Colorado Wildfire Risk Assessment Project

Final Report

Prepared for:

Colorado State Forest Service

Last Updated: February 21, 2013

Prepared by:

Data Transfer Solutions

409 Mason Court, #127

Fort Collins CO 80524

Colorado Wildfire Risk Assessment Project

Final Report

Table of Contents

List of Tables and Figures

1.0 Introduction

This project involved developing an updated Colorado statewide wildfire risk assessment. The project was based on leveraging the data and achievements of the West Wide Wildfire Risk Assessment (WWA) project, and tailoring these to reflect Colorado conditions, requirements and priorities. Once the Colorado Wildfire Risk Assessment (WRA) project was completed, the data would be released to Colorado State Forest Service (CSFS) staff, CSFS partners and collaborators, and the public. The data would be made available by the development of an interactive web mapping application called the Colorado Wildfire Risk Assessment Portal (CO-WRAP).

This report documents the Colorado WRA methods, data and results, as the final report of this project. The Colorado WRA was completed by DTS (Fort Collins, CO) in collaboration with the CSFS.

1.1 Background

Wildfire risk in the western U.S. is increasing and becoming a more complex problem that warrants coordinated assessment, planning and response. The Council of Western State Foresters (CWSF) and the Western Forestry Leadership Coalition (WFLC) embarked on a wildfire risk assessment of all lands for the 17 western states and selected Pacific islands. This assessment is known as the "West Wide Wildfire Risk Assessment, or "WWA". The multi-year project was completed in December 2012.

The WWA documented the risk from wildfire by quantifying the magnitude of the current wildland fire problem in the West. The WWA is unique because it will assess all lands across the west using consistent data and methods, therefore providing information to support planning and decision making at national, regional, and state scales. The WWA results provide a foundation for coordinating policy and baseline data for state level planning, especially for those states with limited resources. The WWA is a separate, regional effort with potential to complement the State Forest Resource Assessments and Forest Action Plans currently maintained by individual states as required by the 2008 Farm Bill and part of USFS State and Private Forestry Redesign.

The WWA resulted in a series of GIS datasets that reflect the inputs and outputs of the assessment. All output data was calibrated for regional use reflecting data distribution across all 17 Western states. Each individual state received the regionally calibrated datasets.

As a leader across the West, the CSFS embarked on using the rich WWA datasets to develop a state calibrated data set. This process of calibrating and adjusting WWA data to reflect Colorado conditions, requirements and priorities is referred to as the Colorado WRA project. This resulted in a set of wildfire risk assessment outputs that focus on specific conditions and requirements within Colorado. The outputs have been calibrated based only on Colorado data and do not incorporate data or parameters from other states. However, the Colorado WRA project does heavily leverage the technical methods and standards developed in the WWA project, ensuring that the outputs are based on a scientifically sound, defendable and robust approach.

1.2 Project Deliverables

With the completion and release of WWA data in November 2012, DTS and the CSFS embarked on the review and enhancement of this data to meet CSFS and Colorado planning requirements. This report describes those processes and enhancements. In addition, CSFS also required capabilities to distribute the assessment results to meet agency obligations. Building on the technical foundation and achievements of the State of Texas Wildfire Risk Assessment Portal, CSFS embarked on implementing a suite of interactive web mapping applications to facilitate dissemination of assessment outputs to the public and local planners.[1] This website is referred to as the Colorado Wildfire Risk Assessment Portal, or CO-WRAP. A brief overview of CO-WRAP is provided in this report, however we encourage readers to visit the CO-WRAP web site at www.ColoradoWildfireRisk.com for more information.

1.3 Project Technical Team

The Colorado WRA project was undertaken by Data Transfer Solutions (DTS, Fort Collins,CO) in collaboration with the Colorado State Forest Service. The team consisted of:

- David Buckley (DTS, Fort Collins, CO), Senior Consultant & Project Manager
- Darian Krieter (DTS, Portland, OR), Lead GIS Analyst
- Jeff Germain (DTS, Fort Collins, CO), Lead Web Developer
- Rich Homann, Colorado State Forest Service, Project Lead & Project Manager
- Boyd Lebeda, CSFS, Fuels and Fire Behavior Technical Lead
- Matt Tansey, CSFS, GIS Manager
- Judy Serby, CSFS, Public Outreach
- Katherine Schaubert, CSFS, Public Outreach
- Lisa Mason, CSFS, Public Outreach
- GayLene Rossiter, CSFS, Web Services
- Dr. Joseph Berry (Berry & Associates, Fort Collins, CO) – GIS Modeling

This final report was developed by David Buckley (DTS) in collaboration with Rich Homann (CSFS) and Darian Krieter (DTS).

1.4 Contact Information

For more information about the Colorado WRA or the CO-WRAP web application please contact Rich Homann at the Colorado State Forest Service at Richard.Homann@Colostate.edu, or the support@ColoradoWildfireRisk.com.

[1] Please refer to the TxWRAP web site at www.TexasWildfireRisk.com for more information.

1.5 Supplemental Documents

Additional documents have been developed to support the Colorado WRA project. These include:

- **WWA Final Report** - the final report for the West Wide Wildfire Risk Assessment project (WWA) that describes all data used and the methods employed to derive data in the assessment. This data and these methods provide the basis of the Colorado WRA. Please refer to the WWA web site at www.WestWideRiskAssessment.com for more information.
- **Colorado Wildfire Risk Assessment: Summary Statistics Report** - a series of tables and charts that summarize the total acres, percent acres and total population for the primary risk outputs. Please refer to Section 3.3 of this report for more information.
- **CO-WRAP User Manual** - documentation that describes how to use the Colorado Wildfire Risk Assessment Portal (CO-WRAP) web application that encapsulates the Colorado WRA outputs. See www.ColoradoWildfireRisk.com for access to this document and other related resource information.
- **CO-WRAP Administrator Manual** - documentation that describes how to use the CO-WRAP Admin application to manage the site, including adding new users for the Professional Viewer application. This document is only provided to the CSFS CO-WRAP System Administrator.

2.0 Assessment Methods

This section describes the methods used to develop the Colorado WRA. The Colorado WRA is based on the deliverables of the West Wide Risk Assessment (WWA) project. WWA was a multi-year project, completed in December 2012, that developed a detailed wildfire risk GIS database and risk outputs for the entire West. Data was delivered per state.

2.1 West Wide Risk Assessment Methods

The WWA project was a regional wildfire risk assessment project conducted by the Western Forestry Leadership Coalition on behalf of the 17 western states and Pacific Islands.[2] While data was developed and delivered on a per state basis, the methods and deliverables were focused on satisfying regional priorities, and accordingly, utilized region wide data classification methods. The full WWA methods and deliverables are documented in the WWA Final Report.[3] Readers are referred to this document for detailed information about the compilation methods for source datasets, descriptions for each dataset, analysis and modeling methods used to derive risk outputs, and project findings and results.

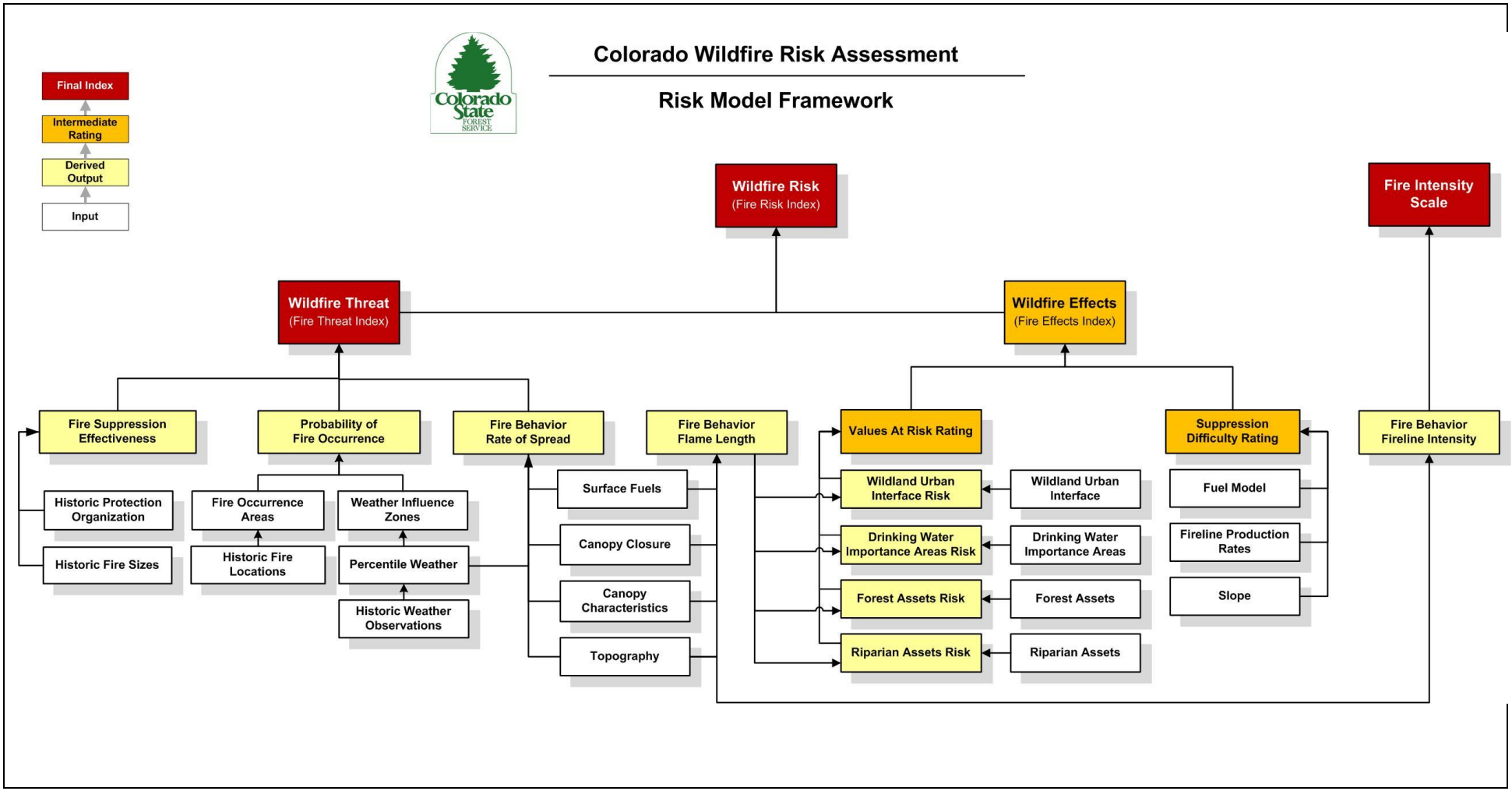
To better satisfy specific Colorado requirements, enhancements were applied to the WWA methods and datasets to derive outputs and results tailored to *Colorado only* data and needs. These methods are described in the next section.

2.2 Overview of Colorado Assessment Methods and Outputs

The following diagram reflects the model flowchart used to derive the Colorado WRA outputs using the WWA deliverables as source data. These methods highly leverage the technical approach developed in the WWA project. Technical changes were undertaken to enhance the outputs to reflect Colorado conditions, requirements and priorities.

[2] See http://www.wflccenter.org/ for more information about WLFC.
[3] West Wide Risk Assessment, Western Forestry Leadership Coalition (2012). West Wide Risk Assessment Final Report. Salem, OR. A final report developed by the WWA Technical Team documenting the methods and specifications of the WWA project.

Figure 1. Colorado WRA flowchart



The following table provides a brief description of the primary datasets in the Colorado WRA. Please refer to Appendix A for a description of each output dataset identified in the process flowchart.

Table 1. Description of Colorado WRA primary datasets

Colorado WRA Output	Description
PRIMARY RISK INDICES	
Wildfire Risk	Possibility of loss or harm occurring from a wildfire, obtained by combining Wildfire Threat and Wildfire Effects
Wildfire Threat	Likelihood of a wildfire occurring or burning into an area
Fire Intensity Scale	Quantifies the potential fire intensity for an area by orders of magnitude
INTERMEDIATE RISK RATINGS	
Wildfire Effects	Represents an overall index of potential effects from wildfire by combining the Values At Risk Rating and the Suppression Difficulty Rating
Values At Risk Rating	Represents an overall rating of the potential impact of a wildfire on all values and assets
Suppression Difficulty Rating	Represents those areas where terrain and vegetation characteristics impede dozer operability based on fireline production rates
DERIVED RISK INDICES	
WUI Risk Index	Represents a rating of the potential impact of a wildfire on people and their homes in the WUI
Drinking Water Risk Index	Measure of wildfire risk to drinking water importance areas
Fire Occurrence	Likelihood of a wildfire starting based on historical ignition patterns
Forest Assets Risk Index	Measure of wildfire risk to forested lands characterized by height, cover and susceptibility/response to fire
Riparian Assets Risk Index	Measure of wildfire risk to forested riparian areas
FIRE BEHAVIOR OUTPUTS	
Characteristic Flame Length	Represents the distance between the tip and base of the flame based on historical percentile weather
Characteristic Rate of Spread	Represents the speed with which a fire moves in a horizontal direction across the landscape based on historical percentile weather
Fire Type (extreme weather)	Potential for canopy fire type for extreme weather conditions (canopy fire potential)
KEY INPUTS	
Drinking Water Importance Areas	Measure of quality and quantity of public surface drinking water categorized by watershed
Fire Ignitions	Fire ignition locations for both local (by zip code) and federal agency fires (lat/long points)
Forest Assets	Forested lands characterized by height, cover and susceptibility / response to fire
Riparian Assets	Forested riparian areas characterized by functions of water quantity, quality and ecology
Surface Fuels	Description of surface vegetation conditions described by fuel conditions that reflect fire behavior characteristics
Vegetation	General vegetation and land cover types

Colorado WRA Output	Description
Wildland Urban Interface (WUI)	Depicts where humans and their structures meet or intermix with wildland fuels. Presented as housing density (houses per acre).

2.3 Description of Methods

A number of tasks were undertaken to modify the WWA data to derive outputs that are considered calibrated for Colorado conditions and requirements. These tasks are primarily based on the adjustment of *Response Function* values used to generate the Wildfire Effects outputs. However, several other adjustments were also undertaken to enhance the WWA data for the Colorado WRA. These included:

1. **Renaming Layers to Match Colorado Terminology**
2. **Developing Additional Risk Outputs**
3. **Adjusting Response Function Assignments to Derive Wildfire Effects Outputs**
4. **Adjusting Class Breaks for Wildfire Effects Outputs**
5. **Adjusting Class Breaks for Primary Risk Outputs**

A detailed description on the use of Response Functions is provided in Adjusting Response Functions section. Please refer to the WWA Final Report for detailed descriptions of the methods used to create the WWA data, and also applied in this project to create the Colorado WRA outputs.

A description of the enhancements is provided below.

1. Renaming Layers to Match Colorado Terminology

The terminology and naming convention for risk assessment outputs used in the WWA project reflects appropriate descriptions for the methods employed that are understood regionally across the West. However, for the Colorado WRA some of the outputs were renamed to better reflect nomenclature and terminology used within the Colorado State Forest Service and its partners and collaborators. Accordingly, the following table presents the list of datasets where names are changed. This is provided so readers can easily associate the Colorado WRA data and outputs with WWA products.

Table 2. Colorado WRA output data name changes (alphabetical order)

Colorado WRA Dataset	WWA Dataset
PRIMARY RISK OUTPUTS	
Fire Intensity Scale	*Not available in WWA*
Values At Risk Rating	Values Impacted Rating
Wildfire Effects	Fire Effects Index
Wildfire Risk	Fire Risk Index
Wildfire Threat	Fire Threat Index

Colorado WRA Dataset	WWA Dataset
INTERMEDIATE RISK OUTPUTS	
Drinking Water Risk Index	DWIA Response Function Score
Forest Assets Risk Index	Forest Assets Response Function Score
Riparian Assets Risk Index	Riparian Assets Response Function Score
WUI Risk Index	WDA Response Function Score
KEY INPUTS	
Wildland Urban Interface (WUI)	Wildland Development Areas (WDA)

2. Developing Additional Risk Outputs

After review of the WWA outputs CSFS decided some additional processing could be applied to generate enhanced outputs that would better meet Colorado conditions, requirements and priorities. These enhancements included:

- Smoothing the fire behavior Flame Length output (used for Response Function processing in Wildfire Effects) to better reflect conditions *around* individual locations, instead of just the condition *at* a specific location.
- Adjusting key risk outputs to reflect the potential movement of wildland fire into urban and municipal areas (referred to as *urban penetration*). This involves extending key fire behavior outputs into urban areas so that these *fringe areas* are considered during the generation of risk outputs. A penetration distance of 0.25 mile was used.
- Development of a Fire Intensity Scale (FIS) output.

A description of each enhancement is provided.

Using Calculated versus Smoothed Fire Behavior Inputs

The Response Function (RF) modeling process requires the integration of the resource value datasets (i.e. WUI, Drinking Water, Forest Assets, Riparian Assets) with Flame Length. A detailed description of the Response Function is provided in the Adjusting Response Functions section of this document. Readers are also encouraged to review the WWA Final Report for an in depth description of the Response Function modeling approach.

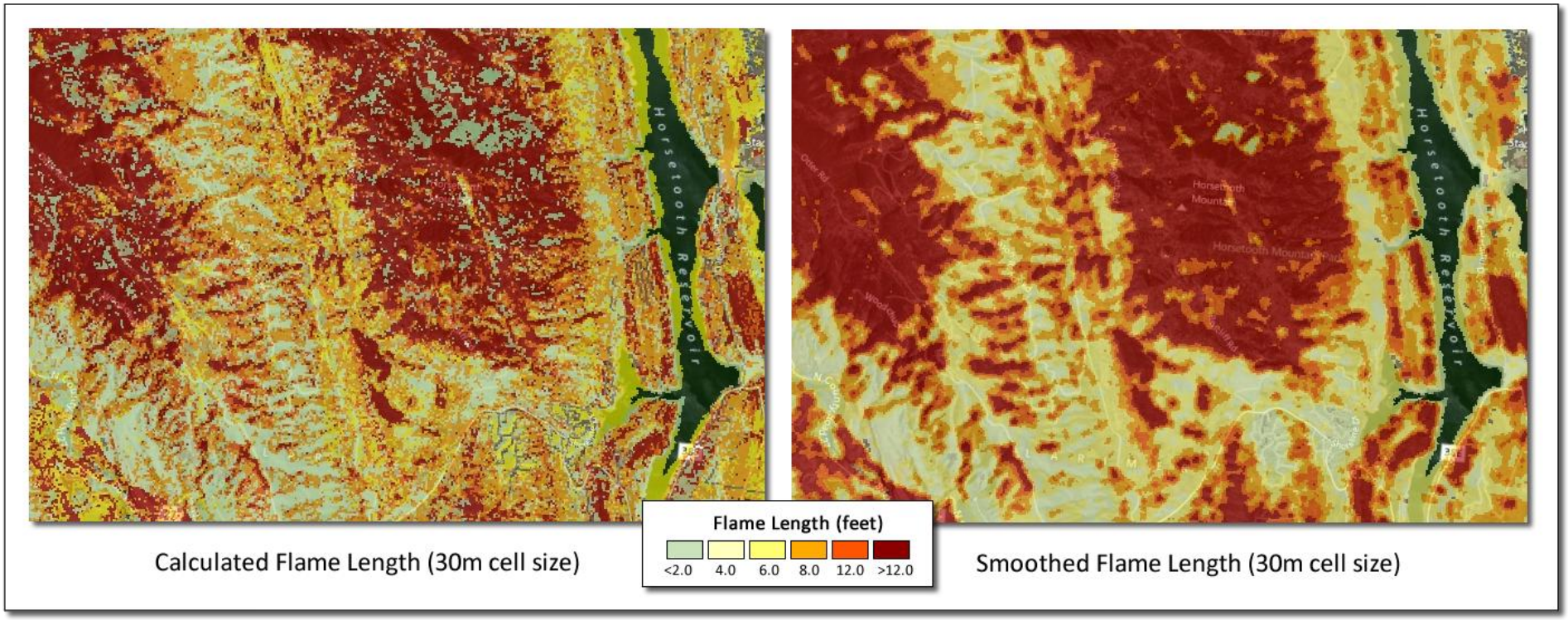
Flame Length (by percentile weather category) was calculated in the WWA project on a per cell basis without any consideration of surrounding cell values. This results in a dataset of *calculated* cell values. The term *cell* refers to a 30m x 30m pixel in the fuels dataset. This is the resolution of the data for the assessment, matching the standard LANDFIRE source fuels data resolution.

Response Function values can be derived using either the *calculated* Flame Length data or *smoothed* Flame Length data. Calculated Flame Lengths were used in the WWA project. Smoothing involves using

a neighborhood GIS function to average cell values based on the values of surrounding cells. Different distance reaches and averaging techniques can be applied. Since CSFS wants to consider not only the conditions at each 30m by 30m cell being processed, but also in surrounding cells (proximity of wildlands), some neighborhood smoothing is required.

Since Flame Length is a *localized* fire behavior output, representing the maximum length of the fire flame in feet, it was decided that smoothing with a small distance reach was more appropriate. Best results were found using a 4 cell circular reach with an inverse distance squared decay function. This ensured that localized cell values were usually retained, yet allowed for consideration of surrounding cell values. This resulted in a more easily understandable and aesthetically pleasing Flame Length map outputs. The following figure presents the calculated Flame Length and smoothed Flame Length data. Both datasets are categorized by the Flame Length categories used for the RFV calculations.

Figure 2. Example of calculated and smoothed Flame Length



Where People Live 2012

Census block data has traditionally been used to define Wildland Urban Interface (WUI) areas. As such, the USFS Silvis dataset has been a de facto standard used for wildland fire planning in the past.[4] SILVIS defines WUI areas based on a combination of housing density and forest cover percent. Recent improvements on defining the WUI have been achieved by Theobald and Romme (2007) to define WUI areas based on combining better sources of land cover with the definition of Community Protection Zones using variable width buffers.[5] Many Western states used analysis approaches based on Theobald and Romme to develop WUI for their State Forest Resource Assessments. For the Colorado State Forest Resource Assessment, Theobald generated new WUI data based on the LANDFIRE vegetation types used in the state assessment. The new data provides information on the 0.5, 1 and 2-mile community protection zones for both 2000 and 2030. The SFRA WUI dataset reflects the intersection of WUI and high severity vegetation types. Housing density, derived from Census data, was used.

In the WWA project considerable investigation was undertaken to evaluate existing WUI data and methods. Based on this investigation, a new housing density dataset was developed (called Where People Live), based on methods developed by DTS (Fort Collins, CO) in the Texas Wildfire Risk Assessment project. For the Texas and WWA projects, DTS built upon methods initially developed in the USFS First Approximation to Wildfire Risk project that utilized LandScan population count data to model housing density.[6] Accordingly, the Where People Live (WPL) dataset was derived by modeling the Oak Ridge National Laboratory LandScan data.[7]

LandScan depicts an estimate of population count on a 90m cell basis. The model used to create LandScan data uses spatial data and imagery analysis technologies and a multi-variable dasymetric modeling approach to disaggregate census counts within an administrative boundary. Since no single population distribution model can account for the differences in spatial data availability, quality, scale, and accuracy as well as the differences in cultural settlement practices, LandScan population distribution models are tailored to match the data conditions and geographical nature of each individual country and region. A key component of the LandScan model is the integration of night time imagery to determine where people are living. LandScan is the preferred choice for population data and given its spatial resolution is ideal for defining *where people live*.

---

[4] Please see http://silvis.forest.wisc.edu/maps/WUI for more information about the SILVIS WUI data.

[5] Theobald, D.H. Romme, W.H. 2007. Expansion of the US wildland-urban interface. Landscape and Urban Planning Journal.

[6] Calkin, David E.; Ager, Alan A.; Gilbertson-Day, Julie, eds. 2010. Wildfire Risk And Hazard: Procedures For The First Approximation. Gen. Tech. Rep. RMRS-GTR-235. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 62 p.

[7] Please refer to the ORNL Landscan web site at http://www.ornl.gov/sci/landscan/ for more information about LandScan.

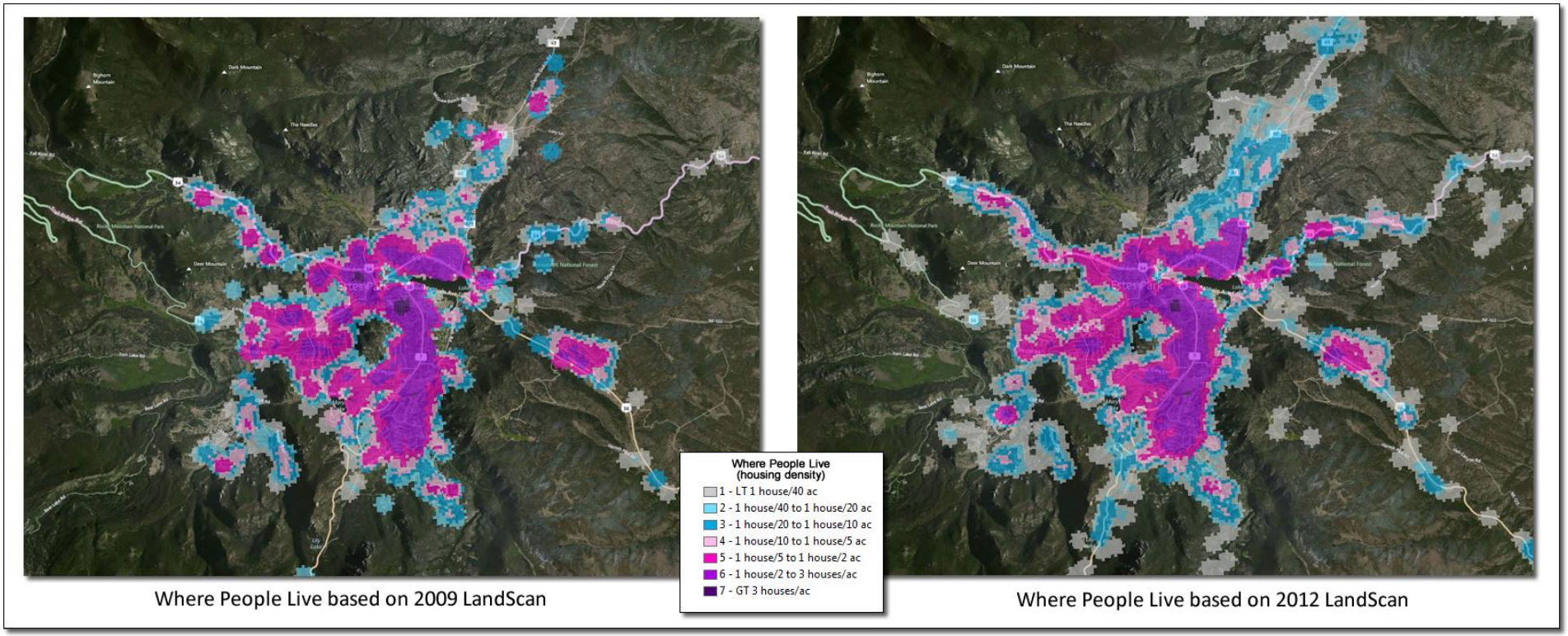
In particular, the resolution and accuracy of the LandScan data provides a better definition of the location of rural and wildland communities and residential population compared to traditional WUI datasets (i.e. USFS Silvis or Theobald) that were developed using Census Block data that has a coarser spatial resolution. For the WWA project LandScan data for 2009 was used to create the WPL dataset. Urban areas were then extracted from the WPL data to create the WWA version of WUI, called Wildland Development Areas (WDA). The WWA project chose not to use the term WUI for this dataset to reflect preferences of the project steering committee.

With delays in the completion of the WWA, and delivery of the Colorado source data to be used in the Colorado WRA, opportunities existed to enhance the Colorado WPL (and WUI) data to reflect more up-to-date LandScan data. Accordingly, LandScan data for 2012 was obtained and modeled to create Colorado WPL and WUI 2012 datasets. These datasets were then used to model WUI Risk for Colorado.

The following figure compares WPL for 2009 and WPL for 2012 for the Estes Park, CO area. The primary difference in 2012 outputs are that they incorporate changes in urban growth patterns that have occurred between 2009 and 2012. In the example shown there are changes in density noticeable in the southwest area of Estes Park where a new subdivision has been developed, and along transportation routes. When combined with Flame Length to calculate the potential risk for WUI, this will provide a more accurate reflection of risk for current conditions.

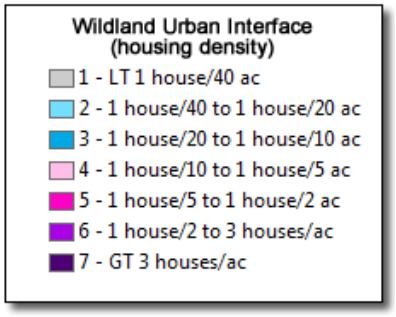
Note that the WPL data incorporates both urban and wildland/rural areas. Using urban penetration methods described in the next section a WUI dataset is derived by simply extracting the urban core areas from the WPL. Examples are shown in the next section.

Figure 3. Comparison of WPL for 2009 and 2012.



WPL & WUI Class Breaks

The WPL and WUI datasets have been calculated to represent the "number of houses per square kilometer", consistent with Federal Register and USFS Silvus procedures and standards. However, to aid in the interpretation and use of this data, the datasets are presented with a legend as "houses per acre". This was done to adhere to common use and understanding of WUI by planners and fire professionals. The same approach is used by the Federal Register and USFS Silvis. The following figure depicts the standard WPL/WUI legends classes used in the Colorado WRA.



Accordingly, in the Colorado WRA and in the CO-WRAP applications, both datasets are depicted as housing density classes in houses per acre. However, if users choose to work directly with the GIS data on their local computer they need to be aware that the actual units of the data are in "houses per square kilometer". A standard conversion is required to obtain "houses per acre". The following table shows the "houses per sq. km" class breaks that reflect the chosen "houses per acre" legend classes. Note that DTS has provided CSFS a simple Excel file that will help the technical GIS user in translating between the two units to determine other class breaks.

Table 3. WPL and WUI class breaks

WPL/WUI Class	Houses/Sq.KM (min. value)	Houses/Sq.KM (max. value)	Houses per acre (min. value)	Houses per acre (max. value)
1	0.000001	6.177635		LT 1 house / 40 acres
2	6.177635	12.355269	1 house / 40 acres	1 house / 20 acres
3*	12.355269	24.710538	1 house / 20 acres	1 house / 10 acres
4*	24.710538	49.42	1 house / 10 acres	1 house / 5 acres
5	49.42	123.55269	1 house / 5 acres	1 house / 2 acres
6*	123.55269	741.31614	1 house / 2 acres	3 houses / acre
7	741.31614	100,000	More than 3 house / acre	

The WPL and WUI "houses per acre" class breaks also adhere to the standard Federal Register and USFS Silvus classes. However, to provide a smoother gradient in housing density a few additional classes have been added. This was undertaken based on feedback from several states where planning standards vary and accordingly, greater delineation of density classes was preferred. WPL/WUI classes 3, 4, and 6 represent new classes that have been inserted into the standard Federal Register classes. These are denoted with the * in the table above.

Urban Penetration

Although non-burnable areas, such as urban, do not directly have a Flame Length assigned due to the lack of surface fuels, it is understood that small urban areas in the wildlands and urban *fringe* areas are both highly susceptible to wildfire from adjacent fuels. The term *urban fringe* is used to refer to those areas on the periphery of highly urban areas that are in close proximity to wildland areas.

Accordingly, so that the Response Function modeling will incorporate these urban areas into the Wildfire Effects outputs, the model must accommodate penetration into urban, non-burnable areas. The agreed upon approach used in the Colorado WRA was to *extend* the Flame Length data into urban areas using GIS neighborhood smoothing techniques.

A maximum penetration distance is defined (i.e. 0.25 mile), and GIS modeling techniques are applied to extend the Flame Length into urban areas. The best outputs were obtained by using an incremental neighborhood smoothing technique where the fire behavior value from the *wildland edge* was smoothed with incremental rings. This *incremental ring* approach ensured that the fire behavior values decayed as they penetrated the urban areas, understandably since the distance from the wildland edge increased, similar to a decay type function. Custom techniques were developed to implement this since the standard Esri neighborhood decay function resulted in interior artifacts of high fire behavior values due to the existence of isolated edge cells. This occasionally produced artificially high values in the urban core that would not be realistic to represent the impact of wildland edges.

Urban penetration of fire behavior mimics the approach where interior urban cells *look out* to consider surrounding wildland cells to determine their susceptibility to wildfire. Consideration and weighting of wildland edge values depends on the distance of the particular urban cell from the wildland edge. The fundamental steps involved in the urban penetration algorithm used are presented in the three following figures.

The first figure presents how urban cells have no fire behavior values to consider for RFV calculations. This relates specifically to the Where People Live housing density (WPL) input data.

The next figure shows how an incremental ring approach can extend fire behavior values into the urban areas, and decay these based on distance from the surrounding wildland edges.

The final figure presents the enhanced fire behavior output where values have been extended into the urban area providing for consideration of susceptibility to wildfire for urban fringe areas. This is especially relevant for the WPL calculations, although the same logic can be applied to calculating potential loss to structures and people for economic impact analysis in the future. Note the following figures use a simple color ramp to portray gradient values of Flame Length (i.e. green is low, yellow is moderate, and red is high).

Figure 4. Urban cells have no fire behavior values to use for RFV calculations

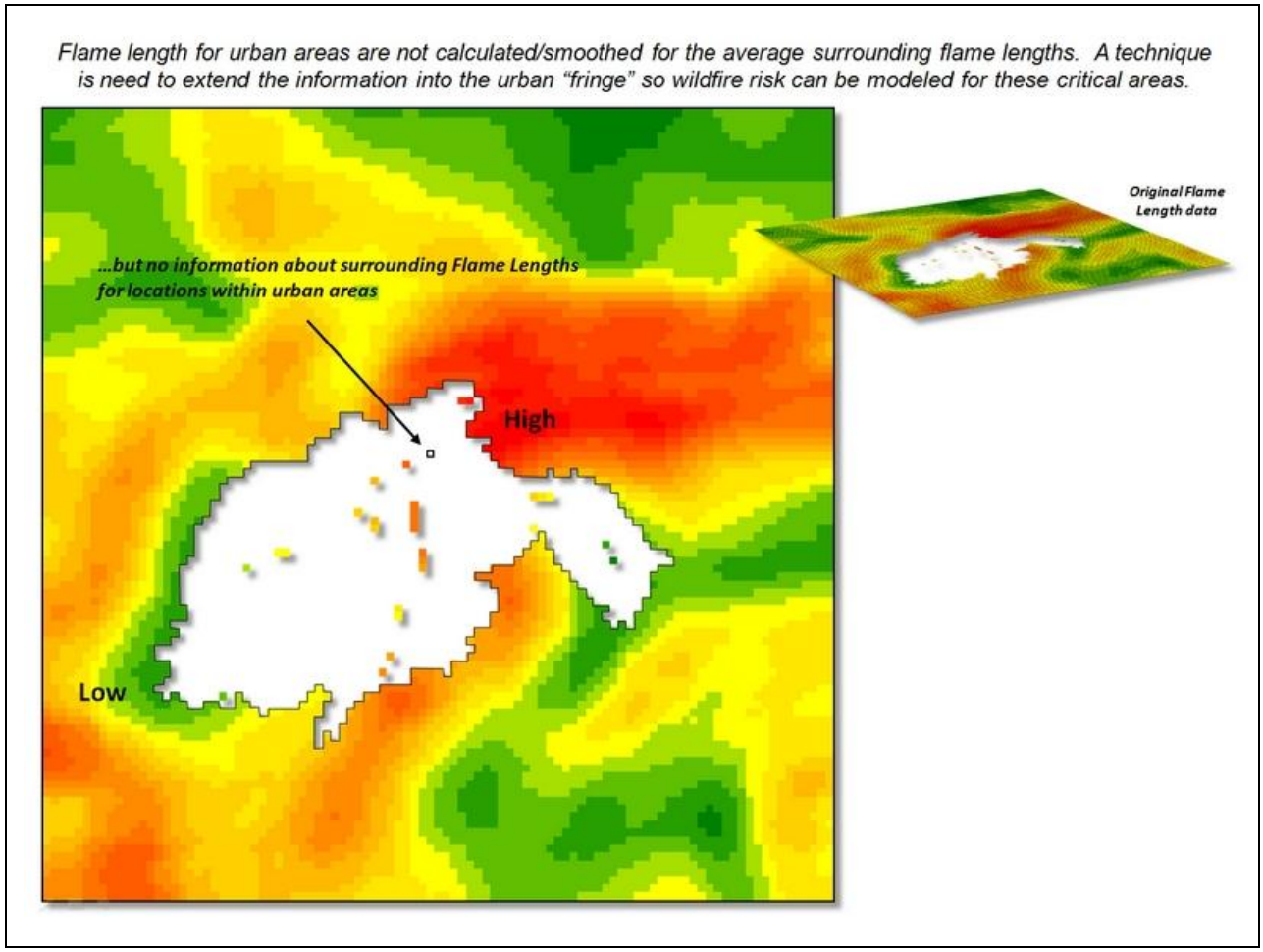


Figure 5. An incremental ring approach can be used to extend fire behavior values into the urban fringe areas

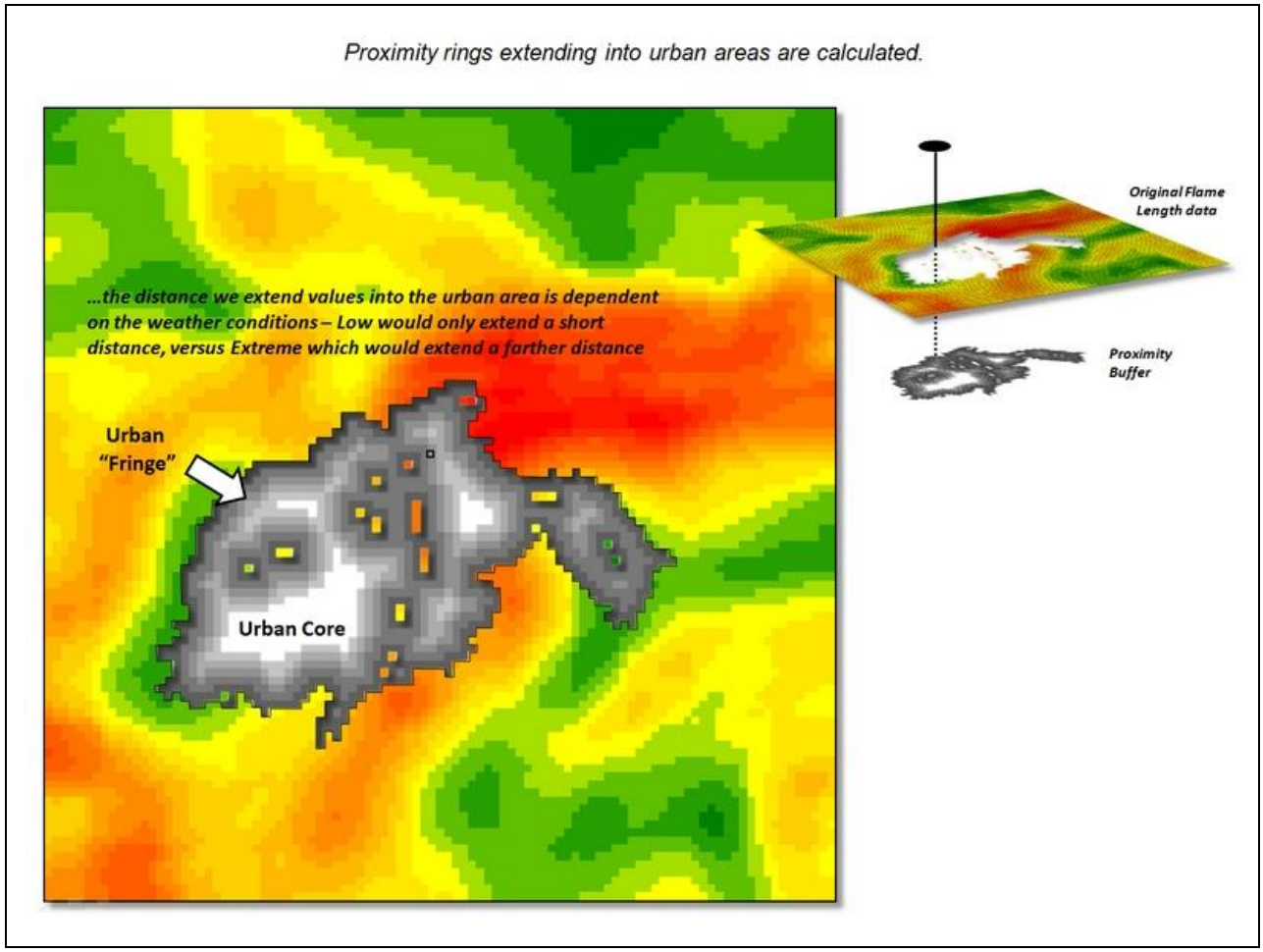
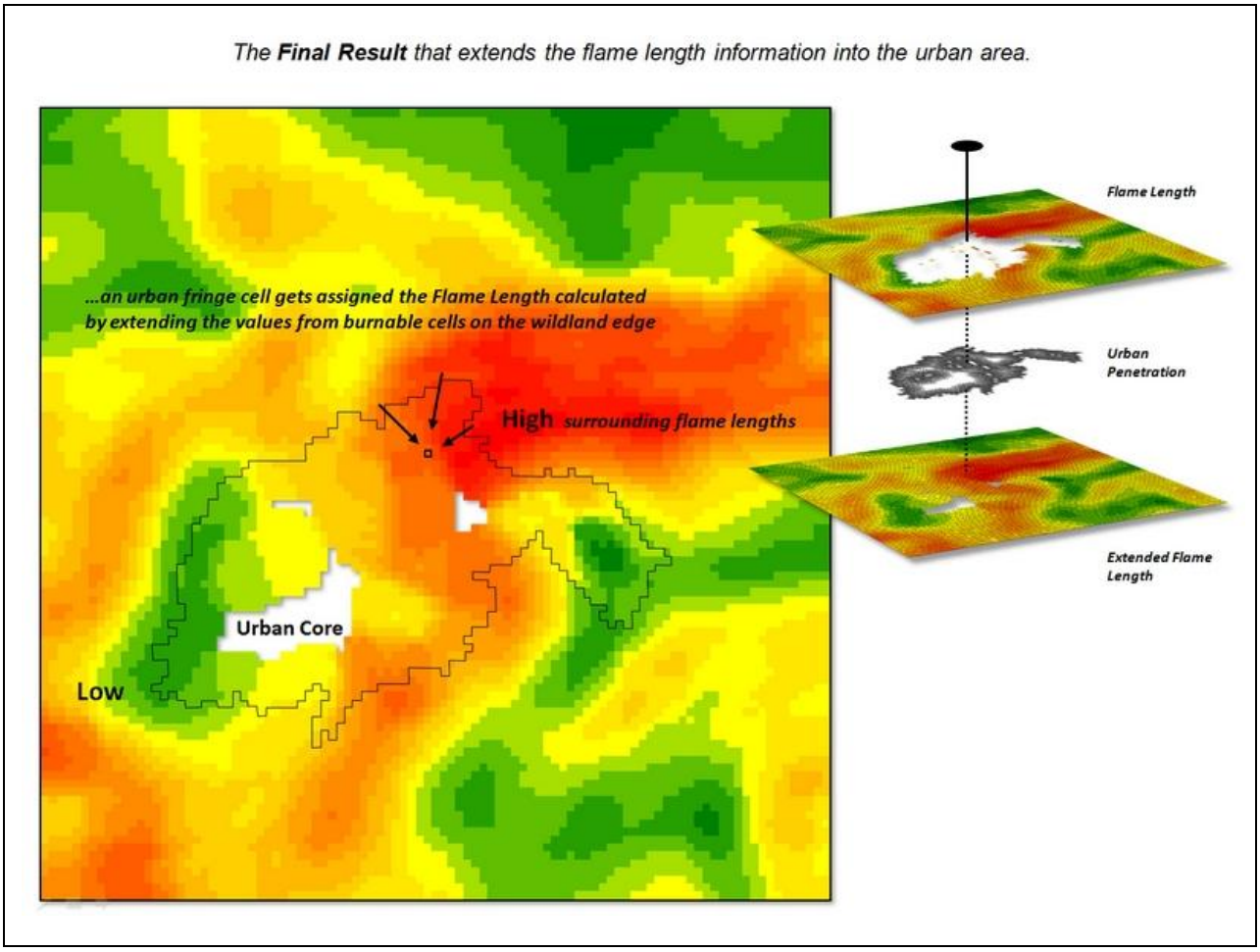


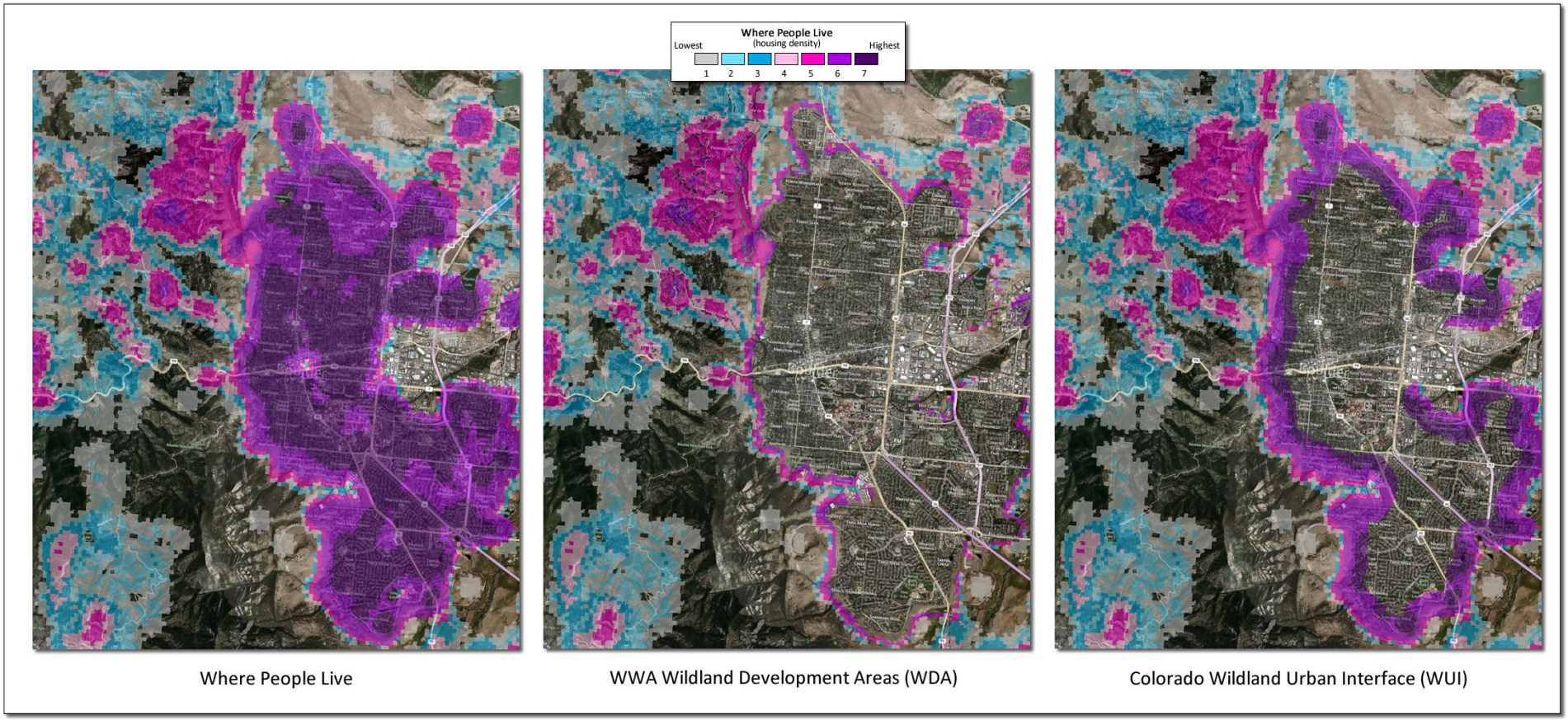
Figure 6. With an extended fire behavior dataset the RFV values can provide a better approximation of susceptibility to wildfire for urban fringe areas



The urban penetration approach was used to enhance the delineation of Wildland Urban Interface. Accordingly, this ensured that urban fringe areas and wildland urban areas were assigned a Response Function value and are reflected in the WUI Risk Index output. As well, this ripples into other outputs that utilize the WUI Risk Index, such as Values at Risk, Wildfire Effects, and Wildfire Risk.

The following figure shows an example of the WUI enhancements achieved with using urban penetration. The map on the left shows the Where People Live housing density data. This dataset is the source for the WUI as it depicts *where people live*. The map in the center shows the WWA Wildland Development Areas (WDA) dataset that does not accommodate urban penetration. Note the strict boundary around the urban core. The map on the right show the WUI with urban penetration included. Areas on the fringe of the urban area are included in the WUI as they are potentially impacted should a wildfire occur, due to their close proximity to wildland fuels areas.

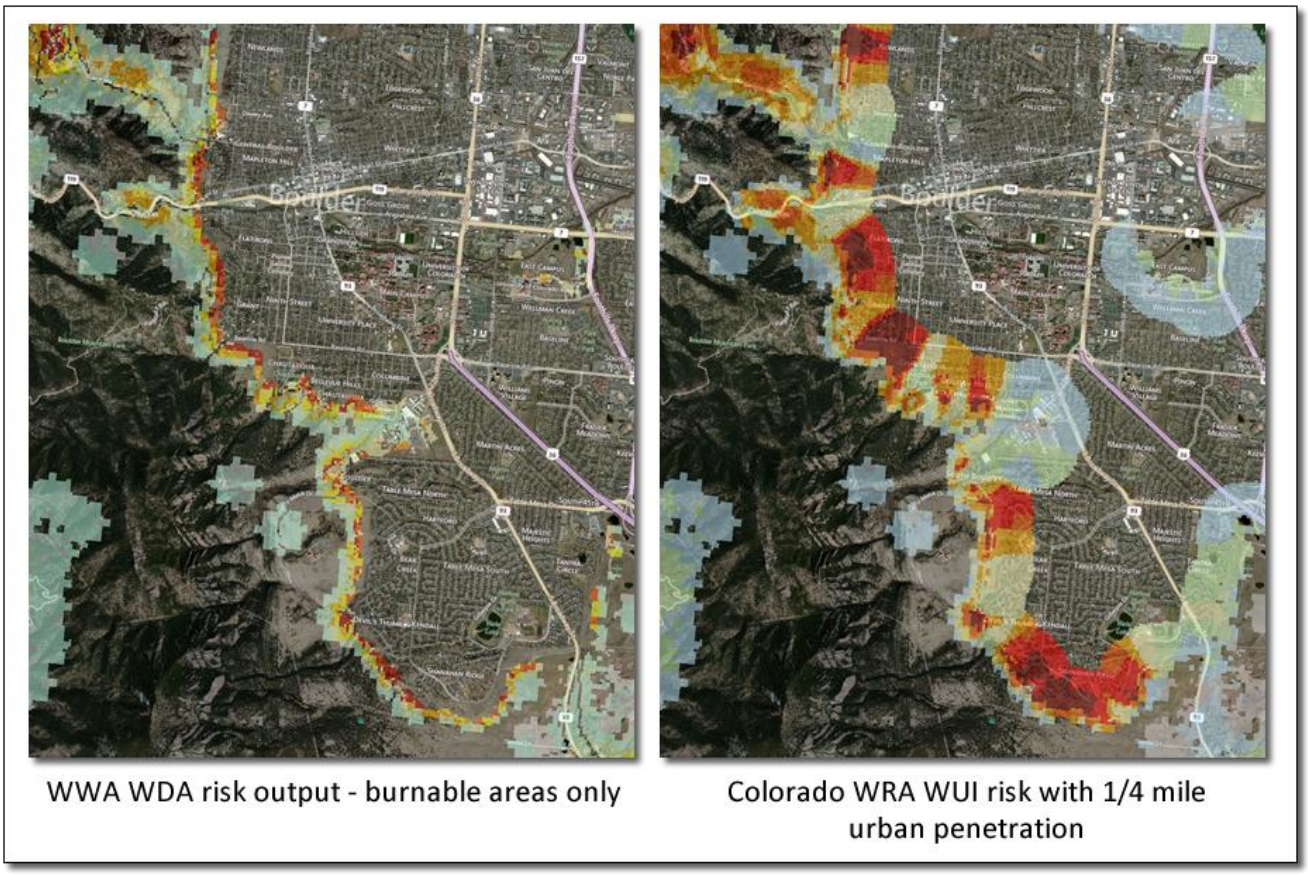
Figure 7. Comparison of WPL vs WDA vs WUI



Note that in the WWA project the WUI dataset is called Wildland Development Areas. For the Colorado WRA it was decided that the term Wildland Urban Interface was better understood by fire planners and the public. Both datasets represent housing density derived using the methods developed in the WWA project to create the source Where People Live (WPL) dataset. WPL is the source for both WWA WDA and Colorado WRA WUI. The Colorado WRA WUI dataset has been enhanced to incorporate urban penetration.

The urban penetration enhancement is focused on the development of the WUI dataset and accordingly results in an enhanced WUI Risk Index output. The following figure presents examples of the WWA WDA risk output (referred to as WDA Response Function Score), and the Colorado WRA WUI Risk Index output. Note that the Colorado WRA WUI Risk Index output incorporates urban penetration and includes urban fringe areas in the delineation of "at risk" areas.

Figure 8. Comparison of WWA WDA risk output and Colorado WRA WUI risk output with urban penetration



Fire Intensity Scale (FIS)

An additional risk index was developed to support public awareness and education. Building upon achievements from the State of Texas risk assessment, it was decided that the Fire Intensity Scale output would be developed in the Colorado WRA.

The Fire Intensity Scale (FIS) quantifies potential fire intensity based on high to extreme weather conditions, fuels, and topography. It is similar to the Richter scale for earthquakes, providing a standard scale to measure potential wildfire intensity by magnitude.

As an alternative way to deal with Byram's wide-ranging fireline intensity values, Joe Scott (2006) suggested using the common logarithm of fireline intensity (kW/m) as a standard scale of wildfire

intensity (called the Fire Intensity Scale, or FIS).[8] The common logarithm is also used in the Richter scale of earthquake magnitude; each unit increase on the Richter scale represents a ten-fold increase in the amplitude of ground shaking.

The same is true of the FIS. Each unit increase in FIS is a meaningful ten-fold increase in fireline intensity. FIS values range from just less than 1 (10 kW/m) to just over 5 (100,000 kW/m), suggesting a classification by orders of magnitude that lends itself to a multi-class dataset.

DTS (Fort Collins, CO) worked with Joe Scott (Pyrologix, Missoula, MT) to develop the FIS model and implement it for use in state risk assessments.[9] The FIS data is ideal for helping non-fire specialists easily understanding the potential risk around a specific location. Accordingly, FIS was developed for Colorado and encapsulated in the CO-WRAP Public Viewer web application to support the identification of risk for specific locations. A custom tool, called What's Your Risk?, was develop to help public users determine the risk for their homes (or businesses) based on FIS values.

To ensure that FIS provides a risk rating that not only considers the specific location defined by the user, but also incorporates risk for the surrounding area (0.5 mile), further modeling was undertaken to enhance the FIS output. A modified FIS output was generated that utilizes a *decay function* to calculate risk for any given location. A 0.5 mile buffer is used, with values closer to the user location weighted higher than those farther away. This results in a FIS value that considers the risk *around* any location, not just the value at the specific location.

The benefit of using FIS for the CO-WRAP Public Viewer *What's Your Risk?* tool is that it provides a description of the potential fire conditions that the user can understand, in units the user can understand. In addition, given the fire conditions associated with each FIS class, CSFS was able to accommodate a general description of prevention recommendations as guidance for the user. This provides the two basic bits of information the public needs: 1) a description of potential fire conditions, and 2) a description of prevention recommendations. We consider this a significant achievement (not included in the WWA) that provides much greater utility to the risk assessment outputs to support public awareness and education. Please review to Section 4 for a detailed description of how the Colorado WRA results have been made available through the CSFS CO-WRAP web application.

FIS consist of 5 classes where the order of magnitude between classes is ten-fold. The minimum class, Class 1, represents very low wildfire intensities and the maximum class, Class 6, represents extreme wildfire intensities. In Colorado, only classes 1 through 5 exist.

[8] Scott, Joe. November 2006. Off the Richter: Magnitude and Intensity Scales for Wildland Fire. A non-published white paper prepared for the AFE Fire Congress, November 2006, San Diego, CA

[9] Joe Scott is a leading wildland fire research scientist best known for his establishment of the 2005 FBPS Fuel Models (Scott & Burgan) and his research into fire behavior analysis for surface and canopy fuels, and related fuels modeling. Mr. Scott actively works with western forestry agencies to provide custom fuels analysis and fire behavior analysis to support values-at-risk assessment.

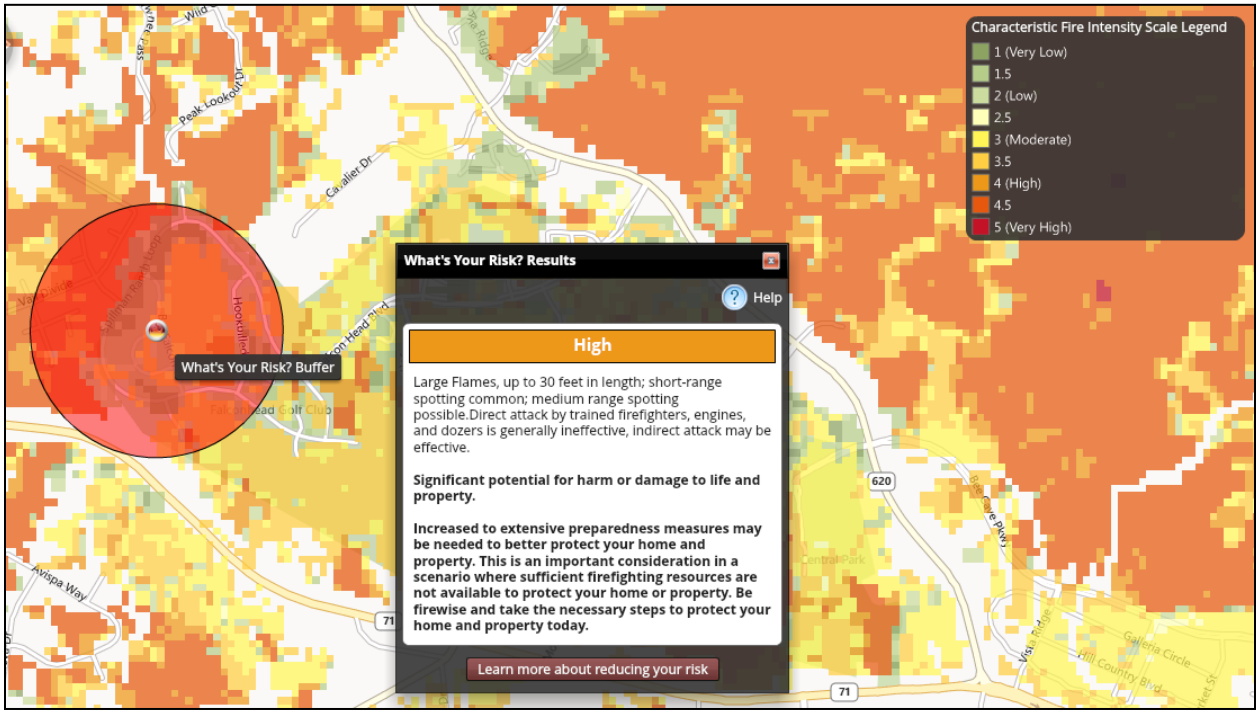
Figure 9. Fire Intensity Scale legend

Class 1 Lowest Intensity	Class 2 (Low)	Class 3 (Moderate)	Class 4 (High)	Class 5 (Very High)	Class 6 Extreme Intensity

FIS data is modeled at 30-meter resolution consistent with all other Colorado WRA outputs. Accordingly, while this is accurate enough to provide general ratings, it is not appropriate for site specific recommendations. For site specific advice, the user would press on the link in the Public Viewer *What's Your Risk?* tool to be directed to the CSFS web site where they can obtain information for contacting a local mitigation planner for help as they can incorporate local conditions not available in the risk assessment scale of data.

The following figure shows an example of FIS output, with the description of fire conditions and general preparedness recommendations, that are provided in the CO-WRAP Public Viewer application WYR tool.

Figure 10. CO-WRAP Example of FIS Data (What's Your Risk? tool)



A detailed description of the FIS classes is provided in the following table.

Table 4. Description of Fire Intensity Scale Classes

Fire Intensity Class	Fire Intensity Scale	I_B, kW/m	Description of fire behavior and potential effects	General Preparedness Recommendations
I	*FIS* < 1	$0 \le I_B < 10$	Very small, discontinuous flames, usually less than 1 foot in length; very slow spread rate; no spotting. Fires suppressible by lay-firefighters without specialized tools. Very little potential for harm or damage. Fires of this intensity occur on the flanks and rear of large fires, and near the beginning and end of burning periods. These fires are relatively rare due to their slow spread rate and easy control.	**Basic preparedness measures will better protect your home and property.** Be firewise and take the necessary steps to protect your home and property today.
II	$1 \le FIS < 2$	$10 \le I_B < 10^2$	Small flames, usually less than two feet long; small amount of very short range spotting possible. Fires easily suppressed by trained hand crews with protective equipment and firefighting tools. Little potential for harm or damage. This intensity class can occur at the head of a fire in a mild fire environment or on the flanks and rear of fires in more severe fire environments. This intensity class is very common, especially on fires not being actively suppressed.	**Increasing potential to cause harm or damage to life and property.** Increased preparedness measures may be needed to better protect your home and property. This is an important consideration in a scenario where sufficient firefighting resources are not available to protect your home or property. Be firewise and take the necessary steps to protect your home and property today.
III	$2 \le FIS < 3$	$10^2 \le I_B < 10^3$	Flames up to 8 feet in length; short-range spotting is possible. Hand crews will find these fires difficult to suppress without support from aircraft or engines, but dozers and plows are generally effective. Increasing potential to cause harm or damage. This intensity class occurs at	**Increasing potential to cause harm or damage to life and property.** Increased preparedness measures may be needed to better protect your home and property. This is an important consideration in

Fire Intensity Class	Fire Intensity Scale	I_B, kW/m	Description of fire behavior and potential effects	General Preparedness Recommendations
			the head and flanks of fires in moderate fire environments, or near the rear of fires in heavy fuel. This intensity class is common.	a scenario where sufficient firefighting resources are not available to protect your home or property. Be firewise and take the necessary steps to protect your home and property today.
IV	$3 \leq FIS < 4$	$10^3 \leq I_B < 10^4$	Large flames, up to 30 feet in length; short-range spotting common; medium-range spotting possible. Direct attack by hand crews and equipment is generally ineffective, indirect attack may be effective. Moderate potential for harm or damage. This intensity class is generally observed at the head of fires in moderate fire environments or near the head and flank of fires in moderate to severe fire environments. This intensity class is relatively common.	**Significant potential for harm or damage to life and property.** Increased to extensive preparedness measures may be needed to better protect your home and property. This is an important consideration in a scenario where sufficient firefighting resources are not available to protect your home or property. Be firewise and take the necessary steps to protect your home and property today.
V	$4 \leq FIS < 5$	$10^4 \leq I_B < 10^5$	Very large flames up to 150 feet in length; copious short-range spotting, frequent long-range spotting; strong fire-induced winds. Indirect attack marginally effective at the head. Great potential for harm or damage. This intensity class is usually observed near the head of fires in severe fire environments. Despite the high spread rate, this intensity class is relative infrequent due to the rarity of the fire environment and spread direction.	**Significant potential for harm or damage to life and property.** Increased to extensive preparedness measures may be needed to better protect your home and property. This is an important consideration in a scenario where sufficient firefighting resources are not available to protect your home or property. Be firewise and take the necessary steps to protect your home and property today.

Fire Intensity Class	Fire Intensity Scale	I_B, kW/m	Description of fire behavior and potential effects	General Preparedness Recommendations
VI	*FIS* ≥ 5	$I_B \geq 10^5$	Extraordinary flame size, greater than 150 feet in length; copious spotting; very strong fire-induced winds. Conditions supporting this behavior are rare and short-lived. All suppression efforts are ineffective. Great potential for harm or damage. This intensity class is usually observed near the head of fires in severe fire environments. Despite the high spread rate, this intensity class is relative infrequent due to the rarity of the fire environment and spread direction.	**Great potential for harm or damage to life and property.** Extensive preparedness measures may be needed to better protect your home and property.

3. Adjusting Response Function Assignments to Derive Wildfire Effects Outputs

A description of the use of Response Functions is provided below, followed by a description of the detailed calibration tasks that were undertaken in the Colorado WRA. Readers are encouraged to review the WWA Final Report for more detailed information on the risk assessment methods employed in the WWA and subsequently used in the Colorado WRA enhancements.

Overview of Response Function Approach

The primary underpinning of the Wildfire Effects model is based on the use of "response functions". Response Functions are a method of assigning a rating of net change to a resource value or asset based on susceptibility to fire intensity. These impacts can be negative or positive. For the WWA and Colorado Wildfire Effects model only adverse effects are being considered at this time, although the model has been designed to accommodate positive effects in the future if desired.[10]

Calculating risk at a given location requires spatially defined estimates of the likelihood and intensity of fire integrated with the identified *resource/asset value*. This interaction is quantified through the use of response functions that estimate expected benefits and losses to values/assets at the specified fire intensities. The measure of fire intensity used in the model is Flame Length. Specific classes of Flame Length have been defined that reflect key thresholds for damage from wildfire to the resource values.

For the CSFS model, response functions are defined for each category of the resource value inputs, for each given flame length category. Flame length categories were defined by the fire experts that reflect key thresholds for rating impacts. Positive response functions indicate a benefit or increase in value to the resource; negative response function values indicate a loss in resource value.

The CSFS model response function uses a value range of +9 to -9. This 1 to 9 range is typical for suitability modeling and provides a consistency with previous risk modeling methods. With this scale, a value of 0 represents no measureable impact; -1 the least negative impact, ramping to a -9 where the worst possible impact or loss occurs. An example *response function value matrix* for the WUI resource value is presented in the following figure.

This WUI example assumes that the higher the flame length the worse the impact on people and their homes. This could also be interpreted as the higher the value the more susceptible to wildfire. Areas with high population/structure density would result in more people/homes impacted while areas with low density would result in less people/homes impacted. The user defined response function value (-1 to -9) would only be applied to areas where the WUI and Flame Length overlap and both occur in the same area. Areas that do not have a Flame Length of WUI value are not assigned a RF value.

[10] More detailed descriptions of response functions and how they can be applied are described in USFS General Technical Report RMRS-GTR-235, Wildfire Risk and Hazard: Procedures for the First Approximation (March 2010), and more recently, Wildfire Threat to Key Resources on the Beaverhead-Deerlodge National Forest,, Joe Scott, Don Helmbrecht, USFS (December 24, 2010).

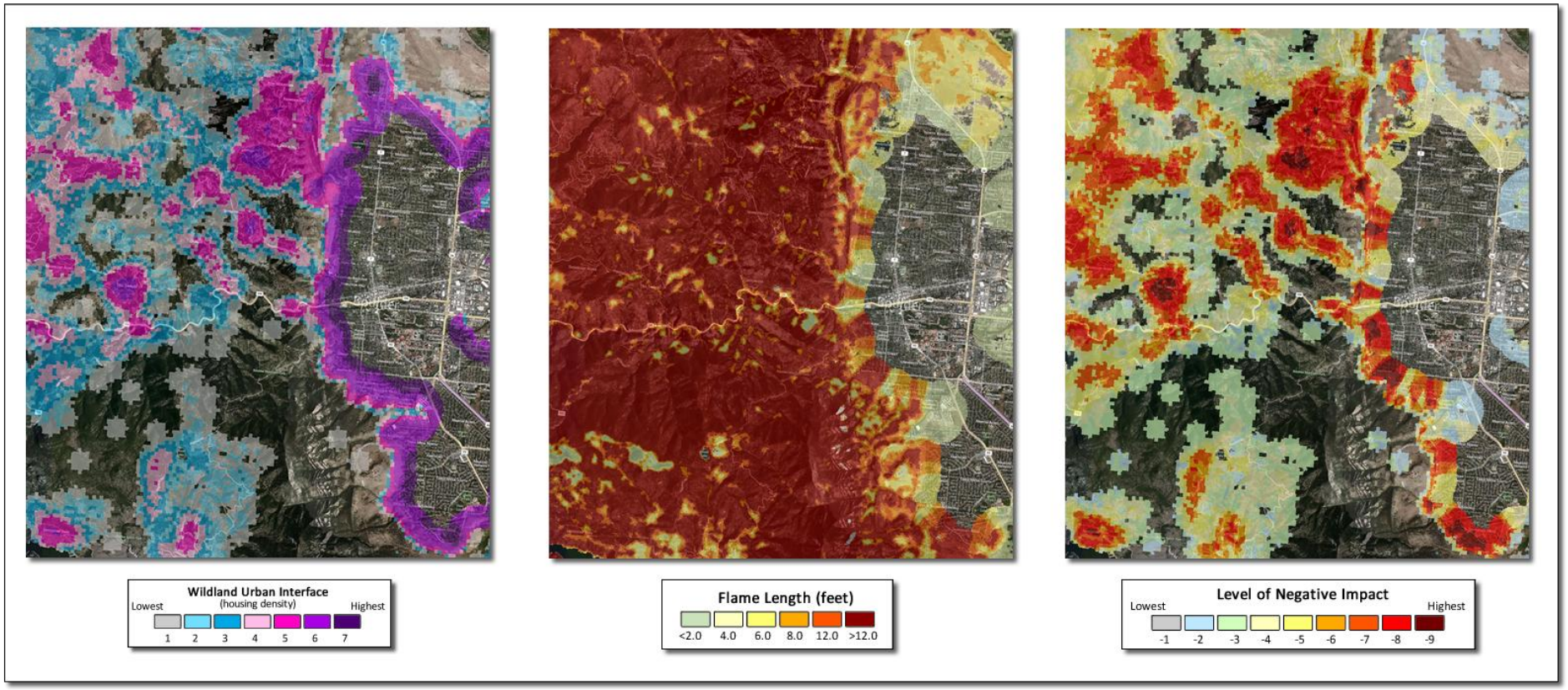
Table 5. Example RF Value Assignments - WUI

Flame Length	Wildland Urban Interface (housing density)						
	LT 1 house /40 ac	**1 house/ 40 - 20 ac**	**1 house/ 20 - 10 ac**	**1 house/ 10 - 5 ac**	**1 house/ 5 - 2 ac**	**1 - 3 houses/ac**	**GT 3 houses/ac**
0-2 ft	-0.5	-0.8	-1.0	-1.4	-1.7	-2.0	-2.0
2-4 ft	-1.0	-1.6	-2.0	-2.8	-3.4	-4.0	-4.0
4-6 ft	-1.25	-2.0	-2.5	-3.5	-4.25	-5.0	-5.0
6-8 ft	-1.75	-2.8	-3.5	-4.9	-5.95	-7.0	-7.0
8-12 ft	-2.0	-3.2	-4.0	-5.6	-6.8	-8.0	-9.0
12+ ft	-2.25	-3.6	-4.5	-6.3	-7.65	-9.0	-9.0

Using the response function matrices, GIS data of flame length and the resource value (WUI in the example above) can be combined to derive an output that reflects those areas where the least or most impact/susceptibility exists. The following figure presents an example response function value (RFV) output using the matrix shown above for WUI.

The map on the left shows the WUI areas presented as housing density. The map in the center is the Flame Length. The map on the right is the RF output that represents and overlay of the two inputs with the RF values in the table above applied to each cell.

Figure 11. Response Function example showing Wildland Urban Interface, Flame Length and WUI Risk Index output.



Response functions represent mathematical relationships between fire characteristics (intensity) and fire outcome. Although fire outcomes could be related to any fire characteristic, response is typically related to some measure of fire intensity, e.g., flame length (Ager and others 2007; Finney 2005). Accordingly, the Colorado Wildfire Effects model uses response functions that correspond to the following flame length classes:

- Low = 0 to 2 ft,
- Low to Moderate = greater than 2 to 4 ft,
- Moderate = greater than 4 to 6 ft,
- Moderate to High = greater than 6 to 8 ft,
- High = greater than 8 to 12 ft, and
- Very High = greater than 12 ft.

In detailed risk analyses conducted at smaller scales it is possible for outcomes to be expressed as absolute benefits and losses, such as people, structures or even dollars. However, such detail is not practical in this scale of statewide assessment. Rather than developing response functions that directly address absolute change in resource or asset value, the Colorado Wildfire Effects model relies on generalized, relative response functions that can be applied to any number of resources values or assets.

Percentile Weather Weights

Response function values are applied to each layer independently to create a RFV output for that layer (resource value). Calculations are first applied on a per weather percentile category (low, moderate, high and extreme) using the Flame Length for each weather category. These interim *weather bin* outputs are then combined to create the final *conditional RFV* output. This output reflects the response of the resource to wildfire assuming that a fire occurs and the Flame Length conditions are met.

A constant weighting that reflects the *percent acres burned in each weather category* is applied to derive a weighted RFV output across the four percentile weather classes for each resource/asset. Using constant weights provides flexibility for production and future modification if desired. The following table shows the default constant weightings used for the RFV calculations.

Table 6. Constant weightings used for RFV calculations

Percentile Weather Category	Weighting
Low	**.01**
Moderate	**.09**
High	**.20**
Extreme	**.70**

Colorado Response Function Assignments

In the WWA project each state provided Response Function value assignments for each Wildfire Effects layer. This included:

- RF values for the five input layers for the WWA Values Impacted Rating
- RF values for the Suppression Difficulty Rating
- weights for combining the five input layers and calculating the WWA Values Impacted Rating output
- weights for combining the WWA Values Impacted Rating and Suppression Difficulty Rating to create the WWA Fire Effects Index

Response functions are a method of assigning a net change in the value to a *resource* or *asset* based on susceptibility to fire at different intensity levels, such as flame length. This modeling approach was used in the WWA project to calculate the potential impacts (or risk) for each Wildfire Effects layer. This approach was also retained for the Colorado WRA.

For the Colorado WRA, Response Function outputs were derived for each input data set and then combined to derive the Values At Risk Rating. This output is referred to as the Values Impacted Rating in the WWA project. In the WWA project five (5) input layers were used. For the Colorado WRA, it was decided that only four (4) input layers would be used. The Infrastructure layer was not included. This was eliminated based on a review of WWA outputs where the Infrastructure layer provided undesirable results for Colorado. It was felt that these assets are better addressed by using other methods to evaluate the wildfire risk.

Additionally, in the WWA, RF outputs were not calculated for each state using the state supplied RF values. Instead, average RF values were derived for the entire West by combining all the RF values provided by the individual states. Outputs were then generated using the *west wide average RF values*. The specific method used to create the west wide average are described in the WWA Final Report.

Accordingly, the individual states, like Colorado, weren't able to visualize the output of their RF value assignments, and no review or refinement of these RF values occurred. For the Colorado WRA, it was decided that CO RF value assignments should be used (instead of the WWA regional averages) to create the RF outputs. In addition, some sensitivity analysis should be conducted with the RF values to refine the values until a final acceptable set of RF value assignments were defined.

With this approach, new RF value assignments were defined for the following Wildfire Effects input layers:

- Wildland Urban Interface
- Drinking Water Importance Areas
- Forest Assets
- Riparian Assets

Appendix B presents the revised RF value assignments used in the Colorado WRA project.

Values At Risk Rating Weights

Once all RF outputs are generated for the four Colorado layers, they were combined using a weighted average to derive the Values At Risk Rating. Since the Infrastructure layer was not utilized these weights were adjusted. The following tables presents the adjusted weights used for the Values At Risk Rating (VAR). The following description applies to the table:

- The "WWA CO Weights" column are the weights provided by CO for the WWA project
- The "WWA Average" are the weights used in the WWA project to calculate the VIR output. This represents a west wide average of weights provided by the individual states.
- The "Adjusted CO Weights" are the new weights used in the development of the Colorado WRA VAR output.

Table 7. Colorado adjusted Values At Risk Rating weights

Values Impacted Rating Weights			
VAR/VIR Input Layer	**WWA CO Weights**	**WWA Average**	**Adjusted CO Weights**
WUI	22.1%	44.7%	**36.4%**
Drinking Water	29.4%	1.0%	**36.4%**
Forest Assets	14.7%	3.6%	**18.2%**
Riparian Assets	7.4%	4.5%	**9.1%**
Infrastructure	26.5%	46.2%	**NA**

Wildfire Effects Weights

Once the VAR output is derived it was combined with the Suppression Difficulty Rating using a weighted average to derive the Fire Effects Index. The following table presents the adjusted weights used for the Fire Effects Index (FEI). The following descriptions apply to the table:

- The "WWA CO Weights" column are the weights provided by CO for the WWA project
- The "WWA Average" are the weights used in the WWA project to calculate the FEI output. This represents a west wide average of weights provided by the individual states.
- The "Adjusted CO Weights" are the new weights used in the development of the Colorado WRA FEI output.

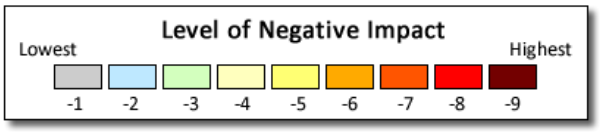
Table 8. Colorado adjusted FEI weights

Wildfire Effects Index Weights			
VIR Input Layer	**WWA CO Weights**	**WWA Average**	**Adjusted CO Weights**
Values Impacted Rating	60.0%	90.0%	**80.0%**
Suppression Difficulty Rating	40.0%	10.0%	**20.0%**

4. Adjusting Class Breaks for Wildfire Effects Outputs

The WWA project utilized *cumulative percentile area* class breaks for all Wildfire Effects outputs. While this provided a consistency with the other WWA risk outputs (i.e. Fire Threat Index, Fire Risk Index), it does make it difficult for the user to *relate* the Wildfire Effects outputs back to the input datasets - namely the input VAR classes and Flame Length class. It was decided that for the Colorado WRA, class breaks would use the standard RF output classes from -1 to -9. With this approach the output classes would adhere to the RF value assignments defined by the Colorado State Forest Service and provide for easier interpretation by the users of the Colorado WRA. Accordingly, the following class breaks and symbology was used for all Wildfire Effects outputs.

Figure 12. Colorado WRA Wildfire Effects legend



These class breaks and color symbology is used for the following outputs:

- WUI Risk Index
- Drinking Water Risk Index
- Forest Assets Risk Index
- Riparian Assets Risk Index
- Values-At-Risk Rating
- Suppression Difficulty Rating
- Fire Effects Index

5. Adjusting Class Breaks for Primary Risk Outputs

The WWA was a regional assessment that utilized the outputs for the entire west to determine class breaks for maps and statistics. Several output data layers, specifically the Fire Risk Index, Fire Threat Index, and Fire Occurrence Area, are comprised of continuous floating point data values. To properly view the data it must be classified into categories to be shown thematically (i.e. from low to high). Multiple different approaches exist to determine class breaks.

The WWA project utilized a standard approach that determined class breaks based on the cumulative percentile values of total area for each class. Nine categories were chosen. Data values for the entire west (all 17 western states) were used as inputs to determine the class breaks. This approach was used for all outputs in the WWA. The following table presents the percentile class breaks defined for the WWA.

Table 9. Cumulative percentiles used for class breaks in the WWA

Category	% Range	Cumulative % of Area	Categorical % of Area
1	0 – 32.9%	32.9%	**32.9%**
2	33.0 - 63.5%	63.5%	**30.5%**
3	63.5 -70.0%	70.0%	**6.5%**
4	70.0 - 77.5%	77.5%	**7.5%**
5	77.5 - 85.5%	85.5%	**8.0%**
6	85.5 - 92.5%	92.5%	**7.0%**
7	92.5 - 96.5%	96.5%	**4.0%**
8	96.5 - 98.5%	98.5%	**2.0%**
9	98.5 - 100.0%	100.0%	**1.5%**

The percent values are based on totaling the area of the raster data. The data is represented as 30m x 30m cells. Accordingly, the cumulative percentiles reflect total area, and as such can be interpreted as acres (i.e. Category 9 reflects the 1.5% of acres with the highest values).

By design, the categories were developed to display the highest rated 14.5% of the cells (area) in categories 6 through 9. The highest rated 22.5% of the cells are in categories 5-9. Notice this places the highest rated cells (areas) into just about half of the categories (5-9) which allows the user to truly locate and distinguish the differences within these highly rated cells (areas).

The class breaks have been defined based on the distribution of data for the 17 western states for each layer. In this regard, the categorical % represents the percentage of area across the entire west, i.e. Category 9 reflects the top 1.5% of area in the entire West.

This approach provides for map classes that are ordinated across the entire west, and it inherently allows for comparison of areas across the entire West. This is ideal for regional planning. However, it does not best reflect the conditions within an individual state, nor facilitate true comparisons only within a state. In Colorado, it was decided that the risk assessment results would have greater utility for Colorado planners if the data was ordinated using only Colorado data. In this regard outputs would reflect conditions only within Colorado (i.e. Category 9 would reflect the top 1.5% of area within Colorado, not the entire West).

It was decided that the percentile class breaks would be retained as defined in the WWA. Nine categories were used and calculated using the same percentiles breaks. This was undertaken for the following outputs datasets:

- Fire Occurrence Areas (FOA)
- Fire Threat Index (Wildfire Threat)
- Fire Risk Index (Wildfire Risk)

While the WWA project also used the cumulative percentile approach for other layers, such as the Wildfire Effects outputs, it was decided that Colorado preferred to use discrete Response Function

categories instead for those outputs. Please refer to the section Adjusting Class Breaks for Wildfire Effects Outputs for a description of the Colorado approach.

The following tables presents the final cumulative percentile class breaks derived for the Colorado outputs for Fire Occurrence, Wildfire Threat and Wildfire Risk.

Table 10. Fire Occurrence class breaks (using Colorado data)

Fire Occurrence Classes					
Category	**Cumulative%**	**CO Min Value**	**CO Max Value**	**WWA Min**	**WWA Max**
1	32.9%	0	0.022486	0	0.018736
2	63.5%	0.022486	0.065905	0.018737	0.022485
3	70.0%	0.065905	0.081638	0.022486	0.029771
4	77.5%	0.081638	0.098884	0.029772	0.047850
5	85.5%	0.098884	0.130968	0.047851	0.086730
6	92.5%	0.130968	0.191981	0.086731	0.158430
7	96.5%	0.191981	0.309597	0.158431	0.290943
8	98.5%	0.309597	0.422359	0.290943	0.505909
9	100.0%		>0.422359	> 0.505909	

Table 11. Wildfire Threat class breaks (using Colorado data)

Wildfire Threat Classes					
Category	**Cumulative%**	**CO Min Value**	**CO Max Value**	**WWA Min**	**WWA Max**
1	32.9%	0	0.000857	0.000001	0.000593
2	63.5%	0.000857	0.002058	0.000594	0.002120
3	70.0%	0.002058	0.002135	0.002121	0.002827
4	77.5%	0.002135	0.002237	0.002828	0.004577
5	85.5%	0.002237	0.002797	0.004578	0.008443
6	92.5%	0.002797	0.005247	0.008444	0.017200
7	96.5%	0.005247	0.009901	0.017201	0.034760
8	98.5%	0.009901	0.01885	0.034761	0.065895
9	100.0%		>0.01885	0.065895	1.000000

Table 12. Wildfire Risk class breaks (using Colorado data)

Wildfire Risk Classes					
Category	**Cumulative%**	**CO Min Value**	**CO Max Value**	**WWA Min**	**WWA Max**
1	32.9%		> -8.38		> -1.56
2	63.5%	-8.38	-15.97	-1.57	6.08
3	70.0%	-15.97	-20.75	-6.09	9.15
4	77.5%	-20.75	-29.42	-9.16	16.91
5	85.5%	-29.42	-47.74	-16.92	36.44
6	92.5%	-47.74	-91.83	-36.45	81.66
7	96.5%	-91.83	-177.85	-81.67	173.05
8	98.5%	-177.85	-332.68	-173.06	350.10
9	100.0%		< -332.68		< -350.11

3.0 Assessment Results and Findings

This section provides a description of the assessment results and findings.

3.1 Project Deliverables

The Colorado WRA project involved the following key deliverables:

1. Statewide Colorado wildfire risk assessment GIS datasets
2. Calibration of WWA data to reflect Colorado conditions, requirements and priorities
3. Final report that documents the data, methods and outputs for the assessment (this document)
4. Development, implementation and hosting of the Colorado Wildfire Risk Assessment Portal (CO-WRAP) web application. This includes loading of the Colorado WRA datasets and customization to support Colorado risk reporting requirements.
5. CSFS user training and documentation for CO-WRAP
6. On-site presentation of project report and results
7. Hosting of CO-WRAP for a predefined period.

3.2 Risk Outputs

Maps are presented for the following key Colorado WRA outputs:

- **Wildfire Risk**
- **Wildfire Threat**
- **Values At Risk Rating**
- **Wildland Urban Interface**

- **WUI Risk Index**
- **Drinking Water Risk Index**

Urban areas are represented in dark grey areas on the maps. County boundaries are also shown.

Figure 13. Colorado Wildfire Risk

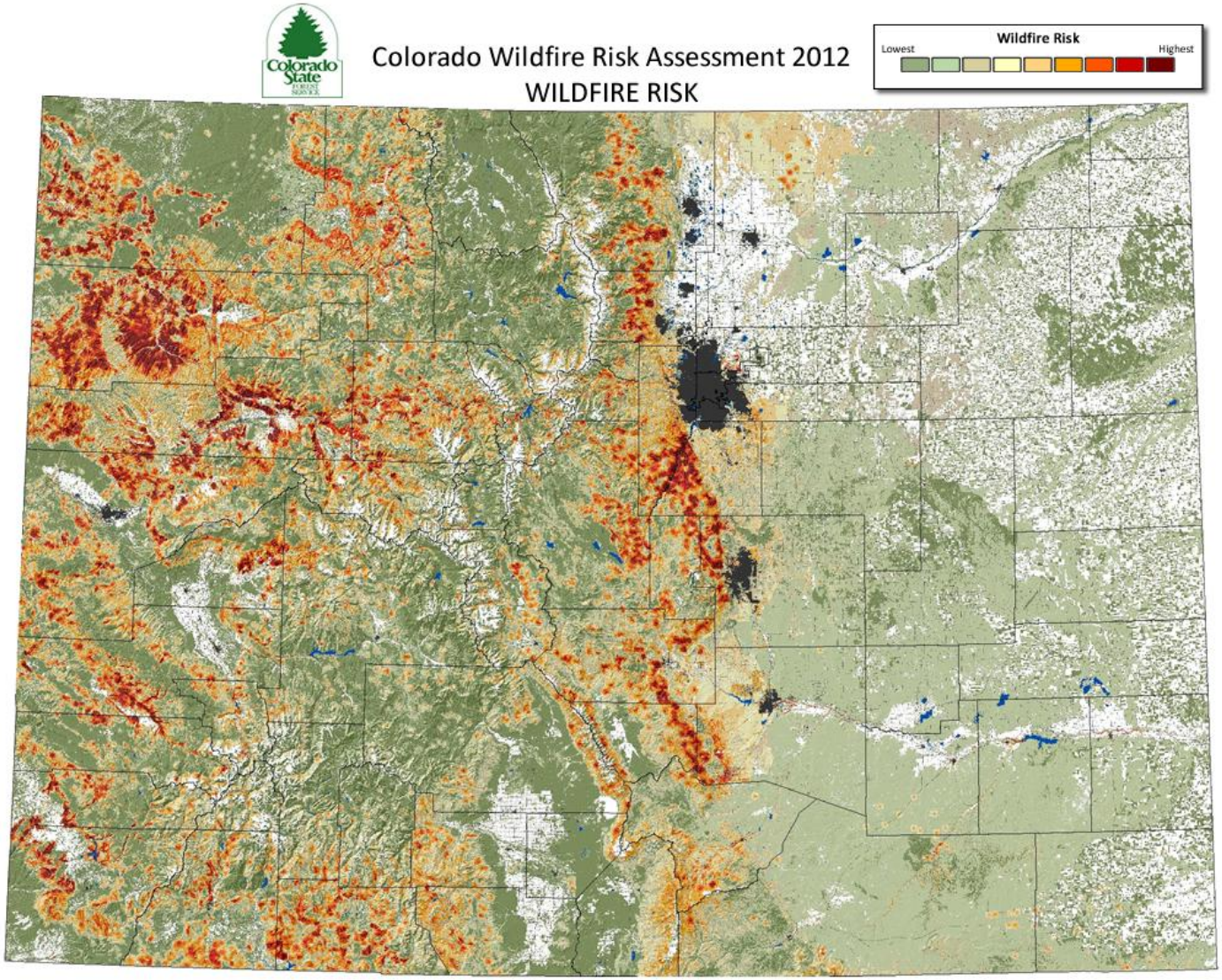


Figure 14. Colorado Wildfire Threat

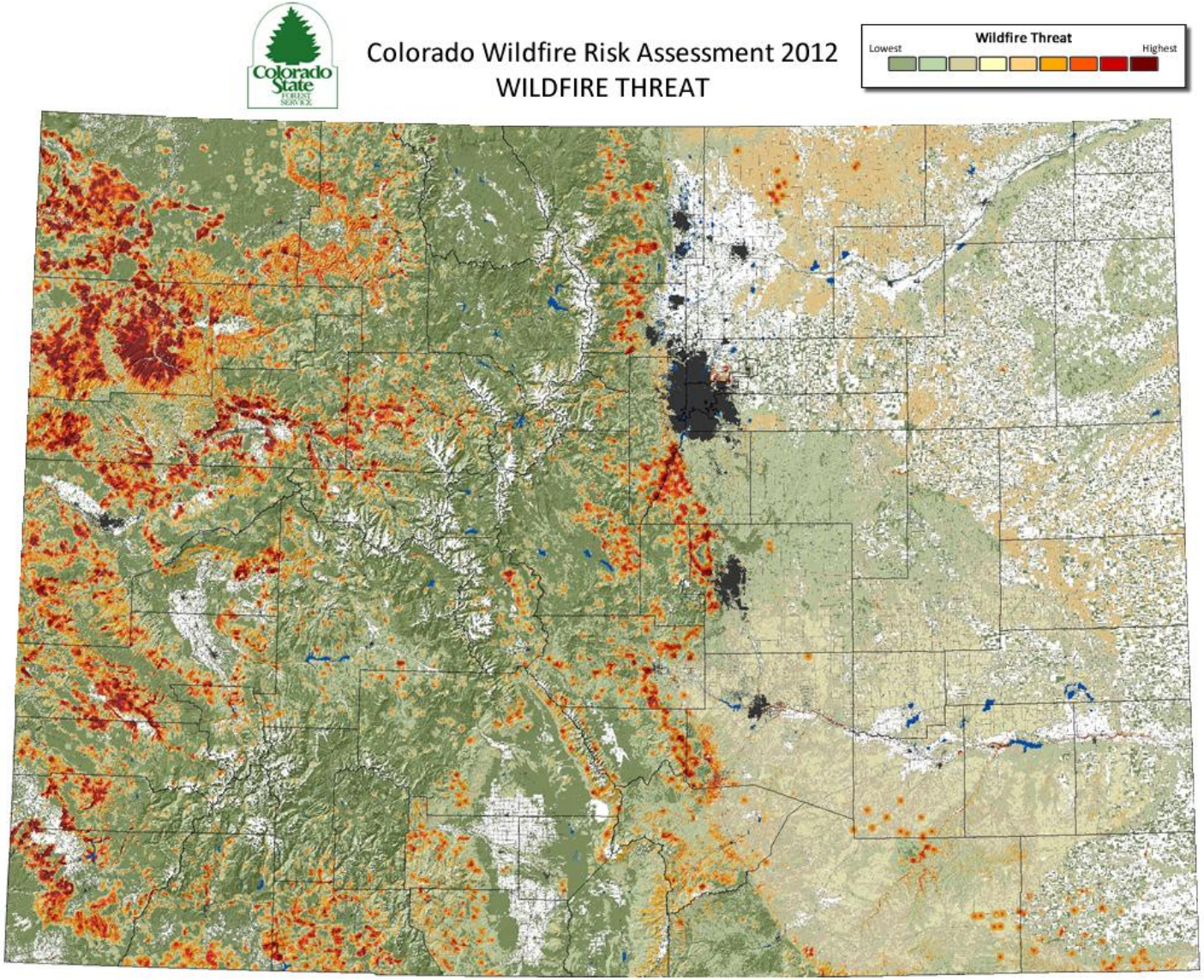


Figure 15. Colorado Values-at-Risk Ratings

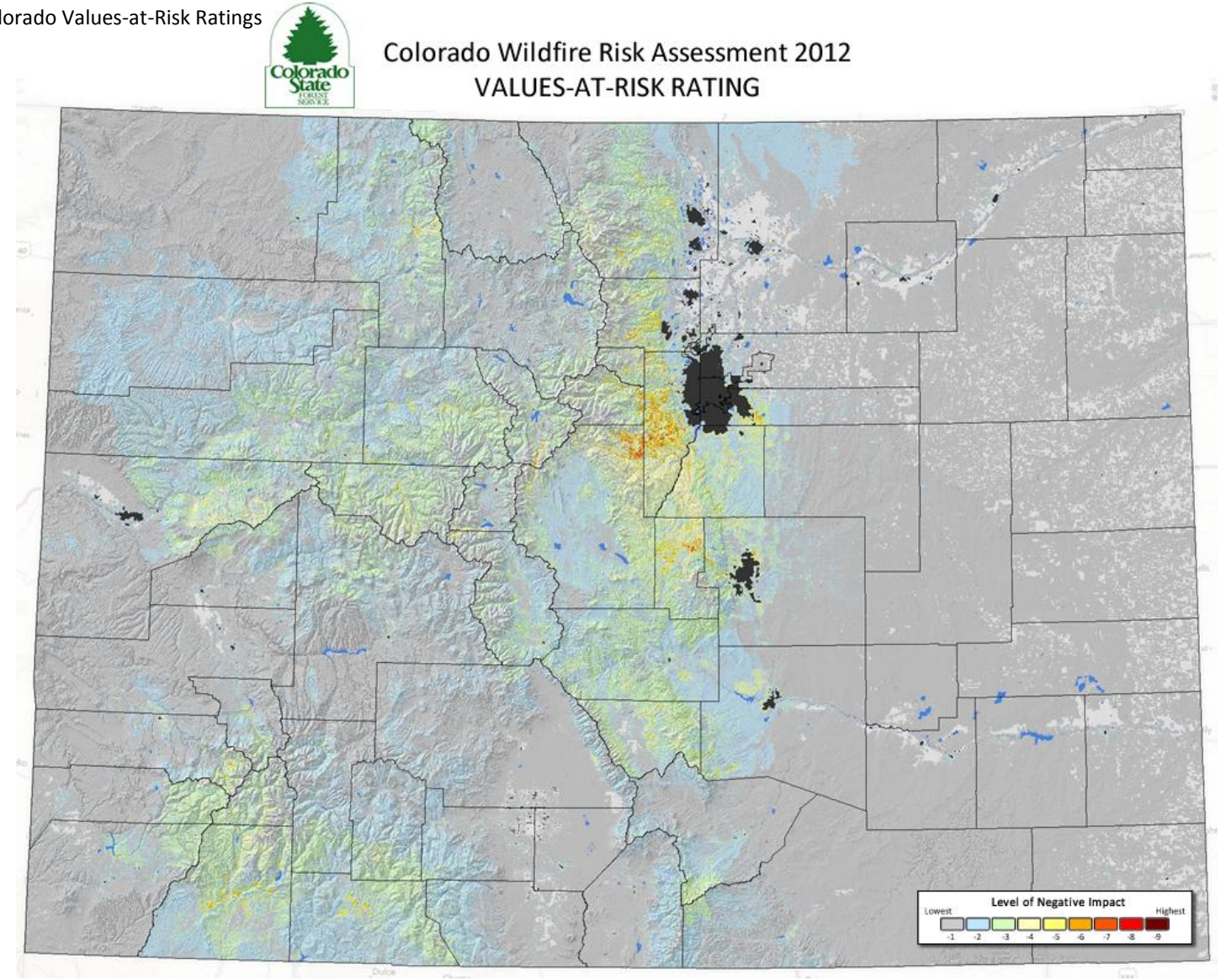


Figure 16. Colorado Wildland Urban Interface

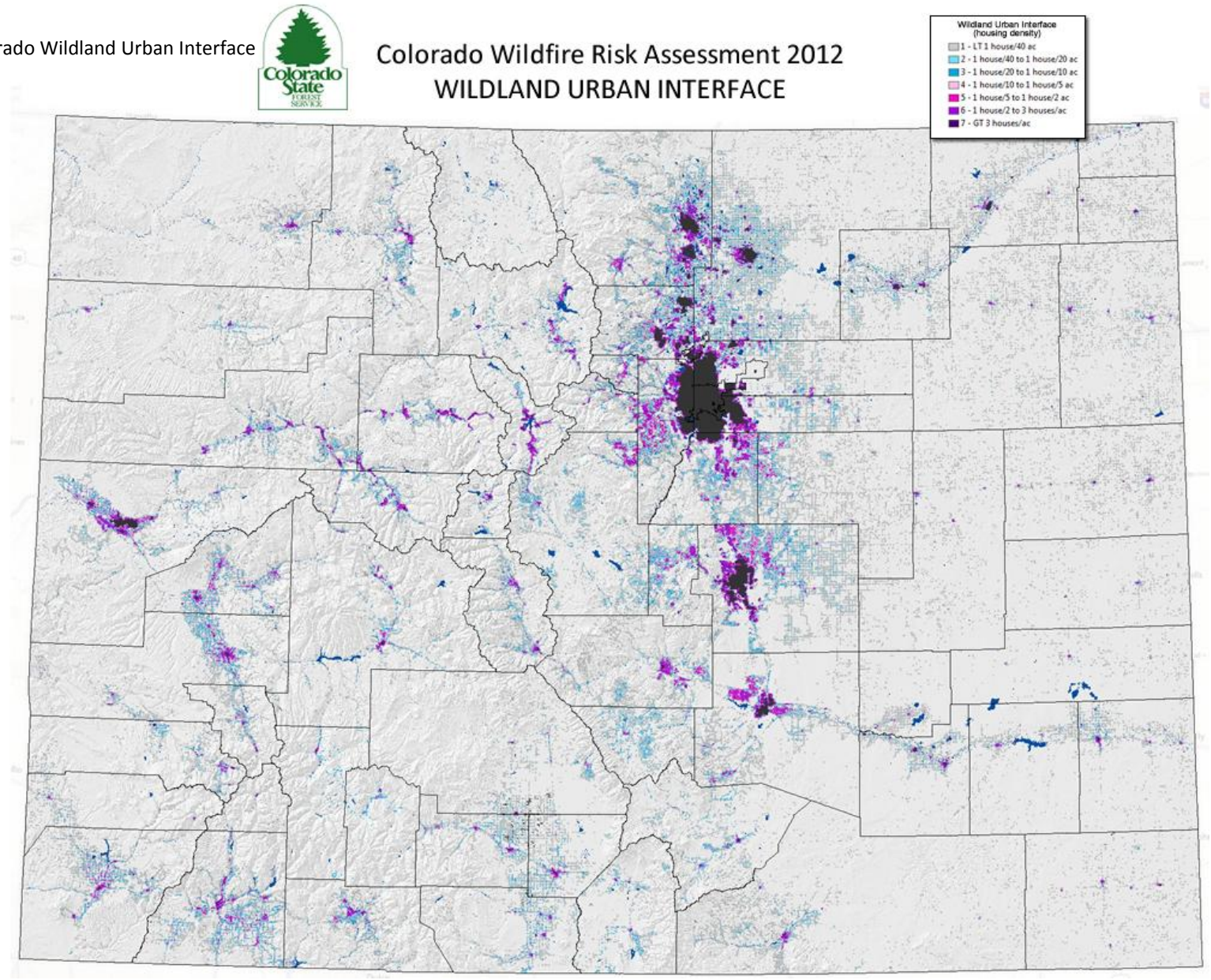


Figure 17. Colorado WUI Risk Index

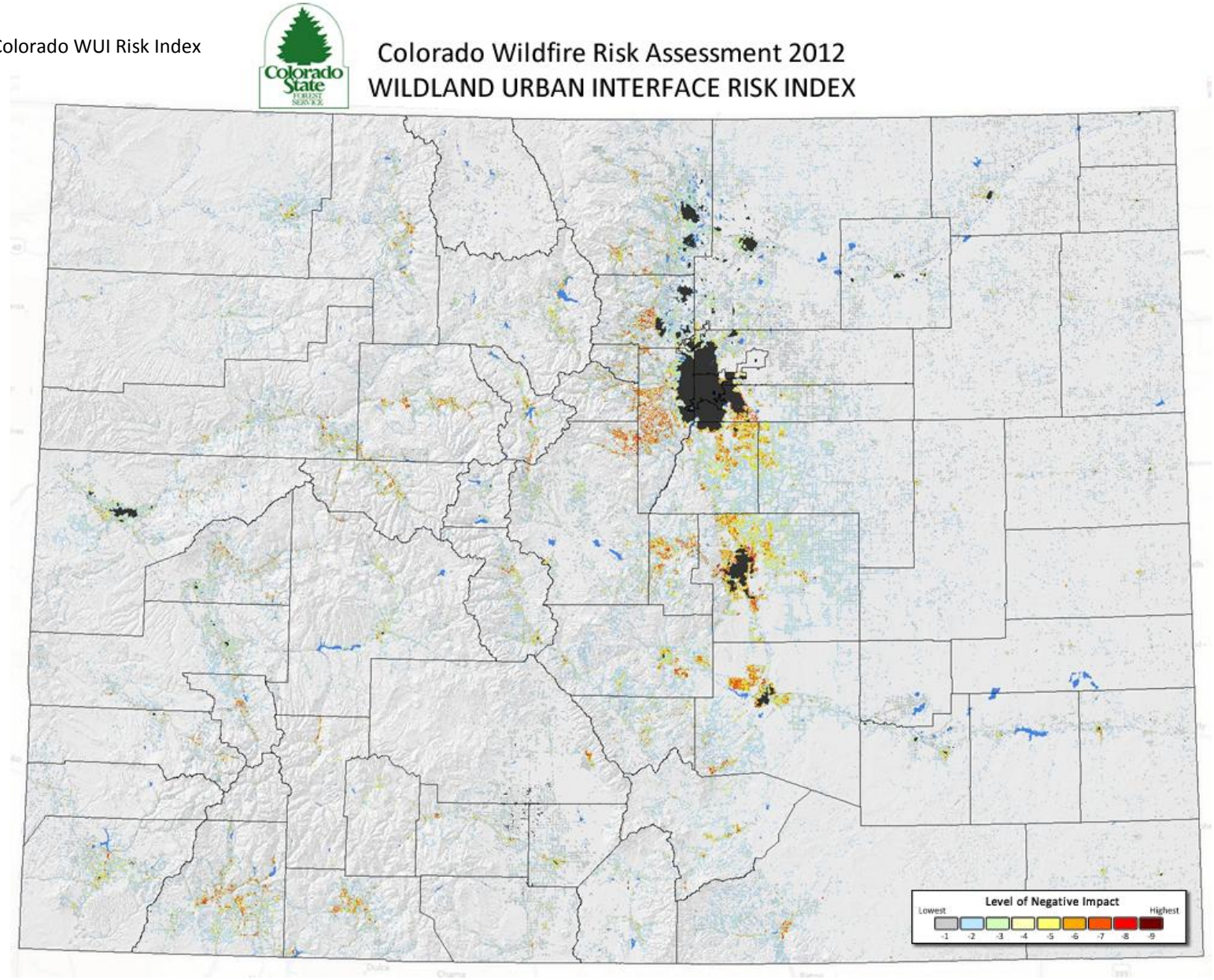
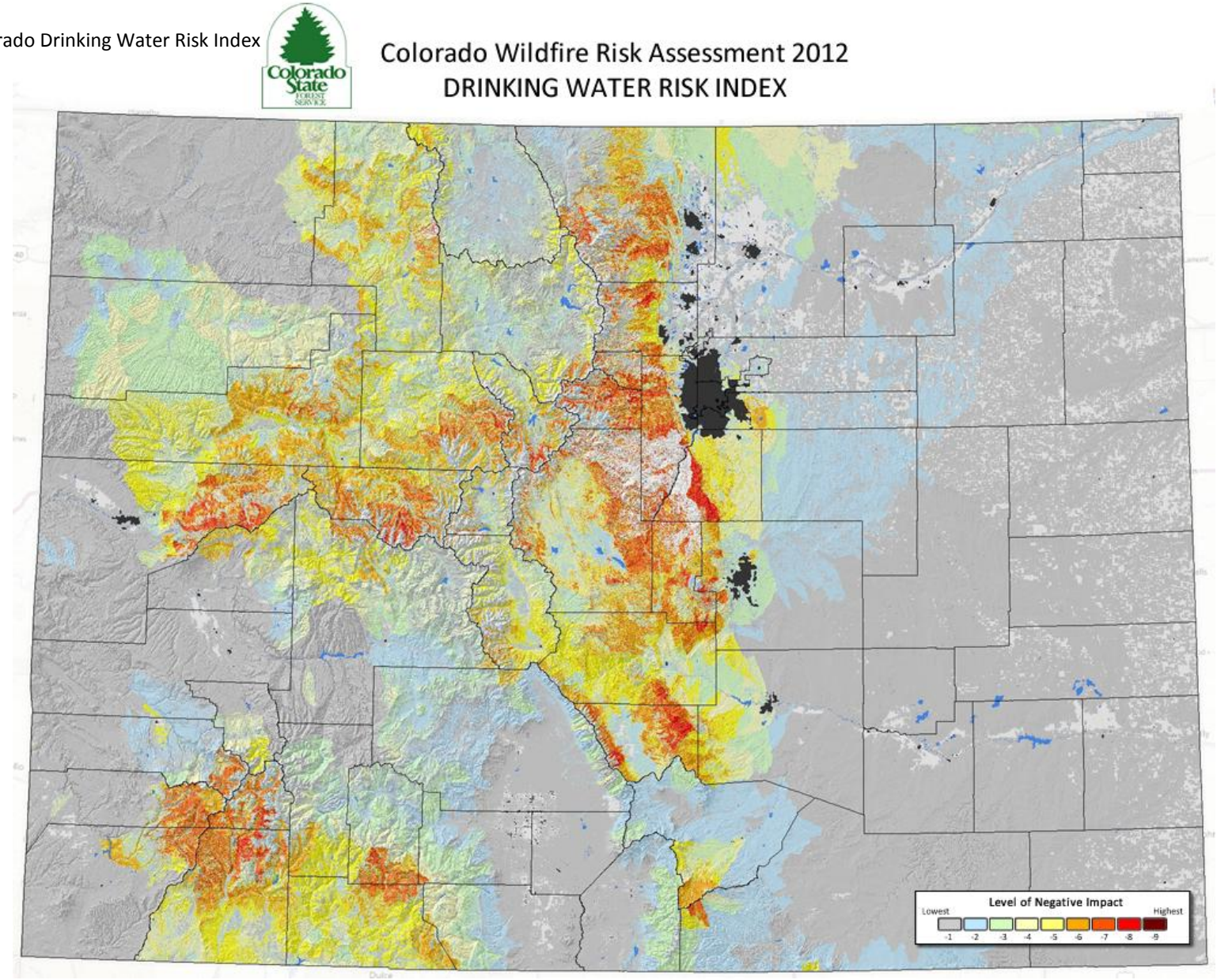


Figure 18. Colorado Drinking Water Risk Index



3.3 Summary Statistics

Summary statistics were derived for the Colorado WRA. These statistics provide a summary of the current wildfire risk situation in Colorado. A separate summary statistics report is available that shows the following statistics:

- **Wildfire Risk**: Total Acres, Percent Acres, and Population by Risk Class
- **Wildfire Threat**: Total Acres & Percent Acres
- **Wildfire Effects**: Total Acres & Percent Acres
- **Values At Risk Rating**: Total Acres & Percent Acres
- **Wildland Urban Interface**: Total Acres & Population by WUI Class
- **WUI Risk Index**: Population by WUI Risk Class
- **Surface Fuels**: Total Acres
- **Number of Fires**: State & Federal Reported VS NFIRS
- **Acres Burned**: State & Federal Reported Fires

In addition to statewide outputs, a summary of key risk outputs per county were also calculated. This includes:

- **Wildfire Risk:** Acres by County
- **Wildfire Threat:** Acres by County
- **Values At Risk:** Acres by County
- **WUI:** Acres by County
- **WUI Risk Index:** Acres by County

A few key summary statistics outputs are provided in this report as reference. However, we encourage readers to review the Colorado Wildfire Risk Assessment Summary Statistics Report for more detailed information.

Figure 19. Colorado Wildfire Risk - Total Acres by Risk Class (5 classes)

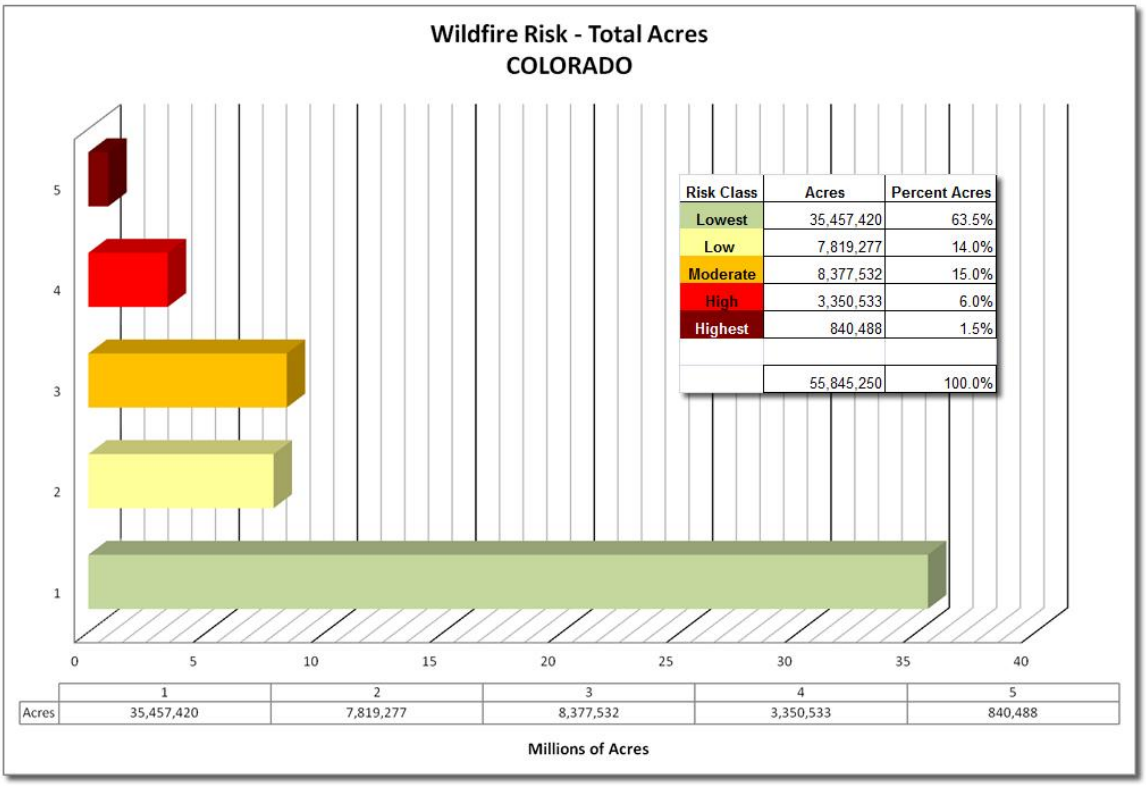


Figure 20. Colorado Wildfire Risk - Total Population by Risk Class (5 classes)

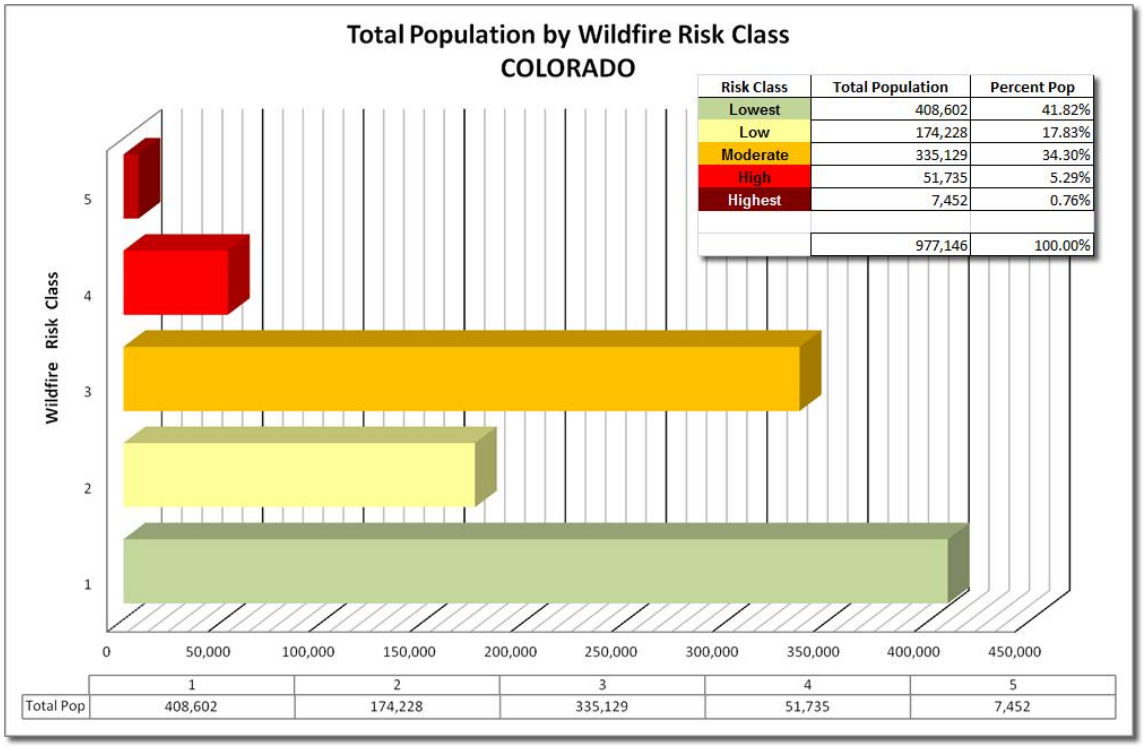
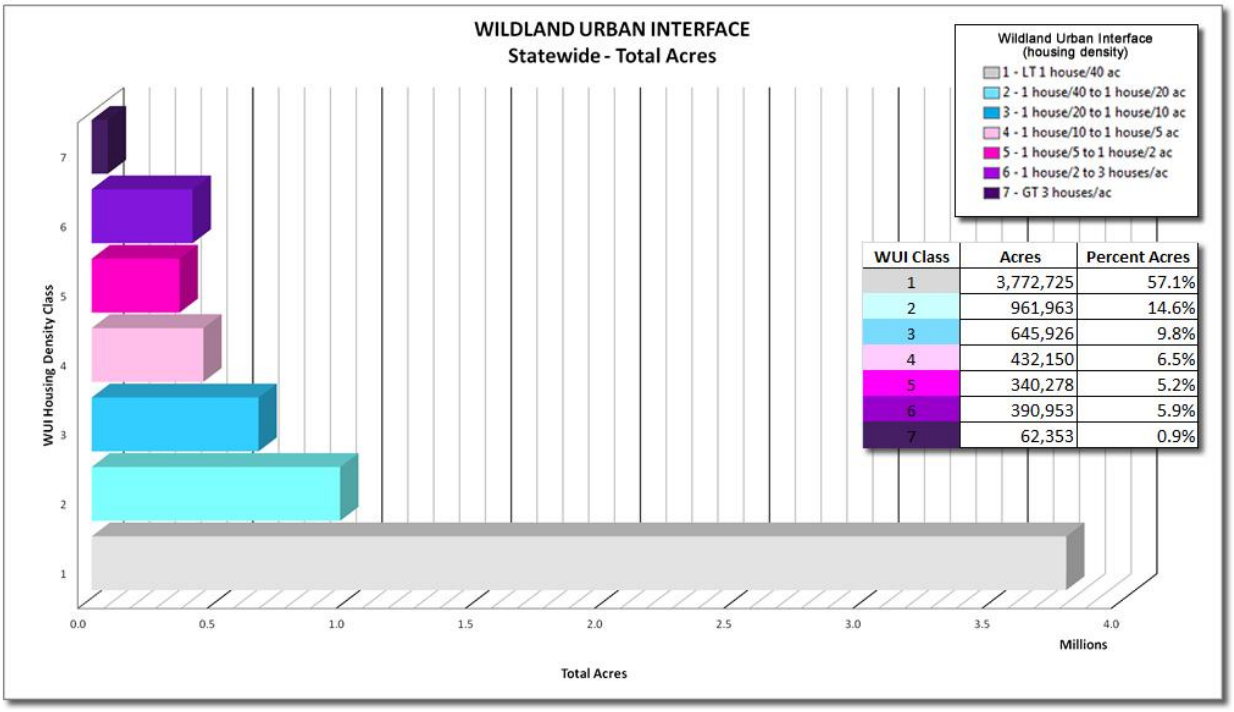
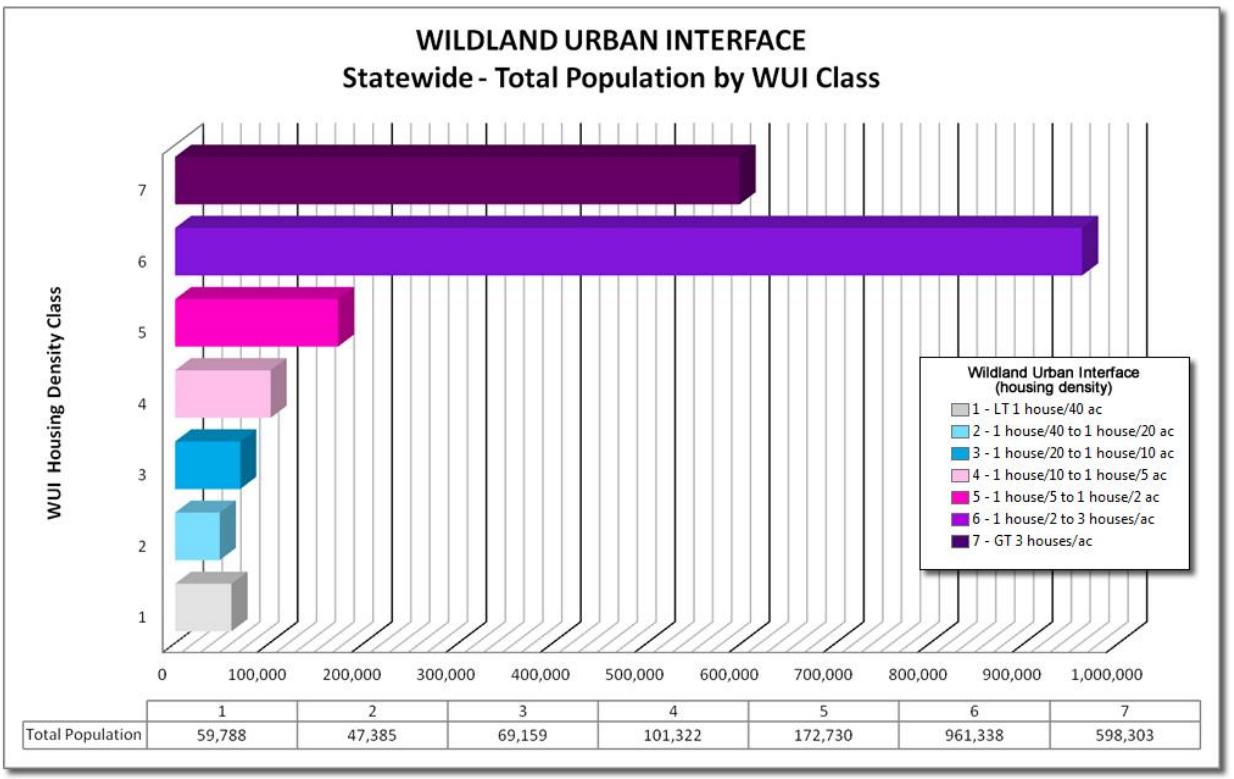


Figure 21. Colorado WUI - Total Acres



WUI Class	Acres	Percent Acres
1	3,772,725	57.1%
2	961,963	14.6%
3	645,926	9.8%
4	432,150	6.5%
5	340,278	5.2%
6	390,953	5.9%
7	62,353	0.9%

Figure 22. Colorado WUI - Total Population by WUI Class



	1	2	3	4	5	6	7
Total Population	59,788	47,385	69,159	101,322	172,730	961,338	598,303

Figure 23. Colorado WUI Risk Index - Total Acres

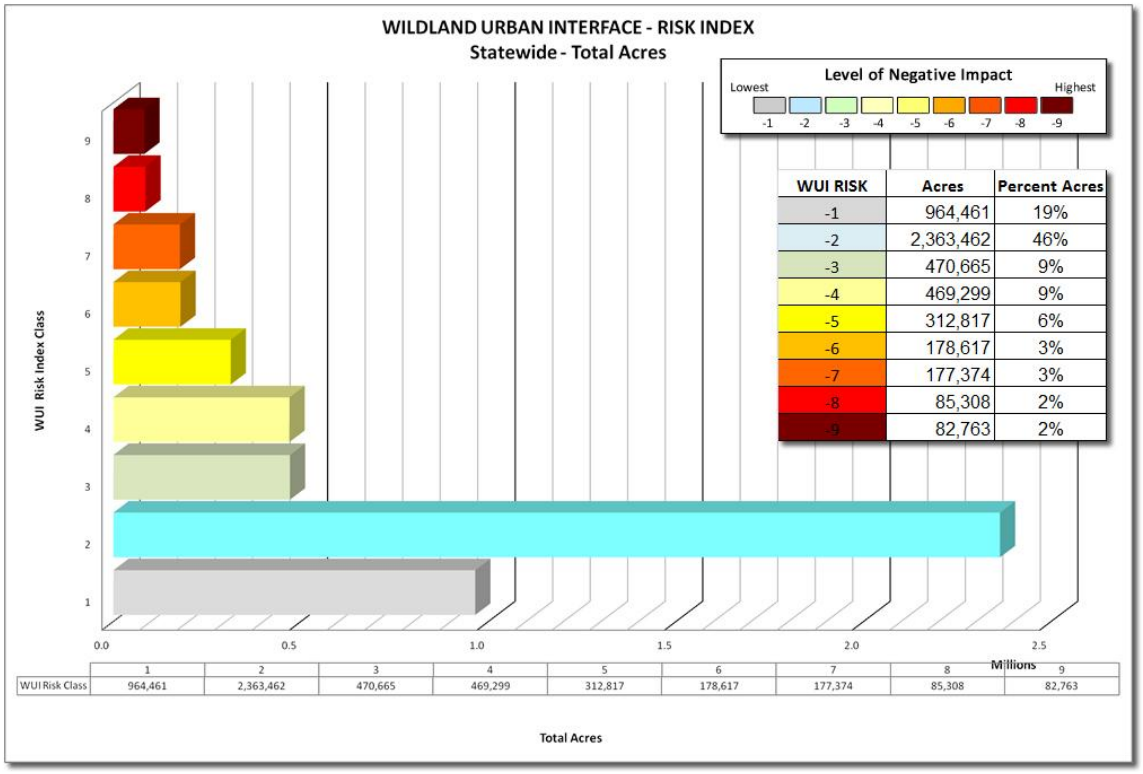
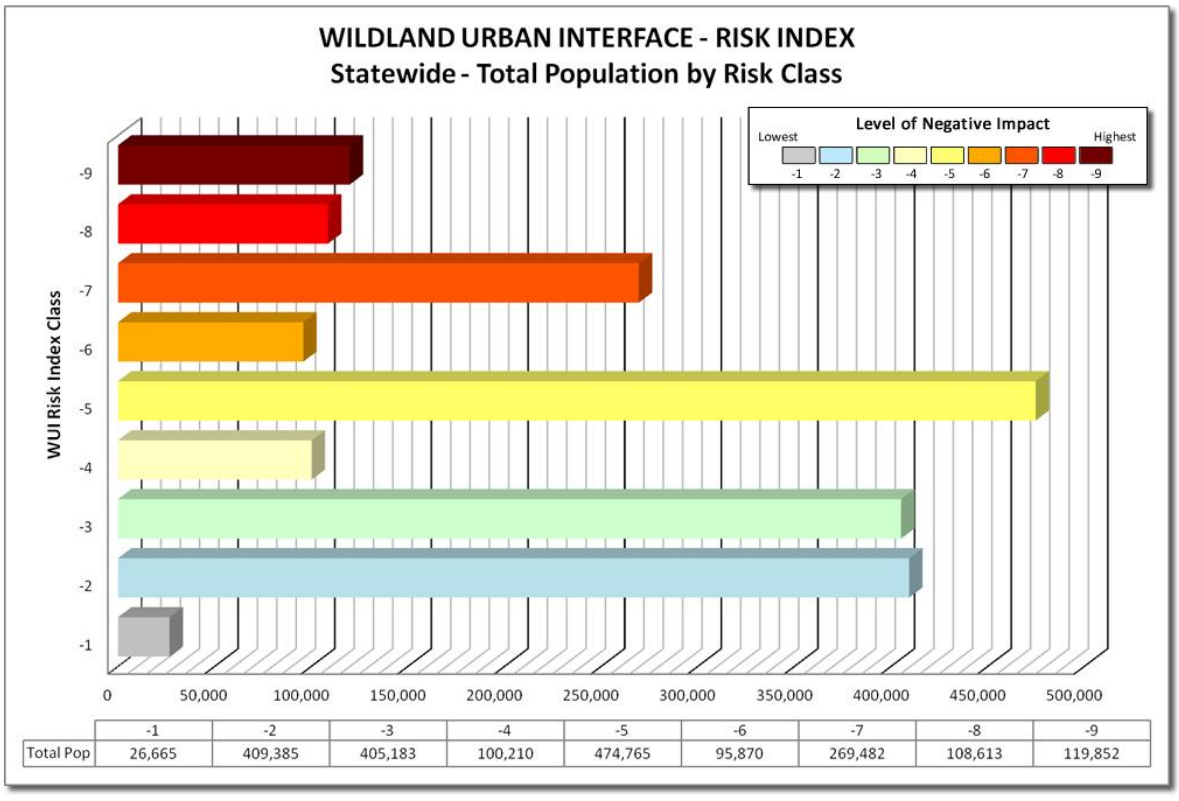


Figure 24. Colorado WUI Risk Index - Total Population by Risk Class



3.4 Future Enhancements

The processing of the WWA results to create the Colorado WRA results identified opportunities for future enhancement in addition to the improvements completed. These opportunities for further enhancement relate to the development of some additional output datasets that may further aid mitigation and prevention specialists with wildland fire planning. They include:

- Community Protection Zones
- Communities-at-Risk
- Fire Adapted Communities
- Values-At-Risk Modeling Tool
- Mobile CO-WRAP Version

Community Protection Zones

Community Protection Zones (CPZ) represent those areas considered highest priority for mitigation planning activities. CPZs are a planning dataset utilized by CSFS in the recent State Forest Resource Assessment to reflect WUI and Wildfire Risk to Communities[11]. CPZs were created by buffering the WUI with distances of 0.5, 1.0 and 2.0 miles to reflect different types of mitigation activities typically conducted. A cost-weighted method was used to allow the shape and distance of the CPZs to confirm to local conditions (vegetation types). This approach was based on methods and data developed by Theobald and Romme.[12]

Building upon these methods, DTS has developed an approach to define CPZs that leverage the more accurate and detailed WUI layer developed from LandScan data, in addition to using the Rate of Spread fire behavior output to determine CPZ distance and extent from WUI areas. Rate of Spread is used instead of vegetation types to incorporate potential fire spread and travel time in the CPZ delineation.[13]

CPZs are based on an analysis of the Where People Live housing density data and the surrounding fire behavior potential. Rate of Spread data is used to determine the areas of concern around populated areas that are within a 2-hour fire spread distance. However, any distance could be used to reflect fire travel time.

[11] Colorado State Forest Service. 2010. State Forest Resource Assessment: A foundation for strategic discussion and implementation of forest management in Colorado.

[12] Theobald, D.M. and W. Romme. 2007. Expansion of the U.S. Wildland-Urban Interface, *Landscape and Urban Planning* 83: 340-354.

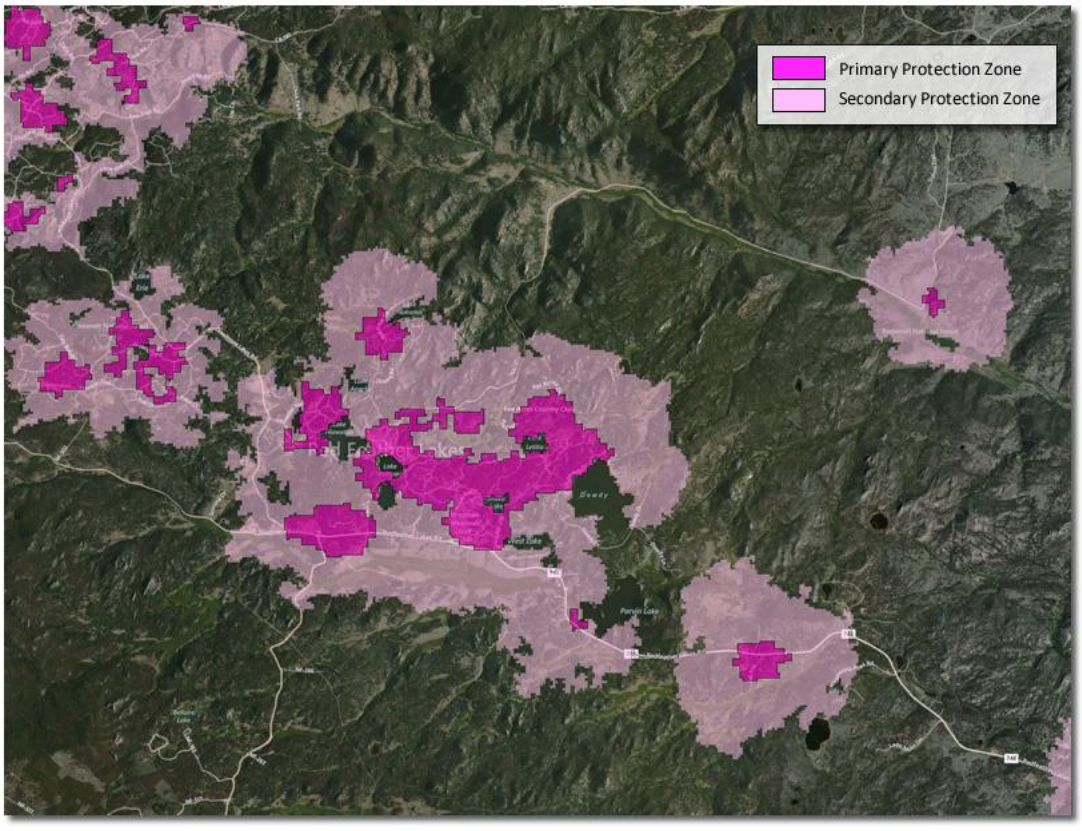
[13] DTS developed these methods for the State of Texas in their recent 2010 risk assessment update, working closely with Joe Scott (Pyrologix, Missoula, MT) and Texas Forest Service mitigation staff.

General consensus among fire planners is that for fuel mitigation treatments to be effective in reducing wildfire hazard, they must be conducted within a close distance of a community. With this approach, the WUI housing density is used to reflect populated areas in place of community boundaries, a dataset often lacking in most states. This ensures that CPZs reflect where people are living, not jurisdictional boundaries.

Accordingly, CPZs represent a variable width buffer around populated areas that are within a 2-hour fire spread distance. CPZs will extend farther in areas where rates of spread are greater and less in areas where minimal rate of spread potential exists. CPZ boundaries inherently incorporate fire behavior conditions.

All areas in Colorado would have the CPZs calculated consistently, which allows for comparison and ordination of areas across the entire state. Data would be modeled at a 30-meter cell resolution, which is consistent with other Colorado WRA layers. The following figure presents an example of CPZs for an area in Larimer County. The Primary Community Protection zone in this example is defined by the WUI housing density of "One house per 20 acres" or greater. The Secondary Community Protection Zone is based on a 2 hour travel time for fire spread using the Rate of Spread data. Both criteria can be modified to meet specific requirements, either density threshold for the primary zone, or fire spread time for the secondary zone. Note that the secondary zone distance varies around primary zone areas. This is based on the travel time of a potential fire using historical percentile weather.

Figure 25. Community Protection Zones map example



Defining Communities-at-Risk

In addition to the development of CPZs, the WUI dataset can be used to define draft community boundaries based on housing density threshold values. This is ideal for wildland and rural areas where population places / communities are typically not incorporated and hence formal boundaries do not exist. Rather, communities are defined by a grouping of homes, often given local names.

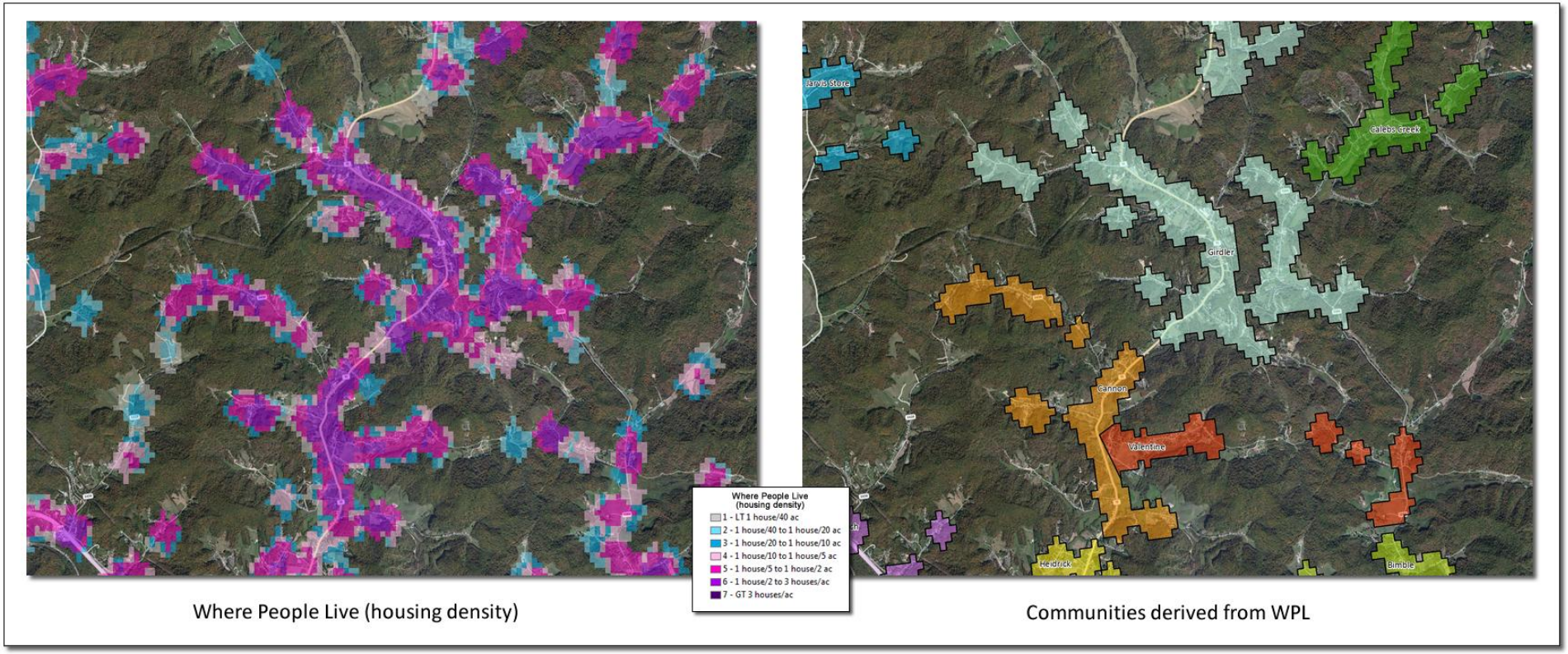
A challenge with many state fire protection agencies, in adherence to the Federal Register and NASF requirements, has been the accurate definition of communities at risk to wildfire,. This includes defining wildland community boundaries and locations, the number of communities, and the risk level of each community.

Building upon methods developed by DTS for the Southern Group of State Foresters, and recently applied to enhance the Southern Wildfire Risk Assessment (SWRA), the opportunity exists to leverage the Colorado WRA WUI dataset to define draft community boundaries. This approach has been successfully tested in Southern states, providing a draft dataset that local agency foresters can then use to name and finalize communities.

The following figure presents an example of WPL data and resultant community boundaries for an area in Kentucky. A threshold of "one house per 7 acres" was used to define the draft community boundaries. This threshold was decided upon by state agency staff based on population patterns in the state. This can be adjusted for any area based on testing to best reflect the housing density appropriate for the state. The map on the left shows the Where People Live reflecting housing density in standard classes. Based on the review of the WPL data, a threshold density value was selected to best represent "community boundaries". Local forestry staff then reviewed the draft boundaries on a per county basis and adjusted them, grouped polygons together to represent a "community", and then applied local names to the communities. The map on the right shows the final communities using arbitrary colors to reflect different communities. Names are shown. Once defined, these communities can then be combined with the wildfire risk data to derive risk ratings for the individual communities.

In addition, with the recent implementation of the Southern Wildfire Risk Assessment Portal (SouthWRAP) web site, a custom web mapping application is being developed by DTS to derive the draft community boundaries and provide the editing tools necessary for local foresters and planners to finalize the boundaries based on the draft boundaries derived from the WUI housing density data. This web application is referred to as the Community At Risk Editor (CARE).These tools, when added to CO-WRAP, would provide capabilities for editing the shape of community polygons, grouping of polygons to represent a single community, naming of the community to adhere to local use, and calculating risk ratings for each community based on the underlying Colorado WRA risk layers.

Figure 26. Example Community boundaries delineated from Where People Live (housing density) data



Fire Adapted Communities - Cohesive Strategy

Creating Fire Adapted Communities is one of three primary goals of the National Cohesive Wildland Fire Management Strategy (Cohesive Strategy). The purpose of the Cohesive Strategy is to address the growing wildland fire challenges in the U.S. across all lands and jurisdictions. The basic premise underlying the creation of Fire Adapted Communities is**:**

> *Preventing or minimizing the loss of life and property due to wildfire requires a combination of thorough pre-fire planning and action, followed by prudent and immediate response during an event. Post-fire activities can also speed community recovery efforts and help limit the long-term effects and costs of wildfire. CWPPs or their equivalents should identify high-risk areas and community-specific requirements. Collaboration, self-sufficiency, individuals' and/or communities' acceptance of the risks and consequences of their actions (or non-action), treating homes and property equally regardless of appraised value (social justice), and facilitating culture and behavior changes are important concepts.*

The Colorado WRA and the CO-WRAP mapping applications provide both planners and individuals the ability to identify the threat and risk to communities and to display that threat and risk visually to inform decision makers. In addition, CO-WRAP provides the capability to generate detailed risk summary reports for user defined project areas. This information specifically addresses the CWPP "risk assessment" requirements.

As the Colorado WRA data becomes better understood by local planners, enhancements to the analysis data and CO-WRAP software tools are possible to incorporate local data and analysis to specifically meet Fire Adapted Communities planning requirements. These enhancements could build upon previously identified enhancements of Defining Communities-at-Risk Boundaries and Community Protection Zones. Opportunities include:

- the ability to incorporate fuel treatment planning and tracking
- tools to analyze the change in risk to communities as fuel treatments are applied (before and after analysis - "what is the change in risk if we apply these planned fuel treatments?")
- incorporate home assessment surveys and defensible space planning information
- incorporate FireWise and other prevention program status information
- track grant program projects
- integrate ingress, egress and evacuation route data, and
- integrate critical infrastructure and facility data.

Values-At-Risk Modeling Tool

The Colorado WRA Values-at-Risk (VAR) outputs were generated using the Response Function approach described in the WWA Final Report and in Section 2.3 (Assessment Methods) of this report. The specific Response Function values (RFV) used to calculate the VAR were developed by a team of technical specialists at the CSFS. These RFVs are documented in Appendix B.

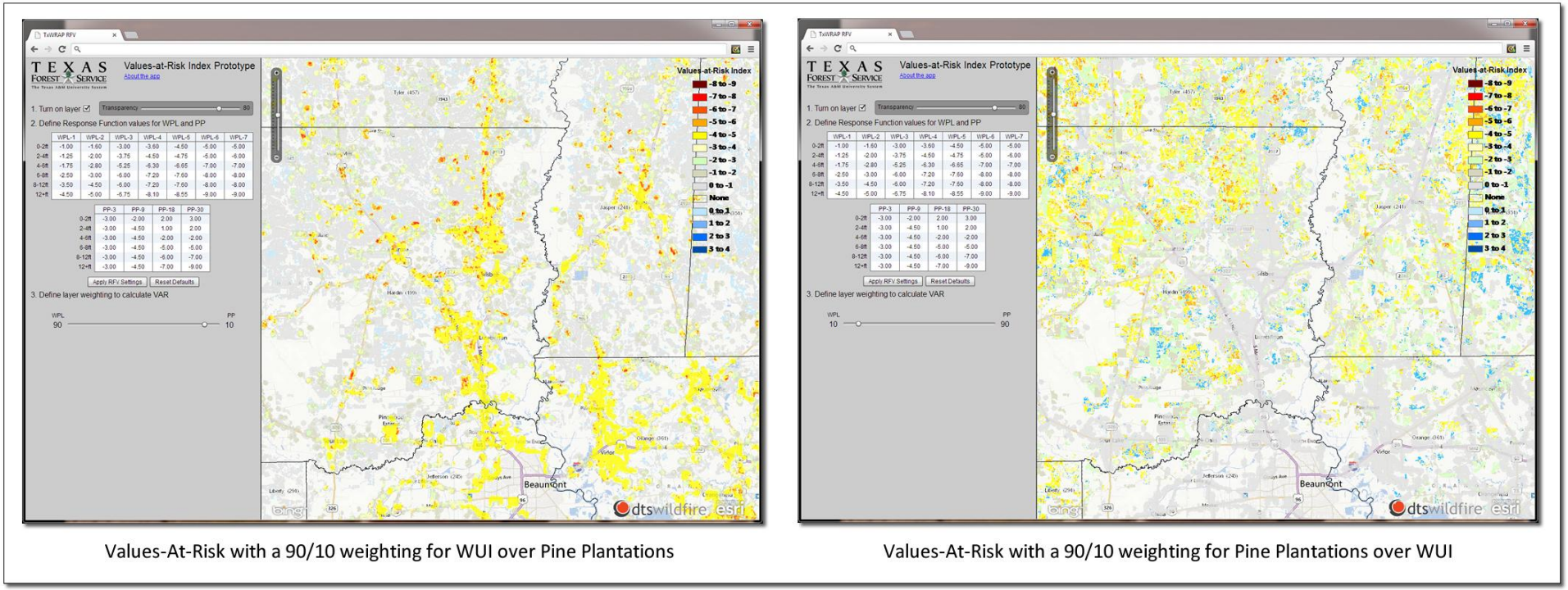
The VAR is comprised of four key input layers that reflect important assets that are considered at risk to wildfire. These are Wildland Urban Interface (people & homes), Drinking Water Importance Areas (primary sources of drinking water), Forest Assets (susceptibility and resilience of the forests), and Riparian Assets (riparian areas susceptibility to fire). The RFVs reflect the potential level of negative impact that wildfire can have on these resources. These values for each input layer were defined by the CSFS technical team based on their knowledge and understanding of statewide concerns and priorities. Weights were defined to combine the four outputs into a single measure of Values-At-Risk.

While the RFVs defined for the statewide assessment provide a consistent and comparable measure of concerns and priorities across the state, they do not incorporate local conditions or priorities. To incorporate consideration of local knowledge, conditions and priorities, the RFVs may need modification by local fire specialists and planners to reflect their needs. This may be required in future for development of detailed local plans, specifically for areas where local priorities and conditions differ from the average statewide situation. To accommodate this need, the Values-At-Risk model utilized in the Colorado WRA could be provided as an additional CO-WRAP application. This VAR application would facilitate local specialists re-running the VAR model to derive new outputs that represent the local situation. This inherently empowers local planning specialists with the ability to develop enhanced outputs, using the standardized Colorado WRA methods, easily and quickly with no additional costs or risk assessment updates required.

The following figure presents an example of a VAR web application prototype developed by DTS for the Texas A&M Forest Service. This prototype was developed as a proof-of-concept to prove that these VAR modeling capabilities could be deployed using a WRAP approach. The maps show VAR outputs generated by combining WUI and Pine Plantations input layers. The protection of pine plantations from fire is a concern in East Texas as this is a major economic driver in the area. This concern for pine plantations varies depending on location with consideration of WUI (people living in the wildland and rural areas). The maps shown reflect outputs based on different priorities.

The map on the left shows the VAR output with a 90/10 weighting for WUI as the priority. The map on the right shows the VAR output with a 90/10 weighting for Pine Plantations as the priority. The web application allows the user to change RFVs, and adjust weights, to reflect their knowledge and understanding of local conditions and priorities. By simply adjusting the inputs the user can immediately see the result of these changes. This model processing is completed in less than 2 seconds. This provides the ability for the user to consider many different priorities (RFVs and weights), until they determine the output that best reflects their situation.

Figure 27. Example Values-At-Risk model as a web application



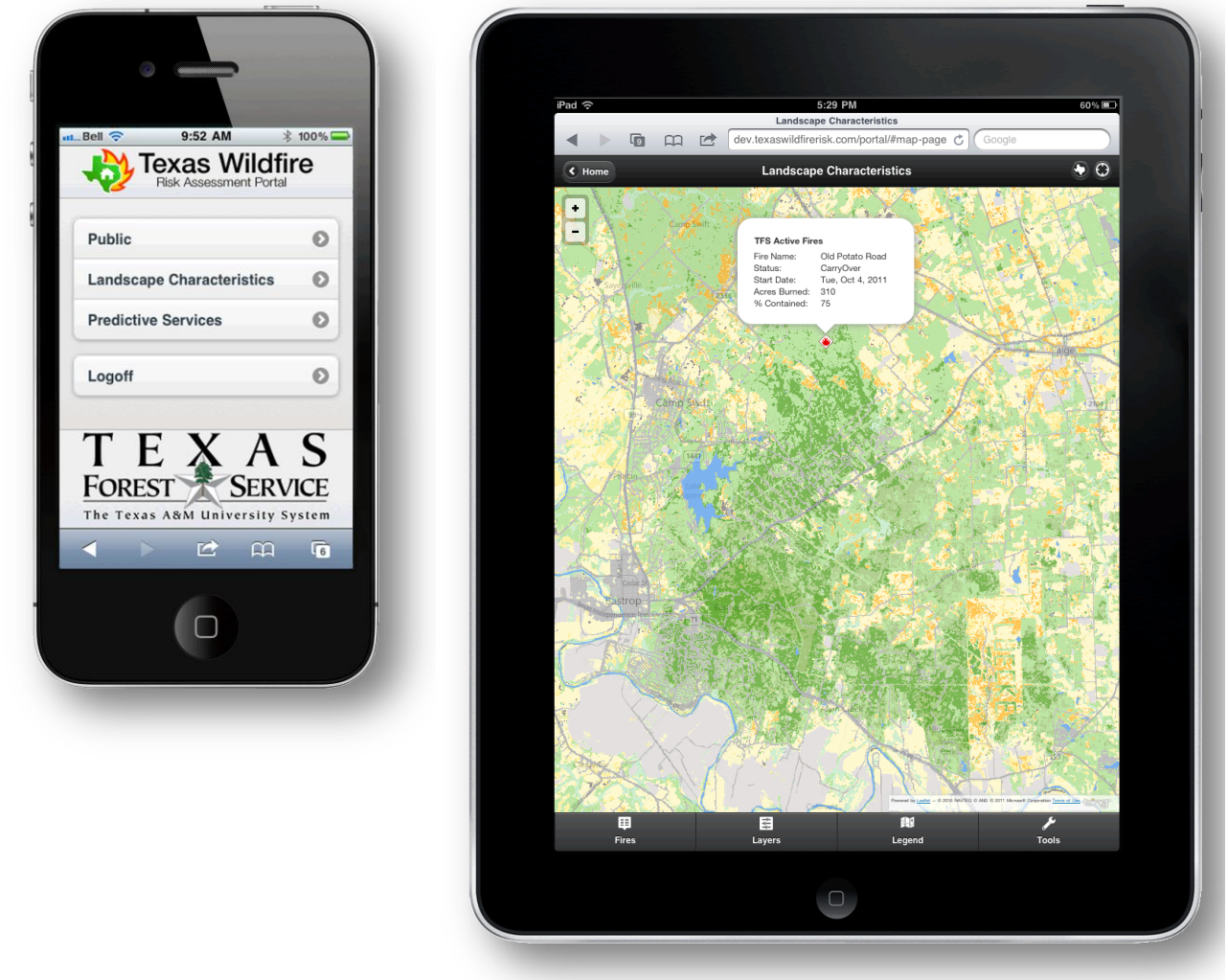
Values-At-Risk with a 90/10 weighting for WUI over Pine Plantations

Values-At-Risk with a 90/10 weighting for Pine Plantations over WUI

Mobile CO-WRAP Version

Options are also available to develop a mobile application that will allow users to view the Colorado WRA data using a Smartphone or Tablet mobile device (i.e. iPhone, iPad, Android, etc). With recent advancements in mobile technology DTS has developed several applications that display web mapping applications into mobile mapping interfaces. This capability will allow users to review risk information while in the field during survey, reconnaissance or even fire incident activities. The following figure presents a recent example of the Texas WRAP application that has been deployed with a custom mobile version. Both Public and Professional Viewer interfaces can be supported to work on any mobile device.

Figure 28. The image on the left shows the Texas WRAP Mobile Browser application operating on an iPhone (main screen), while the image on the right shows the Landscape Characteristics Map Page (surface fuels) of the same mobile application operating on an iPad.



Note that other more advanced applications and deployment options exist for future integration for the Colorado WRA and CO-WRAP. We propose to discuss these items in more detail with CSFS in future as demand and budget warrant. New enhancements and applications are constantly being developed by DTS and our clients to meet other similar requirements and we propose to leverage these efforts in future for the benefit of the State of Colorado and its citizens.

4.0 Colorado Wildfire Risk Assessment Portal - CO-WRAP

This section provides a brief description of the CO-WRAP web application Readers are encouraged to visit the site directly at www.ColoradoWildfireRisk.com for more information.

4.1 Overview

In response to increasing demand for more accurate and up-to-date wildfire risk information across the state, the Colorado State Forest Service (CSFS) established the 2012 Colorado Wildfire Risk Assessment Project (Colorado WRA 2012). The goal of the project is to provide a consistent, comparable set of scientific results to be used as a foundation for wildfire mitigation and prevention planning in Colorado. The results were completed in December 2012. The CSFS developed the Colorado Wildfire Risk Assessment Portal (CO-WRAP) in order to deliver the information quickly and seamlessly to stakeholders. Through CO-WRAP, the CSFS is creating awareness among the public and providing state and local government planners with information to support mitigation and prevention efforts.

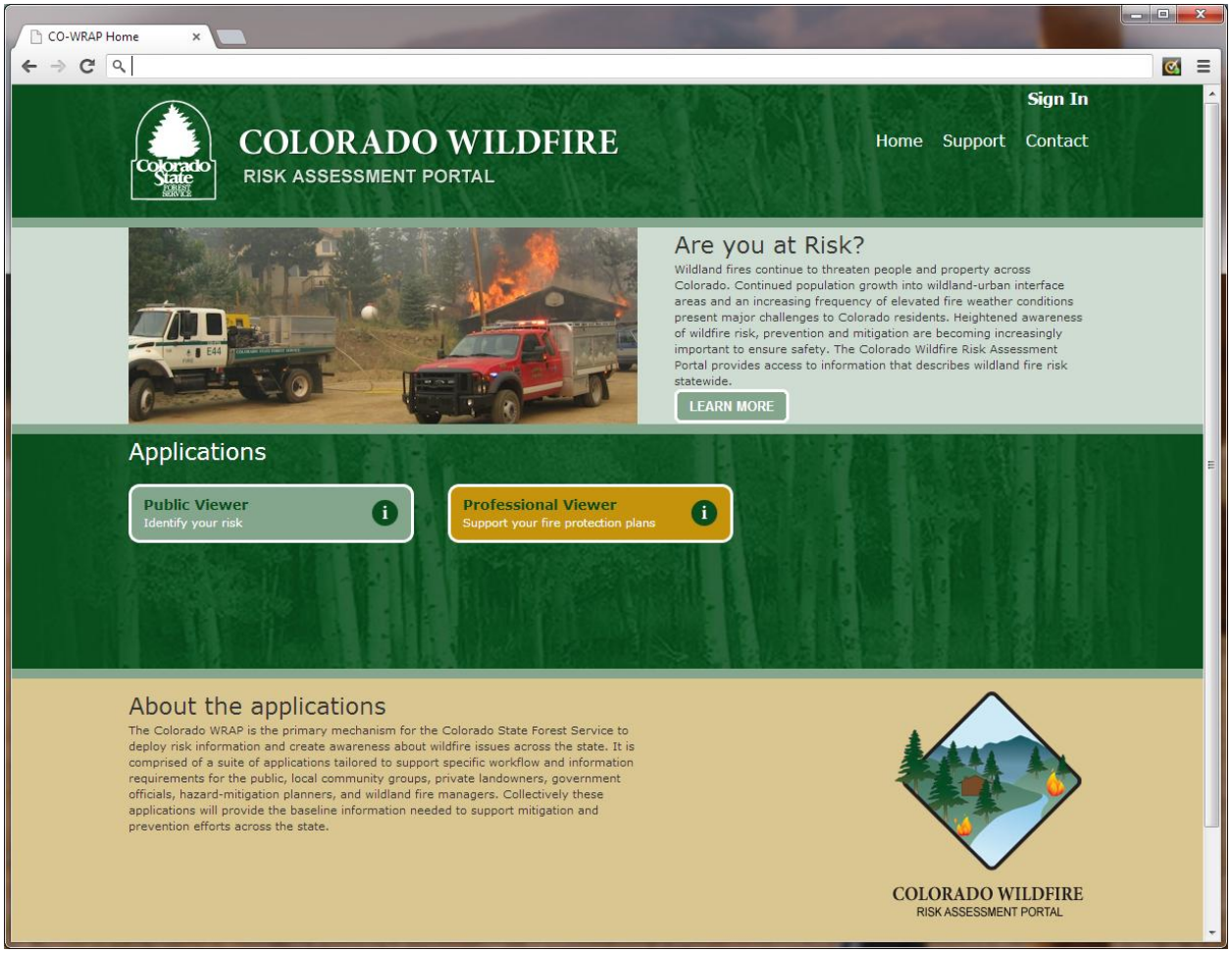
Results of the assessment can be used to help prioritize areas in the state where tactical analyses, community interaction and education, or mitigation treatments might be necessary to reduce wildfire risk. In addition, the information provided in the assessment can be used to support the following priorities:

- Identify areas that may require additional tactical planning, specifically related to mitigation projects and Community Wildfire Protection Planning
- Provide the information necessary to justify resource, budget and funding requests
- Allow agencies to work together to better define priorities and improve emergency response, particularly across jurisdictional boundaries
- Increase communication with local residents and the public to address community priorities and needs
- Plan for response and suppression resource needs
- Plan and prioritize hazardous fuel treatment programs

With the successful completion of the 2012 Colorado Wildfire Risk Assessment project, the CSFS continues to be a national leader in wildland fire management. This latest assessment builds upon and calibrates the West Wide Wildfire (WWA) Risk Assessment results. The WWA risk assessment was completed in spring 2012 and provides baseline risk assessment results for the 17 western states and Pacific Islands. Colorado has enhanced the results to reflect priorities and data distributions only within Colorado to better meet Colorado planning requirements.

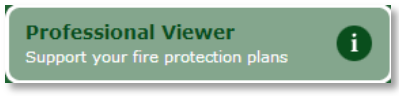
CO-WRAP is the primary mechanism for the Colorado State Forest Service to deploy risk information and create awareness about wildfire issues across the state. It is comprised of a suite of applications tailored to support specific workflow and information requirements for the public, local community groups, government officials, professional hazard mitigation planners, and wildland fire managers. Collectively

these applications will provide the baseline information needed to support mitigation and prevention efforts across the state. The following figure shows the main web portal for CO-WRAP.



Access to the interactive web mapping applications is available from the main portal page. Currently, CO-WRAP has two applications.

Professional Viewer



The Professional Viewer is a web-mapping application designed to support the community wildfire protection planning needs of government officials, hazard mitigation planners and wildland fire professionals. This application contains advanced functionality and additional map themes as compared to the Public Viewer. The key features of this application include the capability to define a project area, generate a detailed risk summary report, and export and download wildfire risk GIS data. Access to the Professional Viewer requires a valid user account from the Colorado State Forest Service. You must register for the site using the link on the Sign In page.

Public Viewer

The Public Viewer is a web-mapping application designed to let users zoom to a place of interest, explore map themes and identify wildfire risk for a specific location on the map. The featured tool in this application is called **"What's Your Risk?"** It allows users to identify potential wildfire intensity near their home, or any other point of interest on the map, and provides a link to additional resources for users wanting to know how to reduce their risk. The application is accessible to any web browser and does not require registration or a login.

4.2 CO-WRAP Support Information

A variety of resources are available to help make the most use of the Colorado Wildfire Risk Assessment (Colorado WRA) results and the Colorado Wildfire Risk Assessment Portal (CO-WRAP) web application. Support, documentation and reference information is available from several sources. Key resources for the Colorado WRA and CO-WRAP applications are provided below.

User Manual

A simple step-by-step guide on how to use CO-WRAP is provided. The manual provides all the information necessary to learn how to use both the Public and Professional Viewer applications.

Training

Custom training on how to use the Colorado WRA results and the CO-WRAP application is available from the Colorado State Forest Service (CSFS). If you are interested in receiving training for your organization, you can reach us by using the Contact page.

Help Desk

Support for use of the Colorado WRA data and the Professional Viewer application within CO-WRAP is available by sending an email to the CSFS at support@coloradowildfirerisk.com. The Professional Viewer application is intended for use by fire planners and land managers. For general inquiries, especially regarding the Public Viewer or the Colorado WRA data, please use the Contact page. This will allow you to pose questions, make suggestions and provide feedback. We welcome and encourage your comments so we can continue to improve CO-WRAP to better meet your needs.

More Information

To aid users in developing a fire protection plan, a few additional resources are provided. This includes guidelines for protecting your home and property from wildfire through mitigation, minimum standards for developing a Community Wildfire Protection Plan (CWPP), requirements for a community to receive the Firewise Communities USA™ designation and templates for developing a CWPP and a Forest Stewardship Plan. Use the links below to access these resources. We also encourage you to check out the information available on the Colorado State Forest Service website at www.csfs.colostate.edu. Key links are provided below.

- Quick Guide - Protecting Your Home from Wildfire: Creating Wildfire Defensible Zones (PDF)

- FireWise Construction: Site Design & Building Materials (PDF)
- Home and Property Wildfire Protection
- Community Wildfire Protection Planning

Example Plan Templates/Guidelines

Planning is essential for the long-term success of wildfire mitigation efforts. CWPPs have become the planning standard, as defined in the Healthy Forests Restoration Act of 2003. The risk summary report capability within the CO-WRAP Professional Viewer application has been specifically designed to support Step 5 in CWPP development, the Community Risk Assessment component. The risk report is generated in a Microsoft WORD format to facilitate easy copy-paste of content directly into a plan. Examples are provided below to get you get started. Links to existing CWPPs developed across Colorado also are provided; please note, however, that these plans were developed before Colorado WRA and CO-WRAP were available.

- Review Current Colorado CWPPs
- CWPP Template
- CWPP Minimum Standards
- Colorado Landowner Forest Stewardship Plan Template

Revision History

This document has undergone the following revisions .

Date	Revised By:	Description of Revision
December 07, 2012	David Buckley	Initial draft for CSFS review.
December 14, 2012	David Buckley	Revisions to incorporate CSFS feedback and changes. Added Mobile CO-WRAP enhancement description.
December 21, 2012	David Buckley Rich Homann	Incorporate comments and feedback from CSFS review.
January 8, 2012	David Buckley	Incorporate final summary statistics charts and maps.

Appendix A: Description of Outputs

This appendix provides a description of the Colorado WRA key output datasets (in alphabetical order). Please refer to the WWA Final Report for a description of all WWA datasets.

Wildfire Risk

Represents the possibility of loss or harm occurring from a wildfire

Wildfire Risk represents the possibility of loss or harm occurring from a wildfire**.** It is the primary output of the Colorado Wildfire Risk Assessment. Risk is derived by combining the Wildfire Threat and the Fire Effects assessment outputs. It identifies areas with the greatest potential impacts from a wildfire – i.e. those areas most at risk.

Wildfire Risk combines the likelihood of a fire occurring (threat), with those areas of most concern that are adversely impacted by fire (fire effects), to derive a single measure of wildfire risk. Since all areas in Colorado have risk calculated consistently, it allows for comparison and ordination of areas across the entire state. For example, a high risk area in Southern Colorado is equivalent to a high risk area in Northern Colorado.

Fire Effects is a key component of Wildfire Risk. Fire Effects is comprised of several inputs focusing on values impacted. The purpose of Fire Effects is to identify those areas that have important values or assets that would be adversely impacted by a wildfire. Fire Effects inputs include Where People Live (derived from 2012 LandScan data for Colorado),Colorado Forest Assets, Riparian Assets and Drinking Water value layers. The Colorado component is a key element of Fire Effects since it represents where people live in the wildland and urban fringe areas.

The risk map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary LANDFIRE surface fuels dataset used in the assessment. While not appropriate for site specific analysis, it is appropriate for regional, county or local planning efforts.

Wildfire Threat

Represents the likelihood of an acre burning.

Threat is derived by combining a number of landscape characteristics including surface fuels and canopy fuels, resultant fire behavior, historical fire occurrence, percentile weather derived from historical weather observations, and terrain conditions. These inputs are combined using analysis techniques based on established fire science.

The measure of wildfire threat used in the Colorado WRA is called Fire Threat Index (FTI). FTI combines the probability of an acre igniting (Fire Occurrence) and the expected final fire size based on rate of spread in four weather percentile categories. Since all areas in Colorado have FTI calculated consistently, it allows for comparison and ordination of areas across the entire state. For example, a high threat area in East Colorado is equivalent to a high threat area in West Colorado.

To aid in the use of Wildfire Threat for planning activities, the output values are categorized into five (5) classes. These are given general descriptions from Lowest to Highest Threat.

The threat map is derived at a 30 meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not

appropriate for site specific analysis, it is appropriate for regional, county or local protection mitigation or prevention planning.

Fire Intensity Scale

Quantifies the potential fire intensity by orders of magnitude.

Fire Intensity Scale (FIS) specifically identifies areas where significant fuel hazards and associated dangerous fire behavior potential exist. Similar to the Richter scale for earthquakes, FIS provides a standard scale to measure potential wildfire intensity. FIS consists of five (5) classes where the order of magnitude between classes is ten-fold. The minimum class, Class 1, represents very low wildfire intensities and the maximum class, Class 5, represents very high wildfire intensities.

1. Class 1, Lowest Intensity:
   Very small, discontinuous flames, usually less than 1 foot in length; very low rate of spread; no spotting. Fires are typically easy to suppress by firefighters with basic training and non-specialized equipment.
2. Class2, Low:
   Small flames, usually less than two feet long; small amount of very short range spotting possible. Fires are easy to suppress by trained firefighters with protective equipment and specialized tools.
3. Class 3, Moderate:
   Flames up to 8 feet in length; short-range spotting is possible. Trained firefighters will find these fires difficult to suppress without support from aircraft or engines, but dozer and plows are generally effective. Increasing potential for harm or damage to life and property.
4. Class 4, High:
   Large Flames, up to 30 feet in length; short-range spotting common; medium range spotting possible. Direct attack by trained firefighters, engines, and dozers is generally ineffective, indirect attack may be effective. Significant potential for harm or damage to life and property.
5. Class 5, Highest Intensity:
   Very large flames up to 150 feet in length; profuse short-range spotting, frequent long-range spotting; strong fire-induced winds. Indirect attack marginally effective at the head of the fire. Great potential for harm or damage to life and property.

Wildfire Threat and Fire Intensity Scale are designed to complement each other. Unlike Wildfire Threat, the Fire Intensity Scale does not incorporate historical occurrence information. It only evaluates the potential fire behavior for an area, regardless if any fires have occurred there in the past. This additional information allows mitigation planners to quickly identify areas where dangerous fire behavior potential exists in relationship to nearby homes or other valued assets.

Since all areas in Colorado have fire intensity scale calculated consistently, it allows for comparison and ordination of areas across the entire state. For example, a high fire intensity area in Eastern Colorado is equivalent to a high fire intensity area in Western Colorado.

Fire intensity scale is a fire behavior output, which is influenced by three environmental factors - fuels, weather, and topography. Weather is by far the most dynamic variable as it changes frequently. To account for this variability, four percentile weather categories were created from historical weather observations to represent low, moderate, high, and extreme weather days for each weather influence zone in Colorado. A weather influence zone is an area where, for analysis purposes, the weather on any given day is considered uniform. There are 11weather influence zones in Colorado. The FIS represents the weighted average for all four weather percentiles.

The fire intensity scale map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not appropriate for site specific analysis, it is appropriate for regional, county or local planning efforts.

Wildfire Effects Themes

Values At Risk Rating

Represents those values or assets that would be adversely impacted by a wildfire

The Values At Risk Rating (VAR) is an overall Fire Effects rating that combines the risk ratings for Wildland Urban Interface (WUI), Forest Assets, Riparian Assets, and Drinking Water Importance Areas into a single measure of values-at-risk. The individual ratings for each value layer were derived using a Response Function approach.

Response functions are a method of assigning a net change in the value to a resource or asset based on susceptibility to fire at different intensity levels. A resource or asset is any of the Fire Effects input layers, such as WUI, Forest Assets, etc. These net changes can be adverse (negative) or positive (beneficial).

Calculating the VAR at a given location requires spatially defined estimates of the intensity of fire integrated with the identified resource value. This interaction is quantified through the use of response functions that estimate expected impacts to resources or assets at the specified fire intensity levels. The measure of fire intensity level used in the Colorado assessment is flame length for a location. Response Function outputs were derived for each input data set and then combined to derive the Values Impacted Rating.

Different weightings are used for each of the input layers with the highest priority placed on protection of people and structures (i.e. WUI). The weightings represent the value associated with those assets. Weightings were developed by a team of experts during the assessment to reflect priorities for fire protection planning in Colorado. Refer to the Colorado WRA Final Report for more information about the layer weightings.

Since all areas in Colorado have the VAR calculated consistently, it allows for comparison and ordination of areas across the entire state. The VAR data was derived at a 30-meter resolution.

Suppression Difficulty Index

Reflects the difficulty or relative cost to suppress a fire given the terrain and vegetation conditions that may impact machine operability.

This layer is an overall index that combines the slope steepness and the fuel type characterization to identify areas where it would be difficult or costly to suppress a fire due to the underlying terrain and vegetation conditions that would impact machine operability (in particular Type II dozer).

The rating was calculated based on the fireline production rates for hand crews and engines with modifications for slope, as documented in the NWCG Fireline Handbook 3, PMS 401-1.

The burnable fuel models in the Colorado WRA were grouped into three categories: slow (0-66 feet), medium (67-165 feet) and fast (greater than 165 feet).

Fireline production capability on five slope classes was used as the basic reference to obtain the suppression difficulty score. To remain constant with the Value Impacted Rating output values, a response function (-1 to –9) is assigned to each combination of fuel model group (slow, medium and fast) and slope category.

Wildland Urban Interface Risk Index

A measure of the potential impact on people and their homes from wildfire.

The Wildland-Urban Interface (WUI) Risk Index layer is a rating of the potential impact of a wildfire on people and their homes. The key input, WUI, reflects housing density (houses per acre) consistent with Federal Register National standards. The location of people living in the wildland-urban interface and rural areas is essential for defining potential wildfire impacts to people and homes.

The WUI Risk Index is derived using a response function modeling approach. Response functions are a method of assigning a net change in the value to a *resource* or *asset* based on susceptibility to fire at different intensity levels, such as flame length.

To calculate the WUI Risk Index, the WUI housing density data was combined with flame length data and response functions were defined to represent potential impacts. The response functions were defined by a team of experts led by Colorado State Forest Service mitigation planning staff. By combining flame length with the WUI housing density data, it is possible to determine where the greatest potential impact to homes and people is likely to occur.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact. For example, areas with high housing density and high flame lengths are rated -9, while areas with low housing density and low flame lengths are rated -1.

The WUI Risk Index has been calculated consistently for all areas in Colorado, which allows for comparison and ordination of areas across the entire state. Data is modeled at a 30-meter cell resolution, which is consistent with other Colorado WRA layers.

Drinking Water Risk Index

A measure of the risk to Drinking Water Importance Areas based on the potential negative impacts from wildfire

In areas that experience low-severity burns, fire events can serve to eliminate competition, rejuvenate growth and improve watershed conditions. But in landscapes subjected to high, or even moderate-burn severity, the post-fire threats to public safety and natural resources can be extreme.

High-severity wildfires remove virtually all forest vegetation – from trees, shrubs and grasses down to discarded needles, decomposed roots and other elements of ground cover or duff that protect forest soils. A severe wildfire also can cause certain types of soil to become hydrophobic by forming a waxy, water-repellent layer that keeps water from penetrating the soil, dramatically amplifying the rate of runoff.

The loss of critical surface vegetation leaves forested slopes extremely vulnerable to large-scale soil erosion and flooding during subsequent storm events. In turn, these threats can impact the health, safety and integrity of communities and natural resources downstream. The likelihood that such a post-fire event will occur in Colorado is increased by the prevalence of highly erodible soils in several parts of the state, and weather patterns that frequently bring heavy rains on the heels of fire season.

In the aftermath of the 2002 fire season, the Colorado Department of Health estimated that 26 municipal water storage facilities were shut down due to fire and post-fire impacts. The potential for severe soil erosion is a consequence of wildfire because as a fire burns, it destroys plant material

and the litter layer. Shrubs, forbs, grasses, trees and the litter layer disperse water during severe rainstorms. Plant roots stabilize the soil, and stems and leaves slow the water to give it time to percolate into the soil profile. Fire can destroy this soil protection.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

Riparian Assets Risk Index

A measure of the risk to riparian areas based on the potential negative impacts from wildfire.

This layer identifies those riparian areas with the greatest potential for adverse effects from wildfire.

The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

The risk index has been calculated by combining the Riparian Assets data with a measure of fire intensity using a Response Function approach. Those areas with the highest negative impact (-9) represent areas with high potential fire intensity and high importance for ecosystem services. Those areas with the lowest negative impact (-1) represent those areas with low potential fire intensity and a low importance for ecosystem services.

This risk output is intended to supplement the Drinking Water Risk Index by identifying wildfire risk within the more detailed riparian areas.

Forest Assets Risk Index

A measure of the risk to forested areas based on the potential negative impacts from wildfire.

This layer identifies those forested areas with the greatest potential for adverse effects from wildfire. The range of values is from -1 to -9, with -1 representing the least negative impact and -9 representing the most negative impact.

The risk index has been calculated by combining the Forest Assets data with a measure of fire intensity using a Response Function approach. Those areas with the highest negative impact (-9) represent areas with high potential fire intensity and low resilience or adaptability to fire. Those areas with the lowest negative impact (-1) represent those areas with low potential fire intensity and high resilience or adaptability to fire.

This risk output is intended to provide an overall forest index for potential impact from wildfire. This can be applied to consider aesthetic values, ecosystem services, or economic values of forested lands.

Primary Input Layers

Surface Fuels

Fire behavior fuel models that contain the parameters needed to calculate fire behavior outputs

Surface fuels, or fire behavior fuel models as they are technically referred to, contain the parameters required by the Rothermel (1972) surface fire spread model to compute surface fire behavior characteristics, including rate of spread, flame length, fireline intensity and other fire behavior metrics. As the name might suggest, surface fuels account only for surface fire potential. Canopy fire potential is computed through a separate but linked process. The Colorado WRA accounts for both surface and canopy fire potential in the fire behavior outputs. However, only surface fuels are shown in this report.

Surface fuels typically are categorized into one of four primary fuel types based on the primary carrier of the surface fire: 1) grass, 2) shrub/brush, 3) timber litter, and 4) slash. Two standard fire behavior fuel model sets have been published. The Fire Behavior Prediction System 1982 Fuel Model Set (Anderson, 1982) contains 13 fuel models, and the Fire Behavior Prediction System 2005 Fuel Model Set (Scott & Burgan, 2005) contains 40 fuel models. The Colorado WRA uses fuel models from the 2005 Fuel Model Set.

The LANDFIRE Program Refresh 2008 version of data products was used to compile the Surface Fuels data for the West Wide Risk Assessment and the Colorado Wildfire Risk Assessment. This reflects data through 2008. Some modifications were completed to reflect recent disturbances, such as large wildfires and pine beetle infestations, prevalent in central Colorado over recent years. These updates reflect changes in the landscape that represent conditions through 2010. Information on the process used to compile the Colorado fuels dataset can be found in the West Wide Assessment Final Report cited on the Reference Page.

Table 13 provides a description of the FBPS 2005 fuel model set (Scott & Burgan, 2005)

Table 13. FBPS 2005 Fuel Model Set used in the Colorado WRA.

Value	Fuel Model Name	Description
101	GR01	Short, sparse dry climate grass
102	GR02	Low load dry climate grass
103	GR03	Low load, very coarse, humid climate grass
104	GR04	Moderate load dry climate grass
105	GR05	Low load humid climate grass
106	GR06	Moderate load humid climate grass
107	GR07	High load dry climate grass
108	GR08	High load very coarse humid climate grass
109	GR09	Very high load humid climate grass
121	GS01	Low load dry climate grass-shrub
122	GS02	Moderate load dry climate grass-shrub
123	GS03	Moderate load humid climate grass-shrub
124	GS04	High load humid climate grass-shrub
141	SH01	Low load dry climate shrub
142	SH02	Moderate load dry climate shrub
143	SH03	Moderate load humid climate shrub
144	SH04	Low load humid climate timber-shrub
145	SH05	High load humid climate grass-shrub
146	SH06	Low load humid climate shrub
147	SH07	Very high load dry climate shrub
148	SH08	High load humid climate shrub
149	SH09	Very high load humid climate shrub
161	TU01	Light load dry climate timber-grass-shrub
162	TU02	Moderate load humid climate timber-shrub
163	TU03	Moderate load humid climate timber-grass-shrub
164	TU04	Dwarf Conifer with Understory
165	TU05	Very High Load, Dry Climate Timber-Shrub
181	TL01	Low load compact conifer litter
182	TL02	Low load broadleaf litter
183	TL03	Moderate load conifer litter
184	TL04	Small downed logs
185	TL05	High load conifer litter
186	TL06	Moderate load broadleaf litter
187	TL07	Large downed logs
188	TL08	Long-needle litter
189	TL09	Very high load broadleaf litter
201	SB01	Low load activity fuel
202	SB02	Moderate load activity or low load blowdown
203	SB03	High load activity fuel or moderate load blowdown
204	SB04	High load blowdown
91	NB01	Urban
92	NB02	Snow and Ice
93	NB03	Agriculture
98	NB08	Water
99	NB09	Bare Ground

Vegetation

General vegetation and land cover types

The Vegetation map describes the general vegetation and landcover types across the state of Colorado. In the Colorado WRA, the Vegetation dataset is used to support the development of the Surface Fuels, Canopy Cover, Canopy Stand Height, Canopy Base Height, and Canopy Bulk Density datasets.

The LANDFIRE program Refresh version of data products (Existing Vegetation Type) was used to compile the Vegetation data for the West Wide Risk Assessment and the Colorado WRA. This reflects data current to 2008. Some modifications were completed to reflect recent disturbances such as large wildfires and pine beetle infestations prevalent in central Colorado over recent years. The LANDFIRE EVT data was classified to reflect general vegetation cover types for representation with CO-WRAP.

Wildland Urban Interface

Reflects housing density depicting where humans and their structures meet or intermix with wildland fuels.

Colorado is one of the fastest growing states in the Nation, with much of this growth occurring outside urban boundaries. This increase in population across the state will impact counties and communities that are located within the Wildland Urban Interface (WUI). The WUI is described as the area where structures and other human improvements meet and intermingle with undeveloped wildland or vegetative fuels. Population growth within the WUI substantially increases the risk from wildfire.

The Wildland Urban Interface (WUI) layer reflects housing density depicting where humans and their structures meet or intermix with wildland fuels. In the past, conventional wildland-urban interface data sets, such as USFS SILVIS, have been used to reflect these concerns. However, USFS SILVIS and other existing data sources did not provide the level of detail needed by the Colorado State Forest Service and local fire protection agencies.

The new WUI data set is derived using advanced modeling techniques based on the Where People Live data set and LandScan USA population count data available from the Department of Homeland Security, HSIP Freedom data set. WUI is simply a subset of the Where People Live data set. The primary difference is populated areas surrounded by sufficient non-burnable areas (i.e. interior urban areas) are removed from the Where People Live data set, as these areas are not expected to be directly impacted by a wildfire.

Data is modeled at a 30-meter cell resolution, which is consistent with other Colorado WRA layers. . The WUI classes are based on the number of houses per acre. Class breaks are based on densities well understood and commonly used for fire protection planning.

Drinking Water Importance Areas

A measure of quality and quantity of public surface drinking water categorized by watershed

This layer identifies an index of surface drinking water importance, reflecting a measure of water quality and quantity, characterized by Hydrologic Unit Code 12 (HUC 12) watersheds. The Hydrologic

Unit system is a standardized watershed classification system developed by the USGS. Areas that are a source of drinking water are of critical importance and adverse effects from fire are a key concern.

The U.S. Forest Service Forests to Faucets (F2F) project is the primary source of the drinking water data set. This project used GIS modeling to develop an index of importance for supplying drinking water using HUC 12 watersheds as the spatial resolution. Watersheds are ranked from 1 to 100 reflecting relative level of importance, with 100 being the most important and 1 the least important.

Several criteria were used in the F2F project to derive the importance rating including water supply, flow analysis, and downstream drinking water demand. The final model of surface drinking water importance used in the F2F project combines the drinking water protection model, capturing the flow of water and water demand, with a model of mean annual water supply. The values generated by the drinking water protection model are simply multiplied by the results of the model of mean annual water supply to create the final surface drinking water importance index.

Water is critical to sustain life. Human water usage has further complicated nature's already complex aquatic system. Plants, including trees, are essential to the proper functioning of water movement within the environment. Forests receive precipitation, utilize it for their sustenance and growth, and influence its storage and/or passage to other parts of the environment.

Four major river systems – the Platte, Colorado, Arkansas and Rio Grande – originate in the Colorado mountains and fully drain into one-third of the landmass of the lower 48 states. Mountain snows supply 75 percent of the water to these river systems.

Approximately 40 percent of the water comes from the highest 20 percent of the land, most of which lies in national forests. National forests yield large portions of the total water in these river systems. The potential is great for forests to positively and negatively influence the transport of water over such immense distances.

Riparian Assets

Forested riparian areas characterized by functions of water quantity and quality, and ecology

This layer identifies riparian areas that are important as a suite of ecosystem services, including both terrestrial and aquatic habitat, water quality, water quantity, and other ecological functions. Riparian areas are considered an especially important element of the landscape in the west. Accordingly, riparian assets are distinguished from other forest assets so they can be evaluated separately.

The process for defining these riparian areas involved identifying the riparian footprint and then assigning a rating based upon two important riparian functions – water quantity and quality, and ecological significance. A scientific model was developed by the West Wide Risk Assessment technical team with in-kind support from CAL FIRE state representatives. Several input datasets were used in the model including the National Hydrography Dataset and the National Wetland Inventory.

The National Hydrography Data Set (NHD) was used to represent hydrology. A subset of streams and water bodies, which represents perennial, intermittent, and wetlands, was created. The NHD water bodies' data set was used to determine the location of lakes, ponds, swamps, and marshes (wetlands).

To model water quality and quantity, erosion potential (K-factor) and annual average precipitation was used as key variables. The Riparian Assets data is an index of class values that range from 1 to 3 representing increasing importance of the riparian area as well as sensitivity to fire-related impacts on the suite of ecosystem services.

Forest Assets

Forested areas categorized by height, cover, and susceptibility/response to fire

This layer identifies forested land categorized by height, cover and susceptibility or response to fire. Using these characteristics allows for the prioritization of landscapes reflecting forest assets that would be most adversely affected by fire. The rating of importance or value of the forest assets is relative to each state's interpretation of those characteristics considered most important for their landscapes.

Canopy cover from LANDFIRE was re-classified into two categories, open or sparse and closed. Areas classified as open or sparse have a canopy cover less than 60%. Areas classified as closed have a canopy cover greater than 60%.

Canopy height from LANDFIRE was re-classified into two categories, 0-10 meters and greater than 10 meters.

Response to fire was developed from the LANDFIRE existing vegetation type (EVT) dataset. There are over 1,000 existing vegetation types in the project area. Using a crosswalk defined by project ecologists, a classification of susceptibility and response to fire was defined and documented by fire ecologists into the three fire response classes.

These three classes are sensitive, resilient and adaptive.

- **Sensitive** = These are tree species that are intolerant or sensitive to damage from fire with low intensity.
- **Resilient** = These are tree species that have characteristics that help the tree resist damage from fire and whose adult stages can survive low intensity fires.
- **Adaptive** = These are tree species adapted with the ability to regenerate following fire by sprouting or serotinous cones

Federal Wildfire Ignitions

Point locations for all federally reported wildfires from 1999 to 2008

Fire history statistics provide insight as to the number of fires, acres burned and cause of fires in Colorado. These statistics are useful for prevention and mitigation planning. They can be used to quantify the level of fire business, determine the time of year most fires typically occur and develop a fire prevention campaign aimed at reducing a specific fire cause.

Ten years of historic fire report data was used to create the fire occurrence summary charts. Wildfire Ignition data was compiled from federal and local sources for the years 1999 through 2008. Federal wildfire ignitions were spatially referenced by latitude and longitude coordinates. All ignitions references were updated to remove duplicate records and correct inaccurate locations.

Federal wildfire ignitions are symbolized in CO-WRAP by the cause of fire. Fire reports were gathered from the following federal data sources:

- US Forest Service
- US Fish and Wildlife Service
- Bureau of Land Management
- Bureau of Indian Affairs
- National Park Service

Non-Federal Wildfire Ignitions

Total non-federal fires reported by zipcode from 1999 to 2008

Fire history statistics provide insight as to the number of fires, acres burned and cause of fires in Colorado. These statistics are useful for prevention and mitigation planning. They can be used to quantify the level of fire business, determine the time of year most fires typically occur and develop a fire prevention campaign aimed at reducing a specific fire cause.

Ten years of historic fire report data was used to create the fire occurrence map layer and the summary history charts provided in the Professional Viewer risk summary report. Wildfire ignition data was compiled from federal and local sources for the years 1999 through 2008. State and local data was spatially referenced by zipcode. All ignitions data sources were updated to remove duplicate records and correct inaccurate locations. Since non-federal ignition data is referenced by zip code, the map layer in CO-WRAP show the total number of fires occurring over the 10 year period for each zip code.

State wildfire ignitions were gathered from fire department reports submitted by:

- Volunteer Fire Departments
- Combination Fire Departments (paid and volunteer)
- Paid Fire Departments
- Fire Protection Districts
- Counties

Fire Occurrence

Likelihood of a wildfire starting based on historical ignition patterns.

Fire Occurrence is an ignition density that represents the likelihood of a wildfire starting based on historical ignition patterns. Occurrence is derived by modeling historic wildfire ignition locations to create an average ignition rate map. The ignition rate is measured in the number of fires per year per 1000 acres.

Historic fire report data was used to create the ignition points for all Colorado fires. Data was obtained from the West Wide Risk Assessment project. The compiled fire occurrence database was cleaned to remove duplicate records and to correct inaccurate locations. The database was then modeled to create a density map reflecting historical fire ignition rates.

The measure of fire occurrence used in the Colorado WRA is called Fire Occurrence. Since all areas in Colorado have ignition density calculated consistently, it allows for comparison and ordination of areas across the entire state. For example, a high occurrence area in East Colorado is equivalent to a high occurrence area in West Colorado.

Fire Occurrence is a key input into the calculation of the Wildfire Threat output. In particular, with most Colorado fires being human caused, there is a repeatable spatial pattern of fire ignitions over time. This pattern identifies areas where wildfires are most likely to ignite and prevention efforts can be planned accordingly.

To aid in the use of wildfire ignition density for planning activities, the output values are categorized into seven (7) classes reflecting average annual ignition rates. These are given general descriptions from Low to Very High. Seven classes are used to present finer detail for mapping purposes so that transitional areas can be easily identified.

The class breaks are determined by analyzing the Fire Occurrence output values for the entire state and determining cumulative percent of acres (i.e. Class 7 has the top 3.5% of acres with the highest occurrence rate). Refer to the Colorado WRA Final Report for a more detailed description of the mapping classes and the methods used to derive these.

The Fire Occurrence map is derived at a 30-meter resolution. This scale of data was chosen to be consistent with the accuracy of the primary surface fuels dataset used in the assessment. While not sufficient for site specific analysis, it is appropriate for regional, county or local protection mitigation or prevention planning.

Appendix B: Revised CO Response Function Value Assignments

This appendix presents the final RF value assignments used to derive Wildfire Effects outputs for the Colorado WRA.

Colorado

Flame Length (classes in feet)					Class	Flame Length Class (1 to 6) 1	2	3	4	5	6	RI
					Feet	0-2	2-4	4-6	6-8	8-12	12+	
Wildland Urban Interface (houses per acre)					1 - LT 1hs/40 ac	-0.40	-0.60	-1.00	-1.40	-1.80	-1.80	25
					2 - 1 hs/40-20 ac	-0.80	-1.20	-2.00	-2.80	-3.60	-3.60	40
					3 - 1 hs/20-10 ac	-1.20	-1.80	-3.00	-4.20	-5.40	-5.40	60
					4 - 1 hs/10-5 ac	-1.50	-2.25	-3.75	-5.25	-7.10	-7.10	90
					5 - 1 hs/5-2 ac	-1.90	-2.85	-4.75	-6.65	-7.90	-8.55	95
					6 - 1-3 hs/ac	-2.00	-3.00	-5.00	-7.10	-9.00	-9.00	100
					7 - GT 3hs/ac	-2.00	-5.00	-7.00	-8.00	-9.00	-9.00	100
Drinking Water (level of importance)					1 - Lowest	-0.10	-0.20	-0.50	-0.60	-0.80	-0.90	10
					2	-0.10	-0.20	-0.50	-0.60	-0.80	-0.90	10
					3	-0.20	-0.40	-1.00	-1.20	-1.60	-1.80	20
					4	-0.30	-0.60	-1.50	-1.80	-2.40	-2.70	30
					5	-0.40	-0.80	-2.00	-2.40	-3.20	-3.60	40
					6	-0.50	-1.00	-2.50	-3.00	-4.00	-4.50	50
					7	-0.60	-1.20	-3.00	-3.60	-4.80	-5.40	60
					8	-0.70	-1.40	-3.50	-4.20	-5.60	-6.30	70
					9	-0.80	-1.60	-4.00	-4.80	-6.40	-7.20	80
					10 - Highest	-1.00	-2.00	-5.00	-6.00	-8.00	-9.00	100
Forest Assets	Sensitive	Closed	0-10 m	77	1	-2.00	-3.00	-4.00	-5.00	-9.00	-9.00	100
	Sensitive	Closed	10+m	77	2	-1.60	-2.40	-3.20	-4.00	-7.20	-7.20	80
	Sensitive	Open/Sp	0-10 m	34	3	-0.88	-1.32	-1.77	-2.21	-3.97	-3.97	X
	Sensitive	Open/Sp	10+m	34	4	-0.71	-1.06	-1.41	-1.77	-3.18	-3.18	X
	Resilient	Closed	0-10 m	78	5	0.00	0.00	-2.00	-3.00	-5.00	-5.00	100
	Resilient	Closed	10+m	78	6	0.00	0.00	-0.60	-0.90	-1.50	-1.50	30
	Resilient	Open/Sp	0-10 m	35	7	0.00	0.00	-0.90	-1.35	-2.24	-2.24	X
	Resilient	Open/Sp	10+m	35	8	0.00	0.00	-0.27	-0.40	-0.67	-0.67	X
	Adaptive	Closed	0-10 m	78	9	0.00	-1.00	-3.00	-4.00	-7.00	-7.00	100
	Adaptive	Closed	10+m	78	10	0.00	-0.50	-1.50	-2.00	-3.50	-3.50	50
	Adaptive	Open/Sp	0-10 m	36	11	0.00	-0.46	-1.38	-1.85	-3.23	-3.23	X
	Adaptive	Open/Sp	10+m	36	12	0.00	-0.23	-0.69	-0.92	-1.62	-1.62	X
Riparian Assets (importance & sensitivity to fire)					1 - Lowest Impt	0.00	0.00	-0.50	-1.00	-1.75	-1.75	25
					2 -Moderate Imp	0.00	0.00	-1.00	-2.00	-3.50	-3.50	50
					3 - Highest Imp	0.00	0.00	-2.00	-4.00	-7.00	-7.00	100

	Value Impacted/ Values At Risk	WWA CO	WWA CO %	WWA Avg	CO WRA Wts	
Value Impacted/Values At Risk Relative Importance	Infrastructure	90	26.5%	46.2%	NA	NA
	Wildland Development Areas	75	22.1%	44.7%	100	**36.4%**
	Drinking Water	100	29.4%	1.0%	100	**36.4%**
	Forest Assets	50	14.7%	3.6%	50	**18.2%**
	Riparian Assets	25	7.4%	4.5%	25	**9.1%**
		340	100.0%		275	100.0%

	Fuel Type	Code	slope steepness 0-25	26-40	41-55	56-74	75+
			1	2	3	4	5
Suppression Difficulty	Grass	1	-1.0	-3.7	-6.9	-8.7	-9.0
	ush/Sla	2	-3.0	-5.2	-7.9	-8.9	-9.0
	TL	3	-4.2	-5.9	-8.0	-8.9	-9.0

	Category	WWA CO	WWA Avg	CO WRA Wts
Fire Effects Weights	Values Impacted Rating	60.0	90.0	**80.0**
	Suppression Difficulty Rating	40.0	10.0	**20.0**
	Total	100.0	100.0	100.0

WWA Values Impacted Weights	
Infrastructure	**46.2%**
Wildland Development Areas	**44.7%**
Drinking Water	**1.0%**
Forest Assets	**3.6%**
Riparian Assets	**4.5%**

CO-WRA Values At Risk Weights	
Wildland Urban Interface	36.4%
Drinking Water	36.4%
Forest Assets	18.2%
Riparian Assets	9.1%