Clear/Bear Creek 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.

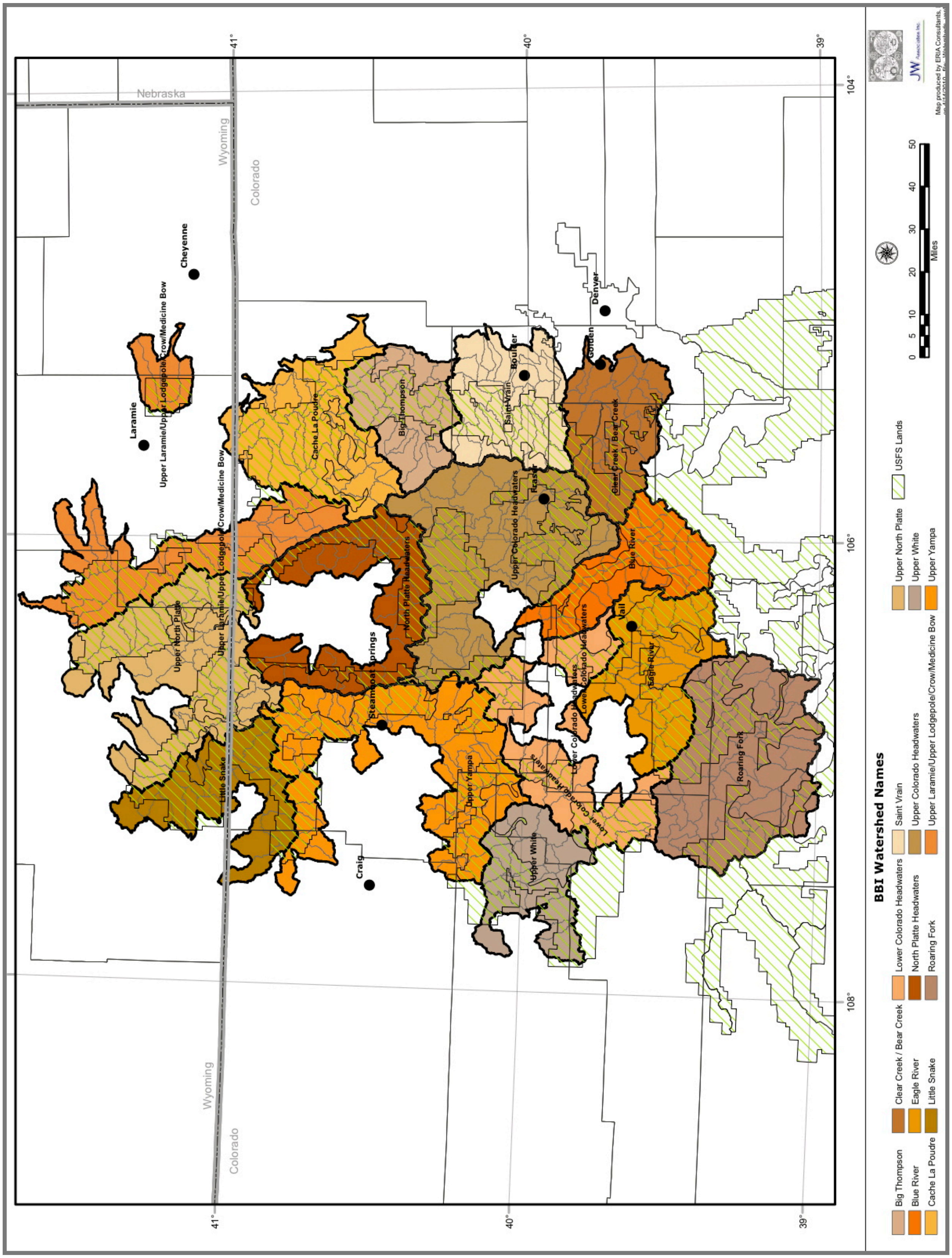

Figure 1. Bark Beetle Incident Phase 1 Watersheds

WATERSHED DESCRIPTION

The Clear/Bear Creek watershed is a Front Range watershed that typically begins at the continental divide and ends at the start of the western edge of the plains. This watershed is a combination of Clear Creek and Bear Creek. Bear Creek is classified as part of the Upper South Platte watershed, but was not part of the Upper South Platte Watershed Assessment, previously completed. Clear Creek and Bear Creek are both tributaries to the South Platte River. This watershed assessment is designed to assess hazards from wildfire to water supply. Therefore, the subwatersheds that are entirely on the plains to the east were eliminated from this watershed assessment. The plains watersheds would have skewed the results of the assessment because they are relatively flat, have higher road densities and very different fire regimes.

The Clear/Bear Creek watershed is one fourth-level[1] (eight-digit) watershed (HUC 10190004) and part of another fourth level watershed (HUC 10190002 that is 508,940 acres in size and contains 28 sixth-level watersheds. For this watershed assessment, four sixth-level watersheds were eliminated based upon their wildfire hazard, ruggedness, and an examination of how well they fit into this assessment. The Clear/Bear Creek watershed used in this analysis is 456,822 acres, contains five fifth-level watersheds and 24 sixth-level watersheds, which are the analysis units for this watershed assessment (Front Range Watershed Protection Data Refinement Work Group 2009). The Clear/Bear Creek 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.

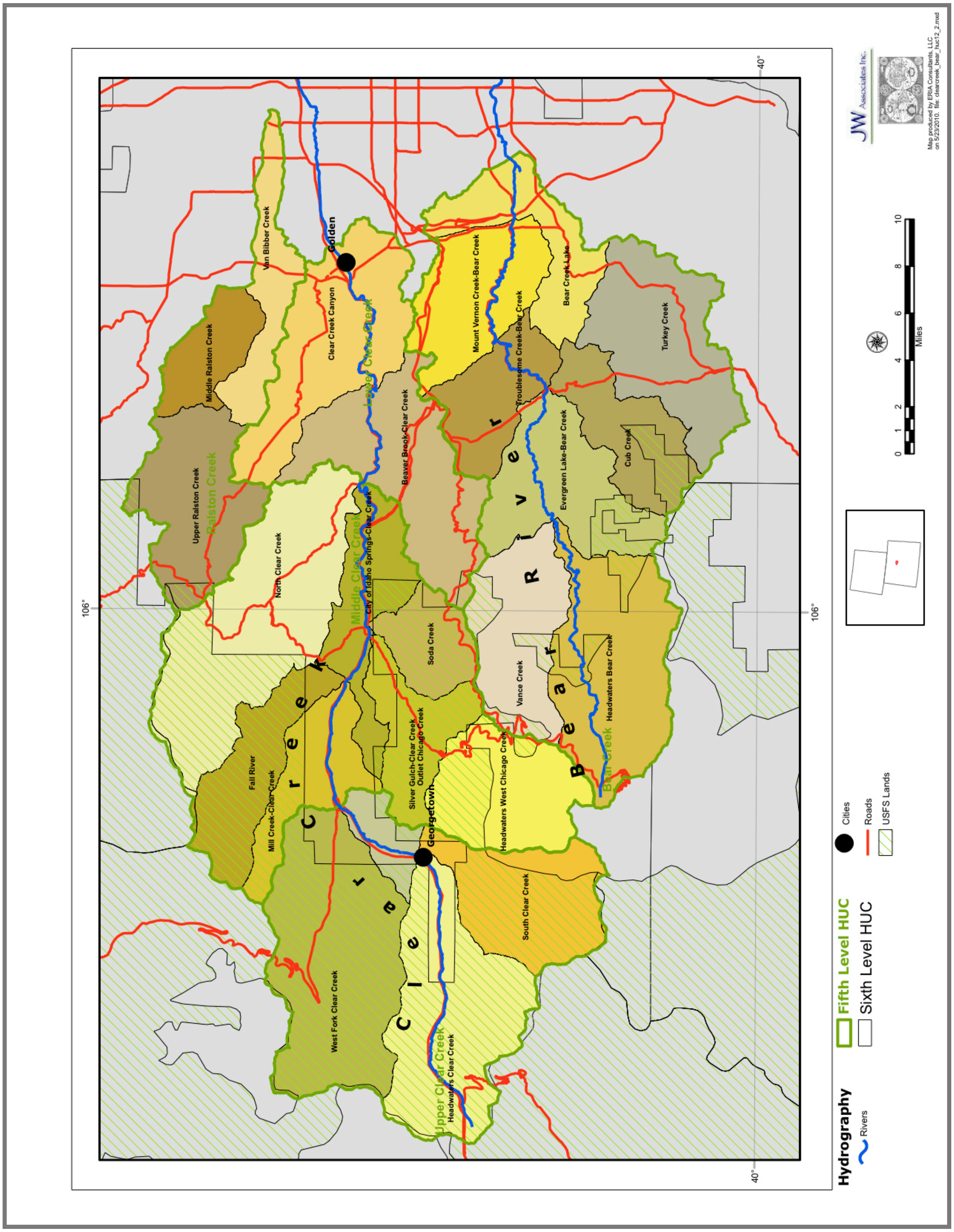

Figure 2. Clear/Bear Creek Watershed Analysis Area[2]

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

Table 1. Fifth-level and Sixth-level Watersheds in Clear/Bear Creek Watershed [3]

Fifth-level Watershed	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)	Map Number
Bear Creek	Vance Creek	18,559	101900020801	271
HUC 1019000208	Headwaters Bear Creek	28,652	101900020802	272
	Evergreen Lake-Bear Creek	20,431	101900020803	273
	Cub Creek	14,241	101900020804	276
	Troublesome Creek-Bear Creek	12,667	101900020805	277
	Mount Vernon Creek-Bear Creek	17,719	101900020806	278
	Turkey Creek	24,197	101900020807	279
	Bear Creek Lake	14,445	101900020808	280
Upper Clear Creek	South Clear Creek	19,295	101900040101	281
HUC 1019000401	Headwaters Clear Creek	30,846	101900040102	282
	West Fork Clear Creek	36,752	101900040103	283
	Silver Gulch-Clear Creek	5,260	101900040104	284
Middle Clear Creek	Fall River	14,976	101900040201	285
HUC 1019000402	Mill Creek-Clear Creek	12,696	101900040202	286
	Headwaters West Chicago Creek	18,607	101900040203	287
	Outlet Chicago Creek	12,142	101900040204	288
	Soda Creek	8,941	101900040205	289
	North Clear Creek	38,491	101900040206	290
	City of Idaho Springs-Clear Creek	14,457	101900040207	291
Ralston Creek	Upper Ralston Creek	20,615	101900040301	292
HUC 1019000403	Middle Ralston Creek	8,973	101900040302	293
	Van Bibber Creek	11,357	101900040303	294
Lower Clear Creek	Beaver Brook-Clear Creek	26,222	101900040401	274
HUC 1019000404	Clear Creek Canyon	26,281	101900040402	275
	Total Area	**456,822**		

[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 - Clear/Bear Creek 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 Clear/Bear Creek 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: Soda Creek, Outlet Chicago Creek and Silver Gulch-Clear Creek. Seven watersheds were ranked as Category 4, which is the next highest category (see Table B-1 in Appendix B). Soda Creek was skewing the categorization because of its high wildfire hazard score. The wildfire hazard score for Soda Creek was manually given a score slightly higher than the next highest score (Table B-1 in Appendix B).

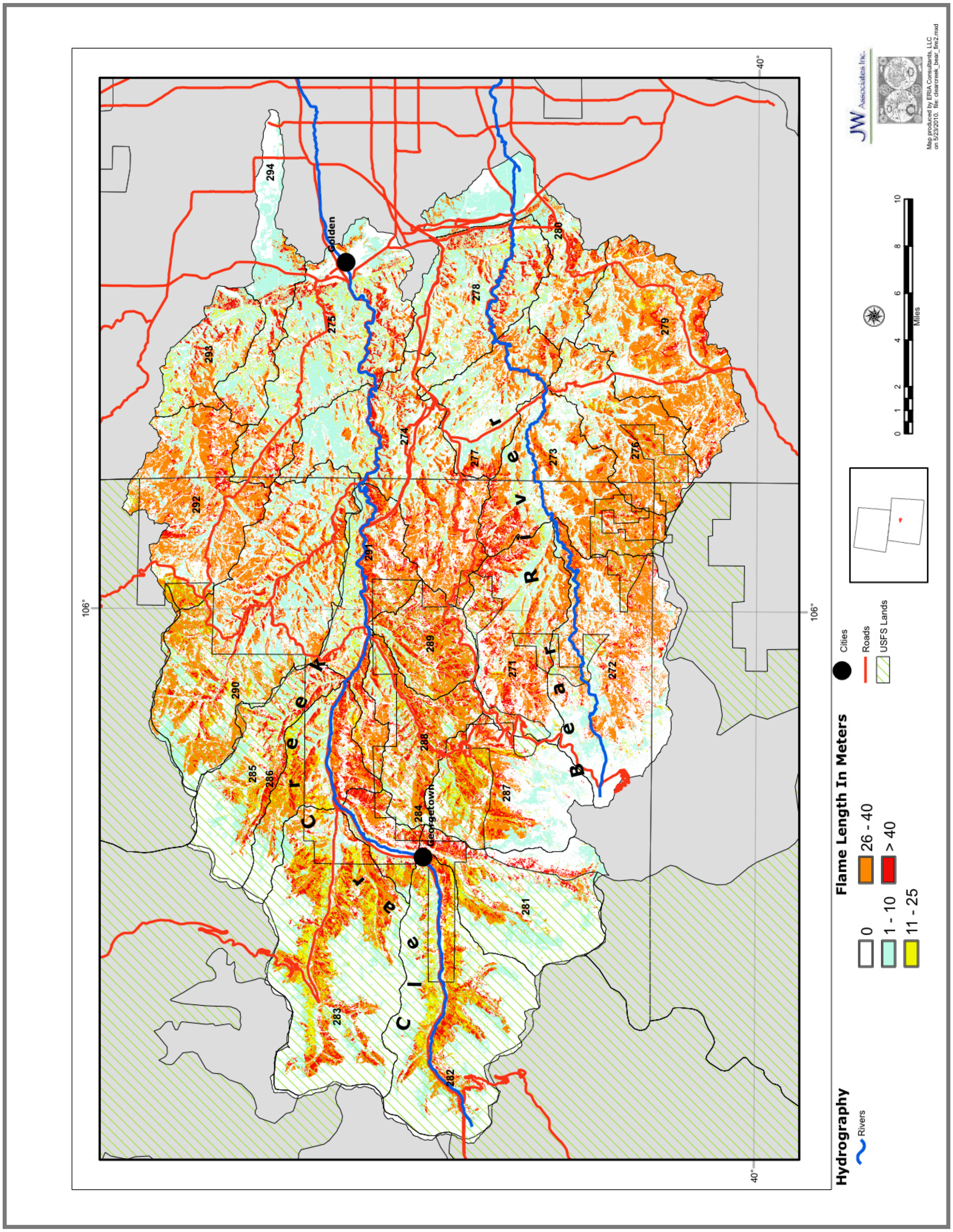

Figure 3. Clear/Bear Creek Watershed Wildfire Hazard Modeling Results

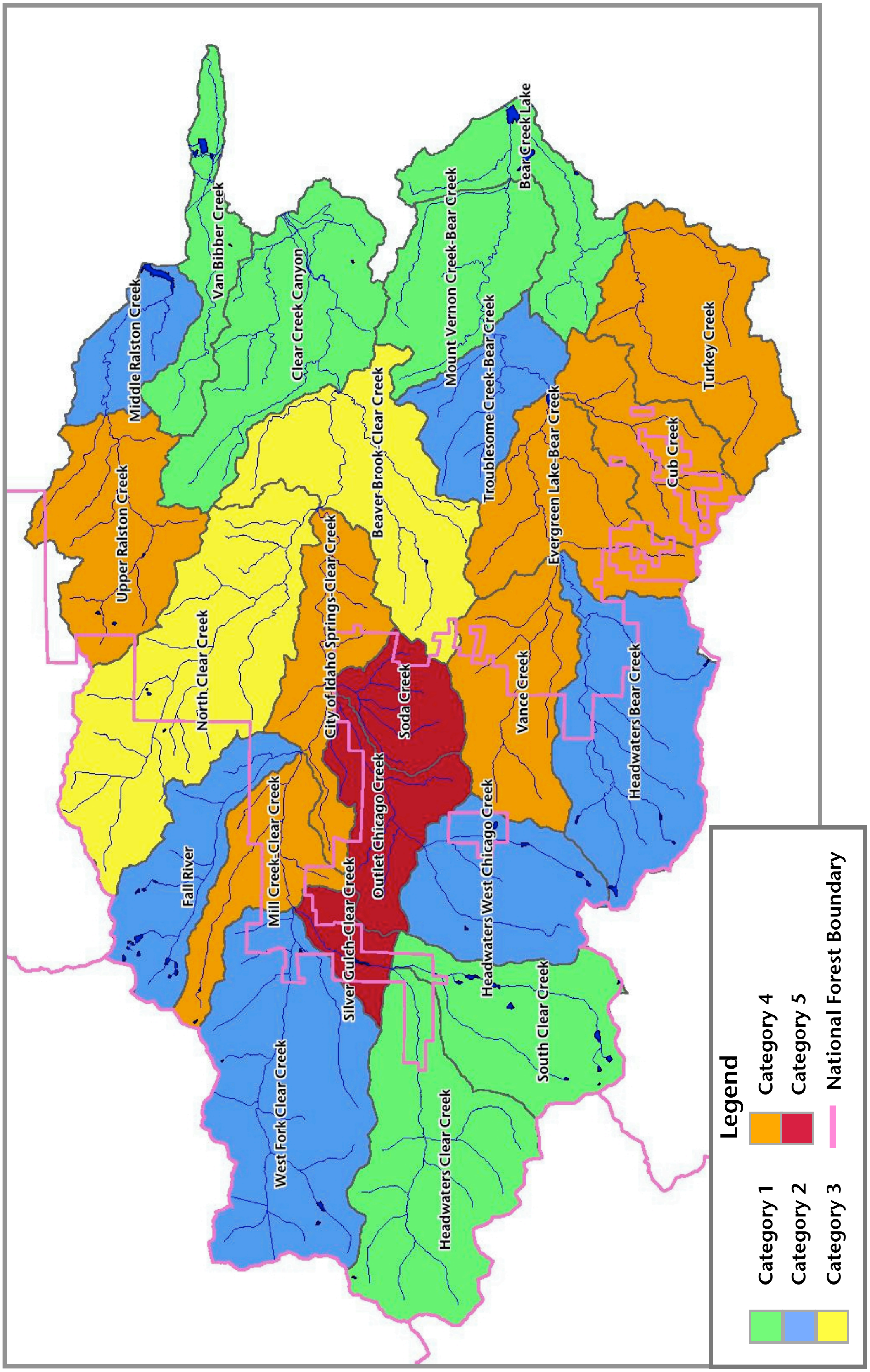

Figure 4. Clear/Bear Creek Watershed Wildfire Hazard Ranking

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; City of Idaho Springs-Clear Creek, Beaver Brook-Clear Creek, North Clear Creek, Troublesome Creek-Bear Creek, and Evergreen Lake-Bear Creek.

Figure 5 displays the categorized ruggedness for the Clear/Bear Creek 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 Silver Gulch-Clear Creek, Mill Creek-Clear Creek and Fall River.

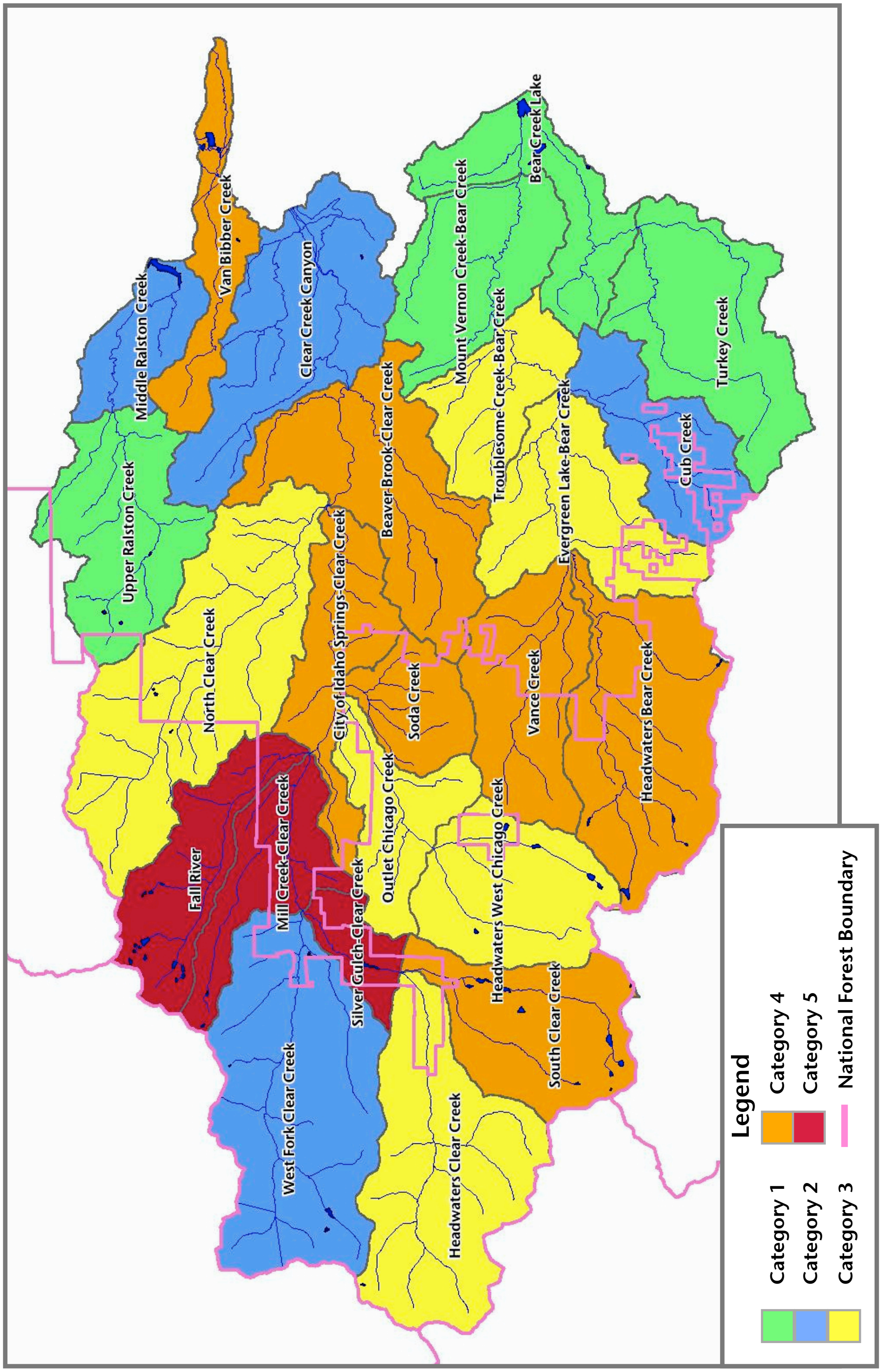

Figure 5. Clear/Bear Creek Watershed Ruggedness Ranking

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 Troublesome Creek-Bear Creek, Bear Creek Lake, Headwaters Clear Creek, Silver Gulch-Clear Creek, City of Idaho Springs-Clear Creek and Van Bibber Creek watersheds were all adjusted down. The adjustments are displayed on Table B-3 in Appendix B.

Figure 7 displays the categorized road density for the Clear/Bear Creek Watershed and tabular results are presented in Appendix B (Table B-3). Figure 7 shows that the highest rankings are in Cub Creek, Turkey Creek, Soda Creek, Mount Vernon Creek-Bear Creek and Troublesome Creek-Bear Creek.

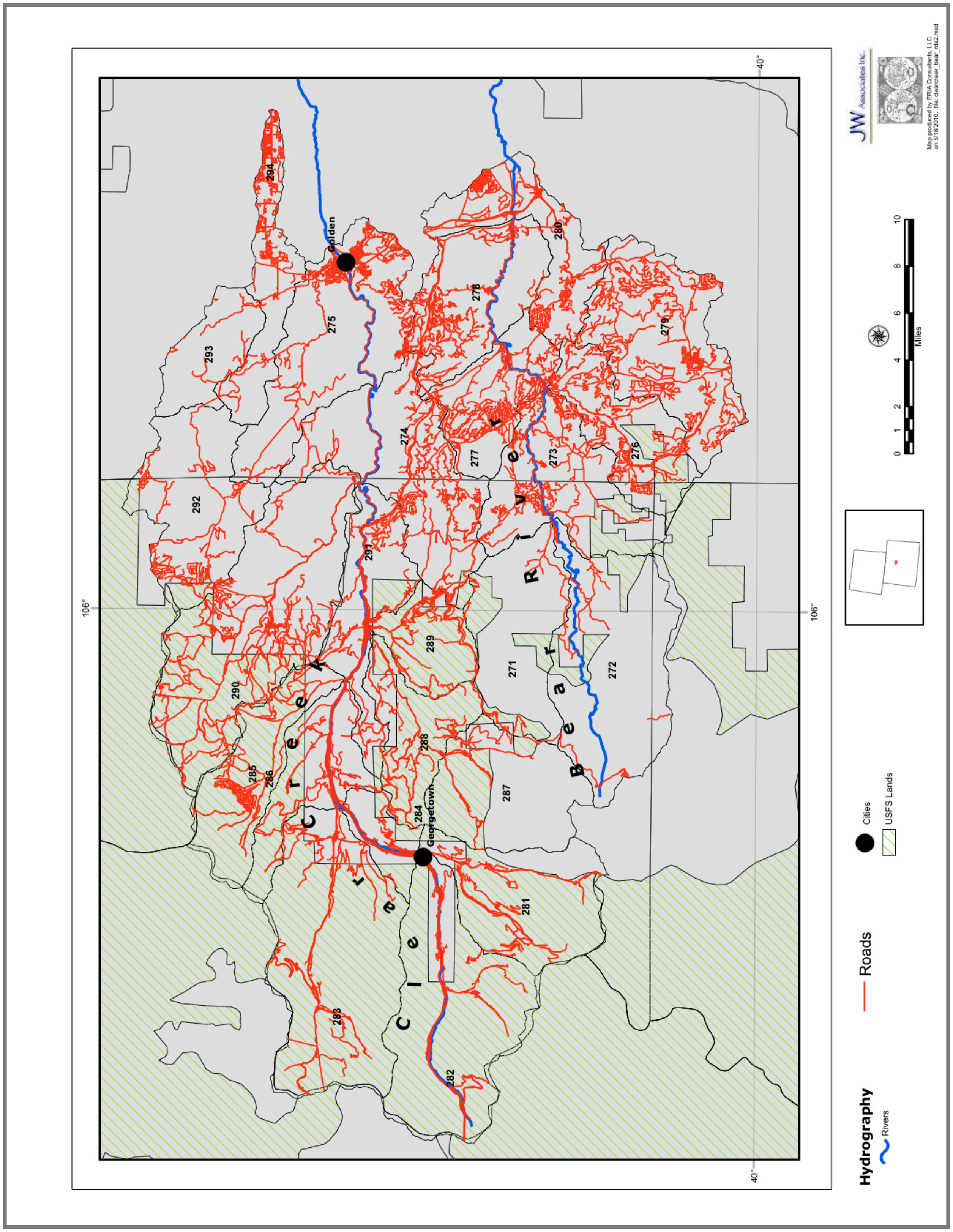

Figure 6. Clear/Bear Creek Watershed Roads Map

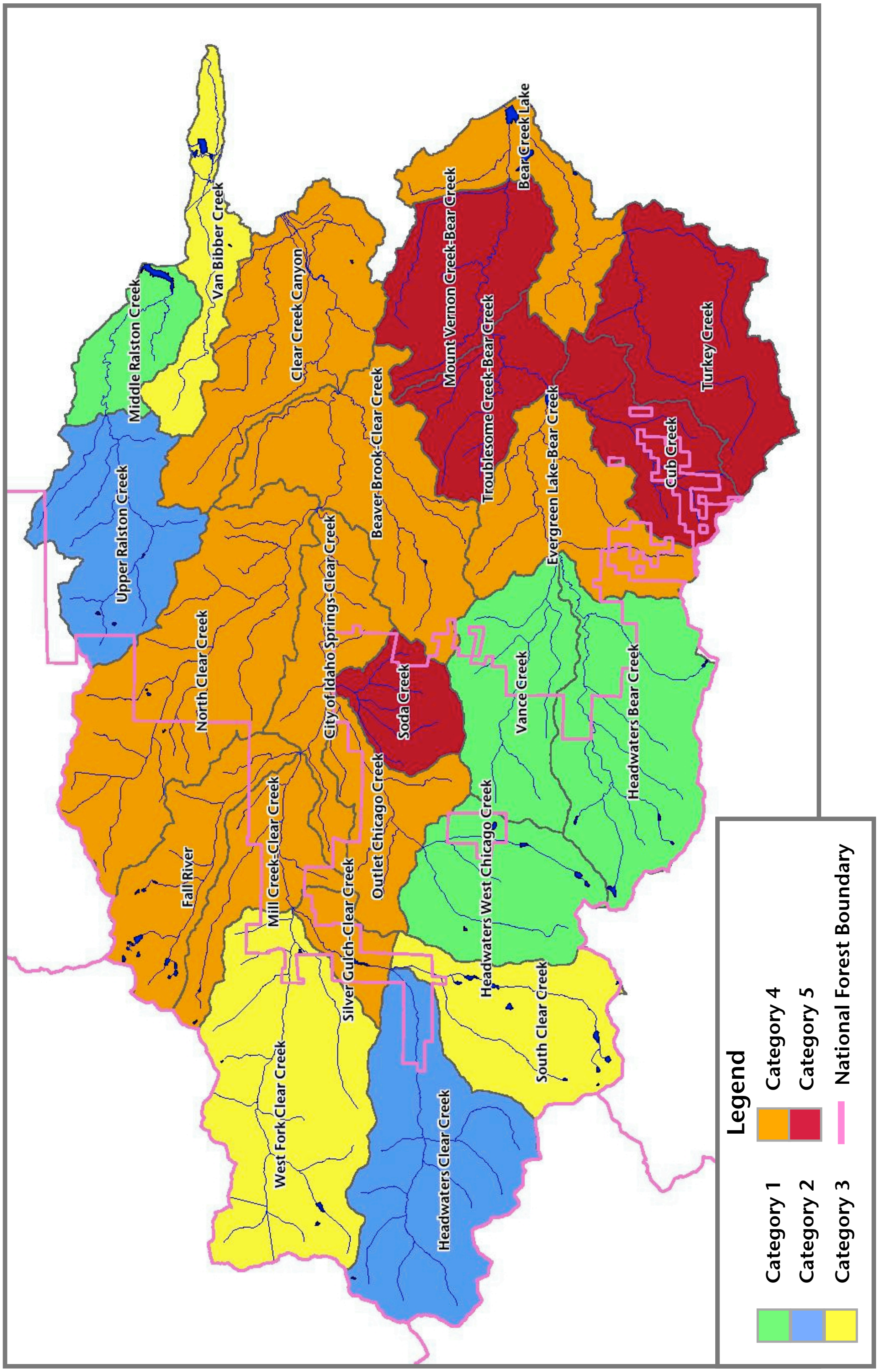

Figure 7. Clear/Bear Creek Watershed Road Density Ranking

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 Cache la Poudre 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 Silver Gulch-Clear Creek, Mill Creek-Clear Creek, Soda Creek and Fall River.

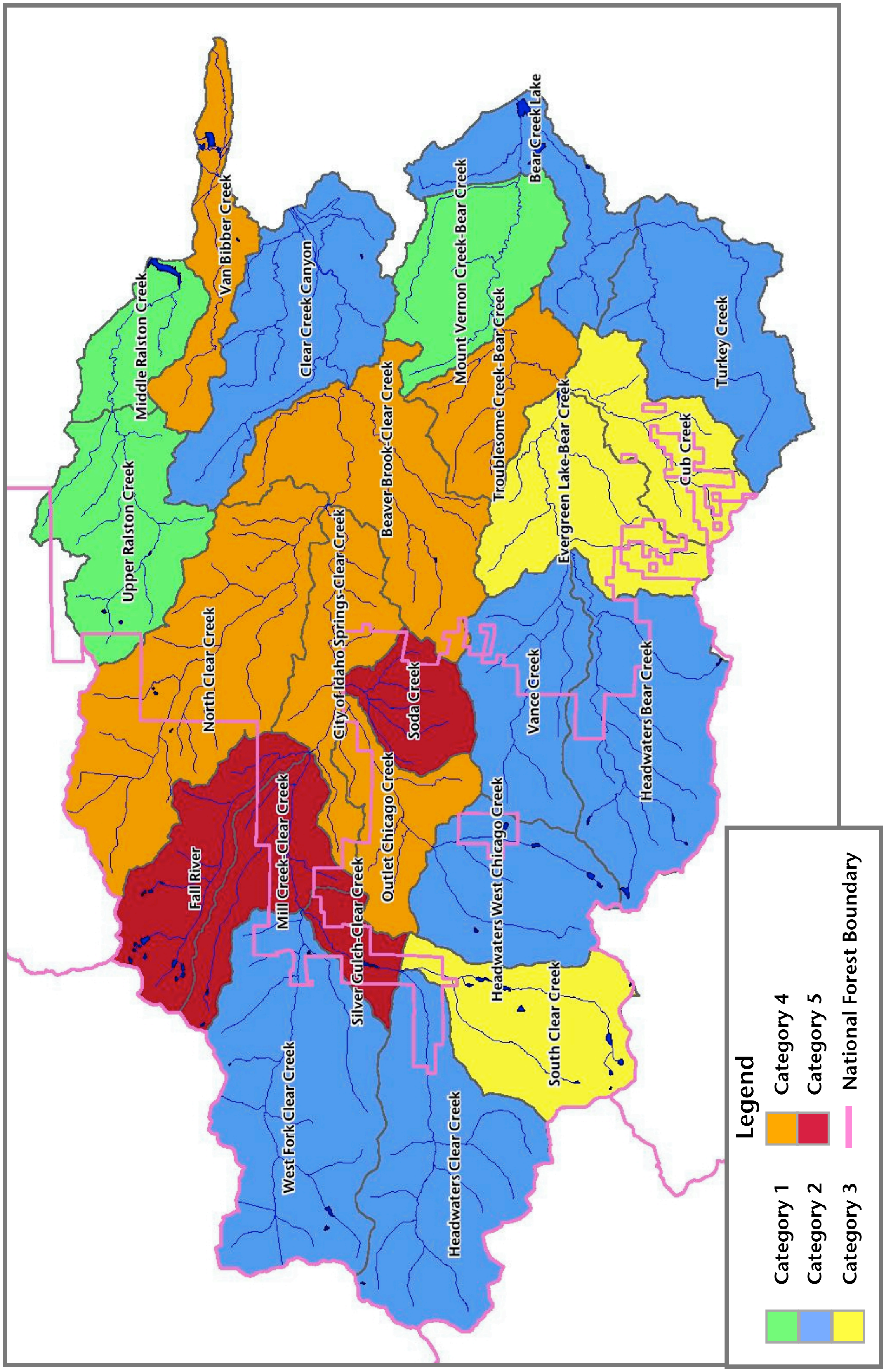

Figure 8. Clear/Bear Creek Watershed Flooding/Debris Flow Hazard Ranking

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 Silver Gulch-Clear Creek, Vance Creek, Mill Creek-Clear Creek, City of Idaho Springs-Clear Creek, and West Fork Clear Creek. The soil erodibility values for Vance Creek, Headwaters Bear Creek, Evergreen Lake-Bear Creek, Cub Creek, and Turkey Creek were adjusted up due to the presence of granitic soils. Silver Gulch-Clear Creek was skewing the categorization because of its high soil erodibility value and was manually given a score slightly higher than the next highest score (Table B-5 in Appendix B).

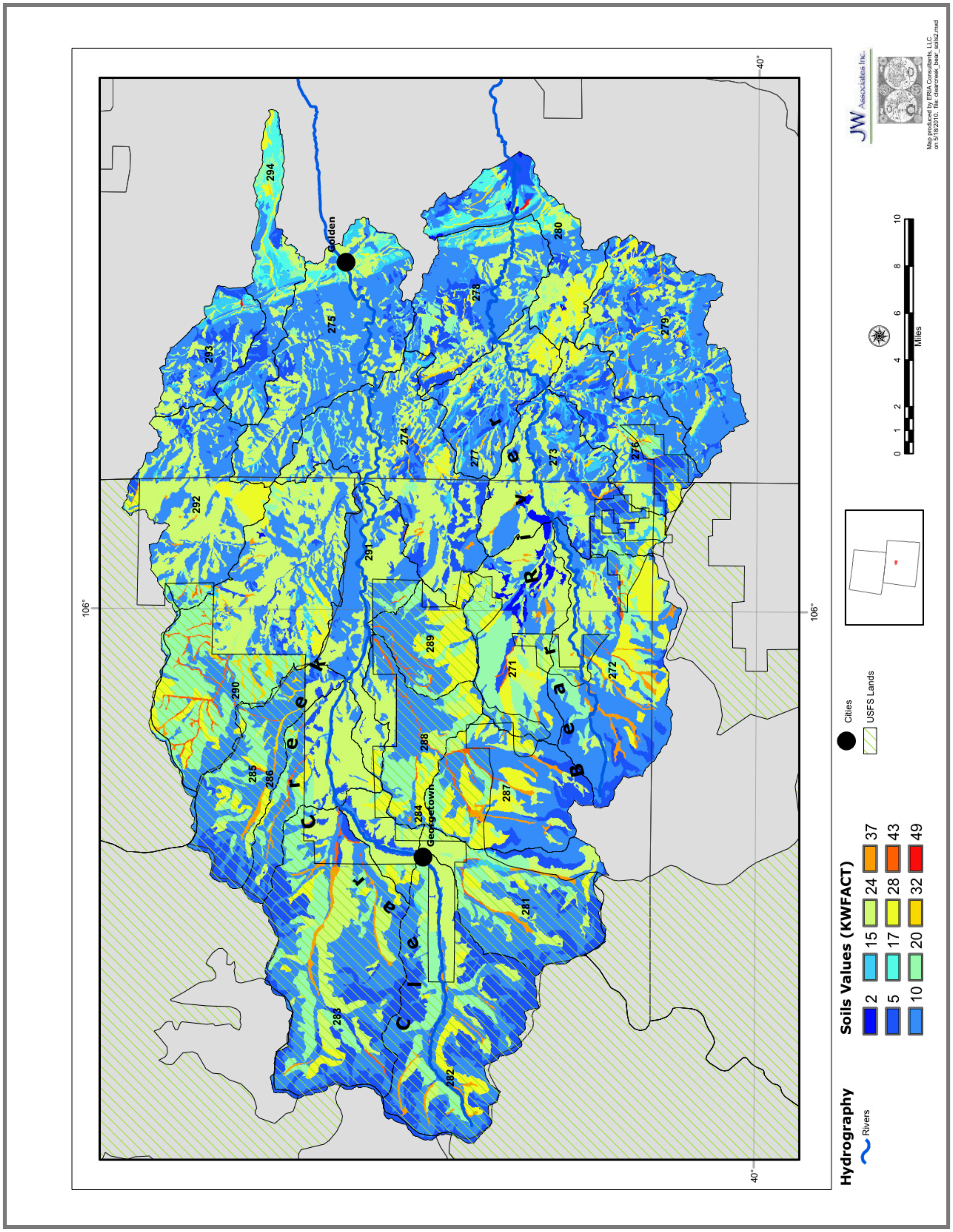

Figure 9. Clear/Bear Creek Watershed Soils K-Factor Map

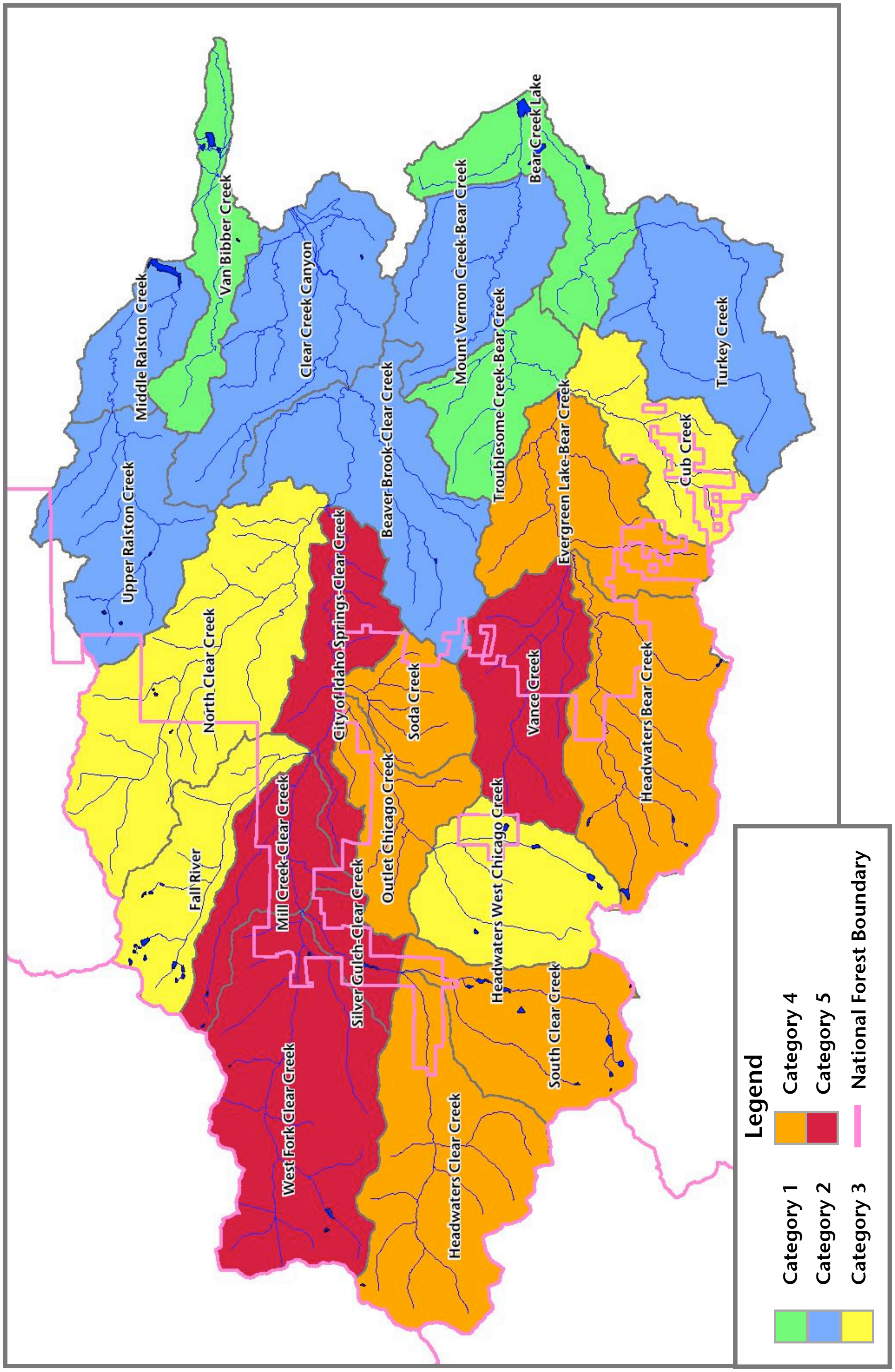

Figure 10. Clear/Bear Creek Watershed Potential Soil Erodibility Hazard Ranking

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 Clear/Bear Creek 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 Silver Gulch-Clear Creek, Mill Creek-Clear Creek, Soda Creek, and City of Idaho Springs-Clear Creek. There are three watersheds in Category 4.

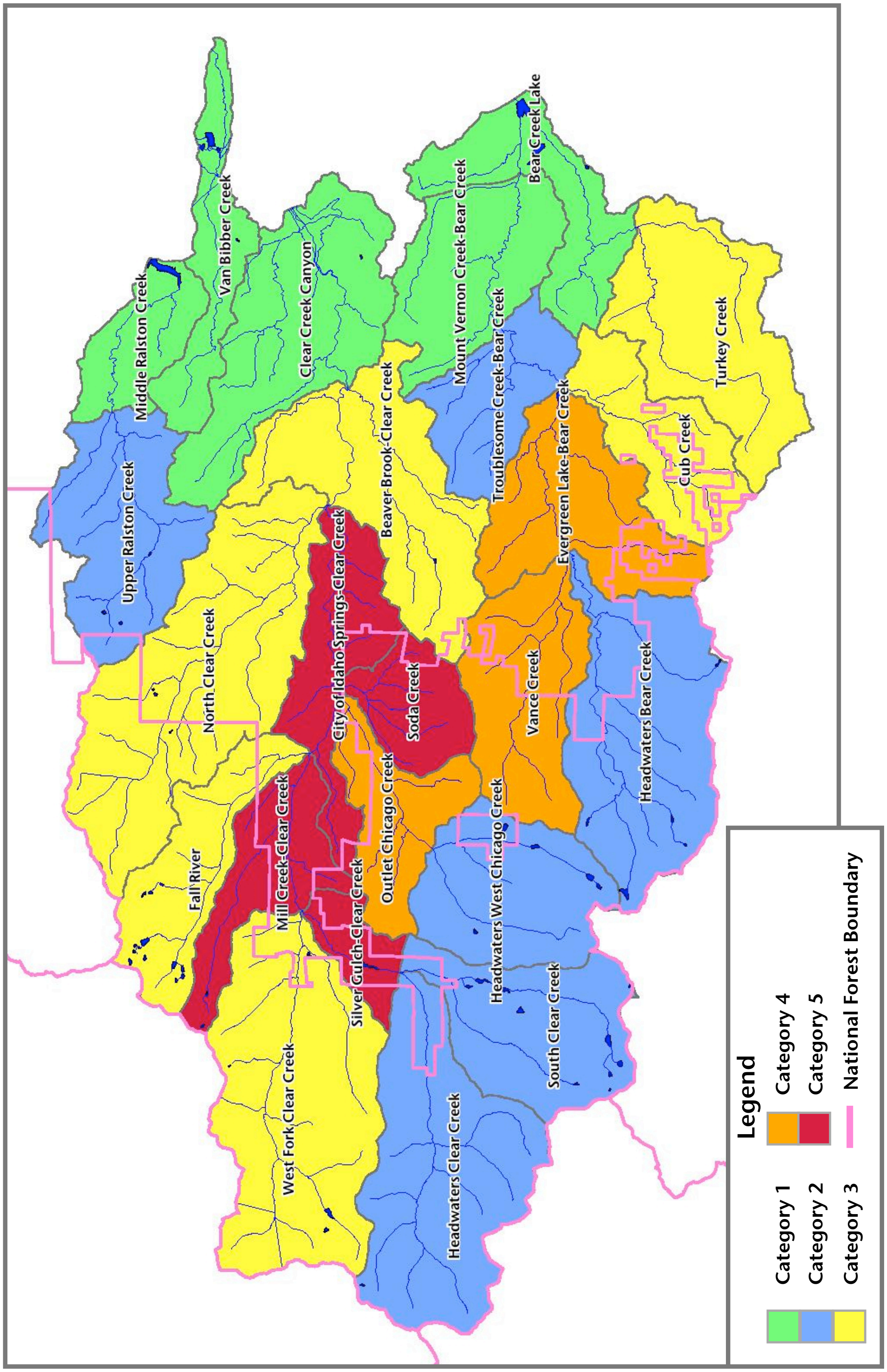

Figure 11. Clear/Bear Creek Watershed Composite Hazard Ranking

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.

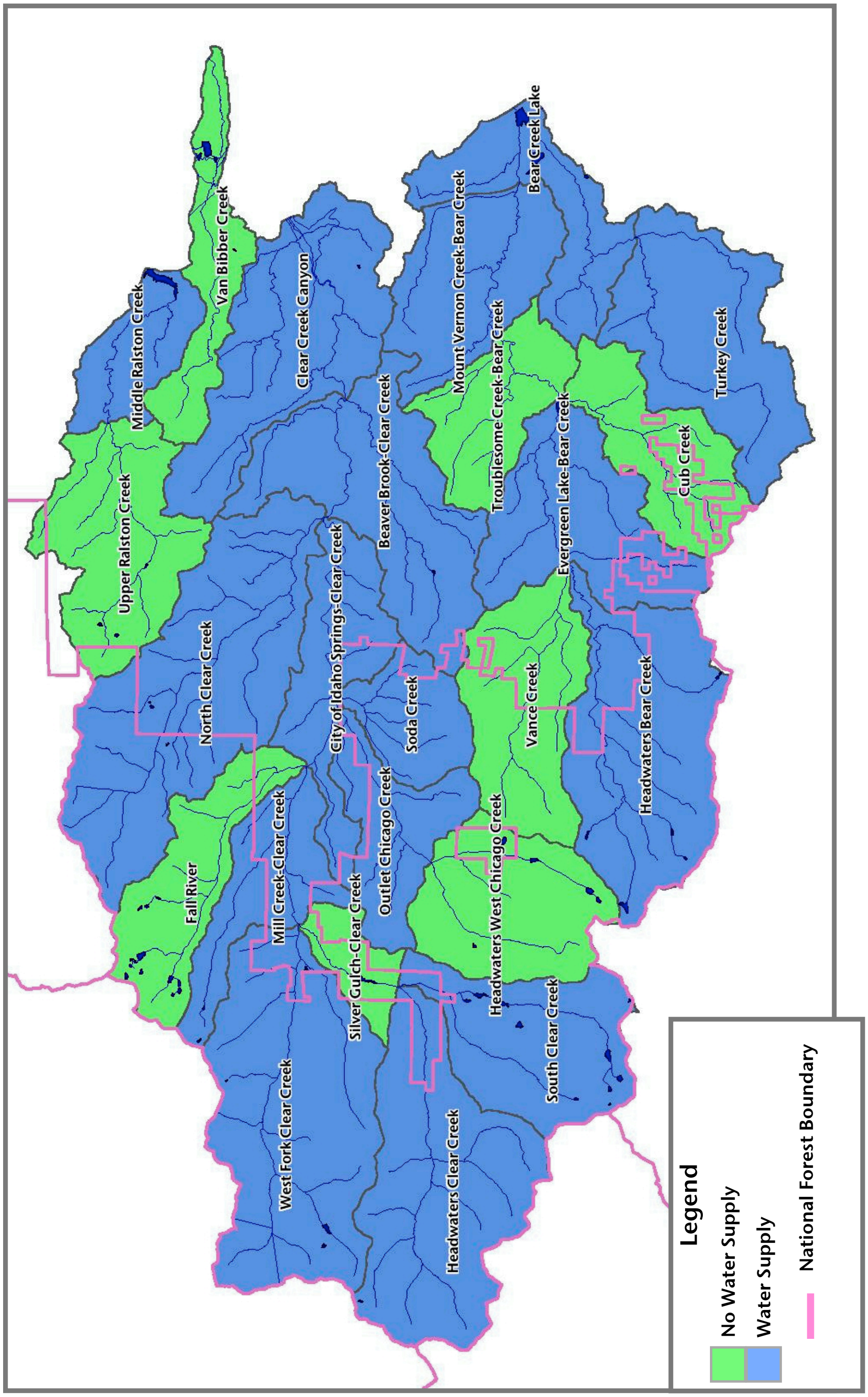

Figure 12. Clear/Bear Creek Watershed Water Supply Map

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APPENDIX A

CLEAR/BEAR CREEK 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 CLEAR/BEAR CREEK WATERSHED ASSESSMENT RESULTS

Table B-1. Clear/Bear Creek Watershed Wildfire Hazard Ranking[1]

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Hazard Rank
Soda Creek	8,941	66.0%	*5.5*
Outlet Chicago Creek	12,142	65.2%	*5.4*
Silver Gulch-Clear Creek	5,260	60.4%	*4.9*
Upper Ralston Creek	20,615	56.9%	*4.5*
Evergreen Lake-Bear Creek	20,431	56.3%	*4.4*
Cub Creek	14,241	55.2%	*4.3*
Mill Creek-Clear Creek	12,696	54.8%	*4.3*
Turkey Creek	24,197	54.0%	*4.2*
Vance Creek	18,559	53.7%	*4.1*
City of Idaho Springs-Clear Creek	14,457	52.8%	*4.0*
North Clear Creek	38,491	44.4%	*3.1*
Beaver Brook-Clear Creek	26,222	43.2%	*3.0*
Middle Ralston Creek	8,973	37.5%	*2.3*
Headwaters West Chicago Creek	18,607	36.7%	*2.2*
Headwaters Bear Creek	28,652	35.9%	*2.2*
Fall River	14,976	35.4%	*2.1*
West Fork Clear Creek	36,752	34.7%	*2.0*
Troublesome Creek-Bear Creek	12,667	32.6%	*1.8*
Mount Vernon Creek-Bear Creek	17,719	28.3%	*1.3*
Clear Creek Canyon	26,281	28.2%	*1.3*
Bear Creek Lake	14,445	24.1%	*0.8*
South Clear Creek	19,295	23.3%	*0.7*
Headwaters Clear Creek	30,846	22.8%	*0.7*
Van Bibber Creek	11,357	21.1%	*0.5*

[1] Soda Creek was skewing the categorization because of its high wildfire hazard score of 77.58. It was manually given a score slightly higher than the next highest score.

Table B-2. Clear/Bear Creek Watershed Ruggedness Ranking[2, 3]

Sixth-level Watershed Name	Maximum Elevation	Minimum Elevation	Difference Elevation	Ruggedness	Ruggedness Rank
Silver Gulch-Clear Creek	12,297	8,220	4,077	0.2400	*5.5*
Mill Creek-Clear Creek	13,133	7,721	5,412	0.2301	*5.2*
Fall River	13,353	7,708	5,645	0.2210	*4.9*
Soda Creek	11,637	7,518	4,120	0.2088	*4.5*
City of Idaho Springs-Clear Creek	11,122	6,914	4,208	0.2054	*4.3*
Van Bibber Creek	9,738	5,340	4,398	0.1978	*4.1*
Headwaters Bear Creek	14,232	7,521	6,711	0.1900	*3.8*
Beaver Brook-Clear Creek	11,467	6,393	5,074	0.1839	*3.6*
South Clear Creek	13,809	8,502	5,307	0.1831	*3.6*
Vance Creek	12,736	7,544	5,192	0.1826	*3.6*
North Clear Creek	12,133	6,914	5,218	0.1802	*3.5*
Troublesome Creek-Bear Creek	9,692	6,708	2,985	0.1797	*3.5*
Outlet Chicago Creek	11,555	7,554	4,002	0.1740	*3.3*
Headwaters West Chicago Creek	13,674	8,804	4,871	0.1711	*3.2*
Evergreen Lake-Bear Creek	10,571	7,055	3,516	0.1667	*3.0*
Headwaters Clear Creek	14,229	8,505	5,724	0.1561	*2.7*
Middle Ralston Creek	8,994	6,032	2,962	0.1498	*2.5*
Cub Creek	10,696	7,032	3,664	0.1471	*2.4*
West Fork Clear Creek	13,632	8,230	5,402	0.1350	*2.0*
Clear Creek Canyon	9,925	5,619	4,307	0.1273	*1.7*
Bear Creek Lake	8,554	5,550	3,004	0.1198	*1.5*
Turkey Creek	10,693	6,858	3,834	0.1181	*1.4*
Upper Ralston Creek	10,489	7,396	3,093	0.1032	*0.9*
Mount Vernon Creek-Bear Creek	8,262	5,733	2,529	0.0910	*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; City of Idaho Springs-Clear Creek (0.1627), Beaver Brook-Clear Creek (0.1501), North Clear Creek (0.1274), Troublesome Creek-Bear Creek (0.1271), and Evergreen Lake-Bear Creek (0.1179).

Table B-3. Clear/Bear Creek 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
Cub Creek	108.8	108.8	22.25	4.89	*5.5*
Turkey Creek	182.4	182.4	37.81	4.82	*5.4*
Soda Creek	63.4	63.4	13.97	4.54	*5.1*
Mount Vernon Creek-Bear Creek	123.7	123.7	27.69	4.47	*5.0*
Troublesome Creek-Bear Creek	119.9	80.4	19.79	4.06	*4.6*
Mill Creek-Clear Creek	77.0	77.0	19.84	3.88	*4.3*
Bear Creek Lake	130.4	87.4	22.57	3.87	*4.3*
Outlet Chicago Creek	71.2	71.2	18.97	3.75	*4.2*
Clear Creek Canyon	148.8	148.8	41.06	3.62	*4.1*
Beaver Brook-Clear Creek	146.3	146.3	40.97	3.57	*4.0*
North Clear Creek	209.2	209.2	60.14	3.48	*3.9*
Fall River	80.5	80.5	23.40	3.44	*3.8*
Silver Gulch-Clear Creek	40.9	27.4	8.22	3.33	*3.7*
Evergreen Lake-Bear Creek	105.5	105.5	31.92	3.30	*3.7*
City of Idaho Springs-Clear Creek	98.9	74.2	22.59	3.28	*3.7*
Van Bibber Creek	91.2	45.6	17.75	2.57	*2.9*
South Clear Creek	74.1	74.1	30.15	2.46	*2.7*
West Fork Clear Creek	135.4	135.4	57.43	2.36	*2.6*
Upper Ralston Creek	71.1	71.1	32.21	2.21	*2.4*
Headwaters Clear Creek	110.7	83.1	48.20	1.72	*1.9*
Headwaters West Chicago Creek	32.1	32.1	29.07	1.10	*1.2*
Middle Ralston Creek	14.1	14.1	14.02	1.01	*1.1*
Vance Creek	20.1	20.1	29.00	0.69	*0.7*
Headwaters Bear Creek	22.9	22.9	44.77	0.51	*0.5*

[4] The road density was adjusted based upon the procedure discussed in the report (p. 12). The original road density values were; Troublesome Creek-Bear Creek (6.06), Bear Creek Lake (5.78), Headwaters Clear Creek (2.30), Silver Gulch-Clear Creek (4.98), City of Idaho Springs-Clear Creek (4.38) and Van Bibber Creek (5.14).

Table B-4. Clear/Bear Creek Watershed Flooding/Debris Flow Hazard Ranking

Sixth-level Watershed Name	Ruggedness Ranking	Road Density Ranking	Combined Numeric Rank	Combined Ranking
Silver Gulch-Clear Creek	*5.5*	*3.7*	14.72	*5.5*
Mill Creek-Clear Creek	*5.2*	*4.3*	14.69	*5.5*
Soda Creek	*4.5*	*5.1*	14.00	*5.2*
Fall River	*4.9*	*3.8*	13.57	*4.9*
City of Idaho Springs-Clear Creek	*4.3*	*3.7*	12.34	*4.4*
Troublesome Creek-Bear Creek	*3.5*	*4.6*	11.50	*4.0*
Beaver Brook-Clear Creek	*3.6*	*4.0*	11.23	*3.8*
Van Bibber Creek	*4.1*	*2.9*	11.01	*3.7*
North Clear Creek	*3.5*	*3.9*	10.88	*3.7*
Outlet Chicago Creek	*3.3*	*4.2*	10.77	*3.6*
Cub Creek	*2.4*	*5.5*	10.26	*3.4*
South Clear Creek	*3.6*	*2.7*	9.90	*3.2*
Evergreen Lake-Bear Creek	*3.0*	*3.7*	9.77	*3.1*
Turkey Creek	*1.4*	*5.4*	8.24	*2.4*
Headwaters Bear Creek	*3.8*	*0.5*	8.14	*2.4*
Vance Creek	*3.6*	*0.7*	7.86	*2.2*
Headwaters West Chicago Creek	*3.2*	*1.2*	7.55	*2.1*
Clear Creek Canyon	*1.7*	*4.1*	7.49	*2.0*
Bear Creek Lake	*1.5*	*4.3*	7.27	*1.9*
Headwaters Clear Creek	*2.7*	*1.9*	7.26	*1.9*
West Fork Clear Creek	*2.0*	*2.6*	6.56	*1.6*
Mount Vernon Creek-Bear Creek	*0.5*	*5.0*	6.02	*1.3*
Middle Ralston Creek	*2.5*	*1.1*	6.01	*1.3*
Upper Ralston Creek	*0.9*	*2.4*	4.25	*0.5*

Table B-5. Clear/Bear Creek Watershed Soil Erodibility Ranking[5, 6, 7]

Sixth-level Watershed Name	Severe (%)	Very Severe (%)	Soil Erodibility Value	Soil Erodibility Rank
Silver Gulch-Clear Creek	21.2%	42.1%	0.630	*5.5*
Vance Creek	25.6%	13.5%	0.626	*5.5*
Headwaters Clear Creek	17.2%	16.7%	0.607	*5.3*
Mill Creek-Clear Creek	24.5%	17.7%	0.598	*5.2*
City of Idaho Springs-Clear Creek	28.0%	15.6%	0.591	*5.1*
West Fork Clear Creek	22.4%	17.9%	0.582	*5.0*
Soda Creek	29.2%	8.8%	0.468	*3.9*
Outlet Chicago Creek	29.5%	8.6%	0.466	*3.9*
South Clear Creek	17.2%	14.0%	0.452	*3.7*
Headwaters Bear Creek	17.6%	4.7%	0.369	*2.9*
Fall River	20.9%	7.4%	0.357	*2.8*
Evergreen Lake-Bear Creek	13.2%	5.7%	0.345	*2.7*
Headwaters West Chicago Creek	20.7%	6.7%	0.340	*2.6*
North Clear Creek	18.9%	7.2%	0.334	*2.5*
Middle Ralston Creek	19.4%	6.4%	0.321	*2.4*
Clear Creek Canyon	20.3%	5.3%	0.309	*2.3*
Beaver Brook-Clear Creek	17.2%	6.8%	0.308	*2.3*
Upper Ralston Creek	15.1%	5.7%	0.264	*1.9*
Mount Vernon Creek-Bear Creek	14.1%	5.0%	0.240	*1.6*
Cub Creek	9.6%	2.0%	0.236	*1.6*
Turkey Creek	6.0%	1.4%	0.188	*1.1*
Troublesome Creek-Bear Creek	11.1%	3.0%	0.170	*0.9*
Bear Creek Lake	12.3%	2.2%	0.166	*0.9*
Van Bibber Creek	7.8%	2.5%	0.128	*0.5*

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

[6] The original soil erodibility values for Vance Creek (0.526), Headwaters Clear Creek (0.587), Headwaters Bear Creek (0.269), Evergreen Lake-Bear Creek (0.245), Cub Creek (0.136), and Turkey Creek (0.088) due to the presence of granitic soils.

[7] Silver Gulch-Clear Creek was skewing the categorization because of its high soil erodibility value (originally 1.054) and was manually given a score slightly higher than the next highest score.

Table B-6. Clear/Bear Creek Watershed Composite Hazard Ranking

Sixth-level Watershed Name	Wildfire Hazard Rank	Flooding/ Debris Flow Rank	Soil Erodibility Rank	Composite Hazard Rank
Silver Gulch-Clear Creek	4.9	5.5	5.5	5.5
Mill Creek-Clear Creek	4.3	5.5	5.2	5.1
Soda Creek	5.5	5.2	3.9	5.0
City of Idaho Springs-Clear Creek	4.0	4.4	5.1	4.5
Outlet Chicago Creek	5.4	3.6	3.9	4.3
Vance Creek	4.1	2.2	5.5	3.8
Evergreen Lake-Bear Creek	4.4	3.1	2.7	3.2
Fall River	2.1	4.9	2.8	3.0
North Clear Creek	3.1	3.7	2.5	2.8
Cub Creek	4.3	3.4	1.6	2.8
Beaver Brook-Clear Creek	3.0	3.8	2.3	2.7
West Fork Clear Creek	2.0	1.6	5.0	2.5
Headwaters Clear Creek	0.7	1.9	5.3	2.2
South Clear Creek	0.7	3.2	3.7	2.1
Turkey Creek	4.2	2.4	1.1	2.1
Headwaters Bear Creek	2.2	2.4	2.9	2.0
Headwaters West Chicago Creek	2.2	2.1	2.6	1.8
Upper Ralston Creek	4.5	0.5	1.9	1.8
Troublesome Creek-Bear Creek	1.8	4.0	0.9	1.7
Middle Ralston Creek	2.3	1.3	2.4	1.5
Clear Creek Canyon	1.3	2.0	2.3	1.3
Van Bibber Creek	0.5	3.7	0.5	0.9
Mount Vernon Creek-Bear Creek	1.3	1.3	1.6	0.7
Bear Creek Lake	0.8	1.9	0.9	0.5