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Money, who needs it?
Natural Resource Damage Assessment

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***Abstract***

A new natural resource damage assessment paradigm has been suggested that emphasizes direct analysis of compensatory restoration rather than analysis of compensating variation for damages.  We consider whether money can be avoided in damage assessment.  Our analysis of compensatory restoration leads us to conclude that money should be considered when measuring preferences.  Failure to consider money leaves trustees unable to judge the adequacy of compensatory restoration.  The problem stems from heterogeneity over restoration scale.  Since environmental quality levels are public, even potential redistribution is precluded.  We also find that service to service restoration does not generally meet standard welfare criteria.

# 1    Introduction

Several authors (Mazzotta et al. (1994), Unsworth and Bishop (1994), Jones and Pease (1997), Unsworth et al. (1999)) have discussed or suggested a shift of emphasis in natural resource damage assessment away from the monetary assessment of damages to direct analysis of compensatory restoration. Rather than first assess the monetary damages of the natural resource injuries and then use the money for restoration, trustees would instead focus on the scale of restoration projects that would make the public whole.

There are two primary justifications given in support of this new paradigm. First, Federal natural resource damage assessment statues explicitly require that recoveries be used for the purpose of enhancing or creating natural resources (Jones and Pease (1997), Mazzotta, Opaluch et al. (1994)).[1] Estimating preferences for both injured and replacement resources may result in a more efficient use of recoveries. Second, directly assessing compensatory restoration may avoid some of the controversy that has been associated with the monetary assessment of damages (Jones and Pease (1997), Randall (1997)). Much of the controversy over monetary damage assessment stems from the measurement of passive use values where small individual household damages can easily aggregate into the billions of dollars. For example, passive use value damages from the Exxon Valdez oil spill damage assessment were estimated at $2.8 billion (Carson et al. (1992)). Direct measurement of compensatory restoration may provide responsible parties relief from the problem of aggregating monetary compensation over millions of

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[1]From an economic perspective, one can separate the problem of the amount of money necessary to compensate for loss and a requirement that restricts spending on specific public goods. Unless the specified public goods are under-supplied, a constraint on how the compensation is spent will only make the public worse off.

households since public goods are used to replace public goods. In accordance with this new shift of emphasis in natural resource damage assessment, recent damage assessments plans in Texas (Texas General Land Office et al. (1999)) and Wisconsin (Wisconsin Department of Natural Resource Services (1999)) were developed with an emphasis on compensatory restoration. It is safe to say that the paradigm shift has already happened.

We consider the question of whether or not money can be altogether avoided in damage assessment. We provide an analysis of the restoration methods that have recently been advanced. The use of pure compensatory restoration will result in some losers and some gainers relative to pre-injury utility levels due simply to the public goods nature of the compensatory goods. As the case with monetary compensation, a rigorous standard is necessary to meaningfully evaluate alternative scales of compensatory restoration. Providing the mean or median level of individual compensatory restoration may have appeal on account of the ease of implementation. Unfortunately, these measures have no grounding in welfare economics when using purely compensatory restoration. The standard we use to judge the adequacy of the proposed methods is whether the resulting restoration projects at least satisfy the condition that the sum of individual compensating variations equal zero, a standard consistent with welfare economics.

Generally we find that from the standpoint of adhering to the principles of welfare economics, money is a necessary condition for sound damage assessment practice. Furthermore, we believe there are other practical reasons to model money along with natural resources under the new damage assessment paradigm.

## 2    Economic Principles of Natural Resource Damage Assessment

Compensating variation is the key concept in most applied welfare economic analysis; it

provides both the economic and legal standard for damage assessment. In the case of natural resource damage assessment, the goal is to determine monetary compensation or restoration projects that could, in principle, make the public whole. For those individuals who suffer a loss from the natural resource injury, willingness to accept (compensating variation), by definition, exactly satisfies the requirement that an individual can be returned to their pre-injury level of utility. Trustees could in principle provide each individual his or her willingness to accept compensation and exactly return the affected individuals to their pre-injury utility levels. Even though the actual remedy may not provide each individual his or her willingness to accept, economic principles provide a clear goal in monetary assessment of damages: estimate aggregate willingness to accept compensation.

Prior to the paradigm shift discussed above, the estimation of aggregate willingness to pay was the goal of damage assessment. The application of recoveries was, for practical and economic purposes, secondary. A great deal of emphasis was placed on accurately estimating aggregate willingness to accept compensation while little or no effort was placed on understanding the most economically efficient application of these recoveries to the compensatory restoration required under law. The reality of the former method that focused on monetary assessment of damages is that at least conceptually, trustees could make the public whole from the first stage of recoveries from the monetary assessment. Whether or not the public was actually made whole from a welfare economic standard was an open question.

It simply does not follow that such emphasis should be placed on the first phase of monetary damage assessment while the application of recoveries is overlooked. The thrust of the new paradigm is to measure losses, after primary restoration, in terms of compensatory

restoration.  Conceptually this new approach facilitates measuring the losses while measuring the necessary scale of restoration.  This new approach has the potential for a real improvement over the old way of conducting damage assessment and the ensuing restoration.

Attribute-based stated choice methods (Swait et al. (1998)) are the logical class of analytical model to consider for restoration assessment since these models are capable of modeling preferences over multiple goods through choice experiments.  Knowledge of preferences over both the injured resource and the compensatory resource is the key to *the new* approach.  Following up on this possibility, the National Oceanic and Atmospheric Administration's guidance document for damage assessment under the Oil Pollution Act of 1990 notes in several places that losses and gains may be measured either in units of natural resources, natural resource services, or money (NOAA (1997)).  At first glimpse, altogether avoiding money appears to eliminate the need to sum across all individuals' values.  The big number problem, for responsible parties, is simply that while $2 compensating variation for a household is not very much, summing $2 per household across the U.S. quickly adds up to a considerable sum.  The big numbers problem is undoubtedly one reason why responsible parties favor valuing losses in terms of compensatory restoration, rather valuing losses in monetary terms.  While avoiding money may eliminate some political unpleasantries for trustees, pure compensatory restoration lacks a rigorous foundation for evaluating the adequacy of a proposed restoration alternatives. We now turn to a simple analysis of compensatory restoration using a random utility framework which is the basic model used in attribute-based stated choice methods.

## 3      Welfare Analysis of Valuation Scaling

Jones and Pease (1997) provide two approaches to resource compensation: the *service to*

*service approach* and the *valuation scaling*. We begin with a discussion of valuation scaling.

Within valuation scaling, Jones and Pease describe two approaches, value to value and the value

to cost. The value to cost approach equates the scale of projects such that the present value of

restoration costs equals the present value of losses due to injury which is basically the way that

damage assessment was conducted prior to the move toward valuing losses in terms of

compensatory restoration. In their discussion of value to cost, Jones and Pease note that "To

apply this procedure, the trustees must judge that the valuation of the lost services is practicable,

but valuation of the replacement natural resources and/or services cannot be performed within a

reasonable time frame or at a reasonable cost."

The value to value approach brings us to the heart of the proposed new paradigm in

natural resource damage assessment. In principle, the value to value approach scales restoration

such that the presented discounted gain from restoration, in monetary terms, equals the present

discounted loss from the injury. Note that this new approach requires the cost-benefit analyst to

simultaneously value the losses and the gains. As several authors (Jones and Pease (1997),

Mazzotta, Opaluch et al. (1994)) have noted, attribute-based stated choice methods are ideally

suited for this task. Attribute-based stated choice methods involve choice experiments that

consist of choices or rankings of projects that involve different attributes such as amounts of

compensatory resources, in-kind or out of kind.[2] While cost is a potential attribute, the NOAA

guidance document (NOAA (1997)) stresses that some stated choice methods are capable of

measuring damages in either monetary or physical restoration units. The key issue that interests

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[2]Typically choice experiment participants are offered a series of choices. According to
Carson et al. (1999), these choices fail to be incentive compatible, an issue we do not take up in
this paper.

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us is whether compensatory restoration facilitates altogether avoiding money in measuring the public's preferences in natural resource damage assessment.

In determining monetary compensation for the injury, mean willingness to accept compensation is the desired measure since aggregate willingness to accept compensation is directly recoverable from this measure. If each individual receives his or her willingness to accept compensation, then we have a distributional scheme that supports full economic compensation. In general benefit-cost analysis, the worth of the project is determined independent of the distribution of benefits and costs. This line of reasoning carries over to the conceptual underpinnings of the economics of damage assessment. As long as we are focusing on money as the unit of compensation and sufficient aggregate compensation is recovered, then the action satisfies the requirement that each affected individual could be returned to their original level of utility. Thus economic principles guide the analyst to focus on the mean willingness to accept compensation.

When resources are the unit of measure, economic principles do not provide a similarly clear prescription. Compensatory restoration cannot be redistributed since we have a common provision level for all individuals.[3] If preferences for the scale of compensatory restoration projects are heterogenous, then exclusively providing compensatory restoration will entail distributional effects.

We begin our discussion with a simple model. Suppose there are only two types of resource service flows, $q_1$ and $q_2$. Throughout the discussion, the first resource service flow will

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[3]Brekke (1997) discusses the use of a numeraire commodity other than money to conduct benefit-cost analysis, but does not emphasize a total compensating variation approach to judge projects.

represent the injured resource. Compensatory restoration will be accomplished by providing more $q_2$. In this section we do not specifically consider the potential temporal dimensions of the problem, although the principles of our analysis directly carry over to explicit consideration of time. Letting the subscript $i$ denote individual $i$, and $y$ represent expenditures on market goods, it follows that there should in principle exist a scaling of compensatory restoration providing a higher level $q_2^{i*} = q_2^0 + \Delta_c^{i*}$ such that the individual is left indifferent to the injury.

$$u_i(q_1^0, q_1^0, y_i) = u_i(q_1^0 - \Delta, q_2^0 + \Delta_c^{i*}, y_i) \tag{1}$$

To the researcher using a random utility model, there exists, in principle, a deterministic component of the utility function and a random component. The random component is usually assumed to be identically distributed with mean zero. Since the typical specification of these models is linear, we present our analysis in this form beginning with a first-order model. Higher order linear models will be taken up below. We utilize $i$ superscripts in order allow for complete heterogeneity of preferences within the linear specification.

$$\beta_1^i q_1^0 + \beta_2^i q_2^0 + \beta_y^i y_i + \varepsilon_0^i = \beta_1^i (q_1^0 - \Delta) + \beta_2^i (q_2^0 + \Delta_c^{i*}) + \beta_y^i y_i + \varepsilon_1^i \tag{2}$$

Given this model, the expected amount of compensatory restoration required to make individual $i$ whole is given as follows.

$$\Delta_c^{i*} = \frac{\beta_1^i}{\beta_2^i} \Delta \tag{3}$$

As made clear by (3), heterogeneity is characterized by differences across the affected population

in the marginal rate of substitution between the injured resource and the compensatory resource. This same characterization of homogeneity also holds for non-linear specifications.

Heterogeneity can take many forms, some of which we take up below. However the primary concern for heterogeneity is the fact there will be a distribution of winners and losers for any amount of compensatory restoration provided.[4] The fact that there are winners and losers implies a need to evaluate the relative gains and losses by some meaningful standard. Absent a meaningful standard and application of this standard, trustees will not be able to determine the benefits and costs of the remedy.

Standard benefit-cost analysis uses money as the unit of analysis because it is a meaningful numeraire. For our purposes it also has the feature that money is divisible among affected households and most importantly it is transferrable. With money in the mix there is a meaningfully and widely accepted standard, compensating variation. If trustees estimate the post-aggregate compensatory restoration, then they have a measure of adequacy that makes economic sense. Letting $\Delta_c$ denote a generic amount of compensatory restoration provided to the public, compensating variation is defined as the amount of money taken away with compensation that just returns the individual to the pre-injury level of utility.

$$u_i(q_1^0, q_1^0, y_i) = u_i(q_1^0 - \Delta, q_2^0 + \Delta_c, y_i - CV_i) \tag{4}$$

In the case of compensatory restoration, $CV_i$ will be positive for winners and negative for losers. By the definition of $\Delta_c^{i*}$, $CV_i$ can be thought of as the willingness to pay for obtaining

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[4]There are two notable exceptions. Trustees could insist on providing the maximum over the entire population of $\{ \Delta_c^{i*} \}$ or the minimum which would respectively result in a distribution of no losers or a distribution of no winners.

more than $\Delta_c^{i*}$ for the winners and willingness to accept compensation for the losers, those who needed more than $\Delta_c$ of compensatory restoration to be made whole. In the first order linear specification, $CV_i$ has the following simple form.

$$CV_i = \frac{\beta_2^i}{\beta_y^i} (\Delta_c - \Delta_c^{i*})$$

(5)

Applying the compensation principle, as noted by Jones and Pease (1997), the scale of compensatory restoration needs to satisfy the condition that the sum over the monetary net welfare effects should exactly equal zero.

$$\sum_i CV_i = \sum_i \frac{\beta_2^i}{\beta_y^i} (\Delta_c - \Delta_c^{i*}) = 0$$

(6)

The only case that constitutes altogether ignoring money is in the case of identical preferences for trading off the injured resources and the compensatory resource, an assumption that is hardly *a priori* justifiable. In the case of heterogeneity of preferences, even if the average over the set $\{ \Delta_c^{i*} \}$ were provided, there is no reason to believe that the sum over the set $\{ CV_i \}$ will necessarily equal zero. The same holds true when providing the median of $\{ \Delta_c^{i*} \}$. The only way of determining if compensation is adequate in a welfare sense is to include money in the choice experiments and estimate the overall effect of any proposed allocation through the sum of the individual compensating variations.

## 4      Forms of Heterogeneity

In this section we discuss some of the forms of heterogeneity that can occur and the

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implied distributional consequences. We begin with the same first order linear model with random parameters. We then turn to an interacted levels model. While all of the models we consider are linear specifications, the distributional consequences are quite varied.

## 4.1     Random Parameters & Heterogeneity

Random utility models that specify one or more random parameters are seeing wider and wider application.[5] Random parameters allows for heterogeneity of one or more of the parameters in the random utility function. In the first order linear model, concern over heterogeneity of $\Delta_c^{i*}$ translates into heterogeneity of the ratio $\beta_1^i/\beta_2^i$. There two potential random parameters, $\beta_1$ and $\beta_2$.

The case where $\beta_1$ is random is easy to deal with, regardless of the specification of parameter randomness. From (3), average $\Delta_c^{i*}$ will simply be the mean of $\beta_1$ multiplied by $\Delta/\beta_2$. The question arises, can we ignore money? The answer is that it depends on whether the marginal utility of income is the same for everyone. If the marginal utility of income is the same for everyone, then providing average $\Delta_c^{i*}$ will imply that the average compensating variation, condition (5), is equal to zero. Note that by (5), there is no conceptual justification whatsoever for providing the median. In a simple normal random specification of $\beta_1$ the mean will equal the median. However when considering more general specifications such as log-normal, the mean will not equal the median and by using the median (5) may be violated. If there is heterogeneity in $\beta_y^i$, then providing the average $\Delta_c^{i*}$ will not result in (5) automatically being satisfied. In this

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[5]Examples include Brownstone and Train (1999) in marketing along with Langford et al. (1998), Layton and Brown (1998), and Morey and Greer Rossman (1999) in environmental economics. Swait and Bernardino (2000) offer an overview and perspective of approaches to modeling preference heterogeneity.

simplest of random parameters model, randomness of $\beta_1$, there is no summary measure of the distribution of $\Delta_c^{i*}$ that will automatically satisfy the compensation test. While homogeneity of the marginal utility of income provides justification for using the average $\Delta_c^{i*}$, the researcher cannot know about the homogeneity of the marginal utility of income without including money in the model.

Moving onto randomness of $\beta_2$ or both $\beta_1$ and $\beta_2$, the complexity of a decision rule that satisfies (5) quickly increases. For the case of $\beta_2$ being random and homogeneity of the marginal utility of income , the welfare adequacy of using the average $\Delta_c^{i*}$ breaks down to the relative sizes of the mean of $\beta_2$ and the mean of $1/\beta_2$.[6] If these two are equal, the decision rule that requires providing the average $\Delta_c^{i*}$ would satisfy (5). When there is heterogeneity of the marginal utility of income, adequacy is determined by the relative sizes of the mean of $1/\beta_y$ and the product of the mean of $\beta_2/\beta_y$ by the mean of $1/\beta_2$. Regardless of whether or not there is homogeneity of the marginal utility of income, the decision rule for the level of compensatory restoration that satisfies (5) must be determined on a case by case basis. When both $\beta_1$ and $\beta_2$ are random and the marginal utility of income is homogeneous, the welfare adequacy of using the average $\Delta_c^{i*}$ breaks down to the relative sizes of the mean of $\beta_1$ and the product of the mean of $\beta_2$ by the mean of $\beta_1/\beta_2$. Under heterogeneity of the marginal utility of income, the key comparison is between the mean of $\beta_1/\beta_y$ and the product mean $\beta_2/\beta_y$ by the mean $\beta_1/\beta_2$. Thus for all cases of random parameters in both $\beta_1$ and $\beta_2$, the adequacy of using the average $\Delta_c^{i*}$ cannot be *a priori* determined. The same will hold true of the median. In closing out this section on random parameters as the form of heterogeneity, we conclude that no simple decision rule such as the

[6]We are assuming that the means of all of the random variables discussed exist.

mean or the median will provide for a adequate amount of compensation when using the compensation principle as the standard. We now turn away from random parameters to consider cases of systematic heterogeneity that depend on characteristics of the individuals.

## 4.2    Individual Characteristics & Heterogeneity

Heterogeneity can be systematic in the sense that differences in $\Delta_c^{i*}$ are driven entirely by individual characteristics as opposed to heterogeneity through different utility parameters. One characteristic that makes sense is income. If income enters the utility specification in a higher order through interaction with either resource, then there will exist heterogeneity in $\Delta_c^{i*}$. The following two equations provide the utility specification and the expected level of adequate, individual compensatory restoration.

$$u(q_0,\ q_1,\ y_i)\ =\ \beta_1\ q_1^0\ +\ \beta_2\ q_2^0\ +\ \beta_y\ y_i\ +\ \gamma_1\ q_1\ y_i\ +\ \gamma_2\ q_2\ y_i\ +\ \varepsilon^i \tag{7}$$

$$\Delta_c^{*i}\ =\ \frac{\beta_1\ \Delta\ +\ \gamma_1\ y_i}{\beta_2\ +\ \gamma_2\ y_i} \tag{8}$$

Another characteristic that makes sense is individual distance from either the injured resource or the compensatory resource. Evidence for this hypothesis is statistically supported in a study by Loomis (2000). Distance is likely to matter greatly to resource users and cases where there are both users and non-users of the respective resources. In user demand models, distance is one of the key factors that determines the opportunity cost of trips. Omitting distance from the model may very well result in omitted variables bias of those parameter estimates included in the model. In order for distance to matter for heterogeneity in the linear specifications considered in this

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paper, distance from the sites would essentially be an interactive effect between the levels of $q_1$ or $q_2$ and the individual's respective distances to these sites.

## 5      Perfect Substitutability & Service to Service

The service to service approach is an alterative method to valuation scaling. The service to service approach is used when restoration alternatives are considered to be of comparable type, quality, and unit value as the damaged resources or services. Use of this method assumes that there exists a common resource or service metric between the damaged and replacement resources. Additionally, this method assumes that society equally values services provided by the two (NOAA (1997)). According to Unsworth and Bishop (1994) and Jones and Pease (1997), individual values for the two resources need not be calculated due to the existence of a common metric. In economic terminology, the service to service approach requires perfect substitutability in all respects except with regard to time for all affected individuals.

The proposed measure of restoration is to provide a present value adjusted amount of the equivalent resource. As an example, suppose there is a release that results in a one period loss of service flows from a particular wetland area. Additional service flows from the perfect substitute resource could be provided in subsequent periods as long as the present value of quantities of flows provided as compensation equal the original quantity of lost flows from the first period.

There are several problems with the service to service approach. An obvious issue is the ease with which replacement resources of a comparable type and quality can be found. The complexity associated with finding replacement services of a comparable type and quality is evident in reading the guidance document for implementation of the service to service approach under the Oil Pollution Act (NOAA (1997)). Another problem is determining whether the

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replacement resource is a perfect substitute without any investigation of preferences, an

impossible task. Finally there is the fundamental problem that providing the present value

equivalent will not guarantee that individuals are left as well off as when no injury had occurred,

even with perfect substitutability, a result that is easy to explain.

Consider the same set-up as presented earlier where the first resource is damaged and a

second resource will be provided as compensation, the only difference being a time lag between

injury and providing compensatory restoration. Perfect substitutability implies that utility in $q_1$

and $q_2$ takes the form $u(q_1, q_2, y) = u(q_1 + q_2, y)$. Now suppose that good one is injured in

the current period and we provide the present value equivalent, using our representative agent's

value of time preference for discounting, in the next period as prescribed by the damage

assessment guidelines.[7] If the marginal utility is diminishing in our perfectly substitutable good,

then providing the present value equivalent in the second period will result in a present value

utility loss. Adequate compensation through the present value equivalent only occurs when the

marginal utility of the perfectly substitutable resources is constant, a fairly restrictive

assumption.[8] Thus in the best of circumstances we generally fail to find that the service to

service method provides adequate compensation.

Attribute-based stated choice methods can be used to explore all of the issues identified

in this section in a reasonably cost-effective manner. Exploratory analysis of preferences can be

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[7]The form of utility for the two periods is given by $u(q_1^0 + q_2^0, y^0) + \delta\, u(q_1^1 + q_2^1, y^1)$ where $\delta$ is the discount factor. The superscripts denote the time period.

[8]In order for service to service to work, the non-discounted marginal utility of having more $q_1$ or $q_2$ must be equal in the two periods. If the level of either resource is changing from one period to the next without injury, this condition will generally be violated.

undertaken with a relatively small group of subjects since subjects are typically offered more than

one choice scenario.   For example Morey et al. (1999) successfully use groups to conduct choice

experiments.  Data from the exploratory analysis can be used to test perfect substitutability,

diminishing marginal utility, and the effect of income on the marginal utility of the injured good.[9]

## 6      Practical Considerations

In addition to judging compensatory restoration by the usual standards of benefit-cost

analysis, there are other practical reasons to include a money metric in damage assessment.  First,

there is the issue of benefits versus costs of compensatory restoration.  Obviously responsible

parties would like to obtain a legally satisfactory outcome at the least cost.  It makes no sense to

provide compensatory restoration projects for which the costs of the project greatly exceed the

benefits, even if the responsible parties have to bear the cost.  By avoiding money in the

estimation of preferences, there is no way to judge whether costs are disproportionately high

relative to benefits.

On the other hand, the costs to the responsible parties should not be the sole determinant

of compensatory restoration either.  It could be the case that there exist multiple projects for

which the benefits justify application of recoveries.  It does not necessarily follow that

responsible parties should always be allowed to implement the least cost project that makes the

public whole.  Projects could have large redistributional effects.  Consider project A that

provides large benefits to a group A, but almost no benefits to group B.  The original injury

severely impacted group B while group A was almost unscathed.  Project A is a winner in the

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[9]Of course if perfect substitutability is rejected, a more complete analysis should be undertaken.

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sense that compensatory restoration benefits to group A are sufficiently high to make up for the net losses to group B. Project B mostly compensates group B, but is more expensive than project B. Should the responsible parties be allowed to implement A simply because it is the least cost? Welfare economics does not have much to offer on this account, but certainly redistributional effects are important to many people. By avoiding money in the damage assessment, some redistributional effects will be impossible to identify.

## 7       **Further Discussion and Conclusion**s

The aim of the new paradigm in natural resource damage assessment is to improve the process of determining the economic damages to the public as well as improve the process by which recoveries are applied in restoration activities. The old approach to damage assessment completely ignored the potential economic inefficiencies that can result from applying recoveries toward compensatory restoration without knowledge of preferences over compensatory resources. We are in no way defending the old way of doing things. Rather we feel that a clear standard needs to be applied in judging the adequacy of compensatory restoration. Given that damage assessment truly is a benefit-cost exercise, the logical standard is the compensation principle.

As we have demonstrated in a random utility framework, the same framework that will likely be used in conjunction with the attribute-based method of damage assessment, heterogeneity of preferences implies there will be distributional consequences of compensatory restoration projects. In order to adhere to a welfare economic principles, these distributional consequences need to be quantified in monetary terms in order to apply the compensation test. Even in the simplest cases of heterogeneity, there is no single provision rule that will

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automatically satisfy the compensation test. Our analysis suggests that adequate compensatory

must be determined on a case by case basis. In order to do so, there must be a monetary

component included in the analysis. Putting aside welfare economic principles, there are still

good reasons to consider money. Trustees need to consider the relative costs and benefits of

potential compensatory restoration projects. Additionally trustees need to understand the

potential redistributional impacts. In both cases, money is necessary.

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