Upper Yampa 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.

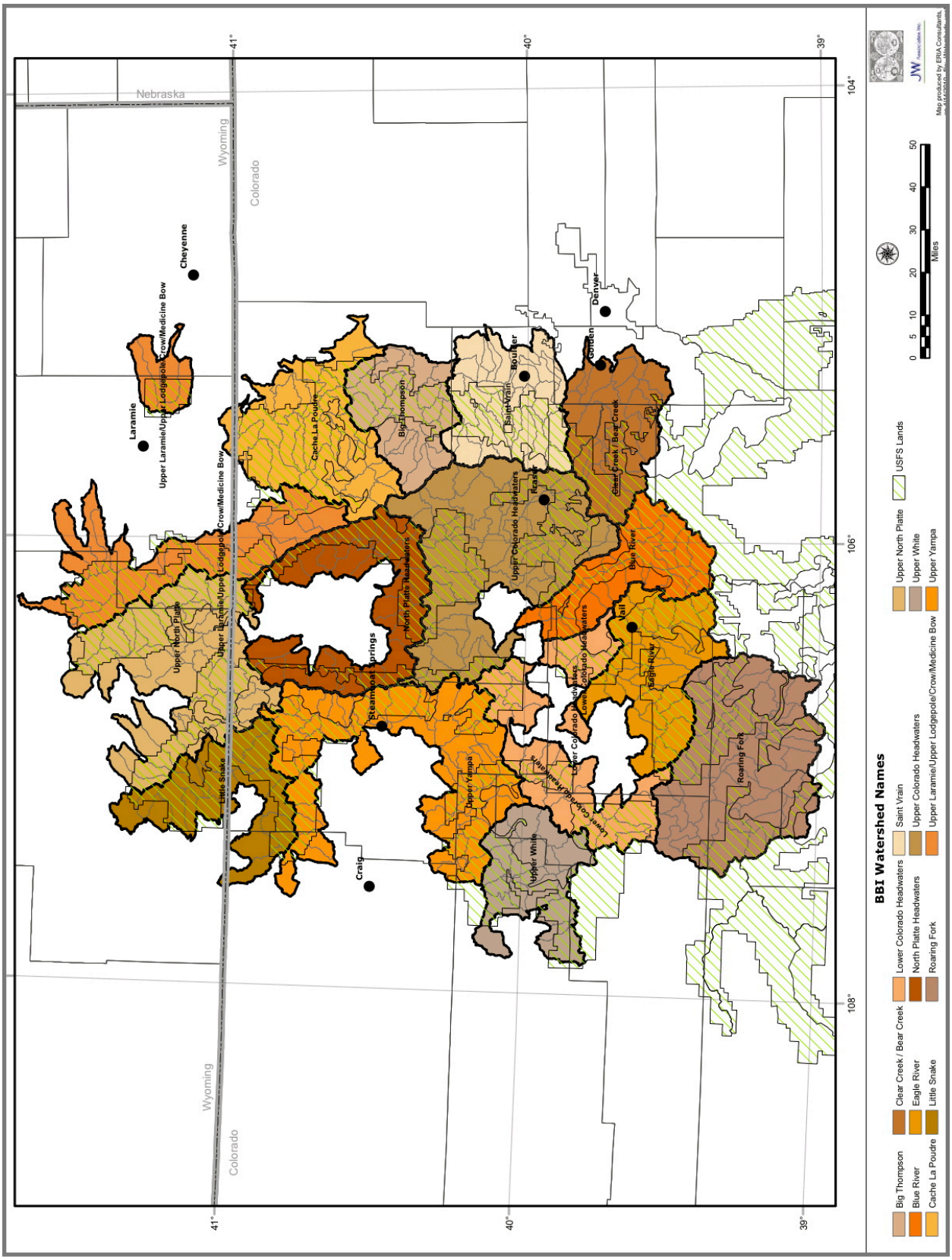


Figure 1. Bark Beetle Incident Phase 1 Watersheds

WATERSHED DESCRIPTION

The Upper Yampa watershed is located in the Colorado Plateau country in northwestern Colorado. The Upper Yampa flows through the Lower Yampa watershed when it emerges from this watershed. Further downstream is the confluence with the Little Snake River and then flows into the Green River just before the state line. 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 Upper Yampa Watershed is approximately 1,677,734 acres in area and is part of one fourth-level[1] (eight-digit) watershed (HUC 14050001). For this watershed assessment, 37 sixth-level watersheds were eliminated based upon their wildfire hazard, ruggedness, and an examination of how well they fit into this assessment. The Upper Yampa watershed used in this analysis is 918,006 acres, contains nine fifth-level watersheds and 48 sixth-level watersheds, which are the analysis units for this watershed assessment (Front Range Watershed Protection Data Refinement Work Group 2009). The Upper Yampa watershed and its fifth-level and sixth-level watersheds are shown on Figure 2 and listed in Table 1.

[I] 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.

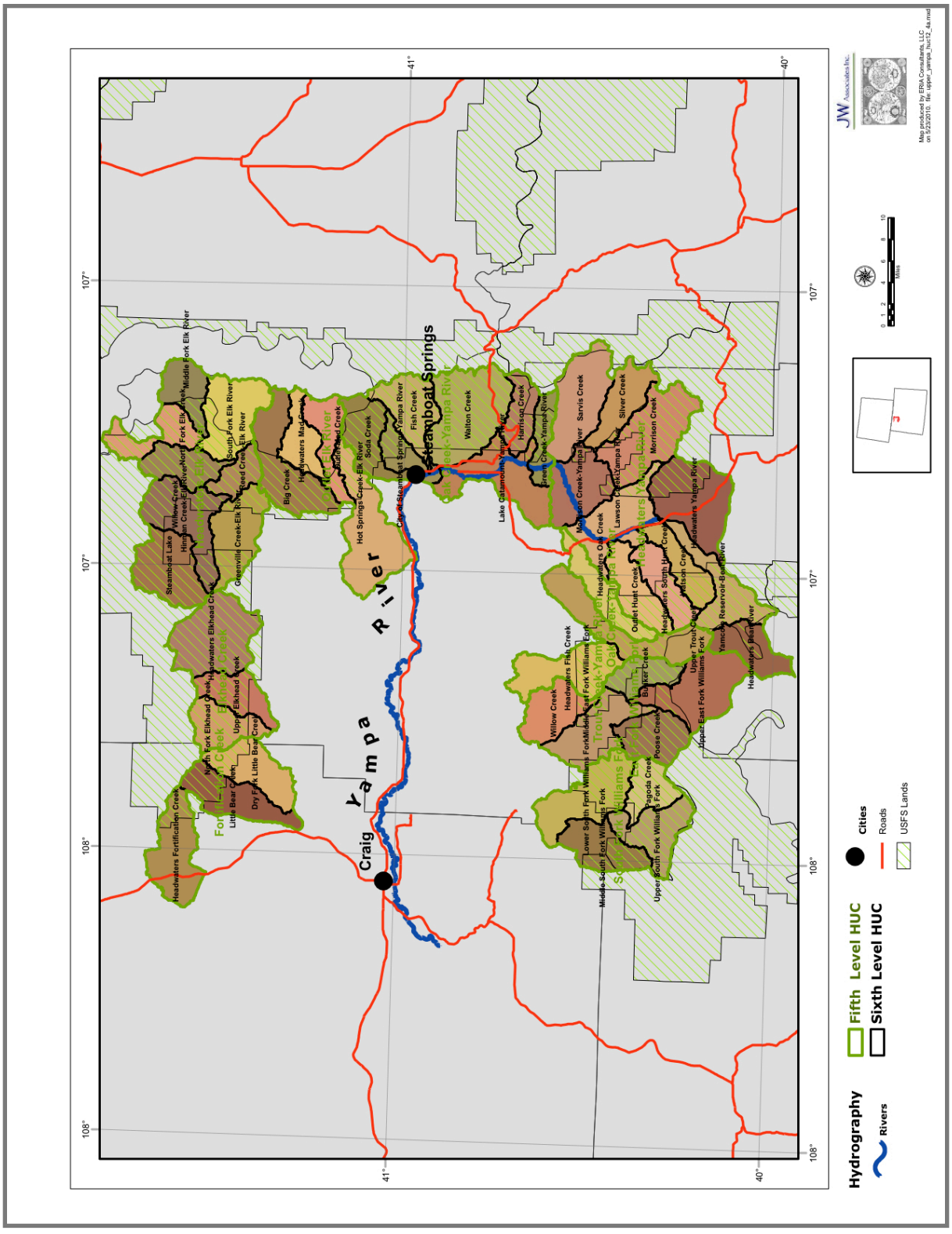


Figure 2. Upper Yampa Watershed Analysis Area[2]

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

Table 1. Fifth-level and Sixth-level Watersheds in Upper Yampa Watershed[3]

Fifth-level Watershed	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)	Map #
Headwaters Yampa River HUC 1405000101	Headwaters Bear River	14,094	140500010101	20
	Yamcolo Reservoir-Bear River	19,214	140500010102	21
	Headwaters Yampa River	29,607	140500010103	22
	Watson Creek	13,147	140500010104	23
	Headwaters South Hunt Creek	13,624	140500010105	24
	Outlet Hunt Creek	16,210	140500010106	25
	Lawson Creek-Yampa River	23,846	140500010107	26
	Silver Creek	15,742	140500010108	27
	Morrison Creek	30,232	140500010109	28
	Sarvis Creek	26,021	140500010110	29
	Morrison Creek-Yampa River	20,251	140500010111	30
Headwaters Elk Creek HUC 1405000102	Middle Fork Elk River	12,653	140500010201	31
	North Fork Elk Creek	13,973	140500010202	32
	South Fork Elk River	23,354	140500010203	33
	Hinman Creek-Elk River	14,193	140500010204	34
	Steamboat Lake	22,601	140500010205	35
	Willow Creek	24,697	140500010206	36
	Reed Creek-Elk River	8,984	140500010207	37
	Greenville Creek-Elk River	20,854	140500010208	38
Outlet Elk River HUC 1405000103	Big Creek	26,241	140500010302	39
	Headwaters Mad Creek	12,232	140500010303	40
	Outlet Mad Creek	13,370	140500010304	41
	Hot Springs Creek-Elk River	31,934	140500010306	10
Oak Creek-Yampa River HUC 1405000104	Green Creek-Yampa River	9,383	140500010401	11
	Harrison Creek	11,544	140500010402	12
	Headwaters Oak Creek	14,650	140500010403	13
	Walton Creek	34,993	140500010405	14
	Lake Catamount-Yampa River	25,552	140500010406	15
	Fish Creek	17,839	140500010407	16
	Soda Creek	16,917	140500010408	17
	City of Steamboat Springs-Yampa River	10,031	140500010409	18
Trout Creek-Yampa River HUC 1405000105	Upper Trout Creek	25,780	140500010501	19
	Headwaters Fish Creek	22,079	140500010503	42
Elkhead Creek HUC 1405000106	Headwaters Elkhead Creek	29,664	140500010601	43
	North Fork Elkhead Creek	14,418	140500010602	44
	Upper Elkhead Creek	13,759	140500010603	45
Fortification Creek HUC 1405000107	Headwaters Fortification Creek	22,603	140500010701	46
	Dry Fork Little Bear Creek	18,551	140500010705	1
	Little Bear Creek	19,347	140500010706	2

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

Table 1. Fifth-level and Sixth-level Watersheds in Upper Yampa Watershed (continued)

Fifth-level Watershed	Sixth-level Watershed	Watershed Area (acres)	Hydrologic Unit Code (HUC)	Map #
South Fork Williams Fork HUC 1405000108	Pagoda Creek	12,151	140500010801	3
	Upper South Fork Williams Fork	18,176	140500010802	4
	Middle South Fork Williams Fork	16,971	140500010803	5
	Lower South Fork Williams Fork	25,083	140500010804	6
East Fork Williams Fork HUC 1405000109	Bunker Creek	11,270	140500010901	7
	Upper East Fork Williams Fork	26,499	140500010902	8
	Poose Creek	16,093	140500010903	9
	Willow Creek	16,268	140500010904	47
	Middle East Fork Williams Fork	21,308	140500010905	48
	Total Area	**918,006**		

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 - Upper Yampa 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 Upper Yampa 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)

One watershed, Silver Creek, was skewing the results of the categorization. Therefore, the wildfire hazard calculation for Silver Creek was manually adjusted from 87% to 75%. 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: Silver Creek, Sarvis Creek and Morrison Creek. Three watersheds were ranked as Category 4, which is the next highest category (see Table B-1 in Appendix B).

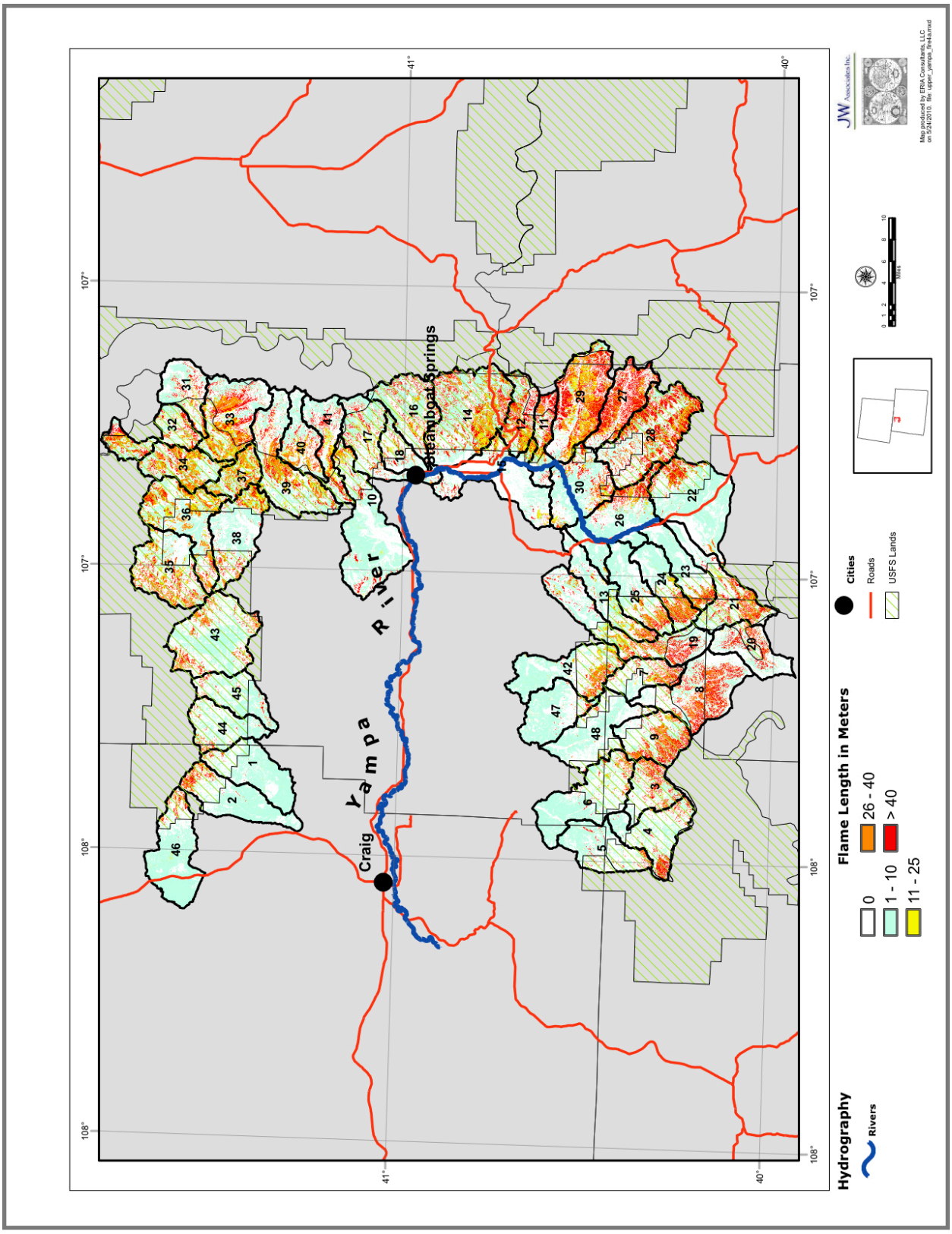


Figure 3. Upper Yampa Watershed Wildfire Hazard Modeling Results

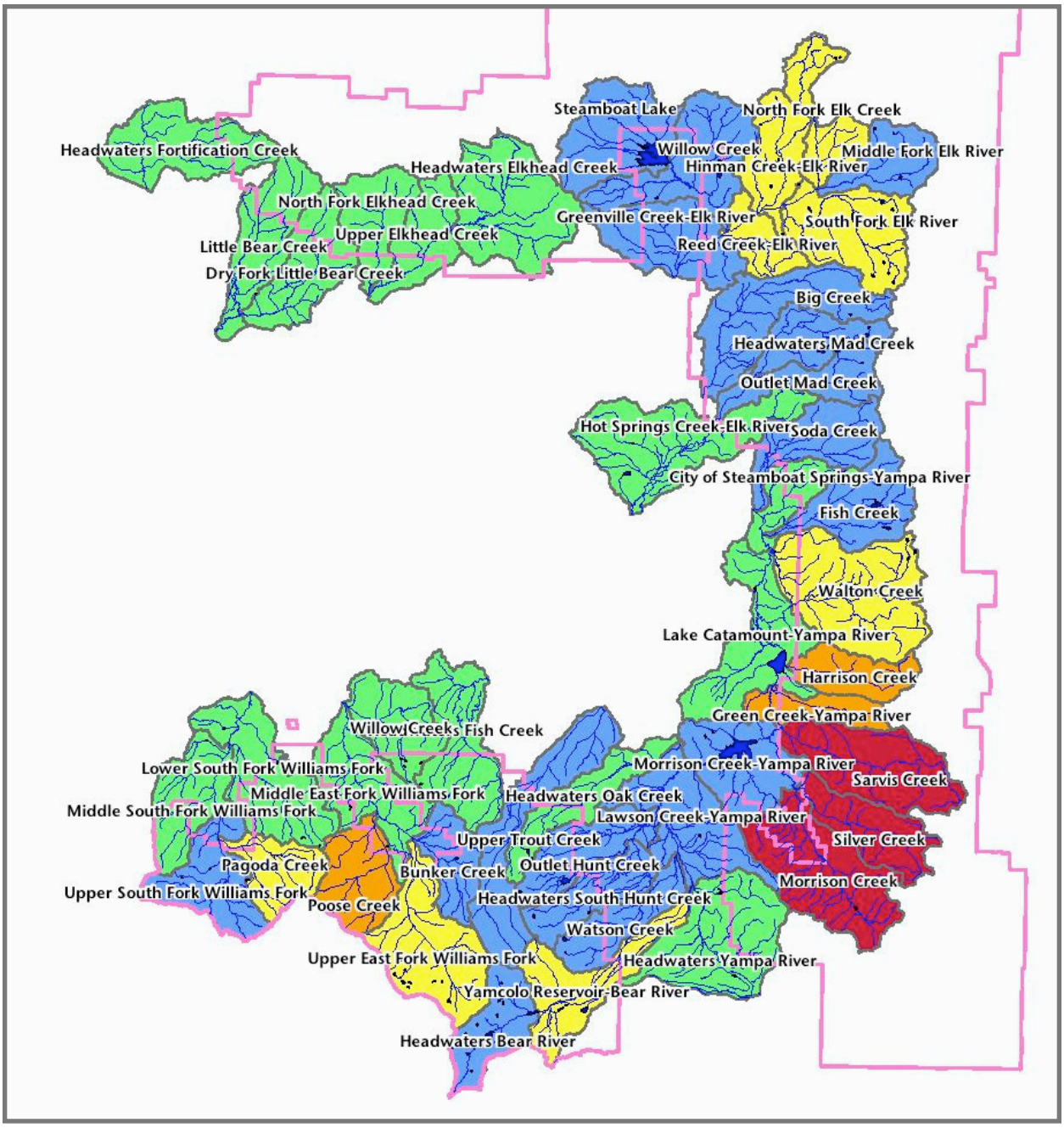
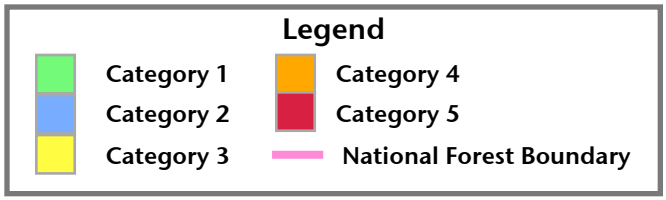


Figure 4. Upper Yampa Watershed Wildfire Hazard Ranking



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.

Figure 5 displays the categorized ruggedness for the Upper Yampa 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 Outlet Mad Creek, Headwaters Mad Creek, MIddle Fork Elk Creek, City of Steamboat Springs-Yampa River, and Green Creek-Yampa River.

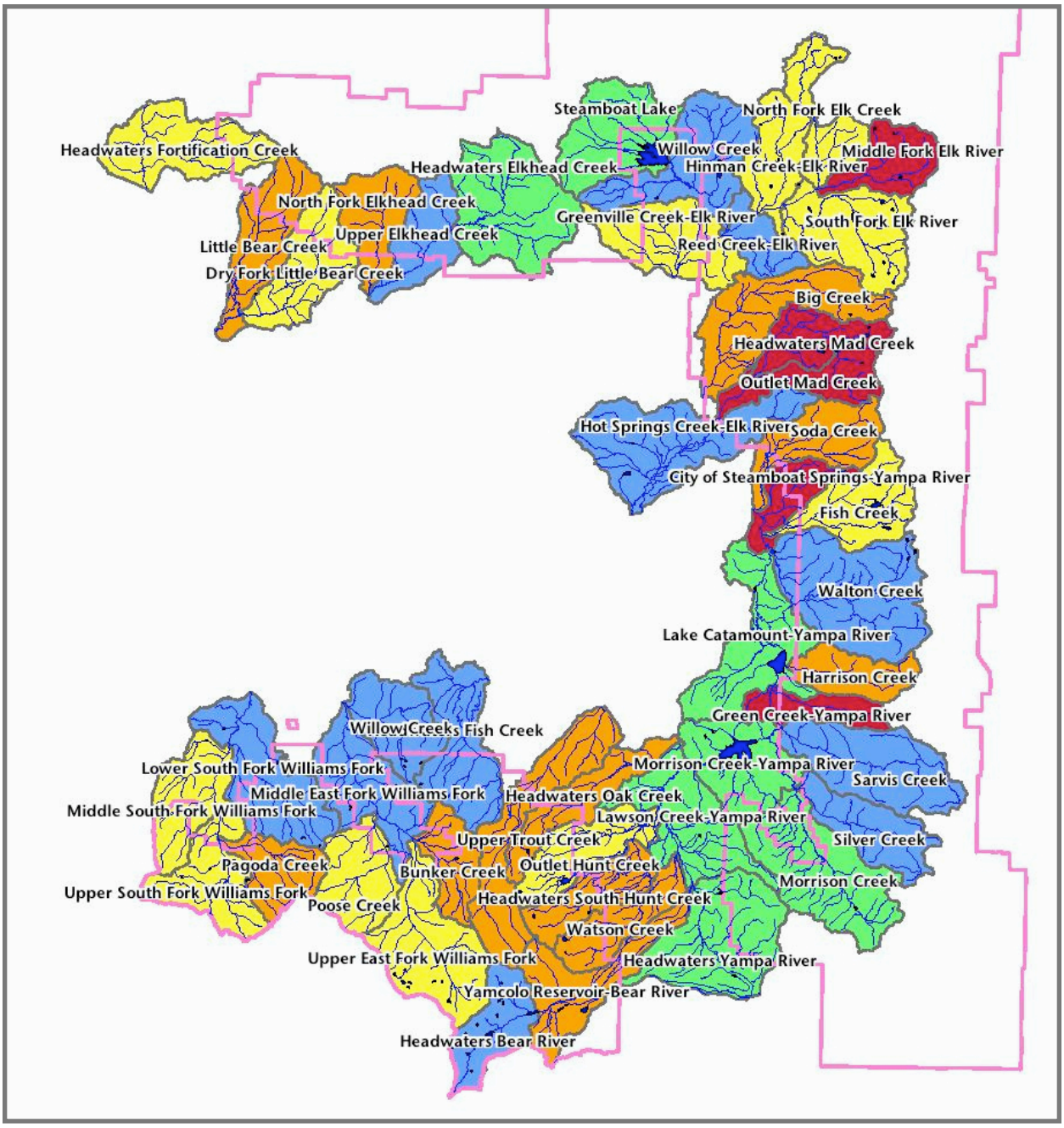
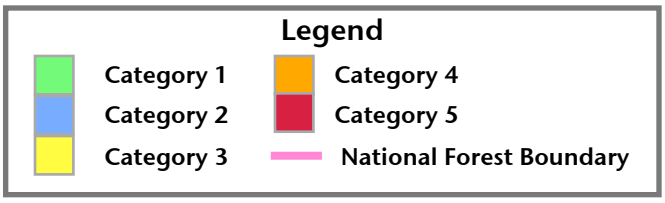


Figure 5. Upper Yampa Watershed Ruggedness Ranking



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 City of Steamboat Springs-Yampa River watershed was adjusted down. The adjustments are displayed on Table B-3 in Appendix B.

Figure 7 displays the categorized road density for the Upper Yampa Watershed and tabular results are presented in Appendix B (Table B-3). Figure 7 shows that the highest rankings are in the City of Steamboat Springs-Yampa River, Lake Catamount-Yampa River, and Headwaters Oak Creek.

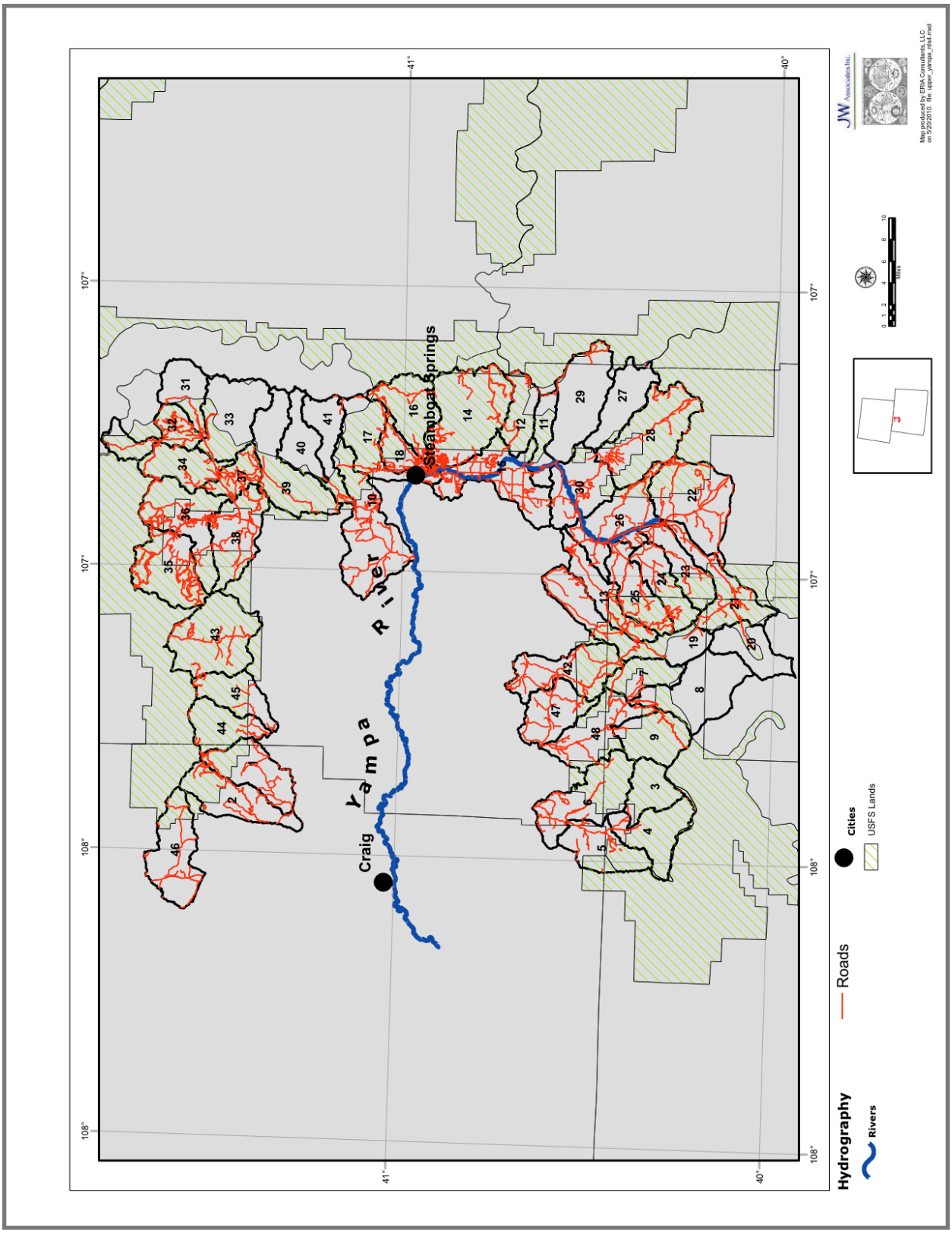


Figure 6. Upper Yampa Watershed Roads Map

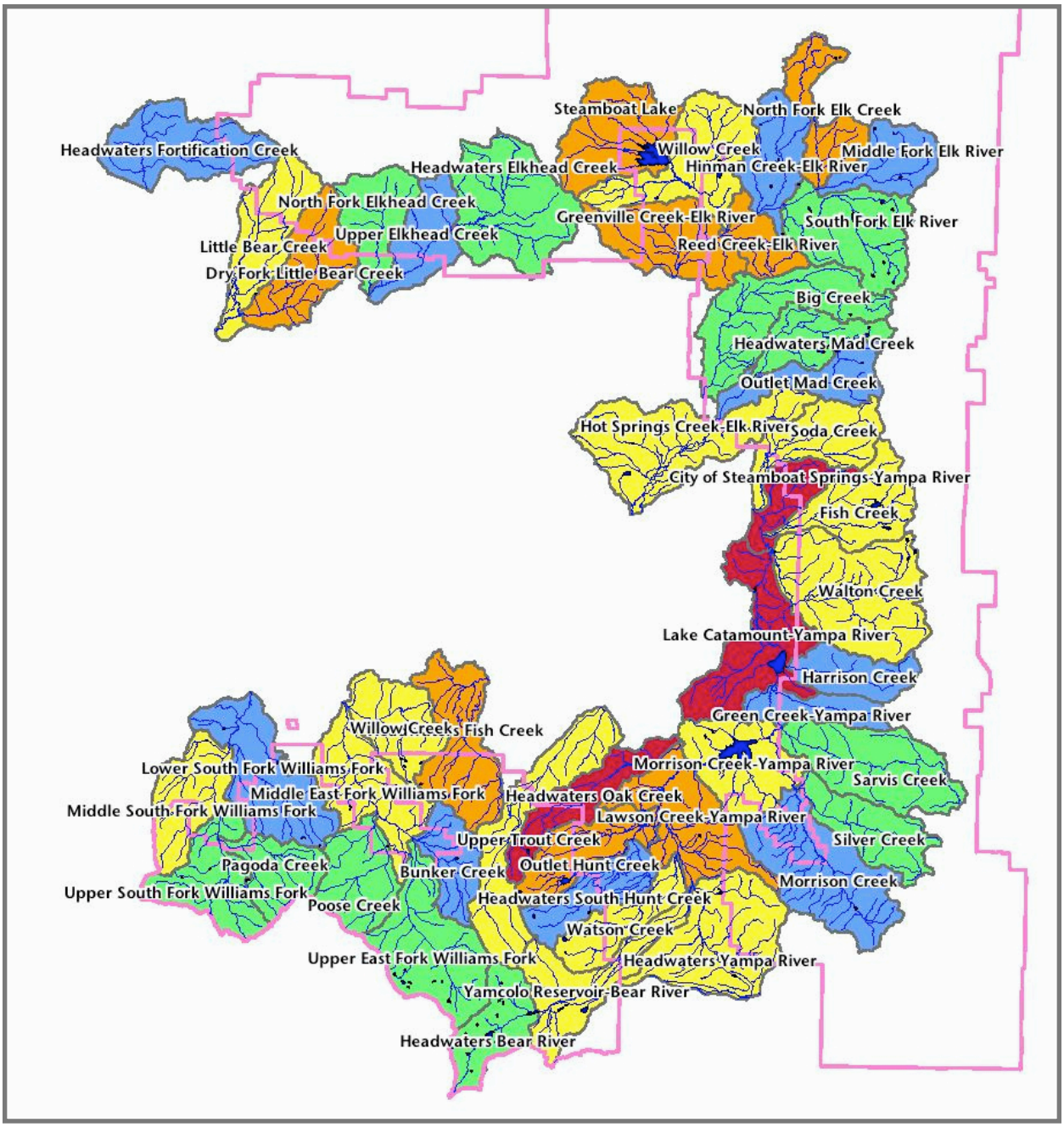
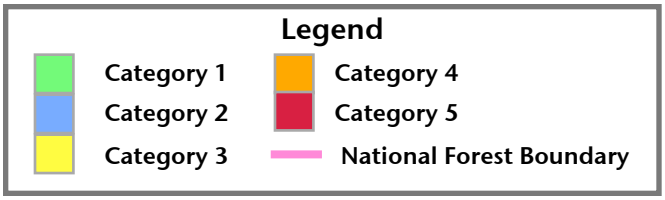


Figure 7. Upper Yampa Watershed Road Density Ranking



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 Upper Yampa 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 City of Steamboat Springs-Yampa River, Outlet Mad Creek, Headwaters Oak Creek, Middle Fork Elk River, Yamcolo Reservoir-Bear River, Headwaters Mad Creek, and Little Bear Creek. The City of Steamboat Springs-Yampa River watershed had a composite numeric rank so high that it was skewing the results of the categorization. It was adjusted down to be slightly higher than the next highest watershed (Table B-4 in Appendix B).

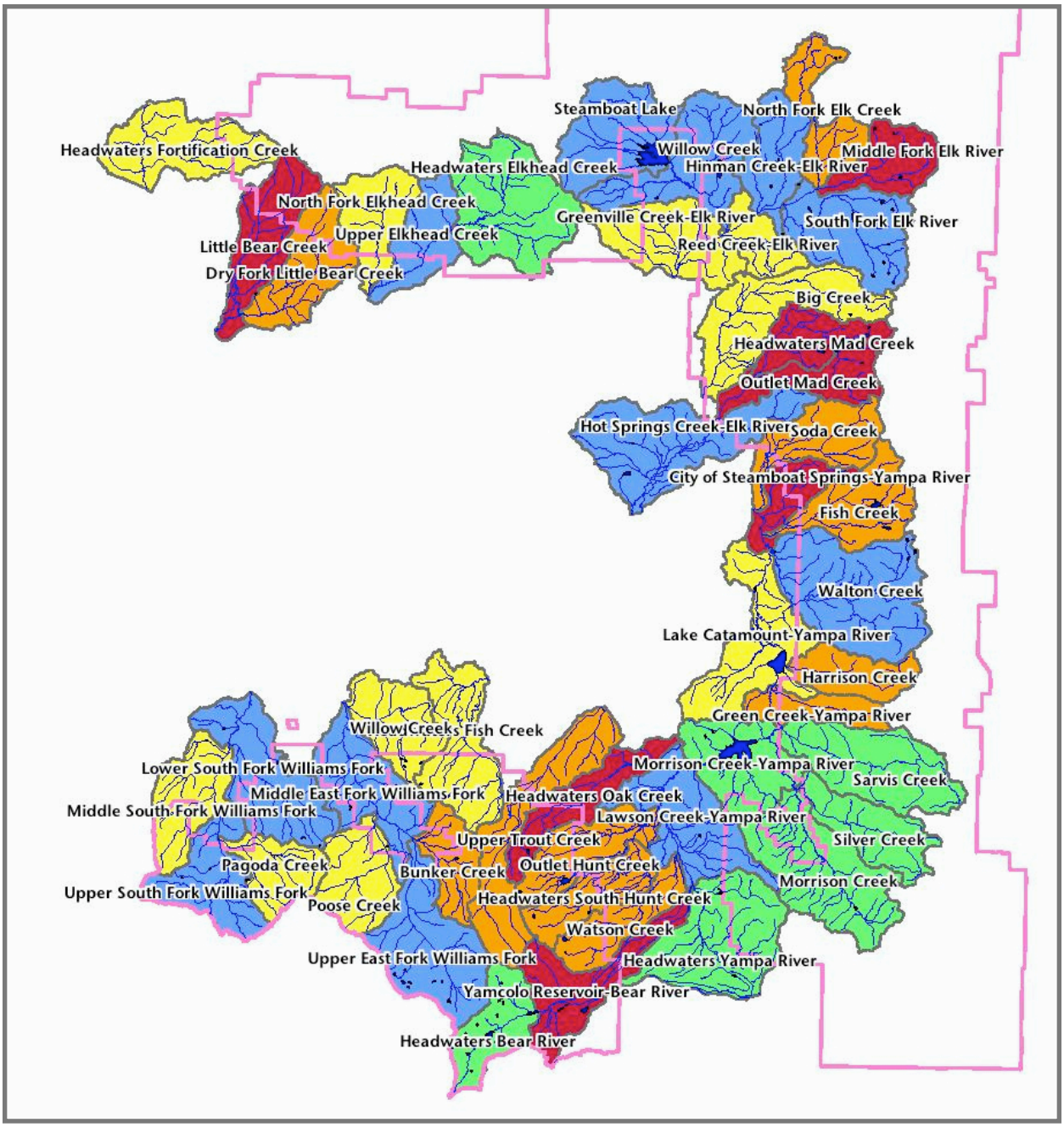
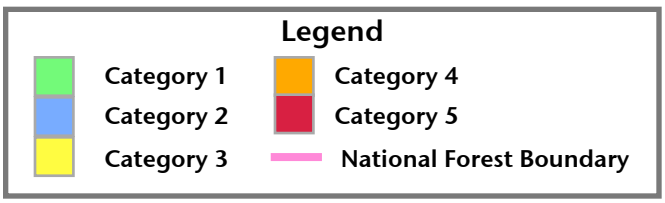


Figure 8. Upper Yampa Watershed Flooding/Debris Flow Hazard Ranking



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 Middle Fork Elk River, Middle South Fork Williams Fork, Upper Trout Creek, Outlet Mad Creek, Lower South Fork Williams Fork, Headwaters Oak Creek, Bunker Creek, and Big Creek. Two watersheds, Middle Fork Elk River and Middle South Fork Williams Fork, had soil erodibility values that were so high that they were skewing the categorization. They were manually adjusted to values slightly higher than the next highest soil erodibility value (Table B-5 in Appendix B).

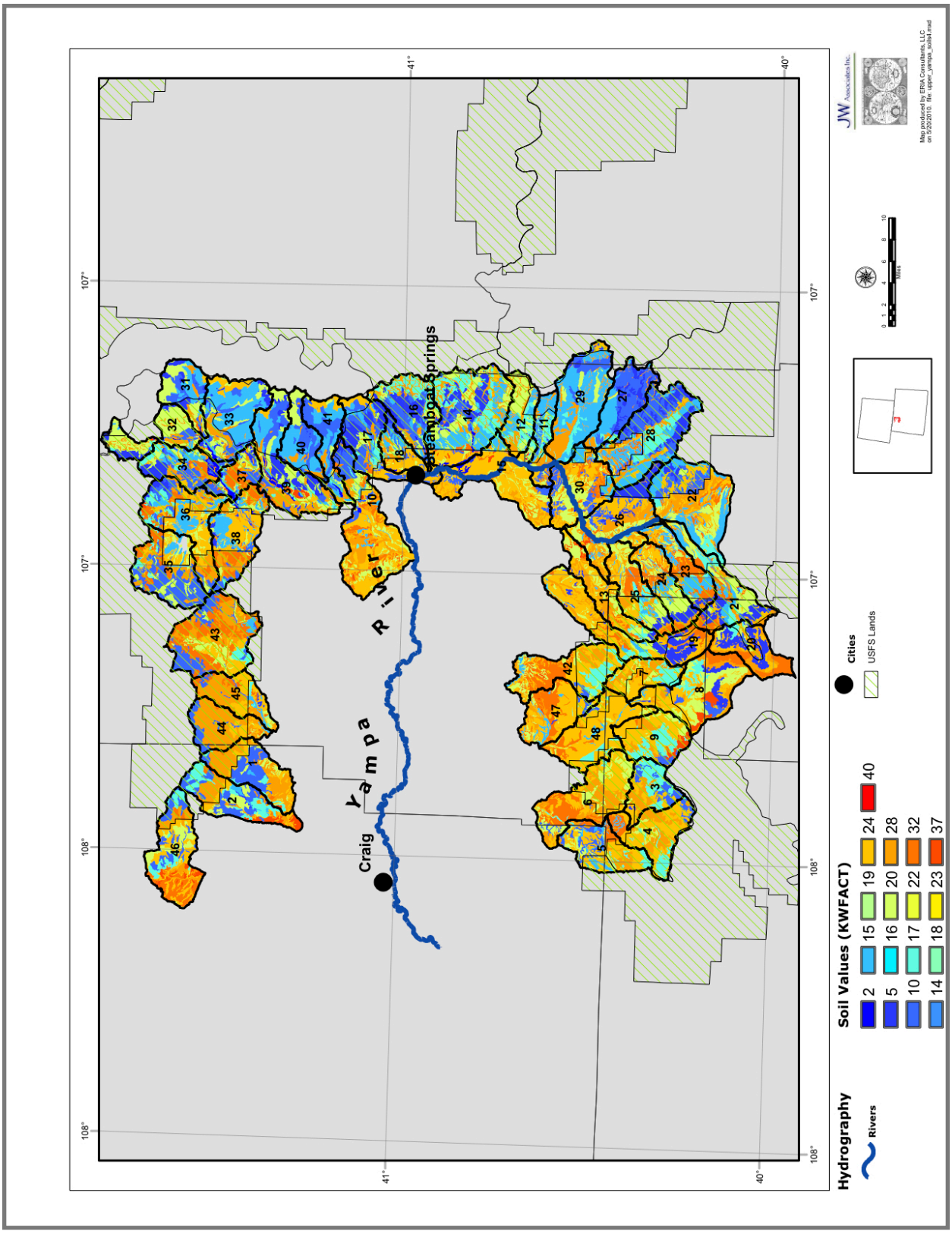


Figure 9. Upper Yampa Watershed Soils K-Factor Map

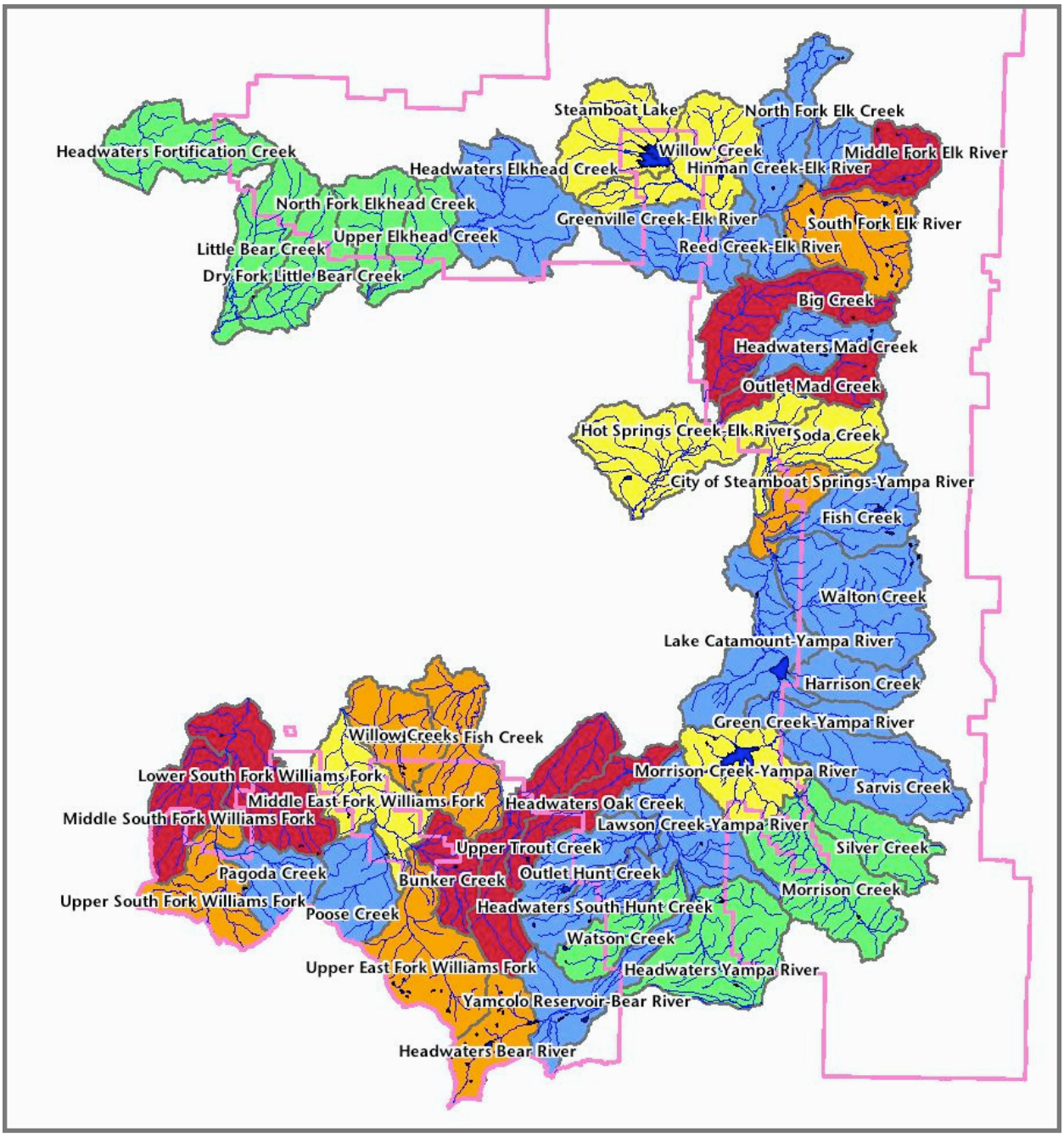
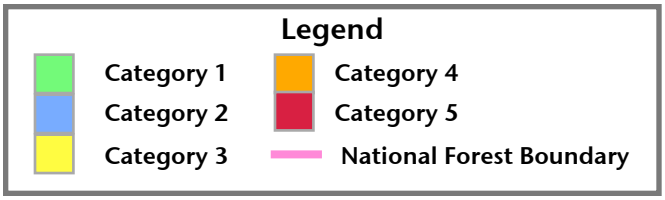


Figure 10. Upper Yampa Watershed Potential Soil Erodibility Hazard Ranking



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 Upper Yampa 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 Outlet Mad Creek, Middle Fork Elk River, Upper Trout Creek, Bunker Creek, Headwaters Oak Creek, and Harrison Creek. There are 11 watersheds in Category 4.

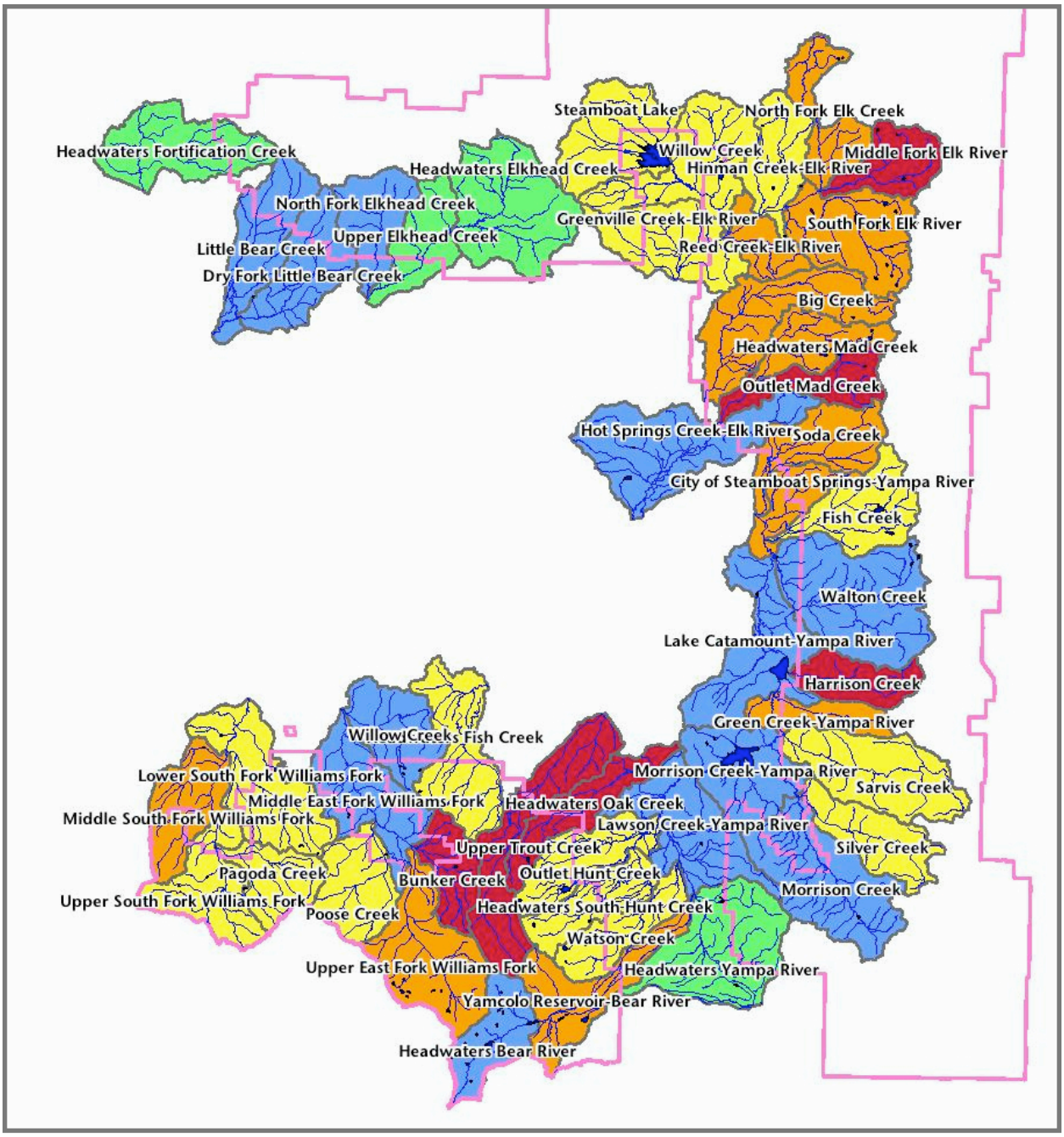
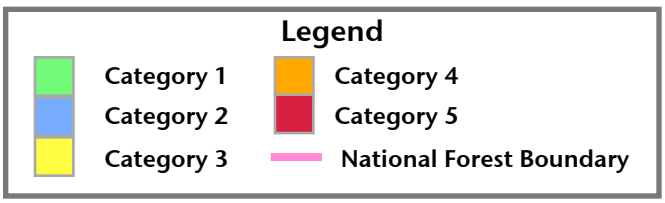


Figure 11. Upper Yampa Watershed Composite Hazard Ranking



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.

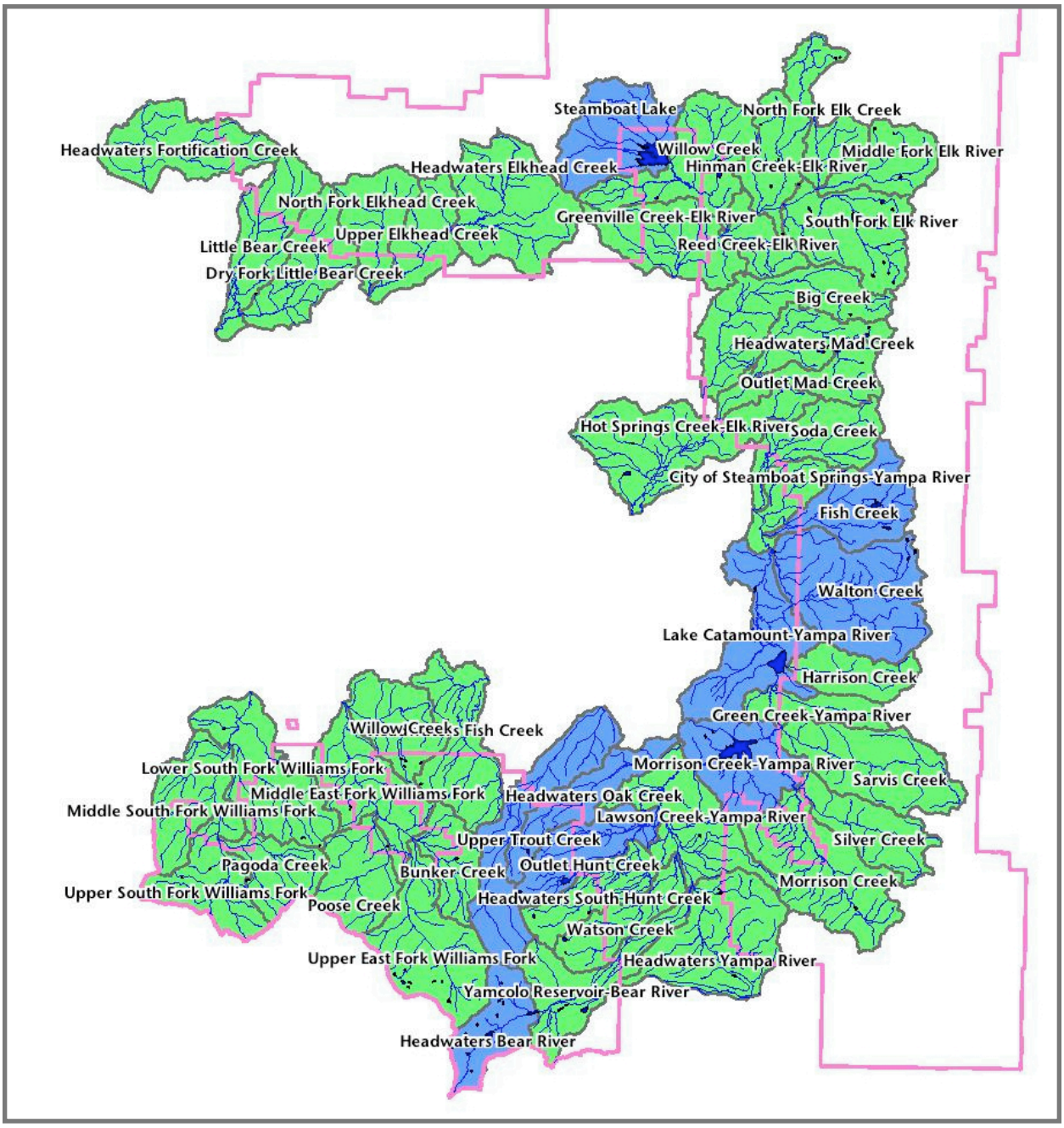
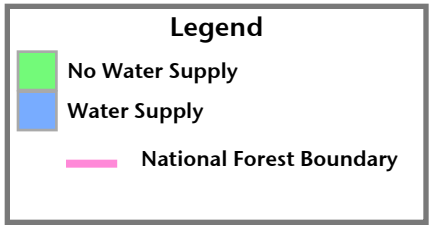


Figure 12. Upper Yampa Watershed Water Supply Map



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APPENDIX A

UPPER YAMPA 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 UPPER YAMPA WATERSHED ASSESSMENT RESULTS

Table B-1. Upper Yampa Watershed Wildfire Hazard Ranking[1]

Sixth-level Watershed Name	Watershed Area (acres)	Wildfire Hazard Calculation	Wildfire Hazard Rank
Silver Creek	15,742	75.0%	*5.5*
Sarvis Creek	26,021	70.4%	*5.2*
Morrison Creek	30,232	65.3%	*4.8*
Harrison Creek	11,544	59.2%	*4.4*
Green Creek-Yampa River	9,383	53.6%	*4.0*
Poose Creek	16,093	46.4%	*3.5*
Upper East Fork Williams Fork	26,499	45.7%	*3.5*
Reed Creek-Elk River	8,984	45.7%	*3.5*
South Fork Elk River	23,354	44.9%	*3.4*
Hinman Creek-Elk River	14,193	42.4%	*3.3*
North Fork Elk Creek	13,973	41.7%	*3.2*
Walton Creek	34,993	39.2%	*3.0*
Pagoda Creek	12,151	33.9%	*2.7*
Yamcolo Reservoir-Bear River	19,214	32.9%	*2.6*
Outlet Mad Creek	13,370	30.7%	*2.4*
Big Creek	26,241	30.6%	*2.4*
Steamboat Lake	22,601	30.1%	*2.4*
Willow Creek	24,697	30.1%	*2.4*
Upper Trout Creek	25,780	30.0%	*2.4*
Bunker Creek	11,270	29.5%	*2.4*
Headwaters South Hunt Creek	13,624	29.3%	*2.4*
Headwaters Bear River	14,094	28.8%	*2.3*
Headwaters Mad Creek	12,232	27.4%	*2.2*
Fish Creek	17,839	26.6%	*2.2*
Lawson Creek-Yampa River	23,846	22.6%	*1.9*
Morrison Creek-Yampa River	20,251	22.6%	*1.9*
Soda Creek	16,917	20.4%	*1.7*
Middle Fork Elk River	12,653	20.3%	*1.7*
Upper South Fork Williams Fork	18,176	19.7%	*1.7*
Greenville Creek-Elk River	20,854	19.2%	*1.7*
Outlet Hunt Creek	16,210	18.9%	*1.6*
Watson Creek	13,147	17.9%	*1.6*
Headwaters Elkhead Creek	29,664	16.3%	*1.5*
Headwaters Fish Creek	22,079	16.0%	*1.4*
Headwaters Yampa River	29,607	15.3%	*1.4*
Headwaters Oak Creek	14,650	15.2%	*1.4*
City of Steamboat Springs-Yampa River	10,031	14.8%	*1.4*
Little Bear Creek	19,347	12.0%	*1.2*
Lake Catamount-Yampa River	25,552	9.6%	*1.0*
Hot Springs Creek-Elk River	31,934	9.0%	*1.0*
Middle South Fork Williams Fork	16,971	8.2%	*0.9*
North Fork Elkhead Creek	14,418	7.9%	*0.9*
Lower South Fork Williams Fork	25,083	7.8%	*0.9*
Upper Elkhead Creek	13,759	7.4%	*0.8*
Headwaters Fortification Creek	22,603	6.0%	*0.7*
Willow Creek	16,268	4.0%	*0.6*
Middle East Fork Williams Fork	21,308	3.2%	*0.6*
Dry Fork Little Bear Creek	18,551	2.4%	*0.5*

[1] Silver Creek was skewing the categorization because of its high wildfire hazard score of 87.64. It was manually given a score slightly higher than the next highest score.

Table B-2. Upper Yampa Watershed Ruggedness Ranking[2]

Sixth-level Watershed Name	Maximum Elevation	Minimum Elevation	Difference Elevation	Ruggedness	Ruggedness Rank
Outlet Mad Creek	11,309	6,708	4,601	0.1907	*5.5*
Headwaters Mad Creek	11,857	7,557	4,300	0.1863	*5.3*
Middle Fork Elk River	12,143	7,957	4,186	0.1783	*5.0*
City of Steamboat Springs-Yampa River	10,270	6,681	3,589	0.1717	*4.7*
Green Creek-Yampa River	10,289	6,891	3,398	0.1681	*4.5*
Bunker Creek	11,477	7,872	3,605	0.1627	*4.3*
Harrison Creek	10,542	6,921	3,621	0.1615	*4.2*
Soda Creek	10,968	6,731	4,237	0.1561	*4.0*
Little Bear Creek	10,850	6,321	4,529	0.1560	*4.0*
Yamcolo Reservoir-Bear River	12,228	7,806	4,422	0.1528	*3.9*
Pagoda Creek	10,945	7,488	3,457	0.1503	*3.8*
Watson Creek	11,204	7,639	3,565	0.1490	*3.7*
Headwaters Oak Creek	11,129	7,383	3,746	0.1483	*3.7*
Big Creek	11,782	6,786	4,996	0.1478	*3.6*
North Fork Elkhead Creek	10,529	6,839	3,690	0.1472	*3.6*
Headwaters South Hunt Creek	11,178	7,626	3,552	0.1458	*3.6*
Upper Trout Creek	12,051	7,200	4,851	0.1448	*3.5*
Fish Creek	10,719	6,731	3,988	0.1431	*3.4*
North Fork Elk Creek	11,483	8,016	3,467	0.1405	*3.3*
Outlet Hunt Creek	11,165	7,439	3,726	0.1402	*3.3*
Dry Fork Little Bear Creek	10,322	6,399	3,923	0.1380	*3.2*
Poose Creek	11,116	7,528	3,588	0.1355	*3.1*
Headwaters Fortification Creek	10,785	6,547	4,238	0.1351	*3.1*
South Fork Elk River	11,742	7,675	4,067	0.1275	*2.8*
Upper South Fork Williams Fork	10,804	7,223	3,581	0.1273	*2.8*
Middle South Fork Williams Fork	10,145	6,737	3,408	0.1253	*2.7*
Greenville Creek-Elk River	10,837	7,144	3,693	0.1225	*2.6*
Upper East Fork Williams Fork	12,011	7,856	4,155	0.1223	*2.5*
Hinman Creek-Elk River	10,608	7,590	3,018	0.1214	*2.5*
Reed Creek-Elk River	9,761	7,380	2,381	0.1204	*2.5*
Willow Creek	9,922	6,888	3,034	0.1140	*2.2*
Silver Creek	10,772	7,875	2,897	0.1106	*2.0*
Upper Elkhead Creek	9,528	6,839	2,689	0.1098	*2.0*
Headwaters Fish Creek	10,253	6,924	3,329	0.1073	*1.9*
Middle East Fork Williams Fork	10,083	6,885	3,198	0.1050	*1.8*
Sarvis Creek	10,489	6,980	3,509	0.1042	*1.8*
Lower South Fork Williams Fork	9,965	6,553	3,412	0.1032	*1.7*
Headwaters Bear River	12,284	9,735	2,549	0.1029	*1.7*
Willow Creek	10,857	7,488	3,369	0.1027	*1.7*
Hot Springs Creek-Elk River	10,339	6,524	3,815	0.1023	*1.7*
Walton Creek	10,565	6,740	3,825	0.0980	*1.5*
Lake Catamount-Yampa River	9,830	6,744	3,086	0.0925	*1.3*
Lawson Creek-Yampa River	10,165	7,259	2,906	0.0902	*1.2*
Steamboat Lake	10,847	8,026	2,821	0.0899	*1.2*
Headwaters Elkhead Creek	10,850	7,731	3,119	0.0868	*1.0*
Morrison Creek-Yampa River	9,486	6,980	2,506	0.0844	*0.9*
Morrison Creek	10,696	7,800	2,896	0.0798	*0.7*
Headwaters Yampa River	10,499	7,813	2,686	0.0748	*0.5*

[2] Ruggedness is based on Melton (1957)

Table B-3. Upper Yampa Watershed Road Density Ranking[3]

Sixth-level Watershed Name	Roads (miles)	Roads Adjusted (miles)	Watershed Area (sq. mi.)	Road density (miles per sq. mi.)	Road Density Rank
City of Steamboat Springs-Yampa River	70.6	35.3	15.67	2.25	*5.5*
Lake Catamount-Yampa River	85.3	85.3	39.93	2.14	*5.2*
Headwaters Oak Creek	46.0	46.0	22.89	2.01	*5.0*
Reed Creek-Elk River	22.7	22.7	14.04	1.62	*4.1*
Lawson Creek-Yampa River	57.8	57.8	37.26	1.55	*3.9*
Steamboat Lake	53.9	53.9	35.31	1.53	*3.9*
Greenville Creek-Elk River	48.4	48.4	32.58	1.49	*3.8*
Headwaters Fish Creek	50.9	50.9	34.50	1.47	*3.8*
North Fork Elk Creek	31.7	31.7	21.83	1.45	*3.7*
Dry Fork Little Bear Creek	40.7	40.7	28.99	1.40	*3.6*
Outlet Hunt Creek	35.2	35.2	25.33	1.39	*3.6*
Yamcolo Reservoir-Bear River	40.5	40.5	30.02	1.35	*3.5*
Hot Springs Creek-Elk River	66.3	66.3	49.90	1.33	*3.4*
Watson Creek	25.9	25.9	20.54	1.26	*3.3*
Walton Creek	68.5	68.5	54.68	1.25	*3.3*
Willow Creek	46.6	46.6	38.59	1.21	*3.2*
Morrison Creek-Yampa River	38.1	38.1	31.64	1.20	*3.2*
Headwaters Yampa River	55.6	55.6	46.26	1.20	*3.2*
Upper Trout Creek	47.9	47.9	40.28	1.19	*3.1*
Little Bear Creek	35.6	35.6	30.23	1.18	*3.1*
Willow Creek	29.7	29.7	25.42	1.17	*3.1*
Soda Creek	30.2	30.2	26.43	1.14	*3.0*
Middle East Fork Williams Fork	37.4	37.4	33.29	1.12	*3.0*
Middle South Fork Williams Fork	25.1	25.1	26.52	0.95	*2.6*
Fish Creek	25.4	25.4	27.87	0.91	*2.5*
Morrison Creek	41.5	41.5	47.24	0.88	*2.5*
Headwaters Fortification Creek	30.3	30.3	35.32	0.86	*2.4*
Lower South Fork Williams Fork	31.9	31.9	39.19	0.82	*2.3*
Headwaters South Hunt Creek	17.2	17.2	21.29	0.81	*2.3*
Harrison Creek	12.8	12.8	18.04	0.71	*2.1*
Hinman Creek-Elk River	15.2	15.2	22.18	0.68	*2.0*
Bunker Creek	11.3	11.3	17.61	0.64	*1.9*
Middle Fork Elk River	11.6	11.6	19.77	0.59	*1.8*
Upper Elkhead Creek	12.0	12.0	21.50	0.56	*1.7*
Outlet Mad Creek	11.0	11.0	20.89	0.53	*1.7*
Green Creek-Yampa River	6.9	6.9	14.66	0.47	*1.5*
Headwaters Elkhead Creek	20.1	20.1	46.35	0.43	*1.5*
Poose Creek	9.4	9.4	25.14	0.37	*1.3*
Big Creek	14.7	14.7	41.00	0.36	*1.3*
North Fork Elkhead Creek	7.6	7.6	22.53	0.34	*1.2*
Sarvis Creek	10.7	10.7	40.66	0.26	*1.1*
Upper South Fork Williams Fork	7.1	7.1	28.40	0.25	*1.1*
South Fork Elk River	9.1	9.1	36.49	0.25	*1.1*
Upper East Fork Williams Fork	7.6	7.6	41.40	0.18	*0.9*
Headwaters Bear River	3.5	3.5	22.02	0.16	*0.9*
Pagoda Creek	2.3	2.3	18.99	0.12	*0.8*
Headwaters Mad Creek	0.7	0.7	19.11	0.04	*0.6*
Silver Creek	0.0	0.0	24.60	0.00	*0.5*

[3] The road density was adjusted based upon the procedure discussed in the report (p. 12). The original road density values were; City of Steamboat Springs-Yampa River (4.51).

Table B-4. Upper Yampa Watershed Flooding/Debris Flow Hazard Ranking[4, 5]

Sixth-level Watershed Name	Ruggedness Ranking	Road Density Ranking	Combined Numeric Rank	Combined Ranking
City of Steamboat Springs-Yampa River	4.7	5.5	13.00	5.5
Outlet Mad Creek	5.5	1.7	12.67	5.3
Headwaters Oak Creek	3.7	5.0	12.31	5.1
Middle Fork Elk River	5.0	1.8	11.73	4.8
Yamcolo Reservoir-Bear River	3.9	3.5	11.23	4.6
Headwaters Mad Creek	5.3	0.6	11.21	4.6
Little Bear Creek	4.0	3.1	11.13	4.5
Soda Creek	4.0	3.0	11.05	4.5
Watson Creek	3.7	3.3	10.70	4.3
Green Creek-Yampa River	4.5	1.5	10.60	4.2
Harrison Creek	4.2	2.1	10.55	4.2
Bunker Creek	4.3	1.9	10.51	4.2
North Fork Elk Creek	3.3	3.7	10.39	4.1
Outlet Hunt Creek	3.3	3.6	10.23	4.0
Upper Trout Creek	3.5	3.1	10.18	4.0
Dry Fork Little Bear Creek	3.2	3.6	10.07	4.0
Headwaters South Hunt Creek	3.6	2.3	9.42	3.6
Fish Creek	3.4	2.5	9.41	3.6
Reed Creek-Elk River	2.5	4.1	9.02	3.4
Greenville Creek-Elk River	2.6	3.8	8.91	3.4
Headwaters Fortification Creek	3.1	2.4	8.61	3.2
Big Creek	3.6	1.3	8.59	3.2
North Fork Elkhead Creek	3.6	1.2	8.50	3.1
Pagoda Creek	3.8	0.8	8.28	3.0
Middle South Fork Williams Fork	2.7	2.6	7.96	2.8
Lake Catamount-Yampa River	1.3	5.2	7.77	2.7
Headwaters Fish Creek	1.9	3.8	7.58	2.6
Poose Creek	3.1	1.3	7.57	2.6
Willow Creek	2.2	3.1	7.47	2.6
Hinman Creek-Elk River	2.5	2.0	7.04	2.4
Hot Springs Creek-Elk River	1.7	3.4	6.82	2.2
South Fork Elk River	2.8	1.1	6.60	2.1
Middle East Fork Williams Fork	1.8	3.0	6.59	2.1
Willow Creek	1.7	3.2	6.59	2.1
Upper South Fork Williams Fork	2.8	1.1	6.58	2.1
Walton Creek	1.5	3.3	6.28	2.0
Lawson Creek-Yampa River	1.2	3.9	6.27	2.0
Steamboat Lake	1.2	3.9	6.19	1.9
Upper East Fork Williams Fork	2.5	0.9	6.01	1.8
Lower South Fork Williams Fork	1.7	2.3	5.76	1.7
Upper Elkhead Creek	2.0	1.7	5.76	1.7
Morrison Creek-Yampa River	0.9	3.2	5.00	1.3
Sarvis Creek	1.8	1.1	4.62	1.1
Silver Creek	2.0	0.5	4.59	1.1
Headwaters Bear River	1.7	0.9	4.28	0.9
Headwaters Yampa River	0.5	3.2	4.17	0.9
Morrison Creek	0.7	2.5	3.88	0.7
Headwaters Elkhead Creek	1.0	1.5	3.50	0.5

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

[5] The City of Steamboat Springs-Yampa River watershed was manually adjusted because it was skewing the results of the categorization because of its high value. The Combined Numeric Rank for that watershed was originally 14.86.

Table B-5. Upper Yampa Watershed Soil Erodibility Ranking[6, 7]

Sixth-level Watershed Name	Severe (%)	Very Severe (%)	Soil Erodibility Value	Soils Rating
Middle Fork Elk River	20.0%	13.2%	0.340	*5.5*
Middle South Fork Williams Fork	23.8%	8.8%	0.330	*5.3*
Upper Trout Creek	14.2%	9.2%	0.327	*5.3*
Outlet Mad Creek	19.6%	4.7%	0.290	*4.7*
Lower South Fork Williams Fork	16.0%	6.4%	0.288	*4.7*
Headwaters Oak Creek	14.6%	6.9%	0.285	*4.6*
Bunker Creek	15.6%	6.4%	0.284	*4.6*
Big Creek	16.3%	5.9%	0.282	*4.6*
Upper South Fork Williams Fork	14.8%	5.9%	0.266	*4.3*
South Fork Elk River	16.1%	4.3%	0.247	*4.0*
Upper East Fork Williams Fork	12.2%	5.9%	0.240	*3.9*
Headwaters Fish Creek	12.2%	5.6%	0.234	*3.8*
Willow Creek	14.0%	4.1%	0.222	*3.6*
City of Steamboat Springs-Yampa River	12.4%	4.8%	0.220	*3.6*
Headwaters Bear River	6.1%	7.9%	0.219	*3.6*
Hot Springs Creek-Elk River	10.0%	4.6%	0.193	*3.2*
Middle East Fork Williams Fork	10.8%	4.2%	0.191	*3.2*
Morrison Creek-Yampa River	12.1%	3.0%	0.181	*3.0*
Soda Creek	13.4%	2.2%	0.178	*2.9*
Steamboat Lake	11.5%	3.0%	0.176	*2.9*
Willow Creek	12.7%	2.1%	0.169	*2.8*
Poose Creek	11.1%	1.9%	0.150	*2.5*
Hinman Creek-Elk River	9.6%	2.3%	0.142	*2.4*
Fish Creek	10.6%	1.7%	0.141	*2.3*
Sarvis Creek	10.6%	1.6%	0.137	*2.3*
Lake Catamount-Yampa River	9.4%	2.1%	0.136	*2.3*
Pagoda Creek	8.7%	2.4%	0.135	*2.3*
Harrison Creek	10.1%	1.7%	0.135	*2.3*
Headwaters Mad Creek	8.6%	2.4%	0.134	*2.2*
Outlet Hunt Creek	8.3%	2.5%	0.134	*2.2*
North Fork Elk Creek	9.5%	1.6%	0.128	*2.1*
Greenville Creek-Elk River	9.0%	1.8%	0.126	*2.1*
Reed Creek-Elk River	8.0%	2.0%	0.121	*2.0*
Green Creek-Yampa River	8.6%	1.5%	0.116	*2.0*
Yamcolo Reservoir-Bear River	5.5%	2.8%	0.111	*1.9*
Walton Creek	7.2%	1.7%	0.105	*1.8*
Headwaters Elkhead Creek	7.9%	1.2%	0.103	*1.8*
Headwaters South Hunt Creek	5.0%	2.3%	0.095	*1.6*
Lawson Creek-Yampa River	5.9%	1.7%	0.092	*1.6*
Upper Elkhead Creek	6.2%	1.2%	0.086	*1.5*
North Fork Elkhead Creek	6.8%	0.4%	0.077	*1.3*
Silver Creek	6.1%	0.4%	0.070	*1.2*
Watson Creek	4.2%	1.1%	0.064	*1.1*
Morrison Creek	4.7%	0.5%	0.057	*1.0*
Headwaters Yampa River	4.0%	0.4%	0.048	*0.9*
Little Bear Creek	4.0%	0.3%	0.046	*0.8*
Dry Fork Little Bear Creek	2.3%	0.2%	0.027	*0.5*
Headwaters Fortification Creek	2.2%	0.1%	0.024	*0.5*

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

[7] The Middle Fork Elk River and Middle South Fork Williams Fork watersheds were manually adjusted because they were skewing the results of the categorization. The Soil Erodibility Values were originally 0.463 and 0.414, respectively.

Table B-6. Upper Yampa Watershed Composite Hazard Ranking[8]

Sixth-level Watershed Name	Wildfire Hazard Rank	Flooding/Debris Flow Rank	Soil Erodibility Rank	Composite Hazard Rank
Outlet Mad Creek	2.4	5.3	4.7	5.5
Middle Fork Elk River	1.7	4.8	5.5	5.3
Upper Trout Creek	2.4	4.0	5.3	5.1
Bunker Creek	2.4	4.2	4.6	4.8
Headwaters Oak Creek	1.4	5.1	4.6	4.8
Harrison Creek	4.4	4.2	2.3	4.6
City of Steamboat Springs-Yampa River	1.4	5.5	3.6	4.4
Green Creek-Yampa River	4.0	4.2	2.0	4.3
Big Creek	2.4	3.2	4.6	4.3
South Fork Elk River	3.4	2.1	4.0	4.0
North Fork Elk Creek	3.2	4.1	2.1	3.9
Upper East Fork Williams Fork	3.5	1.8	3.9	3.8
Soda Creek	1.7	4.5	2.9	3.7
Middle South Fork Williams Fork	0.9	2.8	5.3	3.7
Yamcolo Reservoir-Bear River	2.6	4.6	1.9	3.7
Headwaters Mad Creek	2.2	4.6	2.2	3.7
Reed Creek-Elk River	3.5	3.4	2.0	3.6
Poose Creek	3.5	2.6	2.5	3.5
Sarvis Creek	5.2	1.1	2.3	3.4
Upper South Fork Williams Fork	1.7	2.1	4.3	3.2
Fish Creek	2.2	3.6	2.3	3.2
Hinman Creek-Elk River	3.3	2.4	2.4	3.1
Pagoda Creek	2.7	3.0	2.3	3.1
Headwaters Fish Creek	1.4	2.6	3.8	3.1
Outlet Hunt Creek	1.6	4.0	2.2	3.1
Silver Creek	5.5	1.1	1.2	3.0
Headwaters South Hunt Creek	2.4	3.6	1.6	2.9
Willow Creek	2.4	2.1	2.8	2.7
Lower South Fork Williams Fork	0.9	1.7	4.7	2.7
Steamboat Lake	2.4	1.9	2.9	2.7
Greenville Creek-Elk River	1.7	3.4	2.1	2.6
Watson Creek	1.6	4.3	1.1	2.6
Willow Creek	0.6	2.6	3.6	2.5
Headwaters Bear River	2.3	0.9	3.6	2.5
Walton Creek	3.0	2.0	1.8	2.5
Morrison Creek	4.8	0.7	1.0	2.3
Little Bear Creek	1.2	4.5	0.8	2.3
Hot Springs Creek-Elk River	1.0	2.2	3.2	2.2
Morrison Creek-Yampa River	1.9	1.3	3.0	2.1
Lake Catamount-Yampa River	1.0	2.7	2.3	2.0
Middle East Fork Williams Fork	0.6	2.1	3.2	2.0
Lawson Creek-Yampa River	1.9	2.0	1.6	1.7
North Fork Elkhead Creek	0.9	3.1	1.3	1.7
Dry Fork Little Bear Creek	0.5	4.0	0.5	1.5
Headwaters Fortification Creek	0.7	3.2	0.5	1.2
Upper Elkhead Creek	0.8	1.7	1.5	1.0
Headwaters Elkhead Creek	1.5	0.5	1.8	0.8
Headwaters Yampa River	1.4	0.9	0.9	0.5

[8] 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).