Wildfire Risk to Structures

Island Park Sustainable Fire Community

Island Park/Ashton Ranger Districts
Caribou-Targhee National Forest

Hebgen Lake Ranger District
Gallatin National Forest

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INTRODUCTION

The Island Park Sustainable Fire Community (IPSFC) project area covers approximately 750,000 acres and includes portions of the Island Park and Ashton Ranger Districts of the Caribou-Targhee National Forest in Idaho and the Hebgen Basin of the Hebgen Lake Ranger District of the Gallatin National Forest in Montana (Figure 1).

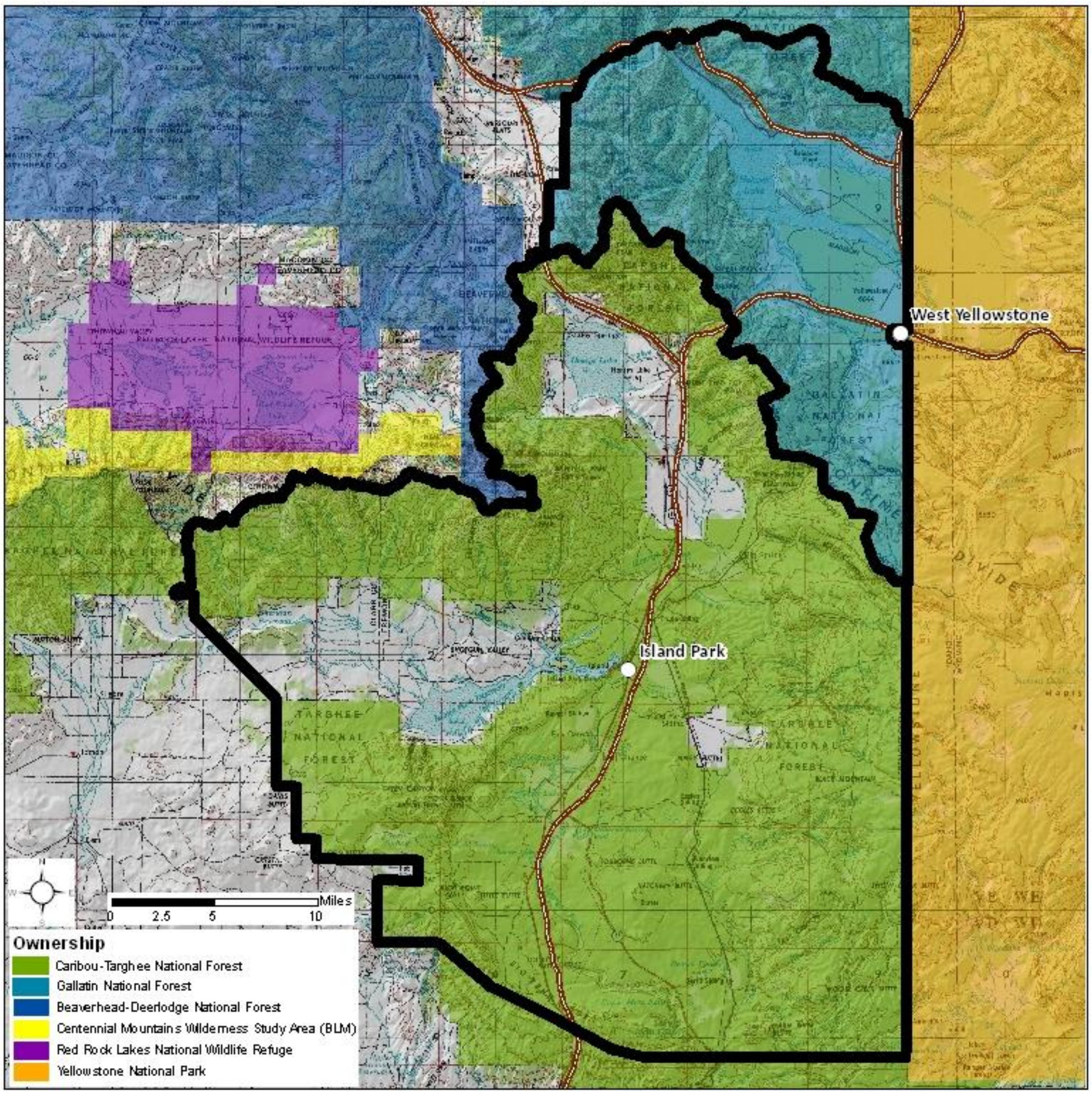


Figure 1. The IPSFC includes portions of Idaho and Montana adjacent to Yellowstone NP

The IPSFC is guided by a collaborative group composed of multiple federal and state agencies, city and county representatives, local homeowners, environmental/conservation groups, and industry representatives (electric, insurance, timber products, etc.). Based on a request from the Island Park/Ashton District Ranger to assist planning and analysis needs initiated by the IPSFC, a research scientist and the Fire Modeling Institute at the Rocky Mountain Research Station completed a project to evaluate wildfire risk to structures using outputs from a variety of fire behavior systems and structure assessment ratings.

The communities of Island Park, Idaho and West Yellowstone, Montana are heavily reliant on recreation and tourism as major components of the local economy. Year-round residents are sparse, but summer populations swell with visitors, part-time homeowners, and tourists passing through the area. Subdivisions and business centers in the project area are distributed in a clumpy nature interspersed with federal lands dominated by grass, sagebrush, Douglas-fir, and lodgepole pine. Water is plentiful and supports numerous riparian shrubs and aspen.

Cabins in the area are often not consistent with FireWise principles developed to inform homeowners of defensible space and the concept of the home ignition zone (www.firewise.org). Many of the road systems are inadequate for structure engines due to road width, turning radius, and overhead hazards which not only present challenges for emergency response but also safe egress of the public during an emergency situation. Many cabins are built with combustible materials including wood siding, wood shingle roofs, and wood decks. Vegetation is often overhanging cabin roofs.

This local effort is guided by a national effort induced by the Federal Land Assistance, Management, and Enhancement (FLAME) Act of 2009 that in turn prompted development of the interagency National Cohesive Wildland Fire Management Strategy known in short as the Cohesive Strategy (refer to www.forestsandrangelands.gov/strategy). The Cohesive Strategy is based on three fundamental elements: restore and maintain resilient landscapes, fire-adapted communities, and wildfire response.

METHODOLOGY

In order to provide science-based metrics to assess subdivisions based on the existing risk from wildfire, an assessment was completed using multiple datasets and simulation systems. Initial steps included evaluating fire occurrence in the project area to determine the scale of past disturbance, ignition patterns in the project area, and patterns of fire growth and behavior. Weather data were analyzed to establish seasonal trends and identify thresholds important for fire growth. Weather and fire records were examined to identify a representative year with fuels and weather conditions suitable for large fire growth in order to complete fire behavior analyses.

Fire Occurrence

Fire occurrence data were provided by the local units; in addition, a national fire occurrence database (Short 2013) produced for Fire Program Analysis (FPA), wildfire polygons from the Wildland Fire Decision Support System (WFDSS), and regional databases were consulted to attempt to compile complete records. Fire occurrence data prior to 1970 are generally not as complete as later records. Although numerous fires have occurred within the project area, most have been less than 100 acres (Figure 2).

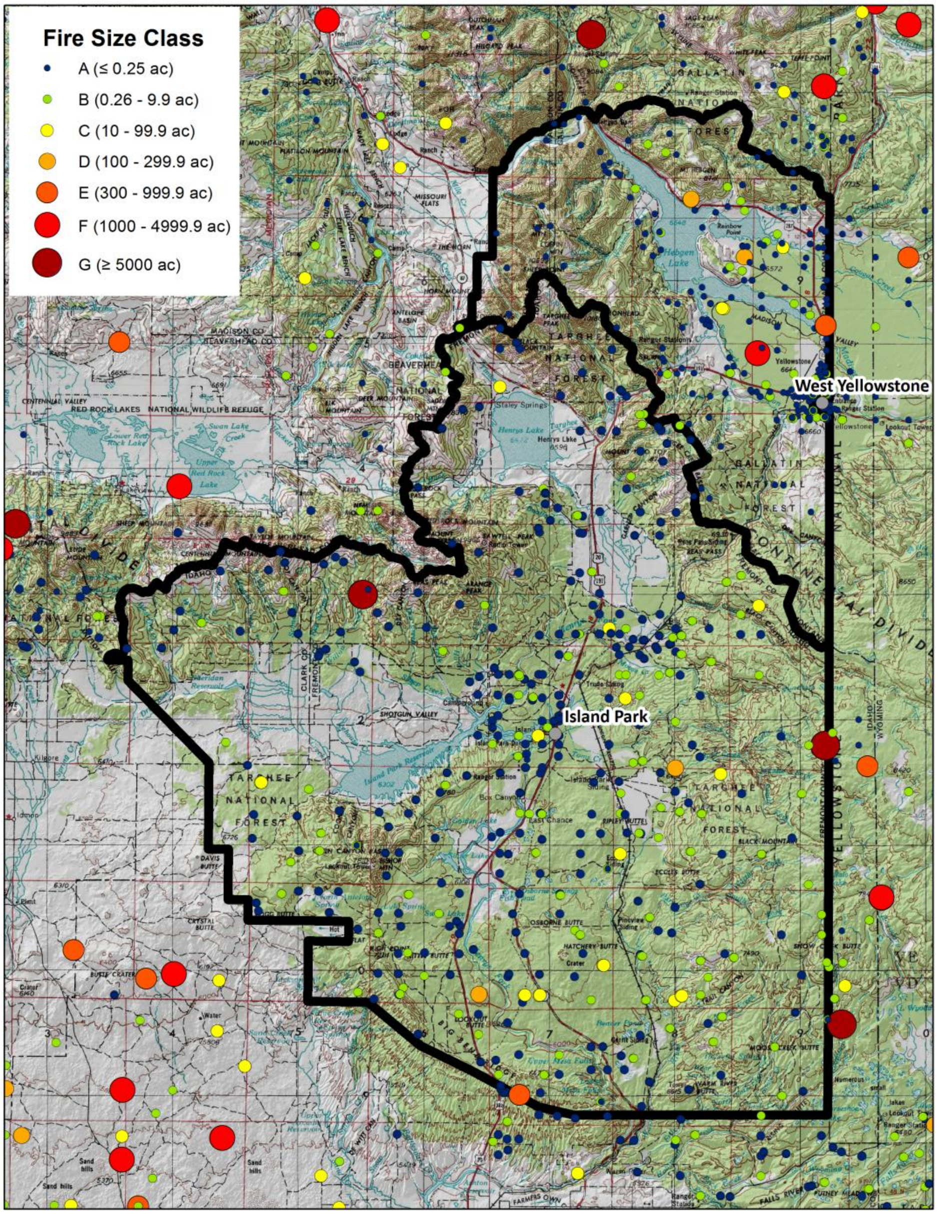


Figure 2. Fire occurrence point data by size class for the project area and adjacent lands, 1970 to 2012

There are numerous contributing factors affecting fire growth, management, and occurrence. Fire growth can be influenced by weather patterns, flammability of vegetation, horizontal and vertical fuel arrangement, topography, and landscape vegetation pattern as influenced by past disturbances and activities. Weather patterns may or may not be conducive for large fire growth; for example, some areas are consistently dry during the fire season while other areas are prone to numerous frontal passages that may increase the potential for fire growth. The flammability of vegetation is related to fuel moisture; certain compounds found within plants can also increase flammability. Horizontal and vertical fuel arrangement directly affects how a fire burns through an area. Topography affects fire spread patterns and directly influences fire behavior. Past disturbances alter vegetation structure and can also affect species composition and size class distribution. Fire management is dictated by standards and protocols within the land management plan; the fire management plan offers a more detailed guide. Wildfires may be managed for multiple resource benefit (formerly known as prescribed natural fire and wildland fire use) in identified areas if prescription criteria are met; adjacent Yellowstone National Park has had a longstanding program that allows management of wildfires to achieve resource benefits. Fire occurrence is heavily influenced by lightning patterns and patterns of human use which generally concentrate human-caused ignitions close to infrastructure (Figure 3).

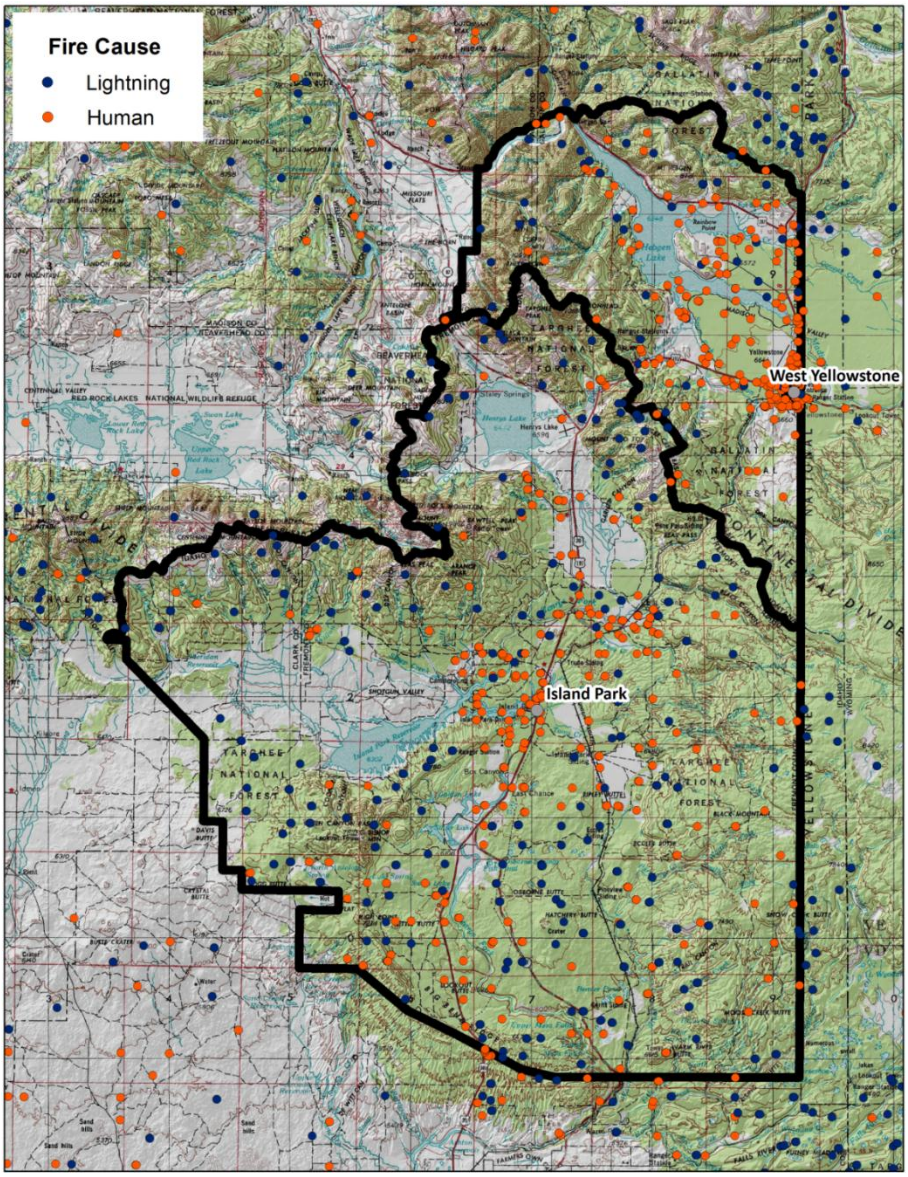
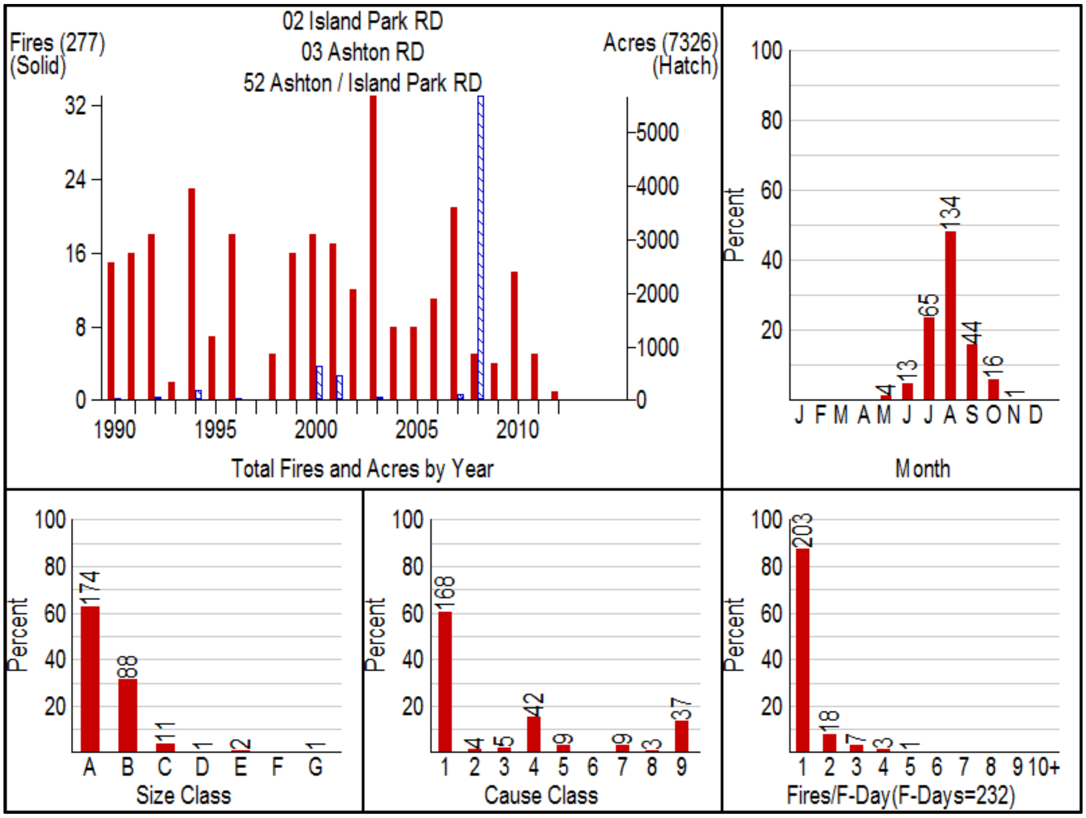


Figure 3. Human versus lightning ignitions, 1970 to 2012

Most fires in the project area occur in July and August (Figure 4) and the greatest number of acres has historically burned these months as well. Although the general fire season in this area ranges from May 1 through October 15, July and August represent the height of the fire season.

a)



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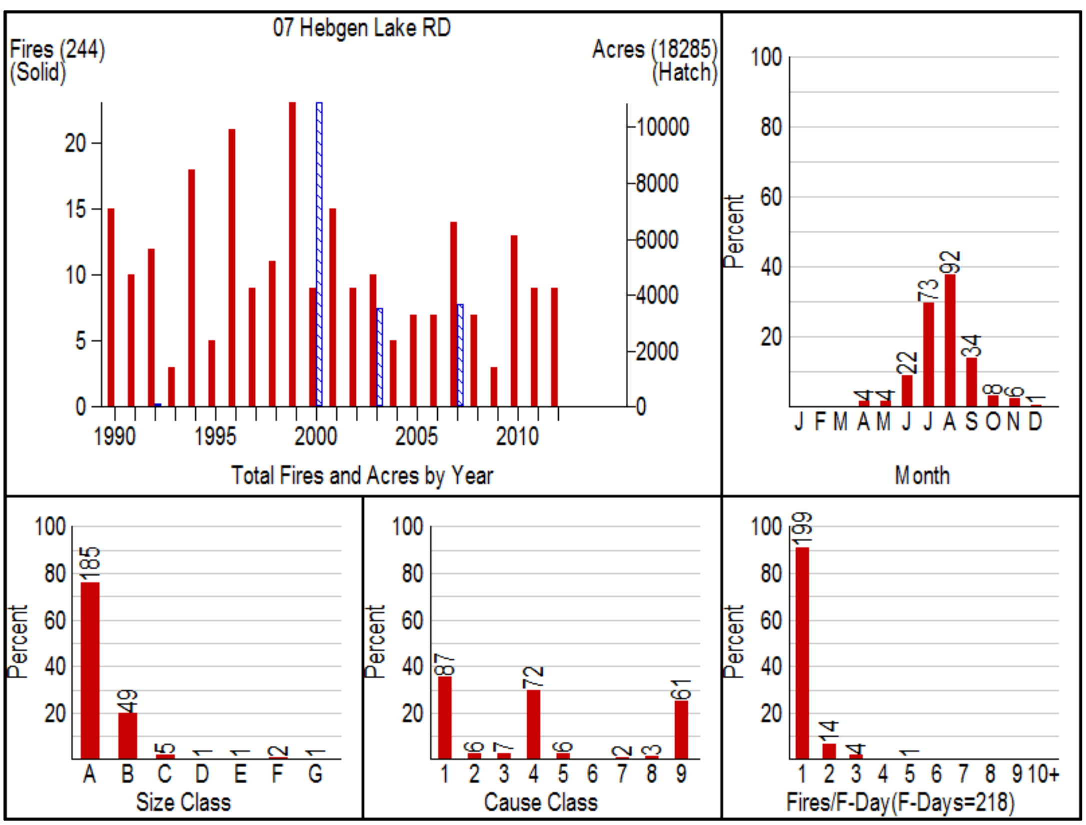


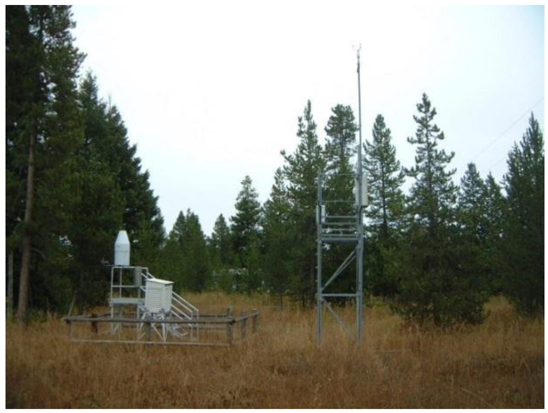
Figure 4. Fire data from 1990 to 2012 for a) Island Park/Ashton RD and b) Hebgen Lake RD

While the trends in fire cause are similar between Island Park and Hebgen Lake, Island Park has far more ignitions caused by lightning (cause code 1) while Hebgen Lake has a higher proportion of human-caused ignitions (cause code 4 = campfires, cause code 9 = miscellaneous).

Weather and Fuel Moisture

Weather data and station catalogs were downloaded from FAMWEB (http://fam.nwcg.gov/fam-web/weatherfirecd) and imported into FireFamilyPlus v4.1 (Bradshaw and Tirmenstein 2009) for the Island Park, Red Rock, and Hebgen Lake Remote Area Weather Stations (RAWS; Table 1).

Table 1. Station information for Island Park, Red Rock, and Hebgen Lake RAWS

Island Park, Idaho 6,284 ft WIMS ID #102105 Aspect – South	
Red Rock, Montana 6,690 ft WIMS ID # 254410 Aspect – Southwest	
Hebgen Lake, Montana 6,667 ft WIMS ID #244603 Aspect – Flat	

Usually representing 1200 or 1300 weather, these observations form the official record and include manual corrections meant to fix errors within the transmitted data, often from a dysfunctional sensor. Additional weather data were downloaded for these weather stations from the Western Regional Climate Center (WRCC, www.raws.dri.edu) for analyses in FireFamilyPlus. The WRCC data include raw hourly observations that have not been corrected. FireFamilyPlus was used to analyze the data to identify anomalous records, identify average versus severe fire weather conditions, and prepare wind and weather files for geospatial fire analyses.

The Island Park RAWS has data from 1967 to present. Fairly complete year-round records are available from 2000 to present, while records generally range from June 1 to September 30 or October 31 prior to 2000. This station is located at 6,284 ft near the middle of the project area at the Island Park Ranger Station. The Hebgen Lake RAWS has records dating back to 1964 but year-round data are only available from 2009 to present. Prior to 2009, observations are generally available from May 1 to September 30 or October 31. The Hebgen Lake RAWS is located in West Yellowstone, Montana in a stand of partially-sheltered lodgepole pine (Table 1). The Red Rock RAWS is situated in the Centennial Valley in Montana northwest of the project area. The location is predominantly grass and therefore lacks a canopy that would shelter surface fuels. Red Rock has fairly complete year-round data for 1988 to present.

Winds were evaluated at Island Park, Hebgen Lake, and Red Rock RAWS (Table 2). Wind speeds cover a wide range at Red Rock, most likely due to the fact that this station is truly unsheltered (Table 1). Hebgen Lake and Island Park are fairly similar and both have a narrower range of wind speeds than Red Rock.

Table 2. Breakdown of wind speeds for different daily periods

RAWS	Wind Speed (mph)	Time (hrs)			
		0800 - 1100	1200 - 1500	1600 - 1900	Combined
Island Park	**1 – 4**	64%	26%	38%	42%
	4 – 8	27%	45%	38%	37%
	8 – 13	7%	23%	19%	17%
Hebgen Lake	**1 – 4**	58%	15%	28%	32%
	4 – 8	28%	53%	50%	44%
	8 – 13	6%	26%	14%	16%
Red Rock	**1 – 4**	35%	6%	8%	16%
	4 – 8	38%	28%	29%	32%
	8 – 13	14%	33%	34%	27%
	13 – 19	7%	24%	20%	17%
	19 – 25	2%	7%	6%	5%

The Island Park RAWS was chosen for wind and weather data for a variety of reasons. The Red Rock station typically has higher wind speeds than either Island Park or Hebgen Lake. This station is located in a valley that may experience diurnal channeling of winds; the topography within the project area (especially in Idaho) is quite different in that it is situated in a caldera. The year-round station record for Island Park is more robust than Hebgen Lake.

Anomalies in the WRCC weather data were discovered using the View Observations and Climatology functions in FireFamilyPlus. The anomalous records were compared to previous and subsequent day's hourly records in FireFamilyPlus to ensure the values in question were consistent with the trend. All the observations seemed reasonable, although all records that had a wet flag set to 1 were reset to 0, essentially just allowing the precipitation to solely influence dips in the Energy Release Component (ERC) trend rather than an area-wide setting. The ERC computes the available energy per unit area for the flaming front at the head of a fire.

The ERC historical record was investigated to isolate years with higher than average ERC trends for the period from 2000 to 2012; the period prior to 2000 was excluded as the weather station was not transmitting year-round records. In simplest terms, ERC tracks seasonal drought. ERC trends are similar between Island Park and Hebgen Lake, with record-setting ERC values in 2003 and high values throughout the summer of 2007 (Figure 5). Based on ERC trends, 2003 appears to have had consistently dry conditions in July and August.

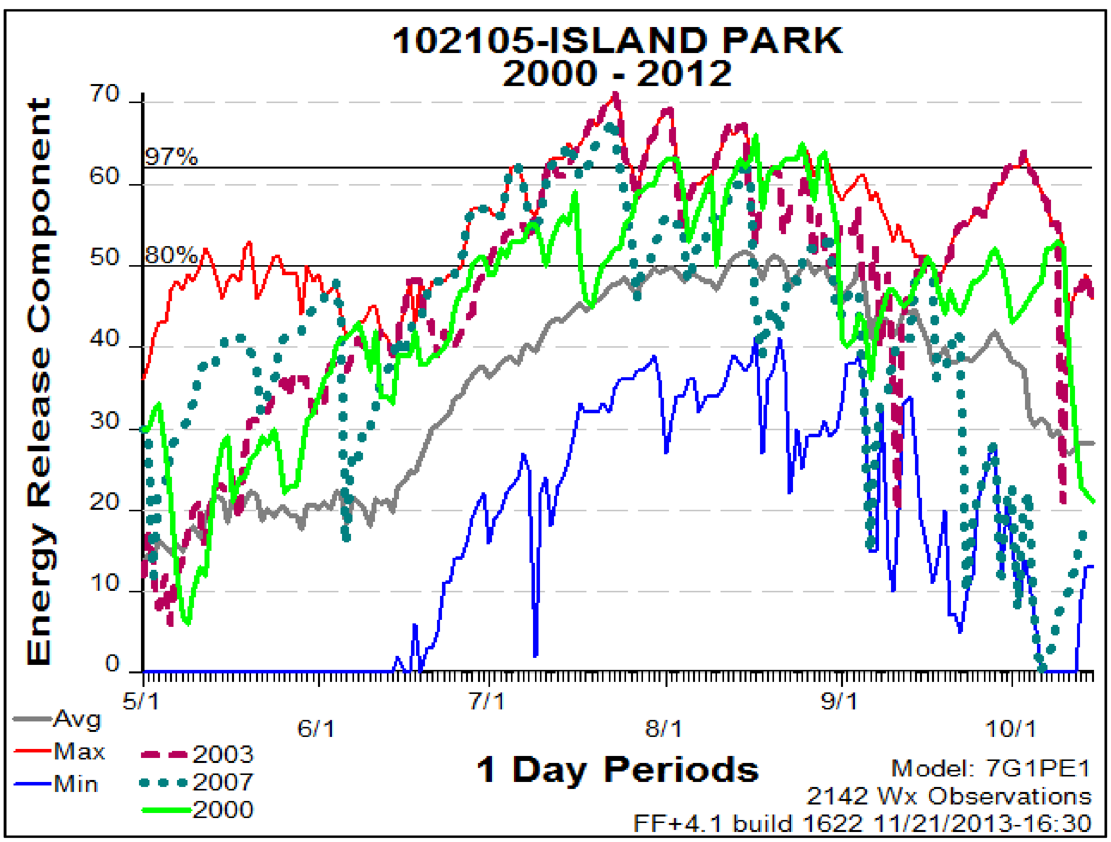
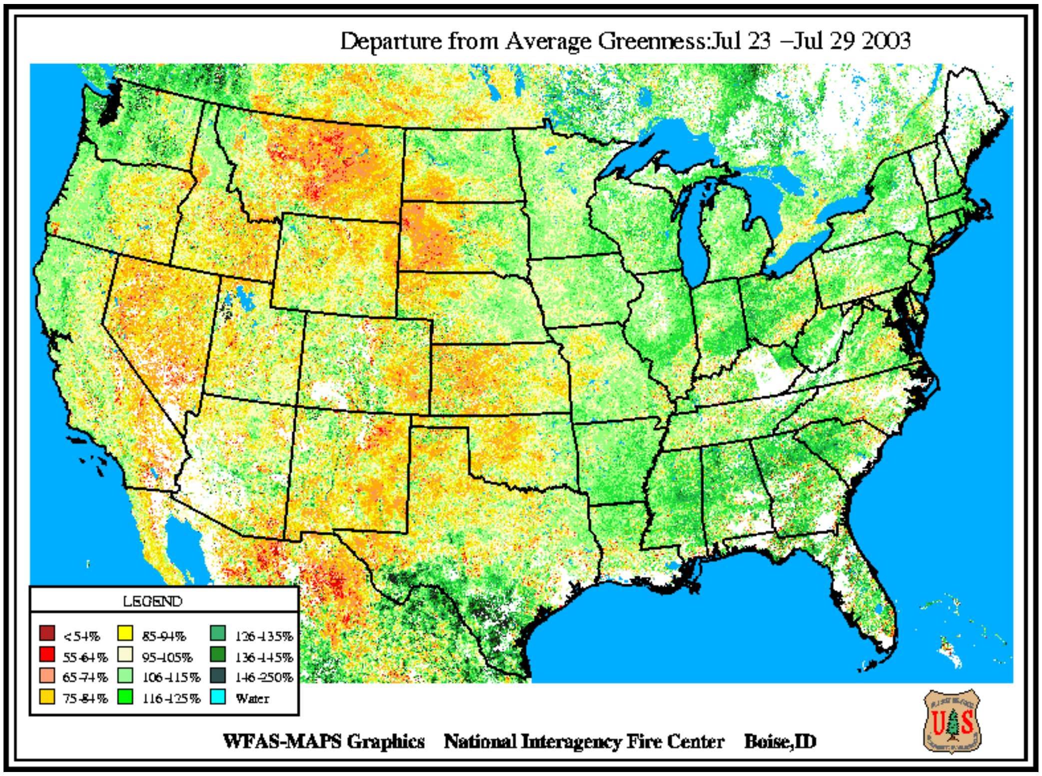


Figure 5. ERC trends for the Island Park RAWS for the period of May 1 to October 15, 2000 – 2012

Another source of information is the Wildland Fire Assessment System (www.wfas.net). Departure from average greenness in this area ranges from 65 to 115% during the latter part of July, 2003 (Figure 6a).

This value compares how green each pixel is compared to its average greenness for that week of the year. Relative greenness maps compare current to historical greenness conditions.

a)



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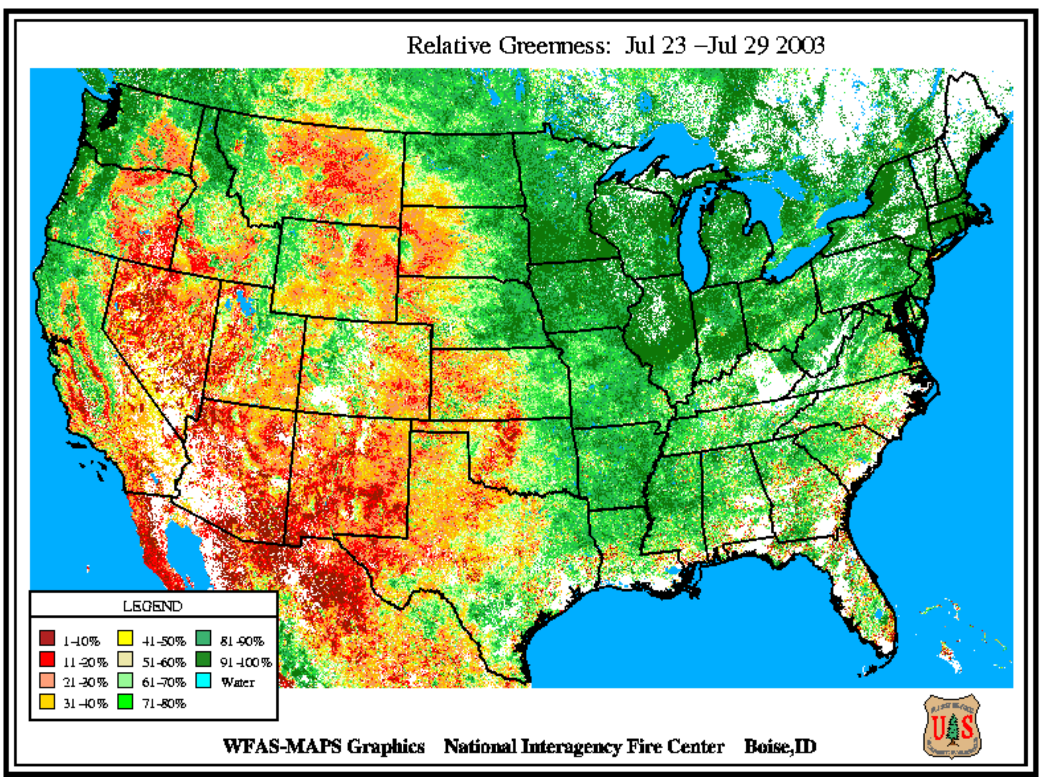

Figure 6. a) Departure from average greenness and b) relative greenness values for July 23 – 29, 2003

The relative greenness maps for southeastern Idaho and southwestern Montana in 2003 range from 30 to 90% (Figure 6b).

The Palmer Z-Index is a metric provided by the NOAA National Climatic Data Center (refer to www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html for information and www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers.php for historical data). The Palmer Z provides a means to evaluate short-term drought based on how the monthly cumulative precipitation deviates from normal. While southeastern Idaho and southwestern Montana were plagued by a significant drought in July of 2003 (Figure 7), moisture conditions improved in Idaho through the summer although southwestern Montana remained in extreme drought through September. However, the short-term drought signals that live fuel moisture values were probably below normal that summer.

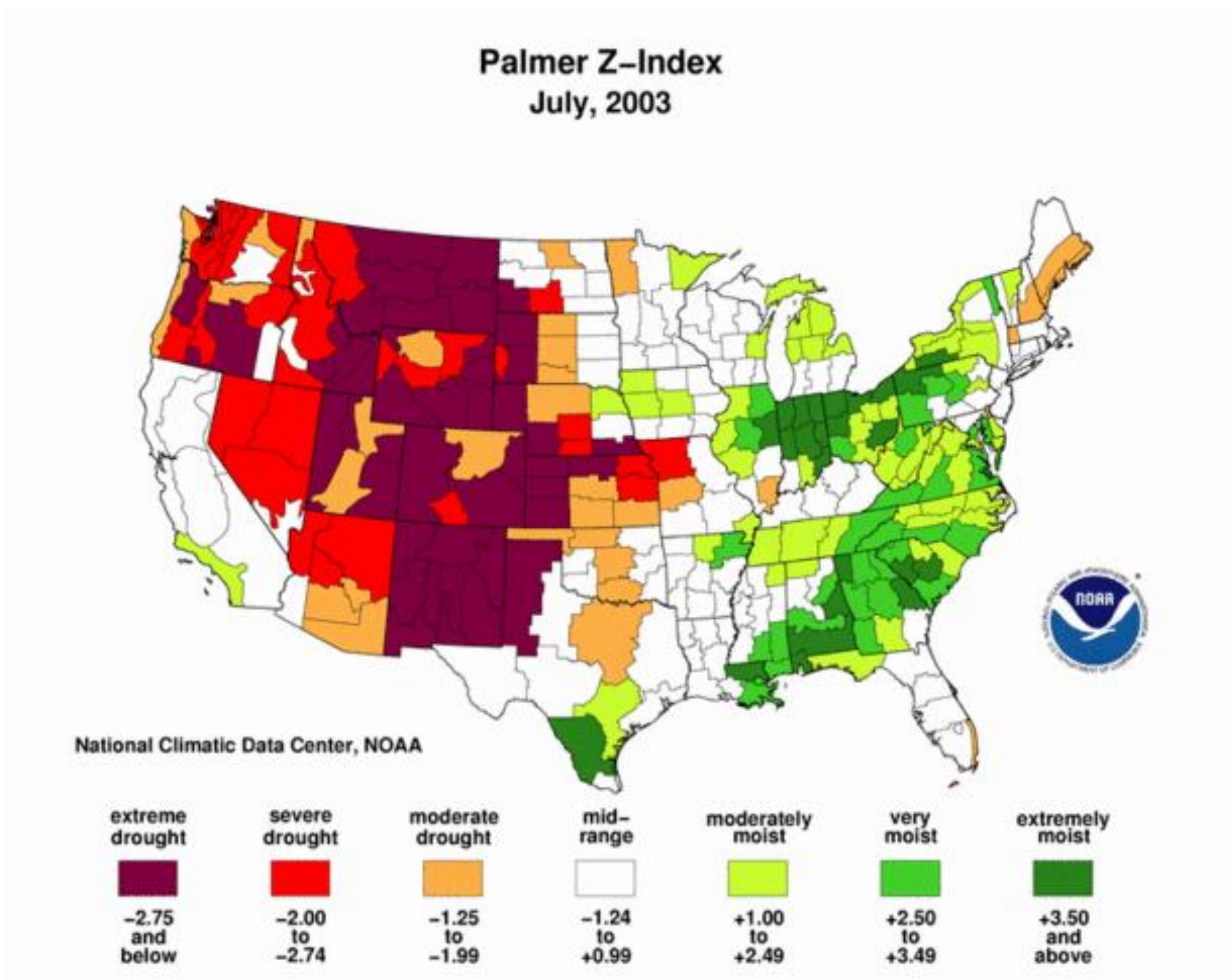

Figure 7. Palmer Z-Index drought indices for July, 2003

The U.S. Drought Monitor (http://droughtmonitor.unl.edu) also shows extreme to exceptional drought in southwestern Montana and southeastern Idaho in July of 2003 (Figure 8).

July 22, 2003 July 29, 2003

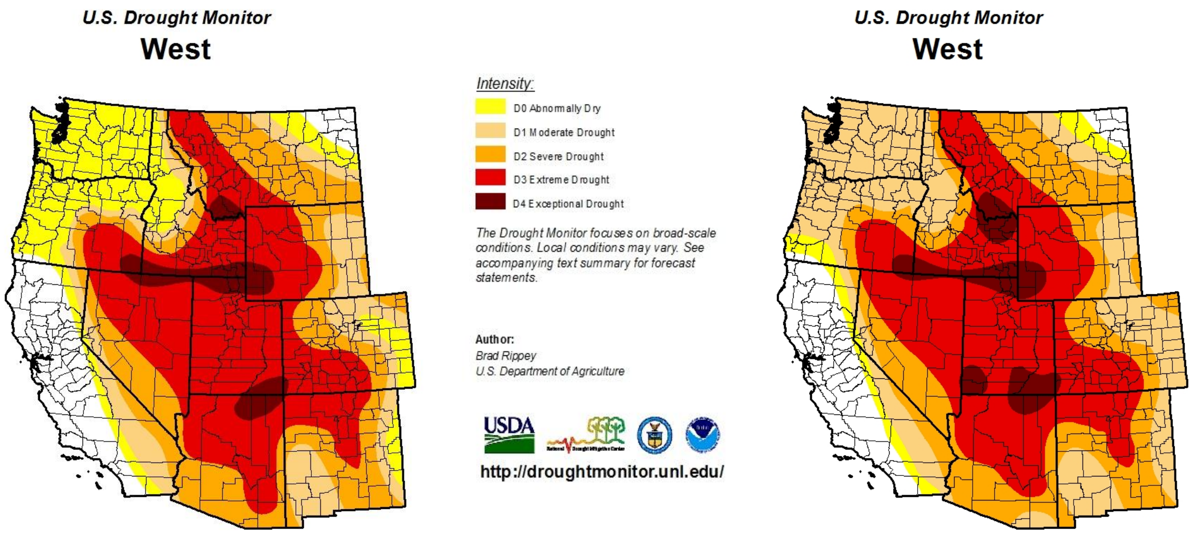

Figure 8. Intensity of drought in the west during the latter part of July, 2003

Historical Wildfires

Notable fires that have occurred in the project area in the last 30 years were queried to explore significant weather patterns, observed fire behavior, and fire growth size and pattern (Figure 9). Most were managed under a full suppression strategy due to location and/or cause (human ignitions cannot be managed for resource benefit). Other large fires that have burned in the area are not discussed here as documentation could not be found.

The Willow Fire started July 14, 2008 and burned in the Centennial Mountains (Figure 9) in Idaho north of Island Park Reservoir. It was managed as a wildland fire use fire for resource benefit and burned over 5,600 acres. Growth was generally north-west. ERC values were about average in 2008 (Figure 10) based on the period from 2000 to 2012.

The Madison Arm Fire was discovered northwest of West Yellowstone, Montana on June 27, 2007 and burned 3,660 acres. Growth the first day was estimated to be 1,200 acres and numerous evacuations went into effect for residences and campgrounds. The fire burned partially as a crown fire and frequent spotting was observed. Growth during the second burning period was estimated to be 1,800 acres and long-range spotting was reported.

The Baker's Hole Fire started just north of West Yellowstone on July 5, 2003 and burned 506 acres. This fire was described as wind-driven with spotting and torching. The Oxkiller Fire started on July 29, 2003 and burned 350 acres the first day. Fire behavior was described as torching and spotting with high rate of spread. It was contained within a few days at 882 acres.

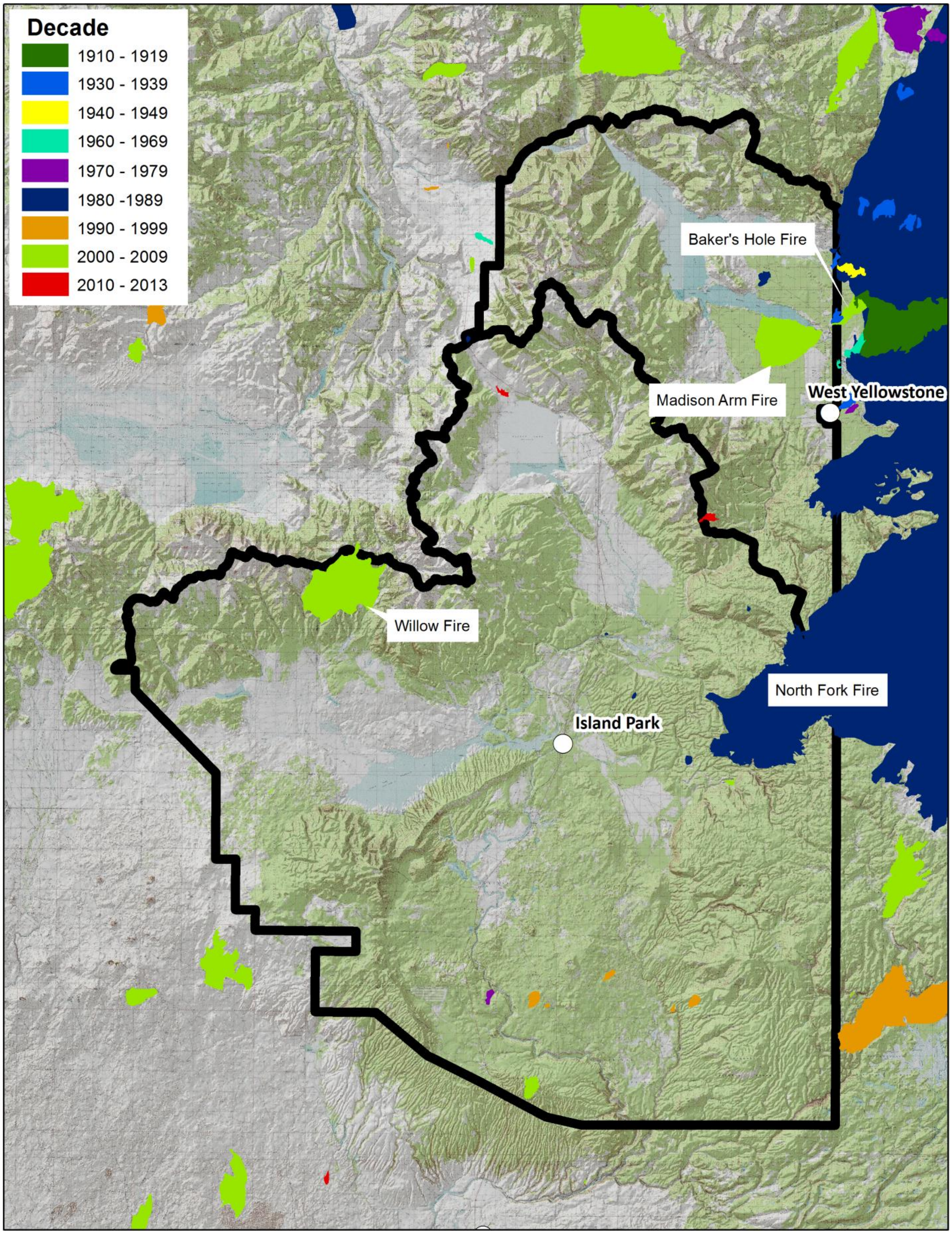

Figure 9. Available perimeters of large fires in the project area by decade, 1910 to 2013

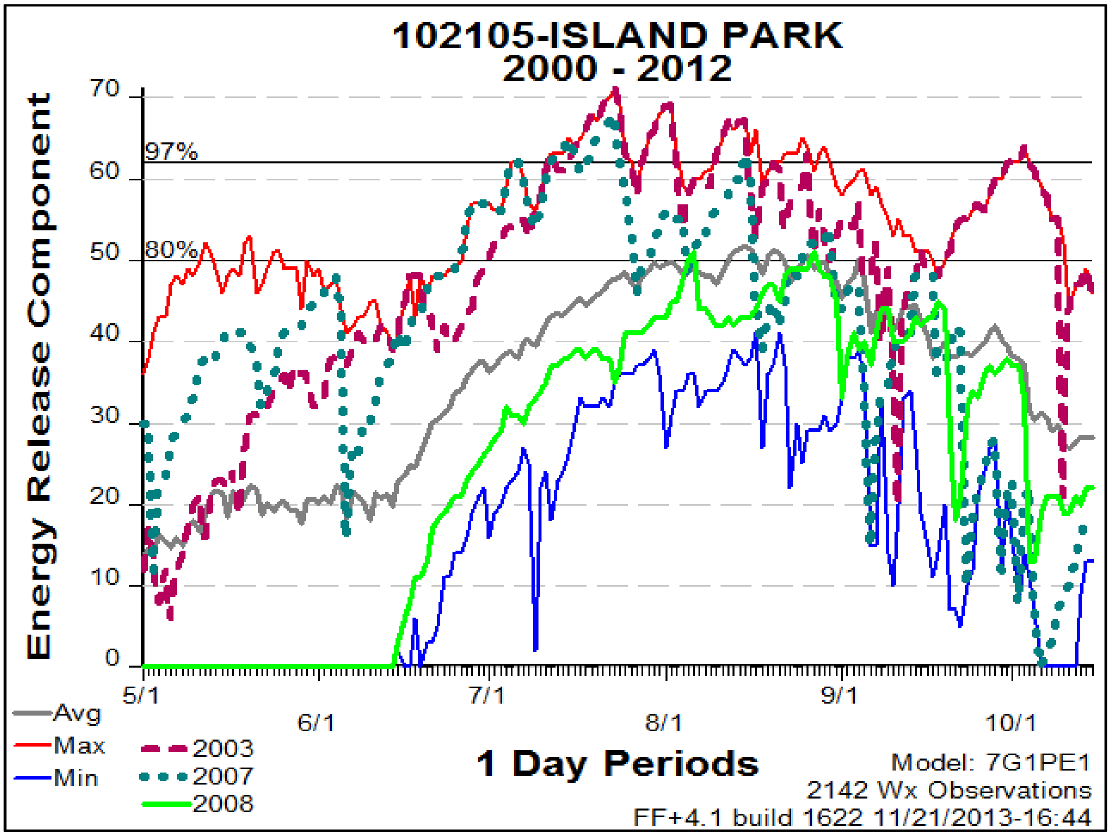

Figure 10. ERC trends for the period of May 1 to October 15, 2000 – 2012, including overlay for 2008

The North Fork Fire started July 22, 1988 by human carelessness and burned over 422,000 acres, mostly in adjacent Yellowstone National Park (YNP). Reports from YNP indicated 1988 was much drier than average, receiving only 32% of normal precipitation based on the period from 1950 to 1980 (Renkin and Despain 1992). Seasonal fuel moisture values for 1000-hr fuels (dead wood greater than 3 inches in diameter) were much lower in 1988 as compared with the previous 23 years (Renkin and Despain 1992). The Island Park RAWS recorded record low precipitation in August of 1988 and also shows that 1988 had the lowest cumulative precipitation for the period from 1967 to 2012. Mean annual precipitation at the Island Park RAWS is 12 inches, whereas 1988 logged 2 inches (17% of average) compared with maximum annual precipitation of 36 inches (286% of average) in 2011. The Red Rock RAWS further north in Montana shows a similar trend as Island Park; about 3 inches of precipitation was recorded in 1988 which is the lowest amount received during the period from 1988 to 2012 and is about 35% of normal.

Renkin and Despain (1992) reported that mature stands of lodgepole pine, Engelmann spruce, and subalpine fir were most likely to burn as a stand-replacing fire in YNP. These stands tend to have ladder fuels consisting of conifer regeneration and substantial amounts of coarse woody debris on the ground (Renkin and Despain 1992). Although the time period analyzed represents a cooler and moister period than at present, it seems likely that the type of forest that tended to burn with high intensities during this period would be similar today. Despain (1983) concluded that multi-story lodgepole pine stands in YNP did not readily support stand-replacing fire based on the fact that these stands are located in areas of lower productivity (rhyolitic soils) and lack a spruce/fir understory.

Wildfire Risk

Wildfire risk can be defined as the cumulative product of three components, namely likelihood, intensity, and effects (Figure 11); this definition is consistent with Miller and Ager's recent review of wildfire risk (2012). Intensity is summarized using flame lengths from FlamMap, burn probabilities as a product of the Large Fire Simulator (FSim) are applied to represent likelihood, and the effect, or value, is supplied by structure hazard assessments within the project area conducted in the Island Park and West Yellowstone communities.

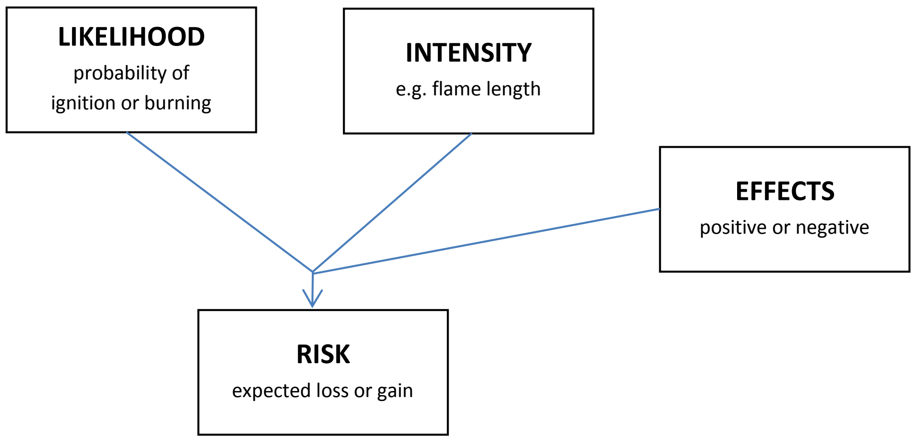

Figure 11. Components of risk (based on Miller and Ager 2012)

This process is similar to other wildfire risk assessments adding to the burgeoning body of literature on this topic, although the components and relationship may vary depending on objectives. Some projects have explored wildfire risk in terms of expected net value change, essentially evaluating risk based on the anticipated positive or negative effects from wildfire to highly valued resources (Finney 2005; Calkin et al. 2010; Thompson and Calkin 2011; Thompson et al. 2011). Scott et al. (2013) describe using a worst-case situation for wildfire intensity (such as low fuel moisture values and moderate to high wind speeds in a FlamMap simulation) to identify areas on the landscape that exceed a threshold wildfire intensity. This analysis presents risk in a slightly different way. Although the three components are the same, likelihood and intensity are combined to yield wildfire potential on one side of a matrix. The effects are found on the other side of the matrix. Presented in this way, the relationship of the risk components is clearly identified. As this analysis focuses on wildfire risk to structures rather than the risk to multiple highly valued resources, it is imperative to quantify the individual components of risk. Not only must federal managers evaluate potential likelihood and intensity of wildfires on public lands, but homeowners must also accept their responsibility in mitigating risks related to their home and immediate surroundings.

INTENSITY – Flame Lengths

Landscape fire behavior was predicted using FlamMap (Finney 2006). A number of scenarios were simulated using FlamMap, a geospatial fire behavior system capable of analyzing large landscapes given a variety of different conditions. FlamMap is conducive for comparing predicted fire behavior for multiple scenarios based on a snapshot in time, meaning that the simulation does not take into account changing weather and winds over time. FlamMap outputs are very useful for comparing fire behavior between different areas within a project area and evaluating how fire behavior may change due to different wind direction, wind speed, or fuel moisture values. FlamMap burns the entire landscape based on a given weather scenario; in this case, weather from the summer of 2003 was used as this was an active fire year in the interior northwest and conditions were dry in southeastern Idaho and southwestern Montana.

Eight physical input themes are required to model surface fire and crown fire in FlamMap; together these eight themes compose the landscape file or LCP. Topographical themes include slope, aspect, and elevation. Canopy data themes include canopy cover, canopy bulk density, canopy base height, and stand height; the final theme is fire behavior fuel models (FBFM, Scott and Burgan 2005). LANDFIRE (Landscape Fire and Resource Management Planning Tools, www.landfire.gov) Refresh 2008 data were downloaded using the LANDFIRE Data Access Tool (LFDAT v2.4) for a buffered area around the IPSFC project area; this entire area including the buffer will be referred to as the analysis area. The data were unzipped and assigned the projection NAD 1983 UTM Zone 12. In order to evaluate each theme individually, LFDAT was used to extract the individual grids from the LCP. Changes were made to the LANDFIRE data based on standard adjustments and professional expertise in Spatial Analyst in ArcGIS (refer to Appendix A). These changes, along with preliminary FlamMap simulations, were evaluated and approved by local fire managers.

In addition to LANDFIRE data, data were also acquired from the Remote Sensing Applications Center (RSAC). RSAC data for the Caribou-Targhee include vegetation dominance type, canopy cover, and tree size class information. Canopy cover is the only attribute directly applicable for fire behavior analyses, although dominance type and size class are sometimes used to help verify or inform other data attributes, such as FBFM. The RSAC data did not cover the entire project area; missing data were supplied by LANDFIRE. Canopy bulk density was calculated for the RSAC/LANDFIRE combined data using allometric equations as described in Appendix A. An analysis was conducted by Chris Toney (2013) with the Rocky Mountain Research Station to compare canopy cover data from LANDFIRE and RSAC with Forest Inventory Analysis (FIA) plot data within the analysis area; based on this comparison the canopy cover data from LANDFIRE had acceptable agreement with the FIA plot data. LANDFIRE data were also used for fire behavior fuel models (as modified in Appendix A), canopy base height, canopy bulk density, overstory height, aspect, elevation, and slope. Three different landscape files were built for FlamMap analyses using three combinations of data, including 1) LANDFIRE data, 2) LANDFIRE plus RSAC-derived data for canopy cover and canopy bulk density, and 3) LANDFIRE data and RSAC-derived data for canopy bulk density; the third data combination was the chosen landscape to yield flame lengths.

Wind and fuel moisture data were compiled for multiple scenarios (Table 3); a range of wind speeds were used to evaluate the effect of wind on fire behavior given different fuels conditions. Wind patterns were also evaluated in relation to suitable wind speed and direction for spatial fire behavior analyses (Figure 12). At the Island Park RAWS, diurnal winds range from south to northwest during the period from May 1 to October 15; wind speeds are generally less than 8 mph but do increase during the afternoon burning period (Table 2).

Table 3. Fuel moisture and wind speed values used for the two scenarios

Parameter	Dry Scenario	Moderate Scenario
Wind Speed	5 mph	5 mph
	15 mph	15 mph
	20 mph	20 mph
1-hr fuel moisture	4%	6%
10-hr fuel moisture	5%	7%
100-hr fuel moisture	7%	9%
Live herbaceous moisture	60%	80%
Live woody moisture	90%	110%

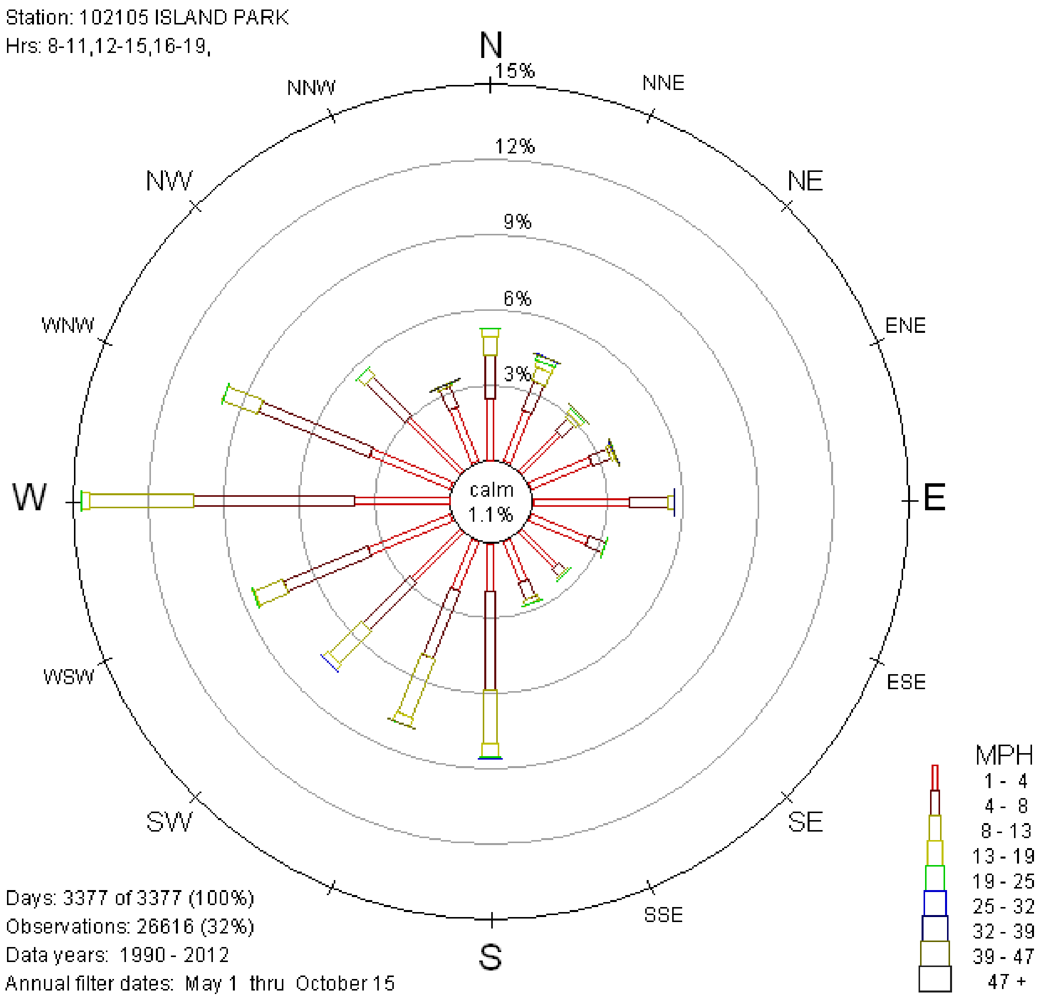

Figure 12. Diurnal (0800 – 1900) wind speed and direction for the period of May 1 to October 15, 1990 – 2012

All simulations used gridded winds which better account for the effects of topography on wind speed and direction. When gridded winds are used, valley bottoms and sheltered areas will have lower wind speeds than ridgetops and other unsheltered areas. Figure 13 displays a comparison between gridded wind outputs for the range of wind speeds used in FlamMap simulations; each gridded wind output has the same scale for ease of comparison.

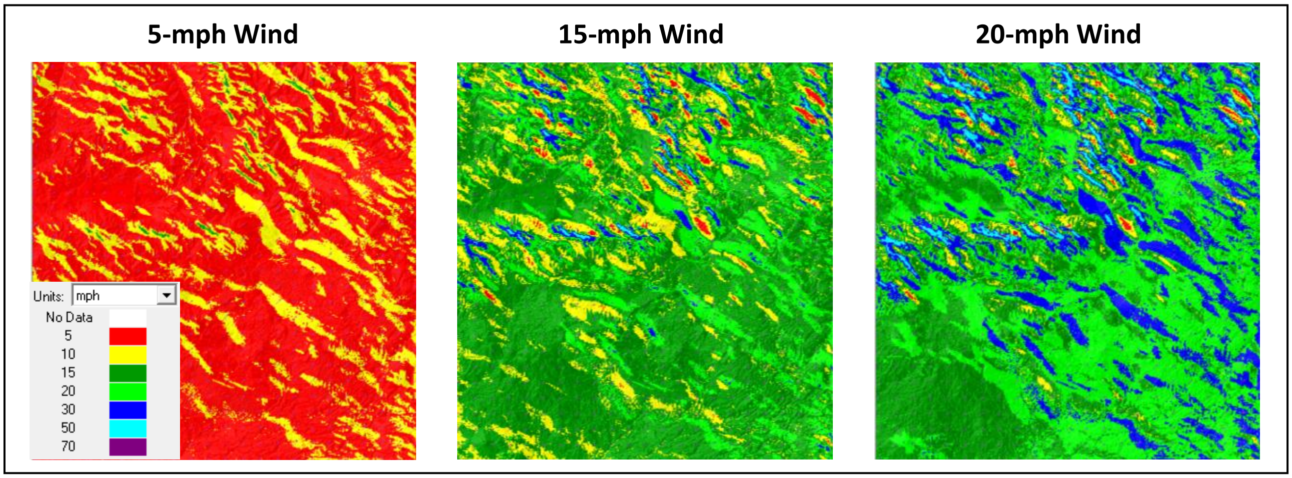

Figure 13. Comparison of gridded wind velocities

Although live fuel moisture values are available in FireFamilyPlus, it is suggested to verify these values with other sources as the live fuel moisture calculations are inherently the weakest model in the system. One of the sources that provide valuable information is the National Fuel Moisture Database (www.wfas.net/index.php/national-fuel-moisture-database-moisture-drought-103). A sample site in Dubois, Idaho tracks the live fuel moisture of Wyoming big sagebrush. Values are not available for 2003, but in July, 2007 Wyoming big sagebrush ranged between 88-92% and dropped to 77% in August. Values in other years are highly variable but range from 92-176% in July and 68-192% in August. Fuel moisture values were consistently high in 2009 and consistently low in 2012. Fuel moisture samples are also recorded at Hebgen Lake but only date back to 2009.

Numerous FlamMap simulations were conducted to evaluate the range of potential fire behavior depending on varying fuel moisture scenarios, wind speed, and direction. The simulation chosen to represent the intensity component of risk uses the dry fuel moisture scenario (Table 3) and 20-ft winds out of the southwest at 15 mph (Figure 14); 20-ft winds are described as winds 20 feet above surface vegetation that are not influenced by surface friction. Gridded wind values were generally less than 20 mph with ridgetop winds of 30-50 mph characterizing a wildfire spreading under high winds. Refer to Appendix B for FlamMap inputs.

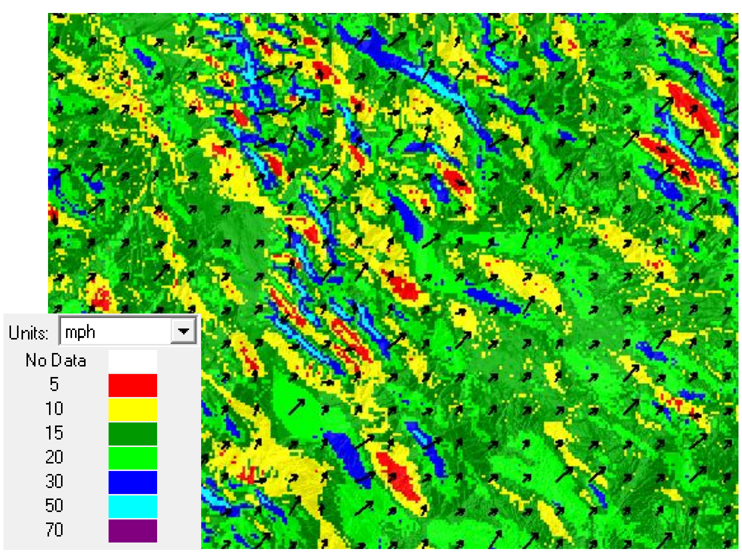

Figure 14. Gridded wind output for 20-ft winds out of the southwest at 15 mph, the arrows indicate wind direction

LIKELIHOOD – Burn Probabilities

Burn probabilities were evaluated using FSim (Finney et al. 2011) for the analysis area. FSim is useful for determining which areas are most likely to burn across the entire landscape but also evaluating potential impacts to values, such as homes and infrastructure. Burn probabilities capture the number of times a cell or pixel burns in a given period. FSim uses historic weather data from an assigned weather station to establish many possible weather scenarios coupled with fire occurrence data to guide the placement of random ignitions on the landscape. Each ignition "grows" a fire based on the minimum travel time model which essentially finds the path of least resistance a fire will travel across the landscape. Only those fire days meeting the minimum ERC threshold will show growth; the minimum ERC equates to the 80th percentile ERC for that individual weather station. For this analysis, the Island Park RAWS was used as it provides representative weather conditions for a large portion of the landscape and has a record of adequate length. Artificial weather streams were created for 30,000 years based on historical weather records from the Island Park RAWS. As FSim simulates large fires, only wildfires that grow larger than 300 acres are included in the final results.

The same landscape (LCP) file developed for FlamMap was used for FSim simulations, although cells were resampled from 30 m to 90 m resolution for computational efficiency. Fuel moisture values can be defined for the 97th, 90th, and 80th percentile in FSim. Live fuel moisture values were designated by fuel model for each percentile scenario (Table 4) rather than using fuel moisture values from the RAWS historical record. Live fuel moisture values as generated from NFDRS (National Fire Danger Rating System) are considered to be the weakest model within the system and therefore remain a current research focus at the Missoula Fire Sciences Laboratory; it is common practice for fire behavior specialists to override the system-generated live fuel moisture values from the weather record. Dead fuel moisture values were generated from the historical weather record. Refer to Appendix C for FSim inputs used. All FSim analyses used a 32-processor computer (Magic) located at the Missoula Fire Sciences Lab.

Table 4. Live fuel moisture values for each percentile scenario

Percentile Scenario	Live Herbaceous	Live Woody
97th	50%	80%
90th	60%	90%
80th	70%	100%

The option exists in FSim to use an ignition probability grid or assume equal spatial ignition probability in the analysis area. An ignition probability grid is determined by previous fire occurrence. This analysis used the ignition probability grid created for FPA. The Frisk file, otherwise known as the FlamMap fire risk export function in FireFamilyPlus, sets parameters for which wind records can be pulled from the historical weather record. The period from 1992-2012 was used. The filter was set to include the entire calendar year using the ten minute average wind speed values between the hours of 1100 to 2000.
The fire day probability distribution file sums the number of times that one or more ignitions have occurred in the historical weather record. Given that a large fire start occurs on any given day in FSim, a random draw then determines the number of large fire starts from the distribution file.

In the FSim executable, suppression can be enabled or disabled. The suppression algorithm calculates the probability of containment based on fuel type (forested versus non-forested) and the quantity of previous high spread versus low spread days (Finney et al. 2009). For the IPSFC simulations, the suppression algorithm was disabled. There are many factors to gauge in order to evaluate fire suppression. Since this analysis is meant to assist the collaborative group with prioritizing subdivisions based on risk, it was opted not to include suppression. In reality, the susceptibility of structures to wildfire can be very high during the first couple of days after a fire starts as has been demonstrated previously in this area with wind-driven, spotting fires that force evacuations.

EFFECTS – Structure Assessment Classification

In order to assess the susceptibility of a structure to wildfire and identify hazards important to emergency responders, Fremont County in Idaho conducted a county-wide assessment of many structures using RedZone software. Hazard ratings range from 15 to 135. RedZone structure hazard ratings were based on numerous criteria evaluated for each structure: siding materials, roofing material, vegetation immediately surrounding the structure, miscellaneous hazards (such as propane tanks), ingress/egress, etc. Each structure was assigned a hazard rating and classification (low, moderate, or high). One record was edited to fix the latitude and longitude coordinates (record 53 in the fremont_redzone shapefile). Additional structure assessments are being conducted by Fremont County and the Hebgen Basin Fire Department has also started assessing structures in the West Yellowstone area using RedZone software.

FIRE POTENTIAL

Fire potential combines likelihood and intensity into one metric; it is the product of burn probability and flame length for each pixel. Four classes were created to categorize results, including: non-burnable, low, moderate, and high. For those pixels defined as non-burnable in the 30 m landscape file used for FlamMap, the fire potential was also defined as non-burnable. If a pixel did not have a burn probability, the fire potential class was defined using flame lengths only (Table 5).

Table 5. Fire potential classes assigned for those pixels with no burn probability

Flame Length	Assigned Fire Potential
≤8 ft	Low
8 – 11 ft	Moderate
≥11 ft	High

Once the fire potential data was prepped, neighborhood statistics were computed using the focal statistics (focalsum) function. Focalsum for each pixel is calculated as the sum of the surrounding pixels within a 9 pixel by 9 pixel window. Focalsum captures and retains high risk values within the neighborhood that are often lost by averaging statistics such as focalmean. Since the RedZone structure assessment data is point data, computation of the neighborhood fire potential using focalsum allowed the area surrounding each structure to be used to represent the fire potential rather than the fire potential for the individual pixel that intersects that structure.

RISK – Wildfire Risk to Structures

This is the end result and identifies the wildfire risk to structures located within the IPSFC project area that have a RedZone structure hazard rating. There are nine possible combinations depending on the classified wildfire potential (combination of intensity and likelihood) and structure hazard class ranging from low wildfire potential/low structure hazard to high wildfire potential/high structure hazard.

RESULTS

INTENSITY – Flame Lengths

FlamMap shows a spectrum of predicted flame lengths based on dry fuel moisture values and moderate to high wind speeds (Figure 15). There are some large contiguous areas with predicted flame lengths less than 8 ft, which can generally be directly attacked with heavy equipment and/or firefighters. Flame lengths are expected to be low in areas that have burned within the last ten years (refer to Figure 9).

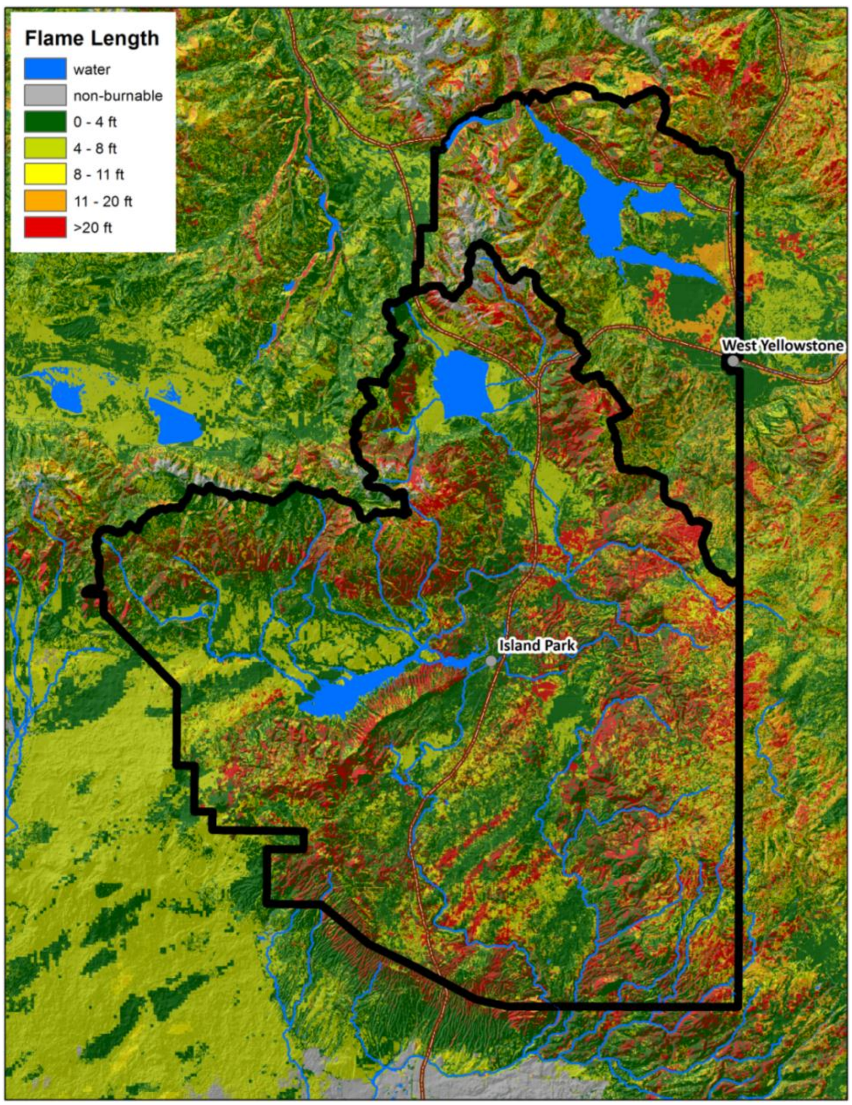

Figure 15. Predicted flame length classes representing a dry fuel moisture scenario and 15 mph wind speed

LIKELIHOOD – Burn Probabilities

Annual burn probabilities from FSim range from 0 to 0.002732 with a mean of 0.001383 for the analysis area excluding non-burnable areas (Figure 16).

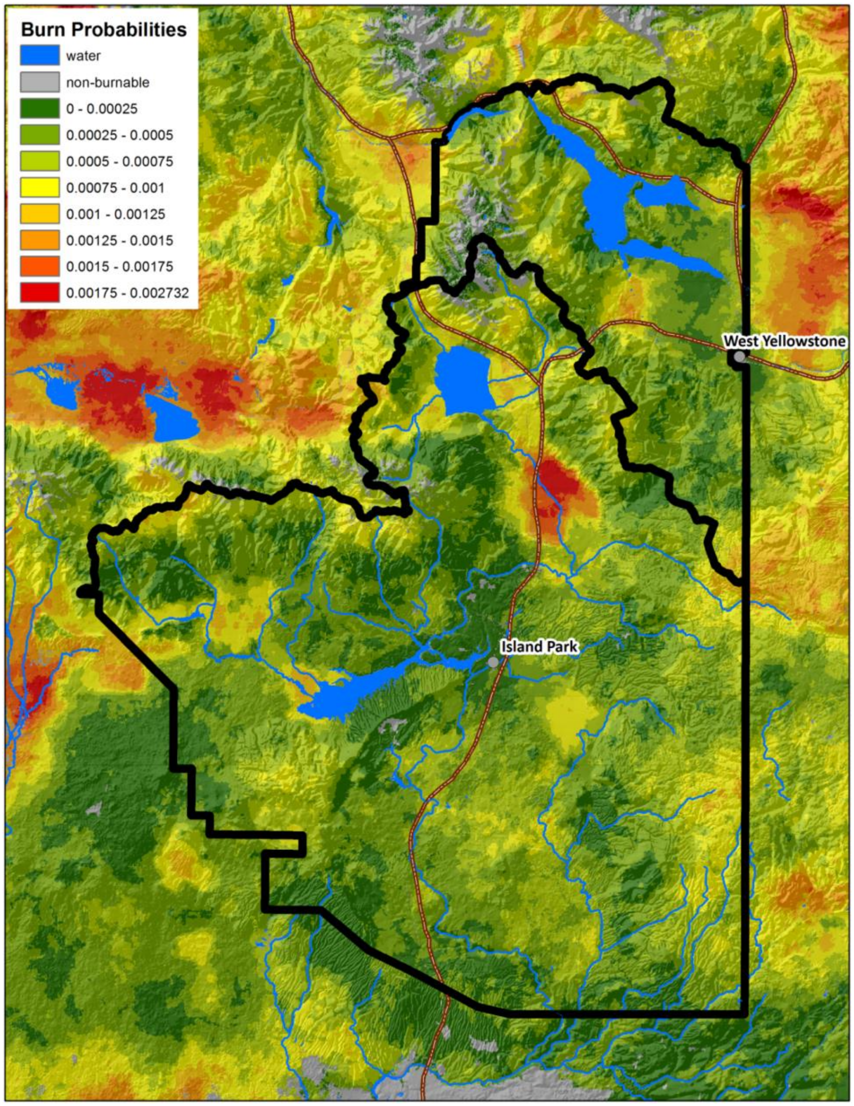

Figure 16. FSim burn probabilities for the IPSFC analysis area (project area defined by black line)

Burn probabilities calculated from FSim were validated against historical burn probabilities for the three fire program units (FPU) within the project area, including 1) GB_ID_004, Eastern Idaho, 2) NR_MT_003, Headwaters, and 3) NR_MT_005, Greater Yellowstone Area North (Figure 17). The Headwaters FPU is not within the project area but is part of the analysis area. These three FPUs total 26,746,845 ac. Based on actual fire occurrence data (Short 2013) from 1992-2010, the average annual burn probability is 0.003964 and the maximum annual burn probability is 0.013742 (Table 6) for the three combined FPUs. Figure 18 compares mean annual burn probability for the three combined FPUs, each individual FPU, and FSim results for the IPSFC analysis area. The mean burn probability for the IPSFC falls within the 95% confidence interval for the combined and individual FPUs.

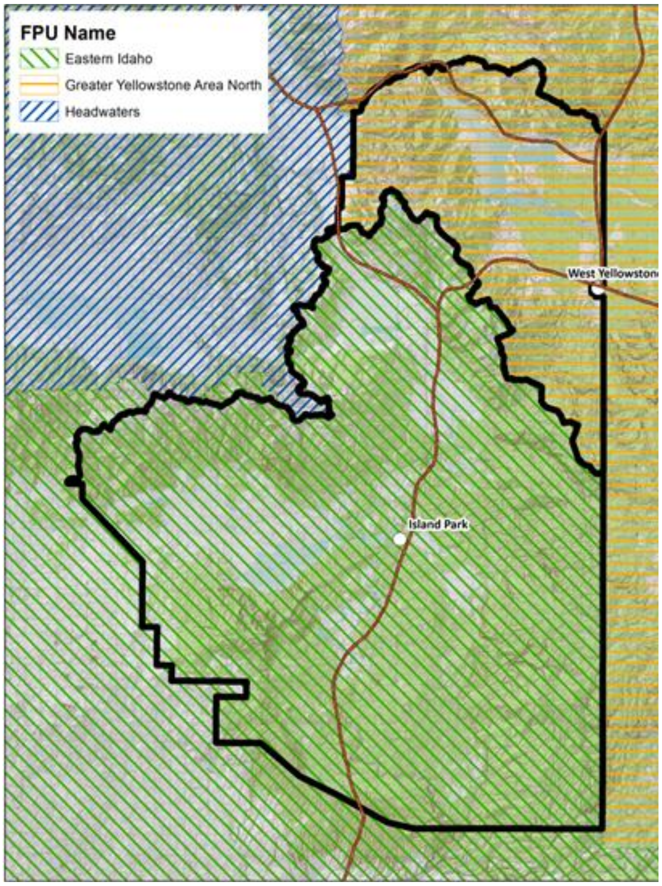

Figure 17. Three FPUs n the IPSFC analysis area

Table 6. Acres burned per year and annual burn probability for the three FPUs combined

Year	FPUx3 Acres Burned	Historical Annual Burn Probability
1992	89,752	0.003356
1993	503	0.000019
1994	107,345	0.004013
1995	22,612	0.000845
1996	250,681	0.009372
1997	3,662	0.000137
1998	69,443	0.002596
1999	94,559	0.003535
2000	326,871	0.012221
2001	57,291	0.002142
2002	16,762	0.000627
2003	127,613	0.004771
2004	1,177	0.000044
2005	48,186	0.001802
2006	367,559	0.013742
2007	212,525	0.007946
2008	34,126	0.001276
2009	22,402	0.000838
2010	161,530	0.006039

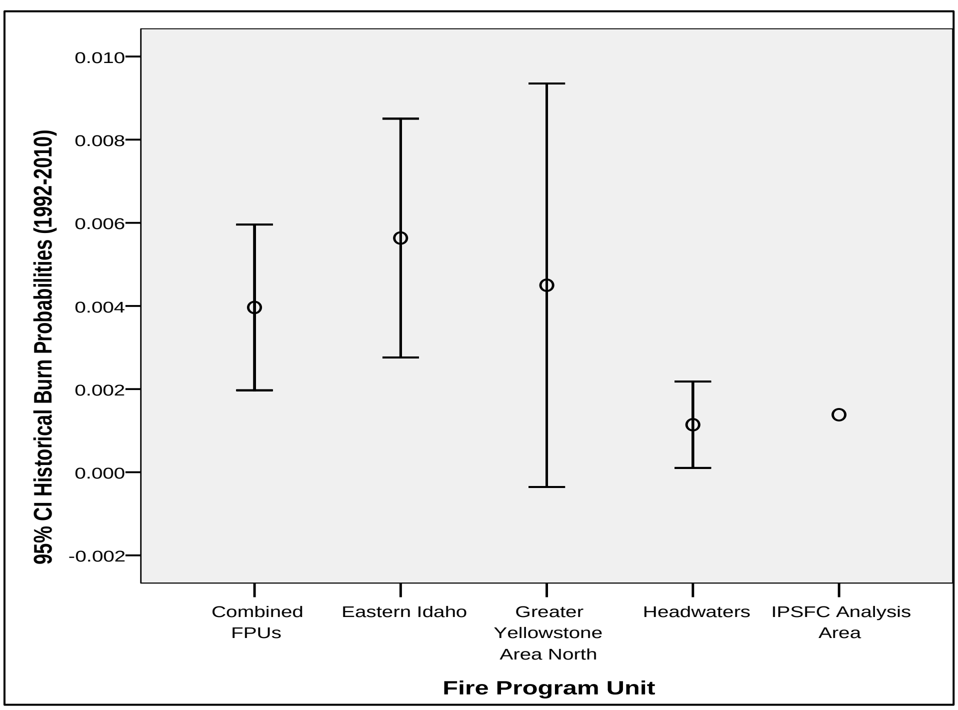

Figure 18. Mean burn probabilities with 95% confidence interval for different FPUs and mean burn probability for the IPSFC

The fire distribution over the analysis area was evaluated to identify the locations where the large fires started and the trend over the landscape (Figure 19). The historical fire occurrence is highly variable, as historic ignitions are not focused in just one area or one vegetation type (Figure 2).

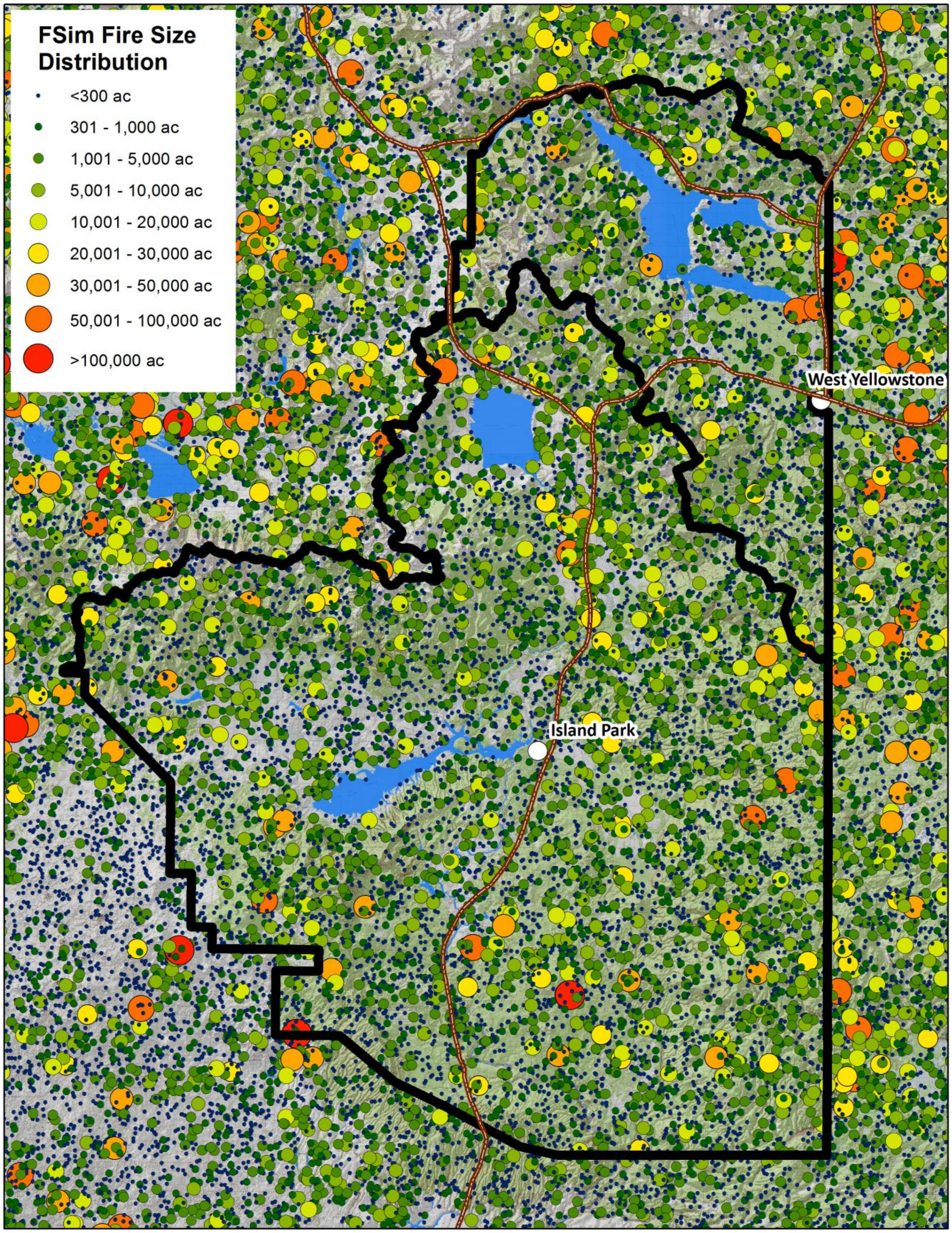

Figure 19. Distribution of simulated fires from FSim within the analysis area

FIRE POTENTIAL

Fire potential is the product of flame lengths and burn probabilities (Figure 20).

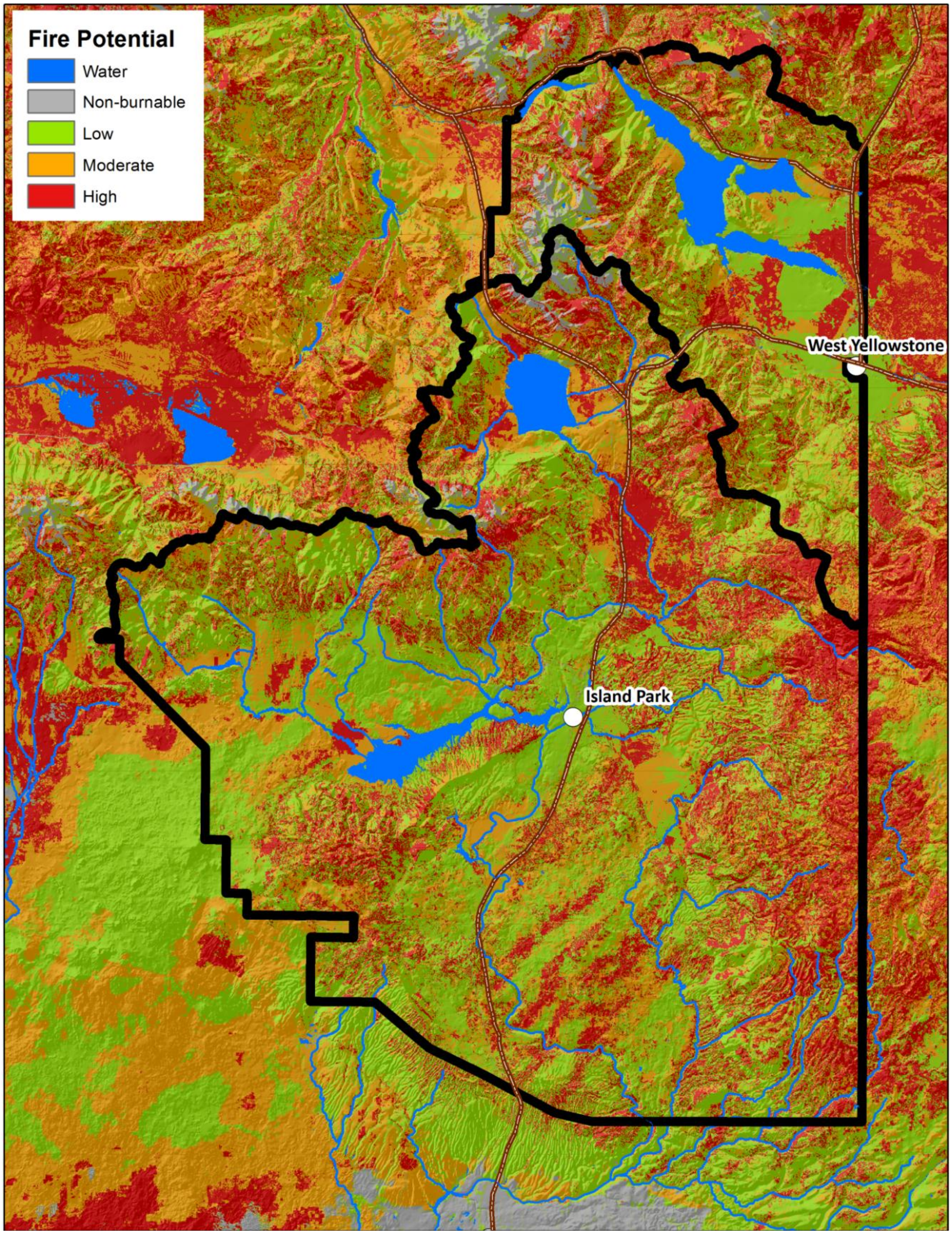

Figure 20. Fire potential within the analysis area, as defined by the combination of burn probabilities and flame lengths (project area defined by black line)

The focalsum statistical function was applied to fire potential (Figure 21).

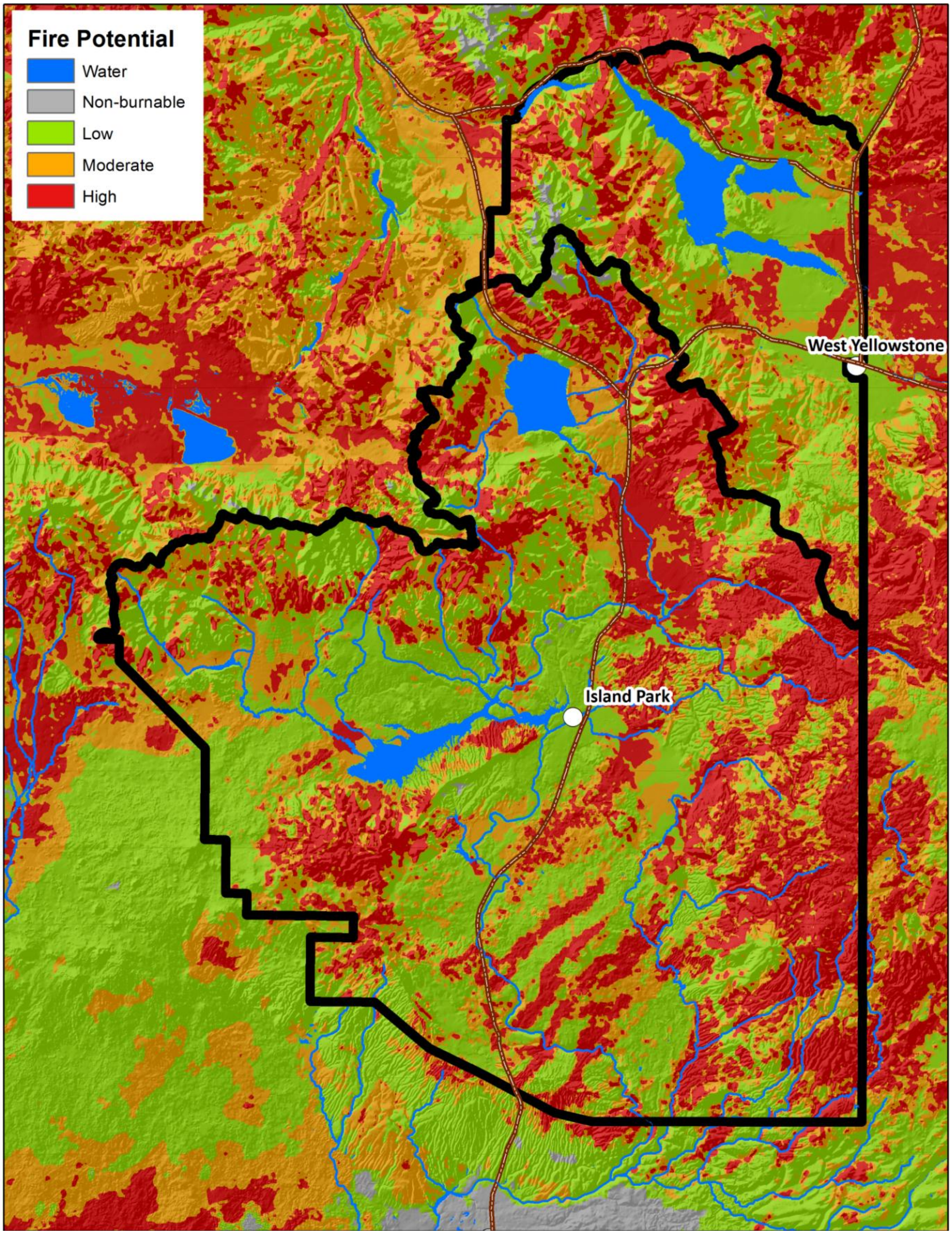

Figure 21. Neighborhood statistics (focal sum function) applied to fire potential (project area defined by black line)

EFFECTS – Structure Assessment Classification

Most of the structures assessed by Fremont County, Idaho were assigned a moderate or high hazard rating (Table 7).

Table 7. Structure assessment classification

RedZone Hazard Class	Value Range	Quantity
Low	0 – 85	305
Moderate	86 – 100	680
High	100 – 135	609

RISK – Wildfire Risk to Structures

The IPSFC project area was split into subdivisions to enable easier prioritization (Table 8). Numerous subdivisions have a low wildfire risk based on the simulation scenarios, but all subdivisions have structures with moderate and high hazard ratings. While some subdivisions should be evaluated for potential treatments designed to modify fire behavior, all subdivisions would benefit by improving ingress and egress and applying FireWise principles to decrease structure susceptibility.

Table 8. Summary of structure assessment and wildfire potential classes by subdivision

Subdivision	Number of Structures	Structure Assessment Class			Wildfire Potential Class		
		Low	Moderate	High	Low	Moderate	High
Aspen Ridge	70	24	28	18		16	54
Bighorn Hills Estates	28	4	13	11		22	6
Box Canyon	47	4	16	27	47		
Buffalo River Area	174	33	83	58	81	34	59
Cowan	94	44	35	15	94		
Fransenville	14	5	8	1	1	3	10
Henry's Lake Outlet	52	19	20	13	33	19	
Macks Inn Area	211	35	76	100	146	52	13
Old West Ranches	15	3	7	5	14	1	
Pinehaven	131	14	63	54	131		
Rancho McCrea	110	18	48	44	83	23	4
Sawtell Estates	75	11	35	29	66	9	
Shotgun West	31	2	9	20	21	10	
Stonegate Area	36	4	23	9	36		
Valley View	37	7	17	13		28	9
Wilding	58	22	26	10	58		
Yale Creek Area	411	56	173	182	206	126	79
TOTAL	**1,594**	**305**	**680**	**609**	**1,017**	**343**	**234**
PROPORTION		**19%**	**43%**	**38%**	**63%**	**22%**	**15%**

A couple of subdivisions have already been identified as priority subdivisions by the collaborative group, including the Yale Creek area just north of Island Park Reservoir. Yale Creek has numerous houses, many of which have been assigned moderate or high RedZone structure hazard ratings (Table 8). When evaluating the wildfire risk to structures in the Yale Creek area, the structures in the northern part of the subdivision have a much higher wildfire potential than those in the south (Figure 22); this trend is due to the adjacent fuels and predicted fire behavior.

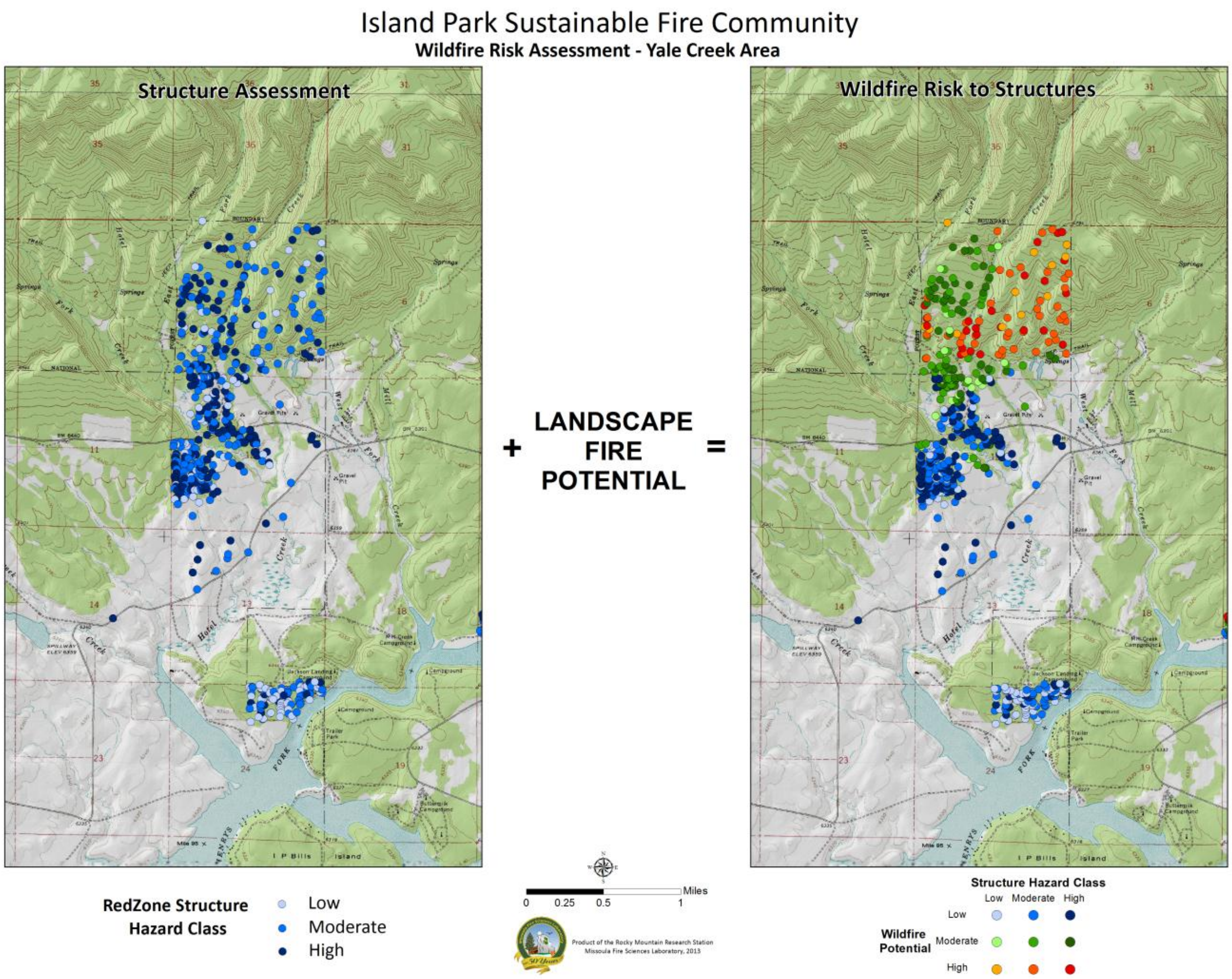

Figure 22. Wildfire risk to structures in the Yale Creek area

It is possible to backtrack to ascertain the source that results in higher wildfire potential in the northern half of Yale Creek. While the burn probabilities are similar throughout the entire subdivision, predicted flame lengths are much higher in the northern half. In the Yale Creek example, a fuels treatment project designed to reduce flame lengths may effectively modify fire behavior; however, effective mitigation would need to include actions to decrease structure flammability and improve road conditions to allow emergency response throughout the entire subdivision.

CONCLUSION

The Island Park Sustainable Fire Community is working to towards a sustainable fire-adapted social and ecological community that is resilient and accepting of disturbance. Since wildfire is an important disturbance process that can have wide-reaching social and ecological implications, the IPSFC has focused their initial efforts to understand and evaluate the potential risk to structures from wildfire. This risk assessment will enable the collaborative group to move forward in subdivision prioritization and potential treatment evaluation in addition to providing a tool to educate homeowners.

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APPENDIX A. Landscape Data Calculations and Adjustments

Remote Sensing Applications Center (RSAC) Data

Canopy bulk density refers to the total canopy fuel available for combustion (usually all foliage and one-half of the finer diameter branch wood). Canopy bulk density calculations are complex, typically requiring diameter, height, crown base height and crown radius for each tree. This information is then used to calculate biomass quantities for each tree using allometric biomass equations; data from individual trees are then aggregated to represent the stand. Biomass data were developed from the RSAC data layers and modeling. To develop new canopy bulk density data built from the RSAC data layers the following process was carried out:

1. The RSAC dominant cover type map was used to stratify forested areas into groups to facilitate modeling efforts. Two main groups were identified: lodgepole pine and Douglas-fir forests.
2. The RSAC tree size data layer had three diameter classes in the forested cover types: 4”, 12” and 20”. The RSAC tree size data layer was not used for non-forested cover types. For each of the two primary species in the study area (lodgepole pine and Douglas-fir), these diameter class groups were linked to expected individual tree characteristics typical for those species in the region. This information is presented in Table A1.

Table A1. Tree characteristics by species and size class groups

	LODGEPOLE PINE		
diameter (inches)	**4**	**12**	**20**
crown radius (m)	1.2	2.2	3.8
ht (ft)	30.0	55.0	85.0
crown ratio	0.6	0.4	0.3
cbh (ft)	12.0	33.0	59.5
cbh (m)	3.7	10.1	18.1
canopy len (m)	5.5	6.7	7.8
diam cm	10.0	30.0	50.0
fol bm (kg/m3)	2.6	15.6	36.2
branch bm (kg/m3)	3.1	34.4	104.5
usable branch bm (kg/m3)	0.5	5.2	15.7
total crwn fuel biomass (kg/m3)	3.0	20.8	51.8
tree footprint (m2)	4.5	15.2	45.3
	DOUGLAS-FIR		
diameter (inches)	**4**	**12**	**20**
crown radius (m)	1.2	2.2	3.8
ht (ft)	30.0	55.0	85.0
crown ratio	0.8	0.7	0.4
cbh (ft)	6.0	16.5	51.0
cbh (m)	1.8	5.0	15.5
canopy len (m)	7.3	11.7	10.4
diam cm	10.0	30.0	50.0
fol bm (kg/m3)	6.0	35.0	82.7
branch bm (kg/m3)	5.6	58.3	173.8
usable branch bm (kg/m3)	0.6	5.8	17.4
total crwn fuel biomass (kg/m3)	6.6	40.8	100.1
tree footprint (m2)	4.5	15.2	45.3

Heights were predicted from diameters using the Lundqvist equation (Stage 1975; Zeide 1993):

$$HT = 4.5 + a * e^{(-b * DBH^{-c})}$$

Biomass quantities were calculated for each tree using equations from Lambert et al. (2005) and Ung et al. (2008). Forest Vegetation Simulator (FVS) was used to calculate other missing prototypical tree attributes. Stand biomass quantities were developed with a simple calculation relating the predicted area footprint of a tree to the total stand area based on canopy cover and tree size, as follows:

TPH=(10000/ TreeFootprintArea)*(PercentCover /100)*2

This yielded the following table of trees per hectare. Combining this information with biomass quantities per tree from Table A1 yielded a table of total canopy biomass per hectare; dividing this biomass by the rectangular volume defined by the difference between canopy height and canopy base height produced the final bulk density layer. This approach is clearly very simplistic in that it assumes homogeneous stands but it provides a relatively straightforward way of building a canopy bulk density spatial data layer from limited input data.

Table A2. Trees per hectare by size class group

% Cover	Trees per Hectare		
diameter (inches)-->	**4**	**12**	**20**
20	885	263	88
40	1769	526	176
55	2433	724	243
65	2875	855	287
80	3539	1053	353
	Douglas-fir Canopy Bulk Density		
	4	**12**	**20**
20	0.08	0.09	0.09
40	0.16	0.18	0.17
55	0.22	0.25	0.23
65	0.26	0.30	0.28
80	0.32	0.37	0.34
	Lodgepole pine Canopy Bulk Density		
	4	**12**	**20**
20	0.05	0.08	0.06
40	0.10	0.16	0.12
55	0.13	0.22	0.16
65	0.16	0.26	0.19
80	0.20	0.33	0.24

LANDFIRE Data

The following adjustments were made to fire behavior fuel model and canopy cover values for LANDFIRE data (Table A3).

Table A3. Adjustments to LANDFIRE data

FIRE BEHAVIOR FUEL MODELS		
Original Value	**Adjusted Value**	**Comments**
107	102	This fuel model would more than likely overpredict rate of spread and flame lengths.
143	142	Changed from humid to dry climate fuel model.
147	142	This fuel model would likely overpredict rate of spread and flame lengths. This is a large area located directly west of Island Park Reservoir. Assuming this is dominated by sagebrush with varying amounts of grass. This could also be reclassified as fuel model 122 if that would be more accurate, which tends to have slightly higher flame lengths and faster rate of spread due to a more continuous fuelbed.
162	161	Changed from humid to dry climate fuel model.
182	161	Not very many pixels, assuming this to be aspen? Changed to a dynamic fuel model.
186	161	Not very many pixels, assuming this to be aspen? Changed to a dynamic fuel model.
CANOPY COVER		
Original Value	**Adjusted Value**	**Comments**
>75%	75%	It's not common to have canopy cover values greater than 75% in the interior Northwest.

APPENDIX B. FlamMap Inputs

Fuel moisture file (FMS)	IslandPark_moderate.fms, IslandPark_dry.fms
Foliar moisture content	100%
WindNinja cell resolution	270 m
Fuel moisture conditioning period	07/15/2003 1400 – 07/23/2003 1400
Weather file (WTR)	IslandPark_2003.wtr
Wind File (WND)	IslandPark_2003.wnd
Crown fire method	Scott and Reinhardt

APPENDIX C. FSim Inputs

Landscape file (LCP)	IPSFC_hybrid_90m.lcp
Custom fuel model file (FMD)	disabled
Rate of spread adjustment file (ADJ)	disabled
Crown fire method	Scott and Reinhardt
Ignition probability grid	All_Fires_BW_50000.asc
Resolution	90 m
Threads per fire	1
Number of simulations (number of seasons)	30,000
Frisk file	IslandPark_frisk.txt
Julian day of year for season start	30
Burn probability file (for output burn probability)	IPSFC_hybrid.asc
Grid distance units	meters
Barrier file	disabled
Fire day probability distribution file	firedistFPU_GBID004_NRMT003_NRMT005.txt
Suppression	disabled
Fire size limit (maximum fire size)	500,000 ac
ERC stream file (ERC; pre-generated)	disabled
Record	Create new random sequence

APPENDIX D. Assumptions and Limitations

Fire Spread Model Assumptions

The surface fire spread model as developed by Rothermel (1972) uses fire behavior fuel models (FBFM) to compartmentalize the physical and chemical fuel inputs necessary for the model. Additional models have incorporated substantive changes including spotting from firebrands (Albini 1979), crown fire initiation (Van Wagner 1977), and crown fire spread (Rothermel 1991) that have been combined in some of the fire behavior systems. The assumptions underlying the surface fire spread model assume homogeneity in what is naturally a dynamic system. It is therefore crucial to combine model outputs with professional judgment to ensure the results are valid and believable (Williams and Rothermel 1992). Draft FlamMap outputs were validated by fire management personnel at the Island Park/Ashton Ranger District. The following assumptions are essential when applying the surface fire spread model and apply to both FlamMap and FSim (Rothermel 1972; Rothermel 1983).

1. The fire is free-burning. Hence, suppression actions are not accounted for and the ignition origin is not influencing the fire.
2. Fine fuels less than 1 inch in diameter are more important to the fire's spread than larger fuels.
3. Fire is predicted at the flaming front (direction of maximum spread). The surface area to volume ratio of the fuels determines the residence time of the flaming front.
4. Fuels are continuous and homogeneous.
5. The basic spread model is for a surface fire burning within surface fuels. Smoldering and long-range spotting are not considered as they are outside the scope of the surface fire spread model. Torching, crowning, or spotting can be predicted with the addition of other models.
6. Weather is uniform and consistent.
7. Topography is uniform.
8. The model has been designed for peak fire season. July and August are the peak fire months for the Island Park/Ashton and Hebgen Lake Ranger Districts as the majority of acres have burned in these two months.
9. The fire perimeter is based on a smooth ellipse.
10. The spread model simulates a fire spreading in a quasi-steady state, whereas spread from any portion of the fire is independent of the other side.

FlamMap Assumptions and Limitations

Refer to Finney (2006) for more information regarding the assumptions and uses of this model.

1. Fire behavior is independent of neighboring cells.
2. Travel time across a cell is not influenced by neighboring cells with the Minimum Travel Time model.
3. FlamMap v. 5.0 includes spotting from firebrands.
4. Wind speed, wind direction, and fuel moistures are constant for the simulation period.
5. Fire spread due to rolling debris or falling snags are not included.

FSim Assumptions and Limitations

The minimum travel time algorithm (Finney 2002) operates under the same assumptions listed above under fire spread model assumptions. FSim relies on reliable historical fire records; the fire occurrence records used in this analysis may include errors or have missing data. The annual variability in fire activity can be substantial. Human land use and fire management policies have changed over time but it is assumed that fire occurrence patterns can be estimated using landscape structure and climatology.

Scientific Accuracy

Modeling has often been described as both an art and a science. While some level of error or uncertainty exists, models are often utilized for providing insight and understanding of complex and intricate phenomenon. It is difficult to predict fire behavior due to the interaction of numerous dynamic components, including weather (wind speed and direction, temperature, and relative humidity), fuel moisture, topography, and the size of the fire front moving through. The best available science has been incorporated where possible in addition to professional judgment where scientific information is lacking or not available.

APPENDIX E. Glossary

aspect – the cardinal direction in which a slope faces.

canopy base height – for modeling in BehavePlus, canopy base height refers to understory ladder fuels and the main canopy layer for a stand of trees.

canopy bulk density – mass of available canopy fuel per unit canopy volume of a stand.

ch/hr – chains per hour (1 chain = 66 ft).

coarse woody debris – dead wood greater than 3 inches in diameter or 1000-hr timelag fuels.

crown fire – a fire that spreads in the canopy of trees or shrubs more or less independent of a surface fire.

fine woody debris – dead wood less than 1 inch in diameter or 1- and 10-hr timelag fuels.

fire type – surface (S), torching (T, [passive crown fire}), or crowning (C, [active crown fire])

fireline intensity – a quantitative measure that describes the rate of heat release per unit time per unit length of the linear fire front.

flame length – within the flaming front, the length of the flame of a spreading surface fire; a function of fire intensity that influences the effect on vegetation.

foliar moisture – moisture content of overstory foliage; one of the attributes used to determine transition from surface to crown fire; 100% refers to mature foliage with new growth complete.

fire behavior fuel model – a cohesive set of parameters that define the necessary inputs to the fire spread model.

ladder fuels – fuels that provide vertical continuity between surface and canopy fuels; an example would be conifer seedlings and saplings.

live fuel moisture – herbaceous and live woody fuels; 100% refers to mature foliage with new growth complete.

midflame wind speed – the wind speed at midflame height above the fuelbed.

passive crown fire – see torching

residence time – the total length of time that the flaming front of the fire occupies one point.

size class – coded attribute representing the fire size.

A	0 – 0.25 acres
B	0.25 – 9.9 acres
C	10 – 99.9 acres
D	100 – 299.9 acres
E	300 – 999.9 acres
F	1000 – 4999.9 acres
G	5000+ acres

slope - the ratio between the amount of vertical rise of a slope and horizontal distance as expressed in a percent.

spotting – embers that are transported ahead of the zone of direct ignition of the main fire that start new fires.

surface fire – a fire that burns close to the ground surface including dead branches, leaves, and low vegetation.

torching – a fire that burns a single tree or group of trees, also known as passive crown fire.

twenty-foot winds – wind speed and direction at 20 feet above the height of the top of the vegetation.