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**Presentation Outline**

- What are economic damages?
  - Real behaviors provide the data
  - The key concept of substitution
- Human Use Losses - Active and Passive
- Restoration scaling for ecological effects
  - HEA and REA
  - Discounting the distant future
  - Baseline, Baseline, Baseline
  - Relationship between NRD and remedial actions
- Ground water - stocks *versus* flows

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**What are Economic Damages?**

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## Natural Resource Damages

- Government Trustees Hold Valued Natural Resources In Trust For The Public

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## Natural Resource Damages

- Government Trustees Hold Valued Natural Resources In Trust For The Public
- Spills and Historic Releases Can Injure Natural Resources

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## Natural Resource Damages

- Government Trustees Hold Valued Natural Resources In Trust For The Public
- Spills and Historic Releases Can Injure Natural Resources
- RPs are Obligated to Pay Damages to Restore Injured Natural Resources and Compensate for Interim Losses

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## Natural Resource Damages

- Government Trustees Hold Valued Natural Resources In Trust For The Public
- Spills and Historic Releases Can Injure Natural Resources
- RPs are Obligated to Pay Damages to Restore Injured Natural Resources and Compensate for Interim Losses
- Recovered monies are to be spent on natural resource restoration (depending on the State or cause of action)

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## Scaling Restoration

- Key issue is: how much restoration is enough?

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## Scaling Restoration

- Key issue is: how much restoration is enough?
  - Focus on services of natural resources

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### Scaling Restoration

- Key issue is: how much restoration is enough?
  - Focus on services of natural resources
  - Estimate the amount of service loss due to release - injury

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### Scaling Restoration

- Key issue is: how much restoration is enough?
  - Focus on services of natural resources
  - Estimate the amount of service loss due to release - injury
  - Identify restoration action(s) that
    - restore resource services to baseline (primary restoration)
    - compensate for any residual loss of services (compensatory restoration)

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### Scaling Restoration

- Key issue is: how much restoration is enough?
  - Focus on services of natural resources
  - Estimate the amount of service loss due to release - injury
  - Identify restoration action(s) that
    - restore resource services to baseline (primary restoration)
    - compensate for any residual loss of services (compensatory restoration)
  - Pay for restoration - damages
    - Plus trustees' costs of process

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## Ecological Services

- Ecological services are beneficial outcomes of biophysical functioning in ecosystems
  - Valued directly or indirectly by people
- Ecological risk drivers can impair functioning and reduce services
  - Ecological services are related to, but not necessarily measured by, risk assessment endpoints

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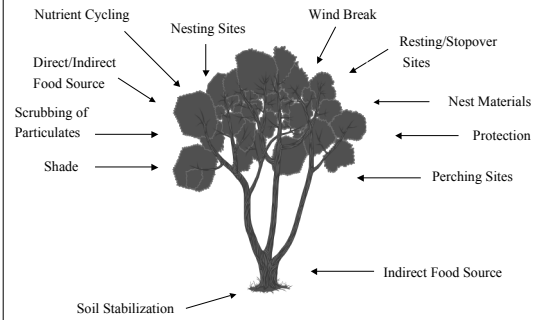
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### Example Services Provided By Trees



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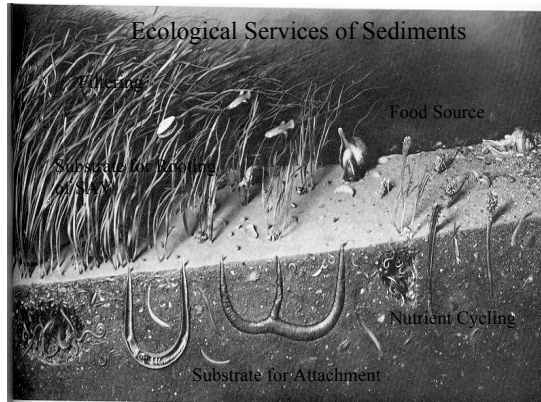
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### Ecological Services of Sediments



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### Scaling Approaches

- Value-to-cost
  - Estimate injury and value it in dollars (compensable value)
  - Spend that much on restoration

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### Scaling Approaches

- Value-to-cost
  - Estimate injury and value it in dollars (compensable value)
  - Spend that much on restoration
- Value-to-value
  - Estimate injury and measure it in dollars
  - Measure benefits of restoration in dollars
  - Do enough restoration to equate the two

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### Scaling Approaches

- Value-to-cost
  - Estimate injury and value it in dollars (compensable value)
  - Spend that much on restoration
- Value-to-value
  - Estimate injury and measure it in dollars
  - Measure benefits of restoration in dollars
  - Do enough restoration to equate the two
- Resource-to-resource
  - Approximation of value-to-value
  - Uses ecological metrics

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## Economic Values

- People change behavior in response to injury
  - Take fewer recreation trips to injured site
  - Buy a house in a different area
  - Switch to bottled water
  - Dig a new well to replace one taken out of service

*Behavioral responses provide data for valuation*

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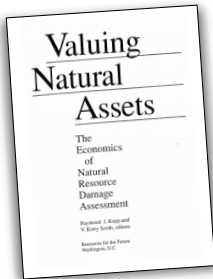
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## Change In Behavior Is Basis for Valuation



"Indirect Methods for Assessing Natural Resource Damages," in Kopp and Smith, Eds. *Valuing Natural Assets*, Resources for the Future, 1993

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## Change In Behavior Is Basis for Valuation



**Kenneth McConnell:**  
"Individuals, discovering the resource has been injured, change their behavior,... leaving footprints for researchers...to estimate...the loss...from impairment of the resource"

"Indirect Methods for Assessing Natural Resource Damages," in Kopp and Smith, Eds. *Valuing Natural Assets*, Resources for the Future, 1993

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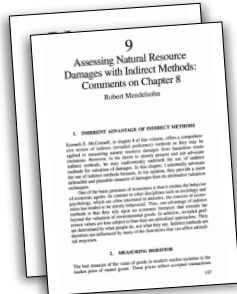
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## Change In Behavior Is Basis for Valuation



**Robert Mendelsohn:**  
"One of the basic premises of economics is that it studies the behavior of economic agents."

"Assessing Natural Resource Damages with Indirect Methods,"  
in Kopp and Smith, Eds. *Valuing Natural Assets, Resources for the Future*, 1993

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## Recreation Valuation

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## Measuring Benefits

- Basic concept is willingness-to-pay (WTP)
  - How much money would an individual pay to preclude the injuries?
- Can be measured as a change in "consumer surplus"

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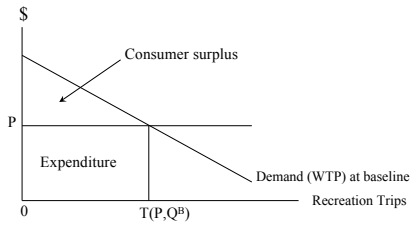
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## Consumer Surplus




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## Travel Cost Models

- The cost of gaining access to a site functions as a “price” of fishing
  - Those who live close by site take several of trips
  - Those who live farther away take fewer trips
  - This is a demand curve
  - Can estimate statistically, and calculate consumer surplus

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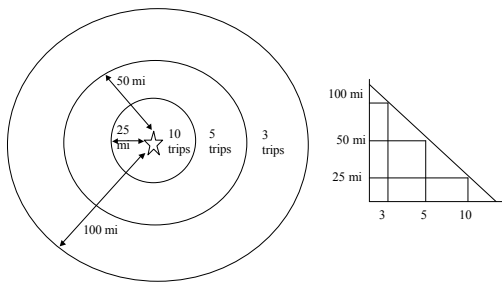
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## Simple Travel Cost Model




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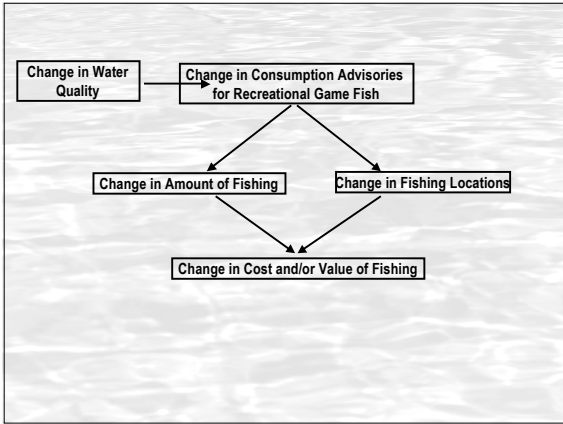
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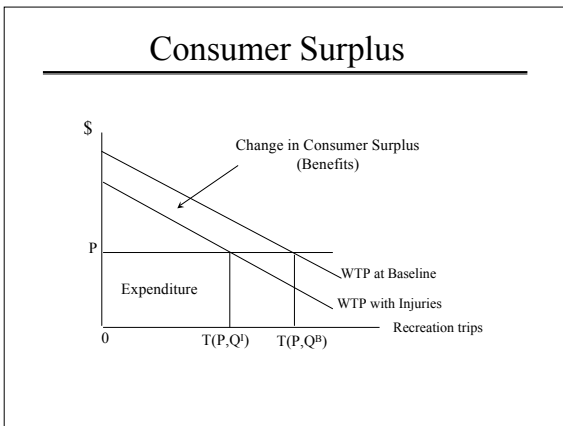
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### Choice Among Fishing Destinations

Site A	Site B
<ul style="list-style-type: none"> <li>◆ 20 miles away</li> <li>◆ Boat ramp</li> <li>◆ Fish consumption advisory</li> <li>◆ Catch rate = .5 fish per hour</li> </ul>	<ul style="list-style-type: none"> <li>◆ 50 miles away</li> <li>◆ No boat ramp</li> <li>◆ No consumption advisory</li> <li>◆ Catch rate = .3 fish per hour</li> </ul>

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### Key Issues

- What is the “right” set of sites to consider?
- Get the travel prices right
  - Value of time
- What are the attributes that matter?
- What is the population that knows about your site?

*Key is Substitution*

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### Passive Use

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### Passive Use Value

- People may hold values for resources that are injured, but independent of observable behavioral trail
- May apply if population-level effects and endangered species are important
- Ecosystem services support quality of life and so use them “indirectly” or passively

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## Passive Use

- Use surveys to obtain data on a behavioral intention
  - What would you do if ...?
  - Would you pay \$X for a program that does ...?
- Controversial and expensive measurement methods
  - Contingent valuation
  - Choice experiments (conjoint analysis)

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## Types of Value

Personal Use	Passive Use	
	Use by Others	Existence Value
Current Period Use	Altruism	No Current Use (By anyone)
Future Use	Request	No Future Use (By anyone)
Uncertain Future Use (Option Value)	Uncertain Future Use (Option Value)	

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## Conjoint Analysis

- Used in marketing research
  - Choice among packages of features on car/price
  - Given these alternative cars, which would you choose
  - Vary across person and sample
  - Estimate WTP for features
- Adapted to environmental valuation
- “Total Value Equivalency Analysis”

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### Conjoint Example

State agencies can achieve different environmental futures, but with limited budgets must make trade-offs.

#### Option A

- No restoration of wetlands to provide fish spawning habitat
- Catch rates for recreational anglers go up by 1 fish per day
- Loss of endangered fish of 1% of population
- Cost for a family like yours \$20/month

#### Option B

- Restoration of 50 acres of wetlands to provide fish spawning habitat
- Catch rates for recreational anglers go up by 1/2 fish per day
- Loss of endangered fish of 10% of population
- Cost for a family like yours \$70/month

*Which do you choose?*

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### Lawyers and Biologists Agree: Economists Make Their Eyes Twitch

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### Lawyers and Biologists Agree: Economists Make Their eyes Twitch

- Scaling using Ecological Metrics
  - Biological/physical scaling approaches
  - Habitat equivalency analysis (HEA)
  - Resource Equivalency Analysis (REA)
  - Trophic scaling

*Passive use values included in principle*

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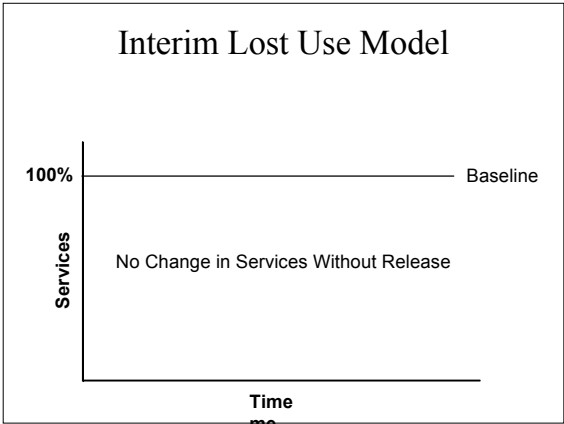
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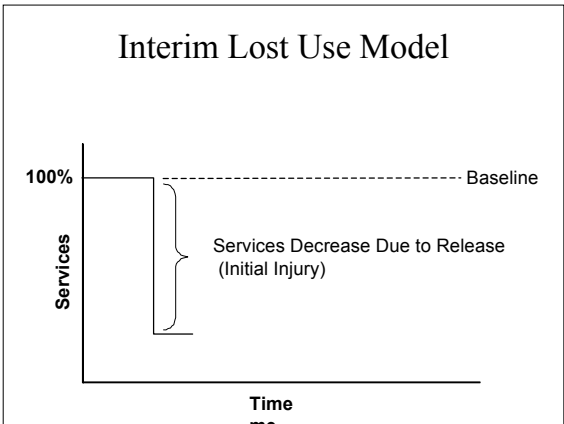
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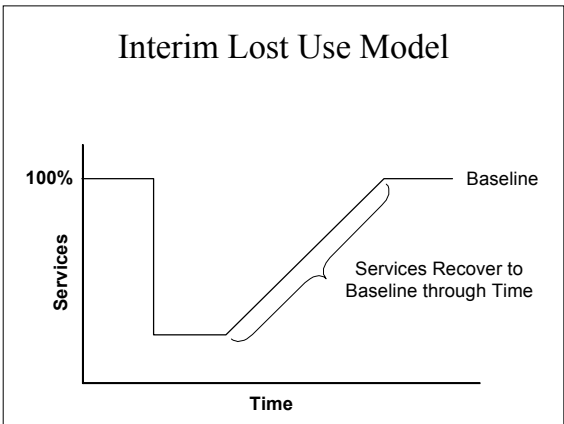
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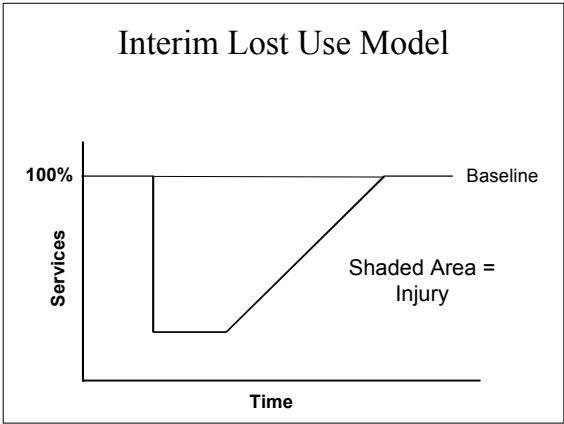
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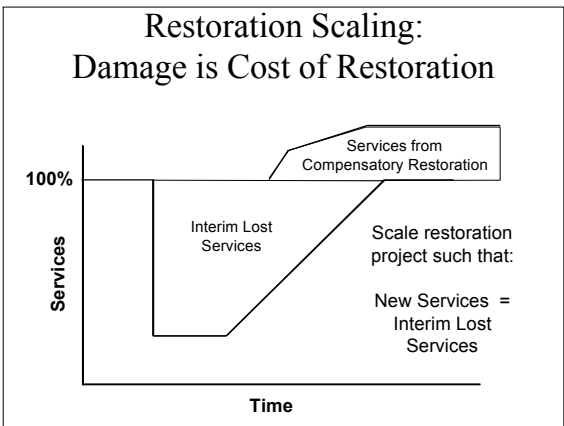
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- ### Some Restoration Examples
- Injuries to sediments (benthos)
    - Provide artificial habitat
    - Reduction in food source: provide fish habitat
  - Injuries to water column
    - Provide water quality improvement via marsh enhancement
  - Injuries to birds
    - Nest protection
    - Habitat enhancements or protection
  - Injuries to recreation
    - Improved access

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## Issues in HEA

- Scientifically defensible only if
  - One service affected (or all move together proportionally)
  - “Small” effects
  - Restoration in kind and same quality
  - Homogeneous values in population
- Essentially *ad hoc* approaches to circumvent these in negotiated settlements
  - Weights across services

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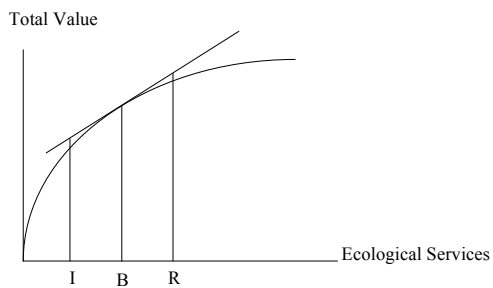
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## HEA



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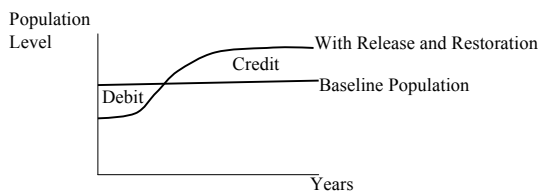
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## Resource Equivalency Analysis

- Unit of measure is a Discounted Animal Year (DAY)
- Impacted populations are elevated to levels above where they otherwise would have been
- Compensation requires the population to produce the same number of DAYS as it otherwise would have



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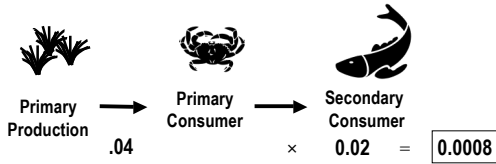
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## Trophic Scaling



Each kg of secondary consumer lost to I&E requires 1,250 (= 1/0.0008) kg of primary production

Given an estimate of wetland primary productivity, acres of wetland to be created or preserved is calculated

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## NRD Measurement Issues

Discounting the Distant Future

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## Discounting

- Typical is fixed 3% rate applied to all future time
- Any restoration credits occurring beyond 150 years discounted to essentially zero
- Recent economic literature supports a declining discount rate
  - Discount more distant future at lower rates

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## NRD Measurement Issues

NRD in a Degraded Environment  
*"Baseline"*

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### *Determination of Baseline Condition*



**Pristine Conditions**



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### *Determination of Baseline Condition*

**Actual Conditions**



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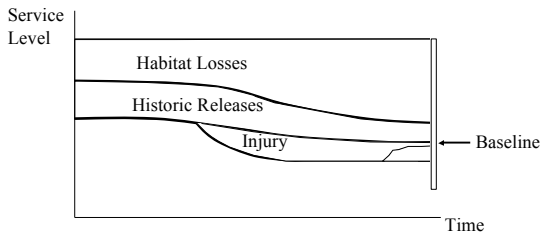
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## Injury in a Degraded System



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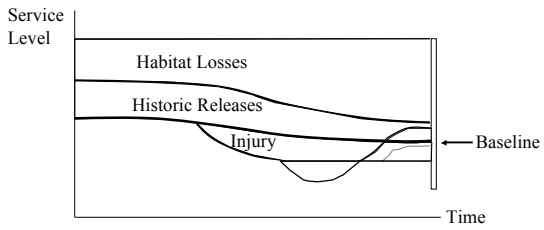
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## With Remediation and Restoration



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## NRD Measurement Issues

Remedial -v- NRD liabilities

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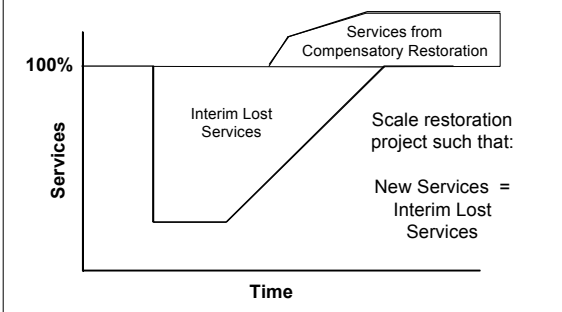
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## Restoration Scaling: Damage is Cost of Restoration




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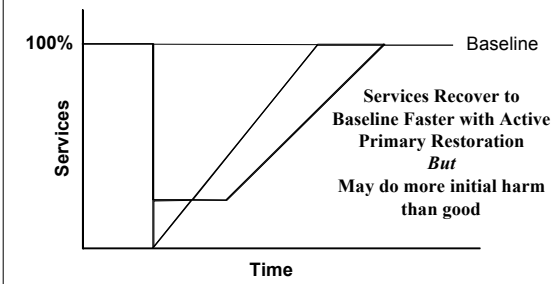
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## *Interim Lost Use Model*




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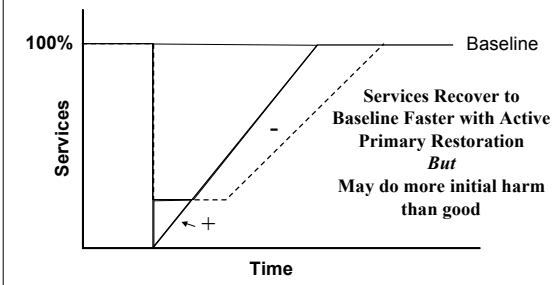
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## *Interim Lost Use Model*




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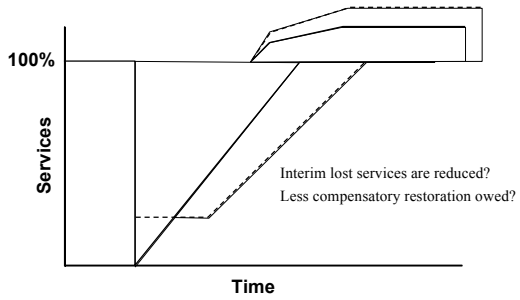
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### *Interim Lost Use Model*

As a result of implementing primary restoration



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### Net Environmental Benefits Analysis

- Method to compare environmental effects across remedial scenarios using HEA/REA
- Is the cure worse than the disease?
- How does remediation affect NRD liability?

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### Ground Water NRD

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## Ground Water Services

- Potentially injured services
  - Extractive
    - residential, commercial, industrial use
  - Ecological
    - when ground water discharges to surface environments
  - *In-situ*
    - preventing salt water intrusion; preventing subsidence
    - drought reserve for possible future use
    - passive use?

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## Baseline Services

- What services are provided *but for* the release at issue?
  - Pre-existing quality issues (e.g. saline)
  - Some in-situ services may not be affected by release (so not 100% loss)
- “Recovery” when services are returned to those at baseline
  - *not* when chemical concentrations are the same

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## Stocks *versus* Flows

- Issue is *not* whether there is a stock of water contaminated

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## Stocks *versus* Flows

- Issue is *not* whether there is a stock of water contaminated
- Issue is changes in the flow of services associated with that stock

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## Stocks *versus* Flows

- Issue is *not* whether there is a stock of water contaminated
- Issue is changes in the flow of services associated with that stock
- Must take into account of actions to mediate effects of injuries
  - Alternate sources of supply
  - What is lowest-cost source?
  - Could be part of remedy or part of restoration

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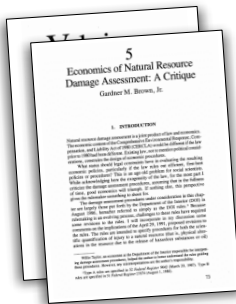
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## Physical and Economic Effects Are Different Due to Substitutes



**Gardner M. Brown Jr.:**  
"...it is imperative to distinguish between physical and economic effects. An environmental insult with immense results on natural...scales might have a trivial economic consequence... because there are close substitutes for the resource in question. Groundwater contamination in an aquifer with no... anticipated withdrawal is an example. Less extreme would be the case in which...uses of groundwater have a very-low-cost alternative water supply...."

"Economics of Natural Resource Damage Assessment: A Critique", Kopp & Smith, Eds. *Valuing Natural Assets, Resources for the Future*, 1993

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**The NJ Formula**  
Approximation of What?

- Simple version of formula

$$\text{area} \times \text{recharge} \times \text{years} = \text{volume}$$

$$\text{\$damage} = \text{volume} \times \text{delivered water price}$$

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**NJ Formula - cont.**

- Cannot be technically defended

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**NJ Formula - cont.**

- Cannot be technically defended
  - Not tied to lost services

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NJ Formula - cont.

- Cannot be technically defended
  - Not tied to lost services
  - Area not adjusted for remediation over time

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NJ Formula - cont.

- Cannot be technically defended
  - Not tied to lost services
  - Area not adjusted for remediation over time
  - Doesn't apply discount rate

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NJ Formula - cont.

- Cannot be technically defended
  - Not tied to lost services
  - Area not adjusted for remediation over time
  - Doesn't apply discount rate
  - Multiply by price  $\neq$  correct economic damage measure

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### NJ Formula - cont.

- Cannot be technically defended
  - Not tied to lost services
  - Area not adjusted for remediation over time
  - Doesn't apply discount rate
  - Multiply by price  $\neq$  correct economic damage measure
  - Is a "damage function approach" debunked in literature

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### NJ Formula - cont.

- Cannot be technically defended
  - Not tied to lost services
  - Area not adjusted for remediation over time
  - Doesn't apply discount rate
  - Multiply by price  $\neq$  correct economic damage measure
  - Is a "damage function approach" debunked in literature
  - Passive use values (if any) not approximated by water price

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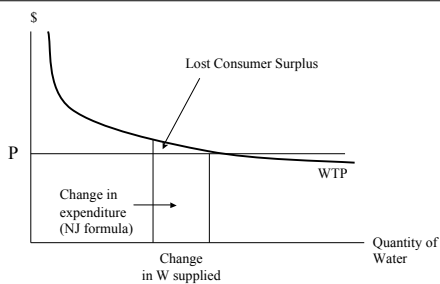
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### Value of Lost Water



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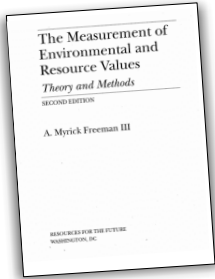
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### Freeman Criticism of the Damage Function Method



A.M. Freeman III, *The Measurement of Environmental and Resource Values*, 2003.

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### Freeman Criticism of the Damage Function Method



"...naive models used in the early literature...are known as the damage function approach."  
"I have characterized the damage function approach as naive because...behavioral and market responses are implicitly ruled out...people can choose defensive or mitigating activities in response to pollution...which should be taken into account in calculating values"

A.M. Freeman III, *The Measurement of Environmental and Resource Values*, 2003.

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### Passive Use Values for Ground Water?

- Arguably, measurable passive use values exist for ecological functioning that is "used" indirectly

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Passive Use Values for  
Ground Water?

- Arguably, measurable passive use values exist for ecological functioning that is “used” indirectly
- Aquifers with *no* changes in services
  - Extractive - current or future
  - Ecological - fully compensated
  - Subsidence/salt water intrusion prevention not affected

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Passive Use Values for  
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- Would “pure” existence value exist?

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Passive Use Values for  
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  - Subsidence/salt water intrusion prevention not affected
- Would “pure” existence value exist?
- Existing research does not address adequately

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