Lower Colorado Headwaters Phase 1 Watershed Assessment

Prioritization of watershed-based hazards to water supplies

Report Prepared for:

USDA Forest Service

Rocky Mountain Region

Bark Beetle Incident

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INTRODUCTION

This Phase 1 Watershed Assessment is designed to be the first phase of a process to identify and prioritize sixth-level watersheds based upon their hazards of generating flooding, debris flows and increased sediment yields following wildfires that could have impacts on water supplies. It is intended to expand upon current wildfire hazard reduction efforts by including water supply watersheds as a community value. The watershed assessment follows the ranking procedure for each of the four integral components as prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009).

This Phase 1 Watershed Assessment is one of 15 that are being completed for the Bark Beetle Incident team in the Rocky Mountain Region (Region 2) of the USDA Forest Service (Figure 1). The Bark Beetle Incident team covers the following three National Forests:

1. White River National Forest
2. Medicine Bow-Routt National Forests
3. Arapaho-Roosevelt National Forests

Phase 2 of the Watershed Assessment process would be to gather the key water supply stakeholders to communicate the suggested process, show them the results of Phase 1, listen to any suggested changes, make appropriate changes and build collaborative support for the assessment process. The stakeholder process is critical to local support for the results of the assessment, and the effectiveness of implementing recommendations that would come out of the assessment process.

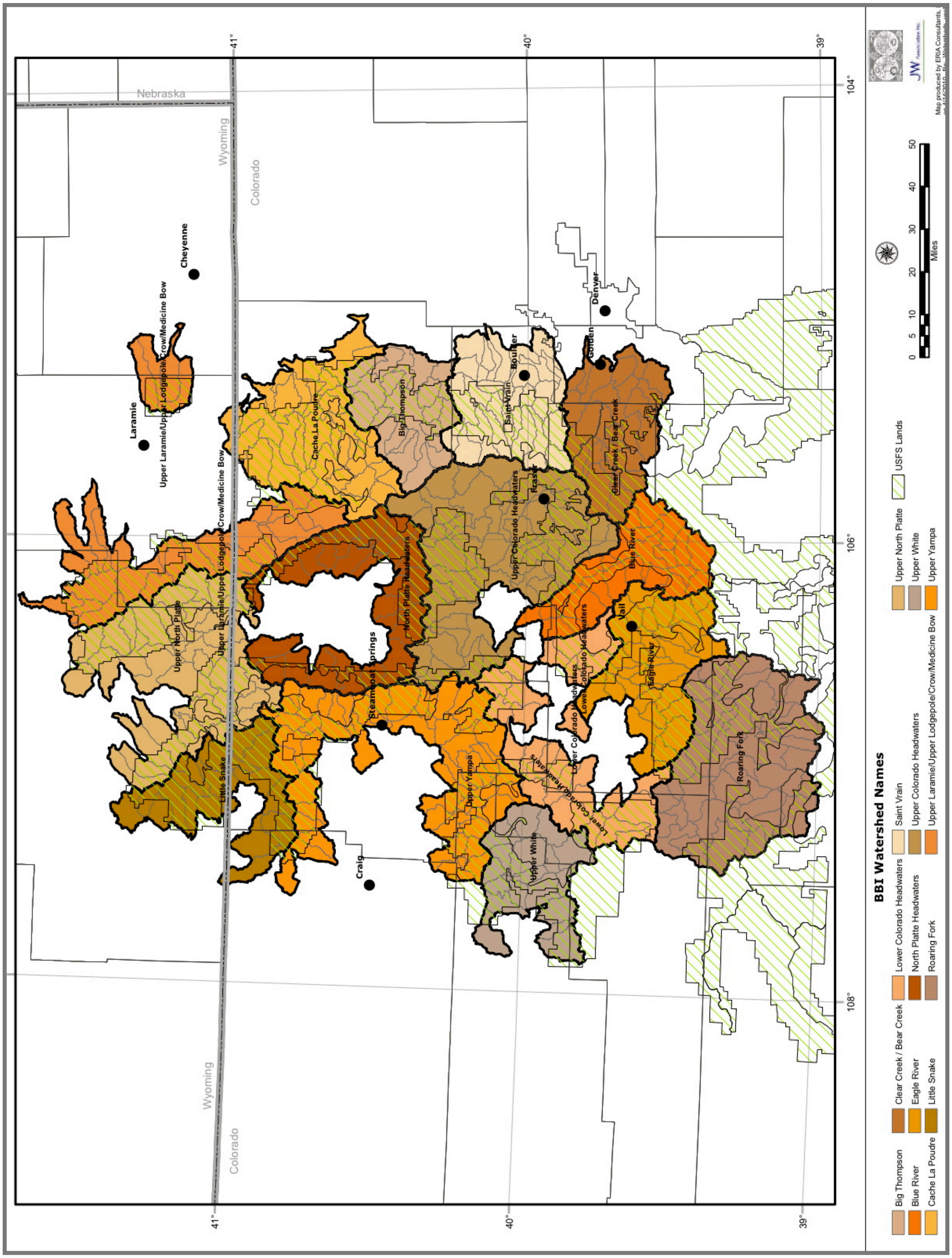

Figure 1. Bark Beetle Incident Phase 1 Watersheds

WATERSHED DESCRIPTION

The Lower Colorado Headwaters watershed is the lower portion of the Colorado Headwaters watershed. This is the headwaters of the Colorado River in Colorado. An assessment on the other portion of this watershed, the Upper Colorado Headwaters watershed, has been previously completed. For that previous assessment, the Colorado Headwaters watershed was divided into upper and lower because the entire watershed was too large. The upper and lower watershed divisions were maintained for this assessment. This watershed assessment is designed to assess hazards from forest fires to water supply. Therefore, the subwatersheds that are mostly non-forested were eliminated from this watershed assessment.

The Lower Colorado Headwaters Watershed is approximately 775,992 acres in area and is part of one fourth-level[1] (eight-digit) watershed (HUC 14010001). For this watershed assessment, nine sixth-level watersheds were eliminated based upon their wildfire hazard, ruggedness, and an examination of how well they fit into this assessment. The Lower Colorado Headwaters watershed used in this analysis is 579,684 acres, contains nine fifth-level watersheds and 27 sixth-level watersheds, which are the analysis units for this watershed assessment (Front Range Watershed Protection Data Refinement Work Group 2009). The Lower Colorado Headwaters watershed and its fifth-level and sixth-level watersheds are shown on Figure 2 and listed in Table 1.

[1] The watersheds that were used are part of the existing national network of delineated watersheds. Hydrologic Unit Codes (HUCs) are nested watersheds and are designated numerically by levels (Federal Geographic Data Committee 2004). Sixth-level HUCs or watersheds, use the 11th and 12th digits in the HUC code. Fifth-level HUCs use the ninth and 10th digits in the HUC code.

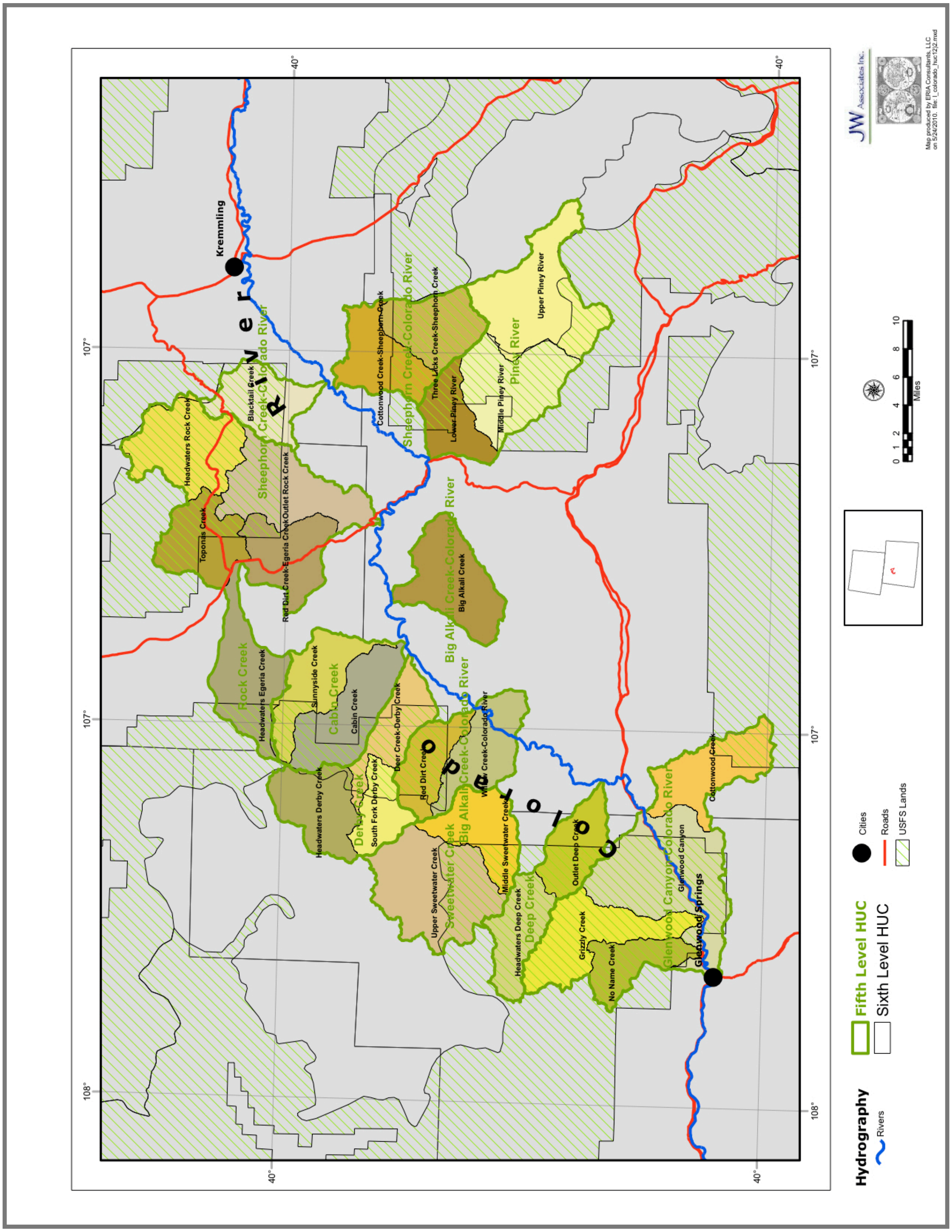

Figure 2. Lower Colorado Headwaters Watershed Analysis Area[2]

[2] The fifth-level watersheds are shown in Figure 2.

Table 1. Fifth-level and Sixth-level Watersheds in Lower Colorado Headwaters Watershed[3]

Fifth-level Watershed	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)	Map #
Piney River HUC 1401000108	Upper Piney River	35,461	140100010801	200
	Middle Piney River	26,108	140100010802	201
	Lower Piney River	14,075	140100010803	202
Sheephorn Creek-Colorado River HUC 1401000109	Blacktail Creek	18,056	140100010902	203
	Three Licks Creek-Sheephorn Creek	18,306	140100010903	204
	Cottonwood Creek-Sheephorn Creek	18,023	140100010904	205
Rock Creek HUC 1401000110	Headwaters Rock Creek	26,782	140100011001	206
	Headwaters Egeria Creek	23,668	140100011003	207
	Toponas Creek	18,653	140100011004	208
	Red Dirt Creek-Egeria Creek	19,256	140100011005	209
	Outlet Rock Creek	27,263	140100011006	210
Cabin Creek HUC 1401000111	Sunnyside Creek	19,045	140100011101	211
	Cabin Creek	23,860	140100011102	212
Derby Creek HUC 1401000112	Headwaters Derby Creek	19,614	140100011201	213
	South Fork Derby Creek	11,526	140100011202	214
	Deer Creek-Derby Creek	15,013	140100011203	215
Sweetwater Creek HUC 1401000113	Upper Sweetwater Creek	36,193	140100011301	216
	Middle Sweetwater Creek	17,813	140100011302	217
Deep Creek HUC 1401000114	Headwaters Deep Creek	16,190	140100011401	218
	Outlet Deep Creek	15,125	140100011402	219
Big Alkali Creek-Colorado River HUC 1401000115	Big Alkali Creek	24,379	140100011502	220
	Red Dirt Creek	13,830	140100011504	221
	Willow Creek-Colorado River	19,199	140100011507	222
Glenwood Canyon-Colorado River HUC 1401000116	Cottonwood Creek	20,628	140100011601	223
	Grizzly Creek	24,799	140100011602	224
	No Name Creek	13,175	140100011603	225
	Glenwood Canyon	43,644	140100011604	199
	Total Area	**579,684**		

[3] Map numbers are used in Figures 3, 6 and 9

WATERSHED ASSESSMENT

The potential of a watershed to deliver sediments following wildfire depends on forest and soil conditions, the physical configuration of the watersheds, and the sequence and magnitude of rain falling on the burned area. High-severity fires can cause changes in watershed conditions that are capable of dramatically altering runoff and erosion processes in watersheds. Water and sediment yields may increase as more of the forest floor is affected by fire.

This Phase 1 - Lower Colorado Headwaters Watershed Assessment provides the analysis for the first three components specified in the Front Range Watershed Protection Data Refinement Work Group (2009) procedure. It provides the analysis for: wildfire hazard, flooding or debris flow hazard, and soil erodibility. This Phase 1 assessment then combines those three components into a composite hazard ranking. This report discusses the technical approach for each component and the process used to assemble the watershed ranking.

The categories used in the prioritization are numbered one though five, with one being the lowest ranking and five being the highest. The numeric ranges for each category are as follows;

Category 1 - 0.5 to 1.49
Category 2 - 1.5 to 2.49
Category 3 - 2.5 to 3.49
Category 4 - 3.5 to 4.49
Category 5 - 4.5 to 5.49

The categories are used in this analysis for the purpose of comparing watersheds to each other within the Lower Colorado Headwaters watershed. Comparisons with other watershed assessments are not valid because this approach prioritizes watersheds by comparing them to the other sixth-level watersheds only in this watershed assessment area.

Component 1 - Wildfire Hazard

The forest conditions that are of concern for the assessments are the wildfire hazard based on existing forest conditions. The wildfire hazard (Flame Length) was determined using the Fire Behavior Assessment Tool (FBAT) (http://www.fire.org) which is an interface between ArcMap and FlamMap. The input spatial data were collected from LANDFIRE project (http://www.landfire.gov/).

After a mountain pine beetle outbreak there are substantial increases in the amount of fine dead fuels in the canopy. The majority of these fuels remain in the canopy for 2-3 years post outbreak (Knight 1987, Schmid and Amman 1992). Therefore, certain input spatial data sets were updated based on Mountain Pine Beetle (MPB) mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey (ADS) Data from the years 2002-2007 (http://www.fs.fed.us/r2/resources/fhm/aerialsurvey/). The assumptions used in the FBAT model are presented in Appendix A.

The flame length results were divided into five categories of wildfire hazard ranging from lowest (Category 0) to highest (Category 4). The flame length categories that were used are;

Flame Length Category 0 - 0 meters

Flame Length Category 1 - 1 to 10 meters

Flame Length Category 2 - 11 to 25 meters

Flame Length Category 3 - 26 to 40 meters

Flame Length Category 4 - >40 meters

Figure 3 shows the results of the wildfire hazard modeling. The results were categorized by sixth-level watershed into five categories that are used throughout the analysis (see Table B-1 in Appendix B) using the following formula.

Wildfire Hazard Ranking = (Percentage in Category 3 + Percentage in Category 4 * 2)

The categorized wildfire hazard by sixth-level watershed was mapped (Figure 4). The map shows that the highest hazards are in the following sixth-level watersheds: Three Licks Creek-Sheephorn Creek, Upper Piney River and Headwaters Rock Creek. Three watersheds were ranked as Category 4, which is the next highest category (see Table B-1 in Appendix B). Three Licks Creek-Sheephorn Creek was skewing the categorization because of its high wildfire hazard score. The wildfire hazard score for Three Licks Creek-Sheephorn Creek was manually given a score slightly higher than the next highest score (Table B-1 in Appendix B).

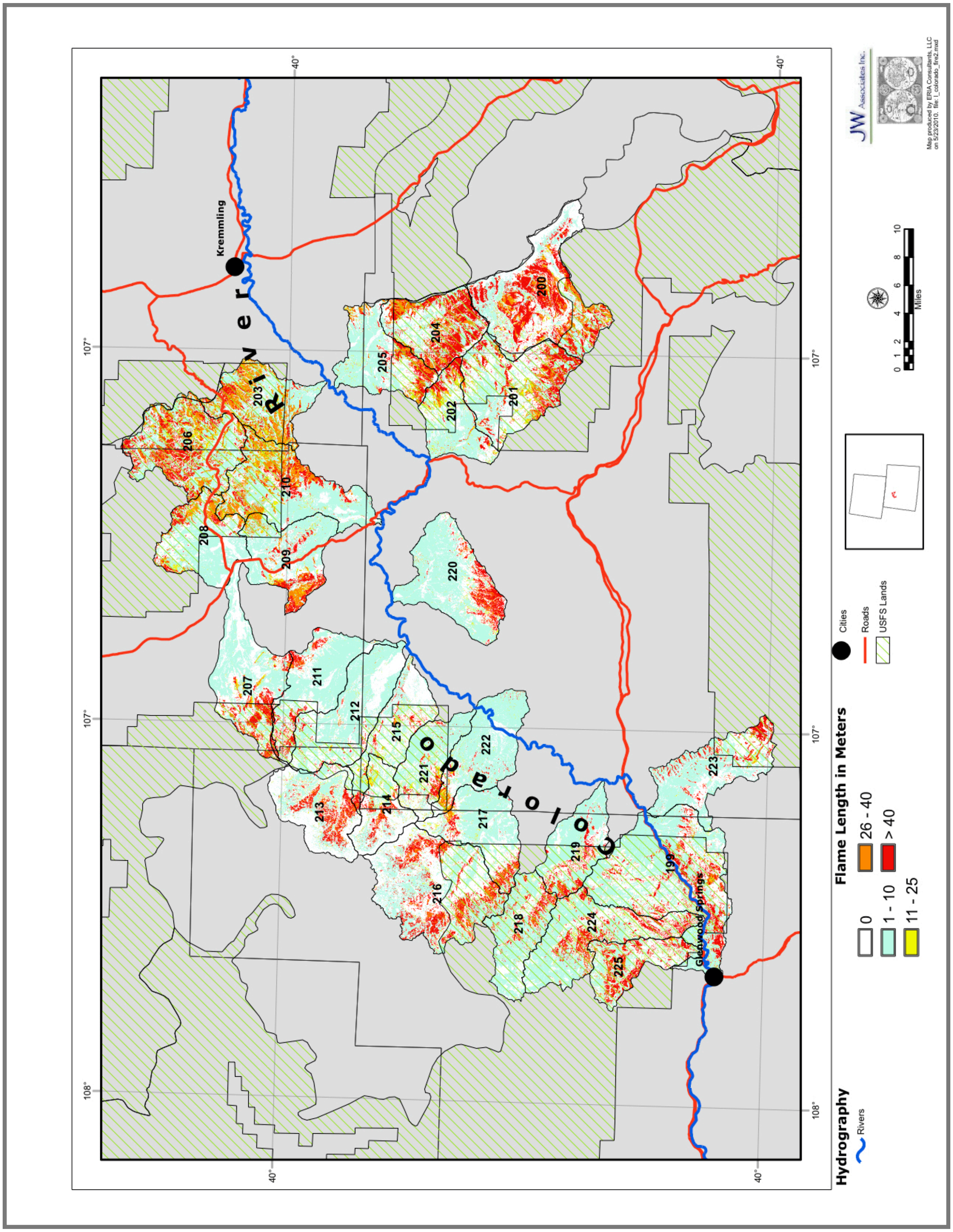

Figure 3. Lower Colorado Headwaters Watershed Wildfire Hazard Modeling Results

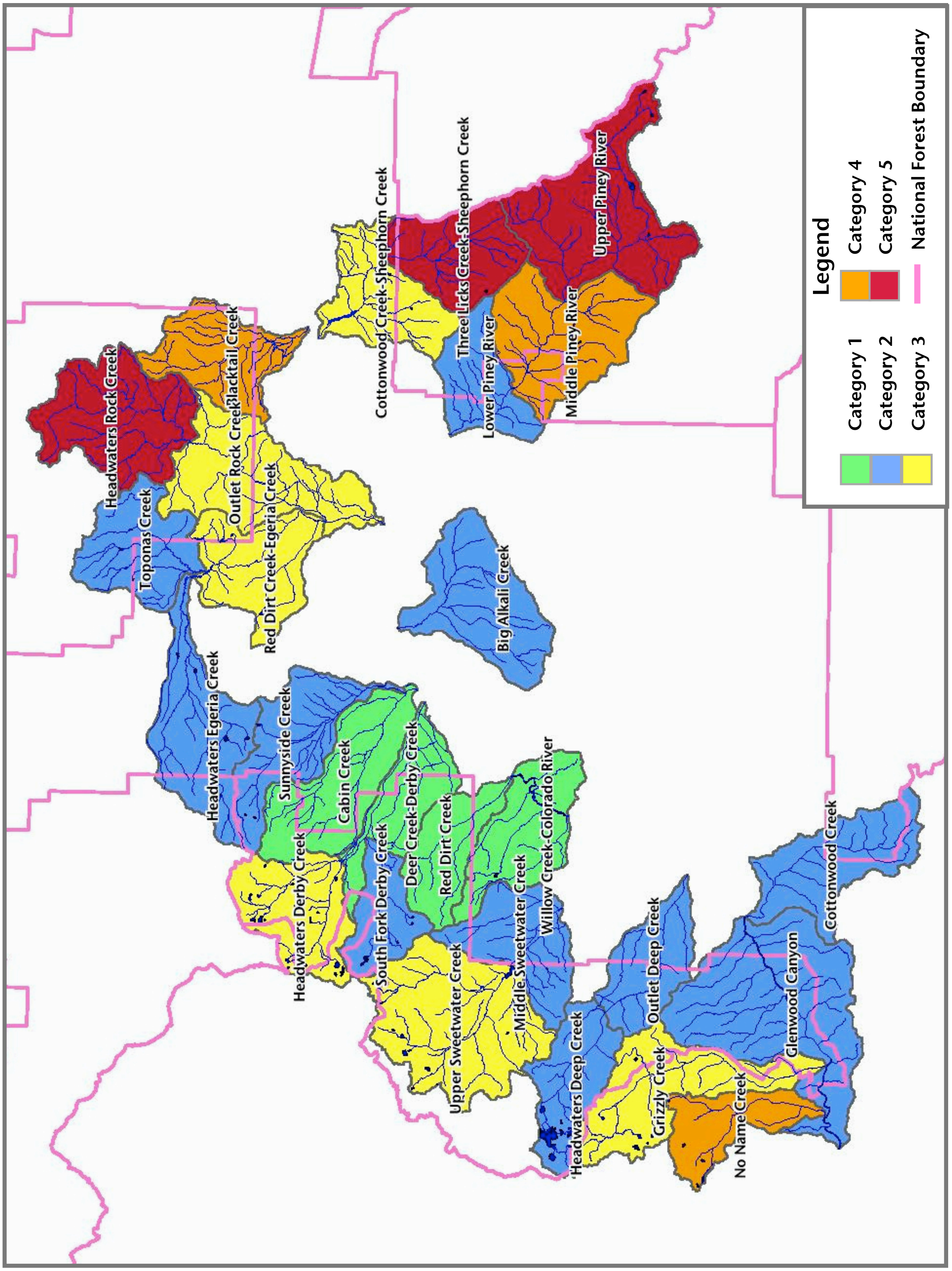

Figure 4. Lower Colorado Headwaters Watershed Wildfire Hazard Ranking

Component 2 - Flooding or Debris Flow Hazard

A combination of ruggedness and road density (miles of road per square mile of watershed area) was used to assess the flooding or debris flow hazard portion of the analysis. The two components, ruggedness and road density, are described below.

Ruggedness

Watershed steepness or ruggedness is an indicator of the relative sensitivity to debris flows following wildfires (Cannon and Reneau 2000). The more rugged the watershed, the higher its sensitivity to generating debris flows following wildfire (Melton 1957). The Melton ruggedness factor is basically a slope index.

Melton (1957) defines ruggedness, R, as;

$$R = H_b A_b^{-0.5}$$

Where A_b is basin area (square feet) and H_b is basin height (feet) measured from the point of highest elevation along the watershed divide to the outlet.

The ruggedness result in some watersheds was adjusted because they do not accurately reflect the slope in those watersheds. Those situations are most common in composite watersheds because they are disconnected from their headwaters. These watersheds can have a high hazard for debris flows because they contain a main stem of a creek or river with several steep first order streams as tributaries. In those situations, the ruggedness calculation was adjusted up by reducing the watershed area. These adjustments were completed on the following watersheds; Upper Piney River, Middle Piney River, Lower Piney River, Three Licks Creek-Sheephorn Creek, Cottonwood Creek-Sheephorn Creek, Outlet Rock Creek, Willow Creek-Colorado River, and Glenwood Canyon.

Figure 5 displays the categorized ruggedness for the Lower Colorado Headwaters Watershed. The tabular results are presented on Table B-2 in Appendix B. The map (Figure 5) shows that the most rugged sixth-level watersheds are No Name Creek, Red Dirt Creek, Lower Piney River, Deer Creek-Derby Creek, Willow Creek-Colorado River and Cottonwood Creek-Sheephorn Creek.

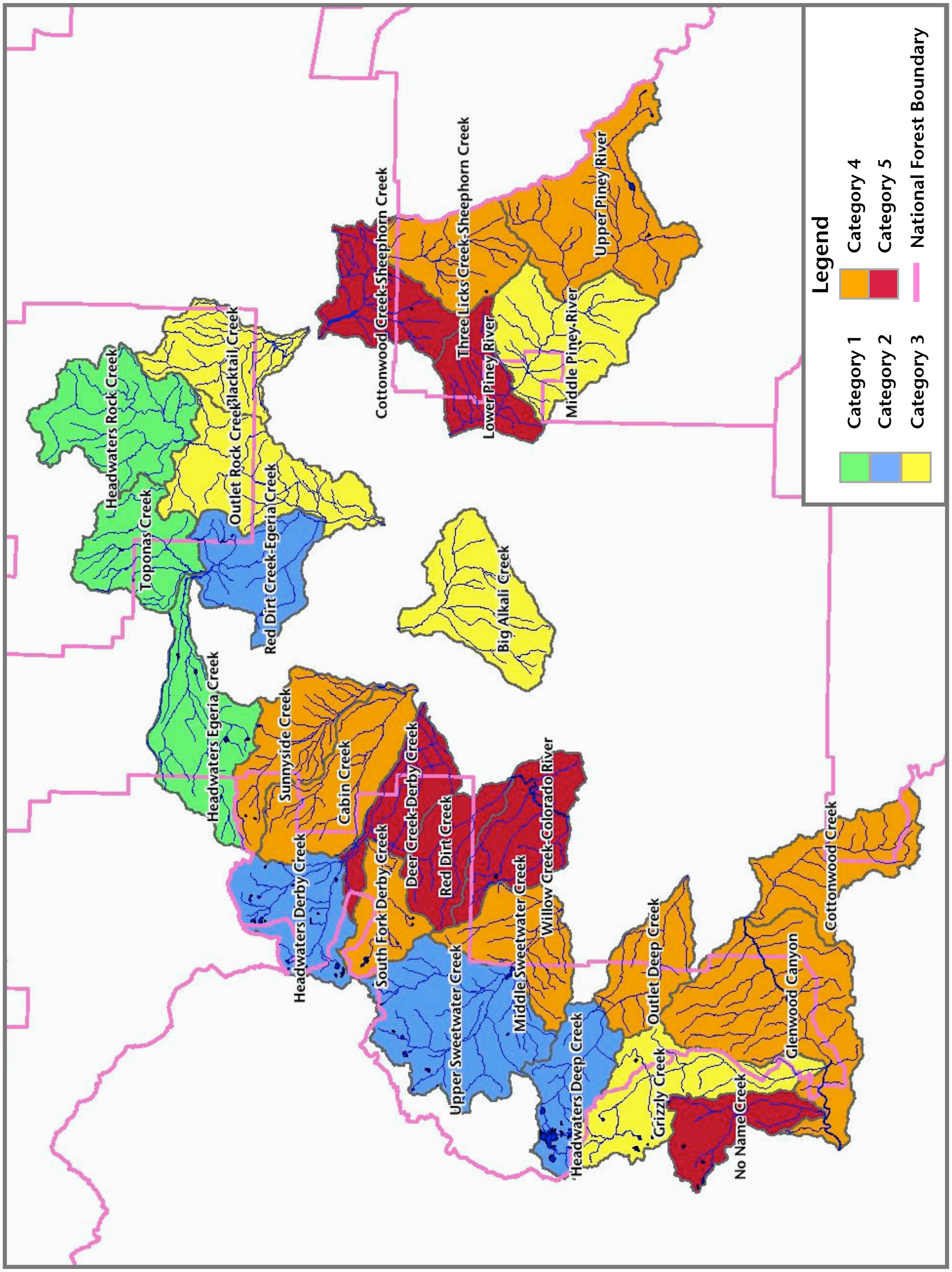

Figure 5. Lower Colorado Headwaters Watershed Ruggedness Ranking

Road Density

Roads can convert subsurface runoff to surface runoff and then route the surface runoff to stream channels, increasing peak flows (Megan and Kidd 1972, Ice 1985, and Swanson et al. 1987). Therefore, watersheds with higher road densities have a higher sensitivity to increases in peak flows following wildfires. Road density in miles of road per square mile of watershed area was used as an indicator of flooding hazard. The U.S. Forest Service roads data was used on National Forest System (NFS) lands because it is the most accurate roads data for those roads in the forest. On all other lands the U.S. Census Bureau's Tiger database was used because it is a consistent roads data layer (Figure 6).

Road densities were adjusted in some watersheds for two separate reasons. One reason for adjusting the road density was the situation where a watershed had a much higher road density than the next highest value, so that watershed was skewing the categorization. In that situation, the watershed was manually given a road density slightly higher than the next highest score.

The other situation where road density was adjusted is where some of the roads within a watershed were within towns, developed areas, or outside the forested areas of the watershed. The roads that are of interest in this analysis are those roads that would increase the risk of flooding or debris flows following wildfires in forested areas. The watersheds were all examined by looking at the roads data overlain on digital images and vegetation mapping. If it was found that there were significant lengths of road outside forested areas, the road density in those watersheds was adjusted down based on ocular estimates.

Road density in the Headwaters Rock Creek watershed was adjusted down. The adjustments are displayed on Table B-3 in Appendix B.

Figure 7 displays the categorized road density for the Lower Colorado Headwaters Watershed and tabular results are presented in Appendix B (Table B-3). Figure 7 shows that the highest rankings are in Headwaters Rock Creek and Headwaters Deep Creek.

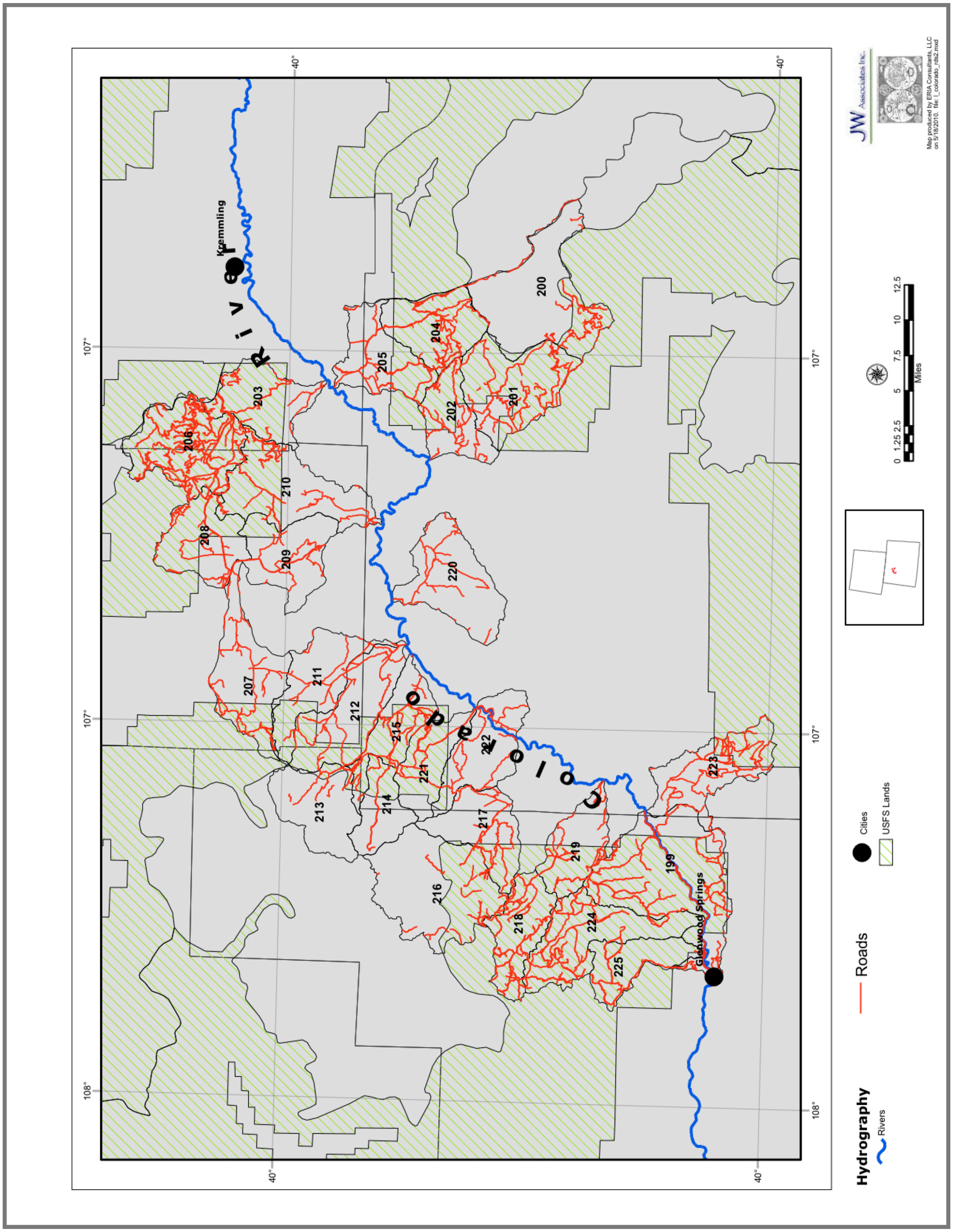

Figure 6. Lower Colorado Headwaters Watershed Roads Map

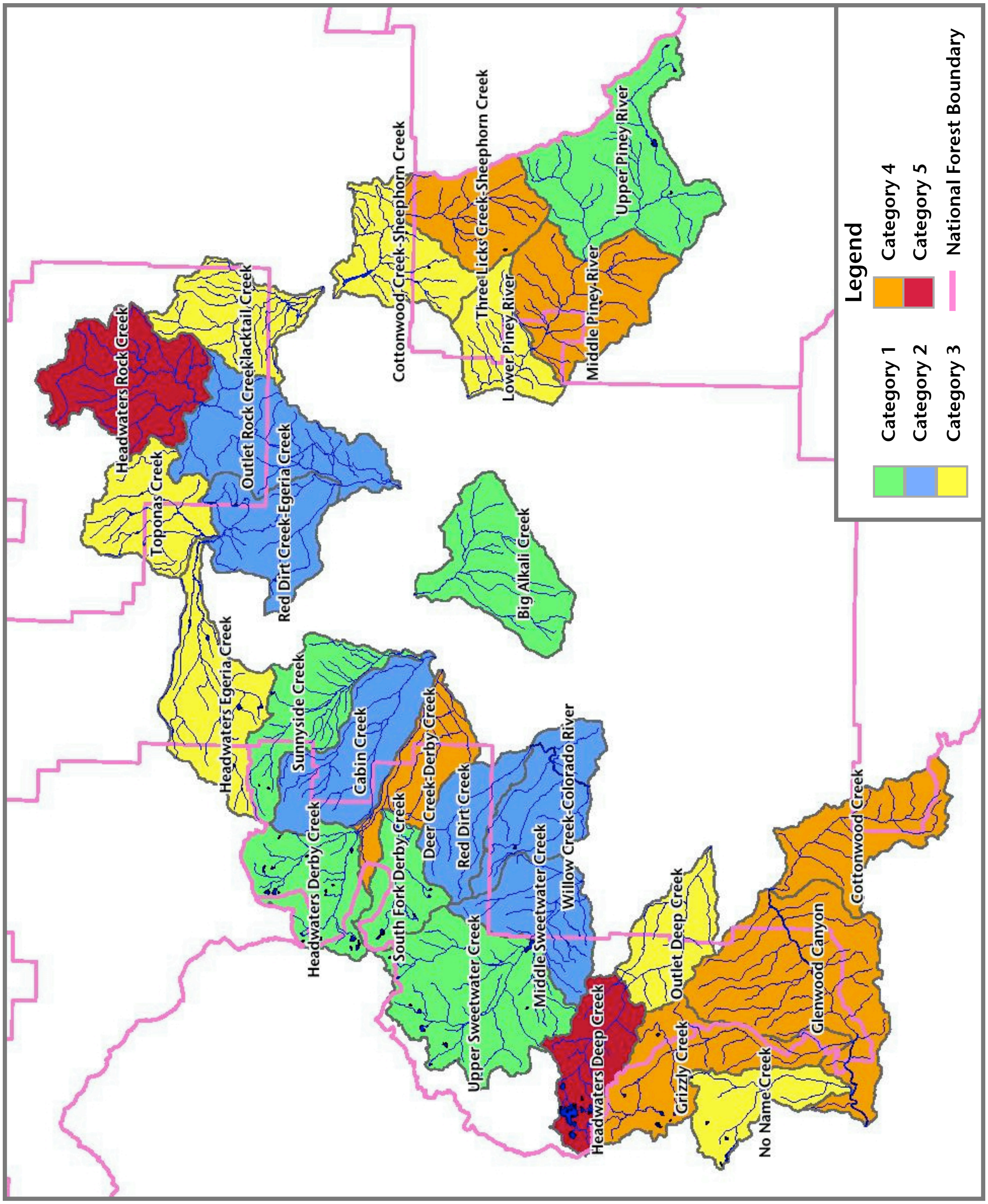

Figure 7. Lower Colorado Headwaters Watershed Road Density Ranking

Flooding or Debris Flow Hazard Ranking

The Flooding or Debris Flow Hazard is the combination of ruggedness and road density. The procedure from the Front Range Watershed Work Group (2009) assigned ruggedness a higher value than road density in this ranking. While ruggedness is the most important factor, an increase in road density will magnify the effects of ruggedness on the flooding/debris flow hazard. Accordingly, the analysis for flooding or debris flow hazard for the Lower Colorado Headwaters Watershed used the following formula. The results of this calculation were then re-categorized into five hazard rankings.

Flooding or Debris Flow Hazard Ranking = (Road Density Ranking + Ruggedness Ranking * 2)

Figure 8 shows that areas of the watershed with high road densities and high ruggedness rank high in this combined factor. The best way to look at this map is to look at a single watershed on the ruggedness and road density maps, noting the rankings on each. Then look at this map and see how they result in the final ranking for this component. The tabular results are presented in Table B-4 in Appendix B.

The highest ranked sixth-level watersheds are Deer Creek-Derby Creek, No Name Creek, Lower Piney River, Red Dirt Creek and Cottonwood Creek-Sheephorn Creek.

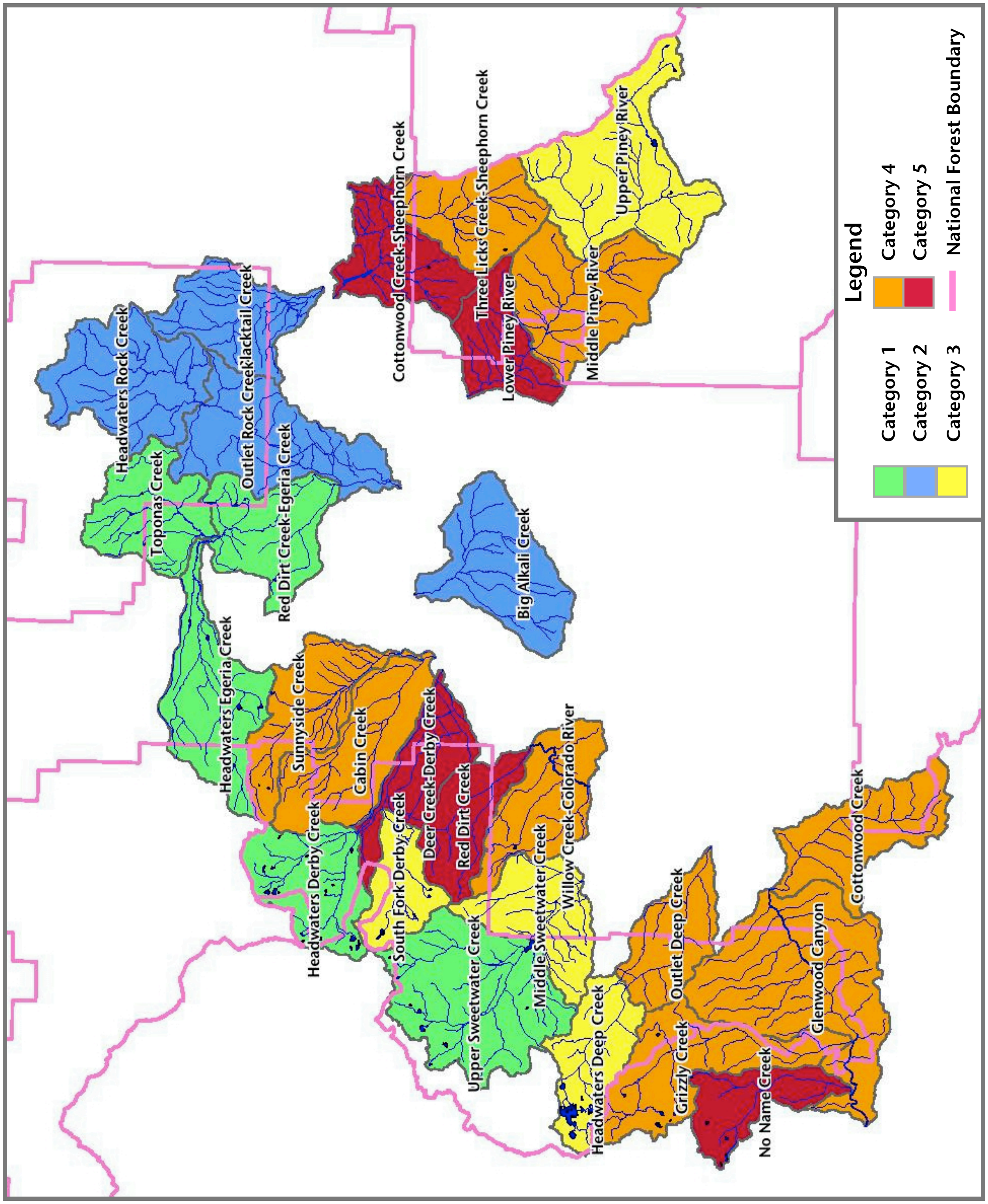

Figure 8. Lower Colorado Headwaters Watershed Flooding/Debris Flow Hazard Ranking

Component 3 - Soil Erodibility

High-severity fires can cause changes in watershed components that can dramatically change runoff and erosion processes in watersheds. Water and sediment yields may increase as more of the forest floor is consumed (Wells et al. 1979, Robichaud and Waldrop 1994, Soto et al. 1994, Neary et al. 2005, and Moody et al. 2008) and soil properties are altered by soil heating (Hungerford et al. 1991).

Two soils data sets were evaluated for use in this analysis. They were the U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS) STATSGO and SSURGO soils data. STATSGO data are relatively coarse soils data, created at a scale of 1:250,000 and are available for the entire watershed assessment area. SSURGO soils data do not cover all the watershed assessment area, though efforts by the NRCS are currently under way to produce an updated soils data layer.

The data used in this analysis is the U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS) SSURGO soils data combined with the U.S. Forest Service soils data. SSURGO data does not cover all the watershed but is available at a preferable scale (generally ranges from 1:12,000 to 1:63,360) than STATSGO data. The U.S. Forest Service soils data is comparable with the SSURGO data in scale and quality. Areas without SSURGO data were filled in with U.S. Forest Service soils data (Figure 9).

The soil erodibility analysis used a combination of two standard erodibility indicators: the inherent susceptibility of soil to erosion (K factor) and land slope derived from Unites States Geological Survey (USGS) 30-meter digital elevation models. The K factor data from the SSURGO spatial database was combined with a slope grid using NRCS (USDA NRCS 1997) slope-soil relationships (Table 2) to create a classification grid divided into slight, moderate, severe and very severe erosion hazard ratings.

Table 2. NRCS Criteria for Determining Potential Soil Erodibility

Percent Slope	K Factor <0.1	K Factor 0.1 to 0.19	K Factor 0.2 to 0.32	K Factor >0.32
0-14	Slight	Slight	Slight	Moderate
15-34	Slight	Slight	Moderate	Severe
35-50	Slight	Moderate	Severe	Very Severe
>50	Moderate	Severe	Very Severe	Very Severe

The potential soil erodibility hazard rankings are shown on Figure 10 and the tabular results are presented in Table B-5 in Appendix B. The map shows areas of high soil erodibility in the assessment area. The highest ranked sixth-level watersheds based on soil erodibility are Glenwood Canyon, Willow Creek-Colorado River, No Name Creek, and Outlet Deep Creek.

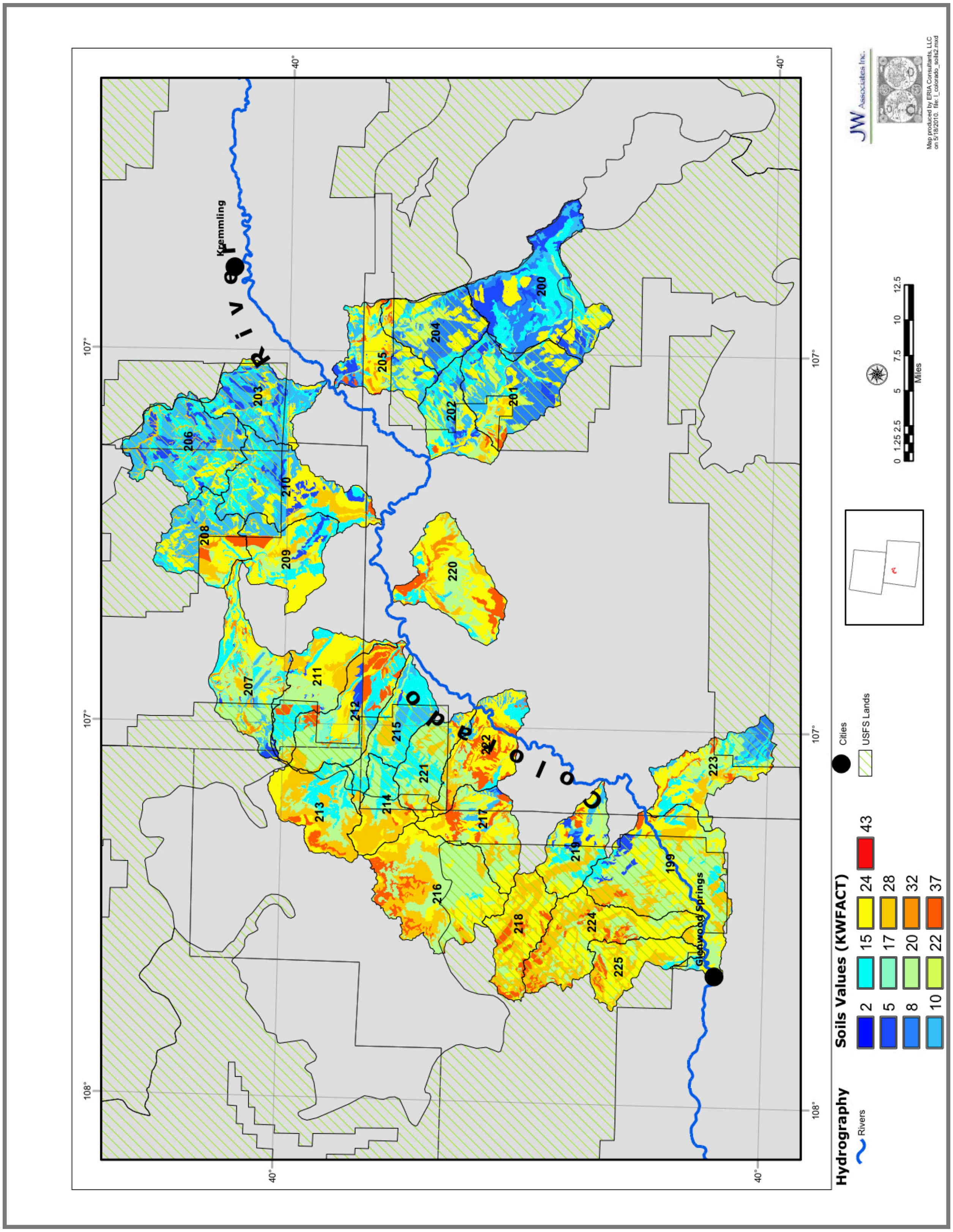

Figure 9. Lower Colorado Headwaters Watershed Soils K-Factor Map

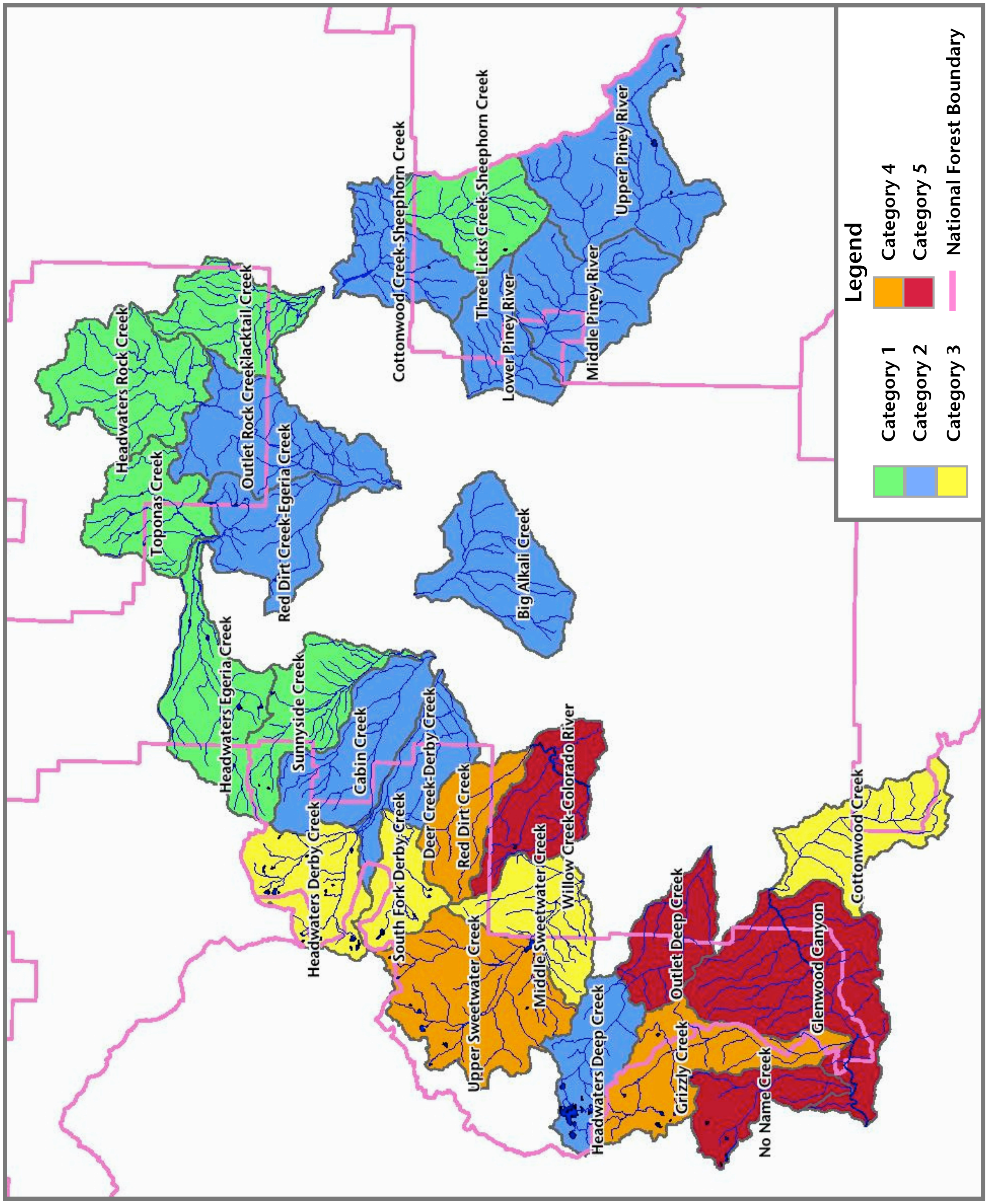

Figure 10. Lower Colorado Headwaters Watershed Potential Soil Erodibility Hazard Ranking

Composite Hazard Ranking

The Composite Hazard Ranking combines the first three components (Wildfire Hazard, Flooding/Debris Flow Hazard and Soil Erodibility) by numerically combining their rankings for each sixth-level watershed and then re-categorizing the results. The Composite Hazard Ranking map is useful in comparing relative watershed hazards based solely on environmental factors. Figure 11 shows the Composite Hazard Ranking for the Lower Colorado Headwaters Watershed. The tabular results that display the rankings for Wildfire Hazard, Flooding/Debris Flow Hazard and Soil Erodibility, as well as the composite rankings are presented in Table B-6 in Appendix B. The highest ranked sixth-level watersheds are No Name Creek, Glenwood Canyon, Outlet Deep Creek, Grizzly Creek, and Three Licks Creek-Sheephorn Creek. There are seven watersheds in Category 4. No Name Creek was skewing the categorization because of its high composite numeric rank. The composite numeric rank for No Name Creek was manually given a score slightly higher than the next highest score (Table B-6 in Appendix B).

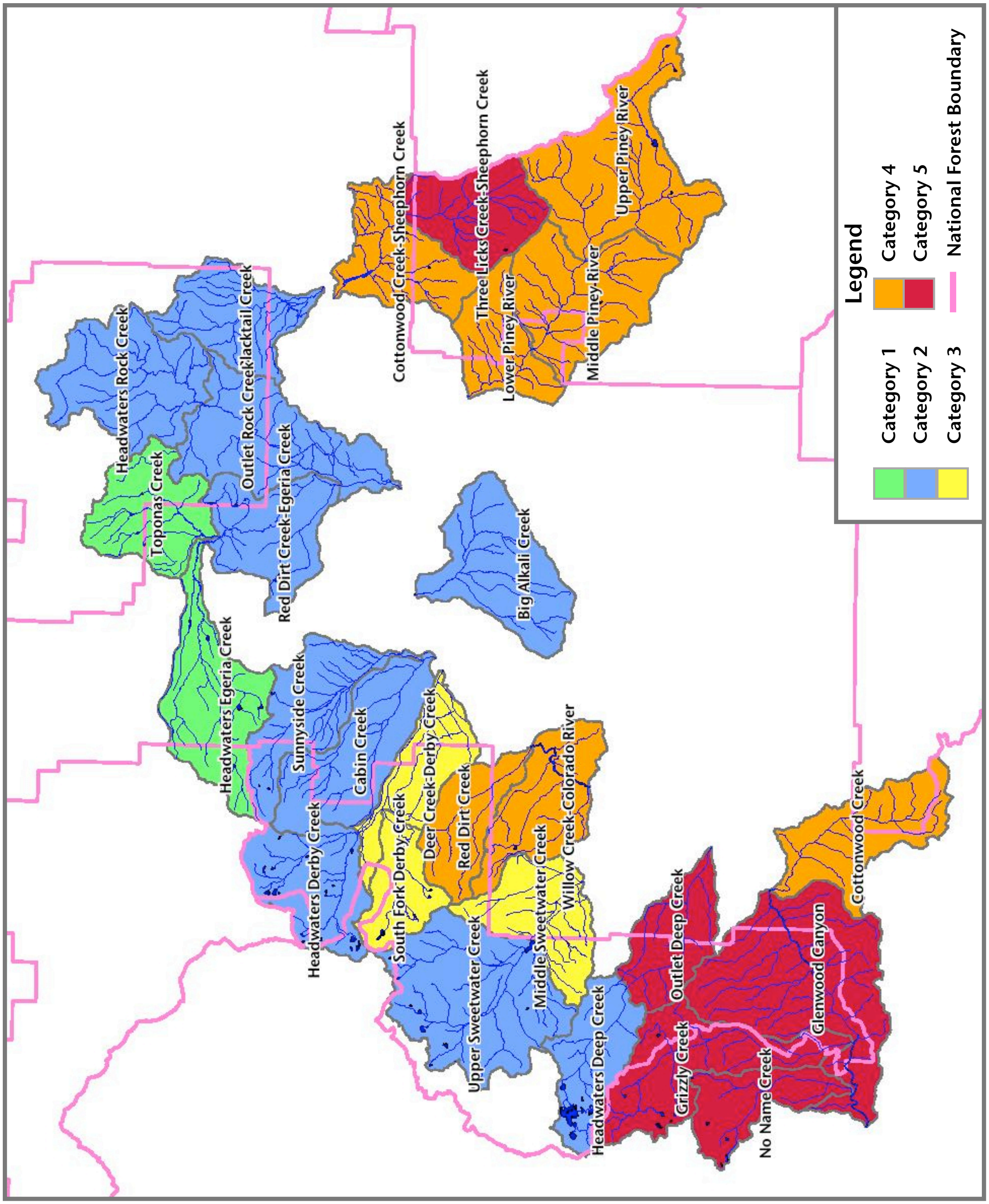

Figure 11. Lower Colorado Headwaters Watershed Composite Hazard Ranking

Component 4 - Water Supply Ranking

Surface water intakes, diversions, conveyance structures, storage reservoirs and streams are all susceptible to the effects of wildfires. The suggested approach from the procedure prescribed by the Front Range Watershed Protection Data Refinement Work Group (2009) is to first rank watersheds based upon the presence of water nodes.

Surface drinking water supply collection points from the Source Water Assessment and Protection (SWAP) Program (see http://www.cdphe.state.co.us/wq/sw/swaphom.html for basic information on the SWAP Program) were used to identify which sixth-level watersheds contain critical components of the public water supply infrastructure in Colorado. For this assessment, water nodes were defined as coordinate points corresponding to surface water intakes, upstream diversion points and classified drinking water reservoirs.

Water supply locations may not be identified in the state's database for some drinking water supply reservoirs that do not have associated direct surface water intakes. Also, some water supply reservoirs may not be identified in the SWAP database. The Water Supply map was modified to include these features by including all named reservoirs.

Figure 12 shows the sixth-level watersheds that have water supply locations in blue and those without water supply locations in green.

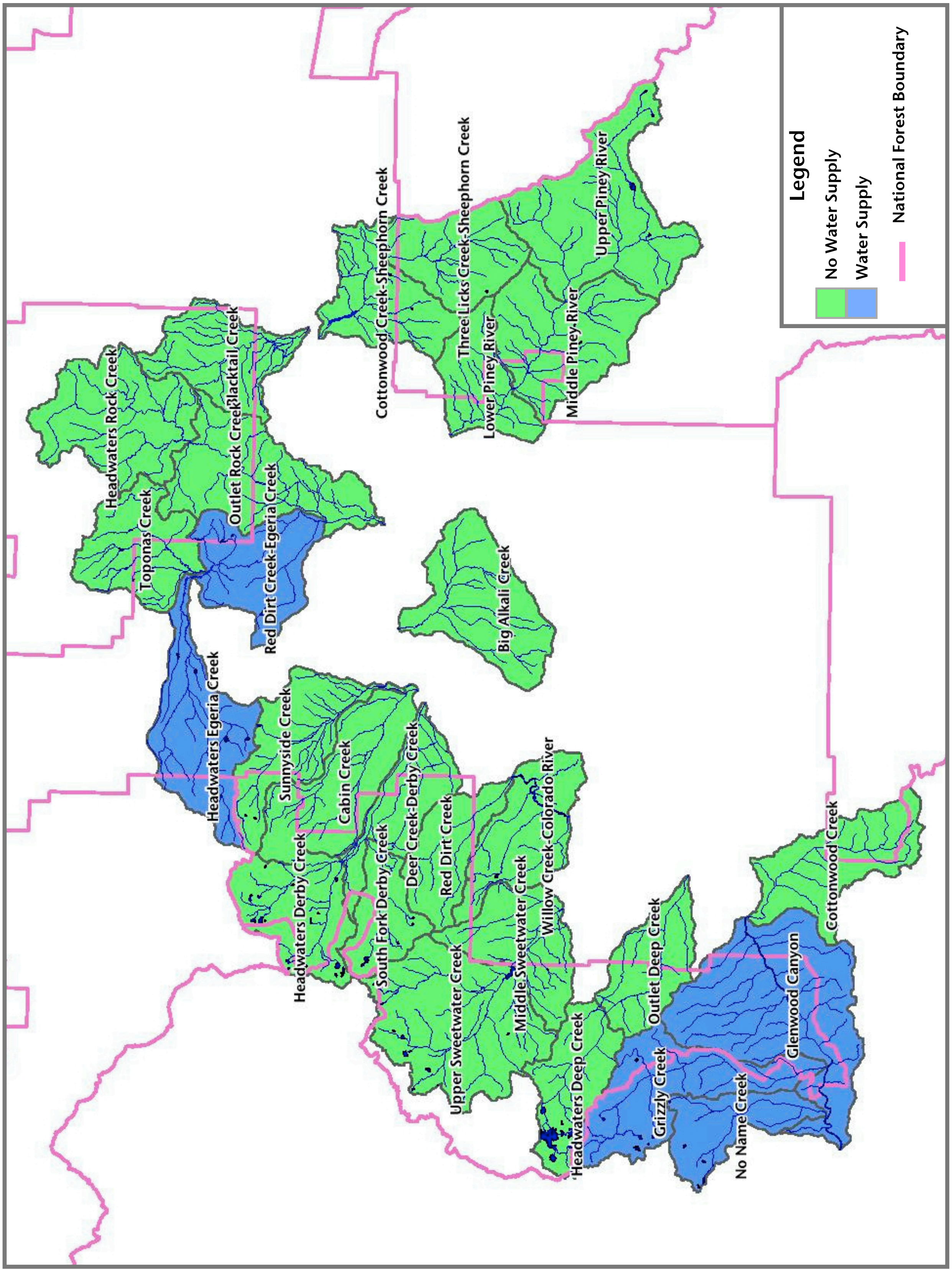

Figure 12. Lower Colorado Headwaters Watershed Water Supply Map

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APPENDIX A

LOWER COLORADO HEADWATERS WILDFIRE HAZARD MODELING METHODOLOGY

The forest conditions that are of concern for the assessments are the wildfire hazard based on existing forest conditions. The wildfire hazard (Flame Length) was determined using the Fire Behavior Assessment Tool (FBAT) (http://www.fire.org) which is an interface between ArcMap and FlamMap. The input spatial data were collected from LANDFIRE project (http://www.landfire.gov/).

After a mountain pine beetle outbreak there are substantial increases in the amount of fine dead fuels in the canopy. The majority of these fuels remain in the canopy for 2-3 years post outbreak (Knight 1987, Schmid and Amman 1992). Therefore, certain input spatial data sets were updated reflecting Mountain Pine Beetle (MPB) mortality conditions using USDA Forest Service, Rocky Mountain Region Aerial Detection Survey (ADS) Data from the years 2002 - 2007 (http://www.fs.fed.us/r2/resources/fhm/aerialsurvey/). The following modeling settings and spatial data modification were used:

Modeling Setting

1. Scott and Burgan (2005) Fire Behavior Model (Fuel Moisture is shown in Table A-1)
2. Uphill wind direction
3. Scott & Reinhardt (2001) crown fire calculation
4. Foliar Moisture at 100%

Spatial Data Modifications

1. Canopy Cover was assigned a value of 10% when coincident with MPB mortality from ADS for years 2002-2007.
2. Canopy Base Height (CBH) was reduced by 25% for MPB mortality derived from ADS for the years 2002-2006.
3. CBH was reassigned a value of 0 for MPB mortality from ADS for the year 2007.
4. Canopy Bulk Density (CBD) was reduced by 50% for MPB mortality derived from ADS for the years 2002-2006

Table A-1. Fuel Moisture (percent) used in FBAT Model Runs

Scott and Burgan (2005) fuel model	1-Hour Fuel	10-Hour Fuel	100-Hour Fuel	Live Herbaceous	Live Woody
1	4	5	8	200	95
2	4	5	8	150	95
3	4	5	8	85	95
4	4	5	8	85	95
5	4	5	8	85	150
6	4	5	8	85	95
7	4	5	8	85	95
8	4	5	8	85	95
9	4	5	8	85	95
10	4	5	8	85	95
11	4	5	8	85	95
12	4	5	8	85	95
13	4	5	8	85	95
14	3	4	8	85	95
15	3	4	8	85	95
16	3	4	8	85	95
17	3	4	8	85	95
18	3	4	8	85	95
19	3	4	8	85	95
20	3	4	8	85	95
21	3	4	8	85	95
22	3	4	8	85	95
23	3	4	8	85	95
24	3	4	8	85	95
25	3	4	8	85	95
26	3	4	8	85	95
27	3	4	8	85	95
28	3	4	8	85	95
29	3	4	8	85	95
30	3	4	8	85	95
31	3	4	8	85	95
32	3	4	8	85	95
33	3	4	8	85	95
34	3	4	8	85	95
35	3	4	8	85	95
36	3	4	8	85	95
37	3	4	8	85	95
38	3	4	8	85	95
39	3	4	8	85	95
40	3	4	8	85	95
41	3	4	8	85	95
42	3	4	8	85	95
43	3	4	8	85	95
44	3	4	8	85	95
45	3	4	8	85	95
46	3	4	8	85	95
47	3	4	8	85	95
48	3	4	8	85	95
49	3	4	8	85	95
50	3	4	8	85	95

Weather Data

The weather data used comes from the Colorado Wildfire Risk Assessment Statewide (CRA) dataset prepared by Sandborn under contract to the Colorado State Forest Service. For the Colorado Fire Risk Assessment nine weather influence zones (WIZ) were developed for analysis purposes. A WIZ is an area where for analysis purposes the weather on any given day is uniform. Within each WIZ, daily weather data was gathered for the years 1980-2006. Where not available, the weather data was gathered from the earliest year through 2006. Several weather stations were analyzed within each WIZ. From this analysis, one representative weather station was selected for each WIZ. From this data set, percentile weather was developed for each WIZ using the Fire Family Plus software package.

For this watershed assessment the percentile weather for WIZ CO 02 (Dowd 1986-2006) was used for all watersheds on the west side of the continental divide and WIZ CO 03 (Coral Creek 1980-2006) was used for all watersheds on the east side of the continental divide. The 20-foot wind speeds for the "High" case was used in the modeling runs (Table A-2).

In addition the wind direction was assumed to be uphill (parallel with slope) in all instances. This setting encourages crown fire initiation and establishes a common baseline for the evaluation of areas within the landscape based upon the fuels hazard represented by vegetation conditions.

Table A-2. Wind Speed (Miles per Hour) used in FBAT Model Runs

Watershed Name	Wind Speed (mph)	Probable Momentary Gust Speed (mph)
North Platte	15	29
Upper North Platte	15	29
Crow/Medicine Bow/Upper Laramie/Upper Lodgepole	12	25
Clear/Bear Creek	12	25
Big Thompson	12	25
Cache la Poudre	12	25
Blue River	15	29
Eagle River	15	29
Upper Yampa	15	29
Little Snake	15	29
Upper White	15	29
Lower Colorado	15	29
Upper Colorado	15	29
Saint Vrain	12	25
Roaring Fork	15	29

Categorization of Results

The FBAT model results were divided into five categories of flame length. These values range from lowest (Category 0) to highest (Category 4) based upon flame length. The flame length categories that were used are:

Flame Length Category 0 - 0 meters

Flame Length Category 1 - 1 to 10 meters

Flame Length Category 2 - 11 to 25 meters

Flame Length Category 3 - 26 to 40 meters

Flame Length Category 4 - >40 meters

APPENDIX B

DETAILED LOWER COLORADO HEADWATERS WATERSHED ASSESSMENT RESULTS

Table B-1. Lower Colorado Headwaters Watershed Wildfire Hazard Ranking[1]

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Hazard Rank
Three Licks Creek-Sheephorn Creek	18,306	60.0%	*5.5*
Upper Piney River	35,461	59.4%	*5.5*
Headwaters Rock Creek	26,782	56.8%	*5.2*
No Name Creek	13,175	48.3%	*4.5*
Blacktail Creek	18,056	43.8%	*4.1*
Middle Piney River	26,108	39.8%	*3.7*
Outlet Rock Creek	27,263	35.6%	*3.3*
Upper Sweetwater Creek	36,193	34.0%	*3.2*
Grizzly Creek	24,799	29.6%	*2.8*
Red Dirt Creek-Egeria Creek	19,256	28.6%	*2.7*
Headwaters Derby Creek	19,614	28.0%	*2.6*
Cottonwood Creek-Sheephorn Creek	18,023	27.6%	*2.6*
Headwaters Egeria Creek	23,668	25.3%	*2.4*
Lower Piney River	14,075	24.4%	*2.3*
Outlet Deep Creek	15,125	23.2%	*2.2*
Glenwood Canyon	43,644	22.8%	*2.2*
Big Alkali Creek	24,379	21.8%	*2.1*
Cottonwood Creek	20,628	20.8%	*2.0*
Toponas Creek	18,653	20.4%	*2.0*
Headwaters Deep Creek	16,190	20.1%	*1.9*
South Fork Derby Creek	11,526	19.0%	*1.8*
Sunnyside Creek	19,045	17.4%	*1.7*
Middle Sweetwater Creek	17,813	16.2%	*1.6*
Red Dirt Creek	13,830	13.3%	*1.3*
Deer Creek-Derby Creek	15,013	12.3%	*1.2*
Willow Creek-Colorado River	19,199	7.0%	*0.8*
Cabin Creek	23,860	3.9%	*0.5*

[1] Three Licks Creek-Sheephorn Creek was skewing the categorization because of its high wildfire hazard score of 74.04. It was manually given a score slightly higher than the next highest score.

Table B-2. Lower Colorado Headwaters Watershed Ruggedness Ranking[2, 3]

Sixth-level Watershed Name	Maximum Elevation	Minimum Elevation	Difference Elevation	Ruggedness	Ruggedness Rank
No Name Creek	11,188	5,770	5,419	0.2262	5.5
Red Dirt Creek	11,690	6,353	5,337	0.2174	5.2
Lower Piney River	11,457	6,747	4,710	0.2127	5.1
Deer Creek-Derby Creek	11,847	6,478	5,369	0.2100	5.0
Willow Creek-Colorado River	11,503	6,271	5,232	0.2023	4.8
Cottonwood Creek-Sheephorn Creek	11,365	6,855	4,510	0.1971	4.6
Sunnyside Creek	12,185	6,635	5,550	0.1927	4.5
South Fork Derby Creek	12,225	8,236	3,988	0.1780	4.0
Cabin Creek	12,205	6,475	5,730	0.1777	4.0
Outlet Deep Creek	10,690	6,176	4,513	0.1758	3.9
Upper Piney River	13,333	7,734	5,599	0.1745	3.9
Middle Sweetwater Creek	11,710	6,911	4,799	0.1723	3.8
Cottonwood Creek	11,175	6,130	5,045	0.1683	3.7
Glenwood Canyon	10,808	5,717	5,091	0.1651	3.6
Three Licks Creek-Sheephorn Creek	11,651	7,541	4,110	0.1627	3.5
Grizzly Creek	11,185	5,904	5,281	0.1607	3.5
Middle Piney River	11,539	7,141	4,398	0.1597	3.4
Big Alkali Creek	11,234	6,550	4,684	0.1437	2.9
Outlet Rock Creek	10,365	6,626	3,739	0.1329	2.6
Blacktail Creek	10,526	6,895	3,631	0.1295	2.5
Headwaters Derby Creek	12,343	8,859	3,483	0.1192	2.2
Red Dirt Creek-Egeria Creek	10,181	6,829	3,352	0.1157	2.1
Upper Sweetwater Creek	11,956	7,695	4,261	0.1073	1.8
Headwaters Deep Creek	11,286	8,692	2,594	0.0977	1.5
Headwaters Egeria Creek	11,267	8,151	3,116	0.0970	1.5
Toponas Creek	10,529	8,138	2,391	0.0839	1.1
Headwaters Rock Creek	10,794	8,580	2,214	0.0648	0.5

[2] Ruggedness is based on Melton (1957)

[3] These watersheds were manually adjusted because they do not accurately reflect the ruggedness in those watersheds. The original values were; Upper Piney River (0.1405), Middle Piney River (0.1304), Lower Piney River (0.1902), Three Licks Creek-Sheephorn Creek (0.1455), Cottonwood Creek-Sheephorn Creek (0.1610), Outlet Rock Creek (0.1085), Willow Creek-Colorado River (0.1809), and Glenwood Canyon (0.1168).

Table B-3. Lower Colorado Headwaters Watershed Road Density Ranking[4]

Sixth-level Watershed Name	Roads (miles)	Roads Adjusted (miles)	Watershed Area (sq. mi.)	Road density (miles per sq. mi.)	Road Density Rank
Headwaters Rock Creek	166.3	116.4	41.85	2.78	*5.5*
Headwaters Deep Creek	69.3	69.3	25.30	2.74	*5.4*
Cottonwood Creek	71.0	71.0	32.23	2.20	*4.3*
Grizzly Creek	83.4	83.4	38.75	2.15	*4.1*
Glenwood Canyon	146.1	146.1	68.19	2.14	*4.1*
Three Licks Creek-Sheephorn Creek	60.9	60.9	28.60	2.13	*4.1*
Deer Creek-Derby Creek	47.4	47.4	23.46	2.02	*3.9*
Middle Piney River	77.5	77.5	40.79	1.90	*3.6*
Outlet Deep Creek	43.1	43.1	23.63	1.83	*3.4*
Toponas Creek	52.7	52.7	29.15	1.81	*3.4*
Lower Piney River	37.7	37.7	21.99	1.72	*3.2*
Cottonwood Creek-Sheephorn Creek	46.4	46.4	28.16	1.65	*3.1*
No Name Creek	32.0	32.0	20.59	1.56	*2.9*
Blacktail Creek	40.9	40.9	28.21	1.45	*2.6*
Headwaters Egeria Creek	52.9	52.9	36.98	1.43	*2.6*
Middle Sweetwater Creek	37.2	37.2	27.83	1.34	*2.4*
Cabin Creek	48.8	48.8	37.28	1.31	*2.3*
Red Dirt Creek	28.2	28.2	21.61	1.30	*2.3*
Outlet Rock Creek	51.8	51.8	42.60	1.22	*2.1*
Red Dirt Creek-Egeria Creek	32.7	32.7	30.09	1.09	*1.9*
Willow Creek-Colorado River	31.3	31.3	30.00	1.04	*1.8*
Big Alkali Creek	31.3	31.3	38.09	0.82	*1.3*
Upper Piney River	44.1	44.1	55.41	0.80	*1.2*
Sunnyside Creek	23.7	23.7	29.76	0.80	*1.2*
South Fork Derby Creek	14.3	14.3	18.01	0.79	*1.2*
Upper Sweetwater Creek	33.5	33.5	56.55	0.59	*0.8*
Headwaters Derby Creek	14.1	14.1	30.65	0.46	*0.5*
Total	1418.9	1369.0	905.76	1.51	

[4] The road density was adjusted based upon the procedure discussed in the report (p. 12). The original road density values were; Headwaters Rock Creek (3.97).

Table B-4. Lower Colorado Headwaters Watershed Flooding/Debris Flow Hazard Ranking[5]

Sixth-level Watershed Name	Ruggedness Ranking	Road Density Ranking	Combined Numeric Rank	Combined Ranking
Deer Creek-Derby Creek	5.0	3.9	13.86	5.5
No Name Creek	5.5	2.9	13.86	5.5
Lower Piney River	5.1	3.2	13.37	5.2
Red Dirt Creek	5.2	2.3	12.77	4.9
Cottonwood Creek-Sheephorn Creek	4.6	3.1	12.26	4.7
Cottonwood Creek	3.7	4.3	11.66	4.3
Glenwood Canyon	3.6	4.1	11.34	4.2
Outlet Deep Creek	3.9	3.4	11.32	4.2
Willow Creek-Colorado River	4.8	1.8	11.27	4.1
Three Licks Creek-Sheephorn Creek	3.5	4.1	11.16	4.1
Grizzly Creek	3.5	4.1	11.08	4.0
Middle Piney River	3.4	3.6	10.48	3.7
Cabin Creek	4.0	2.3	10.32	3.6
Sunnyside Creek	4.5	1.2	10.14	3.5
Middle Sweetwater Creek	3.8	2.4	10.04	3.5
South Fork Derby Creek	4.0	1.2	9.23	3.0
Upper Piney River	3.9	1.2	9.02	2.9
Headwaters Deep Creek	1.5	5.4	8.44	2.6
Blacktail Creek	2.5	2.6	7.64	2.2
Outlet Rock Creek	2.6	2.1	7.34	2.1
Big Alkali Creek	2.9	1.3	7.17	2.0
Headwaters Rock Creek	0.5	5.5	6.50	1.6
Red Dirt Creek-Egeria Creek	2.1	1.9	6.01	1.3
Toponas Creek	1.1	3.4	5.58	1.1
Headwaters Egeria Creek	1.5	2.6	5.58	1.1
Headwaters Derby Creek	2.2	0.5	4.87	0.7
Upper Sweetwater Creek	1.8	0.8	4.42	0.5

[5] Combined Ranking is Ruggedness Ranking times 2 plus the Road Density Ranking

Table B-5. Lower Colorado Headwaters Watershed Soil Erodibility Ranking[6]

Sixth-level Watershed Name	Severe (%)	Very Severe (%)	Soil Erodibility Value	Soil Erodibility Rank
Glenwood Canyon	16.5%	23.5%	0.636	*5.5*
Willow Creek-Colorado River	25.9%	17.9%	0.617	*5.3*
No Name Creek	11.0%	22.8%	0.566	*4.9*
Outlet Deep Creek	13.8%	19.7%	0.533	*4.7*
Red Dirt Creek	20.8%	13.3%	0.475	*4.2*
Grizzly Creek	10.9%	18.2%	0.472	*4.2*
Upper Sweetwater Creek	15.2%	13.0%	0.413	*3.7*
South Fork Derby Creek	12.4%	12.8%	0.380	*3.4*
Middle Sweetwater Creek	17.2%	9.1%	0.355	*3.3*
Cottonwood Creek	15.2%	10.1%	0.355	*3.2*
Headwaters Derby Creek	10.5%	9.4%	0.293	*2.8*
Headwaters Deep Creek	9.1%	7.9%	0.249	*2.4*
Lower Piney River	12.3%	5.6%	0.235	*2.3*
Cottonwood Creek-Sheephorn Creek	14.0%	4.0%	0.221	*2.2*
Big Alkali Creek	13.3%	3.9%	0.212	*2.1*
Red Dirt Creek-Egeria Creek	10.1%	4.4%	0.189	*1.9*
Middle Piney River	11.1%	2.7%	0.164	*1.7*
Outlet Rock Creek	9.1%	3.6%	0.163	*1.7*
Cabin Creek	11.0%	2.1%	0.153	*1.6*
Upper Piney River	14.1%	0.5%	0.151	*1.6*
Deer Creek-Derby Creek	5.6%	4.6%	0.148	*1.6*
Three Licks Creek-Sheephorn Creek	8.6%	2.0%	0.126	*1.4*
Toponas Creek	5.9%	0.5%	0.069	*1.0*
Blacktail Creek	4.0%	1.0%	0.061	*0.9*
Sunnyside Creek	3.3%	0.8%	0.048	*0.8*
Headwaters Egeria Creek	1.8%	0.2%	0.023	*0.6*
Headwaters Rock Creek	1.0%	0.1%	0.011	*0.5*

[6] Soil Erodibility Value is percentage of Severe plus 2 times the percentage of Very Severe.

Table B-6. Lower Colorado Headwaters Watershed Composite Hazard Ranking[7, 8]

Sixth-level Watershed Name	Wildfire Hazard Rank	Flooding/ Debris Flow Rank	Soil Erodibility Rank	Composite Numeric Rank	Composite Hazard Rank
No Name Creek	*4.5*	*5.5*	*4.9*	12.5	*5.5*
Glenwood Canyon	*2.2*	*4.2*	*5.5*	11.8	*5.1*
Outlet Deep Creek	*2.2*	*4.2*	*4.7*	11.0	*4.6*
Grizzly Creek	*2.8*	*4.0*	*4.2*	11.0	*4.6*
Three Licks Creek-Sheephorn Creek	*5.5*	*4.1*	*1.4*	11.0	*4.6*
Red Dirt Creek	*1.3*	*4.9*	*4.2*	10.5	*4.3*
Willow Creek-Colorado River	*0.8*	*4.1*	*5.3*	10.2	*4.2*
Upper Piney River	*5.5*	*2.9*	*1.6*	10.0	*4.0*
Lower Piney River	*2.3*	*5.2*	*2.3*	9.8	*3.9*
Cottonwood Creek	*2.0*	*4.3*	*3.2*	9.6	*3.8*
Cottonwood Creek-Sheephorn Creek	*2.6*	*4.7*	*2.2*	9.4	*3.7*
Middle Piney River	*3.7*	*3.7*	*1.7*	9.1	*3.5*
Deer Creek-Derby Creek	*1.2*	*5.5*	*1.6*	8.3	*3.0*
South Fork Derby Creek	*1.8*	*3.0*	*3.4*	8.3	*3.0*
Middle Sweetwater Creek	*1.6*	*3.5*	*3.3*	8.3	*3.0*
Upper Sweetwater Creek	*3.2*	*0.5*	*3.7*	7.4	*2.5*
Headwaters Rock Creek	*5.2*	*1.6*	*0.5*	7.3	*2.4*
Blacktail Creek	*4.1*	*2.2*	*0.9*	7.2	*2.3*
Outlet Rock Creek	*3.3*	*2.1*	*1.7*	7.1	*2.3*
Headwaters Deep Creek	*1.9*	*2.6*	*2.4*	7.0	*2.2*
Big Alkali Creek	*2.1*	*2.0*	*2.1*	6.2	*1.7*
Headwaters Derby Creek	*2.6*	*0.7*	*2.8*	6.1	*1.7*
Sunnyside Creek	*1.7*	*3.5*	*0.8*	6.0	*1.7*
Red Dirt Creek-Egeria Creek	*2.7*	*1.3*	*1.9*	6.0	*1.6*
Cabin Creek	*0.5*	*3.6*	*1.6*	5.8	*1.5*
Headwaters Egeria Creek	*2.4*	*1.1*	*0.6*	4.1	*0.5*
Toponas Creek	*2.0*	*1.1*	*1.0*	4.1	*0.5*

[7] The Composite Hazard Rank is the average of the Wildfire Hazard Rank, Flooding/Debris Flow Rank, and Soil Erodibility Rank that is re-categorized into 5 categories using the procedure described in Front Range Watershed Protection Data Refinement Work Group (2009).

[8] The No Name Creek watershed was manually adjusted because it was skewing the results of the categorization because of its high value. The Composite Numeric Rank was originally 14.9.