The Watershed Health Assessment Framework

Introduction and Overview:

Exploring the Health of Minnesota's Natural Systems

"Health is the capacity of the land for self-renewal."

Aldo Leopold, Sand County Almanac.

MNDNR

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Contents

Introduction

Why Manage for Health?

Today we are faced with a multitude of challenges that threaten the health of our natural systems and the life support systems for our human communities. These challenges occur at many spatial scales; from local to global, from microscopic to meta-populations. Challenges also occur at many temporal scales; from instant impact to delayed response, from direct cause and effect to centuries of spin off impacts. Managing for the health of the system must allow new approaches to emerge that embrace this complexity.

In the past, management approaches themselves have simplified the system. By assuming static relationships over space and time, resource management goals reflect an assumption that the attainment of stability or a desired steady-state will provide the same services over time. This traditional approach includes finding key elements in a system to protect or restore and can lock managers into managing for an unattainable static condition.

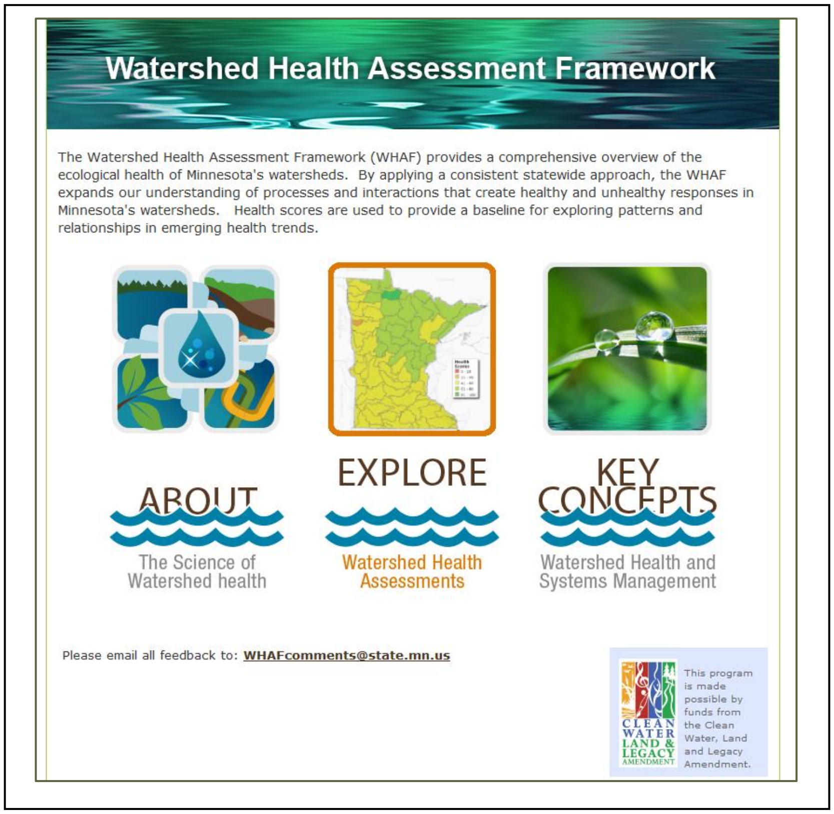
Natural resource management has focused on individual products such as fish production, timber production, hunting success, or providing clean water. The broader human community values these products, and resource management has focused on providing them. In recent decades, the challenges facing our systems have accelerated. With this acceleration comes an urgent need to acknowledge that the products we value are actually derivatives of functioning processes.

While continued management for products will likely lead to more simplified, brittle systems; managing for health seeks to embrace and enhance the processes necessary for healthy systems to emerge and be sustained over time.

Overview: The Assessment Approach

Assessing the health of a complex ecological system like a watershed is a daunting task. The Watershed Health Assessment Framework (WHAF) provides a consistent approach for exploring Minnesota's ecological health. A broad range of statewide GIS data has been synthesized into a suite of statewide, comparable health index scores. The red (low) to green (high) color rankings give visual cues for exploration and comparison of system health at multiple scales, crossing ecological and social boundaries.

The health index scores are delivered through an easily accessible, interactive mapping application. Exploring the health scores at multiple scales enhances the understanding of complex ecological processes and connections that cross space and time. The WHAF embraces the system principle that ***functionally intact ecological processes are essential to the health of watershed ecosystems***, providing resistance to disturbance and resilience over time.



This overview describes three parts of the assessment

1. **The assessment framework** used to organize and deliver watershed health assessment scores

2. **The assessment stages** to step through to explore and apply health scores

3. **The health concepts** to apply and re-visited throughout the assessment process.

The Assessment Framework

The Five Components

The assessment framework uses 5-components to organize and synthesize natural resource information. These 5 components are: Biology, Connectivity, Geomorphology, Hydrology and Water Quality. Each component contains 3 to 5 health index values that quantify some aspect of ecological system health. While intended to be comprehensive in scope, the 5-component approach and the health indices can only provide a snapshot of system condition. The approach applies the concept of "requisite simplicity"; the minimum but sufficient information; simple but not too simple.

Figure 3. The Watershed Health Assessment Framework components and health index list.
http://www.dnr.state.mn.us/whaf/about/scores/index.html

Each index includes a hyperlink to more detail on the WHAF website

Biology: The study of life. The biological systems that encompass and include the plant and animal species present in the stream, riparian lands, and contributing watershed.

- Terrestrial Habitat Quality The amount of land with appropriate vegetation, in the size and shape that make good habitat for animals.
- Stream Species Quality The quality of the fish, invertebrate and mussels communities found in the streams.
- Species Richness The number of fish, mussels, birds and invertebrate species that have been found in the watershed.
- At-Risk Species Richness The number of rare* species that have been found in the watershed.

  **Species of Greatest Conservation Need*

Connectivity: The maintenance of pathways that move organisms, energy, and matter throughout the watershed.

- Terrestrial Habitat Connectivity The presence of connections that allow animals to move between patches of habitat.
- Aquatic Connectivity The number of obstructions that limit the free flow of water, organisms and energy through lakes and streams.
- Riparian Connectivity The availability of land adjacent to streams and rivers for habitat, flooding and natural seasonal processes.

Geomorphology: The study of landscape features; from their origin and evolution to the processes that continue to shape them.

- Soil Erosion Susceptibility Amount of erodible soils and the steepness of their location.
- Groundwater Contamination Susceptibility Ease with which surface contaminants reach the ground water.

- Climate Vulnerability The landscape's ability to balance precipitation with evaporation, measuring tendencies toward too much or too little water.

Hydrology: The inter-relationships and interactions between water and its environment in the hydrological cycle.

- Perennial Cover Amount of permanent vegetation covering the landscape.
- Impervious Cover Amount of hard surface that doesn't allow water to penetrate.
- Water Withdrawal Amount of water withdrawn for manufacturing, agriculture and communities compared to water runoff and stream flow.
- Hydrologic Storage Amount of places to hold water, like wetlands and meandering streams, that remain on the landscape
- Flow Variability Degree to which stream flow patterns deviate from expected patterns

Water Quality: The chemical, biological, and physical characteristics of water; the current condition and future susceptibility of surface water and groundwater to degradation.

- Non-Point Sources Intensity of activities on the landscape that release sediment and contaminants that can reach water
- Point Sources Density of known locations that discharge contaminants into the waterways
- Assessments Percent of lakes and streams studied and found to have contaminants or impaired uses

The Health Scores

The health index scores are available for all 81 major watersheds (HUC8) in Minnesota. In all cases, the lower the health score value, the less healthy the condition represented by that health index. All scores are based on a possible range of values from 0 (red, least healthy) to 100 (green, most healthy). Additional detail on measuring watershed health and the challenges of creating health index values is available on the WHAF website.

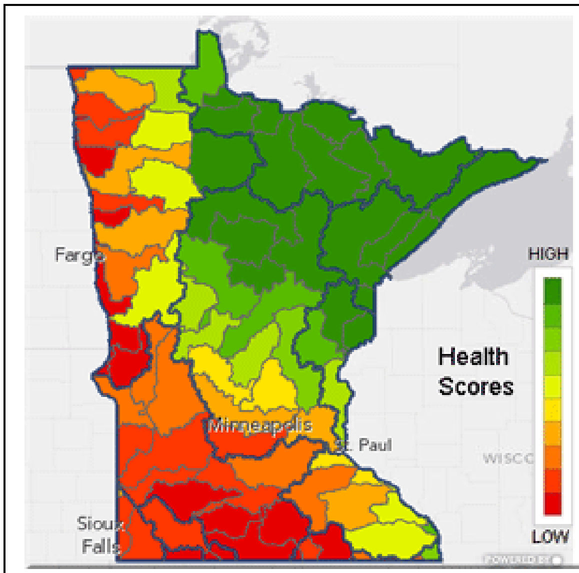


Figure 4. Example of a health index score for Minnesota's 81 major watersheds.

Some health scores have been downscaled to the catchment, which is a smaller subwatershed within the major watersheds.   In the WHAF Explore map, any index that has a 'down arrow' can be expanded to reveal this greater level of detail.

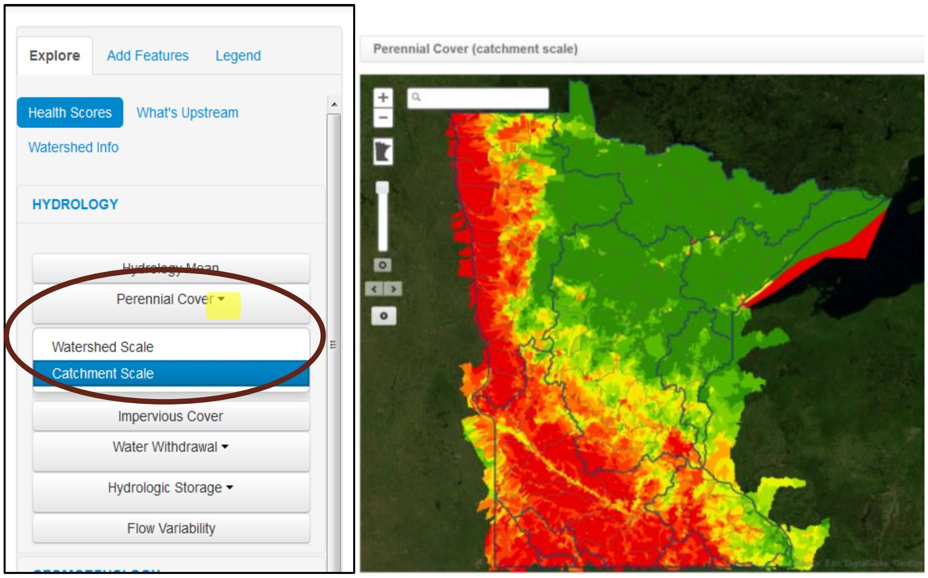


Figure 1 The Perennial Cover index is expanded in the table of contents to reveal catchment (subwatershed) level health scores.

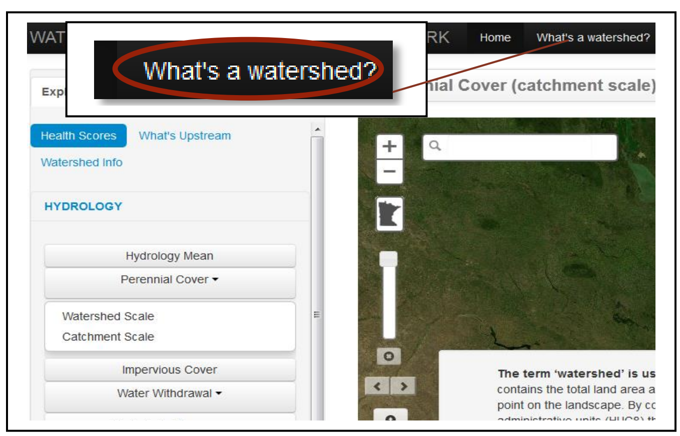
The Watershed Context

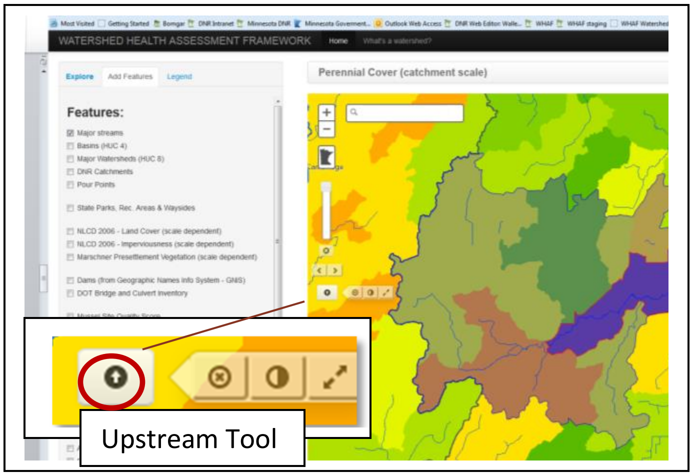
The term 'watershed' is used in many ways. A 'True Watershed' contains the total land area and water features upstream of a given point on the landscape. A watershed contains all the land and water features that drain excess surface water to a specific location on the landscape. In other words, standing on the land and looking around, everything uphill from that position routes water to that point and falls within its watershed.

By contrast, 'Major Watersheds' are administrative units (HUC8) that may artificially divide a larger watershed or major river basin. In Minnesota, more than half of the Major Watersheds are not true watersheds.

More information on 'watersheds' and how the term is used in the WHAF can be found here http://www.dnr.state.mn.us/whaf/key-concepts/ws_def.html .

Additional information is also available inside of the Explore map, by clicking on "What's a watershed?"





Subwatersheds or catchments are also used for delineating upstream areas with the 'upstream tool'. By simply selecting the catchment that contains your area of interest, the upstream land area that contributes surface water flow will be highlighted.

Summary information about that upstream area should be considered during your assessment of system health.

Applying Health Concepts:

A number of broad conceptual questions guide an exploration of watershed health and system function. These same questions should be revisited at the conclusion of an exploration of system health to guide ensuing discussion and decision-making.

From Exploration to Application:

- What ecological and social processes are influencing health scores?
- On what scale do these processes operate?
- On what scale should a management response take place?
- What risks and barriers exist for improving health?
- What opportunities and synergies exist for improving health?

Exploration Outcome:

- Which management scenarios embrace and enhance system resistance and resilience?

Key Concepts

System Resilience

Managing system processes is not a new idea. Ecosystem services and green infrastructure are examples of emerging science that seeks to apply system understanding to find sustainable solutions. The next step will be to move toward managing for system resilience in the face of change. "Resilience is fundamentally a system property. It refers to the magnitude of change or disturbance that a system can experience without shifting into an alternate state that has different structural and functional properties and supplies different bundles of the ecosystem services that benefit people." (Resilience Alliance 5). Managing for resilience will be essential if ecological systems are to continue to provide the services needed by human communities and inter-dependent natural communities over time.

The challenge of resilience lies in its fundamental characteristic as an emergent property of the system itself. Managing for resilience will require an adaptive learning approach. Managing for resilience also comes at a cost. In order to maintain reserves of energy and protect opportunities for the future, current uses of natural and human resources must be limited rather than maximized. A cost-benefit analysis can help identify the trade-offs related to the provision of resilience. (Walker, 2012 22)

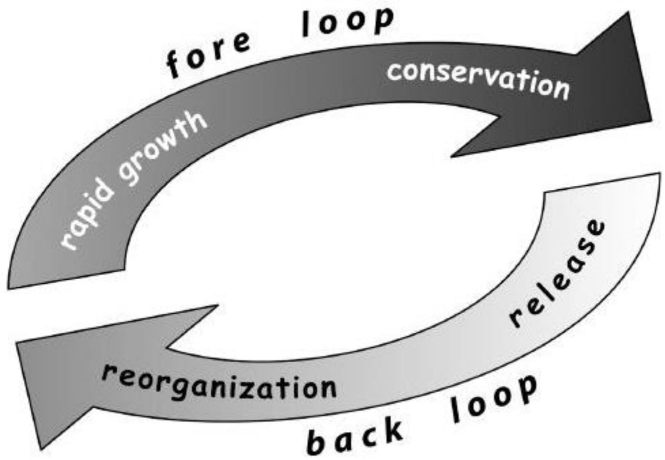
Thresholds

There are limits to the amount of change a system can absorb and still return to its former condition or functional state. When a system changes beyond this point, it has crossed a threshold and will re-organize into a new (often undesirable) state. In social systems, the point at which a system re-organizes into a new form is sometimes referred to as a 'tipping point'. (Walker, 2012 6).

The energy or actions necessary to return an altered system to a previous state by crossing back over a threshold can be slight or it can be prohibitive. Because systems are self-organizing and self-regulating, the response to being disturbed or altered is not always predictable. A lake is an example of a system that will predictably "turn over" seasonally. When the temperature at the surface reaches a threshold value, water density shifts and sinks, and the colder water below is displaced and forced to the surface. However, most thresholds are not so well understood or predictable; as they involve feedback loops and delayed responses. Additionally, as the resilience of the system shifts, the distance to the system threshold may also shift. (Walker, 2012 33).

Adaptive Management

Both human and natural systems are governed by cyclic processes that produce phase changes. Ecosystems tend to cycle through four phases which can be described as rapid growth, conservation of resources, release of resources and reorganization. (Gunderson, 2002 10) Forest fire regimes can be used to illustrate these phases, beginning with rapid growth of colonizing plant species, conservation of nutrient resources and maintenance of structure in mature forests, release of nutrients through fire and forest renewal through the soil seed bank… Understanding how a system changes internally, in terms of its vulnerability to disturbance and its capacity to respond as it moves through different phases of change, can inform the type or timing of management interventions. ***Actions taken during one phase may affect the system quite differently than the same actions taken at other times, and windows of opportunity may be brief***.



"In the fore loop, the system is relatively predictable. The back loop is characterized by uncertainty, novelty, and experimentation. During the back loop there is a release and often a loss of all forms of capital." (Walker, 2012 14)

Figure 2. A simple representation of the adaptive cycle.

Natural systems spend the majority of their time in the fore loop phases which has led to research, management and policy based on the phases of growth and conservation. Although the phases of release and reorganization may be shorter in duration, they hold great potential for influencing processes, that in turn influence the following fore loop. For example, following a flood, the window of opportunity opens to change the way social and ecological systems will be managed for future flood events. It may be possible to buy floodplain property, remove channel obstructions, and change management of infrastructure to allow more natural stream flow regimes.

Social-ecological Integration

Fundamental to managing for healthy and resilient systems is acknowledging that human and natural systems interact; they are not only entwined but are interdependent. The human capacity to alter natural systems impacts the health of natural systems producing unforeseen consequences. But the reverse is also true, natural systems react to human perturbations in ways that also produce unforeseen consequences.

Draining wetlands is an example of the human capacity for alteration that reverberates through the natural and human communities. By fundamentally changing the dynamics of the hydrologic cycle, water is less available for wetland plants and animals and the composition of that community shifts. At the same time, water that is no longer stored enters the stream increasing the potential for flooding of adjacent human communities.

Social and ecological systems interact at multiple levels with feedback loops operating at different rates. Acknowledging and managing this complexity is key to successfully shifting to a “managing for health” paradigm.

Human systems are governed by both formal and informal processes. Culturally based behaviors that develop over long time spans have a very strong influence over human use and interaction with the natural world. From subsistence farming to industrial complexes, cultural differences are embedded in decision making. Formal institutions further embed these perspectives through law, economic markets and property rights.

The melding of ecological processes and human processes will require much greater emphasis on adaptive management principles. Termed “adaptive governance”, characteristics of an adaptive approach will include “experimentation, new policies for ecosystem management, novel approaches to cooperation and relationships within and among agencies and stakeholders; new ways to promote flexibility; and new institutional and organizational arrangements. Adaptive governance systems can enhance general resilience by encouraging flexibility, inclusiveness, diversity and innovation.” (Resilience Alliance 8).

Exploring Watershed Health

Step 1. Exploring the Context: Space and Time

What defines the boundaries for exploration?
Set boundaries to define the scale and scope of what is in and what is out of your assessment of system health. *It is important to remember that these are soft boundaries. The initial exploration starts with these boundaries, but it is essential to also explore at scales that are above and below these boundaries to look for additional interactions.*

Begin initial exploration with an area of interest in mind. The spatial extents that work well for exploration with the WHAF are listed below (from smallest to largest). These different scales represent hydrologic boundaries that are nested inside of each other and should all be used during an exploration of system health:

DNR Catchment
Major Watershed (HUC 8)
Major River Basin

Other spatial boundaries should also be acknowledged and considered during an exploration of system health. The Ecological Classification System (ECS) provides a set of ecological boundaries based on soils, geology and plant community type that influences a range of system dynamics. Political boundaries such as counties, cities and townships provide important context that influences land use, economic activity and social capacity.

Video introducing the WHAF Exploration mapping interface:
http://youtu.be/AhHllX1jgTY

Video tutorial on using the WHAF to explore spatial context:
http://www.youtube.com/edit?o=U&ns=1&video_id=RC7rJK7FxQY

Step 2. Define Primary Issues for Exploration

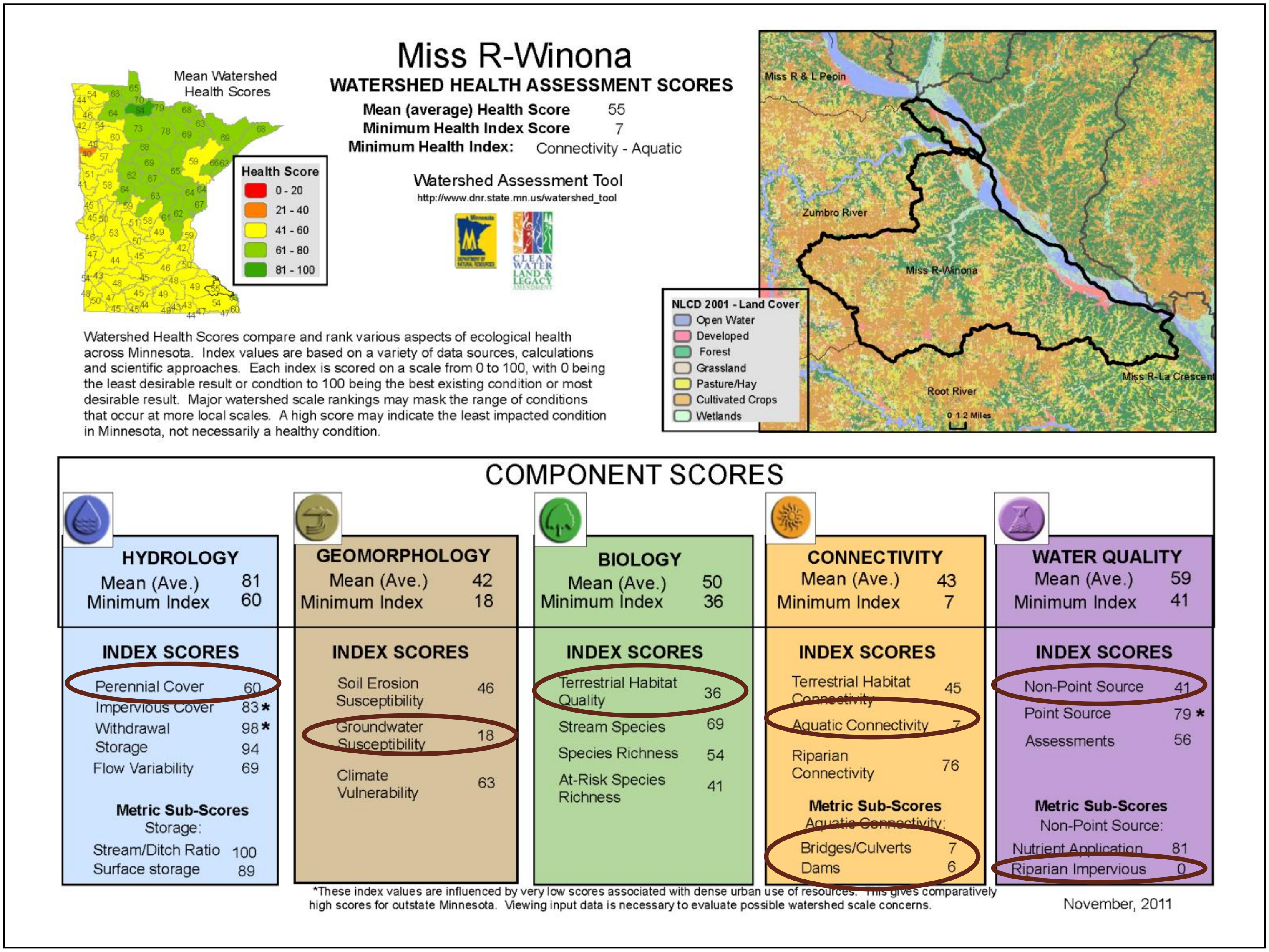
What issues or management concerns are you going to address in this assessment?

Using the "soft" spatial and temporal scales identified in step 1, describe the primary issues that need to be addressed. For each identified issue, ***what related function(s)*** does this system (Whitewater State Park) currently provide? What timeframe is relevant for addressing each issue?

Step 3. Examine Health Status, Drivers and Processes

How healthy are the ecological components of the system you are exploring?

The 5-component model is used to quantify and compare the status of system health. By creating a suite of health index values for each component, health trends become more visible to the user allowing comparison and assessment across the state of Minnesota. At the major watershed scale, score cards (PDF 33 MB) are available that summarize the health scores for all five components for each watershed.

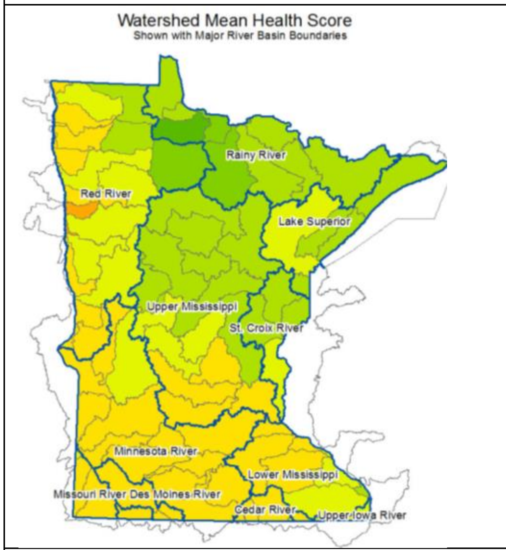


Watershed health scores card for the Mississippi River Winona major watershed; low scoring health index in each component is highlighted. Scores indicate a relative ecological condition or health risk, as compared across the state of Minnesota.

Step 4: Scale it up

An additional step in exploring context is to view trends in health scores at the statewide scale. Walking through the indices from a bird's eye perspective may reveal landscape level processes that should inform more local decisions. While management rarely occurs at the statewide scale, implementation of policy certainly does. Review the spatial context for this location. View statewide health trends for each component and note the ecological and/or social drivers of those trends.

http://www.dnr.state.mn.us/whaf/scores/combined/index.html

<table>
<tr><th>MEAN OVERALL HEALTH SCORES</th><th>SPATIAL CONTEXT</th><th>RELATIONSHIPS:</th></tr>
<tr><td>


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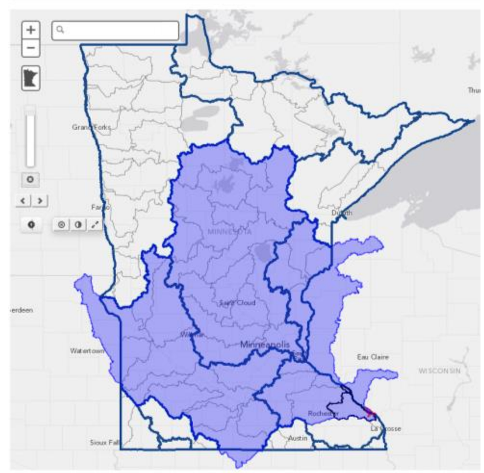

</td><td>Hydrologic:

WS contributes flow directly to the Miss. Rvr., still connected to UMRS as part of the big river system, its floodplain, flyway, commerce etc will all have an influence on system function and system health.</td></tr>
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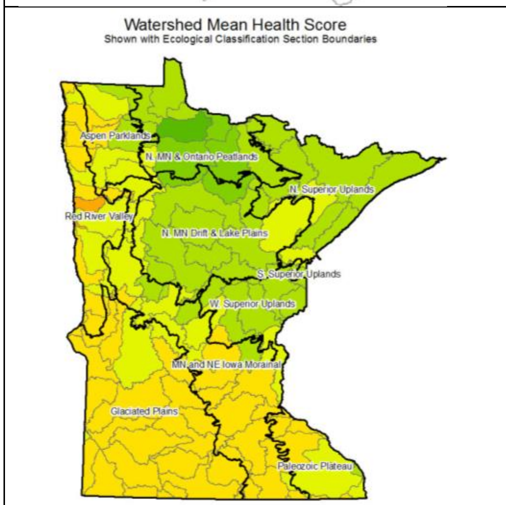

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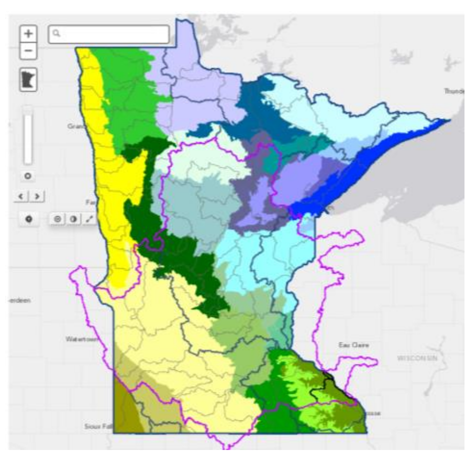
</td><td>Biology/geomorphology:

WS straddles two ecological subsection boundaries, Rochester Plateau and Blufflands. Different topography, soils, eco communities.</td></tr>
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Applying Health Concepts

Revisit these broad conceptual questions as a guide for exploration of watershed health and system function during ensuing discussion and decision-making. Record new observations made after exploring the system with the Watershed Health Assessment Framework.

From Exploration to Application:

- What ecological and social processes are influencing health scores?
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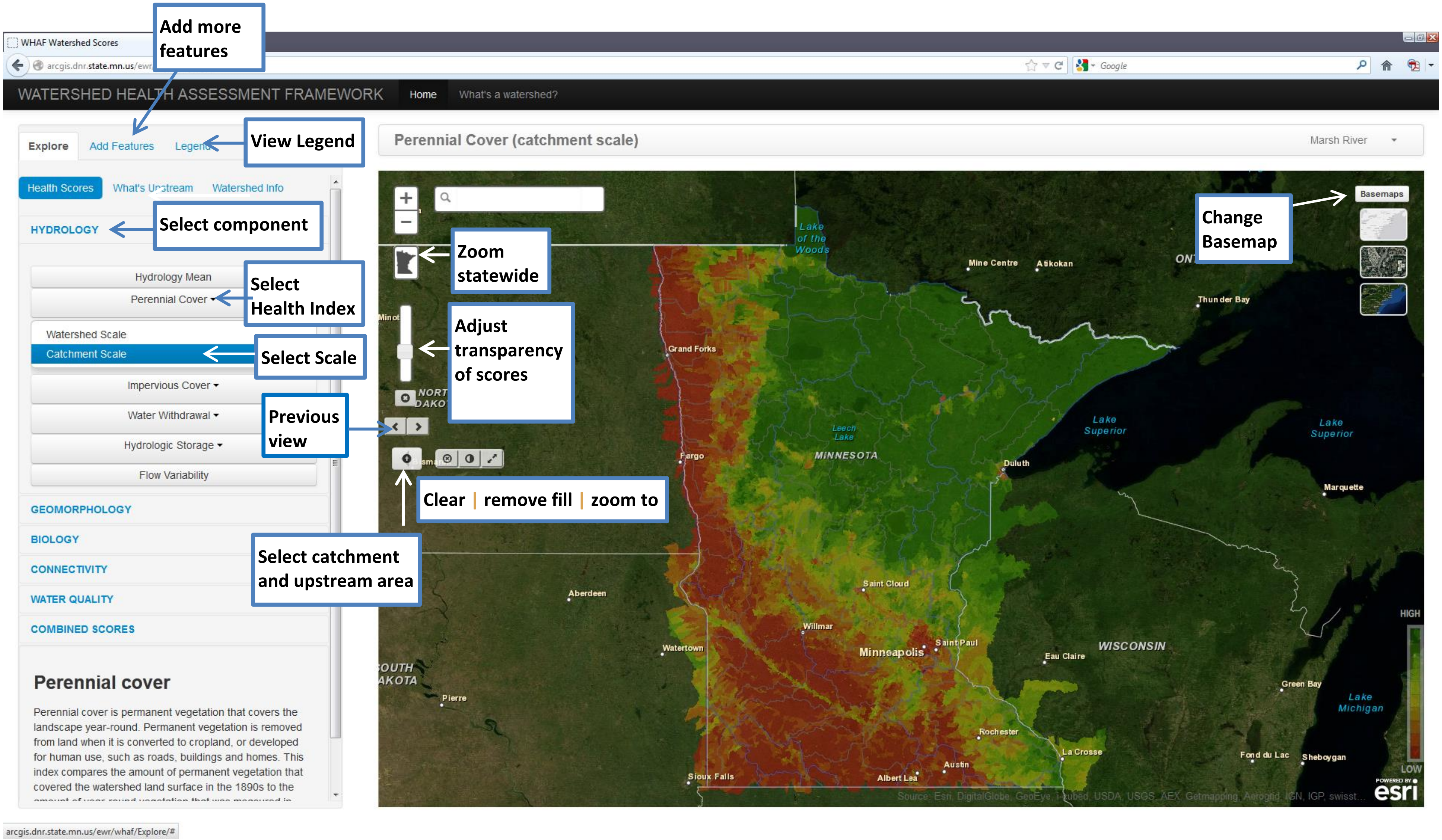
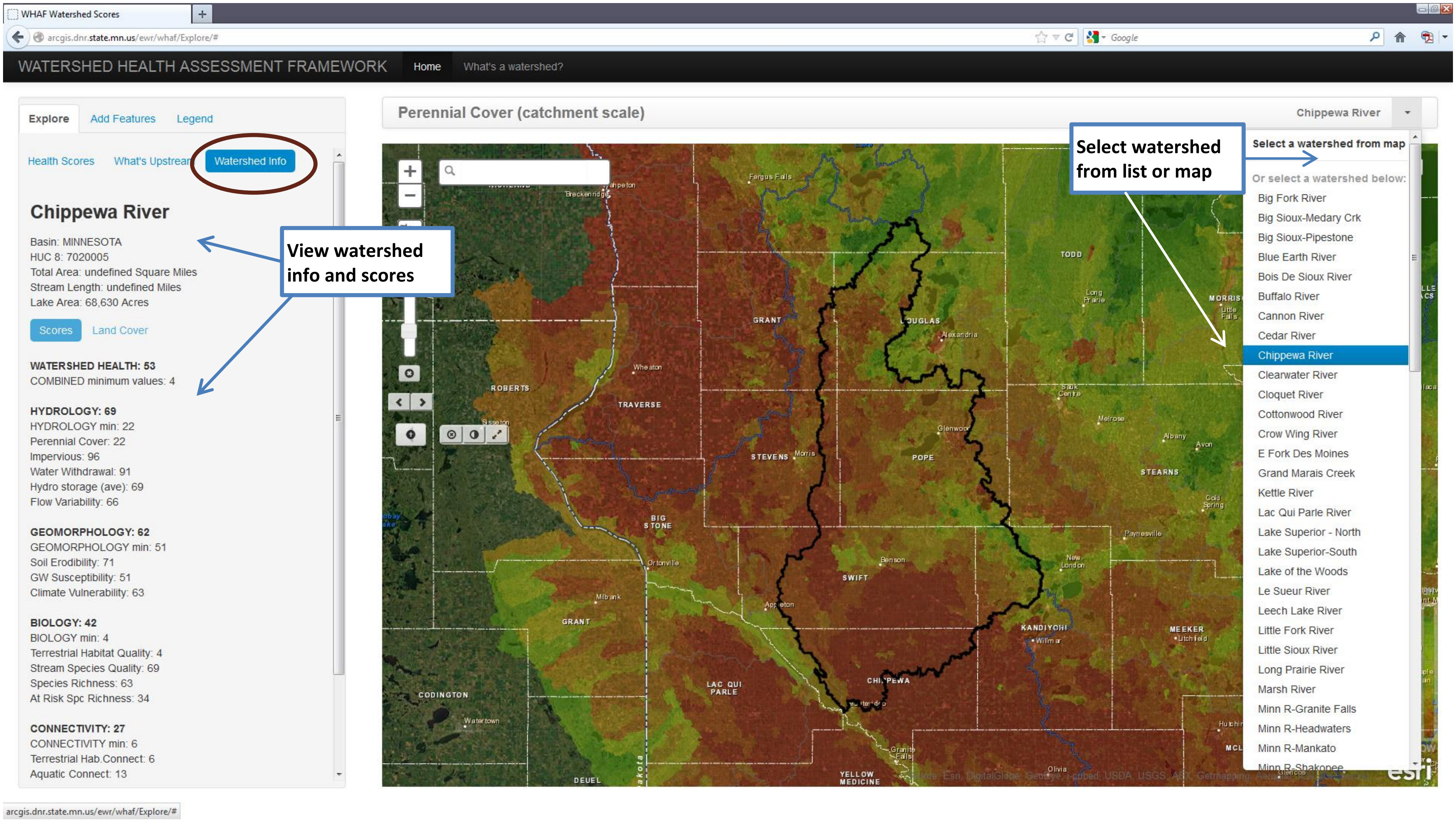
Appendix A - Using the Map Interface
Health Scores



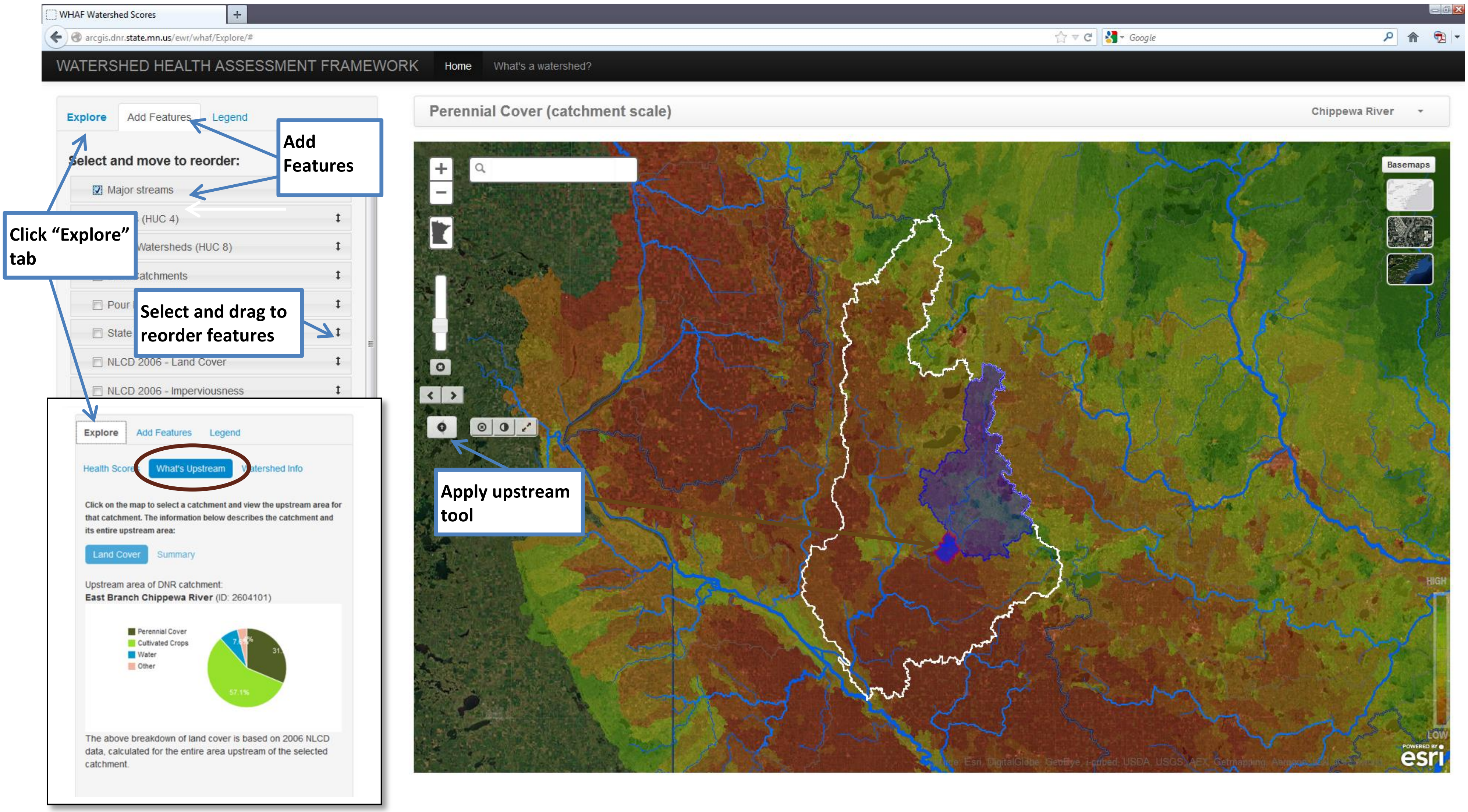
The Watershed Health Assessment Framework – Map Interface

Watershed Information



The Watershed Health Assessment Framework – Map Interface

Upstream Tool and Information



Appendix B: Watershed Health Worksheets – Context

WORKSHEET 1.1

Find your area of interest and identify these related spatial extents:

	Spatial Context
Community/Area of Interest	
DNR Catchment	
Major Watershed (HUC8)	
County	
Major River Basin	
Ecological Classification System (ECS subsection)	
Statewide/Multistate	

WORKSHEET 1.2

Define the timeframe for your exploration:

	Temporal Context
Primary Time Frame of Interest	
Current Condition	
Past Condition of interest	
Future Scenarios	

WORKSHEET 1.3

Define the Primary Issues to investigate:

	Primary Issue	Related System Function	Appropriate Spatial Scale to address issue	Relevant timeframe to address issue
Issue 1				
Issue 2				
Issue 3				

Works Cited

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