Management of wetland-riverine hydrology in Canaan Valley and Erie NWR in order to optimize biological integrity

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Decision Problem

National Wildlife Refuges (NWRs) make annual refuge specific and multi-year planning decisions with regard to the protection, management, and restoration of freshwater ecosystems. Although funding and management decisions are made at the refuge level, these decisions occur within a context of regional and national priorities, and in the face of uncertain conditions and challenges at local, regional, and global scales. This effort seeks to identify decision strategies which will aid in evaluating the range of decisions related to restoration, management, and maintenance of stream, wetland and riparian hydrology within two NWRs, Canaan Valley (WV) and Erie (PA), and management effects on biological integrity, biological diversity, environmental health (BIDEH). In this context we will develop approaches which will aid in decision making by evaluating alternative management actions, scale of their effects, costs, and the likely impacts on objectives including possible tradeoffs (i.e., one management action may have positive benefits to one management objective but negative consequences to another).

To identify the most valuable avenues of management and restoration, a multi-objective decision framework will need to specify alternatives, which can be evaluated against management objectives while acknowledging the uncertainty about the effects of management action(s). As restoring hydrologic integrity for freshwater ecosystems is a common management objective for many NWRs, initial decision framing focused on jointly applicable objectives. The intent of this workshop was to develop a prototype multi-objective decision framework, and use this framework to evaluate refuge specific decisions. We expect that post-workshop efforts will refine each prototype.

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Below are details from the workshop, identifying

1) common NWR management objectives for a freshwater ecosystem in the context of BIDEH,
2) details of a multiple-objective decision-making exercise for Canaan Valley and Erie NWRs, where alternatives (i.e., specific mangement actions), were evaluated against a set of measurable specific objectives for each refuge.

Background

The 1997 National Wildlife Refuge System Improvement Act states that in administering the System the Service shall "… ensure that the biological integrity, diversity, and environmental health of the System are maintained…" (USFWS 2003). The Service defines these terms as:

Biological Integrity	Biotic composition, structure, and functioning at genetic, organism, and community levels comparable with historic conditions, including the natural biological processes that shape genomes, organisms, and communities.
Biological Diversity	The variety of life and its processes, including the variety of living organisms, the genetic differences between them, and the communities and ecosystems in which they occur.
Environmental Health	Composition, structure, and functioning of soil, water, air, and other abiotic features comparable with historic conditions, including the natural abiotic processes that shape the environment.

Where possible management on the Refuge restores or mimics natural ecosystem processes or functions and thereby maintains biological diversity and integrity and environmental health. Specific management actions are guided both by Refuge-specific goals and by landscape-scale conservation goals (e.g., BCR priorities). Given the continually changing environmental conditions and ecosystem patterns of the past and uncertainty about the future, management strategies should support mechanisms that allow species, genetic strains, and natural communities and ecosystems to evolve, rather than trying to maintain stability. As noted in section 3.7, ecologists recommend managing within a natural range of variability rather than emulating an arbitrary point in time.

NWRs, including Canaan Valley and Erie, share the major management goal of preserving biological integrity across complex landscapes. The ecological significance of each refuge stems in part from their diverse mix of freshwater wetland, riverine, riparian habitats and upland habitats, and the diversity of fish and wildlife they support. Refuge managers balance refuge specific requirements (i.e., founding purposes) with regional and national policies (e.g., migratory bird management, and BIDEH). Between these two refuges, there is also a similar understanding of BIDEH which focuses management on maintaining and restoring natural processes, and not on particular abundance and distribution of any one species or communities or their associated biota.

Decision Structure

Problem Statement

The context of these decisions is focused on local allocation of resources for management of an NWR's conservation resources. Within the context of the workshop, the following problem statement was established.

> *When, where, and how do we manage embankments to optimize biological integrity, diversity and environmental health of wetland and riparian habitats of Canaan Valley and Erie NWRs while not exceeding budgetary, political and/or legal constraints.*

It was recognized that in this context, an embankment includes natural and artificial structures that alter hydrology. Examples of embankments include roads, trails, railroad grades, beaver dams, water control structures, and dikes/levees.

Objectives

In the context of this decision, fundamental and means objectives were established focusing on BIDEH and restoration of hydrologic process.

Biological Integrity and Diversity– Maintain and restore the natural processes involved in wetland plant community development (hydrology, including springs, seeps, ground water and surface flow) and the biota which are associated with the communities as they exist and change under natural influences.

Means objectives include:

- maintain/restore biota associated with natural wetland plant communities.
- minimize increase of non-endemic species on refuge
- maximize natural communities and species (terrestrial and aquatic) on refuge that are characteristic/diagnostic of targeted wetland habitats.

Environmental Health - Maintain and restore water quality and flow toward natural variability and continuity. Water quality measures can be easily measured and need to be maintained with the range of expected variability

Means objectives include:

Surface and subsurface flow (essential for health and integrity also)

- surface flows restored or more closely match upgradient areas after embankment removed
- Subsurface flow increases, as measured via average piezometer reading X% on downslope side at assumed or proven hydrologic blockages
- variability of downstream flows becomes more similar to upslope regime
- water table discontinuities and hydrologic interruptions which can be mapped, are reduced or eliminated through restoration.

Water quality

- pH
- Temperature (reduce temperature discontinuities)
- Turbidity, Sediment, Total dissolved solids
- Nitrogen
- Salts (reduction in road deicing chemicals directly to water)
- BOD, DO

Alternatives actions
Within the broadest refuge context, alternatives include specific management actions (e.g. embankment modification at specified location), or suites of linked actions that would affect the biological integrity, diversity and environmental health of wetland and riparian habitats/ecosystems.

Predictive Models
At this point in the workshop, it was decided to focus on one specific refuge, Erie, in order to more completely explore the complete decision structure.

Erie NWR:

Background Erie NWR contains riparian dominated wetlnad systems within the French Creek watershed in western PA. Human-created impoundments and water-control structures for waterfowl management comprise 314 actres out of the refuge's 8800 acres. With recent focus of management shifting toward more trust species, (i.e. migratory birds, endangered mussels and fishes, natural communities) and BIDEH, value of these impoundments and other structures which limit hydraulic processes and connectivity have been questioned. Regulatory authority for Erie NWR includes USFWS, US Army Corps of Engineers, US EPA, and the State of PA (Dept. Environmental Protection). Constraints on management decisions primarily include concerns with public safety and local acceptance of refuge management decisions. Management alternatives may be constrained due to current staff and budget limitations; creative partnerships may be required for gaining cooperation of local governments.

Ecological & Political context French Creek flows southward into the Allegheny River, a tributary of the Ohio River. Refuge lands (8,800 acres) are held in two major divisions, Seneca and Sugar Lake. At least 103 wildlife species of conservation concern occur in Erie NWR. Erie NWR lies entirely within the 790,000-acre French Creek Watershed, an ecologically significant waterway in Pennsylvania and containing more pre-European settelement native species of fish and freshwater mussels than any other comparably sized stream in Pennsylvania In spite of past and current land use practices that can be detrimental to water quality, French Creek supports 89 fish species, 27 freshwater mussel species, and 158 species or natural communities listed as special concern by the Pennsylvania Natural Diversity Inventory (WPC 2002). Human created impoundments and insufficient culverts are of concern within this system. Natural beaver impoundments contribute to creation of wetland and successional habitats in the refuge.

Decision Structure

Erie NWR Problem Statement
The context of this decision is focused on Erie's allocation of resources for management wetland and riparian resources. Within the context of the workshop, the prior decision statement was revised.

When, where, and how do we manage embankments to achieve natural flow regimes (i.e. surrogates for biological integrity, diversity and environmental health) within riparian habitats of Erie NWRs while not exceeding budgetary, political and/or legal constraints.

Erie NWR Objectives

Objectives were elicited individually and consolidated via group collaboration.

Environmental Health

- Improve/Maintain water quality
  - Temperature should decrease
  - Dissolved oxygen should increase
- Dissolved nutrients, nitrogen and phosphorus should decrease
- Restore natural stream flow magnitude, timing (seasonal), variability
- Minimize unnatural (catastrophic/short term) erosion and sedimentation
  - Bedload movement remains stable or decreases
  - Suspended solids would remain stable or decrease

Biotic Integrity

- Increase stream connectivity for FW mussels, host fish species, and native fish (aquatic biota)
  - Miles of continuous stream
- Minimize spread, eliminate occurrence and prevent introduction of invasive species
  - Qualitative (**- 0** +)
- Improve/increase extent, quality and conservation of priority wetland and riparian plant communities associated with a dynamic naturally flowing stream and river system.
  - Increase NatureServe Ranking metric

Diversity

- Minimize negative impacts to existing wetland and riparian plant communities associated with a dynamic naturally flowing stream and river system.
  - Minimize impacts to existing S1 & S2 rare species; G1-G3 rare species/communities
- DIVERSITY should be evaluated at the level of entire project area (watershed) not just at site of management action.
  - Increase α (alpha), β (beta), and δ (gamma) diversity of wetland and riparian plant communities associated with a dynamic naturally flowing stream and river system.
  - Optimize α, β, and δ diversity of wetland and riparian plant communities associated with a dynamic naturally flowing stream and river system.

Refuge Operations

- Minimize staff time and cost to implement alternatives, including maintenance of no action.
  - Minimize cost to implement alternative
  - Minimize cost to monitor and maintain alternative

Public Acceptance

- Maintain/Improve public relations and acceptance for alternatives.
  - Qualitative (low, medium, high)

Public Safety

- Minimize flooding of non-refuge roads, trails, infrastructure
  - Qualitative (**- 0 +**)

Erie NWR Alternatives

For this decision exercise, we focused exploration of potential management actions to a small portion of the Woodcock Creek drainage in Sugar Lake Unit. (Figure 1.)

Pool B and **Pool N,** are seepage-based impoundments; each pool currently outflows to Cooper's Marsh through separate channels. Management alternatives include:

- Remove boards
- Remove water control structure
- Breech embankment
- Remove embankment
- Install flap gate

Pool N Service Road Culvert, channels flows from Pool N under embanked service road to Cooper's Marsh. Recognition that undergroundnatural gas line runs through the Pool N outflow area.

- No action
- Replace with larger sized culvert.

Culverts at 1) State Road (south culvert in Figure 1) **and 2) Township** (north culvert in Figure 1**)** (Hank's road) interrupts flow between Cooper's and Mill marshes.

- No action (either)
- Replace with larger sized culvert (either)
- Remove portion of Hank's Road –Township (road + culvert)

Erie Predictive Models

A simplified consequences table was developed (Table 1) to evaluate three potential alternatives, with no linked decisions or portfolios of actions. Although simple and requiring significant refinement, prior to implementation Erie staff recognized the value of a systematic approach. It is recognized that the rankings were estimates and no weights were placed to indicate the importace of an objective for deciding among alternatives. Some information on mercury contamination in sediments and predicted costs for clean-up, if present, may be objectives to consider in future prototypes. There were two biological diversity objectives, increase/optimize α-,β-,δ- diversity of wetland and riparian plant communities for which it was unclear what appropriate measurable attributes would be; this objective requires additional refinement.

To explore another NWR decision scenario considering BIDEH objectives and freshwater wetlands we explored an example of a management decision for Canaan Valley NWR.

Canaan Valley NWR:

Background Established in 1994 with wetland protection as a founding purpose, Canaan Valley NWR, guides its current management, under BIDEH policy. Within the Blackwater River watershed of West Virginia is a mix of private and public lands adjoining the refuge's >16,000 acres. Most of the refuge is held in one large contiguous unit. Regulatory authority includes USFWS, the state of West Virginia (DNR, DEP), and the US Army Corps of Engineers. There is significant uncertainty regarding effectiveness of management alternatives for reaching the desired restoration outcomes.

Ecological & Political context With the largest area of wetland plant communities in the state, Canaan Valley NWR supports numerous rare communities and species in these high elevation wetlands, and many are of concern at both state and regional scales. These communities also host game species, specifically American Woodcock.; some in WVDNR prefer management strategies that support woodcock habitats. Current areas of development are centered at the south end of the valley with many structures built on the refuge boundary. There are concerns that development and water withdrawal may affect this aquifer (Kozar 1996 – review). Within the human community, some prefer unrestricted access to refuge habitats, and site access restrictions after restorations may present a management challenge to the refuge. Historic influences on plant communities include logging and fire, and these habitats are in various stages of recovery and succession. Defining features of the logging era that remain today are numerous abandoned railroad grades that impede the natural flow of water; these embankments are a substantial management issue. Locally, beaver influence wetland habitat creation.

Decision Structure

Canaan Valley NWR Problem Statement

The context of this decision is focused on ***Canaan Valley NWR***'s allocation of resources for management wetland and riparian resources. Within the context of the workshop, the initial decision statement was revised as follows:

> **How do we manage embankments to achieve natural flow regimes (i.e. surrogates for biological integrity, diversity and environmental health) within wetland habitats of Canaan Valley NWR while not exceeding budgetary, political and/or legal constraints.**

Unlike Erie NWR, there was a realization among those familiar with Canaan Valley NWR that there were some substantial concerns about uncertainty regarding the risk that a management action might have unintended negative impacts on restoration. Some particular areas of concern include uncertainty associated with erosion risk, preventing expansion or presence of invasive species into areas with none, and catastrophic change to natural communities. Some ways to incorporate this into the structured decision making context include making "learning" about the risk in an adaptive manner either part of the decision explicitly, or use capacity for "learning" from a project as an objective in evaluating management actions. Areas of uncertainty for which learning may be important includes: value of filling ditches, source of external fill and its

potential as a source of invasive species contamination, effect of soil compaction on community restoration, and impact of heavy equipment types and operation on restoration success.

Canaan Valley NWR Objectives
Objectives were elicited individually and consolidated via group collaboration.

Biotic Integrity

Invasives

- Minimize potential for invasive establishment and expansion.
    - Minimize Soil Disturbance (linear m)
    - Minimize impact of equipment type (track/wheel) (0 no tracked or wheeled equipment, 1 bobcat, 2 backhoe, 3 backhoe + truck, 5 all equipment)
    - Minimize need to introduce off-site fill (linear m)
    - Maximize distance to source of existing invasives (linear m)

Environmental Health

Flow and contour

- Restore magnitude, variaibility, and geographic pattern of surface of ground and surface flow patterns.
    - Maximize change (reduce difference) in flow on one side of embankment to other. (0=no, 1=yes)
- Maximize restoration of contour.
    - Is ditch in need of filling? (1=no, 0=yes)
- Maintain and restore hydrologic processes to allow natural wetland plant communities to persist and move through successional stages
    - Difficulty in establishing a measurable objective; this objective tabled until later.

Biological Diversity

Habitats

- Minimize risk to rare communities in footprint of project.
    - Are there rare communities that may be impacted by project (n=0, y=1)
- Minimize uncertainty of the effect of the changes in flow, erosion and sedimentation on S1-2/G1-3 upslope/downslope communities

Public Support and Cost

- Maximize acceptance of restoration activities, by maintaining trail use/potential use of embankments
- Minimize costs to implement management action
    - Minimize magnitude of project costs, estimated as $/m and categorized on scale of 0=no cost to 5= maximum expense
- Minimize total costs to implement, monitor and maintain
    - Minimize total project costs, presented as cost/m (above) * project area (linear m)= cost

To more carefully examine relationships among the objectives, an influence diagram was developed to explore the association of selected measurable objectives (Figure 2.).

Canaan Valley NWR Alternatives

For this decision exercise, we focused exploration of potential management actions to a limited set of locations, only considering the issue of railroad grade embankments in Canaan Valley. These embankments fall into four categories, in that they occur generally parallel or perpendicular to the flow of water, and are on either the valley floor or on the toe-slopes. Two of the types (valley floor perpendicular to flow, toe slope parallel to flow) were evaluated.

1. Maintain status quo – natural erosion
2. Total removal includes recontouring and ditch filling
3. Partial removal with ditch filling
    a. Culverts
    b. Sectional Removal
4. Permeable fill replacement and ditch filling
5. Maintain embankment with ditch filling
6. Total removal includes recontouring and ditch filling, and replace grade with boardwalk to permit public access.

Canaan Valley NWR Predictive Models

A consequences table was developed (Table 2) to evaluate six potential alternatives at two sites, with no linked decisions or portfolios of actions. This systematic approach to evaluation underscored preceptions of risk by participants during the assessment, and aided in identifying areas that may require additional evaluation, and possibly research.

Following assignment of values for each objective and attribute for each alternative, values were weighted within sub-objectives to develop a single metric for each objective. Objectives were weighted by their importance to decision making, and summarized below (Table 2).

Objective weights (within objectives or among objectives) were determined using a modified swing weighting exercise (Goodwin and Wright 2004). Each participant individually rated his most important objective at 10, and ranked other objectives in relation to it. As this was a simplistic evaluation late in the workshop, weighting scores were then averaged across observers to assign swing weights for each objective and subobjective, as required. The resulting values were summarized for each alternative. The pitfalls of averaging, as used in this exercise, for expediency, should be carefully elicited in subsequent prototypes.

Future Direction

This workshop provided a valuable opportunity for an important conversation in the context of decision making in R5 NWRs for freshwater ecosystems and the BIDEH policy. Future directions and insights identified in the workshop include those identified below.

Canaan recognized through this process that there was one embankment that dominated their thinking in terms of uncertainty. It became apparent that this particular embankment may require some hydrological research and modeling first, or a careful adaptive management approach. Decisions for the other embankments seemed relatively straight forward and easy to make after this was realized.

Erie recognized through this process that, unlike in Canaan, decisions regarding removal of embankments were probably linked. That is, the effects of decisions on management objectives depended on the order in which embankments were removed or altered. Consequently, the group recognized that a more comprehensive SDM process would involve consideration of a portfolio of actions.

The issue of defining and setting objectives for BIDEH turned out to be best captured by hydrological, water quality, and invasive objectives. This makes sense in hindsight if the goal is to manage within a natural range of variability rather than emulating an arbitrary point in time. However it took a great deal of thought and time to reach this decision.

- Complete the models initiated in workshop for Canaan and Erie NWRs
    - Evaluate site-specific alternatives, as individual management actions and portfolios of actions, and possibly linked decisions.
- Revisit the objectives for each NWR to ensure they are acceptable.
- If management in each refuge necessitates learning about management and restoration for BIDEH, how would an explicit learning objective influence the direction of decision framing, assessment, and implementation?
- Identify partners with essential skills for each refuge, including modeling and facilitation.
- Reconsider the role of project specific assessment measures versus an index of biotic integrity, IBI, for monitoring and assessment of management actions on wetland integrity at the refuge level.
- Examine needs for resolving uncertainty prior to decision making, and methods for addressing uncertainty through adaptive management or designed research.
- Consider the role of freshwater wetland monitoring for each NWR in the context of BIDEH for baseline information and decision support and assessment.

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Table 1. A consequenses table for three alternative actions at Erie NWR.

Objective ranking (scale 0,1,2,3)	Enlarge Culvert at township road	Open WCS (B or N)	Remove Embankment & WCS (B or N)
BioIntegrity1 connectivity	2	1	1
BioIntegrity2 invasives	1	1.5	1.5
BioIntegrity3 NatureServe VegCom	1	2	3
BioDiversity rare species/communities	0	0	0
EnvironmentalHealth Water Quality	1	2	3
EnvironmentalHealth Natural Stream Flow	1	2	3
EnvironmentalHealth Erosion and Sedimentation	3	1	1
Public Maintain/Improve public relations and acceptance for alternatives.	1	0	0
Public Minimize flooding of non-refuge roads, trails, infrastructure	0	0	0
Cost Implementation	2	3	1
Cost Staff	2	2	3
***unweighted* sum**	14	14.5	16.5

Table 2. A consequenses table, summarizing weights and weighted objectives for aiding decision making among alternative actions at Canaan Valley NWR.

			Objectives				
		Objective weights	***8.3***	***8.5***	***1.0***	***5.2***	
Location of Action	**Flow Orientation**	**Action on Embankment**	**Invasives**	**Flow**	**Rare community**	**Cost**	**Sum**
Toe Slope	Parallel	Total Removal	3.7	4.6	0.0	0.1	8.42
Toe Slope	Parallel	Add boardwalk	4.1	4.6	0.0	0.2	8.97
Toe Slope	Parallel	Permeable Fill	4.2	4.6	0.0	0.2	9.03
Toe Slope	Parallel	Partial Removal 10%	3.1	6.2	0.0	0.1	9.39
Toe Slope	Parallel	Culvert	3.6	6.2	0.0	0.1	9.85
Valley	Perpindicular	Total Removal	6.9	0.0	0.0	3.1	10.03
Toe Slope	Parallel	No action	2.6	7.7	0.0	0.0	10.38
Toe Slope	Parallel	Maintain Grade	2.6	7.7	0.0	0.0	10.42
Valley	Perpindicular	Partial Removal 10%	4.9	3.9	0.0	2.1	10.85
Valley	Perpindicular	Culvert	5.0	3.9	0.0	2.1	10.97
Valley	Perpindicular	No action	2.6	8.5	0.0	0.0	11.15
Valley	Perpindicular	Permeable Fill	8.2	0.0	0.0	5.2	13.37
Valley	Perpindicular	Maintain Grade	8.3	7.7	0.0	1.0	17.09

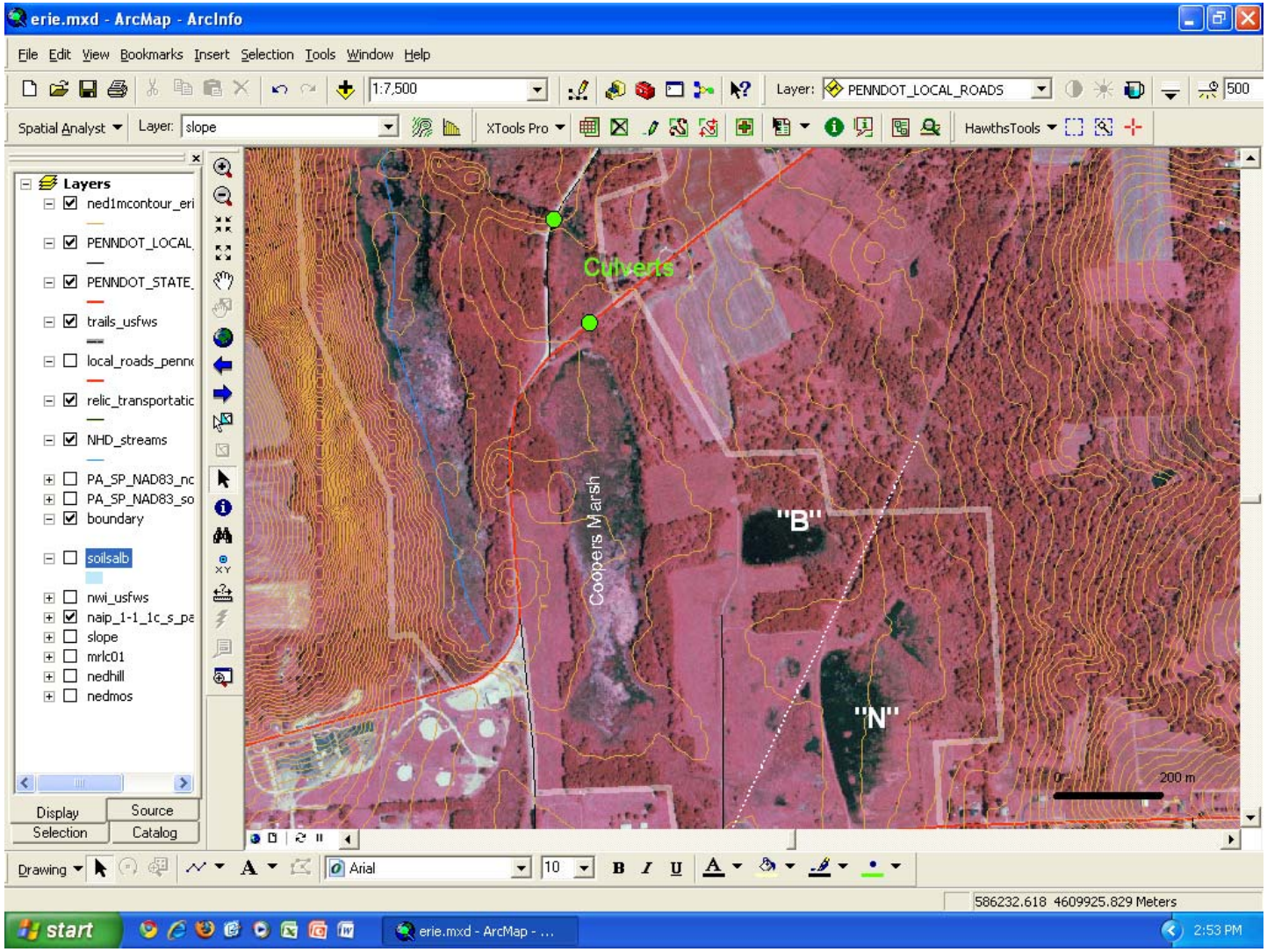

Figure 1. Map of the Erie NWR Sugar Creek unit trial decision area. "B" and "N" indicate impounded seepage wetlands that flow to Cooper's Marsh. Cooper's Marsh drains northward through two culverts, at State Road (south culvert) and Township (north culvert)

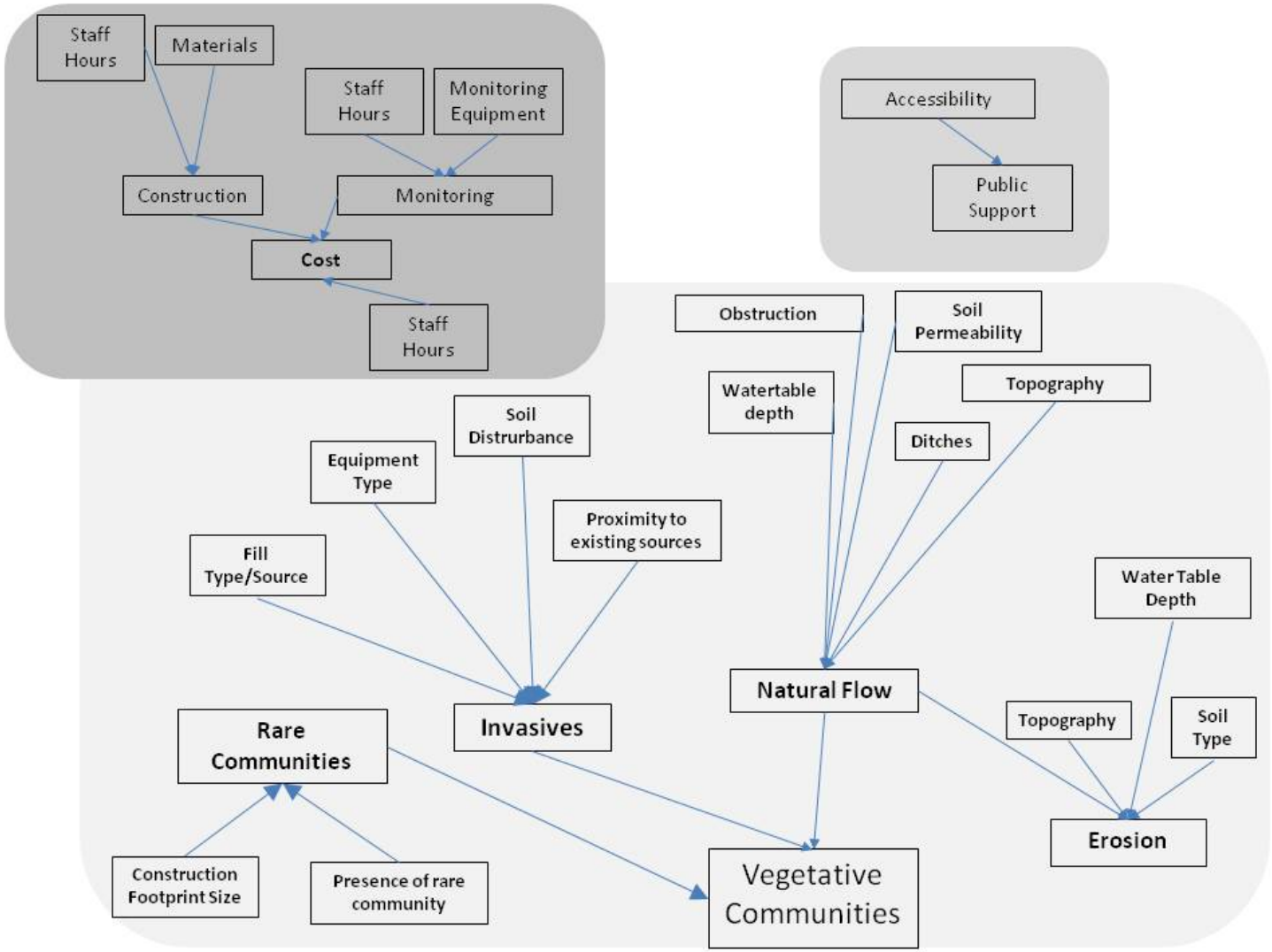

Figure 2. An influence diagram for Canaan Valley NWR demonstrating relationships among physicial and ecological parameters important for management within the biological integrity, biological diversity, environmental health (BIDEH) policy, management costs, and public support objectives.