How Landsat Helps: **FIRE**

A prescribed burn In Frijoles Canyon with the historic Tyuonyi Village pictured in the valley below. Credit: Sally King, NPS

Burning Wildlands and a Burning Need for Landsat

Laura E.P. Rocchio

At 8 p.m. on Thursday, May 4th, 2000, after months of planning, fire boss Mike Powell ignited a routine prescribed fire at the Bandelier National Monument just outside of Los Alamos, New Mexico. The burn was intended to reduce hazardous fuel (like dead trees and accumulated brush) in the Upper Frijoles Creek drainage area on the eastern rim of the Jemez Mountains. Initially it went as expected, but in the early morning hours of May 5 the fire escaped the planned boundaries, and by that afternoon it was declared a wildfire. On May 10, a major wind event, with gusts reaching 60 mph, whipped the flames into a firestorm. At 5 p.m. that night New Mexico Governor Gary Johnson ordered Los Alamos to be evacuated. Three days later, President Bill Clinton declared the fire a major disaster.

The wildland fire, named the Cerro Grande Fire, would burn for a month before being contained on June 6, and it wouldn't be declared out until Sept. 22. In the end, nearly 43,000 acres would burn including over 25,000 acres of the Santa Fe National Forest, 15,200 acres of other federal lands—7,600 acres within the Los Alamos National Laboratory (LANL)—and 2,000 acres of private lands. The conflagration would destroy 235 homes and structures in Los Alamos and a number of temporary structures on the LANL grounds; fortunately no radiation or toxic materials were released from the lab property. In total, Cerro Grande Fire damages exceeded $1 billion and 400 families were displaced.

On May 11, 2000 with both the town of Los Alamos and a national laboratory containing on-site hazardous wastes threatened by a fire that had been intentionally set by the National Park Service, the Secretary of the Interior, Bruce Babbitt called for an interagency investigation. Babbitt, together with Secretary of Agriculture Dan Glickman, ordered a 30-day moratorium on all prescribed burns west of the 100th meridian.

The investigation revealed a number of problems: the burn complexity rating that told the burn boss what to prepare for had been too low; replacement fire crews were brought on too slowly, there had been confusion over which agency should pay for fire fighting resources like helicopters and fire engines; and lastly, there was the devastating, unanticipated and unpredicted wind event.

After decades of fire suppression, federal wildlands had become virtual tinderboxes with enough fuel to unleash massively destructive fires. Planned, prescribed burns had become necessary, but the Cerro Grande fire had brought into question the safety of such prescribed burns. There had been a lack of coordination between agencies in the patchwork of federal lands surrounding Bandelier National Monument. A NPS investigation, concluded that, "The Cerro Grande Prescribed Fire demonstrates the need for all land managing agencies to come to common agreement on future guidelines and protocols for dealing with complex prescribed burns and to advocate for the highest levels of interagency understanding, standardization, and cooperation." Similarly, the interagency incident report recommended that an interagency burn complexity standard be developed and ratings be compiled for geographic regions instead of focusing solely on agency-owned lands. ▶

Photo Information

Above: Silhouette of firefighter at 2012 Bagley wildfire in California.

Below: View from an ancient cavate at Bandelier National Monument. Credit: Sally King, NPS. Credit: Forest Service

Image Information

Landsat 7 image of the Cerro Grande fire captured on May 9, 2000. The fire continued to spread and caused damage to the town of Los Alamos to its east. This image uses Landsat 7 ETM+ bands 7,4,2.

Enter Landsat

After Cerro Grande, President Clinton asked Babbitt and Glickman to devise the best path forward for dealing with wildland fires. The resulting National Fire Plan (today called the National Cohesive Wildland Fire Management Strategy) called for science-based planning for wildland fire management. But the following year, the General Accounting Office stated that, "Federal land management agencies do not have adequate data for making informed decisions and measuring the agencies' progress in reducing fuels."

An efficient, low-cost method for mapping and monitoring vegetation trends, fires, and fuel loads was needed. Land managers turned to Landsat. Since the 1980s the Landsat satellites had been regularly collecting and archiving data about Earth's land surface at a 30-meter spatial resolution. This resolution affords regional coverage with enough information to make landscape-scale decisions.

Importantly, the Landsat Thematic Mapper (launched 1982, 1984) and Enhanced Thematic Mapper Plus (1999) sensors all capture light reflected from Earth in various wavelength regions (including regions both visible and invisible to the human eye) that when used together are particularly good at revealing wildland burn damage and vegetation conditions. Healthy green vegetation reflects strongly in the near infrared (Landsat TM and ETM+ band 4, ~0.75–0.9 µm), while bare ground, soil, and rocks reflect strongly in the shortwave infrared (particularly Landsat TM and ETM+ band 7, ~2.09-2.35 µm). By comparing the amount of reflectance measured in these two wavelength regions before and after a fire event, data analysts can define the extent and severity of fires. This analysis method has proven to perform consistently across the range of biophysical settings found throughout the United States.

In the world of wildland management, good decisions must be buttressed by good information. Landsat supplies needed historic and current information in a consistent format at a spatial scale useful for land managers. In essence, it takes a blindfold off of land mangers trying to plan for and after wildland fires, by giving them a landscape-scale overview of vegetation, soil, fuel, and burn conditions.

Following the Cerro Grande Fire, Landsat data have become essential for three inter-agency national fire-related programs: LANDFIRE, the Burned Area Emergency Response program, and the Monitoring Trends in Burn Severity project.

LANDFIRE

The interagency LANDFIRE, or the Landscape Fire and Resource Management Planning Tools project, was a direct outcome of the National Fire Plan. Its prototype started in 2002, and by 2004 it was a fully chartered program. LANDFIRE characterizes the changing landscape in terms of vegetation types and fuel load; together with weather information this enables crucial fire behavior predictions to be made.

"To the fire community, LANDFIRE data is probably of most value to those in the field who are trying to predict fire behavior," says Dr. James Vogelmann, a USGS Research Ecologist with the project.

"We have used Landsat as the basis for our land cover mapping and vegetation characterization efforts," Vogelmann explains. Landsat data were the primary information source for the initial LANDFIRE vegetation and land cover maps, and each year land cover updates are made based on new Landsat data to keep fuel load maps current.

The scientifically credible maps produced by LANDFIRE can be layered together to help land managers across the U.S. prioritize hazardous fuel reductions, meet conservation goals, and establish resource management plans.

A tract of Bureau of Land Management land near Ely, Nevada before and after a prescribed burn. The photos were taken on July 7, 2009 (left, by Donald Ohlen, USGS) and on June 7, 2010 (right, Stephen M. Howard, USGS.) LANDFIRE provides land managers with important information for prioritizing where prescribed burns are needed.

Burned Area Response

During the Cerro Grande Fire, large areas were burned upstream of Los Alamos. After the fire, peak runoff flows from denuded slopes were 1000 times higher than before the fire putting townspeople at risk for flash floods and landslides. Immediately following the fire, the Burned Area Emergency Response, or BAER team, made assessments about the fire's effects on vegetation and soils and came up with a plan for rehabilitation. BAER treatments included hand-applied straw mulching of 2,700 acres within the burn scar. The treatment efforts were prioritized based not only on their modeled runoff flows and impacted population estimates, but also on the transport of contaminated sediments from the Los Alamos National Laboratory. In the three years following the fire, the Pueblo Canyon area recorded significantly elevated concentrations of plutonium-239 and -249 in their storm runoff. In the end, Forest Service post-fire treatments costs following the Cerro Grande blaze topped $14 million.

The threat of erosion, landslides, and flooding is greatly increased after a fire because of a two-fold fire effect: (1) burned vegetation no longer anchors the soil with its roots and (2) burned soils become largely impervious, increasing runoff. This is especially dangerous in mountainous regions adjacent to developed areas where flooding and landslides can be a major threat to human safety. BAER first responders, armed with their ground condition assessments, can target regions that need immediate attention to stem erosion and flooding and then implement remediation measures such as culvert placement, debris fence installations, reseeding, or straw mulching.

"BAER teams respond in the immediate aftermath of wildfires and are responsible for assessing burn severity and mitigating post-fire threats to life, property, water quality, and ecosystems," explains Carl Albury, a Remote Sensing Specialist with the Forest Service's Remote Sensing Application Center (RSAC) in Salt Lake City, Utah.

Photo Information

Above: A wildfire on Trinity Ridge in the Boise National Forest , Idaho. Credit: B. Washa, U.S. Forest Service

Photo Information

Above: Sunset at the Bagley Fire, four miles west of Big Bend, CA. This lightning-started wildfire was ignited on Saturday Aug. 18, 2012. Credit: U.S. Forest Service

"These threats are predominately caused by flash floods and landslides resulting from the removal of vegetation and impaired hydrologic function of affected watersheds."

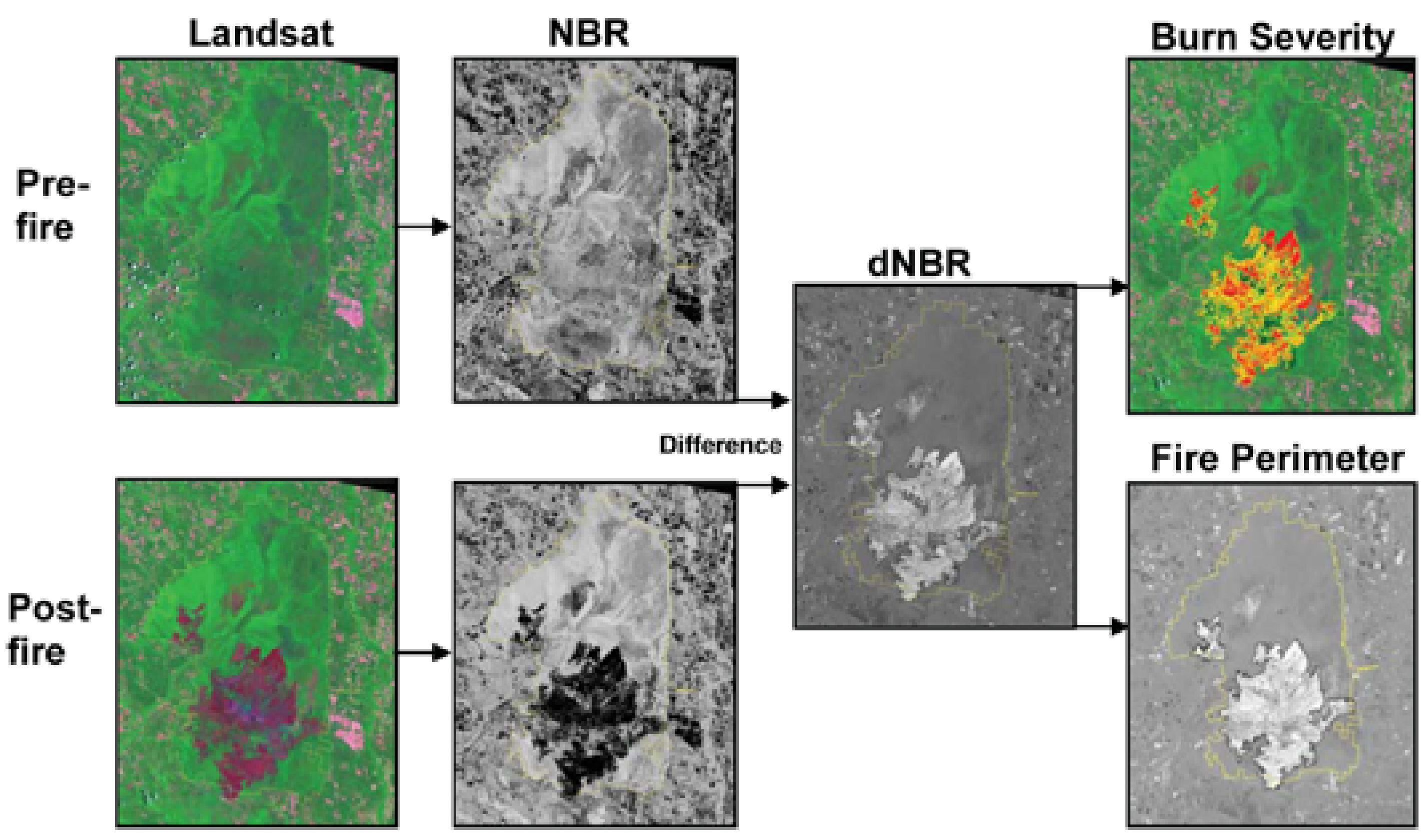
BAER assessments and stabilization plans must be completed within seven days of a fire event. The U.S. Geological Survey's Earth Resources Observation and Science (EROS) Center and the Forest Service RSAC teams work together to quickly get data to the BAER teams. Based on the BAER results, federal funds are requested to enable mitigation measures. Starting in 2001, EROS and RSAC began regularly incorporating Landsat satellite imagery into their burned area mapping services.

"With the large size, rugged terrain and inaccessibility of many burned areas, it can be difficult for BAER teams to assess a burned area within the seven day deadline," Albury describes. "To expedite this process, RSAC and EROS obtains pre-fire and post-fire Landsat imagery and produces a change detection product." This product, called a Burned Area Reflectance Classification, provides crucial information for the stabilization strategy.

"The Landsat based approach to soil burn severity mapping replaced earlier more costly, less accurate, and less repeatable methodologies based upon the manual interpretation of burn characteristics and impacts and field sketch mapping techniques," explains BAER support program leader and USGS Geographer Randy McKinley. Since incorporating Landsat into the BAER program, analysts have mapped over 1100 fires and 37 million acres in support of BAER teams deployed across the U.S. and occasionally to international locations.

"Historic, current and future availability of Landsat data are vital to the BAER program," says Albury. ▶

Determining Burn Severity and Fire Perimeters with Landsat



This graphic shows the steps used to map burn severity and delineate a fire perimeter using Landsat. NBR is the Normalized Burn Ratio (Landsat Band 4 – Band 7) / (Band 4 + Band 7); dNBR is the Differenced Normalized Burn Ratio. In the Post-fire image, the fire scar is magenta. In the Burn Severity image, red shows areas of most severe damage. This fire occurred in the Okefenokee National Wildlife Refuge on the Georgia/Florida border. Image credit: Eidenshink et al., 2007

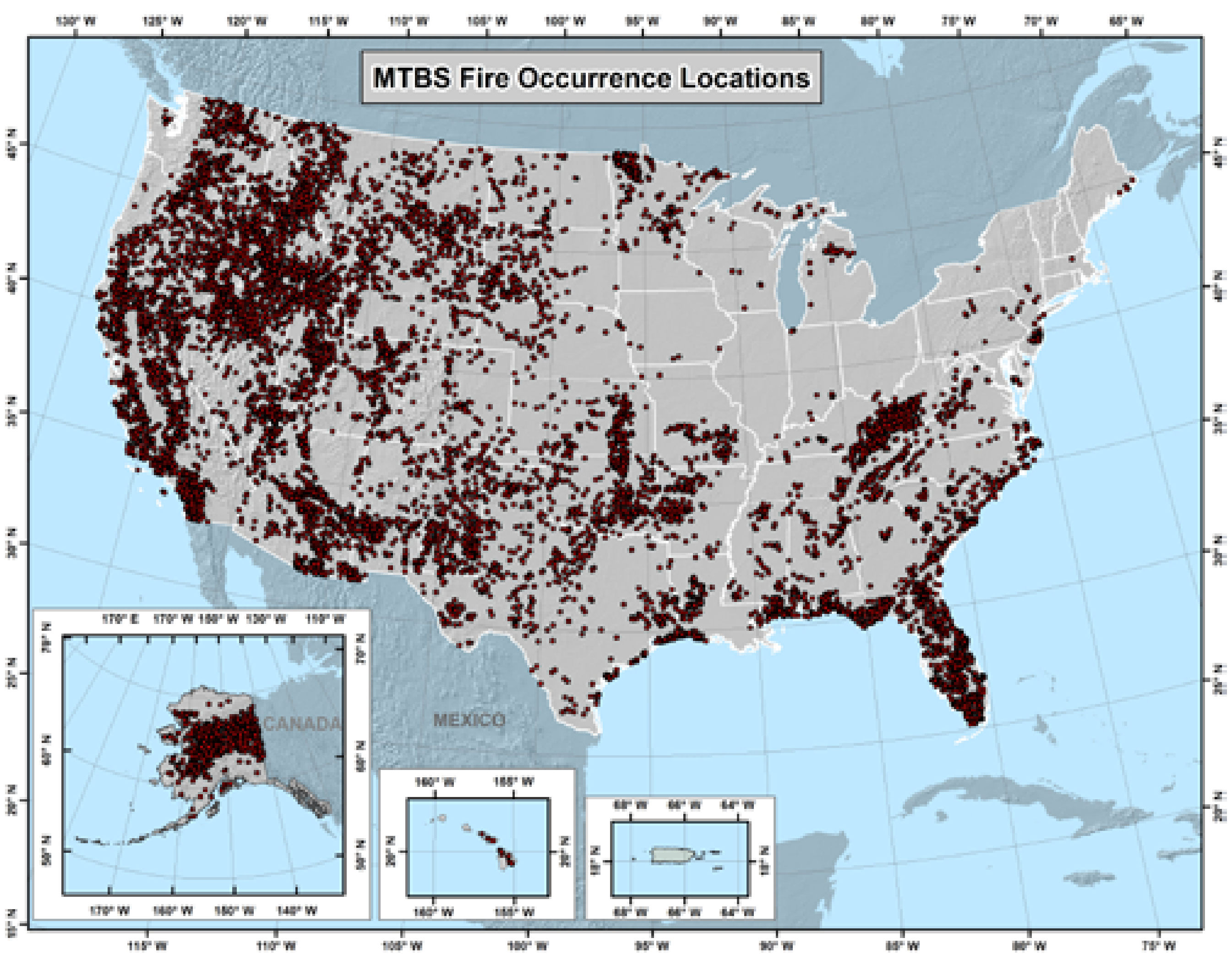
[Photo Information](#)

Above: A BAER scientist surveys a watershed in central Washington after a Sept. 2012 fire. Credit: Bob Nichols, U.S. Forest Service

Monitoring Trends in Burn Severity

In 2004, the General Accounting Office recommended that a nationwide comprehensive assessment of fire burn severity be conducted to help monitor fire trends and to determine the efficacy of the National Fire Plan. Soon after, the governing wildland fire council initiated a corresponding program to determine the environmental implications of large wildland fires and to track trends in the burn severity of U.S. wildland fires.

To tackle such large questions, managers again turned to Landsat because of its ability to provide consistent and historic information for the entire U.S. The resulting Monitoring Trends in Burn Severity (MTBS) project has used Landsat to map all fire extents and severity from 1984 through the present for fires larger than 1000 acres in the west and 500 acres in the east. The MTBS project—another RSAC and EROS collaboration—mapped 14,945 fires that occurred between 1984 and 2010 using over 10,000 unique Landsat images. Analysis of this massive archive of information is currently underway to answer those expansive original questions put forth by the Wildland Fire Leadership Council.



Location map of the 14, 945 U.S. fires occurring 1984–2010 mapped by the Monitoring Trends in Burn Severity project (MTBS). Credit: MTBS.

The MTBS project has been extended beyond its initial 1984–2010 period and annual updates now regularly occur. Additionally, MTBS fire disturbance data is fed into the annual LANDFIRE updates providing important fuel load revisions each year, and places like the Grand Canyon National Park use MTBS information to make decisions on tactical fire management and suppression.

Better Prepared

In the aftermath of the Cerro Grande Fire, Landsat proved to be a comprehensive data source pivotal to interagency efforts to better manage wildland fires.

"Landsat provides the 'view from above' and an ideal combination of resolution and ▶

"Historic, current and future availability of Landsat data are vital to the BAER program." —Carl Albury

A large smoke plume rises from the Pole Creek wildfire in the Deschutes National Forest near Bend, OR on Sept. 12, 2012. Credit: Tom Iraci, U.S. Forest Service spatial coverage that shows severely burned areas and resources at risk in the proper spatial context so priorities can be determined and the proper mitigation measures implemented," says Stephen Howard, a USGS scientist with the MTBS team.

With Landsat 5's TM sensor recently retired after 27 years of service, and the 13 year-old Landsat 7 ETM+ sensor working at a reduced (75%) capacity, the fire and fuel mapping teams for LANDFIRE, BAER, and MTBS are all delighted with the successful launch of Landsat 8 in February 2013.

"The every eight day repeat coverage originally provided by the Landsat 5 and Landsat 7 satellites was very timely for BAER team reporting requirements," McKinley says. "The loss of the Landsat 5 satellite's Thematic Mapper (TM) instrument in late 2011 was a severe blow to BAER and related mapping programs." In 2012, with wildfire coverage reduced to every 16 days with Landsat 7's ETM+, BAER mapping specialists were unable to provide timely soil burn products to a number of BAER teams on the ground.

With Landsat 8 in orbit with Landsat 7, the wildfire coverage was restored to every 8 days starting in June 2013.

Meet Carl Albury, Remote Sensing Specialist with the BAER team

Carl Albury
GIS/Remote Sensing Specialist
Burned Area Emergency Response Imagery Support Program
Remote Sensing Applications Center
Salt Lake City, Utah

Growing up, Carl Albury was an avid reader with a penchant for Jack London adventures. Albury didn't have a clear future career vision, but he was fairly certain that he'd end up in the natural sciences. He took a job with a surveying company as a teen and began his journey measuring and assessing the physical world around him. He majored in Geology at the University of South Florida and went on there to earn a Master's degree focusing on hydrogeology and requiring a fair amount of field research. Albury's first post-graduate job was assessing and remediating groundwater contamination. From there he migrated into water resources and started using aerial photography and satellite imagery—including Landsat—to assess environmental conditions.

"When I had an unexpected opportunity to get into the fire mapping world, I jumped on it," Albury says. In 2011, he took a job as a contractor with the Forest Service's Remote Sensing Application Center in Salt Lake City, Utah and today Albury manages the BAER imagery support program there.

"My diverse background and firm foundation in the earth sciences helps me understand both the modeling that we perform and the implications of translating the results of those models to action on the ground," Albury shares. "The work I perform here provides real, tangible help to the BAER teams who are in turn taking action to protect human life, property, and natural resources. I find the fact that my work has an immediate and positive impact on people's lives very meaningful."

Satellite Data Requirements:

- 8-day revisit (w/ L7)
- ≤ 30 m resolution
- Vis, NIR, SWIR, TIR
- continuous spatial coverage
- archive continuity & consistency
- rapid delivery of free, unrestricted data
- geolocation ≤ 0.5 pix
- ≤ 5% radiance calibration
- 8-bit data digitization