THE GEOLOGICAL SOCIETY
OF AMERICA

3300 Penrose Place
P.O. Box 9140
Boulder, Colorado
80301–9140

Tel 303.447.2020
Fax 303.357.1070

www.geosociety.org

June 10, 2004

Randle W. Olsen
United States Geological Survey
Denver Federal Center
Building 810, MS-150
Denver, Colorado 80225

Reference:
Wildland Fire Impacts on Watersheds—Understanding, Planning and Response:
Final Report
BLM Agreement Number: 1422RAI03-0034
USGS Agreement Number: 38172 0001
Requisition Number: 03CRPR01448

Dear Randy:

This letter, together with the enclosures, comprises the final report required for the conference, Wildland Fire Impacts on Watersheds—Understanding, Planning and Response that was held in Denver October 21-23, 2003.

Briefly, the objectives of the conference were to:

1. Transfer technology between the scientific research community and the land and resource management community.
2. Develop working relationships between scientists and land managers so that scientific research will be applied to problems in the field.
3. Give scientists an opportunity to learn about the range of current research and develop cooperative and collaborative relationships.
4. Partner with appropriate Federal, State and Local agencies, organizations and not-for-profit associations to maximize knowledge transfer between scientific and land management communities.

GSA and its partners are very pleased with the outcomes of the conference. Several enclosures describe how the objectives were met and illustrate the success of the conference:

1. "Wildland Fire Impacts on Watersheds Conference a BIG Success", *GSA Today*, Vol. 14, No. 3, March 2004, page 12-13, describes how the conference objectives were met.
2. "Wildland Fire — Post-Meeting Survey Summary and Analysis" is a synopsis of key observations by conference participants
3. Results of a survey of participants conducted immediately following the conference gives more detail about specific aspects of the conference.
4. A copy of the conference notebook that contains copies of Powerpoint presentations made at the conference as well as abstracts for the posters that were displayed.
5. A CD-Rom containing both the talks and abstracts presented at the conference in addition to various materials originally distributed in a conference notebook will be forwarded as soon as it is available.

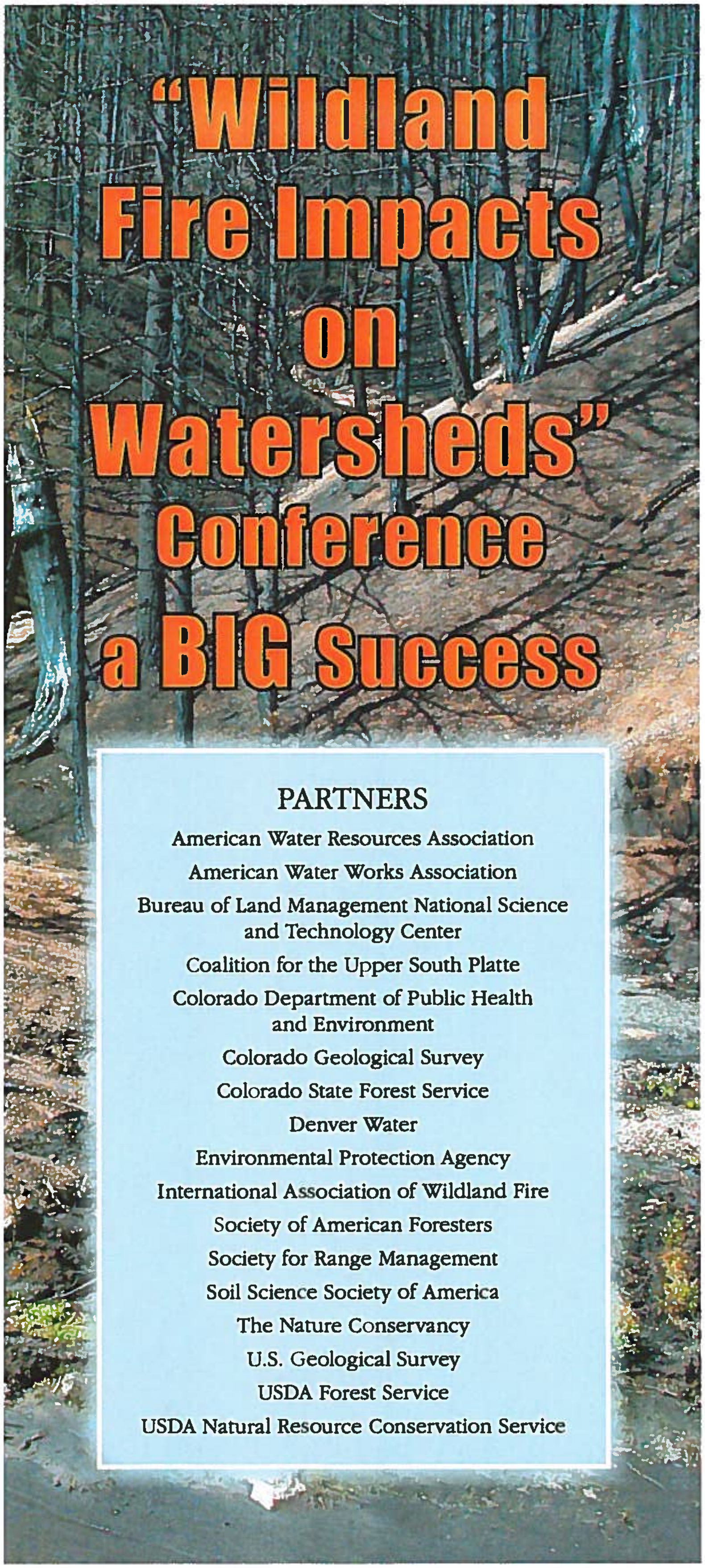
We very much appreciate the opportunity to work with USGS and with the JFSP on this project. In addition, GSA is very pleased with the response to the conference, with the information presented, and the dialogue and networking that was encouraged. We are actively seeking future opportunities to offer the conference again in other locations and would welcome the chance to partner with USGS and the JFSP again.

Sincerely,

Jack

John W. Hess
Executive Director

GEOSCIENCE KNOWLEDGE TRANSFER IN ACTION



Hayman, CO, July 5, 2002 — A mud slide occurred just off HW 67 in the Hayman Fire burn area. Photo by Michael Rieger/FEMA News Photo.

***Ann Cairns**, Director, Geological Society of America Communications*

GSA is actively committed to moving geoscience information and expertise into the hands of those who need it. Last October, the Society offered a knowledge-transfer specialty conference, "Wildland Fire Impacts on Watersheds," in Denver, Colorado. Nearly 200 resource managers and fire mitigation specialists from around the world joined geoscientists in exploring the geomorphological consequences of wildland fire.

The conference evolved from a topical session at GSA's 2002 Annual Meeting. "Geomorphic Impacts of Wildfire" drew 46 volunteered papers, resulting in two oral sessions and one poster session. Session organizers Sue Cannon and Deborah Martin of the U.S. Geological Survey and Charlie Luce of the USDA Forest Service met with GSA staff at the meeting. All agreed the leading-edge information presented would be valuable for those who deal with the aftermath of wildland fire. But significant questions remained: Who, specifically, are those people? What information, exactly, do they need? And how do we reach them?

Identifying the Audience

A partial answer to those questions came to Diane Matt, GSA's director of strategic partnerships, in conversation with Carl Norbeck of the Water Quality Control Division, Colorado Department of Public Health and Environment. "It was right after the catastrophic Hayman fire in Colorado," said Matt. "Carl told me that people were calling CDPHE and saying, 'The water running into the treatment plant looks like chocolate milk. What do we do?'"

Thus was born a context for knowledge transfer on soil erosion, debris flows, flooding, degraded water quality, and other impacts of wildland fire on watersheds.

Cannon, Luce, Martin, and Matt began networking in earnest. An extensive community of water, wildlife, and other resource specialists, geoscientists, land managers, and fire management planners revealed itself in the process. A technical program committee was formed with members from federal, state, and local governments, associations, and other not-for-profit organizations.

Who Attended?

Conference participants came from the United States, British Columbia, and Australia. Virtually all had background in some aspect of the natural sciences (i.e., biology, forestry, hydrology, geology, and chemistry).

A number of participants held high-level positions, including national program managers for the USDA Forest Service and the Bureau of Land Management

This article reprinted from GSA Today, Vol. 14, No. 3, March 2004, p. 12–13.

GEOSCIENCE KNOWLEDGE TRANSFER IN ACTION

> **PARTICIPANT FEEDBACK**
>
> *"I will use the information to improve current and future fire fuels research."*
>
> *"I now better understand the entire framework in which managers have to deal with fire."*
>
> *"I'm currently working on rehabilitation of a burned area. Most of the information shared at the conference will be used in this effort."*
>
> *"Excellent! Probably one of the most stimulating and interesting conferences I have attended."*

Burned Area Emergency Rehabilitation program. Other attendees were specialists in land and other resource management. A combination of professionals who work with immediate after-effects of wildland fire and specialists in long-term rehabilitation further diversified the group.

Presentations, Discussion Groups, and a Day in the Field

Scientific content began with foundational work on how different geological terranes respond after a fire. Broad geological, geomorphological, and fire-related topics followed, such as burn severity and vulnerability to erosion. From there, specific elements of vulnerability, erosional styles, and mitigation strategies were addressed.

Conference format was varied. It included invited speakers in technical sessions and smaller breakout groups that encouraged informal discussion and networking.

Paul Perkins of the Centre for Resource and Environmental Studies, Australian National University, delivered the conference keynote address. He shared very recent experience of the devastating 2002 Australian bushfires and their impact on watersheds.

Day three of the conference was spent in the field. Participants visited recent burn areas in Colorado, viewing research plots where long-term mitigation strategies are under study. Discussion ranged from viewing soils and watersheds as protectable resources, to determining the best type of mulch for minimizing post-fire erosion until vegetation grows back.

What GSA Learned

Conference participants weren't the only ones who received an education. This was GSA's first meeting for a completely new audience. Much was learned about the importance of partnering. Building relationships with organizations that serve and routinely communicate with the target audience made for relevant, valuable content. Those organizations also provided the means for effectively promoting the conference.

Participant feedback was very favorable. Attendees expressed strong interest in holding another meeting in a couple of years, and GSA is taking the suggestion into consideration.

More to Follow

GSA plans to continue offering meetings that transfer geoscience knowledge to professionals who need that knowledge in their work. Members are encouraged to offer suggestions for topics and supporting rationale to Director of Strategic Partnerships Diane Matt (dmatt@geosociety.org), or to Annual Program Committee Chair Barbara Tewksbury (btewksbu@hamilton.edu).

> **FUNDING & ADDITIONAL SUPPORT**
>
> Colorado Department of Public Health and Environment (through a grant from the U.S. Environmental Protection Agency)
>
> Denver Water
>
> Rite in the Rain
>
> Society of American Foresters
>
> Joint Fire Science Program
>
> U.S. Environmental Protection Agency

Hayman, CO, July 5, 2002 — A mud slide occurred just off HW 67 in the Hayman Fire burn area. Photo by Michael Rieger/FEMA News Photo.

This article reprinted from GSA Today, Vol. 14, No. 3, March 2004, p. 12–13.

The Geological Society of America
Wildland Fire — Post-Meeting Survey
Summary and Analysis

October 21-23, 2003
Sheraton Denver Tech Center

194 surveys sent
99 responses
51% response rate

General Observations

- Nearly half of respondents (47%) were Resource Specialists
- Just over half (51%) heard about the program from a colleague
- Another 42% learned about it from e-mail from GSA or other conference partners
- The Web site was heavily visited and unanimously deemed helpful and effective (98% / 2% n/a)
- Overall, program rating was overwhelmingly positive (96%)
- Among Program Components—
  Highest ratings (combined Excellent/Good) were given to:
    Knowledge transfer in the plenary sessions (95%)
    Topics presented in posters (90%)
    Quality of networking (85%)
  Lowest ratings (combined Fair/Poor) went to:
    Reference value of the conference notebook (23%)
    Exhibits and interaction with exhibitors (23%)
    Knowledge transfer in the breakout sessions (19%)
    Discussion during poster sessions (18%)
- The survey indicated a great demand for more information on the conference topics.
- 92% thought the conference should be repeated at some future date.

Verbatims: Common themes
Respondents reported the following general ways that they would use information gained from the conference:

- to focus, plan, or improve research
- to perform better on the job; make better decisions
- to integrate current work into a larger perspective and to better understand others' work in context
- to improve communication and interactions with other stakeholders
- to disperse information and share ideas with others
- to inform grant proposal development
- to maintain network contacts made at the conference

Operational Pros:

- Excellent organization
- Excellent food

Operational Cons:

- Crowded field trip agenda: cut sites, stick to timetable better
- Better notebooks: current and complete handouts, more sensible organization
- Breakouts not as effective as plenary sessions. Were presentation topics necessary as breakouts? Or should breakouts be oriented to discussion?

Summary of Content Suggestions:

- More rangeland topics / was weighted to forrested lands
- Broader scope for follow-up conference
- More balanced assessment of risk from fires vs. risk from activities undertaken to reduce fire severity
- More information about relative costs of treatment related to benefits
- More in depth sessions on emergency stabilization and rehabilitation treatments applied and success and failures; talk with experienced fire rehab people
- Took-kit goal for attendees not quite met
- Allow a little more time
- Input from FEMA and the insurance industry (future directions)
- More local expert involvement vs. Federal expertise
- More attention to prioritizing pre-fire treatment
- More on the application of treatments: What worked and what didn't
- Rehabilitation: What worked and what didn't
- Field trip: more on water supply and catchment area
- Better balance between technical and managerial perspectives (too technical)
- More water managers as speakers
- Breakout sessions: more discussion, less presentation
- Publish proceedings to make speakers' papers available
- Posters that focus on physical / biological responses to wildfire

Conclusions

- This very well received first foray into the technology transfer arena portends a positive future direction for GSA specialty meetings and strategic partnerships.

- Pre-conference planning acknowledged that this event was striving for a delicate balance between technical and managerial audiences. How did we do at reaching the desired target audience? (registration stats?)

- Survey results underscore the importance of word-of-mouth advertising and partner collaboration for market penetration with this type of meeting.

- The promotional strategy of driving traffic to the GSA web site is very cost-effective and delivers good results.

- Exhibits did not seem to be an integral part of this conference. GSA should evaluate, and possibly re-structure, their inclusion at future specialty meetings.

- Develop better facility for using breakout sessions, in relation to the program subject matter, to enhance the conference experience. (Or perhaps in choosing breakout leaders?) When does content dictate? How should they be structured to add utility to the learning experience?

Wildland Fire
Impacts on Watersheds
Participant Satisfaction Survey

The results of your survey are displayed below. If your survey includes text responses, click the "View" button to read individual results.

To exclude a particular response, click the Included Responses button. You can then view the set of individual responses that are currently included and select those you wish to exclude. Results below contain only Included responses.

EXCLUDE BLANK RESPONSES

Go to Individual Responses:

☐ Show respondent's emails.

INCLUDED RESPONSES

EXCLUDED RESPONSES

Launch Date: 10/28/2003

Close Date: 11/18/2003

Total Invitations: 0

Total Respondents: 99

Included Respondents: 98

Excluded Respondents: 1

- **Cross Tabulate**
  Cross-reference two different questions
- **Results via Email**
  Receive results in spreadsheet format
- **See Who's Responded**
  See who has and hasn't responded to your survey

Thank you for your participation in the "Wildland Fire: Impacts on Watersheds" conference. In order to aid with future planning, we would like to learn about your conference experience and receive your recommendations for improvement.

1. Which of the following most closely describes your current position?	Number of Responses	Response Ratio
Water Provider	6	6%
Community Organization	0	0%
Planner	3	3%
Resource Specialist (e.g., biologist, hydrologist)	45	47%
Information/GIS Specialist	4	4%
Land/Resource Manager	7	7%
Program Manager	6	6%
Student	7	7%
Researcher	18	19%
Total	96	100%

2. How did you hear about the Wildland Fire Conference?	Number of Responses	Response Ratio
Contact / e-mail from GSA	18	18%
GSA Today	2	2%
E-mail from a conference partner	24	24%
Mail from a conference partner	2	2%
From a colleague	50	51%
Flyer or handout	2	2%
Total	98	100%

3. Did you find the Wildland Fire Conference Web site to be helpful and effective?	Number of Responses	Response Ratio

Yes	96	98%
No	0	0%
NA	2	2%
Total	98	100%

4. How would you rate the following aspects of the conference?

The top percentage indicates total respondent ratio; the bottom number represents actual number of respondents selecting the option	1 Excellent	2 Good	3 Fair	4 Poor	5 No opinion
1. Knowledge transfer in the plenary sessions	48% 47	47% 46	4% 4	0% 0	1% 1
2. Knowledge transfer in the breakout sessions	24% 24	50% 49	18% 18	1% 1	6% 6
3. Learning value of the field session	36% 35	33% 32	4% 4	2% 2	25% 24
4. Reference value of the conference notebook	25% 24	53% 51	19% 18	4% 4	0% 0
5. Topics presented in posters	34% 33	56% 55	7% 7	1% 1	2% 2
6. Discussion during poster sessions	21% 20	41% 40	15% 15	3% 3	20% 19
7. Exhibits and interaction with exhibitors	12% 11	45% 43	18% 17	5% 5	20% 19
8. Quality of networking to enhance your professional relationships	38% 37	47% 46	11% 11	2% 2	2% 2

5. How would you rank the Wildland Fire conference overall?

	Number of Responses	Response Ratio
Excellent 1.	47	48%
Good 2.	47	48%
Fair 3.	4	4%

Poor 4.	0	0%
No opinion 5.	0	0%
Total	98	100%

6. How will you use the information that you gained from the conference?

VIEW 74 Responses

7. How well did the conference balance information on **pre-fire planning, mitigation,** and **response and rehabilitation**?	Number of Responses	Response Ratio
Excellent balance 1.	12	12%
Good balance 2.	47	48%
Fair balance 3.	34	35%
Poor balance 4.	3	3%
No opinion 5.	2	2%
Total	98	100%

8. Would you like more information on the specific topics in question 7? (Check all that apply.)	Number of Responses	Response Ratio
Yes, pre-fire planning	39	41%
Yes, mitigation	36	38%
Yes, response and rehabilitation	57	60%

No	23	24%

9. Do you have any additional comments about the Wildland Fire Conference?

VIEW 67 Responses

10. Should GSA repeat this conference?	Number of Responses	Response Ratio
Yes	87	92%
No	8	8%

11. What other conference topics related to geoscience would you find useful?

VIEW 32 Responses

NOTE TO RESPONDENTS: GSA may use anonymous quotes from this survey feedback for reporting or promotional purposes.

You answered 'yes' to Question 10 (Should GSA repeat this conference?).

12. How soon?

	Number of Responses	Response Ratio
Next year	26	31%
In 2 years	53	62%
In 5 years	6	7%
Total	85	100%

13. With what modifications?

VIEW 64 Responses

14. Where?

VIEW 70 Responses

THE GEOLOGICAL SOCIETY
OF AMERICA

Wildland Fire Impacts on Watersheds

Understanding, Planning and Response

October 21-23, 2003
Sheraton Denver Tech Center Hotel
Englewood, Colorado

The Geological Society of America
3300 Penrose Place
Boulder, Colorado 80301
303-357-1014

Partner Organizations

GSA is very grateful to the following partner organizations for their assistance and support in developing and promoting the conference. These visionary organizations have recognized the value of bringing together scientists, researchers and the land and water management community in order to prevent and mitigate the effects of wildland fire on watersheds.

American Water Resources Association
American Water Works Association
Bureau of Land Management National Science and Technology Center
Coalition for the Upper South Platte
Colorado Department of Public Health & Environment
Colorado Geological Survey
Colorado State Forest Service
Denver Water
Environmental Protection Agency
International Association of Wildland Fire
Society of American Foresters
Society for Range Management
Soil Science Society of America
The Nature Conservancy
U.S. Geological Survey
USDA Forest Service
USDA Natural Resource Conservation Service

Funding Support

This conference was produced with partial funding support from several sources. GSA gratefully acknowledges this financial assistance.

- Colorado Department of Public Health and Environment through a grant from the U.S. Environmental Protection Agency
- Joint Fire Science Program
- U.S. Environmental Protection Agency

Technical Program Committee

GSA is grateful to the Technical Program Committee for the knowledge, expertise and enthusiasm they brought to the planning and organization of this conference. Without their dedicated work, this conference could not have been offered.

Ben Alexander, City of Fort Collins Utilities
Karen Berry, Colorado Geological Survey
Jeff Burns, Society of American Foresters, Colorado Chapter
Chuck Bushey, International Association of Wildland Fire
Sue Cannon, U.S. Geological Survey
Herman Garcia, USDA Natural Resource Conservation Service
Rick Harmon, American Water Works Association
Melody Holm, USDA Forest Service
Steve Lohman, Denver Water
Charlie Luce, USDA Forest Service
Deborah Martin, U.S. Geological Survey
Diane Matt, Geological Society of America
Randy McKinley, USGS EROS Data Center / SAIC
Randy Olsen, U.S. Geological Survey
Eric Philips, Boulder County Land Use
Larry Schmidt, USDA Forest Service
Ayn Shlisky, The Nature Conservancy
Brian St. George, BLM National Science and Technology Center
Charisse Sydoriak, BLM National Science and Technology Center
Mary Tyler, Natural Resource Conservation Service

Sponsors

GSA is most appreciative of the generous support from our sponsors.

- Denver Water
- Rite in the Rain
- Society of American Foresters

Conference Notebook

The conference notebook will be available following the meeting at: www.geosociety.org/wildlandfire.

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3300 Penrose Place
P.O. Box 9140
Boulder, Colorado
80301–9140

Tel 303.447.2020
Fax 303.357.1070

www.geosociety.org

October 20, 2003

Dear Friends,

The Geological Society of America is pleased to host *Wildland Fire Impacts on Watersheds—Understanding, Planning and Response* in cooperation with our respected partner organizations.

While we know that wildland fires are inevitable, recurring events in many terrestrial ecosystems around the world, entire landscapes and the values they contain may be destabilized as a result of wildland fires. Wildland fires and associated post-fire erosion, floods and landslides are inevitable in many of these landscapes. By offering this conference, GSA is working to meet its vision of, "applying geoscience knowledge and insight to human needs and aspirations and stewardship of the Earth."

I hope you find the conference a valuable forum for the exchange of information about the hydrologic and geomorphic effects of wildland fire and that you can successfully apply this scientific information in real situations. In addition, because good working relationships enhance on-the-ground results, I encourage you to get to know each other during the conference.

Thank you for participating in this conference. We appreciate your interest in geoscience applied to the challenges presented by wildland fire.

Best regards,

John W. Hess
Executive Director

THE GEOLOGICAL SOCIETY
OF AMERICA

Wildland Fire Impacts on Watersheds

Understanding, Planning and Response

Introduction

This three-day technology transfer conference focuses on understanding interactions among major wildland fire, geomorphic and hydrologic processes and vegetation. The conference is designed to prepare land and resource specialists and planners to advise decision makers about what can be done to plan for and mitigate the effects of wildland fire—erosion, debris flow, flooding and water quality degradation.

Opportunities to reduce predictable impacts from post-fire processes before a severe wildland fire occurs will be discussed. Through improved understanding and building collaborative relationships, we aim to improve the effectiveness and diversity of preparation, response and mitigation options and strategies used.

The conference will bring together scientists, technical experts, planners and resource specialists/practitioners from communities, conservation districts, counties, state and federal agencies. The state-of-knowledge and technical tools will be presented. Participant interests and needs for further research and technology will be identified.

Purpose & Need

Wildland fires are inevitable, recurring events in most terrestrial ecosystems in the United States. While many ecosystems, particularly those in the Western U.S., are fire-dependent, historic land management practices and current development have altered these ecosystems so that modern wildland fires are more frequently widespread and catastrophic. Extremes in climatic conditions such as extended drought exacerbate the potential for large wildland fires such as those experienced in 2000 and 2002 that left whole landscapes unprotected by vegetation.

Primary water sources for many major metropolitan areas are at risk when the watersheds on which municipalities depend burn. Many, if not all, of these watersheds will burn—it's simply a question of when and how severely. Entire wilderness and rural landscapes and the resource values they contain may be destabilized as a result of future major wildland fires. Wildland fires and associated post-fire erosion, floods, and landslides are inevitable in many of these landscapes.

Wildland Fire Impacts on Watersheds—
Understanding, Planning and Response

Conference Schedule

Monday, October 20, 2003—On Site Registration, Set Up	
3—7 p.m.	**Conference Registration Desk Open, Exhibitor and Poster Set-Up**
Tuesday, October 21, 2003—Understanding Wildland Fire Impacts on Watersheds	
8—8:30 a.m.	**Networking over Coffee**
8:30—9:20 a.m.	**1-1 Opening Remarks** James E. Hubbard, Colorado State Forester Dwight Atkinson, EPA
9:20—9:30 a.m.	**Networking Break**
9:30—11:30 a.m. Networking break at 10:15 a.m.	**1-2 How Geology and Geomorphology Affect Landscape Response to Fire** Grant Meyer, University of New Mexico John Moody, United States Geological Survey Sue Cannon, United States Geological Survey Fred Pierson, Agricultural Research Service Pauline Ellis, USDA Forest Service
11:30 a.m.—12 p.m.	**Networking Break**
12 p.m.—12:45 p.m.	**Lunch and Networking**
12:45-1:15 p.m.	**1-3 Luncheon Keynote Speaker: Australian Bushfires and Watershed Impacts** Paul Perkins, Centre for Resource and Environmental Studies, Australian National University
1:15—1:30 p.m.	**Networking Break**
1:30—3 p.m.	**1-4 Burn Severity, Fuels Management and Geomorphic and Watershed Impacts** Kevin Ryan, USDA Forest Service Russell Graham, USDA Forest Service Colin Hardy, USDA Forest Service Ward McCaughey, USDA Forest Service
3—3:30 p.m.	**Networking Break with light refreshments, Displays Open**
3:30—5 p.m.	**1-5 Evaluating Watershed Vulnerability—Hazards and Downstream Values** John Thornton, USDA Forest Service Amanda Rosenberger, USDA Forest Service Erv Gasser, National Park Service Ben Alexander, City of Fort Collins Utilities
5:30—7 p.m.	**Poster Session and Networking, Displays Open**

Wednesday, October 22, 2003—Planning and Response Tools to Mitigate Wildland Fire Impacts on Watersheds	
8—8:30 a.m.	**Networking over Coffee**
8:30—10:30 a.m.	**2-1 Erosion, Flooding, Landslide—When? Where? Why? A State-of-the-Art Review** Charlie Luce, USDA Forest Service Jim McKean, USDA Forest Service John Moody, United States Geological Survey Deb Martin, United States Geological Survey Pete Robichaud, USDA Forest Service
10:30—10:45 a.m.	**Networking Break**
10:45—11:45 p.m. 1:00—2:00 p.m. 2:15—3:15 p.m.	**Round Robin Break Outs** Each participant will attend all three Break Outs. **2-2 Emergency and Long Term Planning and Response Approaches—Conference Room 5+6** Herman Garcia, USDA Natural Resources Conservation Service Erv Gasser, USDI National Park Service Annette Parsons, USDA Forest Service **2-3 Landslide and Debris Flow Hazard Identification—Planning and Response Tools—Hospitality Center** Erkan Istanbulluoglu, Massachusetts Institute of Technology Sue Cannon, United States Geological Survey **2-4 Surface Erosion Hazard Identification—Planning and Response Tools—Conference Room 9+10** Pete Robichaud, USDA Forest Service Lee Macdonald, Colorado State University Jeff Bruggink, USDA Forest Service Michael Parenti, Consultant
11:45 a.m.—12:45 p.m.	**Networking Lunch, Displays Open**
1:00—2:00 p.m.	**Break Outs**
2—2:15 p.m.	**Networking Break**
2:15—3:15 p.m.	**Break Outs**
3:15—3:30 p.m.	**Networking Break**
3:30—4:30 p.m.	**2-5 Case Study: Putting it all Together: Upper South Platte Watershed Case Study** Carol Ekarius, Coalition for the Upper South Platte Rocky Wiley, Denver Water Paula Fornwalt, USDA FS
4:45—5:30 p.m.	**2-6 Open Discussion: What do Specialists, Planners, Managers Need to Improve Understanding and Mitigation of the Hydrogeomorphic Impacts caused by Wildland Fire?**
5:30—7 p.m.	**Poster Session and Networking, Displays Open**

Thursday, October 23, 2003—Field Session: Flooding, Mitigation, Rehabilitation Practices	
7:30—8 a.m.	**Field Trip Bus Loading** (Up to four buses will rotate through the same stops, although in differing order.)
8—4 p.m.	**Field Sessions** • NRCS second year rehabilitation practices at High Meadows Fire • USFS thinning project Top of the World • Hayman Fire rehabilitation practices • Denver Water rehab post Hayman Fire • CSFS thinning techniques • Denver Water Spring Creek Debris Flow

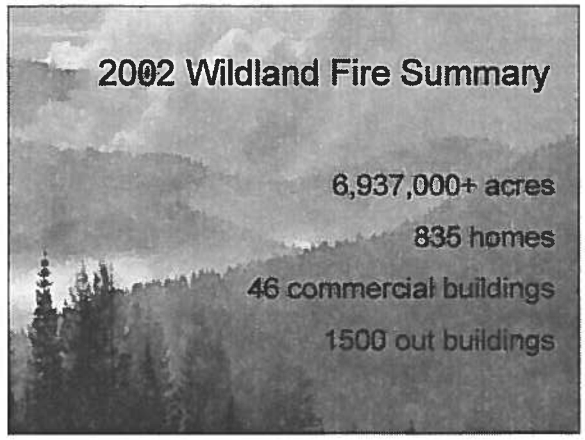
1-1

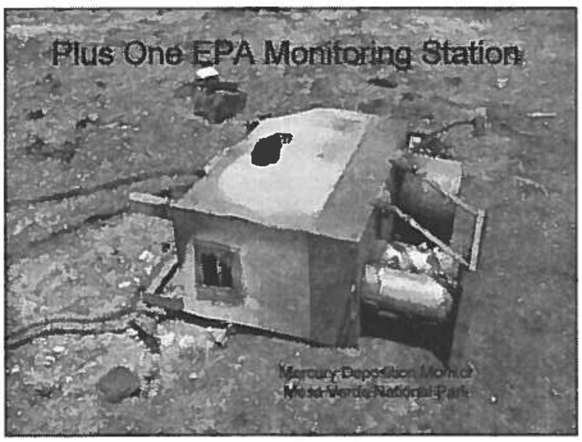
Opening Remarks

Wildland Fire & Watershed Impacts

Challenges for Scientists, Managers, and the Public

Dr. R. Dwight Atkinson
US EPA

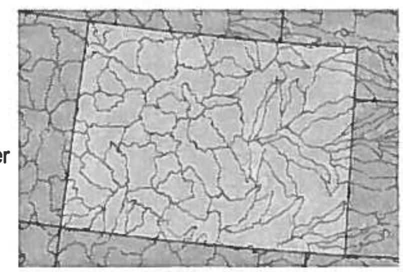




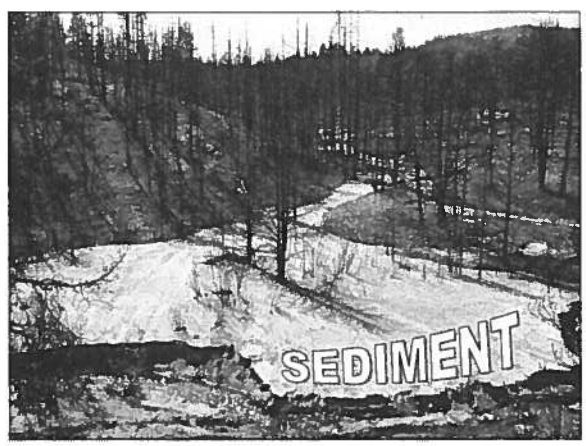
Why Watersheds?

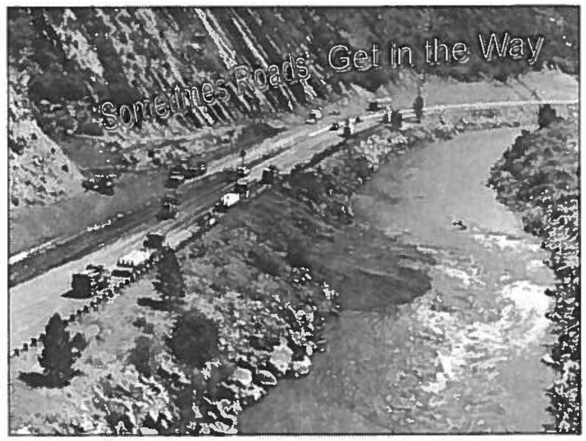
"The region draining into a river, river system, or body of water." Webster's

>70 4th-Order Watersheds



>800 4th-Order Watersheds





A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment

10-Year Comprehensive Strategy

August 2001

GOALS

1) Improve Prevention & Suppression
2) Reduce Hazardous Fuels
3) Restore Fire-Adapted Ecosystems
4) Promote Community Assistance

On Setting Restoration and Fuels Management Priorities -

"…there should be an ongoing process whereby the local, tribal, State and Federal land management, scientific, and regulatory agencies exchange the requisite technical information to make fully informed decisions. At a minimum, the information that is shared should include assessment of the communities at risk, current vegetative conditions with respect to the likelihood of severe wildland fire, **threats to key habitat and water quality (such as post-fire erosion),** air quality and local economies…."

From, A Collaborative Approach for Reducing Wildland Fire Risks to Communities and the Environment – 10-Year Comprehensive Strategy, August 2001

Primary Challenge – Direct Risks from Wildfire

- Identify factors influencing post-fire erosion events, including landslides
  - Slope
  - Fuel loadings/ burn severity
  - Vegetation type
  - Soil type
- Determine relative risks to watersheds
  - Factor in drinking water sources, infrastructure, & habitat
- Communicate to decisionmakers & public
  - Apply to setting fuel treatment priorities and BAER
- UNPRECEDENTED NON-REGULATORY OPPORTUNITIES

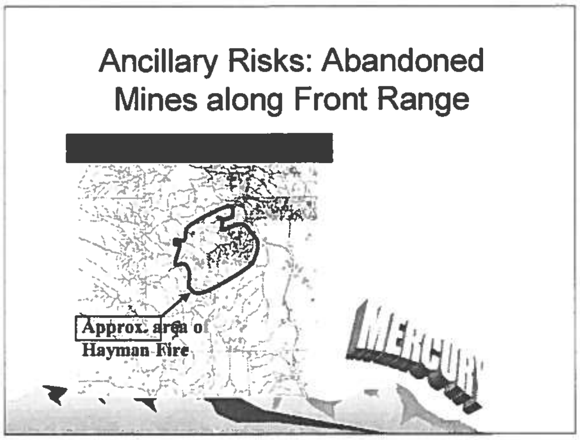
Extended Challenge – Ancillary & Existing Risks

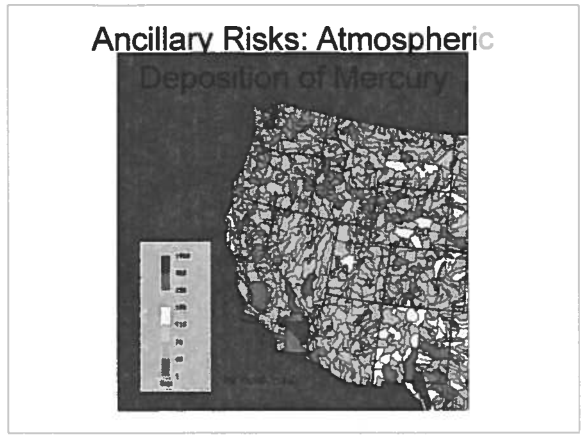
Ancillary Risks

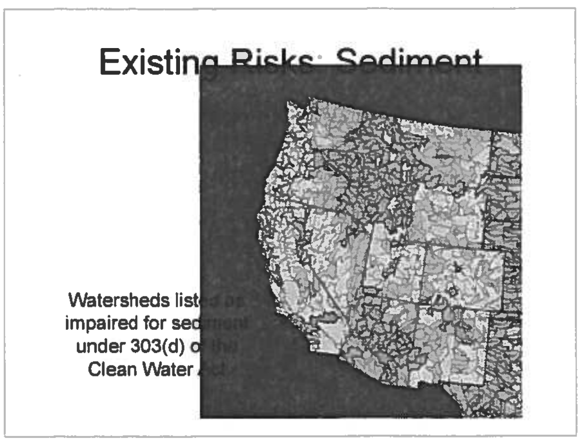
Effects of materials and compounds transported along with the sediment

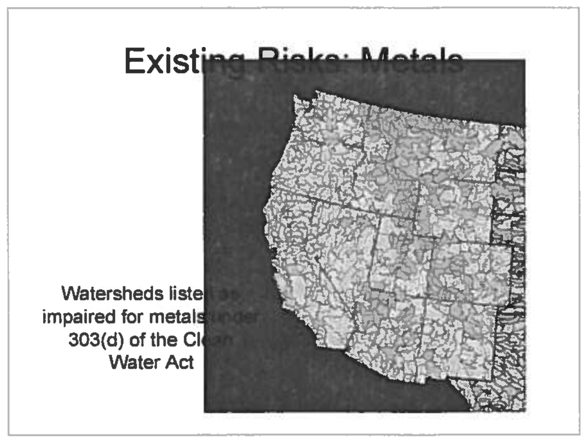
Existing Risks

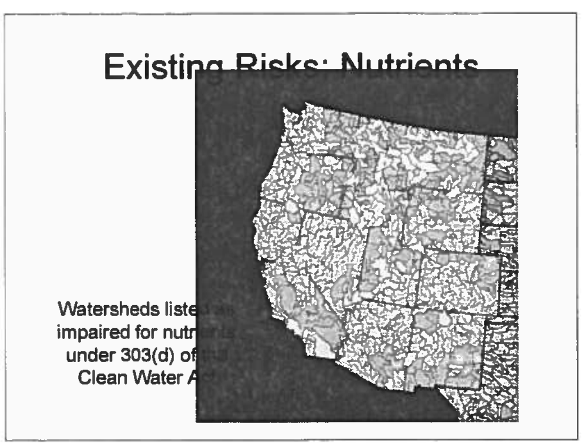
Non-wildfire related factors influencing watershed health


Ancillary Risks: Abandoned
Mines along Front Range
Approx. area of
Hayman Fire
MERCURY


Ancillary Risks: Atmospheric
Deposition of Mercury


Existing Risks: Sediment
Watersheds listed as
impaired for sediment
under 303(d) of the
Clean Water Act

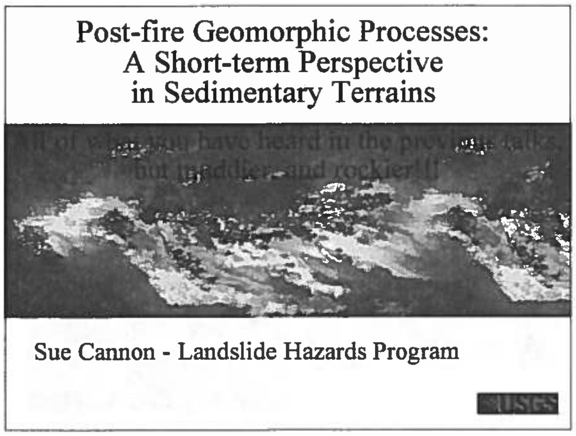

Existing Risks: Metals
Watersheds listed as
impaired for metals under
303(d) of the Clean
Water Act


Existing Risks: Nutrients
Watersheds listed as
impaired for nutrients
under 303(d) of the
Clean Water Act

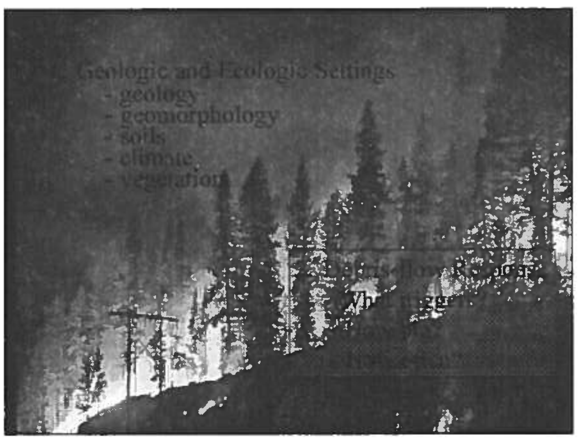

Putting It All Together
Direct Risks + Ancillary Risks +
Existing Risks = TOTAL RISKS
Land Managers & the Public
Fuel Treatment & BAER Priorities &
Decisions

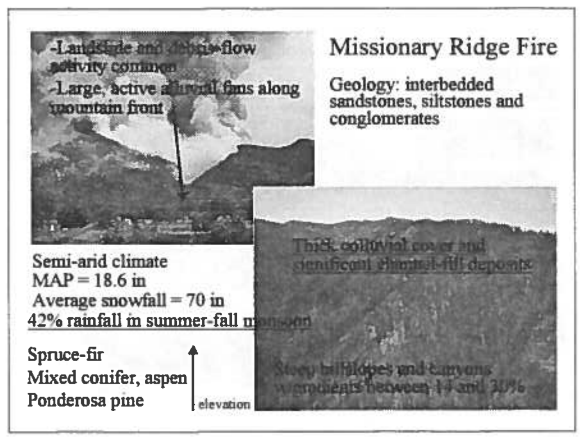
1-2

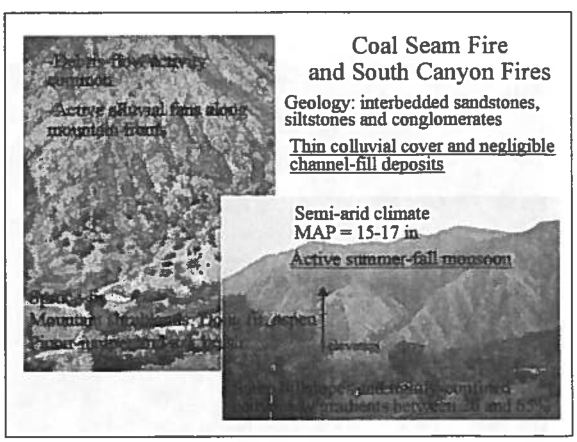
How Geology and Geomorphology Affect Landscape Response to Fire

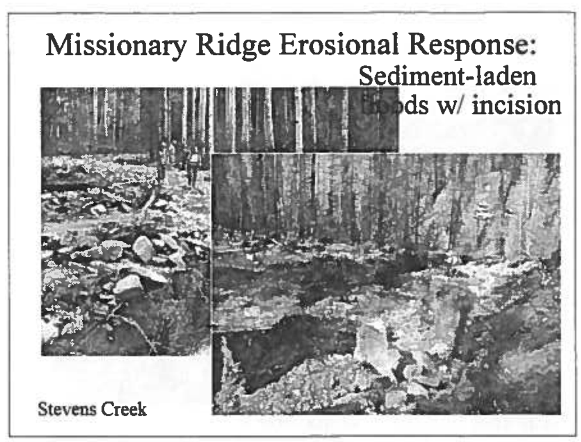

Post-fire Geomorphic Processes:
A Short-term Perspective
in Sedimentary Terrains
Sue Cannon - Landslide Hazards Program

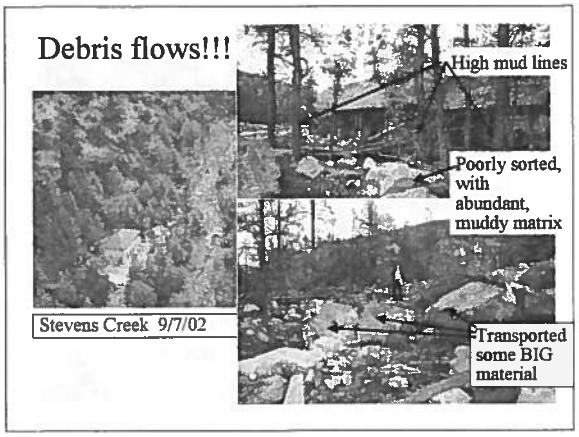

Colorado

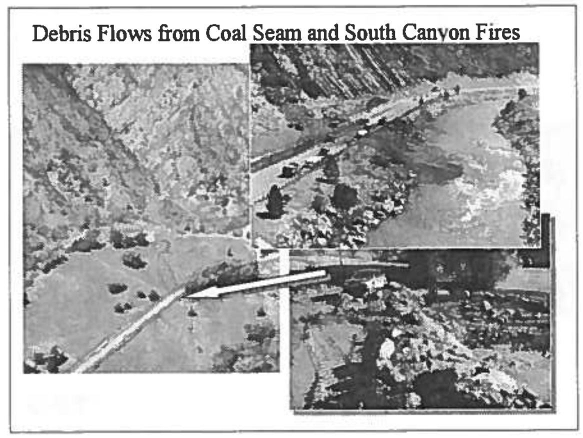

- geology
- geomorphology
- soils

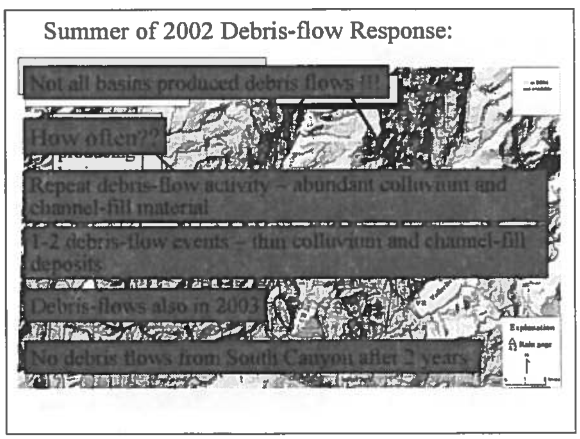

Missionary Ridge Fire
Geology: interbedded sandstones, siltstones and conglomerates
Semi-arid climate
MAP = 18.6 in
Average snowfall = 70 in
Spruce-fir
Mixed conifer, aspen
Ponderosa pine
elevation

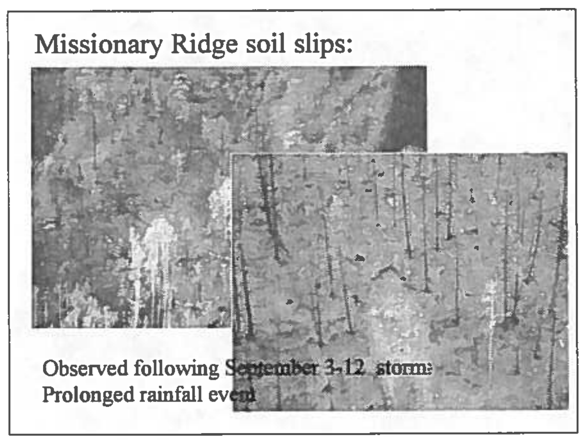

Coal Seam Fire
and South Canyon Fires
Geology: interbedded sandstones, siltstones and conglomerates
Thin colluvial cover and negligible channel-fill deposits
Semi-arid climate
MAP = 15-17 in
Active summer-fall monsoon

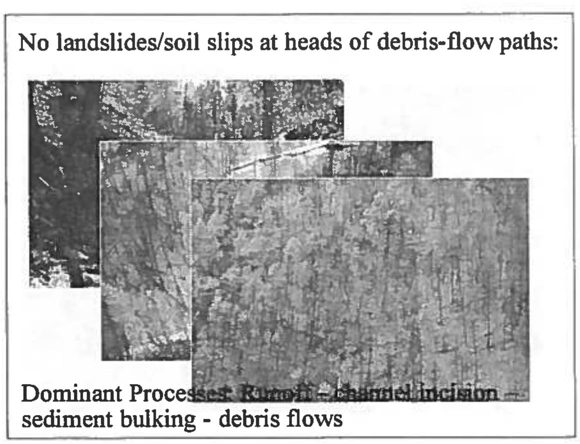

Missionary Ridge Erosional Response:
Sediment-laden
Stevens Creek

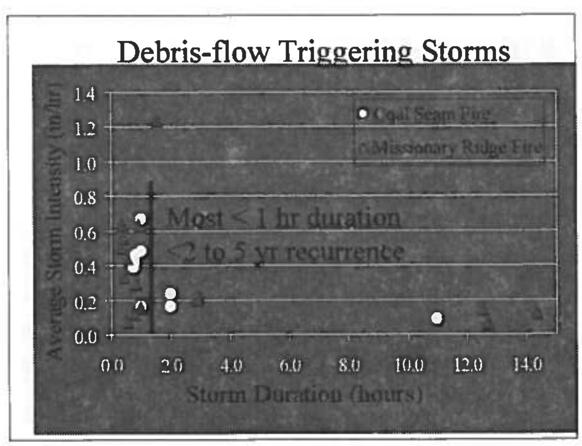

Debris flows!!!
High mud lines
Poorly sorted, with abundant, muddy matrix
Stevens Creek 9/7/02
Transported some BIG material

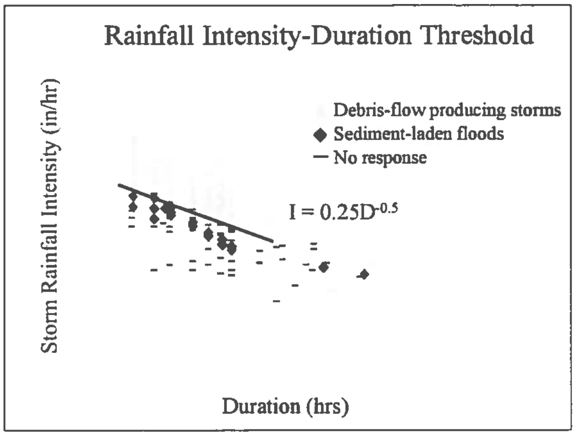

Debris Flows from Coal Seam and South Canyon Fires

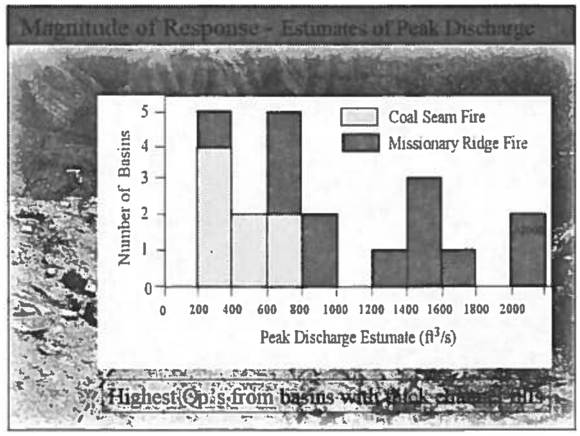

Summer of 2002 Debris-flow Response:
Not all basins produced debris flows !!!
How often??
Repeat debris-flow activity – abundant colluvium and channel-fill material
1-2 debris-flow events – thin colluvium and channel-fill deposits
Debris-flows also in 2003
No debris flows from South Canyon after 2 years
Explanation
Rain gage

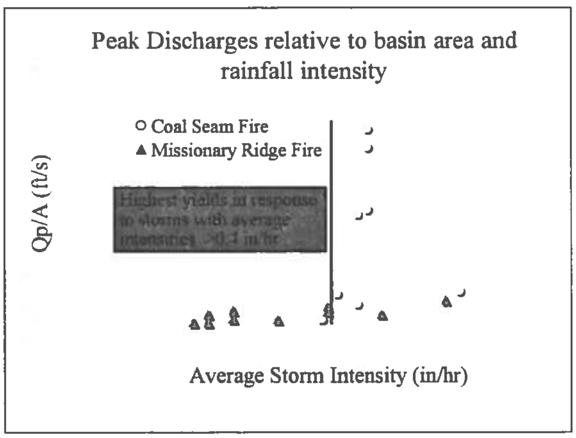

Missionary Ridge soil slips:
Observed following September 3-12 storm:
Prolonged rainfall event

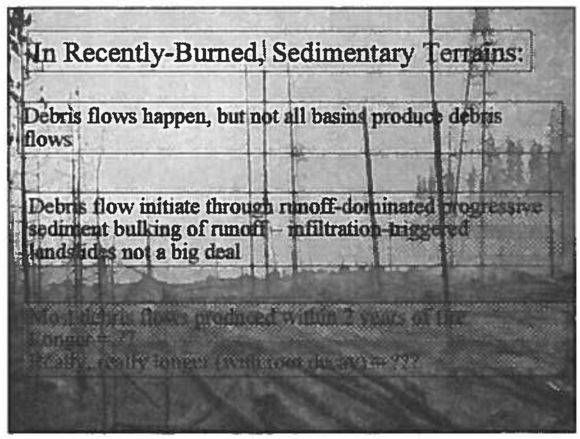

No landslides/soil slips at heads of debris-flow paths:
Dominant Processes: Runoff – channel incision – sediment bulking - debris flows

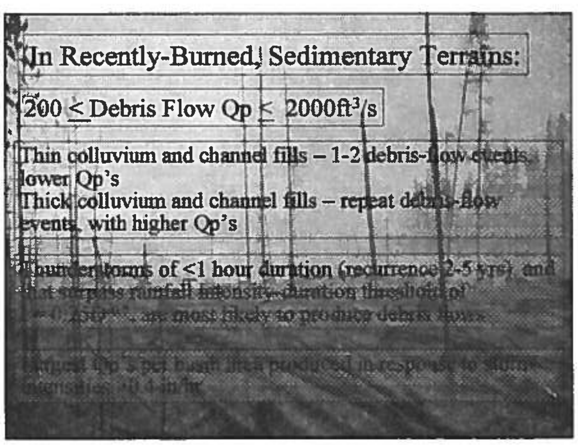

Debris-flow Triggering Storms
Average Storm Intensity (in/hr)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Coal Seam Fire
Missionary Ridge Fire
Most < 1 hr duration
<2 to 5 yr recurrence
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Storm Duration (hours)











For further reading:

Cannon, S.H., Gartner, J.E., Holland-Sears, A., Thurston, B.M., and Gleason, J A., 2003, **Debris-flow response of basins burned by the 2002 Coal Seam and Missionary Ridge fires, Colorado**, *in* Boyer, D.D , Santi, P.M., and Rogers, W P , eds , Engineering geology in Colorado–Contributions, Trends, and Case Histories. AEG Special Publication 15, ColoradoGeological Survey Special Publication 55, 31 pp., on CD-ROM

Cannon, S H., Gartner, J.E., Parrett, C , and Parise, M., 2003, **Wildfire-related debris flow generation through episodic progressive sediment bulking processes, western U.S.A.**, *in* Rickenmann, D. and Chen, C.L., eds., Debris-Flow Hazards Mitigation - Mechanics, Prediction, and Assessment, Proceedings of the Third International Conference on Debris-Flow Hazards Mitigation, Davos, Switzerland, 10-12 September 2003 A.A. Balkema, Rotterdam, p 71-82.

Cannon, S.H., and Gartner, J.E., in press, **Debris flow and wildland fire from a hazards perspective**, in Jacob, M., and Hungr, O., eds Debris flows and debris avalanches – a practically oriented overview of the state-of-the-art Springer-Verlag

Cannon, S.H., Kirkham, R.M., and Parise, Mario, 2001, **Wildfire-related debris-flow initiation processes, Storm King Mountain, Colorado** Geomorphology, v 39, no. 3-4, pp 171-188.

Cannon, S.H., 2001, **Debris-flow generation from recently burned watersheds** Environmental & Engineering Geoscience, v 7, no. 4, p 321-341

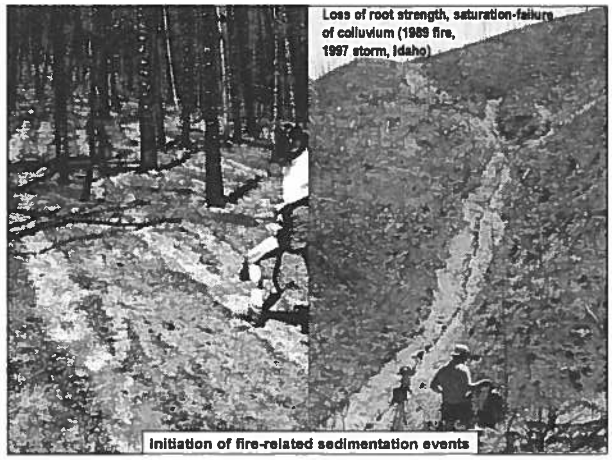
Cannon, S.H., Powers, P.S., and Savage, W.Z., 1998, **Fire-related debris flows on Storm King Mountain, Glenwood Springs, Colorado, USA** Environmental Geology, v 35, no. 2-3, p. 210-218

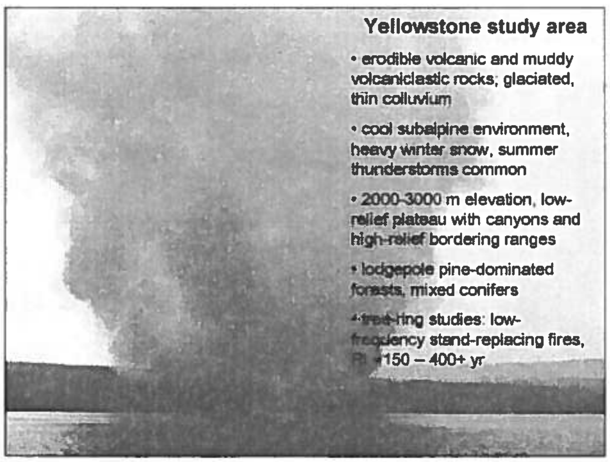

Questions???

Geologic, Geomorphic, and Climatic Controls on Fire-induced Erosional Events in Yellowstone and Central Idaho

Grant A. Meyer
Jennifer Pierce
Department of Earth and Planetary Sciences
University of New Mexico

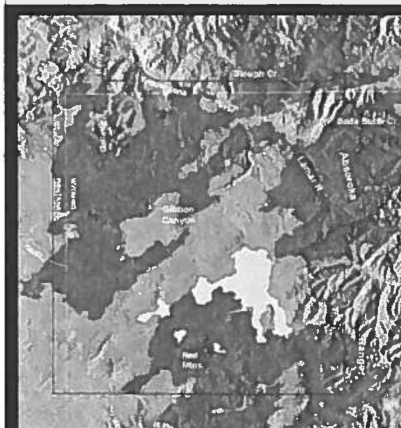
Spencer Wood
Department of Geosciences
Boise State University



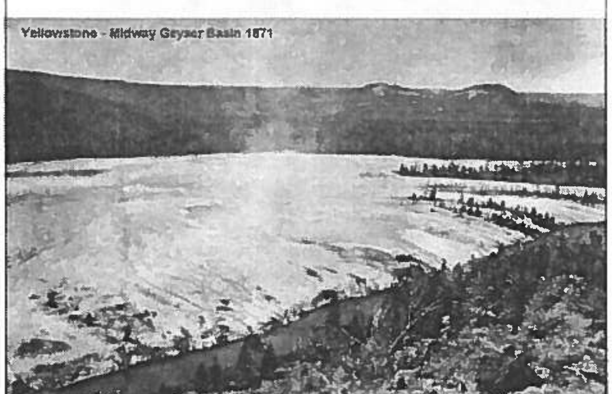


Yellowstone study area

- erodible volcanic and muddy volcaniclastic rocks; glaciated, thin colluvium
- cool subalpine environment, heavy winter snow, summer thunderstorms common
- 2000-3000 m elevation, low-relief plateau with canyons and high-relief bordering ranges
- lodgepole pine-dominated forests, mixed conifers
- tree-ring studies: low-frequency stand-replacing fires, FI ~150 – 400+ yr

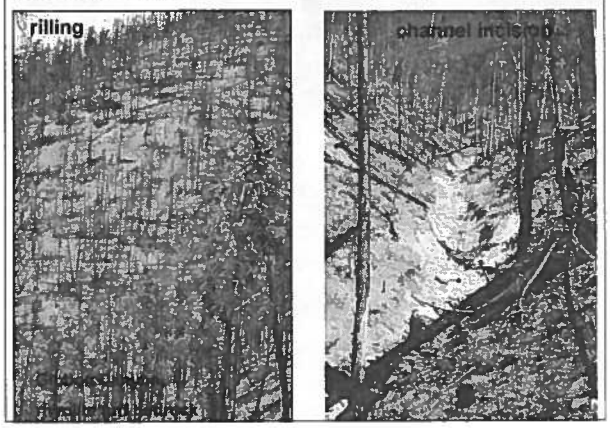


-dense lodgepole stands before fire suppression!



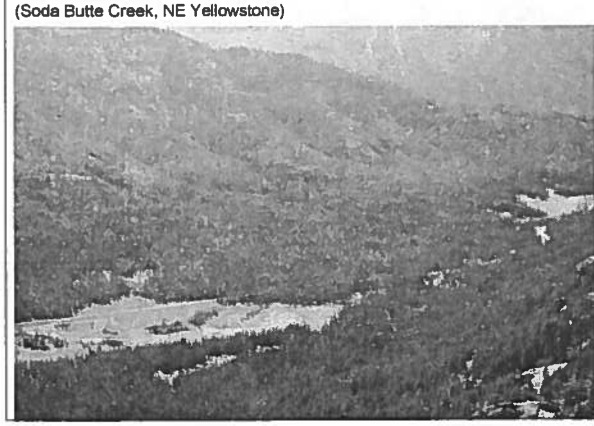
- runoff-generated debris-flow & flash flood events from brief, intense summer thunderstorms
- fine surface soil texture plus ash cause reduced infiltration from surface-sealing(?)
- erosion of fine surface soils provides muddy matrix fluid for debris flows
- basin sizes ~10 to 5700 ha, relief ratios 0.1-0.4 produced debris flows-flash floods
- basins >500 ha: predominantly floods

pervasive runoff generation with sediment bulking through:



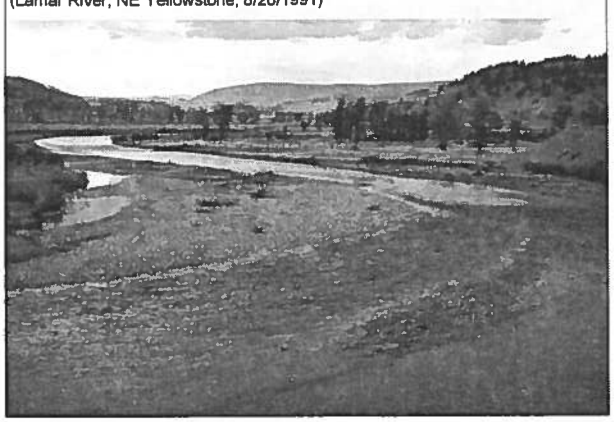
1989 debris-flow event, Gibbon Canyon, Yellowstone

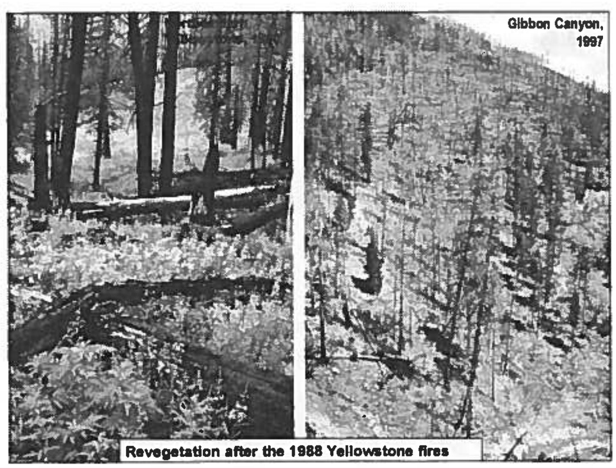
-fire-induced sediment stored on alluvial fans in broad glacial trough valleys (Soda Butte Creek, NE Yellowstone)



1989 debris-flow event, NE Yellowstone: abundant fine sediment from rill erosion of loose, fine surface soils on muddy volcaniclastics (30% of sediment budget)

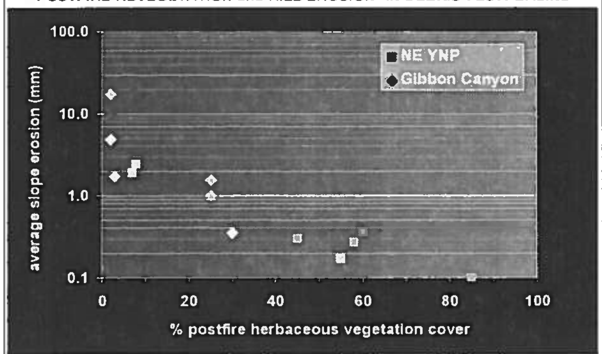
-transient fine sediment loading from summer thunderstorms (Lamar River, NE Yellowstone, 8/26/1991)





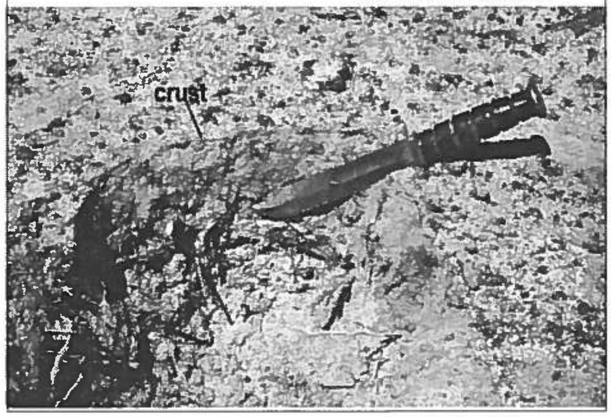
Revegetation after the 1988 Yellowstone fires

POSTFIRE REVEGETATION and RILL EROSION IN DEBRIS-FLOW BASINS



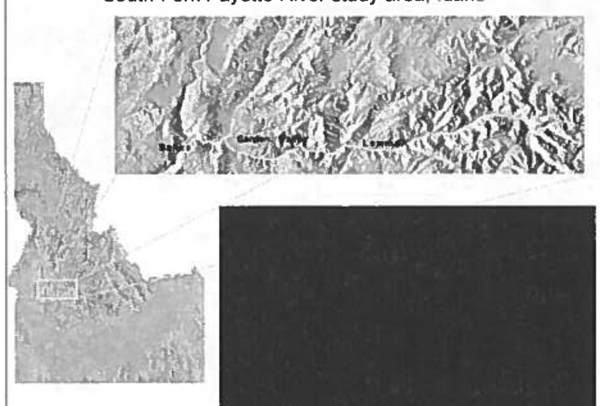
Runoff power index, slope (m/m) x slope length: ■ >40 ▣ 15-40 □ <15

1989 soil surface, Yellowstone: surface-sealing, not water-repellent soil

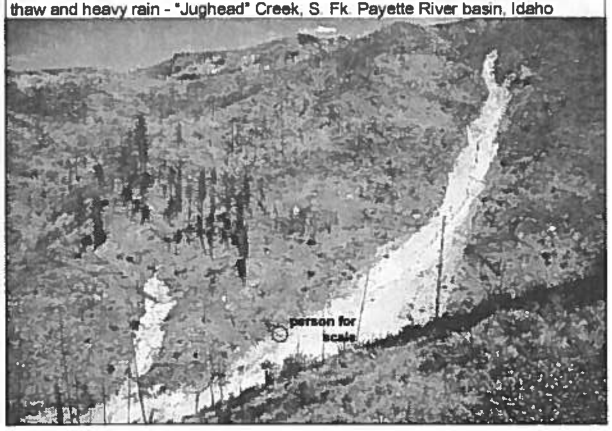


1991 sheetflood-dominated event, NE Yellowstone: strongly crusted soil = greater runoff but less fine sediment from slopes?

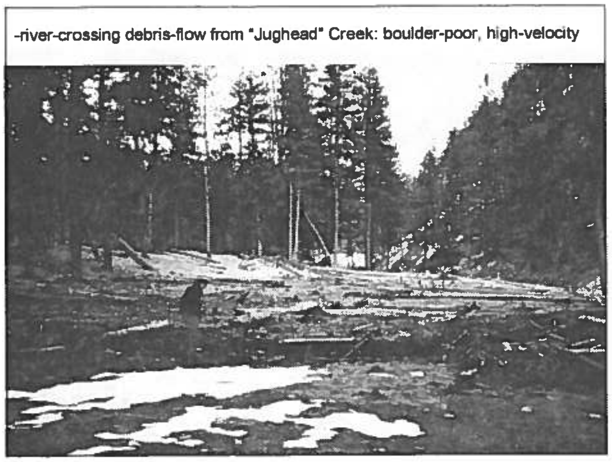
South Fork Payette River study area, Idaho

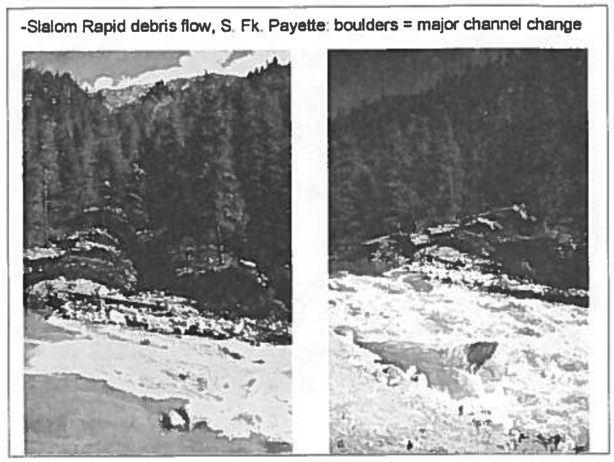


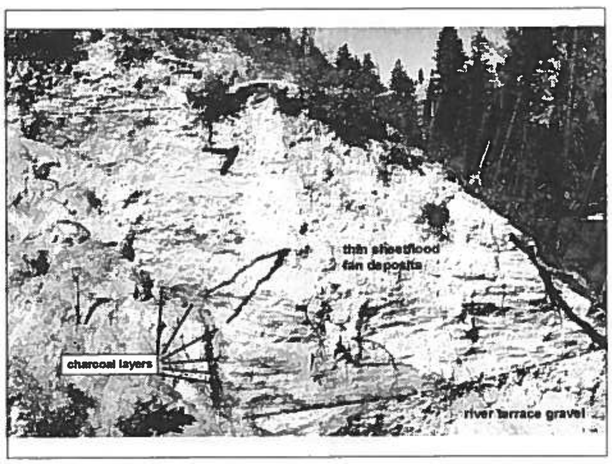
"soil slips" (colluvial failures) in 1989 Lowman fire area from 1996-1997 winter thaw and heavy rain - "Jughead" Creek, S. Fk. Payette River basin, Idaho

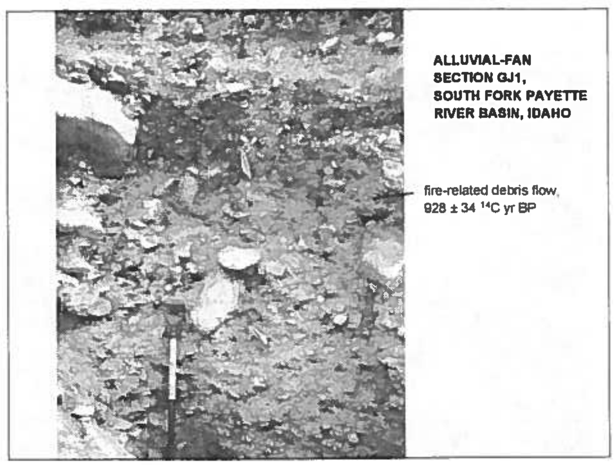


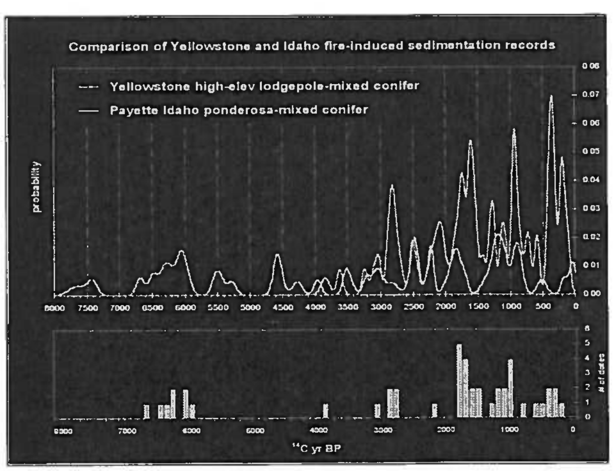
"JUGHEAD" CREEK BASIN MOUTH

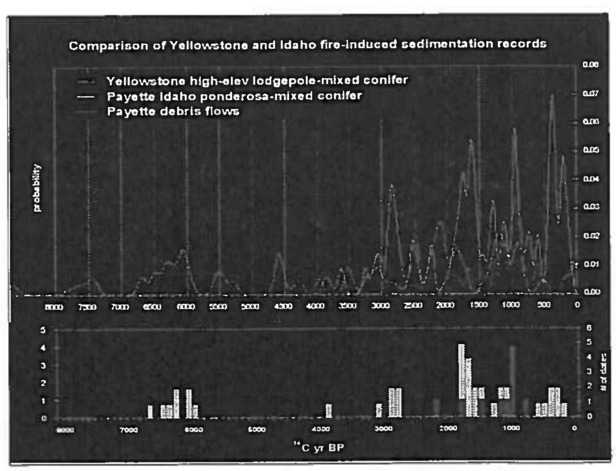

-river-crossing debris-flow from "Jughead" Creek: boulder-poor, high-velocity

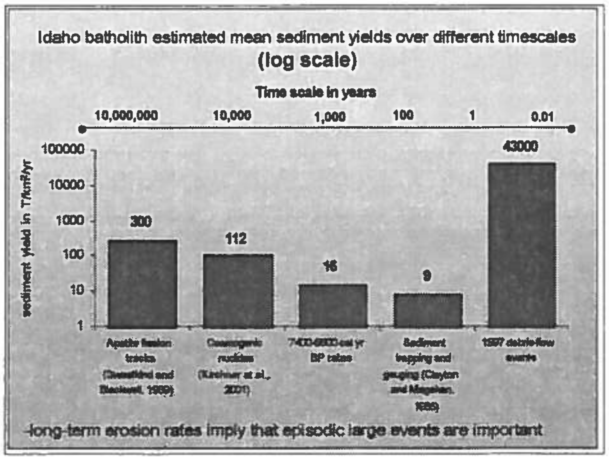

-Slalom Rapid debris flow, S. Fk. Payette: boulders = major channel change


thin sheetflood fan deposits
charcoal layers
river terrace gravel


ALLUVIAL-FAN SECTION GJ1, SOUTH FORK PAYETTE RIVER BASIN, IDAHO
fire-related debris flow, 928 ± 34 14C yr BP


Comparison of Yellowstone and Idaho fire-induced sedimentation records
Yellowstone high-elev lodgepole-mixed conifer
Payette Idaho ponderosa-mixed conifer
probability
# of dates
14C yr BP


Comparison of Yellowstone and Idaho fire-induced sedimentation records
Yellowstone high-elev lodgepole-mixed conifer
Payette Idaho ponderosa-mixed conifer
Payette debris flows
probability
# of dates
14C yr BP



Conclusions

Fire-related debris flow-flash flood generation:
- runoff-sediment bulking in convective storms (transient over ~one-several yr after fire, before herb. revegetation)
- saturation-failure of colluvium with heavy rainfall-snowmelt after roots decay (8-20 yr?)

Flow processes, event magnitude dependent on:
- precipitation magnitude, intensity, timing
- colluvium thickness
- available sediment texture, soil surface conditions
- event sequence, reloading of channels

Event frequency, magnitude dependent on:
- fire regime: severity, extent of burns
- **<u>CLIMATE</u>**
  - short-term drought frequency and severity
  - millennial-scale climate trends

Comparison of the Erosional Response after Wildfire in Two Geological Terrains

John A. Moody, Deborah A. Martin, and Susan H. Cannon
U.S. Geological Survey

GSA Wildland Fire Impacts on Watersheds
October 21-23, 2003

Acknowledgments

Spring Creek
- Lisa Pine
- Tanya Ariowitsch
- David Kinner
- David Mixon
- Jim Smith

Rendija Canyon
- Erica Bigio
- Joe Gartner
- John Gartner
- Brian Ragan

Terrain Characteristics

- Sediment properties
- Channel vegetation
- Tree density
- Hillslope erosion style

	Spring Creek	Rendija Canyon
Elevation range (m):	1,880--2,360	1,910--2,990
Watershed area (ha):	2,680	2,480
Percent burned:	79%	78%
Relief ratio:	0.046	0.085
Channel slope:	0.03--0.33	0.04--0.39
Channel density (km/km^2):	6.9	?
Rock Type:	Granite	Volcanic

Moody et al., 2003

Erodibility

= Detachment + Transport

Moody et al., 2003

Channels (convergent flow)

Detachment:
- ~Initial Main Channel Erodibility
- ~Initial Tributary Erodibility

Transport: Channel Change with Time

Hillslopes (flow on planar or convex surfaces)

Detachment & Transport

Moody et al., 2003

Erosional Response depends on the sequence of rain storms

Main channel erodibility based on deposition measurements

Tributary channel erodibility based on erosion measurements

"Simple Model" to compare resuspension and transport at channel cross sections

Change in cross-section area

Normalization by drainage area (assumes uniform rain over entire drainage area)

Use empirical relation for I30 vs discharge/unit area to calculate stream power and efficiency

Channel Sediment Transport Processes

Eolian

Baseflow

Flash floods

Moody et al., 2003

Detachment efficiency:

$$E \sim \frac{\text{Submerged weight / time above } Q_{crit}}{\text{Stream power}}$$

Assumptions:

1. most of work required to detach sediment during the initial erosional event

Moody et al., 2003

Resuspension & Transport efficiency:

$$E \sim \frac{\text{Submerged weight / time above } Q_{crit}}{\text{Stream power}}$$

Stream power = Water density x g x Discharge x Slope

Moody et al., 2003

Hillslope Erosional Response

Interrill--planar or convex surfaces

Rills--concentrated flow but ephemeral

Moody et al., 2003

Hillslope Interrill Sediment Transport Processes

Dry Ravel

Rain Splash

Overland Flow

Rain Flow

Moody et al., 2003

Hillslope Erodibility efficiency:

$$E \sim \frac{\text{Submerged sediment transport rate}}{\text{Hillslope Stream power}}$$

Assumptions:

1. all rain runs off
2. assumes a kinematic wave not at equilibrium

Moody et al., 2003

Channel Summary

1. Erosion for both terrains is very dependent on the sequence of rain storms.

2. Initial erodibility efficiencies (detachment estimates) were similar (1-10%) for granitic and volcanic terrains.

Moody et al., 2003

Channel Summary continued

3. Erodibility (resuspension & transport) varied with time:

A. Granitic terrain: depended on the occurrence of baseflow or flash-flood transport processes.

B. Volcanic terrain: was less "efficient" because the stream power was reduced by absorbing water in the sediment itself and trapping it in the bed (i.e. no visible baseflow).

Moody et al., 2003

Hillslope Summary

1. Erodibility efficiency on hillslopes (~0.001%) is much less than in channels (1-10%), and may be unimportant at the watershed scale.

However, if it is desirable to model at smaller scales then...

Moody et al., 2003

Hillslope Summary continued

2. Erosion for both terrains is very dependent on the sequence of rain storms.

3. Erodibility measurements depend on sediment availability.

A. In the volcanic terrain measurements were made immediately after the fire during the first year.

B. In the granitic terrain measurements were made during the second and third year after the fire.

Moody et al., 2003

Hillslope Summary continued

4. The simple stream power model for hillslopes is "too simple". Other transport processes (dry ravel, rainsplash, rainflow) may be important at certain times.

5. New models of hillslope erosion need to include the effects of ash, soil moisture and microbial properties and the surface sealing process.

Moody et al., 2003

Selected References:

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Gerlach, T., 1967, Hillslope troughs for measuring sediment movement, Revue Geomorphologie Dynamique, 17(4), 173-174.

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Moody, J.A., and Martin, D. A., 2001, Post-fire, rainfall intensity-peak discharge relations for three mountainous watersheds in the western USA, Hydro. Processes, 15, 2981-2993.

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Impacts of Fire on Hillslope Hydrology in Steep Mountain Big Sagebrush Communities

Frederick B. Pierson, Jr.
Research Hydrologist

USDA -ARS
Northwest Watershed Research Center, Boise, Idaho

Peter R. Robichaud
Research Engineer

USDA - FS
Rocky Mountain Research Station, Moscow, Idaho

Kenneth E. Spaeth
Range Hydrologist

USDA - NRCS
Northwest Watershed Research Center, Boise, Idaho

Research funded by: USDA - Agricultural Research Service
Joint Fire Sciences Program
NRCS - Grazing Lands Technology Institute
BLM - Idaho State Office

Study Areas

- Fires:
  - 1996, Eighth Street Fire, Boise Front, SW Idaho
  - 1999, Denio Fire, Pine Forest Range, NW Nevada
- Slopes: 30-40%
- Soils: Granitic, Sandy Loams from Decomposed Granite
- North Slopes: Big Sagebrush, Snowberry, Idaho Fescue, Blue Bunch Wheatgrass, Deep soils
- South slopes: Bitterbrush, Blue Bunch Wheatgrass, Sandbergs Bluegrass, Cheatgrass, Shallow soils
- Annual Precipitation: 400-500 mm

Objectives

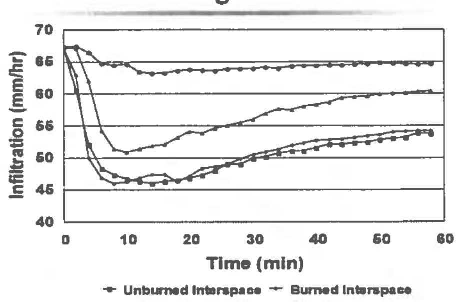
- Quantify the effects of wildfire on infiltration, runoff and erosion processes within coarse-textured, sagebrush dominated watersheds
- Determine rate of ecological and hydrological recovery of these systems following wildfire

Hillslope Processes

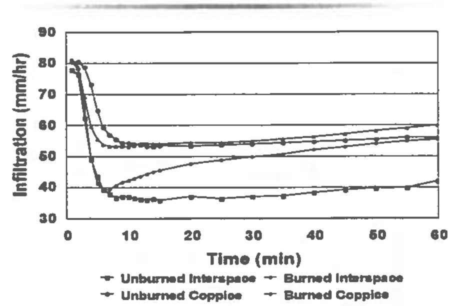
Fire Impacts on:

- Infiltration - Fire-induced water repellent soils
- Runoff Generation - Timing and Amount
- Erosion - Relative Importance of:
  - Interrill Erosion
  - Rill Erosion
- Hydrologic Recovery - Rate and Controlling Factors

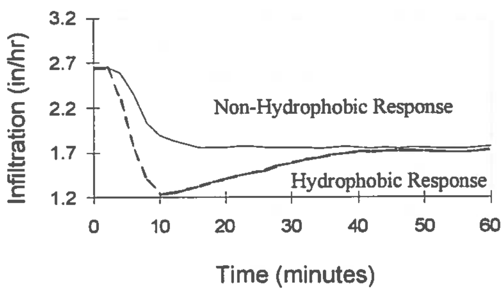
Infiltration - Eighth Street Fire



Infiltration - Denio Fire



Water Repellent Soils



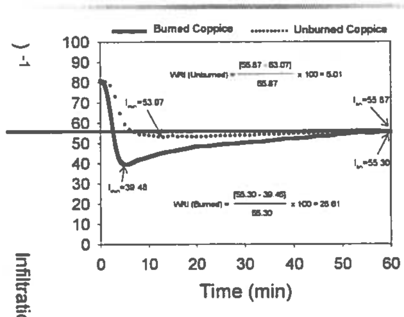
Water Repellency Index (WRI)

$$WRI = \frac{[I_{fin} - I_{min}]}{I_{fin}} \times 100$$

Where:

Imin = minimum infiltration rate throughout the rainfall simulation
Ifin = final infiltration rate measured at the end of the simulation

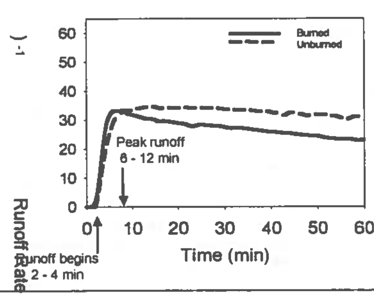
Water Repellency: Denio Fire



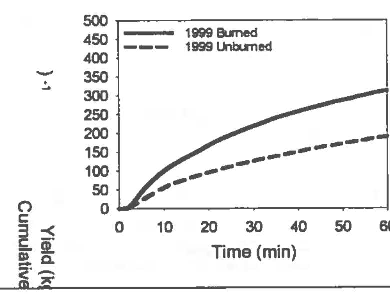
Water Repellency Index

Average WRI (%)BurnedUnburnedCoppiceInterspaceCoppiceInterspaceEighth Street

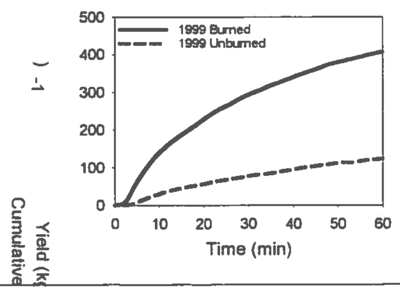
Runoff: Denio Fire



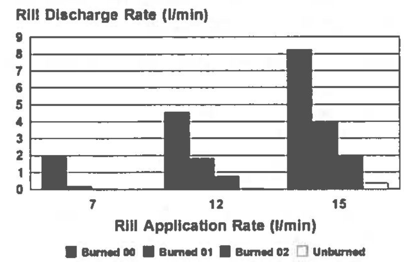
Interrill Erosion: Denio Fire



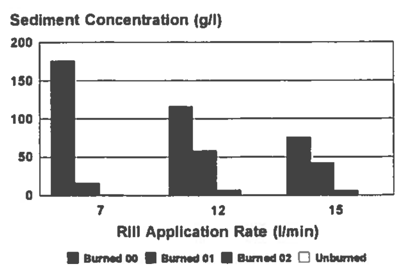
Coppice Erosion: Denio Fire



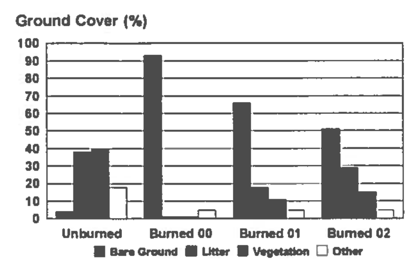
Rill Runoff: Denio Fire



Rill Erosion: Denio Fire



Recovery of Ground Cover: Denio Fire



Summary - Infiltration

- Fire had only small negative impact on infiltration
- All burned and unburned sites exhibited significant water repellent soil conditions
- Burned coppice areas had the most significant increase in soil water repellency
- Unburned interspaces also showed significant water repellency
- Temporal variations in infiltration can be greater than fire-induced impacts

Summary - Runoff

- Similar rapid runoff response for both burned and unburned conditions
- Both burned and unburned sites began to generate runoff very quickly under high intensity rainfall (2-4 min)
- All burned and unburned sites rapidly reached peak runoff rates (6-12 min)
- Difference between burned and unburned hillslope runoff response is strongly influenced by soil surface cover
- Removal of soil cover by burning decreases surface storage of water, allows water to concentrate more quickly resulting in greater runoff velocity/erosive energy

Summary - Erosion

- Fire had small,but significant impact on interrill erosion particularly from burned coppice areas
- Fire had greatest and most long-lasting impact on rill erosion dynamics
  - Rilling is dominant form of soil erosion
  - Fire reduces soil surface cover
  - Overland flow becomes concentrated and increases in velocity
  - Soil surface cover takes longer to recover after fire than canopy cover
- Fire rehabilitation efforts should focus on slowing overland flow and rilling in addition to increasing infiltration

1-4

Burn Severity, Fuels Management and Geomorphic and Watershed Impacts

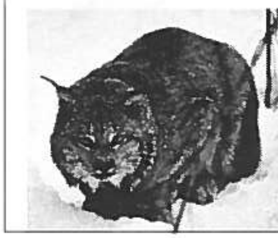
RMRS

Burn Severity and Vegetation (Fuels) Management

Russell T. Graham
USFS Rocky Mountain Research Station
Moscow, ID
rtgraham@fs.fed.us

RMRS

Forest Values


RMRS

Fire Excluded Ponderosa Pine Forests

- Nutrient/organic matter compression towards the soil surface

RMRS

Litter/humus/ fermentation (Duff) build-up



RMRS

Nutrient/biomass compression

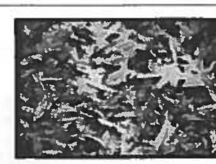
Crowns

Soil surface

Roots/myco/nutrients

RMRS

Forest Soils

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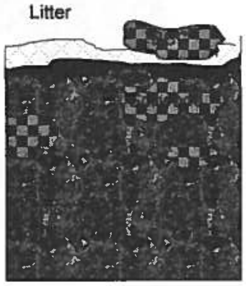
Forest Soil



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Forest Residues

- New: recent dead logs and branches
- Incipient: Decay processes starting
- Intermediate: Large amounts of soft wood, some BCC
- Advanced: Mostly BCC

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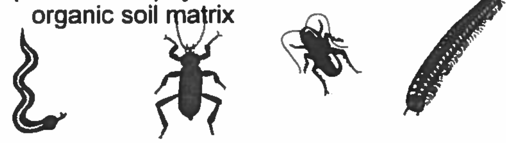
Importance of Residue

- Physically protects soil
  - Compaction
  - Erosion
- Protects seedlings from animals
- Nitrogen fixation (0.3 – 1.7 kg/ha/yr)
- Provides OM to lower layers

RMRS

Microbes

- Decay fungi / fauna
  - break down plant residues
  - release nutrients in plants and other organisms
  - produce the physical character of the organic soil matrix



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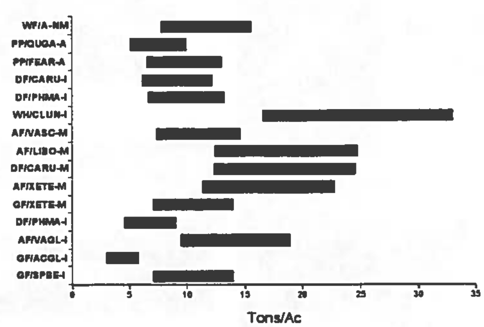
CWD Recommendations



RMRS

Machine Piles

Tractor piling
- Distribute CWD across harvest units
- Separate fine materials from CWD
- Can compact and displace soil
- Limited by slope

Grapple piling
- Separate fuels
- Work on steep slopes
- Minimize soil disturbance

Roller Chopping and Chipping

- Create compacted layers
- Insulating soil surface
- Slowing decomposition
- Especially on cool sites
- Destroys
  - Nitrogen fixation
  - Animal habitat
  - Site protection

Fire

Prescribed Fire

Fire Effects

Residues

Litter
Humus

Soil wood

Mineral
Soil

Prescribed Fire

- Does not concentrate fine fuels
- Removes hazard fuels
- Under proper conditions (high lower duff moisture)
  - Can maintain forest floor
  - Capture nutrients released during burning

Prescribed Fire

- Charring does not appreciably interfere with decomposition or function of CWD
- Greatest limitation
  - Smoke emissions

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Fire Effects

- Residues
  - Consume all 3” minus
  - Consume portion of 3” plus

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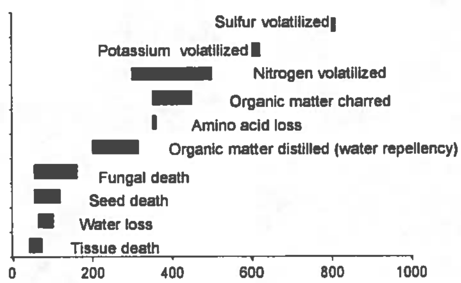
BCC/CWD Consumption

RMRS

Critical Soil Temperatures

Nutrient, Physical, & Vegetation Impacts



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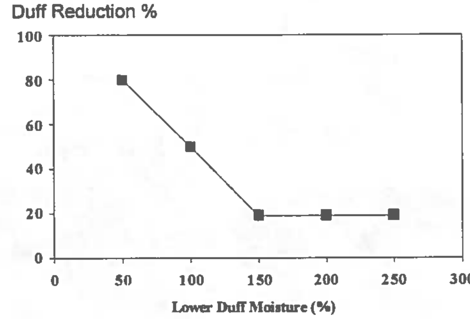
Duff Reduction



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Exotic species cheatgrass

- Large soil seed reserves
- Multiple germination seasons
- High heat resistance of seeds
- Highly flammable
- Interfere with succession

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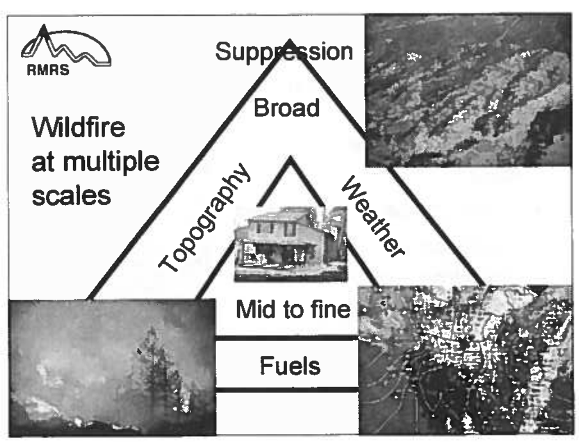
Wildfire at multiple scales



RMRS

Hayman, Colorado
June 8-28, 2002
1 start ----137,759 Acres

RMRS

Hayman Study Team

- Executive committee
  - Dr. Marcia Patton-Mallory:RMRS Director
  - Rick Cables: RM Regional Forester
  - Jim Hubbard: Colorado State Forester
- Analysis team leaders
  - Dr. Russell Graham: Leader RMRS, Moscow, ID
  - Dr. Mark Finney: Fire behavior-RMRS, Missoula, MT
  - Jack Cohen: Structures-RMRS, Missoula, MT
  - Dr. Brian Kent: Social/economics-RMRS, Fort Collins, CO
  - Dr. Pete Robichaud: Rehabilitation-RMRS, Moscow, ID
  - Dr. Bill Romme: Ecological effects-CSU, Fort Collins, CO
  - Dave Tippets/Bill Rice: Communications-RMRS/R2
  - Louise Kingsbury: Publications-RMRS, Ogden, UT

RMRS

Final Reports

Hard copy
CD
Web

http://www.fs.fed.us/rm/hayman_fire/

RMRS

Fuels planning: Science synthesis and integration. An interagency research/management partnership to support the Ten-Year Fire Plan in the Dry Forests of the Interior West

Russell T. Graham, RMRS
Sarah M. McCaffrey, NCRS

RMRS

Fuels Planning

- Peer-reviewed synthesis and integration
  - fuels treatments in dry forests/wildland-urban interface
- Current scientific knowledge and uncertainties
  - Silviculture,
  - Fire behavior
  - Fire ecology
  - Social science
- Target audiences
  - Fuels management specialists
  - Resource specialists
  - Planning team leaders
  - Line officers

RMRS

Synthesis Teams

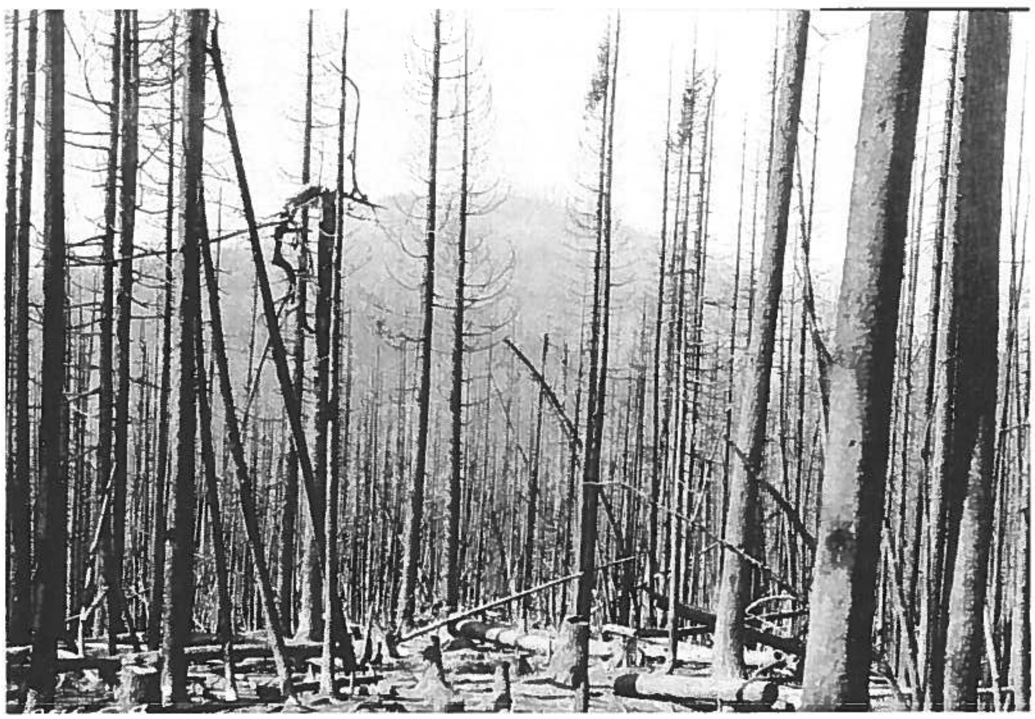
- Forest structure and fire behavior
  - Dave Peterson-PNW
  - Influence of stand and landscape structure on fire behavior
- Treatment effects
  - Elaine Sutherland-RMRS
  - Effects of fuel and restoration treatments
- Economic uses of material
  - Jamie Barbour PNW
  - Economic trade-offs among fuel reduction treatments
- Public understanding, beliefs, attitudes, and behaviors
  - Pam Jakes-NCRS
  - Relevant to fuel treatments
- Integration - Around risk and uncertainty

Fuels planning: Science synthesis and integration. An interagency research/management partnership to support the Ten-Year Fire Plan in the Dry Forests of the Interior West

Leaders:

Russell T. Graham, Synthesis Leader, USDA, Forest Service, Rocky Mountain Research Station, Moscow, ID

Sarah M. McCaffrey, Deputy Synthesis Leader, USDA Forest Service, North Central Research Station, Evanston, IL



Project

This effort will produce a peer-reviewed synthesis and integration of the scientific knowledge about fuels treatments in dry forests/wildland-urban interface areas of the Western US and it deliver to planning teams in the Forest Service and the Department of Interior bureaus. This synthesis will represent the current level of understanding of scientific knowledge and uncertainties (knowledge gaps) relevant to key management questions underlying implementation of the Ten-Year Fire Plan. The synthesis will represent the collective judgment of the most knowledgeable scientific experts in silviculture, fire behavior, fire ecology, social science, and other fields. Target audiences for the products of this effort include fuels management specialists, resource specialists, planning team leaders and ultimately the line officers that make decisions based on their recommendations. This proposed initiative will demonstrate a model for more effective integration, delivery, and application of science relevant to other important issues in fire and forest health management.

The benefits of this effort include:

- Greater efficiency in environmental analyses by helping field planning teams catch up with the relevant bodies of science and by alleviating project-level planning teams of the burden of collecting and synthesizing disparate and rapidly emerging scientific findings.
- Higher quality decision making, due to more complete access to relevant scientific information and a clearer and thoroughly reviewed logic for evaluating alternatives.
- Blueprint for more productive relationships between management and research.
- Testing a potentially more effective approach for packaging and delivery of science findings.
- Making lasting changes in the way fuels analyses are conducted by introducing new methods and tools for evaluating treatment effects, trade-offs, and interactions.

Synthesis Teams

- Forest structure and fire behavior: Leader, Dave Peterson USDA Forest Service, Pacific Northwest Experiment Station, Seattle, WA. Influence of stand and landscape structural changes made by fuels and restoration treatments on elements of fire behavior.
- Treatment effects: Leader, Elaine Sutherland, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT. Effects of fuel and restoration treatments on environmental resources and values such as human structures, fish, wildlife, and T&E species habitat, air quality, carbon sequestration balances and dynamics, water resources and hydrological processes, and invasive species populations.
- Economic uses of material. Leader, Jamie Barbour, USDA Forest Service, Pacific Northwest Experiment Station, Portland, OR. Provide information on the economic trade-offs among fuels reduction treatments and the ability of forested landscapes to produce a range of amenity and commodity outputs. Simplify methods to evaluate the financial aspects of prescribed burning and mechanical fuels reduction treatments. Evaluate opportunities to use wood removed in treating fuels and restoring fire-adapted ecosystems.

- Public understanding, beliefs, attitudes, and behaviors: Leader Pam Jakes, USDA Forest Service North Central Research Station, St. Paul, MN. Public understanding, beliefs, attitudes, and behavior relevant to fuel treatments and structural vulnerability measures (i.e. FIREWISE practices), methods for communicating risk, and ways to incorporate the public's values into the design and communication of fuel treatment programs.
- Integration. Characterization of the implications of the synthesis results (above) for key management decisions. These implications will include interactions among findings, possibilities of cumulative effects and uncertainties, variations in spatial and temporal applicability, and key tradeoffs.

Each synthesis team will produce one or more synthesis documents. In addition, the leadership team will produce a separate integration report. All documents will be produced in a clear, understandable style and format for ready access by planning teams. Documents will contain narrative interpretation and implications that managers and communities could consider in designing and implementing fuels programs and projects. Interim products will be available by November 2003 with the final products available by September 2004.

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SDA United States Department of Agriculture

Forest Service

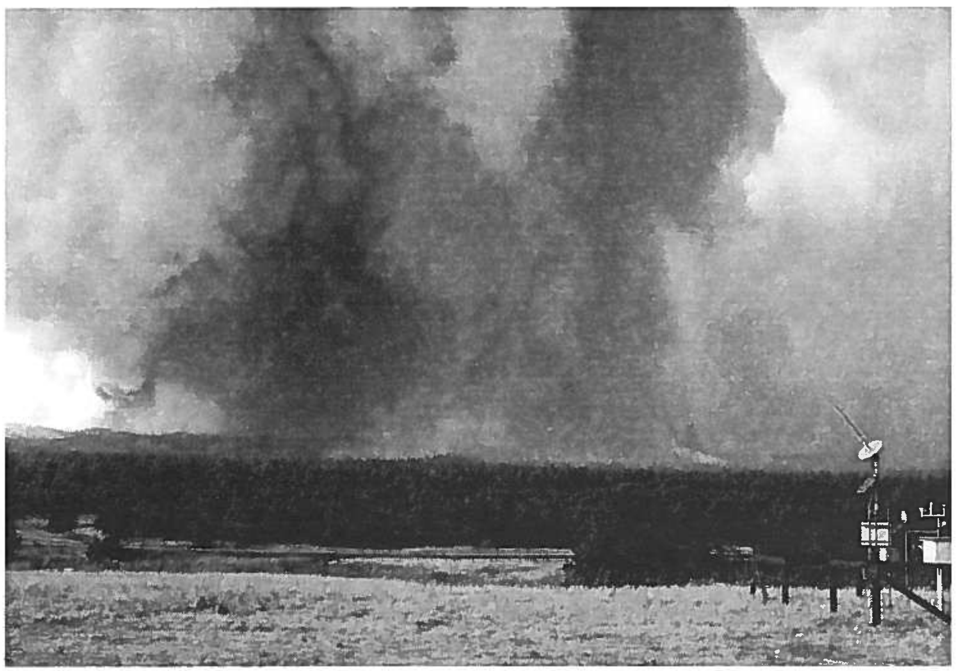
Rocky Mountain Research Station

General Technical Report RMRS-GTR-115

September 2003

Hayman Fire Case Study: Summary

Russell T. Graham, Technical Editor



Abstract

Graham, Russell T., Technical Editor. 2003. **Hayman Fire Case Study: summary**. Gen. Tech. Rep. RMRS-GTR-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 32 p.

This publication summarizes the findings in the 400-page companion document, *Hayman Fire Case Study*, Gen. Tech. Rep. RMRS-GTR-114. This summary document's purpose is to convey information quickly and succinctly to a wide array of audiences.

In 2002 much of the Front Range of the Rocky Mountains in Colorado was rich in dry vegetation as a result of fire exclusion and the droughty conditions that prevailed in recent years. These dry and heavy fuel loadings were continuous along the South Platte River corridor located between Denver and Colorado Springs on the Front Range. These topographic and fuel conditions combined with a dry and windy weather system centered over eastern Washington to produce ideal burning conditions. The start of the Hayman Fire was timed and located perfectly to take advantage of these conditions resulting in a wildfire run in 1 day of over 60,000 acres and finally impacting over 138,000 acres. The Hayman Fire Case Study, involving more than 60 scientists and professionals from throughout the United States, examined how the fire behaved, the effects of fuel treatments on burn severity, the emissions produced, the ecological (for example, soil, vegetation, animals) effects, the home destruction, postfire rehabilitation activities, and the social and economic issues surrounding the Hayman Fire. The Hayman Fire Case Study revealed much about wildfires and their interactions with both the social and natural environments. As the largest fire in Colorado history it had a profound impact both locally and nationally. The findings of this study will inform both private and public decisions on the management of natural resources and how individuals, communities, and organizations can prepare for wildfire events.

Keywords: Wildfire, fuel treatments, wildfire behavior, social and economic wildfire effects, ecological effects of wildfires

Acknowledgments

The Hayman Fire Case Study involved the timely assembling, analyzing, and reporting on large volumes of data. A project of this size cannot be accomplished without the help and understanding of the families, friends, and coworkers of all of those involved. We, the Study Team, thank them all. We thank the many people who attended our public meetings and those who provided critical reviews of our Interim Report and the peers who reviewed our final reports. The devil is in the details of a study such as this, and the Publication Team is thanked by the other Team members for their excellent work in producing the publications.

Cover photo: Photograph taken from the headquarters of the Manitou Experimental Forest located on the eastern perimeter of the Hayman Fire, as the fire approached on June 18, 2002.

Hayman Fire Case Study: Summary

Case Study Leader
Russell T. Graham

Research Forester
USDA Forest Service, Rocky Mountain Research Station
Moscow, Idaho

Fire Behavior, Fuel Treatments, and Fire Suppression Team Leader
Mark A. Finney

Research Physical Forester
USDA Forest Service, Rocky Mountain Research Station
Missoula, Montana

Ecological Effects Team Leader
William H. Romme

Professor
Department of Forest, Rangeland, and Watershed Stewardship
Colorado State University
Fort Collins, Colorado

Home Destruction Team Leader
Jack Cohen

Research Physical Scientist
USDA Forest Service, Rocky Mountain Research Station
Missoula, Montana

Postfire Rehabilitation Team Leader
Pete Robichaud

Research Engineer
USDA Forest Service, Rocky Mountain Research Station
Moscow, Idaho

Social/Economic Team Leader
Brian Kent

Research Forester
USDA Forest Service, Rocky Mountain Research Station
Fort Collins, Colordao

Hayman Fire Case Study Team Members and Affiliations

Executive Committee
Marcia Patton-Mallory, Station Director, USDA Forest Service, Rocky Mountain Research Station (RMRS), Fort Collins, CO
Rick Cables, Regional Forester, USDA Forest Service, Rocky Mountain Region, Golden, CO
Jim Hubbard, Colorado State Forester, Colorado State Government, Fort Collins, CO

Case Study Leader
Russell Graham, Research Forester, USDA Forest Service, Rocky Mountain Research Station (RMRS), Moscow, ID

Fire Behavior, Fuel Treatments, and Fire Suppression Team
Mark A. Finney, Team Leader, RMRS, Fire Sciences Laboratory, Missoula, MT
Roberta Bartlette, RMRS, Fire Sciences Laboratory, Missoula, MT
Larry Bradshaw, RMRS, Fire Sciences Laboratory, Missoula, MT
Kelly Close, Poudre Fire Authority, Fort Collins, CO
Brandon M. Collins, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Paul Gleason, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Wei Min Hao, RMRS, Fire Sciences Laboratory, Missoula, MT
Paul Langowski, USDA Forest Service, Rocky Mountain Region, Lakewood, CO
Erik J. Martinson, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
John McGinely, NOAA Forecast Systems Laboratory, Boulder, CO
Charles W. McHugh, RMRS, Fire Sciences Laboratory, Missoula, MT
Phillip N. Omi, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Wayne D. Shepperd, RMRS, Fort Collins, CO
Karl Zeller, RMRS, Fort Collins, CO

Ecological Effects Team
William H. Romme, Team Leader,Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Geneva Chong, U.S. Geological Survey and Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO
Jan E. Cipra, Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO
Catherine Crosier, Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO
Lynn M. Decker, USDA Forest Service, Washington Office
Laurie Huckaby, RMRS, Fort Collins, CO
Merrill R. Kaufmann, RMRS, Fort Collins, CO
Eugene F. Kelly, Department of Soil and Crop Sciences, Colorado State University, Fort Collins, CO
Jeffrey L. Kershner, USDA Forest Service, Washington Office, Logan, UT
Natasha B. Kotliar, U.S. Geological Survey, Fort Collins, CO
Zamir Libohova, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Lee MacDonald, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Greg Newman, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, CO
Rebecca Parmenter, USDA Forest Service, Rocky Mountain Region, Lakewood, CO
Eric Patterson, Rocky Mountain Ecological Services, Fort Collins, CO
Claudia M. Regan, USDA Forest Service, Rocky Mountain Region, Lakewood, CO
David A. Shadis, USDA Forest Service, Rocky Mountain Region, Lakewood, CO
Rosemary Sherriff, Department of Geography, University of Colorado, Fort Collins, CO
Sara Simonson, Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO
Tom Stohlgren, U.S. Geological Survey and Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO
Dave Theobold, Natural Resource Ecology Lab, Colorado State University, Fort Collins, CO
Thomas T. Veblen, Department of Geography, University of Colorado, Boulder,CO
David Winters, USDA Forest Service, Rocky Mountain Region, Lakewood, CO

Home Destruction Team
Jack Cohen, Team Leader, RMRS, Fire Sciences Laboratory, Missoula, MT
Rick D. Stratton, Systems for Environmental Management, Missoula, MT

Postfire Rehabilitation Team
Peter Robichaud, Team Leader, RMRS, Forestry Sciences Laboratory, Moscow, ID
Louise Ashmun, RMRS, Forestry Sciences Laboratory, Moscow, ID
Jeff Freeouf, USDA Forest Service, Rocky Mountain Region
Lee MacDonald, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO
Deborah Martin, U.S. Geological Survey, Boulder, CO
Dan Neary, RMRS, Southwest Forest Science Complex, Flagstaff, AZ

Social/Economic Team
Brian Kent, Team Leader, RMRS, Natural Resources Research Center, Fort Collins, CO
Greg Alward, USDA Forest Service, Inventory and Monitoring Institute, Fort Collins, CO
Holly Wise Bender, Integrated Resource Solutions, Boulder, CO
David Calkin, Dept. of Marketing, California State University, Long Beach, CA
Matt Carroll, Department of Natural Resources, Washington State University, Pullman, WA
Patricia J. Cohn, Department of Natural Resources, Washington State University, Pullman, WA
Carol Ekarius, Coalition for the Upper South Platte, Hartsell, CO
Krista Gebert, RMRS, Forestry Sciences Laboratory, Missoula, MT
Yoshitaka Kumagai, Department of Natural Resources, Washington State University, Pullman, WA
Wade Martin, Department of Economics, California State University, Long Beach, CA
Ingrid Martin, Dept. of Marketing, California State University, Long Beach, CA
Sarah McCaffrey, USDA Forest Service, North Central Station, Evanston, IL
Ervin Schuster, RMRS, Forestry Sciences Laboratory, Missoula, MT
Dan Williams, RMRS, Natural Resources Research Center, Fort Collins, CO

Spatial Team
Jim Menakis, Team Leader, RMRS, Fire Sciences Laboratory, Missoula, MT

Communications Team
David Tippets, Team Leader, RMRS, Ogden, UT
Doug Young, Congressman Mark Udall's staff, Westminster, CO
Bill Rice, USDA Forest Service, Rocky Mountain Region, Lakewood, CO
John Bustos, Front Range Fuels Partnership, Fort Collins, CO
Katharine Timm, Colorado State Forest Service, Lakewood, CO
Barbara Timock, Pike-San Isabel National Forest, Pueblo, CO
Pam Gardner, USDA Forest Service, Rocky Mountain Region, Lakewood, CO

Publications Team
Louise Kingsbury, Team Leader, RMRS, Team is stationed in Ogden, UT
Nancy Chadwick
Suzy Stephens

Contents

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Hayman Fire Case Study: Summary

Introduction

Historically, wildfires burned Western forests creating and maintaining a variety of forest compositions and structures (Agee 1993). Prior to European settlement lightning along with Native Americans ignited fires routinely across many forested landscapes. After Euro-American settlement, fires continued to be quite common with fires ignited by settlers, railroads, and lightning (Pyne 2001). In August 1910 came a pivotal change in how Westerners in particular, and policymakers in general, viewed fire. Starting early in that summer, fires were ignited and continued to burn throughout western Montana and northern Idaho. By mid August over 1,700 fires were burning throughout the region, but most forest managers figured the area could weather these fires if no dry strong winds developed. On August 20 and 21, the dry winds did blow, and by the time the time the flames subsided over 3.1 million acres of the northern Rocky Mountains burned (fig. 1). These fires killed 78 firefighters and seven civilians and burned several communities including one-third of Wallace, Idaho (fig. 2) (Pyne 2001; USDA 1978). This event solidified the negative aspects of wildfires in the view of the public and policymakers and led to the strong

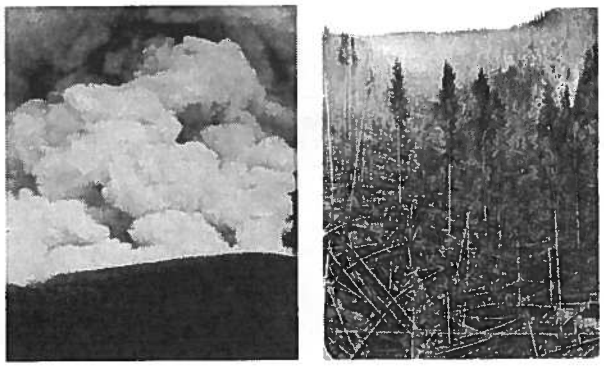

Figure 1—The wildfires of the Northern Rocky Mountains in 1910 burned over 3.1 million acres, destroying valuable timber resources.

Figure 2—Over one-third of Wallace, ID, burned during the wildfires of 1910.

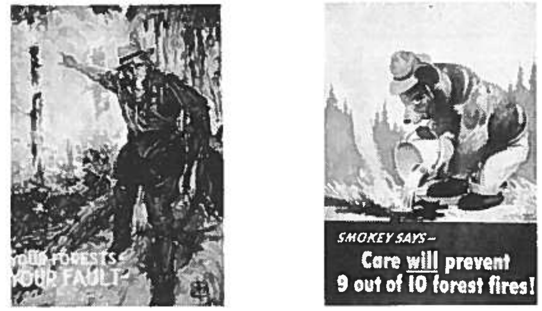

Figure 3—Early fire prevention posters showing the urgency of suppressing wildfires.

firefighting ethic that prevails yet today (fig. 3) (Pyne 2001).

Wildfires continue to be aggressively extinguished with smoke-jumpers, hot-shot crews, retardant bombers, and sophisticated firefighting organizations. Even with this aggressive approach, wildfires continue to burn throughout the West, and the total area burned in the United States decreased until the 1960s when the trend reversed with the number of acres burned each year increasing (Agee 1993). This trend was exemplified by the fires that burned in and around Yellowstone Park in 1988 and once again brought under scrutiny the wildfire policies in the United States (fig. 4) (Carey and Carey 1989). What appears to be different about the recent fires is the number of ignitions that contributed to burning large areas. More than 1,700 fire starts were responsible for burning the 3.1 million acres of the Northern Rocky Mountains in 1910, and 78 starts burned more than 350,000 acres in the Bitterroot Valley in western Montana in July 2000 (fig. 5) (USDA 1978, 2000). Contrast these fire events to the Rodeo-Chediski Fire where only two fire starts burned

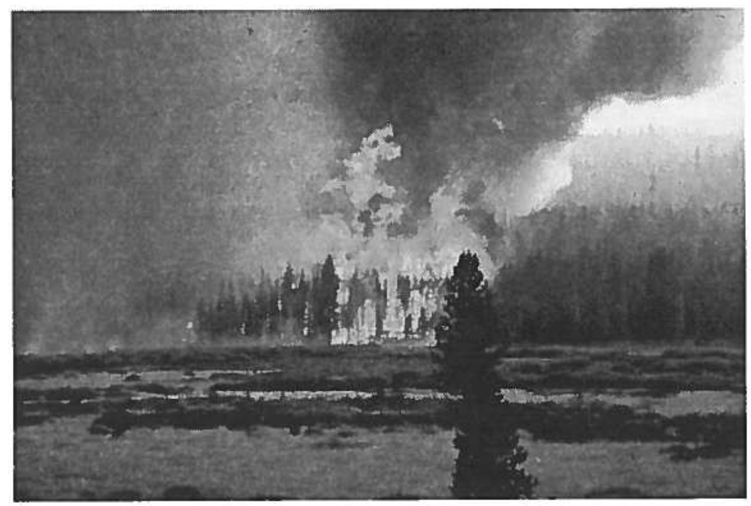

Figure 4—Photograph showing one of the many wildfires that burned in Yellowstone Park during the summer of 1988.

Figure 5—Seventy-eight wildfires burned in the Bitterroot Valley of western Montana during the summer of 2000. (Photo by Karen Brokus)

more than 450,000 acres in 2002 in Arizona. Similarly, on June 8, 2002, one start along the Colorado Front Range of the Rocky Mountains led to the Hayman Fire burning more than 138,000 acres in 20 days (fig. 6).

The weather systems along the Colorado Front Range beginning in 1998 tended to bring below-normal precipitation and unseasonably dry air masses. These conditions occurred approximately the same time as the phenomenon known as La Nina began forming in the eastern Pacific Ocean. The winter of 2001 and 2002 saw a marked worsening of drought conditions. The predominantly ponderosa pine and Douglas-fir forests throughout the region became drier with each passing season, and by the spring

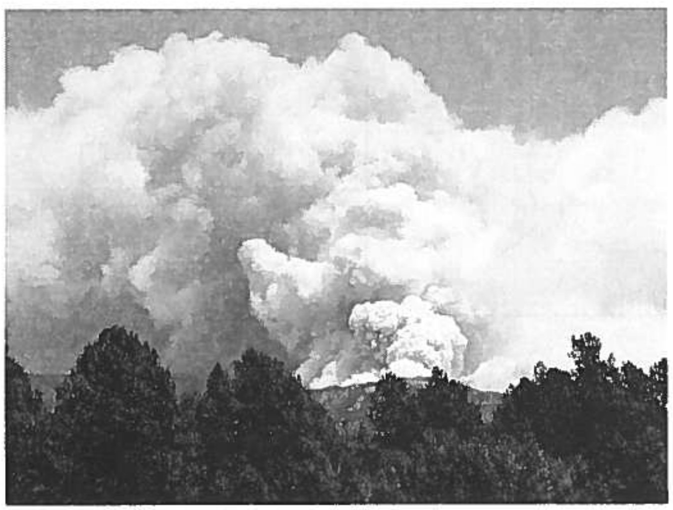

Figure 6—The Hayman Fire was ignited on afternoon of June 8, 2002, and by the morning of June 9 it was uncontrollable.

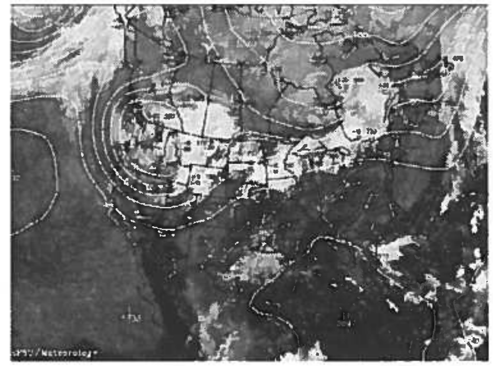

Figure 7—On June 8, 2002, the winds in Colorado, created by a low pressure system centered in eastern Washington, were consistently exceeding 15 mph and gusting to over 30 mph.

of 2002 the fuel moisture conditions were among the driest seen in at least the past 30 years. The moisture contents of the large dead logs and stems along the Front Range were extremely low: most less than 10 percent and some less than 5 percent moisture content.

During the first week of June 2002 a weak weather system passed through forests west of Denver and Colorado Springs, Colorado, dropping some precipitation, but this rain had virtually no effect on the parched surface and dormant live fuels. On Saturday, June 8 the air mass over Colorado was extremely dry and an upper level low pressure system centered over eastern Washington brought winds exceeding 15 mph all day with gusts exceeding 30 mph (fig. 7). The counter clockwise winds circulating around this low aligned perfectly with the topography of the South Platte River corridor (fig. 8). At approximately 4:55 p.m. just south of Tarryall Creek and Highway 77 near Tappan Mountain, the Hayman Fire was reported (fig. 9). An aggressive initial attack response consisted of air tankers, helicopters, engines, and ground crews, but they were unable to contain the fire (fig. 10). Within a few hours torching trees and prolific spotting advanced the fire to the northeast, allowing it to burn several hundred acres.

Saturday night remained warm and dry (60 °F and 22 percent humidity at Lake George near fire start) and by 8:00 a.m. on June 9, the fire was estimated

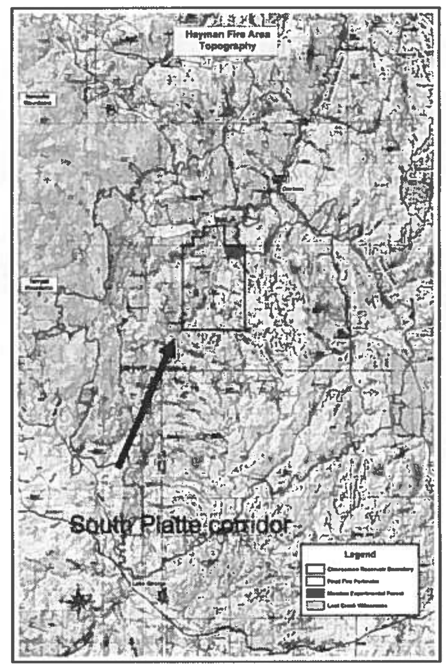

Figure 8—The southwest to northeast orientation of the South Platte River corridor aligned perfectly with the winds blowing from the southwest.

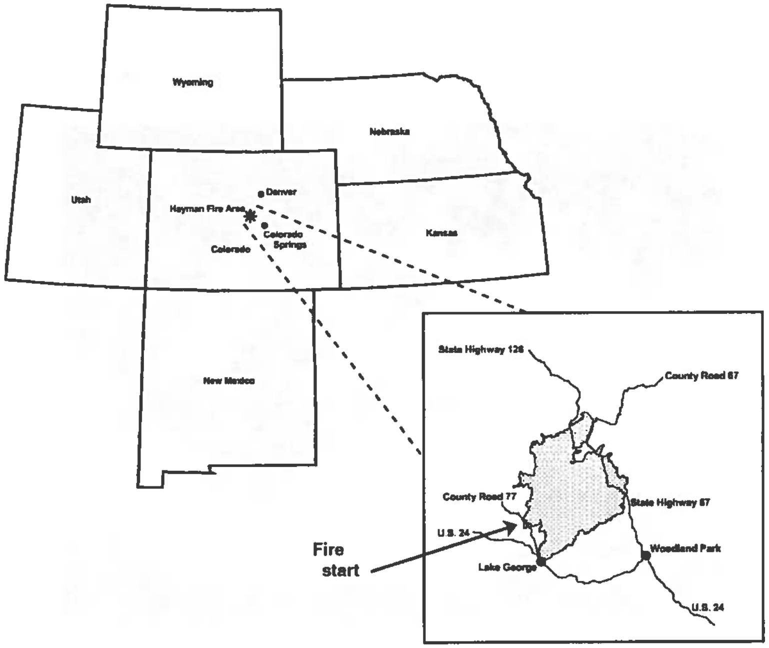

Figure 9—The Hayman Fire started just south of Tarryall Creek and County Highway 77 near Tappan Mountain on the Front Range of the Rocky Mountains between Denver and Colorado Springs, CO.

Figure 10—An aggressive initial attack of the fire consisting of ground crews, fire engines, helicopters, and air tankers could not control the fire. (Photo by Karen Wattenmaker)

at 1,000 to 1,200 acres in size. Downwind from the ignition location for at least 10 miles fuels were generally continuous with little variation in both structure and composition. Surface fuels generally consisted of ponderosa pine duff and needle litter, short grasses, and occasional shrub patches. Low crowns of the ponderosa pine, Douglas-fir, and blue spruce facilitated the transition of the fire from the surface to burning tree crowns (fig. 11).

As the day progressed, the southwest winds gusted to 51 mph and the relative humidity hovered around 5 to 8 percent (fig. 12) enhancing the

Figure 11—The fuels down wind from the ignition point were continuous, consisting of trees with low crowns, shrubs, and a deep layer of needles on the forest floor.

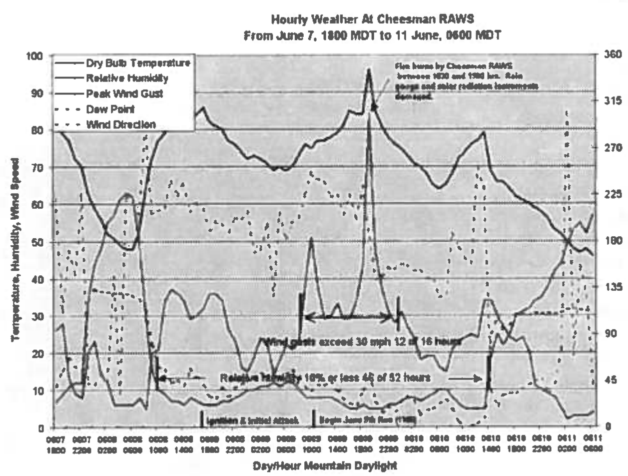

Figure 12—During the first days of the fire the winds were gusty, and the relative humidity of the air was dry, hovering below 10 percent.

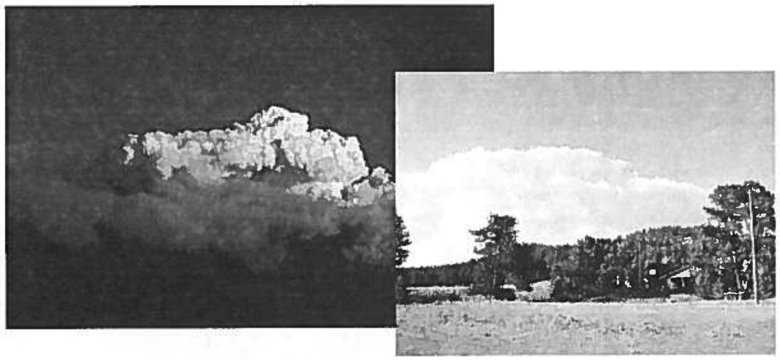

Figure 13—Photographs on June 9 showing pyrocumulus clouds developing to 21,000 feet over the fire.

spread of the fire to the northeast. The combination of fuels, weather, and topography positioned the fire for a major run lasting the entire day and burning 60,000 acres along the South Platte River corridor for 16 to 19 miles. Evacuations were performed in front of the fire, but no suppression actions were possible forward (east) of Highway 24 (fig. 9). The fire burned with extreme intensity with long crown fire runs and long-range spotting (1 mile or more). Fire spread rates averaged more than 2 mph and pryocumulus clouds developed to an estimated 21,000 feet (fig. 13).

On the afternoon of June 10, the high winds decreased and the relative humidity increased, moderating the weather (fig. 12) and persisting until the afternoon of June 17. During this period, the fire advanced mostly to the south and several miles to the east (fig. 14). The high winds and low humidity returned on June 17 and 18, increasing the fire intensity across the entire east flank of the fire, driven by west to northwest winds

Figure 14—From June 11 through the afternoon of June 17 the weather moderated as did the fire intensity.

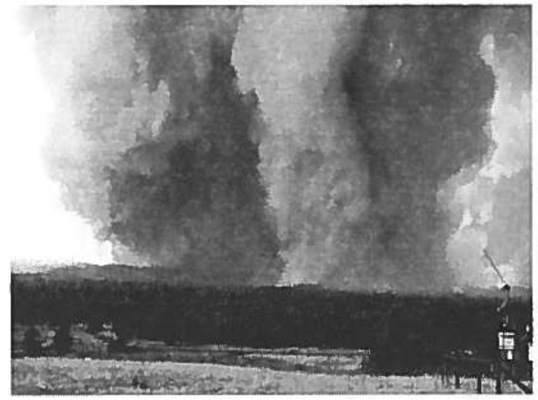

Figure 15—On June 17 and 18 gusty winds and low humidity returned, facilitating intense fire behavior as the fire advanced to the east.

(fig. 15). The fire advanced to the east 4 to 6 miles on June 18, crossing Highway 67 and encircling more than 137,000 acres. Because moist monsoon weather arrived, the fire burned small amounts of additional acres after June 18. By June 28, the Hayman Fire impacted more than 138,000 acres of the Colorado Front Range (fig. 16).

The mountains and forests of the Front Range between Denver and Colorado Springs are critical for supplying water to communities and cities, prized for their scenery, provide numerous recreational opportunities, are home to many fishes and animals, and are the setting for many homes, businesses, and communities. Because of the setting, the Hayman Fire attracted intense local, regional, and national interest. Before the flames had died, Congressman Mark Udall of Colorado on June 26, 2002,

Date	Acres
June 8	290
June 9	60,878
June 10	86,725
June 11	99,689
June 12	104,638
June 13	102,897
June 14	100,186
June 15	104,415
June 16	114,674
June 17	140856
June 18	137,762
...	
June 28	138,114

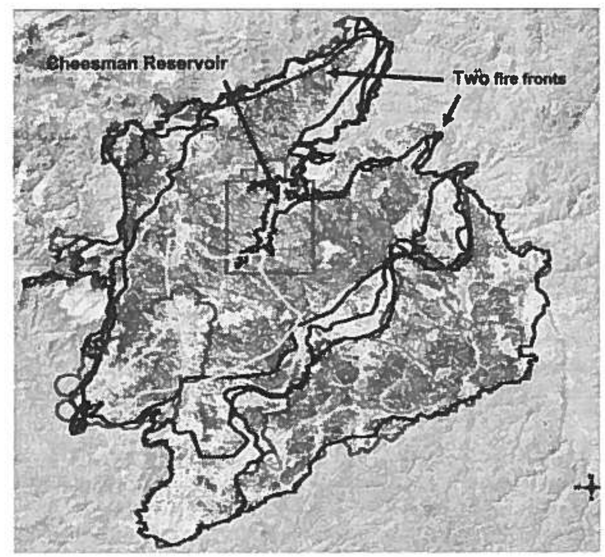

Figure 16—By June 28 the Hayman Fire had impacted over 138,000 acres of the Front Range.

indicated that it would "be instructive to take a close look at the behavior of the fire, examine the factors that led to its intensity, and see if the way it behaved when it encountered previously affected or treated areas can be instructive in designing future risk-reduction projects." He went on to suggest that the Chief of the Forest Service establish a Hayman Fire Review Panel. Its purpose would be to focus on the future rather than attempt to assign blame for past events.

Congressman Udall raised several issues ranging in scope from how the fire behaved to how the fire impacted the soil and water resources of the Front Range. Using Congressman Udall's suggestion as a basis, on July 22, 2002, the USDA Forest Service Rocky Mountain Research Station in cooperation with USDA Forest Service Rocky Mountain Region, and the State of Colorado Forest Service assembled the Hayman Fire Case Study Team. This Team of Federal, State, and local experts from throughout the United States came together and developed an analysis to address the Congressman's issues. Analysis questions were divided among subteams addressing fire behavior, home destruction, social and economic impacts, fire rehabilitation, and ecological effects. Using the Congressman's issues each team developed a set of analysis questions and study direction. Techniques used by the subteams included interviews, analysis of existing data, expert opinion, Hayman Fire reports, and other available information. In November 2002 the Team presented its interim findings to the Congressman, public, forest managers, nongovernmental organizations, and the scientific community. These groups and individuals provided critical input to the findings, and in February 2003 the subteams began assembling their final reports incorporating these reviews and criticisms. The reports underwent scientific peer review before the final drafts were prepared. The following highlights each subteam's findings addressing the analysis questions.

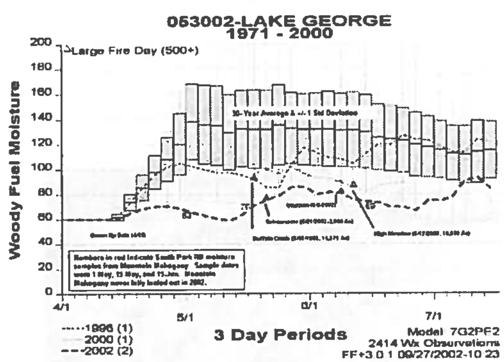

Figure 17—The moisture contents of the woody fuels within the Hayman Fire area in 2002 were much drier than those occurring over the previous 30 years.

Fire Behavior

Team Leader Mark Finney, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

This team used existing and new data on fire climatology and meteorology, fire behavior, fuel treatments, road density, fire suppression activities, and fire emissions. Selected findings of the team:

- The potential for extreme fire behavior was predisposed by drought. Below normal precipitation the past several years and the acute drought in 2002 brought about excedptionally low moisture contents of live foliage, duff, and dead fuels of all size classes (fig. 17).

- The Hayman Fire began and ended with extreme weather episodes lasting about 2 days each (June 8 and 9, and June 17 and 18). More moderate weather occurred during the intervening 6 days. Extreme weather conditions consisted of high winds (20 to 50 mph) and low humidity (5 percent). Widespread crown fire and long-range spotting lead to rapid growth and ultimately the large size of the fire. Abatement of winds and higher humidity during less extreme weather moderated fire behavior and effects, even with the abnormally low fuel moisture contents (fig. 12).
- Different wind directions associated with the two extreme weather episodes increased the size of the fire. The east flank of the fire that developed under southwest winds of June 8 and 9 became a heading fire on June 17 and 18 when winds shifted from the northwest and west (fig. 15).
- Continuous surface and crown fuel structure, both horizontally and vertically, in many ponderosa pine and Douglas-fir stands rendered them susceptible to torching, crown fire, and ignition by embers, even under moderate weather conditions (fig. 11).
- Continuous fuels across the landscape surrounding the South Platte River drainage afforded only limited opportunity for significant disruption of growth of the fire or for improved suppression. The few large areas on the Hayman landscape that recently experienced wildfires or management activities (Schoonover wildfire 2002, Polhemus prescribed burn 2001, Big Turkey wildfire 1998) produced significant but isolated effects on fire growth.
- Orientation of the South Platte River drainage was aligned with the strong southwest winds on June 8 and 9 and likely enhanced the direction and rapid spread of the fire on those dates (fig. 8).
- The presence of Cheesman Reservoir and the adjacency of the recent Schoonover wildfire (May 2002) in the center of the spread path created and maintained the characteristic forked shape of the Hayman Fire, which had formed two distinct heads by the afternoon of June 9 (fig. 16).
- The Hayman Fire encountered most of the fuel treatments, prescribed burns, and previous wildfires within the perimeter on June 9 when the weather was extreme. Continuous crown fire and long-range spotting dominated the burning of approximately 60,000 acres that day from late morning through late evening. These extreme conditions and fire behaviors permitted intense surface fire through treated areas, leaving them with high levels of overstory crown damage. Fuel breaks and treatments were breached by massive spotting and intense surface fires.
- The fire was perhaps 20,000 acres when it encountered its first fuel treatments toward the southeastern side of Cheesman Reservoir toward mid-afternoon on June 9. At that time it was in the middle of the burning period and had developed a large convection column (fig. 13).
- Weather conditions were relatively moderate beginning on June 10 through 16 as the fire burned through Turkey Rx1990, Rx1995, Rx1987, and the 1998 Big Turkey wildfire. Fire behavior these days was predominated by surface fire, although torching and some crown fire occurred in some drainages and hillslopes (fig. 14).

- Extreme weather returned on June 17 and 18. Crown fire and long-range spotting was occurring just before the fire burned into fuel treatments in the Manitou Experimental Forest and the North Divide prescribed burns (fig. 15). Observations and weather records suggest a wind shift occurred just before fire entered Manitou.
- Extreme environmental conditions (winds, weather, and fuel moisture) and the large size of the Hayman Fire that developed on June 9 overwhelmed most fuel treatment effects in areas burned by the heading fire that day. This included almost all treatment methods including prescribed burning and thinning.
- Several exceptions to this included the Polhemus prescribed burn (2001), the Schoonover wildfire (2002), and the Platte Springs wildfire (2002) that occurred less than 1 year earlier. These areas did actually appear to stop the fire locally, illustrating that removal of surface fuels alone (irrespective of thinning or changes to canopy fuels) can dramatically alter fire behavior within 1 year of treatment. The potential for prescribed fire to mitigate wildfire behavior will undoubtedly decrease over time. Thus, the recent occurrence of fuel modification in these areas suggests caution in trying to generalize about fuel treatment performance over many years. Fuel treatments are expected to change fire behavior but not necessarily stop fires (fig. 18).

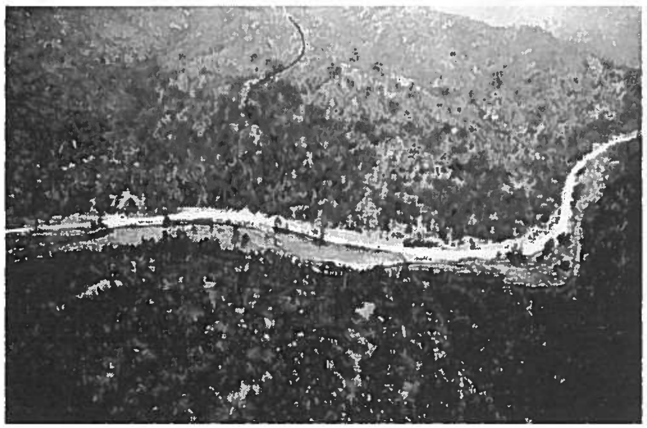

Figure 18—The Polhemus prescribed fire (fall 2001) altered the behavior of the Hayman Fire. Note the boundary between the Polhemus prescribed burn unit and the Hayman Fire (moving from the foreground away from the camera). (Photo by Karen Wattenmaker)

- Fire behavior was modified but not stopped by stand thinning operations conducted at Manitou Experimental Forest. The operations apparently moderated fire behavior and effects during extreme weather on June 18 (fig. 19). A fortuitous shift in winds also contributed to the changes in fire behavior at Manitou. The fire burned rapidly through areas of the Wildcat wildfire (1963) and the Northrup prescribed burn (1992) south of Cheesman Reservoir, but the open forest structure of these areas probably increased the survival of trees and stands within them.
- Under more moderate wind and humidity conditions (June 10 through 16), recent prescribed burns appeared to have lower fire severity than older burns. This is consistent with trends in fuel accretion and changes in forest fuels over time. Examples include the sequence of Turkey (Rx1987, Rx1990, Rx1995) prescribed burns.

Figure 19—A low intensity surface fire minimally scorched even the smallest trees in a ponderosa pine stand that had been thinned.

- Cutting treatments where activity fuels were not removed experienced high surface fire intensities but were less likely to support crown fire. For example, residual trees in the Sheepnose timber sale (2001) were scorched and probably killed, but their foliage was generally not consumed by crown fire. When these needles fall they mulch the forest floor reducing soil erosion (fig. 20). However, the Goose Creek timber sale was followed by prescribed fire but made little difference to severity on June 19 (fig. 21).
- Several landscape effects of treatment units and previous wildfires were important in changing the progress of the fire. These include the Polhemus prescribed burn (2001), which stopped the forward progress of the eastern head burning as a crown fire under extreme weather conditions (fig. 20), the Big Turkey wildfire (1998) and adjacent prescribed fires (Rx1990, Rx1995), which prevented initiation of crown fire along a 2 mile segment of the perimeter when extreme weather returned on June 17 (fig. 22), and the Schoonover Wildfire (May 2002),

Figure 20—The Sheepnose timber sale where the surface fuels consisting of logging slash were not removed prior to the Hayman Fire. The area burned as an intense surface fire on June 9 rather than a crown fire because of the stand structure created by the treatment.

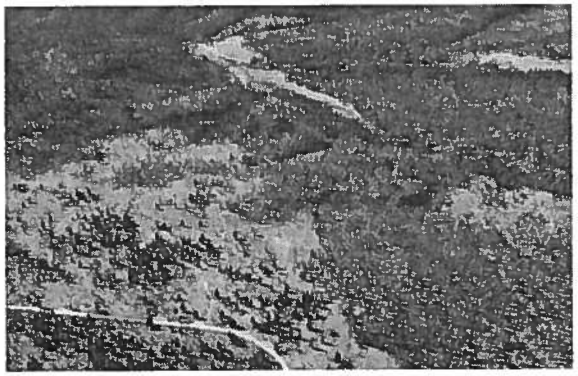

Figure 21—The Goose Creek timber sale area in the foreground (1986 through 1993) in which the logging slash was piled and burned in 1993 through 1995. Even with these fuel treatments, adequate surface fuel was available for a high intensity surface fire to occur on June 9, 2002.

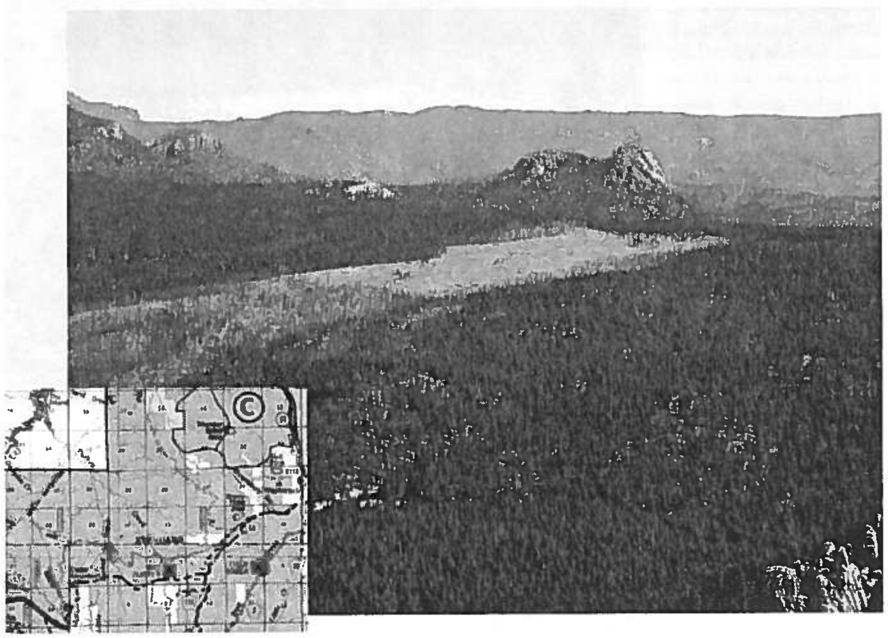

Figure 22—Oblique view of area burned by the Big Turkey wildfire (1998, oriented approximately along an east-west axis) looking northeast. Area in the foreground was inside the prescribed fire unit Turkey 1990. This area was burned between June 10 and 13. (Photo by Rick Stratton)

which, together with Cheesman Reservoir, split the head of the Hayman Fire on June 9 (fig. 23) and prevented it from flanking toward the town of Deckers (fig. 24, 25).

- The size of the fuel treatment unit relative to the size of the wildfire was probably important to the impact on both progress and severity within the treatment unit. Large areas such as the Polhemus prescribed burn (approximately 8,000 acres) were more effective than small fuel breaks (Cheesman Ridge, 51 acres) in changing the fire progress. Under extreme conditions of June 9, spotting easily breached narrow treatments, and the rapid movement of the fire circumvented small units (fig. 26).
- No fuel treatments were encountered when the fire was small. The fire had time and space to develop a broad front and generate a large convection column before encountering most treatment units. Fuel treatments may have been more effective in changing fire behavior if they were encountered earlier in the progression of the Hayman Fire before mass ignition was possible.

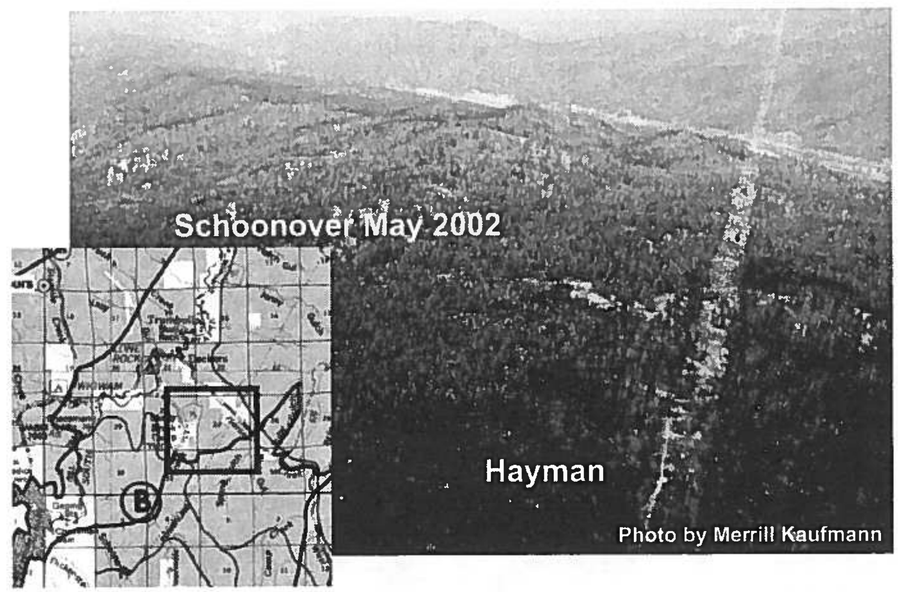

Figure 23—Green strip of underburned forest divides the Hayman Fire (left) and Schoonover wildfire (May 2002, right). The green strip was underburned by the Schoonover Fire 3 weeks before the Hayman Fire occurred and was not reburned by the Hayman Fire. Note the power line corridor in the picture and the inset map. (Photo by Merrill Kaufmann)

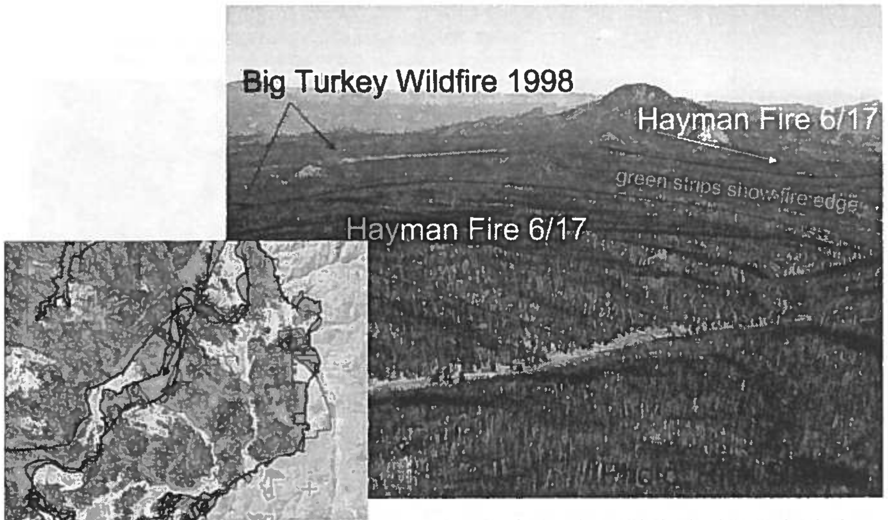

Figure 24—Oblique photograph showing the green bands of conifer forest at the locations where the two heads of the fire stopped after the burning period on June 17. Note that these heads originated from the north and south of the Big Turkey wildfire and adjacent prescribed burns (Rx1990, Rx1995). (Photo by Rick Stratton)

Figure 25—Satellite imagery showing burned area within the Hayman Fire on June 13. Several points are visible, (a) green strip separating the Schoonover wildfire on the north (May 2002) from the Hayman Fire on the south, (b) the green diagonal strip indicating the edge of the fire at the end of the June 9 burning period, and (c) the Big Turkey wildfire (1998).

Figure 26—Strong winds on June 8 and 9 flattened the smoke column, obscuring fire position and making fire progression estimation difficult. Photo is from June 9.

- Few fuel treatments had been performed recently, leaving most of the landscape within the final fire perimeter with no treatment or only older treatments. This is significant because the high degree of continuity in age and patch structure of fuels and vegetation facilitates fire growth that, in turn, limits the effectiveness of isolated treatment units.
- Road density varied considerably within the perimeter of the Hayman Fire but was not found to be associated with fire severity or bio-physical conditions related to fire behavior.
- At the time of initial attack, even the unusually strong compliment of firefighting resources (air and ground) was not sufficient to contain or stop the fire due to extreme weather conditions and fuel structures that facilitated crown fire and spotting (fig. 10).
- On the days of extreme fire growth (June 8 and 9, and June 17 and 18), burning conditions and weather dictated an indirect attack strategy with efforts focused on evacuation, structure protection where safely allowable, and direct methods on the heel and flanks of the fire.
- In the Lost Creek Wilderness little active suppression took place. Efforts were primarily directed at aerial observation, patrolling, and location and evacuation of hikers.
- Suppression efforts had little benefit from fuel modifications within the Hayman Fire. Exceptions include the Polhemus prescribed fire (2001), two previous wildfires (Schoonover 2002 and Big Turkey 1998), and thinning operations at Manitou Experimental Forest. One of the only sections of fireline indicated as controlled through June 16 (fig. 18) was in the Polhemus burn.
- On active burning days direct line was often not held and crews retreated to safety zones until fire conditions moderated, then returned to mop up around structures or defend structures where safely obtainable (fig. 27).
- On days with moderate weather and fire growth, the lines were defendable and structure protection was successful. For example, on June 12 structures in the Sportsman Paradise as well as in the Cedar Mountain, Turkey Creek, and along Turkey Creek were defendable even when fire behavior picked up in the afternoon hours.

Figure 27—A fire crew protecting a structure when the weather conditions allowed. (Photo by Karen Wattenmaker)

- Indirect tactics were used when fire behavior dictated for safety reasons and when access and rough steep terrain came into play. At times, burnout operations did not take place due to unfavorable weather conditions, were not completed due to changing weather conditions, or interrupted during operational periods because work-rest ratio guidelines would have been exceeded.
- Nightshifts were used, but only on focused areas, usually around subdivisions. Night operations primarily focused on patrolling of subdivisions where burnout operations had taken place during the day, structure protection in areas that had recently experienced fire activity, patrolling of divisions, and improving and extending anchor points (fig. 28).
- After overall weather moderated with arrival of monsoon conditions after June 20, construction of and holding of direct firelines was successful (fig. 29).

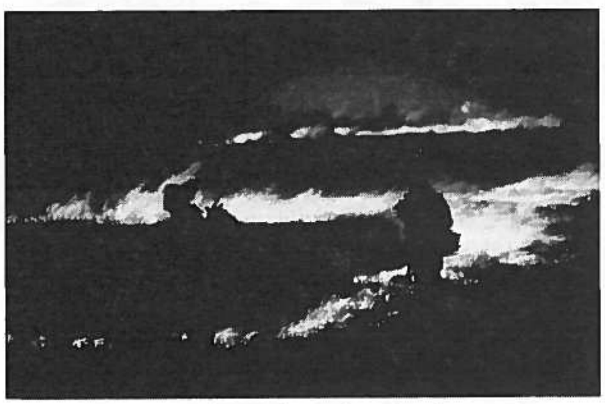

Figure 28—Night-time operations burning fuels within the fire line that were not consumed. (Photo by Karen Wattenmaker)

- The Hayman Fire was a significant source of atmospheric carbon monoxide (CO) and fine particulates (less than 2.5 μm). For Colorado, the CO emitted by the Hayman Fire was at least five times the annual (1999) amount produced by industry, and the fine particulate emitted by the Hayman Fire was about twice that produced annually by Colorado industries (fig. 30).

Figure 29—When the weather moderated, direct fireline construction was possible and firelines held. (Photo by Karen Wattenmaker)

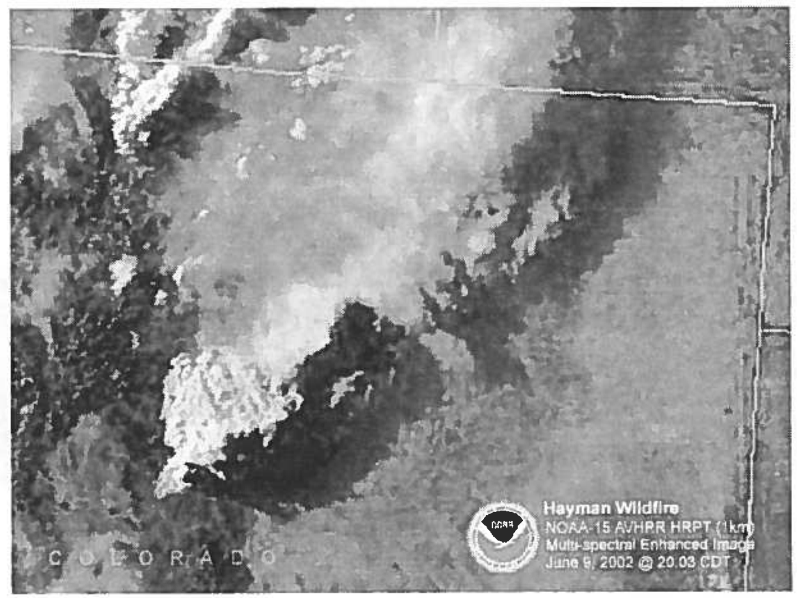

Figure 30—Satellite image of Hayman Fire on June 9 shows the convection column and smoke plume extending across Denver into Wyoming carrying carbon monoxide and fine particulates.

Fire Ecology and Fire Effects

Team Leader Bill Romme, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado

The ecology and fire effects team used existing data collected in and around the Hayman area, limited observations by team members within the burned area, and expert opinion. Fire ecology, terrestrial plant ecology, aquatic ecology, soil science, wildlife ecology, and geospatial sciences were included in the information they gathered in 2002 and 2003. This information was supplemented with information from the fields of fire and ecosystem management. Selected findings of the team:

- We have a high degree of confidence in many of our interpretations, but some are offered as tentative hypotheses rather than firm conclusions because of limited prefire research.
- Reconstructions of fire history and forest dynamics in the Cheesman landscape, located near the center of the Hayman burn, reveal (1) an average fire interval of about 50 years during the period 1300 through 1880, but no major fires between 1880 and 2002; (2) a mix of nonlethal surface fire and lethal, stand-replacing fire in the historic burns; and (3) a striking increase in forest density from 1900 to 2002.
- The extent of high-severity burn in 2002 within the Cheesman landscape was unprecedented in the past 700 years, in part because of the dense forest conditions that had developed during the 20th century and in part because of the extreme fire weather conditions that existed in 2002 (fig. 31).

Figure 31—The extent of the high severity burn in the Hayman Fire was unprecedented as exemplified by the large expanses of trees totally blackened.

Figure 32—In many areas within the Hayman Fire area, dense forest conditions existed with tree crowns extending to the forest floor. These conditions facilitated the transition of fire from the surface to the tree crowns.

- Although the extent of high fire severity in the Cheesman landscape was unprecedented, fires of comparable size and severity have occurred elsewhere in the Front Range during the last several centuries (for example, in 1851), especially in high-elevation forests (spruce, fir, and lodgepole pine) and possibly also in ponderosa pine forests. Infrequent but large, severe fires are a normal component of many forests in Colorado and are not an artifact of 20th century fire suppression in all forests.
- In the Colorado Front Range as a whole, 20th-century fire suppression probably has altered fuel conditions and fire regimes most significantly in low-elevation ponderosa pine forests where fires were relatively frequent prior to the late 19th century. In contrast, impacts of fire suppression probably are minimal in high-elevation forests of spruce, fir, and lodgepole pine, where fires have never been frequent but where high-severity fires have always been the norm. Within the middle forest zone of ponderosa pine and Douglas-fir, the extent to which fire suppression has altered forest structure and fire regimes is uncertain, and probably varies from place to place (fig. 32). Additional research is needed to clarify historical fire regimes in mid-elevation forests of the Colorado Front Range.
- Areas of high severity burn are likely to have the greatest alterations in soil characteristics, including loss of surface soil organic matter and fire-induced synthetic water repellency. Areas where organic matter was entirely burned off may not return to the prefire state for decades or centuries, but water repellent soil layers will be more ephemeral, persisting for 2 to 6 years (fig. 33).
- Reduced ground cover in places of high fire severity will likely result in decreased infiltration of water, increased surface runoff and peak flows, and the formation of pedestals, rills, and gullies. Erosion rates should substantially decline by the third summer after burning, and erosion from winter storms is expected to be minimal.

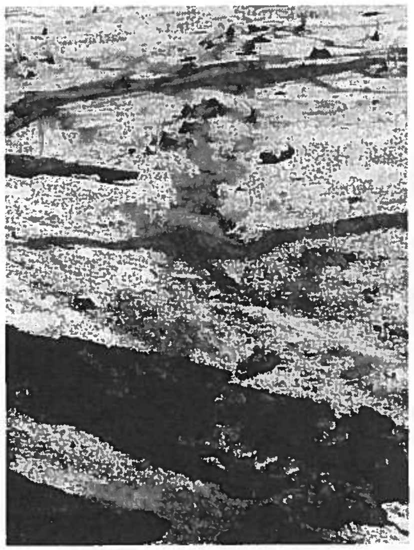

Figure 33—In addition to burning the vegetation of the area, the Hayman Fire in many places burned organic materials in and on the soil surface, decreasing productivity and creating water impermeable layers. (Photo by Theresa Jain)

- The aquatic ecosystems of the South Platte River within the Hayman Fire area represent a highly altered landscape that has been influenced by a variety of activities including mining, vegetation management, road building, urbanization, recreation, and water development.
- The recovery of the hillslope and riparian vegetation will influence how quickly the aquatic environments recover. Clearly, areas that were less severely burned will likely recover to prefire conditions most rapidly. Recovery of aquatic ecosystems within severely burned watersheds will be most dependent on riparian recovery, the juxtaposition to high quality habitats that can provide sources for re-colonization, and the mitigation of additional chronic disturbances.
- Rehabilitation of the aggrading perennial streams downstream from the fire will be difficult and costly because of the large volume of sediment in the system and poor access in many areas. Efforts to accelerate the recovery of the hillslopes will help by reducing the future inputs of sediment, but so much sediment has already been mobilized, or is poised to move into the downstream areas, that relatively little can be done to stop the problem. Hence large amounts of sediment will continue to be delivered into Cheesman Reservoir and the South Platte River, reducing reservoir storage capacity and potentially affecting fish and macroinvertebrate habitat (fig. 34). Over a longer period, however, the trend will likely be toward recovery of aquatic ecosystems if other kinds of chronic disturbances can be minimized.

Figure 34—The greatest risk to the soil and water resource following the Hayman Fire is erosion and sediment delivery to the streams and reservoirs.

- Because the ecosystems that burned in 2002 have a long history of fire, the native species and populations in this area generally have mechanisms for enduring fire or becoming reestablished after fire. Therefore, much or even most of the terrestrial vegetation is likely to recover normally without intervention, and in some areas our well-intentioned rehabilitation efforts actually could interfere with natural recovery processes.
- Where the vegetation is dominated by sprouting species (for example, aspen, cottonwood, many shrub species, many grasses, and other herbaceous species), a rapid return to prefire conditions is generally expected (fig. 35). We also expect a rapid return to prefire conditions in areas dominated by nonsprouting species (for example, ponderosa pine and Douglas-fir forests) wherever the fire burned at low severity and did not kill most of the forest canopy.
- Vegetation that is different from prefire conditions, but within the historical range of variability, is likely to develop in ponderosa pine and Douglas-fir forests where the fire burned with moderate severity, and also in small patches of high-severity burn. We anticipate that a new cohort of ponderosa pine seedlings will become established in these areas over the next several years.
- Development of vegetation that is different from prefire conditions and also is dissimilar to or at extremes of the historical range of variability for this ecosystem is expected in ponderosa pine and Douglas-fir forests within large patches of high-severity burn because of high local seed mortality coupled with long distances to seed sources outside the burned area. Natural reforestation of these areas may require many decades (fig. 31).

Figure 35—Areas within the Hayman Fire responded rapidly by sprouting new vegetation within weeks of the fire.

- Development of vegetation that is outside historical range of variability for this ecosystem is expected wherever invasive, nonnative species become dominant. Invasion of burned areas by nonnative species is a serious threat throughout the Hayman burn because the invasive species may cause declines of native plant species and changes in fire regimes, nutrient cycling processes, and hydrology.
- Over the short term (next approximately 5 years), riparian areas are likely to be the most vulnerable to invasion by nonnative plant species. Rehabilitation activities may facilitate the invasion of nonnative species and may alter postfire dynamics of riparian ecosystems (fig. 36).

Figure 36—Mulch was aerially applied to reduce soil erosion. These activities have the potential to introduce nonnative species and alter natural vegetation development.

Over a longer term (approximately 50 to 100 years), without control measures, nonnative plant species would be expected to persist in riparian and drainage areas, open-canopy areas, and along disturbance corridors such as roads.

- The potential effects of the Hayman Fire on animal and plant species listed as threatened or sensitive species for the Pike National Forest are expected to vary based on the patterns of fire severity and rehabilitation implemented. In areas of mixed-severity burn, we expect that the fire will create habitat for several species such as woodpeckers, cause minimal negative impacts for most species in the short term, and may enhance habitat availability for many native species in the long term.
- Large patches of crown fire will also create habitat for several species of concern but likely will diminish habitat availability and quality in the short term for many species that prefer mature conifer forest (fig. 31). The long-term effects of the large patches of crown fire are more equivocal and will depend on postfire response of vegetation communities.
- Rehabilitation efforts (such as salvage logging, seeding, soil scarification) and hazard tree removal may remove or diminish critical structure (for example, snags, bare mineral soil) for wildlife that was created by fire.
- Concern remains for the threatened Pawnee Montane Skipper because of its restricted habitat and range. Further research is needed to determine how the skipper responds to burn-severity patterns and potential interactions with effects of the 2002 drought.

Home Destruction

Team Leader Jack Cohen, USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana

An onsite assessment of each home destroyed, documentation and photographs during the fire, postfire aerial reconnaissance, and meetings with Federal, County and private individuals were the main sources of information used in the analysis. Although the team specifically assessed the homes destroyed, surviving homes were also considered. Home sites were visited 3 months after the Hayman Fire when much of the specific evidence describing the nature of home destruction and survival was lost. Selected findings of the team:

- Discussions with fire personnel and residents indicate that most homes were not actively protected when the Hayman Fire burned in the residential areas.
- The Hayman Fire resulted in the destruction of 132 homes (that is, homes on permanent foundations, modular homes, and mobile homes—both primary and secondary). Within what is now the final perimeter of the Hayman Fire, 794 homes existed. Thus, 662 homes were not destroyed. The Hayman Fire resulted in about 17 percent destruction of the total homes within the fire area.
- The wildland fire intensity associated with the destroyed homes varied as much as the fire intensity associated with homes that survived. Figure 37 shows the range of wildland fire intensities associated with homes destroyed and a similar range with those that survived.

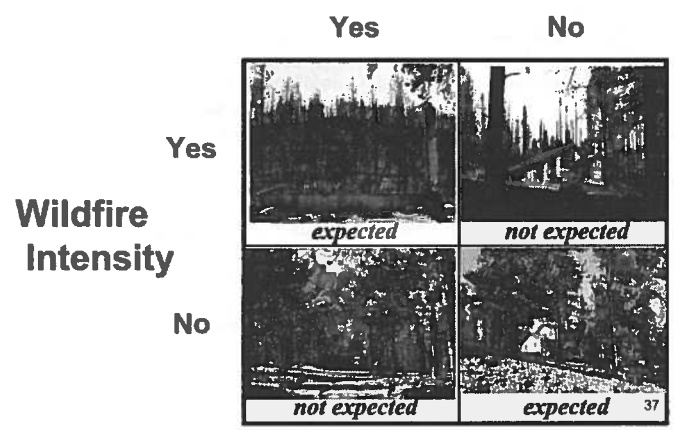

Figure 37—Expectations of home destruction as a result of wildfire. Home survival is expected if low fire intensities occur (lower right cell) and unexpected if the home is destroyed (lower left cell).

- Research has shown that the characteristics of the home in relation to its immediate surroundings (within 30 to 60 m) principally determine home ignitions during wildland fires. This area that includes the home characteristics and its immediate surroundings is called the "home ignition zone."
- The wildland fire intensity in the general area does not necessarily cause home destruction or survival. This distinguishes the difference between the exposures (flames and firebrands) produced by the surrounding wildland fire from the actual potential for home destruction (home ignition zone) given those exposures.
- The home ignition zone implies that the issue of home destruction can be considered in a home site-specific context rather than in the general context of the Hayman Fire.
- Seventy homes were destroyed in association with the occurrence of torching or crown fire, at least in a portion of the area surrounding a home (fig. 37 upper left case).
- Sixty-two homes were destroyed with no high intensity fire, torching, or crown fire, in the area surrounding the home (fig. 37 lower left case).
- Significant site disturbance in the time lapsed between the fire occurrence and our assessment prohibited any further analysis as to whether these high intensities could have directly caused home ignition.
- Significant patterns of destruction were not observed. This can likely be attributed to the wide variety of home types, designs, building materials, the scattering of destroyed homes, the significant number of surviving homes within the fire perimeter, and the wide range of fire intensities associated with home destruction.
- Teller and Park Counties did not have regulations related to reducing wildland-urban fire risks.
- In 1994 Douglas County adopted an amended version of NFPA 299 (1991) to the Uniform Building Code, making all developments after the adoption date subject to the regulations.
- Jefferson County required "defensible space" permits on the construction of habitable space greater than 400 ft^2 since 1996, but because of little new construction, few—if any—homes fell into this category in the Hayman Fire area.

Postfire Rehabilitation

Team Leader, Pete Robichaud, USDA Forest Service, Rocky Mountain Research Station, Moscow, Idaho

Selected findings of the team:

- Postfire rehabilitation efforts in the Hayman Fire area were designed to reduce the projected increases in peak-flows and soil erosion, and thereby minimize adverse downstream impacts on structures and aquatic ecosystems. The Burned Area Emergency Rehabilitation (BAER) team report included:
  1. Estimates of the potential magnitude of the increases in runoff and erosion.

  2. Assessment of the risks posed by the increases.
  3. Recommendations for mitigation treatments on National Forest lands.

- The recommended treatments were applied, with some modifications, as soon as fire suppression activities allowed. Land treatments included aerial and ground-based hydromulch (fig. 38), aerial dry mulch (fig. 36), and scarification with either aerial or ground-based seeding. Each of these treatments included a 70 percent barley/30 percent triticale seed mix. In addition to land treatments, road and site protection treatments were applied. By the end of 2003, approximately $18 million will be spent to provide emergency rehabilitation treatment on 45,500 acres (39 percent) of the 116,300 acres that burned.
- Most of the treatments recommended by the postfire rehabilitation team have not been systematically studied, making it difficult to predict expected effectiveness. More quantitative data on rehabilitation treatment effectiveness, based on climate, burn severity, soil types, and so forth, would enable BAER teams to refine their recommendations for each area.
- Previous experience indicates that rehabilitation treatments are least ineffective in high intensity rainstorms, particularly in the first 2 years after burning. Such storms are common in the Colorado Front Range, but in summer 2002 there were fewer such storms than average.
- Much of the postfire treatment effectiveness monitoring that has been done in the past has been anecdotal and qualitative. The application of such observations to current treatment decisions is difficult without specific information on site conditions, storm events, and measured responses (runoff, erosion rates, and so forth). Without quantitative measurements of runoff and erosion rates, downstream sedimentation rates are difficult to estimate, and predictive models cannot be rigorously tested and calibrated to different burned forest environments. To discern treatment effectiveness, it is also necessary to monitor comparable burned but untreated areas. Treated and control sites have been established in the Hayman Fire area, but these monitoring efforts need to be expanded and continued until recovery to near background conditions. The results of this monitoring need to be regularly and publicly reported.

Figure 38—Ground application of hydromulch aimed at reducing soil erosion.

- The efficient placement of rehabilitation treatments involves the use of predictive models to locate the areas of greatest risk and greatest potential for effectiveness. The development and adaptation of climate, runoff, and erosion models for use in burned forest environments are currently hindered by several knowledge gaps that include:
  1. Improved mapping of burn severity and better characterization of postfire soil water repellency (fig. 33).
  2. Improved prediction of runoff responses at different spatial scales from short-duration, high-intensity thunderstorms.
  3. Relative magnitudes and consequences of hillslope verses channel erosion.
  4. Sediment deposition and routing within drainages.

Social and Economic Issues

Team Leader Brian Kent, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado

The social and economic issues of the Hayman Fire were addressed by conducting four studies: (1) on economic and social effects of the fire; (2) prefire and postfire workshops with the Ridgewood Homeowners Association; (3) interviews with key informants in the Woodland Park area in August 2002, soon after the fire was suppressed; and (4) another set of interviews with Woodland Park area representatives of governmental and nonprofit organization members in February 2003, about 6 months after the fire was suppressed. Selected findings of the team:

- The effects a catastrophic wildfire such as the Hayman has on human social and economic systems are complex. Unlike many ecological effects of a wildfire, the geographic scale of influence for social/economic effects extends considerably beyond the area actually burned.
- Most likely no human alive during the Hayman Fire will live long enough to see the burned area recover to anything like it was prefire. Those who used this area have lost something and they will need to look elsewhere to replace it, and the local economies likely have lost the economic contributions those users made.
- The economic aspects of a large-scale fire occurring in proximity to human populations, such as the Hayman Fire, are difficult to measure and highly variable. Some aspects are straightforward and relatively easy to measure, such as the actual suppression expenditures or property losses. Assessing other aspects, such as the effect on a regional economy, or changes in recreation and tourism, are easily confounded by other factors, such as general economic downturns or a shift of economic activity from one location to another.
- While the Hayman Fire was not extraordinarily expensive on a cost per acre basis, the size of the fire made it one of the most expensive fires in the last several years. No fire in Colorado's history has cost as much to suppress (fig. 39). The $38 million spent by the Forest Service on the Hayman Fire was more than three times the average annual

Figure 39—The costs to suppress the Hayman Fire were not that excessive on a per acre basis, but because of its size the fire was the most expensive in Colorado history.

suppression expenditures (1992 to 2001) for all of USDA Forest Service Region 2 (Rocky Mountain Region). Adding expenditures by the State and the other Federal agencies, suppression expenditures totaled more than $42 million. In addition to the money spent fighting the fire, rehabilitation and restoration expenditures (already expended and planned) connected with the fire are expected to cost at least another $74 million.

- Additional expenditures related to the fire totaled almost $2 million. These expenditures included Federal Emergency Management Agency (FEMA) reimbursements, State of Colorado expenses, and disaster relief by the American Red Cross.
- The proximity of the fire to human populations led to a loss of 600 structures, including 132 residences (fig. 40). Real property losses were substantial, totaling $24 million, with a majority of the losses occurring in Teller County ($14 million) and Douglas County ($8 million) with total insured private property losses estimated at $38.7 million. Loans and grants from Small Business Administration and FEMA for uninsured losses totaled almost $4.9 million. Additionally, damage to transmission lines was estimated at $880,000.
- More difficult to measure are the effects on resource values (including tourism and recreation) and the regional economy. The fire closure order occurred during the busiest time of the tourist season (fig. 41). Concessionaires who manage the developed recreation sites within the affected Ranger Districts of the Pike-San Isabel National Forest reported a total decline in revenue in 2002 of $382,000 from 2001 levels.

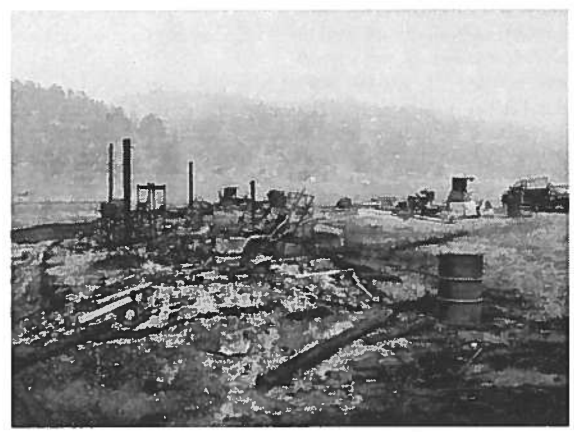

Figure 40—Many structures dotted the Hayman landscape, and 600 of them burned during the fire, resulting in real property losses of $24 million.

Figure 41—The Hayman Fire occurred at the peak of the tourist season, impacting many sectors of the travel economy from daily forest visitors to destination resorts.

- It is possible that recreation losses occurring within the vicinity of the Hayman Fire were offset by gains to other areas of Colorado.
- On the Pike-San Isabel National Forest, financial losses attributed to water storage decreases were estimated at $37 million, and the value of timber lost was estimated at $34 million.
- There was little evidence of a substantial economic decline in the Primary Impact Area—the four affected Counties during the months of the Hayman Fire. In some areas and sectors, the Hayman Fire most likely decreased economic activity. That more substantial effects were not detected is probably due to: (1) tourism-related sectors constitute a relatively small part of the economies in the Primary Impact Area and (2) the economies of the Primary Impact Area are large, complex, and able to withstand economic shocks.
- The Ridgewood Homeowner's Association (RHOA), located adjacent to the Manitou Experimental Forest on the eastern perimeter of the fire (fig. 8, 16), comprises residents that have had notable experience with wildfire, are quite knowledgeable on these issues, and yet are still motivated to learn more. These homeowners recognize the need for active management on the Forest and realize the potential dangers that wildfire poses. The homeowners most preferred the mechanical removal of hazardous fuels (even more since the Hayman Fire). Second, they prefer prescribed fire in combination with mechanical removal, and third, they are somewhat neutral on prescribed fire. Interestingly, this preference has remained constant from before to 6 months after the Hayman Fire.
- According to these residents (RHOA), the City and County fire departments are helpful and perceived as highly credible entities, while research reports and environmental organizations were not viewed as helpful or credible sources of help or information. The Colorado State Forest Service is only perceived as somewhat credible as an institution.

The USDA Forest Service, bordering many of these residents' land, is viewed as providing somewhat helpful information and as less credible than the USDI National Park Service, County and City fire departments, State Forest Service, and neighbors and friends. This could explain some of the trepidation associated with prescribed fire; the residents may view prescribed fire as something needed but not preferable since they know the Forest Service is the entity implementing the treatments. These sentiments for prescribed fire may also reflect the knowledge of the Forest Service employee who pled guilty to starting the Hayman Fire.

- The residents of the RHOA feel highly vulnerable to the effects of fire, are highly susceptible to the consequences of fire, and feel that there is a high probability (78 percent) that a wildfire will occur near their home in the near future. Yet the measures of perceived efficiency for both specific and general risk reduction actions only explain a few of the homeowners' mitigating actions. These residents feel that mitigating actions are, for the most part, effective, and they also believe strongly in their ability to carry them out. The question then remains as to why there are not more mitigating actions being implemented on homeowners' lands.
- The residents' (RHOA) strong feelings of vulnerability from wildfire risks are enhanced by inaction of their neighbors, thereby negating the effect of homeowner risk reduction actions. The residents not only believe that they are responsible for defending their property, but also that all neighbors, including homeowners, the Forest Service, and the RHOA, should be involved in mitigating these risks.
- These findings suggest that information on wildfire issues should be disseminated through City and County fire departments, which hold more credibility with homeowners. Education should focus on including the actions of the land management agencies and other community projects so that homeowners feel it is truly a community effort and that it is not something they are doing on their own.
- To gain support for prescribed fire as a treatment option, the Federal, State, and local governments need to educate residents about the benefits of prescribed fire, and perhaps even the benefits of prescribed fire over mechanical removal.
- Postfire experience points to the importance of identifying and establishing relationships with preexisting community assets and organizations early on in a wildfire incident. This can help incorporate local knowledge into firefighting and rehabilitation efforts and establish a recovery base that will continue once emergency Federal agency personnel and resources have left the community.
- Partnerships should be developed as early as possible during the fire by the incident command, and several interviewees thought that they should be developed by local Federal officials well before any fire. Such up front collaboration was seen as a good way to systematize actions, increase efficiency, and decrease potential contention between locals and Federal agencies by building trust.

- While trust has been shown to be important in all natural resource management matters, it is particularly important with wildfires where a crisis brings in powerful outsiders to work in a community for a limited but highly emotional period of time.
- Many evacuees expressed frustration with being forbidden to go back to their homes. There was little understanding of how thin law enforcement was stretched, and people were restricted from going back to houses not only just for safety reasons but also as the only manageable means of preventing burglaries in evacuated areas on a fire the size of Hayman (fig. 41).
- Informing the public prior to fire events about what is involved in firefighting and rehabilitation efforts, including limitations prior to a major event, should make public expectations more realistic
- The educational process should not be one way. Federal fire managers need to work to better understand the actual capabilities and limitations of volunteer fire departments.
- While agencies have developed effective means of coordinating policy and actions during a fire, similar efforts need to be made with rehabilitation work, particularly between the Forest Service and National Resource Conservation Service.
- Given the complexity and importance of rapidly developing effective solutions to minimize current and future wildfire damage, it is important to think out of the box as much as possible. Instead of relying on traditional and often engrained methods and approaches, the ability to be open to new and adaptive techniques and to meet locally identified needs will be critical.
- The mix of social and economic effects of a large fire such as the Hayman, especially when it occurs within the wildland urban interface, is both complex and far ranging.
- The Hayman Fire has taken on national significance by becoming an example of a consequence of what is wrong with current forest management policy. Consequently, the more we can learn from it, the more we can use the Hayman experience to inform future debates over both forest and wildfire management strategies.

Conclusions

The Hayman Fire was at the wrong place at the wrong time. The fires of 1910, and the resulting views of fire suppression, started the sequence of events that helped facilitate the Hayman Fire. In 2002 much of the Hayman area was rich in dry vegetation as a result of fire exclusion and the droughty conditions that prevailed in recent years. These dry and heavy fuel loadings were continuous along the South Platte River corridor on the Front Range of Colorado. These topographic and fuel conditions combined with a dry and windy weather system centered over eastern Washington to produce ideal burning conditions. The start of the Hayman Fire was timed and located perfectly to take advantage of these conditions, resulting in a wildfire run in 1 day of over 60,000 acres at a distance of 16 to 19 miles.

The Hayman Fire Case Study revealed much about wildfires and their interactions with both the social and natural environments. As the largest fire in Colorado history it had a profound impact both locally and nationally. We hope the findings of this study will inform both private and public decisions on the management of natural resources and how individuals, communities, and organizations can prepare for wildfire events. This study was part of a learning process that began in 1910 and continues today, to provide knowledge on the behavior, severity, and impact of wildfires.

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RMRS
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The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

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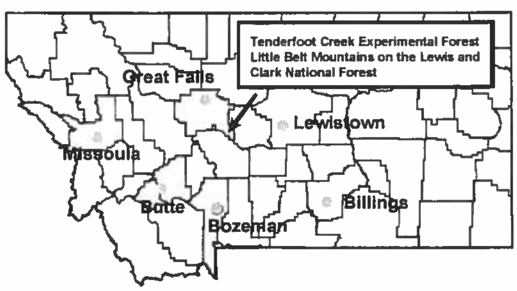
Fuel Reduction Treatments (harvesting and prescribed burning) in Lodgepole pine Stands on the Tenderfoot Creek Experimental Forest

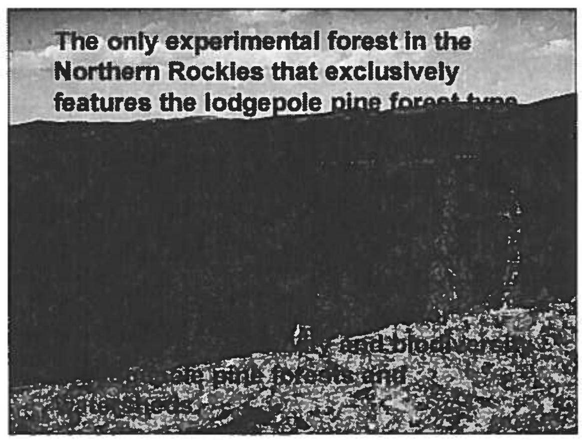
By
Ward McCaughey
USDA, Forest Service
Rocky Mountain Research Station

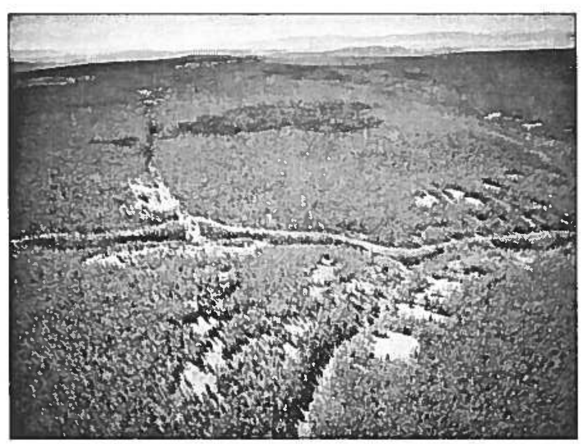
Experimental Forests

Dedicated to research in the ecology and management of a wide spectrum of ecosystems



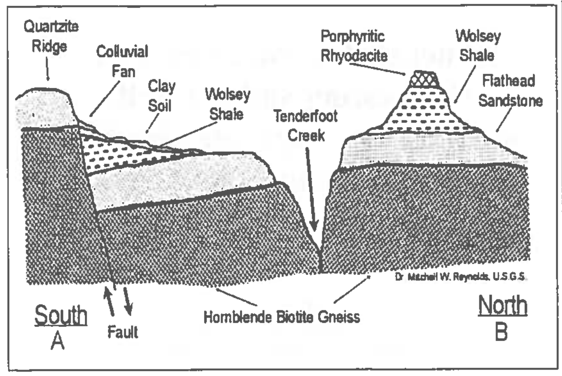
Average annual precipitation ranges from 30" at the lower elevation of 6300' to 35" at the highest elevation of 7600'. The majority of the precipitation comes as snow.



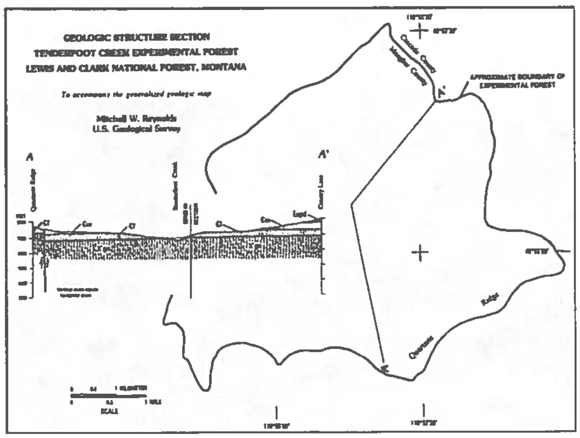


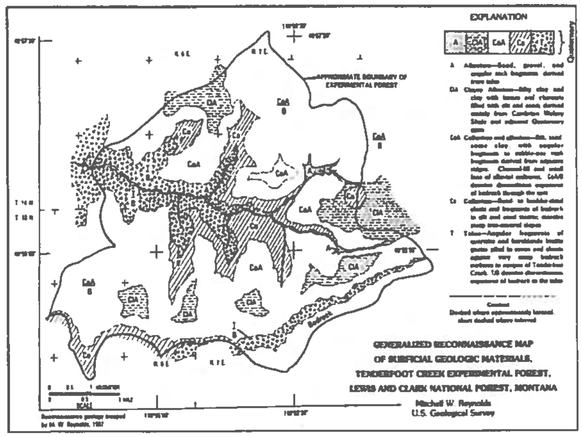
Geology

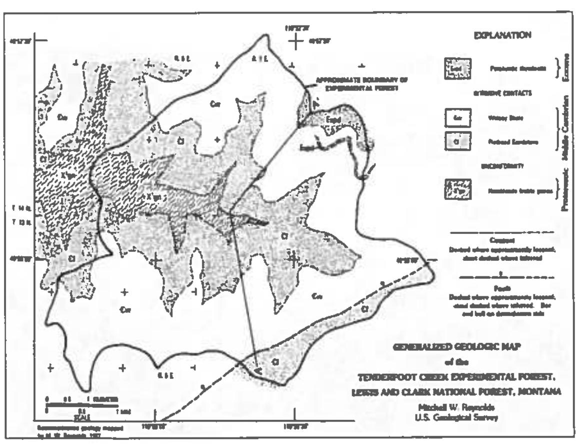
The Geology is characterized by igneous intrusive sills of quartz porphyry, Wolsey shales, Fathead quartzite, and granite gneiss. The northern part of the forest occupies the highest elevations and steepest upland topography and is underlain by igneous intrusive granitic rocks. The arched bedrock in the area was formed from metasediments of Cambrian Age consisting mainly of argillites and quartzites. Glaciation has influenced the landform, producing broad basins in which the streams are beginning to regain a water-carved dendritic pattern.



Geologic cross section of the Tenderfoot Creek Experimental Forest







Objectives of the Tenderfoot Research Project

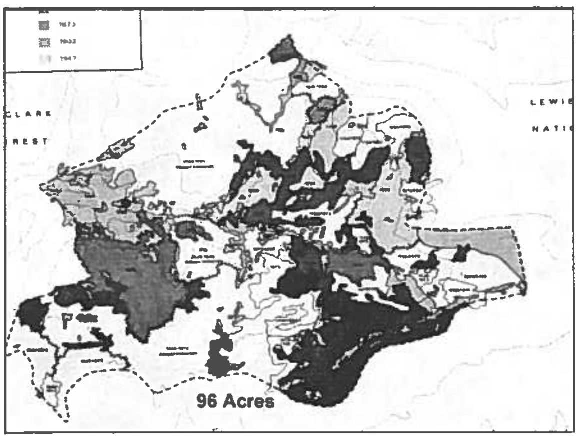
- **Evaluate and quantify the ecological and biological effects of alternative two-aged silvicultural treatments including prescribed burning in lodgepole pine forests.**
- **Develop linkages between vegetation management activities, hydrology, water quality, climate and wildlife.**

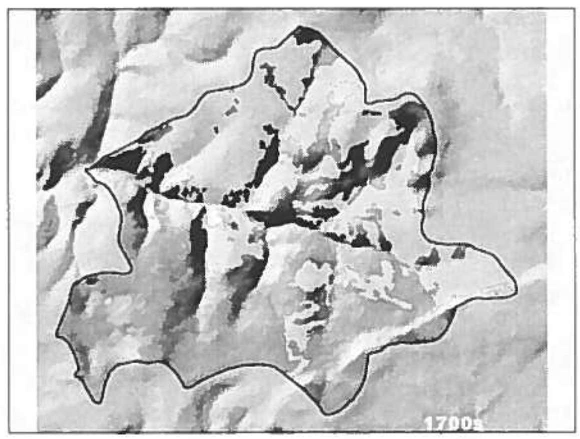
Fire History

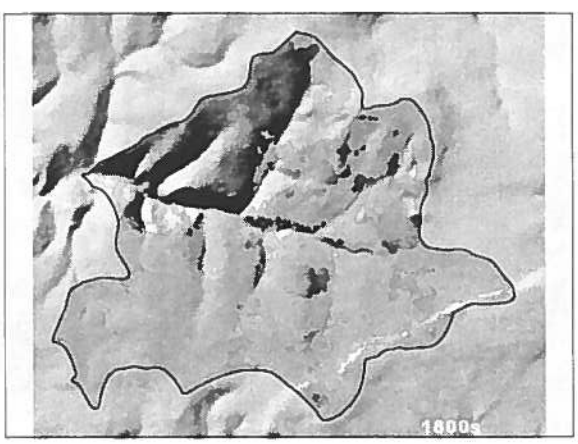
Fire Year	Acreage		Fire Year	Acreage	
1580	96		1882	147	
1676	79		1889	104	
1726	2737		1902	548	(86 %)
1765	1984	(52 %)	1921	35	
1831	134		1947	28	
1845	2604		1996	<1	(<01 %)
1873	4295		Total	12807	

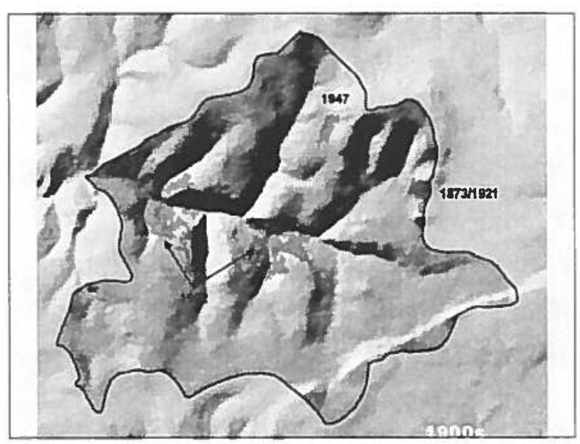
Fire History

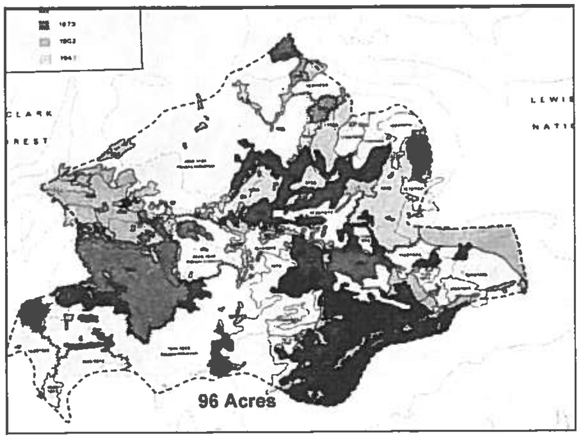
Cover type	Acreage	Percent of total forest
Nonforested	808	8.8
1-aged stands	3929	42.0 (46%)
2-aged stands	4488	49.2 (54%)
Total	9125	100





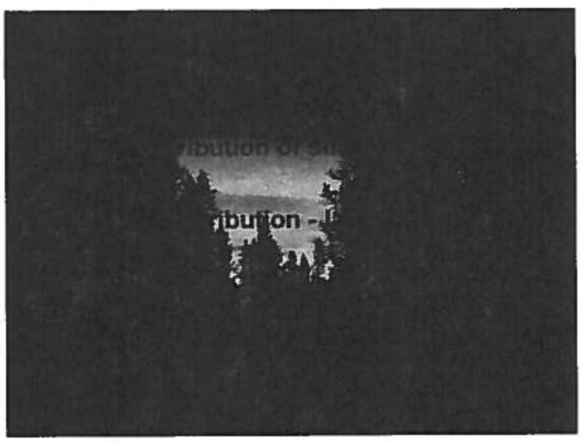


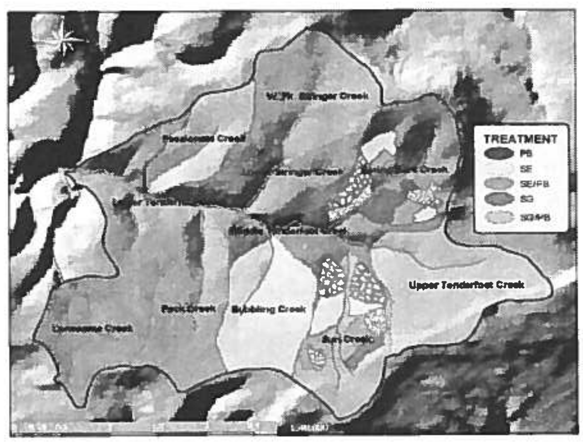


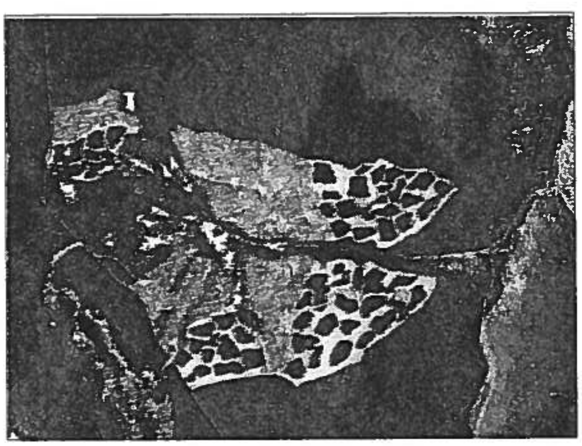


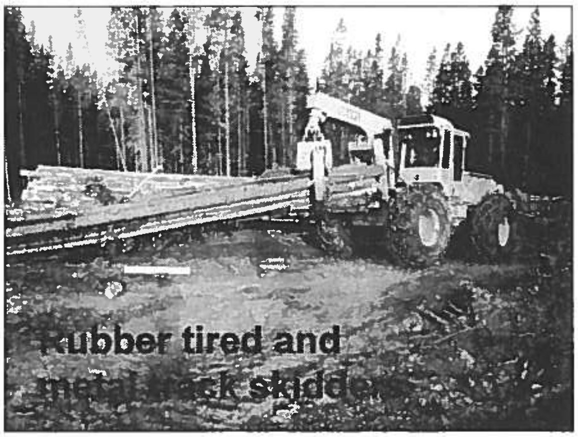
Experimental Design

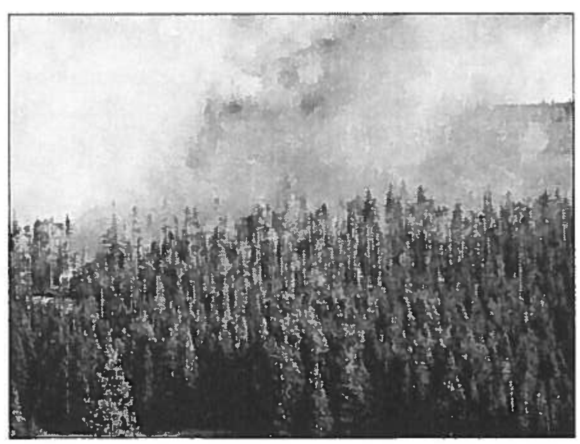
- Two treatment sub-watersheds (north and south)
- Two hydrologically matched control subwatersheds
- Eight shelterwood with reserve treatments per sub-watershed (four with even distribution; four with group distribution - one half of treatments burned and one half of treatments not burned
- Two mixed-severity burn units, one per sub-watershed



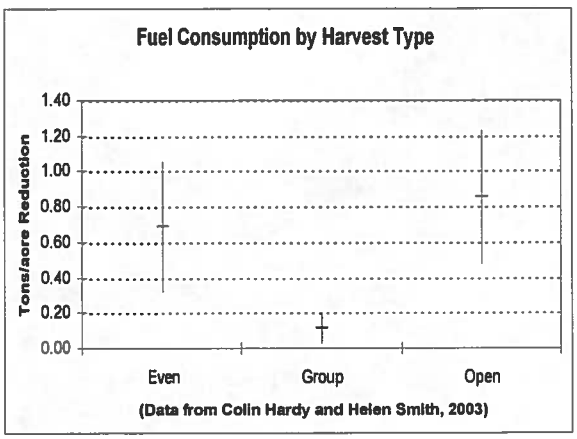





Rubber tired and

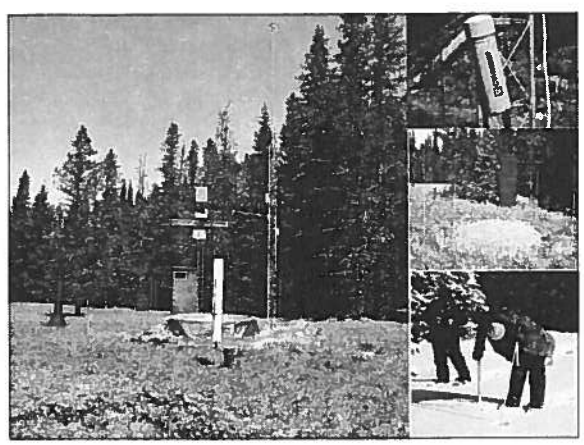


Fuel Reduction



Plausible explanations of why there was significantly less consumption in the ***Groups*** include the fact that there were no activity fuels in the ***Groups*** so the fuel profile was dramatically different. Also, the fuels found inside the ***Groups*** were not exposed to the same solar insolation and surface winds during the burns. In addition, fire application may have varied (some deliberately through ignition strategies) particularly with respect to the ***Groups*** (Hardy and Smith, 2003)

Treatment Effects on Water and Sediment Production



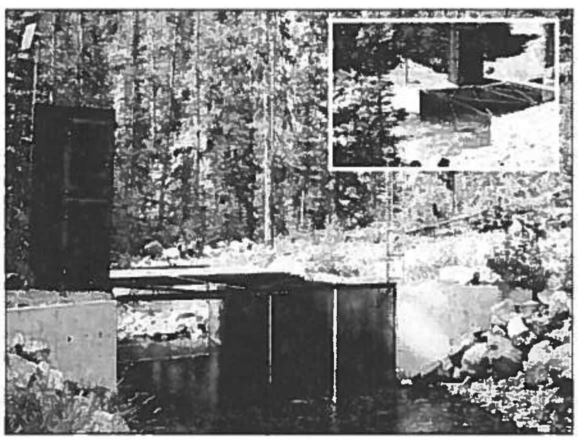
Snow water equivalent, in mm, of open and canopy snow pillows at Onion Park SNOTEL

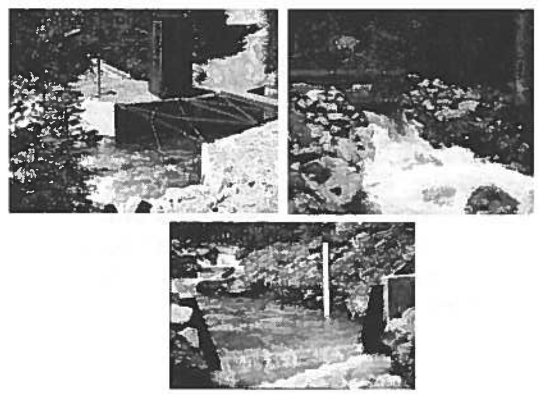
Rule of Thumb

For every 4 to 5 percent of a watershed in clearcut or equivalent clearcut acres –

Expect approximately 1% increase in water production
(Natural Resources Conservation Service)

Approximately 25% of each treatment sub-watershed was treated with equivalent clearcut acres.





Increased water yields typically come in average or above average years.

Water Year Flow (cfs) Oct 1 – Sept 30
(Sum of Mean Daily Flows)

Year	Sun Creek	Bubbling Creek (control)	Spring Park Creek	Up. Stringer Creek (control)
1993	583	—	—	—
1994	522	488	661	—
1995	442	440	643	674
1996	399	433	448	738
1997	600	500	689	701
1998	337	389	491	445
1999	287	300	390	425
2000	252	332	398	481
2001	263	264	316	353
2002	331	291	314	480

Cumulative Sediment Production
For the period - May 1st through September 30th
(Tons)

Year	Sun Creek	Bubbling Creek (control)	Spring Park Creek	Lower Stringer Creek (control)
1997	3.3736	4.1561	1.9537	8.1167
1998	1.2330	1.5594	1.9583	4.7294
1999	2.8632	2.0592	2.0150	4.5539
2000 Thinning YR	0.9338	1.1579	2.1854	1.8736
2001	1.3760	2.0325	1.4083	4.0060

There was no significant change in sediment production for treatment year 2000 or for 2001. Snow pack in 2000 was 65% of avg. and 90% of avg. in 2001. Sediment production was highest at Lower Stringer - the drainage area above the sampler is twice that of Spring Park.

Session 1-4:

Burn Severity, Fuels Management and Geomorphic and Watershed Impacts

Panel: Kevin Ryan, Colin Hardy, Russ Graham, & Ward McCaughey

Objectives:

To inform participants about the current status of our knowledge regarding the effects of pre-wildland fire fuels-management on the vegetation ground cover/soil interface and the hydro-geomorphic effects (e.g. floods, erosion, sedimentation.)

Upon completion participants will be able to: (cont.)

- **Define burn severity as it relates to hydro-geomorphic processes.**
- **Identify and describe primary fuels and fire regimes that can make landscapes particularly vulnerable to erosion and flooding after wildland fire.**
- **Describe management implications and priorities for action relating to fuels management.**

Upon completion participants will be able to: (cont.)

- **Describe how burn severity can be altered by pre-fire fuels management.**
- **Highlight key facts regarding fuels management and its effects on burn severity relating to hydro-geomorphic processes. Specifically how fire impacts soils, duff and ground cover in the hydro-geomorphic context.**

Upon completion participants will be able to: (cont.)

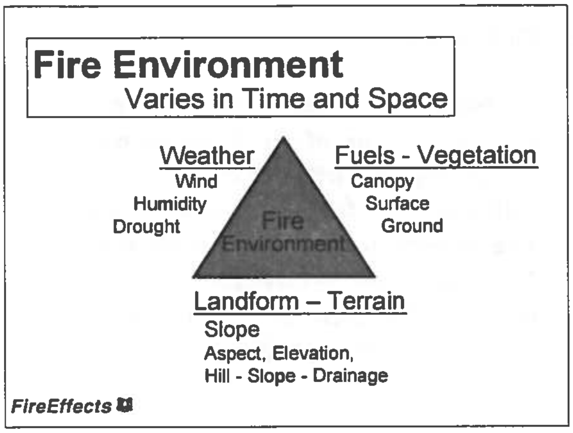
- **Contrast and compare strategies for pre-wildland fire fuels reduction that focus on tactical community protection versus strategic landscape management.**
- **Have an understanding of possible mitigative management actions that might reduce the need for post fire rehabilitation.**

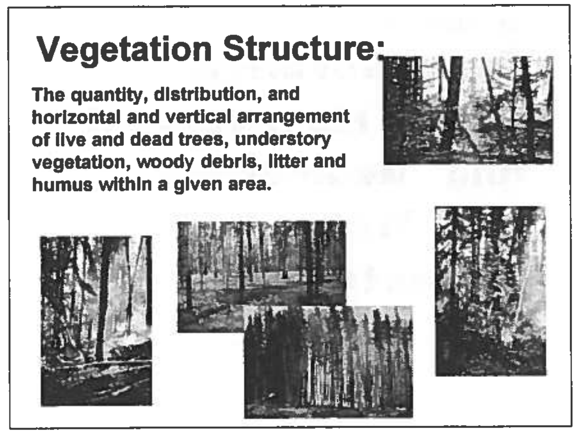
Approach:

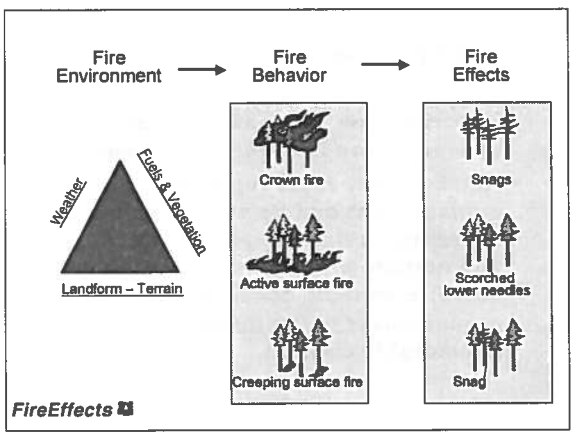
Panel presentation followed by Q & A

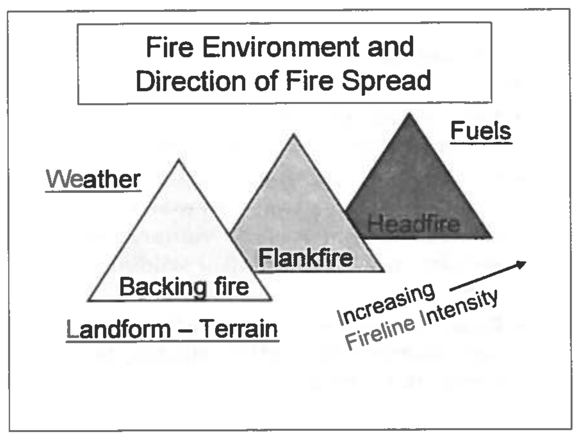
Panelists:

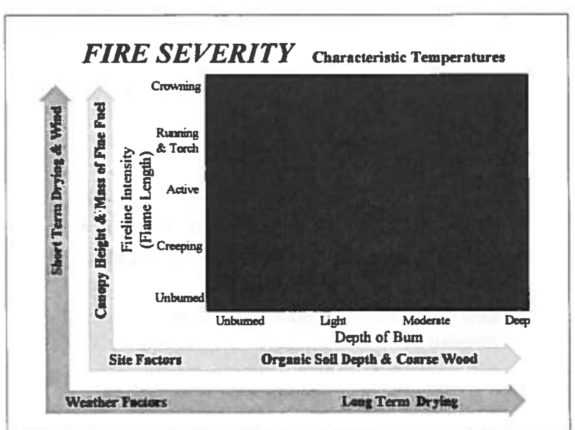
- **Kevin Ryan, Fire Sciences Lab, Missoula**
- **Colin Hardy, Fire Sciences Lab, Missoula**
- **Russel Graham, Forestry Sciences Lab, Moscow**
- **Ward McCaughey, Fire Sciences Lab, Missoula**

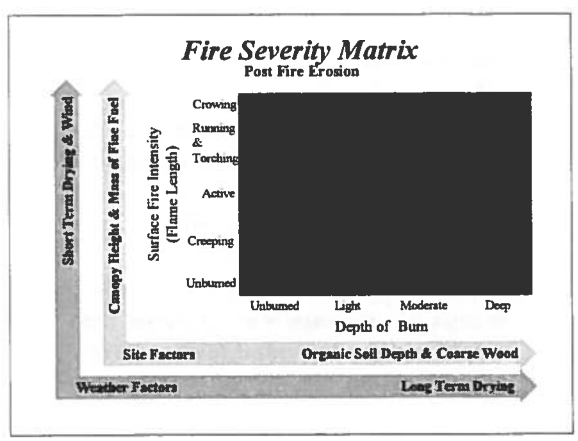

Fire Environment
Varies in Time and Space
Weather
Wind
Humidity
Drought
Fuels - Vegetation
Canopy
Surface
Ground
Fire Environment
Landform – Terrain
Slope
Aspect, Elevation,
Hill - Slope - Drainage
FireEffects


Vegetation Structure:
The quantity, distribution, and horizontal and vertical arrangement of live and dead trees, understory vegetation, woody debris, litter and humus within a given area.


Fire Environment
Fire Behavior
Fire Effects
Weather
Fuels & Vegetation
Landform – Terrain
Crown fire
Active surface fire
Creeping surface fire
Snags
Scorched lower needles
Snag
FireEffects

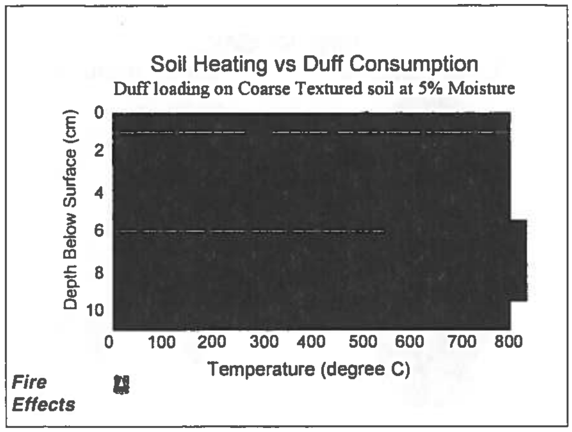

Fire Environment and Direction of Fire Spread
Weather
Fuels
Headfire
Flankfire
Backing fire
Landform – Terrain
Increasing Fireline Intensity

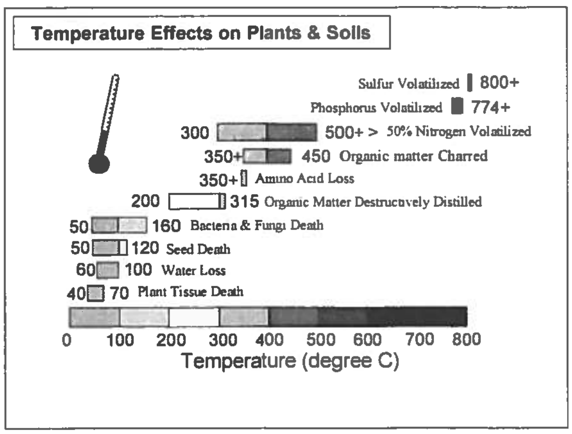

FIRE SEVERITY Characteristic Temperatures
Crowning
Running & Torch
Active
Creeping
Unburned
Fireline Intensity (Flame Length)
Short Term Drying & Wind
Canopy Height & Mass of Fine Fuel
Unburned
Light
Moderate
Deep
Depth of Burn
Site Factors
Organic Soil Depth & Coarse Wood
Weather Factors
Long Term Drying

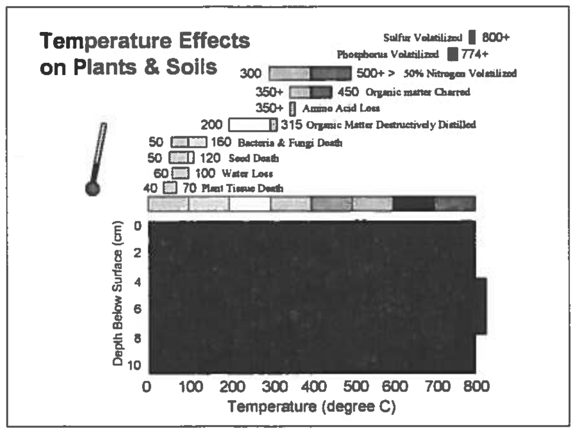

Fire Severity Matrix
Post Fire Erosion
Crowning
Running & Torching
Active
Creeping
Unburned
Surface Fire Intensity (Flame Length)
Short Term Drying & Wind
Canopy Height & Mass of Fine Fuel
Unburned
Light
Moderate
Deep
Depth of Burn
Site Factors
Organic Soil Depth & Coarse Wood
Weather Factors
Long Term Drying

Moisture Content and Duff Consumption

- **At less than 30% duff moisture content, duff layers burn on their own once ignited.**
- **At 30 to 120% duff moisture content, duff consumption depends on the consumption of associated fuel.**
- **At more than 120% duff moisture content, duff doesn't burn.**

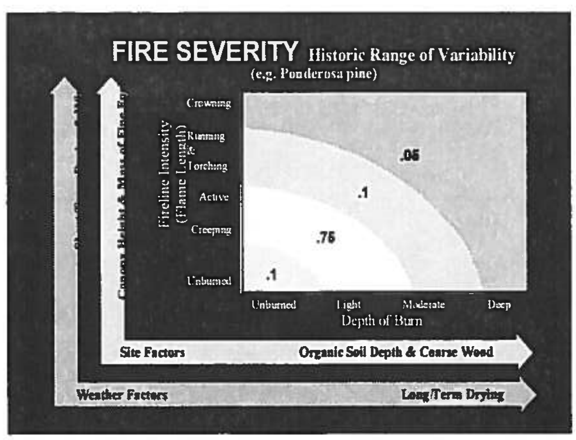


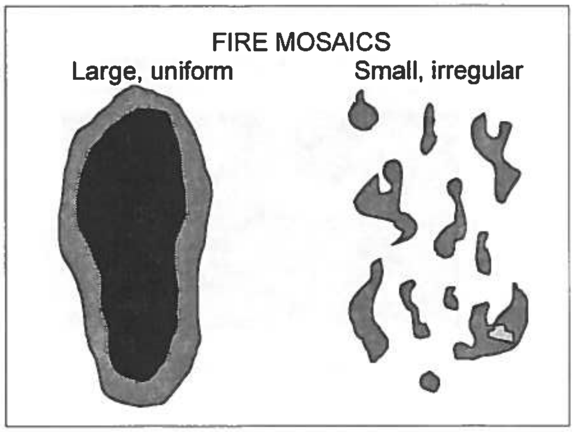




Fire Tools

- Fire Family +
- BEHAVE Plus
- NEXUS
- FOFEM
- FEIS
- CONSUME
- http://fire.org





Thank you

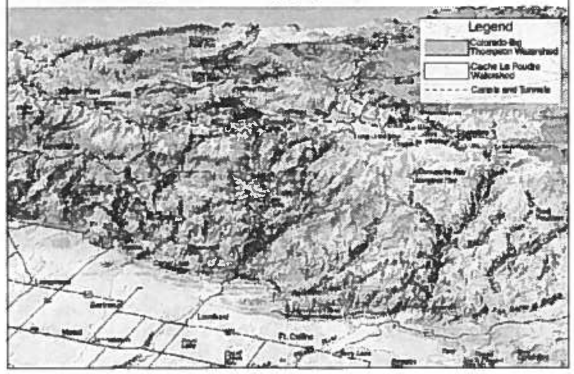
1-5

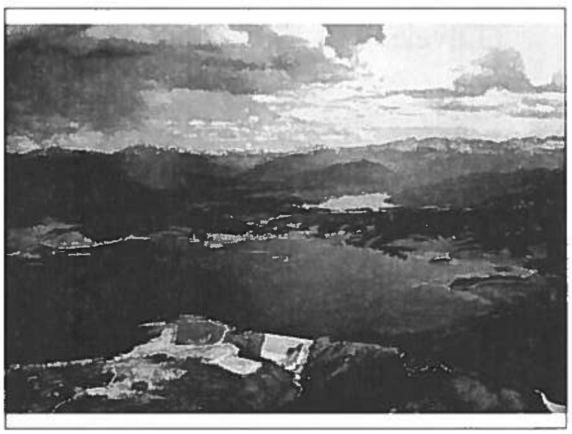
Evaluating Watershed Vulnerability—Hazards and Downstream Values

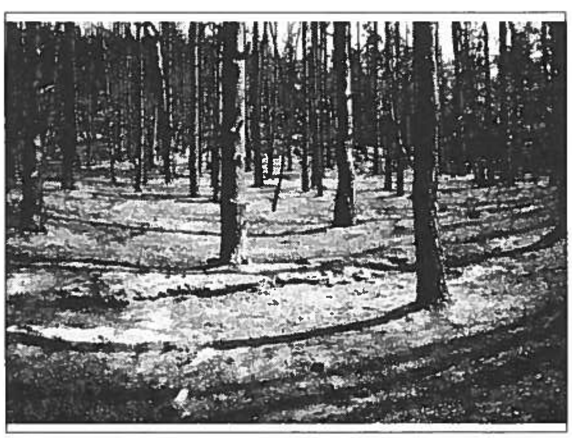
Forest Fire Impacts on Drinking Water Quality

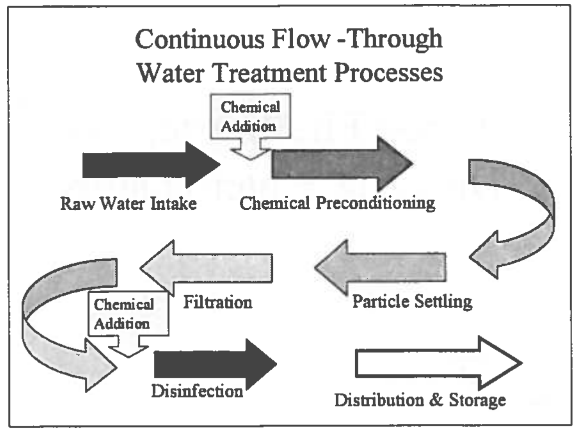
Prepared By Ben Alexander
Watershed Protection Manager
City of Fort Collins – Utilities &
Watershed Assessment Committee Chair
Big Thompson Watershed Forum
October 15, 2003

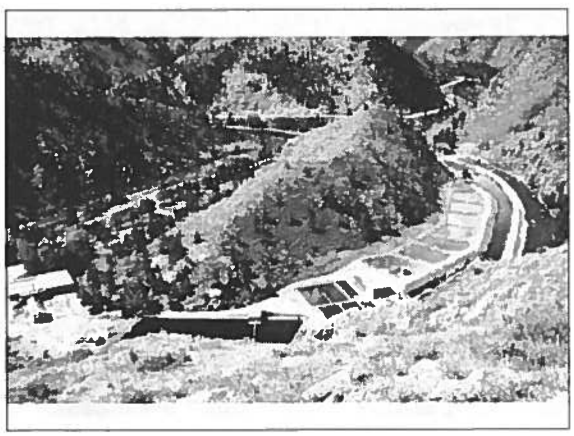
Drinking Water Supply Watershed Area

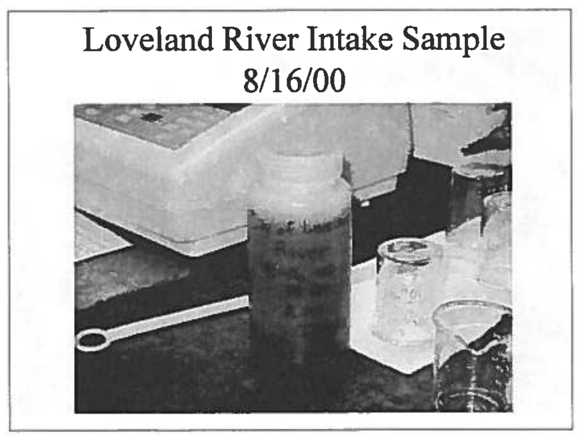


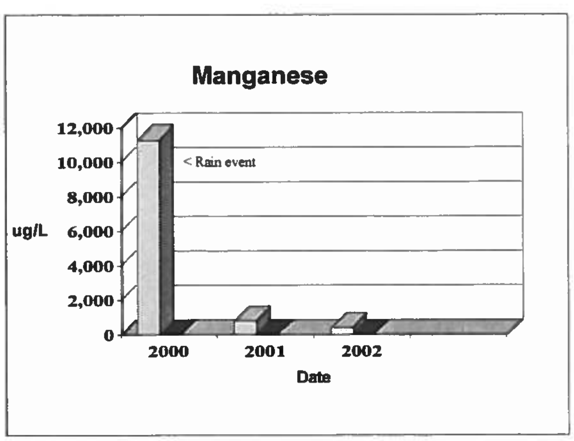


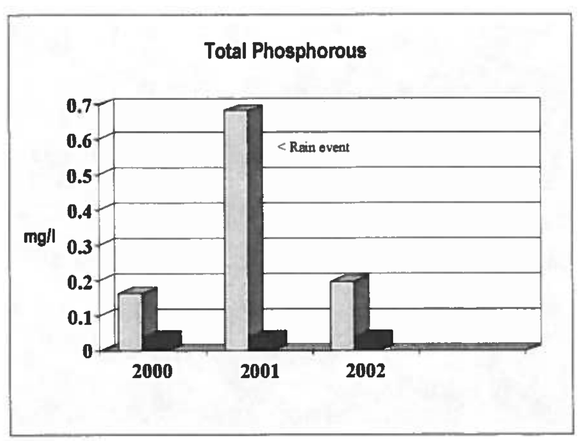


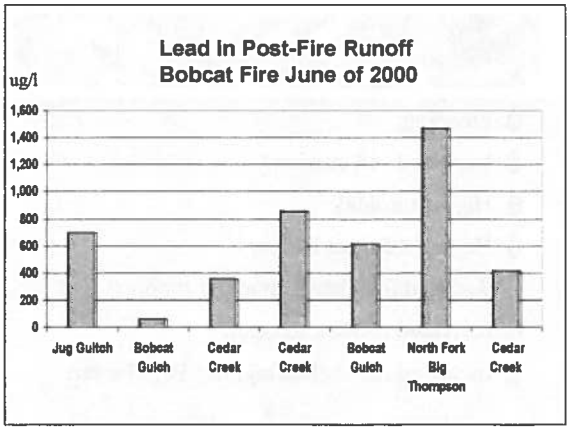

Continuous Flow -Through
Water Treatment Processes
Chemical Addition
Raw Water Intake
Chemical Preconditioning
Filtration
Particle Settling
Chemical Addition
Disinfection
Distribution & Storage

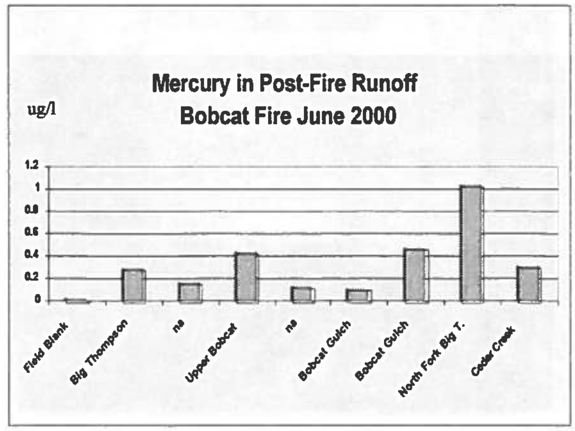



Loveland River Intake Sample
8/16/00


Manganese
12,000
10,000
8,000
ug/L 6,000
4,000
2,000
0
< Rain event
2000
2001
2002
Date

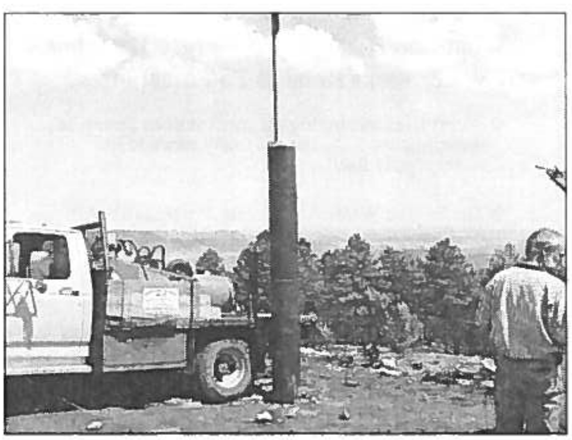

Total Phosphorous
0.7
0.6
0.5
0.4
mg/l 0.3
0.2
0.1
0
< Rain event
2000
2001
2002

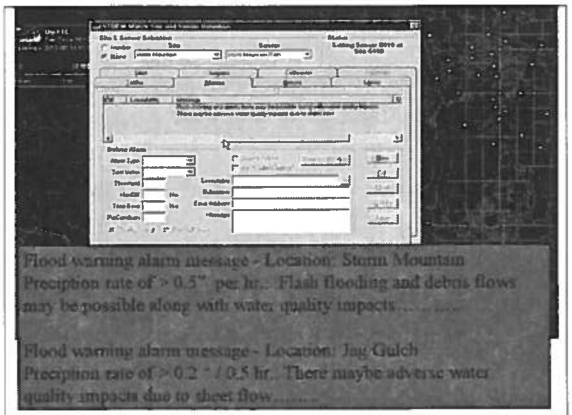




What Is The Most Effective Water Treatment Strategy (for Dealing With Post-Fire Runoff)

???





[redacted]

- Flooding
- Increased soil erosion
- Higher turbidity
- Higher sediment loading
- Reduced flow between major runoff events
- Increased nutrient loading
- Increased metals loading, Hg, Pb, Mn, etc.

On-going Concerns and Questions

- ❖ What if there isn't enough water to duck?
- ❖ What are the post-fire impacts on the receiving reservoirs and streams?
- ❖ How long will it take to return to "normal"?
- ❖ Are there forest management practices that will produce a healthy on-going balance that supports sustained yield and protects water quality?

http://www.ucar.edu/ucar/search.html>

Mercury in smoke

Hans and Larry became interested in smoke from biomass burning as a potential source of atmospheric mercury when their wildfire research called their attention to the high levels of mercury threatening Arctic Inuit communities. The elevated levels of sulfur dioxide coming off forest fires in the Los Angeles basin suggested that other pollutants absorbed by trees might also be liberated in a wildfire's intense heat. To conduct laboratory tests, they enlisted financial support from EPRI and cooperation from the Meteorological Service of Canada, which provided a state-of-the-art Tekran mercury vapor analyzer and the methodology to measure mercury contained in smoke particles. Their work with Julia Lu (MSC) will be reported in a forthcoming paper in *Geophysical Research Letters*.

Since most of what burns in a wildfire is foliage and ground litter, not tree trunks, volunteers collected samples from seven forests across the continental United States. Those samples were set alight at the U.S. Forest Service Fire Science Laboratory's burn facility in Missoula, Montana. All the coniferous and deciduous samples contained mercury at levels ranging from 14 to 71 nanograms per gram of fuel. Ground litter had the highest concentrations, reflecting accumulation during annual or biannual cycles before the leaves or needles were shed.

Table 1. Summary of burns of regionally collected fuels: % fuel burned, total mercury in fuel and ash, and % mercury emitted.

Composition	Fuel ng Hg/g	Ash ng Hg/g	Mercury Emitted %	Burn Loss (weight) %
Coniferous				
Litter				
MT Ponderosa (5)	21.9	1.41 (3)	97.5-99.8	94.1-96.2
MT Western White Pine	43.7	0.89	99.75	89
FL Longleaf Pine	27.4	6.89	98	93.7
SC Loblolly Pine	26.4	1.44	99.8	96.1
Live				
FL Longleaf Pine	13.9	5.31	52.9	42.5
SC Loblolly Pine *	14.5	2.08	97.1	88.8
WA 3/4 Cedar *	58.7	0.52	99.6	88.1
WA 1 Douglas Fir *	30.1	1.48	99.7	87.7

What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

- ❖ Forest fires are among the most serious threats to water quality ……..and in many cases to the water supply itself.
- ❖ The Source Water Assessment Process (SWAP) for forested watershed areas must include an assessment of the risk to public health from drinking water contaminants derived from forested areas that have or someday will be impacted by forest fires.
- ❖ Airborne contaminants released by forest fires impact downwind water supplies in addition to impacting air quality.

Source Water Assessment & Protection

- The 1996 amendments to the Safe Drinking Water Act (SDWA) mandated that States delineate watershed and well head protection areas, then conduct source water assessments within those areas to determine the relative safety of the drinking water supplied to the affected public.
- This EPA program is commonly referred to as SWAP, the acronym for Source Water Assessment and Protection program.

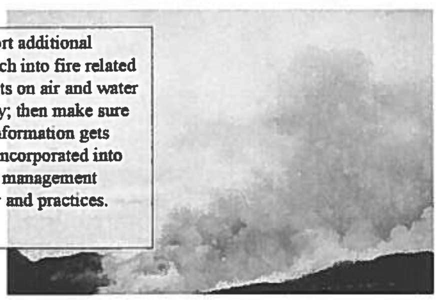
What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

❖ *It is impossible for local government and private watershed stakeholders to forge effective partnerships, designed to address the full range of watershed protection needs, on federal agencies that are not required to support public utilities and individual states in meeting federal mandates for protecting drinking water supplies. Therefore:*

The United States needs to ensure that federal agencies that manage watershed land areas and federal agencies that own and operate water project facilities actively partner with local entities in regional watershed protection endeavors designed to monitor and protect drinking water supplies.

What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

Support additional research into fire related impacts on air and water quality; then make sure that information gets fully incorporated into forest management policy and practices.



What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

Always consider the needs of the affected watersheds when developing forest policy and management plans.

What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

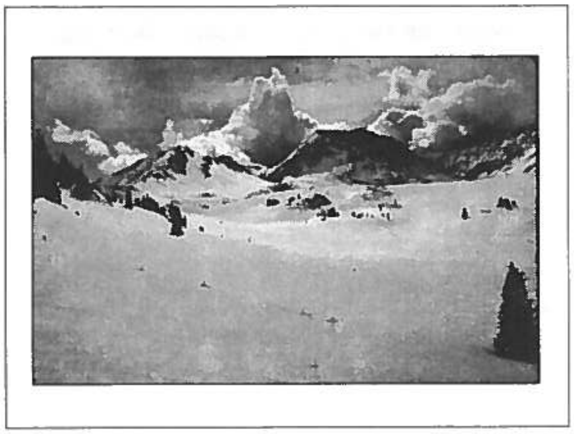
❖ Implement policy changes that put forest management directly into the hands of professional forest managers.

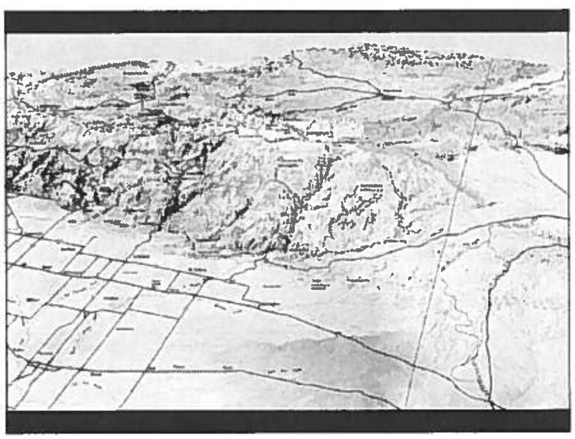
❖ Provide the forest managers with all of the essential criteria, training and information necessary to protect water quality by most effectively managing the land area they are responsible for.

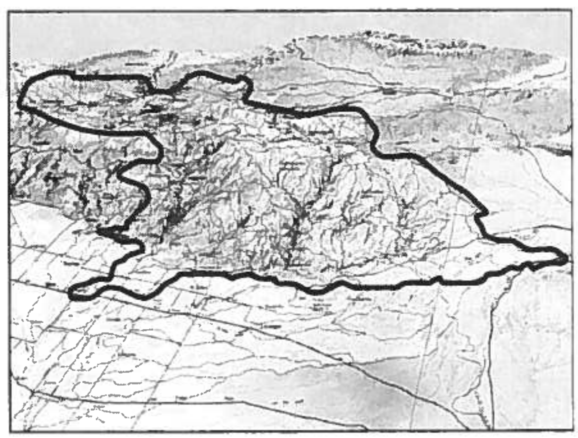
What Can Be Done To Reduce Drinking Water Risks Related To Forest Fires?

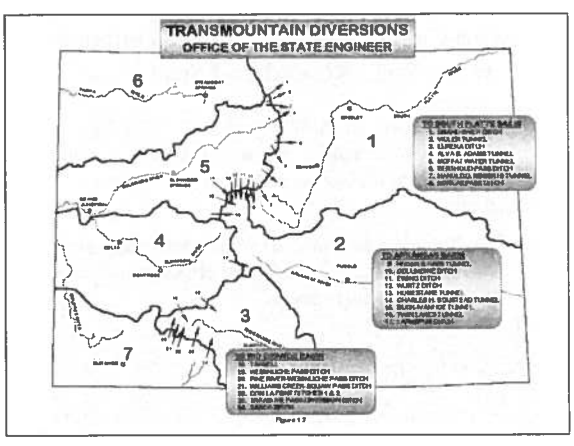
❖ Always apply the most appropriate BMPs for proactively managing fuel accumulation through mechanical harvesting and small prescriptive burns.

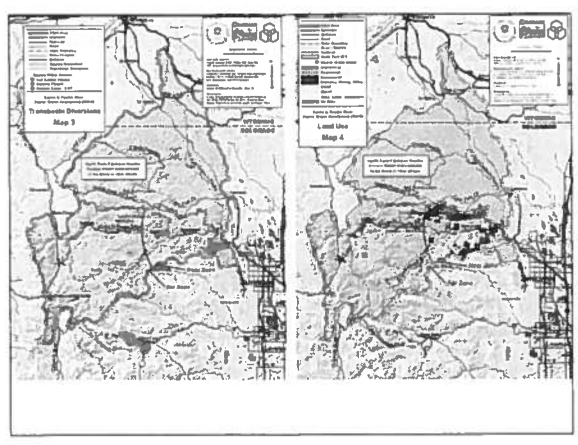
❖ BMPs designed to protect water quality also need to be applied to all other forest activities and land management practices.

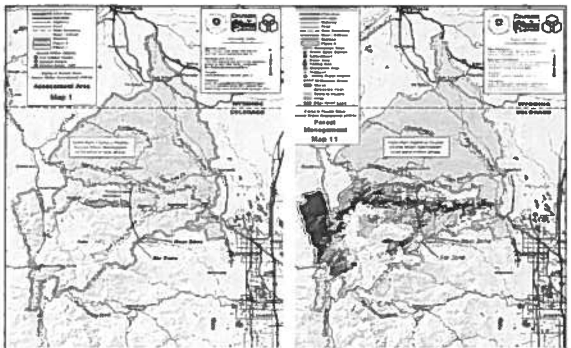


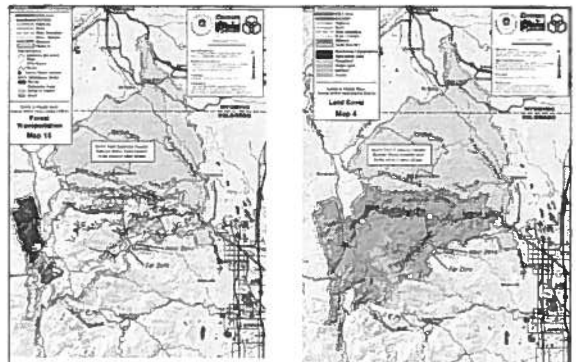





TRANSMOUNTAIN DIVERSIONS
OFFICE OF THE STATE ENGINEER
1
2
3
4
5
6
7







In Conclusion –
There is a lot of opportunity for improved coordination between those responsible for providing and protecting public drinking water supplies and the federal agencies that oversee public lands and publicly owned water projects. New, more effective partnerships need to be formed in order to adequately protect our drinking water supplies.

University of Idaho
Ecohydraulics Research Group

BASL
USDA Forest Service Rocky Mountain Research Station
Boise Aquatic Sciences Lab

Evaluating Watershed Vulnerability: a Fishes' Perspective on Fire

Amanda Rosenberger
Jason Dunham
Bruce Rieman

NATIONAL FIRE PLAN

Fire and Fish: Key Questions

- When and where does fire or fire management pose a threat?
- How can we manage threats?
  - ✓Pre-fire
  - ✓During fires
  - ✓Post-fire

How did fire fit in then?

Vulnerability of Fish to Disturbance

Disturbance is a fundamental component of ecosystems

Species in fire-prone landscapes have evolved in and are adapted to dynamic systems

- Life history diversity
- Use of internal refugia

Can Fire Benefit Fish?

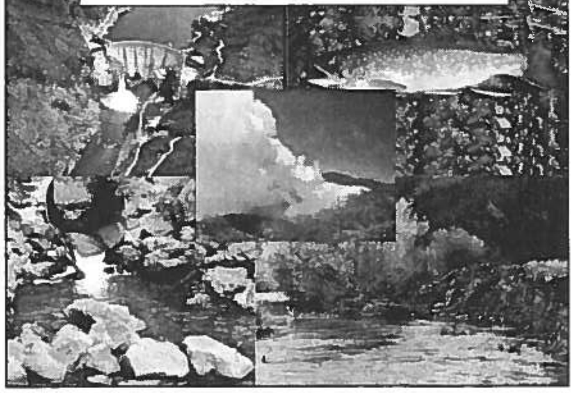
Habitat formation:

- Woody debris
- Sediment
- Complexity

Stream Productivity:

- Decreased Canopy
- Increased Sunlight
- Nutrient influx from runoff

How does fire fit in now?



Hypothesis:

Vulnerability to fire is conditional

Related to:

	· Life history diversity
Fragmentation	· Population isolation
	· Population/ habitat size
	· Habitat diversity
Degradation	· Habitat quality

What management alternatives are most likely to benefit fish?

Alternative (Dale et al. Bioscience 2001)	Assessment (Dunham et al. 2003)
Pre-fire management	Proactive – general improvement in ecosystem integrity
Manage during the fire	Reactive and Risky – does not address ecosystem, only fire
Post fire management	Reactive – may be too late to deal with post fire disturbance

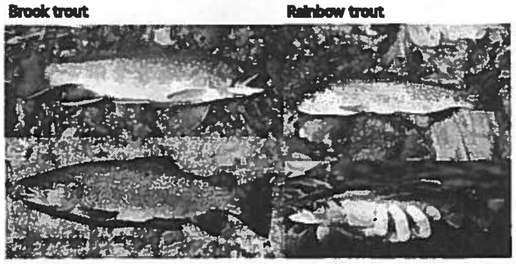
Pre-fire Management:

Address Fragmentation and Degradation

- Restore Connectivity
- Allow for diversity of life histories
- Restore Ecosystem Integrity
  - watershed and riparian function
  - habitat diversity
  - nonnative control

The Wild Card: Do fires facilitate invasions? Do invasions negate management?

Brook trout — Rainbow trout



Brown trout — Cutthroat trout

Our Study Focus

Does fire matter? When and where?

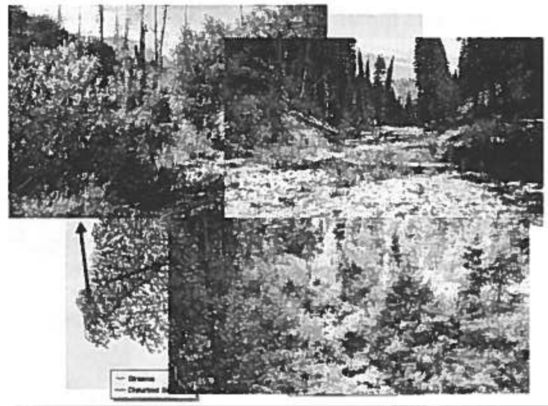
Examine fire effects across a wide gradient of landscapes

Key Questions:

- Are our monitoring tools reliable?
- Does fire affect persistence of native fish?
- How does fire affect stream temperature?
- Does fire increase stream productivity?
- Does fire facilitate nonnative invasions?

Headwater streams

- Bull trout
- Rainbow trout
- Brook trout (nonnative)
- Shorthead sculpin
- Tailed frog



Validation of monitoring/sampling

- Compare population estimates
- Estimate sampling efficiencies
- Develop sampling guidelines
  - Presence/ Absence
  - Abundance
  - Length frequencies

Patterns of Species Occurrence

Treatments:
- Unburned (control)
- Burned
- Burned with debris flows

Context:
1. Roads
2. Barriers to movement
3. Differences among species
   Nonnatives?

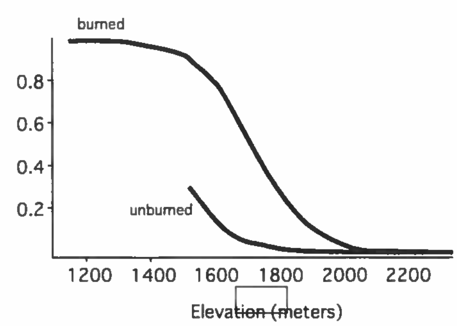
How does fire affect stream temperature?

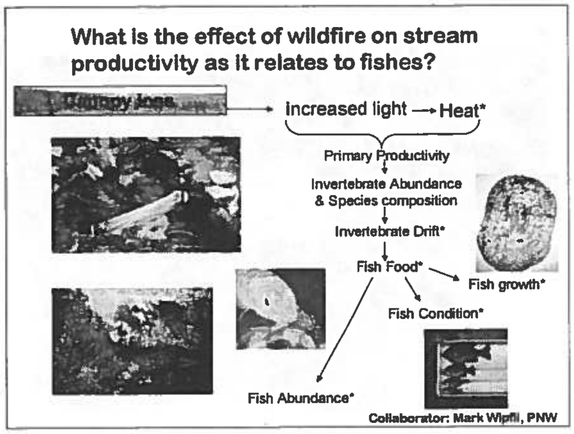
Why is temperature important?

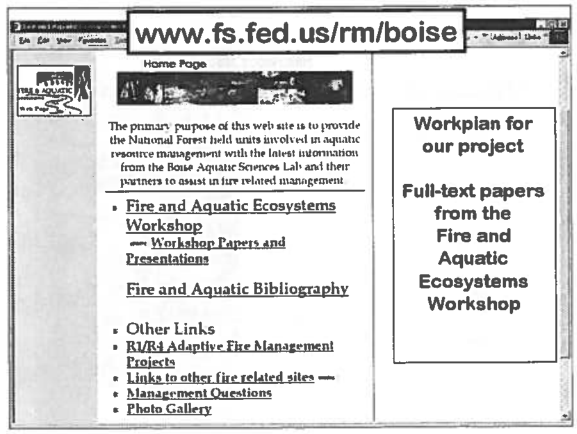
- Fire and debris flows
  - Loss of stream shading
  - Solar radiation increases temperature
- Fish responses to high temperatures:
  - Physiological stress
  - Changes in distribution
  - Invasion of tolerant species (nonnatives)

Probability of exceeding 20°C

Middle Fork Boise River in August 2002




What is the effect of wildfire on stream productivity as it relates to fishes?
Increased light → Heat*
Primary Productivity
Invertebrate Abundance & Species composition
Invertebrate Drift*
Fish Food*
Fish growth*
Fish Condition*
Fish Abundance*
Collaborator: Mark Wipfli, PNW


www.fs.fed.us/rm/boise
Home Page
The primary purpose of this web site is to provide the National Forest field units involved in aquatic resource management with the latest information from the Boise Aquatic Sciences Lab and their partners to assist in fire related management
Fire and Aquatic Ecosystems Workshop
Workshop Papers and Presentations
Fire and Aquatic Bibliography
Other Links
R1/R4 Adaptive Fire Management Projects
Links to other fire related sites
Management Questions
Photo Gallery
Workplan for our project
Full-text papers from the Fire and Aquatic Ecosystems Workshop

2-1

Erosion, Flooding, Landslides—When? Where? And Why? A State-of-the-Art Review

USGS *National Research Program, Boulder*

Wildland Fire:
Water Quality Effects

Deborah A. Martin

GSA Conference:
Wildland Fire Impacts On Watersheds
October 21-23, 2003

U.S. Department of the Interior
U.S. Geological Survey

A little early morning chemistry:

Combustion:

$(CH_2O)_n + 15O_2 \rightarrow CO_2 + H_2O + \text{energy}$

lignin
carbohydrates
cellulose

USGS

Combustion:

$(CH_2O)_n + 15O_2 \rightarrow CO_2 + H_2O + \text{energy}$

\+

Boron
Chloride
Iron
Magnesium
Manganese
Mercury
Nitrogen
Phosphate
Potassium
Silica
Sodium
Sulfur
Zinc

\+

Gasses
Aerosols
Particulates

\+

Ash
Char:
Charcoal
Black Carbon

USGS

Water quality variables commonly analyzed by municipalities:

- Discharge
- Temperature
- pH
- Dissolved oxygen
- Specific conductance and/or total dissolved solids (TDS)
- Turbidity and/or total suspended solids (TSS)
- Fecal coliform and/or fecal strep bacteria
- Alkalinity
- Hardness
- Nitrate
- Ammonia
- Phosphorus
- Total organic carbon (TOC)
- Safe drinking water act (SDWA) metals

USGS

Water quality variables most affected by fire:

Short term:
- Discharge
- Temperature
- Dissolved oxygen
- Turbidity and TSS
- Nitrate
- Phosphorus
- Total organic carbon
- Manganese

Longer term:
- Discharge
- Turbidity and TSS
- Nitrate
- Total organic carbon
- Mercury

USGS

Post-wildland fire chemistry is a function of:

- Fuel characteristics
- Fire characteristics
- Geologic/soil characteristics
- Meteorological events

USGS

Post-wildland fire chemistry is a function of:

- Fuel characteristics
  - Species
  - Decay status

USGS

Post-wildland fire chemistry is a function of:

- Fire characteristics
  - Type of fire (backing vs. heading)
  - Fire intensity
  - Fire phase:
    - Pre-ignition
    - Flaming phase
    - Smoldering phase
    - Glowing phase

USGS

Post-wildland fire chemistry is a function of:

- Geologic/soil characteristics
  - Alteration of soil mineralogy
  - Increase of readily available material for rock weathering
  - Alteration of detachment characteristics
  - Modification of hydrologic pathways

USGS

Export of chemicals from the watershed:

- Floatable organics including ash, charcoal and coarse woody debris
- Dissolved phase
- Particulate phase:
  suspended sediment
  bedload

USGS

Composition of pine wood ash Source: Misra et al., 1993	
Element	Weight % of ash
calcium	29
potassium	16
magnesium	7
sulfur	1
phosphorus	< 1
manganese	4
zinc	< 1
pH	10-14

USGS

Post-Wildland Fire Processes:

Short Term:
- Surface flow
- Atmospheric deposition of gases, aerosols, particulates

Long Term:
- Normal hydrologic pathways, including subsurface flow
- Vegetation regrowth

Conclusions:

- Sediment is a major water quality impact
- Short term effects are dominated by surface flow
- Impacts on soil properties may persist
- Inter-basin atmospheric deposition may supply nutrients to water bodies

USGS

Selected References:

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- Misra, M. K., Ragland, K. W., and Baker, A. J., 1993, Wood ash composition as a function of furnace temperature: Biomass and Bioenergy, vol. 4, p. 103-116.
- New Mexico Environment Department, 2001. Special water quality survey of the Pecos and Gallinas Rivers below the Viveash and Manuelitas Fires, 2000. http://www.nmenv.state.nm.us/swqb/Viveash_Fire_Report_02-2001.html

USGS

Selected References:

- Raison, R.J., Khanna, P.K., and Woods, P.V., 1985a, Mechanisms of element transfer to the atmosphere during vegetation fires: Can. J. For. Res., vol. 15, p. 132-140.
- Raison, R.J., Khanna, P.K., and Woods, P.V., 1985b, Transfer of elements to the atmosphere during low-intensity prescribed fires in three Australian subalpine eucalypt forests: Can. J. For. Res., vol. 15, p. 657-664.
- Raison, R.J., Keith, H., and Khanna, P. K., 1990, Effects of fire on the nutrient-supplying capacity of forest soils: *in* Dyck, W.J. and Mees, C.A., Impact of intensive harvesting on forest site productivity, Proceedings, IEA/BE A3 Workshop, South Island, New Zealand, IEA/BE T6/A6 Report No. 2, p. 39-54.
- Walker, J., Raison, R.J., and Khanna, P.K, 1986, Fire: Chapter 8 *in* Russell, J.S. and Isbell, R.F., eds., Australian soils– The human impact, St. Lucia, Queensland, Australia, University of Queensland Press, p. 185-216.

USGS

Many thanks to:
Sheila Murphy

USGS

Effects of Wildfires on Landslide Initiation and Runout

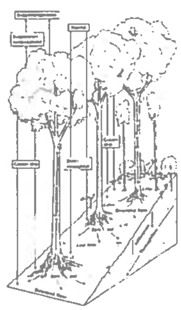
The mechanical effects of tree removal on slide initiation include:

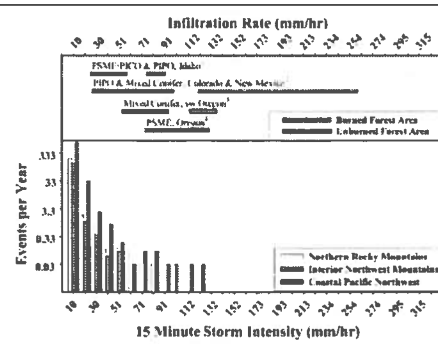
- Change in watershed hydrology
- Loss of shear strength provided by roots.

The first of these happens very quickly and the second takes a number of years to develop.

They have different implications for shallow, high-velocity slides that often happen during single intense storms and deeper, lower-velocity slides in the bedrock that occur in response to higher than normal annual precipitation.

Hydrologic Effects





Soil-infiltration rates in burned- and unburned-forest areas (top panel) and rainfall intensity (bottom panel). Infiltration data is from (1) Robichaud (2000), (2) Moody and Martin (2001a), (3) McNabb et al. (1989), and (4) Johnson and Beschta (1981). PSME: (Douglas fir); PICO: (lodgepole pine); PIPO: (ponderosa pine). Rainfall data from NOAA 15 min precipitation records for the Quinault Ranger Station, WA (Coastal Pacific Northwest); Ukiah, OR (Interior Pacific Northwest); and McCall, ID (Northern Rocky Mountains). (Wondzell and King, 2003)

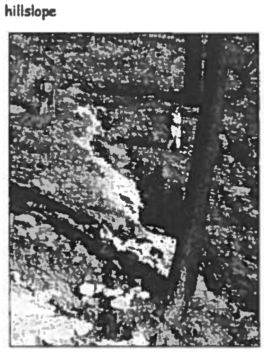
Debris Flows

Initiation by overland flow in channels

Sites with available unconsolidated material stored in the channel, perhaps less loose soil on the slopes or very conductive soils, intense storms leading to high peak runoff.

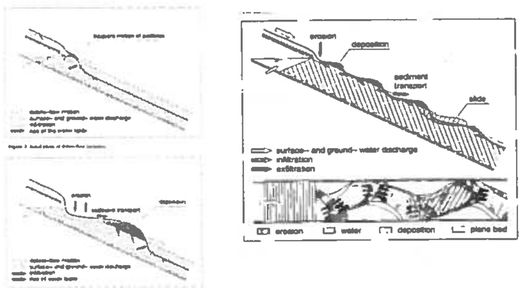
Bear Creek, Idaho debris flow source (one of two): in-channel debris that was mobilized.

Debris flow initiation from rills and gullies on a hillslope



Sites with available unconsolidated regolith on slope, perhaps hydrophobicity in soils after a fire, intense precipitation or rain-on-snow.

(Photo by Sue Cannon)

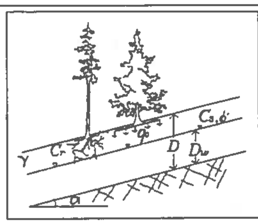


Physical model prediction of debris flow initiation by overland flow (Tognacca and Bezzola, 1997)

Debris flow initiation by slope failure

(Photo by Charlie Luce)

A convenient context for this discussion is the usual analysis of the balance of static forces that exists on hillslopes.



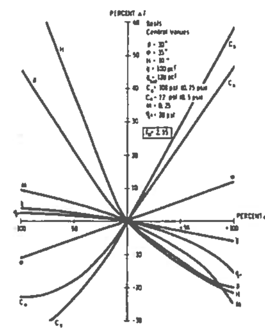
A 2D static limit equilibrium analysis of slope stability: the infinite slope equation with trees. (Modified from Hammond et al., 1992)

$$FOS = \frac{C_r + C_s + (\gamma D\cos^2\theta - u)\tan\phi}{\gamma D\sin\theta\cos\theta}$$

where
C_r = cohesive strength from roots
C_s = cohesive strength of soil
_ = unit weight of the soil
D = soil thickness
_ = slope angle
u = pore water pressure
_ = soil friction angle
Normally we neglect q_o in our analyses

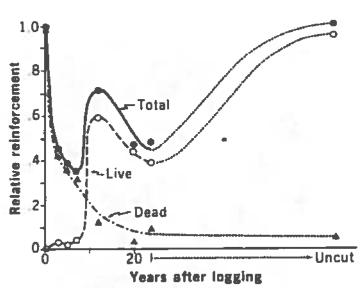
The mechanical effects of tree removal on slope stability include:

- Loss of shear strength provided by roots: C_r
- Change in pore water pressure conditions: u

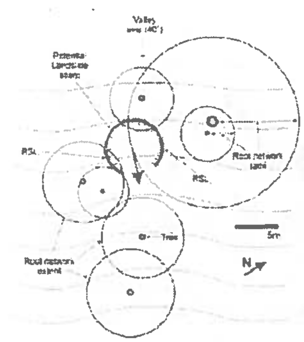


Sensitivity Analysis. Percent change in slope safety factor versus percent change in input variables. Base safety factor was computed using the median value for all variables. (Gray and Megahan, 1981)

Root Strength Effects



The relative soil reinforcement by live roots increases while that by dead roots decreases with time after forest removal. The total reinforcement by live and dead roots dropped to a minimum about 7 years after logging in northern California. (Ziemer, 1981)

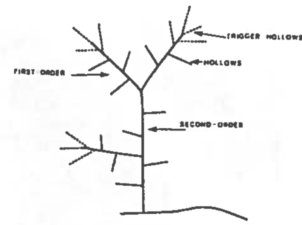


Planview map of an unchanneled valley that did not fail during a major storm. (Roering et al., 2003)

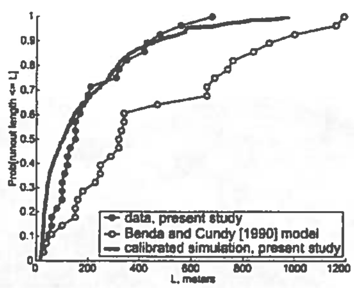
Photograph of broken roots (highlighted) in landslide scar within Elliot State Forest (Oregon Coast Range). Roots broke in tension rather than pulling out. Note person (in circle) for scale and absence of roots on the basal surface of the landslide. (Schmidt et al., 2001)

Debris Flow Runout Distance Controls:

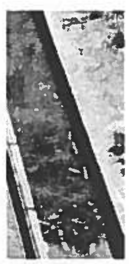
- Volume of Debris (this will likely change during flow)
- Gravitational Acceleration (channel gradient)
- Frictional Deceleration
  - Travel around bends, through vegetation, over rough terrain
  - Maintenance of high pore water pressure during flow
- Channel Confinement



The Most Generally Used Rule:
Debris flow deposition occurs when the channel gradient is < 3.5° or the flow encounters a junction with another channel and the junction angle is >70° (Benda and Cundy, 1990).
This is an empirical prediction based on a sample of 79 debris flows in Oregon and Washington Coast Ranges.



Mechanistic versus empirical analysis of debris flow runout length. (Lancaster et al., 2003)



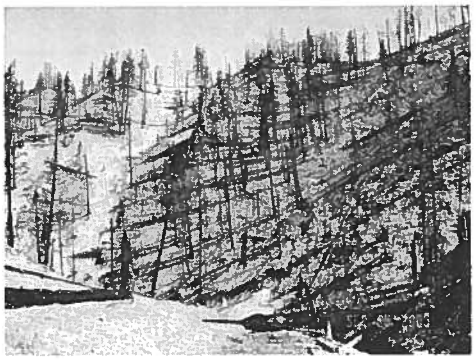
Wood in debris flow flume experiment (Lancaster et al., 2003)

Lake Creek: unconfined low gradient reach

Lake Creek: confined steeper reach

Lake Creek debris source area (one of many): zero order drainages or hollows.

Lake Creek tributary scoured to bedrock.



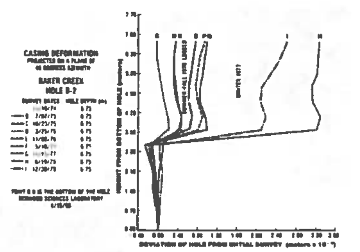
Bear Creek, Idaho unfailed hollows after July 2003 fire/storm sequence.

Bear Creek debris fan after July 2003 fire/storm sequence. Note low gradient and fine-grained material.

Lake Creek debris fan after July 2003 fire/storm sequence. Note steeper gradient and larger particles.

Deeper landslides that often fail into bedrock and move at slower rates

- There is some limited evidence (but not much data) that the velocity of these slides will increase after tree removal (by any means)
- The logical mechanical explanation is that disruption of transpiration leads eventually to an increase in pore water pressure
- These slides are normally deeper than the rooting zone and are large enough that lateral root



4-year record of movement of a 3.3 m deep block glide landslide in SW Oregon. Precipitation was below a 29-year average during the 1976 and 1977 water years. The post logging movement rate was 2-4 times the pre-logging rate (Swanston, 1981).

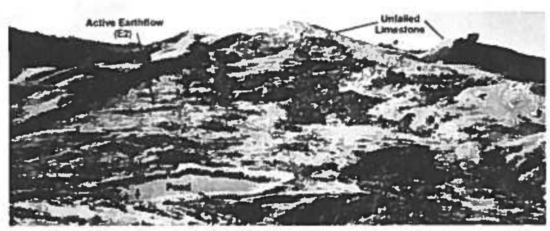


TABLE 3 Monthly and seasonal transpiration, mm, 1973-1974 at Whakarewarewa State Forest Park, Rotorua, New Zealand

	st/ha	APR 1973	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN 1974	FEB	MAR	MAY-AUG	SEP-APR	ANNUAL
PINUS CONTORTA																
1958	2037	38	12	7	16	9	20	49	36	84	128	63	76	44	314	358
1966	500	19	4	4	7	5	9	38	19	39	60	31	39	20	344	264
1908	321	24	7	4	11	7	9	27	19	40	61	34	39	29	229	258
PINUS RADIATA																
1968	2200	63	29	21	53	35	48	124	78	148	194	92	109	140	856	996
1968	1100	44	17	13	45	31	36	96	60	106	148	68	82	106	638	744
1934	1500	75	30	21	42	31	34	104	84	130	169	78	87	130	741	871
1947	600	72	34	18	30	38	38	95	53	101	114	58	65	120	598	718
PSEUDOTSUGA MENZIESII																
1938	1600	42	12	8	18	37	43	148	66	130	292	91	75	55	788	843
1907	100	7	3	1	4	3	2	14	10	22	34	28	13	11	124	135
CLIMATIC DATA																
Precipitation	mm	136	81	149	31	181	228	31	122	158	11	190	98	442	893	1340
Days ≤ 1 mm	#	22	17	19	26	18	14	26	17	23	28	21	25			
Mean Sunshine	Hours	4.4	5.9	3.4	4.7	3.1	5.3	5.7	5.0	6.5	7.3	5.1	5.9			
Mean Air Temperature	°C	13.3	10.3	7.4	5.4	6.8	10.5	13.2	15.4	17.5	17.3	19.0	14.6			

Typical tree transpiration rates (Swanson, 1981)

Characterizing Convection Rainfall:

Driver of Runoff and Erosion in Burned Landscapes

John A. Moody

U.S. Geological Survey

GSA Wildland Fire Impacts on Watersheds

October 21-23, 2003

I. Time Variability

II. Spatial Variability

Definition: Storm

Area of continuous rain but containing rain cells of of varying intensity

Duration of Storms:

Buffalo Creek Fire-- Spring Creek

Cerro Grande Burn-- Rendija Canyon

Hayman Burn

Duration of interstorm intervals:

Rainfall Intensities

In Convective storm regimes, runoff correlates with rainfall intensity.

- Maximum 30-minute intensity is common
- Many others are possible

Rainfall thresholds may exist, but

- May change with time
- May be depend on soil properties

Intensity-duration-frequency curves

Have been generally based on daily data.

Empirical equations permit prediction of durations shorter than one hour.

Higher resolution rainfall data analysis (partial duration series) suggests that recurrence intervals associated with a given intensity are less than those predicted by annual series analysis

Time distribution of rain intensity

Spatial Variability

Raingage Networks

Doppler Radar

Spatial Characteristics

1. Each storm contains areas of with very different recurrence intervals
2. Rainfall intensity may depend upon topographic control
   - A. Rainfall in Rendija Canyon may depend on elevation
   - B. Historic rainfall over Hayman burn area
3. Runoff from rainfall will depend upon the direction of movement of the storm

Storm size

Size relative to the watershed is critical

Summary

Rainfall-runoff models for convective rainfall regimes can no longer use steady, uniform, and stationary rainfall

Time: Convective rainfall is not steady

Space: Convective rainfall is not uniform

Dynamic: Convective rainfall is moving

Rainfall-runoff models need to use realistic rainfall inputs based on measurements to accurately predict floods, erosion, and deposition.

High resolution analysis in both space and time is needed to characterize convective rainfall

Summary continued

Some convective storm characteristics are:

- Storm duration
- Interstorm interval
- Time distribution of rainfall
- Intensity-duration-frequency curves
- Rainfall dependence on elevation
- Storm size (total accumulation, rain intensity)
- Storm rose showing preferred propagation directions
- Storm speed

Selected References

Arkell, R.E. and Richards, Frank, 1986, Short duration rainfall relations for the western United States, in Conference on Climate and Water Management, Amer. Meteorolgical Society, Boston, Mass., 136-141.Chow, V.T., Maidment, D.R., and Mays, L.W, 1988, Applied Hydrology, McGraw-Hill Book Co., Chapters 12572p.

Hershfield, D.M., 1961, Rainfall frequency atlas of the United States for duration from 30 minutes to 24 hours and return periods from 1 to 100 years, US Dept. Comm., Technical Paper No. 40, 107 p.

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Madsen, Henrik, Mikkelsen, P.S., Rosbjerg, Dan, and Harremoes, Poul, 2002, Regional estimation of rainfall intensity-duration-frequency curves using generalized least squares regression of partial duration series statistics, Water Res. Research, 38(11), 1239-

Miller, J.F., Frederick, R.H., Tracey, R.J., 1973, Precipitation-Frequency Atlas of the Western United States, Colorado, NOAA Atlas 2, vol. III, National Weather Service, 67 p.

Moody, J.A., and Martin, D. A., 2001, Post-fire, rainfall intensity-peak discharge relations for three mountainous watersheds in the western USA, Hydro. Processes, 15, 2981-2993.

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2-2

Emergency and Long Term Planning and Response Approaches

Emergency Watershed Protection

The purpose of the Emergency Watershed Protection (EWP) program is to undertake emergency measures, including the purchase of flood plain easements, for runoff retardation and soil erosion prevention to safeguard lives and property from floods, drought, and the products of erosion on any watershed whenever fire, flood or any other natural occurrence is causing or has caused a sudden impairment of the watershed.
It is not necessary for a national emergency to be declared for an area to be eligible for assistance. Program objective is to assist sponsors and individuals in implementing emergency measures to relieve imminent hazards to life and property created by a natural disaster. Activities include providing financial and technical assistance to remove debris from streams, protect destabilized streambanks, establish cover on critically eroding lands, repairing conservation practices, and the purchase of flood plain easements. The program is designed for installation of recovery measures.
Work is authorized by section 216, P.L. 81-516, (33 U.S.C. 701b1) and Sections 403-405, P.L. 95-334, (16 U.S.C. 2203-2205).
Excerpt from Section 216, P.L.81-516 (as amended) that pertains to NRCS EWP Program

> "The Secretary of Agriculture is authorized to undertake emergency measures, including the purchase of floodplain easements, for runoff retardation and soil erosion prevention, in cooperation with landowners and land users, as the Secretary deems necessary to safeguard lives and property from floods, drought, and the products of erosion on any watershed whenever fire, flood, or any other natural occurrence is causing or has caused a sudden impairment of that watershed."

Additional Information

- EWP Enabling Legislation
- EWP Manual (to be released at a later date)
- EWP Fact Sheet
- Questions and Answers
- EWP Contracting Questions and Answers
- The River Concept
- EWP Success Stories

Emergency Watershed Protection Fact Sheet

The Program

The Emergency Watershed Protection (EWP) program helps protect lives and property threatened by natural disasters such as floods, hurricanes, tornadoes, and wildfires. The program is administered by the USDA's Natural Resources Conservation Service (NRCS), which provides technical and financial assistance to preserve life and property threatened by excessive erosion and flooding.

Traditional Types of Assistance

EWP provides funding to project sponsors for such work as clearing debris from clogged waterways, restoring vegetation, and stabilizing river banks. The measures that are taken must be environmentally and economically sound and generally benefit more than one property owner.

NRCS provides up to 75 percent of the funds needed to restore the natural function of a watershed. The community or local sponsor of the work pays the remaining 25 percent, which can be provided by cash or in-kind services.

Floodplain Easement Option

Background

Section 382 of the Federal Agriculture Improvement and Reform Act of 1996, Public Law 104-127, amended the Emergency Watershed Program (EWP) to provide for the purchase of floodplain easements as an emergency measure. Since 1996, NRCS has purchased floodplain easements on lands that qualify for EWP assistance. Floodplain easements restore, protect, maintain, and enhance the functions of the floodplain; conserve natural values including fish and wildlife habitat, water quality, flood water retention, ground water recharge, and open space; reduce long-term federal disaster assistance; and safeguard lives and property from floods, drought, and the products of erosion.

Land Eligibility

NRCS may purchase EWP easements on any floodplain lands that have been impaired within the last 12 months or that have a history of repeated flooding (i.e., flooded at least two times during the past 10 years). Purchases are based upon established priorities. Landowner applications for the program far exceed funding. NRCS maintains a list of easement offers that meet basic eligibility criteria at the time of application. These offers continue to be eligible pending availability of funding.

Easement Payments

Under the floodplain easement option, a landowner voluntarily offers to sell to the NRCS a permanent conservation easement that provides the NRCS with the full authority to restore and enhance the floodplain's functions and values. In exchange, a landowner receives the least of one of the three following values as an easement payment: (i) a geographic rate established by the NRCS state conservationist; (ii) a value based on a market appraisal analysis for agricultural uses or assessment for agricultural land; or (iii) the landowner offer.

Restoration of the Floodplain

The easement provides NRCS with the authority to restore and enhance the floodplain's functions and values. NRCS may pay up to 100% of the restoration costs. To the extent practicable, NRCS actively restores the natural features and characteristics of the floodplain through re-creating the topographic diversity, increasing the duration of inundation and saturation, and providing for the re-establishment of native vegetation. The landowner is provided the opportunity to participate in the restoration efforts. NRCS may pay 75 percent of the cost of removing buildings when appropriate.

Landowner Use

Landowners retain several rights to the property, including quiet enjoyment, the right to control public access, and the right to undeveloped recreational use such as hunting and fishing. At any time, a landowner may obtain authorization from NRCS to engage in other activities, provided that NRCS determines it will further the protection and enhancement of the easement's floodplain functions and values. These compatible uses may include managed timber harvest, periodic haying, or grazing. NRCS determines the amount, method, timing, intensity, and duration of any compatible use that might be authorized. While a landowner can realize economic returns from an activity allowed for on the easement area, a landowner is not assured of any specific level or frequency of such use, and the authorization does not vest any right of any kind to the landowner. Cropping is not authorized and haying or grazing would not be authorized as a compatible use on lands that are being restored to woody vegetation.

Eligibility

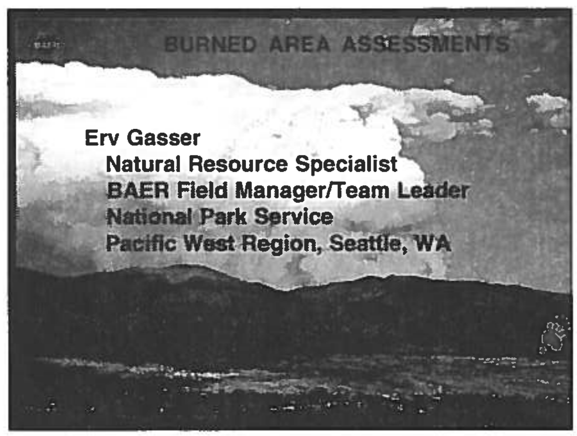
Owners, managers, and users of public, private, or tribal lands are eligible for EWP assistance if their watershed area has been damaged by a natural disaster.

Sponsors

Each EWP project, with the exception of floodplain easements, requires a sponsor who applies for the assistance. A sponsor can be any legal subdivision of State or local government, including local officials of city, county, or State governments, Indian tribes, soil conservation districts, U.S. Forest Service, and watershed authorities. They determine priorities for emergency assistance while coordinating work with other Federal and local agencies. Sponsors are needed to provide legal authority to do repair work, obtain necessary permits, contribute funds or in-kind services, and maintain the completed emergency measures.

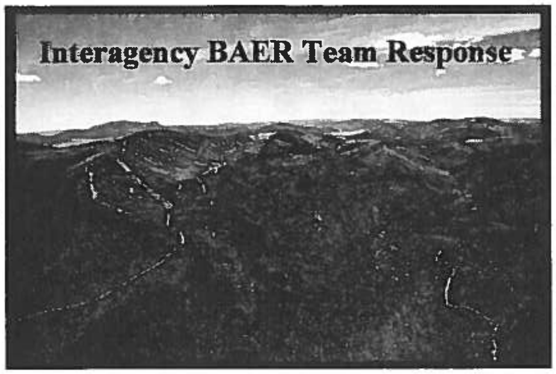
For More Information

For more information on assistance under the Emergency Watershed Protection program, contact the USDA Natural Resources Conservation Service office serving your county. Your USDA Service Center is listed in the telephone book under U.S. Department of Agriculture.



BAER Team

- Hydrologist
- Geologist
- Soil Scientist
- Archaeologist
- Wildlife Biologist
- Operations Spec.
- GIS Specialist
- Environmental Protection
- Vegetation Specialist
- Computer/Doc Specialist
- Photographer
- Team Leader



BAER Team

Objectives

EMERGENCY STABILIZATION

- **Threats to Human Life, Safety, and Property**
- **Threats to Critical Cultural & Natural Resources**
- **To Promptly Stabilize & Prevent Further Degradation to Resources**
- **Mitigate Fire Suppression Damages**

BAER Team

Objectives

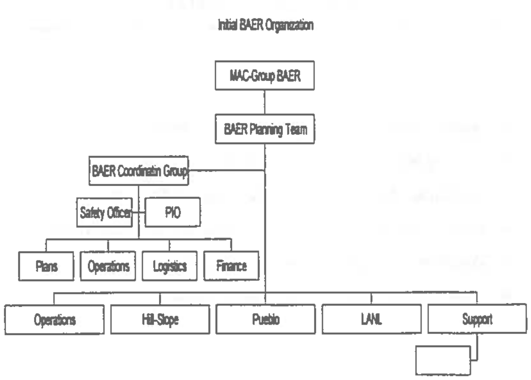
REHABILITATION:

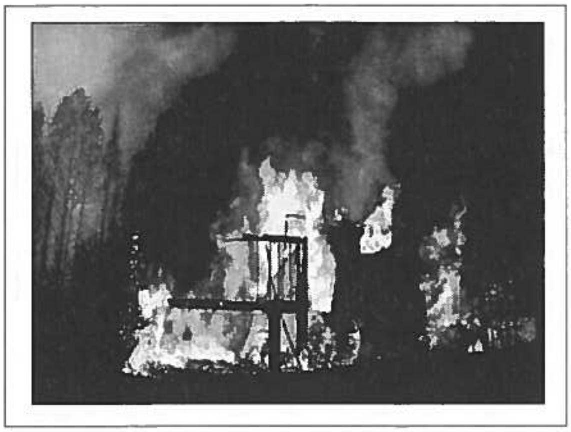
- **To Repair Lands Unlikely to Recover Naturally**
- **To Restore or Establish Healthy/Stable Ecosystems**

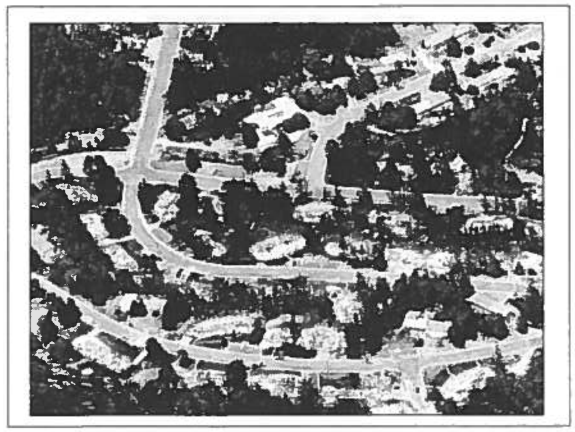
Interdisciplinary

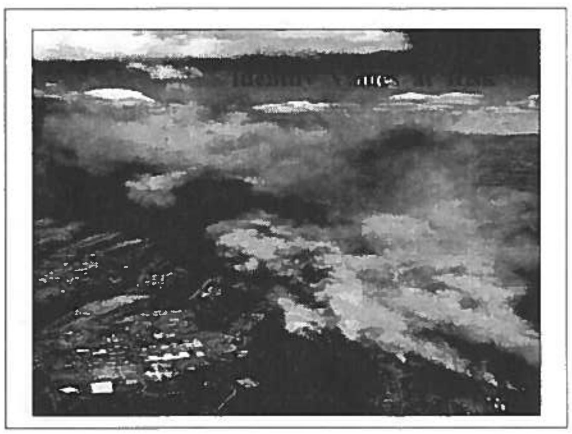
- Hydrologist
- Geologist
- Soil Scientist
- Archeologist
- Wildlife Biologist
- Forester
- Vegetation Specialist
- Engineer
- Environmental Protection Specialist
- Geographic Information Specialist
- Computer/Documentation Specialist
- Photographer
- Operations Specialist
- Landscape Architect
- Contracting Specialist
- Public Affairs Specialist
- Team Leader

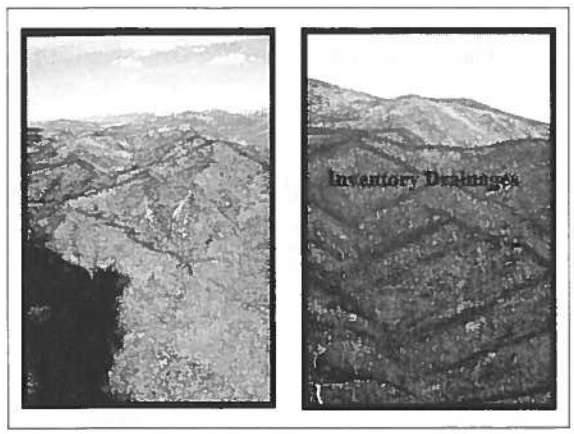
BAER - Interagency

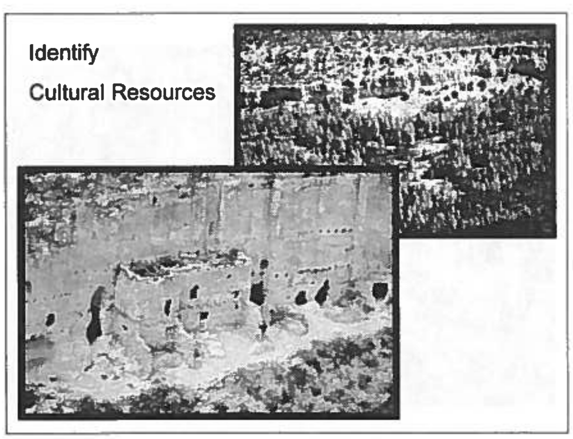


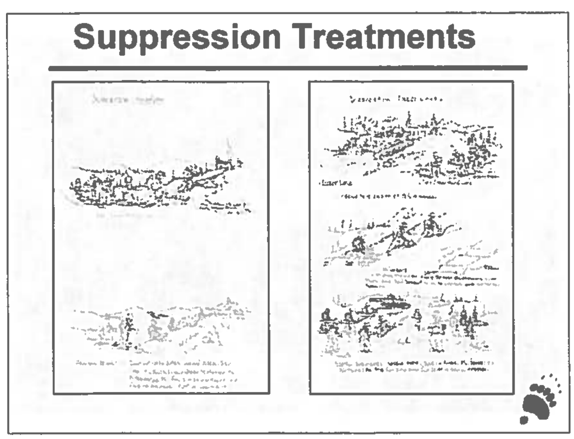


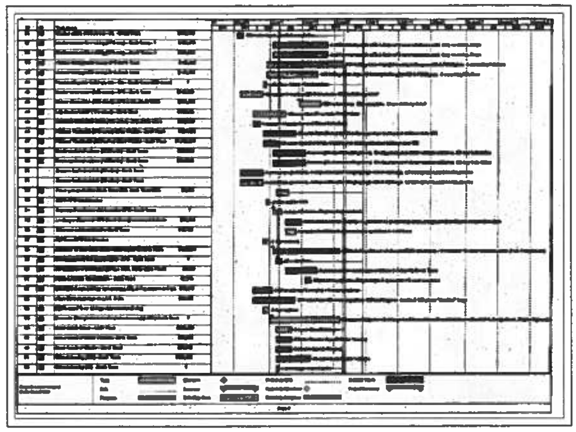




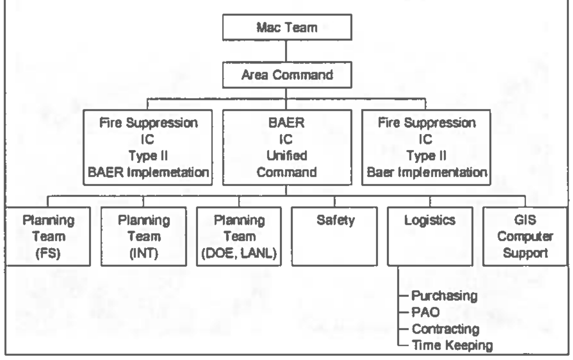

Inventory Drainages


Identify
Cultural Resources

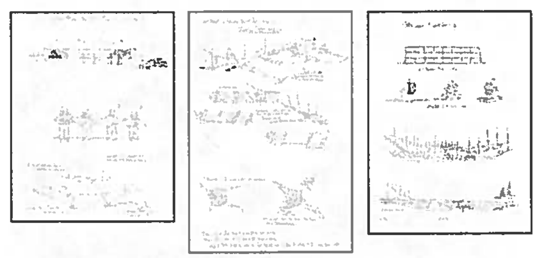

Suppression Treatments

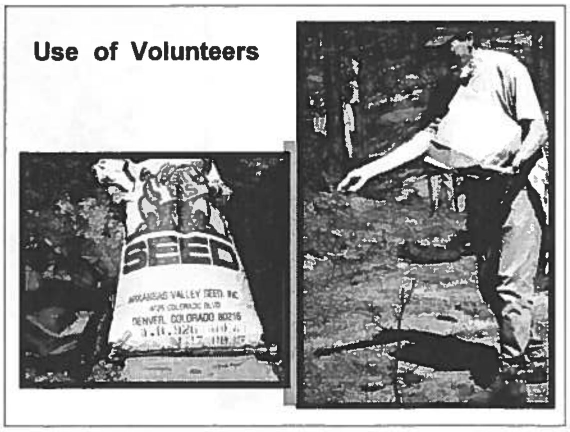


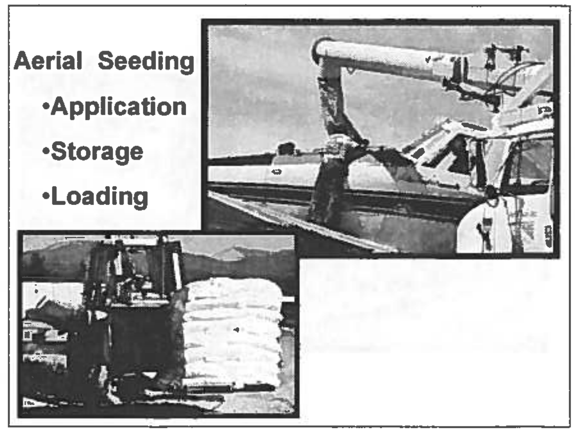
Planning & Implementation Organization

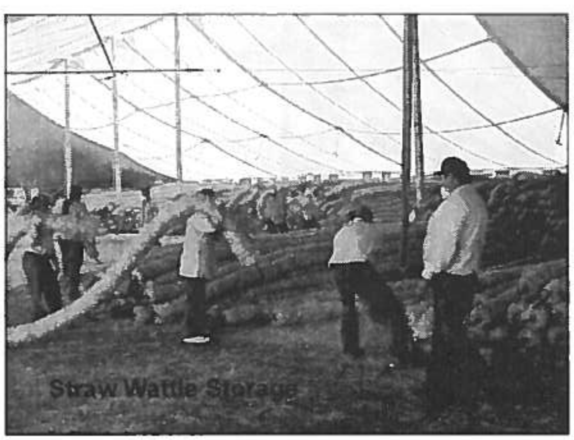


Hillslope Treatments




Use of Volunteers
SEED

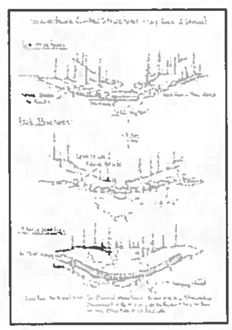

Aerial Seeding
•Application
•Storage
•Loading

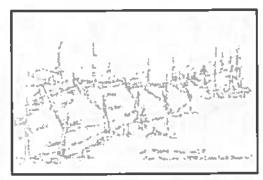

Straw Wattle Storage

Log Erosion Barriers

Contour Felling

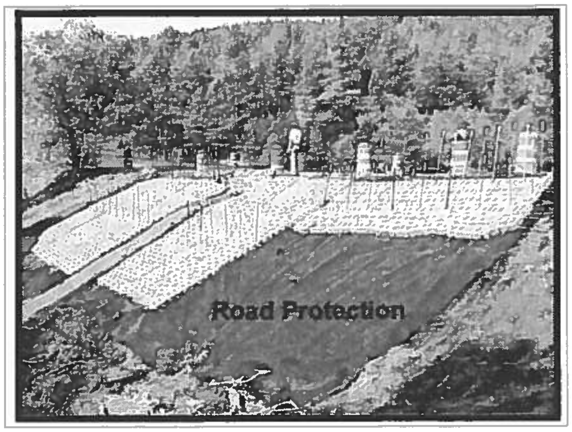
Channel Treatments



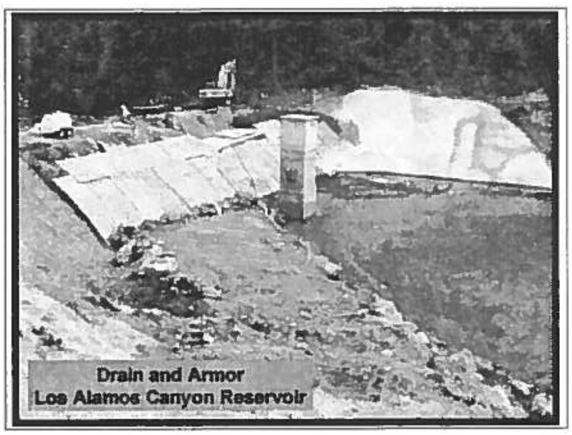


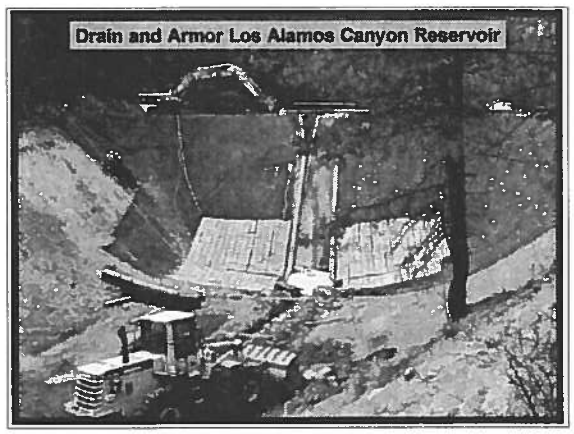
Directional Tree Felling

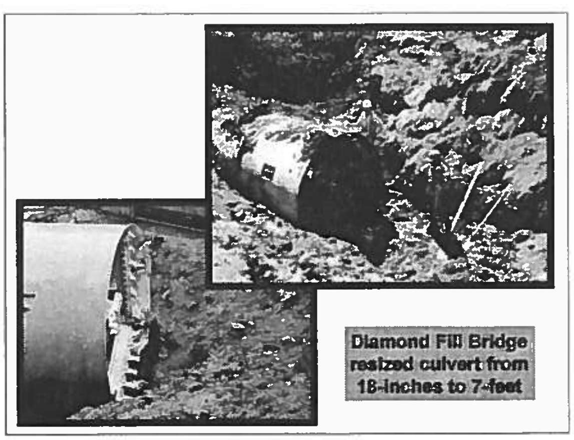
Grade Control Structure

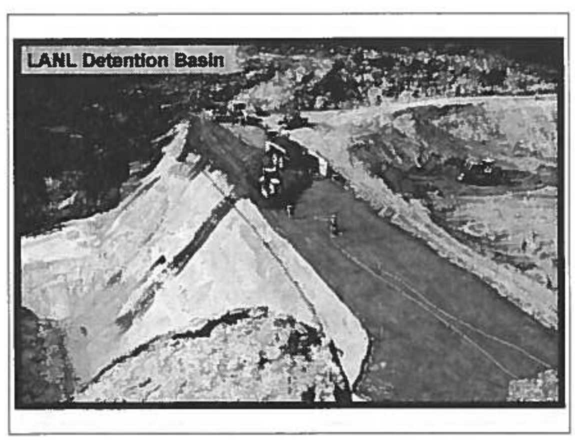

Road Protection

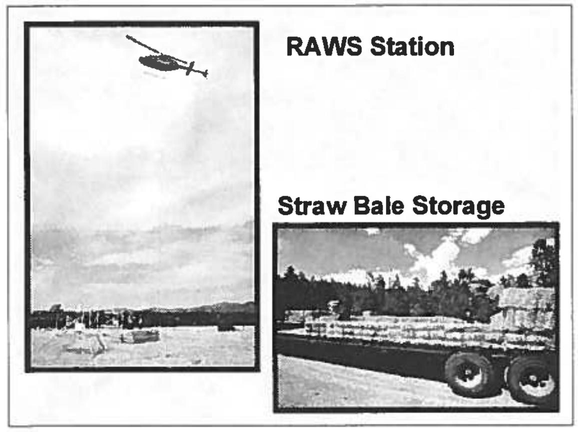

Abandoned Land Bridge
strengthened earth dam

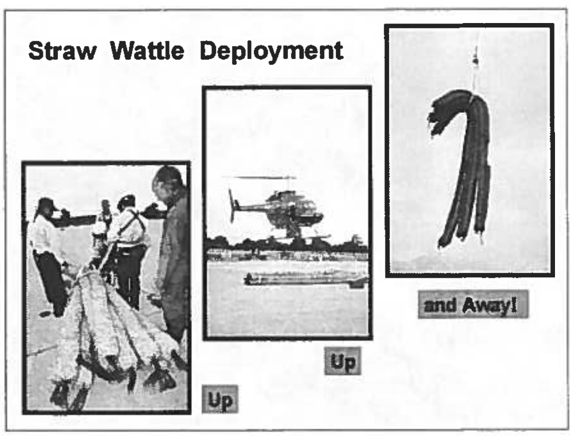

Drain and Armor
Los Alamos Canyon Reservoir

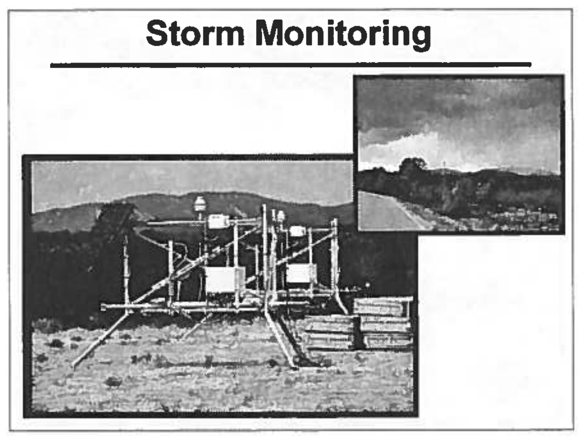

Drain and Armor Los Alamos Canyon Reservoir


Diamond Fill Bridge
resized culvert from
18-inches to 7-feet


LANL Detention Basin







BAER "GRANDE"

- Most Expensive BAER Planning Incident
- Largest BAER Team
- First BAER-MAC Group
- First BAER Incident to Outspend Suppression
- First Large-Scale Use of Crews for BAER

Large Incidents - Lessons Learned

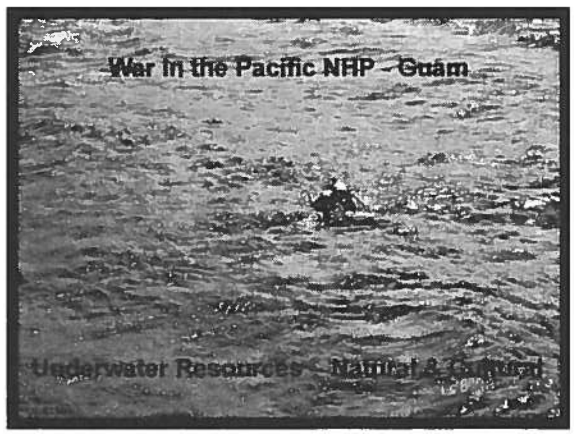
- Use of BAER MAC Group
- BAER Assists IMT with Suppression Rehab
- Consistent Policy & Handbook
- Standing BAER Teams

Large Incidents - Lessons Learned

- Integration of BAER Team with IMT
- General Agreement
- Cooperation, Communication, Coordination

All Risk Response

- Super-Typhoon Paka - WAPA
- Molycorp Releases Clean-Up - MOJA
- New River Gorge Floods - NERI



New River Gorge National Scenic River

Emergency Rehabilitation Issues

- **Protection of life, public safety, property, and critical cultural and natural resources.**
- **Cultural and natural resource values impacted by flooding, slides, erosion, or debris flows.**
- **Facilities, roads, trails, or other improvements impacted by flooding, slides, erosion, or debris flows.**
- **Assessment of watershed stability relating to the protection of human life, property, and critical cultural and natural resources.**
- **Coordination of Emergency Rehabilitation treatments.**
- **Implementation of treatments in a timely manner.**
- **Rehabilitation requirements established by Federal law, policies, and relevant agency resource management mandates.**

RAT Team

Interdisciplinary

- **Hydrologist**
- **Geologist**
- **Geomorphologist**
- **Historical Architect**
- **Buildings & Grounds**
- **Cultural Resource Specialist**
- **Water Quality Specialist**
- **Aquatic Ecologist**
- **Biologist**
- **Restoration Specialist**
- **GIS Specialist**
- **Roads & Trails**
- **Computer/Doc Specialist**
- **Team Leader**

Cultural Resources Discovered

Roads Eroded Away

Bridge Stabilization Begins

Recommendations

- Evaluate property acquisition options in hazardous locations.
- Evaluate options for removing park infrastructure and private residences from hazardous locations.
- Monitor road, trails and strip benches during high runoff events.

National Park Service
USGS science for a changing world
USDA
US Army Corps of Engineers
NRCS Natural Resources Conservation Service
EPA United States Environmental Protection Agency
U.S. Department of Transportation Federal Highway Administration

Cooperation, Communication, Coordination

West Virginia DNR
DEP West Virginia Department of Environmental Protection
Babcock State Park

All Risk Response

- Identify Issues
- Identify Resources at Risk
- Identify Disciplines
- Pre-plan Report Format
- Identify Funding Strategy
- Conduct Reconnaissance
- Conduct Briefings

All Risk Response cont.

- Prepare Specifications & Assessments
- Review with Team and Agency
- Present Emergency Stabilization and Rehabilitation Plan

Emergency Stabilization & Rehabilitation
Interagency
BAER
Team
Burned Area Emergency Response

Resource Advisor Pre-Incident Planning

- Identify Roles & Responsibilities of:
  - Superintendent, Fire Management Officer, Resource Advisor, Technical Specialists
- Identify & Map Park Resources
- Information Needs Identified & Procured
- Prepare Delegation of Authority:
  - Name Resource Advisor
  - Suppression Rehab Requirement

Resource Advisor Pre-Incident Planning (continued)

- Develop Incident Library of Park Planning Documents
- Preplan Treatment Strategies & Locate Equipment/Material Suppliers
- Compile Resource Contact List (technical specialists, agency contacts, neighbors, Tribal Councils, etc.)
- Prepare Cooperative Agreements
- Allow Staff Time & Budget for Pre-Incident Planning

Resource Advisor Pre-Incident Planning (continued)

- Complete Preseason Physical Fitness Test and Refresher and Obtain Red Card Courses:
  - *I-100 Introduction to ICS
  - *S-110 Wildland Fire Suppression Orientation for Non-Operations Personnel
  - *Standards for Survival
  - *Fitness Level of Light Duty
- Notify FMO and Dispatch, if Necessary
- Prepare Resource Advisor Kit

Resource Advisor Pre-Incident Planning (continued)

- Resource Advisor Kit:
  - Office Supplies: laptop, printer, note pad, file folders, forms (Unit Log, Division Assignment List, etc.), etc.
  - Personal Gear: Personal Protective Equipment (PPE), compass, camera, radio, GPS, binoculars, fireline handbook, etc.

Resource Advisor Incident Planning

- Named Resource Advisor in Delegation of Authority
- Identify Resources at Risk
- Gather Resource Information
- Participate in Incident Planning Activities (attend planning/operation meetings, develop rapport with IMT)
- Monitor Resource Impacts, Keep IMT and Park Superintendent Advised of Resources at Risk

Resource Advisor Incident Planning

- Determine Need for Potential Emergency Stabilization of Fire Effects and Level of Complexity to Conduct Assessment
- Identify Specialists Needed to Conduct Assessment (contact Regional BAER Coordinator for assistance)
- Resource Order Specialists or BAER Team
- Coordinate Resource Order with IMT and Park Superintendent

Resource Advisor Incident Planning

- Involve Media/Public as Appropriate through IMP/Park
- Conduct Orientation to Resource Specialists/BAER Team (fire, resources at risk, IMT, resources available, resource objectives)
- Conduct Suppression Impact Inventory and Resource Assessment
- Prepare Suppression Rehab Specifications

Resource Advisor
Incident Planning

- Implement/Coordinate/Oversee Suppression Rehab Specifications
- Prepare Emergency Stabilization and Rehabilitation Specifications
- Initiate Compliance Consultation (SHPO, THPO, USFWS, etc.)
- Coordinate Contracts, Purchases, Agreements, etc.:
  - *for Suppression Rehab with Finance
  - *for Emergency Stabilization with Contracting Officer at Park

Resource Advisor
Incident Planning

- Attend Daily Briefings (Operations, Planning, BAER Team)
- Prepare BAER Plan for Submission
- Prepare Documentation for Compliance Requirements (NEPA, NHPA, etc.)
- Conduct Park Briefing of BAER Plan (assessments, treatment recommendations, budget, maps, compliance, and supporting documentation)
- Ensure Recommendations Meet Park Objectives

Resource Advisor
Incident Planning

- Submit BAER Plan for Review and Approval through Park Superintendent
- Organize Assessment and Compliance Documentation
- Release Specialists/BAER Team

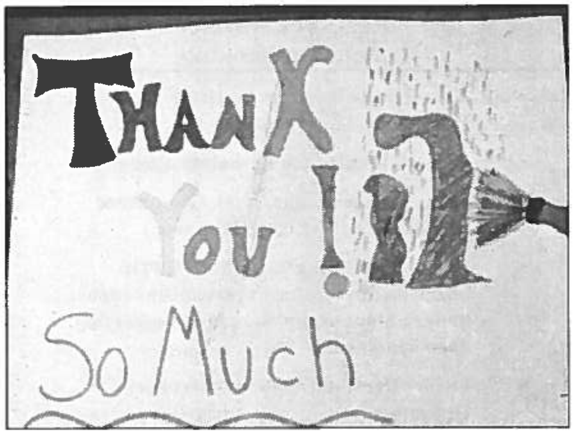
Resource Advisor
Emergency Stabilization Treatment Implementation

- Track BAER Plan Review and Approval Progress
- Conduct Transition from Assessment to Treatment Implementation
- Involve Media/Public as Appropriate through Park
- Amend Implementation Treatments
- Prepare Supplemental Treatment Requests

Resource Advisor
Emergency Stabilization Treatment Implementation

- Track Financial Documentation
- Conduct Maintenance and Monitoring of Treatments
- Prepare Annual Monitoring Reports for Submission to Approval Authority
- Compile Project Documentation
- Prepare Final Accomplishment Report for Approval Authority

Thanks !



INTERAGENCY
Emergency Stabilization & Rehabilitation
BAER
Burned Area Emergency Response
TEAM

INTERAGENCY
Emergency Stabilization & Rehabilitation
BAER
Burned Area Emergency Response
TEAM

RESOURCES CHECKLIST
Planning for Resource Protection

PRE-INCIDENT PLANNING:

___ **Roles/responsibilities identified:**

Resource Advisors, BAER Team Leader/member, technical specialists, Fire Management Officer, Superintendent, etc.

___ **Park resources identified (cultural, natural, infrastructure), mapped**

___ **Delegation of Authority – prepared identifying Resource Advisor, with rehabilitation requirement**

___ **Information needs identified and compiled into GIS**

___ **Agency planning documents available**

___ **Preplan treatment strategies and locate equipment/material suppliers**

___ **Compile resource contact list (BAER/emergency coordinators, technical specialists, other agency contacts, neighbors, Tribal Councils, etc.**

___ **Prepare cooperative agreements**

___ **Allow staff time and budget for pre-incident planning**

___

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RESOURCES CHECKLIST
Planning for Resource Protection

INCIDENT PLANNING:

___ Represent park for protection of resources to Incident Management Team

___ Identify resources at risk

___ Participate in incident planning activities (attend planning/operation meetings)

___ Determine need for rehabilitation and level of complexity to conduct BAER assessment

___ Identify BAER Team make-up

___ Mobilize BAER Team

___ Conduct orientation to fire, resources at risk, Incident Management Team, resources available to the BAER Team

___ Involve media and public as appropriate

___ Resource Advisor/BAER Team and ICS coordination during the incident

___ Resource Advisor/BAER Team coordination with the Agency Administrator during the incident

___ Identify Resource Advisor Implementation Leader to work with the BAER Team

___ Conduct resource assessment (assign staff specialists to assist BAER Team)

___ Conduct suppression impact inventory

___ Prepare suppression rehabilitation specifications

___ Implement/coordinate/oversee suppression rehabilitation specifications

___ Prepare emergency stabilization and rehabilitation specifications

INCIDENT PLANNING (continued):

- ___ Initiate compliance consultation (SHPO, USFWS, etc.)
- ___ Coordinate contracts, purchases, agreements, etc. with Finance/Budget and Contracting Officer
- ___ Attend BAER Team daily debriefings of assessment findings
- ___ Prescribe emergency stabilization and rehabilitation treatments
- ___ Prepare BAER Plan
- ___ Prepare documentation for compliance requirements (NEPA, NHPA, etc.)
- ___ Presentation of the BAER Plan (survey, assessments, treatment recommendations, budget, maps, compliance, and supporting documents)
- ___ Submit BAER Plan for review and approval
- ___ Organize/file BAER documentation
- ___ Release BAER Team
- ___
- ___
- ___
- ___
- ___
- ___
- ___
- ___
- ___

RESOURCE ADVISOR CHECKLIST
Planning for Resource Protection

EMERGENCY STABILIZATION TREATMENT IMPLEMENTATION:

___ Track BAER Plan review and approval progress

___ Conduct transition from assessment to treatment implementation

___ Involve media and public in emergency stabilization and rehabilitation progress as appropriate

___ Coordinate contracts, purchases, agreements, etc.

___ Amend implementation treatments

___ Prepare supplemental treatment requests

___ Track financial documentation

___ Prepare annual monitoring reports

___ Conduct maintenance and monitoring of treatments

___ Publish/distribute stabilization/rehabilitation treatment successes/failures

___ Compile rehabilitation documentation and finalize files

___ Prepare final Accomplishment Report

___

___

___

___

___

___

___

BURNED AREA EMERGENCY STABILIZATION & REHABILITATION
National Contacts

For information about the policy, Interagency BAER Guide Handbook (e-book), Field Guide (draft), and the National Interagency BAER Teams see the following websites:

BIA: **http://www.fire.nps.gov/bia/BAER/baer.htm**

USFS: **http://www.fs.fed.us/biology/watershed/burnareas**

USFWS: **http://fire.r9.fws.gov/ifcc/rehab/links.htm**

NATIONAL BAER COORDINATORS:

Bureau of Indian Affairs
Andy Bellcourt
3833 S. Development Ave.
Boise, ID 83705
208-387-5372
208-387-5581 (fax)
andrew_bellcourt@nifc.gov

Bureau of Land Management
Jack Hamby
1849 C St., NW (201LS)
Washington, DC 20240-9998
202-452-7747
202-653-5279 (fax)
jack_hamby@blm.gov

National Park Service
Steve Botti
3833 S. Development Ave.
Boise, ID 83705
208-387-5210
208-3875250 (fax)
stephen_botti@nps.gov

US Fish & Wildlife Service
Bill Leenhouts
3833 S. Development Ave.
Boise, ID 83705
208-387-5584
208-387-5568 (fax)
bill_leenhouts@fws.gov

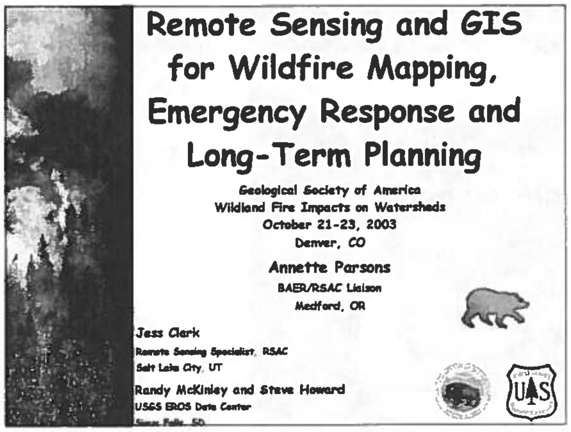
DOI IOS
Wally Josephson
1849 C St. NW, Stop 3060
Washington, DC 20240
202-606-3053
202-205-1599 (fax)
202-746-6327c
wally_josephson@ios.doi.gov

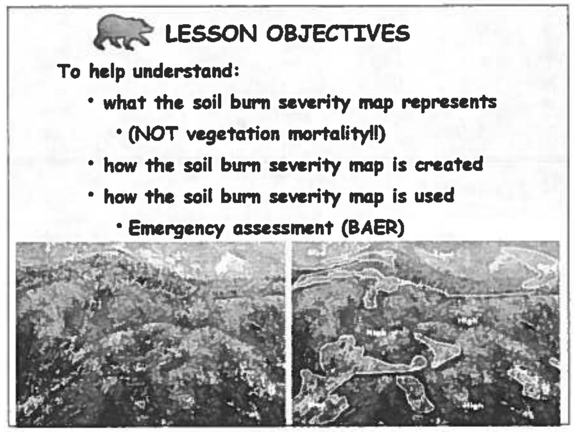
US Forest Service
Meredith Webster
201 14th Street SW
Washington, DC 20024
202-205-0804
202-205-1599 (fax)
mmwebster@fs.fed.us

NATIONAL INTERAGENCY BAER TEAM LEADERS:

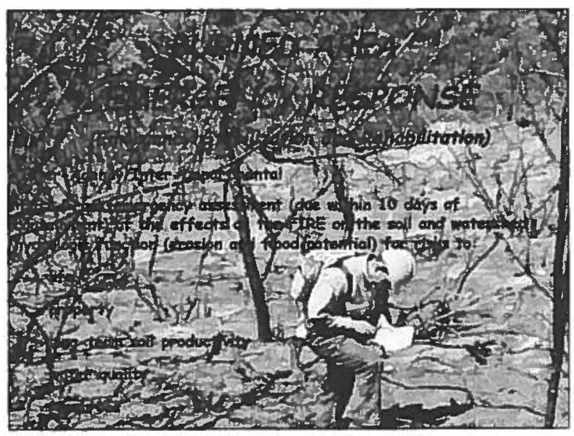
North Team
Erv Gasser
NPS – Columbia Cascades SO
909 First Ave.
Seattle, WA 98104
206-220-4263
206-220-4160 (fax)
erv_gasser@nps.gov

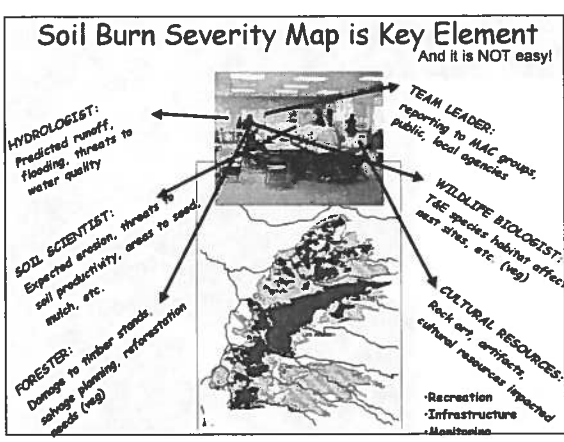
South Team
Dave Smith
USFWS – Hanford Reach NM
3250 Port of Benton Blvd.
Richland, WA 99352
509-371-1801
509-357-0196 (fax)
david_n_smith@fws.gov

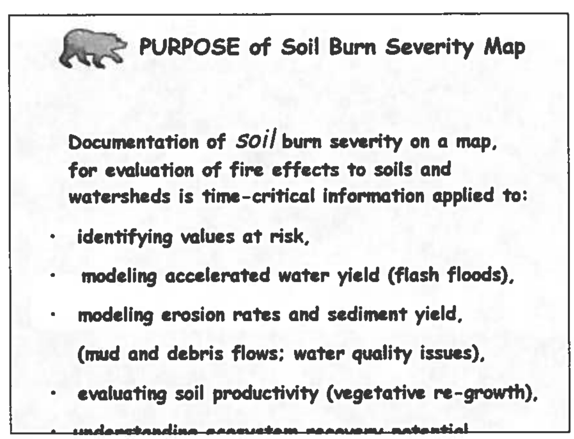

Remote Sensing and GIS for Wildfire Mapping, Emergency Response and Long-Term Planning
Geological Society of America
Wildland Fire Impacts on Watersheds
October 21-23, 2003
Denver, CO
Annette Parsons
BAER/RSAC Liaison
Medford, OR
Jess Clark
Remote Sensing Specialist, RSAC
Salt Lake City, UT
Randy McKinley and Steve Howard
USGS EROS Data Center

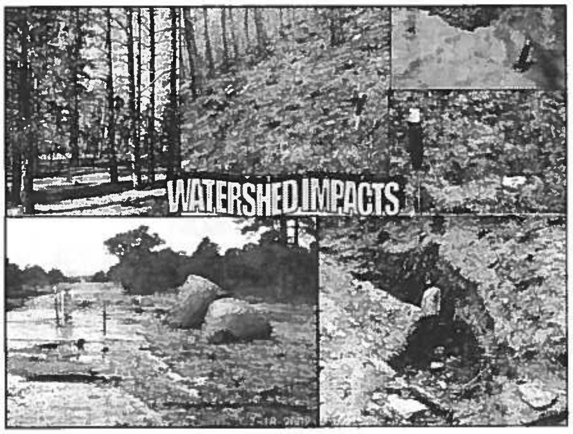

LESSON OBJECTIVES
To help understand:
• what the soil burn severity map represents
• (NOT vegetation mortality!!)
• how the soil burn severity map is created
• how the soil burn severity map is used
• Emergency assessment (BAER)

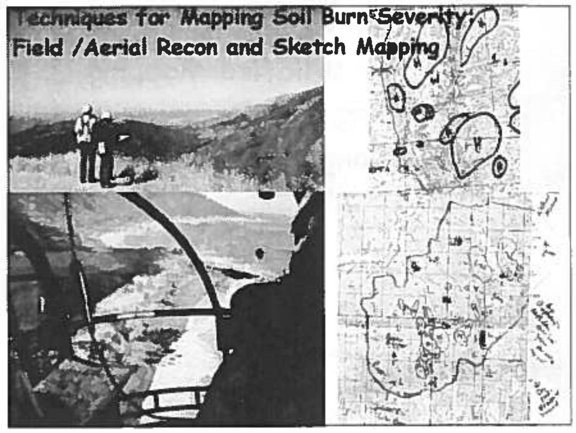

WHAT IS BAER?

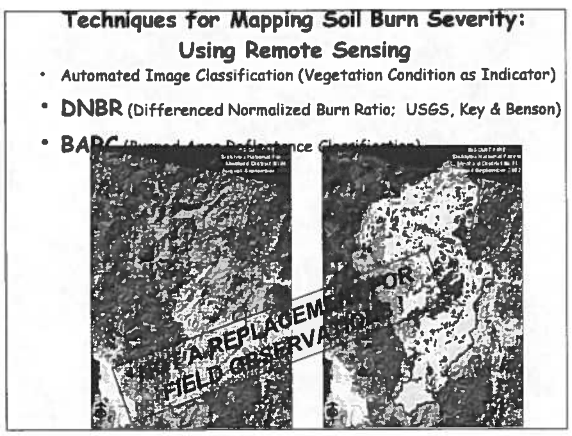


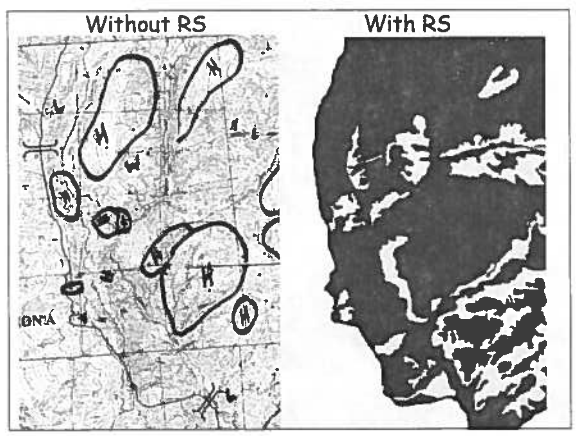

Soil Burn Severity Map is Key Element
And it is NOT easy!
HYDROLOGIST: Predicted runoff, flooding, threats to water quality
TEAM LEADER: reporting to MAC groups, public, local agencies
SOIL SCIENTIST: Expected erosion, threats to soil productivity, areas to seed, mulch, etc.
WILDLIFE BIOLOGIST: T&E species habitat affected, nest sites, etc. (veg)
FORESTER: Damage to timber stands, salvage planning, reforestation needs (veg)
CULTURAL RESOURCES: Rock art, artifacts, cultural resources impacted
·Recreation
·Infrastructure

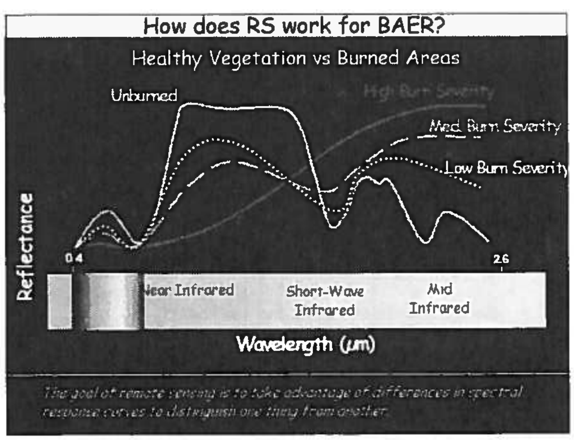

PURPOSE of Soil Burn Severity Map
Documentation of soil burn severity on a map, for evaluation of fire effects to soils and watersheds is time-critical information applied to:
• identifying values at risk,
• modeling accelerated water yield (flash floods),
• modeling erosion rates and sediment yield, (mud and debris flows; water quality issues),
• evaluating soil productivity (vegetative re-growth),


WATERSHED IMPACTS

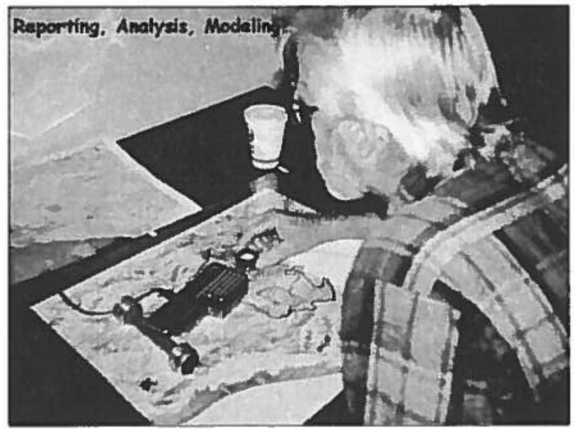

Techniques for Mapping Soil Burn Severity:
Field /Aerial Recon and Sketch Mapping

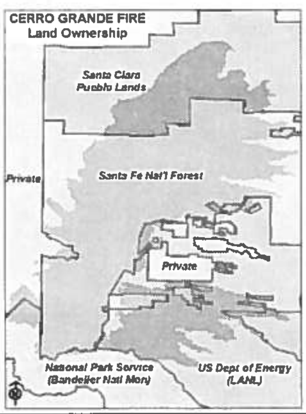

Techniques for Mapping Soil Burn Severity:
Using Remote Sensing
• Automated Image Classification (Vegetation Condition as Indicator)
• DNBR (Differenced Normalized Burn Ratio; USGS, Key & Benson)
• BA


Without RS
With RS


How does RS work for BAER?
Healthy Vegetation vs Burned Areas
Unburned
High Burn Severity
Med. Burn Severity
Low Burn Severity
Reflectance
0.4
2.6
Near Infrared
Short-Wave Infrared
Mid Infrared
Wavelength (µm)
The goal of remote sensing is to take advantage of differences in spectral response curves to distinguish one thing from another.


NOT A REPLACEMENT FOR FIELD OBSERVATIONS !!
Cerro Grande Fire
May 2000

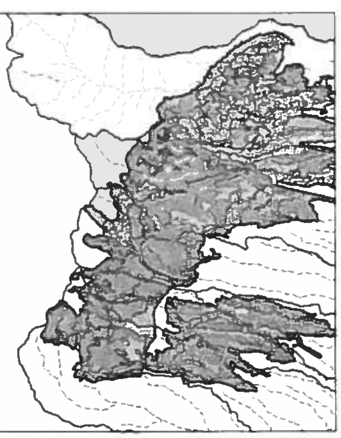




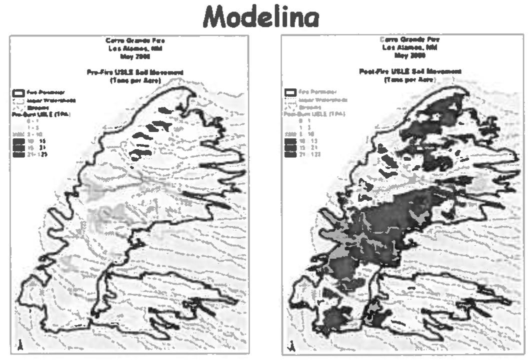
OWNERSHIP	ACRES
DOE	7373
USFS	25628
Indian Lands	6967
NPS	827
Private	2060
TOTAL	42855

OWNERSHIP	BURN SEV	ACRES
Dept of Energy	High	200
	Low/Unb	6370
	Mod	811
Dept of Energy Total		7381
USFS	High	12325
	Low/Unb	12196
	Mod	1108
USFS Total		25630
Indian Lands	High	2047
	Low/Unb	3526
	Mod	1395
Indian Lands Total		6968
NPS	High	94
	Low/Unb	696
	Mod	39
NPS Total		828
Private	High	62
	Low/Unb	1781
	Mod	225
Private Total		2068
Grand Total		42875

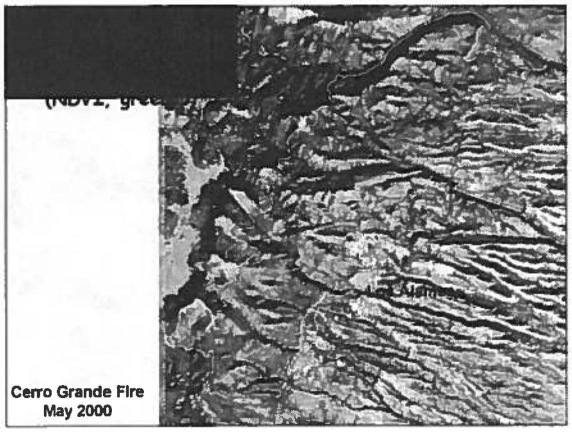
- FIRE PERIMETER
- OWNERSHIP
- BURN SEVERITY
- WATERSHEDS
- SOILS
- VEGETATION
- C[...]RAL FEATURES

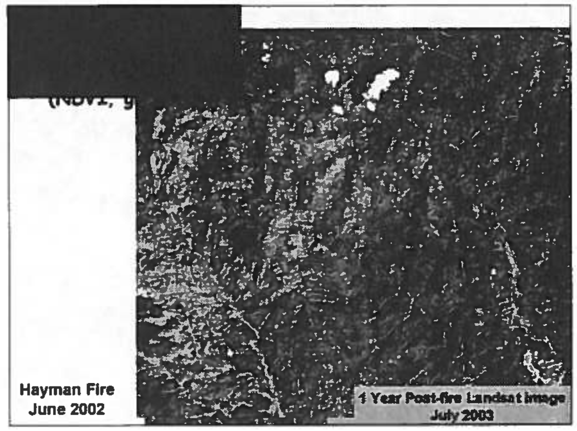


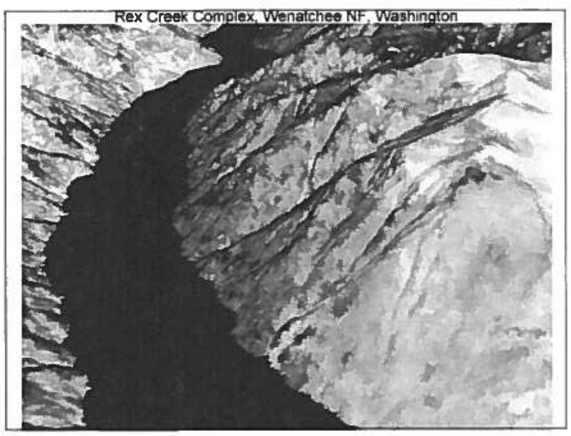
Erosion and Runoff Modeling



Weighted average tons/acre soil movement by sub-watershed, etc...


Cerro Grande Fire
May 2000


Hayman Fire
June 2002
1 Year Post-fire Landsat image
July 2003


Rex Creek Complex, Wenatchee NF, Washington


All this technology takes EXTRA memory!

2-3

Landslide and Debris Flow Hazard Identification—Planning and Response Tools

Methods for Assessing for Post-Wildfire Debris-flow Hazards in the Intermountain West

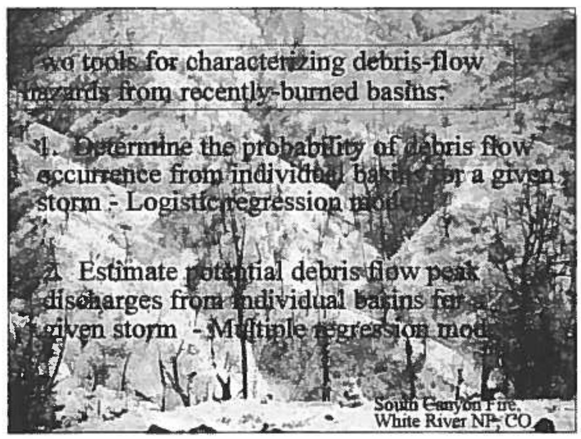
Sue Cannon, Joseph Gartner, Michael Rupert, Alan Rea, Steve Garcia, Chuck Parrett, Ken Pierce, Matt Trebish, Nicole Davis - U.S.G.S.
John Metesh and Katie MacDonald – M.B.M.&G.

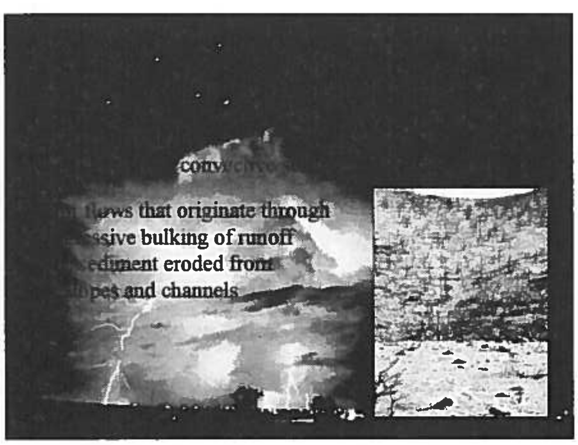
USGS
science for a changing world

Objective: Develop tools and methodologies that can be used to rapidly evaluate post-fire **debris- flow** hazards using readily available data

Application: Focus pre-fire treatments
Focus post-fire mitigation efforts

Approach: Monitoring, data collection
Statistical analyses
GIS-based evaluations

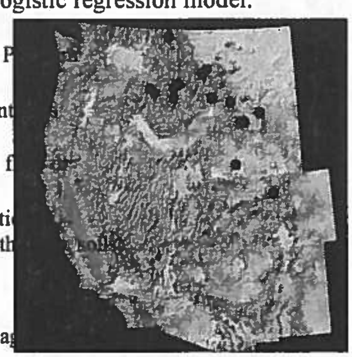




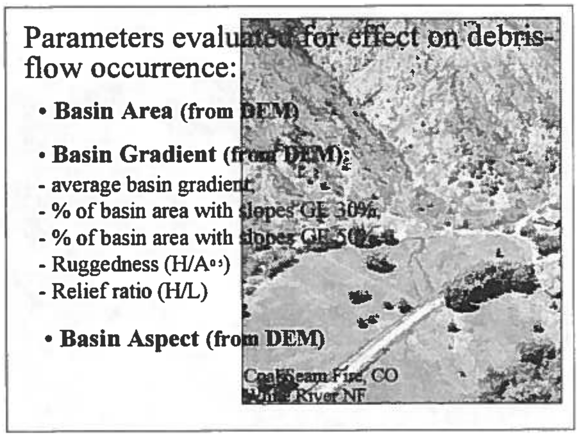
Tool #1: Estimate probability of debris-flow occurrence using logistic regression model:

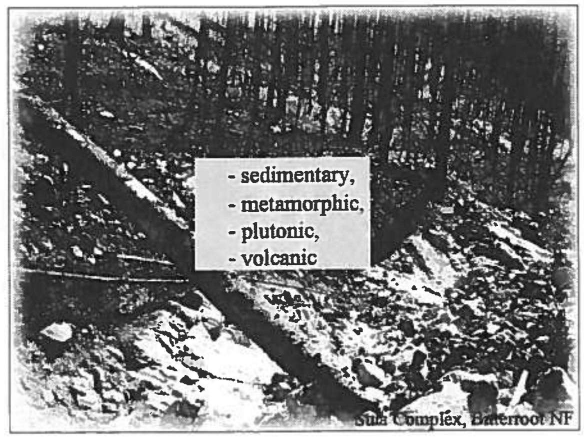
Post-Fire Monitoring P
(1994-2002+/-)

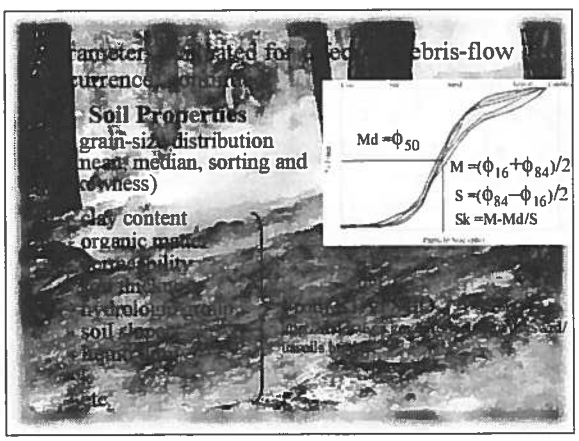
401 basins in 15 recent

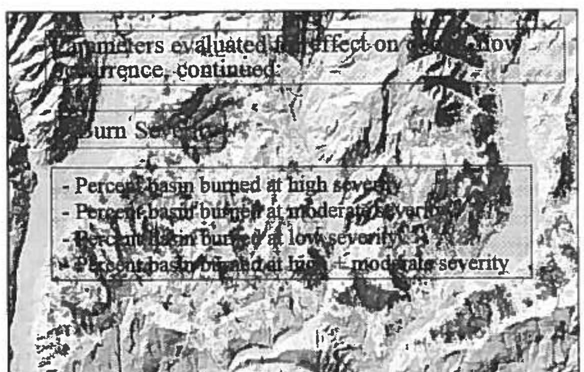


1. Response (debris f
flooding?)
2. Basin characteristi
(area, gradient, lith
3. Burn severity
4. Storm rainfall
(tipping bucket ga

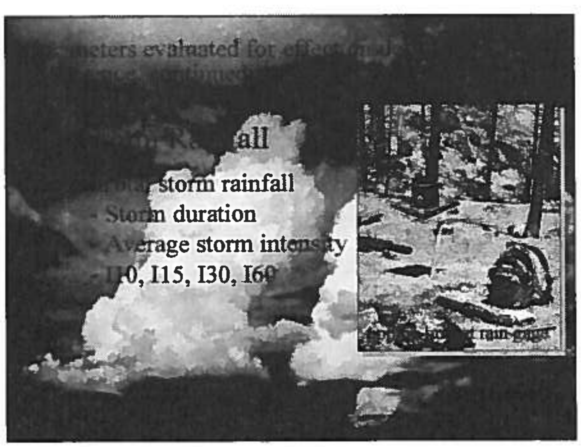


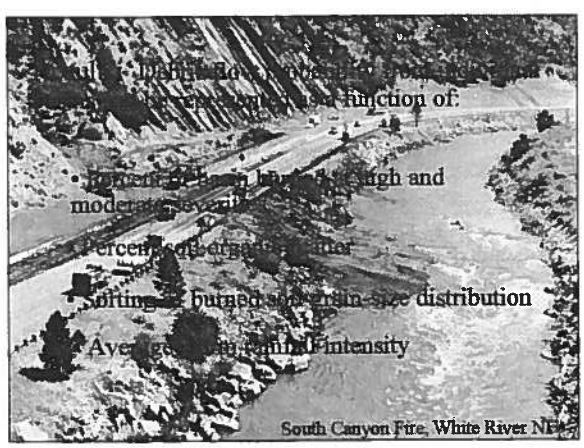






Map of Burn Severity: Missionary Ridge Fire, Durango, CO





The model:

$$\text{Probability of debris flow occurrence} = \frac{e^x}{1 + e^x}$$

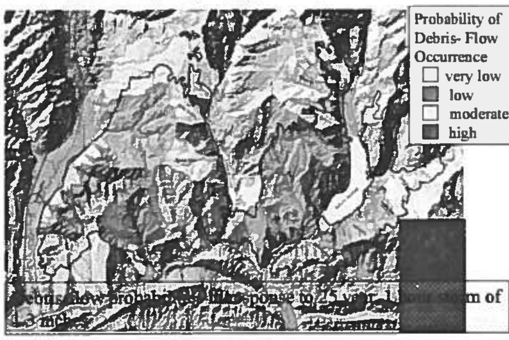
$$x = -3.0 + 8.0*A_b + 2.2*S + 0.06*I + 3.2*O - 5.2*(A_b*O)$$

and A_b = % of basin burned at high and moderate severity
S = sorting of burned soil grain-size distribution
I = storm rainfall intensity
O = % organic matter (by wt)

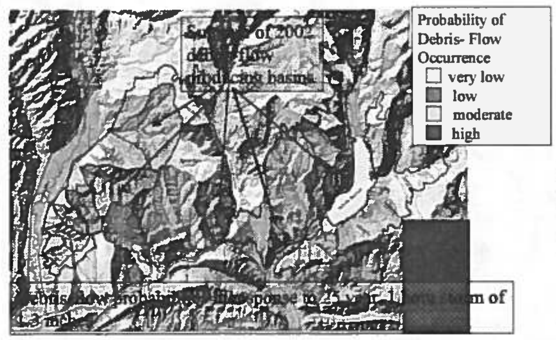
How to apply the model –
an example from the Missionary Ridge Fire:

1. Identify and delineate basins of interest (all impacted, above values at risk, etc.)
2. For each basin, extract measures of
   - area burned at high and moderate severity (from burn severity coverage)
   - percent soil organic matter (from STATSGO coverage)
   - sorting of burned soil grain-size distribution (from field sample)
3. For a storm of interest (average storm intensity), calculate P for each basin
4. Partition P into classes, and assign classification to basins

An example of application of the model –
Missionary Ridge Fire, Colorado



How well did this prediction do?
A bit of a test……



Tool #2: Estimate potential of debris-flow peak discharges using a multiple regression model:

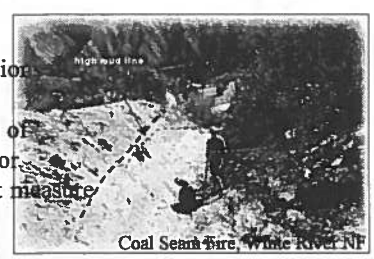
Post-Fire Monitoring
(1994-2002+/-)
and Literature Search

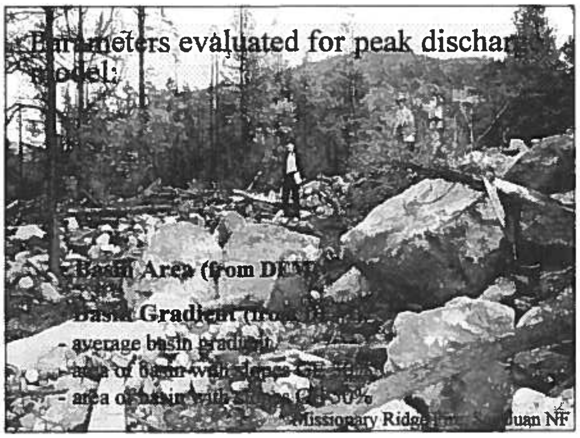
For 53 basins in 5 fi

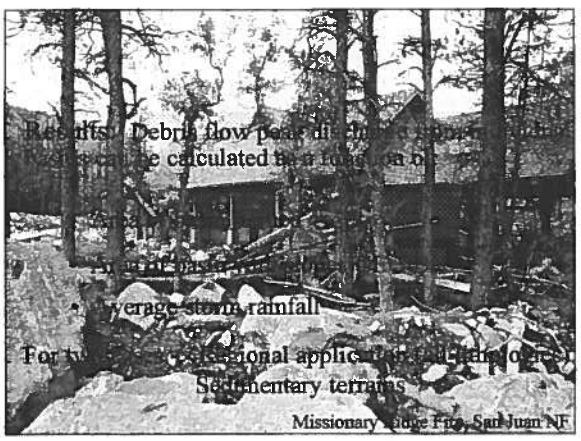
1. Estimates of debr
2. Basin characterist
   (area, gradient, li
3. Burn severity
4. Storm rainfall

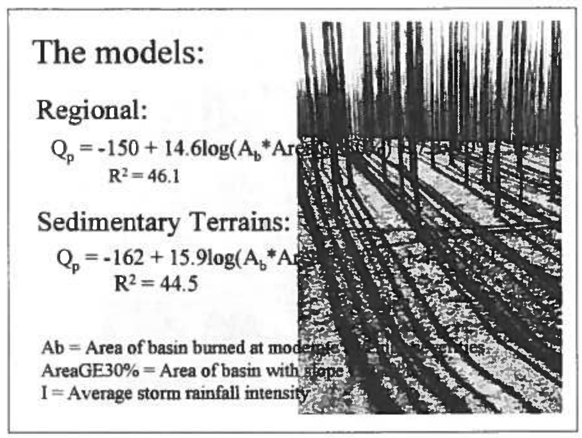
Estimates of debris-flow peak discharges

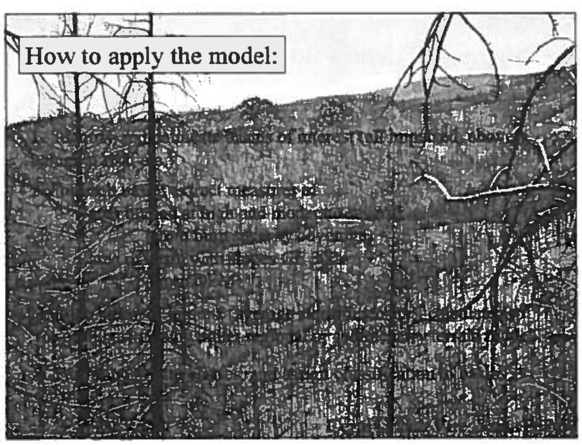
Based on
- Reconstructio
flow paths
- Assumption o
critical flow, o
- Independent
of velocity

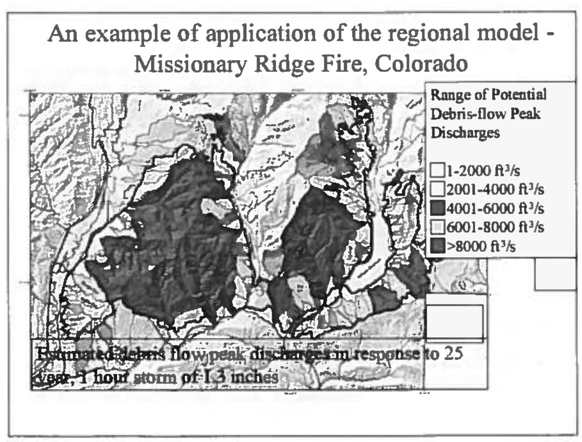


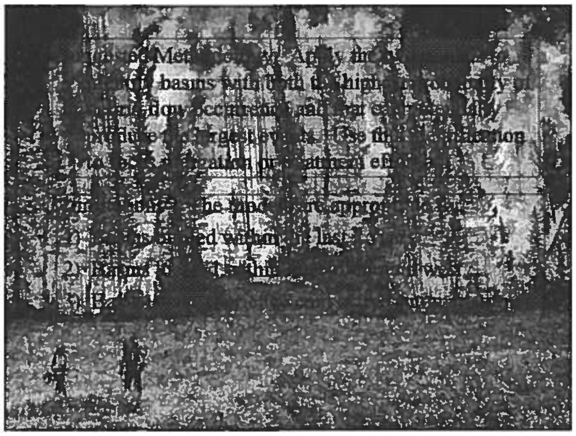

evaluated for peak discha
Basin Area (from DE
- average basin gradient
- area of basin with slopes GE 30%
Missionary Ridg


e calculated
average storm rainfall
Missionary Ridge Fire, San Juan NF

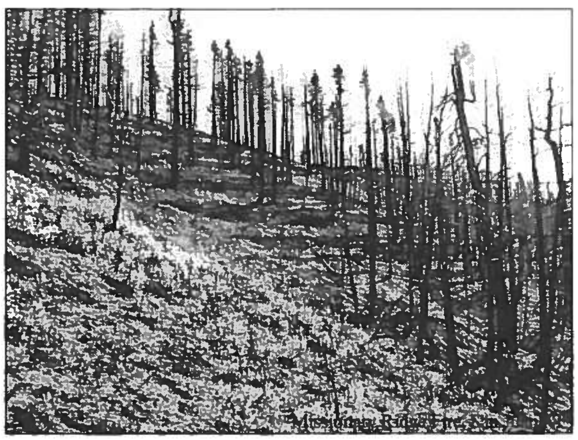

The models:
Regional:
Q_p = -150 + 14.6log(A_b*Ar
R^2 = 46.1
Sedimentary Terrains:
Q_p = -162 + 15.9log(A_b*A
R^2 = 44.5
Ab = Area of basin burned at mode
AreaGE30% = Area of basin with slope
I = Average storm rainfall intensity


How to apply the model:


An example of application of the regional model -
Missionary Ridge Fire, Colorado
Range of Potential Debris-flow Peak Discharges
1-2000 ft³/s
2001-4000 ft³/s
4001-6000 ft³/s
6001-8000 ft³/s
>8000 ft³/s
flow peak response to 25
storm of 1.3 inches




Where to find this stuff??



MODELS FOR LANDSLIDES AND DEBRIS FLOW HAZARD IDENTIFICATION: PLANING FOR SHORT & LONG TERM OBJECTIVES

ERKAN ISTANBULLUOGLU
M.I.T. civil and environmental engineering dept.
Cambridge, ma
Email: erkan@mit.edu

<u>**OUTLINE**</u>

- **Mapping landslide potential using Digital Elevation Models (DEMs): SINMAP model**
- **Mapping gully erosion potential using DEMs: PCI model**
- **Quantifying long term geomorphic consequences of wildfires: A complex iterative approach**

SINMAP Software

A Tool for Terrain Stability Mapping

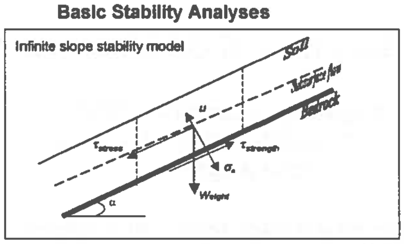
<u>**Developed By:**</u>
David Tarboton, Robert T. Pack and Craig Goodwin
Utah State University
•**Available from** http://www.engineering.usu.edu/dtarb/

INTRODUCTION

This seminar introduces a "**stability index**" mapping tool that will assist professionals in doing this work.

- Analytical methods used in SINMAP software
- Data input requirements and limitations
- Data output interpretation and limitations

Basic Stability Analyses



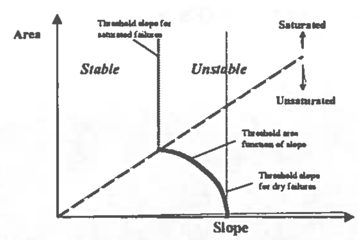
$$\text{Factor of Safety} = \frac{\text{Sum of Resisting Forces}}{\text{Sum of Driving Forces}} \qquad FS = \frac{\tau_{strength} + (\sigma_n - u)\tan\phi}{\tau_{stress}}$$

FS>1 : STABLE
FS<1 : UNSTABLE

<u>FS</u> ~ soil & root cohesion, *slope*, *drainage area*, recharge rate, soil hydraulic conductivity, soil depth....

Thresholds for Landsliding for ideal conditions:

Constant soil parameters and rainfall

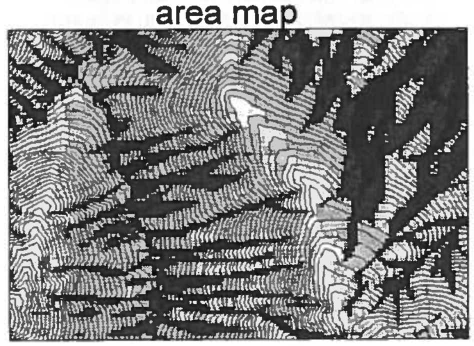


Saturation line gives the upslope area required to saturate a given slope gradient

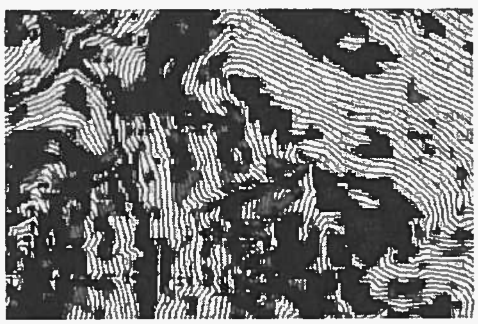
The SINMAP Formulation

- Based on Infinite Slope Stability Model
- Uses Grid DEM data format
- Spatial distributions rely on shallow subsurface groundwater flow convergence and topographic slope
- Parameter uncertainty incorporated through ranges of soil and hydrology parameters
- Is interactively calibrated
- ArcView © GIS based.

Example specific catchment area map



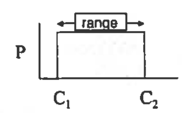
Example slope map



How Uncertainty is Handled

- Soil parameters are assumed to be uncertain and are modeled as having "Uniform Probability Distributions" with a specific range

– C ~ $U(C_1, C_2)$
– R/T ~ $U(x_1, x_2)$
– tan ø ~ $U(t_1, t_2)$



Produces a range of FS values (probability distribution) for a given point that has upslope area and slope

Stability Index SI

- If FS > 1*, SI = FS
- If FS < 1*, SI = Prob(FS > 1)

*(using most conservative end of each parameter range)

Stability Classes

tionClassPredicted StateParameter RangePossible Influence of FactorsNot ModeledSI > 1.5Stabl

Summary of SINMAP Inputs

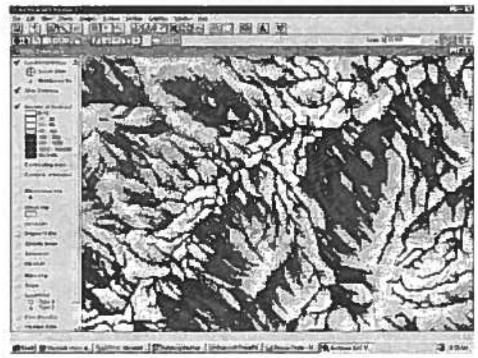
Topography (dictated by DEM)
a - specific catchment area
_ - slope angle

Soil Parameters (given as a range)
C - dimensionless cohesion
tan _- tan of soil internal friction angle
R/T - soil hydraulic parameter

Summary of SINMAP Outputs

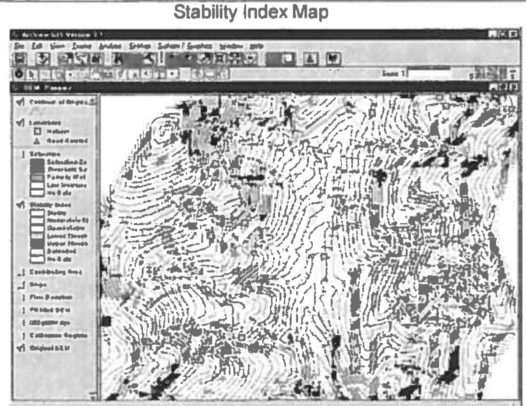
1. Specific Catchment Area Map
2. Stability Index Map
3. Soil Wetness Map
4. Calibration Plot
5. Statistical Tables

Specific Catchment Area Map

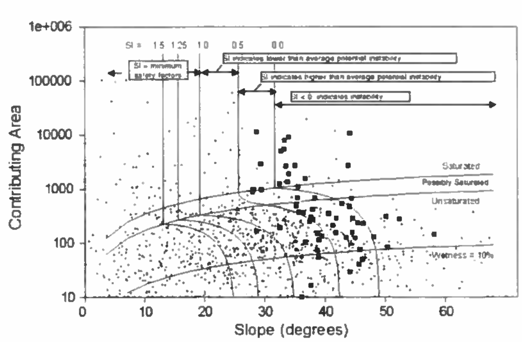


Soil Wetness Map

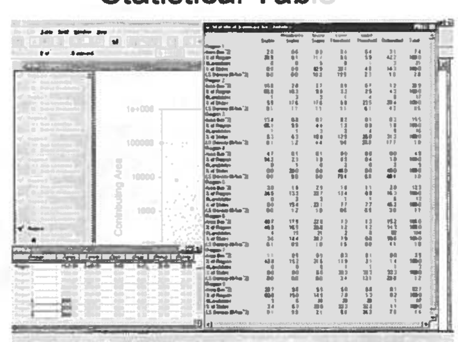
Stability Index Map



Calibration Plot



Statistical Table



Probabilistic Models for Quantifying Erosion Risks and Basin Sediment Yields

E. Istanbulluoglu, D. Tarboton, R.T. Pack, C. Luce

RELATED PAPERS:

Istanbulluoglu, E., D. G. Tarboton, R. T. Pack and C. Luce, 2002. A probabilistic Approach for Channel Initiation, *Water Resources Research*, 38(12), 1325, doi:1310.1029/2001WR000782.

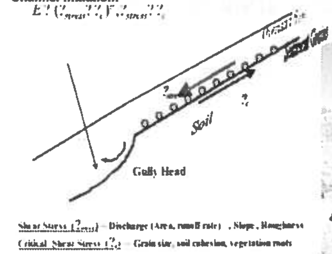
Istanbulluoglu, E., D. G. Tarboton, R. T. Pack and C. H. Luce, 2003. A Sediment Transport Model for Incision of Gullies On Steep Topography, *Water Resources Research*, 39(4), 1103, doi:10.1029/2002WR001467

Istanbulluoglu, E., D. G. Tarboton, R. T. Pack and C. H. Luce. Modeling of the Interactions Between Forest Vegetation, Disturbances and Sediment Yields, *JGR-Earth Surface*, (In minor revision).

web.mit.edu/erkan/Public/Papers

PROBABILISTIC MODEL FOR CHANNEL INITIATION

Channel Initiation:



Channel incises when overland flow shear stress is greater than critical shear stress

Area-Slope Threshold for Channel Initiation

$$\tau_{stress} \ge \tau_c \quad \text{OR} \quad aS^\alpha \ge C$$

where,

$$C \propto (d_{50}; n_a; r)$$

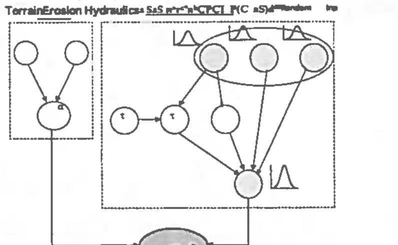
Median sediment size of hillslope material

Additional surface roughness

Runoff rate

The PCI Theory

- Hydraulic and hydrologic hillslope properties are treated as random variables with spatially homogenous probability distributions.



$$PCI^{*} = P(C \le aS^\alpha) = \int_0^{aS^\alpha} f_C(C)dC$$

Field Area

North Fork of the Boise river

- Mountainous forested basin
- V-shaped valleys
- Episodic hollow evacuation
- Burned by a wildfire in 1995
- Gullied due to a convective storm in 1996

Field observations

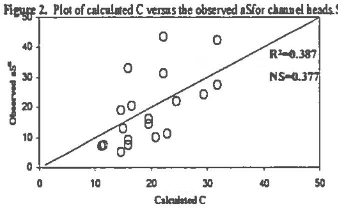
- Channel head locations identified
- Local slopes estimated in the field.
- Contributing areas were derived from the DEM.
- Sediment size samples were collected just above the headcuts.
- Gully cross-section areas measured.

WHY DO WE NEED A PROBABILISTIC APPROACH?

Point-wise Comparison of the Observed aS^{α} and Calculated C at Channel Heads

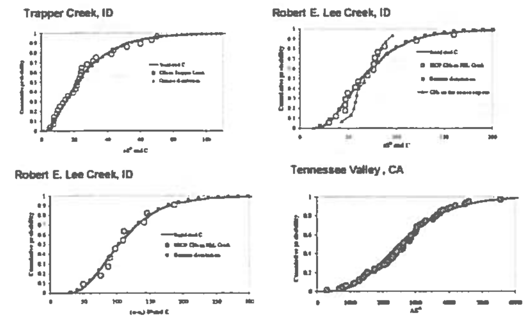
- The theory developed suggested that variation in d_{50}, n_s and r is responsible for the variation in aS^{α} at channel heads. We used the measured values of d_{50} to test the contribution of d_{50} to this variability. We set α=1.167, r = 35 mm/h, n_s= 0.052.

Figure 2. Plot of calculated C versus the observed aS for channel heads.



The regression R^2 and Nash-Sutcliff (NS) error measure indicate that about 40% of the variability in observed aS^{α} may be attributed to d_{50}.

MODEL TEST: COMPARISON OF OBSERVED AND SIMULATED PROBABILITY DISTRIBUTIONS OF AREA-SLOPE THRESHOLDS



PCI Maps: Effects of Wildfire on Erosion

Combining erosion initiation and sediment transport

Sediment transport theory

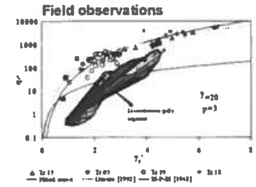
$$q_r = \frac{q_s(=V_s/TW_r)}{\sqrt{g(s-1)d^3}} = \frac{V_s}{T\chi_s(rA)^{m_s}S^{n_s}\sqrt{g(s-1)d^3}}$$

$$T_* = \frac{\tau}{\rho g(s-1)d} = \frac{\chi_t(rA)^{m_t}S^{n_t}}{\rho g(s-1)d}$$

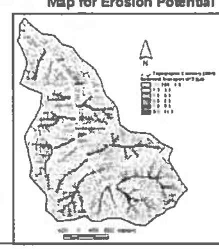
Probabilistic channel initiation

$$PCI^{*} = P(C \le aS^{\alpha}) = \int_0^{aS^{\alpha}} f_C(C)dC$$

Field observations



Map for Erosion Potential



SUMMARY FOR THE PCI MODEL

- Maps the potential for gully erosion
- Based on area-slope threshold formulation that is a function of sediment size, runoff rate and surface roughness
- Uses Grid DEM data format
- <u>Spatial distributions</u> rely on drainage area and topographic slope calculated from DEMs.
- <u>Parameter uncertainty</u> incorporated through ranges or probability distributions of runoff rate, roughness and median sediment size
- Can be interactively calibrated
- Code is in Scilab

MORE COMPLEX MODELS FOR MORE COMPLEX QUESTIONS

Examples of complex questions;

• How do forest cover conditions influence the Frequency & Magnitude of Sediment Yields

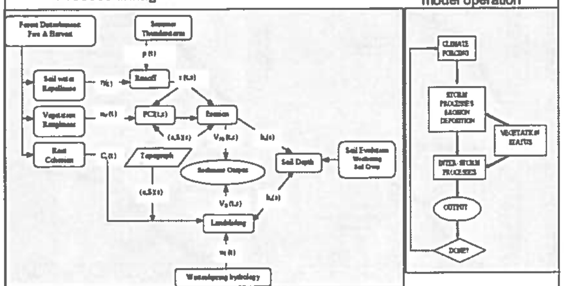
•How do natural and human disturbances alter the long term Sediment Delivery Regime

• How do biologic and aquatic communities respond to disturbances

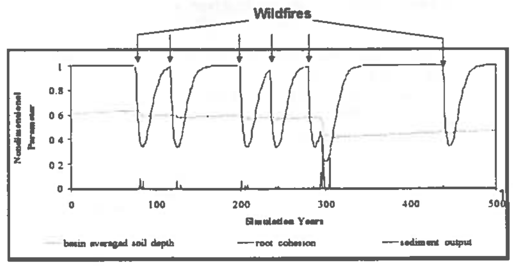
MODELING SURFACE PROCESSES OVER A LONGER TIME SCALE

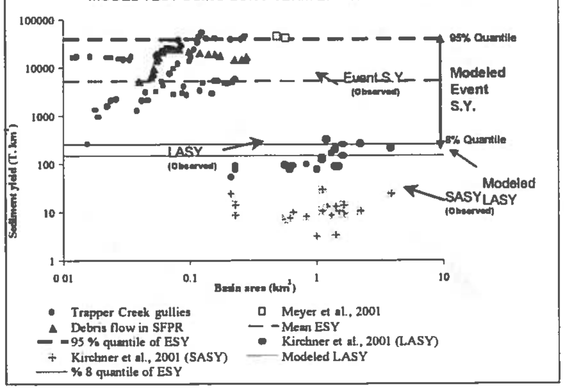
Process linkages

Flow chart for model operation

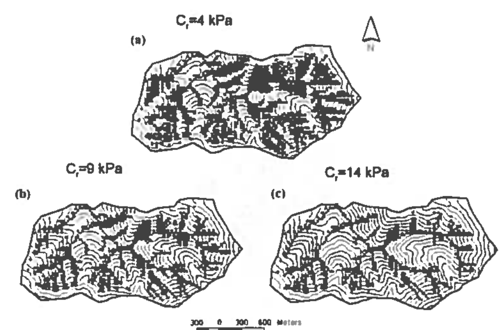


BASIN RESPONSE TO WILDFIRES

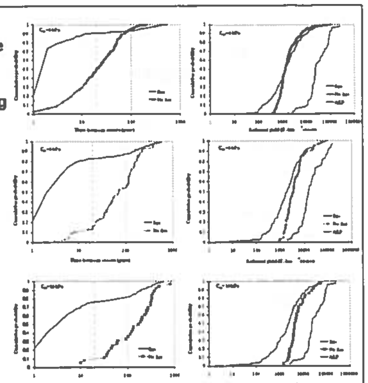




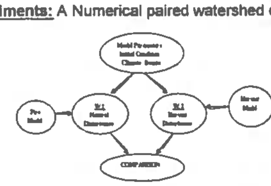
SPATIAL EXTENT OF EROSION UNDER FOREST FIRE DISTURBANCES: Simulation for 7000 years

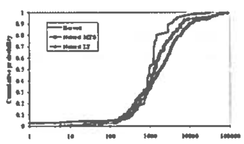


More complex results: **Sediment output regime of a basin for different root cohesion values under stochastic forcing of fires, thunderstorms and winter recharge**



Complex Experiments: A Numerical paired watershed experiment





Statistical parameter	Sediment yield (T km²/event)		
	Harvest	Natural	Long term
Mean	1,814	3,964	5,363
St. Deviation	3466	9749	11640
Skewness	6.74	4.62	4.34
q=0.05	110	175	164
q=0.95	4,900	15,048	30,960

MTS: management time scale
LT: long term

SUMMARY

- Some landuse and forest management decisions may require considering the interactions of complex processes over longer time scales
- Decisions based on short term observations may be misleading
- There may be a "greater risk" than predicted

2-4

Surface Erosion Hazard Identification—Planning and Response Tools

2-5

Putting It All Together: Upper South Platte Watershed Case Study

MUD FLOODS AND MUDFLOW MODELING

BAILEY, Peggy, Tetra Tech, Inc, P.O. Box 1659, Breckenridge, CO 80424, peggy.bailey@ttisg.com.

ABSTRACT: In the summer of 2002, fires burned thousands of acres of forested areas in Colorado. Physical evidence indicates flood events following fires are a relatively frequent occurrence, representing the joint probability between the recurrence of fires and subsequent rainfall (USGS). Rainfall events that generate very little runoff on adjacent unburned watersheds, have the potential to generate large volumes of fire-related mud floods and mudflows. Fire-related sedimentation and rainfall events can produce a wide range of concentrations from slightly diluted to hyperconcentrated or slurry-type mixtures. In the case of extreme fire events, such as Storm King Mountain in Glenwood Springs, Colorado, the potential volume of sediment loading can be severe resulting in destructive mudflows.

FLO-2D is a two-dimensional flood routing model with both channel and unconfined overland flow components. It is a finite difference numerical model that uses a square system of grid elements overlaid on the topographic mapping.

This poster presents the application of FLO-2D on a watershed in Glenwood Springs, Colorado, that experienced a minor burn. Subsequent thunderstorms produced mud flows that impacted a downfan neighborhood. The modeling effort required the incorporation of developed portions of town including streets, houses and buildings; and the development of a mitigation plan. This paper will include comparisons of pre- and post-fire runoff modeling and examples of how to apply the model to mudflow control.

PLANNING FOR WILDLAND FIRE: OPPORTUNITIES AND CONSEQUENCES

BLACK, Anne E., MILLER, Carol, and LANDRES, Peter, Aldo Leopold Wilderness Research Institute, Rocky Mountain Rsch Station, P.O. Box 8089, Missoula, MT 59807, aeblack@fs.fed.us

Successful cost containment on large fires requires change at multiple levels of the fire management hierarchy. Key among these is the generation and use of information identifying when and where fire may assist in meeting management objectives – fuels-, fiscal- or resource-related.

Using currently available data and computer programs (e.g., FireFamily+, FlamMap, WEPP), we have developed and are refining a GIS-based process that quantifies, simultaneously, the potential risks and opportunities for use of fire across the landscape. Maps, digital data and reports produced during the process include: stand or landscape-based information on potential fire behavior under a variety of threshold fire weather conditions, fire effects on vegetation and erosion processes, fire effects on species' habitat and landscape structure, fire effects relative to the desired future or future vegetative or hydrological condition of the landscape, and annual or decadal probability of fire. The process is designed to be used by land managers in any type of agency: federal, state and non-governmental organizations.

Information produced may be used to guide fire management decisions from the long-range, broad-scale resource planning documents to the Wildland Fire Situation Analysis and Wildland Fire Implementation Plan. Information may be used to develop and assess feasibility of long-term resource targets, fire use zones, or to prioritize areas for WFU, prescribed fire or mechanical treatment. The process is also useful in helping managers and the public understands the trade-offs and consequences of alternative courses of action. When linked to cost data, it can help contain costs by identifying stands in which fire under particular conditions will result in a net benefit to the resource from those in which resources are 'at risk'. Armed with this information, Incident Commanders may be able to more efficiently allocate suppression forces.

This poster will present the conceptual design and results for several types of projects: long-range planning, fire management plan development, and endangered species consultations.

GREATER VANCOUVER REGIONAL DISTRICT'S WILDFIRE RISK MANAGEMENT SYSTEM

BONIN, Derek S., Policy & Planning, Greater Vancouver Regional District, 4330 Kingsway, Burnaby, BC V5H 4G8, Canada, dbonin@gvrd.bc.ca, BLACKWELL, Bruce A., BA Blackwell and Associates Ltd, 3087 Hoskins Road, North Vancouver, BC V7J 3B5, Canada, HAWKES, Brad, Pacific Forestry Centre, Canadian Forest Service, 506 West Burnside Road, Victoria, BC V8Z 1M5, Canada, OHLSON, Dan W., Compass Resource Mgnt Ltd, 2nd Floor 1260 Hamilton Street, Vancouver, BC V6B 2S8, Canada, and TAUDIN-CHABOT, Phil, Protection Branch, Ministry of Forests, 2100 Labieux Road, Nanaimo, BC V9T 6E9, Canada

Greater Vancouver Regional District began a collaborative project to develop a Wildfire Risk Management System as a result of a new Watershed Management Plan that is based upon a risk management approach. The Plan covers three municipal watersheds (Capilano, Seymour and Coquitlam) that provide drinking water for two million residents in southwestern British Columbia. Wildfire in these forested coastal watersheds can potentially impact water quality, public safety, property, and air quality values. Historically, these areas have been exposed to low frequency (300-600 years), stand replacement fires (Green and Blackwell 1999). Although the probability of wildfires within these watersheds is considered low, the consequences associated with these wildfires could impact both the watersheds and the adjacent interface communities.

The Wildfire Threat Rating System (Blackwell et. al. 2002, Hawkes and Beck 1997) incorporates attribute rating scales for fire risk, suppression capability, fire behavior and values at risk. This system enables managers to strategically design fire management strategies that vary from high probability-low consequence to low probability-high consequence across the landscape. Managers can adjust the attribute-rating scales to test a variety of scenarios with the objective to protect values and optimize the allocation of resources.

The application of this system will enhance GVRD's fire management program by developing fire management zones that are based upon variable levels of wildfire threat throughout the watersheds. The zones that reflect a greater threat will require a more intensive management effort, including: • incorporate fire management zones into fire preparedness plans and emergency response plans; • conduct a detailed wildfire risk assessment in zones with the greatest threat • operate additional weather monitoring stations to more accurately record the range of fire danger ratings; • coordinate the utilization of suppression resources and improve suppression capabilities in high risk areas; • assess community interface fuel loadings and implement fuel reduction practices; and • develop public awareness of the threat of wildfire and provide information to community education programs to minimize wildfire hazards.

EFFECTS OF WILDLAND FIRE ON STEEP,

MARTÍNEZ-HACKERT, Bettina and **BURSIK, Marcus Ivan**, Geology, SUNY at Buffalo, 876 Natural Science Complex, Buffalo, NY 14260-3050, mib@acsu.buffalo.edu

Wildland fire is a major factor in increased hillslope erosion. A high severity fire in particular destroys duff and tree trunks, and therefore has major effects not only on vegetation and wildlife but also on the soil erosion rate.

A field study was conducted in the San Francisco Volcanic Field, Arizona, on short-term hillslope degradation due to natural rainstorm events. The study was commenced just after the Hochdoerffer Hills fire of 1996, which was the largest fire in Arizona history at that time. The western flank of a 2.3 ma old extinct volcano composed of loose, scoriaceous clasts was burned. Data collected for the five years following burn reveal extremely large increases in erosion rate due to the destruction of the Ponderosa Pine forest. In the first years before the surface started to recover, the high severity burn areas were prone to intense erosion by raindrop impact and with increasing storm size, to overland flow. Measurements taken by splashboards reveal increased erosion rates of up to 11.7 t/ha/yr averaged over five years at midslopes (16.5 degree slope angle) and 24.0 t/ha/yr at upper midslopes (22 degrees) from a typical nonburn value of 1.72 t/ha/yr (10.5 degrees). Areas of medium and low severity burn showed a healthy recovery rate within the Ponderosa-Aspen fire cycle. Vegetation either recovered quickly (low severity) or fallen, browned pine needles provided a protective cover against raindrop impact transport (medium severity). Measurements of erosion rates for these environments ranged up to 5.73 t/ha/yr (10 degrees, medium severity burn).

Our data show that up to soil saturation, the high severity burned areas eroded two to four times faster than medium or low severity areas, and eroded an order of magnitude faster than unburned areas. These data are currently being used to test the GeoWEPP model on steep, burned hillslopes.

GEOCHEMICAL COMPARISON OF PRE- AND POST-WILDFIRE STREAM SEDIMENT AND WATER SAMPLES FROM DRAINAGES IMPACTED BY LARGE WILDFIRES OF 2000, CENTRAL IDAHO, USA

EPPINGER, Robert G.[1], BRIGGS, Paul H.[1], RIEFFENBERGER, Betsy[2], and VAN DORN, Carol[3], (1) U.S. Geol Survey, M.S. 973, Denver Federal Center, P.O. Box 25046, Denver, CO 80225-0046, eppinger@usgs.gov, (2) U.S. Forest Service, Salmon-Challis National Forest, Rural Route 2, Box 600, Salmon, ID 83467, (3) U.S. Forest Service, Santa Fe National Forest, PO Box 1689, Santa Fe, NM 87505

A baseline stream sediment and water geochemical study was undertaken in central Idaho in 1996, with the intent of providing a geochemical "snapshot" of the area as an aid to land managers. In 2000, much of the area was burned by the Clear Creek (> 206,000 acres) and Wilderness Complex (> 182,000 acres) wildfires. The area was re-sampled in 2001 to assess changes caused by the wildfires. In both studies, bedload sediment and water samples were collected during 3-week periods from rivers and major tributaries at 83 coincident sites along Panther Creek, the Middle Fork of the Salmon River, and a portion of the Main Salmon River. The area is underlain by Cretaceous Idaho Batholith granitoids, Proterozoic to Lower Paleozoic metasedimentary rocks, and lesser Eocene granitic plutons.

Nonparametric Wilcoxon matched pair and sign tests were used to determine statistically significant differences between the pre- and post-wildfire datasets. For sediments, no statistical differences (p-levels > 0.05) were found for Bi, Ca, Ce, CO3--, Fe, Ho, K, La, Nb, Nd, Sb, Te, Th, or Ti. However, post-wildfire sediments are generally higher (p-levels < 0.05) in Al, Ba, organic C, total C, Co, Cu, Li, Mg, Mn, Ni, Sc, V, and Zn. The higher C content in sediments is explained by abundant charcoal and ash in post-fire sediments. Higher post-fire concentrations of rock-forming elements (Al, Ba, Li, Mg, Mn, Ni, Sc, V, and Zn) are likely the result of addition of fine, immature, unwinnowed, sediment from debris flows and landslides derived from granitoids and black slates. In the Panther Creek basin, where stratabound Co-Cu deposits exist, increased concentrations of Co and Cu in post-fire sediments may be due to metalliferous soils entrained in the debris flow and landslide deposits. For water samples, no statistical differences (p-levels > 0.05) were found for the major ions Ca, F-, K, Mg, Na, and Si, indicating no significant changes between the two sampling periods. Waters from 1996 were variably higher in temperature, conductivity, alkalinity, and in concentrations of Ba, Cl-, Co, Cu, Mn, Ni, SO4--, U, V, and Zn (all with p-levels < 0.05). This suggests that waters collected in early June of 2001 were more dilute than those collected in mid-July of 1996. Effects of the wildfires on stream water compositions were not observed in samples collected 10 months later.

TOWER MOUNTAIN - GEOLOGIC LESSONS LEARNED FROM AN OPPORTUNISTIC FIRE

FERNS, M.L., Oregon Department of Geology and Mineral Industries, 1510 Campbell St, Baker City, OR 97814-3442, mark.ferns@state.or.us.

Tower Mountain is a large, late Oligocene rhyolite caldera complex that was first discovered following large fire in 1995 and 1996, when more than 50,000 acres were burnt following lightening storms. The resurgent core to the caldera formed a densely forested highlands flanked by more sparsely forested benchlands of onlapping Columbia

River Basalt lava flows. Striking contrasts exist in both geomorphology and forest cover between the heavily forested rhyolite core and the adjoining basalt lava flow plateau. Much of the caldera was covered by dense stands of lodgepole pine. Areas covered by the Columbia River Basalt tend to be dominated by open stands of ponderosa pine which follow more permeable intraflow breccias, forming layered ridges where grasslands are separated by tree bands. The lodgepole dominated rhyolites are high silica rocks with, for Oregon, unusually high levels of potassium. The ponderosa pine dominated basalts are low silica rocks with low to moderate levels of potassium. The rhyolite core has been subjected to some hydrothermal alteration, and is locally silicified and zeolitized. Alteration tends to harden the rhyolite, allowing it to weather into angular chips. Fortunately the clay component is low and few bedrock landslides occur within the caldera. Large bedrock landslides are most prevalent in 2 geologic settings: 1) where rhyolite ash-flows overlie tuffaceous sediments atop an eroded surface of impermeable pre-Tertiary rocks and 2) where Columbia River Basalt flows overlie an eroded surface of rhyolite.

EROSION FROM WATERSHEDS AFTER WILDFIRE: AN EVALUATION OF LOG EROSION BARRIERS

GARTNER, John, Department of Geography, Univ of Colorado, 260 UCB, Boulder, CO 80304, john.gartner@colorado.edu.

Log erosion barriers (also known as contour felled logs) are used increasingly to control runoff and erosion after wildfires, yet their effectiveness at different scales is poorly understood. Following the June 2000 Hi Meadow Fire near Bailey, Colorado, I examined erosion from 4 adjacent, severely burned watersheds (1 to 17 ha) to determine the effect of log erosion barriers (LEBs). Two watersheds were treated with LEBs, and two were not. I instrumented the watersheds with a total of twelve rainfall gages, 4 check dams at the bottom of the watersheds, and eight 10-meter long sediment traps on the hillslopes. I measured cross sectional area of rills on hillslopes above sediment traps and throughout the basins. The study period, June to October 2001, provided 117 mm of precipitation with a maximum intensity of 5.5 mm in 10 minutes. Six storms produced runoff. The resulting sediment yields approximated 910 and 700 g m^{-2} in the untreated watersheds and 630 and 120 g m^{-2} in the treated watersheds. One of the treated watersheds had significantly less sediment yield than the untreated watersheds; the other did not (alpha=0.05, paired t-test, d.f.=5). Sediment yields estimated from the hillslope traps averaged 283 (sd=358) and 46 (sd=52) g m^{-2} in the untreated and treated watersheds, respectively. More than 60% of sediment yield from the watersheds came from channels. The difference in mean sediment yield between treated and untreated hillslopes was not significant (p=0.17, paired t-test, d.f.=3). Rills, which were strongly correlated with sediment yield from hillslopes (r^2=0.82), were also similar in the treated and untreated watersheds. The results indicate that LEBs are not effective in reducing erosion from hillslopes. At the watershed scale, LEBs may reduce sediment yield; however, irrespective of treatment, most sediment came from channel erosion rather than hillslopes. This study can help guide future studies on runoff and erosion mitigation as well as cost-benefit analysis of post-fire rehabilitation.

CONDUCTING RESOURCE ASSESSMENTS, FOLLOWING WILDLAND FIRE, THAT MEET POLICY, MANAGEMENT, AND COMPLIANCE REQUIREMENTS

GASSER, Erv, Department of the Interior, National Park Service, NPS-CCSO-NR, 909 First Ave, Fl 5, Seattle, WA 98104, erv_gasser@nps.gov.

Fire effects to watersheds, vegetation, wildlife, threatened and endangered species, cultural resources, and infrastructure and potential post-fire processes may result in adverse community and/or ecological consequences. Therefore, the primary purpose for evaluating resources is to determine if the fire created emergency conditions, damaged resources during suppression, or impacted critical infrastructure. The emergency conditions can range from flash floods and debris flows to impacted threatened and endanger species and their habitat to damaged archeological sites to infrastructure damaged sufficiently to impact human health and safety. If emergency conditions are found then the magnitude and scope of the emergency is mapped and described, threats to human life,

property and critical natural and cultural resources are identified, and treatment prescriptions are developed to protect the values at risk. Watershed stabilization treatments include hillslope and channel treatments and help mitigate further damage to resources. Elements of the assessment provide the foundation for watershed rehabilitation and post-fire flood hazard emergency response planning. This series of posters (8) will cover the assessment process, compliance requirements, and the application of Burned Area Emergency Stabilization and Rehabilitation policy.

CONTRIBUTING FACTORS TO POST-FIRE FLOODING, RESULTING FROM HIGH-INTENSITY, SHORT-DURATION RAINFALL ON BURNED PONDEROSA PINE FORESTED WATERSHEDS WITHIN THE BLACK HILLS OF SOUTH DAKOTA

GOULD, Jessica J, Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, SD, jjgould@fs.fed.us.

Hydrologic modeling of post-fire flood flows was performed for the 83,500-acre Jasper Fire, located in the southern Black Hills of South Dakota. Due to the highly permeable nature of the underlying geology, and predominantly ephemeral or intermittent drainages, stream flow prior to the fire was almost nonexistent. Average annual precipitation ranges from 18 to 20 inches per year, most of which falls as rain from high-intensity thunderstorms in spring and early summer. The Burned Area Emergency Response (BAER) analysis concluded that there was no serious threat of flooding, based upon the lack of hydrophobic soil conditions and fire severity. The resulting severity classification, highly permeable geology, and lack of perennial water misled watershed specialists, and the magnitude of watershed response was drastically underestimated. No watershed treatments were recommended, nor were flood warnings issued to downstream property owners. Significant flooding did occur during the following summer's thunderstorm events. Flood magnitudes increased 100,000 percent over unburned conditions, caused significant damage to the local transportation network, and threatened several residences. The removal of duff, precipitation duration, and intensity were primary factors contributing to the flooding – soil hydrophobicity was not. The consumption of duff removed an agent by which water was stored in the soil allowing it to slowly infiltrate deeper and eventually into the underlying karst geology. Without duff, the water is not present on the landscape long enough to infiltrate and thus, underlying highly permeable geology does not significantly contribute to reducing post-fire floods. This same scenario also happened in New Mexico, following the Chino Well Fire. In light of the recent increase in wildfires burning in urban and developing areas, it is imperative to accurately map severity to reflect post-fire watershed conditions. It is equally important to recognize that although soil hydrophobicity is an important post-fire watershed characteristic, it is not the only contributor to post-fire flooding and the lack thereof does not equate to a low risk of flooding.

ENVIRONMENTAL IMPLICATIONS OF FIRE-RETARDANT CHEMICALS

LITTLE, Edward E, CALFEE, Robin D., and FINGER, Susan E, Ecology Branch, USGS Columbia Environmental Rsch Ctr, 4200 New Haven Rd, Columbia, MO 65201, edward_little@usgs.gov

Each year millions of liters of chemicals are used to suppress wildland fires in the U.S. Since 1995 this laboratory has been involved in the evaluation of the toxicity of fire-suppressant chemicals to fish and wildlife. In recent studies with long-term retardants, we found that the presence of sodium ferrocyanide(SF) increases the toxicity of fire retardants. In laboratory and field tests, the toxicity of fire retardants containing FS significantly increased in the presence of solar ultraviolet radiation and toxic concentrations of cyanide were observed. Fish are capable of avoiding fire-retardant chemicals in streams. Fire retardant residues in soil samples obtained from unburned sites in the vicinity of Lake George in the Hayman Reservoir watershed remained toxic for at least 90 days after application. Therefore, toxicity of fire retardants may persist in rainwater runoff particularly from sandy or rocky substrates. Persistence declines with increasing content of organic matter in the soil and cation exchange capacity. Combustion eliminates the toxicity of the retardant. Other fire-related factors such as ash effluents and high temperatures may

exceed the chemical toxicity of fire-retardant chemicals. The environmental risk posed by the use of fire-retardant chemicals is event- and site-specific because risk is a function of the toxicity of the substance, the amount applied, persistence in the environment, area treated and dilution/mixing ratios of the watershed.

CHANGES IN RUNOFF RESPONSE DUE TO BURN SEVERITY IN SMALL WATERSHEDS

NEBELSICK, Daniel D., Civil and Environmental Engineering, South Dakota School of Mines and Technology, Connolly Hall, 501 E. St. Joseph, Rapid City, SD 57701, daniel.nebelsick@sdsmt.edu, FONTAINE, Thomas A., Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, and WILLIAMS, Monte L., USDA Forest Service, Black Hills National Forest, Custer, SD 57730

Relationships between burn severity and increased watershed runoff have been developed for a 2002 fire in the Black Hills of South Dakota. The goal of this project was to obtain data on a hillslope to small watershed scale that could be used for post fire flood prediction. In August 2003 the Battle Creek Fire consumed 12,450 acres of the Black Hills National Forest. In order to monitor the changing hydrologic response of the burned catchments, sections of the burn area were immediately instrumented with dense networks of rain and streamflow gages. Specific catchments were gaged to include three conditions: low, moderate and high burn severity. Burn severity was used as a post fire indicator of the condition of duff. The duff layer plays a critical role in increased infiltration of intense rainfall, and removal of this layer results in severe post fire floods and erosion. A ground survey was conducted of the area following the fire, and a burn severity map was developed by combining the ground survey with satellite imaging. Two unburned watersheds were also gaged in order to compare pre and post fire watershed response. Twenty-two flow measuring devices were placed at the outlets of interior watersheds in 6 main basins, with watersheds varying in size from 10 to 750 acres. A network of 14 tipping bucket rain gages was placed throughout the 6 basins. Discharges were monitored during the summer of 2003, including a major rainfall event in early July, and the flows were compared to the size of watershed and the burn severity. Results relate post fire rainfall runoff response and the condition of the duff layer. Low burn areas with a relatively intact duff layer produced little to no flow, whereas moderate and high burn areas had greatly increased runoff. These results can be used to identify areas that are most in need of flood protection and watershed treatments.

12,000-YEAR RECORD OF FIRE ACTIVITY, LAKE-LEVEL CHANGE, AND FOREST SUCCESSION AT MATHEWS POND, PISCATAQUIS COUNTY, MAINE, USA

NURSE, Andrea M., Climate Change Institute, Univ of Maine, Room 101Environmental Science Laboratory, Orono, ME 04469, abnurse@hotmail.com.

This study established a 12,000-year record of paleohydrology, fire activity, and vegetation change for the watershed encompassing Big Reed Forest Reserve, the largest stand of old-growth forest in the northeastern United States. Mathews Pond is a 7.4 ha, closed-basin, groundwater-seepage lake located in an upland, forested region of the Aroostook River drainage system. Changes in the water level of Mathews Pond reflected changes in the underlying groundwater aquifer.

The lake existed as a shallow pool in the deep area of the basin between 11.0 and 9.4 ka (1 ka=1000 14C yr BP). Water levels rose to near-modern levels by 8.4 ka, and, except for a slight decline around 7.5 ka (8200 cal yr BP), remained high until 4.8 ka, when a distinct low-stand lasted until 3.0 ka. After 3.0 ka the lake level rose to the modern level with intermittent low and high fluctuations of 200-500 year duration. Periods of increased fire activity generally coincided with lower lake levels, evidence of drier climatic conditions. Increased lake levels after 2.0 ka

were accompanied by increased charcoal deposition, an indication of heavy winter precipitation followed by dry summers.

Integration of lake-level, charcoal, and pollen data at centennial-scale temporal resolution identified subtle increases in groundwater recharge in response to decreased forest transpiration following local forest fires at 9.5 ka, 8.5 ka, and 2.0 ka.

CANBERRA WILDFIRE, 2003

PERKINS, PJ[1], WASSON, RJ[1], KNEE, RM[2], and WHITEWAY, Tanya[2], (1) Centre for Resource and Environmental Studies, Australian National Univ, Canberra, 0200, pjp@platypuspartnerships.com.au, (2) ECOWISE Environmental Pty Ltd, PO Box 1834, Fyshwick, 2609, Australia

The January 2003 wildfires in Canberra, Australia, resulted in the loss of 4 lives and over 400 homes. Additionally, 100% (200 square kilometres) of the primary water catchment (Cotter Catchment) was burnt.

The severity of the fire and the subsequent impact on catchment condition and water quality was exacerbated by the simultaneous occurrence of a significant drought. In the two months following the fires, two small, intense thunderstorms rendered the water in the three Cotter Catchment dams unusable. The almost complete loss of all ground cover, ground litter and riparian zone vegetation markedly increased the erosional susceptibility (or erodibility) of the hill slopes and drainage lines.

Ash, sediment and organic matter was transported from the catchment to the reservoirs causing turbidity, iron and manganese levels that exceeding drinking water guidelines. About 1,600 tonnes of inorganic sediment and 23 tonnes of particulate organic carbon (POC) were deposited in the upper (Corin) reservoir in the six months following the fire, 5 – 6 times the long term average annual loads. An estimated 20 - 25 times the annual load is expected to eventually reach the reservoirs. In addition, it is estimated that 28 tonnes of iron and 1 tonne of manganese are stored in the post-fire reservoir sediments. The scenario of elevated turbidity, iron and manganese levels is likely to continue sporadically, but the catchment stabilising function of the regenerating vegetation will probably be close to pre-fire levels in 10 – 15 years. New water treatment facilities, are now under construction and a program to understand the stocks and flows of organic matter, iron and manganese has been proposed.

Water quality, quantity and biological monitoring of rivers has now been significantly increased. Assessments of erosion, sedimentation and vegetation recovery have been supplemented by collection of GIS data including: ortho-rectified aerial photography, high resolution digital terrain models (DTM), reservoir bathymetry and limnology reviews, remotely sensed data, and DGPS data on fire trails, swamps, monitoring sites, etc. Pre-fire development of a data collection and management system with spatial capability assisted fire management strategies during the event, and is supporting the management and dissemination of post fire data.

MONITORING BURN AREA RECOVERY WITH MODIS

QUAYLE, Brad, USDA - Forest Service, 2222 West 2300, South, Salt Lake, UT 84119, bquayle@fs.fed.us.

Remote sensing data and image processing techniques are useful tools in monitoring the recovery of burned areas. The USDA Forest Service Remote Sensing Application Center (RSAC) is currently evaluating the use of Moderate-resolution Imaging Spectroradiometer (MODIS) data for long term burn area recovery monitoring. MODIS provides frequent, cost-effective image data at a suitable spatial resolution that can be analyzed to identify general recovery trends for large burn areas.

USDA FOREST SERVICE BAER IMAGERY SUPPORT

QUAYLE, Brad, USDA - Forest Service, 2222 West 2300, South, Salt Lake, UT 84119, bquayle@fs.fed.us.

One of the first tasks of a Burned Area Emergency Response (BAER) team dispatched to a wildfire is to prepare a burn severity map. The map is subsequently used for modeling and GIS analysis in the development of the BAER team post-fire treatment plan. The USDA Forest Service Remote Sensing Application Center (RSAC) provides remotely sensed image data and image-derived products to facilitate burn severity mapping and other BAER team efforts. RSAC utilizes the availability of multiple remote sensing platforms to provide imagery and data according to the time frame and needs of BAER teams.

USDA FOREST SERVICE MODIS ACTIVE FIRE DETECTION AND MAPPING

QUAYLE, Brad, USDA - Forest Service, 2222 West 2300, South, Salt Lake, UT 84119, bquayle@fs.fed.us.

A synoptic view of the wildland fire situation at a regional and national level is valuable for strategic assessment and planning. To achieve this objective, the USDA Forest Service Remote Sensing Application Center's (RSAC) MODIS Active Fire Mapping program utilizes MODIS satellite imagery to detect and monitor fire activity for the entire United States. The program produces a variety of geospatial products on a daily basis including active fire maps, satellite imagery, GIS detection data, and associated fire information products.

USING LOGISTIC REGRESSION TO PREDICT THE PROBABILITY OF DEBRIS FLOWS OCCURRING IN AREAS RECENTLY BURNED BY WILDLAND FIRES

RUPERT, Michael G.[1], CANNON, Susan H.[2], and GARTNER, Joseph E.[2], (1) U.S. Geol Survey, 201 West 8th Street, Suite 200, Pueblo, CO 81003, mgrupert@usgs.gov, (2) U.S. Geol Survey, Box 25046, MS 966, DFC, Denver, CO 80225

Logistic regression was used to predict the probability of debris flows occurring in areas recently burned by wildland fires. Multiple logistic regression is conceptually similar to multiple linear regression because statistical relations between one dependent variable and several independent variables are evaluated. In logistic regression, however, the dependent variable is transformed to a binary variable (debris flow did or did not occur), and the actual probability of the debris flow occurring is statistically modeled. Data from 15 wildland fires that burned during 2000-2002 in Colorado, Idaho, Montana, and New Mexico were evaluated. More than 35 independent variables describing the burn severity, geology, land surface gradient, rainfall, and soil properties were evaluated. The models were developed as follows: (1) Basins with and without debris flows were delineated from National Elevation Data using a Geographic Information System (GIS). (2) Data describing the burn severity, geology, land surface gradient, rainfall, and soil properties were determined for each basin. These data were then downloaded to a statistics software package for analysis using logistic regression. (3) Relations between the occurrence/non-occurrence of debris flows and burn severity, geology, land surface gradient, rainfall, and soil properties were evaluated and several preliminary multivariate logistic regression models were constructed. All possible combinations of independent variables were evaluated to determine which combination produced the most effective model. The multivariate model that best predicted the occurrence of debris flows was selected. (4) The multivariate logistic regression model was entered into a GIS, and a map showing the probability of debris flows was constructed. The most effective model incorporates the percentage of land burned at medium and high burn severity in each basin, storm intensity (millimeters per hour), particle size sorting, and soil organic matter content. The model may be significantly improved in the future by including wildland fire data from a greater variety of terrains such as wildland fires in Arizona, California, Oregon, and Washington. The results of this study demonstrate that logistic regression is a valuable tool for predicting the probability of debris flows occurring in recently-burned landscapes.

WILDFIRE EFFECTS ON STREAM SEDIMENTATION AND WATER QUALITY WITH LINKAGES TO RIPARIAN VEGETATION REGENERATION

RYAN, S.E. and DWIRE, K.A., USDA Forest Service, Forestry Sciences Laboratory, 222 S. 22nd St, Laramie, WY 82070, sryanburkett@fs.fed.us

The effects of wildland fire on watersheds include immediate impacts, such as burned vegetation and reduced soil infiltration, and longer ranging effects, including increased flooding, hillslope erosion, stream sedimentation, and significant alteration of terrestrial and aquatic habitat. Post-fire erodability is related to a multitude of factors, including fire severity, topography, underlying geology, and nature of soils, thus making potential sedimentation impacts difficult to predict. Increases in water yield may occur in burned watersheds due to elimination of vegetative cover, altered soil infiltration rates, and subsequent decreases in transpiration. There may also be a tendency for flows from spring snowmelt to be higher following fire and arrive earlier. The greatest erosional threat occurs when severe fire is followed by major rainstorms, potentially causing widespread hillslope erosion, flashy peak flows, and flooding.

Increased erosion and flooding from burned areas inevitably impacts rates of sediment transport and the morphology of streams downstream. While rates of hillslope erosion typically return to the original levels within a few years to one decade, the sediment load delivered to and stored in channels and in riparian areas can take many more years to work its way through the system. Greater flow and increased sediment loading can produce episodes of exceptionally high rates of sediment transport which, because they are highly dependent on pulse inputs, tend to be transient and irregular. While these events may be fleeting, the aftermath is often significant as they can cause substantial fish kills and clog the streambed with fine sediment. Changes in bedload and channel form are more difficult to predict due to the irregularity of processes by which bedload is moved. Increased runoff and flashier storm responses may cause parts of the channel to degrade, particularly in higher elevations where streams tend to be steeper and confined by hillslopes. In flatter reaches, the channel may aggrade as coarse materials scoured from upstream are deposited in response to reduced slope and widening of the channel. Depending on the nature of the sediment load and geomorphic sensitivity of the watershed, the impacts of wildfire on channels downstream of burned areas can last for decades.

What is less clear is how post-fire flooding and sedimentation impacts aquatic habitat and how vegetation regeneration, particularly that growing along stream corridors, affects the rate by which sediment is transferred from burned hillslopes to streams. Substantial differences in invertebrate functional feeding groups, transport and storage of organic matter, and movement of large wood have been observed between burned and reference streams. While aquatic biota often recovers to pre-fire conditions within a few years, the rate of recovery appears to be linked to the regeneration of streamside vegetation. However, rates of re-growth in riparian areas and the specific interactions between understory vegetation and overland sedimentation have not been directly examined. Correspondingly, downed trees can also affect the transfer of sediment from hillslopes to streams, providing effective traps for material moving by diffusive processes. The effect becomes more substantial as burned trees fall and vegetative re-growth increases. In riparian areas, burned trunks often fall or are transported into the channel where they act to increase the storage capacity of the system. While wood recruitment to streams can continue for decades following fire, the source, timing, and movement of large wood remains largely unquantified. Yet, substantial changes in channel morphology are often associated with the movement and redistribution of large wood during high flows and wood is vital in creating high quality aquatic habitat. Hence, riparian vegetation and large wood exert important controls on the movement and storage of sediment from hillslopes to streams following wildfire. However, additional research is needed to better understand the complex interactions and feedbacks among physical processes, re-growth of riparian vegetation, movement of wood, and changes in aquatic communities in burned watersheds.

In this presentation, we describe preliminary results from a study that quanitifies sedimentation rates, changes in organic matter storage and transport, and vegetation re-growth in a burned watershed from which there are extensive pre-burn data on watershed processes. Furthermore, most of the burn was contained within one sub-watershed while an adjacent sub-watershed remained largely unburned. The sub-watersheds are similar in size, aspect, and geology, presenting an opportunity to compare disturbance and recovery processes within burned and unburned areas of the same watershed.

Fire Effects Study in Little Granite Creek

In August 2000, a fire in the Gros Ventre Wilderness area on the Bridger-Teton National Forest, northwestern Wyoming, burned most of the forest vegetation in the Boulder Creek watershed. This watershed comprises about 40% of the area of Little Granite Creek where researchers from the USGS and USFS have collected data on sediment transport processes (bedload and suspended sediment) during 13 runoff seasons between 1982 and 1997. Other types of data collected during this effort include several years of flow record, channel surveys, and data on dissolved load and aquatic communities. Hence, the Boulder Creek Fire within the Little Granite Creek watershed presents a unique opportunity for evaluating the downstream effects of fire-related sedimentation relative to established baselines, as well as interactions among physical processes, recovery of riparian vegetation, and water quantity and quality.

Scientists from the USDA Forest Service, Rocky Mountain Research Station initiated studies in 2001 to capture the transitory portion of the early sediment record during runoff generated by spring snowmelt and summer thunderstorms. This included monitoring streamflow, suspended sediment concentration, bedload, channel scour and deposition, and movement of large wood. Additional work initiated in 2002 included studies on the post-fire dynamics of organic matter (dissolved, fine, and coarse), inventories of aquatic macroinvertebrates and fish, and sampling to assess the re-establishment of riparian vegetation.

Results to date

Due to drought conditions throughout the western United States, flows in Little Granite Creek were relatively low in water years 2001-02. For example, during snowmelt runoff in 2001, flows exceeded bankfull for only a few hours during a prolonged rainstorm in May. In the first year post-fire, measured rates of suspended sediment transport were about 5x higher on the rising limb of the snowmelt hydrograph relative to pre-burn values, while there were no substantial differences observed for the falling limb. Rates of bedload transport were similar to those measured before the fire. During mid-summer, a few low to moderate-intensity thunderstorms raised the hydrograph from the burned watershed by a small amount, similar to runoff patterns prior to burning. There were, however, large increases in suspended sediment associated with these storms. Rainfall rates of 1-6 mm in 15 minutes produced increases in SSC between 1-2 orders of magnitude. Concentrations returned to baseline values with a few hours or days following these smaller "blackwater" events. By contrast, no measurable increase in SSC was observed in the unburned watershed during these periods.

In late summer, two larger rainstorms produced the highest SSC measured at Little Granite to date. A brief (< 15 minutes) but intense rainfall (~2 inches hr^{-1} or 50 mm hr^{-1}) on August 9 generated a few fine-grained mudflows from gullies within the burned area. Suspended sediment concentration was about 3 orders of magnitude greater than baseline values and it took over a week for these values to return to baseline. By contrast, SSC increased by 1 order of magnitude in the control watershed, returning to baseline within 8 hours. A second series of storms on September 13 produced a substantial spike in flow and SSC in streams below the burned areas. Flows in the burned watershed exceeded bankfull and were substantially greater than those measured during snowmelt runoff. Suspended sediment concentration peaked at about 48,000 mg L^{-1} which is 4 orders of magnitude greater than baseline values. SSC in the control watershed was 1,300 mg L^{-1} or about the same peak concentration observed during snowmelt runoff. During later reconnaissance, we noted areas with shallow (~6 inches or 0.15 m) soil slips, scoured gullies, fresh mudflow tracks, and out-of-bank flow marks. Additionally, several wood jams that had been tagged for monitoring earlier in the summer had been dismantled and large tree trunks could be traced up to 0.5 km (0.3 miles) from the site where they were originally surveyed. Channel cross-sections within the burned area showed localized zones of deposition and scour which were frequently associated with the rearrangement of large wood.

With each storm and subsequent blackwater event, channel beds in streams below the burned area became increasingly infused with fines, consisting of a mixture of burned organic matter and inorganic materials. Measurements taken in 2002 indicated that the degree of embeddedness in the burned watershed (92% ± 4%, mean ± 1 s.e.) was substantially greater than that observed in the control watershed (59% ± 2%).

During the second year post-fire, substantial thunderstorms still produced blackwater events, though not to the extent observed in 2001. Export of coarse particulate organic matter (CPOM) was greater from the burned drainage and samples were composed of 6-30% charcoal, whereas samples from the reference stream contained < 2% charcoal. While the mean annual concentrations of dissolved organic carbon (DOC) were lowest in the unburned watershed (1.63 ± 0.56 mg L^{-1}) there were no significant differences in DOC between sites. DOC concentrations were elevated during the rising limb of the hydrograph, somewhat diluted during peak flow, and ranged between 1 and 2 mg L^{-1} throughout most of the summer. Higher concentrations of DOC (6 – 7 mg L^{-1}) were observed below the burned area only during a 2 day rainstorm (Sept 6-7 2002). Stream temperatures were consistently higher in the burned basin from mid-May through August 2002 (range 3.2° to 14.5° C) and lower in late September and early October, demonstrating the importance of solar inputs to this stream due to lack of vegetative cover.

Regrowth of riparian vegetation, while sparce in the first year post-fire, increased substantially during the second and third years and appears to be intercepting shallow sediment flows from hillslopes in some locations. However, resprouting streamside shrubs are subject to high levels of browse (40 – 65%) by native ungulates (and in 2003, by livestock). In the third post-fire year, cover of clonal shrubs (*Ribes lacustre, Rosa woodsii, Spiraea betulifolia*) has increased by over 60%. The fire killed approximately 10% of the riparian shrubs sampled.

On-going and future research includes the continued monitoring of discharge, measuring sediment and organic matter (DOC, FPOM, CPOM) transport, and examining relationships between turbidity, sediment, and organic matter concentrations. In subsequent analyses, the relationships between sediment and organic matter dynamics and the recovery of riparian plant communities and benthic macroinvertebrate assemblages will be assessed.

EFFECTS OF WILDLAND FIRE ON LOWLAND LEOPARD FROGS AT SAGUARO NATIONAL PARK, ARIZONA

SWANN, Don E.[1], **SCHON, Kathy H.**[1], and WALLACE, J. Eric[2], (1) Saguaro National Park, 3693 South Old Spanish Trail, Tucson, AZ 85730, Kathy_Schon@nps.gov, (2) School of Renewable Natural Resources, Univ of Arizona, Biological Sciences East 325, Tucson, AZ 86721

Large wildfires in areas with long suppression histories can have dramatic short-term and long-term effects on watersheds in western North America, including elevated run-off, heavy ash flows, and large increases in sediment load. Impacts of fires on fish populations have been studied, but less is known about impacts on other aquatic vertebrates, particularly reptiles and amphibians. We monitored lowland leopard frog abundance, distribution, and reproduction, as well as hydrologic parameters, approximately once/month for three years prior and three years after a large wildland fire in 1999 at Saguaro National Park in southern Arizona. We also monitored frogs for a shorter period before and after a large wildfire in 2003. In addition we retrospectively evaluated the impacts of fire on leopard frogs throughout the Rincon Mountains during the period 1985-2000. Leopard frog abundance and distribution varied greatly due to natural processes, particularly drought. Ash flows following fires led to immediate deterioration of water quality in leopard frog habitat and very high (>95%) mortality or displacement of tadpoles. Adults were initially able to survive, but reproduction remained low and the frog population in the major study canyon had disappeared within 3 years after the fire. Observations on shorter and longer time scales suggest that wildfires may be a major factor in range-wide declines and extirpations of leopard frogs in the Rincon Mountains and throughout southern Arizona. We believe that potential declines of aquatic vertebrates support increased use of prescribed fire to lessen fuel loads and reduce fire impacts on watersheds in mountainous areas of southern Arizona.

HYDROLOGIC IMPACTS AND WATERSHED RECOVERY FOLLOWING THE 1999 LOWDEN RANCH FIRE, LEWISTON AREA, TRINITY COUNTY, CALIFORNIA

SHALLER, Philip J.[1], MEDLEY, Edmund[2], HAMILTON, Douglas[1], LYLE, Jene[1], MATHIESON, Elizabeth[3], and WEIRICH, Frank[4], (1) Exponent® Failure Analysis Associates, 320 Goddard, Suite 200, Irvine, CA 92618, pshaller@exponent.com, (2) Exponent® Failure Analysis Associates, 149 Commonwealth Drive, Menlo Park, CA 94025, (3) Exponent® Failure Analysis Associates, 1970 Broadway, Suite 250, Oakland, CA 94612, (4) Exponent® Failure Analysis Associates, 5401 McConnell Avenue, Los Angeles, CA 90066

The Lowden Ranch Fire (LRF) began as a prescribed fire set by the Bureau of Land Management (BLM) near Lewiston, California, on July 2, 1999. The fire jumped control lines, burning 1,904 forested acres (771 hectares) and 23 residences in four days. According to the BLM Burned Area Emergency Rehabilitation Plan (BAER report) dated July 21, 1999, 30% of the burn area experienced high forest mortality (over 70% of basal area killed). Most of the burn occurred on steep slopes underlain by weathered Mesozoic granite. The slopes are incised by flat-bottomed drainages containing thick accumulations of granitic sand. Lewiston receives 35 to 40 inches (89 to 102 cm) of rain per year, so erosion control was an immediate concern after the fire. The BAER report recommended numerous post-fire actions, most of which were implemented before the first rains in November. Over the next three years, site-specific post-fire flood and erosion assessments were prepared by a consultant for several private landowners, forming a principal basis for damage claims filed in 2002 against the BLM. In March 2002, Exponent engineers and scientists reviewed these reports, performed an aerial and ground reconnaissance, and independently analyzed runoff and erosion potential for the claimant properties. We observed minimal erosion and sediment transport since the fire and attribute this to: 1) moderate rainfall in 1999-2000; 2) deep, permeable granitic sand in the affected watersheds that reduced runoff; and 3) a lack of notable new landslides or debris flows in the burn area. Based on our field data, sediment yields modeled using the Modified Universal Soil Loss Equation (MUSLE) showed that by 2002 the area had recovered about 70% of its pre-fire erosion resistance, due mainly to post-fire recovery of ground cover and the break down of any low-permeability hydrophobic layer that had formed in the fire. Initial burn mortality was probably less than originally estimated. The level of vegetative recovery in the affected watersheds and the use of appropriate sediment modeling protocols were critical elements supporting our conclusions. The fire and its effects reinforce the need to develop and follow up post-fire mitigation plans to ensure their adequacy and to reassure the public.

WILDLAND FIRE AND SOCIAL SCIENCE

TAYLOR, Jonathan, HOGAN, John, and GILLETTE, Shana, Fort Collins Science Center, Fort Collins, CO 80526, jonathan_taylor@usgs.gov

Nearly half of the issues facing wildland fire managers in the U.S. are "people problems." The National Wildfire Coordinating Group has created a Fire Social Science Task Group to address these difficulties. Yet less than 10% of mainline fire science research support is dedicated to social science. Nevertheless, social science is working on a number of fronts to supply useable knowledge to the fire management community: research on fire communication; structure and techniques for public participation and community partnerships; perceptions, knowledge, and decision-making in the Wildland Urban Interface. One project, focused on post-fire mitigation, is exploring the effects of having WUI fire-impacted communities participate actively in erosion and mass-movement control, reseeding, recovery monitoring, and education on fire ecology and varying effects of different fire intensities.

WILDFIRE MITIGATION AND FOREST RESTORATION OF THE BUTTON ROCK PRESERVE WATERSHED

TOBLER, Matt, Blue Mountain Environmental Consulting LLC, 125 Peterson St., Suite 2, Ft. Colliins, CO 80524, matt@bluemountain1.net and MORAGA, Rod, Anchor Point Group LLC, 3775 Iris Ave., Suite 2, Boulder, CO 80301

Blue Mountain Environmental Consulting and the Anchor Point Group, developed under contract, a forest stewardship plan for the Button Rock Preserve in Lyons, Colorado. The 3,000 acre Preserve contains the Longmont and Ralph Price Reservoirs which provide storage for Longmont's water utility. The forest stewardship plan addressed the needs to reduce risks of catastrophic wildfire, to control noxious weeds, and to reduce the incidence of forest insect and disease epidemics. An iterative procedure was employed that included database searches, literature reviews, GIS mapping, purposeful sampling of noxious weeds, landscape level assessments of understory and overstory conditions, and wildfire behavior modeling. The historical range of variability for Front Range ponderosa pine forests was compared with current conditions to develop management prescriptions. FlamMap fire software was used to predict fire behavior and to identify high risk areas. Implementation of this plan will protect the watershed from catastrophic wildfire and the resulting impacts on soils (hydrophobic soils and severe post-burn erosion) while restoring ecological function.

MEETING THE NEED FOR ASSISTANCE IN WILDFIRE IMPACTED WATERSHEDS AND PUBLIC WATER SYSTEMS DURING COLORADO'S 2002 WILDFIRE SEASON

WILLIAMS, Sharon Israel, RISTAU, Randal J., and DAVIS, Donna, Water Quality Control Division, Colorado Dept. of Public Health and Env, 4300 Cherry Creek Drive South, Denver, CO 80246, sharon.williams2@state.co.us

The Water Quality Control Division of the Colorado Department of Public Health and Environment is Colorado's leading agency for monitoring and reporting on the quality of state waters, preventing water pollution, protecting, restoring and enhancing the quality of surface and groundwater, and assuring that safe drinking water is provided from all public water systems. During the record wildfire season of 2002, the Division responded to acute water quality problems affecting Colorado's watersheds and public water systems. The Division also led an inter-agency response to wildfires in Colorado as a charter partner of the Multi-Agency Restoration and Rehabilitation Team. Water quality problems caused directly by wildfires in 2002 were exacerbated by ongoing severe drought conditions statewide. The Division's response team provided technical assistance, financial assistance, public relations, and education. Assistance related to impacts on Colorado's watersheds included tracking ecosystem degradation, erosion, deforestation and loss of habitat. Financial assistance was provided to watershed groups in the form of grants to support efforts toward reforestation and reduction of non-point source pollution via debris and soil stabilization projects. The Division also tracked impacts on public water systems statewide and assisted public water systems challenged by poor raw water quality and wildfire-impacted surface water intakes and treatment facilities. To assist and educate impacted public water systems, Division staff provided on-site technical support and free classes on treating affected water. Financial assistance to public water systems included grants funding alternate sources and facility upgrades. The Division also exercised enforcement discretion with systems struggling to meet compliance and treatment requirements due to wildfire impacts. More than a year later, the Division is still responding with ongoing assistance and outreach efforts.

EFFECTIVENESS OF POST-FIRE EROSION CONTROL TECHNIQUES IN NORTHWESTERN MONTANA

WOODS, Scott and GROEN, Amy, College of Forestry and Conservation, Univ of Montana, 32 Campus Drive, Missoula, MT 59812, swoods@forestry.umt.edu

Soil erosion rates in undisturbed forested watersheds are typically very low. However, substantial increases in erosion rates have been observed after forest fires due to the loss of the protective litter and duff layers, and changes in the physical characteristics of the soil that increase surface runoff rates. The potential problems associated with post-fire increases in erosion include reduced soil productivity, and adverse impacts to downstream water quality and aquatic habitat. Various techniques have been used to stabilize hillslopes and reduce surface erosion after forest fire. However, there is relatively little quantitative information on the effectiveness of these techniques.

We used a rainfall simulator to compare erosion and runoff rates from 0.5 m^2 plots treated with either grass seed or straw mulch to untreated control plots in an area burned by the 2002 Fox Creek Fire in northwestern Montana. Each treatment and control plot had ten replicates. Rainfall was applied at an intensity of approximately 80 mm/hr for 1 hour. Runoff from the plots was collected every minute for the first 10 minutes and then every 2 minutes. Sample volumes were used to calculate runoff rates and total runoff volume. Samples were filtered to determine the mass of sediment eroded from the plot. The straw mulch treatment significantly reduced both runoff and erosion rates relative to the control plots. However, in most of the grass-seeded plots, only a few seeds had sprouted, and there was no significant difference in erosion and runoff rates between the treatment and control plots.

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National Interagency Fire Center	www.nifc.gov
Joint Fire Science Program Projects	http://jfsp.nifc.gov/
EPA Watershed Academy: Erosion	http://www.epa.gov/owow/watershed/wacademy/wam/erosion.html
Fire Home Pages	
Aldo Leopold Wilderness Research Institute	http://leopold.wilderness.net/research/fire.htm
BIA	http://www.bianifc.org/
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FWS	http://fire.fws.gov/
International Association of Wildland Fire	http://www.iawfonline.org/
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Fire Terms Glossary	http://www.fs.fed.us/r2/fire/fbgloss.htm
CLIMAS (Climate Assessment for the Southwest); Fire-related links	http://geo.ispe.arizona.edu/links_db/fire_links.asp
Montana State Library Natural Resource Information System; Fire response data page: GIS data layer access; fire links	http://nris.state.mt.us/fire/ (click on FIRE)
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BAER-ESR Reports	Search for BAER or ESR

Wildland Fire Impacts on Watersheds—
Understanding, Planning and Response
October 21-23, 2003

List of Exhibitors

Exhibitor Contact Information and Business Description
Rod Moraga - Anchor Point Group LLC 3775 Iris Avenue, Suite 2A Boulder, CO 80301 Ph: 303-665-3473 rod@anchorpointgroup.com **Description: Anchor Point Group LLC** is comprised of active firefighters with decades of wildland and structural fire experience. Anchor Point operates as a team of fire managers and natural resource professionals, utilizing individual consultants that specialize in complementary fields to provide our clients with a truly scientific and comprehensive approach to fire management.
Matt Tobler - Blue Mountain Environmental Consulting LLC 125 Peterson St., Ste. 2 Ft. Collins, CO 80524 Ph: 970-224-0851 matt@bluemountain1.net **Description: Blue Mountain Environmental Consulting LLC** is a consortium of environmental professionals dedicated to the sustainable management of ecological systems. We provide timely and cost effective natural resource management services specializing in forestry and range ecology, biological inventories, noxious weed management, wetland delineation and compliance.
Tom Bowman - Bowman Construction Supply Rocky Mountain Bio Products 2310 S. Syracuse Way Denver, CO 80231 Ph: 303-696-8964 tom@bowmanconstructionsupply.com **Description: Bowman Construction Supply** supplies Biosol the All Natural 100% Organic Fertilizer. A slow release, long lasting fertilizer to develop and promote a sustainable growing environment for all types of vegetation. Proven results for over 25 years. A suppler of organic soil amendments and erosion control products.

Exhibitor Contact Information and Business Description, cont'd.

Chuck Bushey – International Association of Wildland Fire
Montana Prescribed Fire Services
1333 Colton Blvd.
Billings, MT 59102-2436
Ph: 406-248-8307
mpfs@mindspring.com

Description: **The International Association of Wildland Fire (IAWF)** is a non-profit, professional association representing members of the global wildland fire community. The purpose of the association is to facilitate communication and provide leadership for the wildland fire community.

Jack Hess, Diane Matt – The Geological Society of America
TheGeological Society of America
3300 Penrose Place
Boulder, CO 80301
Ph: 303-357-1000
jhess@geosociety.org
dmatt@geosociety.org
www.geosociety.org

Description: **The Geological Society of America** works to advance the geosciences, enhance the professional growth of its members and promote the geosciences in the service of humankind. GSA publishes premier scientific literature; organizes global, national and regional scientific meetings and awards student research grants. In addition, the society is known for providing opportunities for professional development and developing earth science curriculum resources for educators.

Jeff Burns - The Society of American Foresters
515 McDaniel Blvd.
Canon City, Colorado 81212-4164
Ph: 719-275-6865
csfccc@rmi.net

Description: **The Society of American Foresters** is the national scientific and educational organization representing the forestry profession in the United States. Founded in 1900 by Gifford Pinchot, it is the largest professional society for foresters in the world. The mission of the Society of American Foresters is to advance the science, education, technology and practice of forestry; to enhance the competency of its members; to establish professional excellence; and to use the knowledge, skills and conservation ethic of the profession to ensure the continued health and use of forest ecosystems and the present and future availability of forest resources to benefit society. SAF is a nonprofit organization meeting the requirements of 501 © (3). SAF members include natural resource professionals in public and private settings, researchers, CEOs, administrators, educators and students.

Exhibitor Contact Information and Business Description, cont'd.

Yesenia Diaz – Trimble Navigation Limited
7403 Church Ranch Blvd., #100
Westminster, CO 80021
Ph: 800-480-0150
Yesenia_diaz@trimble.com

Description: Trimble is a leading innovator of Global Positioning System (GPS) technology. In addition to providing advanced GPS components, Trimble augments GPS with other positioning technologies as well as wireless communications and software to create complete customer solutions. Trimble's worldwide presence and unique capabilities position the Company for growth in emerging applications including surveying, automobile navigation, machine guidance, asset tracking, wireless platforms, and telecommunications infrastructure. Founded in 1978 and headquartered in Sunnyvale, Calif., Trimble has more than 2,000 employees in more than 20 countries worldwide.

Richard Mommer – Uniscope, Inc.
310 S. 1st St.
Johnstown, CO 80534
Ph: 970-587-4614
dwalker@uniscope-inc.com

Description: Uniscope is an agricultural research and development firm whom has recently developed a 1-step, dense, mulching nugget which is easy to apply in remote areas. Product can be custom formulated to post-fire rehabilitation specific needs (hydrophilic agent, fertilizer, etc.) Uniscope is a vendor seeking industry feedback.

Pat Schassburger - US Geological Survey
Office of Communications
P.O. Box 25046, MS 150
Denver, CO 80225
Ph: 303-202-4767
pat_schassburger@usgs.gov

Description: The USGS serves the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy and mineral resources; and enhance and protect our quality of life.

Wildland Fire Impacts on Watersheds—
Understanding, Planning and Response
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List of Speakers

Name	Affiliation	E-mail
Alexander, Ben	City of Fort Collins Utilities	BenAlexander@compuserve.com
Atkinson, R. Dwight	US EPA	atkinson.dwight@epa.gov
Bruggink, Jeff	US Forest Service	jbruggink@fs.fed.us
Cannon, Susan H.	US Geological Survey	cannon@usgs.gov
Ekarius, Carol	Coalition for the Upper South	uspwpa@chaffee.net
Ellis, Pauline	San Juan Public Lands	peellis@fs.fed.us
Fornwalt, Paula	US Forest Service	pfornwalt@fs.fed.us
Garcia, Herman	NRCS	herman.Garcia@co.usda.gov
Gasser, Erv	National Park Service	erv_gasser@nps.gov
Graham, Russ	US Forest Service	rtgraham@fs.fed.us
Hardy, Colin	USDA Forest Service	chardy01@fs.fed.us
Hubbard, James	Colorado State Forest Service	jhubbard@lamar.colostate.edu
Istanbulluoglu, Erak	M.I.T.	erkan@mit.edu
MacDonald, Lee H.	Colorado State University	leemac@cnr.colostate.edu
Martin, Deborah A.	US Geological Survey	damartin@usgs.gov
McCaughey, Ward	Rocky Mtn Research Station	wmccaughey@fs.fed.us
McKean, Jim	USDA Forest Service	jmckean@fs.fed.us
Meyer, Grant A.	Univ New Mexico	gmeyer@unm.edu
Moody, John A.	US Geological Survey	jamoody@usgs.gov
Parenti, Michael	M. Parenti & Associates	michaelparenti@msn.com
Parsons, Annette	USFS and BLM	aparsons@fs.fed.us
Perkins, Paul	Australian National University	pjperkins@cres.anu.edu.au
Pierson, Fred	Agricultural Research Service	fpierson@nwrc.ars.usda.gov
Robichaud, Pete	Rocky Mountain Research Station	probichaud@fs.fed.us
Rosenberger, Amanda	USDA - US Forest Service	arosenberger@fs.fed.us
Ryan, Kevin	USDA Forest Service	kryan@fs.fed.us
Thornton, John	USDA Boise	jwlthornton@fs.fed.us
Wiley, Rocky	Denver Water	rocky.wiley@denverwater.org

Wildland Fire Impacts on Watersheds—
Understanding, Planning and Response
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List of Participants

Name	Affiliation	E-mail
Ben Alexander	City of Fort Collins Utilities	BenAlexander@compuserve.com
Marc R. Alston	EPR-EP	alston.marc@epa.gov
R. Dwight Atkinson	US EPA	atkinson.dwight@epa.gov
Ann Marie Aubry	BLM	ann_marie_aubry@blm.gov
James A. Bashor		James_Bashor@wy.blm.gov
Paula Belcher	Bureau of Land Management	Paula_Belcher@co.blm.gov
Sharon Bernia		sbernia@ci.westminster.co.us
Deborah Bieber	Environmental Security	bieberdj@pendleton.usmc.mil
Erica Bigio	University of Arizona	ebigio@ltrr.arizona.edu
Anne Black	Rocky Mountain Research Statio	aeblack@fs.fed.us
Daniel Blake	NOAA Fisheries	dan.blake@noaa.gov
Jacek Blaszczynski	Bureau of Land Management	jacek_blaszcz@blm.gov
Ryan Boggs	The Nature Conservancy	rboggs@tnc.org
Derek Bonin	Greater Vancouver Regional Dist	dbonin@gvrd.bc.ca
David S. Borland	Bureau Land Management	david_borland@nm.blm.gov
Tom Bowman	Bowman Construction Supply	tom@bowmanconstructionsupply.com
Joe Brinton	U.S. Forest Service	jbrinton@fs.fed.us
Karl Brown	USGS - Biological Resources	karl_brown@usgs.gov
Tom Browning	CWCB	tom.browning@dwr.state.co.us
Jeff Bruggink	US Forest Service	jbruggink@fs.fed.us
Jeff Burns	Colorado State Forest Service	csfscc@rmi.net
Craig R. Busskohl	Umatilla National Forest	cbusskohl@fs.fed.us
Dana Butler	USDA Forest Service	danabutler@fs.fed.us
Scott Campbell	Colorado Springs Utilities	Scampbell@csu.org
Susan H. Cannon	US Geological Survey	cannon@usgs.gov
Tom Casadevall	US Geological Survey	tcasadev@usgs.gov
Earl Cassidy	USGS	ecassidy@usgs.gov
Robert Bruce Cavill	Greater Vancouver Reg'l Distri	bob.cavill@gvrd.bc.ca
Karletta Chief	University of Arizona	kchief@hwr.arizona.edu
Catherine Costello	USGS	ccostello@usgs.gov
Michael A. Crump		emergeo@yahoo.com
Scott E. Davis		scott_davis@blm.gov
Marsha Davis	National Park Service	marsha_davis@nps.gov
Dale Deiter		ddeiter@fs.fed.us
Lara Derasary	BLM	Lara_Derasary@blm.gov
Mimi Diaz	Arizona State University	slidehazard@hotmail.com
Yesenia Diaz	Trimble Navigation Limited	yesenia_diaz@trimble.com
Elizabeth Dickerson	U.S. Fish and Wildlife Service	Elizabeth_Dickerson@fws.gov
Debra Dinville	Bureau of Land Management	debra_dinville@blm.gov

Name	Affiliation	E-mail
Duane Dipert	U. S. Forest Service	ddipert@fs.fed.us
Cynthia Dott	Fort Lewis College	dott_c@fortlewis.edu
Robert Doyle	US Geological Survey	bdoyle@usgs.gov
Christina Dueber	U.S. DOC, NOAA, NMFS	Christina.Dueber@noaa.gov
Kathleen Dwire	USDA Forest Service	kadwire@fs.fed.us
James Egnew	USDA Forest Service	jegnew@fs.fed.us
Carol Ekarius	Coalition for the Upper South	uspwpa@chaffee.net
Larry D. Ellicott	USDA-NRCS	larry.ellicott@ut.usda.gov
Pauline Ellis	San Juan Public Lands	peellis@fs.fed.us
Garth Englund	Douglas County	genglund@douglas.co.us
Robert G. Eppinger	US Geological Survey	eppinger@usgs.gov
Mark Ferns	Oregon Department of Geology	mark.ferns@state.or.us
Laurie Fisher	CDPHE-WQCD-OA	laune.fisher@state.co.us
Paula Fornwalt	US Forest Service	pfornwalt@fs.fed.us
Suzanne C. Fouty		sfouty@fs.fed.us
Joe Gartner	U.S. Geological Survey	jegartner@usgs.gov
John Gartner		jdgartner@hotmail.com
Erv Gasser	National Park Service	erv_gasser@nps.gov
Jessica J. Gould		jjgould@fs.fed.us
Russell Graham	Forest Service	rtgraham@fs.fed.us
Thomas Halferty		thomas.halferty@noaa.gov
Jack L. Hamby	1849 C St NW	jhamby@blm.gov
Kyle Hamilton		khamilton@ch2m.com
Colin Hardy	USDA Forest Service	chardy01@fs.fed.us
Bob Harvey		firescapesco@yahoo.com
Bahman Hatami	CWCB	bahman.hatami@dwr.state.co.us
Diedtra Henderson		dhenderson@denverpost.com
John W. Hess, Jr.	Geological Society of America	jhess@geosociety.org
James R. Hessil	US ARMY	mckays@hua.army.mil
Melanie Hood-Lofthouse	USGS - NMD	mkhood@usgs.gov
Eric P. Howell		ehowell@csu.org
James Hubbard	Colorado State Forest Service	jhubbard@lamar.colostate.edu
Ken Hubbert		khubbert@fs.fed.us
Emanuel Hudson	USDA	ehudson@fs.fed.us
Kevin Hyde		kgeogmt@cs.com
Erkan Istanbulluoglu	M.I.T.	erkan@mit.edu
Jacq Marie Jack	US Environmental Protection Ag	jack.jacq@epa.gov
Tommy J. John		tjohn@fs.fed.us
Peter B. Johnsen	National Marine Fisheries Service	peter.johnsen@noaa.gov
Ken Juvik	Greater Vancouver Regional Dis	ken.juvik@gvrd.bc.ca
Jason E. Kahn		Jason.Kahn@noaa.gov
Allen King	US Forest Service	apking@fs.fed.us
Steve Kiracofe	BLM	steve_kiracofe@blm.gov
Jaime Krakowiak	Tetra Tech, Inc.	jaime.krakowiak@ttisg.com

Name	Affiliation	E-mail
James Kulbeth	DECAM	James.Kulbeth@carson.army.mil
Robert W. Lange		bob_lange@blm.gov
Bill Leenhouts		bill_leenhouts@fws.gov
Laila Lienesch	U. S. Fish and Wildlife Servic	Laila_Lienesch@fws.gov
Jeffrey Linn	DECAM	Jeffrey.Linn@carson.army.mil
David Litke	USGS	dwlitke@usgs.gov
Edward E. Little	CERC	edward_little@usgs.gov
Charles H. Luce	USDA Forest Service	cluce@fs.fed.us
Lee H. MacDonald	Colorado State Univ	leemac@cnr.colostate.edu
Deborah A. Martin	US Geological Survey	damartin@usgs.gov
Diane Matt	Geological Society of America	dmatt@geosociety.org
Ward McCaughey	Rocky Mtn Research Station	wmccaughey@fs.fed.us
Patrick McCusker	DECAM	Patrick.McCusker@carson.army.mil
Patricia McGlothlin	Pat McGlothlin & Associates	pmcglothlin@msn.com
Jim McKean	USDA Forest Service	jmckean@fs.fed.us
Bill McKee	CDPHE-WQCD-OA	billmckee@state.co.us
Grant A. Meyer	Univ New Mexico	gmeyer@unm.edu
Alisha R Miller	USDA Forest Service	alishamiller@fs.fed.us
Bill Mills	Colorado Springs Fire Dept	wmills@springsgov.com
Richard Mommer	Uniscope, Inc.	dwalker@uniscope-inc.com
Peter Monahan		monahan.peter@epa.gov
John A. Moody	US Geological Survey	jamoody@usgs.gov
Don Moore	Douglas County	dmoore@douglas.co.us
Rod Moraga	Anchor Point Group, LLC	rod@anchorpointgroup.com
Dan Muller	BLM / NSTC	Dan_Muller@blm.gov
Sheila Murphy	USGS	sfmurphy@usgs.gov
Zigmund Napkora	BLM	zig_napkora@blm.gov
Daniel Nebelsick	SDSM&T	daniel.nebelsick@sdsmt.edu
Connie D. Neff	US Forest Service	cneff@fs.fed.us
Carl Norbeck	CDPHE-WQCD-WS	carl-norbeck@state.co.us
Andrea Nurse		abnurse@hotmail.com
Randle W. Olsen	U.S. Geological Survey	rwolsen@usgs.gov
Mary A. Ott	USEPA	ott.toney@epa.gov
Richard Parachini	CDPHE-WQCD-OA	dick.parachini@atate.co.us
Michael Parenti	M. Parenti & Associates	michaelparenti@msn.com
Sharon Paris	Bureau of Land Management	sharon_paris@blm.gov
Annette Parsons	USFS and BLM	aparsons@fs.fed.us
Paul Perkins	Australian National University	pjperkins@cres.anu.edu.au
Fred Pierson	Agricultural Research Service	fpierson@nwrc.ars.usda.gov
Elizabeth Pine	URS Corporation	lisa_pine@urscorp.com
Carol Purchase	Medicine Bow-Routt Nt'l Forest	cpurchase@fs.fed.us
Brad Quayle	USDA Forest Service	bquayle@fs.fed.us
Charley R. Rains		charley.rains@noaa.gov
Christina Randall	Colorado Springs Fire Dept	crandall@springsgov.com

Name	Affiliation	E-mail
Mike M. Reddy	US Geological Survey	mmreddy@usgs.gov
Kathleen Reilly	CDPHE-WQCD-OA	Kathleen.reilly@state.co.us
Philip N Reinholtz	Rio Grande National Forest	pnreinhol@fs.fed.us
Randal J. Ristau	CDPHE - WQCD -OA - B2	randal.ristau@state.co.us
Pete Robichaud	Rocky Mountain Research Station	probichaud@fs.fed.us
Amanda Rosenberger	USDA - US Forest Service	arosenberger@fs.fed.us
Edward Rumbold	Bureau Land Management	erumbold@blm.gov
Michael Rupert	US Geological Survey	mgrupert@usgs.gov
Sandra Ryan	USDA Forest Service	sryanburkett@fs.fed.us
Kevin Ryan	USDA Forest Service	kryan@fs.fed.us
Roberto Salvati	Univ Roma TRE	salvati@uniroma3.it
Pat Schassburger	US Geological Survey	pat_schassburger@usgs.gov
Nick Scheidt		scheidtn@uidaho.edu
Larry Schmidt	USDA Forest Service	lschmidt@fs.fed.us
Elizabeth Schnackenberg		lschnackenberg@fs.fed.us
Kathy Schon	National Park Service	kathy_schon@nps.gov
Richard Schwab	Bureau of Indian Affairs	richard_schwab@nifc.gov
David Scott	Okangan University College	dscott@ouc.bc.ca
Philip Shaller	Exponent	pshaller@exponent.com
Wesley T. Smith		wsmith@fs.fed.us
Rebecca Smith		rsmith@fs.fed.us
Brent Sobotka	Bureau of Land Management	brent_sobotka@blm.gov
Adam Solt	USFS	asolt@fs.fed.us
Jon Sorensen	URS Corporation	Jon_Sorensen@URSCorp.com
Brian St George	BLM	Brian_stgeorge@blm.gov
Shelley Stanley	City of Northglenn	sstanley@northglenn.org
Joanna Stansbury	City of Boulder	stansburyj@ci.boulder.co.us
Susan Stitt	U.S. Geological Survey	susan_stitt@usgs.gov
Michael L. Strobel	US Geological Survey	mstrobel@usgs.gov
Bob Sturtevant	Colorado State University	bsturt@lamar.colosate.edu
Seema Sutarwala		ssutarwala@exponent.com
Don E. Swann	Saguaro National Park	Don_Swann@nps.gov
William Swartz	Forest Service	wswartz@fs. fed.us
Tim Sweeney	USDA NRCS	tim.sweeney@co.usda.gov
John Thornton	USDA Boise	jwlthornton@fs.fed.us
Matt Tobler	Blue Mountain Environmental	matt@bluemountain1.net
Kevin L. Traylor		kevin.traylor@noaa.gov
Steve Vandas	US Geological Survey	svandas@usgs.gov
Bill Wall	USFS	wwall@fs.fed.us
Frank Weirich	Exponent/U of Iowa	fweirich@exponent.com
Chris Welcker		welcker@uidaho.edu
Stacy Welding	USGS	slwelding@usgs.gov
Mandy Wiedeman	Colorado State Forest Service	zaraw@lamar.colostate.edu
Rockford D. Wiley	Denver Water	rocky.wiley@denverwater.org

Name	Affiliation	E-mail
Sharon I. Williams	W2LD-B2-T5V	sharon.williams2@state.co.us
Eric Winthers		ewinthers@fs.fed.us
Kathryn R. Winthrop		Kate_Winthrop@blm.gov
Peter Wohlgemuth	USDA Forest Service	pwohlgemuth@fs.fed.us
Scott Woods	University of Montana	swoods@forestry.umt.edu
Ann Youberg	Arizona Geological Survey	ann.youberg@azgs.az.gov
Bill Ypsilantis	Bureau of Land Management	bill_ypsilantis@blm.gov
Joe Zendt	Yakama Nation	jzendt@ykfp.org
Kay Zillich	San Juan Forest/BLM	czillich@fs.fed.us