BURNED AREA EMERGENCY REHABILITATION (BAER)

SOIL BURN SEVERITY DEFINITIONS
And
MAPPING GUIDELINES

DRAFT

Annette Parsons*
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*Compiled with review and input from: Andrew Orlemann, USDA Forest Service Remote Sensing Applications Center; Marsha Davis, US National Park Service; Bruce McCammon, USDA Forest Service Region 6; Steve Howes, USDA Forest Service Region 6; Pete Robichaud, USDA Forest Service Rocky Mountain Research Station; Dean Sirucek, Flathead National Forest, MT; Henry Shovic, Gallatin National Forest, MT; USDA Forest Service Regional BAER Coordinators.

ISSUE

The increasing size of wildfires in recent years, along with new mapping technologies and a growing understanding of the natural role of fire in ecosystems, has intensified interest in fire effects mapping and assessment. Typically, an initial post-fire assessment is conducted by a USDA Forest Service (FS) or Department of the Interior (Interior) Burned Area Emergency Response (BAER) team. The primary objectives of the BAER program are:

(1) determine if fire-caused changes in soil hydrologic function have resulted in an emergency that threatens life, health, property, or critical cultural and natural resources due to flooding, erosion, and debris flows;
(2) prescribe and implement emergency stabilization treatments to minimize these threats.

A secondary objective for the Interior BAER program is rehabilitation. Here the goal is to repair lands unlikely to recover naturally and to restore healthy ecosystems.

The most important component of a BAER assessment is the soil burn severity map – a map of fire-caused changes to soils. Referred to in the past as the “burn intensity” map or “burn severity” map, the soil burn severity map identifies areas where post-fire soil conditions present potential for accelerated post-fire erosion or flooding. Recent developments in fire effects science have generated new interest in the meaning and applications of the BAER team’s soil burn severity maps, especially as they relate to increased concern over other identified values-at-risk. These developments include a more holistic assessment of fire effects on a broad range of resources (not just soils and watersheds), larger fires, often in the context of multiple ownerships, increased use of satellite imagery in mapping fire effects, and a greater scrutiny of federal land management practices by the public.

In response, BAER teams have diversified from the traditional soil and hydrologic focus. Depending on the incident, BAER teams may now include a large number of technical experts who assess and document fire effects to other resources. This growing number of natural and cultural resource specialists and their unique perspectives on fire and its effects has introduced ambiguity into the development, interpretation and application of soil burn severity maps. Burn severity maps are now being made and used by resource specialists across a range of disciplines, both in the context of BAER (immediate post-fire resource assessment and emergency response) and in studying long-term ecological recovery. The term “burn severity” has diverse meanings relative to the frame of reference of the user.

OBJECTIVE

The question of what the BAER burn severity map represents is a topic of frequent debate among BAER team members as well as non-BAER users of the information. This paper is an attempt to clarify terminology, context, and use of the soil burn severity map. In addition, this paper sets forth clear classification guidelines for use in mapping soil burn severity during a BAER assessment. It also attempts to clarify the appropriate use of the terms “severity” and “intensity”.

DISCUSSION

Two major areas of confusion exist:

1. What is the meaning of “burn severity”?
2. What is the difference between “severity” and “intensity”?

1. Meaning

As discussed above, many management programs, research efforts, and disciplines are interested in fire effects. As a result, the term “burn severity” has been applied to a variety of applications, indicating a number of things, including timber or vegetation mortality, long term or immediate ecosystem effects, or position along the scale of historical range in variability over a landscape. Within the fire effects literature, the term “severity” is increasingly used to describe ecological impacts of fires.

Clearly, however, the most imminent threats to life, property, or critical cultural and natural resources following a wildfire are threats from potential flooding and erosion (including landslides and debris flows). The most important purpose of a soil burn severity map in a BAER assessment is to identify areas of impaired soil function. The soil burn severity map is the key element in determining if threats exist. It is not a map of vegetation mortality, or timber mortality, nor does it represent a composite of fire effects to all resources. It is not a temporal geospatial representation of ecological condition, nor does it reflect a historical range in variability for the fire regimes over a landscape.

While there are still some differences between the USFS approach to BAER as compared to the Interior approach to BAER, both departments agree that the BAER team’s initial map should be a map of fire-caused changes in soil characteristics that affect the soil hydrologic function. For this reason, consistently using the term “soil burn severity” in referring to these maps will help avoid confusion and clarify the focus of the maps. This soil burn severity map can then be used as an input in development of a “runoff response” map for purposes of hydrologic modeling, and for modeling soil erosion potential, or as an intermediate product in the mapping of timber mortality or effects to wildlife habitat. This spatial and temporal “snapshot” of soil burn severity then becomes a baseline for monitoring changes in soil hydrologic function and vegetative productivity as watersheds recover.

2. Difference

Besides the confusion resulting from different definitions of the term “burn severity” in regards to fire effects, an additional area of confusion has been the often interchangeable use of the terms “burn intensity” and “burn severity”. In the past, the BAER team’s map has been called the “burn intensity” map or the “fire intensity map”, and these outdated terms are still found in some of the older manuals. Carl Key (2001) and others (White and Pickett, 1985 as cited by Ryan, 2002) have argued convincingly that the term “intensity” is most appropriately applied to the fire during the burning episode, i.e. the “…physical force of the event per area per time period”. A fire can thus appropriately be described in terms of its behavior as high or low intensity[1].

Pickett further states that the term “severity pertains to the *impact* on the organism, community or ecosystem” (emphasis added). The term “severity” is thus appropriate in reference to the *effects* of the fire, and can be observed after the fire has occurred. Severity is defined variously as effects to vegetation, soil, or long-term ecosystem health. A high intensity fire often results in high soil burn severity, for example, where surface and ground fuels are abundant. The correlation between fire intensity and soil burn severity is not always direct, however, because aside from the *amount* of heat generated, *duration* plays a critical role in fire effects to soil (DeBano, et.al 1998; Hartford and Frandsden, 1992 as cited by Ryan 2002). A high intensity fire exhibiting extreme fire behavior (high flame length, rapid rate of spread) might result in low or moderate soil burn severity. Crown fires in forests, or shrub or grassland fires are typical examples of this situation. Conversely, a low intensity fire (smoldering log) can produce intense heat and long duration, resulting in high soil burn severity in the area under the log or woody debris concentration. Using these terms consistently and clearly in these contexts will help to avoid some of the confusion. Figure A graphically depicts a way to think about these terms and how they differ.

3. Vegetation effects terminology

Besides the confusion of terms discussed above in relation to soil burn severity, there are many strong opinions about the meaning of terms such as ‘fire severity’ or ‘burn intensity’ in relation to vegetation

[1] Fire intensity terms vary among fire behavior specialists. Fire intensity is accepted as heat per unit area (Byram, 1959, as cited by Ryan, 2002), while fireline intensity has been defined as fuel heat component x mass x rate of spread (Rothermal [1972] as cited by Ryan, 2002).

effects. This paper does not venture into that debate, except to say that using the term "vegetation burn severity" eliminates all ambiguity.

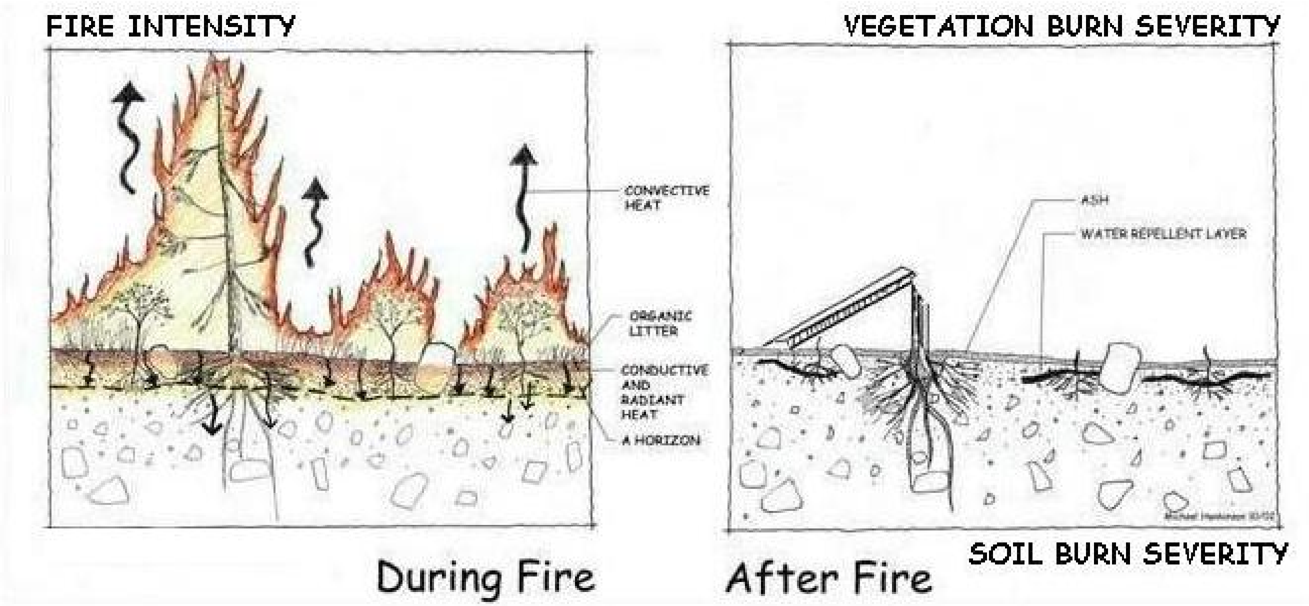

Figure A. "Intensity" refers to the burning period of the fire. "Severity" refers to the after-effects. By referring to the BAER soil effects map as a "soil burn severity" map, clarification as to the focus makes it less confusing to all users of the information[2]. Graphic modified from Mike Hankinson, National Park Service.

RECOMMENDATIONS

Terminology:

1) Use the term "severity" rather than "intensity" in referring to fire effects;
2) Preface the term "burn severity" with the word "soil" when referring to the fire effects to soils.

While efforts have been made to describe and define classes of burn severity that incorporate an understanding of fire effects to soil parameters (Key and Benson, 2001; DeBano *et al*., 1998; the Forest Service Handbook (FSH 2509.13), and the National Wildfire Coordinating Group's Fire Effects Guide (NFES 2394)), none of these captures precisely the needs for the initial BAER soil burn severity map. By drawing from each of these, however, we have developed guidelines for identifying soil burn severity classes in the field for use by BAER teams in mapping soil burn severity. These guidelines follow:

[2] Current fire effects literature describes and embraces this use of the semantics (Key and Benson, 2002; Ryan, 2002; White and Pickett, 1985 as cited by Ryan 2002).

Field Guide for Classifying BAER Soil Burn Severity

(Adapted from the National Wildfire Coordinating Group, Fire Effects Guide; Hungerford, as cited by DeBano, et al; and USFS Handbook 2509.13)

Soil Burn Severity: Soil burn severity is a term that qualitatively describes classes of fire-caused changes to soil hydrologic function, as evidenced by soil characteristics and surface fuel and duff consumption. Large diameter down, woody fuels and organic soil horizons are consumed during long-term, smoldering and glowing combustion. The amount of duff or organic layer reduction is also called depth of burn, or ground char (Ryan and Noste 1985, as cited by the Fire Effects Guide). The amount and duration of subsurface heating determine the degree of soil burn severity, and can be inferred from fire effects on ground fuels (plants other organic matter) and soils.

Descriptive classes

An example of a set of soil burn severity classes is given below, in narrative as well as tabular format. Users must recognize that these are guidelines to visual indicators only, and the boundaries between the classes often become "blurred" in real world situations.

(a) **Unburned to very low soil burn severity**[3]. Fire has not entered the area, or has very lightly charred only the litter and fine fuels on the ground; soil organic matter, structure, and infiltration unchanged.

(b) **Low soil burn severity**. Low soil heating or light ground char occurs; mineral soil is not changed; leaf litter may be charred or partially consumed, and the surface of the duff may be lightly charred; original forms of surface materials, such as needle litter or lichens may be visible; very little to no change in runoff response. Indicators include very small diameter (<¼ inch) foliage and twigs are consumed, some small twigs may remain; generally, foliage may be yellow; the surface is mostly black in a grassland or shrubland ecosystem, but some gray ash may be present; above-ground portions of vegetation may be consumed, but root masses are intact. Change in runoff response is usually slight.

(c) **Moderate soil burn severity**. Moderate soil heating with moderate ground char; soil structure is usually not altered; decreased infiltration due to fire-induced water repellency[4] may be observed; litter and duff are deeply charred or consumed; shallow light colored ash layer and burned roots and rhizomes are usually present. Indicators include understory foliage, twigs (¼ to ¾ inch) are consumed; rotten wood and larger diameter woody debris are deeply charred or partially consumed; on shrubland sites, gray or white ash is present and char can be visible in the upper 1 cm of mineral soil, but the soil is not altered; in forested ecosystems, brown needles or leaves may remain (but not always) on overstory trees—these are important as mulch, and should play a role when identifying treatment candidate sites; increase in runoff response may be moderate to high, depending on degree of fire-caused changes to the pre-fire vegetation community, density of pre-fire vegetation, and presence or absence of mulch potential, sprouting vegetation, etc.

(d) **High soil burn severity**. High soil heating, or deep ground char occurs; duff is completely consumed; soil structure is often destroyed due to consumption of organic matter; decreased infiltration due to fire-induced water repellency is often observed over a significant portion of the area; top layer of mineral soil may be changed in color (but not always) and consistence and the layer below may be blackened from charring of organic matter in the soil; deep, fine ash layer is present, often gray or white; all or most organic matter is removed; essentially all plant parts in the duff layer are consumed; increase in runoff response is usually high. Other indicators include large fuels > ¾ inch including major stems and trunks are consumed or heavily charred. On a shrub site, shrub stems and root crowns are often consumed. In forested ecosystems, generally no leaves or needles remain on standing trees; high soil burn severity areas are primary treatment candidate sites if there are downstream values at risk;

[3] The "Unburned" class may include some areas of very low soil burn severity, particularly when deriving soil burn severity maps using remote sensing, since canopy reflectance is unchanged. The degree of severity is so slight that the soil and vegetation are not significantly altered from an unburned condition.

[4] Forest Service Manual 2509.13 contains guidelines for identifying and classifying water repellency. These guidelines are included in Appendix A.

Table 1. BAER Soil Burn Severity Class Indicators.

Soil Burn Severity Class	**Substrate - litter/duff**	**Vegetation - understory/shrubs/herbs**	***ANCILLARY FACTORS ONLY!*** *Highly variable and **NOT** key to determining soil burn severity; Very General Guide ONLY:* **Overstory – conifer/hardwoods**
Unburned	not burned	not burned	no fire-caused mortality; overview of canopy appears unchanged
Low	mineral soil unchanged; litter charred or partially consumed; upper duff layer charred; wood/leaf/needle structures charred but recognizable	foliage and smaller twigs (less than ¼ inch) scorched or partially consumed; grasses mostly consumed, black or gray ash; shrub stems intact, canopy scorched.	slight tree mortality possible but generally less than about 10%; overview of canopy may show individuals or small pockets of mortality (brown needles or black sticks)
Moderate	moderate soil heating, moderate ground char; soil structure intact; litter mostly charred but not ashed, however some areas of litter consumption may be found, leaving shallow ash; duff and wood partly consumed; wood/leaf structures may be recognizeable; burned roots and rhizomes usually still present; reduced permeability may be present over some of the area.	foliage, twigs and small stems (¼ to ¾ inch) consumed; shrub stems charred, root crowns intact, shrub canopy consumed.	tree mortality may be mixed and range widely; seedlings are usually consumed, large trees often killed but retain some fine twigs, brown needles or leaves (future mulch) and cones with light to moderate bark char; where tree cover had been dense, the area is usually not dominated by black sticks, but can be in some cases; specific characteristics of this class and percent tree mortality need to be defined for each fire as they can vary by ecosystem
High	High soil heating, deep ground char; litter and duff consumed leaving fine ash, often more than an inch or two deep and often gray or white; surface soil may be visibly altered, often blackened or reddish and usually lacking structure; all or most organic matter is removed; fine roots and rhizomes may be consumed; reduced permeability may be pronounced (strong and/or thick water repellant layer) over much of the area; large fuels completely consumed or nearly so.	all plant parts consumed, including fuels greater than ¾ inch, leaving some or no major stems/trunks of shrubs.	generally 80 to 100% tree mortality; saplings and large trees are dominantly black sticks with moderate to heavy bark char and no needles or leaves remaining. Individuals or small pockets of live trees may remain, but are not dominant in the delineation.

MAPPING SOIL BURN SEVERITY

When identifying and delineating classes of soil burn severity based on ground conditions, it must be recognized that often the various classes occur intermixed on the landscape and it may be difficult to separate out discreet pure delineations of a soil burn severity class within the minimum size delineation guidelines used on a given fire. (Generally, a minimum polygon size of 40 acres is appropriate, but it may be as large as 100 or more acres on very large fires, or as small as 10 acres in areas of critical values at risk.) It is best to assign the dominant class of a given delineation, and recognize the mosaic nature and diversity in a written description of soil burn severity classes for the specific fire rather than to label a delineation as a ‘complex’ such as “Low to Moderate” or “Low and High”. Keeping the legend simple and standard facilitates later compiling soil burn severity maps for analysis on a regional or national level.

ROLE OF GEOSPATIAL TECHNOLOGIES

Remote Sensing

Remote Sensing and GIS techniques allow BAER teams to use satellite imagery and other remotely sensed images to assist in rapid assessment and mapping of burned areas. The USDA Forest Service Remote Sensing Applications Center (RSAC) in Salt Lake City and the USGS EROS Data Center (EDC) in Sioux Falls have provided operational support to BAER teams for the past two fire seasons (Orlemann *et al* 2002; Parsons 2002). One of the items typically provided to BAER teams by RSAC or EDC is a satellite image of the burned area and a preliminary classification representing change in condition. These preliminary products (prior to field verification) are referred to as Burned Area Reflectance Classifications (BARC), and can be used to guide the initial assessment of watershed condition. The BARC may be modified by a BAER team to represent soil burn severity after proper field validation of soil characteristics.

Requesting Remote Sensing Support

Regardless of whether a BAER team is primarily FS or Interior, there is now one point of contact to request remote sensing support on an incident:

http://www.fs.fed.us/eng/rsac/baer/

Click on “Request Imagery & BARC Maps”. This will take you to the Interagency BAER Imagery Support web page. This page contains contact information and what information you will need before you call. The site also contains information on how the imagery is used, an on-line remote sensing training module that explains how to use and edit the BARC products, and other useful information and links.

If you are in a situation where you do not have internet access, call:

Andrew Orlemann (801) 975-3769, USDA Forest Service RSAC BAER support unit

GIS

It is worth pointing out that many of the questions asked by managers, other resource specialists, the media, and the public can be answered with Geographic Information System (GIS) modeling after the initial BAER soil burn severity map is complete. For example, with a GIS, the BAER team can map soil burn severity and overlay this with a pre-fire vegetation map to model first-year post-fire runoff potential in shrub fields vs. forests, since these ecosystems respond to precipitation events differently given the same soil burn severity. Using a similar process—overlaying soil burn severity and pre-fire vegetation—the BAER team can also better define, for each fire, the range in tree mortality to be expected in the areas of different soil burn severity. The overlay of BARC with pre-fire vegetation also helps in refining the soil burn severity map by accounting for pre-fire vegetation communities such as grasslands, or shrubby rocky areas whose reflectance might be similar to a high severity forested areas. By using the soil burn severity map and pre-fire vegetation information in this way, we can avoid the conflict caused when a BAER team properly focuses its map on soil condition rather than stand mortality or ecological burn severity.

Other examples of using GIS to derive fire effects information include overlaying the burn severity map with soils, or ownership, for use in modeling soil erosion, or measuring acres of burn severity by ownership. More advanced analyses for implementation planning can be done using a GIS to model proximity of high severity areas to nest sites, or cultural resources, or to determine natural reseeding likelihood based on polygon size and shape (edge effect). In short, the soil burn severity map can be used by a variety of resource specialists after the BAER team has finished its work and the possibilities for further GIS analysis and modeling are many.

CONCLUSION

In closing, it is important that the BAER community identify a common set of indicators and definitions of soil burn severity to be used in all BAER rapid assessments. The guidelines described here will help focus the BAER mapping on post-fire soil conditions rather than overstory or ecosystem condition. The system used by the BAER community needs to be fully and clearly documented along with locally specific definitions of soil burn severity classes, since these will vary by fire. This documentation should be delivered along with any and all digital and hard copy versions of BAER soil burn severity maps that are provided to managers, other agencies, resource specialists, community groups, media, and individuals.

In addition, every BAER soil burn severity map and related digital products should include the label "BAER Soil Burn Severity" and the meaning of that label (metadata and definitions discussed above) should be readily accessible. The BARC disclaimer (Appendix C) will be included on all plots of the BARC produced by RSAC or EDC. This will help to make it clear that the initial products from RSAC or EDC represent image reflectance and have not been ground verified. Other interpretations or conclusions about things like vegetation mortality can then be drawn by other qualified specialists if necessary. Finally, all BAER team members should be trained to consistently use these terms and guidelines.

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APPENDIX A. Water Repellancy Guidelines

FSM 2509.13 contains guidelines to identifying and classifying water repellant soils as follows:

<u>23.31</u> - <u>Water-Repellent Soils.</u> Water-repellent soils can occur naturally. Burned areas with high-intensity fire or long residence times are candidates for intensified water-repellent conditions. In addition, soil texture, moisture content, plant communities, and depth of litter also affect the development or degree of water-repellency as a result of the fire. Evaluate all areas with intensified water-repellent conditions resulting from the fire as potential flood source areas.

1. <u>Degree of Water-Repellency</u>. The degree of water-repellency is based on the time required for the absorption of a drop of water on a dry soil surface:

a. Weak - Less than 10 seconds.
b. Moderate - Between 10 and 40 seconds.
c. Strong - Longer than 40 seconds.

2. <u>Classes of Water-Repellency</u>. Assess classes of water repellency by using the following rating system:

a. Low - No strong repellency except at the immediate soil surface and no moderate repellency below 1/2 inch. Repellency is very spotty in occurrence.

b. Medium - Some moderate repellency below 1/2 inch, but no strong repellency below 1 inch.

c. High - Moderate repellency between 3 and 6 inches or strong repellency below 1 inch. The degree of repellency is uniform in extent.

NOTE: Newly available lightweight and compact field infiltrometers make rough quantification of infiltration rates possible, and may provide values that can be used in runoff models. It is important to compare burned and unburned areas to understand the degree of change caused by the fire.

APPENDIX B: Sample Field Data Collection Form

Interagency BAER Soil Burn Severity & Potential Watershed Response Field Data Table

Incident Name: ____ **Page** _____ **of** _____

Watershed: ______________________________ **Date:** __________ **Evaluators:** __________

FIRE EFFECTS ON SOIL: BAER SOIL BURN SEVERITY ASSESSMENT										BAER POTENTIAL WATERSHED RESPONSE ASSESSMENT							
Data Point	Fire Effects on Ground Fuels		Soils		Water Repellency				Fire Effects on Soil: BAER Soil Burn Severity Rating	% Slope	Fire Effects on Vegetation	Cover* Density		Subsurface Plant Material **	Sediment Release Potential (identify sediment source areas)	Comments & Other Observations (e.g. drainage density; channel conditions)	Potenti Watersh Respon Rating
	Amount of litter & duff consumed		Texture	Structure	Depth	Thickness	Duration	Continuity			Size of overstory & understory fuels consumed	Existing	Potential				
	Char / Ash																
	Color	Depth															

* (rock fragments, litter, plant basal area, mat-forming vegetation, potential needle cast)
** (fibrous roots, fungal mycelium, seed bank)

NOTES:

Interagency BAER Soil Burn Severity & Potential Watershed Response Field Data Table (revised Feb03)

APPENDIX C. DRAFT BARC Disclaimer

DRAFT BARC Disclaimer v01

Feb 06, 2003

The classes depicted on this map are based on a preliminary classification of the reflectance properties of the target area as recorded by a satellite sensor. The Burned Area Reflectance Classification (BARC) map is intended to support immediate post-fire assessment by Burned Area Emergency Response (BAER) teams. The BARC map can be used to guide the initial assessment of emergency watershed conditions. The BARC map may be modified to represent soil burn severity after proper field validation of soil characteristics. Using this map for other than its intended purpose may yield inaccurate or misleading results.

The USDA Forest Service uses the most current and complete data available during immediate assessment of post-burn emergency conditions. Geospatial data accuracy may vary. The USDA Forest Service reserves the right to correct, update, or modify geospatial inputs to this map without notification. For additional information, please contact the Remote Sensing Applications Center (801-975-3750).