Region 2: Rio Grande National Forest Quantitative Wildfire Risk Assessment: Methods and Results

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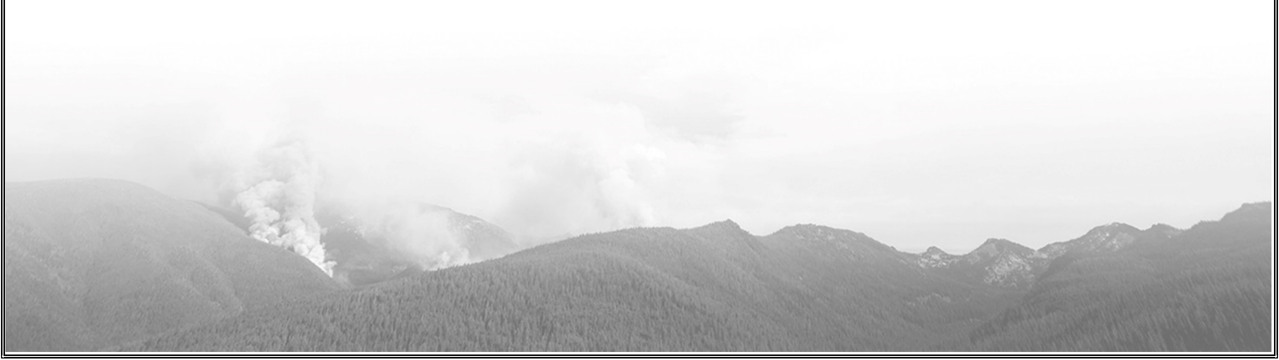

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1.1 Purpose of the Assessment

The purpose of the Region 2: Rio Grande National Forest Risk Assessment (R2RG) is to provide foundational information about wildfire hazard and risk to highly valued resources and assets across the geographic area. Such information supports wildfires, fuel management planning decisions, and revisions to land and resource management plans. A wildfire risk assessment is a quantitative analysis of the assets and resources across a specific landscape and how they are potentially impacted by wildfire. The R2RG analysis considers several different components, each resolved spatially across the Forest, including:

- likelihood of a fire burning,
- the intensity of a fire if one should occur,
- the exposure of assets and resources based on their locations, and
- the susceptibility of those assets and resources to wildfire.

Assets are human-made features, such as commercial structures, critical facilities, housing, etc., that have a specific importance or value. Resources are natural features, such as wildlife habitat, federally threatened and endangered plant or animal species, etc. These also have a specific importance or value. Generally, the term "values at risk" has previously been used to describe both assets and resources. For R2RG, the term Highly Valued Resources and Assets (HVRA) is used to describe what has previously been labeled values at risk. There are two reasons for this change in terminology. First, resources and assets are not themselves "values" in any way that term is conventionally defined—they *have* value (importance). Second, while resources and assets may be exposed to wildfire, they are not necessarily "at risk"—that is the purpose of the assessment.

To manage wildfire in the Forest, it is essential that accurate wildfire risk data, to the greatest degree possible, is available to drive fire management strategies. These risk outputs can be used to drive the planning, prioritization and implementation of prevention and mitigation activities, such as prescribed fire and mechanical fuel treatments. In addition, the risk data can be used to support fire operations in response to wildfire incidents by identifying those assets and resources most susceptible to fire. This can aid in decision making for prioritizing and positioning of firefighting resources.

1.2 Project Analysis Area

1.2.1 *Analysis Area*

The Analysis Area (AA) is the area for which valid burn probability (BP) results are produced. The AA for the Region 2, Rio Grande (R2RG) FSim project was initially defined as the Rio Grande National Forest boundary buffered to a 5-km boundary. After initial review it was discovered the buffer could cause issues due to irregular shapes and overlap. Minor boundary modifications were made to mitigate potential issues.

1.3 Quantitative Risk Modeling Framework

The basis for a quantitative framework for assessing wildfire risk to highly valued resources and assets (HVRAs) has been established for many years (Finney, 2005; Scott, 2006). The framework has been implemented across a variety of scales, from the continental United States (Calkin et al., 2010), to individual states (Buckley et al., 2014), to a portion of a national forest (Thompson et al., 2013b), to an individual county. In this framework, wildfire risk is a function of two main factors: 1) wildfire hazard and 2) HVRA vulnerability (Figure 1).

Wildfire hazard is a physical situation with potential for causing damage to vulnerable resources or assets. Quantitatively, wildfire hazard is measured by two main factors: 1) burn probability (or likelihood or burning), and; 2) fire intensity (measured as flame length, fireline intensity, or other similar measure). For this analysis, we used the large fire simulator (FSim) to quantify wildfire potential across the landscape at a pixel size of 120 m (approximately 3.5 acres per pixel).

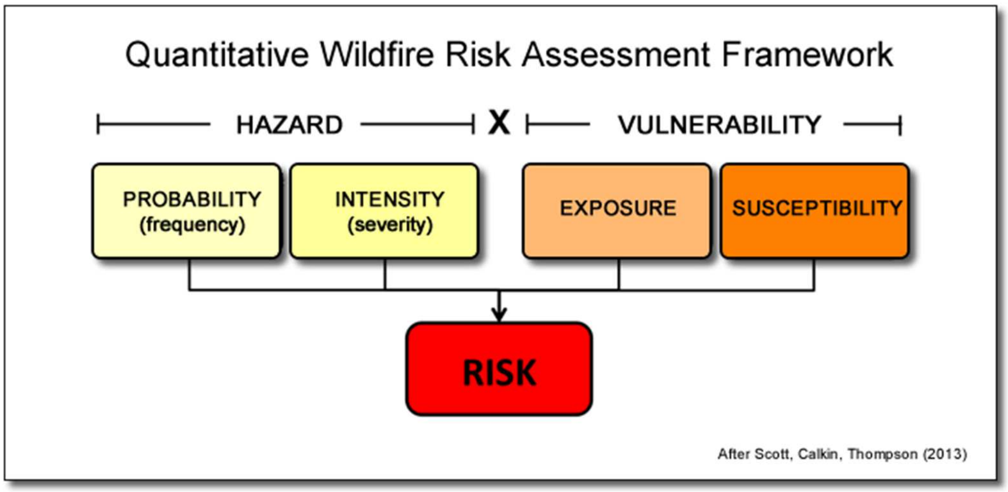

Figure 1. The components of the Quantitative Wildfire Risk Assessment Framework used for R2RG.

HVRA vulnerability is also composed of two factors: 1) exposure and 2) susceptibility. Exposure is the placement (or coincidental location) of an HVRA in a hazardous environment—for example, building a home within a flammable landscape. Some HVRAs, like critical wildlife habitat or endangered plants, are not movable; they are not "placed" in hazardous locations. Still, their exposure to wildfire is the wildfire hazard where the habitat exists. Finally, the susceptibility of an HVRA to wildfire is how easily it is damaged by wildfire of different types and intensities. Some assets are *fire-hardened* and can withstand very intense fires without damage, whereas others are easily damaged by even low-intensity fire.

2 Analysis Methods and Input Data

The FSim large-fire simulator was used to quantify wildfire hazard across the AA at a pixel size of 120 m. FSim is a comprehensive fire occurrence, growth, behavior, and suppression simulation system that uses locally relevant fuel, weather, topography, and historical fire occurrence information to make a spatially resolved estimate of the contemporary likelihood and intensity of wildfire across the landscape (Finney *et al.*, 2011).

FSim used in this assessment was produced as part of the Stochastic Wildfire Simulation for the BLM Colorado Southwest District project. Please reference the final report “BLM-CO-SWD-FSim.pdf” provided with this project’s deliverables for information on FSim modeling. The final pixel-based rasters used in the calculations along with the report for the FSim data are included with project deliverables.

3 HVRA Characterization

Highly Valued Resources and Assets (HVRA) are the resources and assets on the landscape most likely to be protected from or enhanced by wildfire and those considered in a Land and Resource Management Plans, Fire Management Plans, or in spatial fire planning in the Wildland Fire Decision Support System (WFDSS). The key criterion is that they must be of high value to warrant inclusion in this type of assessment, both for the sake of keeping within the scope of the assessment and to avoid valuing everything to the point nothing is truly *highly* valued.

There are three primary components to HVRA characterization: HVRAs must be identified and their spatial extent mapped, their response to fire (positive, negative, or neutral) must be characterized, and their relative importance with respect to each other must be determined.

3.1 HVRA Identification

A set of HVRA were identified by the Rio Grande National Forest and provided to Pyrologix for final Effects Analysis. Representatives from the Rio Grande National Forest identified seven HVRAs in total: two assets and five resources for inclusion in the wildfire risk assessment. The complete list of HVRAs and their associated data sources are listed in Table 1.

To the degree possible, HVRAs are mapped to the extent of the Analysis Area boundary (Figure 2). This is the boundary used to summarize the final risk results. Some HVRA are limited to the Forest boundary, due to the nature of the data (e.g., extracted from US Forest Service (FS) databases for FS land only).

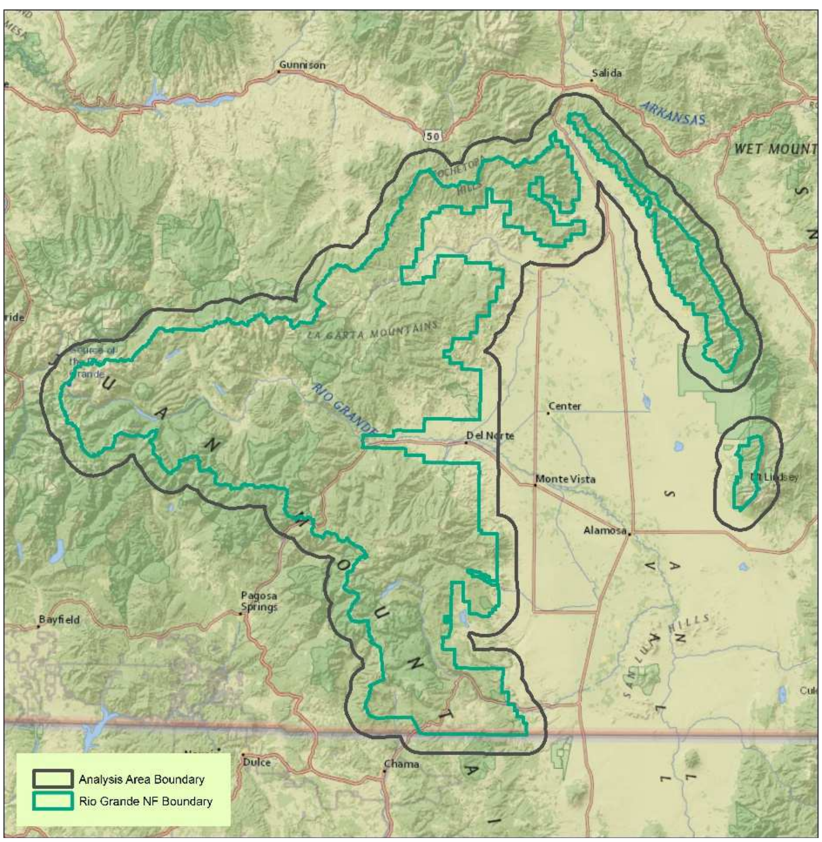

Figure 2: Rio Grande National Forest: HVRA Analysis Area Extent.

3.2 Response Functions

Each HVRA selected for the assessment must also have an associated response to fire, whether it is positive or negative. Pyrologix proposed initial Response Functions (RFs) based on past projects and worked with Forest personnel to adjust for their HVRA. We relied on input from Forest representatives, Resource Specialists and the Forest Fuels Specialist at a workshop held May 16, 2019. In the workshop, the group reviewed initial RFs and determined the refinements needed to characterize how each resource or asset responded to fires of different intensity levels using values ranging from -100 to +100. The flame length values corresponding to the fire intensity levels reported by FSim are shown in Table 2. The response functions (RFs) used in the risk results are shown in Table 3 through Table 19 below.

3.3 Relative Importance

The relative importance (RI) assignments are needed to integrate results across all HVRAs. Without this input from leadership, all HVRAs would be weighted equally. The RI assignments were also discussed during a workshop on May 16, 2019. The focus of this discussion was to establish the importance and ranking of the primary HVRAs relative to each other along with within-HVRA importance ranking. The People and Property (WUI) HVRA received the greatest share of RI at 44 percent, followed by the Watershed HVRA, receiving 18 percent of the total importance. Vegetation Condition was allocated 11 percent and Infrastructure received 10 percent, while the Lynx Habitat, Timber and Aquatic Wildlife Habitat HVRAs received less than 10 percent of the total landscape importance (Figure 3). These importance percentages reflect the overall importance of all mapped HVRA.

Sub-HVRA relative importance was also determined in the workshop with Forest personnel. Sub-RIs are based on both the relative importance per unit area and mapped extent of the Sub-HVRA layers within the primary HVRA category. In Table 3 through Table 19 we provide the share of HVRA relative importance within the primary HVRA.

Relative importance values were generally developed by first ranking the Sub-HVRAs then assigning an RI value to each. The most important Sub-HVRA was assigned RI = 100. Each remaining Sub-HVRA was then assigned an RI value indicating its importance relative to the most important Sub-HVRA.

The RI values apply to the overall HVRA on the assessment landscape as a whole. The calculations need to account for the relative extent of each HVRA to avoid overemphasizing HVRAs that cover many acres. This was accomplished by normalizing the calculations by the relative extent (RE) of each HVRA in the assessment area. Here, relative extent refers to the number of 30-m pixels mapped to each HVRA. In using this method, the relative importance of each HVRA is spread out over the HVRA's extent. An HVRA with few pixels can have a high importance per pixel; and an HVRA with a great many pixels can have a low importance per pixel. A weighting factor (called Relative Importance Per Pixel [RIPP]) representing the relative importance per unit area was calculated for each HVRA.

Table 1. HVRA and sub-HVRA identified for the Region 2: Rio Grande wildfire risk assessment and associated data sources.

HVRA & Sub-HVRA	Data source
Infrastructure (Investments)	
Electric transmission lines	Electric Power Transmission Lines extracted from Utilities geodatabase provided by Rio Grande National Forest
Railroad Line	Railroad line features representing Cumbres & Toltec Railroad extracted from provided Rio Grande geodatabase
Railroad Infrastructure	Railroad infrastructure (deemed burnable) extracted from Rio Grande geodatabase; features represent Cumbres & Toltec Railroad Landmarks
Communication sites	RAWS Communication sites provided by USFS by Rio Grande NF
Dams and Associated Reservoir	Extracted portion of HUC12 watershed with potential to affect Dams based on site location and associated waterbodies.
Superfund Sites	Summitville Superfund site; geospatial data provided by Rio Grande NF
Rec Residences	Recreation sites/structures extracted from geodatabase provided by Rio Grande NF. Using attributes focused on high-development recreation sites (buildings, visitor centers, lodges, resorts, cabins, etc.)
Ski Areas Sites	Wolf Creek ski area site locations extracted from the Rio Grande NF Structures geodatabase
Ski Area Boundary	Wolf Creek Ski area boundary extracted from Rio Grande NF geodatabase
People and Property	
WUI	Housing density classes extracted from Rio Grande NF Structures geodatabase; assigned based on dataset attributes.
Timber – Suitable Timber	
Timber Stock	Extracted data from Timber Stock dataset provided by Rio Grande NF highlighting values that demonstrate gain/loss in economic value due to fire; assigned based on dataset attributes and selection criteria from Silviculturist.
Vegetation – Diverse and Resilient Vegetation	
Vegetation Type/Condition Class	Vegetation type data layer provided by Rio Grande NF with Landfire Vegetation Condition Class added as a covariate
Watersheds	
Watersheds	Forest to Faucets dataset extracted for analysis area. Normalizing importance value (IMP) based on max value.
Terrestrial Habitat	
Lynx	Habitat suitability map provided by Rio Grande NF
Aquatic Species	
Cutthroat Trout	Habitat suitability map extracted from Rio Grande NF Wildlife-Fish geodatabase
Sucker	Habitat suitability map extracted from Rio Grande NF Wildlife-Fish geodatabase
Chub	Habitat suitability map extracted from Rio Grande NF Wildlife-Fish geodatabase

Table 2. Flame length values corresponding to Fire Intensity Levels used in assigning response functions.

Fire Intensity Level (FIL)	1	2	3	4	5	6
Flame Length Range (feet)	0-2	2-4	4-6	6-8	8-12	12+

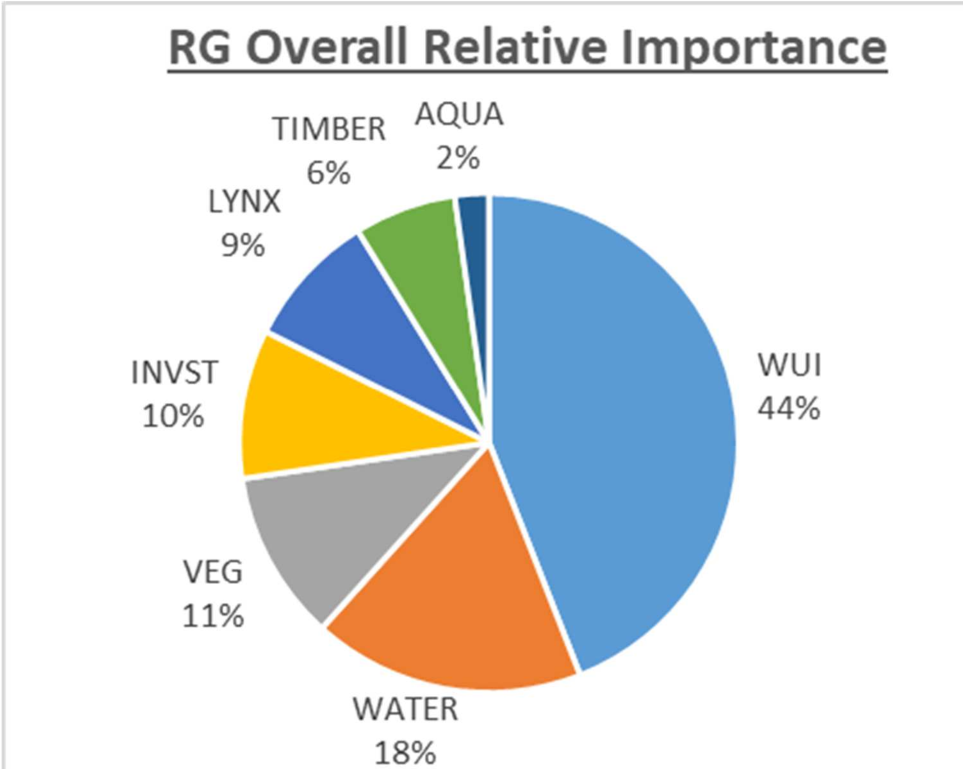

Figure 3. Overall HVRA Relative Importance for the primary HVRAs included in R2RG

3.4 HVRA Characterization Results

Each HVRA was characterized by one or more data layers of sub-HVRA and, where necessary, further categorized by an appropriate covariate. Covariates include data such as erosion potential or habitat age/quality/disturbance level, and housing density classes. The main HVRAs in the R2RG Assessment are mapped below along with a table with the set of response functions assigned, the within-HVRA share of relative importance, and total acres for each sub-HVRA. These components are used along with fire behavior results from FSim in the wildfire risk calculations described in section 3.5.1.

3.4.1 *Infrastructure*

3.4.1.1 Ski Area Sites

Ski area infrastructure in Rio Grande National Forest are mapped in Figure 4. The site locations were extracted from a geodatabase provided by the National Forest, converted to 30-m pixels and expanded out two pixels using the Annulus Neighborhood of the ArcGIS *Focal Statistics* tool to allow for mapping uncertainties in the HVRA.

The RF for ski area infrastructure show a low negative response at the lowest flame lengths (FIL1) with increasingly negative responses as FILs increase (FILs 2-6) (Table 3).

Ski area infrastructure received 2.23 percent of the total Infrastructure HVRA relative importance because there are so few acres mapped relative to the other Infrastructure HVRA. The share of HVRA importance is based on relative importance per unit area and mapped extent.

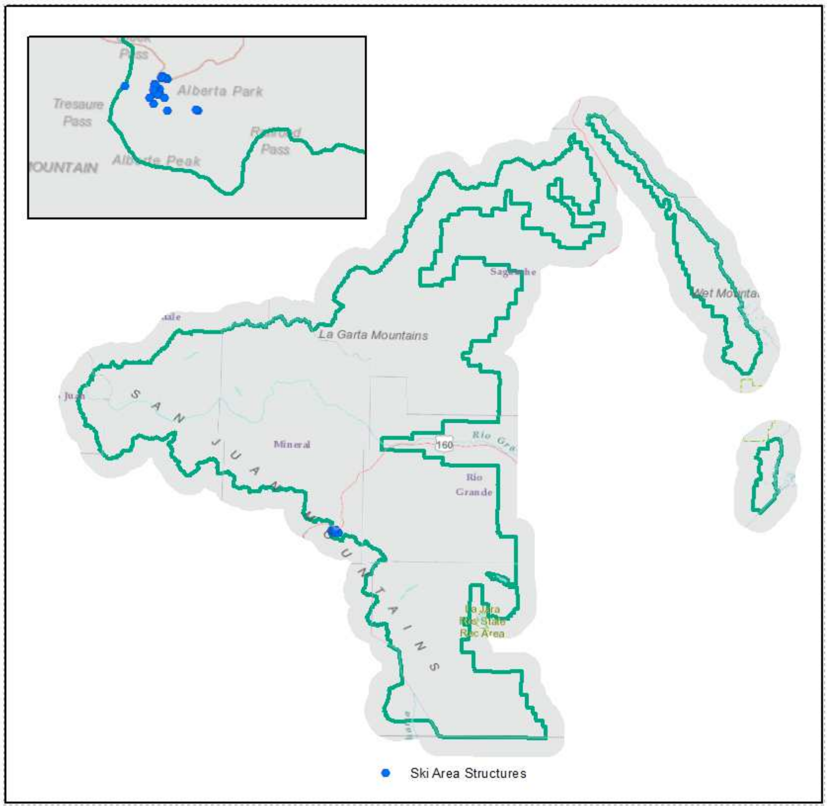

Figure 4. Map of ski area infrastructure in the R2RG analysis area.

Table 3. Response functions for the Infrastructure HVRA to highlight ski areas infrastructure

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.2 Ski Area (Wolf Creek)

The Wolf Creek ski area boundary in Rio Grande National Forest is represented in Figure 5. The boundary was extracted from a geodatabase provided by Rio Grande National Forest and converted to a 30-m raster.

The RF for ski areas show a neutral response at the lowest flame lengths (FIL1); becoming increasingly negative with increasing intensity levels for FILS 2-6 (Table 4).

The ski area received 5.59 percent of the total Infrastructure HVRA relative importance because it has relatively little area mapped compared with other Infrastructure HVRA. The share of HVRA importance is based on relative importance per unit area and mapped extent.

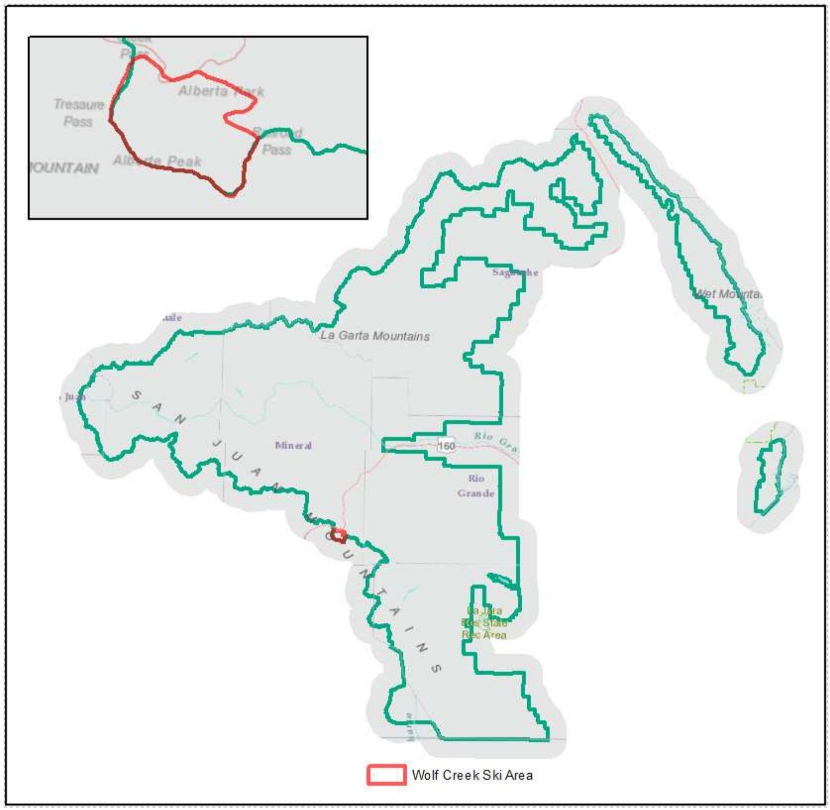

Figure 5. Map of Wolf Creek Ski Area in the R2RG analysis area.

Table 4. Response functions for the Infrastructure HVRA to highlight ski areas.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.3 RAWs Communication Sites

Communication sites and cell towers mapped for Rio Grande National Forest are shown in Figure 6. Included in the data are sites related to communication sites (towers, antenna, and microwave buildings) and RAWs Stations. The site locations were converted to 30-m pixels and expanded out two pixels using the Annulus Neighborhood of the ArcGIS *Focal Statistics* tool allowing for mapping uncertainties in the HVRA location and/or fuel mapping.

In this assessment, communication sites/cell towers have a slightly negative response to FIL1, becoming increasingly negative for FILs 2-3, and showing the maximum negative response for FILs 4-6 (Table 5).

Communication sites and cell towers received 3.35 percent of the total Infrastructure HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

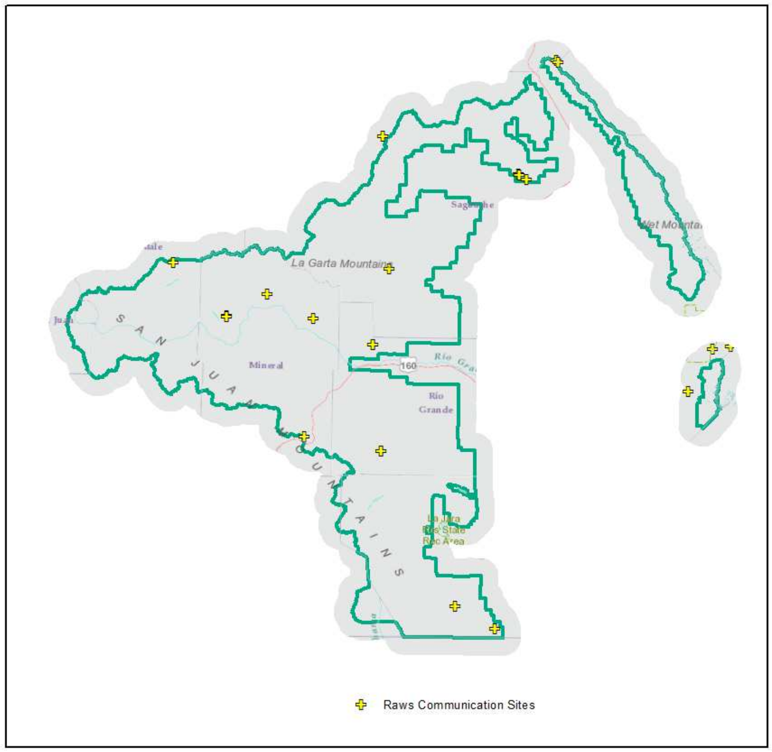

Figure 6. Map of RAWs communication sites in the R2RG analysis area.

Table 5. Response functions for the Infrastructure HVRA to highlight RAWs communication sites.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.4 Cumbres & Toltec Railroad Burnable Infrastructure

Cumbres & Toltec Railroad burnable infrastructure mapped for R2RG are shown in Figure 7. The highlighted Cumbres & Toltec Railroad infrastructure represent sections houses, trestles and Osier. The site locations were converted to 30-m pixels and expanded out two pixels using the Annulus Neighborhood of the ArcGIS *Focal Statistics* tool allowing for mapping uncertainties in the HVRA location and/or fuel mapping

In this assessment, the railroad's burnable infrastructure have an increasingly negative response to FILs1-3, and show the maximum negative response for FILs 4-6 (Table 6).

The Cumbres & Toltec Railroad burnable infrastructure received 0.56 percent of the total Infrastructure HVRA relative importance because there are so few acres mapped relative to the other Infrastructure HVRA. The share of HVRA importance is based on relative importance per unit area and mapped extent.

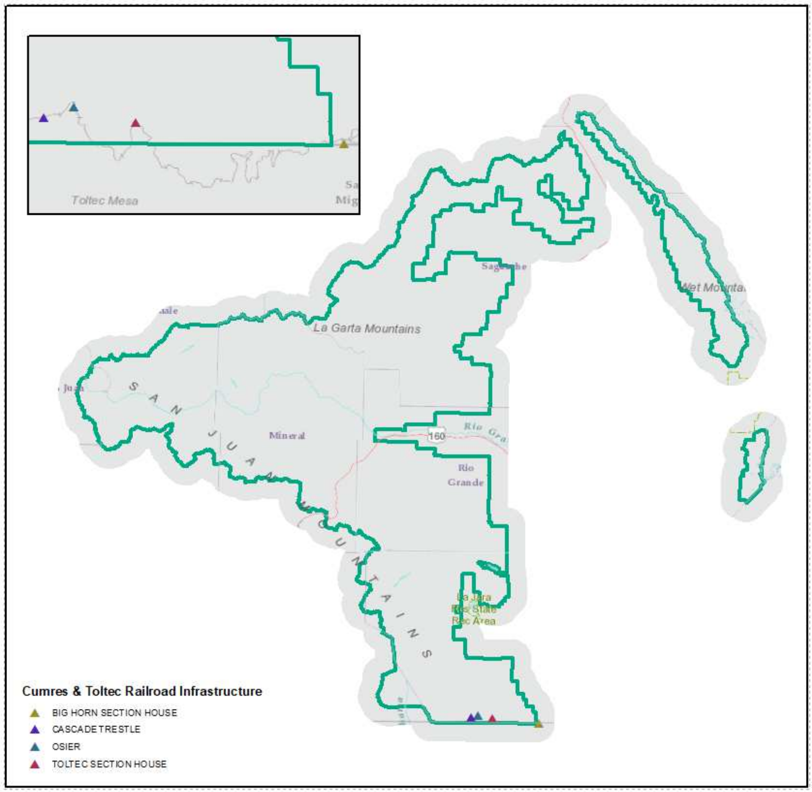

Figure 7. Map of burnable Cumbres & Toltec Railroad infrastructure in the R2RG analysis area.

Table 6. Response functions for the Infrastructure HVRA to highlight Cumbres & Toltec Railroad burnable infrastructure.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.5 Cumbres & Toltec Railroad

The Cumbres & Toltec Railroad mapped for the Rio Grande National Forest is shown in Figure 8. Due to its historical significance the Cumbres & Toltec Railroad was highlighted for this HVRA analysis. Railroad line features were converted to 30-m raster and expanded 1 pixel (per side) using the ArcGIS *Expand* tool to capture the area impacted by wildfire.

In this assessment, railroads are shown to have an increasingly negative response to fires of increasing intensity (Table 7) but tend to be more resilient to higher intensity fires than other infrastructure HVRA, according to the RFs below.

Railroads received 2.23 percent of the total Infrastructure HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

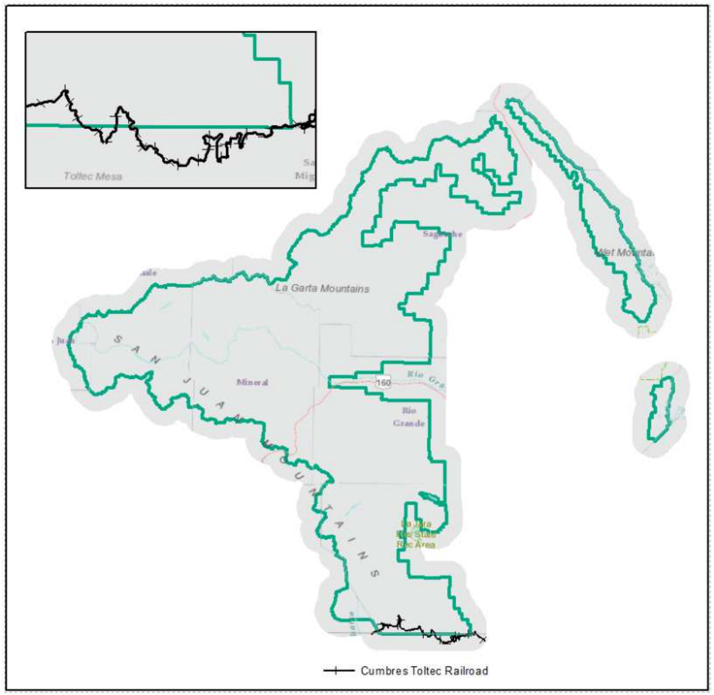

Figure 8. Map of Cumbres & Toltec Railroad in the R2RG analysis area

Table 7. Response functions for the Infrastructure HVRA to highlight Cumbres & Toltec Railroad.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.6 Developed Recreation Sites

Recreation sites mapped for R2RG are shown in Figure 9. These data are from a variety of sources provided by Rio Grande National Forest with varying degrees of attribute information. Buildings, visitor centers, lodges, resorts, developed campgrounds, and cabins were classified high-development recreation sites. Backcountry/horse campsites, vault/pit/other toilets, and trailheads were considered low-development recreation sites and excluded from the analysis.

The recreation site locations were converted to 30-m pixels and expanded out two pixels using the Annulus Neighborhood of the ArcGIS *Focal Statistics* tool allowing for mapping uncertainties in the HVRA location and/or fuel mapping.

The response functions for high value recreation sites are slightly negative at FIL1 becoming increasingly negative for FILs 2-6 (Table 8).

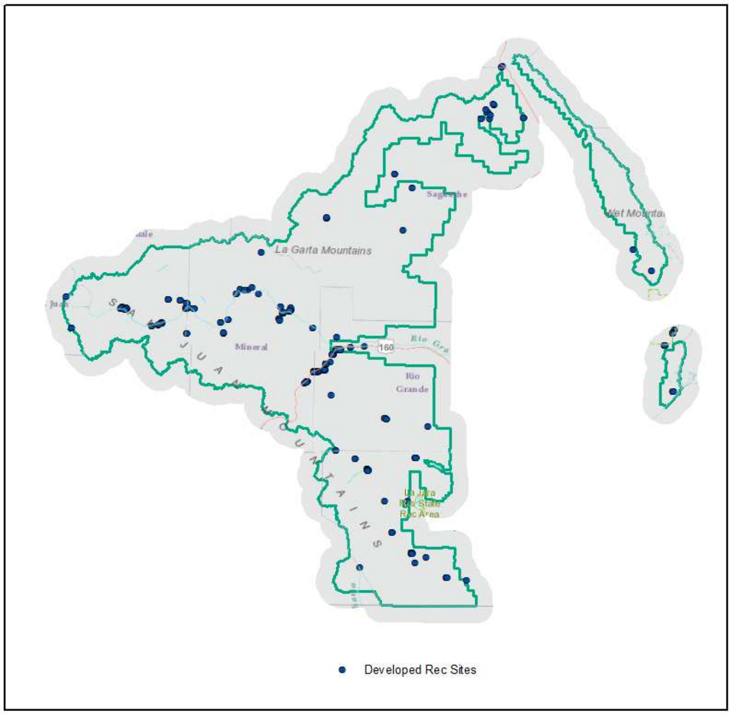

Figure 9. Map of developed recreation sites in the R2RG analysis area.

Recreation sites, in total, received 27.93 percent of the total Infrastructure HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 8. Response functions for the Infrastructure HVRA to highlight developed recreation sites.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.7 Dams/Reservoirs

Dams and their associated reservoirs for R2RG are shown in Figure 10. In order to accurately portray RFs for dams it was necessary to determine the reservoir feeding into a dam due to potential blockage/failure following a fire incident.

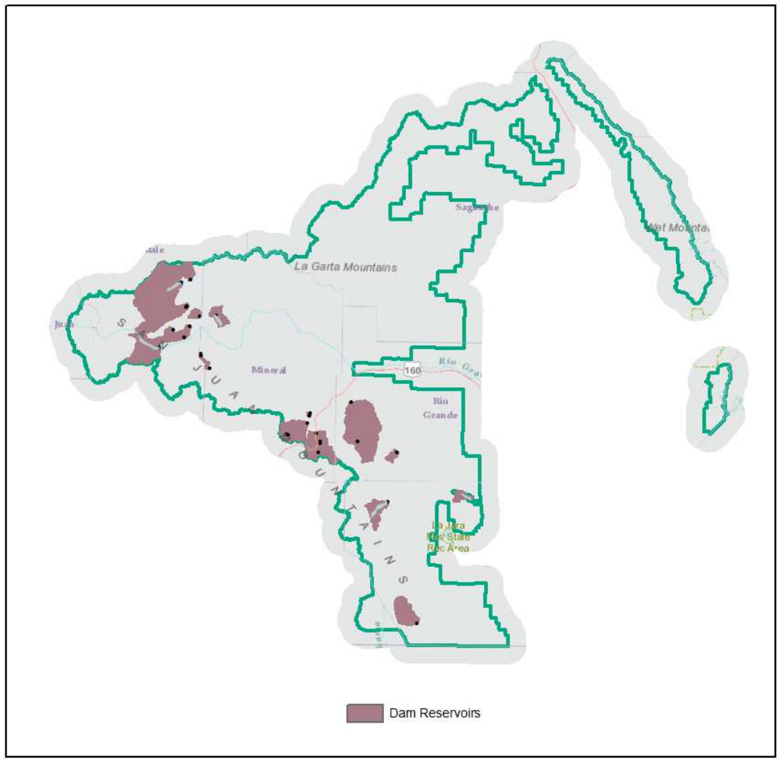

Figure 10. Map of Dams/Reservoirs in the R2RG analysis area.

Using dam locations, HUC12 delineations and 30-m DEMs, 30-m reservoirs rasters were determined for each site using the ArcGIS *Hydrology Toolbox*. For each dam we ran in sequential order the *Flow Direction and Flow Accumulation* tools. To calculate a *Snap Pour Point,* the dam location was used in conjunction with output from *Flow Accumulation*. The resultant output was used with the calculated flow direction as inputs into the *Watershed* tool to determine the 'watershed' or reservoir feeding into the dam. The derived watershed delineations, although close, overrepresented the reservoir. Using topographic base layers as a guide, adjustments were made by hand.

The RFs for dams (and associated reservoirs) indicate a neutral response for lower intensity levels (FIL 1 to 3), but demonstrated an increasingly negative response to intensity starting at FIL4 (Table 9). Dam reservoirs received 11.17 percent of the total Infrastructure HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

Table 9. Response functions for the Infrastructure HVRA to highlight water basins affecting Dams/Reservoirs

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.8 Electric Transmission Lines

Electrical transmission lines mapped for R2RG are shown in Figure 11. A series of electrical transmission line datasets were provided by Rio Grande NF. They were merged (keeping only transmission lines), converted to 30-m raster and expanded 1 pixel (per side) using the ArcGIS *Expand t*ool to capture the area impacted by wildfire.

The RF for electrical transmission lines show a mildly negative response at the lowest flame lengths (FIL1) and increasingly negative response functions with each increasing intensity level (Table 10).

Due to the number of acres mapped on the landscape and their importance to infrastructure, electric transmission lines received 44.69 percent of the share of the Infrastructure HVRA importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

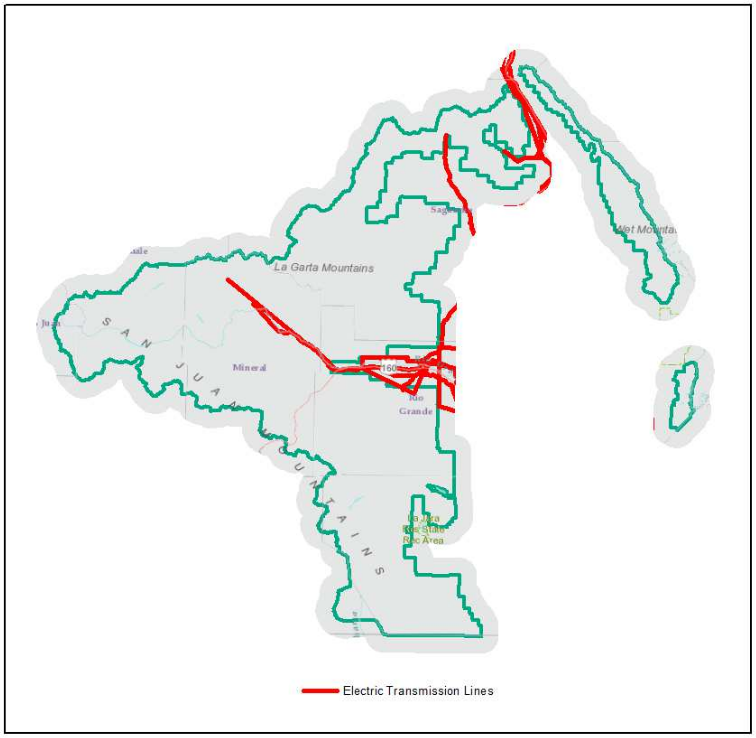

Figure 11. Map of electric transmission lines in the R2RG analysis area

Table 10. Response functions for the Infrastructure HVRA to highlight electric transmission lines.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.1.9 Summitville Superfund Site

Due to the potentially sensitive and disruptive nature of superfund sites in relation to wildfire, the Summitville site was included in the HVRA analysis. A polygon highlighting the site location was provided by Rio Grande National Forest and converted to 30-m raster (Figure 12)

The RF for Summitville indicates a neutral response function for lower intensity FILs (FIL1 and FIL2) with increasingly negative RFs as fire intensity levels increase past FIL3 (Table 11).

The Summitville superfund site received 2.23 percent of the total Infrastructure HVRA relative importance because there are so few pixels relative to the other Infrastructure HVRA. The share of HVRA importance is based on relative importance per unit area and mapped extent.

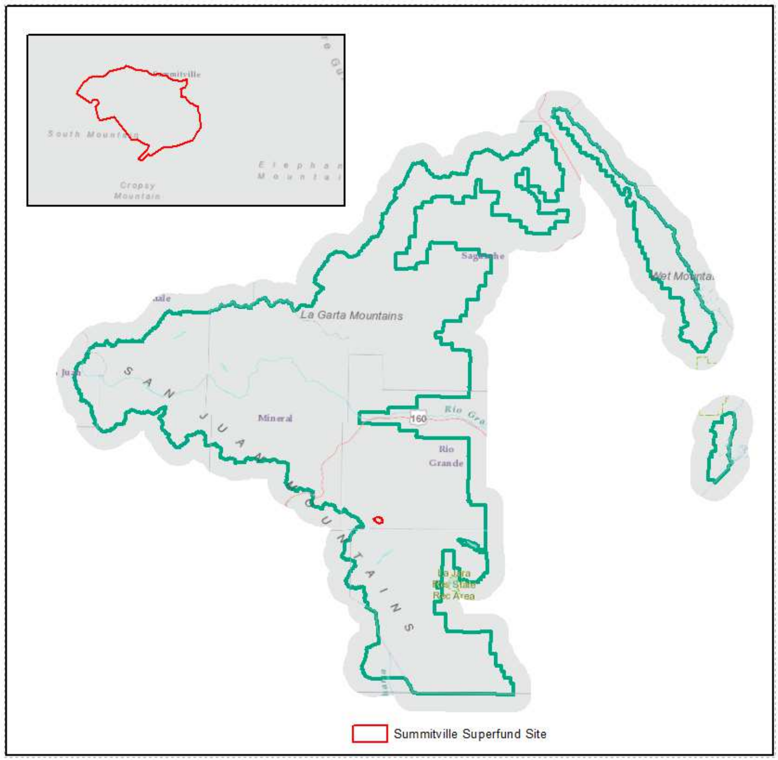

Figure 12. Map of Summitville Superfund Site within the R2RG study area

Table 11. Response functions for the Summitville Superfund Site HVRA.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Ski Area - infrastructure	2.23%	46	-10	-20	-40	-80	-100	-100
Ski Area - boundary	5.59%	1899	0	-10	-10	-20	-30	-40
RAWS - Communication Sites	3.35%	60	-10	-20	-60	-100	-100	-100
C/T Railroad - burnable infrastructure	0.56%	12	-40	-60	-80	-100	-100	-100
C/T Railroad - line	2.23%	1932	-10	-20	-30	-40	-50	-50
Infrastructure - High Value Recreation Sites	27.93%	569	-10	-50	-80	-100	-100	-100
Dams - Reservoirs	11.17%	148892	0	0	0	-40	-60	-80
Electric Transmission Line	44.69%	12112	-10	-20	-40	-60	-100	-100
Superfund - Summitville	2.23%	715	0	0	-30	-50	-75	-100

[1] Within-HVRA relative importance

3.4.2 *People and Property: WUI*

3.4.2.1 Housing Density and Private Inholdings

The People and Property or WUI HVRA consisted of homes/trailers, multi-family dwellings, lodges and resort sites. An initial dataset was provided by Rio Grande NF. To derive a raster dataset at 30-m, ArcGIS *Point Statistics* was used to sum structures within a circle with a 227-meter radius (determined by converting 40 acres to square meters). We then classified the structures into six housing density classes ranging from very dense (>120 housing units per 40 acres) to sparse (1 - 2 housing unit per 40 acres) (Figure 13). We used the ArcGIS *Zonal Statistics as Table* tool to calculate the density class midpoints used in RI calculations (Table 12). Pixels in the highest density classes (teal color) are concentrated around the more populated areas, while pixels in the lower density classes (dark and light brown) are scattered throughout the project area.

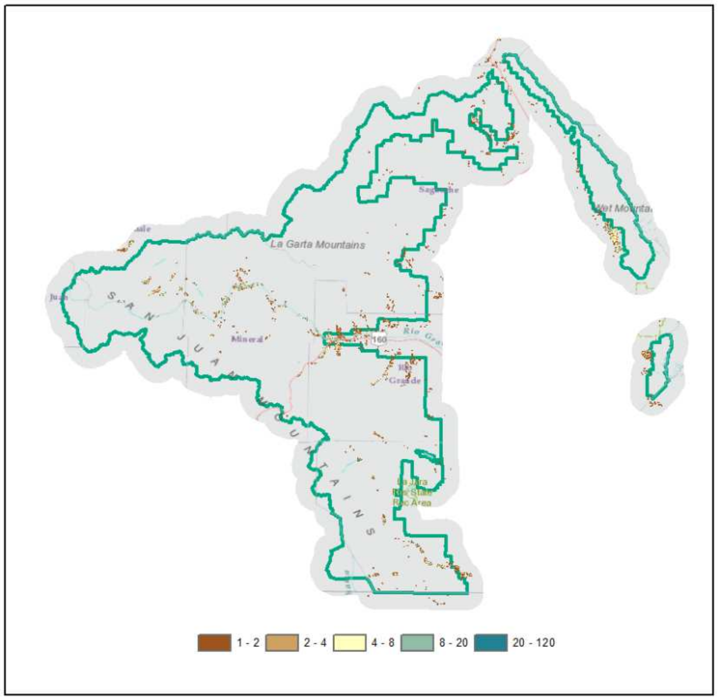

Figure 13. Map of housing density per acre in the R2RG analysis area.

Response functions were increasingly negative for all housing densities across FILs 1-6 (Table 12), showing slightly higher negative response functions associated with the higher density classes due to the impact to more houses and possibly overwhelmed suppression resources with high population exposure.

The relative importance per unit area is in proportion to the housing density class, but the share of the WUI importance held by the most-densely populated class is only 12.06 percent, while the next density class holds the greatest share at 28.44 percent (Table 12) due to the differences in acres present on the landscape. The remaining classes each hold a share in proportion to density and mapped extent.

Table 12. Response functions for the People and Property HVRA

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
20-120 structures per 40 acres	12.06%	856	-10	-50	-80	-100	-100	-100
8-20 structures per 40 acres	28.44%	4454	-10	-50	-80	-100	-100	-100
4-8 structures per 40 acres	20.38%	6456	-10	-40	-60	-80	-100	-100
2-4 structures per 40 acres	14.18%	8224	-10	-40	-60	-80	-100	-100
1-2 structures per 40 acres	24.93%	38863	-10	-30	-50	-80	-100	-100

[1] Within-HVRA relative importance

3.4.3 *Lynx – Highly Selected Habitat*

3.4.3.1 Lynx Habitat

Highly selected Lynx habitat mapped for R2RG is shown in Figure 14. A data layer outlining Lynx habitat was provided by Rio Grande National Forest and converted to 30-m raster for analysis.

The RF for Lynx habitat indicates a negative response for all intensity levels, increasing with increasing intensity (Table 13).

Since Lynx habitat is a separate HVRA altogether, it received 100% of the HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent.

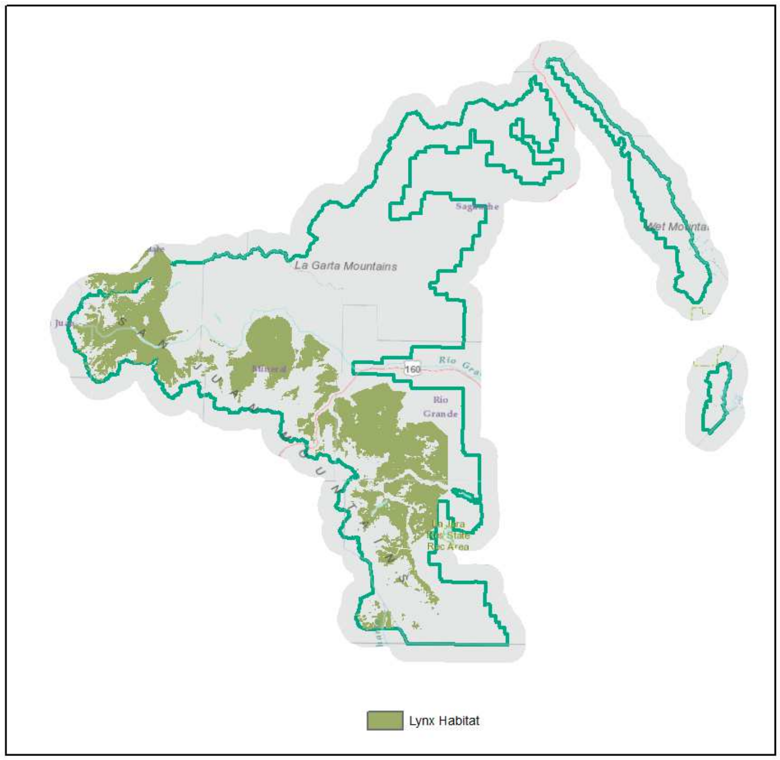

Figure 14. Map of Lynx habitat in the R2RG analysis area.

Table 13. Response functions for the Lynx HVRA

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Highly selected habitat	100.00%	365063	-20	-30	-40	-70	-100	-100

[1] Within-HVRA relative importance

3.4.4 *Aquatic Wildlife Habitat*

3.4.4.1 Rio Grande Cutthroat Trout Streams

Rio Grande Cutthroat trout stream distribution for the Rio Grande NF analysis area is shown in Figure 15. Rio Grande cutthroat trout were included in the assessment because of concern over species isolation and damage to critical habitat. The stream distribution was obtained from Rio Grande NF, converted to 30-m raster and expanded 1 pixel (per side) using the ArcGIS *Expand* tool - highlighting habitat areas impacted by wildfire.

The Rio Grande cutthroat trout's response to fire is characterized as negative, showing increasingly negative responses as flame lengths increase. (Table 14).

Rio Grande cutthroat trout habitat received 20.00 percent of the total Aquatic Wildlife Habitat HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent

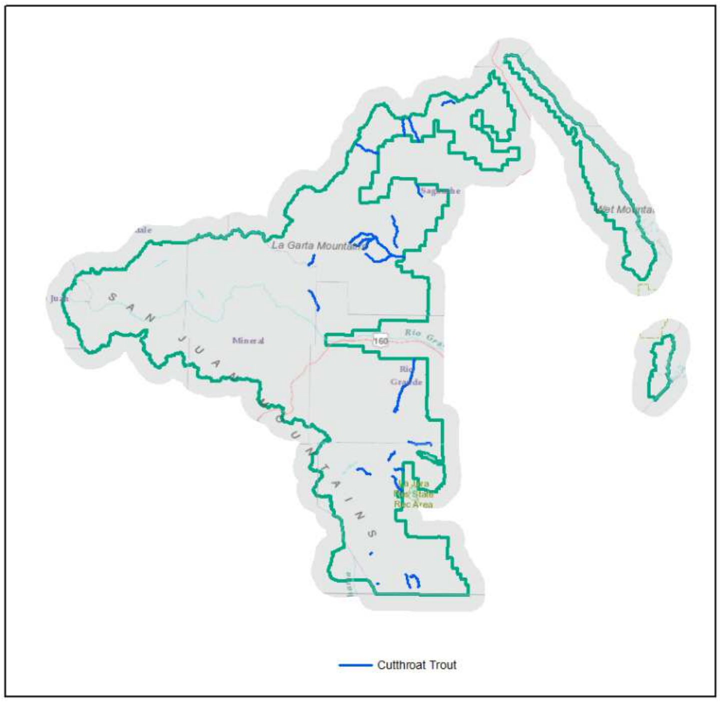

Figure 15. Map of Rio Grande cutthroat trout streams in the R2RG analysis area.

Table 14. Response function for Aquatic Wildlife Habitat HVRA highlighting Rio Grande cutthroat trout.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Cutthroat stream	20.00%	4379	-20	-30	-40	-50	-60	-70
Sucker stream	40.00%	1486	-20	-30	-40	-50	-60	-70
Chub stream	40.00%	227	-20	-30	-40	-50	-60	-70

[1] Within-HVRA relative importance

3.4.4.2 Rio Grande Chub Streams

Rio Grande chub stream distribution for the Rio Grande NF analysis area is shown in Figure 16. The Rio Grande chub was included in the assessment because of concern over species isolation and damage to critical habitat. The stream distribution was obtained from Rio Grande NF. Stream features were converted to 30-m raster and expanded 1 pixel (per side) using the ArcGIS *Expand* tool to capture the area impacted by wildfire.

The Rio Grande chub's response to fire is characterized as negative, showing increasingly negative responses in FIL1 through FIL6 as flame lengths increase (Table 15).

Rio Grande chub stream habitat received 40.00 percent of the total Aquatic Wildlife Habitat HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent

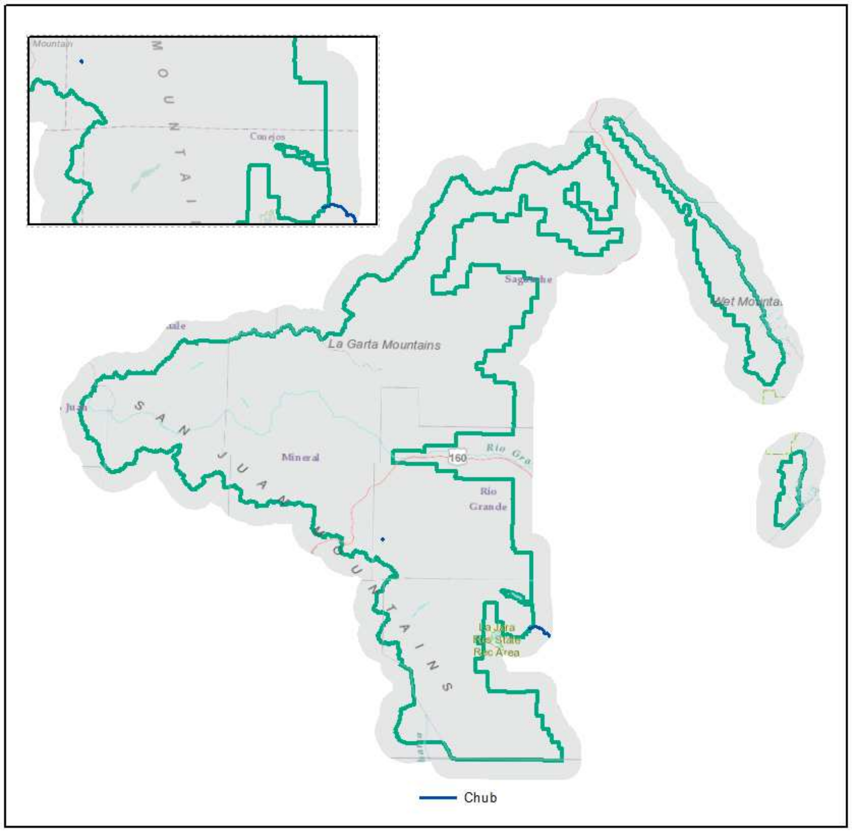

Figure 16. Map of the Rio Grande chub stream in the R2RG analysis area

Table 15. Response function for Aquatic Wildlife Habitat HVRA highlighting Rio Grande chub.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Cutthroat stream	20.00%	4379	-20	-30	-40	-50	-60	-70
Sucker stream	40.00%	1486	-20	-30	-40	-50	-60	-70
Chub stream	40.00%	227	-20	-30	-40	-50	-60	-70

[1] Within-HVRA relative importance

3.4.4.3 Rio Grande Sucker Streams

Rio Grande sucker stream distribution for the Rio Grande NF analysis area is shown in Figure 17. The Rio Grande sucker was included in the assessment because of concern over species isolation and damage to critical habitat. The stream distribution was obtained from Rio Grande NF. Stream features were converted to 30-m raster and expanded 1 pixel (per side) using the ArcGIS *Expand* tool to capture the area impacted by wildfire.

The Rio Grande sucker's response to fire is characterized as negative, showing increasingly negative responses in FIL1 through FIL6 as flame lengths increase (Table 16).

Rio Grande sucker stream habitat received 40.00 percent of the total Aquatic Wildlife Habitat HVRA relative importance. The share of HVRA importance is based on relative importance per unit area and mapped extent

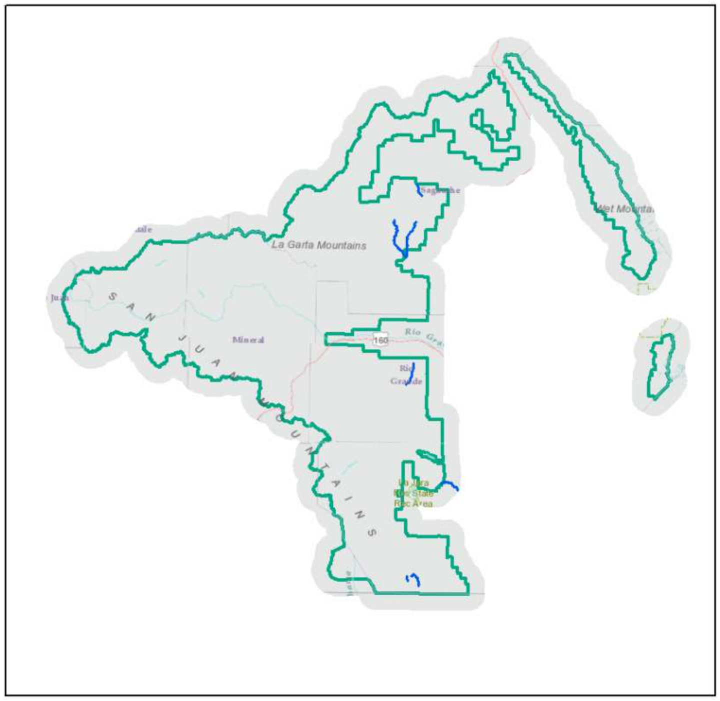

Figure 17. Map of Rio Grande sucker streams in the R2RG analysis area.

Table 16. Response functions for Aquatic Wildlife Habitat HVRA highlighting Rio Grande sucker.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
Cutthroat stream	20.00%	4379	-20	-30	-40	-50	-60	-70
Sucker stream	40.00%	1486	-20	-30	-40	-50	-60	-70
Chub stream	40.00%	227	-20	-30	-40	-50	-60	-70

[1] Within-HVRA relative importance

3.4.5 *Critical Watersheds*

3.4.5.1 Drinking Water Importance (DWI)

Critical watershed resources were mapped using the USDA Forest Service, Forests to Faucets (F2F) dataset. Using the index of importance to surface drinking water (IMP) we mapped the normalized (on a 0-100 scale) importance of each pixel within a basin. The resulting importance map is shown in Figure 18.

The response functions shown in Table 17 are for a breakout of 10 importance classes. As can been seen in the table, RF assignments are the same throughout all classes. FIL1 and FIL2 show positive responses to low intensity fire; with FIL3 through FIL6 becoming increasingly negative as intensity increases.

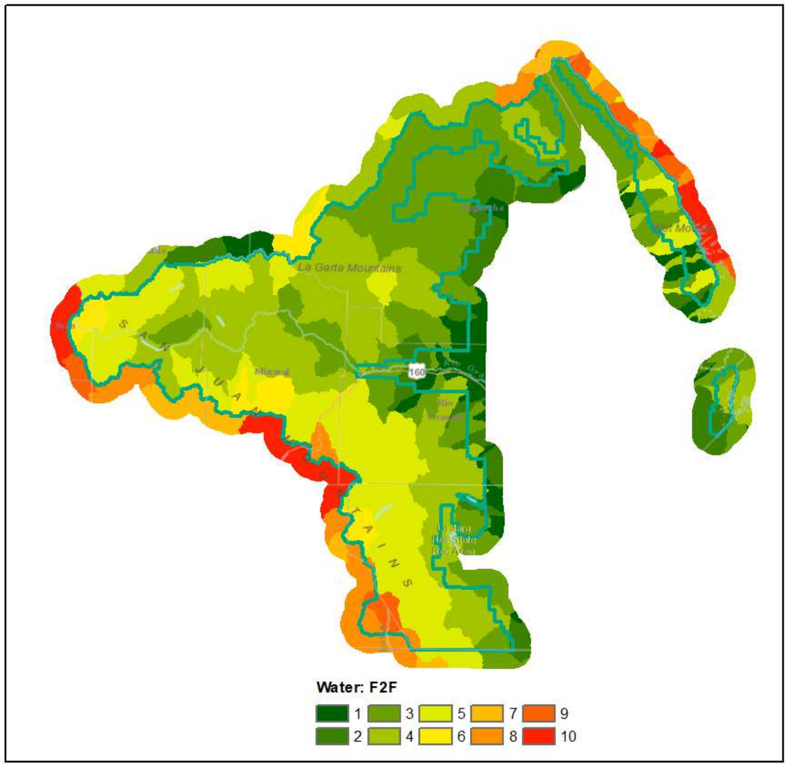

Figure 18. Map of Critical Watersheds (Importance within the R2RG analysis area.

Table 17. Response functions for the Watershed Forest to Faucets: Importance HVRA.

Sub-HVRA	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
DWI=100	8.95%	124258	10	20	-10	-40	-60	-90
DWI=90	4.32%	66596	10	20	-10	-40	-60	-90
DWI=80	9.47%	164403	10	20	-10	-40	-60	-90
DWI=70	4.13%	81882	10	20	-10	-40	-60	-90
DWI=60	4.65%	107510	10	20	-10	-40	-60	-90
DWI=50	22.16%	615194	10	20	-10	-40	-60	-90
DWI=40	24.79%	860219	10	20	-10	-40	-60	-90
DWI=30	16.96%	784619	10	20	-10	-40	-60	-90
DWI=20	3.43%	238072	10	20	-10	-40	-60	-90
DWI=10	1.15%	160215	10	20	-10	-40	-60	-90

[1] Within-HVRA relative importance

3.4.6 *Vegetation*

3.4.6.1 Diverse and Resilient Vegetation/Vegetation Condition Class

The Vegetation HVRA for R2RG was developed using a Forest Service diverse and resilient vegetation data layer (provided by Rio Grande NF). The Rio Grande Silviculturist provided selection criteria based on stand 'type' and condition class to make HVRA assignments. The provided vegetation dataset was converted to a 30-m raster and combined with the Landfire 2014 Vegetation Condition Class. The resultant combination of vegetation 'type' and condition classes are represented in Figure 19.

Response functions assess the resistance/resiliency of that forest type to fire and is intended to capture short-term impacts (5-10 years). Forest 'type' was used to identify stands and Fire Effects Information System (FEIS) to estimate relative values (Table 18).

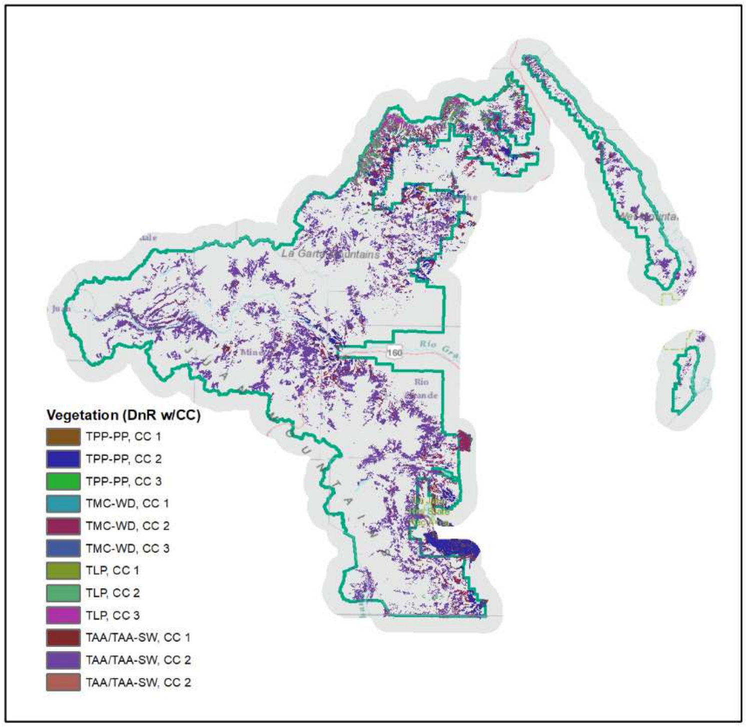

Figure 19. Map of Vegetation HVRA within the R2RG analysis area.

Table 18. Response functions for Vegetation Condition Class HVRA

Sub-HVRA and covariate	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
TPP-PP, CC 1	2.10%	10038	30	60	10	0	-50	-100
TPP-PP, CC 2	12.14%	58133	50	75	20	-10	-75	-100
TPP-PP, CC 3	0.16%	777	50	75	100	-50	-100	-100
TMC-WD, CC 1	1.10%	5248	25	50	0	-25	-75	-100
TMC-WD, CC 2	10.42%	49912	50	75	-25	-50	-100	-100
TMC-WD, CC 3	0.23%	1113	100	100	-50	-75	-100	-100
TLP, CC 1	0.48%	2318	25	50	100	100	75	75
TLP, CC 2	3.57%	17110	50	75	100	100	50	50
TLP, CC 3	2.09%	10031	0	50	50	-25	-75	-75
TAA/TAA-SW, CC 1	5.88%	28155	100	100	100	100	75	75
TAA/TAA-SW, CC 2	61.22%	293215	100	100	100	100	75	75
TAA/TAA-SW, CC 3	0.61%	2919	50	100	100	-25	-50	-50

[1] Within-HVRA relative importance

3.4.7 *Timber*

3.4.7.1 Suitable Timber

The Timber HVRA (Figure 20) was developed using a suitable timber dataset provided by Rio Grande NF and selection set criteria for attribute assignment provided by Rio Grande NF Silviculturist. Using the provided selection set criteria, an HVRA attribute was added to the spatial data layer, updated and used to create a 30-m raster.

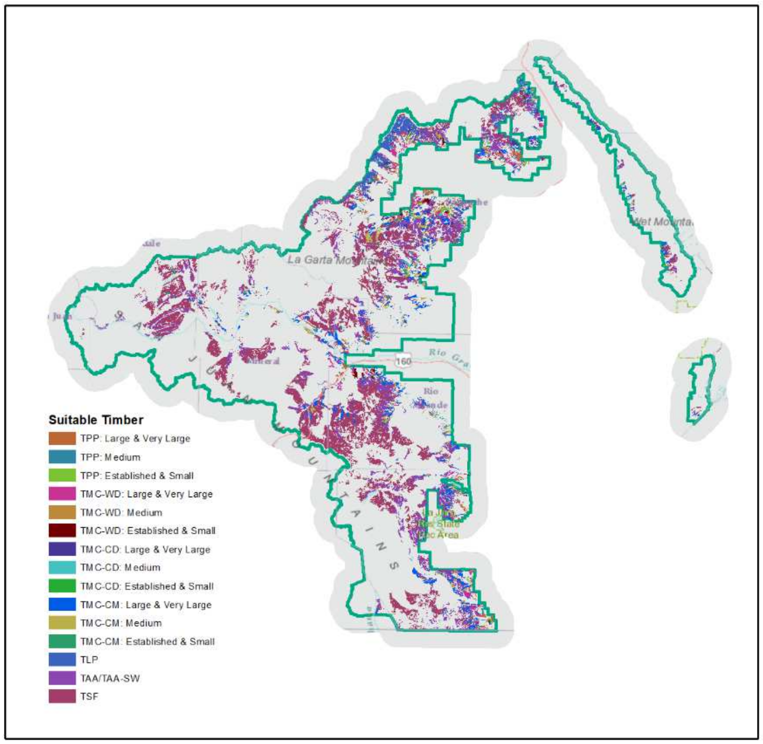

Figure 20. Map of Timber Base HVRA within the R2RG analysis area.

Response function assignments reflect the loss/benefit of fire to timber as an economic value rather than as an ecosystem value and are intended to capture short-term (5-10 years) wildfire impacts to timber values. Species type and size class were used to identify stands and Fire Effects Information System (FEIS) to estimate relative values.

A pattern emerges in the response functions showing smaller trees having a more negative response to fire, with increasingly negative responses for all as flame lengths (Table 19).

Table 19. Response functions for Suitable Timber Base HVRA

Sub-HVRA and covariate	% of HVRA	Acres	FIL1	FIL2	FIL3	FIL4	FIL5	FIL6
TPP: Large & Very Large	2.86%	13101	20	0	0	-20	-60	-100
TPP: Medium	0.78%	3565	20	0	-20	-60	-100	-100
TPP: Established & Small	0.59%	2721	-10	-40	-80	-100	-100	-100
TMC-WD: Large & Very Large (Species: DF, WF & PP)	4.11%	18781	10	-10	-60	-100	-100	-100
TMC-WD: Medium (Species: DF, WF, & PP)	0.65%	2988	5	-40	-80	-100	-100	-100
TMC-WD: Established & Small (Species: DF, WF, & PP)	0.76%	3469	-20	-60	-100	-100	-100	-100
TMC-CD: Large & Very Large (Species: DF & WF, BS, AS, LP, & Limber)	2.09%	9553	5	-20	-60	-100	-100	-100
TMC-CD: Medium (Species: DF & WF, BS, AS, LP, & Limber)	1.07%	4917	0	-60	-100	-100	-100	-100
TMC-CD: Established & Small (Species: DF & WF, BS, AS, LP, & Limber)	0.16%	725	-40	-80	-100	-100	-100	-100
TMC-CM: Large & Very Large (Species: DF, WF, Limber, & BS)	9.03%	41316	10	-40	-80	-100	-100	-100
TMC-CM: Medium (Species: DF, WF, Limber, & BS)	4.29%	19630	0	-20	-80	-100	-100	-100
TMC-CM: Established & Small (Species: DF, WF, Limber, & BS)	0.93%	4270	-40	-60	-80	-100	-100	-100
TLP	3.88%	17754	5	-60	-80	-100	-100	-100
TAA/TAA-SW (Aspen & Conifers)	24.06%	110067	0	-60	-80	-100	-100	-100
TSF	44.73%	204627	0	-60	-80	-100	-100	-100

[1] Within-HVRA relative importance

3.5 Effects Analysis Methods

An effects analysis quantifies wildfire risk as the expected value of net response (Finney, 2005; Scott et al., 2013b) also known as expected net value change (eNVC). This approach has been applied at a national scale (Calkin et al., 2010), in regional and sub-regional assessments (Thompson et al., 2015; Thompson et al., 2016) and several forest-level assessments of wildfire risk (Scott and Helmbrecht, 2010; Scott et al., 2013a). Effects analysis relies on input from resource specialists to produce a tabular response function for each HVRA occurring in the analysis area. A response function is a tabulation of the relative change in value of an HVRA if it were to burn in each of six flame-length classes. A positive value in a response function indicates a benefit or increase in value; a negative value indicates a loss or decrease in value. Response function values ranged from -100 (greatest possible loss of resource value) to +100 (greatest possible increase in value).

3.5.1 *Effects Analysis Calculations*

Integrating HVRAs with differing units of measure (for example, habitat vs. homes) requires relative importance (RI) values for each HVRA/sub-HVRA. These values were identified in the RI workshop, as discussed in Section 3. The final importance weight used in the risk calculations is a function of overall HVRA importance, sub-HVRA importance, and relative extent (pixel count) of each sub-HVRA. This value is therefore called relative importance per pixel (RIPP).

The RF and RIPP values were combined with estimates of the flame-length probability (FLP) in each of the six flame-length classes to estimate conditional NVC (cNVC) as the sum-product of flame-length probability (FLP) and response function value (RF) over all the six flame-length classes, with a weighting factor adjustment for the relative importance per unit area of each HVRA, as follows:

$$cNVC_j = \sum_{i}^{n} FLP_i * RF_{ij} * RIPP_j$$

where i refers to flame length class (n = 6), j refers to each HVRA, and RIPP is the weighting factor based on the relative importance and relative extent (number of pixels) of each HVRA. The cNVC calculation shown above places each pixel of each resource on a common scale (relative importance), allowing them to be summed across all resources to produce the total cNVC at a given pixel:

$$cNVC = \sum_{j}^{m} cNVC_j$$

where cNVC is calculated for each pixel in the analysis area. Finally, eNVC for each pixel is calculated as the product of cNVC and annual BP:

$$eNVC = cNVC * BP$$

3.5.2 *Downscaling FSim Results for Effects Analysis*

FSim's stochastic simulation approach can be computationally intensive and therefore time constraining on large landscapes. A resulting challenge is to determine a resolution sufficiently fine to retain detail in fuel and terrain features yet produce calibrated results in a reasonable timeframe. Moreover, HVRA are often mapped at the same resolution as the final BP and FLPs produced by FSim. To enable greater resolution on HVRA mapping, we chose to downscale the FSim results to 30 m, consistent with HVRA mapping at 30 m.

We downscaled FSim results using a multi-step process. First, we resampled the original, 120-m BP and FLP grids to 30 m. Next, we used the Focal Statistics tool in ESRI's ArcGIS to calculate the mean BP and FLP, of burnable pixels only, within a 7-pixel by 7-pixel moving window. Finally, we used the smoothed BP and FLP values to "backfill" burnable pixels at 30 m that were coincident with non-burnable fuel at 120 m. The final smoothed grids resulted in original FSim values for pixels that were burnable at both 120 m and 30 m, non-zero burn probability values in burnable pixels that were non-burnable at 120 m, and a BP of zero in non-burnable, 30-m pixels.

4 Analysis Results

4.1 Effects Analysis

The cumulative results of the wildfire risk calculations described in section 3.5.1 are the spatial grids of cNVC and eNVC, representing both the conditional and expected change in value from wildfire disturbance to all HVRAs included in the analysis. Results are therefore limited to those pixels that have at least one HVRA and a non-zero burn probability. Both cNVC and eNVC reflect an HVRAs' response to fire and their relative importance within the context of the assessment, while eNVC additionally captures the relative likelihood of wildfire disturbance. Cumulative effects of wildfire vary by HVRA (Figure 21) with a net positive eNVC for Vegetation Condition Class, a relatively minimal net negative eNVC for Watershed and Aquatic Wildlife Habitat. Increasingly negative eNVC values are shown for Infrastructure, Suitable Timber and Lynx Habitat, with WUI (People/Property) showing the most highly negative net eNVC result. Figure 22 shows cNVC results by percentile across the analysis area, with beneficial effects shown in light blue and negative effects shown in dark red. Adjusting cNVC by fire likelihood (i.e., burn probability) focuses the map to the areas with both the greatest wildfire likelihood and the greatest consequence as seen in the eNVC map in Figure 23.

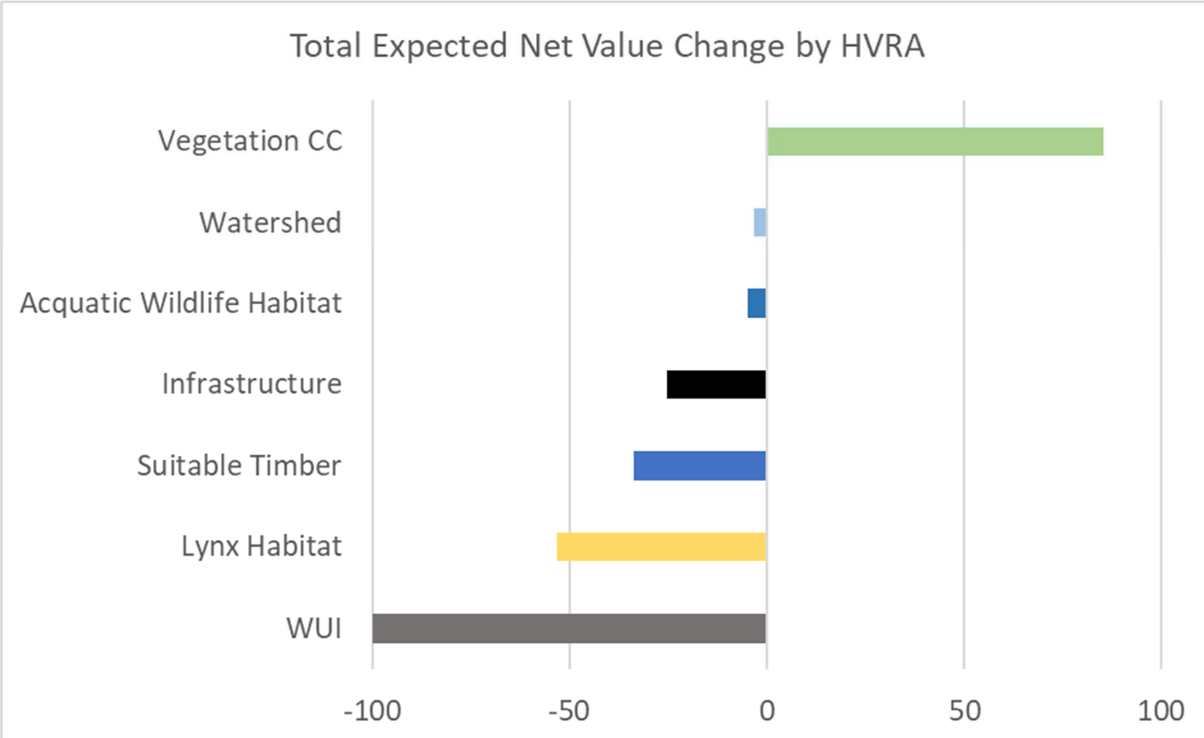

Figure 21: Weighted net response over all highly valued resources and assets (HVRAs) in the assessment. HVRAs are listed in order from greatest expected positive net value change (response) at the top, to greatest negative net value change at the bottom.

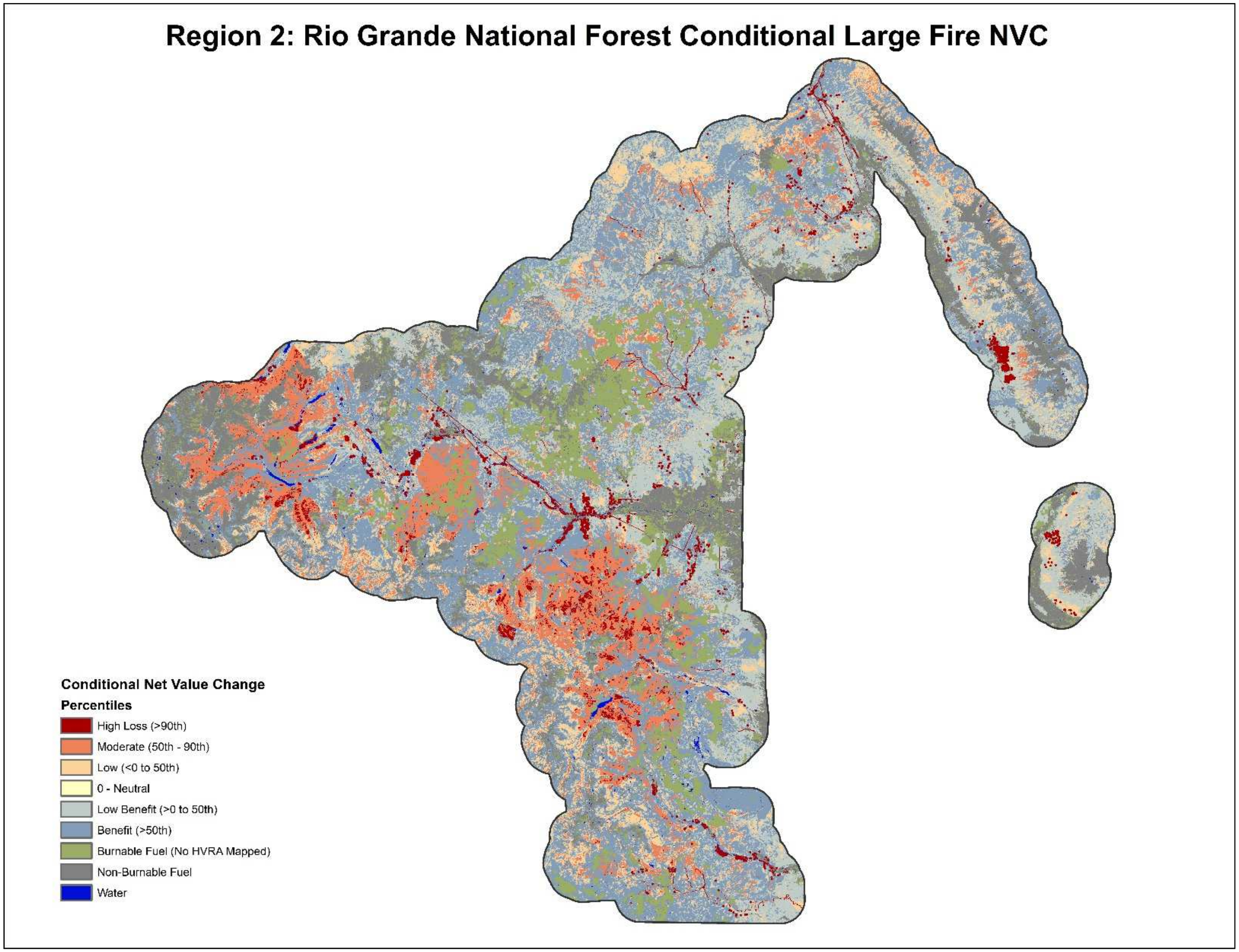

Figure 22: Map of Conditional Net Value Change (cNVC) for the R2RG analysis area.

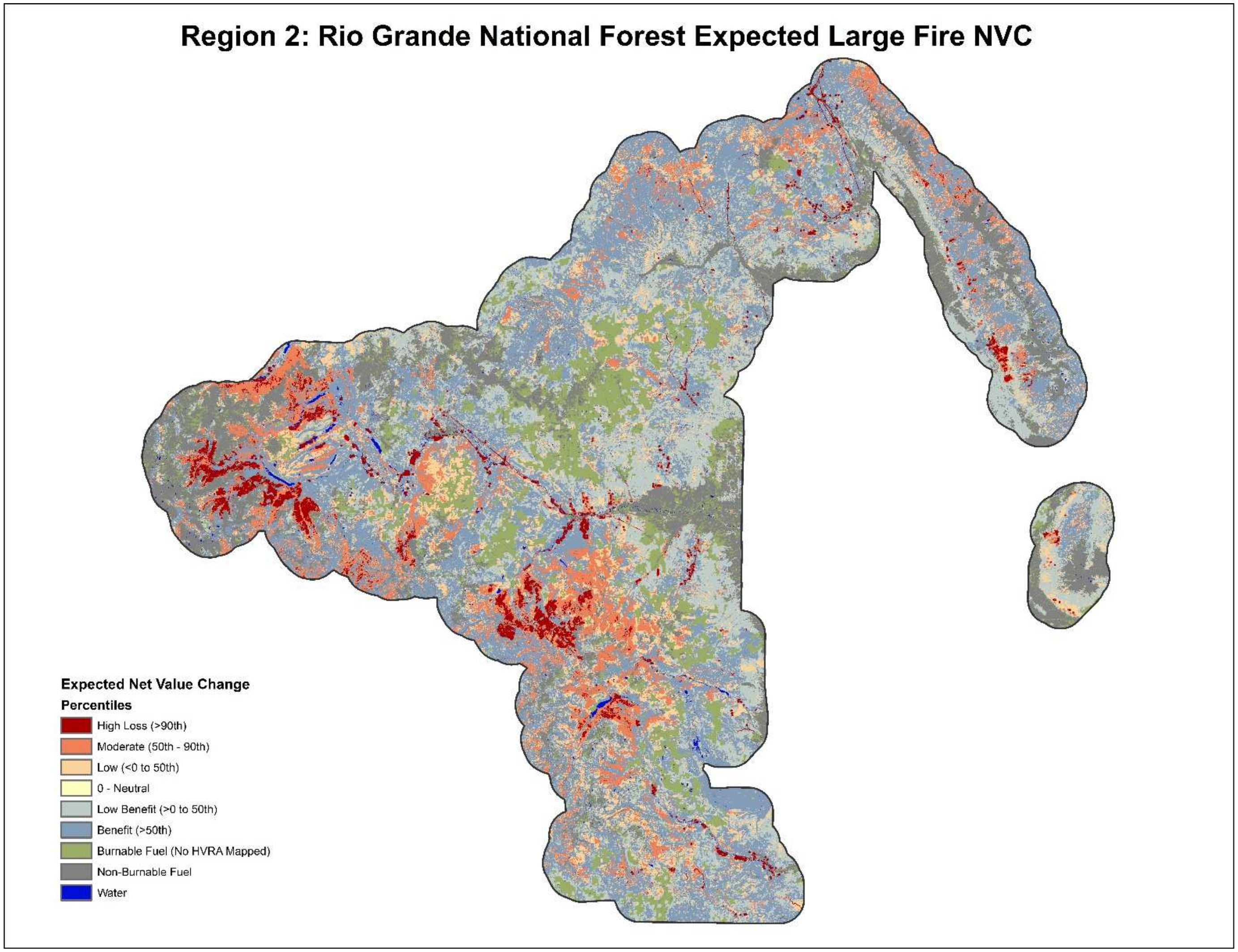

Figure 23: Map of Expected NetValue Change (eNVC) for the R2RG analysis area.

5 Analysis Summary

The Region 2, Rio Grande National Forest QWRA provides foundational information about wildfire risk to highly valued resources and assets across the Forest. The results represent the best available science across a range of disciplines. While this report was generated by Pyrologix LLC, the overall analysis was developed as a collaborative effort with numerous Forest Fire/Fuels Staff and Leadership, Resource Specialists, Wildlife Biologists, Geospatial Analysts, and Information Specialists. This analysis can provide great utility in a range of applications including: resource planning, prioritization and implementation of prevention and mitigation activities and wildfire incident response planning. Lastly, this analysis should be viewed as a living document. While the effort to parameterize and to calibrate model inputs should remain static, the landscape file should be periodically revisited and updated to account for future forest disturbances. Additionally, the HVRA mapping may also need to be updated to account for forthcoming resource challenges and needs within the geographic area.

6 Data Dictionary

1. **RG_RiskResults_20190916.gdb –** This geodatabase contains 64 rasters representing HVRA for Rio Grande National Forest and their associated Expected Net Value Change (eNVC), Conditional Net Value Change (cNVC) and totals.
    a. All datasets within the geodatabase are 30-m cell size representation of wildfire risk to one or more Highly Valued Resource or Asset (HVRA) selected for inclusion in the R2RG Quantitative Wildfire Risk Assessment. This data layer is part of a set of wildfire risk results developed for the Region 2: Rio Grande National Forest Wildfire Risk Assessment (R2RG). Please reference the R2RG project report for information on data sources and reference the "RGF_RF-RI_08.26.19.xlsx" spreadsheet for raster value interpretation along with wildfire response functions and relative importance used in these calculations. The results use 30-m FSim wildfire behavior results. For information on downscaling methods, please see the metadata associated with the SWCO_FSim_120_d1_30.gdb results.
2. **RG_RiskResults_20190919_UnWeighted.gdb**
    a. All These products are UNWEIGHTED among HVRA categories. To use, decide the appropriate proportion of relative importance for each HVRA. To generate a new "Total" eNVC or cNVC, we recommend using the ArcGIS Weighted Sum Tool in the Spatial Analyst Toolbox to assign new importance weights. If new values are not assigned, HVRA importance is equally allocated among HVRA groups.
3. **SWCO_FSim_120_d1_30.gdb** – This geodatabase contains 13 rasters representing mosaic data results from the FSim simulations in the four FOAs within the R2RG project area:
    a. **FLEP_GT2 –**

       This dataset represents the conditional probability of exceeding a nominal flame-length value (also known as flame-length exceedance probability, or FLEP). There are five FLEP rasters. FLEP_GT2 is the conditional probability of exceeding a flame length of 2 feet; it is calculated as the sum of iFLP_FIL2 through iFLP_FIL6. FLEP_GT4 is the conditional probability of exceeding a flame length of 4 feet; it is calculated as the sum of iFLP_FIL3 through iFLP_FIL6. FLEP_GT6 is the conditional probability of exceeding a flame length of 6 feet; it is calculated as the sum of iFLP_FIL4 through iFLP_FIL6. FLEP_GT8 is the conditional probability of exceeding a flame length of 8 feet; it is calculated as the sum of iFLP_FIL5 and iFLP_FIL6. There is no raster for FLEP_GT0 because, by definition, for all burnable pixels there is a 100 percent probability that flame length will exceed 0, given that a fire occurs.

       The iFLP_FILx rasters are the integrated (project wide) conditional probabilities of observing flame length in each of six classes: iFLP_FIL1 represents flame lengths from 0 - 2 ft., iFLP_FIL2 represents flame lengths from 2 - 4 ft., iFLP_FIL3 represents flame lengths from 4 - 6 ft., iFLP_FIL4 represents flame lengths from 6 - 8 ft., iFLP_FIL5 represents flame lengths from 8 - 12 ft., and iFLP_FIL6 represents flame lengths >12 ft.
    b. **FLEP_GT4** – see FLEP_2 description above
    c. **FLEP_GT6** – see FLEP_2 description above
    d. **FLEP_GT8** – see FLEP_2 description above
    e. iBP_30 –

       This dataset is a 30-m cell size (downscaled from 120-m) raster representing annual burn probability across the project area. The individual-FOA BPs were integrated into this overall result for the project area using a natural-weighting method that Pyrologix developed on an earlier project and subsequently published (Thompson and others 2013; "Assessing Watershed-Wildfire Risks on National Forest System Lands in the Rocky Mountain Region of the United States”). With this method, BP values for pixels well within the boundary of a FOA are influenced only by that FOA. Near the border with another FOA the results are influenced by that adjacent FOA. The weighting of each FOA is in proportion to its contribution to the overall BP at each pixel.

f. **iCFL –**

This dataset is a 30-m cell size (downscaled from 120-m) raster representing the mean conditional flame length (given that a fire occurs). It is a measure of the central tendency of flame length. This raster was calculated as the sum-product of iFLP_FILx and the midpoint flame length of each of the six iFLP_FILs. For iFLP_FIL6, for which there is no midpoint, we used a surrogate flame length of 100 feet (representing torching trees).

g. **iFLP_FIL1_30 –**

This dataset is a 30-m cell size (downscaled from 120-m) raster representing the mean conditional flame length (given that a fire occurs). This is also called the flame-length probability (FLP) and is a measure of the central tendency of flame length. This raster was calculated as the sum-product of the probability at each flame-length class and the midpoint flame length value of each of the six FILs. For FIL6, for which there is no midpoint, we used a surrogate flame length of 100 feet (representing torching trees) in timber fuel models and a flame length of 20 feet in all in grass, grass-shrub and shrub fuel types.

The individual-FOA iFLP_FILx rasters were integrated into this overall result for the project area using a natural-weighting method that Pyrologix developed on an earlier project and subsequently published (Thompson and others 2013; “Assessing Watershed-Wildfire Risks on National Forest System Lands in the Rocky Mountain Region of the United States”). With this method, the iFLP_FILx values for pixels well within the boundary of a FOA are influenced only by that FOA. Near the border with another FOA the results are also influenced by that adjacent FOA. The weighting of each FOA is in proportion to its contribution to the overall BP at each pixel.

h. **iFLP_FIL2_30** – see iFLP_FIL1 description above
i. **iFLP_FIL3_30** – see iFLP_FIL1 description above
j. **iFLP_FIL4_30** – see iFLP_FIL1 description above
k. **iFLP_FIL5_30** – see iFLP_FIL1 description above
l. **iFLP_FIL6_30** – see iFLP_FIL1 description above
m. **iMFI_30 –**

This dataset is a 30-m cell size (downscaled from 120-m) raster representing the mean conditional fireline intensity (kW/m) given that a fire occurs. It is a measure of the central tendency of fireline intensity. The individual-FOA MFI rasters were integrated into this overall result for the project area using a natural-weighting method that Pyrologix developed on an earlier project and subsequently published (Thompson and others 2013; “Assessing Watershed-Wildfire Risks on National Forest System Lands in the Rocky Mountain Region of the United States”). With this method, the iMFI values for pixels well within the boundary of a FOA are influenced only by that FOA. Near the border with another FOA the results are also influenced by that adjacent FOA. The weighting of each FOA is in proportion to its contribution to the overall BP at each pixel.

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