Metrics for Environmental Benefits Analysis

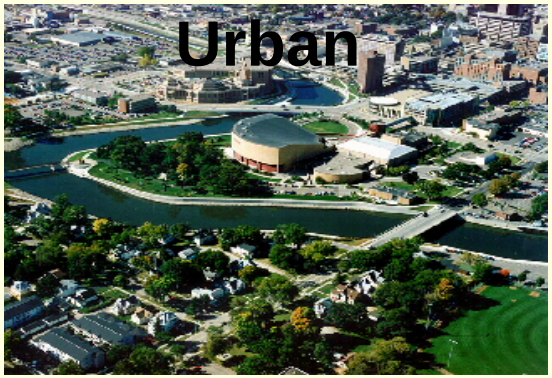
Kyle McKay
Environmental Laboratory
U.S. Army Engineer Research and Development Center

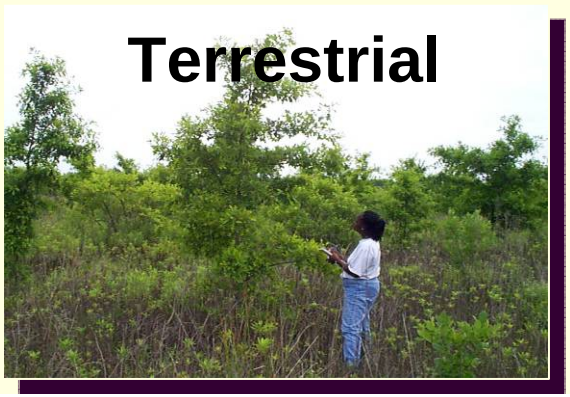
Environmental Benefits Analysis Seminar
May 12, 2009

Overview

- Acknowledgements:
  - USACE: Craig Fischenich, Andy Casper, Dick Cole, Sarah Miller
  - Metrics Workshop: Alan Covich, Bruce Pruitt, Melissa Kenney, Mark Harberg, John Boland
- Presentation Overview:
  - Environmental Benefits Analysis (EBA)
  - Metrics Workshop
    - Metrics in general
    - Objectives
    - Metric Development

The Corps Challenge





Environmental Benefits R & D Goal

*"Improvements in benefit/output evaluation techniques with emphasis on **scientifically-based and peer-recognized metrics** for the analysis of ecosystem restoration projects and alternatives with the goal of comparing projects and alternatives on a national basis in support of the Federal investment."*

John Paul Woodley

Assistant Secretary of the Army for Civil Works

Keystones of the EBA Program

- Full participation by external experts
- Active and continual exposure to critical peer review
- Real partnering of ERDC with Corps HQ, Districts, and Divisions
- Proactive methods for tech-transfer of new research results

EBA Technical Themes

- Conceptual models
  - Link restoration actions to predicted benefits
  - Cause & effect relationships
- Metrics
  - Assessing benefits across ecosystem type, region, spatio-temporal scale, and programmatic scale
- Ecological evaluation and forecasting
  - Empirical, stochastic and mechanistic forecasting/modeling of ecosystem response
- Decision analysis
  - Support risk informed planning & multi-criteria applications

EBA Technical Themes

- Environmental benefits quantification
  - Evaluate alternatives
  - Assess success
  - Document contributions to NER Account
- Ecosystem services
  - Using economic principles to account for social, economic, and ecological benefits
  - Services provided by ER projects
- Programmatic assessment
  - Comparison across projects at regional and national levels
  - Budget criteria
  - Cost-effectiveness and incremental cost analyses (CE/ICA)

- Unofficial 8th Focus Area:
  Information and Technology Transfer

Metrics in the Corps Context

- National Economic Development (NED)
  - Economic Focus (often $)
  - Cost-Benefit
- National Ecosystem Restoration (NER)
  - Over $500M Annually
  - Purpose: “…to restore significant ecosystem function, structure, and dynamic processes that have been degraded”
  - Environmental focus
  - NER projects “should be viewed on the basis of non-monetary outputs”
  - Cost Effectiveness and Incremental Cost
- NED/NER

EBA Metrics: Workshop

Objectives:

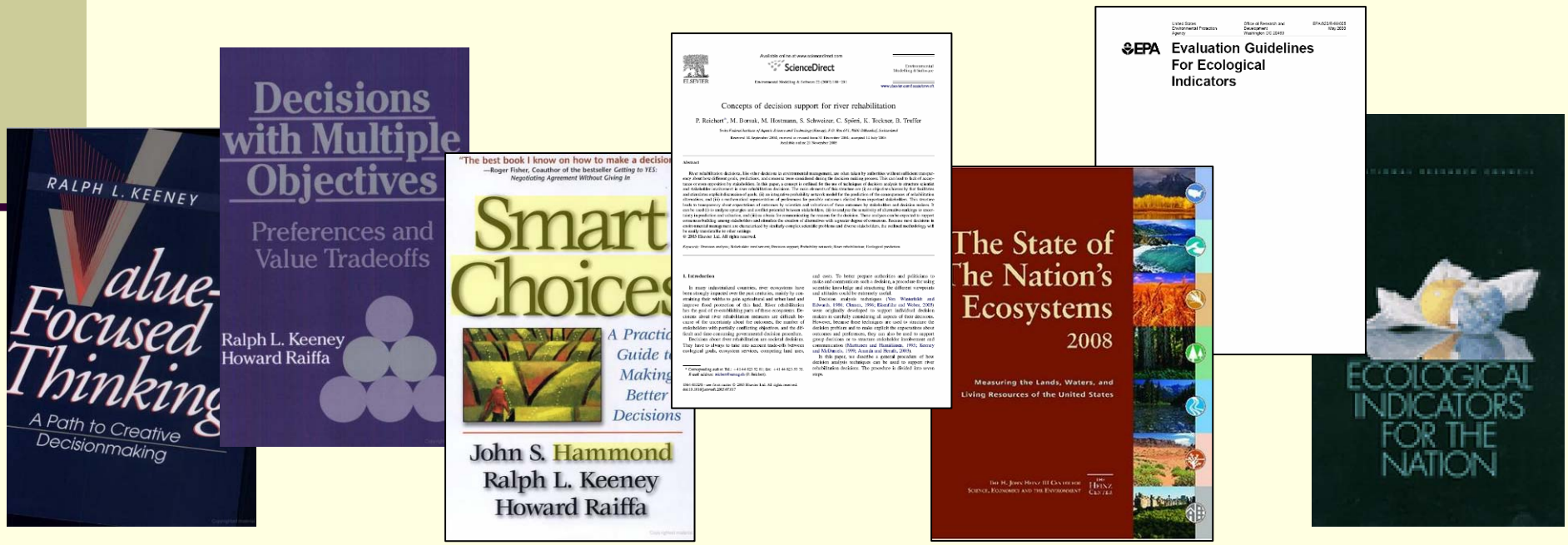
- Assess:
  - State of the science
  - State of the practice
- Produce interim guidelines
- Outline research needs
- Contribute to a framework for EBA at the project and programmatic levels

- Alan Covich, U of Georgia
  Stream Ecology
- Bruce Pruitt, Nutter & Associates
  Wetland Biogeochemistry
- Melissa Kenney
  Johns Hopkins & NCED
  Decision Analysis
- Mark Harberg, USACE Ft. Worth
  Field Representative
  Biology
- Craig Fischenich, ERDC-EL, Program Representative
  Ecological Engineering
- John Boland (corresponding)
  Johns Hopkins
  Environmental Economist

What is a metric?

- Definition – measurable system properties used to quantify the degree of achieving the objectives (Reichert et al. 2007)
- Other commonly applied terms: attribute, indicator, performance measure, criterion, and assessment endpoint

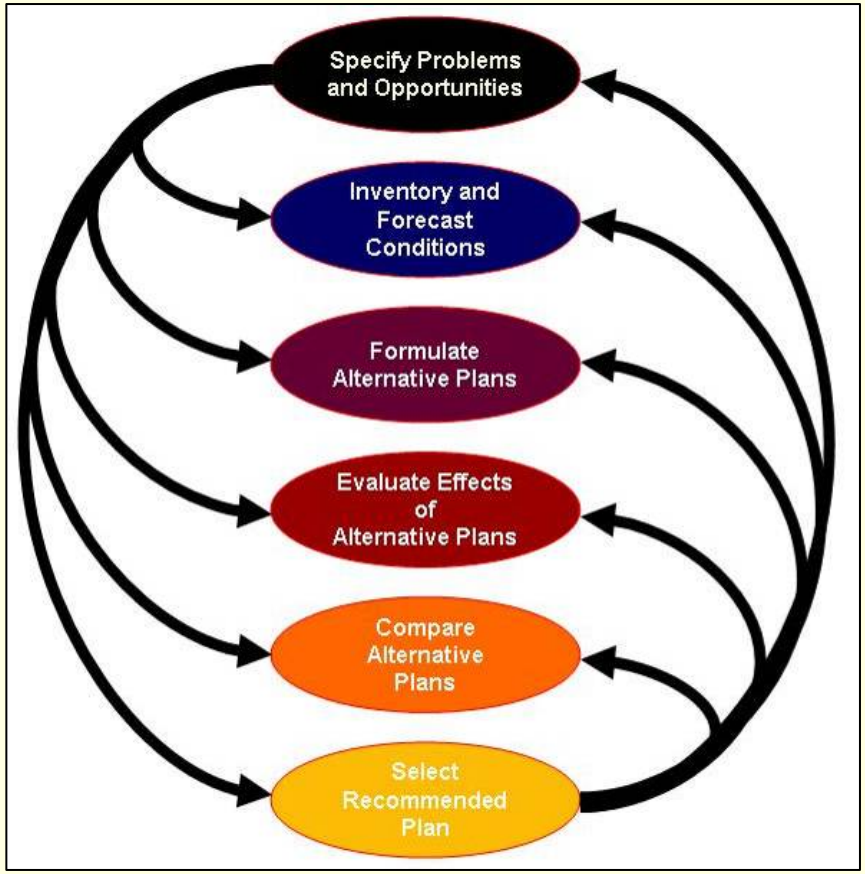
- Two “camps” in restoration metric development
  - Social Sciences
  - Life and Physical Sciences



Where do metrics and objectives fit in?

Metrics are needed for:

- Project alternative comparison
- Project performance monitoring
- Regional assessment
- National assessment and portfolio management



Why are metrics hard to develop?

- Eco-centric v. Socio-centric
- Universal v. Flexible
- Static v. Process
- Abiotic v. Biotic
- Spatio-temporal issues
  - Scaling
  - Non-linearity – trajectories, thresholds
  - External shifts – climate, land use, invasives, etc.
- Ecosystem specific constraints
- Risk and Uncertainty
  - Knowledge-based uncertainty
  - Numerical uncertainty
  - Stochastic Ecosystems
  - Professional judgment
- Scientific v. Societal Value
- Combination of metrics – How do we do it?

State-of-the-Practice

- Metrics are often:
  - Not clearly mapped to objectives
  - Focused on one aspect of restoration (e.g. quantity)
  - Poorly documented
  - Difficult to translate from project to programmatic scales
  - Different throughout the project life cycle (e.g. reconnaissance v. O&M)

Fundamental Objectives for Ecosystem Restoration

- USACE ER-1165-2-501
  - “The purpose…is to restore significant ecosystem function, structure, and dynamic processes that have been degraded”

- Five criteria for ecologically successful river restoration (Palmer et al. 2005)
  - Guiding image of dynamic state
  - Ecosystems are improved
  - Resilience is increased
  - No lasting harm
  - Ecological assessment is completed

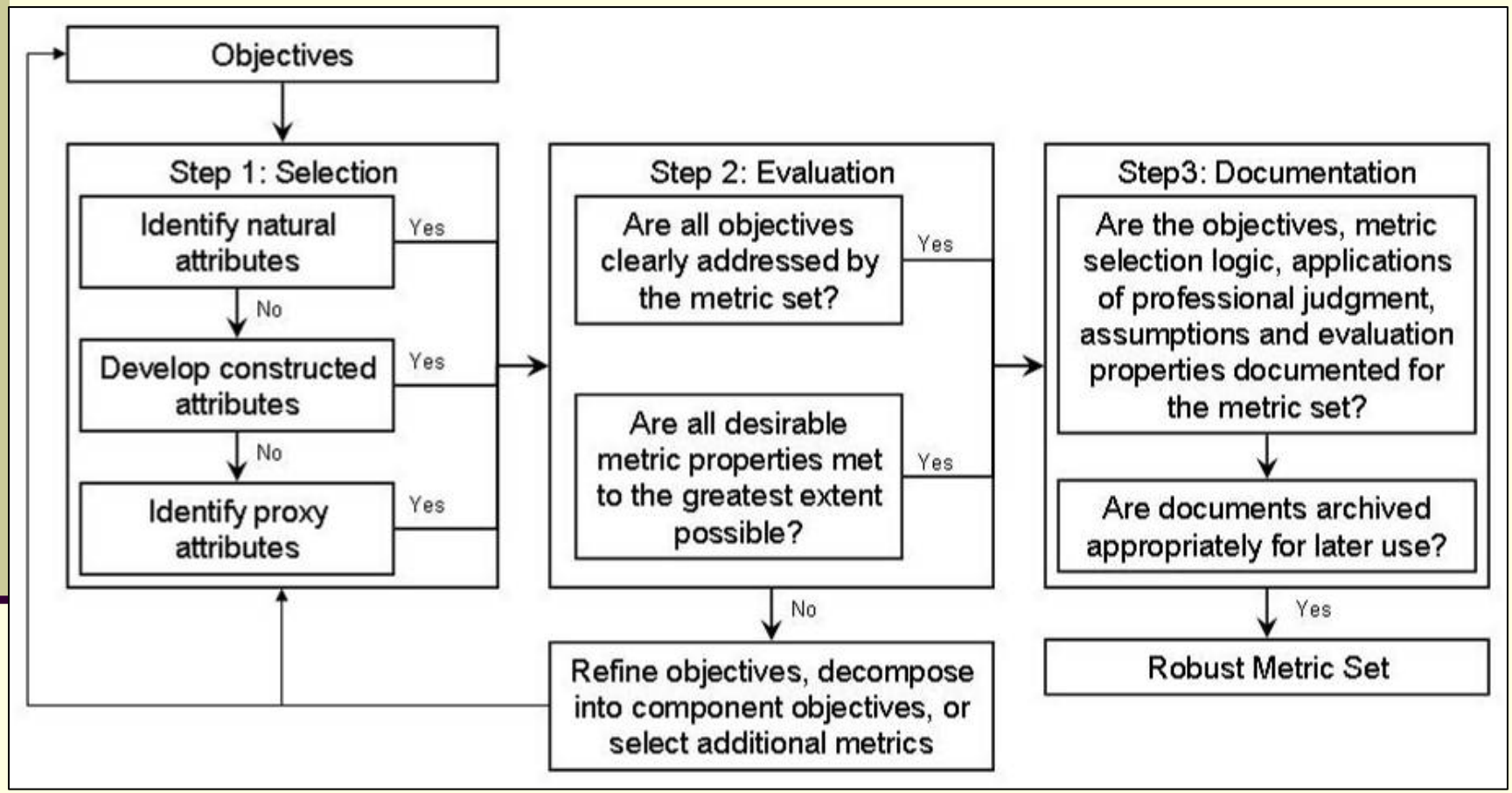
Improving Ecosystem Integrity

- Hydrogeomorphology
- Biogeochemistry
- Biological Systems
- Socioeconomics
- Cultural, Demographic, and Political System
- Landscape Character

Objective Setting

- Write down the concerns you want to address
- Convert general concerns into succinct objectives
  - Verb-object structure
    - e.g. Increase habitat for critters
  - Be clear
  - Be comprehensive
- Separate ends (fundamental objectives) from means
  - “Means objectives represent way stations in the progress toward a fundamental objective”
  - “Fundamental objectives constitute the broadest objectives directly influenced by your decision alternatives”
- Clarify what is meant by each objective

Metric Development Process



What's a good metric set look like?

EPA (2000) – EMAP

1: Conceptual relevance
- 1.1: Relevance to the assessment
- 1.2: Relevance to ecological function

2: Feasibility of implementation
- 2.1: Data collection methods
- 2.2: Logistics
- 2.3: Information management
- 2.4: Quality assurance
- 2.5: Monetary costs

3: Response variability
- 3.1: Estimation of measurement error
- 3.2: Temporal variability (within-season)
- 3.3: Temporal variability (across-year)
- 3.4: Spatial variability
- 3.5: Discriminatory ability

4: Interpretation and utility
- 4.1: Data quality objectives
- 4.2: Assessment thresholds
- 4.3: Linkage to management action

NRC (2000) – National Ecological Indicators

General Importance	Conceptual Basis
Reliability	Statistical Properties
Data Requirements	Necessary Skills
Robustness	International Compatibility

Temporal and Spatial Scales of Applicability

Costs, Benefits, and Cost-Effectiveness

Keeney and Gregory (2005) – Decision Metrics

Comprehensive	Direct
Operational	Understandable
Unambiguous	

Desirable Metric Properties

Relevant

Unambiguous

Comprehensive

Direct

Operational

Understandable

Key Take-away Points

- Environmental Benefits Analysis (EBA) research program is underway
- Metrics are a key component to measuring the achievement of objectives
- Although restoration projects vary widely, a common goal of improving ecosystem integrity helps define objectives.
- A framework has been proposed to develop metrics from the objectives

Future Research: Underway and Potential

- Objective Setting for Ecosystem Restoration Projects
- Comparing Benefits for Projects with Dissimilar Metrics
- Spatio-Temporal Considerations for Ecosystem Restoration Projects
- Identifying Key Thresholds in Ecosystem Restoration
- Discounting Non-Monetary Metrics
- Defining “significance”
- Developing Ecosystem-Specific Metric Sets
- Cumulative Effects Analysis
- Incorporating scientific and societal value/utility
- Techniques for including spatial and temporal variability in metrics
- Identification of appropriate decision models for a given application
- Essential v. Supplemental Metrics
- Applying, combining, and comparing ordinal metrics
- Metric documentation and archival

Questions and Feedback

Contact Information
Kyle McKay
601-415-7160
Kyle.McKay@usace.army.mil

Environmental Benefits Analysis Research Program Website
http://cw-environment.usace.army.mil/eba/

Current and Forthcoming Publications:

McKay, Pruitt, and Covich. (2009). Monitoring Ecosystem Integrity. 2009 Georgia Water Resources Conference, Athens, GA.

Covich, McKay, Kenney, Pruitt, Harberg, Fischenich, and Boland. Enhancing Aquatic Ecosystem Integrity with Effective Objectives and Metrics for Restoration. In prep for *Ecological Restoration*.

McKay, Pruitt, Harberg, Covich, Kenney, Miller, and Fischenich. Metric Development and Application for Environmental Benefits Analysis. ERDC TN-EBA.

Cole, R. Measuring Environmental Value In Nonmonetary Terms: A Review of Common Practices and Elements. ERDC TR-EBA.

Cole. A New Metric for Indicating Benefits from USACE Ecosystem Restoration Projects. ERDC TR-EBA and TN-EBA.

Lin. 2009. The Functional Linkage Index: A Metric for Measuring Connectivity among Habitat Patches Using Least-Cost Distances. Journal of Conservation Planning. Vol. 5, pp. 28-37.

Lin. 2008. A Metric and GIS Tool for Measuring Connectivity Among Habitat Patches Using Least-Cost Distances. ERDC TN-EBA-02.

McKay and Fischenich. Considering Uncertainty in Environmental Benefits Analysis: Coastal Wetland Restoration Case Study. ERDC TN-EBA.

Conyngham, McKay, Fischenich, and Artho. EBA of Fish Passage on the Truckee River, Nevada: A Case Study Emphasizing the Treatment of Dependencies. ERDC TN-EBA.

Other Work Units

A New Metric for Biodiversity

- New Non-Monetary Metric
  - Project and Program Applications
- Biological Security Index (BSI)
  - Security Status
  - Distinctiveness
- Emphasizes biodiversity hotspots

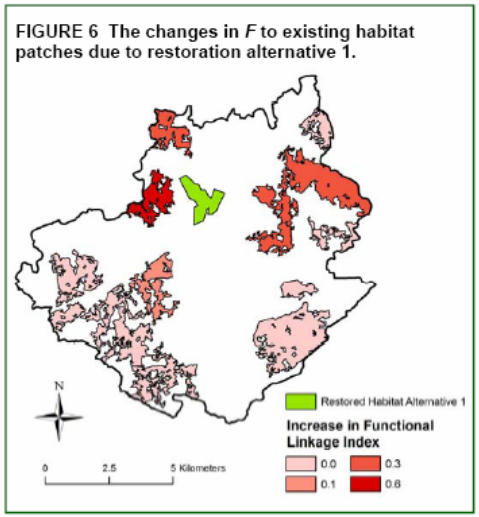
NatureServe Explorer Security Status (Conservation Status)	
G5	**Secure**
G4	**Generally secure**
G3	**Vulnerable**
G2	**Imperiled**
G1	**Greatly Imperiled**
GH	**Possibly Extinct**
GX	**Presumed Extinct**

$$BSI = \sum_{S=1\ldots n} ((wD)(wG))_s$$

Where: *wG* = policy weighted indicator of species security status
wD = policy weighted indicator of species distinctiveness
S = indicator species

Patch Connectivity Calculator

- Connectivity among habitat is critical
- New Metric – Functional Linkage Index
- Compares relative influence of restoration alternatives on connectivity
- Publicly available add-in to ESRI's ArcGIS



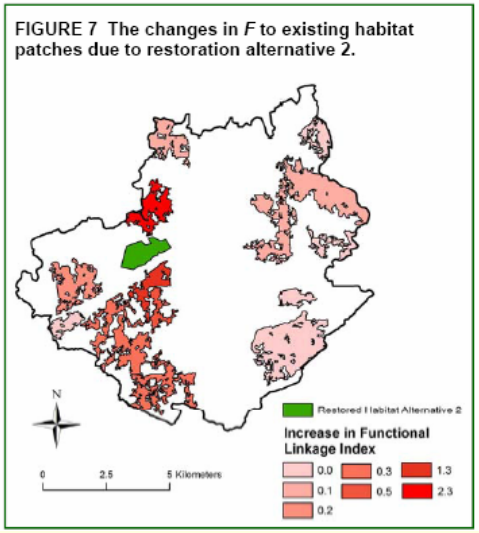
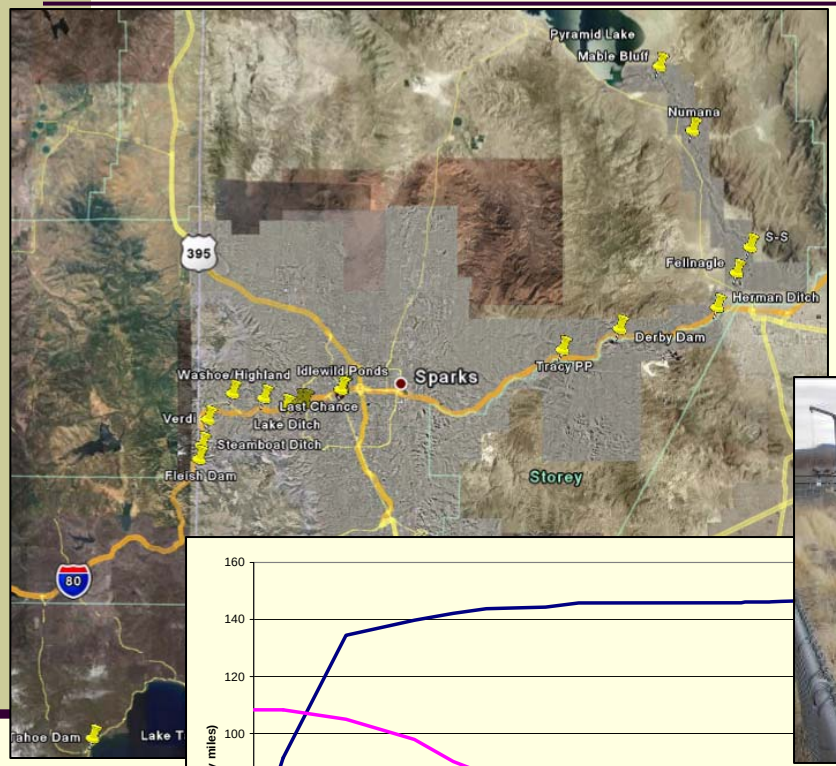


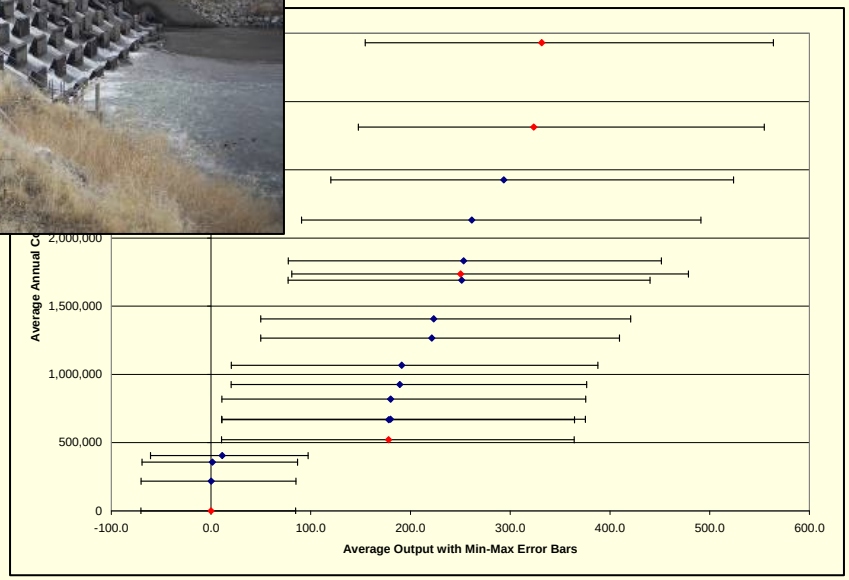
FIGURE 1 A cost grid showing the least-cost path (light grey cells) as compared to the Euclidian path (hatched cells) between two focal patches (black cells). The numbers are the movement cost for traversing one linear unit within the associated cell resolution (ESRI 2007). Assuming a 10 x 10 linear unit cell resolution, the total cost distance of the Euclidian path is 226.27, while the total cost distance of the least-cost path is 102.78.

1	2	2	2	3	3
1	1	2	2	3	3
2	5	5	5	5	3
1	1	1	5	5	5
1	1	1	2	5	5
1	1	3	3	1	1

Case Study: Truckee River Fish Passage Restoration

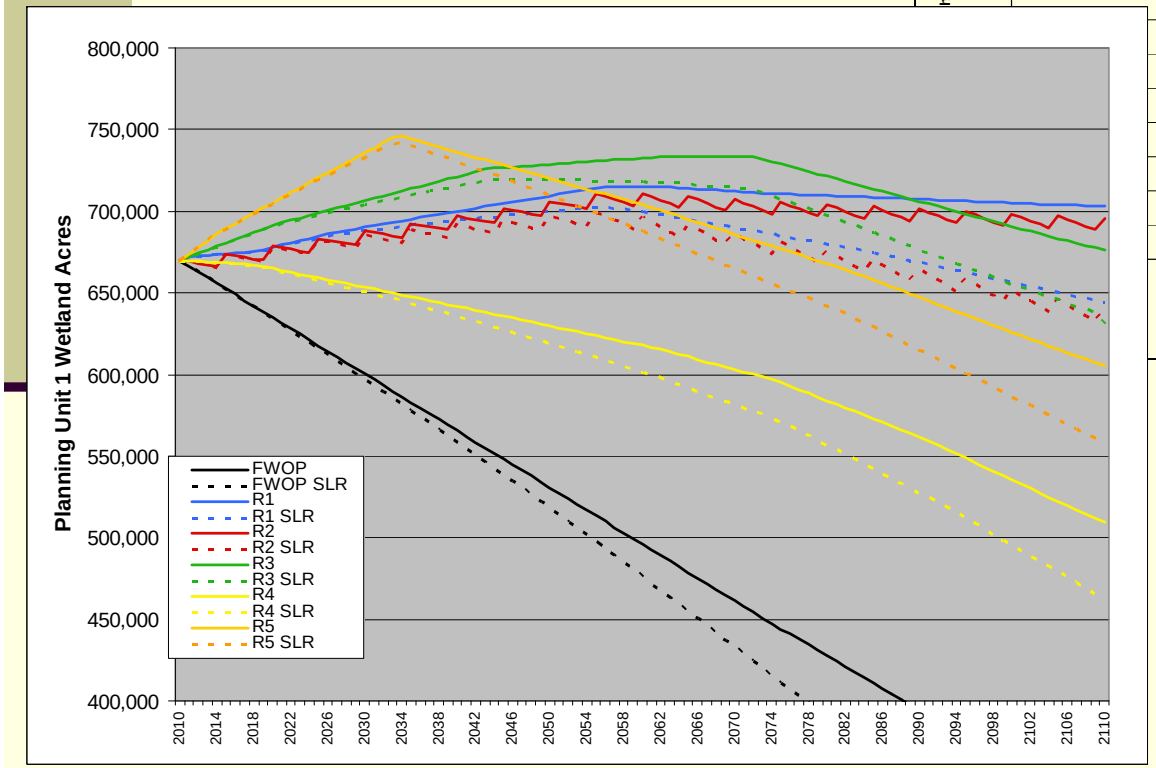


- Metric Development
  - Conceptual Model
  - Dependency in Benefits
  - Professional Judgment
- Uncertainty



Case Study: Louisiana Coastal Protection and Restoration

- Watershed Scale Analysis
- Collaborative Planning
- Adapting Available Tools
- Value Elicitation



- Metric Identification
- Uncertainty
  - Parameter
  - Scenario