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# Assessment of cartographic design in post wildfire BAER mapping| A study of Fire Logistics Inc.

Ira L. Eisen
*The University of Montana*

# AN ASSESSMENT OF CARTOGRAPHIC DESIGN IN POST WILDFIRE BAER MAPPING A STUDY OF FIRE LOGISTICS INC.

by

Ira L. Eisen

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Approved by:

Paul B Wilson

Chairperson

[signature]

Dean, Graduate School

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An Assessment of Cartographic Design in Post Wildfire BAER Mapping:
A Study of Fire Logistics Inc.

Advisor: Paul B. Wilson

The purpose of this thesis is to critique the cartographic quality of BAER maps to see how well they utilize accepted cartographic design elements. To answer this, the author devised a survey to qualitatively rate cartographic design elements of maps. The method utilized to assess the maps is the Stapel Scale of qualitative assessment. Two surveys were given; one to test the validity of the elements in the survey, and the second an evaluators' survey to determine the cartographic quality of the maps.

The pretest found that the elements in the survey all produced valid results, however slight changes in methods were made in order to better facilitate the evaluators' survey. The evaluators' survey was completed by two Cartographic Technicians, two GIS Specialists, one Forestry Professor, and one Wildfire Research Ecologist. The results showed that the maps created by Fire Logistics were rated slightly above average and that the major problem areas on the maps were text, symbolism, legend, scale, and data source.

To improve the quality of BAER maps, a protocol was created that is made up of suggestions that can be used to create high quality wildfire maps. Other factors affecting the quality of the maps including the amount of time and pressure to produce a map are then discussed. In conclusion, the use of a protocol such as the one suggested in this thesis can be used to improve the quality of wildfire maps. Ultimately, the end quality of any wildfire map is going to be determined by the skill of the cartographer and the time constraints placed on map production.

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# Chapter 1

# Introduction

Wildfire has played a critical role in the Rocky Mountain West for millennia. In its natural state, low intensity wildfires cleansed and rejuvenated the forests of the West. However, after one hundred years of fire suppression, high intensity burns have been occurring at an alarming frequency in ponderosa pine forests.[1] It is only in recent history that we are beginning to recognize the importance of managing fires as a resource to avoid catastrophic high intensity fires. While steps have been initiated to educate the public as to the danger, and plans have been implemented to better manage our forests, the solutions to many of our resource issues lie in post wildfire rehabilitation. Managing natural resources after fires has become more important as we see how quick rehabilitation plans are crucial in minimizing harmful effects on soil, water, and threats to human life and property.[2] Creating high quality maps of rehab plans are essential to the success of the overall rehabilitation. Without good cartographic quality in these often quickly produced maps, poor decisions can be made regarding important resources. Burned Area Emergency Rehabilitation (BAER) managers often have short timelines to implement and complete rehabilitation plans, therefore maps have to be quickly made that accurately display the rehab plans.[3] Critiquing post wildfire maps is important because such a survey will show where post wildfire mapping stands in terms of

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[1] Stephen F. Arno, *The Historical Role of Fire on the Bitterroot National Forest* (Ogden, UT: Intermountain Forest and Range Experiment Station, USDA Forest Service, 1976), 1, Research Paper INT-187.

[2] USDA Forest Service, *Burned-Area Emergency Rehabilitation Handbook* (Washington D. C., USDA Forest Service, 1995), 5, WO Amendment 2509, 13-95-3.

[3] Ibid.

cartographic design. By surveying post wildfire maps, a protocol can be devised that will help wildfire cartographers improve the quality of their work.

**Wildfire in the Rocky Mountain West**

Fire has always had a strong influence on the ecology of the Rocky Mountain forest.[4] Fire serves many functions in nature; it converts dead and organic material to ash, recycles nutrients, exposes mineral soil, restricts some plants and animals while favoring others, regulates plant succession and wildlife habitat, maintains biological diversity, reduces biomass, and controls insects and disease.[5] Essentially, fire keeps nature in balance by recycling old materials and allowing habitat rejuvenation to occur. However, the recent increased frequency and size of wildfires in the West has led to significant questions regarding our management policies.[6] Not only have suppression costs and threats to life and property increased, significant environmental impacts have occurred.[7] Western ecosystems that have a natural history of regular, low-intensity wildfires are now being affected by high-intensity wildfires that have significant environmental impacts.[8]

**Wildfire in Rocky Mountain Forest Ecosystems**

In this section, the role fire plays in relation to three different Rocky Mountain ecosystems will be discussed. The three categories of Western Pine and Quaking Aspen

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[4] Arno, 1.

[5] Robert W. Mutch, "A Return to Ecosystem Health," *Journal of Forestry* 92, no. 11 (1994): 31-33.

[6] R. N. Sampson, R. D. Atkinson, and J. W. Lewis eds., *Mapping Wildfire Hazards and Risks* (New York: Haworth Press, 2000), 2.

[7] Ibid.

[8] Ibid.

(Trembling Aspen), Northern Rocky Mountain Forests, and Boreal High Elevation Forests were selected as that is how they were classified in Barnes et al. 1998.[9]

Western Pine and Quaking Aspen

Wildfire plays an important role in the western pine forests of the Rocky Mountain West. Lodgepole pines regenerate after a fire "largely from seeds stored in serotinous cones of trees killed by the fire, to form dense, even-aged, post fire pioneer stands."[10] This regeneration was seen in Yellowstone National Park after the fires of 1988. If left unchecked by fire, areas of lodgepole will give way to more tolerant species such as Engelmann spruce and subalpine fir in the Rockies and Douglas-fir as you move towards the Northwestern United States.[11] In lower elevation and warmer locations, ponderosa pine and juniper are heavily influenced by fire. Without fire, species such as Douglas-fir, incense-cedar, and white-fir will succeed the ponderosa pine and juniper.[12]

Quaking aspen is also significantly influenced by wildfire in the Rocky Mountain West. Although it is a hardwood tree, it is still able to compete in the Northern Rockies by growing in the higher, cooler, and wetter sites.[13] In the Southern Rockies, root suckering occurs after fires.[14] Root suckering is the primary method by which quaking aspen reproduce. They are capable of seed production but usually reproduce by sending their roots out underground and growing new stems.[15]

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[9] Burton V. Barnes, Donald R. Zak, Shirley R. Denton, and Stephen H. Spurr, *Forest Ecology* (New York: John Wiley & Sons Inc, 1998), 417.
[10] Ibid., 417-426.
[11] Ibid., 418.
[12] Ibid.
[13] Ibid.
[14] Ibid.
[15] Ibid.

Northern Rocky Mountain Forests

The Northern Rocky Mountain forests are noted for having multiple burns, which often stay without tree cover for long periods of time.[16] In areas of Western Montana, Northern Idaho, and Eastern Washington, catastrophic fires that kill complete stands are common.[17] This is because the region has a drier summer climate along with the build up of fuels caused by insects and disease and increased fire protection after the 1940s.[18] Arno's study of the fire history in the Bitterroot National Forest found that fires occur at a mean six year interval in the Ponderosa pine found near the valley edge to the montane slopes.[19] While the lodgepole pine and Douglas fir of the lower subalpine locations had a mean fire occurrence of seventeen years, whitebark pine in the upper subalpine locations had a mean fire occurrence of forty-one years.[20]

Boreal/High Elevation Forest

Although fire occurs at lesser intervals, and most small spot fires are relatively ecologically insignificant, the few large fires that occur are important to the high elevation forests within the Rockies. Arno noted "a remarkable example is the grove of whitebark pines on a dry ridge in western Montana in which individual trees have open fire scars dating from approximately 1608 and 1892, with nothing in between."[21] Despite fires occurring so infrequently, "seven of the ten major tree species are pioneers with

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[16] Ibid., 426.
[17] Ibid.
[18] Ibid.
[19] Stephen F. Arno, *The Historical Role of Fire on the Bitterroot National Forest* (Ogden, UT: Intermountain Forest and Range Experiment Station, USDA Forest Service, 1976), 4, Research Paper INT-187.
[20] Ibid.
[21] Stephen F. Arno, "Forest Fire History in the Northern Rockies," *Journal of Forestry* 78, (1980): 465.

adaptations for rapid invasion of burned areas."[22] Fire is directly responsible for the amount of plant and animal diversity found in the higher elevation forests of the Rocky Mountain West.[23]

In this section, the role fire plays in relation to three different Rocky Mountain ecosystems was presented. The three categories of Western Pine and Quaking Aspen, Northern Rocky Mountain Forests, and Boreal High Elevation Forests were discussed on how the role of wildfire affects each ecosystem.

## Wildfire Mapping

To fight wildfires, and to manage the resources after wildfires, it is crucial to have good mapping. Without quality maps, poor decisions can be made that put fire fighters' lives in jeopardy or cause resources that could be managed to be destroyed. Also, as the Wildland Urban Interface (WUI) continues to grow in human population, the threats to residents and their property are increasing. The WUI is the zone of intermingled wildlands and adjacent development.[24] In this section, incident command will be discussed, along with the types of wildfire maps they are creating. Lastly, brief comparisons of wildfire mapping to other types of hazard mapping will be discussed.

### Incident Command

Many private and government agencies work in the pursuit of wildfire mapping. On type one or two incidents, wildfire mapping can be done by several different interagency and private organizations. Type one incidents are the largest or most threatening fires while type two incidents are secondary fires. There is no specific

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[22] Barnes, 426.

[23] Ibid.

[24] Hanna J. Cortner, Philip D. Gardner, Jonathan G. Taylor "Fire Hazards at the Urban-Wildland Interface: What the Public Expects," *Environmental Management* 14, no. 1 (1990): 57.

acreage that classifies a type one or two fire; it depends on the opinion of the fire managers or the amount of money and man power needed to fight a fire. An interagency staff can be made up of Forest Service, BLM, NPS, or members of any other federal, state, local, or private agency. In recent years, there has been good coordination among agencies mapping wildfire in that they are willing to share data for the overall benefit to fight the fire.[25]

Wildfire incidents are managed through an incident command team (See Figure 1-1).[26] An incident command team is a group of interagency employees that are assigned to manage the wildfire or any other type of disaster. Leading the incident command team is the incident commander who is in charge of all work on the fire.[27]

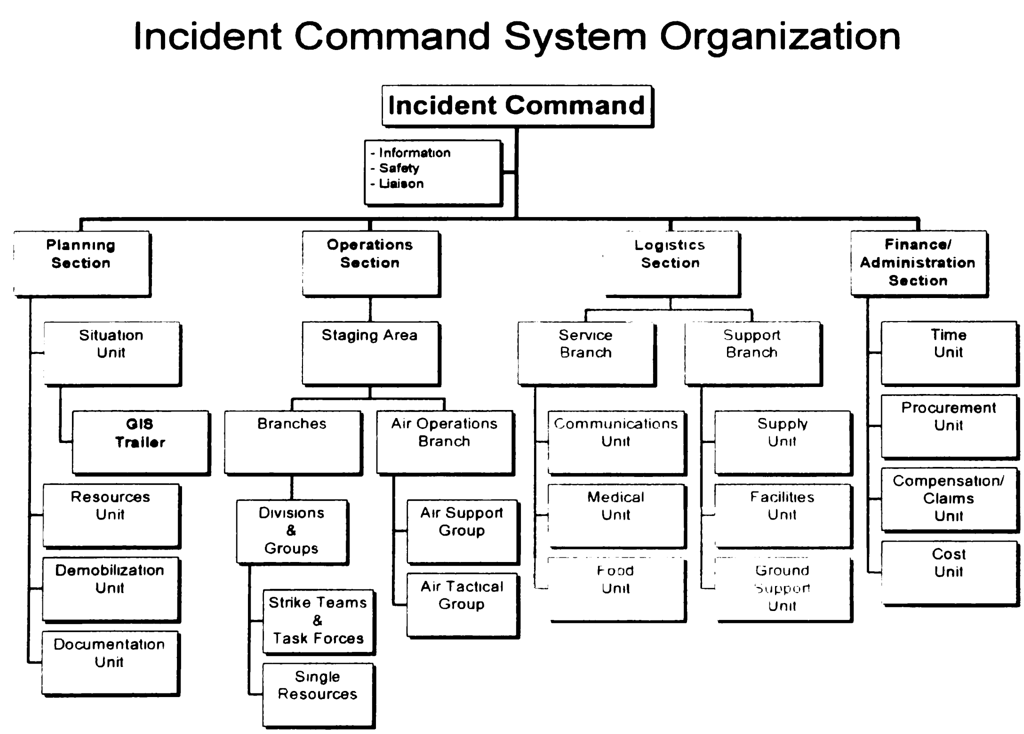


Figure 1-1 Incident Command System Organization[28]

[25] Information derived from personal experience working on wildfire incidents.
[26] Fire Logistics, Inc. "2003 Standard Operating Procedures and References" (2003), 7.
[27] Ibid.
[28] Ibid.

Under the incident commander there are several sections including planning, operations, logistics, and finance/administration. The operations section is in charge of all operations being done to fight a fire. This includes work on the fire lines and air operations.[29] The logistics section is in charge of things like communication, grounds, facilities, food, medical, and supplies. Logistics are the support needed to run a fire camp and to supply the fire fighters with all that they need.[30] The finance/administration section is in charge of time, compensation, and costs. Finance makes sure everyone gets paid and that there is money to fight the fire.[31] Working with the incident team but not under a unit are the information and safety officers. The information officer works with the public by holding town hall meetings and doing news interviews. The safety officers assess hazards on a fire and come up with mitigations to those hazards.

The planning section is made up of the resources unit, demobilization unit, documentation unit, as well as the situation unit.[32] The resources unit assigns crews to jobs they will have on the fire, the demobilization unit checks people in and out of fire camp, and the documentation unit maintains records for the fire. The situation unit is in charge of assessing the situation on the fire and reporting it to the planning section heads and the incident commander.[33] The GIS is within the situation unit and reports to the situation unit leader directly. The GIS trailer makes maps for daily briefings, for tactical planning, for recovery and rehabilitation planning, as well as any other need that arises. Mobile fire mapping is a relatively new concept with the U. S. Forest Service which implemented a mobile unit for the first time for the Humboldt-Toiyabe National Forest in

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[29] Information derived from personal experience working on wildfire incidents.
[30] Ibid.
[31] Ibid.
[32] Ibid.
[33] Ibid.

1996.[34] Since then other government and private companies have begun to see how the quick response of a mobile mapping unit can be critical to fire suppression efforts.

One such mobile mapping company, Fire Logistics Inc, is the focus of this thesis. Fire Logistics, Inc. of Montana City, MT is a wildfire mapping and consulting firm that works as GIS support on type one and two fire incidents. An upstart company, Fire Logistics is relatively new to the wildfire mapping scene. However, even with only three years of experience mapping wildfire incidents, they are becoming well respected and sought by incident command teams throughout the West. They have mapped fires in Montana, Colorado, and Idaho for incident command teams that have come from all around the country. Fire Logistics sends one or two GIS Specialists, with a GIS equipped trailer housing computers and printers used to create the maps. They also have a GIS in a trunk in case they need to go to fires while the trailer is assigned elsewhere. The GIS in a trunk includes a computer, plotter, and software that can be sent in the trunk of a car to work on a fire. This thesis surveys maps from the first two years Fire Logistics has offered mapping services. The maps are surveyed for cartographic design and quality to help the upstart company improve their methods of producing maps.

Also within the situation unit are Field Observers (FOBS) and Palm Infrared users.[35] FOBS are placed around a fire to watch for flare ups and report any fire movements of note. They also do some GPS work. Palm Infrared fly the fire in helicopters with their infrared equipment to GPS hotspots within the fires perimeter. Both FOBS and Palm Infrared people work closely with the GIS trailer and supply much of the data put on maps.

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[34] Rick Connell, "Mobile Fire-Mapping Units Support Wildland Fire Suppression," *Fire Management Notes* 62, no. 2 (2001): 19.

[35] Information derived from personal experience working on wildfire incidents.

The incident command system represents a way in which all facets of fire fighting operations can be accomplished in an organized structure where the incident commander is the supreme boss. Often times in years such as 2003 in Western Montana, area commanders will be brought in to manage several fires within a geographic area.[36] Then the incident commanders on each of those fires will report to the area commander.

Often times BAER is dealt with separately from the incident command system. The local national forest or other interagency will likely have a BAER team since incident command teams often come from out of the region to fight wildfires. Local forest or range managers will be doing the rehab plans rather than people unfamiliar with the area. However, the mapping done for the BAER team is often done by the GIS trailer. Often times the local interagency GIS will work in coordination with the GIS trailer to make BAER maps. Since the GIS trailer has an abundance of data about the fire, it is often best equipped to do the BAER mapping.[37]

**Types of Wildfire Maps**

There are two types of wildfire mapping, real time mapping and post fire rehabilitation (BAER) mapping. Real time wildfire mapping involves making maps for any tactical operations that might be occurring on an incident, this includes planning and operations maps. These maps often need to be created quickly because the information mapped is dynamic. Often by the time a map is created, it is already inaccurate based on the movement of the fire, therefore it is crucial that maps be produced quickly.

Additionally, BAER maps are quickly produced because of the importance in rapidly starting burned area rehabilitation. Burned Area Emergency Rehabilitation is

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[36] Ibid.
[37] Ibid.

defined as "projects undertaken following wildfires necessary to minimize negative effects on soil productivity and water quality, and to minimize sources of damage to human life and property."[38] BAER inventory, analysis, and rehabilitation planning for treatments should be completed within three days after a fire of over 300 acres has burned out.[39] Many treatments have to be completed before the first major storms of the season in order for them to be effective.[40] Often BAER maps are created showing burn intensities and soil erosion to monitor the flooding potential of a burned area.[41] However, BAER maps can be created to monitor noxious weeds, hazardous trees, fence repair, and aerial seeding. These quickly produced maps are used to decide important resource management issues; therefore, it is very important that they are produced with high cartographic quality. Maps that allow poor resource decisions could lead to soil erosion causing the loss of nutrients. As well, the increased runoff could lead to poor water quality because of increased scouring and sedimentation in streams.[42] Lastly, the potential threats to life and property are many as a result of poor decision making. High water, sediment, debris flows, and mass wasting events are all threats to lives and property following a wildfire.[43] BAER maps are created to help resource decision makers prevent these situations from occurring, and for protecting lives, property, and the natural resources.

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[38] USDA Forest Service, *Burned-Area Emergency Rehabilitation Handbook* (Washington D. C., USDA Forest Service, 1995), 5, WO Amendment 2509, 13-95-3.

[39] Henry Lachowski, Robert Griffith, Annette Parsons, and Ralph Warbington, "Faster, Better Data, Burned Watersheds Needing Emergency Rehabilitation," *Journal of Forestry* 95, no. 6 (1997): 4.

[40] Ibid.

[41] Ibid., 6-7.

[42] USDA Forest Service, *Burned-Area Emergency Rehabilitation Handbook* (Washington D. C., USDA Forest Service, 1995), 2, WO Amendment 2509, 13-95-3.

[43] Ibid.

Wildfire Mapping versus Other Hazard Mapping

In the scheme of hazard mapping, wildfire mapping has received very little attention. In Monmonier's book *Cartographies of Danger*, wildfire mapping is not even discussed. Monmonier says of the omitted hazards in his book that while they are "either rare, insignificant in their impact on humans, or cartographically uninteresting, others would prove usefully revealing."[44] For this thesis the later will be assumed, since none of the previous three descriptions suit. Flood hazard mapping seems to be the most widely studied type of hazard mapping.

In this section, an overview of the incident command system was given showing how each section and unit operates. As well, descriptions of the different kinds of wildfire maps created by the GIS unit were discussed. With this in mind, the next section will discuss what is proposed to be done for this thesis. A statement of purpose will be followed by questions the thesis hopes to answer.

**Purpose**

**The purpose of this thesis is to critique the cartographic quality of BAER maps to see how well they utilize accepted cartographic design elements.** The focus of this research is on maps created by a private firm; Fire Logistics Inc. of Montana City, Montana. In order to reach conclusions on the use of accepted cartographic design elements, the research is organized around the following questions:

- How well do the maps use the accepted design elements of visual hierarchy, balance/orientation of graphics, and the ability of the map to communicate?

[44] Mark Monmonier, *Cartographies of Dangers* (Chicago: The University of Chicago Press, 1997), xi.

- How well do the maps use the accepted feature elements of color/gray scale, line, text, symbolism, inset/legend, scale/north arrow, data source, and date/cartographers name?
- What cartographic design errors could be perceived to have an affect on resource management decision-making?

To answer these questions, first a literature review was conducted. Next, a methodology was developed to answer these questions. Maps were accessed, and a pretest survey was given to assess the quality of the questions to be used in the evaluators' survey. Changes were made to the survey and an evaluator's survey was given to critique the maps. Data from the evaluator's survey was analyzed and conclusions were offered. Lastly, applications of such surveys and potential research questions for the future were discussed.

By answering these questions, it is hoped that an understanding of the state of cartographic design in BAER maps might be achieved. In addition it is hoped a better understanding of cartographic design in BAER maps might lead to higher quality maps and ultimately to better resource management decisions being made. A written protocol will be created that can be used by wildfire cartographers to improve the quality of the maps they create.

# Chapter 2

# Literature Review

In this chapter, a history of wildfire mapping will be presented along with how wildfire mapping is done today. The role of wildfire maps will be discussed, as well issues of data sharing and wilderness wildfire mapping will be given. Cartographic quality issues will be discussed, and the cartographic design elements to be used in the survey will be explained. This chapter will enforce the importance placed on wildfire mapping and show how each individual cartographic design element should be utilized on a map.

## Historic Wildfire Mapping

### 1940s-1960s

Wildfire mapping has come a long way since the days of sketching wildfires on topographic map sheets. From the 1940s to 1950s, aerial photography was put into service to map wildfires. The main problem with using aerial photographs in wildfire mapping is that smoke tends to obscure the downwind fire boundary making it difficult to map. A 1958 Forest Service manual says, "relatively expensive photographic equipment is required if a good map from which acreage figures can be secured is made."[45] It goes on to explain how the use of such equipment is only justified if the fire would be too difficult or costly to map from the ground.[46] Helicopters were also used in obtaining an

[45] USDA, Forest Service, *Manual for Forest Fire Control, Fire Fighting Methods and Techniques* (Chatham, NY, Northeastern Forest Fire Protection Commission, 1958), 137.
[46] Ibid.

aerial survey of wildfires; however, they were very expensive to operate in the 1950s and became more prominently used in the 1960s.[47]

In the early 1960s, Project FIRESCAN was developed which implemented a fire mapping technique using thermal infrared systems.[48] Infrared systems allowed fire managers to create maps of the fire that were not obscured by smoke. The thermal infrared scanners used rotating optical systems that covered an area perpendicular to the flight path of the aircraft (See Figure 2-1).[49] Not only could thermal infrared detect a fire boundary, it could also help in determining the relative intensity of the fire, the location of hot spots, locations of unburned areas, existence of major fuel types, as well as the locations of developed areas.[50]

<u>1970s-Present</u>

During the 1970s Landsat images were used in the detection and mapping of wildfires.[51] Landsat satellites used more accurate sensors that allowed for faster data processing than aerial detection equipment. From the 1980s to present, advances in Advanced Very High Resolution Radar (AVHRR) as well as Airborne Global Positioning Systems have dominated the wildfire-mapping scene. AVHRR is preferred over Landsat satellite images because of the increased observation frequency, as well as increased spectral range. AVHRR detection works best in the middle infrared band, where average

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[47] Ibid., 138.

[48] USDA Forest Service, "The Pioneers (Some of Them) and Their Equipment (a Little of It) in Forest Service Infrared Fire Mapping and Detection Research and Operations," *Fire Management Notes* 52, no. 3 (1991): 32.

[49] USDA, Forest Service, *Project Fire Scan Fire Mapping Final Report* (Missoula, MT, USDA Forest and Range Experimental Station Northern Forest Fire Laboratory, 1966), Research Paper INT-49, 6.

[50] Ibid.

[51] Emilio Chuvieco and M. Pilar Martín, "Global Fire Mapping and Fire Danger Estimation Using AVHRR Images," *Photogrammetric Engineering & Remote Sensing* 60, no. 3 (1994): 564.

wildfire temperatures between 440-1340° F are found.[52] These satellites travel around the earth in an orbit that allows them to fly over a location on the earth up to several times a day. Within the satellites are sensors that are used to detect all colors of the spectrum, but thermal infrared is used because it gives the fire a distinct signature. The images are then relayed back to earth and processed at places like EROS Data Center in Sioux Falls, South Dakota.

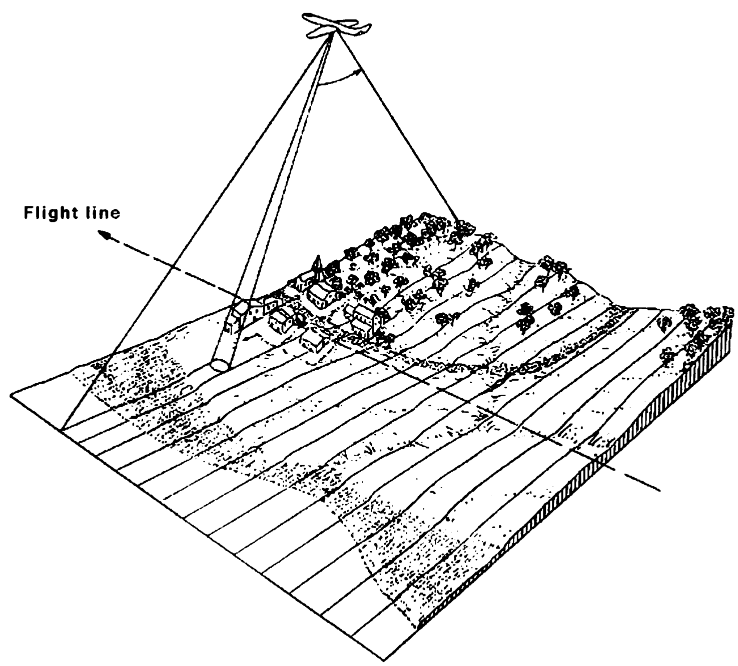


Figure 2-1 Thermal Infrared Scanning[53]

In 1984, a government survey was done to assess the equipment needs of wildfire fighters. That survey found the biggest problems were with communications gear carried by the fire fighters.[54] By comparison, a similar survey done in 1998 found the same

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[52] Ibid.

[53] T. M Lillesand and R. W. Kiefer. *Remote Sensing and Image Interpretation* (New York: John Wiley and Sons, 1979).

[54] USDA Forest Service, *Wildfire Equipment Development Priority Needs, A Comparison 1984-1998* (Washington D. C., USDA Forest Service, November 2000), 2, 0051-2856-MTDC.

communication problems, as well as problems with GPS procedures for situational mapping.[55] The importance of GPS was beginning to be recognized.

Airborne GPS mapping of wildfires began in the 1980s when pilots would fly the perimeter of a wildfire in an airplane or helicopter. Airborne GPS is commonly used today to gather fire perimeter and hot spot data.[56] The benefit GPS has brought to wildfire mapping is that it has increased the speed in which information can be processed and delivered to the people fighting the wildfire. In 1990, a test of a GPS system was given for Forest Service officials at the scene of a wildfire in the Black Hills National Forest.[57] For the test, a GPS was used in a helicopter as it circled a thirty-five mile perimeter of the fire enclosing some 14,200 acres (See Figure 2-2).[58] The flight took fifty-five minutes, and with a couple hours of post-processing, the data was mapped and given to the fire fighters. Ground-based GPSing of the fire would have literally taken days, and by that time the fire lines may have changed enough to make that data worthless.[59]


Figure 2-2 Helicopter used for GPSing Wildfires[60]

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[55] Ibid., 9.
[56] Information derived from personal experience working on wildfire incidents.
[57] Philip L. Drake, "Fire Mapping Using Airborne Global Positioning," *Fire Management Notes* 52, no. 3 (1991): 25.
[58] Ibid., 25-26.
[59] Ibid., 26.
[60] Photograph by Fire Logistics Inc. 2001.

At present, Satellite and GPS mapping are even more precise with quicker processing times than even a few years ago. In a 2001 comparison of GPS receivers, the less expensive GPS units were found to get a signal faster under a tree canopy; however, the data they collected was not as accurate as the more expensive units.[61]

Real time high altitude fire mapping also became greater utilized in the mid 1990s. A NASA remote sensing system called STARLINK was used along with high altitude aircraft to get Thematic Mapper[62] images of a fire and relay them to a satellite and then to analysts on the ground and the Internet.[63] Older systems that transmitted the data directly from the plane to the ground often took eight hours to several days to process the data.[64] STARLINK is a data relay system that transfers images taken from high altitude aircraft, and almost instantaneously sends the data to the people doing the decision making.[65]

Airborne Infrared is also commonly used to gain perimeter and hot spot data on fires. The flights usually take place between 0000 and 0300 in the morning depending on the weather. After an hour or two of post-processing, a GIS Specialist on a fire is able to access the perimeter and hot spot data off an FTP site for the 0600 morning briefing.[66]

Wildfire mapping is becoming more interactive; Internet GIS using ArcIMS is being used in present day wildfire mapping. GEOMAC, which stands for the Geospatial Multi-Agency Coordination Group is using Internet based mapping systems to allow fire

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[61] USDA Forest Service. *Comparison of GPS Receivers Under A Forest Canopy, After Selective Availability Has Been Turned Off* (Washington D. C., USDA Forest Service, May 2001), 17, 0171-2809-MTDC.

[62] Thematic Mapper is an imagery sensor used to take infrared images of fires.

[63] Dana Cole, Jeffrey Myers, and Wayne Mitchell, "Real-Time High-Altitude Fire Mapping," *Fire Management Notes* 58, no. 4 (1998): 26.

[64] Ibid., 28-9.

[65] Ibid., 26.

[66] Information derived from personal experience working on wildfire incidents.

personnel to download information about a fire.[67] This service was also made available to the public at http://geomac.usgs.gov/. Literally anyone with an Internet capable computer can use the interactive mapping features of GEOMAC to monitor wildfires. The future trends in wildfire mapping point to the Internet as a quick and efficient way for people and agencies to share wildfire data.

**Role of Wildfire Maps**

Wildfire maps play an important role in resource decision making. Having worked with type one and type two incident command teams, the importance these maps play cannot be understated. The maps are crucial for the incident command and BAER teams to make decisions. While these maps are extremely important, cartographic design has been approached by wildfire mapping agencies in many ways. Some agencies have no protocols for the creation and mapping of wildfire incidents.[68] Fire Logistics Inc. has a basic protocol set up to help the cartographer design the map. Their protocol gives basic elements that should be on a map. For this thesis, a protocol will be created that expands upon Fire Logistics' protocol by offering not just what elements to use, but suggestions on how to use them.

**Data Sharing**

Data sharing among agencies is improving allowing for better exchanges of information that allows for faster mapping. Working on the Mineral-Primm Complex Fire showed this. The Montana DNRC supplied the initial data. Throughout two weeks on the fire, GIS data was accessed from Missoula County, the Lolo National Forest, Plum Creek Timber, the Salish and Kootenai Confederated Tribes, as well as the State of

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[67] USDA, USDI. "GEOMAC Wildland Fire Support." 2002. Available from: http://geomac. usgs. gov. Internet accessed 5 June 2003.

[68] Information derived from personal experience working on wildfire incidents.

Montana. Data exchange was made easy through the use of an FTP site maintained by the U. S. Forest Service.

**Wilderness Wildfire Mapping**

Wilderness wildfire mapping is dealt with the same as any fire mapping, although some special considerations need to be taken into account. Working on the Mineral-Primm Complex, part of the fire burned into the Rattlesnake Wilderness Area. The most important consideration when mapping a wildfire that is burning in wilderness or towards wilderness is to specify on maps where the wilderness boundary occurs. Since wilderness areas are managed for fire as a part of the ecosystem, there is no need to suppress wilderness fires unless they threaten developed areas.[69] It is critical to map where dozers and other large equipment should not enter as to not disturb the wilderness. Firelines put into the wilderness are usually hand lines or cold trails since these require little rehabilitation.[70]

## Cartographic Quality

Maps are used to portray many types of data for enumerable purposes. In general, maps can be very detailed, or not at all; they can be used for reference, or in critical decision-making. Quality is vital to cartography because major decisions are often made based on the information a map contains. In the fast paced world of GIS mapping, individuals with little or no training in cartography can learn to work with spatial data and mapping software packages. As a result, cartographic quality has suffered. While many competent mapmakers are trained in the visual arts and the use of computer software packages, they may fail to utilize the cartographic techniques necessary to create

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[69] Information derived from personal experience working on wildfire incidents.
[70] Ibid.

quality maps.[71] The cartographic design skills of GIS users will have to improve to make sure the maps being produced are understandable to the map reader.[72] Regardless of the subject, cartographers should always be concerned with producing a quality product.[73] Producing quality cartographic products is important in any map created, but especially crucial in the production of wildfire maps.

**Visualization Quality**

Poor visualization quality on a map can lead to two types of analysis errors. These errors are referred to as type one and type two errors.[74] A type one analysis error is observing something incorrectly or identifying patterns and relationships that are wrong on the map.[75] A type two analysis error is not seeing some pattern or relationship that exists on the map.[76] Symbolization and classification of data play an important role in the avoidance of visualization errors. The cartographer should test different classification schemes and symbolization types before producing a final map. Often different classification schemes will show a different picture on a map. As well, transforming or projecting data can lead to visualization errors. It is important that the cartographer have a good understanding of how projections work to avoid creating maps that give an incorrect impression. Now that issues of cartographic quality have been discussed, how cartographic design elements and features are used in the creation of maps will be discussed.

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[71] Mark Monmonier, *How to Lie with Maps* (Chicago: The University of Chicago Press, 1991), 1.

[72] Peter F. Fisher, "Is GIS Hidebound by the Legacy of Cartography?" *Cartographic Journal* 35, no. 1 (1998): 5.

[73] Jeff Simley, "Improving the Quality of Mass Produced Maps," *Cartography and Geographic Information Science* 28, no. 2 (2001): 97.

[74] Alan M. MacEachren, *Some Truth with Maps: A Primer on Symbolization & Design* (Washington D. C.: The Association of American Geographers, 1994), 68.

[75] Ibid.

[76] Ibid., 69.

## Cartographic Design

Proper use of cartographic design qualities are essential for creating high quality maps. The cartographic qualities discussed in this section include the broad categories of overall map design and the use of cartographic features. The elements of overall map design describe how the map elements look together. They include the visual hierarchy, balance/orientation of graphics, and the ability of the map to communicate/cartographic literacy of the map. The cartographic features discussed include the use of color/gray scale, lines, text, symbolism, legend/insets, scale/north arrow, data source, the date, and the cartographers name.

### Overall Map Design

To begin, the proper uses of visual hierarchy, balance/orientation of graphics, and the ability of the map to communicate are discussed in this section. Then the importance that each of these factors plays in the overall design quality of the map is given. Lastly, poor examples of each of these elements will be demonstrated and discussed.

Visual Hierarchy

Just as anyone trying to communicate effectively needs to formulate and prioritize their ideas, cartographers must do the same in designing a map. A visual hierarchy is the method by which the cartographer communicates the most vital information on the map, while also showing more marginal reference information. Dent describes the visual hierarchy as "the intellectual plan for the map and the eventual graphic solution that satisfies the plan."[77] In creating a map, the cartographer must sort through all of the

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[77] Borden D. Dent, *Cartography, Thematic Map Design* (Dubuque, IA: Wm. C. Brown Publishers, 1996), 256.

components of the map to determine the importance of each element.[78] He or she then needs to assign a dominant visual setting to the components deemed to have greater importance on the map. Because map readers tend to see objects that are distinguishable from the background, in designing a map, the cartographer should use the figure-ground phenomena to help construct the visual hierarchy.[79] The figure-ground phenomenon is a person's inclination to organize what they see into two categories — figures and grounds, the figures being the most important objects they see, and the ground being the background or less important objects.[80] The following is an example of poor use of visual hierarchy on a map (See Figure 2-3). This map has a poor visual hierarchy because it is difficult to distinguish between areas of land and water. As well, there is no figure-ground difference in the lines used on the map to represent boundaries and flight paths as compared to coast lines.

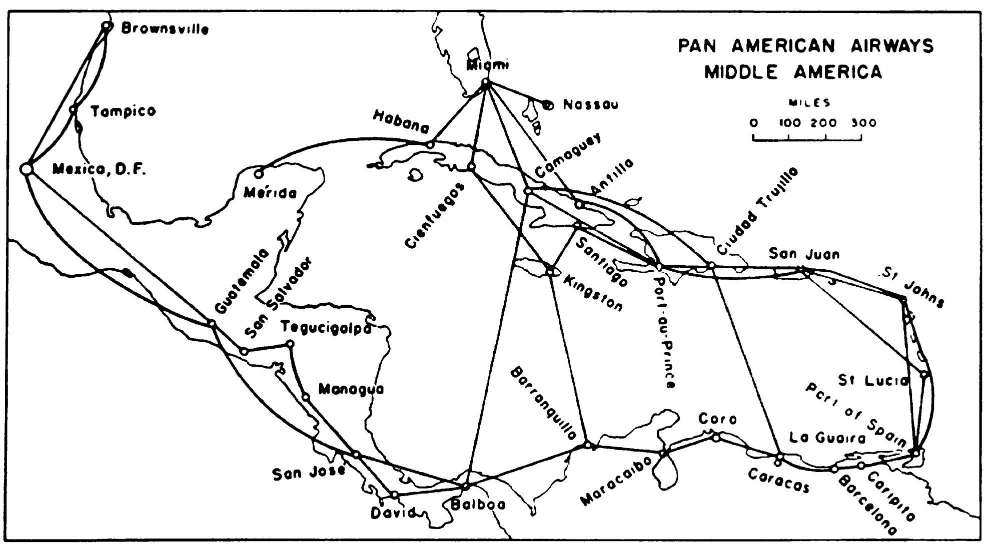


Figure 2-3 Poor Visual Hierarchy Map[81]

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[78] Ibid.
[79] Ibid., 257-58.
[80] Ibid., 245.
[81] Ibid., 257.

Balance/Orientation of the Graphics

Balance and orientation of the graphics involve the way the map components are displayed within the map frame. Rudolph Arnheim, a researcher of the psychological principles of art, suggested that weight and direction are the two main factors in attaining visual balance.[82] Arnheim's study of weight and direction of components can be summarized in seven remarks.

1. Visual weight depends on location. Objects in the upper portion of a map pull more weight than the bottom, objects to the right of a map pull more weight than left, and the weight of an object increases in proportion to the distance from the center.
2. Visual weight depends on size. Larger objects look heavier than smaller.
3. Weight depends on color, interest and, isolation. Bright colors appear heavier than dark colors, objects of interest appear heavier than less interesting objects, and isolated objects appear heavier than objects near other elements.
4. Visual weight depends on shape. Regularly shaped objects appear heavier than oddly shaped ones; as well, compact objects appear heavier than non-compact.
5. Visual direction depends on location. The weight of an element attracts nearby elements.
6. Visual direction depends on shape. Elements impart directional forces in two opposite directions.

[82] Rudolph Arnheim, *Art and Visual Perception* (Berkley: University of California Press, 1965), 14.

7. Visual direction depends on the subject matter. Objects having intrinsic directional forces can impart visual direction to other elements in the map.[83]

Figure 2-4 contains examples of how balance in a map has an effect on the eye of the map reader. Balance occurs when there is complete equilibrium between all visual elements on a map. Good map balance is reached when moving any element any farther would cause a visual degradation to the map reader.[84] The middle right map has the best balance of the six in Figure 2-4. A study by Antes, Chang, and Mullis showed that the balance of a map has an initial effect on the map reader; however, the longer a map reader views the map the less of an effect balance has on the readability of the map.[85]

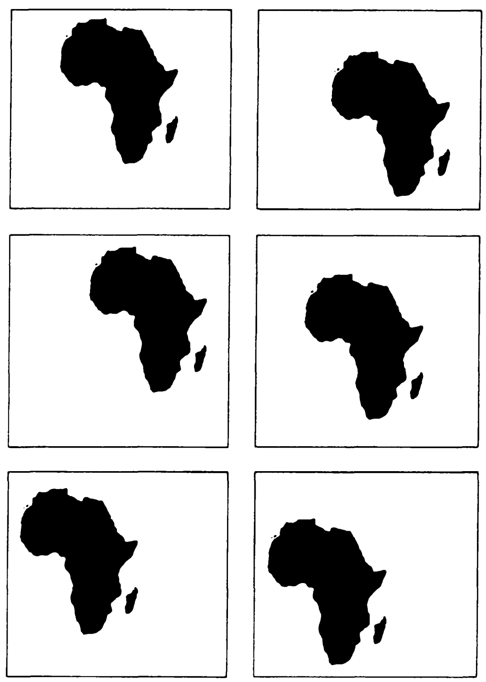

Figure 2-4 Examples of Balance on a Map[86]

[83] Ibid., 14-17.
[84] Ibid.
[85] James R. Antes, Kang-tsung Chang, and Chad Mullis, "The Visual Effect Of Map Design: An Eye-Movement Analysis," *American Cartographer* 12, (1985): 143.
[86] Dent, 244.

Ability of the Map to Communicate

The ability of a map to communicate effectively depends on a variety of factors. The purpose of a map has a major influence on the ability of the map to communicate. Some maps are more important than others, therefore, different specification and generalization are needed in creating the map.[87] Specification and generalization of a map tell how specific or how general a map needs to be in order to meet the purpose it was created. If a map has too little information for a specialized purpose, it may not communicate well. If a map has too much information for a generalized purpose, it may not communicate well.

Symbology used on a map also has an influence on the ability of the map to communicate. Complex symbolization or use of any symbol that causes confusion could lead to a map communicating poorly. Figure 2-5 is an example of a map that might have difficulty communicating because of an overly complex design. If looked at for a while, the land and water areas tend to interchange in perception.

Another factor that has an influence on the ability of a map to communicate is the cartographer making the map. If an untrained cartographer makes a map, he or she is more likely to create communicative errors than someone who has had cartographic training. Simply put, an untrained cartographer will not know what to look for on maps that could be potentially confusing and lead to poor communicability. This is a major problem concerning wildfire maps since many GIS Specialists do not have sufficient cartographic backgrounds.

[87]Terry A. Slocum, *Thematic Cartography and Visualization* (Upper Saddle River, NJ: Prentice Hall, 1999), 6.

Lastly, cartographic literacy could lead to the inability of a map to communicate. When a cartographer makes a map that the reader can not understand there is a problem. In such cases, the cartographer has to recognize that the audience cannot understand the map, and he or she must try to show the important information in a more understandable way. If the audience cannot read a map, it serves no purpose. For purposes of this survey, cartographic literacy is combined with the ability of the map to communicate because if someone cannot read a map, the map cannot communicate.

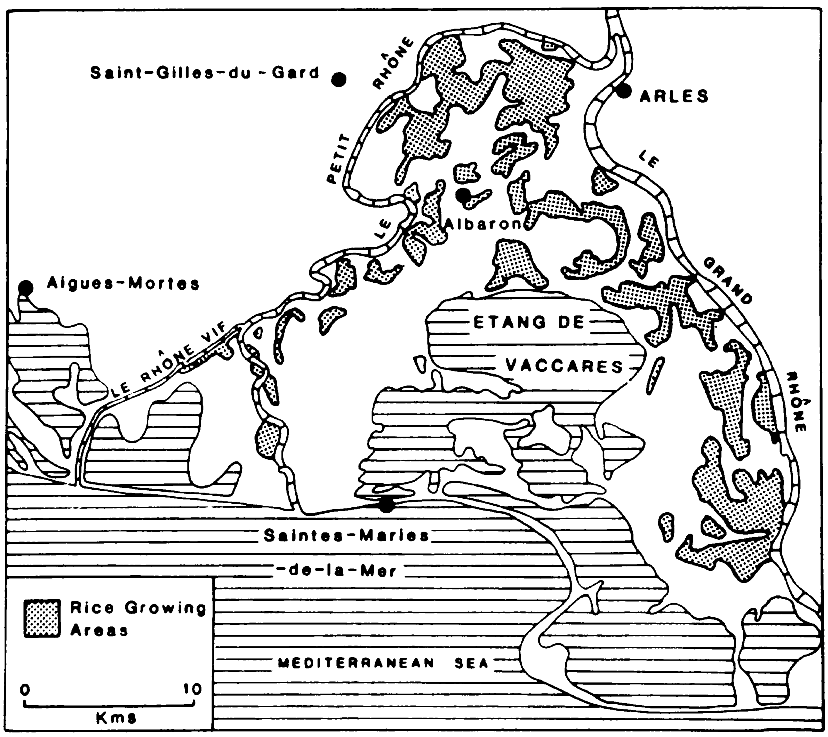


Figure 2-5 Potentially Confusing Map.[88]

**Cartographic Features**

In this section, the cartographic features to be analyzed in the survey are discussed. The importance each of these features plays in the overall design quality of

[88] Dent, 265.

the map is discussed, along with a justification for any groupings devised for the survey. As well, examples of several of the features are shown.

Color/Gray Scale

Color is an important cartographic design element used to enhance the figure-ground relationship on a map as well as to give it aesthetic qualities.[89] The use of pastel colors on a map is preferred over very bright or very dull colors. The warmer colors of yellow, orange, and red tend to be better figure colors while the cooler colors of green, blue, and purple tend to be better ground colors.[90] Contrast is important in colored maps; it can lead to greater clarity that makes the map easier to read.[91] There are many conventions in color maps, for example shades of blue should be used to represent water bodies while green should be used to represent forests. Sticking with conventions is a safe way to make a map that will be understood. The cartographer should not use any more color values than are necessary in making a map, since using too many can lead to confusion.

Gray scales are also used to produce maps. The main benefit of a gray scale is that color printing has been historically more expensive than black and white.[92] Gray scales rarely use more than five tones to distinguish between classes because it becomes progressively more difficult to distinguish between more than five tones. Color and gray scales were lumped together for the survey because they are both forms of shading on a map.

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[89] Ibid., 303.
[90] Ibid.
[91] Ibid., 304.
[92] Slocum, 6.

Lines

Lines can function on maps as borders, neatlines, quantitative or qualitative symbols, or as graphics amongst others.[93] There are numerous symbols that can be used as lines on a map, but as with color there are conventions that are widely used. For example, a dashed line might be used to represent an intermittent stream while a solid line might be used to represent a perennial stream. Lines have weights and color which the map reader uses to determine the importance of, or what the line represents on a map.

Text

Text on a map is used to relate marginal information, as well as to label information on the map. Marginal information includes things like the projection, data source, and cartographer's name. There are a numerous letter fonts that can be used to represent text. As well, size of lettering plays a factor in the amount of importance the cartographer wants to place on the text. Using easy to read fonts and avoiding extremely small fonts are important in making a readable map.

Symbolism

Symbolism is very important in creating an interesting, legible map. The two major types of symbols are replicative and abstract.[94] Replicative symbols are those that closely resemble the geographic phenomena they represent on the map. Good examples of replicative symbols used on maps are railroads, schools, and airfields (See Figure 2-6).[95] Abstract symbols usually take the shape of some geometric figure and are used to

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[93] Dent, 303.
[94] Ibid., 16.
[95] Ibid.

represent anything necessary for the map user to know.[96] The following are examples of replicative versus abstract symbolism.

Replicative Abstract

Figure 2-6 Replicative Symbolization and Abstract Symbolization.[97]

Legends/Insets

Legends do not need to be elaborate, but they do need to be informative. They do not need to include all symbol information for the map but should focus on those items that can be helpful to the reader if included. Some information such as state or county boundaries would be obvious to most map readers, and may not be necessary for the legend. Insets were grouped with legends because none of the maps studied contained an inset; however, the author thought it was important to discuss insets as they are often used on maps.

If a small scale map does not allow the cartographer to show as much detail as desired, map insets are useful elements to portray detailed data of smaller areas. Insets are also used on large scale maps where the cartographer wants to show where the map location is within a recognizable region. The following is an example of a good utilization of an inset (See Figure 2-7).

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[96] Ibid.
[97] Symbols created using ArcGIS 8.2, ESRI Corporation, Redlands, CA, 2002.

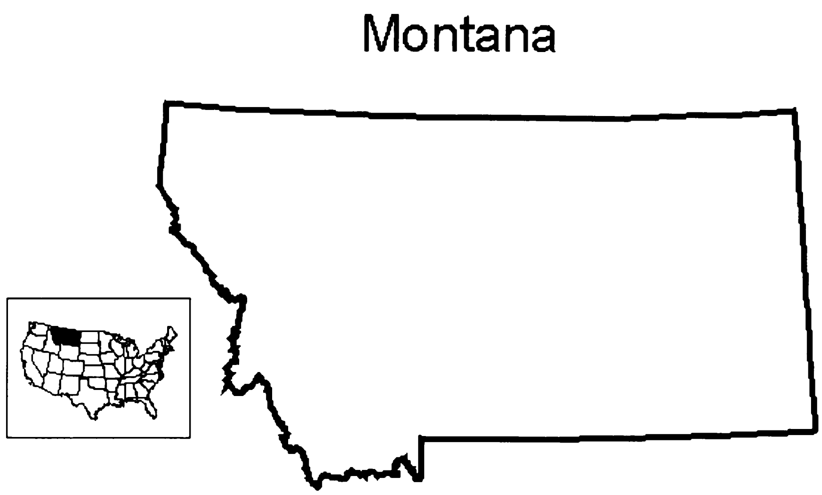


Figure 2-7 Use of an Inset Map[98]

Scale/North Arrow

Part of the marginal information of any high quality map, a scale is a very important map element. Scales can be verbal, representative fraction, or graphic (See Figure 2-8).[99] An example of a verbal scale would be if a map had printed on it "one inch equals two miles." A representative fraction scale might look like "1:24,000" on a map, meaning one unit on the map represents 24,000 of the same units on the earth. Scale and north arrow were combined for purposes of the survey as the north arrow often accompanies the scale. While the scale has much more importance to a map, the north arrow was also lumped in for purposes of minimizing the amount of work needed to survey the maps.

A north arrow helps orient the reader on a map (See Figure 2-9). On large scale maps, it is important that the map reader distinguish between true north and magnetic

[98] Map created using ArcGIS 8. 2, ESRI Corporation, Redlands, CA, 2002.
[99] Dent, 37.

north since navigating with a compass requires knowledge of the current magnetic declination at their location.

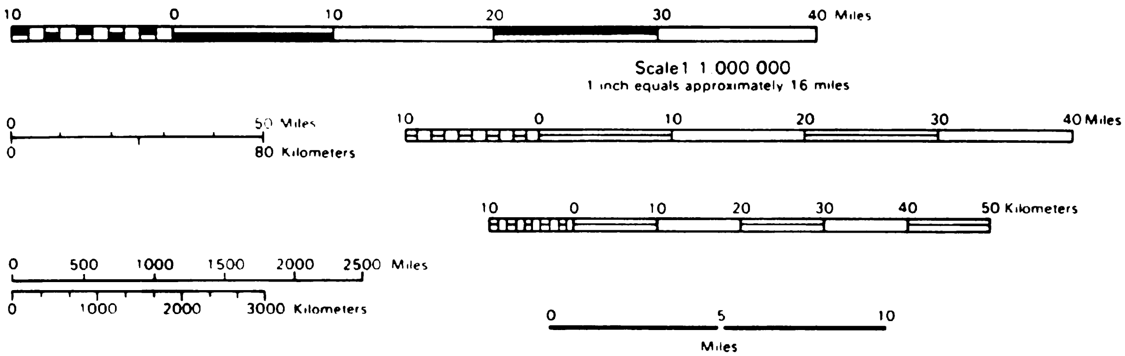


Figure 2-8 Examples of graphic scales[100]

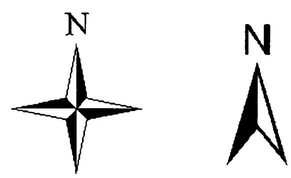


Figure 2-9 North arrow examples.[101]

Data Source

If data is gathered from any location, or is created by the cartographer, citing the source of the data is extremely important. Not only does it give the map reader reference to the data set, it tells the map reader something about the quality of the data. It is important to cite the data source in case questions arise about the quality of the data.

[100] Ibid., 238.
[101] Symbols created using ArcGIS 8.2, ESRI Corporation, Redlands, CA, 2002.

### Date/Cartographers Name

Similar to the data source, the date and cartographer's name are important information to include on any map to help the reader verify when the map was created and by whom. The date is especially important in resource management since maps are constantly changing hands. The cartographers name is important in case the map reader would like to find out more information about the map. The date and cartographers name were combined to minimize the amount of information asked on the survey, as well they are both parts of the marginal information on the map.

## Summary

In this chapter a history of wildfire mapping was presented along with how wildfire mapping is done today. The role wildfire maps play was given; as well issues of data sharing and wilderness wildfire mapping were discussed. Cartographic quality issues were explained, and the cartographic design elements to be used in the survey were given. Overall, this chapter enforced the importance placed on wildfire mapping and showed how each individual cartographic design element should be utilized on maps concerning wildfire management.

# Chapter 3

# Methods

This chapter discusses the methods employed to carry out this study. First, a basic outline of the methods employed is given with justifications as to why certain methods were employed. The initial outline of the methods is followed by a discussion of the Stapel Scale, the method employed in the survey. Lastly there is an in depth discussion of the methods used in the pretest, changes made to the survey, and the evaluators' survey.

## Outline

In order to do this thesis, maps had to be accessed that could be critiqued. Maps were sought out from the U.S. Forest Service and Fire Logistics Inc. Fire Logistics Inc. gladly offered assistance, as they are always looking for ways to improve the quality of their work. For this thesis the author was unable to obtain maps from the U.S. Forest Service despite early indications to the contrary. Lack of time to help was the reason given why the U.S. Forest Service employees could not offer their service. Having maps from only one private agency ended up being an advantage since the author had previously assumed private agency cartography is likely to be better than government cartography. The assumption is based on personal experience working with both private and government cartographers. Therefore, only the best wildfire maps would be assessed. Another advantage of working exclusively with Fire Logistics was their willingness to help the author access maps and data at no cost.

After the source of the maps was chosen, a literature review was conducted to give background about wildfire and wildfire mapping as well as to learn how cartographic quality and design are important in mapping. After completing a literature review, maps were accessed from Fire Logistics Inc. in digital form. The author initially believed a survey of the maps in digital form might work and would be easier to conduct. Next, a survey was devised to assess the cartographic design elements and features of the maps. The survey components are those discussed in the cartographic design section of the literature review. The elements were selected to be surveyed because they are widely accepted by cartographers as essential parts of a map. Institutional Review Board (IRB) exemption was garnered from the University of Montana since the study did not test vulnerable subjects. A pretest was then given to geography graduate students to assess the validity of the survey questions using nine different maps. As a result of this pretest, all of the map elements were deemed valid although the method of giving the survey was changed. It was decided that paper copies of the maps were needed to give the evaluators' survey as this would simulate real map reading conditions. Paper copies of six maps were obtained and the evaluators' survey was given to six evaluators. The thinking behind this was that each map would be surveyed twice which guaranteed that any cartographic error missed by one evaluator would be caught by another. After the completion of the evaluators' survey, results were given as to how the maps utilized the cartographic design elements. A protocol was then devised for improving wildfire maps and final conclusions were given.

## Discussion

After the focus of the research was decided, a literature review was conducted and a survey was created to critique the wildfire maps. The next section will discuss the method employed by the survey, the Stapel Scale. This will be followed by a discussion of the pretest and the methods used to conduct it. Changes made after the pretest are then discussed and the evaluators' survey method is introduced.

**Stapel Scale**

The Stapel Scale is used to rate the use of each cartographic element in the survey. The Stapel Scale is a good method of measuring the appropriateness of an image.[102] Not only does it allow the reader to determine whether a description or phrase meets the criteria, it also allows the reader to assign a qualitative rating to how well the description was used or how it met the criteria.[103] For this thesis, the Stapel Scale takes the cartographic elements selected and measures them on a scale of 1 to 7 with 1 being poor use of an element and 7 being excellent use of an element. Any element inapplicable was not factored into the rating. In assigning a rank, the purpose of the map was taken into consideration. This was done because some maps may have a more important purpose then others and therefore should be held to a higher standard. Stapel Scale measurements may take either the mean or median value of the survey as the rank.

**Pretest**

As noted above, a pretest was given to help determine the validity of the survey questions, as well as to help determine better ways to conduct the survey. Initially, five or six geography graduate students were to be surveyed, but after four, the results began to be redundant. The four geography graduate students who took the survey had a range of cartographic capabilities from beginner to intermediate. The nine maps used in the pretest survey were all created by Fire Logistics Inc. during the 2001 and 2002 fire seasons. The maps in the pretest survey dealt with a wide array of BAER mapping

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[102] Pamela A. Alreck and Robert B. Settle, *The Survey Research Handbook* (Homewood, IL: Irwin, 1985), 153.

[103] Ibid.

subjects relating to three separate fires. The first map came from the Moose Fire of 2001; it showed the type of rehabilitation that was done in the Cyclone Lake area. The Moose Fire was in Northwestern Montana in and around Glacier National Park. The next set of four maps came from the 2002 Hayman Fire just outside of Denver, Colorado. The four maps in this set included two BAER treatment maps from August 2$^{nd}$ and 26$^{th}$ 2002, a map of seeding scarification and ATV treatments, and lastly a map of aerial hydro mulching. The seeding scarification and ATV treatments map displayed a plethora of rehabilitation methods that had been implemented. ATV treatments simply involve seeding an area via all-terrain vehicles. Aerial hydro mulching is a more complex rehabilitation method that involves dumping a slurry of seeds, mulch, and water from a helicopter onto a burned area. The last set of four maps used for the pretest came from the Kraft Springs Fire of 2002. This fire was located in Southeastern Montana between Ekalaka, Montana and Camp Crook, South Dakota. The four maps in this set displayed BAER hazard trees, noxious weeds, range fence repair, and soil erosion. The BAER hazard tree map showed locations of trees that could be hazardous to fire fighters working on rehabilitation projects. The other maps chosen were self explanatory as to what rehabilitation could be done.

Each survey was given in person, on maps that were in JPEG (Joint Photographic Experts Group) format on a CD-ROM. As noted earlier, the author thought that giving the survey in digital form would be easier to conduct since it would be difficult to obtain paper copies of the maps. To the contrary, surveying large maps on a smaller computer screen turned out to be difficult since the surveyor had to zoom in and out to see the whole map and its detail. To give the survey, Adobe Photoshop was used to display the maps. Each student surveyed three maps, meaning a total of twelve maps were surveyed. The surveyor was asked to rate the use of each of the cartographic design elements discussed in the literature review using a Stapel Scale as the qualitative method (See Figure 3-1). Lastly the survey asked the evaluators to list the design errors they could perceive that might affect resource management decisions?

**Map Observation Survey**

Name:
Cartographic Traning:
Date:
Map:

Please pick a number from the scale below that best describes the use of the following map elements and write it next to the element. Please take into account the purpose of the map as well any element inapplicable should be left blank.

**Scale**
**Poor Use 1 2 3 4 5 6 7 Excellent Use**

**Map Design:**

_______ Visual Hierarchy

_______ Balance/Orientation of Graphics

_______ Ability of the Map to Communicate Cartographic Literacy (Easy to Read)

**Map Features:**

_______ Color,Gray Scale Usage

_______ Line Usage, Neatlines

_______ Text Usage, Title

_______ Symbolism

_______ Insets/Legend

_______ Scale, North Arrow

_______ Data Source

_______ Date, Cartographers Name

What design errors could you percieve affecting resource management decisions?

Figure 3-1 Map Observation Form

**Changes to the Survey**

The pretest survey found the questions to be valid although several methods needed to be changed before giving the evaluators' survey. All of the cartographic design elements and features were useful in helping to determine the cartographic quality of the maps so they were not changed. Overall, the survey form itself did not need to be changed for the evaluators' survey. For the evaluators' survey the author decided to reduce the number of maps from nine to six and have each of the cartographic or wildfire evaluators look at two maps each. It was found that the survey took longer than had originally been planned; therefore to get the highest quality results each of the evaluators would survey one less map. The evaluators' survey was conducted using actual paper map copies of the six maps selected. The pretest surveyors suggested it would be easier and more realistic for them to survey the paper maps rather than a computer screen map.

Fire Logistics Inc. gladly supplied paper copies of the maps for the research. The six maps to be used in the evaluators' survey are the maps that produced the most interesting results from the pretest. As well, two new maps were added to the evaluators' survey to add other types of BAER maps to analyze. The maps taken from the pretest survey include two from the Hayman fire which were the BAER Treatments 8-02 and 8-26. The other two maps from the pretest survey were from the Kraft Springs Fire and they included the BAER Soil Erosion and the BAER Noxious Weeds maps. The two new maps added specifically for the evaluators' survey are maps from the 2001 Fridley Fire. These maps were a BAER Slope map and BAER Fire Intensity map from the Southwestern Montana Fire. With the appropriate changes made to the method of surveying, the evaluators' survey was then given.

**Evaluators' Survey**

The evaluators' survey was given to six evaluators who each surveyed two maps. The six evaluators were made up of two Cartographic Technicians, two GIS Specialists, a Forestry Professor, and a Wildfire Research Ecologist. The survey was given in person using full size paper copies of the maps so that the maps were being assessed in field-like conditions and any questions could be easily clarified by giving it in person. Following the survey, Stapel Scale image profiles were created for map design and map feature elements to show which elements were most essential to the production of well-designed wildfire maps. Answers to each of the following questions were discussed in the results and examples of certain cartographic errors were highlighted.

- How well does each map use the accepted design elements of visual hierarchy, balance/orientation of graphics, and the ability of the map to communicate?
- How well does each map use the accepted feature elements of color/gray scale, line, text, symbolism, inset/legend, scale/north arrow, data source, and date/cartographers name?
- What cartographic design errors could be perceived to have an affect on resource management decision-making?

After completing the results, a protocol was designed on how to properly use the cartographic design elements for making wildfire maps. Potential influences on cartographic design were discussed and conclusions were made on the quality of wildfire maps. Lastly, suggestions on future research were offered.

## Summary

This chapter discussed the methods utilized to assess the cartographic quality of wildfire maps. An outline of the methods was given followed by an in depth discussion of the methods employed. Justification for the use of only Fire Logistics maps was offered, and a description of the Stapel Scale was given. There was discussion of the methods utilized in the pretest and the survey form was shown. Lastly, changes made after the pretest were discussed and the evaluators' survey method was introduced.

# Chapter 4

## Results and Analysis

In this chapter, a discussion of the results of the evaluators' survey is given. An introduction to the evaluators is offered followed by a discussion of the results from each of the six maps surveyed. For each of the six maps, a description of the map is given. This is followed by results of the use of the cartographic design elements and features from the survey. Crucial cartographic errors are discussed and some are displayed. Tables showing the evaluators' ratings are given with each map and a final table will be offered that shows the overall results of the survey.

Before the results and analysis of the survey are presented, the evaluators are discussed. Some anonymity was promised to the evaluators so names will not be mentioned, however, their credentials and agency affiliation will be given. The following table shows each of the evaluator's credentials and employer (See Table 4-1). The letter assigned to each evaluator can be used to match the tables showing the results from each map later in the chapter. The evaluators had considerable cartographic training as well as good cartographic literacy. In order to decipher the results, Table 4-2 can be used as a legend for the column headings. The headings are abbreviations of the cartographic design elements.

Table 4-1 Evaluators and their Credentials

| Evaluator | Profession | Agency |
|---|---|---|
| A | Cartographic Technician | BLM |
| B | Cartographic Technician | BLM |
| C | GIS Coordinator | USFS |
| D | Wildfire Research Ecologist | USFS |
| E | GIS Specialist | USFS |
| F | Professor of Forestry | U of MT |

Table 4-2 Legend for Wildfire Map Results

| | |
|---|---|
| **Evaluator** | Person who took the survey (See Table 4-1) |
| **Vis Hier** | Visual Hierarchy |
| **Bal/Orient** | Balance/Orientation of Graphics |
| **Comm** | Ability of the Map To Communicate/Cartographic Literacy |
| **Color** | Use of Color/Gray Scale |
| **Line** | Use of Lines |
| **Text** | Use of Text |
| **Symb** | Use of Symbols |
| **Legend/In** | Use of a Legend and Insets |
| **Scale/N.A.** | Use of a Scale and North Arrow |
| **Data Source** | Use of a Data Source |
| **Cart/Date** | Use of a Cartographers Name / Date |

**Fridley BAER Fire Intensity Map**

For this thesis, the first map concerns the Fridley Fire from September 7, 2001 and is a BAER Fire Intensity map.[104] This map was created from Infrared data, GPS surveys, and FOB (Field Observation) data. It shows the fire perimeter and the burn intensities within areas of the fire. There are three categories of burn intensity used on the map: low, moderate, and high intensity burns. The map also shows the fire in relation to a wilderness study area, as well roads and streams. Ownership is oddly labeled on the map with no boundaries to contain the individual properties.

Map Design Results

Overall, the evaluators rated the map design elements above average. They found the map to be aesthetically pleasing to look at. One suggestion for improving the visualization even more would have been to add hillshading in the background. The hillshading would give the reader a better understanding of the topography of the area. The ability of the map to communicate and the visual hierarchy received a mean score of 6.5 while balance and orientation received a score of 5 (See Table 4-3).

[104] Full images of the maps are located on the CD that accompanies this thesis. The maps are in JPG format and can be viewed using any imaging software package.

Table 4-3 Fridley BAER Intensity Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 6 | 5 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 5 | 6 |
| A | 7 | 5 | 7 | 7 | 7 | 4 | 5 | 5 | 6 | 7 | 4 |
| **Mean:** | **6.50** | **5.00** | **6.50** | **6.50** | **6.00** | **4.50** | **5.00** | **4.50** | **5.00** | **6.00** | **5.00** |
| **Median:** | **6.5** | **5** | **6.5** | **6.5** | **6** | **4.5** | **5** | **4.5** | **5** | **6** | **5** |

## Map Feature Results

Feature usage on the Fridley Intensity map received average to above average ratings by the evaluators. The evaluators thought the use of color on the map was good. The use of lines, text, symbolism, and data source received slightly above average marks. One issue with the lines was that roads and streams were not labeled; moreover there was no mention of them in the legend (See Figure 4-1). Often basic information on maps is left out of a legend, however, in this case the roads and streams were not labeled on the map, therefore adding them to the legend would have helped with the readability of the map. One of the evaluators thought the legend was two small for its intended purpose. Also, it was difficult to tell which areas were inside or outside the wilderness study area since the boundary was not labeled very well. Erroneous text concerning land ownership was also found on the map which further limited its usefulness (See Figure 4-1).

The source information and credits on the map were sufficient. Map scale received average ratings. The map lacked a representative fraction scale which might have been helpful to the management team to calculate the size of the area they need to rehab. Also, the scale bar used an unusual interval (.4 miles) limiting its utility. More familiar intervals should be used to avoid confusion for the map reader. The scale bar also overlapped other text, so it was poorly placed.

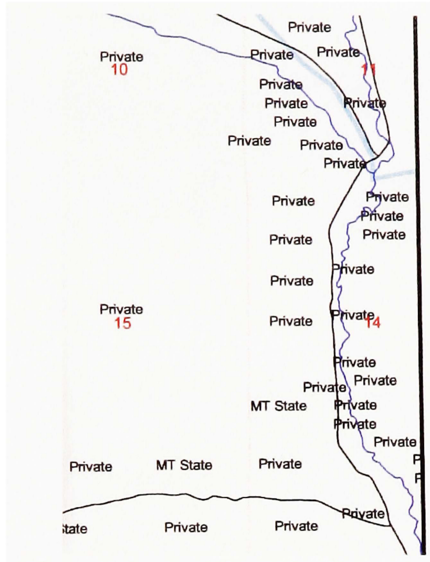


Figure 4-1 Poor and Erroneous Representation of Ownership and no Labels on Roads and Streams

**Fridley BAER Slopes Map**

Similar to the fire intensity map, the BAER Slopes map dates from September 7, 2001. The BAER Slopes map is a visually complicated map of slopes derived from USGS 30 meter DEMs (Digital Elevation Models.) The map uses three classifications for slope, those being 0-14.3%, 14.8-40%, and 40.2-289.8%. It also contains a soils type layer and shows the fire perimeter in relation to a wilderness study area. The slope data was placed on top of the same base layers used in the fire intensity map without the fire intensity data. As well, PLS (Public Land Survey) polygons were added to the map.

<u>Map Design Results</u>

Visual hierarchy, balance, and the ability of the map to communicate received average scores (See Table 4-4). Other than the fire perimeter, nothing else stands out visually; the map appears to be a confusing mesh of color, lines, and text. Clipping the slope to the fire boundary would have improved this and the other map design elements. Problems with the legend made the map difficult to read.

Table 4-4 Fridley BAER Slope Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D | 2 | 6 | 3 | 1 | 1 | 1 | 4 | 3 | 3 | 6 | 1 |
| B | 7 | 5 | 4 | 7 | 7 | 4 | 4 | 2 | 3 | 6 | 6 |
| **Mean:** | **4.50** | **5.50** | **3.50** | **4.00** | **4.00** | **2.50** | **4.00** | **2.50** | **3.00** | **6.00** | **3.50** |
| **Median:** | **4.5** | **5.5** | **3.5** | **4** | **4** | **2.5** | **4** | **2.5** | **3** | **6** | **3.5** |

Map Feature Results

Map features received average to poor ratings for the BAER Slope Map. There were some issues on which different evaluators widely disagreed, but in general a slightly below average rating sufficiently describes this map. It was the one of two maps that had a large discrepancy in evaluators' agreement. As with the previous map, there are erroneous ownership labels on the map. As well, the number of line types on the map was distracting to the evaluators. Using shaded polygons is one possible solution to this issue (See Figure 4-2). Also, the colors used for the slope are similar to the colors of the lines used for section boundaries and wilderness study areas. One of the evaluators thought there were not enough categories of slope for the map to be entirely useful. Two or three more categories would have been helpful to distinguish the different degrees of slope. The cartographer's name and the date were missing. Contact information is very important on any map created. Symbolism, insets and legends, and scale received average to slightly below average ratings.

One issue that could lead to resource decision confusion is the legend. The first category of the legend shows the second two classifications of slope, while it should show the lowest classification of slope (See Figure 4-3). The data source on the map received a high rating because it was clearly mentioned that the slopes come from 30 Meter DEMs (Digital Elevation Models).

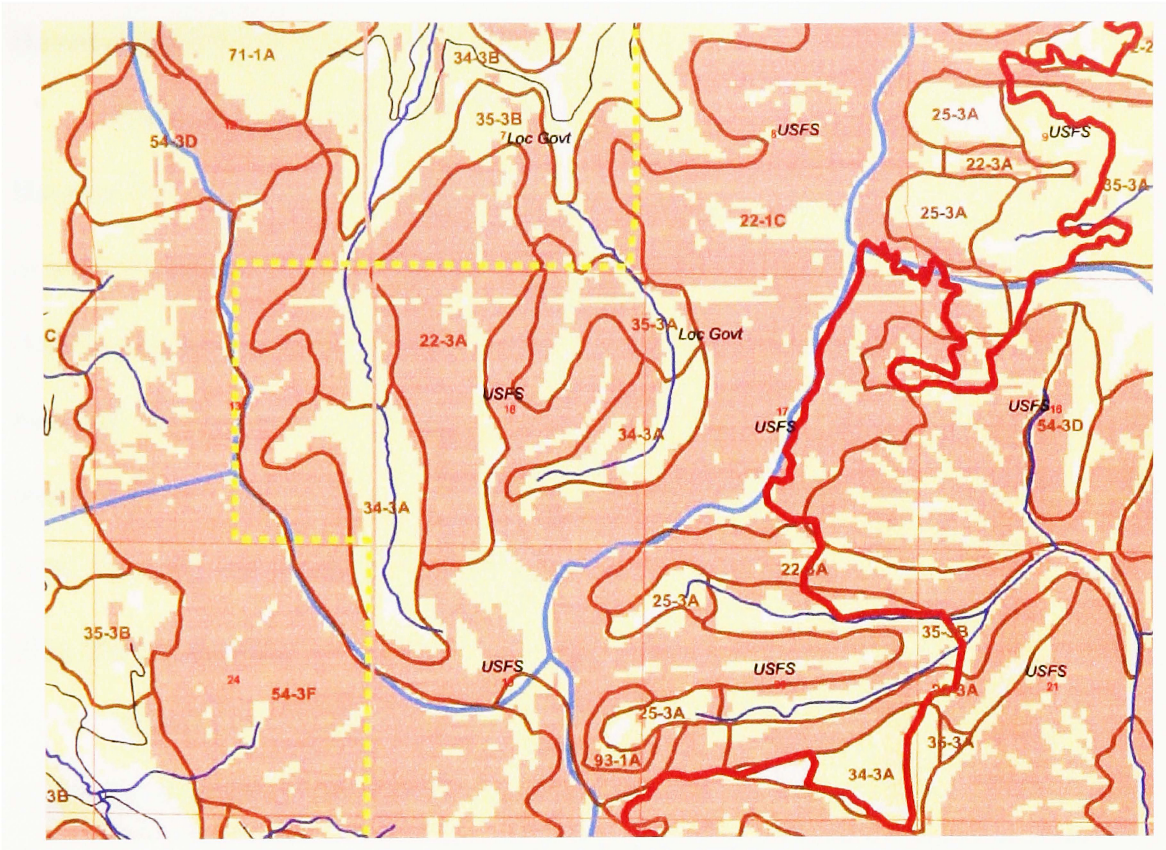


Figure 4-2 Line Usage and Boundary Colors Match Slope Data

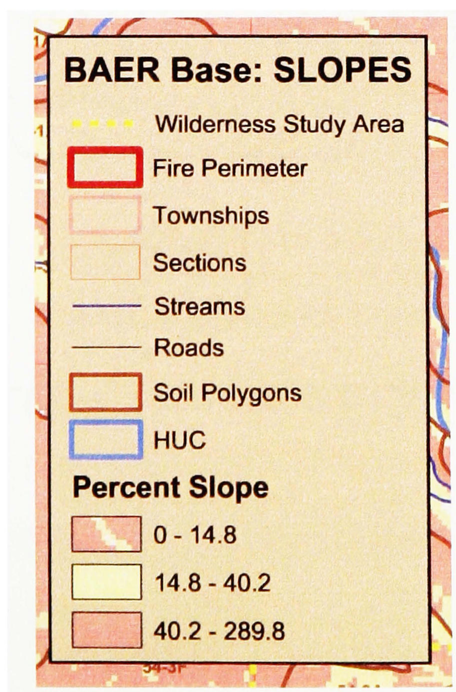


Figure 4-3 Legend and Classification Scheme

## Hayman BAER Progress 8-02-02 Map

Planned or in progress BAER treatments are the topic of the first map from the Hayman Fire from August 2, 2002. This map shows seven different rehab tasks that are or will be completed along with an entire basemap for the area. Digital Raster Graphics (DRG) map files at the scale of 1:100,000 are used for the basemap, along with several base data layers. Some of the base data layers include check points, barricades, and open mine shafts to mention a few. The rehab plan is based on BAER assessment teams using GPS, Palm IR, and basic field observations.

<u>Map Design Results</u>

Map design qualities received average to above average ratings from the evaluators (See Table 4-5). In general they thought the map had good balance/orientation of the graphics. The map received average in its ability to communicate which is good considering its complexity. One evaluator suggested a DEM be used instead of a DRG to show the background. They thought the map looked too cluttered and that removing the abundance of text and contours on the DRG would simplify things. Visual hierarchy received an average score because there are some lesser important things on the map that have greater visual hierarchy than things that should be more important. For example, the division boundaries and labels seem a bit large considering the purpose of the map is to show BAER rehab progress (See Figure 4-4).

Table 4-5 Hayman BAER 08-02 Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D | 4 | 6 | 5 | 5 | 6 | 3 | 5 | 3 | 6 | 3 | 3 |
| B | 7 | 7 | 3 | 7 | 5 | 6 | 5 | 7 | 5 | 7 | 7 |
| **Mean:** | **5.50** | **6.50** | **4.00** | **6.00** | **5.50** | **4.50** | **5.00** | **5.00** | **5.50** | **5.00** | **5.00** |
| **Median:** | **5.5** | **6.5** | **4** | **6** | **5.5** | **4.5** | **5** | **5** | **5.5** | **5** | **5** |

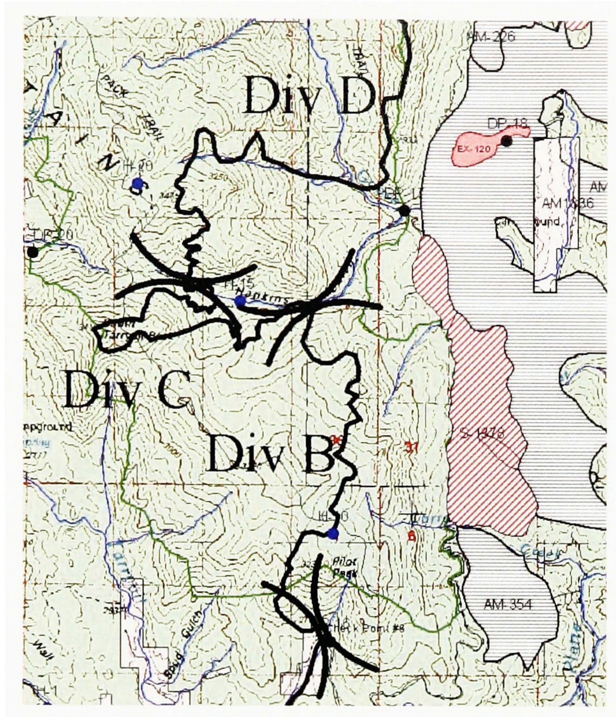


Figure 4-4 Division Breaks with High Visual Hierarchy

Map Feature Results

An average to above average rating was given to the features on the map by the evaluators despite some discrepancies in evaluators' opinions. Any discrepancies were the result of the importance that the different evaluator gave to the each element, and in the end the average to above average rating suits the map. The use of color, line, and scale were rated average to above average, as were the text, symbols, legend, data source, and credit. Some issues with the map features that the evaluators thought could lead to poor resource decision making included the use of the legend. One evaluator thought the legend descriptors were not intuitive or targeted at the user of the map. For example instead of saying "no progress" for a certain rehab type, the evaluator thought it should read, "future BAER planned." For the purpose of the map, the evaluators also thought there was unnecessary text and use of symbols. They thought the text showing the division breaks was too prominent since divisions are set up to help fight the fire rather than using it to plan rehabilitation. As well, the data source for rehab areas is missing from the map. Lastly, an error in the legend was found for the helispots. The color used to mark helispots on the map is different than the one used on the legend (See Figure 4-5). If this map were to be used to fly areas of the fire, potential confusion could result.

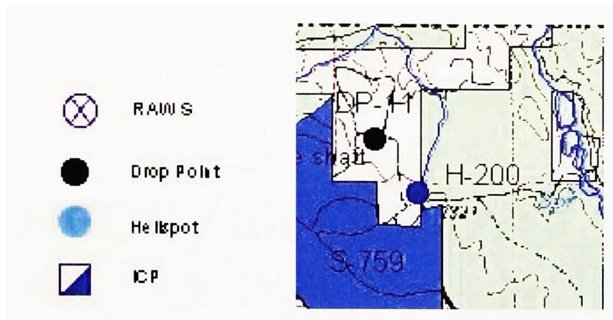


Figure 4-5 Color used for Helispots in Legend and on Map

**Hayman BAER Progress 8-26-02 Map**

Planned or in progress BAER treatments are also the topic of the Hayman Fire map of August 26, 2002. This map is similar to the first Hayman map, but is more detailed. The map shows what stage each treatment was in, as well as eight different treatment types that had occurred. The map shows that a lot of rehabilitation was completed in the three and one-half weeks between the dates of the two maps.

Map Design Results

Design elements on this map received an average to above average rating from the evaluators (See Table 4-6). They thought the map had good visual hierarchy and balance but was not the easiest to read. Several elements made the map difficult to communicate. For example, there was no explanation of what the numbers labeling the rehab polygons meant (See Figure 4-6); as well there was no indication of the spatial accuracy of the polygons. The evaluators wanted to know how the polygons were derived, but there was no information available. As well, various lines and polygons were easily confused because of the large number of combinations of symbols used.

Table 4-6 Hayman BAER 08-26 Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 6 | 6 | 4 | 6 | 6 | 6 | 6 | 5 | 6 | 6 | 6 |
| E | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 6 | 5 | 5 | 6 |
| **Mean:** | **5.50** | **5.50** | **4.00** | **5.00** | **5.50** | **5.00** | **5.50** | **5.50** | **5.50** | **5.50** | **6.00** |
| **Median:** | **5.5** | **5.5** | **4** | **5** | **5.5** | **5** | **5.5** | **5.5** | **5.5** | **5.5** | **6** |

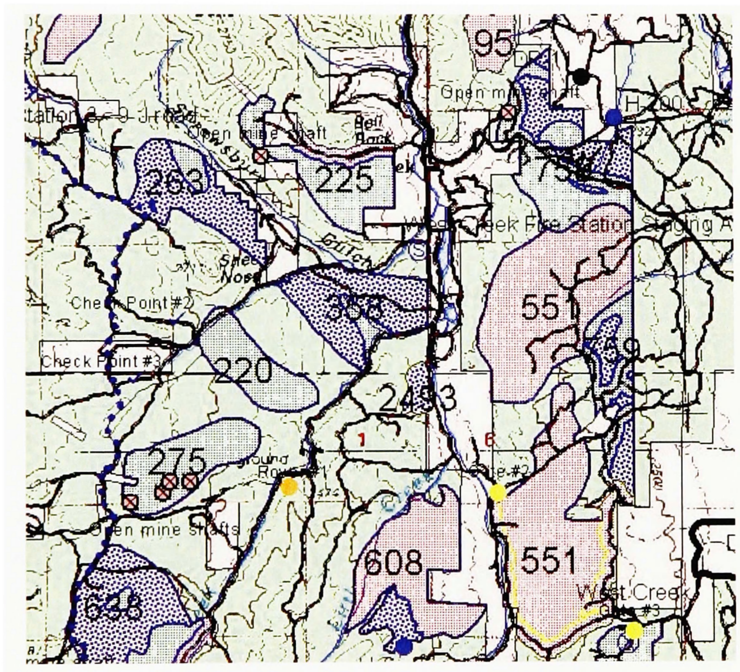


Figure 4-6 Rehab Numbers with no Description

Map Feature Results

Map features received average to slightly above average ratings from the evaluators. They thought the use of text was good despite the text on the rehab polygons containing no explanation. In addition, some of the text labels overlap with dark areas on the background topo map and are difficult to read. The use of color on the map, especially in the legend, led to some confusion. With so many different symbols being used on one map, it was difficult to match the colors on the map to those in the legend.

As well, since a topographic map was used as a background, the colors symbolized on the map did not match a legend with a white background. Matching the rehab area on the map to the legend had to be done by the process of elimination rather than just being able to observe which rehab area was which (See Figure 4-7). The graphic scale was adequate although it would have helped to also have had a representative fraction. The data source and citation were average, although one evaluator suggested it would be helpful to put the map projection and datum on for reference.

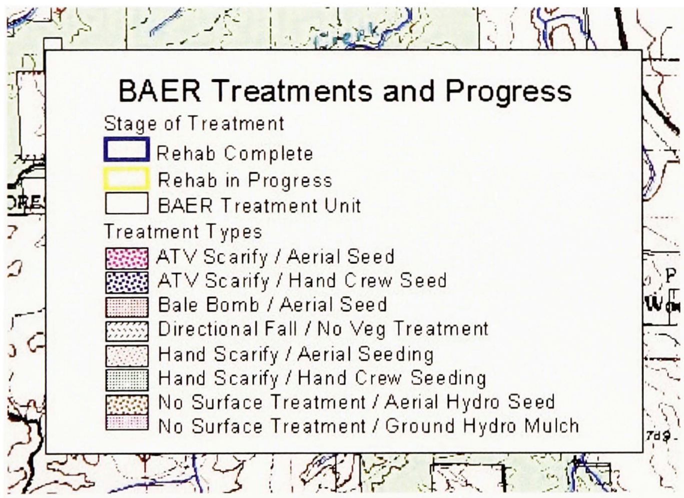


Figure 4-7 Excessive Symbolization

**Kraft Springs BAER Noxious Weeds Map**

The first map from the Kraft Springs Fire on September 12, 2002 is of BAER Noxious Weeds. Seven different types of noxious weeds are shown along with the different types of firelines on the map. These firelines mark where dozer lines, blade lines, and disk lines were created to stop the advance of the fire. No information is given as to what might be done about the noxious weeds, it is primarily a map that would be used by the BAER team to decide where and how rehab should be completed.

<u>Map Design Results</u>

Overall, the evaluators found this map to be less pleasing then the others, although it communicated the information for the most part. The visual hierarchy and balance were rated about average, while its ability to communicate was above average (See Table 4-7). The hatching was too bold showing the 1988 Brewer Fire and hurt the visual hierarchy of the map (See Figure 4-8). All evaluators that looked at this map thought the Brewer Fire was too high in the visual hierarchy since the purpose of the map was to show the locations of noxious weeds. Also with no data shown for South Dakota, the map had only average balance.

Table 4-7 Kraft Springs Noxious Weed Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 5 | 5 | 6 | 4 | 5 | 5 | 4 | 5 | 5 | 3 | 5 |
| A | 2 | 5 | 7 | 6 | 7 | 7 | 4 | 6 | 5 | 1 | 7 |
| **Mean:** | **3.50** | **5.00** | **6.50** | **5.00** | **6.00** | **6.00** | **4.00** | **5.50** | **5.00** | **2.00** | **6.00** |
| **Median:** | **3.5** | **5** | **6.5** | **5** | **6** | **6** | **4** | **5.5** | **5** | **2** | **6** |

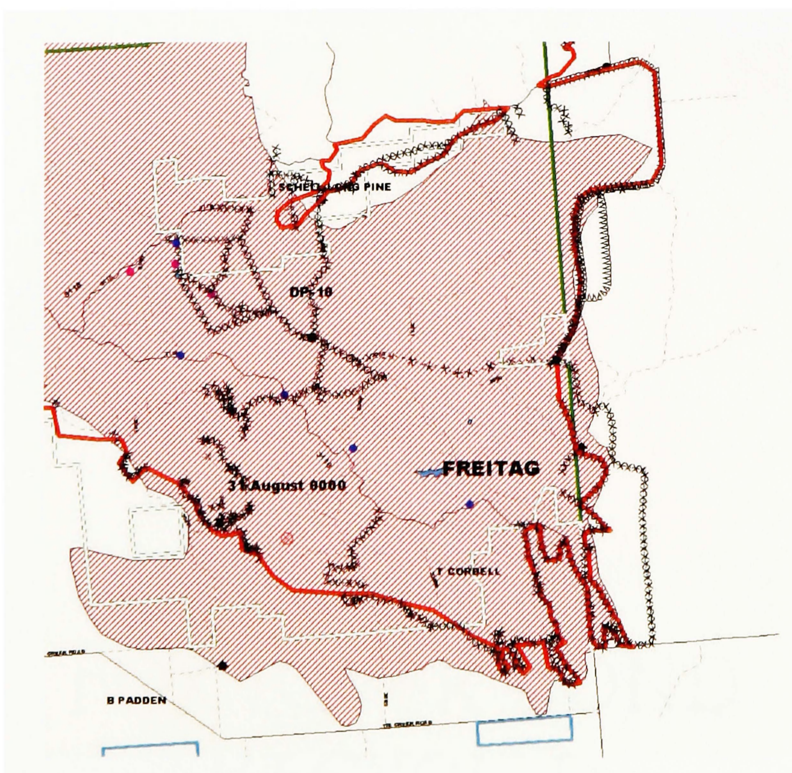


Figure 4-8 Hatching on Brewer Fire too high in Visual Hierarchy

<u>Map Feature Results</u>

Color received an average score on this map from the evaluators. Line and text usage were also average. Some sort of shaded polygons should have been used to display land ownership because it was impossible to tell whether a particular type of ownership was inside or outside the line (See Figure 4-9). The evaluators also thought the fire lines were difficult to read in certain areas but still gave them above average ratings. If the purpose of this map is for BAER planning, using thinner lines to display the fire lines would have allowed it to be easier to read in the areas where different types are congested.

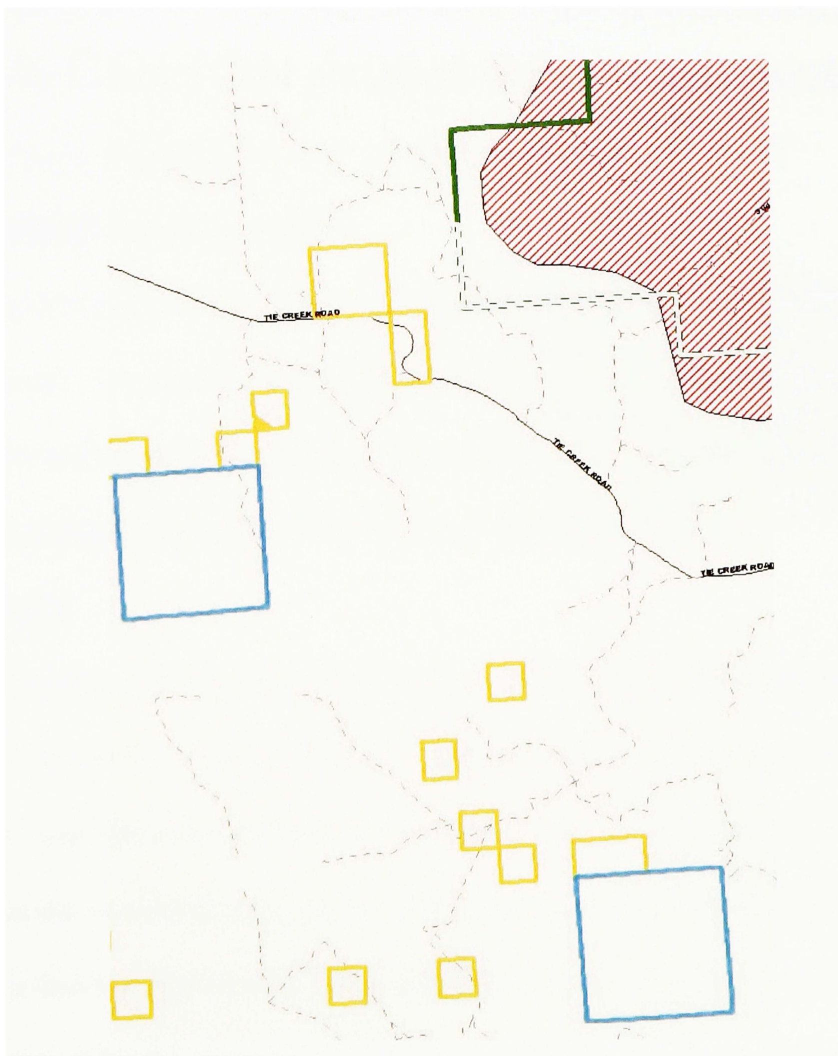


Figure 4-9 Ownership Inside or Outside of the Polygons

Symbolism received an average score on the map. The evaluators thought different types of symbols could have been used to display the locations of the noxious weeds. The symbol used for spotted knapweed, which was a dark blue, and musk thistle, which was black, were too similar to those used for the drop points. Accidentally spraying for noxious weeds at a drop point, or dropping people off at noxious weeds could accidentally result from the use of these poor choices for symbols. One of the evaluators suggested the noxious weed symbols be shown larger since they were the reason the map was made. This map has a ratio scale but contains no scale bar, thus a major element was left off. The map lacks a data source other than the one for the fire perimeter. It would be useful to know who did the GPS work or mapped the locations of the noxious weeds, but this information is not cited on the map.

**Kraft Springs BAER Soil Erosion Map**

The second map from the Kraft Springs Fire on September 13, 2002 was of BAER Soil Erosion. Two classifications of soil erosion were shown on the map: high and moderate-low soil erosion. The map displays the Brewer Fire Boundary from 1988 and the data was gathered through GPS surveys and field observations.

Map Design Results

Average ratings on visual hierarchy, balance and readability were given by the evaluators (See Table 4-8). The overlapping of polygon symbols could lead to some confusion on the map since the hatching and shading could overlap. The Brewer fire was likely too high in the visual hierarchy and it could have been shown without a hatching for fill to make it less visually striking. One problem area of readability exists since there is no base data shown for the areas in South Dakota. This could lead to confusion on the map, and it detracts from the balance on the map (See Figure 4-10). Since not much is labeled on the South Dakota side, it almost makes it seem less important.

Table 4-8 Kraft Springs Soil Erosion Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 4 | 6 | 6 | 6 |
| E | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 5 |
| **Mean:** | **5.00** | **4.50** | **4.50** | **5.00** | **5.00** | **5.00** | **5.00** | **4.50** | **5.00** | **4.50** | **5.50** |
| **Median:** | **5** | **4.5** | **4.5** | **5** | **5** | **5** | **5** | **4.5** | **5** | **4.5** | **5.5** |

Map Feature Results

Map features received averaged remarks from the evaluators. Color was rated good, lines were easily distinguishable, but polygons were harder to read. Similar to the previous map, polygons used to show land ownership were drawn with an outline. Therefore it was tough for the evaluators to determine if the land ownership was located inside or outside of the line.

Use of text was decent as well as symbolization on this map. One issue with the drop points was that they overlapped the fire perimeter and were often hard to read. The legend was given only an average rating on this map. The evaluators felt a greater explanation of symbol classes could have been given. For example, the numbers that defined the classes of soil erosion as high and moderate were given no citation of how they were derived. The evaluators also thought that symbols on a map should be the same size as in the legend to prevent confusion. The map source was good other than not telling where the erosion classes came from. The map citation was sufficient but the scale could have been improved. On this map, a representative fraction was used but no scale bar was used (See Figure 4-10). It would be helpful to have both in most cases.

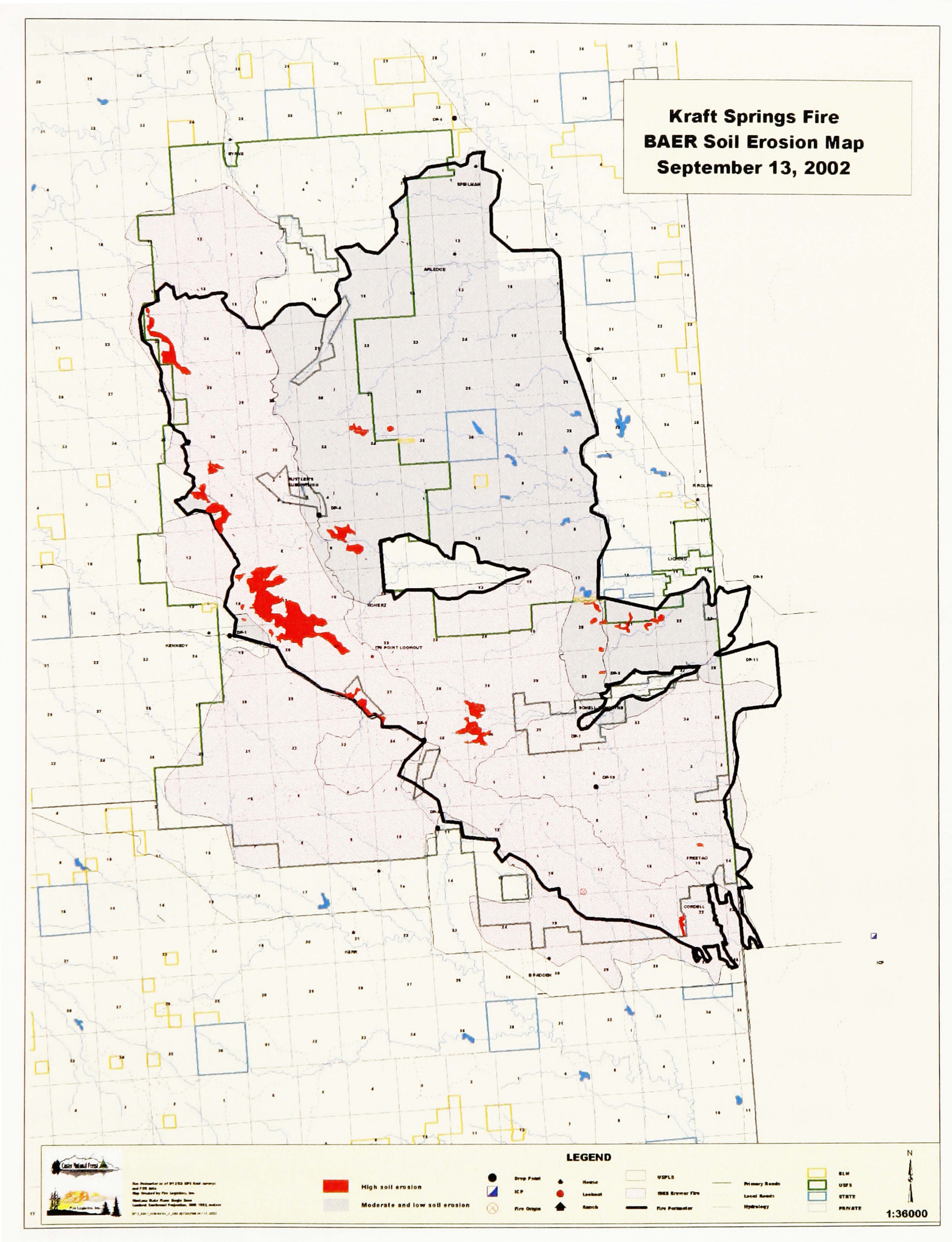


Figure 4-10 Problems with Map Balance and no Graphical Scale

## Overall Results

To evaluate the overall results from the maps, a table was created to assess the design and quality of each design element and feature (See Table 4-9). The mean and median of each category for all six maps were compiled. All features and elements averaged between a 4.5-5.5 rating, meaning in terms of cartographic design these maps are all just above average. Concerning the cartographic elements, visual hierarchy and balance scored 5.08 and 5.33, with medians of 5.5 and 5 respectively. The ability of the map to communicate, which is possibly the most important design element had the lowest mean with a score of 4.83 and a median of 4.5.

Table 4-9 Evaluators Survey Results

| Evaluator | Vis Hier | Bal/Orient | Comm | Color | Line | Text | Symb | Legend/In | Scale/N.A. | Data Source | Cart/Date |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 6 | 5 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 5 | 6 |
| A | 7 | 5 | 7 | 7 | 7 | 4 | 5 | 5 | 6 | 7 | 4 |
| D | 2 | 6 | 3 | 1 | 1 | 1 | 4 | 3 | 3 | 6 | 1 |
| B | 7 | 5 | 4 | 7 | 7 | 4 | 4 | 2 | 3 | 6 | 6 |
| D | 4 | 6 | 5 | 5 | 6 | 3 | 5 | 3 | 6 | 3 | 3 |
| B | 7 | 7 | 3 | 7 | 5 | 6 | 5 | 7 | 5 | 7 | 7 |
| F | 6 | 6 | 4 | 6 | 6 | 6 | 6 | 5 | 6 | 6 | 6 |
| D | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 6 | 5 | 5 | 6 |
| C | 5 | 5 | 6 | 4 | 5 | 5 | 4 | 5 | 5 | 3 | 5 |
| A | 2 | 5 | 7 | 6 | 7 | 7 | 4 | 6 | 5 | 1 | 7 |
| F | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 4 | 6 | 6 | 6 |
| E | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 5 |
| **Mean:** | **5.08** | **5.33** | **4.83** | **5.25** | **5.33** | **4.58** | **4.75** | **4.58** | **4.83** | **4.83** | **5.17** |
| **Median:** | **5.5** | **5** | **4.5** | **6** | **5.5** | **4.5** | **5** | **5** | **5** | **5.5** | **6** |

Overall, map features had average to slightly above average ratings. Color, line, and cartographer/date received 5.25, 5.33, and 5.17 with medians of 6, 5.5, and 6 respectively. This means these features had the best design on the maps for their intended purpose. Text, symbolism, legend, scale, and data source were the biggest problems on the maps. They received scores of 4.58, 4.75, 4.58, 4.83, and 4.83 with medians of 4.5, 5, 5, 5, and 5.5 respectively.

Throughout, the results and analysis of the maps text, symbolism, scale, and data source were the most often features described as being poorly designed. The text was often overlapping which led to a low score, the symbols used often did not match the legends or were easily confused with other symbols. Legends often contained too much information that overwhelmed the reader or it did not match what was being shown on the map. On several occasions maps had some sort of scale, but it would have been helpful to show both scale bars and a representative fraction. Lastly, data source was commonly downgraded because there was only mention of where the fire perimeter had been derived. Rarely was a BAER data source displayed on the maps. The overall mean for all map features and elements was 4.96 and a median of 5 meaning everything was rated slightly above average.

**Summary**

In this chapter, a discussion of the results and analysis of the evaluators' survey was given. An introduction to the evaluators was offered followed by a discussion of the results from each of the six maps surveyed. A description of each map was given, followed by results and analysis of the use of the cartographic design elements from the survey. Crucial cartographic errors were discussed and some highlighted. Tables showing the evaluators' ratings were given with each map and a final table was offered that shows the overall results of the survey. Answers to the questions about the use of the cartographic design elements and features were discussed, and some affects cartographic errors could have had on resource decisions were offered.

# Chapter 5

# Discussion

The results of the evaluators' survey show that improvements can be made in the quality of Fire Logistics' wildfire maps. In this chapter, a protocol will be given on how to make higher quality wildfire maps. While Fire Logistics has a protocol for creating maps, it only specifies what elements should be used and not how they should be used. Therefore, the protocol created will take a look at each of the cartographic design features and elements and give recommendations on appropriate usage. The protocol is a series of statements for the design elements that should apply to any wildfire map. It can be set up in check list format so that a wildfire cartographer can check off completion of the cartographic elements. After the protocol is offered, a discussion of other factors affecting map quality will be given. Conclusions will then be offered on the design quality of wildfire maps. Lastly, there will be a discussion of future cartographic quality and design assessing as well as future applications of wildfire map assessing.

## Protocol

The proposed protocol is based on the findings of the research described in the results chapter. Additionally, it was devised through analysis of the literature review and knowledge gained from working on wildfire incidents. The protocol derives many of its statements in a response to the surveyor's thoughts on what affects cartographic errors could have on resource decisions. The numerical ratings given to the cartographic design and feature elements were primarily to get a picture of how well elements were used, not to suggest how they should be used. The protocol is a list of things to do that can be followed by wildfire cartographers to improve the quality of BAER maps.

Wildfire Map Protocol

- The most important features on the map have the highest visual_hierarchy.
- The map is visually balanced to the center of the page.
- The purpose of the map is clearly reflected in the output.
- Unfamiliar terms and features are explained.
- Color/Gray Scale
    - Color classifications on maps use no more then 5-7 shades.
    - Red is used for fire perimeter and hot spots.
    - Blue is used for incident command points.
    - Black is used for incident command lines and text.
    - Other colors are distinguishable and an excessive number of colors are avoided.
- Lines
    - Incident command lines use standard symbolization. Ventura Tools extension in Arc View 3.x (See Figure 5-1).
    - Avoid using several styles of dashed lines.
    - Line thickness is distinguishable.
- Text
    - Small font size should be avoided.
    - Fancy font styles should be avoided.
    - Text uses a halo if it is the same color as the ground in which it is placed.
    - Map has a title.

- Symbolism
    - Use standard symbols created for wildfire mapping. Ventura Tools extension in Arc View 3.x (See Figure 5-2).
    - Symbols are distinguishable from other symbols on a map.
    - Representative symbols are used over abstract symbols.
- Legend
    - Symbol size and color in legend matches symbols on the map.
    - Legend is large enough on wall maps to be read at a distance.
- Insets
    - Insets contain a scale bar.
- Scale
    - Both scale bar and representative fraction are used.
- North Arrow
    - A north arrow is on the map.
- Data Source
    - Base data source is given.
    - BAER data source is given.
- Date
    - Date the map was created is on the map.
- Cartographers Name
    - Credit is given to the maps creator or logo is used.
- Other Marginal Information
    - Map contains a disclaimer.


Figure 5-1 Standard Incident Command Lines[105]

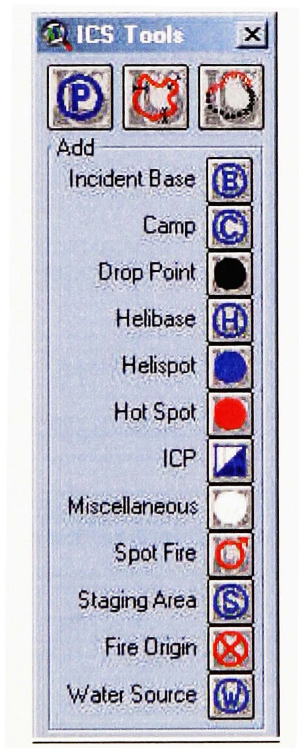


Figure 5-2 Standard Incident Command Points[106]

[105] Screen capture of the Ventura Tools Extension, ICS lines, Arc View 3.3, ESRI Corporation, Redlands, CA, 2002. Ventura Tools for Arc View 3.x is an extension that contains standard symbolization for wildfire maps. The figures show the available symbols that come with the tool.

While a protocol will be helpful in the creation of wildfire maps, there are other factors involved with mapping that have an affect on the overall quality.

**Time Constraints and Pressure to Produce**

Although the maps received average to slightly above average ratings, the author would equate a majority of those cartographic errors to time constraints and pressure to produce maps. Cartographers on wildfire incidents are under considerable strain to produce maps quickly; therefore creating a useable product is often more important than paying attention to every design detail. While the GIS software has some tools that can quickly improve the design on the map, it is ultimately going to fall on the cartographer's shoulders to produce maps that are useful to the Incident Command or BAER teams.

One problem that can arise is that people tend to take anything they read on a map as fact, and Incident Command and BAER teams are much the same. Therefore, it is important for the cartographer to produce maps quickly, but also try his or her best to not make mistakes that could lead to poor decision making. Cartographic errors also vary in their affect on decision making. For example, inserting an incorrect date or a spelling error may not be serious errors. However, creating a map that shows roads that are improperly labeled or entering coordinates for locations of helispots and drop points that are incorrect could lead to serious problems. All the cartographer can do is be as careful as possible to produce accurate and quality maps, and if he has time, then he can enhance the design qualities of the map.

A functional map is more important on a wildfire then an aesthetically pleasing map so long as there are no serious cartographic errors. Good advice to any cartographer

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[106] Screen capture of the Ventura Tools Extension, ICS points, Arc View 3.3, ESRI Corporation, Redlands, CA, 2002.

is to put a disclaimer on any product produced. As cartographic errors are almost impossible to avoid, this is one way for the cartographer to let the map reader know there is the potential for errors and to not take the map too literally.

**Conclusions**

Having worked on Type 1 and Type 2 incidents as a GIS Specialist, the time constraints to produce maps have led the author to conclude that cartographic quality and design are often not as important as producing a usable product. While using a protocol such as the one created in this thesis can greatly improve the quality of the maps, the ability of the cartographer to quickly produce a useable product often takes precedent on an active incident. Having worked on the Jimtown Fire near Helena, MT in mid-July 2003, the author gained practical experience in this area. After arriving in the fire camp at 2200 hours, the GIS Specialists were expected to produce Incident Action Plan maps and a Briefing Map for the morning briefing. While producing such maps under no time constraints would be simple, creating them under stressful time constraints proved to be a challenge. To complete this task, the specialists ended up working until 0200 to finish the project. Often this job requires working late into the night while the fire fighters sleep. In the end, being able to focus on what needed to be done and keeping calm in the face of stress ultimately led to the maps being created in an appropriate amount of time.

Anyone interested in working in the business needs to have good patience and understand their capabilities well. If a person does not have a calm demeanor or the ability to multi-task he or she will find themselves unable to produce what the Incident Command or BAER teams need. Having a calm demeanor and being confident in your cartographic abilities was proven by a trainee who worked with the author on the

Mineral-Primm Complex in August of 2003. While the cartographic trainee knew the software and had a good understanding of wildfire, he was not able to perform his job when he ran into problems. Getting flustered and frustrated are things that you can not let happen to you while working on mapping wildfires. Time constraints usually will not allow for it, moreover it will make everyone involved look unprofessional. In conclusion, the use of a protocol such as the one suggested in this thesis can be used to improve the quality of wildfire maps created. However, the end quality of any wildfire map is going to be determined by the skill of the cartographers and the time constraints.

**Other Applications of the Survey**

Although the survey is designed primarily for maps to be used in resource decision making, it can be used for design and quality assessing of any maps. Using this or a similar method; any state, local, federal government agency or private firm can gage the design quality of the maps they produce. Any entity creating maps under vague cartographic limitations or those that do not follow limitations can use such a method to improve the design quality of the maps they produce. While the quality of resource maps is important, other mapping areas can prove to be just as important. In one way or another, all maps are important and serve a purpose. Whether it is nautical and aerial charting, city planning, or military purposes, maps created with poor cartographic quality can lead to poor decision making.

**Where Next**

While similar studies would prove interesting, any mapping done under time constraints and in a stressful environment is bound to have a similar outcome as the wildfire map survey. Assessing the way wildfire mapping is done in another five to ten years may lead to completely different results because of newer technology that gives cartographers faster and better accuracy in the maps they produce. The one thing that will never change is cartographers' understanding of what they are doing and how they relate to the creation of a map. Although computers may become faster and software may become more powerful, the basic cartographic principles used to produce high quality maps are not likely to change. Therefore, as presently, the future of wildfire mapping will rely mostly on the shoulders of the cartographer.

In the future, there may be better methods of assessing cartographic design. The method used in this thesis produced results but made it difficult to quantify how a rating for the errors would affect resource decisions. The rating helped show how well an element was used but it did not tell the proper way of using an element. Proper use was derived from the responses to how errors could affect resource decisions.

An idea of how someone could survey wildfire maps is to somehow measure the amount of cartographic error on a map and relate that to the cost it takes to run a GIS trailer or workstation on a fire. Then a study could be done to compare government versus private industry wildfire mapping to see which is the most cost effective for producing less error. The amount of error could also be compared to acreage so a figure could be derived that compares total cost to run the GIS to error per acre. This would be the ultimate way to judge how well private companies compare to government agencies in mapping capability. Though, someone would have to figure out another way of computing the amount of error on a map.

A final project suggestion would be to create an interactive website that the GIS Specialist and wildfire managers in the field could use to communicate and update geographical data. Using ArcIMS, a website could be developed that contains all of the basic data needed for the maps. This website could be utilized by fire managers in the field with laptop computers or palm Internet service to access real-time fire data from the GIS Specialist. Also, the fire managers could use the ArcIMS site to send the GIS Specialist locations of new drop points, and other important locations in real-time. The future of wildfire mapping appears promising using Internet services.

In this chapter, a protocol was offered on how to improve the quality of BAER maps. After the protocol was offered a discussion of other factors affecting map quality was given. Conclusions were then offered on the quality of wildfire maps. Lastly there was a discussion of future cartographic quality and design assessing as well as future applications of wildfire mapping and assessment.

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