critical watershed wildfire protection plans* should be communicated to policy makers, community leaders, and local citizens.

Development and implementation of *critical watershed wildfire protection plans* would provide a viable mechanism for reducing the hazard of high-intensity wildfires to critical Front Range watersheds. They are familiar, related to Community Wildfire Protection Plans, and are consistent with and promote the strategy of the FRFTP Roundtable.

The threat of high severity wildfires to critical watersheds of the Front Range of Colorado can be significantly reduced. A concerted effort is required; one that is focused, based on sound science, supported by the public, and sustained in implementation. Front Range water providers have a unique role to play because of their comparatively small number and, of course, the relative scarcity and essential nature of the resource they provide.

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APPENDIX A

Recommendations of the Front Range Fuels Treatment Partnership Roundtable

The Front Range Fuels Treatment Partnership Roundtable developed and recommended ten initiatives for Front Range community protection and forest restoration. The initiatives included suggested actions for federal, state, and local stakeholders and are listed below with minor editing.

A. Increase funding for treatments

1. Identify new state and local funding sources for treatments on state and private land.
    - *Colorado General Assembly*: Authorize and appropriate direct funding for fire risk mitigation on non-federal land.
    - *Colorado State Forest Service*: Identify and pursue opportunities for those dependent on good forest health, e.g., municipal water supplies and consumers, to contribute to treatment costs.
    - *County Commissioners*: Create Forest Improvement Districts (self-taxed) for the purpose of funding and carrying out treatments in the wildland-urban interface.
2. Increase treatment incentives for private landowners.
    - *Colorado General Assembly*: (a) Enact a tax-credit program to encourage treatments on private lands; (b) revise the Forest Agriculture Tax Program to allow eligibility in the program if landowners reduce the risk of wildfire (even if the resulting products do not generate a profit).
3. Advocate for additional federal funding for Front Range treatments.
    - *Colorado Congressional Delegation*: (a) Seek increased funding for the federal State Fire Assistance Program to assist communities and non-federal landowners; (b) seek additional federal funding through hazardous fuels reduction programs.
    - *USDA Forest Service and other federal land management agencies*: Accelerate opportunities to use the Wyden Amendment Authority to extend federal land treatments onto adjacent non-federal land, when possible.
    - *Colorado State Forest Service*: Pursue opportunities to use the Good Neighbor Authority to extend private land treatments and contracts onto federal land when possible.

B. Reduce the cost of treatments

4. Increase appropriate application of prescribed fire and wildland fire use as a management tool.
    - *Colorado State Forest Service*: Lead the formation of a statewide Prescribed Fire Council to promote the appropriate use of fire and reduce barriers to the application of prescribed fire.
    - *Colorado General Assembly*: Initiate and pass a resolution supporting the establishment of a Prescribed Fire Council and the accomplishment of associated goals.

5. Increase utilization of woody biomass for facility heating.
    - *Colorado Congressional Delegation*: (a) Seek funding for the Biomass Commercial Use Grants in the Energy Policy Act of 2005 to subsidize a facility's cost of purchasing biomass; (b) seek funding for the Improved Biomass Use Grants in the Energy Policy Act of 2005.
    - *Colorado General Assembly*: (a) Require the feasibility of bioheating to be explored for new public buildings on the Front Range; (b) provide subsidies for the conversion of heating units to bioheating in existing state buildings; (c) Revise the state's renewable energy bill (Amendment 37) to include bioheating; (d) enact tax credits to encourage businesses to service bioheating consumers.
    - *Colorado Wood (Colorado State University)*: Act as a market place to bring together potential bioheating suppliers and consumers.
    - *Governor's Office of Energy Management and Conservation*: Explore the development of bioenergy tax districts.

6. Increase contract sizes and durations with stewardship contracts on federal land.
    - *Arapaho, Roosevelt, and Pike National Forests and other federal land management agencies*: Initiate long-term, landscape-scale stewardship contracts that promote achievement of forest restoration and Front Range community protection goals.
    - *Colorado State Forest Service*: Support stewardship contracts on federal land by identifying complementary projects on private and state lands.
    - *Non-Governmental Organizations*: Join multi-party monitoring groups to ensure stewardship contracts are implemented to achieve forest restoration and Front Range community protection goals and sound ecological practices.

C. Ensure local leadership and planning

7. Limit the growth of fire risk in the wildland-urban interface (WUI).
    - *County Commissioners*: (a) Include a wildfire component in comprehensive county land-use plans; (b) require Firewise compliance as part of the land development and building permit approval process; (c) require that fire risk information and Firewise educational material be provided to applicants for new building construction.
    - *Rock Mountain Insurance Information Association*: Work with insurance providers to ensure policy holders living in forested areas follow Firewise practices.
    - *Colorado Real Estate Commission*: (a) Add fire risk disclosure to the Seller' Property Disclosure (as currently exists for flood risk); (b) Require real estate brokers to provide educational materials on Firewise practices to buyers of forested properties.

8. Promote the development of Community Wildfire Protection Plans (CWPPs) for Front Range communities at risk.
    - *Colorado Congressional Delegation*: Establish dedicated funding for creation of CWPPs.
    - *County Commissioners*: Ensure all communities-at-risk within each county have CWPPs in place within three years.
    - *Local Governments, Fire Departments, and Fire Protection Districts*: Complete CWPPs for all communities-at-risk within three years.
    - Colorado State Forest Service: (1) Work with local planning teams to incorporate key findings of the Front Range Fuels Treatment Partnership Roundtable and related studies into CWPPS; (2) ensure continuity across CWPPs by providing state-level guidelines.
    - *Arapaho, Roosevelt, and Pike National Forests and other federal land management agencies:* (a) Support development of CWPPs by providing specialized natural resource knowledge, technical expertise, and financial assistance; (b) prioritize federal projects in approved CWPPs.
    - *Colorado Division of Emergency Management*: Provide technical expertise in community-level hazard-response planning.
    - *Non-Governmental Organizations*: (a) Inform communities about the benefits of CWPPS; (b) Encourage local participation and implementation of projects prioritized in CWPPs.

D. Set clear priorities and ensure progress toward common goals

9. Adopt a clear and common framework for prioritizing treatments.
    - *All Front Range land managers:* (a) Focus treatments in the lower montane life zone; (b) focus treatments in forest types above and below the lower montane on site-scale treatments to achieve community protection goals; (c) ensure treatment programs are consistent with goals established through CWPPs.

10. Convene follow-up Roundtable of forest stakeholders to ensure implementation of current recommendations and challenges.
    - *Front Range Fuels Treatment Partnership:* Convene follow-on Roundtable meetings every six months to review implementation progress and provide support, guidance, and leadership where and when needed
    - *Colorado General Assembly:* Adopt a resolution endorsing current Roundtable findings and recommendations and the formation of a follow-up Roundtable to monitor progress and address treatment challenges.