WORKING DRAFT (18 April 2021)

Technical Report:

Modeling and Identification of Watersheds (Healthy Watersheds) and Water Bodies (High Quality Waters) for Water Resources Protection Purposes in Wisconsin

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DISCLAMER:

This document is currently in a preliminary, working draft state and is meant for informative purposes only for those interested in ongoing direction, methods, processes, and work. The document will be updated as more information and results are available as a result of ongoing work and incorporation of internal and external feedback. Thus, we do not suggest citation of this document until the report is in its final draft state. However, if this is unavoidable, please contact the authors for further information and please check back for updates at this website: http://dnr.wisconsin.gov/topic/surfacewater/HQW.html.

Forward

This technical report is a companion report to other Healthy Watersheds, High Quality Waters documents such as the Kickoff Strategy and is not intended to be a stand-alone document. Thus, additional information about this effort and its overall context should be obtained there.

Introduction

Our objective was to identify the healthiest (i.e. those of highest remaining ecological integrity) watersheds and waterbodies in Wisconsin using the best known and available scientifically defensible datasets and processes to enable water resources protection activities at both watershed and waterbody scales across the state.

Before engaging in further modeling or identification approaches, we *a priori* defined both healthy watersheds and high quality waters to guide and focus our efforts. We defined healthy watersheds (HW) using US EPA's Definition (US EPA 2012):

"*A healthy watershed is one in which **natural land cover** supports:*

1) *dynamic **hydrologic** and **geomorphologic** processes within their natural range of variation,*
2) ***habitat** of sufficient size and connectivity to support native aquatic and riparian species, and*
3) *physical and chemical **water quality** conditions able to support healthy **biological communities**.*"

Within this definition are 6 primary focal areas (bolded within definition above; also Figure 1).

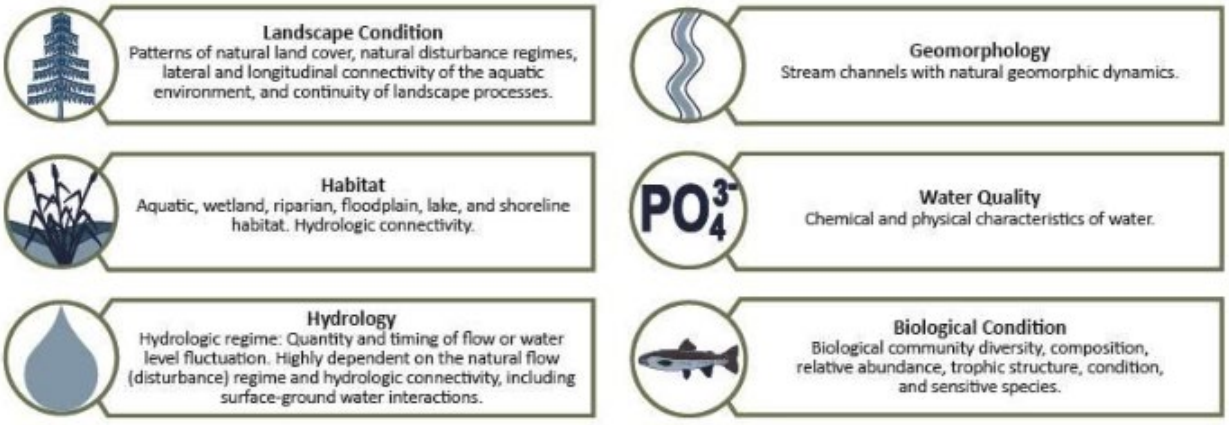

Figure 1. Focal areas/components of healthy watersheds assessments (from US EPA 2012).

We defined high quality waters (HQW) as:

"Lakes, streams and rivers which meet at least two of the following attributes:

- *Unique or rare resource*
- *Attainment of state water quality standards*
- *"Good" or "Excellent" biological integrity*

OR

wetlands which meet one or more of those attributes."

Methods

Review of Existing Conservation Tools

A number of existing conservation planning tools for Wisconsin and beyond were reviewed but ultimately were not selected for inclusion in identification of HW or HQW due to a number of concerns (A non-exhaustive list of those reviewed are in future appendix. These concerns included:

1) Age of information- some tools relied on datasets that were upwards of 10-15 years old at the time of review or were created nearly a decade ago
2) Availability- some tools relied on models, data, and methods that were not readily accessible, or personnel that were responsible for creation of the tools or aspects of the tools no longer (or not easily) available to clarify or provide information
3) Flexibility- similar to availability, tools which likely could not be readily updated with current data or customized to include only portions of certain tools
4) Quality of information (defensibility)- the extent to which tools were created based on data vs. best professional judgement
5) Scope/Coverage- some tools only were designed for specific areas or regions of the state (i.e. not statewide or multi-region within the state) or generated results at scales which have or were likely not to gain

Given the difficulties and limitations discovered during the review of the existing conservation planning tools, it was determined that no single tool or combination of tools even with adaptations would fulfill the objective. Thus, alternative tools, datasets, and processes were sought.

US EPA Recovery Potential Screening Tool

The US Environmental Protection Agency (USEPA) developed the Recovery Potential Screening (RPS) Tool for application within the context of "protecting the best of what's left" and identifying areas for restoration (recovery) in watersheds identified as having impaired waters such as TMDL areas (USEPA 2021a). The RPS tool overall addressed many of the types of limitations that were concerns for other conservation planning tools.

1) Age of information- The RPS relies on the Watershed Index Online (WSIO; USEPA 2021b), which is regularly refreshed as updated datasets become available.
2) Availability- the tool is publicly available from USEPA and has dedicated staff and contractor (Cadmus Group) support.
3) Flexibility- The tool allows for customization and selection of pertinent variables from WSIO, including separate indices for estimation of ecological, stressor, and social (capacity) factors. Additionally, custom state-specific variables can be added when available and desired.
4) Quality of information (defensibility)- the RPS tool includes the most updated data at the most resolute scale available.
5) Scope/Coverage- The tool is able to model at multiple scales of interest (e.g. statewide, major basins and sub-basins, ecoregion) based on user selection with the HUC 12 as the basic unit of the model.

As aforementioned, the RPS includes multiple indices to account for ecological, stressor and social factors. We used the RPS Ecological Index to model and identify the current healthiest watersheds in the state for protection. More specifically, we reviewed and customized US EPA's Preliminary Healthy Watersheds Assessment (PHWA; US EPA 2017) and its sub-indices to achieve this objective. More details about the PHWA and the adaptations/customizations are included in the *Ecological Index* section to follow.

Ecological Index

We customized US EPA's Preliminary Healthy Watersheds Assessment- Watershed Health Index (PHWA-WHI) and its sub-indices to generate the Ecological Index within the RPS tool. We chose to use the PHWA-WHI as a base modeling approach because its sub-indices account for the 6 primary focus areas within US EPA's definition of a Healthy Watershed. The sub-indices also closely align with categories used as part of previous modeling efforts to identify HW in Wisconsin (USEPA 2014).

Original PHWA-WHI sub-indices and corresponding variables included the following (further descriptions and acronyms included within USEPA 2021b and USEPA 2017):

- Landscape Condition
  - % Natural Land Cover (Ws)
  - % Natural Land Cover (HAZ)
  - Population Density (Ws)
  - Population Density (Rz)
  - Mining Density in Watershed
- Hydrology
  - % Agriculture on Hydric Soil (Ws)
  - Dam Storage Ratio (Ws)
  - % Forest Remaining (Ws)
  - % Wetlands Remaining (Ws)
  - % Impervious Cover (Ws)

    - Road Stream Crossing Density (Ws)
- Geomorphology
    - Dam Density (Ws)
    - % Ditch Drainage (Ws)
    - Road Density (Rz)
    - %High-Intensity Land Cover (RZ)
- Habitat
    - NFHP Habitat Condition Index Local Watershed
- Water Quality
    - Mean probability of Good Biological Condition (Ws)
    - Biological Condition at Watershed Outlet
- Biological Condition
    - Difference between % Assessed HUC12 Stream length Supporting vs. Impaired
    - Difference between % Assessed HUC12 Waterbody area Supporting vs. Impaired

Of the original variables, Mining Density within the Landscape Condition sub-index was the only variable not retained for analysis given limited occurrence and distribution across the state.

In addition, we took advantage of the flexibility of the PHWA-WHI to include a number of variables representing the most up-to-date advances in aquatic resource condition and functional modeling available in Wisconsin. These included the following:

- Wetlands by Design: A Watershed Approach- WDNR and The Nature Conservancy (TNC) partnered to create Wetlands by Design (WbD) and an associated decision support system (Wetlands and Watersheds Explorer) to guide and enable prioritization of voluntary and regulatory wetland and watershed conservation across Wisconsin. WbD used extensive GIS analyses to estimate ecosystem service provision of remaining wetlands on the landscape based on the landscape position of each wetland (more information is available at wetlandsbydesign.org). After consultation with TNC, we obtained statewide coverage of HUC-12 scale estimates of wetlands providing "high" and "very high" estimated levels of ecosystem service provision for 5 separate ecosystem services. We incorporated each ecosystem service as follows into PHWA-WHI sub-indices:
    - Hydrology
        - WbD Surface Water Supply
    - Geomorphology
        - WbD Flood Abatement
    - Water Quality
        - WbD Sediment Retention
        - WbD Nutrient Transformation
    - Biological Condition
        - WbD Fish and Aquatic Habitat

- Modeled "Good" and "Excellent" Condition Stream Macroinvertebrate Hilsenhoff Biotic Index- Percent predicted good and excellent HBI scores indexed to HUC12. Department and USGS staff developed statistical models to estimate the current physical, chemical, and biological conditions of all inter-confluence wadeable stream segments (n= 110,000) in Wisconsin. Sampling data from 5,000 stream sites from across the state and numerous landscape variables for each of these sample sites' watershed were used to train the models to estimate the current conditions of the tens of thousands of inter-confluence stream segments in the state that lack monitoring data. Data from approximately 1000 sampled stream sites not used in the models development were used to evaluate the bias, precision, and accuracy of the physical, chemical, and biological predictive models developed. A complete description of the models can be found in the department report: *Development of Ecological Expectations for Wisconsin Streams* EGAD# 3200-2016-4 (Miller et al. 2017a). We included this information within the Biological Condition index

Customization of PHWA-WHI and Score Normalization Process

EPA and CADMUS provided customized R code that was used for their Preliminary Healthy Watersheds Assessment, and this script was edited to include more specific data for Wisconsin. To complete the Ecological Index, the input metrics were modified within the script utilizing the following techniques:

First, metrics were extracted from EPA's RPS database and Wisconsin DNR data layers after deliberation as to why and how they relate to the makings of healthy watershed. After metrics were selected and related to Wisconsin's HUC12's, they initially went through a windsorizing process to remove any large outliers in the datasets and bring the outlier data down to the 1st and 99th percentiles of the data range.

The windsorized metrics were then normalized to a range of zero to one to create congruency in the ranges of the different metrics. Since some metrics are percent-based and others are created through different area calculations, normalizing helps provide equal value between metrics.

Next, the normalized metrics were analyzed individually as whether higher values meant healthier or less healthy status. For example, a high value in the population density metric would relate to poorer health status. If the high end of a metric range was associated with poor health, then the values for that metric were inverted within the zero to one range so all metrics' values would accurately reflect good or poor health.

The metrics were then placed within their respective sub-indexes relating to the factors of healthy watersheds: landscape, hydrology, geomorphology, biological habitat, and water quality. Weights were placed on certain metrics within each sub-index, then the final six sub-index scores were averaged together to come up with the final ecological health index score for each HUC12. This ecological health index score will be used as a standalone product, and also within the Recovery Potential Screening tool.

After completing PHWA-WHI variable customization, we conducted correlation matrix analyses using the *ggcorrplot* package in R to investigate potential metric redundancy within each sub-index (ggcorrplot and R citation here). Normalized metric scores were used for these analyses as previously described. Overall, very few metrics were strongly correlated ($r^2 > 0.7$) within any given sub-index with the following exceptions (Table _____):

- Landscape Condition
    - Natural Land Cover (Ws) and Natural Land Cover (HAZ) [+]
    - Population Density (Ws) and Population Density (Rz) [+]
- Water Quality
    - WbD Sediment Retention and WbD Nutrient Transformation [+]
- Biological Condition
    - Mean probability of Good Biological Condition (Ws) and Biological Condition at Watershed Outlet [+]

Initial Healthy Watersheds Modeling Checks

After the initial results for HW were completed, Statewide and HUC 6 scale maps were sent to WDNR Water Quality Biologists across the state for review in late January 2021. The opportunity for review was intended for experienced regional staff to generally assess whether initial HW modeling results matched their relative broad in-field observations of watershed health, as well as identify potential factors not captured within the model that might explain any deviations. Staff were asked to identify broader scale trends and factors (if possible) that would point towards potential systemic modeling effects that were not capturing reality on the ground. A number of trends were identified and are synopsized within the major observations below:

- Staff Observation 1: *Watersheds in the Central Sands and Driftless areas of the state*- Staff from WDNR's Office of Great Waters and local biologists in the Water Quality Program noted that a large number of watersheds in both the Central Sands and Driftless Areas were scoring higher than anticipated despite known water quality issues related to nitrogen and other issues in these areas. Additionally, biologists in the Central Sands noted that extensive ditching, drainage and water level management due to agriculture (i.e. row, root, and bed crops) did not seem to be adequately accounted for in the model despite multiple dam and ditch related indicators within various sub-indices. Staff also noted large flooded areas and water level manipulation of existing and former wetlands in this area that likely were not accounted for in the model. Additionally, they noted WbD metric scores for these watersheds seemed particularly high in some instances.
- Staff Observation 2: *Watersheds in Lake Superior Basin*- Staff from WDNR's Office of Great Waters and local biologists in the Water Quality Program noted that watersheds with known field conditions representing minimal to low anthropogenic disturbance were scoring more poorly than they would have

expected at a statewide scale. In particular, they noted WbD metric scores for these watersheds seemed particularly low in some instances.

- Staff Observation 3: *WbD Fish and Aquatic Habitat included in the Biological Condition Sub-index*- Staff pointed out that this metric was more closely related to the Habitat Sub-Index based on the description provided in WbD documentation.

To account for these observed patterns, we combed through modeling results to identify factors which may have led to the broader systemic patterns above which could be adjusted to increase accuracy. Additionally, where adjustment of existing factors within subindices did not appear to be an option, we searched for additional datasets within WSIO and within state (with statewide coverage) to add if justified. Added variables were prepared as noted in the previous section for incorporation into the model sub-indices. A number of changes were made to the initial model:

- Model Change 1: *A new metric called % Watershed with Agriculture on Nitrogen Sensitive Soils (WI NRCS 590) was added to the Landscape Condition sub-index*. After consultation with EPA and Cadmus Group, it was determined that no metrics within existing sub-indices or WSIO would adequately capture biologist concerns related to nitrogen. Thus, a new indicator was created by intersecting the 2019 USDA Cropland Data Layer with the WI NRCS 590 Standard Soils that were previously determined as susceptible to groundwater N leaching and relativizing that to a HUC12 scale (see DATCP 2021 for resources related to WI NRCS 590 Standard). These changes were intended to partially address concerns within Staff Observation 1.
- Model Change 2: *Individual WbD metrics were adjusted in their weight to 0.25 within their respective sub-indices*. WbD scores as well as the WbD Viewer (Wetlands and Watersheds Explorer) were reviewed in both the Lake Superior Basin as well as the Central Sands Region given Staff Observations 1 and 2. In the Lake Superior basin, a number of watersheds received very low scores for some WbD variables despite having little to no known wetland loss or modification and had large acreage of apparent riparian and/or headwater wetlands. In the Central Sands, it was discovered that bed crop agricultural operations (i.e. cranberry operations) were considered as wetlands within WbD and tended to score high or very high functionally on the WbD viewer despite being heavily hydrologically modified and anthropogenically altered. Thus, we down weighted these metrics to account for these discrepancies rather than removing the metric altogether because they still include the best available wetland functional information at hand.
- Model Change 3: *WbD Fish and Aquatic Habitat was moved to the Habitat Condition Sub-Index to satisfy Staff Observation 3*.

After incorporation of the above model changes, staff who provided feedback and additional staff met with the modeling team in Early April 2021 to review the changes and approved the

changes based on a number of modified maps which resulted. These modified maps are included as an Appendix.

Remaining Challenges:

- An outstanding issue is islands (e.g. Apostle Islands) and watersheds (n=16) considered to be "non-contributing" to adjacent watersheds continued to score low after the model improvements. Some of the non-contributing watersheds have been evaluated and are, in fact, hydrologically connected via wetland complexes, for example, to down-gradient watersheds. An "adjustment" indicator, based on objective criteria, may be integrated into the model as a correction for this pattern.
- Currently all HUC6 watersheds are displayed as designated in Wisconsin. There are several small portions of Lake Superior HUC6s (i.e. St. Louis River and South Central Lake Superior) that will may be combined to create a single Lake Superior Basin. On the flip side, the Wisconsin River Basin is large and may be separated into two sub-basins – the Upper and Lower Wisconsin – to align with other program efforts like TMDLs.

High Quality Waters Identification

While the RPS has many advantages for modeling the health and protection potential of watersheds, it is not intended to model the health of individual lakes, rivers, streams, and wetlands. Thus, an alternative process was needed to identify HQW.

We considered our definition of HW and reviewed existing available internal classification schemes and data to create data-driven requirements for a given water to be considered a HQW. To be considered a HQW, a water body had to meet at least two of the three criteria areas below:

- Criteria Area 1: Unique and Rare Natural Communities
    - State Natural Areas (waters within and adjacent)
    - Trout Streams and/ or springs
    - Outstanding and Exceptional Resource Waters
    - Wild Rice Waters (GLIFWC/WDNR 2019 List)
    - Waters in ecologically significant coastal wetlands along Lakes Michigan and Superior as identified in the Coastal Wetlands of Wisconsin
    - Federal or state waters designated as wild or scenic rivers
    - 2-Story fishery lakes with at least one non-stocked native coldwater species
- Criteria Area 2: Water Quality Standards
    - Attaining uses and currently described as "healthy" (Category 2a and 2b Waters)
- Criteria Area 3: Biological Condition
    - Good and/or Excellent macroinvertebrate IBI or Fish IBI scores if a stream or river
    - A rank of "attaining" or "Good" using the Macrophyte Assessment of Condition for Lakes (Mikulyuk et al. 2017)

Wetlands are not currently monitored for Clean Water Act assessment purposes in Wisconsin because numeric water quality criteria have not been established. Therefore, meeting water quality standards was not an option for wetlands, which we anticipated would extremely limit the number of wetlands able to make the HQW list if meeting 2 criteria areas was the threshold for inclusion. Thus, we decided that wetlands needed to only meet one of the following criteria areas for HQW inclusion:

- Criteria Area 1: Unique and Rare Natural Communities
    - Wetland natural communities ranked as vulnerable, imperiled, or critically imperiled within Global or Statewide rankings on the WDNR Natural Heritage Inventory Working List (G1, G2, or G3 with any Srank OR S1 and S2 with any Grank; WDNR 2021)
- Criteria Area 3: Biological Condition
    - Reference Quality Wetlands (O'Connor and Doyle 2017)

Criteria areas were verified by compiling datasets from multiple DNR databases (SWIMS, NHI Inventory, etc.) into Microsoft Excel and using the PivotTable function to gain a count for number of criteria area that were met.

Results

Preliminary draft maps (incorporating initial biologist feedback) displaying ecological index scores for HW have been generated at both statewide and HUC6 scales (Figures 2, 3, and 4). We will report on remaining HUC6s, as well as on general trends, if observable, during future iterations.

Given the sheer number of anticipated identified HQW, we anticipate display of HQW through alternative means such as an interactive map through our WDNR Surface Water Data Viewer or by other reasonable means. Lists of HQW for each HUC12 will likely also be available.

Ongoing and Future Work Towards Completion

Adapting the Recovery Potential Screening Tool as Protection Potential Screening Tool for Wisconsin

Stressor and Social Indices, which are also included within the RPS, were not explicitly included within the calculations for determination of the healthiest watersheds (though some variables inferentially account for the absence of stressors within some variables in the Ecological Index). Instead, we intend to customize the RPS Stressor and Social Indices to reflect 1) trend-based stressors/vulnerabilities (hurdles to watershed protection), and 2) protection opportunities (existing known assets and leverage for watershed protection), respectively. These indices are still in development in collaboration with US EPA, Cadmus, and others providing datasets, but a basic description is provided hereafter for context.

The Vulnerability Index will likely include information such as modeled climate change variables, trends in extent/intensity of permitted water resources alterations, watershed loss of wetland ecosystem services, and land use change variables (i.e. conversion of natural cover to

anthropogenic dominated cover). The Protection Opportunities Index will likely include metrics such as % of lands and shorelands already protected from conversion in the watershed, WDNR Wildlife Conservation Opportunity Areas, WDNR Fisheries priority areas (e.g. Brook Trout Environmental Resilience Reserves), and many others. While Ecological, Vulnerability and Protection Opportunity Indices can be modeled (and viewed if plotted on maps) individually, the use of all three indices as intended within the RPS also can generate a calculated Protection Potential Index—similar to how other states have used the RPS for identifying recovery (restoration) potential. This PPI may constitute a way to prioritize those healthiest watersheds with the greatest potential for protection success in areas with the least modeled vulnerability and greatest known opportunities. More information on the PPI will be included in a later version of this report as the modeling process nears completion.

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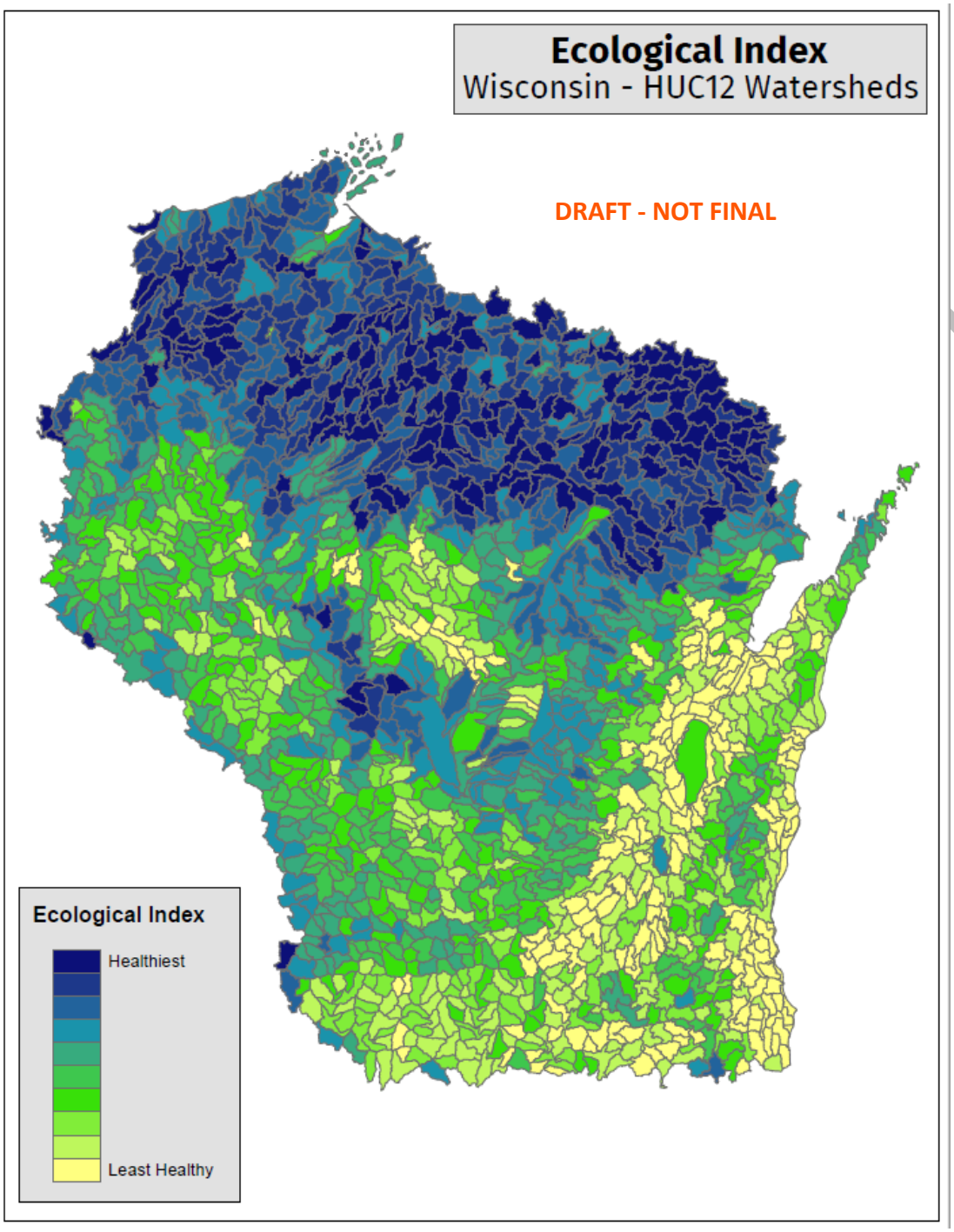
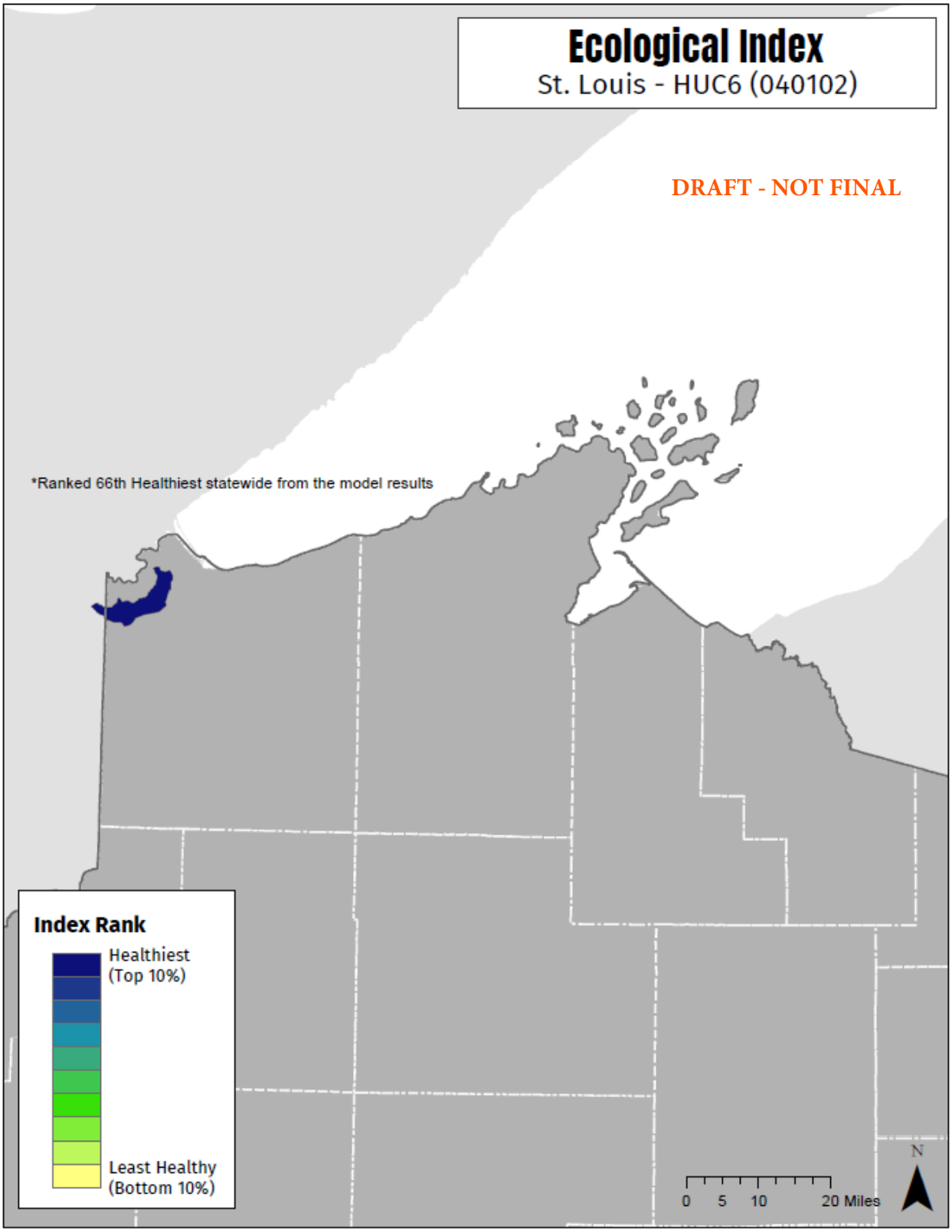
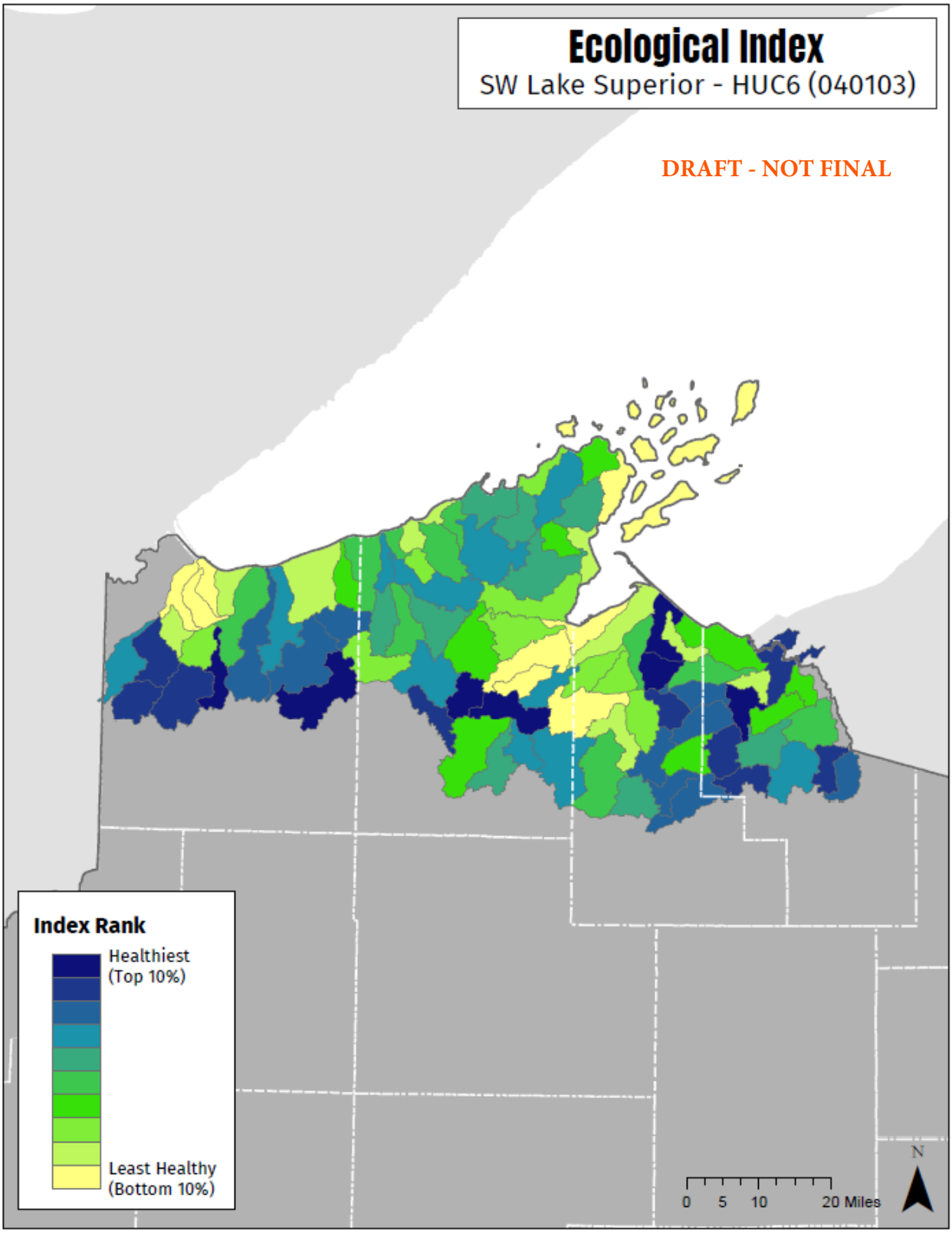
APPENDIX: DRAFT HEALTHY WATERSHED MAPS




Ecological Index
St. Louis - HUC6 (040102)
DRAFT - NOT FINAL
*Ranked 66th Healthiest statewide from the model results
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 5 10 20 Miles
N


Ecological Index
SW Lake Superior - HUC6 (040103)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
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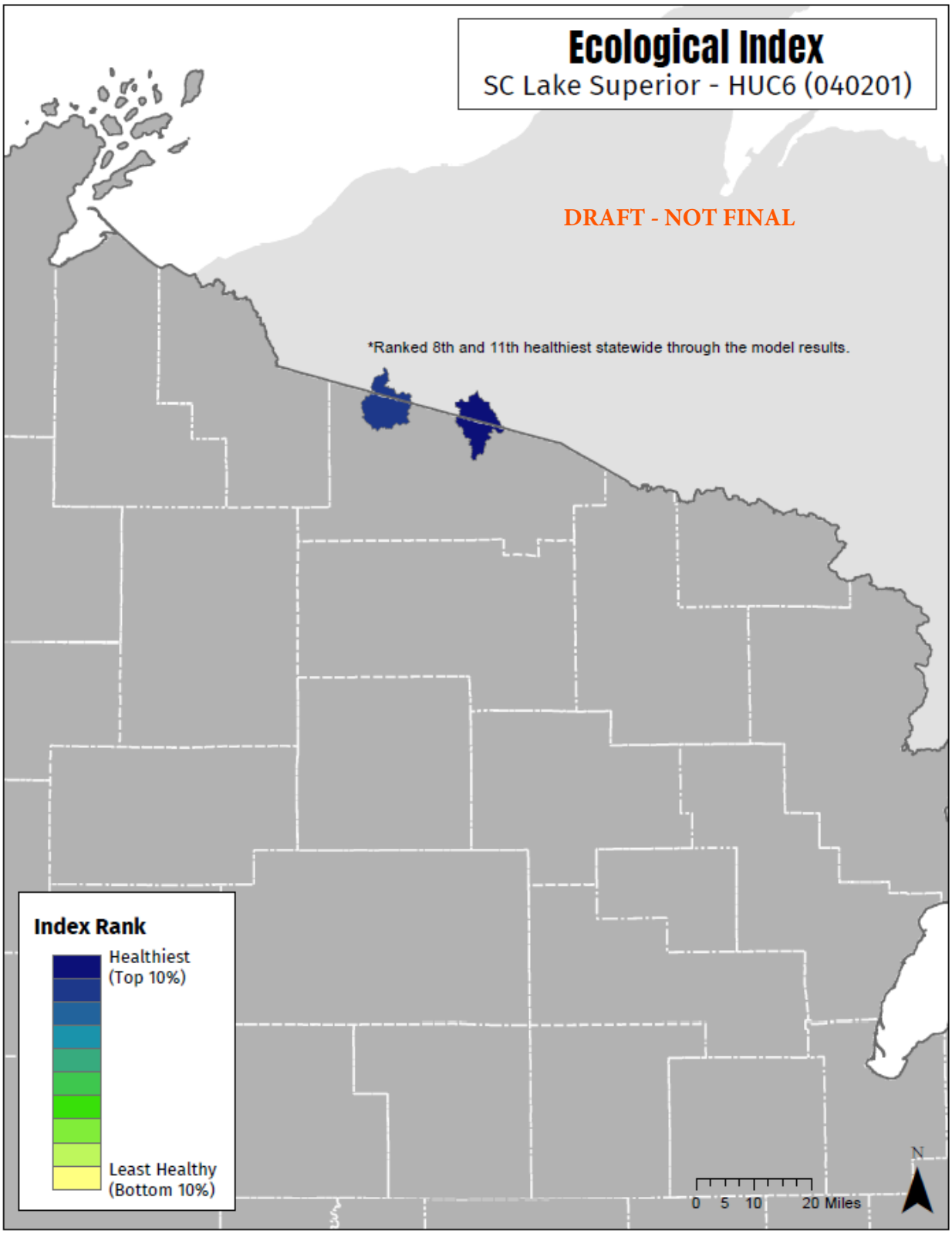
N


Ecological Index
SC Lake Superior - HUC6 (040201)
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*Ranked 8th and 11th healthiest statewide through the model results.
Index Rank
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Least Healthy
(Bottom 10%)
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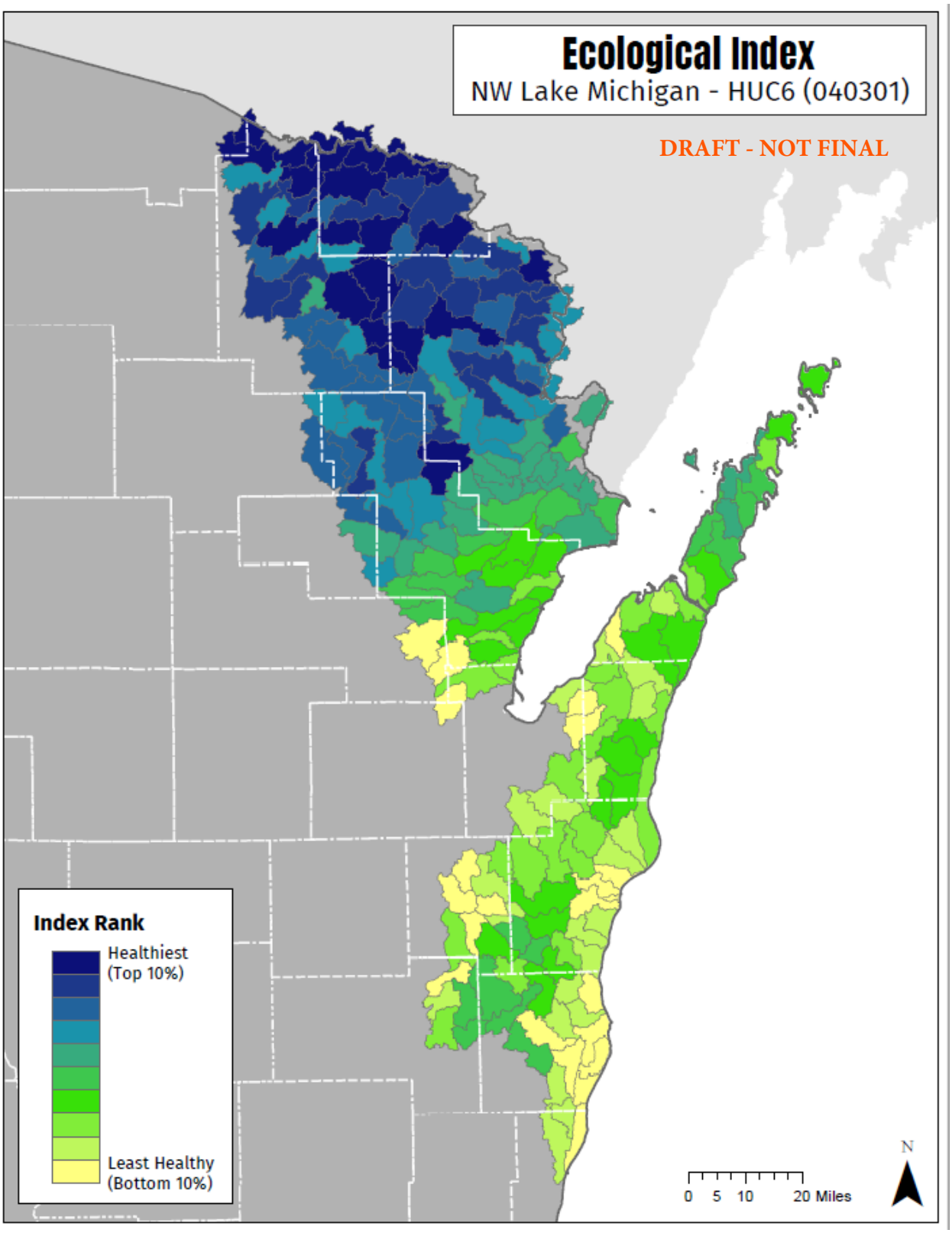
Ecological Index
NW Lake Michigan - HUC6 (040301)
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Least Healthy
(Bottom 10%)
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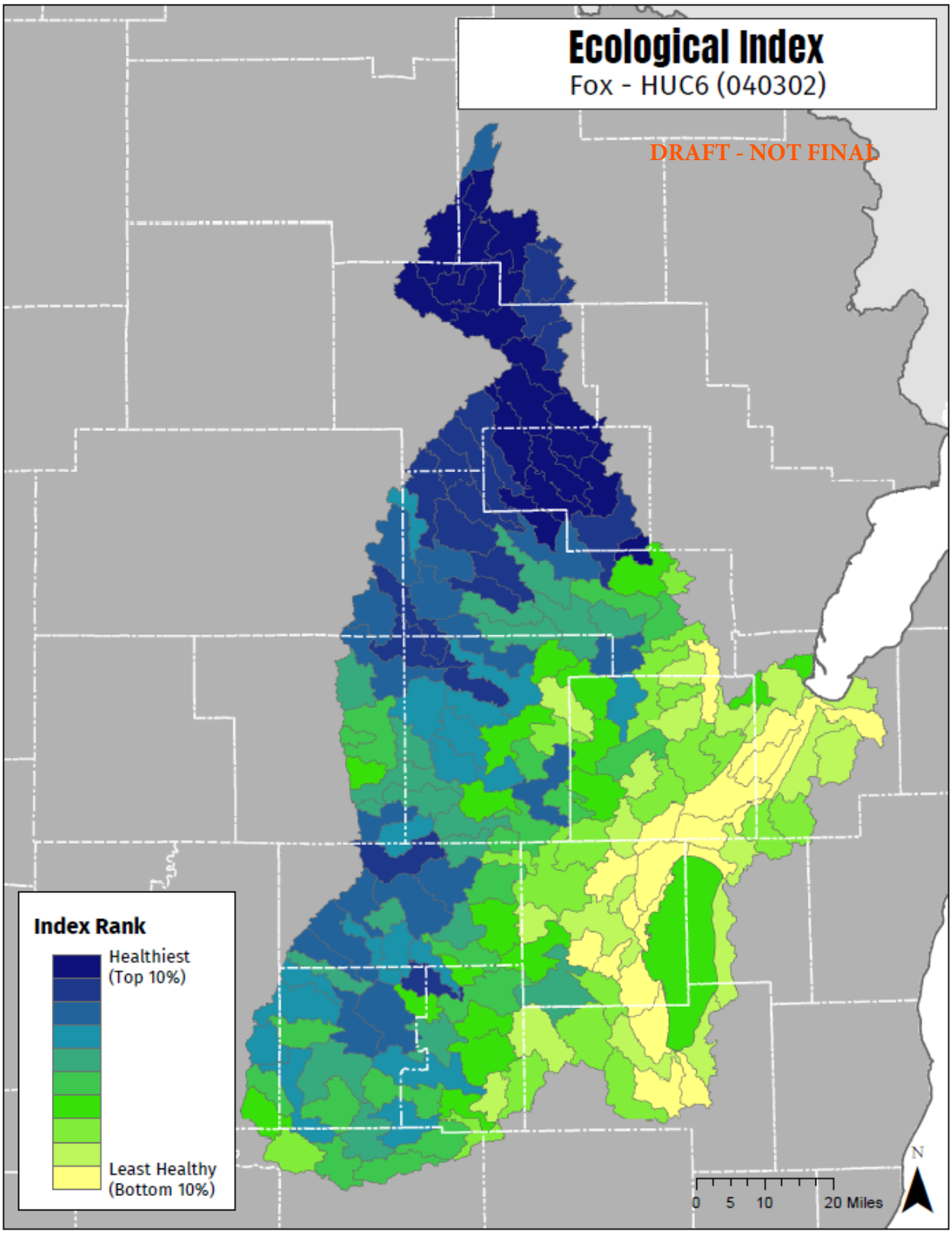
N


Ecological Index
Fox - HUC6 (040302)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
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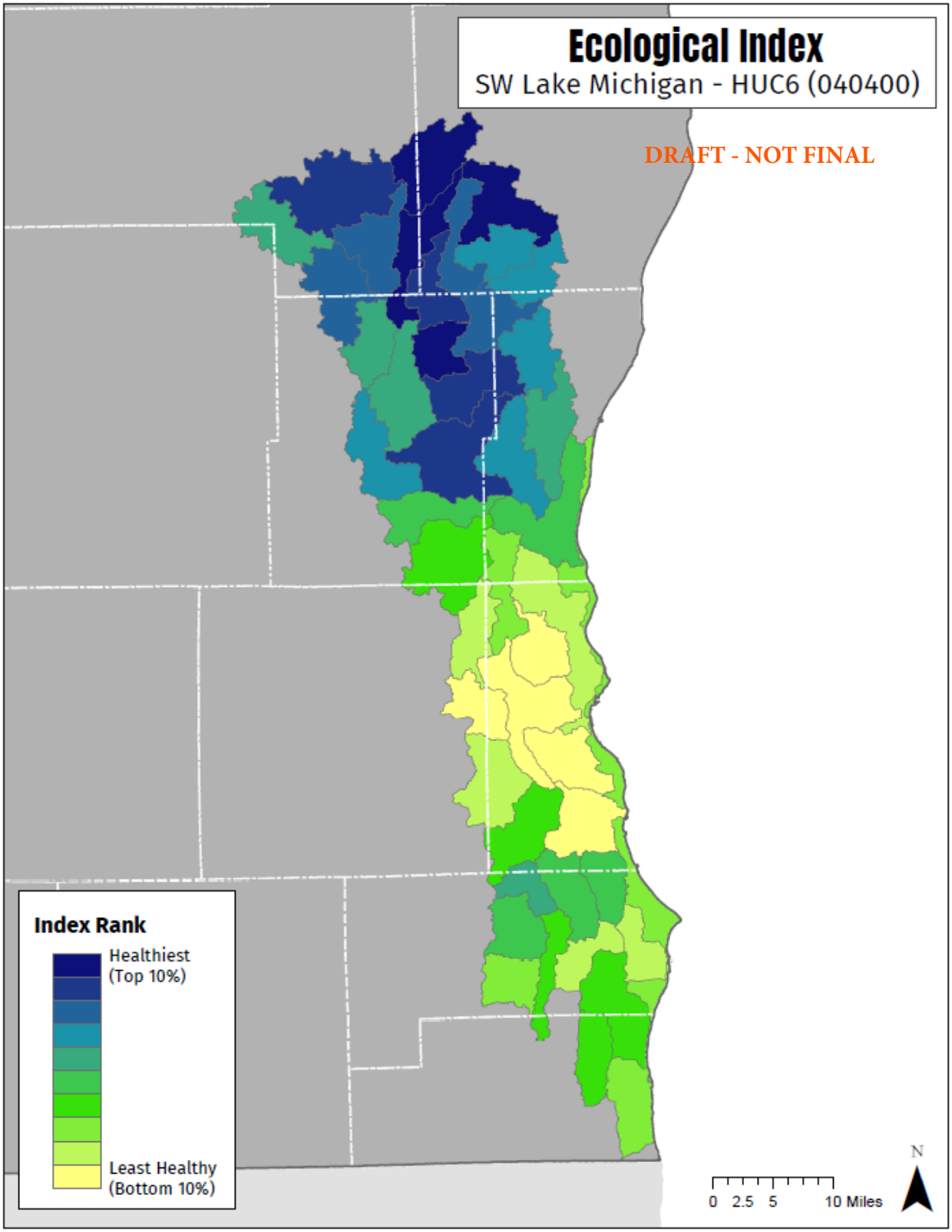
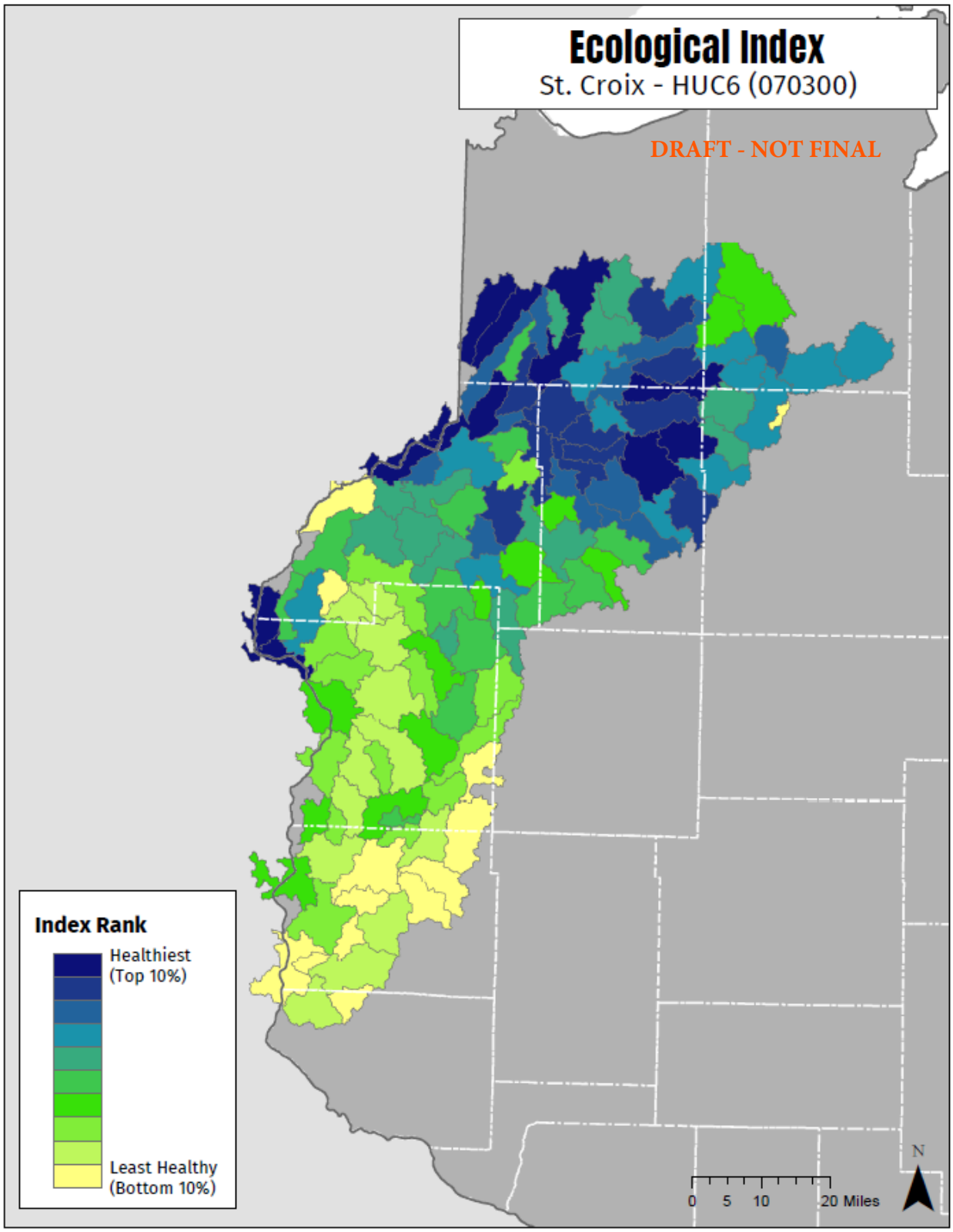
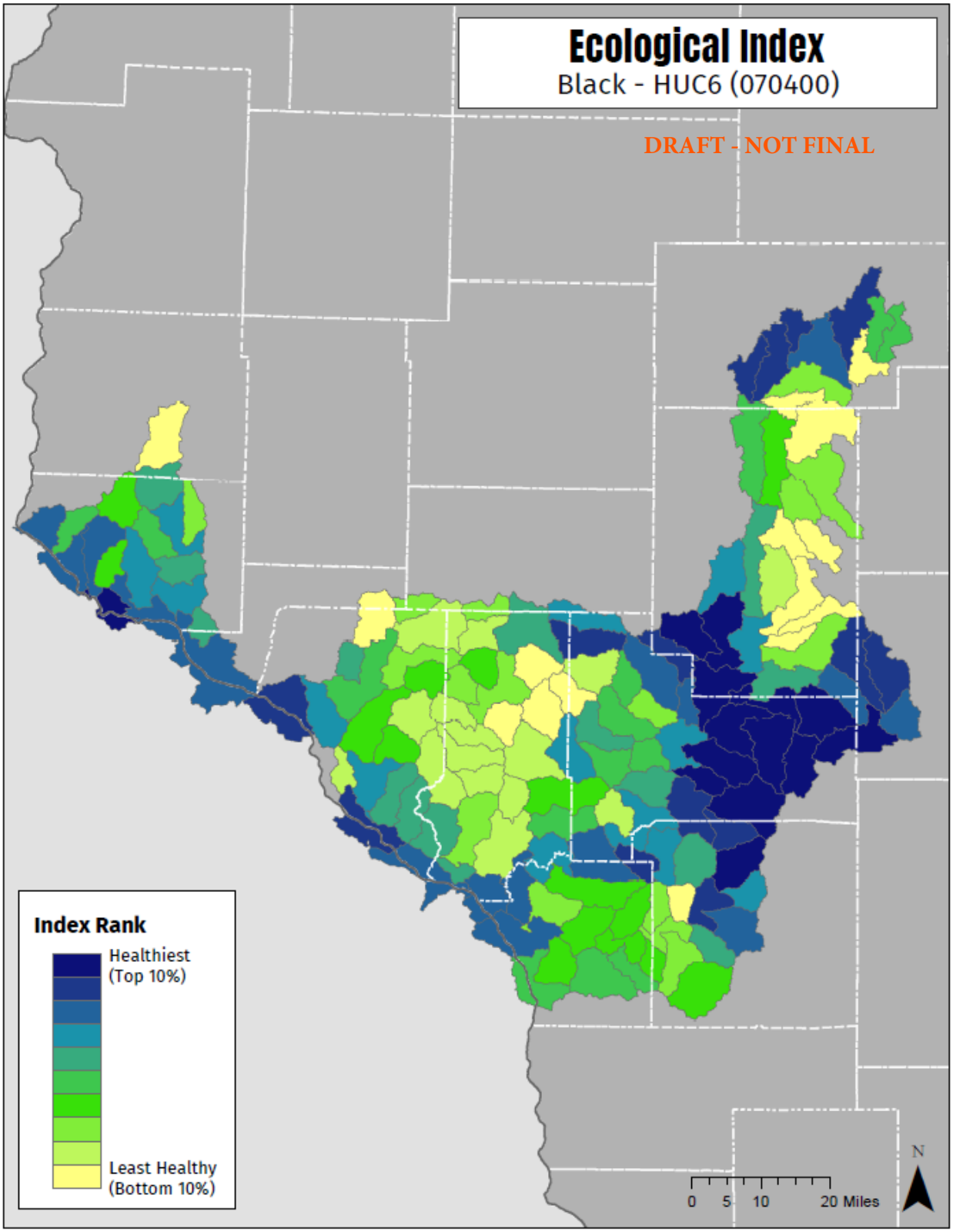
N


Ecological Index
SW Lake Michigan - HUC6 (040400)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 2.5 5 10 Miles
N


Ecological Index
St. Croix - HUC6 (070300)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 5 10 20 Miles
N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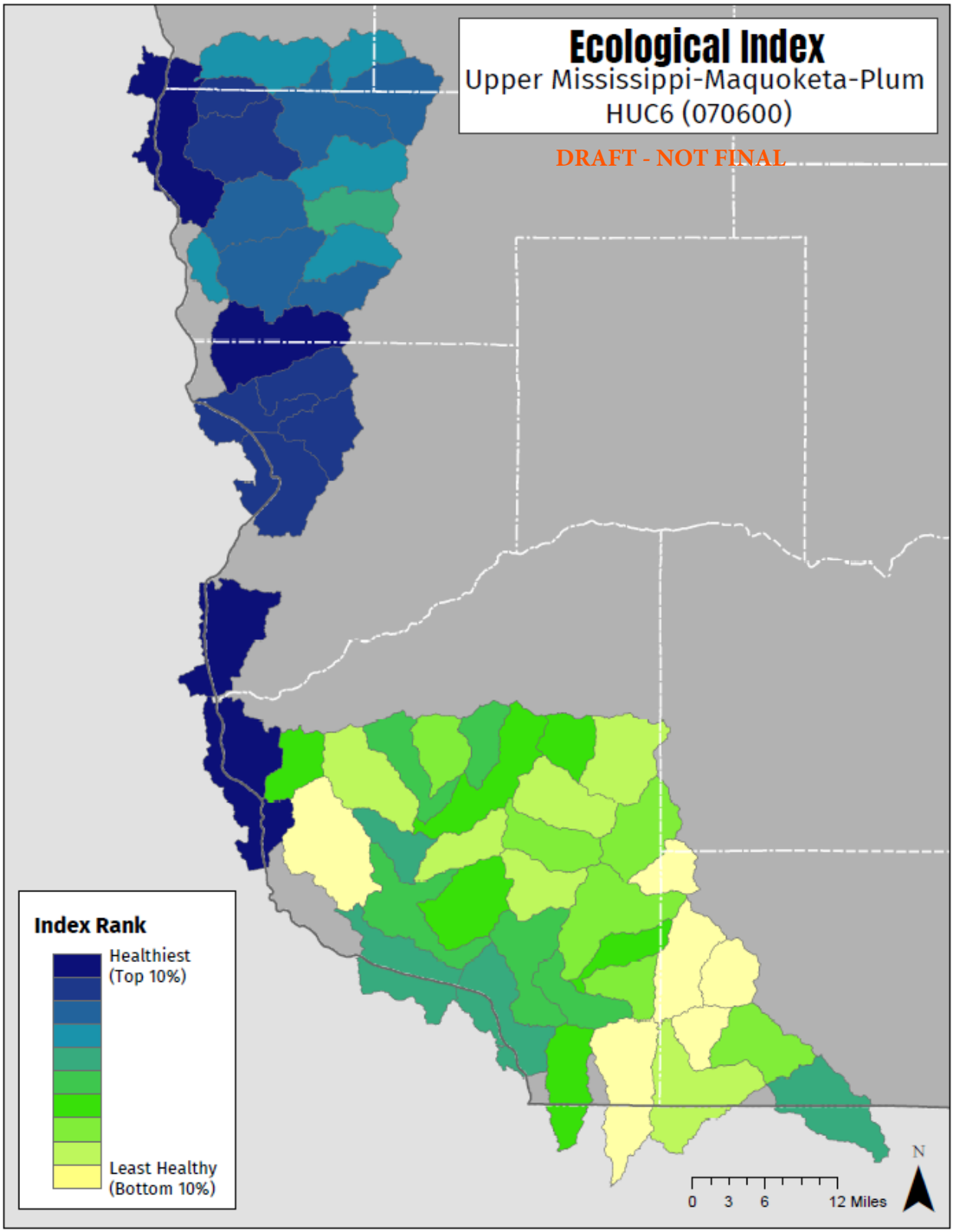
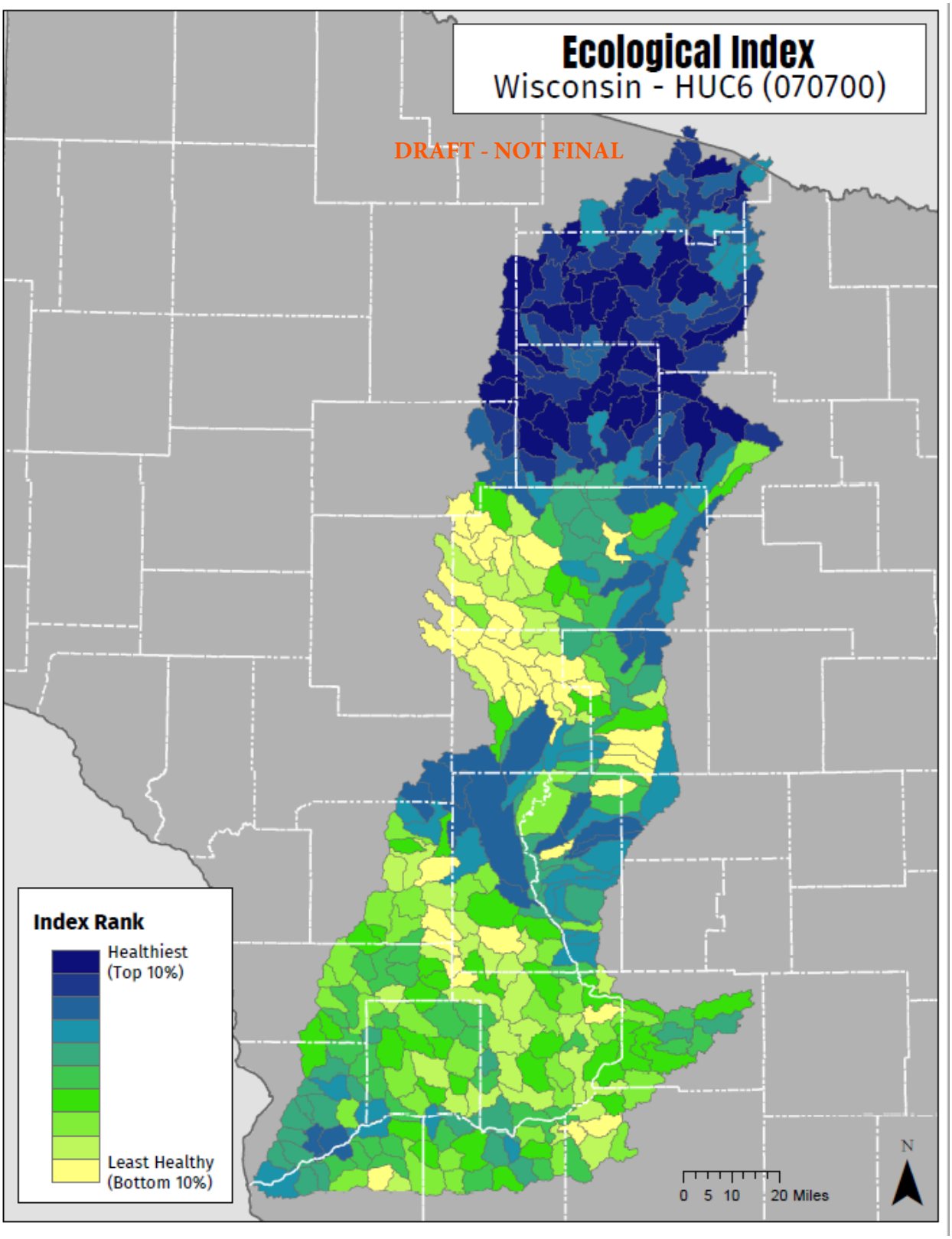
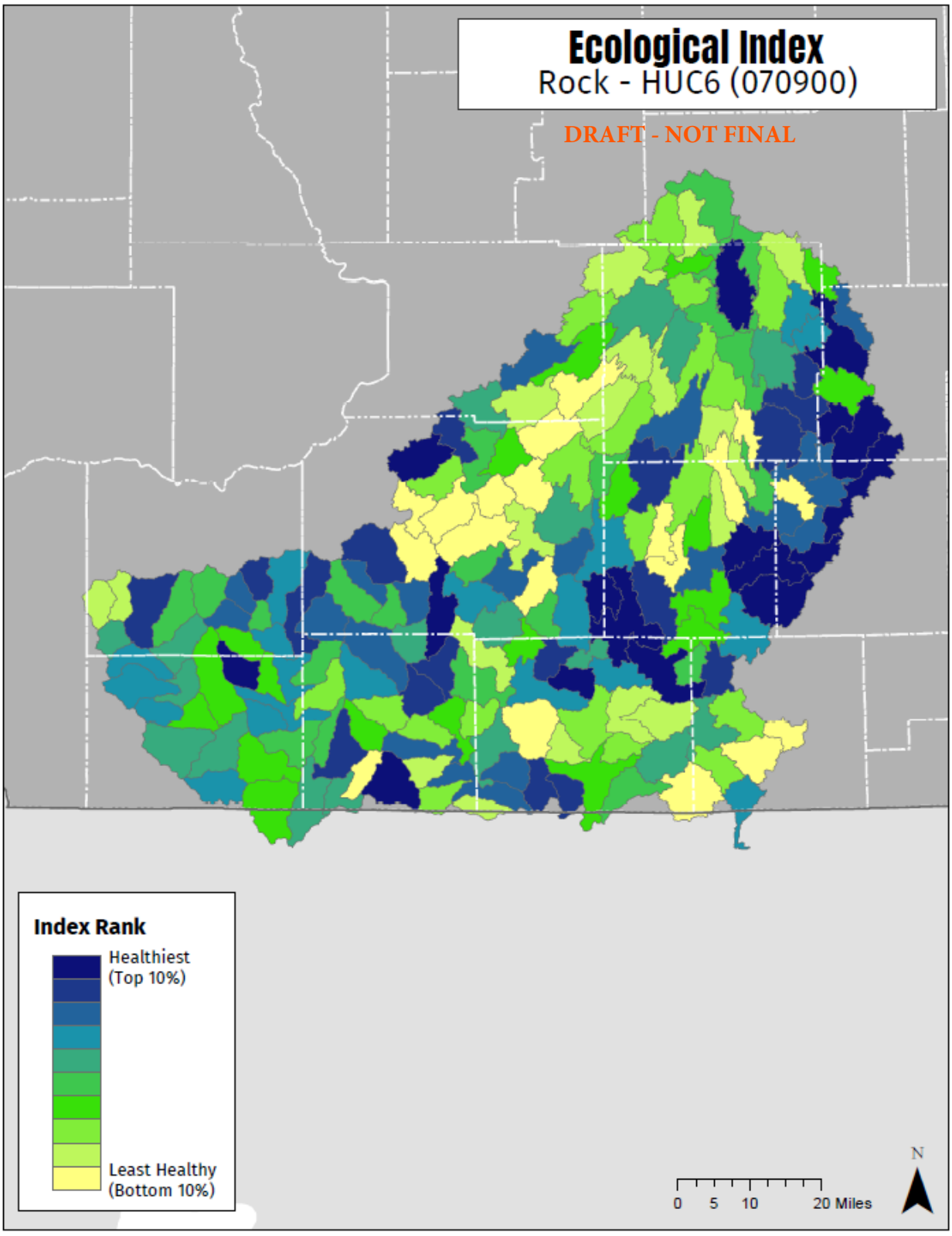
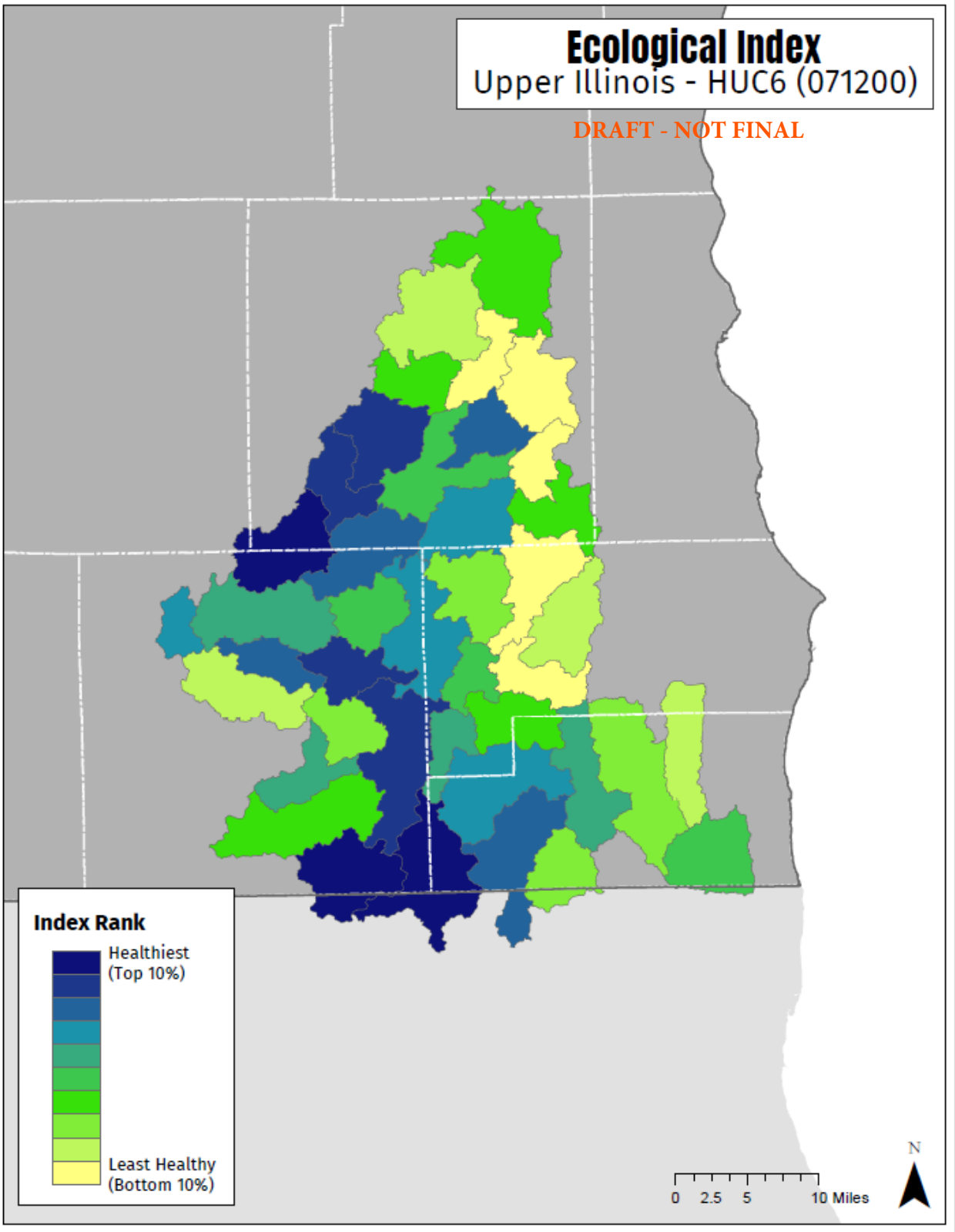

Ecological Index
Upper Mississippi-Maquoketa-Plum
HUC6 (070600)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 3 6 12 Miles
N


Ecological Index
Wisconsin - HUC6 (070700)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 5 10 20 Miles
N


Ecological Index
Rock - HUC6 (070900)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 5 10 20 Miles
N


Ecological Index
Upper Illinois - HUC6 (071200)
DRAFT - NOT FINAL
Index Rank
Healthiest
(Top 10%)
Least Healthy
(Bottom 10%)
0 2.5 5 10 Miles
N