Modeling Home Survival on the Wildland Urban Interface: A Mitigation Cost-Effectiveness Analysis

Keith D. Stockmann
University of Montana, College of Forestry and Conservation

Presentation Overview

- Describing the research problem and objectives
- My use of the latest Structure Ignition Assessment Model (SIAM) prototype
- My use of the Simulating Patterns and Processes at Landscape Scales (SIMPPLLE) ecological disturbance modeling tool
- Work remaining to complete my dissertation

Quadrennial Fire and Fuels Report

WUI growth rates in the US between 1990-2000 were estimated at three times that of non-WUI areas.

This leads to an expectation of approximately 8 million new WUI homes between 2000 and 2010 based on growth rates for the last decade.

The intermix areas, often outside fire district protection, appear to be experiencing the fastest residential development.

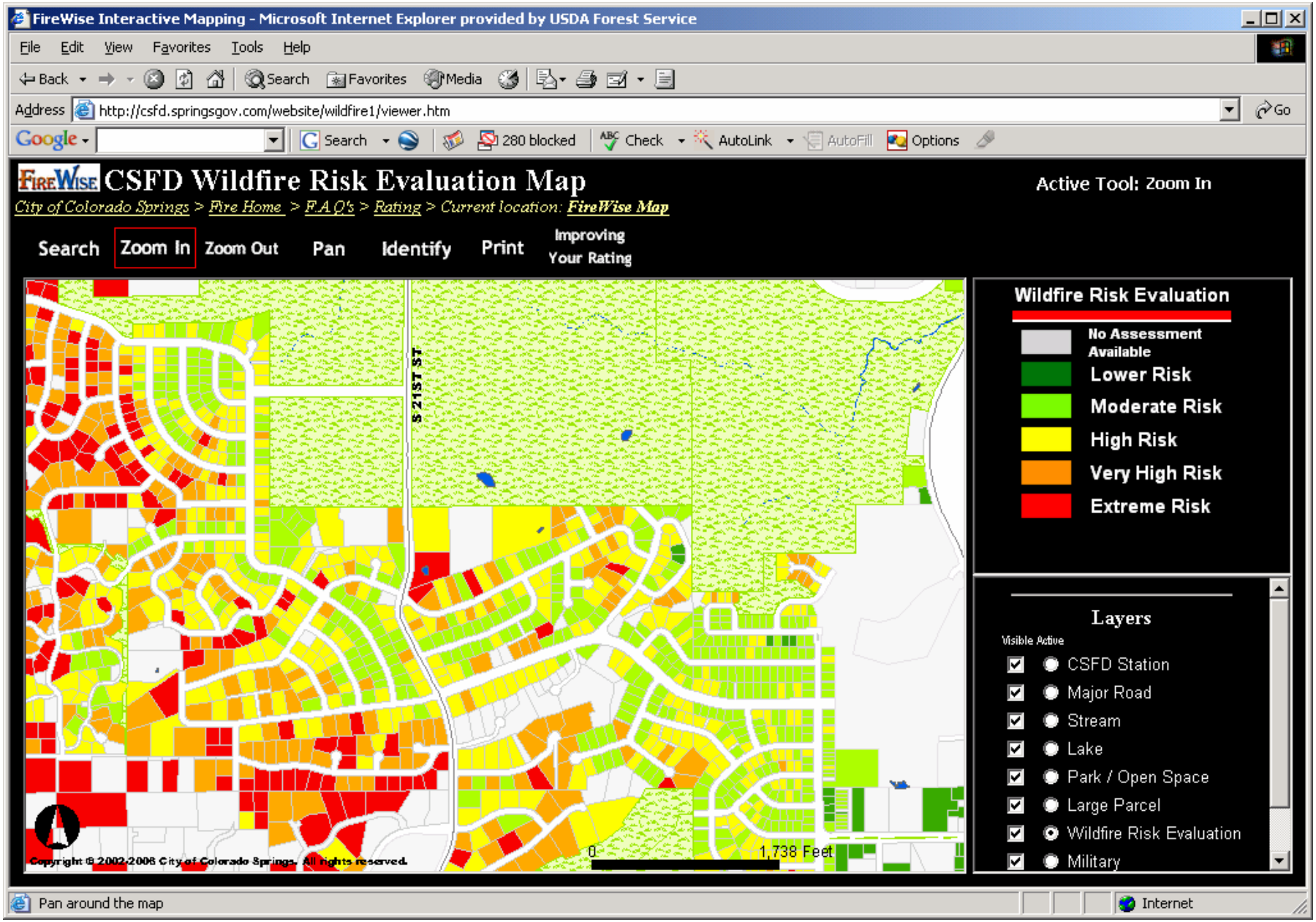
Wildfire Suppression Costs and Structures burned 2000-2004.

Year	**Primary Residences Burned**	**Total Federal Agency Suppression Costs**
2004	315	$0.89 Billion
2003	4090	$1.3 Billion
2002	835	$1.6 Billion
2001	731* All Structures	$0.78 Billion
2000	861* All Structures	$1.3 Billion

Source: National Interagency Fire Coordinating Group

The Problem

- Growing numbers of homes and communities in WUI areas at risk from wildfire.
- Large numbers of homes lost annually to wildfire
- Scarce resources and funds
- Community Wildfire Protection Plan efforts to address the problem lack mitigation cost effectiveness information


FireWise Interactive Mapping - Microsoft Internet Explorer provided by USDA Forest Service
File Edit View Favorites Tools Help
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Address http://csfd.springsgov.com/website/wildfire1/viewer.htm
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CSFD Wildfire Risk Evaluation Map
Active Tool: Zoom In
City of Colorado Springs > Fire Home > F.A.Q's > Rating > Current location: FireWise Map
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S 21ST ST
Wildfire Risk Evaluation
No Assessment Available
Lower Risk
Moderate Risk
High Risk
Very High Risk
Extreme Risk
Layers
Visible Active
CSFD Station
Major Road
Stream
Lake
Park / Open Space
Large Parcel
Wildfire Risk Evaluation
Military
0
1,738 Feet
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Pan around the map
Internet

The Research Question

How does the cost effectiveness compare between:

(1) mitigations in the Home Ignition Zone and,

(2) thinning and burning treatments applied to forest stands within an area extending 1.5 miles from structures

Using a probability-based approach to demonstrate how we can use emerging modeling tools to address larger questions of social equity, investment planning, etc.

Objective 1

1. Assess the current hazard to WUI structures
   A. Develop home ignition estimates
      i. Collect field data for representative homes
      ii. Model homes with SIAM to obtain probabilities
      iii. Use a classification system to apply home ignition zone modeling results to the remaining homes
   B. Develop stand level fire probabilities
      i. Assemble historical and existing vegetation information and model the landscape with SIMPPLLE for 30 years
   C. Multiply probabilities to model existing hazards

Example of the Math

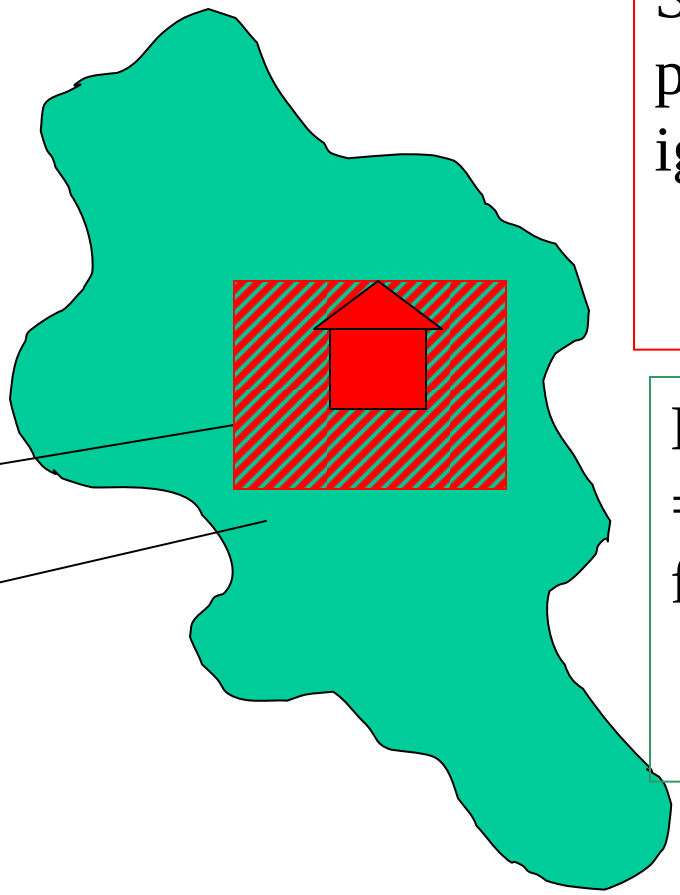
Calculating the existing hazard

.80

X .13

= .10

Objective -1



SIAM Option = Reduce the probability of structure ignition given a wildfire

Objective -2

MAGIS / SIMPPLLE Option = Reduce the probability of fire reaching each structure

Objective -3

Major Assumptions

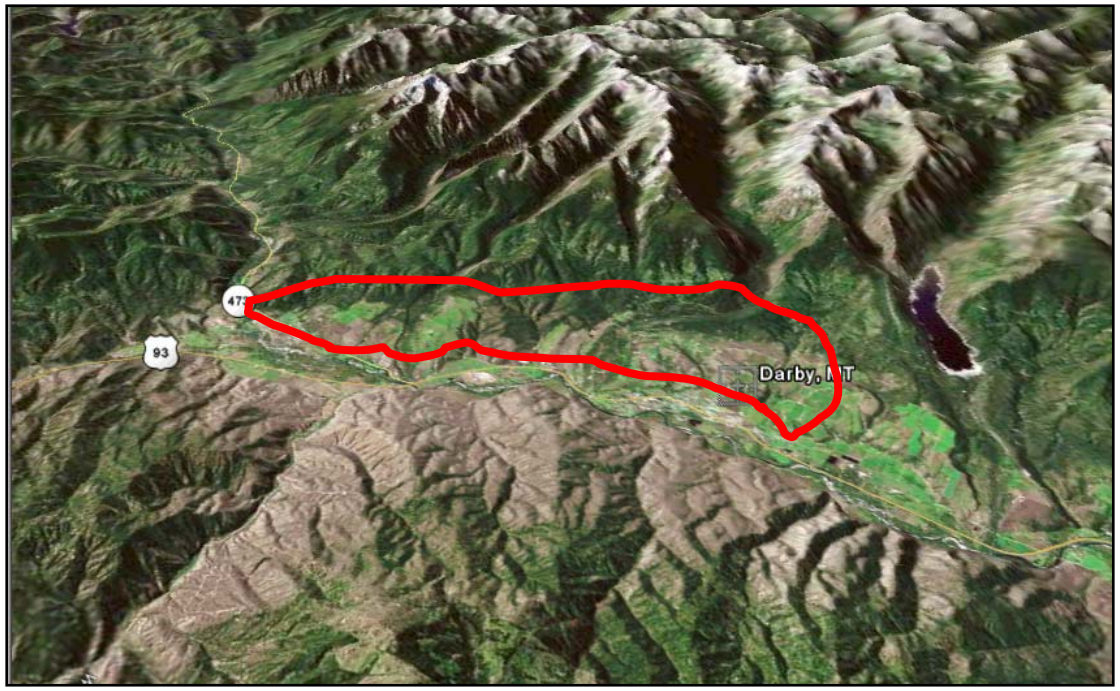
- **Structure protection is the sole objective**
- **Reduction in the average (n=291) residential structure ignition probability from 2004-2034 is the metric of effectiveness***
- **Reducing the ignition expectation for each home is equally important**
- **We are modeling with extreme fire weather and with NO SUPPRESSION.**

The Weather Scenario

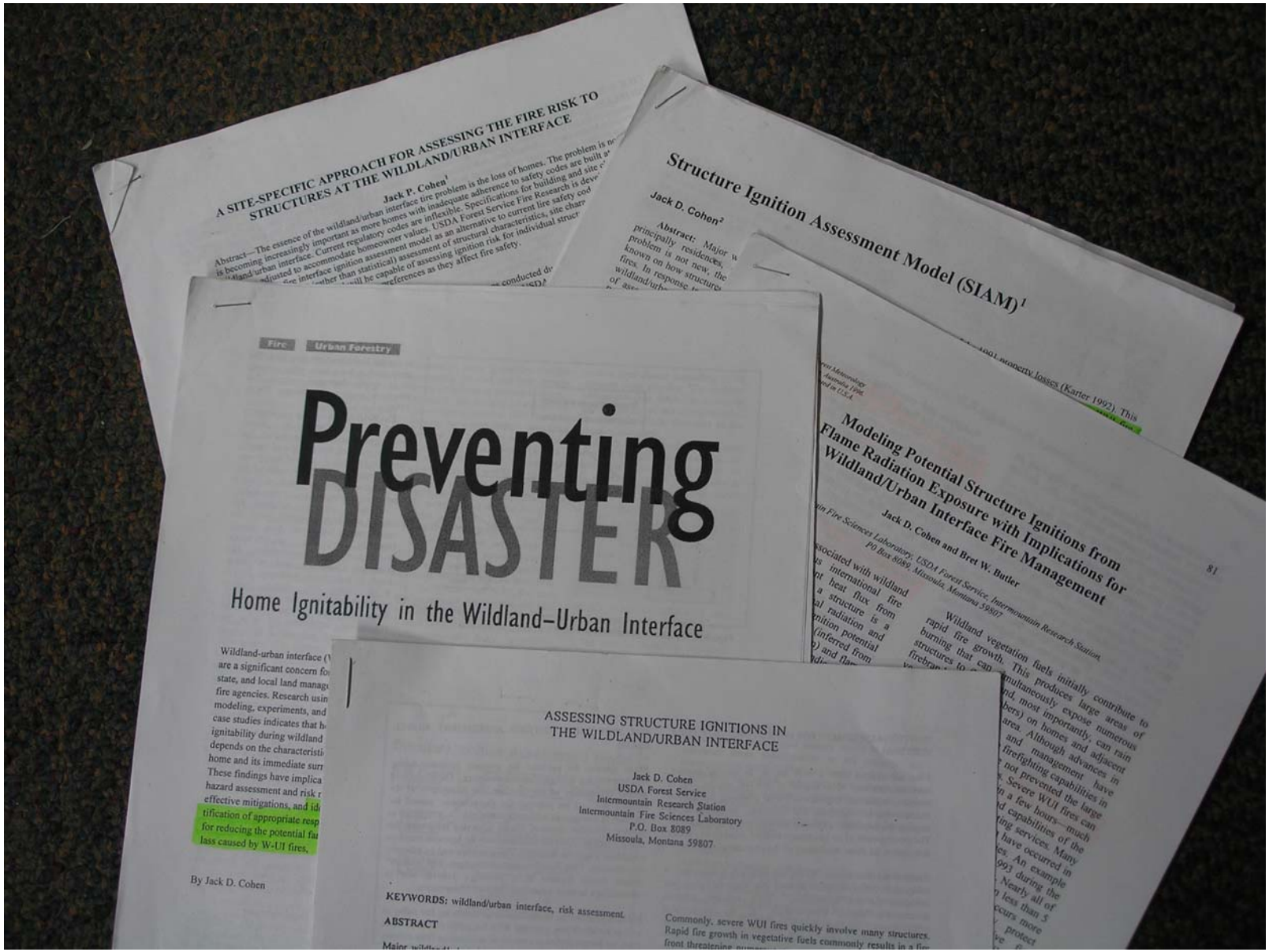
SIAM Default: 90 Degrees F, 20 mph wind towards all sides,
SIMPPLLE : SW Wind (0,1, or 5% of fires burn with 30mph winds)

The Study Area

- 381,362 acres
- Generally west and southwest of Darby, MT
- During the Fall of 2005, I visited 40 of the 291 structures in my Study Area WUI. They are within 1.5 miles of USFS land, limited to low density housing and were limited by my field work area.



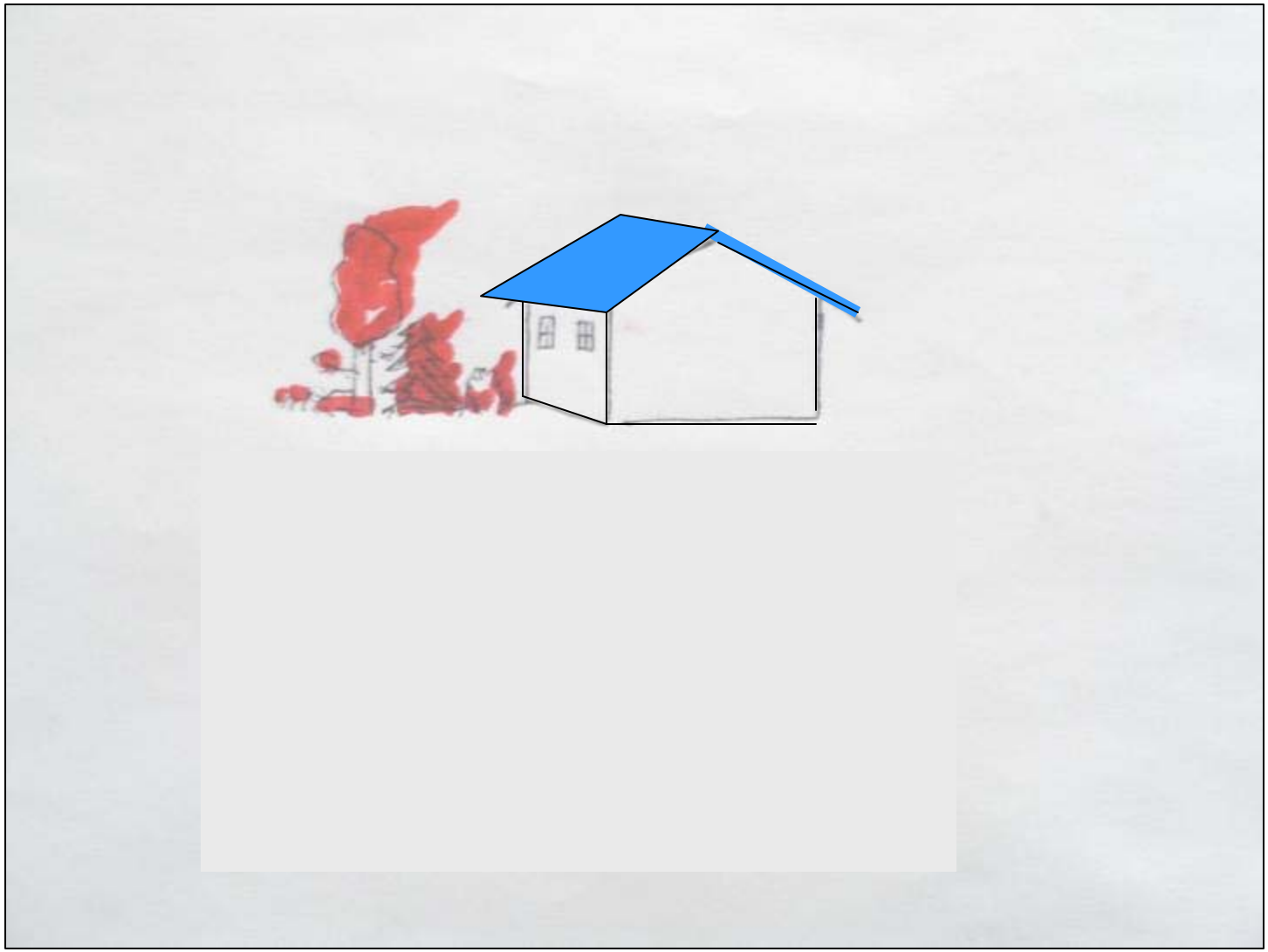
Jack Cohen's SIAM Model



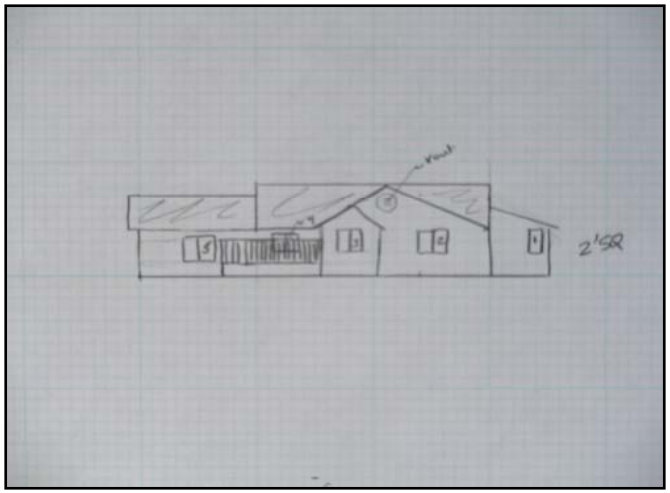
ELEMENTS OF SIAM

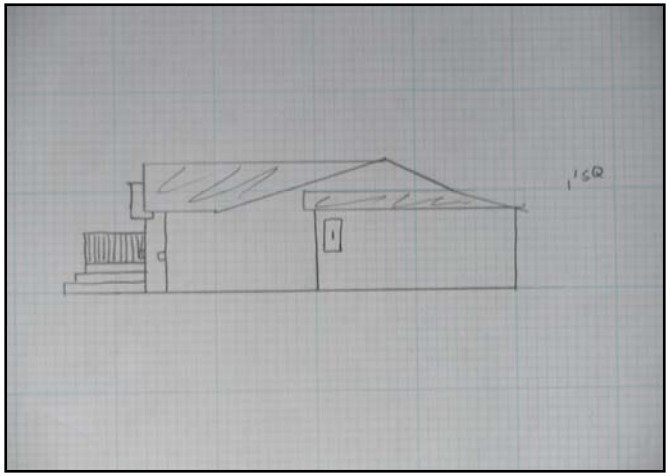
- Format: An elevation view and plan view
- Ignition possibilities:
  - Roof ignition from firebrands
  - Radiation delivered to siding (thirds of each side)
  - Convective heating delivered to siding (thirds of each side)
  - Window breaks with firebrands (thirds of each side)
  - Nook and cranny ignitions from firebrands (each side)

The SIAM Modeling Approach

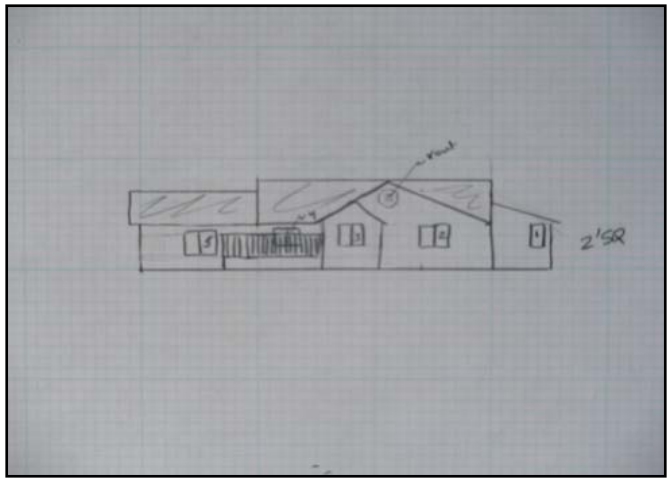


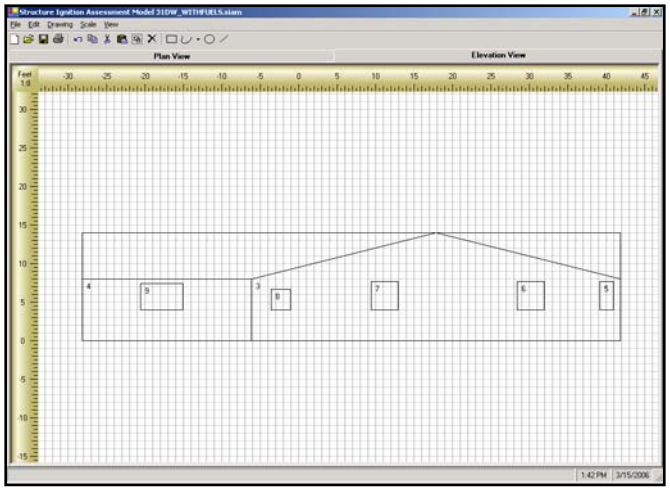
Comparing Field Data with Photos

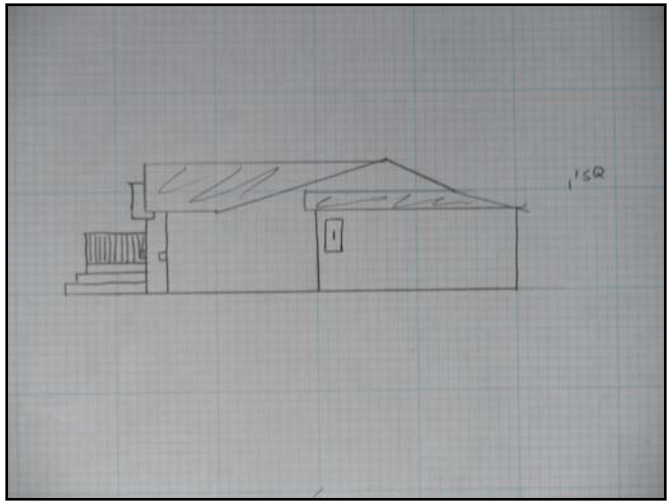


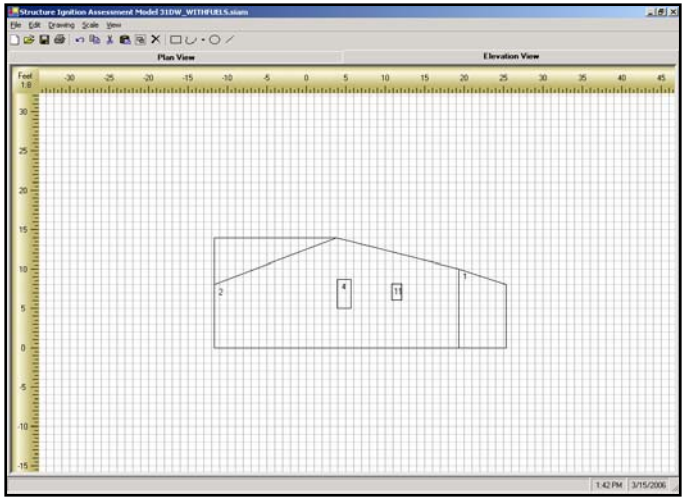


Comparing Field Data with SIAM









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No Transition | Common Tasks

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DW 26

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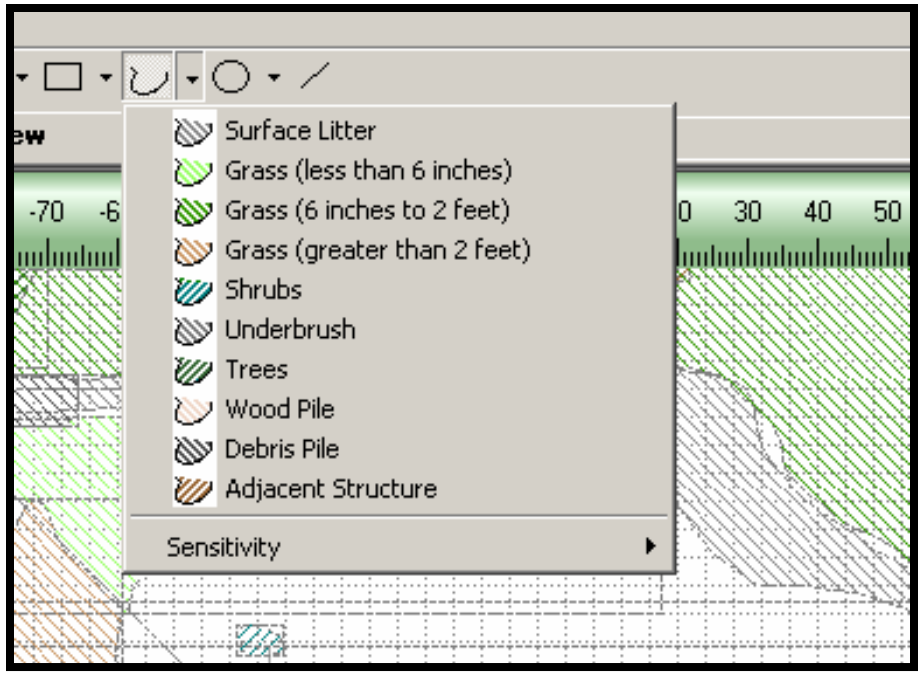
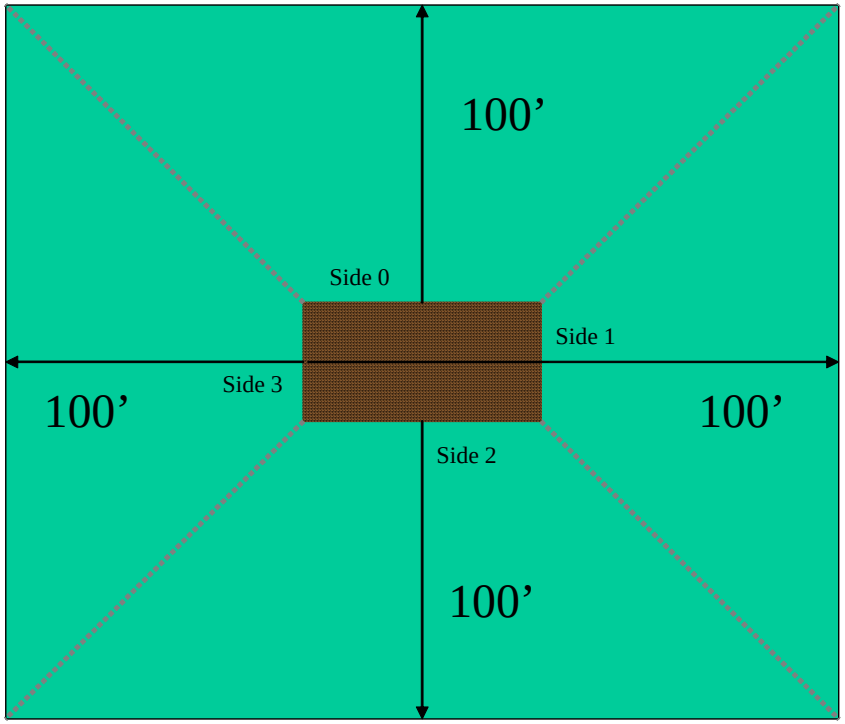
SIAM Fuels Legend



Home Ignition Zone



Note: The Home Ignition Zone was defined as an area extending 100’ feet from each side of each structure

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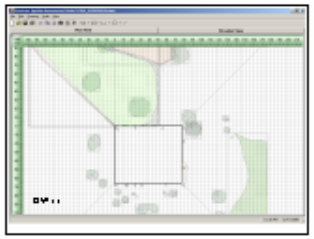
66%

No Transition

Common Tasks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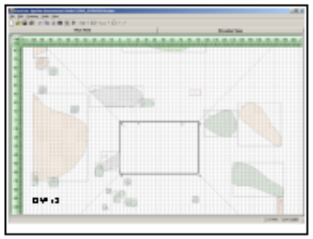
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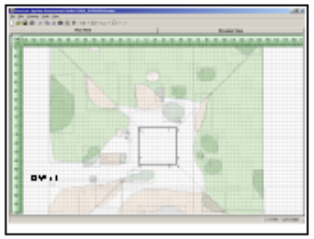
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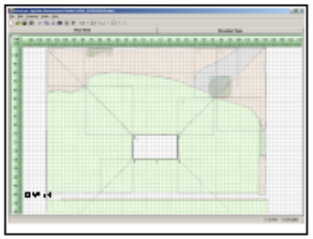
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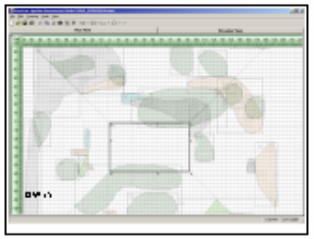
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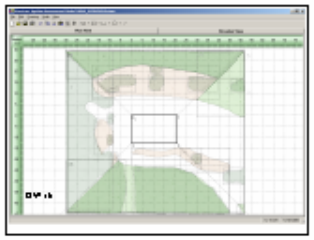
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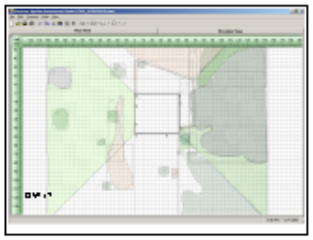
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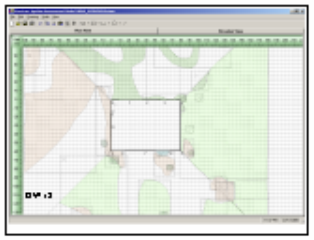
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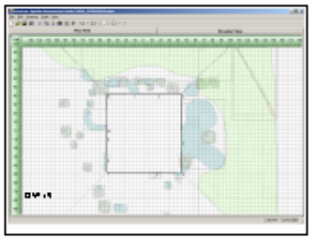
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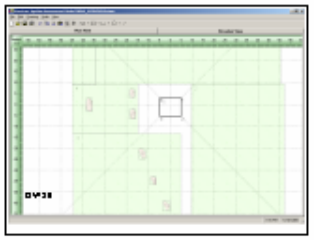
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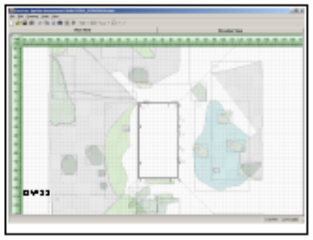
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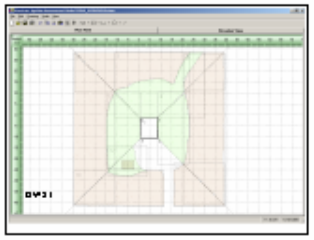
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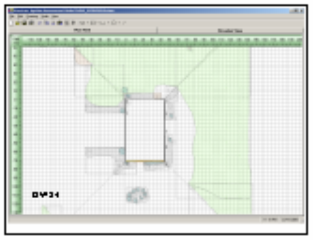
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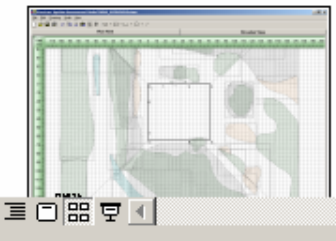

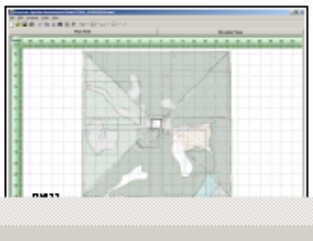

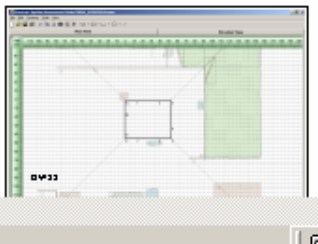

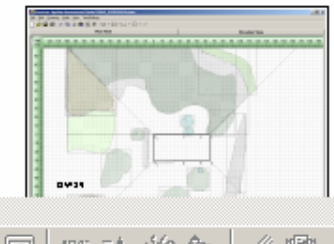

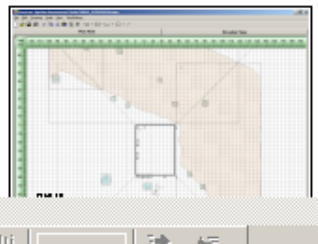

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Default Design

Adjacent Structures are not included in the analysis,
yet clearly they increase ignition potential

Summary Statistics for Existing SIAM Ignition Probabilities*

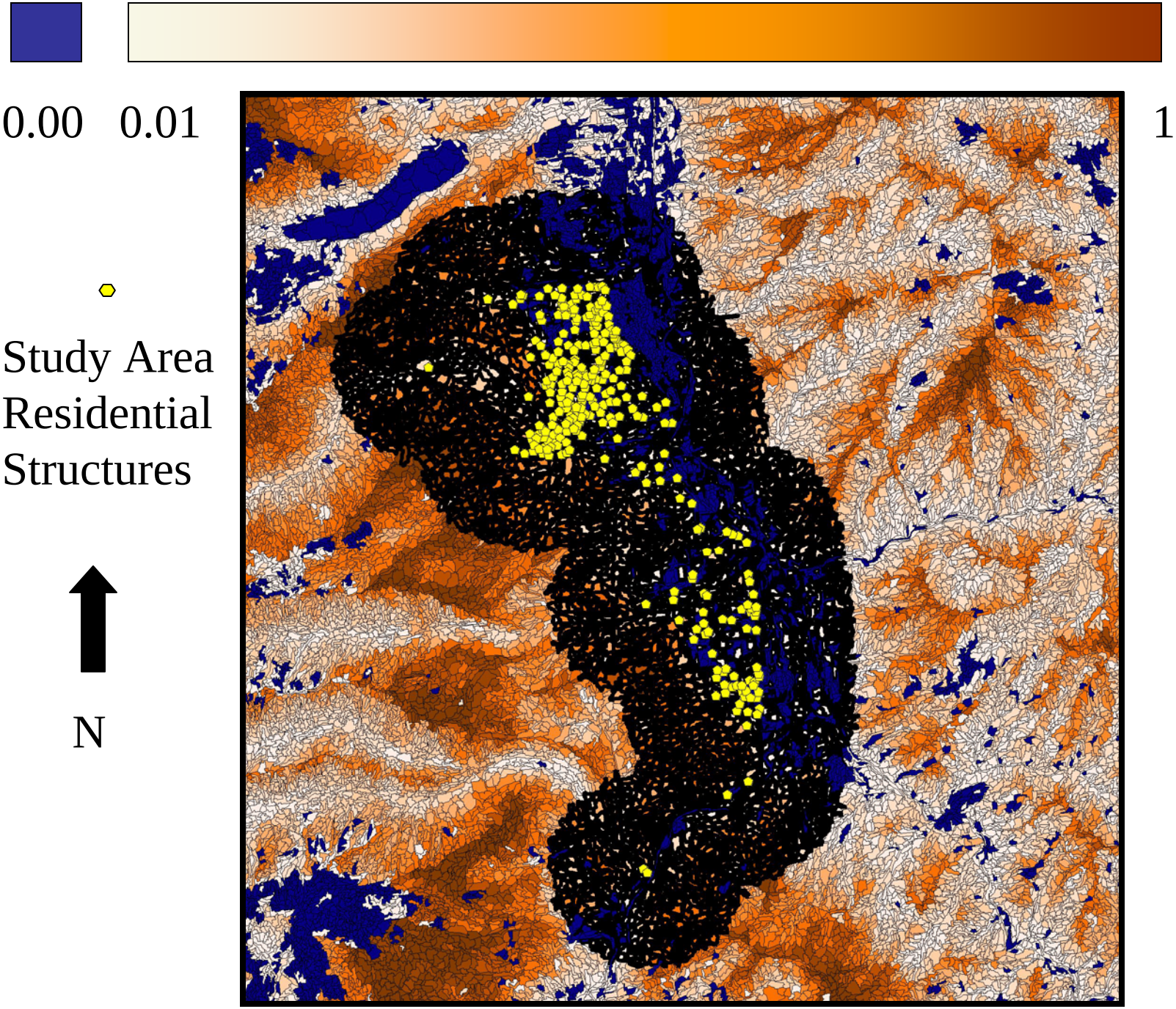
- N = 40
- 37 Structures had an existing ignition probability of 1.0
- 3 Structures had an existing ignition probability < 1.0 (0.996, 0.985, 0.814)
- The mean for 40 structures was 0.994.

***Based on maximum probability of the four sides**

- The mean average for 4 sides of the 40 structures was 0.784.

SIMPPLLE Overview

- Succession based disturbance model
  - Fire Logic:
    - Fischer, W. C. and A.F. Bradley 1987. Fire ecology of western Montana forest habitat types. USDA Forest Service, Intermountain Research Station, GTR INT-223. 95p.
    - Smith, J. K. and W.C. Fischer. 1997. Fire ecology of the forest habitat types of northern Idaho. USDA Forest Service, Intermountain Research Station, GTR INT-363. 142p.
- Adjacency contagion logic between stands for fire is uphill and/or downwind spread
- Input recent fires (`95-04), insect &disease locations (`04), fuel treatments and harvest activities (`05-04) for initial decade


0.00
0.01
1.0
Study Area
Residential
Structures
N

Preliminary Existing Conditions 2004 through 2034

- Homes with 0.00 probability ~180 (62%)
- Maximum probability 0.45
- Average probability 0.06
- Median probability 0.03

HIZ Mitigation Summary

A. Upgrade all windows to double pane
B. Replace siding with non flammable material
C. Upgrade windows and replace siding
D. Light Fuels modification only
E. Light Fuels modification and replace siding
F. Full Fuels removal
G. Full Fuels / Full Structural improvements

SIAM Modifications in the HIZ

Option	Number of Homes with option available /40	Mean Ignition Probability **for structures with option available**	Mean Ignition Probability **for all 40 structures**
A	7	1.0 to 1.0	0.99
B	34	1.0 to 0.92	0.93
C	7	1.0 to 0.98	0.93
D	37	0.99 to 0.89	0.90
E	9	1.0 to 0.76	0.80
F	40	0.99 to 0.36	0.36
G	35	1.0 to 0.37	0.36

Replace Siding Option

- ~ 83 percent of homes visited have this option available, with a mean of 41.4 sq.*
- Hardi-plank replacement

Material =	$85/square
Labor =	$130/square
Total =	$215/sqaure

- $215 * 41.4 = $8,900 per structure
- $8,900 * 34 homes = $302,600

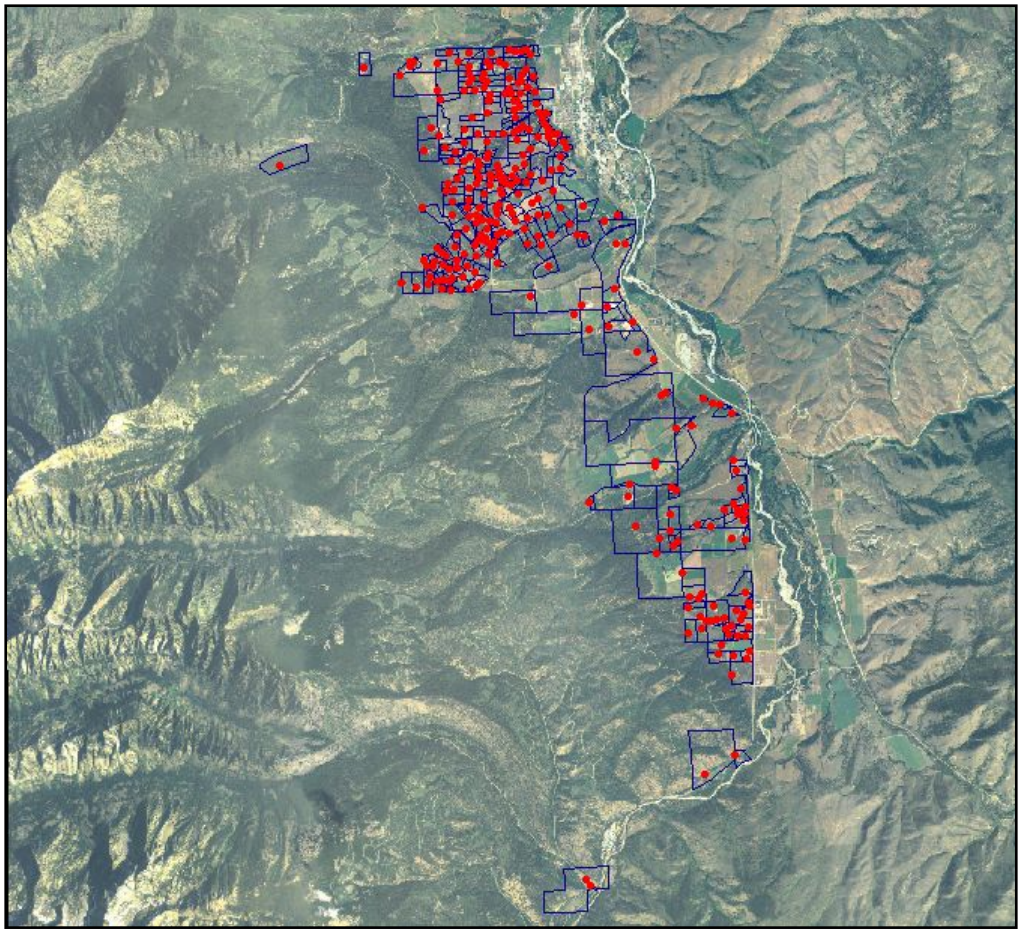
* A square is 10’x10’

IMPROVEMENTS TO THE LAND definitions DWELLING NUMBER 1 General Info - Dwelling #1	
DWELLING TYPE	D - Dwelling
STYLE OF DWELLING	11, (log)
YEAR BUILT	1980
EFFECTIVE YEAR OF DWELLING	85
PHYSICAL CONDITION	4, (average)
GRADE (WORKMANSHIP & MATERIALS)	5, (average)
CONDITION, DESIRABILITY, USEFULNESS	GD (good)
STORY HEIGHT	1
EXTERIOR WALL CONSTRUCTION	4, (log, not over frame)
EXTERIOR WALL FINISH	0, (other)
ROOF TYPE	3, (gable)
ROOF MATERIAL	6, (wood shake)
HEATING SYSTEM	1, (non-central)
HEATING SYSTEM TYPE	7, (electric baseboard/radiant)
HEATING FUEL TYPE	4, (electricity)
FOUNDATION	2, (concrete)
BASEMENT	3, (full)
FINISHED BASEMENT (SQ FT)	0 2565
BASEMENT QUALITY	3, (typical)
TOTAL ROOMS (EXC HALLS AND BATHS)	8
BEDROOMS	4
FAMILY ROOMS	1
FULL BATHROOMS	2

Classification of Remaining Homes Using Cadastral Information

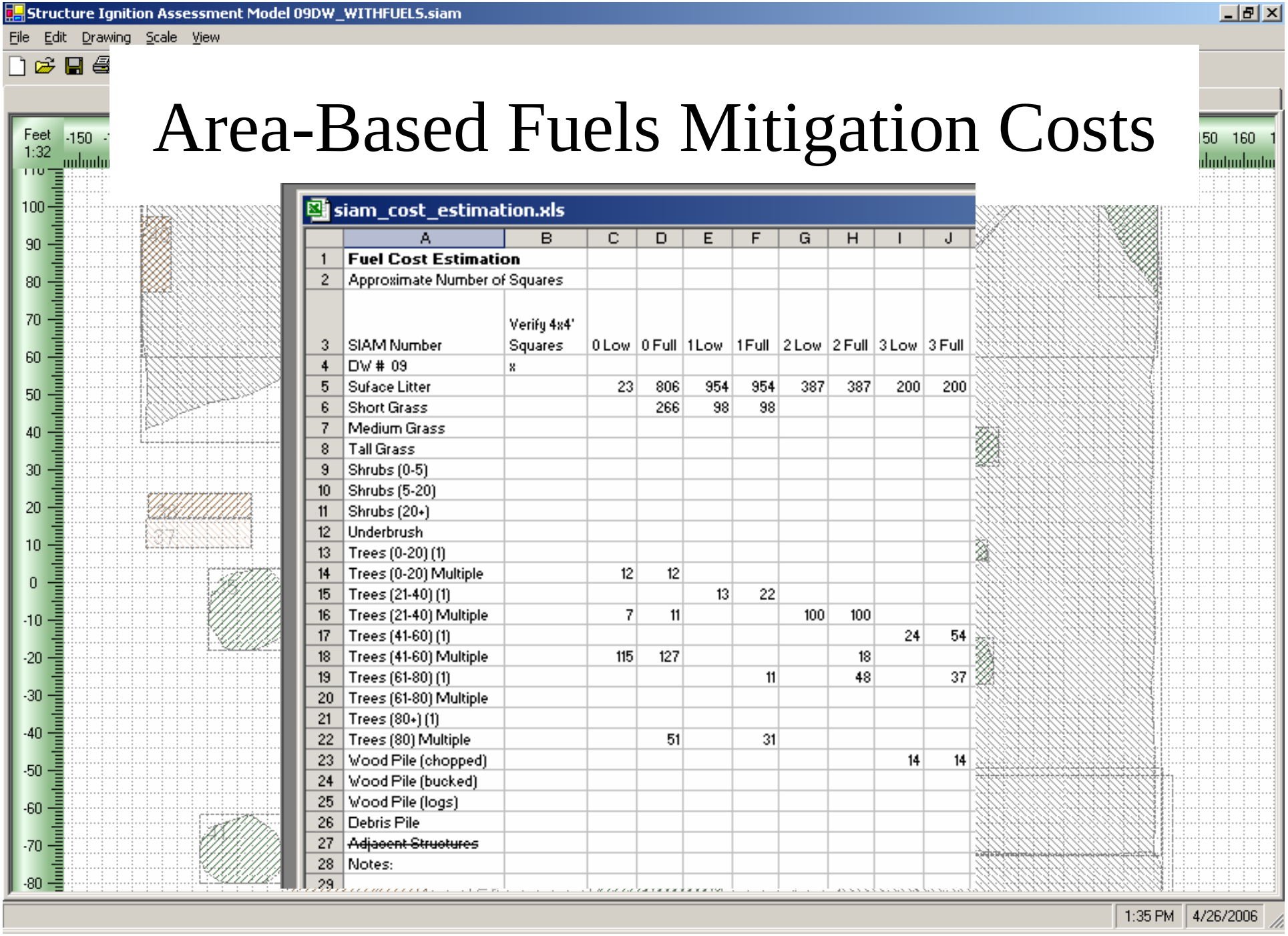
	Ignitable	Nonignitable	Unknown	Total
Roof	0	289	2	291
Siding	206	47	38	291

Applying the modeling results to the larger WUI study area



$8,900	*	(0.83*291) =	$2,153,800
Cost/structure		% in DW WUI	Cost for this option

Area-Based Fuels Mitigation Costs



	A	B	C	D	E	F	G	H	I	J
1	**Fuel Cost Estimation**									
2	Approximate Number of Squares									
3	SIAM Number	Verify 4x4' Squares	0 Low	0 Full	1 Low	1 Full	2 Low	2 Full	3 Low	3 Full
4	DW # 09	x								
5	Suface Litter		23	806	954	954	387	387	200	200
6	Short Grass			266	98	98				
7	Medium Grass									
8	Tall Grass									
9	Shrubs (0-5)									
10	Shrubs (5-20)									
11	Shrubs (20+)									
12	Underbrush									
13	Trees (0-20) (1)									
14	Trees (0-20) Multiple		12	12						
15	Trees (21-40) (1)				13	22				
16	Trees (21-40) Multiple		7	11			100	100		
17	Trees (41-60) (1)								24	54
18	Trees (41-60) Multiple		115	127				18		
19	Trees (61-80) (1)					11		48		37
20	Trees (61-80) Multiple									
21	Trees (80+) (1)									
22	Trees (80) Multiple			51		31				
23	Wood Pile (chopped)								14	14
24	Wood Pile (bucked)									
25	Wood Pile (logs)									
26	Debris Pile									
27	~~Adjacent Structures~~									
28	Notes:									
29										

siam_cost_estimation.xls

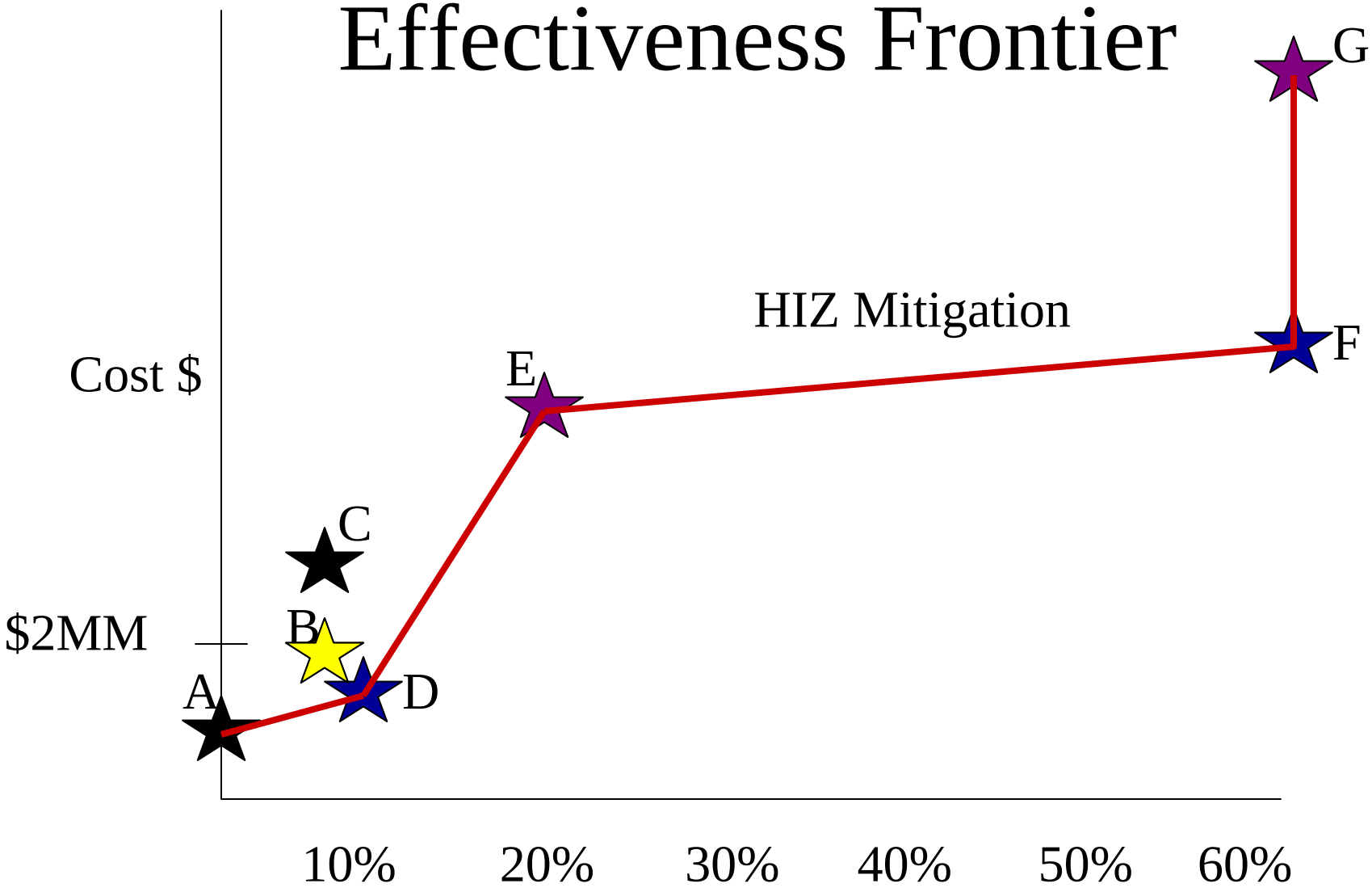
	A	K	L	M	N	O	P	Q	R	S	T	U
1	**Fuel Cost Estimation**											
2	Approximate Number of S											
3	SIAM Number		0 Low	0 Full	1 Low	1 Full	2 Low	2 Full	3 Low	3 Full	Low Cost Sur	Full Cost Sum
4	DW # 09	Costs/16ft.sq.	Squares * Cost/square									
5	Suface Litter	$ 1.00	$ 23.00	806	954	954	387	387	200	200	$1,564	$2,347
6	Short Grass	$ 3.00	$ -	798	294	294	0	0	0	0	$294	$1,092
7	Medium Grass	$ 6.00	$ -	0	0	0	0	0	0	0	$0	$0
8	Tall Grass	$ 5.00	$ -	0	0	0	0	0	0	0	$0	$0
9	Shrubs (0-5)	$ 1.50	$ -	0	0	0	0	0	0	0	$0	$0
10	Shrubs (5-20)	$ 2.50	$ -	0	0	0	0	0	0	0	$0	$0
11	Shrubs (20+)	$ 6.00	$ -	0	0	0	0	0	0	0	$0	$0
12	Underbrush	$ 6.00	$ -	0	0	0	0	0	0	0	$0	$0
13	Trees (0-20) (1)	$ 8.00	$ -	0	0	0	0	0	0	0	$0	$0
14	Trees (0-20) Multiple	$ 10.00	$ 120.00	120	0	0	0	0	0	0	$120	$120
15	Trees (21-40) (1)	$ 9.00	$ -	0	117	198	0	0	0	0	$117	$198
16	Trees (21-40) Multiple	$ 11.00	$ 77.00	121	0	0	1100	1100	0	0	$1,177	$1,221
17	Trees (41-60) (1)	$ 3.00	$ -	0	0	0	0	0	72	162	$72	$162
18	Trees (41-60) Multiple	$ 4.00	$ 460.00	508	0	0	0	72	0	0	$460	$580
19	Trees (61-80) (1)	$ 5.00	$ -	0	0	55	0	240	0	185	$0	$480
20	Trees (61-80) Multiple	$ 6.00	$ -	0	0	0	0	0	0	0	$0	$0
21	Trees (80+) (1)	$ 7.00	$ -	0	0	0	0	0	0	0	$0	$0
22	Trees (80) Multiple	$ 8.00	$ -	408	0	248	0	0	0	0	$0	$656
23	Wood Pile (chopped)	$ 3.00	$ -	0	0	0	0	0	42	42	$42	$42
24	Wood Pile (bucked)	$ 2.00	$ -	0	0	0	0	0	0	0	$0	$0
25	Wood Pile (logs)	$ 4.00	$ -	0	0	0	0	0	0	0	$0	$0
26	Debris Pile	$ 1.00	$ -	0	0	0	0	0	0	0	$0	$0
27	~~Adjacent Structures~~										Low Fuels	Full Fuels
28	Notes:										$ 3,846.00	$ 6,898.00

Trial (2) | Cost Estimation DEMO | Sorting Progression | **Trial**

Draw ▾ AutoShapes ▾

Ready

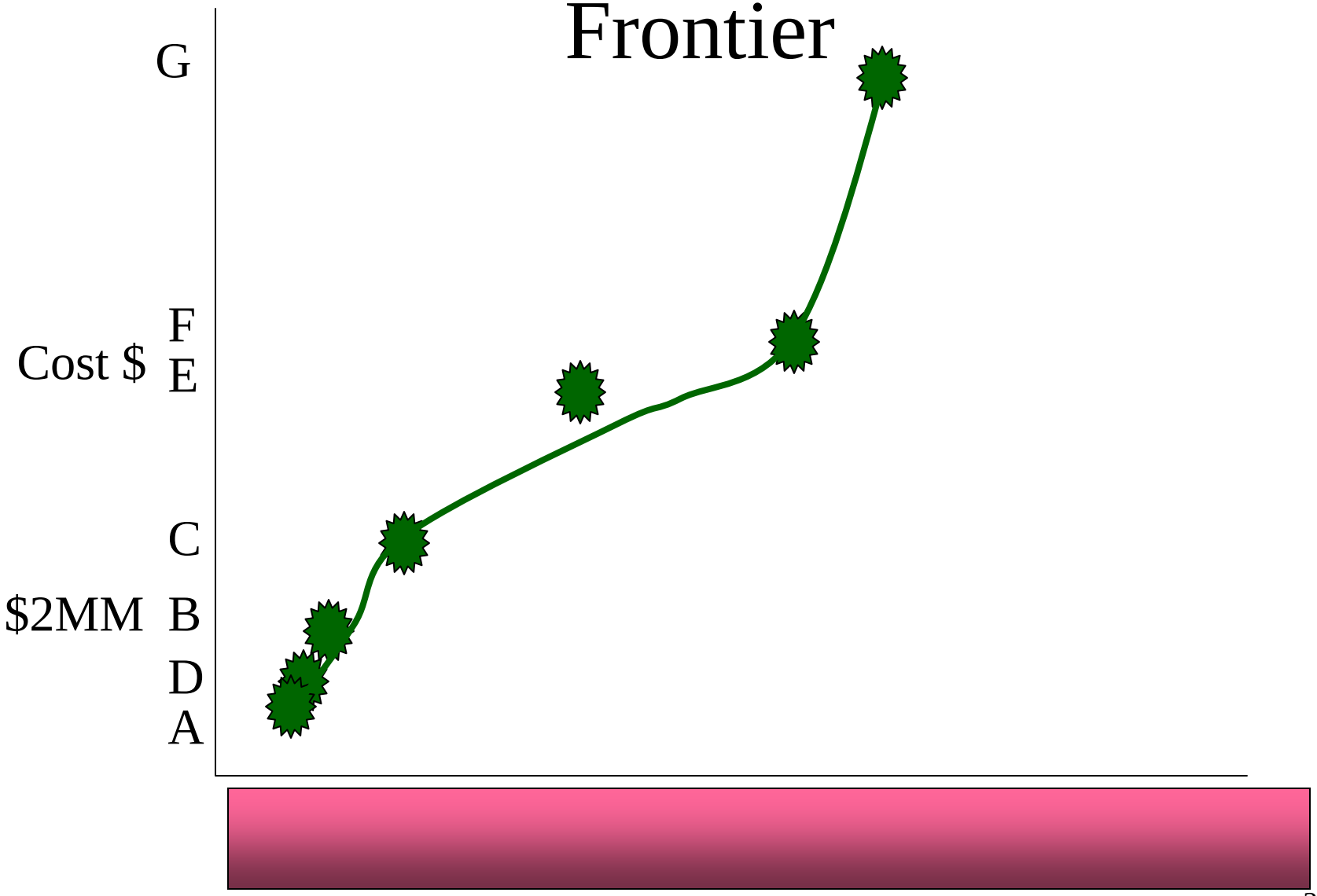
Home Ignition Zone Mitigation Cost Effectiveness Frontier



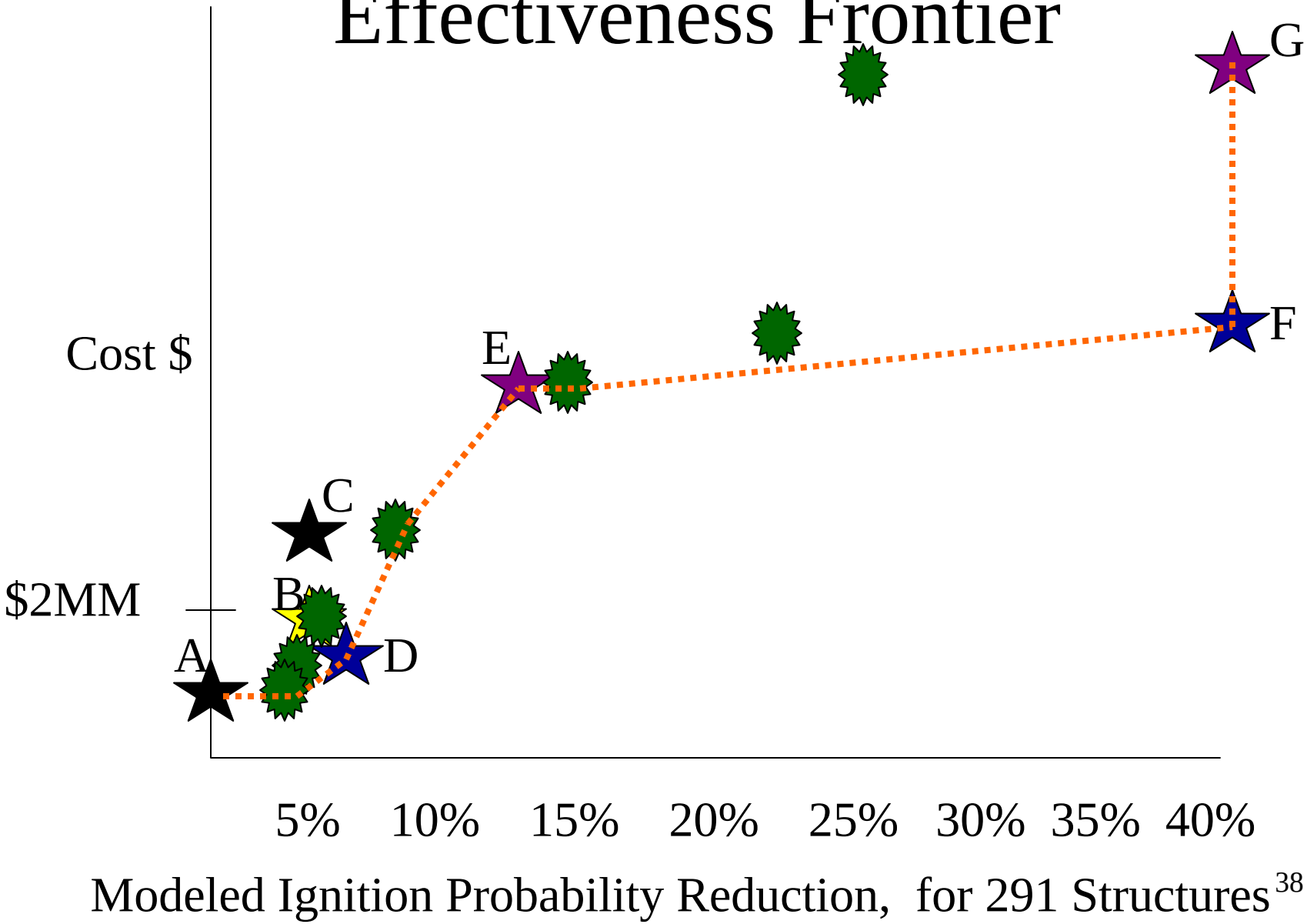
Thinning and Burning Options

- Use the Multi-resource Analysis and GIS (MAGIS) software to optimize treatments at various budget levels that correspond to HIZ mitigation costs across the study area.
- Objective Function: Minimize the three decade probability of fire reaching any vegetative community hosting a WUI residence in the study area.
- Jurisdictionally blind treatment options

Thinning and Burning Cost Effectiveness Frontier



The Goal – Modeling System Cost Effectiveness Frontier



Looking at the X axes and thinking about the cost effectiveness

The reduction may be greater in terms of probability for SIAM but we should be considering the change in proportions

Because the independent conditional probability is a simple product of two the two probabilities, a reduction of hazard of equal proportion has equal impact on the final probability figure. For example a shift in probability from 1.0 down to 0.9, as with mean probability of structure ignition after applying the low fuel and siding option has the same impact as a reduction from 0.10 down to 0.09 in the probability of fire reaching the structure in the next thirty years. Thus **the modeling system yields a different CE result than one gets by looking at the two paths to reduce hazard independently.**

Remaining Dissertation Work

- Improve cost estimates for HIZ mitigation activities
- Apply cost estimates from SIAM mitigations to thinning and burning using MAGIS schedules run back through SIMPPLLE
- Generate actual cost effectiveness frontiers for each option, possibly with optimization software.
- Generate cost effectiveness frontier for the combined modeling system
- Provide context with additional resource protection objectives

Additional Management Objectives

- critical infrastructure,
- timber values
- land value
- aesthetics
- sensitive wildlife habitat,
- soil productivity,
- air quality

Ecosystem Functions

(Graham et al. (2004) Weaver 1943, Reynolds et al. 1992, Covington and Moore 1994, Covington et al. 1997, Fulé et al. 1997, Swetnam et al. 1999, Conrad et al. 2001, Kalabokidis et al. 2002, Cohen and Stratton 2003).

Project Partners

The University of Montana

College of Forestry and Conservation,
Department of Forest Management

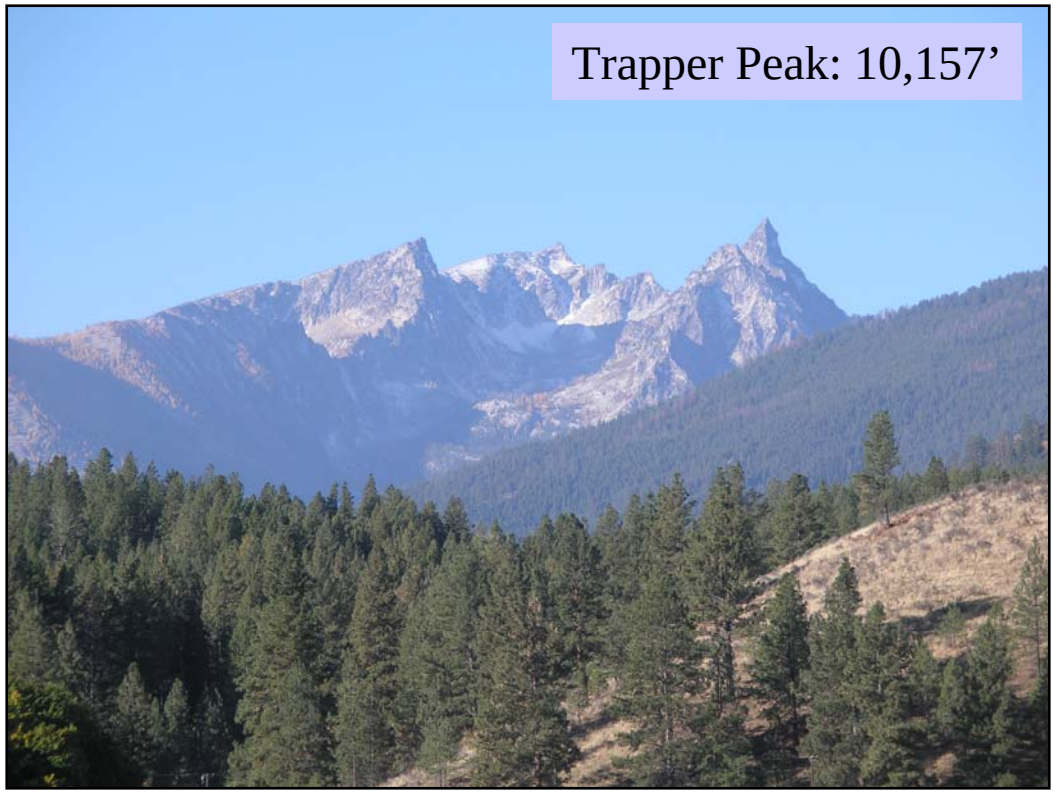
"World Class in the Rockies"

RMRS

United States Department of Agriculture – Forest Service
Rocky Mountain Research Station

Missoula Fire and Forest Science Laboratories

Questions or Points of Clarification?



Contact: 406.542.3247
keith.stockmann@umontana.edu,
kstockmann@fs.fed.us