Ecosystem Modeling for the Missouri River Cottonwood Management Plan

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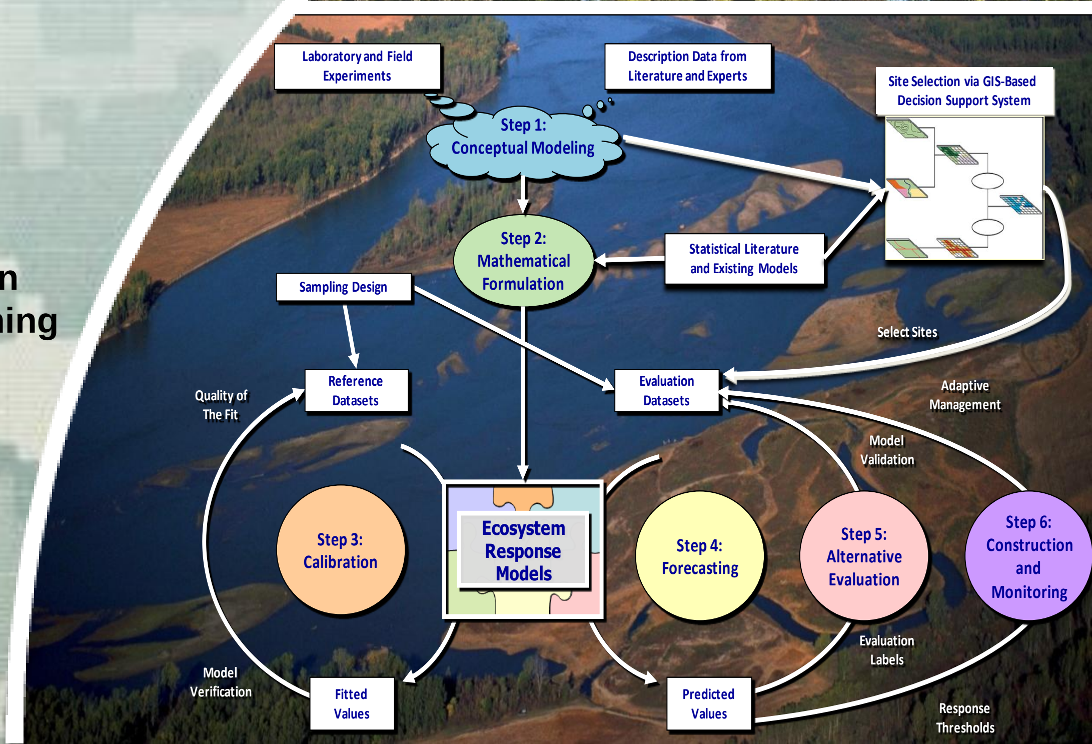

US Army Corps of Engineers
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Overarching Research Question

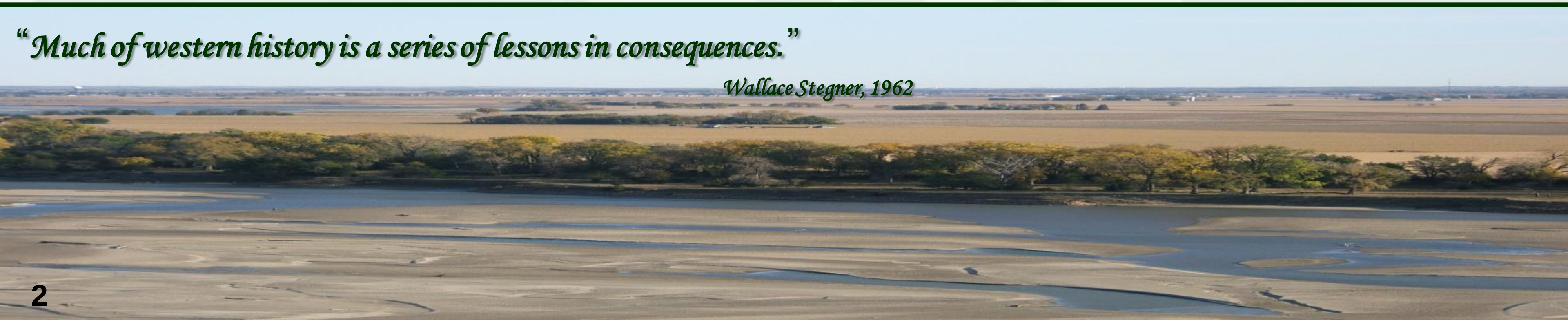
Problem:

The construction of large-scale flood control and navigation projects on river systems across the country has resulted in **significant** (but unintended) **system-wide effects** that now must be redressed. Unfortunately, decisions regarding their recovery are complicated by:

- **competing interests**
- **shifting goals**
- **gaps in scientific understanding**
- **constraints on time and resources**

Solution:

These large-scale mitigation efforts require a new decision making paradigm – one that communicates risk to decision makers by integrating dynamic ecological, hydrological, spatial, and sociopolitical information in a transparent, engaging fashion.



Research Questions To Consider

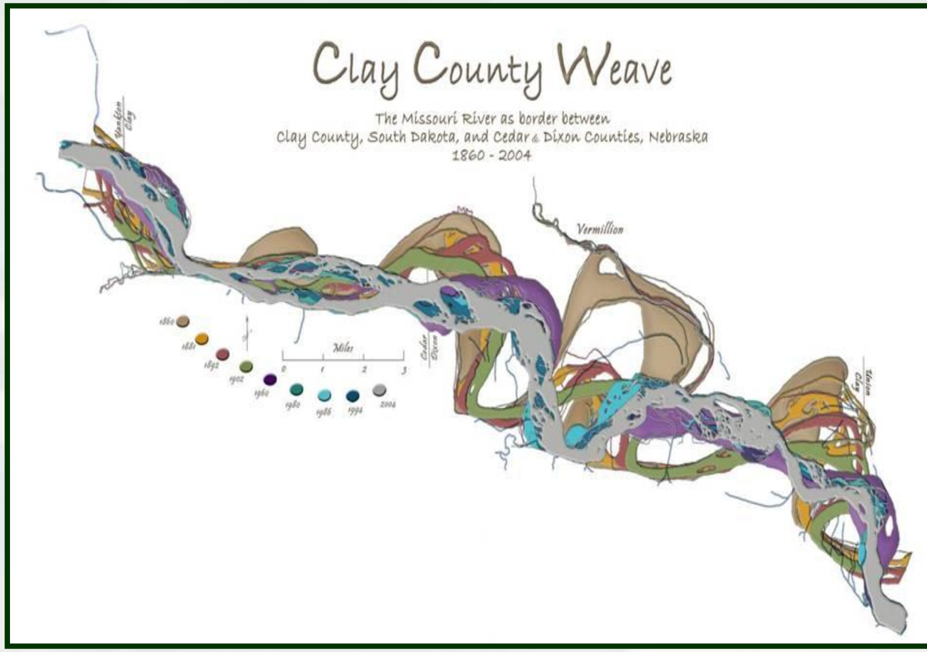
- **How do you mitigate for thousands of miles of impacts under shifting, oftentimes conflicting political, social, and ecological decision-making paradigms?**

- **How do you measure success, when ecosystem integrity or system wholeness can never be restored with any degree of certainty?**

To meet this challenge, computer-based solutions ("hard science") must be coupled with collaborative, participatory techniques ("soft science") to generate a forum that advances rapid decision-making in the face of constant change.

Study Area

- **Missouri River Basin Facts**
  - 530,000 mi^2
  - 1/6 of the continent
  - Runs from the Rockies to the Mississippi River
  - Spans 10 states
  - Was once a highly dynamic system characterized by constant fluvial geomorpholgical process
    - Stream narrowing (abandonment),
    - Re-meandering, and
    - Flood deposition



Study Background

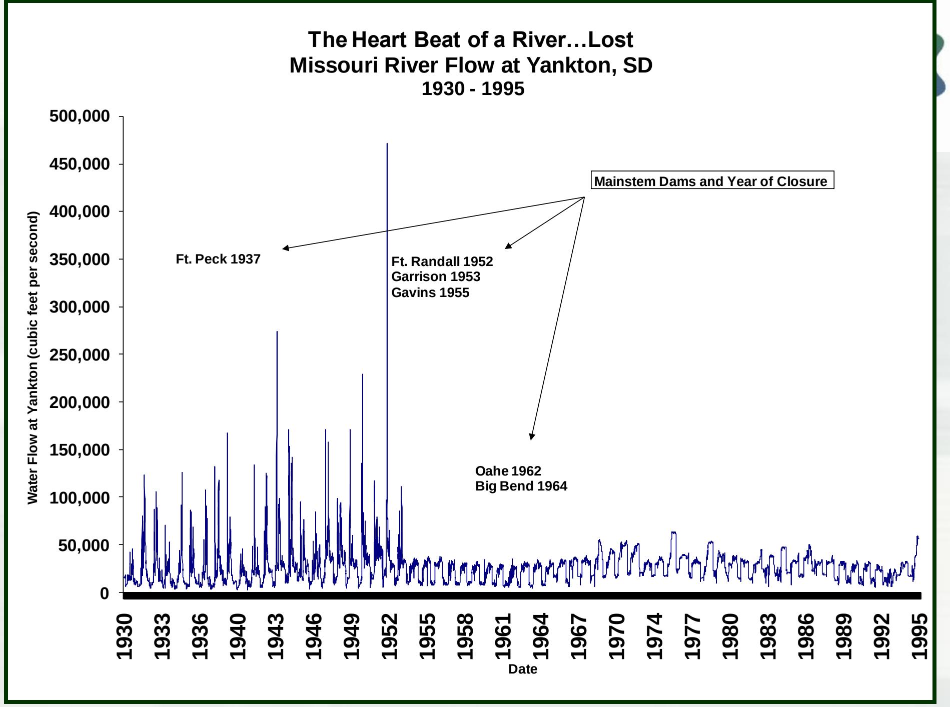
1920's Roosevelt's "Stimulus" Package (during the Great Depression)

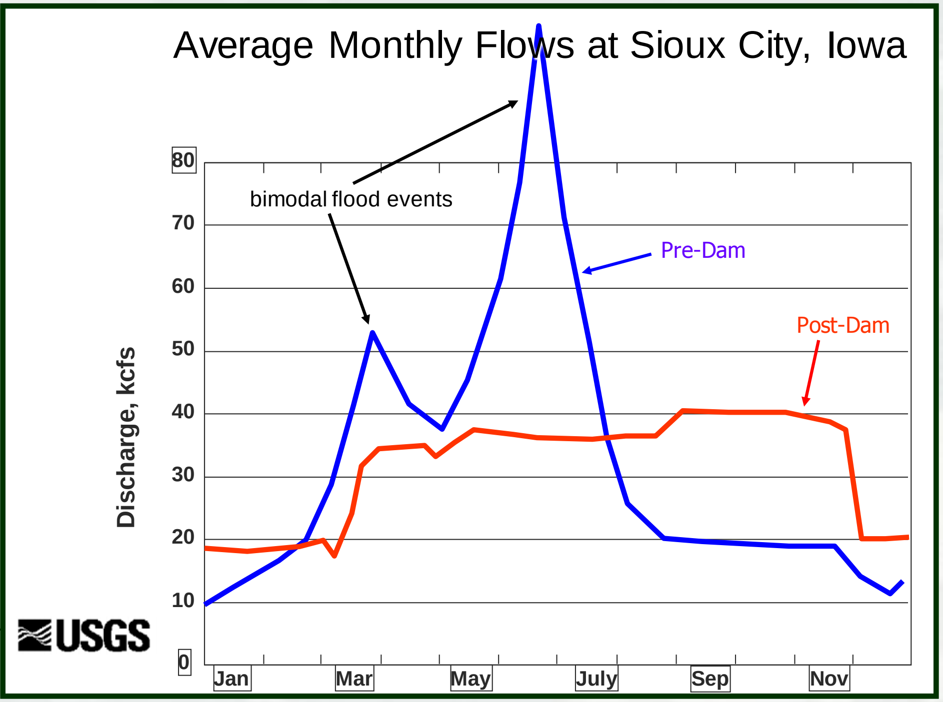
- **"Harness the rivers"** and provide jobs and growth
    - 50+ dams – 6 on Mo River
    - Length reduced by >200 miles
    - The amplitude and frequency of the river's natural peak flows have been dramatically reduced
    - Peaks occur several months later
    - Erosion and deposition are sharply reduced
    - River has ceased to meander and point bars are no longer formed

- Nearly **3 million** acres of natural riverine and floodplain habitat have been altered through land-use changes, inundation, channelization and levee building.

- Several species, the **least tern**, **piping plover**, and **pallid sturgeon** have been placed on the federal Endangered Species List. . . . In 2000 USFWS finds "jeopardy" and directs USACE to mitigate on an unprecedented scale.

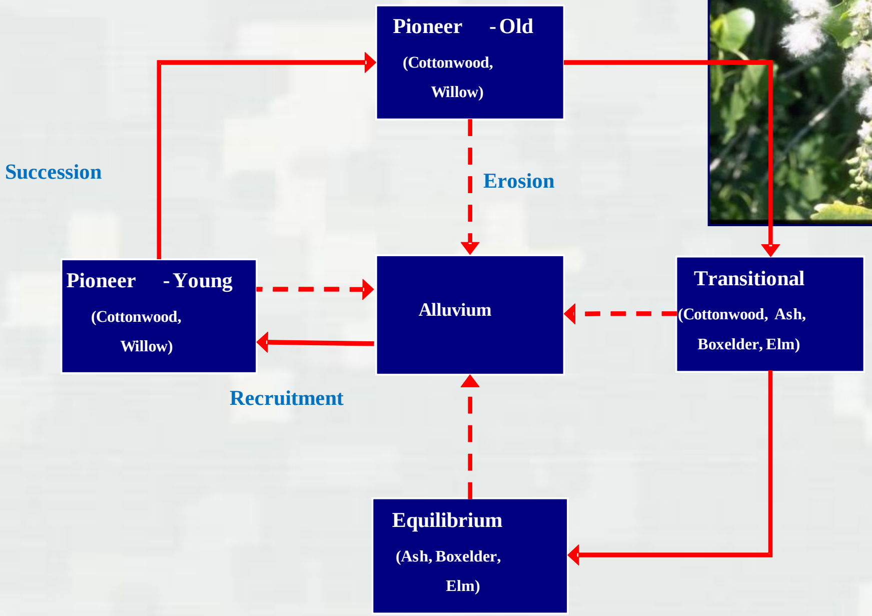
- **Cottonwood forest reproduction** (historically the most abundant and ecological significant species on the river's extensive floodplain) has **largely ceased**





Cottonwood Life History Traits

- ***Populus deltoides*** **Marsh. Subsp.** ***monilifera*** **(Ait.) Eckenw**
  - ▸ Disturbance-loving species
  - ▸ Seed dispersal via wind/water occurs in late May/early June coinciding with the pre-regulated Missouri River bimodal spring and summer rises
  - ▸ Need bare, moist sand/silt (point bars and islands) to germinate
  - ▸ They are poor competitors and shade intolerant
  - ▸ First year saplings remain vulnerable to drought
  - ▸ Easily washed away or scoured away by ice in the first 1-2 yrs
  - ▸ Recruitment conditions are favorable only 2 out of every 10 years
  - ▸ Life span = ~100 years



(adapted from Johnson 1992)

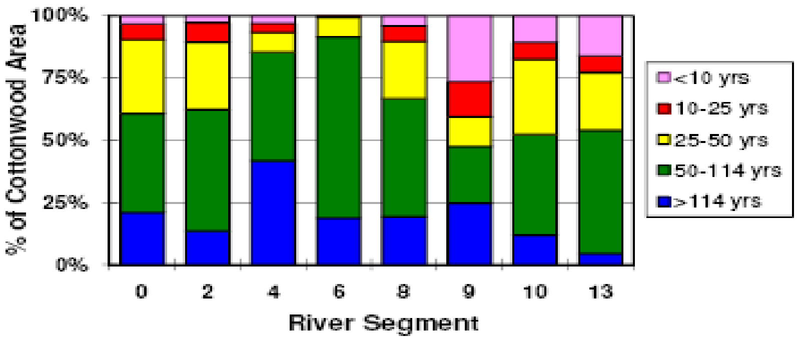


Figure 8. Relative area of different cottonwood age classes on each study segment.

Graphic provided by M. Dixon, 2009

Goals & Objectives

Cottonwood Management Plan Goal:

*Provide a single, comprehensive and **integrated planning and management strategy** to guide the efficient and effective preservation and restoration of critical cottonwood community structure and function in the Missouri River Basin in compliance with the USFWS 2000 Biological Opinion (and 2003 amendment)*

- **Develop a planning approach** and engage critical stakeholders
- **Conceptualize** the overall system (including the key drivers and stressors)
- **Develop** a community-based index model to assess basin conditions
- **Identify and prioritize** potential preservation/restoration sites.
- **Develop** an adaptive co-management strategy based on risk and uncertainty that uses monitoring and management triggers to stimulate agency response.

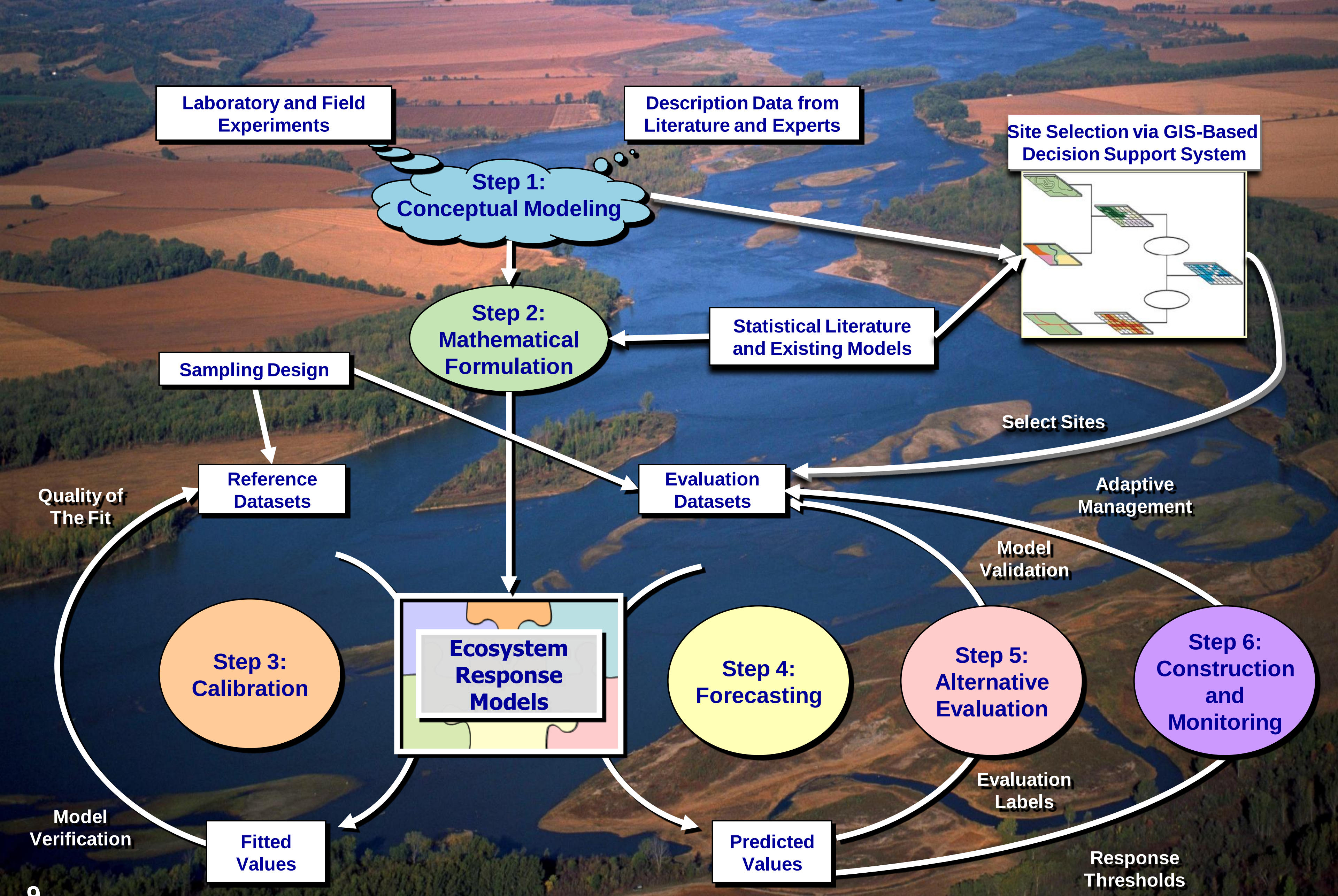
Why model Cottonwood Habitat? What's the point?

- **The Problem:**
  - Planning, management, and policy decisions require information on the **status**, **condition** and **trends** of these complex ecosystems and their components at various scales (e.g. local, regional, watershed and system levels) **to make reasonable and informed decisions** about the planning management and conservation of sensitive or valued resources.

- **By definition community index models are:**
  - comprehensive
  - multi-scale
  - grounded in natural history
  - relevant
  - helpful
  - flexible
  - measurable
  - able to integrate terrestrial and aquatic environments

- **Purpose of the MNRR Cottonwood Model:**
  - Broadly capture **existing, baseline conditions**, and **compare changes** that would occur to the resources present given different project scenarios or alternatives under the standard USACE planning paradigm.

Structured Ecosystem Planning Approach



Transdisciplinary Teaming

Processes that foster social learning include:

- careful facilitation
- small group work
- repeated meetings
- opportunities to influence the flow of events in a given process
- open communication
- diverse participation
- unrestrained thinking
- inclusion of multiple sources of knowledge

The daydreams of cat herders

My Team:

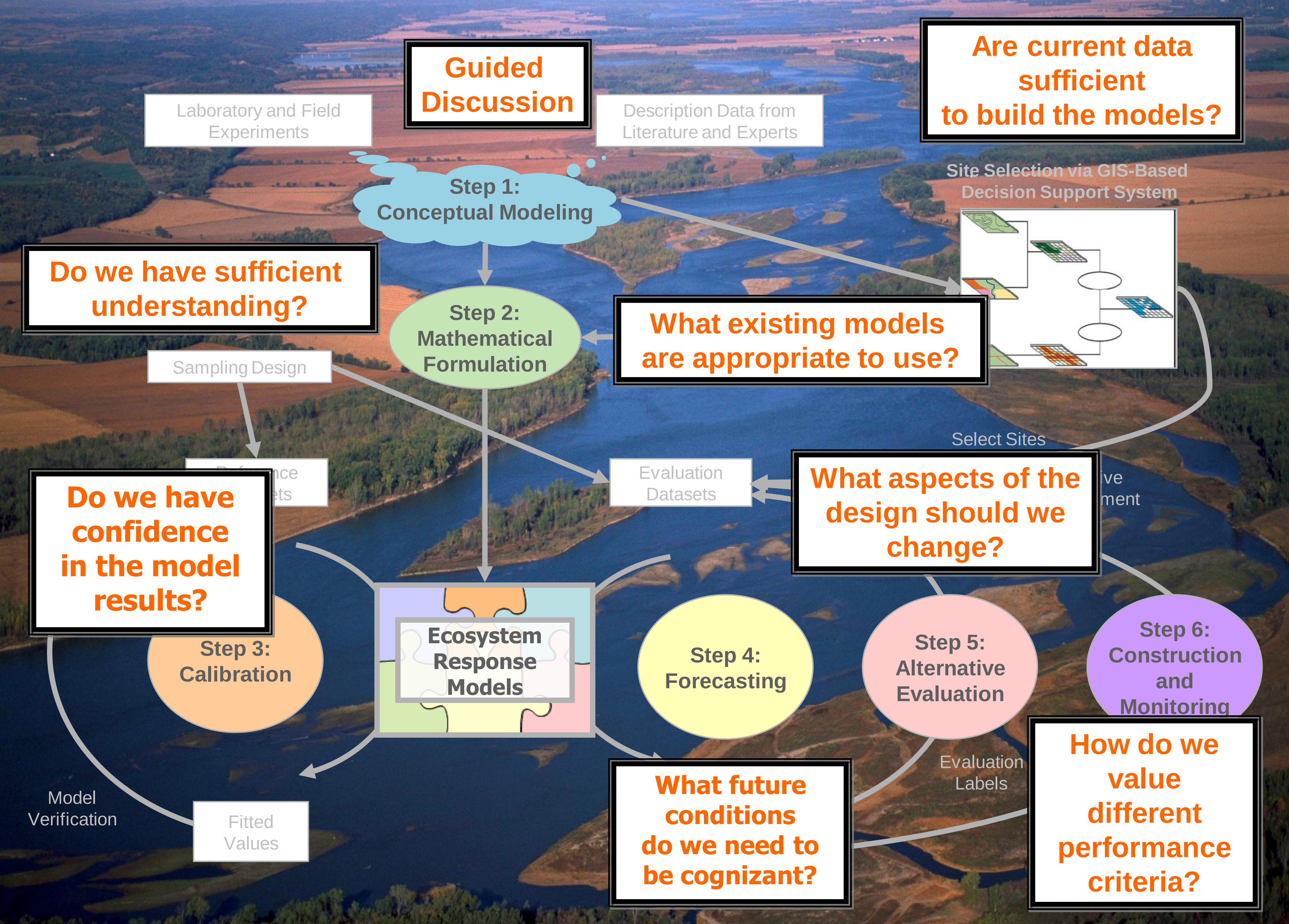
- **Federal**
  - Corps of Engineers - Omaha and Kansas City Districts, Engineer Research and Development Center
  - National Park Service
  - Natural Resource Conservation Service
  - U.S. Environmental Protection Agency
  - U.S. Fish and Wildlife Service
  - U.S. Geological Survey
- **Tribal**
  - Cheyenne River Sioux Tribe
  - Lower Brule Sioux Tribe
  - Omaha Tribe
  - Pine Ridge Agency (Oglala Sioux Tribe)
  - Rosebud Sioux Tribe
  - Winnebago Tribe of Nebraska
- **Other**
  - Izaak Walton League of America
  - The Nature Conservancy
  - Missouri River Futures

States

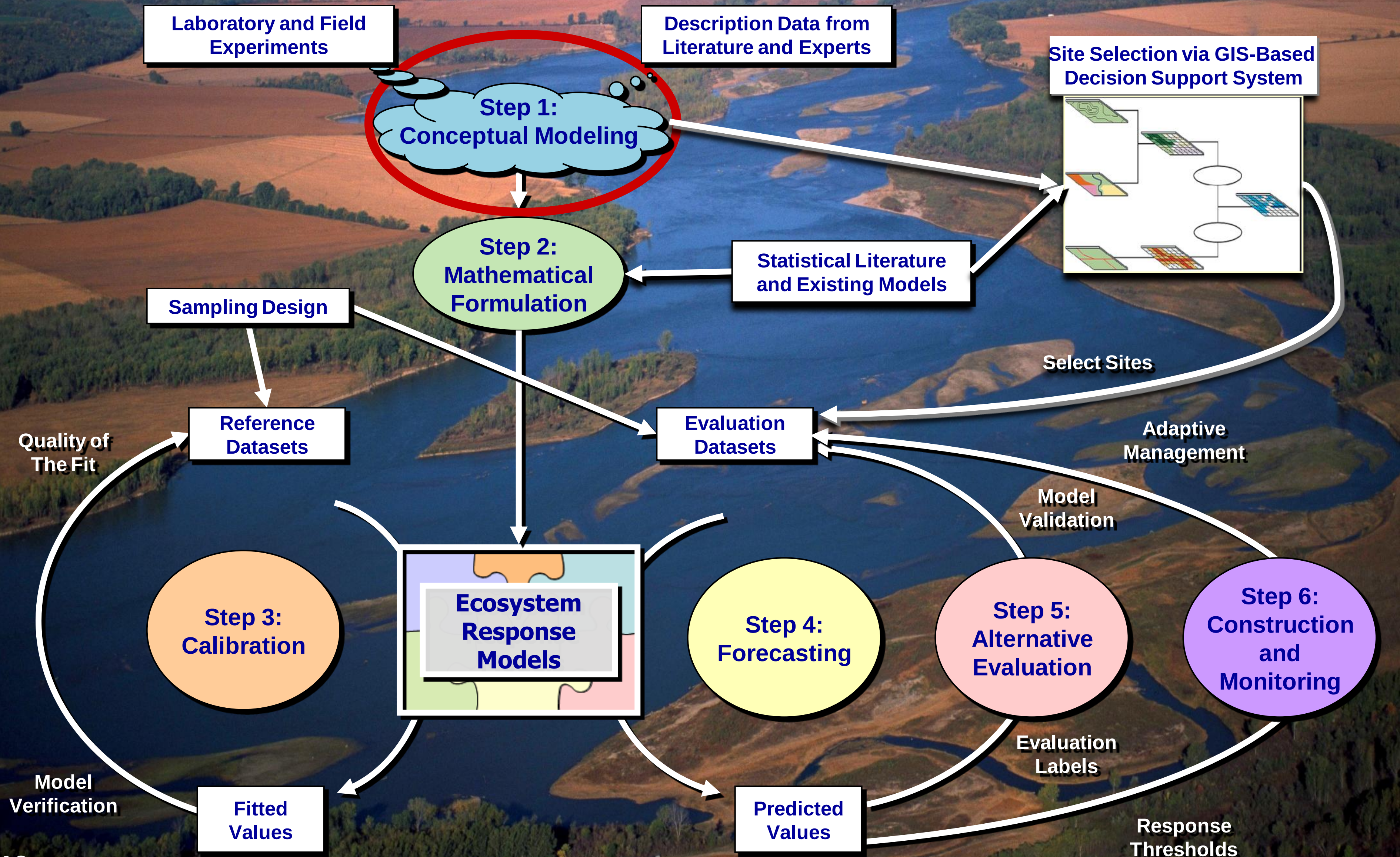
- Iowa Department of Natural Resources
- Kansas Department of Wildlife and Parks
- Lewis & Clark Natural Resource District
- Missouri Department of Conservation
- Nebraska Forest Service
- Nebraska Game and Parks Commission
- South Dakota Department of Game, Fish, and Parks
- South Dakota Department of Agriculture

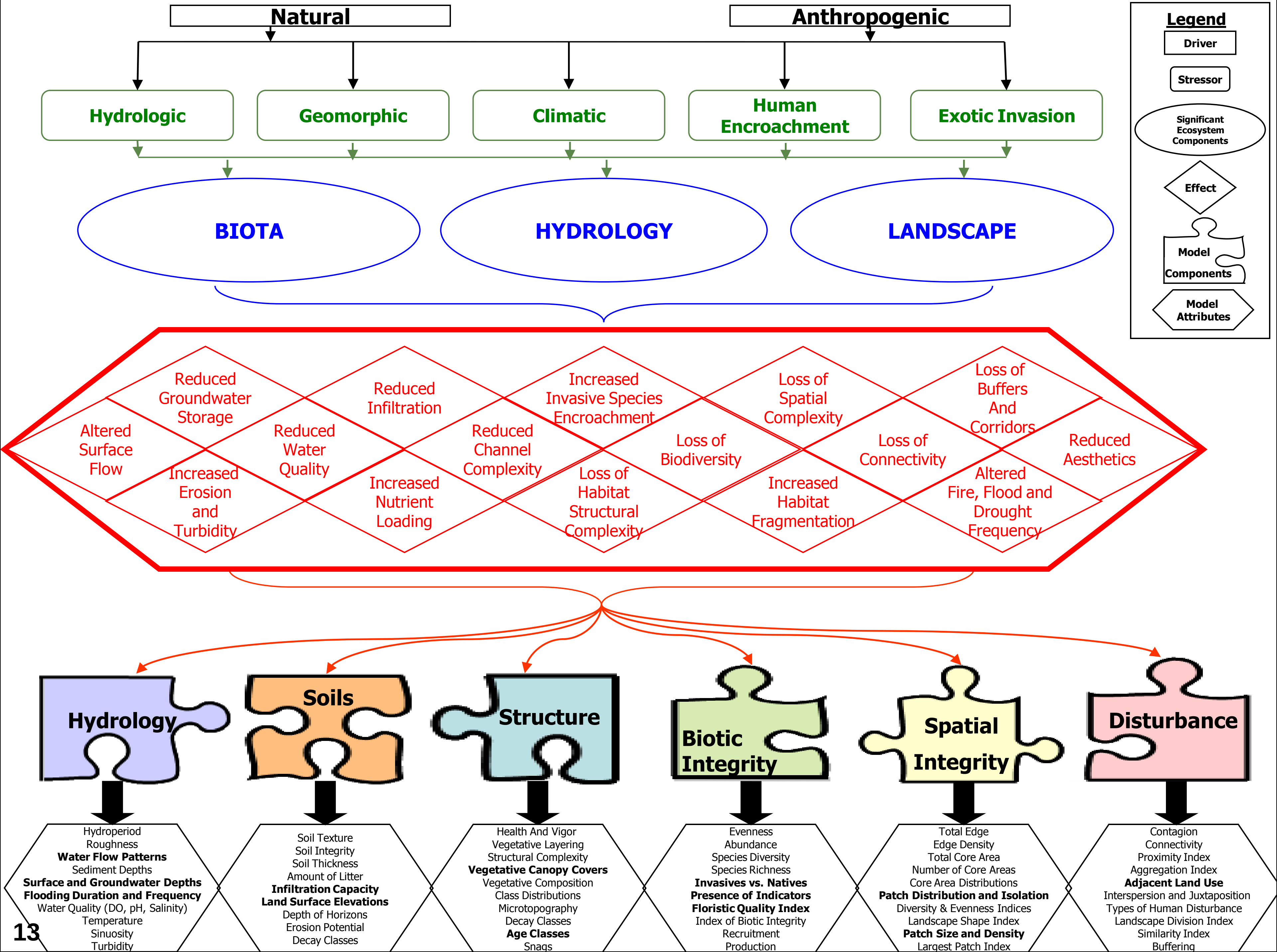
Academia

- Benedictine College
- South Dakota State University
- University of Nebraska
- University of South Dakota
- USD - Missouri River Institute

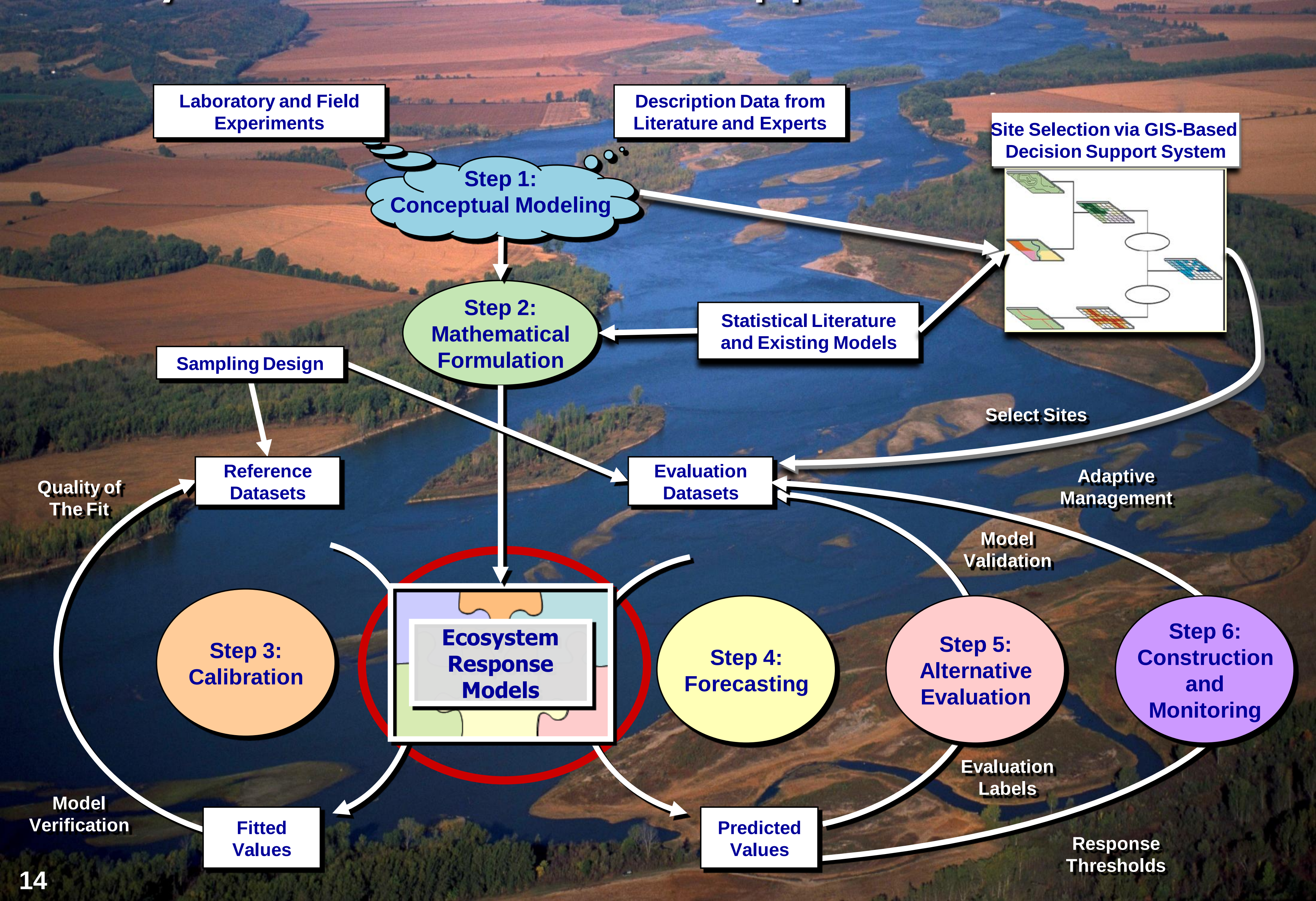

Guided Discussion
Laboratory and Field Experiments
Description Data from Literature and Experts
Are current data sufficient to build the models?
Step 1: Conceptual Modeling
Site Selection via GIS-Based Decision Support System
Do we have sufficient understanding?
Step 2: Mathematical Formulation
What existing models are appropriate to use?
Sampling Design
Select Sites
Evaluation Datasets
What aspects of the design should we change?
Do we have confidence in the model results?
Step 3: Calibration
Ecosystem Response Models
Step 4: Forecasting
Step 5: Alternative Evaluation
Step 6: Construction and Monitoring
Evaluation Labels
Model Verification
Fitted Values
What future conditions do we need to be cognizant?
How do we value different performance criteria?

Ecosystem Assessment Approach

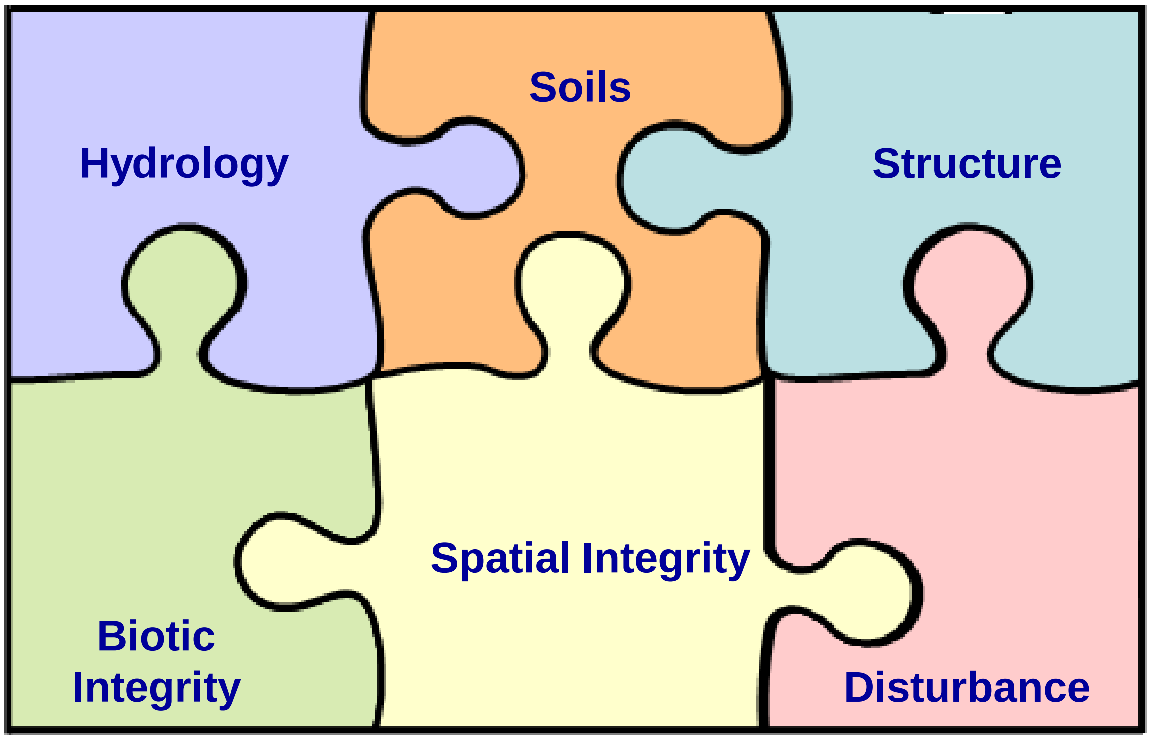



Natural
Anthropogenic
Legend
Driver
Stressor
Significant Ecosystem Components
Effect
Model Components
Model Attributes
Hydrologic
Geomorphic
Climatic
Human Encroachment
Exotic Invasion
BIOTA
HYDROLOGY
LANDSCAPE
Reduced Groundwater Storage
Reduced Infiltration
Increased Invasive Species Encroachment
Loss of Spatial Complexity
Loss of Buffers And Corridors
Altered Surface Flow
Reduced Water Quality
Reduced Channel Complexity
Loss of Biodiversity
Loss of Connectivity
Reduced Aesthetics
Increased Erosion and Turbidity
Increased Nutrient Loading
Loss of Habitat Structural Complexity
Increased Habitat Fragmentation
Altered Fire, Flood and Drought Frequency
Hydrology
Soils
Structure
Biotic Integrity
Spatial Integrity
Disturbance
Hydroperiod
Roughness
Water Flow Patterns
Sediment Depths
Surface and Groundwater Depths
Flooding Duration and Frequency
Water Quality (DO, pH, Salinity)
Temperature
Sinuosity
Turbidity
Soil Texture
Soil Integrity
Soil Thickness
Amount of Litter
Infiltration Capacity
Land Surface Elevations
Depth of Horizons
Erosion Potential
Decay Classes
Health And Vigor
Vegetative Layering
Structural Complexity
Vegetative Canopy Covers
Vegetative Composition
Class Distributions
Microtopography
Decay Classes
Age Classes
Snags
Evenness
Abundance
Species Diversity
Species Richness
Invasives vs. Natives
Presence of Indicators
Floristic Quality Index
Index of Biotic Integrity
Recruitment
Production
Total Edge
Edge Density
Total Core Area
Number of Core Areas
Core Area Distributions
Patch Distribution and Isolation
Diversity & Evenness Indices
Landscape Shape Index
Patch Size and Density
Largest Patch Index
Contagion
Connectivity
Proximity Index
Aggregation Index
Adjacent Land Use
Interspersion and Juxtaposition
Types of Human Disturbance
Landscape Division Index
Similarity Index
Buffering

Ecosystem Assessment Approach

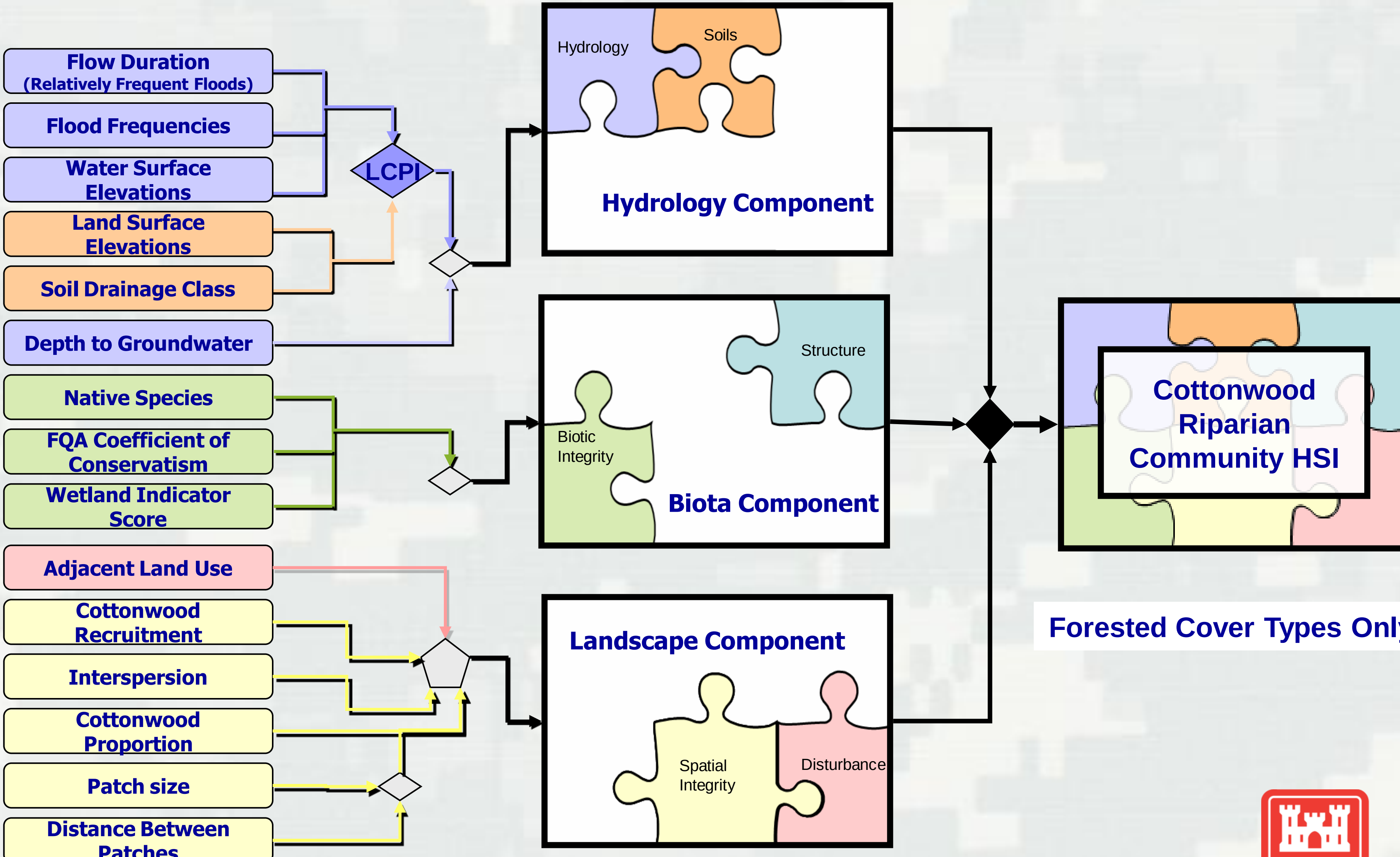


Model Components Combined to Form the Ecosystem Puzzle

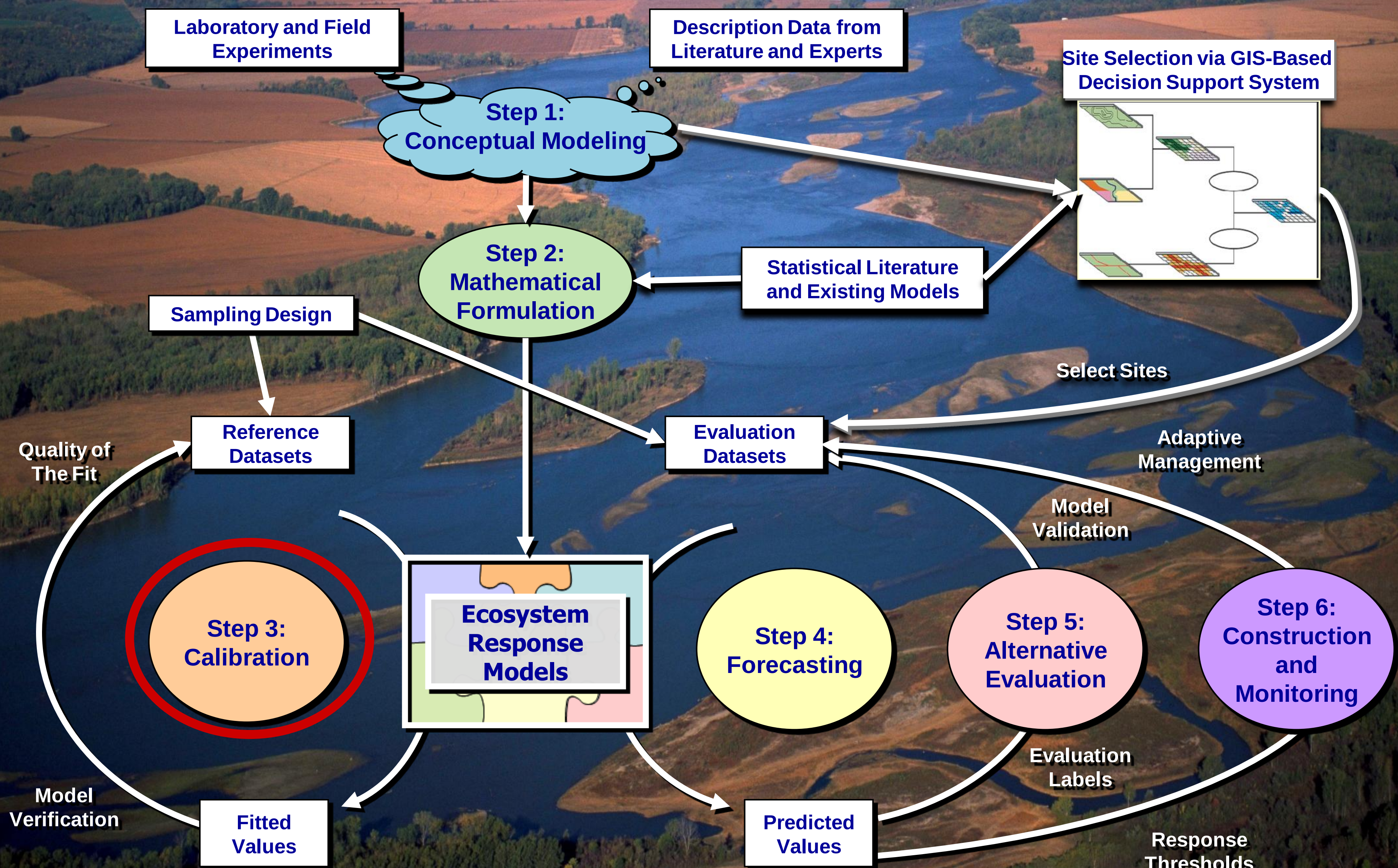


Community based index models are constructed from combinations of components, that when combined capture the essence of the system's functionality.

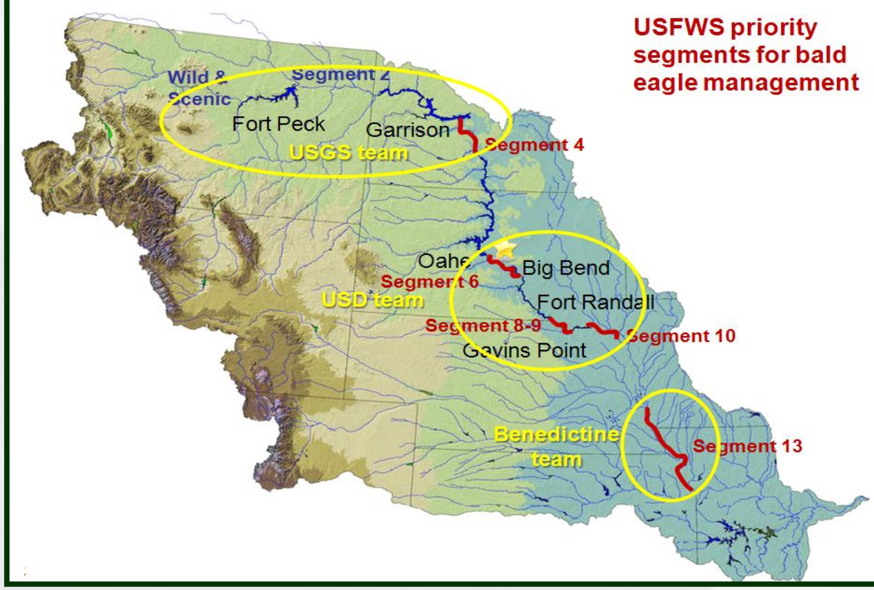
Modeling the Ecosystem



Ecosystem Assessment Approach

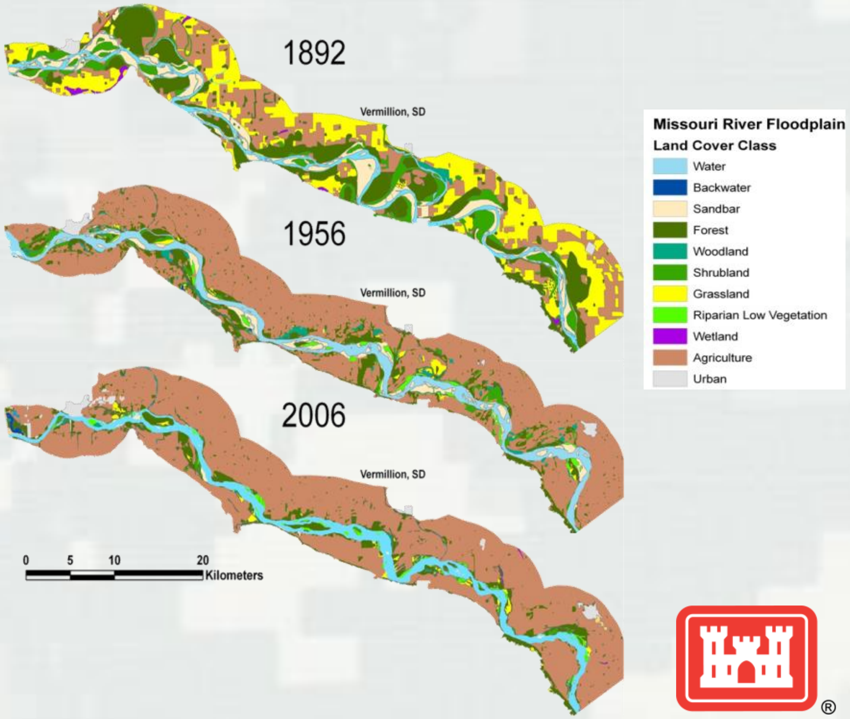


Reference Based Calibration Datasets



Historic & Current Conditions & Trends

- More than **100 separate GIS layers** have been compiled
- Minimum Mapping Unit = **½ acre**
- **27** land use types clustered to flow easily into the community model
- **Google Earth** Technology allows the team to virtually fly the site back and forth through time.



2007-2009 Sampling Season

- 5 Age Classes Identified
  - Old growth (>114 years old)
  - Mature (50-114 years old)
  - Young (25-50 years old)
  - Pole (10-25 years old)
  - Sapling (<10 years old)

A total of 332 stands

- 216 cottonwood
- 32 disturbed cottonwood
- 74 non-cottonwood
- 10 planted cottonwood

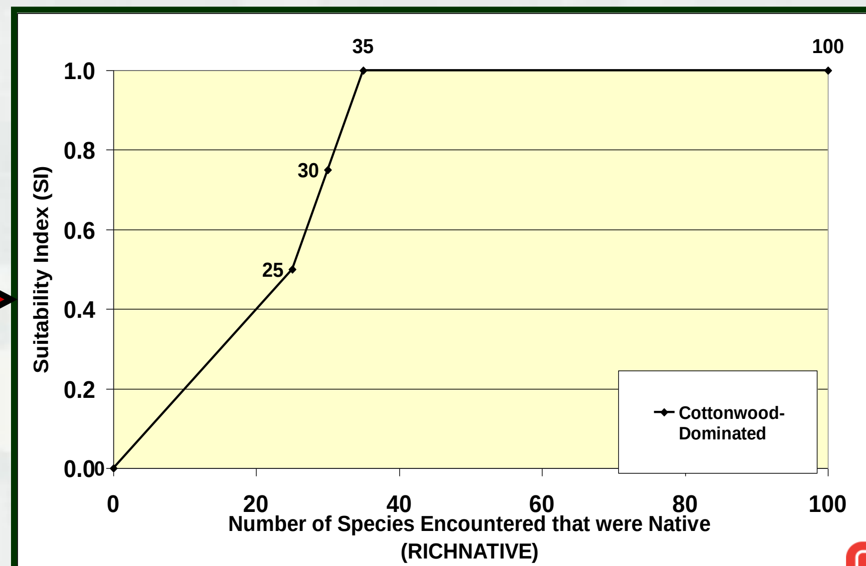
Model Development

- ## Model Calibration

“The use of known (reference) data on the observed relationship between a dependent variable and an independent variable to make estimates of other values of the independent variable from new observations of the dependent variable.”

- **Calibration was based on correlations between model variables and independent data**
  1. Field parameters (vegetative characteristics) were correlated (Spearmans/Pearsons/Kendall) with percent exotic species (indicating negative disturbance factors).
  2. GIS parameters (patch dynamics) were calibrated with 1950s (post damming) mapping of the reaches.
  3. LCPI & Groundwater parameters were calibrated using expert elicitation techniques.

- Flow Duration (Relatively Frequent Floods)
- Flood Frequencies
- Water Surface Elevations
- Land Surface Elevations
- Soil Drainage Class
- Depth to Groundwater
- Native Species
- FQA Coefficient of Conservatism
- Wetland Indicator Score
- Adjacent Land Use
- Cottonwood Recruitment
- Interspersion
- Cottonwood Proportion
- Patch size
- Distance Between Patches



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Mathematical Relationships

Component (Life Requisite) Code	Variable Code	Applicable Cover Type Code(s)	BIOTA Life Requisite Suitability Index (LRSI) Formula(s)
CBIOTA	RICHNATIVE CVALUE WIS CANHERB CANSHRUB	SHRUBS ONLY	$$\frac{\left[\frac{\left(V_{RICHNATIVE} + V_{CVALUE} + V_{WIS}\right)}{3}\right] + \left[\frac{\left(V_{CANHERB} + V_{CANSHRUB}\right)}{2}\right]}{2}$$
	RICHNATIVE CVALUE WIS	FOREST ONLY	$$\frac{V_{RICHNATIVE} + V_{CVALUE} + V_{WIS}}{3}$$

Component (Life Requisite) Code	Variable Code	Applicable Cover Type Code(s)	WATER Life Requisite Suitability Index (LRSI) Formula(s)
CWATER	DEPTHGW LCPI	FOREST ONLY	$$\frac{V_{DEPTHGW} + V_{LCPI}}{2}$$
	LCPI	SHRUBS ONLY	V_{LCPI}

Component (Life Requisite) Code	Variable Code	Applicable Cover Type Code(s)	LANDSCAPE Life Requisite Suitability Index (LRSI) Formula(s)
CLANDSCAPE	ADJLANDUSE PATCHSIZE DISTPATCH PROPCTW RECRUIT INTERSPERS	ALL FOREST AND SHRUB COMBINED	$$\frac{\left\{\left[\frac{\left(V_{PATCHSIZE} + V_{DISTPATCH}\right)}{2}\right] X\ V_{PROPCTW}\right\} + V_{ADJLANDUSE} + V_{RECRUIT} + V_{INTERSPERS}}{4}$$

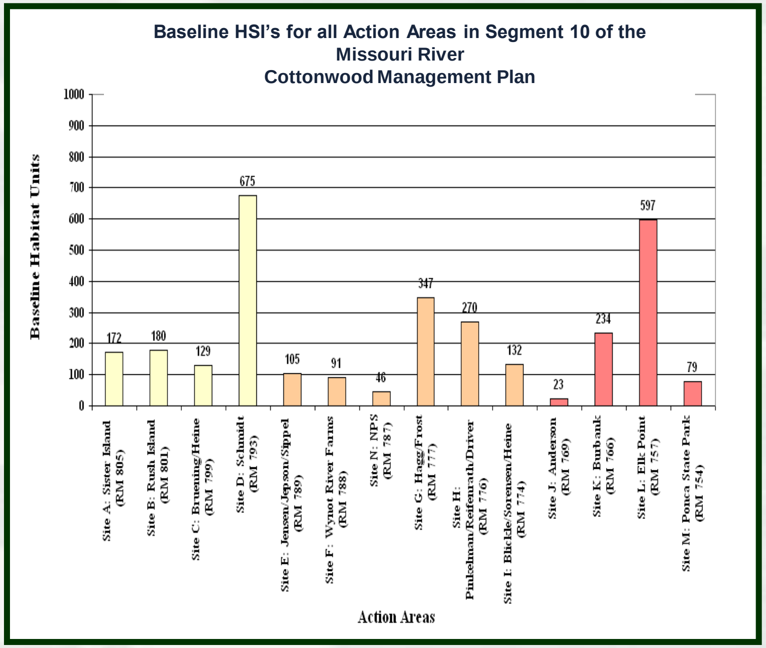
OVERALL HSI	$$\frac{V_{CBIOTA} + V_{CWATER} + V_{CLANDSCPAPE}}{3}$$

Model Verification and Validation

- ## Model Verification

The confirmation by examination and/or provision of objective evidence that specified requirements of the model have been fulfilled with the intention of assuring that the model performs (or behaves) as it was intended.

- **Verification asked whether the model was responding as they experts believe it should.**
  1. Compared/contrasted Undistrubed vs. Disturbed Cottonwood sites
  2. Compared/contrasted Cottonwood-dominated vs. Riparian-dominated sites
  3. Set aside cross-validation data sets aside from the original sampling effort to run through the model independently



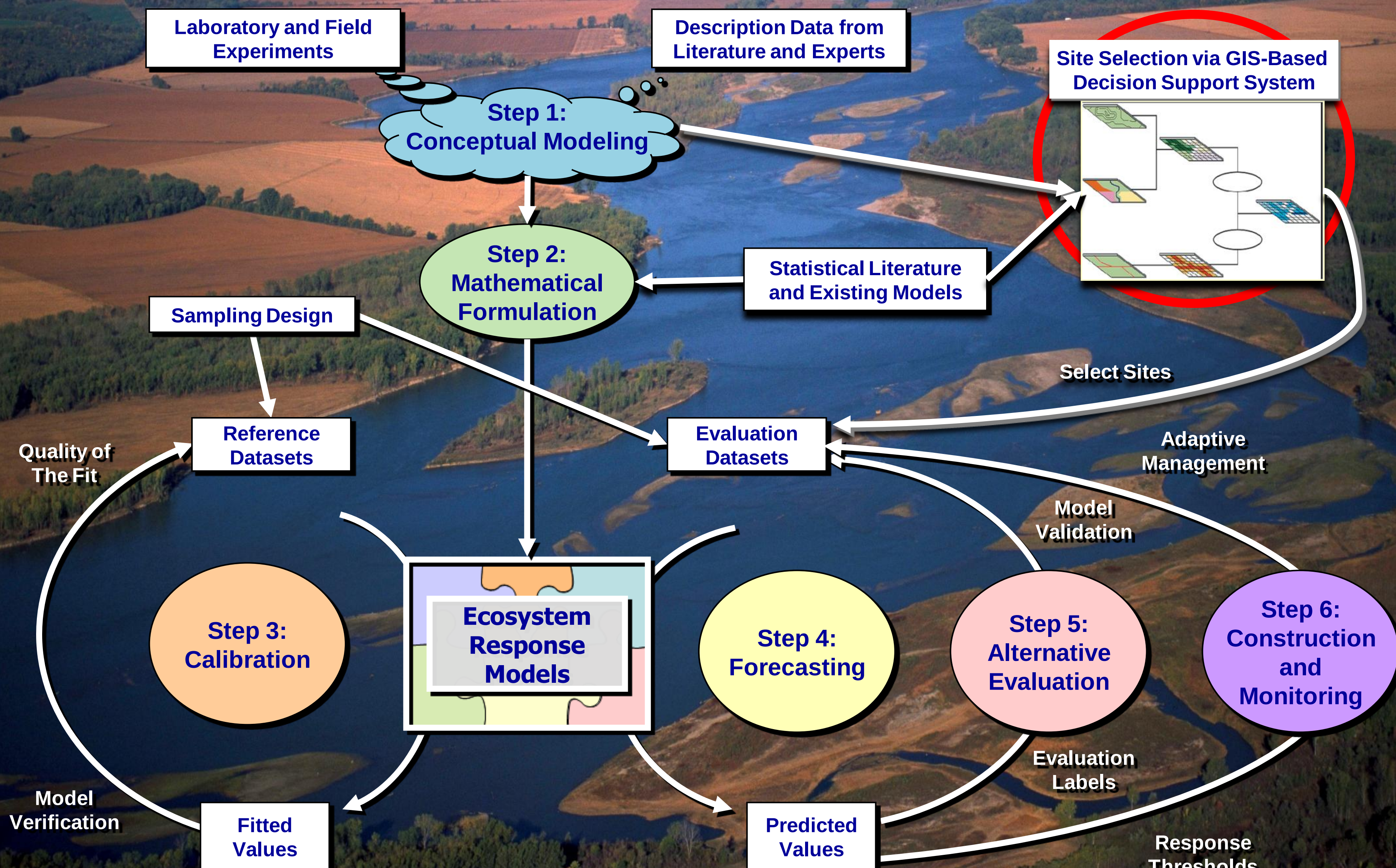
- ## Model Validation

Establishing by objective yet independent evidence that the model specifications conform to the user's needs and intended use(s). The validation process questions whether the model is an accurate representation of the system based on independent data not used to develop the model in the first place.

- **2009 Bird Surveys performed by USD**
  - Presence/Absence by Species
  - Density by Species
  - Will be compared against HSI scores at the sites

- **Bald Eagle Nesting Maps**

Ecosystem Assessment Approach



Structured Decision Making

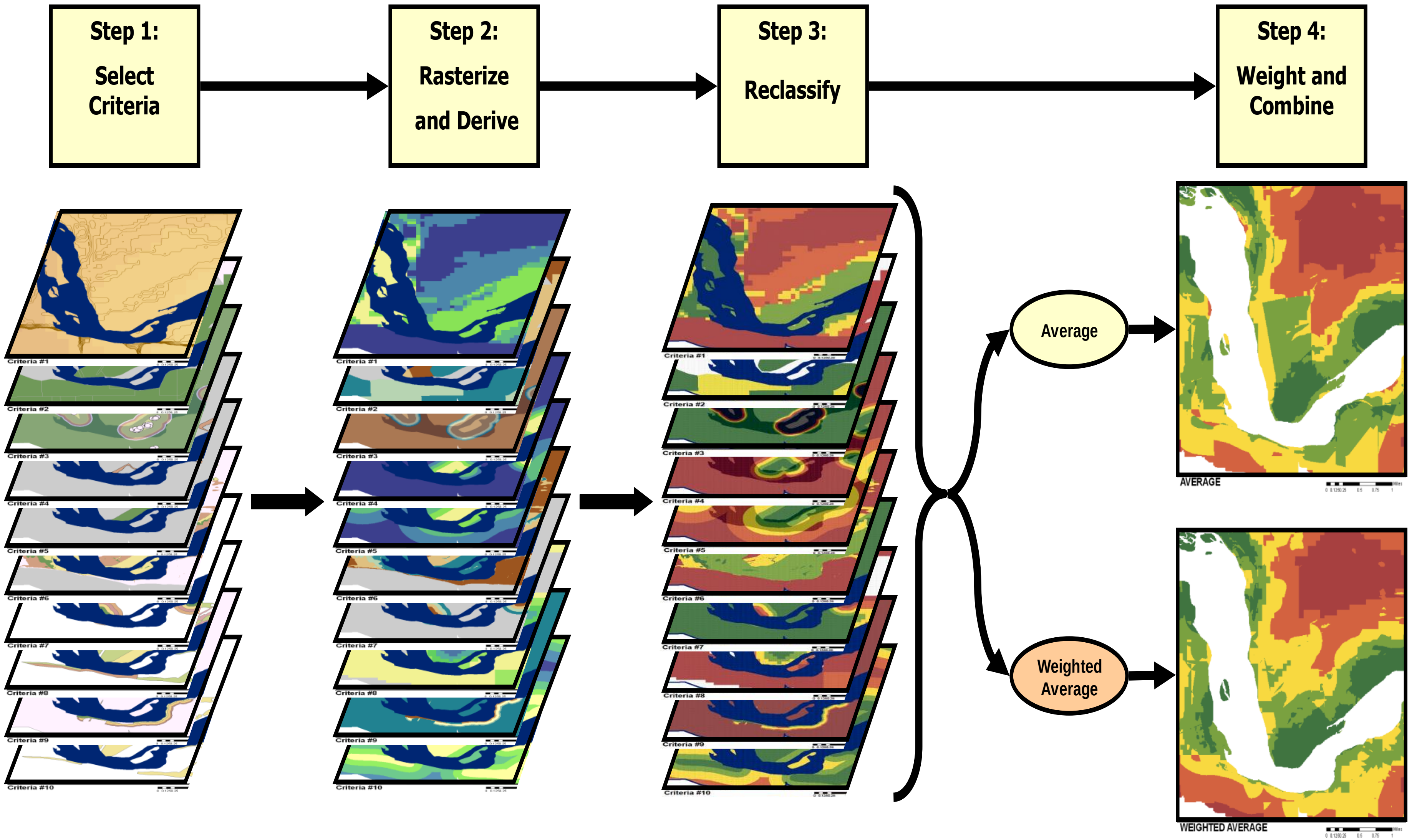
CRISIS: Cottonwood Restoration Integrated Site Identification System

- A Participatory GIS-based sieve-mapping system
- Employs expert elicitation to identify spatially-explicit "siting" criteria
- Uses a Multi-Criteria Decision Analysis (MCDA) framework to screen and prioritize potential restoration and preservation targets.

Site Selection Criteria

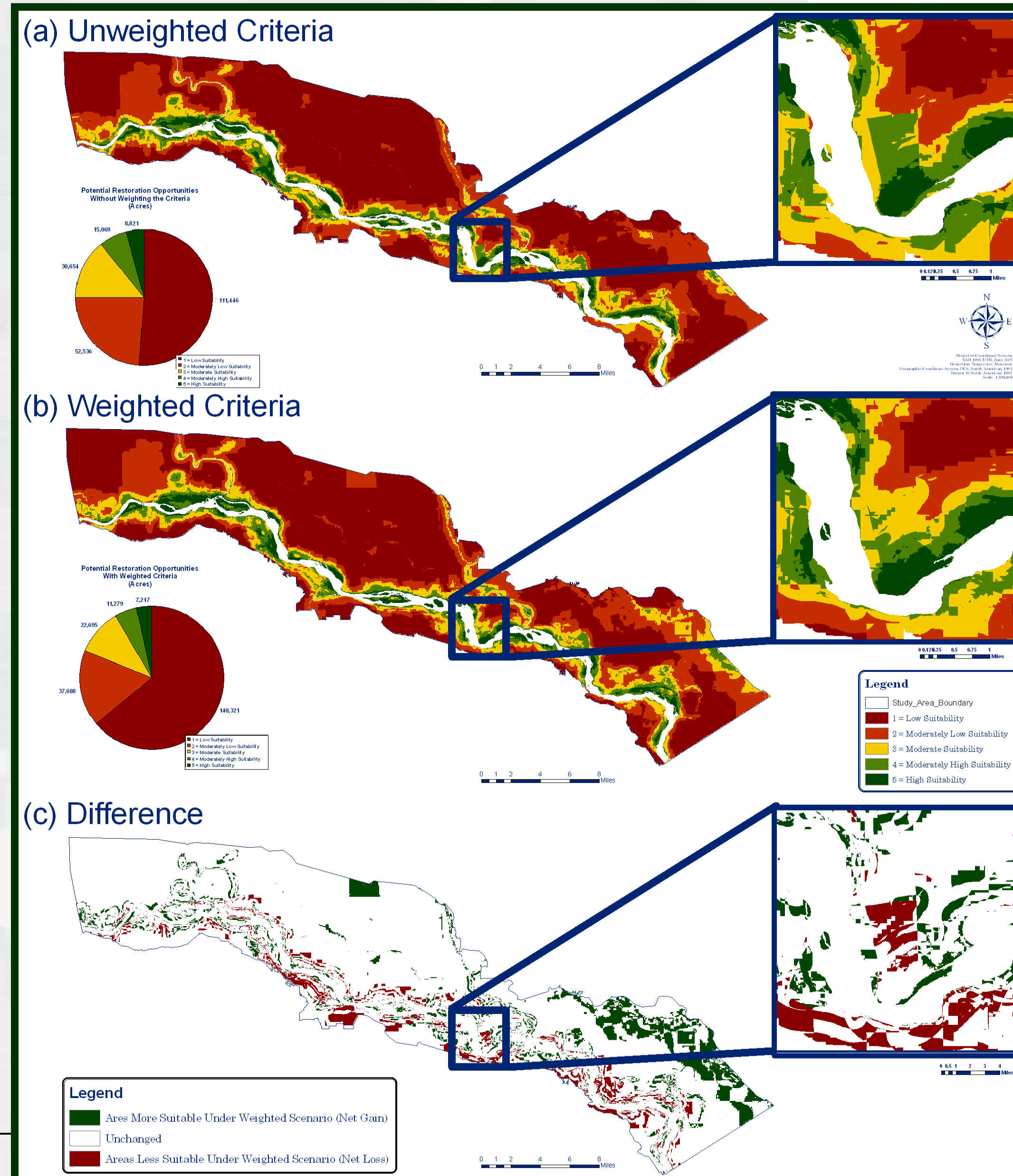
1) Find areas with **suitable groundwater** depths
2) Find sites **inside the MNRR** boundary
3) **Avoid Tern & Plover** restoration sites; preference to sites adjacent to mainland
4) Sites that overlap with existing or potential **backwater restoration**
5) Find sites that are **adjacent to existing young** cottonwood stands
6) Find sites **subject to periodic inundation**
7) Find sites outside areas that are **actively eroding** or likely to erode
8) Find sites that would potentially **provide connectivity** and add to the size of existing cottonwood/riparian forest patches, thus **decreasing fragmentation**
9) Find sites that would otherwise be **at risk from development or landuse change** (agricultural expansion)
10) Find sites **near existing seed sources**

GIS Analyses

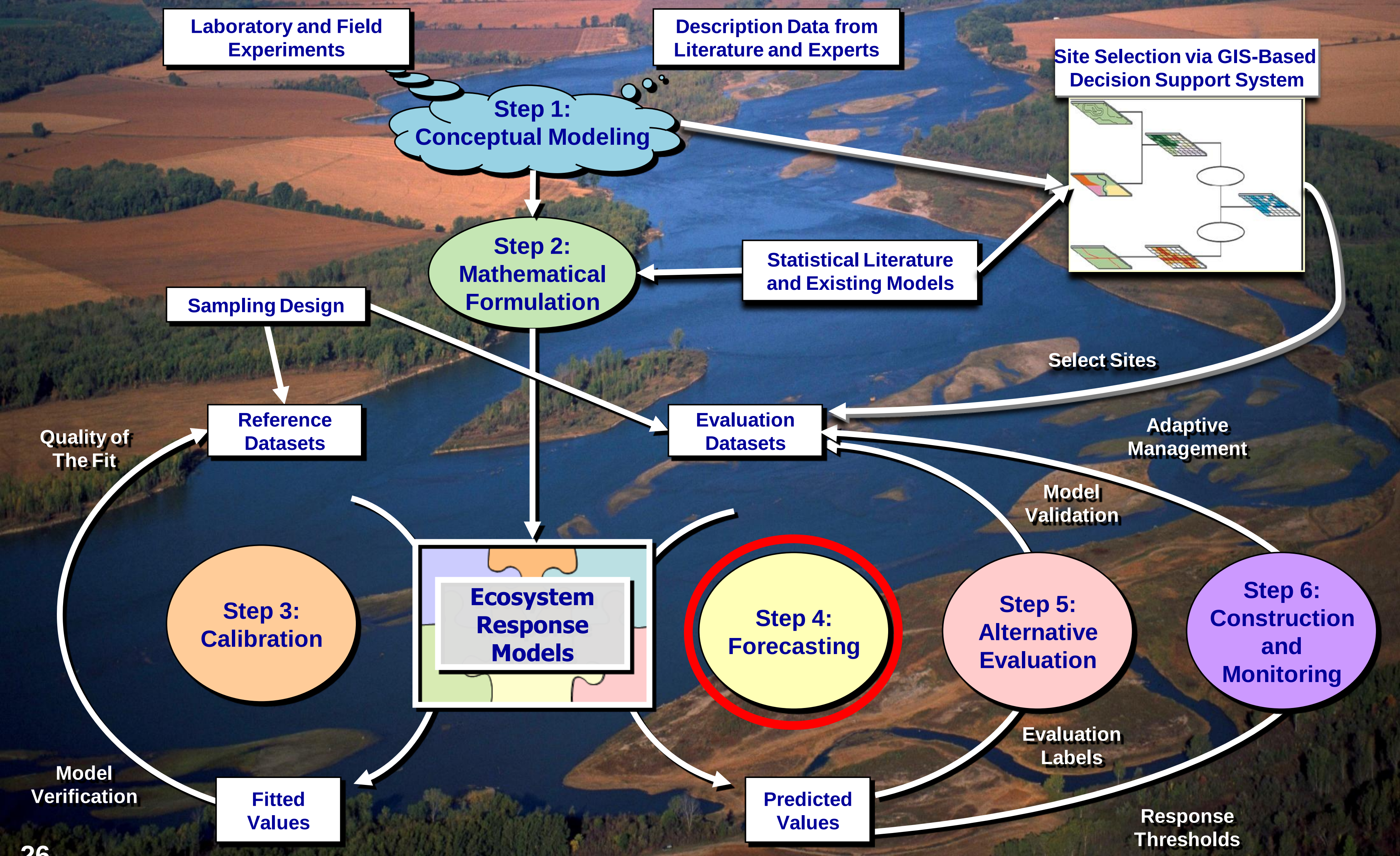


Did our structured approach make a difference?

- Extremely well-received by the stakeholders – **transparent and visually engaging**
- Spatial Analyst Comparisons
  - ▸ Weighted vs. Unweighted
  - ▸ Draft Tech Note 2009:
    “Using Multi-Criteria Decision Analysis to Support Ecosystem Restoration Planning”
- Next Steps
  - ▸ Interest Group Comparisons
    - COE vs. Academia
    - COE vs. State
    - COE vs. Tribes
    - COE vs. Other
    - Individual Maps

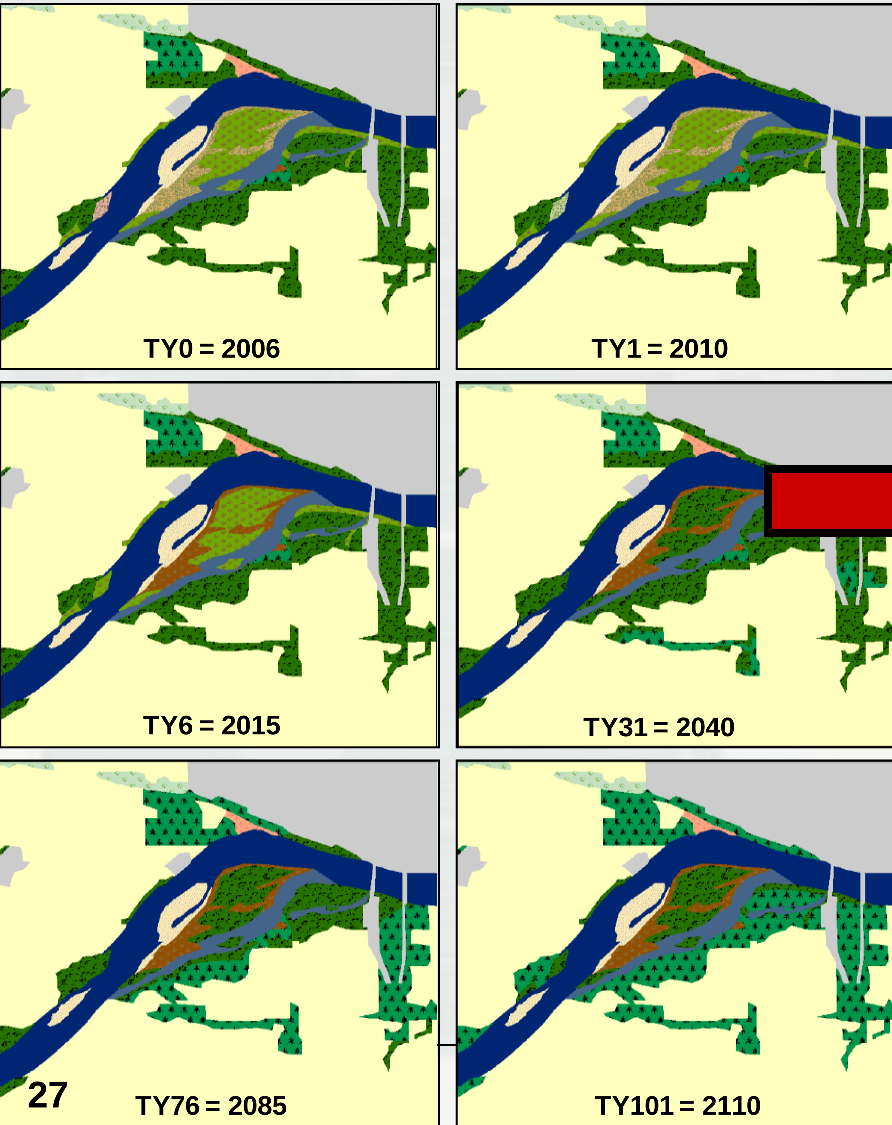


Ecosystem Assessment Approach

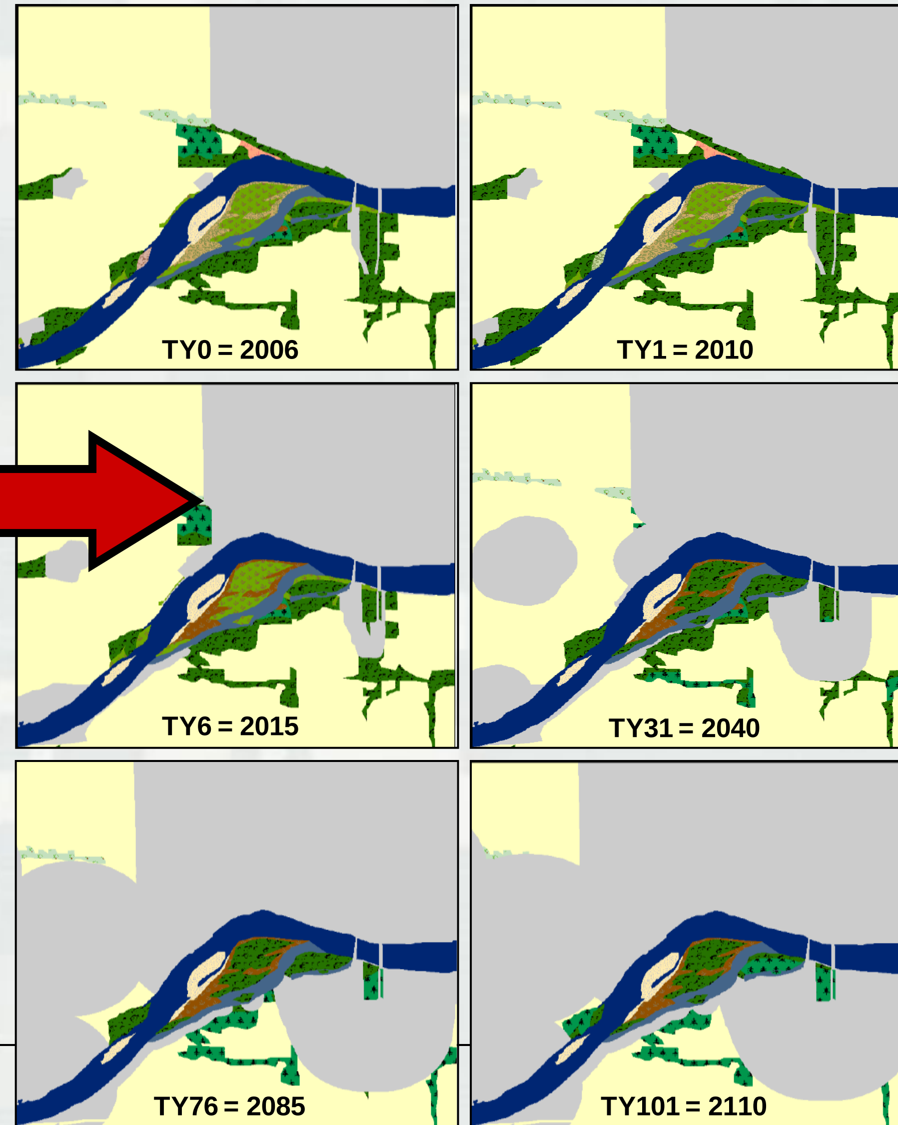


Vegetative Succession

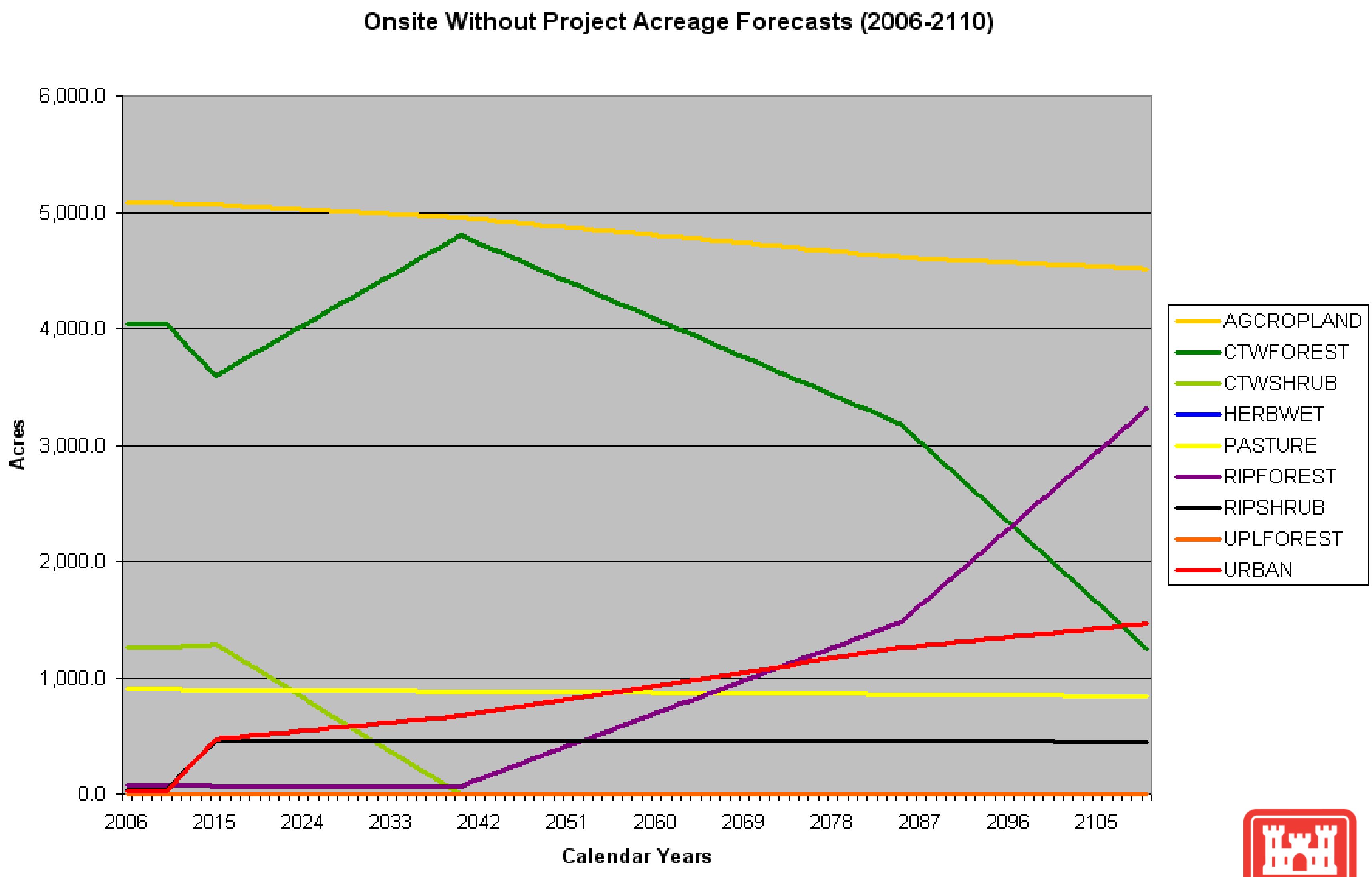
Natural Succession Model



Succession + Urban Land Conversion

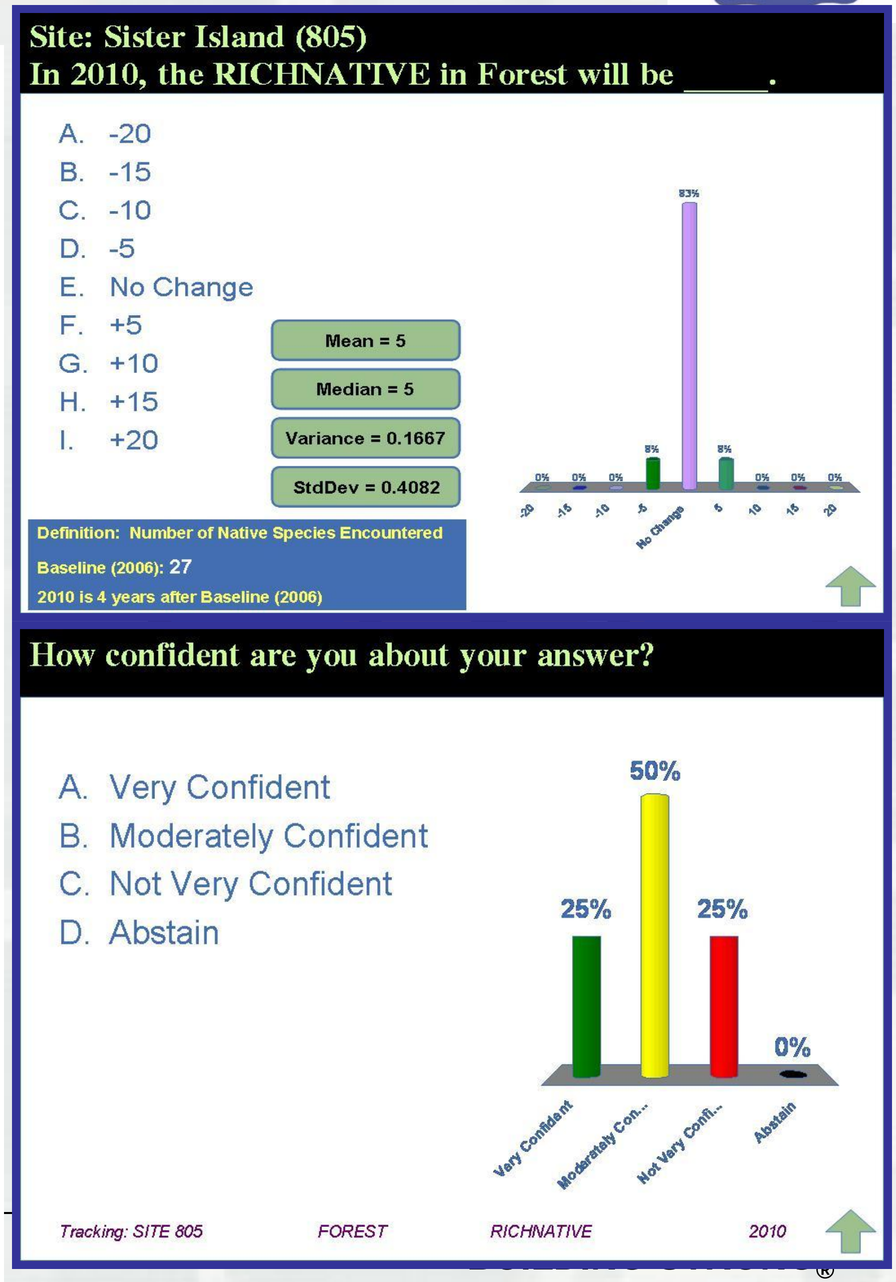


Landuse Forecasts (Quantity)

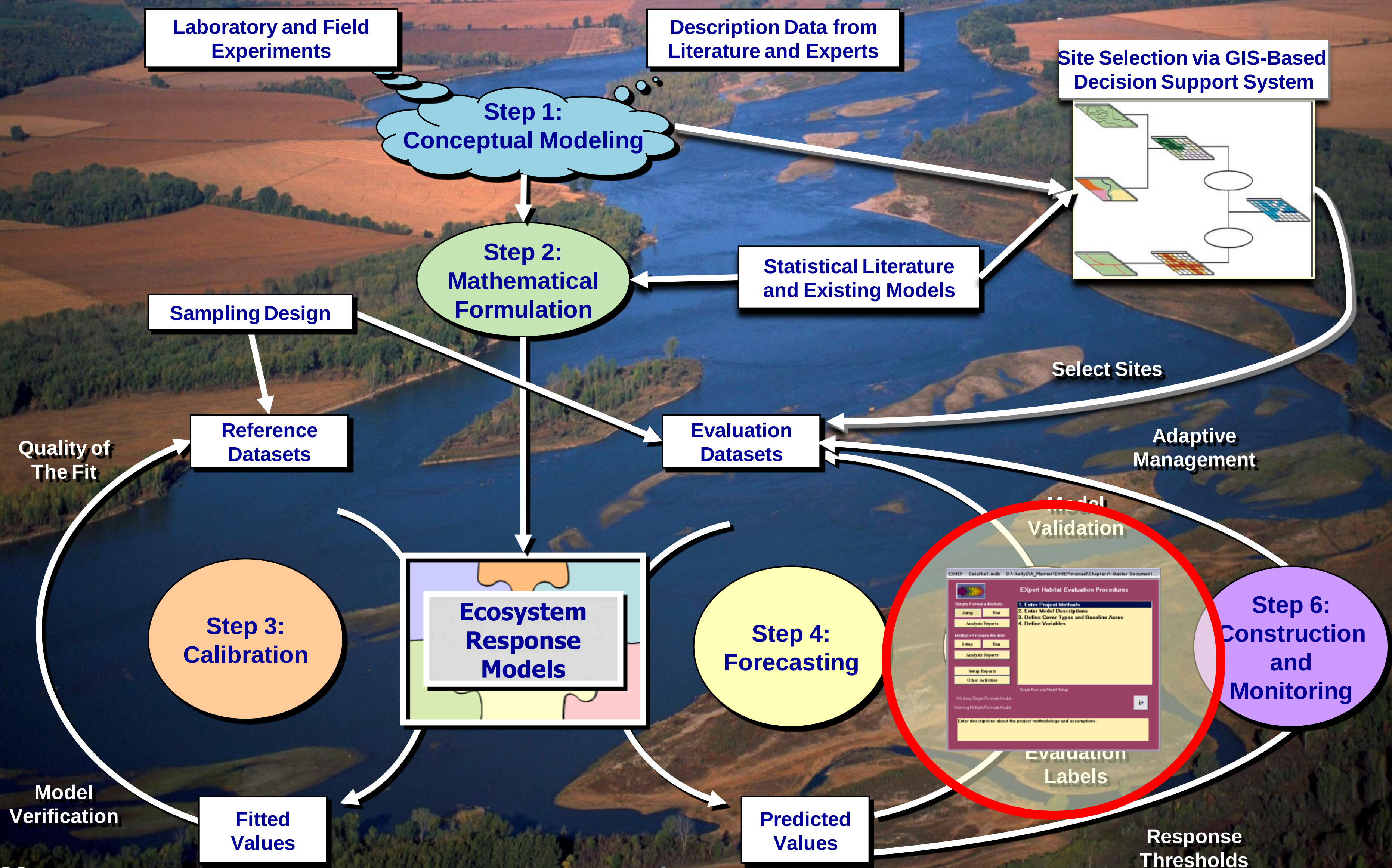


Variable Forecasts (Quality)

- **GIS-based analysis based on the landuse trends provided the trends for the landscape parameters**
- **Remaining Variables**
  - In past studies, **bias** occurred when
    - Expressions of the expert's thinking did not match their actual thinking at the time of elicitation
    - The estimates did not follow normative statistical or logical rules
  - There were two types of biases experienced:
    - Motivational – driven by an emotional need or wish of the expert
      - **"Group Think"**
        - The experts tended to modify their judgment so that it agreed with that of the group (or the leader).
        - They were somewhat unaware that they'd modified their judgment to be in agreement (but the facilitators saw it)
    - Cognitive – arises from the limitation of the human mind
      - **"Anchoring"**
        - The experts failed to sufficiently adjust from their first impressions – even when new information was introduced
- **ERDC's Solution**
  - Deploy **Turning Point Technology to forecast** future conditions and **capture** a level of **uncertainty**
  - **Web-enabled** for next application

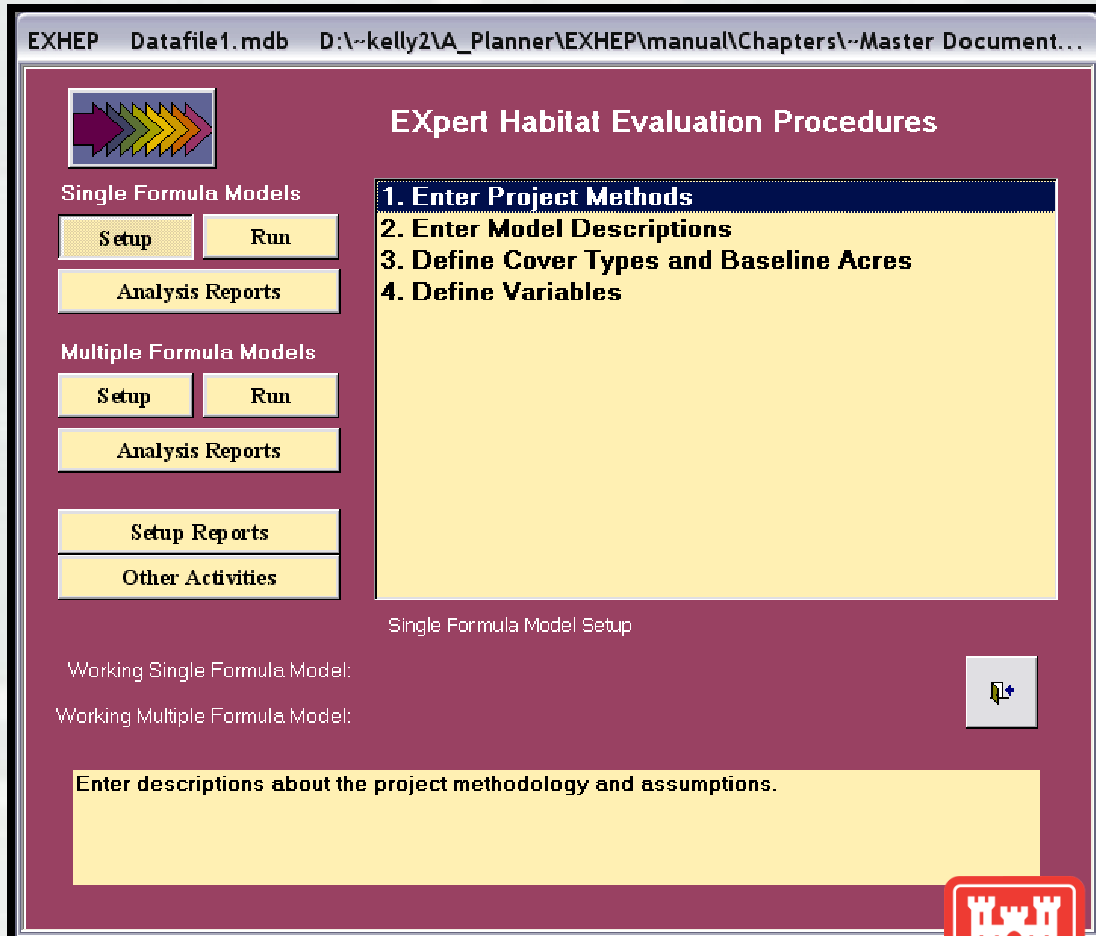


Ecosystem Assessment Approach

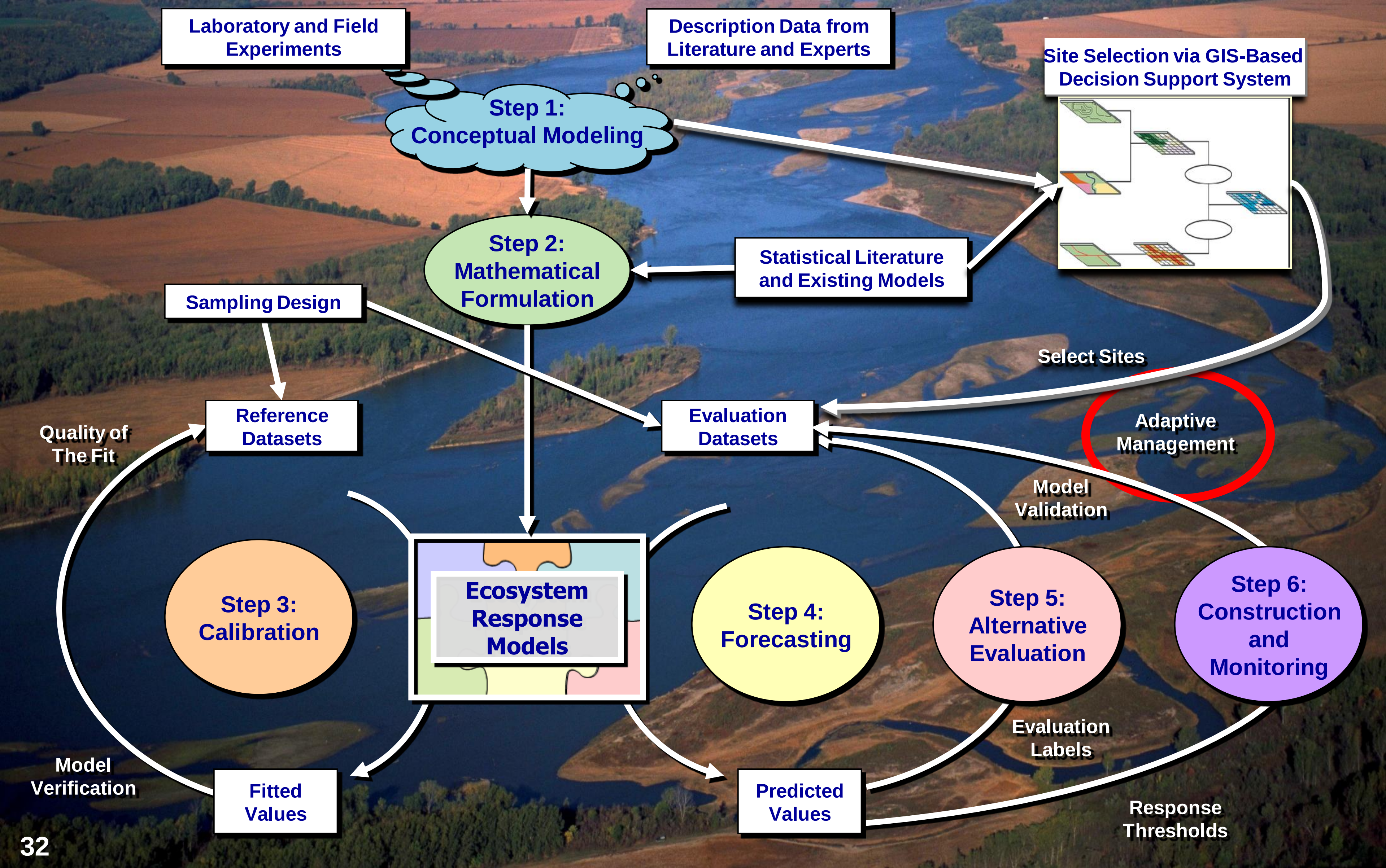


Ecosystem Assessment

- HEAT: Habitat Evaluation and Assessment Tools
  - EXHEP
  - EXHGM
  - Recommended for Certification!
- MS Access db
  - (Office 2003 & 2007)
- Not Spatially Explicit
- Just Software – not a model

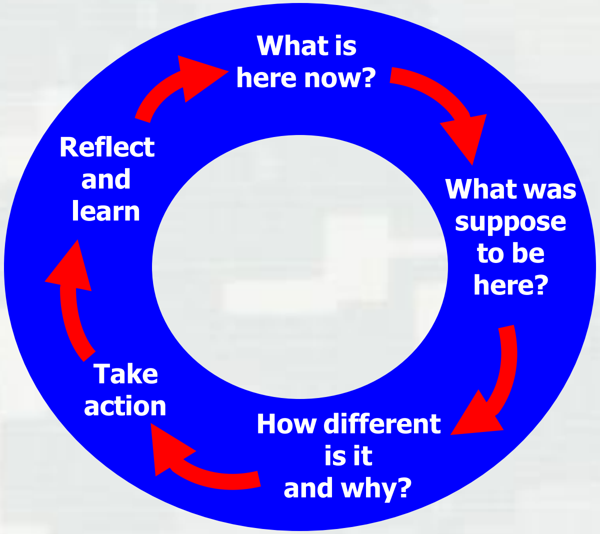


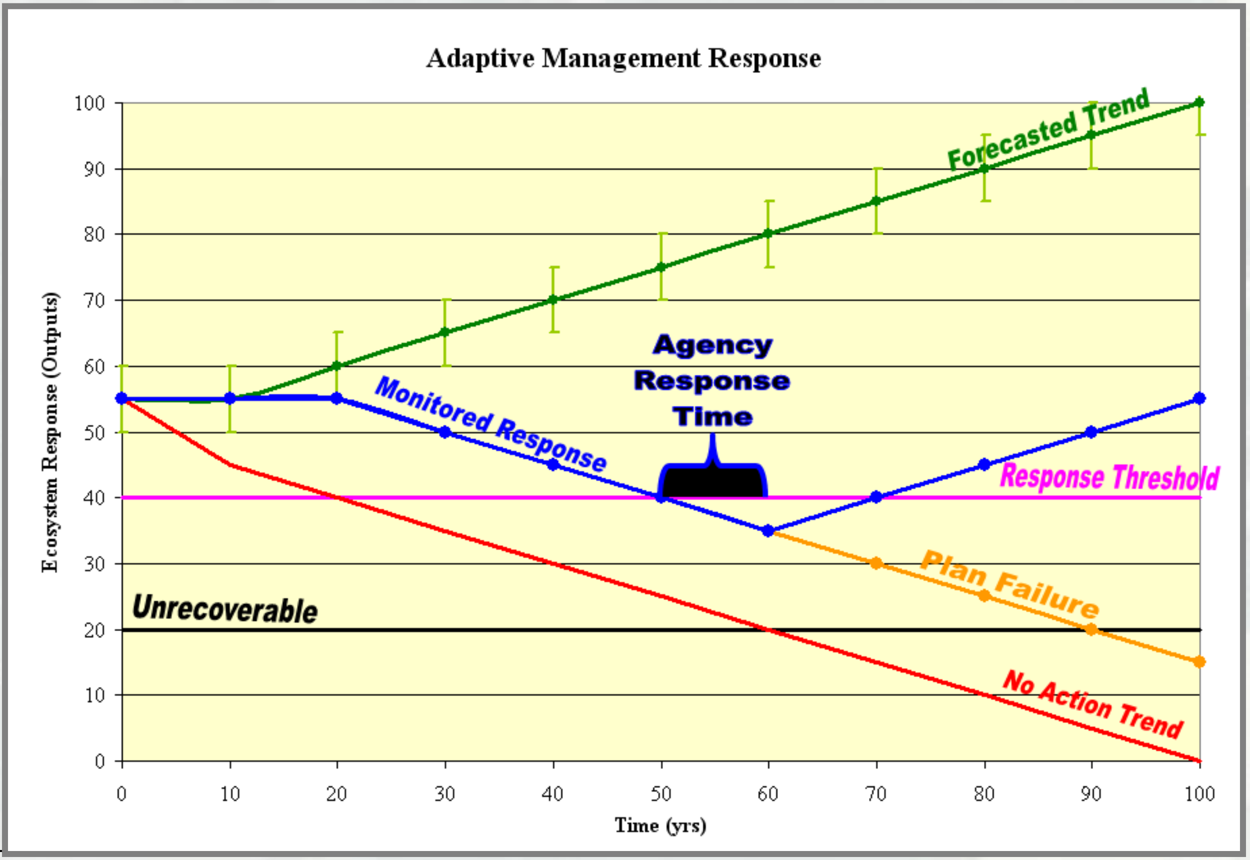
Ecosystem Assessment Approach



Adaptive Co-Management Process

Empower Collaborators to assist in the selection of Management actions based on available information while coping with unexpected outcomes and uncertainties that cannot be quickly resolved today by **specifying future thresholds** where feedback and new information that will help answer questions about the system being managed can be incorporated into the decisions to **trigger agency response**.





Collaborative, Hierarchical Monitoring Strategy

- **Goal:**
  - **Improve management decision making, increase transparency and accountability, reduce risk and uncertainty, foster learning, and improve the ways in which projects are implemented.**

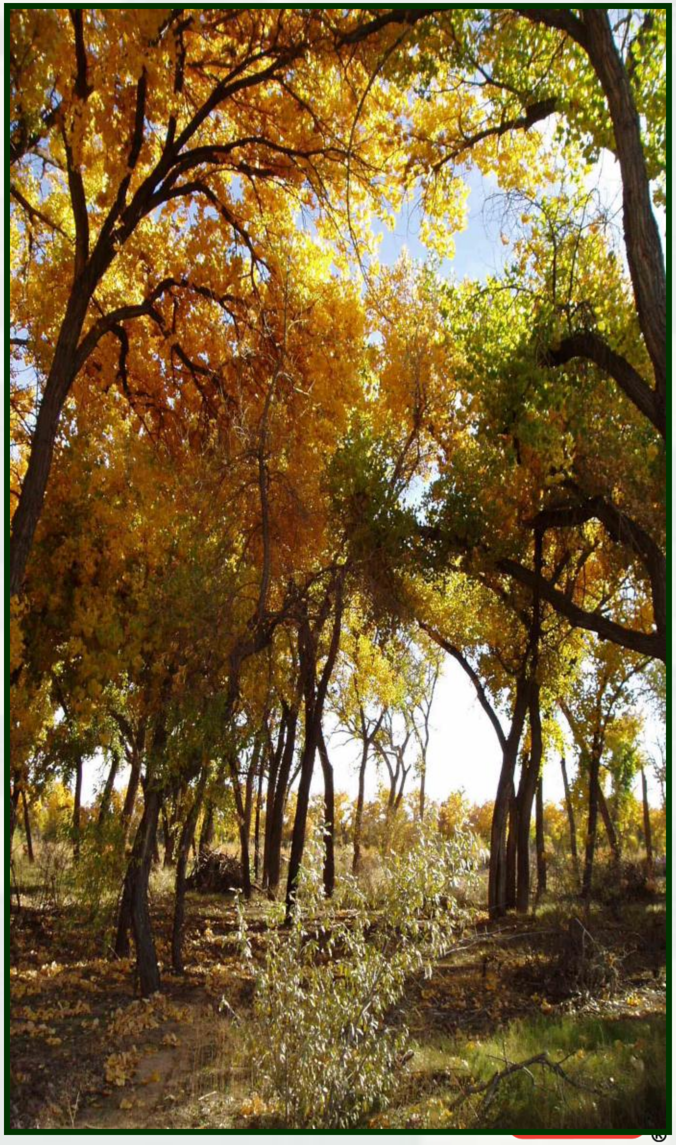
- **Intent:**
  - **Assess the relative state of the system**, warn managers about approaching events or crises, and improve understanding of system function.

- **Varying Scales (Temporal and Spatial)**
  - **Program/Segment Level**
    - Landscape level monitoring
    - Same methods used for baseline data
    - Completed every 5 years
  - **Site Level (annual)**
    - Dependent on implemented measure(s)
    - Based on Community Model parameters
  - **Planting (regularly per prescriptions)**
    - Propagation success
    - Annual monitoring

Take Away Points

Benefits of the Approach

- **Structured decision making** promotes transparency, ensures productiveness, and supports “social learning” via iteration of “soft-hard systems” modeling resulting in a **common, shared vision**
- **Transdiciplinary Teaming** yields **transparent** decision making
- **Community-based index modeling** offers comprehensive, multi-scale characterization of the system that is grounded in natural history yielding relevant, measureable outputs for system assessment and alternative comparisons
- Professional judgment is not only necessary, it is desirable in order to inject valuable **on-the-ground knowledge** of experts and stakeholders into the study’s strategic plan
- **Spatially-explicit decision support tools** provide a unique scenario-based environment to select and prioritize restoration opportunities system-wide
- Adaptive co-management **empowers stakeholders and decision makers** alike to target and refine the restoration strategies over the long-term – learning along the way




Questions?