

# Defining the Spatial and Temporal Extent of Ecosystem Restoration Project Environmental Benefits

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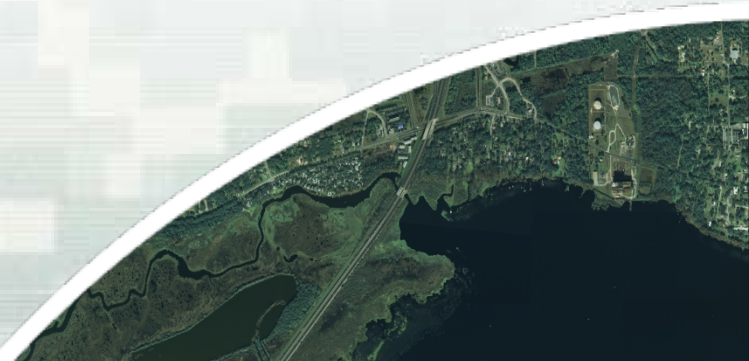
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# US Army Corps of Engineers Civil Works Planning Context

- Ecosystem Restoration goal: to restore significant aquatic ecosystem structure, function and dynamic processes that have been degraded (EP 1165-2-501)
- Ecosystem restoration should achieve naturalistic, functioning, and self-regulating systems and should result in less degraded, more natural condition in concert with acknowledged constraints presented by human activities – sometimes necessitating partial (EP 1165-2-502)





# Ecosystem Structure and Function

- *Structure* refers to both the composition of the ecosystem and to its physical and biological organization (NRC 2005)
- *Functions* are the physical, chemical, and biological processes that create and sustain an ecosystem (Fischenich 2005); a set of interconnected processes can define a broader ecosystem function



# Framework for Science-Based Environmental Benefits Analysis

- In cases where full return to pre-disturbance conditions is not feasible, the ability to evaluate partial restoration of ecosystem structure and function and to quantify benefits associated with restoration actions serves as a basis for the EBA process

## Quantify Environmental Benefits to:

- **Compare different alternatives, projects or programs**
- **Assess return on investment for a particular restoration initiative**
- Prioritize restoration projects in the face of limited budgets
- Maximize environmental benefits per dollar spent
- Ensure mitigation requirements are met or to calculate banking credits



# Environmental Benefits Analysis in Corps 6-Step Planning Process

- Phase 1 of the EBA, the qualitative phase, is consistent with Step 1 of the planning process (*Specify Problems and Opportunities*)
- Activities in this phase include:
  - ▶ Development of a conceptual ecological model
  - ▶ **Identification of appropriate temporal and spatial scales for system evaluation**
  - ▶ Initial consideration of an adaptive management approach
  - ▶ Identification of key uncertainties
- The conclusion of EBA Phase 1 is development of objectives for the restoration effort



# Environmental Benefits Analysis: The Problem

- Benefits ascribed to ecosystem restoration projects may be underestimated if limited to those within the project footprint, or to project design life or planning timeframe



# Research Objectives and Approach

- Summarize scientifically defensible frameworks from the literature for determining spatial and temporal boundaries for ecosystem restoration benefits
- Summarize important considerations for:
  - ▶ Setting scientifically meaningful boundaries for ecosystem restoration project effects
  - ▶ Assessing benefits through a reasonable and practicable planning timeline
  - ▶ Reasonably accounting for the full suite of anticipated ecosystem restoration project benefits
  - ▶ Enabling a more realistic environmental benefits accounting of the Corps' ecosystem restoration Program



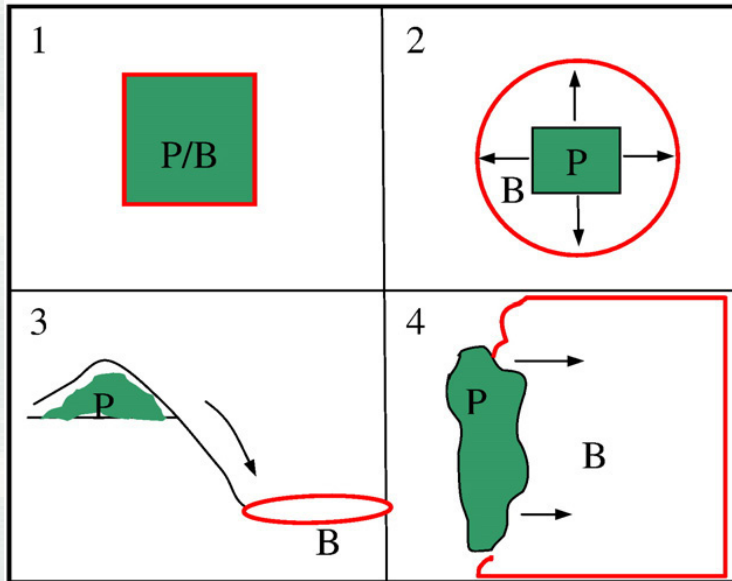
# Spatial Considerations – Our Assumptions

- Environmental Benefits represented by change in ecosystem structure and function resulting from restoration actions directly linked to project objectives
- A project site is primarily defined by its footprint – the geographic extent of restoration actions – though benefits often extend further
- In general, environmental benefits diminish with distance from the project footprint
- There are many caveats, nuances and exceptions to this assumption





# Potential spatial relationships between restoration activities at Project site (P) and Benefit areas (B) (from Fisher et al. 2009)



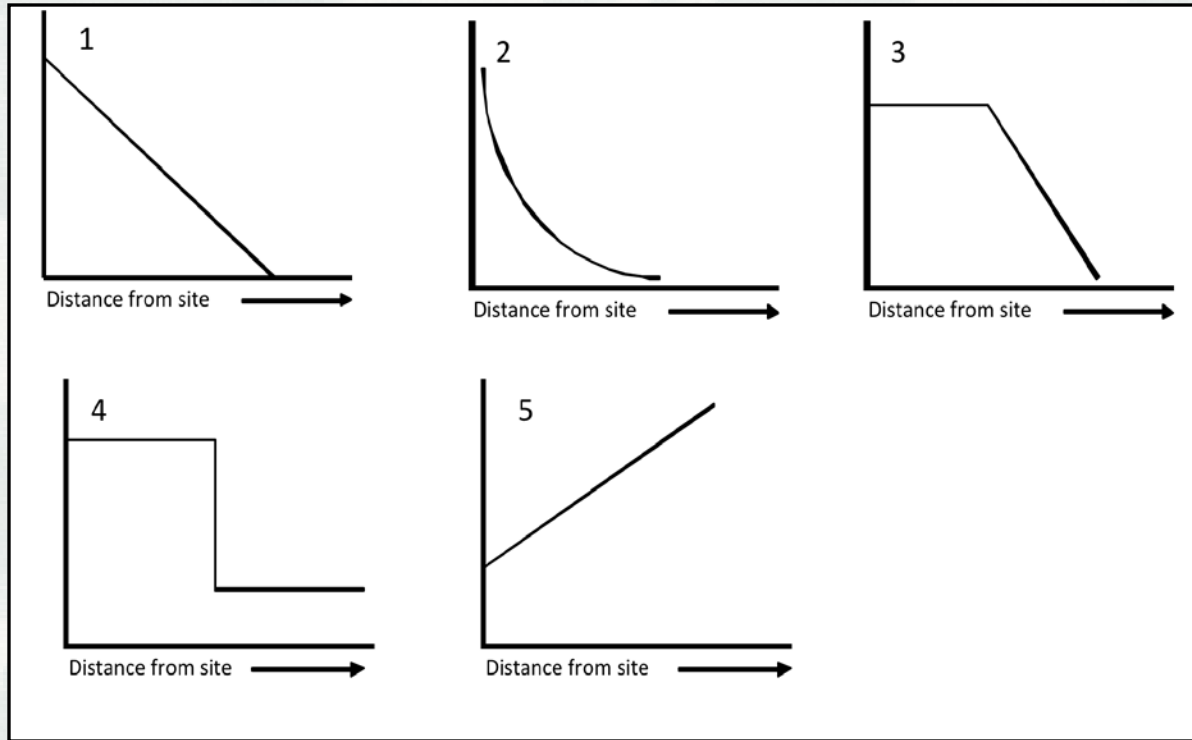
- 1 All Benefits contained within Project site (e.g., benthic habitat improvement)
- 2 Benefits extend some distance into the landscape surrounding the Project site (e.g., source populations)

- 3 Benefits occur completely outside the Project area (e.g., change hydrologic regime through dam modification / management)
- 4 Some overlap in Benefits and Project areas (e.g., barrier island or fringe wetland creation providing storm surge attenuation and sediment deposition)



# Potential effects on ecosystem benefits with distance from

## Project site:



- 1 Linear decrease (e.g., wildlife utilization relative to prime habitat)
- 2 Exponential decrease (e.g., reduction in flood recurrence intervals without strong geomorphic control)

- 3 No change, then linear decrease (e.g., salamander population with distance from vernal pool)
- 4 Stepped decline, such as a resource with strong geomorphic barrier (e.g., benefits maximal in wetlands, much lower in uplands)
- 5 Linear increase that results when larger area includes more habitat (e.g., depressional wetlands like prairie potholes or vernal pools)



# Additional Scale Considerations

- There is a lower limit to what we can measure – making EBA more difficult for smaller projects or restoration with geographically diffuse or shifted effects
- Relative value and distribution of ecosystem type matters – scarcity, connectivity, significance
- Structural and Functional boundaries can differ markedly



# Attributes of ecosystem boundaries, from Post et al. 2007.

## Types of definition:

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Structural	Based on physical boundaries (e.g., watersheds, aquatic–terrestrial)
Functional	Based on changes in the rates of interactions and exchanges among units of study

## Relationship to process of interest:

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Structural	Structural boundaries can be process-independent
Functional	By definition, functional boundaries depend upon the process of interest

## Origin:

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### *Structural:*

Geomorphic	Topographical boundaries including watersheds, aquatic–terrestrial boundaries, continental shelf vs. deep sea, etc.
Physiochemical	Thermoclines and chemoclines, e.g., freshwater–saltwater boundaries in estuaries.
Dimensional	Surface-related boundaries including surface vs. soil, benthic vs. pelagic, ground vs. canopy.
Biological	Physical boundaries among habitats, e.g., the boundary between old fields and forest.

### *Functional:*

Material and energy flow	Ecosystem boundaries defined by steep gradients in the flow of material and energy including resource sheds, nutrient spiraling, and discontinuities in nutrient or energy exchange. Often mediated by structural boundaries that limit exchange between ecosystems.
Species interactions	Community boundaries defined by the location of weak(er) species interactions. At times mediated by structural boundaries that limit interactions among species.
Movement of organisms	Population boundaries set by limits to immigration or emigration, and gene flow. Often mediated by structural boundaries that limit migration and gene flow.

## Activities:

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Transmission	The boundary is semi-permeable and allows only a fraction of organisms or material to pass, or reduces the strength of species interaction.
Transformation	The boundary changes the state of material or species interactions, e.g., N transformation at the soil–stream interface.
Absorption or reflection	The boundary is impermeable and either stops or redirects interactions among species or the flow of organisms and material.
Neutral	The boundary does not affect the flow of material or species interactions. Can only apply to structural boundaries.

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# Temporal Considerations

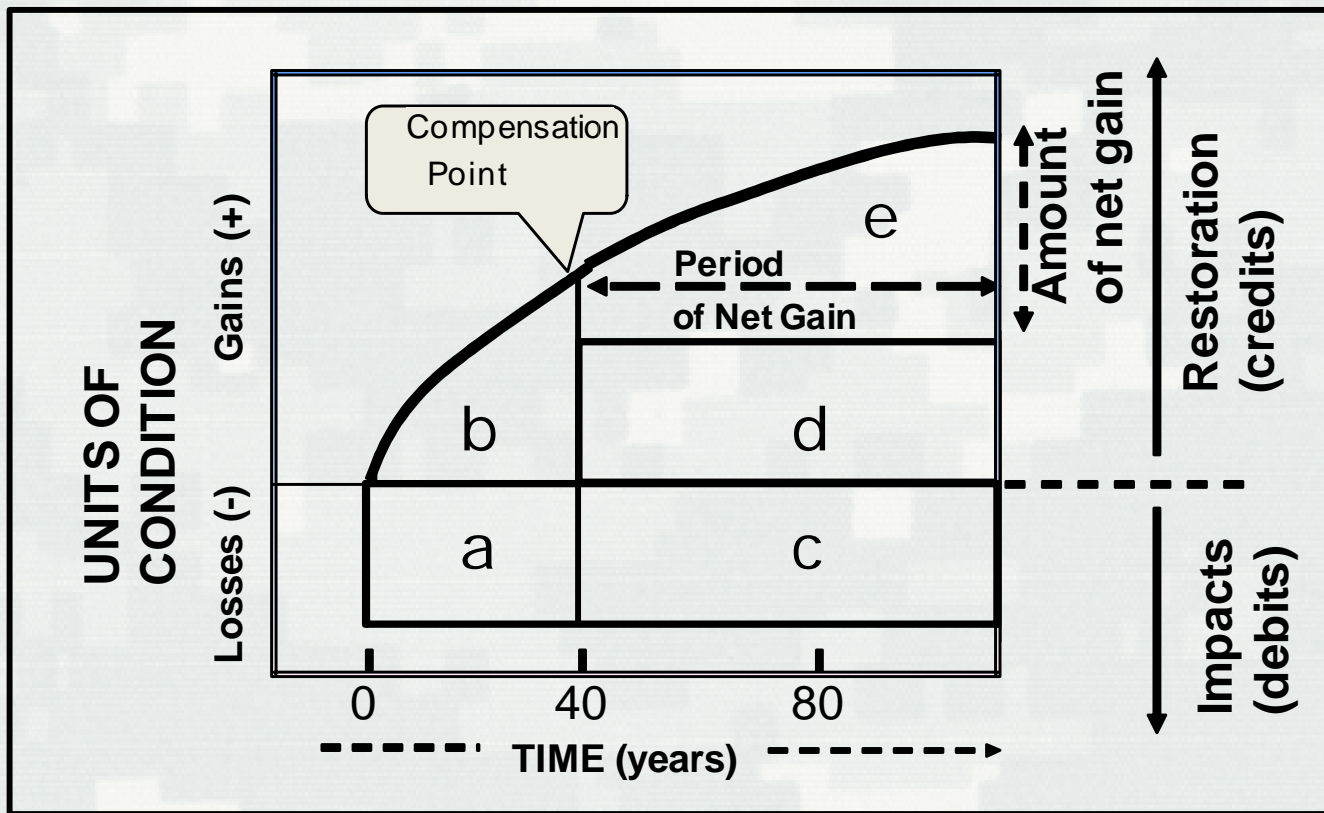
- Historical condition (separate from reference condition) sets the benchmark against which to:
  - ▶ Assess relative degradation
  - ▶ Calculate previous degradation rates
  - ▶ Determine thresholds and construct trajectories



# Temporal Considerations

- Immediate -- Final benefits – when and in what order do benefits occur? Proper accounting can limit “double counting”
  - ▶ Improved hydrologic regime => restoration of wetland soil properties => return of vegetation
  - ▶ Nutrient and sediment source control => clearer water => return of submerged aquatic vegetation
- Rate of recovery from restoration and persistence of benefits compared to project “design life” or planning timeline (e.g., 50yr)

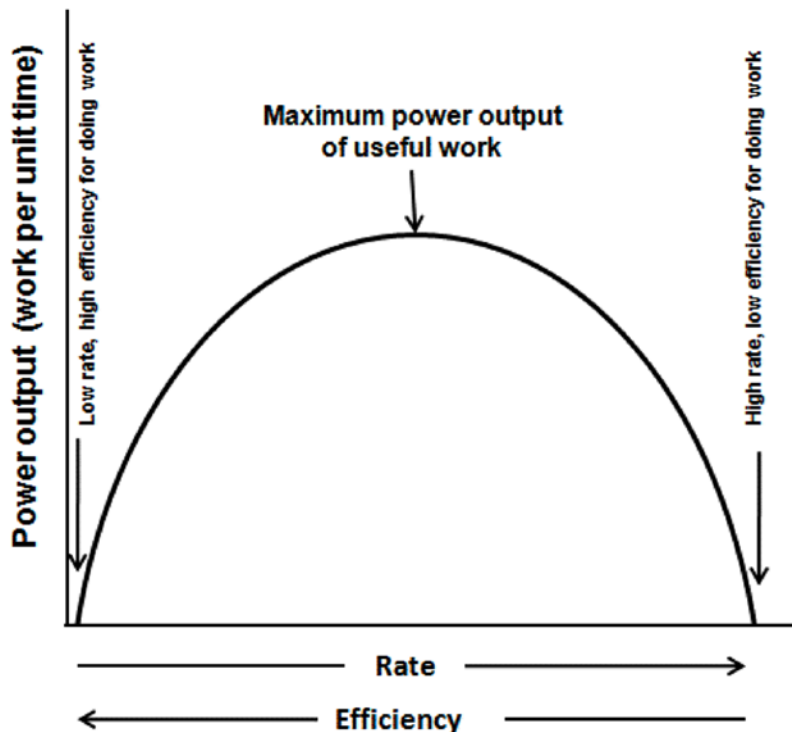




Assuming no additional degradation, a degraded control site (without project) would continue to show a loss of function (negative condition) ( $a + c$ ). A restored site could gain function over time such that lost functions would be compensated at yr 40 ( $b = a$ ). After that period, there would be net gain ( $e$ ) in function.



The relationship of power output to rate and efficiency: maximum power output occurs at an intermediate rate and efficiency (from Hall et al. 1995).



- Balancing rate of restoration and (assumed) associated rate of accrual of benefits with expense
- Highest efficiency in environmental benefits production is at low rate/cost – slow but cheap
- Least efficient is at high rate/cost – expensive, but fast





# In Summary:

- Effective project area can be defined by the geographic extent of changes to ecosystem structure and function linked to restoration objectives
- Benefits can occur, accrue and persist from the time of restoration action, through project design life or 50yr planning timeline, and beyond
- Incorporating the combination of these considerations should enable more complete accounting for the full suite of anticipated ecosystem restoration project benefits at both project and Program scales



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Sarah J. Miller – **THANK YOU!**

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## QUESTIONS?

