STARFIRE

GEAR HEAD

Key Concepts of STARFire Valuation:
The MARS Method and Principles of Application

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1 WHY MARS?

Public officials are required to make quick decisions that involve protecting or enhancing marginal resource value when managing fire events or planning for fuel treatments. Despite great strides in valuation theory and empirical measurement techniques, land managers continue to face a scarcity of information regarding marginal valuation of resources affected by fire. To address this issue, STARFire uses a valuation method recently developed by ***Rideout et al. (2008)*** known as "Marginal Attribute Rate of Substitution" (MARS).

MARS is based on the micro-economic principles of derived demand and utility theory. The mathematics of MARS, utility theory and how MARS relates to more traditional valuation methods such as the Contingent Valuation Method (CVM) are discussed in the ***2008 paper***. The intent of this document is to summarize selected concepts that are required for applying MARS to STARFire and interpreting the results.

1.1 WHAT IS MARS?

MARS is a non-market and non-monetized valuation system for the management of fire effects. The MARS method is used to estimates relative marginal values[1] of fire effects. Understanding this and related economic concepts is essential to understanding the application of MARS in assessing fire effects in STARFire. The marginal value of fire effects refers to the change in value from fire effects for a particular resource relative to the change in value for another resource. This involves assessing loss for damaging fire effects and value added for positive fire effects. Loss as defined here refers to the reduction in value from fire. The change in value, positive or negative, is then addressed by making comparisons with the value change in other resources (substitution effects). In the language of economics, relative marginal values are called "marginal rates of substitution". Rates of substitution are expressed and measured in MARS by Implicit Attribute Prices (IAPs). Implicit price refers to the idea that while we cannot directly observe prices, we will construct comparisons and evaluate them to generate the equivalent of a price. MARS will describe the value of one resource in terms of the other through ratios. The ratio of MARS-generated IAPs estimates their rate of substitution or marginal relative value. The IAPs generated in MARS reflect both the change in

[1] Marginal value is defined as a change in total value for resource A relative to a change in value for resource B. "Value, in Economics, Means Exchange Value. The value of any commodity is the maximum amount of some other good that an individual is willing to part with in order to gain an extra unit of the good in question. ... the marginal value ...is ...called...the marginal rate of substitution..." (Silberberg and Suen 2001). Also note that the concept of NVC as used in fire is not a marginal value -- making NVC and IAP unequal concepts.

resource value from fire and the substitution effect. The following example explores these ideas in more detail.

Consider two resources, A and B. The marginal rate of substitution between resource A and resource B is the ratio of their IAPs:

$$IAP_A/IAP_B = Z \tag{1}$$

Using numbers for illustration, suppose that (1) can be expressed as:

$$0.6/0.2 = 3 \tag{2}$$

This states that the rate of substitution between resources A and B is three to one. This means that having one more unit of resource A is three times more valuable than a having one more unit of resource B. For this ratio to have meaning, resources A and B must be measured in comparable units. If the measurement units of A and B are the same (say, both are measured in acres), the units cancel and the ratio in box (1) is the approximate "price ratio" between the resources and the IAP for A is three times the IAP for B. Perhaps the most important concept to arise from taking a ratio of IAPs is that "currency" and "money" are irrelevant to their definition. A non-monetized valuation system such as MARS helps immensely with communication among resource specialists about relative marginal values and promotes clarity in the elicitation of the IAPs.

When we reference the value of improvement (value added) by introducing fire or the loss from undesirable fires, we do so without considering management cost. Including management cost considerations, such as treatment or protection costs, would produce a "net value." Management costs will be included after the valuation process is complete so that STARFire can use "net value" for specific kinds of analysis (like locating fuel treatments) and "gross" value (IAPs) in other places such as the ***landscape assessment*** that measures the change in landscape value with respect to fire management alternatives.

1.1.1 UNDERSTANDING IAPS

IAPs can be generated for all fire-affected resources that have an associated physical location on the planning unit and can be mapped in an associated GIS layer. These include natural and cultural resources on the landscape who's IAPs are affected by fire.

These fire events can have positive (value-added) effects, such as low-intensity fires that benefit a fire-dependent stand of trees, or they can have negative effects (value loss). Examples of loss include fire effects on homes in the Wildland Urban Interface (WUI) or the degradation of wildlife habitat. These fire effects are assessed for each resource and they are defined using a common spatial unit of measure. For example, we would speak of one acre of fire-dependent trees or one acre of WUI; where "one acre" is the common metric[2]. The IAPs have the following common set of properties:

- IAPs denote marginal "gross" value: not "net" value[3]
- Positive, Negative and Zero IAPs:
  - Negative IAPs denote the loss (reduction in value) from the introduction of fire at a given intensity and ecosystem condition.
  - The highest IAP will be -1.0 for fire-affected structures (greatest loss).
  - An IAP of 0.00 denotes indifference – that there is no desire or potential to avert loss or to improve the resource with fire.
  - Positive IAPs denote the value added from the fire effect.
- The scale is proportional in that the movement from -0.1 to -0.2 is equal to the movement from -0.5 to -1.0. A resource with an IAP of -1.0 denotes that twice the loss would be incurred as compared with a resource with an IAP of -0.5. Similarly a resource at -0.25 would suffer half the loss as a resource an IAP of -0.5.
- Positive and negative IAPs are symmetrical (mirror image). The loss incurred on a cell with an IAP of -0.3 is exactly the same change in value as the value added by introducing fire to a cell with an IAP of +0.3. The fire manager would be "equally happy" with either result.

In sumary, IAPs are:

- Marginal
- Relative
- Non-monetized
- Measured per unit area (acre, raster cell, hectare, etc.)
- Do not involve cost (they are "gross")
- They can be positive, negative or zero
- They must be symmetrically consistent and proportional

[2] Related attempts at such comparisons that do not clearly define the unit of measure do not have economic meaning.

[3] Sometimes "importance" is used to convey the idea of value in a managerial context and we used importance in previous applications of MARS. Because importance does not distinguish between "gross" and "net" value, we found it to be ambiguous such that it is no longer used to describe MARS or IAPs.

1.2 WHAT MARS IS NOT

Understanding MARS means making distinctions between ideas that clarify what it is. The following are a collection of items identifying what MARS is not:

Total value is irrelevant

Because MARS only addresses marginal values, we do not need to know the total value of any resource; we are only interested in the fire effect on values (value added or loss). This is a key concept and a major simplification relative to many other valuation systems such as CVM. Consider certain species of mature fire-adapted timber. Some can protect themselves from low intensity fire with thick bark and other characteristics such that they benefit from such fires. While this resource may be highly valued (total value), its IAP for protection at low intensity would be zero if there were no loss from fire. If the fire effects were beneficial, it would have a positive IAP.

Order is not used or implied

Relative prices are not priorities to the extent that priority implies order. Ordering of resources, projects or alternatives is a separable consideration.

Ranking is not enough information

Rankings can reveal which IAPs would be higher or lower, but they do not reveal how close resources are in marginal value. Ranking can be a start to establishing IAPs, but IAPs require information on how close values are to one another. Relative values include ranking information and how close the rankings are.

MARS is not an index

The IAPs are not an index; they are a defined unit of an implicit pricing system. They are not an index in the same sense that the price of apples compared with the price of milk is not an index. The values in MARS have a defined unit of measure (defined by the numeraire[4] IAP) and indices do not. Weight is a general term often used in decision sciences where the unit of measure may be unclear. Weight often implies arbitrariness that is inconstant with MARS.

1.3 ELICITATION OF IAPS

We designed MARS to be applied in a pragmatic way that does not require weeks (or more) of work. Instead, it usually only requires about a day of work (if groups are focused, experienced and properly facilitated). Elicitation of non-market values in any credible valuation method, such as the Contingent Valuation Method or the MARS

[4] A basic standard by which values are measured with a fixed price of 1.0 to facilitate comparisons.

method is a highly structured process that should be guided with the direct involvement of a resource economist.

For a defined planning unit with a single ownership, a custom list of fire-affected resources and their relative IAPs are elicited from the fire and resource specialists who have the most intimate, local knowledge of the full range of resources and fire effects on the planning unit. Each resource must be carefully defined before it is priced (Add link to doc) and the elicited IAPs for each fire-affected resource only apply to changes in the resource due to fire effects. To ensure that the elicitation process is intuitively understood and transparent to all participants, the process begins with a comprehensive introduction to MARS concepts and their application to fire management valuation.

To facilitate communication and to keep the relative values transparent a scale from -1.0 to +1.0 is used where +1.0 should rarely be observed. Negative IAPs denote the need for protection, because the fire-affected resource would be harmed while positive IAPs denote the fire-affected resource would be improved (value added). A value of 0.0 reflects indifference. Scaling and bounding helps to control an important concern in value elicitation: the "outrageous" response.

1.3.1 RESOURCE LOSS (NEGATIVE IAPS) FROM FIRE

For credible elicitation of IAPs for resources that would be damaged by fire, four things are held constant:

1. the cell size (all comparisons are made "per cell")
2. fire intensity/severity
3. ecosystem condition (e.g., maintenance vs. restoration)
4. management cost (MARS addresses value added, not cost or net value)

The fire-affected resource generating the greatest loss (from fire) is defined and placed at the low end of the scale and assigned an IAP of -1.0. This is should be WUI or some other form of developments such as a cell containing houses. Because values are defined by rates of substitution, the process requires careful comparisons. For resource protection, we can take advantage of the fact that the greatest expected loss is set to -1.0 from the outset. This enables comparisons of other negative fire effects to be made relative to the -1.0 IAP. For example, if a resource (RCW habitat) on a particular cell would burn (with no fire management protection) at a given intensity, the question could be framed as: **"How much expected loss (reduction in value) is introduced by burning a cell of RCW habitat relative to burning a cell containing a house (already known to be -1.0)?"** If the amount of loss is half, then the resulting RCW IAP is required to be -0.5. Note that the question includes the concept of value change and substitution. All negative IAPs need to be checked against all other negative IAPs for proportional consistency. They will also need to be checked against positive IAPs for symmetry. Consider starting with the econometrically derived values listed in Table 1.3.3 in this document for perspective and consistency.

1.3.2 APPLICATION OF FIRE FOR RESOURCE IMPROVEMENT

Positive IAPs denote that a resource would be improved (value added) by fire. Many natural and some cultural resources can benefit from fire; especially fire managed at lower intensities. For credible elicitation of positive IAPs, the same four things are held constant:

1. the cell size
2. fire intensity/severity
3. ecosystem condition
4. management cost

Recall that IAPs are defined by rates of substitutions and substitutions require comparisons of marginal values. Establishing negative IAPs began with defining the resource loss through fire protection at -1.0. This was a useful benchmark for making comparisons and for establishing other negative IAPs. There is no equivalent benchmark for beneficial fire effects because the highest positive IAP is unlikely to be +1.0 due to symmetry. However, the econometrically derived IAPs that appear in Table 1.3.3 of this document provide important context, starting points and a check on consistency. Considering the process as taking place in the following steps can be useful:

- A pragmatic start can be to list and rank the positive fire effects – start with getting them in the right order by finding out, if fully treated with fire (at a given intensity), which would produce the greatest value added. Continue placing resources in order by declining value added.
- Select two fire-affected resources from the list for comparison and establish their relative value added. For example, if we have RCW habitat and cougar denning habitat that will benefit from fire, establish how much value added is generated from RCW habitat. Assuming treatment is fully effective: **"How much value added is produced by treating a cell of cougar habitat as compared with treating a cell of RCW habitat?"** If the answer is 3:1 then we have established the ratio, or rate of substitution for these IAPs.
- Recall that positive IAPs need to be symmetrical with the negative IAPs. Next, one or both of the positive IAPs should be compared with the negative IAPs to establish symmetry between the negative and positive fire effects. The change in value is equivalent for IAPs that are equal, but have opposite signs. The loss from burning a resource at -0.5 produces the same magnitude of value change as does burning a resource with an IAP of +0.5. The fire manager would be equally happy with protecting against the loss indicated by the negative IAP or introducing fire to obtain the positive IAP. This last step will establish the IAPs for each of the two resources.

- The remaining positively affected resources can be priced relative to the other positive IAPs.

1.3.3 CHECKING RESULTS

Results need to be checked for appropriateness and consistency. All proportions need to be verified and pass the test of symmetry. Use the data from Table 1.3.3 at the beginning of the elicitation process to provide a context and framework. The consistency of the results can be verified by comparing them to the IAPs in Table 1.3.3. To confirm the consistency of your IAPs with those in the table, identify the appropriate resource value category. For example, to verify that the IAP selected for a rare archeological resource is appropriate you would begin by referencing the categories identified in Appendix A. A highly valued cultural resource fits category 4. Using Table 1 you can verify that the IAPs are within the confidence limits for the corresponding intensity and ecosystem condition category.

Table 1.3.3. Econometrically estimated IAPs by fire intensity and ecosystem condition for National Parks and Refuges where HR denotes high intensity and restoration, HM denotes high intensity and maintenance, LR denotes low intensity and restoration, LM denotes low intensity and maintenance, CI denotes confidence interval and R^2 denotes percentage of variation in observations explained by the econometric analysis.

Category	HR	HR CI 95%	HM	HM CI 95%	LR	LR CI 95%	LM	LM CI 95%
1	-1.00	0.00	-1.00	0	-0.96	0.039	-0.96	0.0393
2	-0.82	0.059	-0.82	0.0587	-0.73	0.171	-0.73	0.1851
3	-0.61	0.057	-0.46	0.0876	-0.41	0.084	-0.36	0.1091
4	-0.82	0.058	-0.82	0.0587	-0.96	0.039	-0.96	0.0393
5	-0.61	0.057	-0.46	0.0876	-0.41	0.084	-0.36	0.1091
6	-0.61	0.057	-0.46	0.0876	-0.41	0.231	-0.36	0.1091
7	-0.61	0.057	-0.46	0.0876	0.51	0.090	0.46	0.0765
8	0.46	0.159	0.21	0.2069	0.51	0.090	0.46	0.0765
9	-0.61	0.057	0.21	0.21	0.51	0.090	0.46	0.0765
10	0.46	0.159	0.42	0.204	0.51	0.090	0.46	0.0765
R^2	0.931		0.895		0.984		0.945	

The categories represented in the table may not account for all resources identified during the MARS process, but it provides a guideline for the majority of resources.

1.4 USING THE IAPS

Once the IAPs have been generated and controlled for quality, there are two general ways to use them:

1. assessment of the fire management condition and
2. guiding fire management decisions.

These purposes should be distinguished in the same way that taking your temperature is an aid in assessing the condition of your health, but it is insufficient for making health care decisions (additional information is required). We will begin with using IAPs to assess the fire management landscape.

1.4.1 ASSESSING THE LANDSCAPE CONDITION

A recent and unique development in STARFire involved the recognition of the central role that IAPs can play in assessing the fire management condition of the landscape. Landscapes are generally not in the fire management condition that we would like: there is nearly always an opportunity to improve protection of valuable assets (loss averted) or to add value to the ecosystem condition through fire. Another way of saying this is that that there is a scarcity of "desired" fire management condition (DFMC). These are the two fundamental reasons for fire management and for fire management resources.

Consider the role of fire management in protecting resources from loss (loss averted[5]). First, consider the condition where there is no current need in a particular cell for protection from fire. The IAP for our cell is 0.00. This cell is in the DFMC and fire protection would have no marginal value. Equivalently, there is no potential loss to avert. This benchmark defines a DFMC from a protection perspective. In contrast, suppose that the elicited IAP for a cell is -0.8. This means that the amount of loss incurred by unprotected fire would be 20% less than that for a cell containing housing or other valuable structures. If fire protection was free and we, in effect, parked a fire engine on the cell, this would fully mitigate the loss and the marginal benefit would be 0.80. With the engine on the cell, it would be in a DFMC. An equivalent way of viewing this is that this cell has a deviation of 0.80 from the desired fire management condition. This is shown in Figure 1 where the y-axis measures the deviation from the desired fire management condition and the x-axis shows increasing amounts of fire protection effort (FME). From the elicited IAP of -0.80, we are able to apply increasing protection effort to bring the deviation from the current condition to the DFMC of zero. Also consider a cell with an elicited IAP of -0.40 that is half way down the cure in Figure 1. This cell would have half of the deviation from the DFMC and it could be improved with fire protection effort. Note that the curve reflects diminishing returns to FME. By direct extension, higher IAPs indicate higher deviations from the DFMC. Because we can now measure the distance of any cell from it's DFMC, we can also extend the logic from the cell to the landscape. We can now measure the distance of any cell, or each cell, from the DFMC of zero.

[5] Note that "loss averted" is the inverse of loss and attained by applying fire management effort.

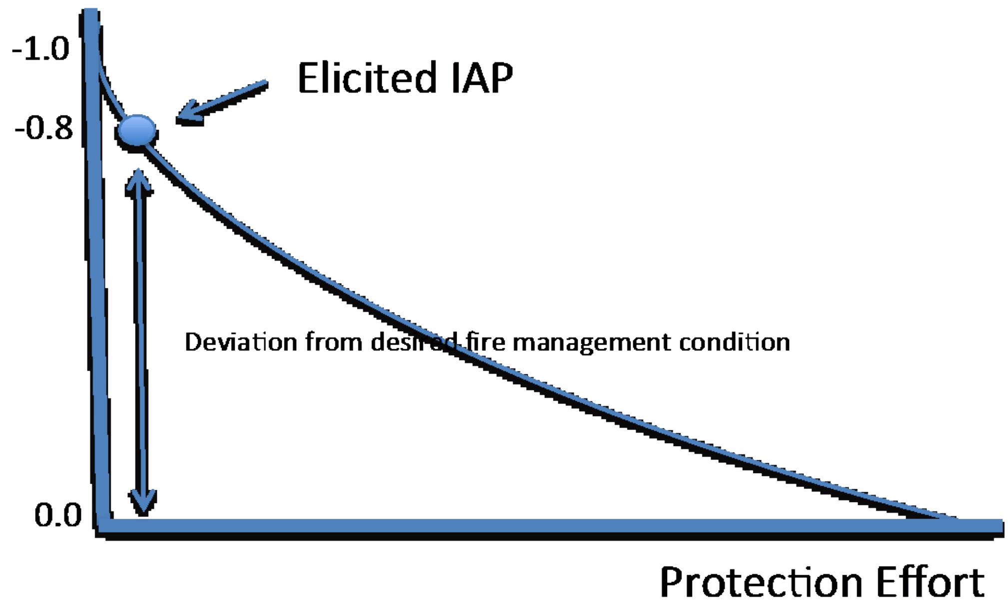

Figure 1.4.1. Marginal value of fire protection with increasing fire management effort.

Now consider the use of fire for improving the condition of the landscape. This can be equivalent to assessing the role of fire and fire management in restoration. Consider improving the fire regime condition class (FRCC). Again, assume that we have elicited an IAP of zero. This means that introducing fire cannot improve this cell fire. Either it is already in a desired ecological condition, or fire cannot improve the condition. Either way, it is in the DFMC. Now assume that we have elicited an IAP of +0.6 meaning that introducing fire will improve the condition of the cell (value added) (by 60% as much as the loss averted by protecting a cell with a highly valued structure). This is shown in Figure 2. Suppose that our elicited IAP of 0.60 also corresponds with a management condition commonly referred to as being in need of “Restoration” such as is commonly associated with FRCC III. If this is the case, we could treat the cell until it was fully restored from a fire management perspective such that no additional fire management effort could improve the condition of the cell resulting in FRCC I. This would result in a zero marginal value for additional FME. The cell would be fully restored, in a “maintenance” condition and be in the DMFC. Another option would be to apply enough FME to partially restore the cell and bring it into a maintenance condition (suppose also FRCC I) but where additional restoration effort would still provide some value added. This would correspond with marginal values between 0.00 and 0.30. A maintenance condition is always closer to the desired condition than a restoration condition and it will correspond with a lower IAP.

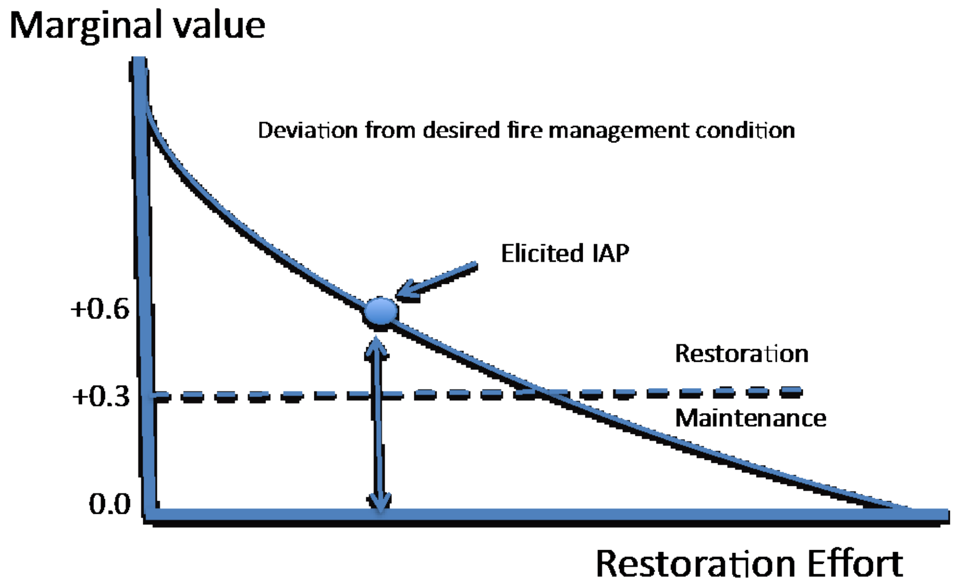

Figure 1.4.2. Marginal value of fire management effort for restoration.

1.4.2 GUIDING FIRE MANAGEMENT DECISIONS

IAPs reflect marginal values that are important in addressing current or future landscape conditions. Landscape conditions can be altered through fire management decisions that involve the use of fuel treatments. Suppose we are considering implementing a fuel treatment and we must choose between two cells (we can assume that our treatment would be fully effective in bringing the marginal value to zero). The first cell has an IAP of 0.60 (restoration condition) and the other cell has an IAP of 0.20 (maintenance condition). If we only consider the IAPs, the value added from treating the restoration cell would be three times that of treating the maintenance cell. However, fuel treatment decisions require that cost is included in the decision process and in general, the cost of treating areas in a restoration condition is higher than treating areas in a maintenance condition. To get the most benefit out of scarce treatment funds, we would always choose to treat the restoration cell as long as the cost of restoration remains 1/3 the cost of maintenance. If, however the cost of restoration exceeds three times the cost of maintenance, then we would choose to treat the maintenance cell. For example if it cost $200/acre to treat an area in restoration and $50/acre to treat an area in maintenance, then the benefit cost ratios for the restoration and maintenance areas would be 6/200 (0.03) and 2/50 (.04) making the maintenance treatment the better choice. In contrast, suppose that the cost of treating in maintenance is $100 and the other information is the same. The benefit cost ratios would be 6/200 (.03) and 2/100 (.02) making restoration treatments the better choice. In these conditions the benefit-cost ratios will provide the same decision result as maximizing net benefit. The

STARFire fuel treatment optimizer has been designed to address these economic decision criteria.

STARFire's ability to assist in the assessment of fire management conditions and guide fire management decisions is dependent upon the above concepts of "gross" and "net" valuation. The ability to preform assessments is a crucial element in estimating the value added from a system of fuel treatments that might be scheduled across the landscape and it requires "gross" value. Once cost estimates are known, STARFire can use "net" values to help guide decisions such as identifying which cells on the landscape will make the best use of limited funds.

1.5 SUMMARY

This document provides an introduction to the principles of the MARS valuation process that supports STARFire. It also includes a set of econometrically estimated IAPs that can be used as a reference and starting point for arriving at other IAPs. This document ends with showing how IAPs can be used for assessing the fire management condition of the landscape and, in contrast, how IAPs can be used to inform decisions when cost information is introduced. More information on the theory can be found in the paper by ***Rideout et al. (2008)***.

2 RAQS (RARELY ASKED QUESTIONS):

Dear MEL: I've been thinking a lot about fire effects lately and it seems to me that they are getting more involved with these droughts and global warming. This might increase the impact on fire-affected resources. Should I use an IAP of -1.5? Signed: Worried in the WUI.

> **Dear Worried in the WUI:** We all like a little inflation in the economy, but in this case, we would just divide all of the IAPs by 1.5 to ensure transparency and for input into STARFire. --MEL

Dear MEL: I really want to make sure that this comes out right so it might help if we put in some trial IAPs and then adjust them after we look at the results of the analysis. How about that? Signed: High Intensity Analyst.

> **Dear High Intensity:** No. The value of fire effect does not depend on the STARFire analysis results and adjusting values to change the results discredits the entire analysis. --MEL

Dear MEL: I heard that the end of the world is near, or did that pass? I even went to an end of the world party and knocked down a few IAPs, but here I am! Should we raise taxes or cut spending? Signed: One Foot in Either Side of the Fiscal Cliff.

> **Dear Cliff:** I can't tell for sure, but you might be looking at it. Anyway, don't let the cliff get any wider and save some IAPs. --MEL

Dear MEL: I though you left, went away and faded into the sunset. What happened to you and where have you been? Caring in California.

> **Dear California:** Oh I remember when I was truly popular and my buddies and I collected more flat files than an FMO has walkie-talkies. Our support group, IIAA and of course Mr. Sparhawk were so helpful. We used to play hide and seek and every once in a while they would even locate me (MEL), or so they thought. They even brought in consultants to gussy us up because we though correlation meant causation. Oh, those were the days! Well, I left and went underground in Argentina to start a vineyard. I'm starting to understand the difference between inputs and outputs, but sometimes the old ways creep back like the correlation between suppression and grapes. I still show up every now and again to comfort folks with the old ways. I tried to make an appearance in the HFRA, and some folks think I did!! Can you believe that! Keep the faith, and keep up the spending—it's the only way to reduce spending. --MEL

Dear MEL: Were you around for the Waldo Canyon fire that was so devastating? Signed: Where's Waldo.

> **Dear Waldo:** I saw you on U-Tube from Argentina! It can't be true. I watched it over and over (winemaking takes a lot of time). It seemed that the suppression forces were always working on homes that had fuel treatments and defensible space. OMG, they spent the suppression money where the fuel treatments had been! In my day we promised that fuel treatments meant that we would spend less on suppression. Promises, promises. What is this world coming to? --MEL

3 APPENDIX A

3.1 ECONOMETRICALLY DERIVED CATEGORIES FOR MARS VALUATION

1) **WUI:** This category includes any areas that have the highest priority for protection from fire. This includes highly valued buildings, structures, developments, sensitive boundaries, developed boundaries and the highest valued historic or cultural locations.

2) **High Value Anthropogenic Sites:** This category includes infrastructure type areas. Some examples include power lines, monitoring sites, highway corridors and boundaries that protect infrastructure.

3) **Lower Value Anthropogenic Sites:** This category includes areas that still require protection from fire but are not as highly valued as the other two categories. Examples include campgrounds, boardwalks and restrooms.

4) **High Value Cultural Areas/Forests to Protect:** This category includes highly valued cultural or archeological resources as well as unique forest that require protection. Examples of these forests include the unique Spruce Fir Forests in the Great Smoky Mountain National Park , the 'Giant Forest' of sequoia trees in SEKI, and the mature forest wetlands in the Okefenokee.

5) **Moderate Valued Cultural Resources:** This category includes cultural, archeological, historical and heritage resources that are less valued than those included in the above category.

6) **Threatened or Endangered Species and areas of conservation except for birds in (8):** This category includes species (flora or fauna) that have been designated as threatened, endangered or species of concern within the state or nationally or areas designated for conservation. Examples include the Pedio Cactus, the Cape Sable Seaside Sparrow and the Hemlock conservation area at GRSM.

7) **Birds that require mature forests for nesting including T&E:** This category includes bird species of concern that require mature forests for nesting habitat. Examples include the Red Cockaded Woodpecker, Bald Eagles, Goshawks and the Mexican Spotted Owl.

8) **Non Fire Resistant Conifer:** This category includes cover types that are not resistant to fire effects. Examples include Spruce Fir, lodegpole pine and mixed conifer.

9) **Fire Resistant Conifer:** This category includes cover types that when mature are resistant to fire effects. Examples include Douglas-fir, Ponderosa Pine, Sequoia and longleaf pine.

10) **Scrub Shrub:** An area dominated by scrub or brush. Examples include chaparral, scrub cypress and prairie grasses.