Integrating the Cropland and Wildlife Components of CEAP to Assess and Forecast Benefits of Agricultural BMPs to Biological Endpoints Across the Western Lake Erie Basin Watershed

A Proposal to the Wildlife Component of the USDA NRCS Conservation Effects Assessment Project

Submitted By

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BACKGROUND AND INTRODUCTION

In recent years there has been increased interest in a more thorough understanding and accounting of the benefits of conservation practices to fish and wildlife. This increased interest is particularly strong in agricultural landscapes as a result of the significant increase in funding for conservation programs authorized under the 2002 Farm Bill. In response, the Conservation Effects Assessment Project (CEAP) was initiated by the USDA Natural Resource Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES) to help inform society of the benefits of USDA conservation program funding. The original goal of CEAP was to establish a scientific understanding and methodology for estimating environmental benefits and effects of conservation practices on agricultural landscapes at national, regional, and watershed scale (Maresch et al. 2008). In 2005, USDA engaged the Soil and Water Conservation Society (SWCS) to assemble a panel of academics and conservation community leaders (the SWCS CEAP Blue Ribbon Panel). This panel was charged with providing recommendations on 1. how to ensure that CEAP is and remains relevant, responsive, and credible and 2. how to ensure that CEAP products have utility for program managers, policy makers, and the conservation community. While the panel strongly endorsed CEAP's overarching goal, it recommended that the CEAP plan be expanded and adjusted: "CEAP must change direction to become the coherent, science-based assessment and evaluation system … needed" (SWCS 2006).

Following release of the Blue Ribbon Panel's recommendations, CEAP expanded research, assessment, education, and outreach efforts. CEAP is complementing retrospective assessments of the effects and benefits of conservation practices with forward-looking assessments to help determine how to best manage agricultural landscapes to more effectively meet environmental goals at local, regional, and national levels. The goal of CEAP is to improve efficacy of conservation practices and programs by providing the science and education needed to enrich conservation planning, implementation, management decisions, and policy. CEAP is addressing this goal by creating and using knowledge gained through CEAP research to enhance conservation planning, models, and decision tools and by continuing to assess environmental and ecosystem effects of conservation.

Three principal coordinated activities will guide investments in addressing the goal of CEAP: (1) research to advance our knowledge of linkages between conservation practices and environmental quality, (2) retrospective assessments of conservation benefits and (3) forecasting costs and benefits of practices to a broader suite of ecosystem endpoints to enhance conservation planning and improve the effectiveness and efficiency of conservation programs. The research and assessment activities will continue to address the effects of conservation on four components: croplands, wetlands, wildlife, and grazing lands (Duriancik et al. 2008). However, to work toward establishing an operational framework for assessing, reporting, and forecasting benefits to the full suite of ecosystem services affected by USDA conservation programs, CEAP must seek to integrate the research and assessment efforts across these four components (Maresch et al. 2008).

CEAP teams responded quickly to the need for integration between and across the four components. The Wildlife Component of CEAP used methods that would facilitate integration with the Cropland Component when it launched the Great Lakes CEAP project in 2008 to provide the science needed to assess and forecast the benefits of NRCS conservation practices to biological endpoints. The overarching question of Phase 1 of the Great Lakes CEAP project was;

Can a fine-resolution SWAT model be developed across a large geographic region and can resulting model outputs (water quality and quantity predictions) serve as inputs to models that predict biological endpoints?

As detailed by Sowa et al. (2011) and Einheuser et al. (In Press A and B), the collective answer to this question was—Yes. However, the Great Lakes CEAP project also identified room for improvement, including limitations of this proof of concept project. Suggestions for addressing these limitations to improve the accuracy the models and assessments are listed below, but a detailed description for each is provided in **Appendix A.**

1. Further downscale SWAT models to increase sample sizes necessary for accurate predictions by biological models
2. Incorporate multiple taxonomic groups for biological endpoints
3. Fill critical data gaps for key predictor variables, like drainage tiles
4. Incorporate future climate scenarios into SWAT models
5. Incorporate a spatially distributed calibration into the SWAT model calibration process
6. Use complementary outputs of SWAT and SPARROW models to provide data inputs for the biological models

The Great Lakes CEAP project is a successful proof of concept project and up to this point has worked independently from the Cropland National Assessment Team. However, through recent meetings, these two teams have determined that enough groundwork has been done within each discipline that they are now ready to combine their knowledge bases and work together to address the recommendations of the Blue Ribbon Panel, Sowa et al. (2011), and Einheuser et al. (In Press A & B) listed above. These two-team meetings led to the development of the project proposed herein, which will foster a more formal integration of the Wildlife and Cropland Components of CEAP and provide important benefits to all of the major partners collaborating on this project. Specifically, our **goal is to advance strategic conservation through the integration of the research and modeling elements of the Wildlife Component of CEAP with the assessment and modeling elements of the Cropland Component of CEAP.** In other words, our goal is to – get the right amount of the right conservation practices to the right places to achieve ecologically-meaningful outcomes.

PROJECT AREA

Our proposed project area includes most of the Western Lake Erie Basin (WLEB) watershed and nearshore habitats within Maumee Bay (Figure 1). Specifically, our proposed project will focus on the Maumee, Sandusky, and River Raisin watersheds, from which three to five priority subwatersheds will ultimately be selected. Working with key partners, we will develop detailed conservation prescriptions with Cropland and Wildlife conservation methods and metrics. . The WLEB is dominated by agricultural land use and has been identified as a top priority for The Nature Conservancy (TNC) and many other conservation organizations and agencies. The basin covers portions of three states—Indiana, Michigan, and Ohio.

Figure 1. Map of the proposed Western Lake Erie Basin (WLEB) CEAP project area.

GENERAL APPROACH

Our approach has two primary components: 1) Science and Technology Component (STC) and 2) Communication and Collaboration Component (CCC). The STC involves many data development and analytical tasks that collectively address the recommendations of the Blue Ribbon Panel and Sowa et al. (2011) to foster a deeper integration of the Wildlife and Cropland Components of CEAP. For sake of brevity the body of the proposal focuses on the specific tasks and outputs of this collaborative effort. However, **Appendix B** provides a more thorough description of the core data inputs, modeling methods, and outputs of the Cropland National Assessment and the Great Lakes CEAP project, as well as the proposed points of integration. Discussion in **Appendix B** goes on to clearly describe how this integration will be operationalized and what benefits can be expected to result. The CCC involves a series of education, outreach, and collaborative decision making tasks to communicate the outputs from the science component in a manner that is easily understood, which should promote acceptance of the science and resultant conservation recommendations. Ultimately it is the CCC that will translate science into actions taken by policy makers, resource managers, and other sectors of society.

OBJECTIVES AND MAJOR TASKS

Science and Technology Component (STC)

Objective 1: Develop a downscaled SWAT model for WLEB
For this objective the USDA ARS will work with a Postdoctoral student and technician to construct, calibrate, validate and run land use and climate scenarios for SWAT simulations across the WLEB. The SWAT outputs will be used as instream habitat predictor variables and will serve as inputs to the models developed to model biological indicators across WLEB (Objective 2).

Successful completion of this objective requires completion of three tasks:

1.1 *Construct baseline SWAT simulation*

A downscaled baseline SWAT model will be constructed for the WLEB using the primary 1:100,000 National Hydrography Dataset-Plus (NHD-Plus) units as the SWAT subbasins/routing units. The NHD-Plus units will be aggregated as needed with an average subbasin drainage area of less than five square miles. The SWAT output will provide daily time series of flow, sediment, nitrogen, phosphorus, and atrazine loads and concentrations at each subbasin outlet based on both historic and current land cover/use. These daily time series values will then be used to generate monthly, seasonal, and annual estimates for each variable.

The following data will be assembled and processed to create the SWAT input files.

Base Model Data

- Topography – US Geological Survey (USGS) 30m (or better) Digital Elevation Models (DEM).
- Soils – USDA/Natural Resources Conservation Service, Soil Survey Geographic (SSURGO) data.
- Landuse – USDA/National Agricultural Statistics Service (NASS), Cropland Data Layer (30m) Additional data from previous years may be used to better define crop rotations as deemed necessary.
- Historic land cover – USDOI Landfire potential natural vegetation layer
- Fertilization Rates – Derived from US agricultural census crop yield and fertilizer sales data at the USGS 8 digit HUC level.
- Tillage –USGS published estimates for conservation and no-till by crop at the USGS 8 digit HUC level. These data were derived from surveys collected by the Conservation Technology Information Center.
- Streams – Derived from USGS National Hydrography Dataset (NHD). May be aggregated as needed to maintain model feasibility.

- Climate –Temporally seamless daily (1950-2010) temperature and precipitation derived from National Weather Service first order and Cooperative Observer Network observations.
- Crop Management – Planting dates, harvest dates and tillage operations will be derived from NRCS typical management scenarios by crop management zone.
- Point Sources –Estimates produced by the USGS Spatially Referenced Regressions on Watershed Attributes (SPARROW) research group.
- Subsurface Tiled Area
- Atrazine Application Rates

Calibration/Validation Data

- Streamflow – Gaging stations (USGS, Heidelberg College) data will be separated into surface runoff and baseflow fractions.
- Sediment and Nutrient Loads – Rating curves will be developed by regressing discrete sampling data (sediment, nitrogen and phosphorus) with measured streamflow. The resulting rating curves will be used to predict monthly or annual loads at individual sites for use in calibration/validation. Existing sediment and nutrient load estimates will be included where available. The number of site will be based on a feasibility assessment at the time of model calibration.
- SPARROW - Sediment, nitrogen, and phosphorus total annual load and concentration estimates from the regional SPARROW model.

1.2 *Calibration and Validation of SWAT Model*

The USGS has assembled national and local databases for sediment and nutrients to develop total annual loads for regional SPARROW models. We will use load data they have assembled and SPARROW output to spatially calibrate SWAT to total annual loads at the 12 to 10 digit watershed scale. After achieving spatial calibration, further calibration and validation will be performed with gaged time series data from USGS, Heidelberg College, and other sources. Calibrations and validations will be performed on monthly and annual time series and will include both organic and inorganic forms of nitrogen and phosphorus.

1.3 *SWAT Model Modifications and Scenario Development to Support Objective 3*

In collaboration with local scientists and engineers, scenarios will be developed based on projected climate change, land use, and land management practices. SWAT will be enhanced to include new drainage practices that show promise in controlling soluble phosphorus. The research team in Temple, Texas will modify SWAT to: 1) include new management practices, 2) provide calibrated model and all baseline data, and 3) assist in developing SWAT scenario data sets used in Objective 3. The local research team will work with the WLEB Advisory Panel (see Objective 4) and other local conservation district and NRCS staff to help with developing and implementing the SWAT scenario analysis simulations used in Objective 3.

Objective 2: Develop models that predict selected riverine biological endpoints based on SWAT output variables and other relevant watershed and local catchment variables

For this objective TNC and Ohio Sea Grant will work with a postdoctoral student and technician to follow and build upon the modeling and assessment methods developed by the Great Lakes CEAP project. The modeling outputs and maps for this objective will provide estimates of current biological thresholds and/or conditions for selected fish and macroinvertebrate metrics for each SWAT subbasin across the entire WLEB project area.

Successful completion of this objective requires completion following four tasks:

2.1 *Compile available biological data for WLEB project area*

We will compile available biological data for both fish and macroinvertebrates for the entire WLEB project area and spatially link it to the modified NHD-Plus developed in task 1.1. There are many excellent sources of publicly available biological data for WLEB, including: Ohio Environmental Protection Agency (OH EPA), Michigan Department of Natural Resources (MDNR), National Oceanographic and Atmospheric Administration (NOAA), and the Midwest Biodiversity Institute. We estimate as many as 10,000 fish and/or macroinvertebrate community samples are available for the WLEB project area. Within ArcGIS we will spatially join each biological collection to the modified NHD-Plus via spatial joins and manual methods similar to those used by the Great Lakes CEAP project.

2.2 *Compile available data on physiographic and human disturbance factors*

We will compile existing data on physiographic and human disturbance factors that influence selected biological endpoints and spatially link it to the modified NHD-Plus developed in task 1.1. Data for natural landscape features like geology, soils, and landform will be obtained from the United States Geological Survey (USGS) Great Lakes Aquatic Gap Analysis Program (GAP) Project. Data for non-agricultural human disturbances that also alter riverine habitats will be compiled from multiple sources, including;

1. USGS Great Lakes Aquatic GAP
2. U.S. Fish and Wildlife Service National Fish Habitat Action Plan (NFHAP) national assessment
3. University of Michigan Great Lakes Environmental Assessment and Mapping Project
4. USEPA Great Lakes Environmental Indicators Project

These data will be quantified for each local catchment and overall watershed for each of the stream reaches in the modified NHD-Plus across the entire WLEB project area.

2.3 *Identify ecological thresholds and relations between SWAT outputs and biological endpoints*

We will use multiple analyses to identify ecological thresholds for select fish and macroinvertebrate biological response variables and to isolate relations between these response variables and SWAT model outputs. We will use an integrated set of univariate and multivariate analytical and modeling methods, similar to those used by Sowa et al. (2011) and Einheuser (2011) for this task. The outputs for this task will provide a set of estimates of current biological thresholds and/or conditions for selected fish and macroinvertebrate metrics for each SWAT subbasin across the entire WLEB project area.

2.4 *Model and map estimates of current biological conditions for selected biological metrics across the entire WLEB.*

An integrated set of modeling and ArcGIS mapping methods developed by Sowa et al. (2011) and Einheuser (2011) will be applied to visualize the model estimates across the WLEB project area. These methods do not produce a single model to predict current biological conditions, but rather sets of models (multimodel) that are used collectively to produce a single mapped estimate of current biological conditions. The outputs for this task will be maps that display single mapped estimates of current biological thresholds and/or conditions for selected fish and macroinvertebrate metrics for each SWAT subbasin across the entire WLEB project area.

Objective 3: Use SWAT and the companion biological models to map estimated changes in water quality, quantity, and biological endpoints likely to result from multiple conservation scenarios.

To help develop realistic and strategic conservation plans for the WLEB project area we will develop sets of possible future conservation scenarios that consist of different combinations and densities (e.g., low, medium, and high) of selected conservation practices. We will then use the models developed in Objectives 1 and 2 to estimate the costs and forecast changes in water quality, quantity, and biological endpoints likely to result from these conservation scenarios. Outputs from these models will be used to help establish realistic goals for conservation practices within each priority subwatershed, consisting of an achievable amount of practices that should produce ecologically meaningful improvements in the biota.

Successful completion of this objective requires completion of the following six tasks:

3.1 *Select 3-5 priority subwatersheds across the WLEB project area*

Because of the relatively large size and complexity of the WLEB, coupled with the time and cost of using SWAT to develop future conservation scenarios across such a large area, we propose selecting 3-5 priority subwatersheds (~ 8 digit HU in size) to provide a representative subset with which to demonstrate the modeling capabilities developed in this project.The project team and WLEB Advisory Panel (see Objective 4) will select priority subwatersheds to primarily represent varying proportions of agricultural land cover (25 to 80+%). We will also attempt to represent variations in the current densities of conservation practices, and in existing ecological conditions. Having subwatersheds with different levels of agricultural impacts will allow us to perform "macro-level" comparisons of costs versus benefits associated with each conservation scenario.

3.2 *Select 10-15 representative conservation practices or suites of practices*

We will use NRCS practice data combined with expert judgment to select a set of 10 – 15 conservation practices or suites of practices to include in scenarios for analysis. The practice data will be used to determine the frequency of various practices across the WLEB and within the 3-5 priority subwatersheds. Most of the 10-15 practices will be represented by the most frequent practices that are also beneficial for hydrologic improvement. For the remaining practices we will use expert knowledge to select less-common practices that would provide significant ecological benefit, potentially including practices that are not yet used in NRCS programs or included as options in SWAT (e.g., two-stage ditches). This selection process will need to also consider differences in conservation practice "preferences" between Ohio, Michigan and Indiana.

3.3 *Select three potential future climate scenarios*

Several climatic factors, such as the amount, timing, and intensity of precipitation, are projected to change significantly in many parts of the United States, including the Great Lakes (Magnuson et al. 1997). These changes will likely translate into significant changes in surface runoff, erosion, and thus sediment and nutrient loading to receiving waters. The Great Lakes CEAP project found that incorporating these projected changes are essential to forecasts of likely benefits of future conservation investments (Einheuser et al. In PressB). Failing to account for such changes might lead to inflated estimates of likely benefits to water quality, quantity and biological endpoints. To address this issue the project team will work with the WLEB advisory panel to select/define three likely climate change scenarios for the project area and select the data to be used for incorporating these scenarios into SWAT.

3.4 *Develop 3-5 potential future conservation scenarios*

We will develop a set of 3-5 possible future conservation scenarios that consist of different combinations and densities (e.g., low, medium, and high) of the selected conservation practices. The different practice densities may range from no practices applied (similar to the Cropland National Assessment) to practices placed on 25, 50, or even 100% of the farmland in each subwatershed. Having this range of practice densities will allow us to develop cost-benefit curves between the cost of each scenario and the estimate change (benefit) in the water quality, quantity, and biological metrics to help select realistic goals.

3.5 *Model and map estimates of likely future biological conditions for selected biological metrics across the entire WLEB.*

For each of our priority subwatersheds we will use SWAT and the associated biological models to estimate the likely future water quality, flow, and biological conditions resulting from the 9-15 conservation-climate scenarios (*Note we will have 3-5 conservation scenarios times the 3 climate scenarios*). We will then map the resulting estimates within a GIS to visualize the patterns of predicted changes across the priority subwatersheds. The outputs for this task will be maps showing estimates of likely future water quality, flow, and biological conditions for each SWAT subbasin throughout each priority subwatershed.

3.6 *Compare and contrast the estimated benefits of the conservation scenarios*

The project team will work with the WLEB advisory panel to compare and contrast the predicted outcomes from the different conservation scenarios, looking both within and among the priority subwatersheds. These comparisons will consider the estimated costs, benefits, and social, economic, and logistical realities of the scenarios. These comparisons will give us a basis for setting realistic goals for the types, amounts, and locations of conservation practices within and across each subwatershed based on our ability and cost of reaching predicted, ecologically-meaningful, improvements in biological conditions.

Communication and Collaboration Component (CCC)

Objective 4: Develop and implement effective communication and collaboration strategies for the WLEB CEAP project

To be an effective application of science, the outputs from this project must be relayed to stakeholders in a way that will encourage the use of good science in the development of realistic conservation goals and strategies to achieve them. The CCC is designed to make the results accessible to stakeholders in a way that will enable them to understand, accept, and incorporate the scientifically based principles in their land-management decision making. To do this we will need to work with key partners to demonstrate the connections our project fosters between science, technology, strategic conservation, and realistic improvements in water quality and biological conditions. The outputs from this project, particularly those developed in tasks 2.4 and 3.6, need to be integrated into land management policies and procedures funded by public agencies and by appropriate industries. This approach represents fundamental change to how conservation goals and strategies are established and it will be necessary to begin developing support for it among agencies and the agricultural industry at the beginning and throughout the project. To that end, we will work both regionally (i.e., within the WLEB) and nationally to communicate and seek input on project and approach.

Successful completion of this objective requires completion of the following three tasks:

4.1 *Establish a WLEB Advisory Panel to help guide the WLEB CEAP project*

To garner acceptance and facilitate the use of the project outputs locally, we will create a WLEB Advisory Panel with representatives from TNC, state NRCS, USEPA, land grant extension agencies, active watershed groups, Farm Bureau, research universities, USDA service centers, and the national CEAP effort (e.g., Charlie Rewa, Lee Norfleet). This Advisory Panel functions will include:

- Serve as a sounding board for technical, logistical, and sociopolitical aspects;
- Help develop and execute regionally specific outreach efforts;
- Test the various model estimates locally;
- Demonstrate how the projects outputs can be used to develop realistic goals and guide strategic conservation
- Facilitate communication and acceptance of the project outputs with resource managers, administrators, legislators, and most importantly landowners.

4.2 *Establish an Expanded National CEAP Team to help guide the WLEB CEAP project*

The methods of this proposed project can be used anywhere there is sufficient input data to develop downscaled SWAT models and the associated biological models. Given the interest and need for integrating the Wildlife and Cropland components of CEAP beyond just the Great Lakes, we propose there is a need to inform other regions of this work to facilitate expansion of this approach both regionally and nationally. To help meet this challenge we propose to establish a National Advisory Panel. The national CEAP representative from the WLEB Advisory Panel will also sit on a National Advisory Panel to provide communication and continuity. A representative with similar skills, knowledge, and interests as members of the project team, from the Upper Mississippi River or other Major River basin will sit on the panel to provide "outside" input and assist with transferring acceptance to other regions. The National Panel should also have representation from the leads of each CEAP component (i.e., Wetland, Rangeland, Cropland, Wildlife, and Watershed), the two Post Docs hired for this project, and the project leads from TNC and participating universities. The

National Advisory Panel will help communicate rationale and benefits of the approach used in this project to both regional and national audiences to:

- Facilitate expanding this approach to other regions of the US; and
- Influence administration, funding and legislative policies that advance using the results of this work to inform strategic conservation.

4.3 *Develop and implement an effective overarching project management strategy*

Our proposed project requires and represents a large collaborative effort involving a large number of people and organizations with the right skills, knowledge, and resources needed to successfully complete specific tasks. However, successful completion of the four objectives and the overall goal of this project demands that these discrete activities are effectively integrated at all stages of the project, which can only be accomplished through effective communication and coordination among all members of the larger project team. To facilitate such interaction, within the first 6 months of the project, we will develop an overarching project management strategy that serves to integrate the actions of the individual partners over the course of the project. Specifically, we will develop objective specific work plans to clarify the roles and responsibilities of each partner for each deliverable and task for each objective and also the timelines for completion. We will also develop a communications strategy to guide the interaction and exchange of information among all members of the overall project team.

BENEFITS

Our proposed project addresses many of the recommendations made by the Blue Ribbon Panel for future directions of CEAP and integration of the various subcomponents. Specifically, the science elements of our project fosters integration of the Cropland and Wildlife Components of CEAP to enable both retrospective assessment and forecasting of likely benefits of conservation practices to physical, chemical, and biological endpoints. The collaboration component fosters improved communication between stakeholders with different interests and needs. Through improved dialogue around science linking socioeconomic and ecological data and perspectives we anticipate that future conservation efforts within the WLEB watershed can be strategically designed to meet reasonable goals across stakeholders. Finally, this project offers many tangible benefits to all of the major partners collaborating on this project.

Table 1. List benefits of this proposed project to each major partner

Wildlife Component of CEAP:

a. Putting science developed in the Wildlife Component into practice
b. Providing assessments and forecasts of biological conditions resulting from existing or possible future conservation practices and climate scenarios.

Cropland Component of CEAP:

a. First rigorous test of the accuracy of a downscaled SWAT model covering a relatively large geography.

b. Expanded applicability of the SWAT model: proof of concept of the ability to use SWAT model outputs (water quality and quantity predictions) as inputs for models that predict biological endpoints

TNC Great Lakes Project:

a. Provide a spatially explicit, science-based, foundation to develop realistic expectations for biological conditions across Western Lake Erie Basin watershed.
b. Serve as a proving ground for integrating multiple TNC Great Lakes Project strategies within a single geography.
c. Provide national and international leadership and guidance for linking conservation actions to biological endpoints in a scientifically rigorous manner to inform conservation actions.

The Ohio State University and Ohio Sea Grant College Program:

a. A research project that pushes the frontier of science-based strategic conservation and developing the models that help support it.
b. An example and experience for students of collaborative research that integrates the science, economics, and social elements of agricultural systems and conservation that influence Lake Erie and the Great Lakes.

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Appendix A: Possible solutions, identified by Great Lakes CEAP, for addressing issues affecting accuracy of biological models based upon SWAT outputs.

1. SWAT models must be downscaled in order to increase output to provide adequate input to meet sample size requirements of biological models

There are an immense number of ecological factors that collectively determine the distribution and abundance of fish and other freshwater taxa. Identifying significant relations within this realm of complexity demands an extremely large sample size for both predictor and biological response variables. This is particularly true when trying to isolate the influence of a particular subset of variables, like water quality and flow variables. Unfortunately, nearly 70% of the original 1,022 fish community samples compiled for this project were unusable due to SWAT model's current scaling and the current inability to further downscale the SWAT model and generate model outputs for every single stream segment containing a fish community sample. **(Figure A1).** We firmly believe we would have been able to explain significantly more variation in fish community metrics and develop more accurate predictive models if we had been able to use all of those 1022 samples. What prevented us from using those data was our inability to further downscale the SWAT model and generate model outputs for every single stream segment containing a fish community sample. So, we suggest every effort must be made, regionally and nationally, to develop finder resolution SWAT models.

Fortunately, in the two years since our project began, rapid advances in computing power combined with technical advances in the SWAT model algorithms (which have reduced computer processing and memory demands), the technical limitations that hindered our project have been eliminated (Jeff Arnold, personal communication). In fact, the CEAP Cropland Modeling team is working on the development and calibration of a national SWAT model that will provide predictions for all of the individual reaches (i.e., between consecutive tributaries) contained within a slightly modified version of the NHD-Plus. The development of these downscaled SWAT predictions and the associated processing capabilities hold significant promise for improving the accuracy of models for which sample size is critical to providing the statistical power needed to collectively assess the complex array of variables that influence local biological assemblages.

2. Incorporate multiple taxonomic groups for biological endpoints

Both fish and aquatic macroinvertebrates have been used successfully as biological indicators of disturbance in lotic systems (Berkman et al. 1986; Plafkin et al. 1989). However, depending on the environmental conditions and the factors being examined, fish communities may prove to be better indicators of stream health than macroinvertebrate communities, or vice versa (Berkman et al. 1986). The regional Great Lakes CEAP project only focused on fish community metrics as biological endpoints. However, a complementary set of analyses linking SWAT model outputs with biological endpoints including both fish and macroinvertebrate metrics were done for the Saginaw River watershed (Einheuser et al. A and B, In Press). These analyses found that SWAT variables were able to consistently explain significantly more variation in macroinvertebrate metrics (~50%) than fish community metrics (~20%), suggesting that when possible, multiple taxonomic groups should be included in future CEAP wildlife projects.

3. Fill critical data gaps for key predictor variables

The Great Lakes CEAP project incorporated a large number of predictor variables.   However, it did not adequately address some critical variables known to have a significant influence on water quality and hydrology. For instance, our project did not include data for drainage tiles, which occur extensively throughout much of the project area. Incorporating geospatial data on these and other critical factors for which we currently lack good data would likely help improve the SWAT models and the associated biological models, which would ultimately improve strategic delivery of conservation practices based on model outcomes.

4. Incorporate future climate scenarios into SWAT models

Climate change may significantly impact several climatic factors, such as the amount, timing, and intensity of precipitation in the Great Lakes. These changes will likely translate into significant changes in surface runoff, erosion, and approaches to land management. All of these factors may influence sediment and nutrient loading to receiving waters. The Great Lakes CEAP project found that incorporating these projected changes are essential to forecasts of likely benefits of future conservation investments (Einheuser et al. In PressB). Failing to account for such changes might lead to inflated estimates of likely ecological benefits.

5 Incorporate a spatially distributed calibration into the SWAT model calibration process

Obviously, we should expect better relations between biological metrics and observed water quality and flow data than SWAT model predicted water quality and flow data based on past quantifications. However, because of the many potential benefits of SWAT for advancing strategic conservation, improving the accuracy of downscaled SWAT models is a top priority. One such option for improving SWAT is incorporating spatially extensive, but temporally discrete (e.g., average annual nutrient concentrations) water quality data into the SWAT model calibration process. A limitation of the SWAT modeling process used in our project, and most SWAT modeling projects, is that the model is calibrated to one or a few gage stations within the watershed. Incorporating additional calibration sites would help account for the spatial heterogeneity in water quality and flow conditions that consistently occur across large regions and are not fully accounted for by existing equations like RUSLE.

6. Use complementary outputs of SWAT and SPARROW to provide inputs for biological models

All data and models have strengths and weaknesses. One major strength of SWAT is its ability to be calibrated and offer predictions at a daily or larger time step. The benefit of this temporally intensive calibration is evident in this study, where seasonal variables consistently revealed the strongest relations to fish community metrics.. However, while able to process data at a refined temporal scale, SWAT was not originally designed for application at fine spatial scales.There are other models, like the USGS SPARROW model, that were developed to provide fine spatial resolution, yet suffer from the inability to provide detailed time step predictions (http://water.usgs.gov/nawqa/sparrow/). So, the strength of SWAT is a weakness of SPARROW and vice versa. Integrating the strengths of these two models to produce water quality and flow predictor variables could significantly improve our ability to predict biological endpoints.

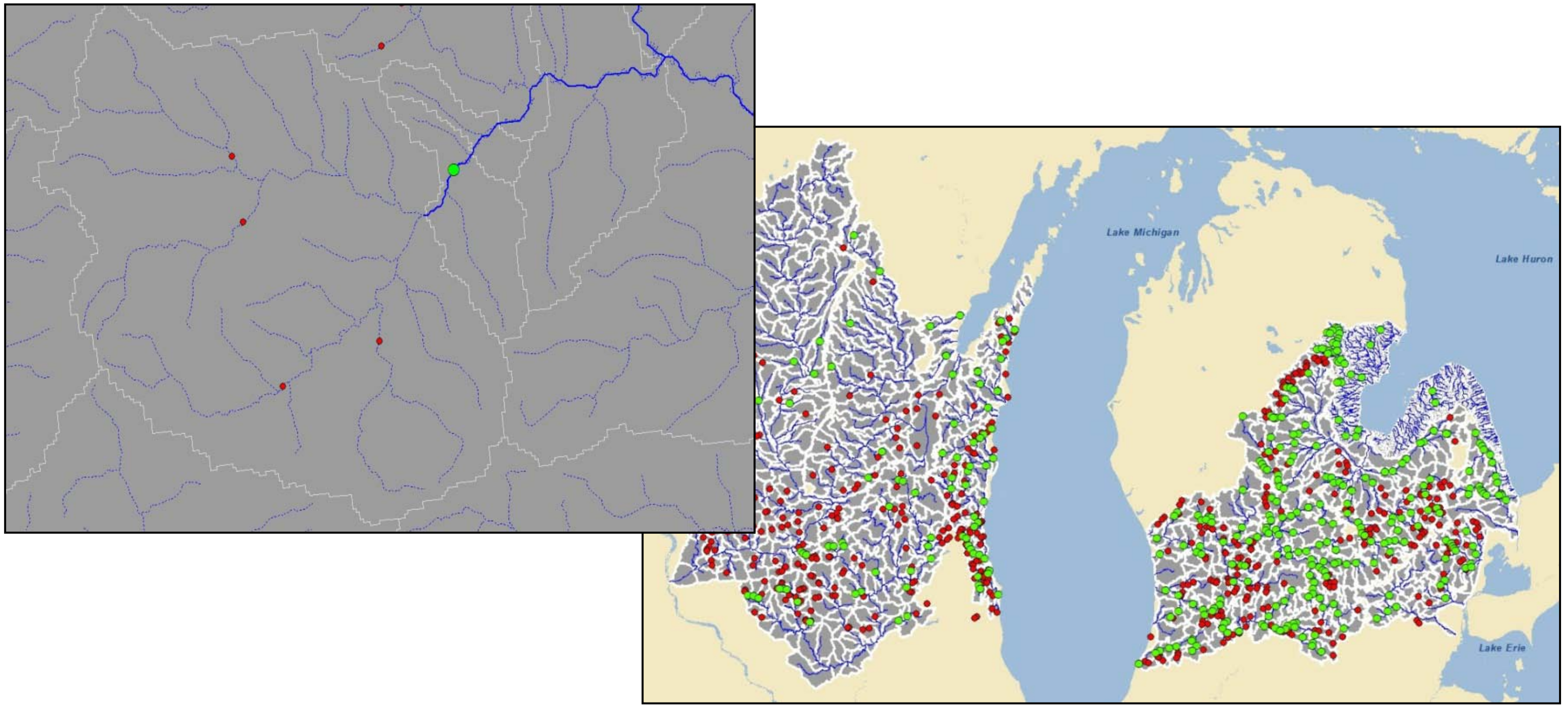

Figure A1. Map of Great Lakes CEAP project area showing all 1022 fish community samples overlaid on SWAT subbasins for which instream water quality and quantity predictions were generated as input for statistical models seeking to establish relations between these variables and biological endpoints. Green sample points represent samples with a corresponding subbasin, and thus corresponding water quality and quantity predictor variables, which could be retained for analyses. Red sample points represent those samples without a corresponding subbasin that had to be discarded. The inset map shows a specific example where four fish community samples had to be discarded since the SWAT model predictions for the outlet of the subbasin containing those samples is not reflective of the local conditions of where the samples were taken. This problem could be resolved with further downscaling the SWAT model to generate reach scale predictions for all reaches in the 1:100K NHD-Plus, which is shown with the blue stream lines in the inset map. This downscaling is a focus of our proposed WLEB CEAP project.

Appendix B: Core elements of the Cropland National Assessment and the Great Lakes CEAP projects and the proposed points of integration that will be the focus of the proposed WLEB CEAP project.

THE NATIONAL ASSESSMENT FOR CROPLAND COMPONENT OF CEAP
The purpose of the National Assessment for Cropland is to estimate the environmental benefits and effects of conservation practices applied to cultivated cropland and cropland enrolled in long-term conserving cover (e.g. Conservation Reserve Program). This Cropland Component of CEAP has three specific goals:

1. Estimate the effects of conservation practices currently present on the landscape.
2. Estimate the need for and potential benefits of additional conservation practices
3. Simulate alternative options for implementing conservation programs on cropland in the future.

The CEAP Cropland National Assessment is a collaborative effort led by NRCS in partnership with USDA's Agricultural Research Service and Texas Agri-Life Research of Texas A&M University. USDA's National Agricultural Statistics Service and Farm Service Agency also contribute. The Cropland Component uses **a sampling and modeling approach** to estimate both edge of field and receiving water benefits of conservation practices at relatively large subregional and regional scales (Figure B1). The approach consists of a set of data input, modeling, and output steps described below and outlined in Figure B2.

Data Inputs for Cropland National Assessment:
A subset of the USDA National Resources Inventory (NRI) sample points has been selected to serve as "representative fields" for the CEAP national assessment. These NRI sample points, which are located on cultivated cropland and land in long-term conserving cover, provide the base statistical framework for the both the APEX and SWAT models used by CEAP. USDA also developed and implemented the CEAP Cropland Farmer Surveys to collect the information needed at the selected NRI sample points to run the field-level process model APEX (Agricultural Policy Environmental Extender) which is used to assess the cumulative edge of filed benefits of conservation practices across each subregion and entire study region. The survey involves the National Agricultural Statistics Service (NASS) interviewing cooperating farmers to obtain current information on farming practices (crops grown, tillage practices, nutrient and pesticide application, conservation practices, etc.). Both models used by the CEAP Cropland assessments require climate, physiography (geology, soil, and landform or topography), land use data as inputs. The raw forms of these data come from various national datasets and monitoring networks. Selected subsets of these data are used as inputs in the APEX models based on their relevance and proximity to the selected NRI sample points. Summaries of these climate, physiography, and land use data were also generated for each of the ~2,150 8-digit Hydrologic Units of the United States and put into a relational database (HUMUS database) to support national water resource assessments. These summarized data are used as input for the watershed-level model SWAT (Soil and Water Assessment Tool) which

is used to assess the cumulative receiving water benefits of conservation practices across each subregion and entire study region.

Modeling steps for the Cropland National Assessment:
Onsite Field-Scale Model: The CEAP Cropland Component uses the physical process model called APEX (Agricultural Policy Environmental Extender) to estimate cumulative edge of field benefits for each subregion and the entire study region. APEX is a variant of the EPIC (Erosion Productivity Impact Calculator) model that allows one to assess the effects of buffers, grassed waterways, and other conservation practices and subsequently estimate reductions in runoff and associated reductions in soil, nitrogen, phosphorus, and pesticide loss from farm fields. APEX also allows us to evaluate soil quality enhancement as a result of practice implementation. APEX allows for both retrospective assessments of existing conservation practices and forecasts of benefits likely to result from future scenarios of conservation practices.

Offsite Watershed Level Model: CEAP Cropland Component incorporates model outputs from APEX into the watershed model SWAT to estimate and assess the benefits of conservation practices to receiving waters in terms of water quality and availability. The SWAT model to simulate the transport of water and potential pollutants from the land to receiving streams, and routes the flow downstream to the next watershed and ultimately to the estuaries or embayment and oceans or Great Lakes. SWAT allows one to estimate reductions of in-stream concentrations and loads for sediments, nutrients, and pesticides resulting from implementation of conservation practices. Like APEX, SWAT also allows for both retrospective assessments of existing conservation practices and forecasts of benefits likely to result from future scenarios of conservation practices.

Outputs of Cropland National Assessment:
Edge of Field Benefits: APEX is used to provide retrospective estimates of absolute and percent reductions in runoff and associated reductions in soil, nitrogen, phosphorus, and pesticide loss from farm fields. CEAP also provides forward-looking estimates of potential edge of field improvements resulting from additional conservation treatments based on erosion control and nutrient management practices. Estimated cumulative benefits due to existing and potential future practices are reported for each subregion and the overall study region.

Receiving Water Benefits: SWAT is used to estimate reductions of in-stream concentrations and loads for sediments, nutrients, and pesticides resulting from implementation of conservation practices. CEAP also provides forward-looking estimates of potential receiving water benefits resulting from additional conservation treatments. Estimated cumulative receiving water benefits, due to existing and potential future conservation practices, are reported for each subregion and the overall study region.

Desired Future Directions of Cropland Component of CEAP

Assessing Benefits to a Broader Suite of Ecological Endpoints

Currently the Cropland Component assessments report on existing and potential future cumulative benefits of conservation practices to water quality and quantity in terms of reduced runoff and edge-of-field losses of sediment, nutrients, and pesticides from cropland as well as reduced loadings and concentrations of these materials in our nation's receiving waters. While water quality and quantity are certainly of great interest to citizens of the United States, such percent reduction statistics are often hard to interpret unless they can be more directly linked to socially valued measures like biological condition, human health, or ecosystem services (e.g., beach closings, flooding). As stated earlier, CEAP has an interest in assessing and reporting on the benefits of USDA conservation practices to a much broader suite of ecological endpoints (e.g., biological) and ecosystem services. However, to do so requires the necessary science to unveil the complex linkages between water quality and quantity parameters and meaningful biological, human health, or ecosystem service endpoints, which is the focus of the Wildlife Component of CEAP. A specific case in point is the Great Lakes CEAP project, detailed below, which is working to unveil the complex relations between water quality and quantity and biological endpoints using a method that fosters integration of the Cropland and Wildlife components of CEAP.

Downscaling Models and Assessments to Inform Local Planning and Management

The Cropland National Assessments currently reports on existing and potential future benefits of conservation practices for very large assessment units (subregions and regions). These large scale, coarse-grain, assessments are very useful for broadly assessing the benefits of conservation practices and determining future conservation investment needs. However, conservation practices are implemented at a very local scale and require additional detail for effective planning. Across these large subregions and regions there is significant variation in runoff, erosion, and delivery of sediments, nutrients and pesticides to receiving waters. Accounting for these finer scale variations would facilitate conservation planning to strategically allocate limited conservation dollars to maximize returns on each conservation dollar invested. There are many finer-grained modeling and assessment efforts across the United State that use APEX, SWAT or other models. However, these efforts are highly fragmented and often lack the larger context provided by the CEAP National Assessments. For these and other reasons the Cropland Component of CEAP has been asked to develop more detailed (i.e., downscaled/finer grained) SWAT models for the United States and is taking steps to develop such models across the U.S. based on a slightly modified version of the 1:100,000 NHD-Plus dataset. Fortunately, these downscaled models are exactly what are needed for the modeling and assessment methodology developed and used by the Great Lakes CEAP project.

THE WILDLIFE COMPONENT OF CEAP AND THE GREAT LAKES CEAP PROJECT

The CEAP Wildlife component is an effort to quantify the effects of USDA conservation programs and practices on fish and wildlife and their habitats. CEAP Wildlife projects have mostly investigated the response of terrestrial ecosystems or species to a subset of NRCS practices (e.g., Burger Jr. et al. 2006a; Heard et al. 2000), or have targeted water quality issues by using hydrological models to assess sediment and contaminant loading in streams after conservation practice implementation (Westra et al. 2005). However, a pilot study concluded that NRCS conservation practices do have the potential to improve stream habitat conditions for a variety of aquatic species by targeting specific conservation practices to specific watersheds (Comer et al. 2007). The authors of this study also noted that the specific or cumulative benefits of NRCS conservation practices to aquatic communities is poorly understood and further scientific investigation through a combination of a) localized, field based, watershed studies and b) geographically extensive, associative, modeling studies were needed. The Great Lakes CEAP project grew out of this realization and is working to provide the science needed to assess and forecast the benefits of NRCS conservation practices to stream fish communities to help advance strategic conservation of freshwater biodiversity across the agricultural regions of the southern Great Lakes.

Furthermore, recognizing the interest and need for integrating the various components of CEAP, the Great Lakes CEAP Project is using a modeling and assessment methodology to foster such integration across the spectrum of data inputs, modeling, and outputs.

Data Inputs for Great Lakes CEAP

The primary objective for the Great Lakes CEAP project is to, in essence, extend the predictive capabilities of SWAT to include biological endpoints and address one of the recommendations of the CEAP Blue Ribbon Panel. To do this requires using the primary data outputs of the Cropland Component as one of the primary data inputs for modeling of the Great Lakes CEAP project (see Figure B2). This two-stage modeling approach used by the Great Lakes CEAP project serves to integrate the Cropland and Wildlife components of CEAP through common data and modeling platforms. However, we also fully recognize that riverine fishes are influenced by numerous landscape and in-channel factors and processes operating at multiple spatial and temporal scales (Rabeni and Sowa 1996). Of particular interest are those natural landscape factors and human disturbances operating within the overall watershed and local catchment draining to a stream segment (Sowa et al. 2007). Watershed and local catchment metrics, like percent of a particular surficial geology or percent impervious surface, can indirectly capture habitat patterns and processes (e.g., stream channel morphology, thermal regime, bedload movement, etc.) that are not effectively captured by discrete field samples or even modeled by complex and temporally dynamic models like SWAT. Failing to account for these factors that often serve as higher level constraints on fish communities could lead to erroneous expectations in Phase 2 of our project as we develop future conservation scenarios with SWAT that will not address the full suite of potential limiting factors. Consequently, to supplement the predictor variables provided by SWAT we also included a broad suite of predictor variables pertaining to overall watershed and local catchment physiography and human disturbances using the 1:100,000 NHD-Plus reaches and catchments (see Figure B2).

Modeling Steps for Great Lakes CEAP

There are two distinct modeling components for the Great Lakes CEAP Project (see Figure B2). The first modeling component is a retrospective statistical modeling exercise focused on isolating and modeling relations between SWAT model outputs for current instream water quality and flow (and other relevant factors) and biological endpoints. The multivariate relations between instream habitat, human disturbances, conservation practices, and biological metrics are complex and often nonlinear. As a result, the Great Lakes CEAP project uses a complimentary set of multivariate, univariate, linear, and nonlinear statistical modeling to unveil these complex relations (Sowa et al. 2011). These sets of analyses serve three primary purposes; a) identify informative predictor variables and reduce number of predictor variables, b) provide multiple lines of evidence by examining consistency of results among analyses, and c) providing a means of predicting current biological conditions and/or potential. The second modeling component of the Great Lakes CEAP project is a forward-looking modeling exercise that uses both SWAT and the previously established statistical relations between biological metrics and SWAT model outputs (see Figure B2).

Outputs of Great Lakes CEAP

<u>Realistic expectations based on natural or non-agricultural disturbance constraints</u>

Agricultural is often the dominant limiting factor to freshwater biodiversity in the agricultural regions of the Great Lakes. However, in many watersheds or coastal systems, agriculture is just one of many human activities that have altered ecological conditions and in some instances agricultural best management practices alone may not be sufficient for achieving desired conditions. We must therefore try to account for all human disturbances affecting to help us ensure we are getting the right practices to address the right problems at the right places to avoid wasting limited resources (e.g., investing in AG BMPs in watersheds where urban smart growth BMPs are more needed). The Great Lakes CEAP project does this by developing relations between biological endpoints and a broad array of human disturbance metrics and then mapping the thresholds for these constraints for each NHD-Plus reach across the entire study region (Figure B3).

<u>Estimates of likely current biological conditions</u>

Using the relations between biological metrics and predicted water quality and quantity variables, The Great Lakes CEAP project can use the SWAT model estimates for relevant water quality and quantity variables to estimate thresholds or likely mean values for select biological metrics (Figure B4). These estimates are made and mapped for each SWAT subbasin across the entire study region.

<u>Estimates of likely future biological conditions</u>

For priority subwatersheds the Great Lakes CEAP project is developing sets of possible future conservation scenarios and using SWAT to predict the likely changes to relevant water quality and flow conditions. These predicted changes to instream habitat will then be translated to likely changes in biological conditions based on the previously established statistical relations. However, these predictions will only be made for those streams where non-agricultural constraints (e.g., percent impervious surface in the watershed) are serving as the primary limiting factor and are not addressed with agricultural BMPs used in the scenarios. These estimates of likely future conditions will be made and mapped for each SWAT Subbasin throughout each priority subbwatershed.

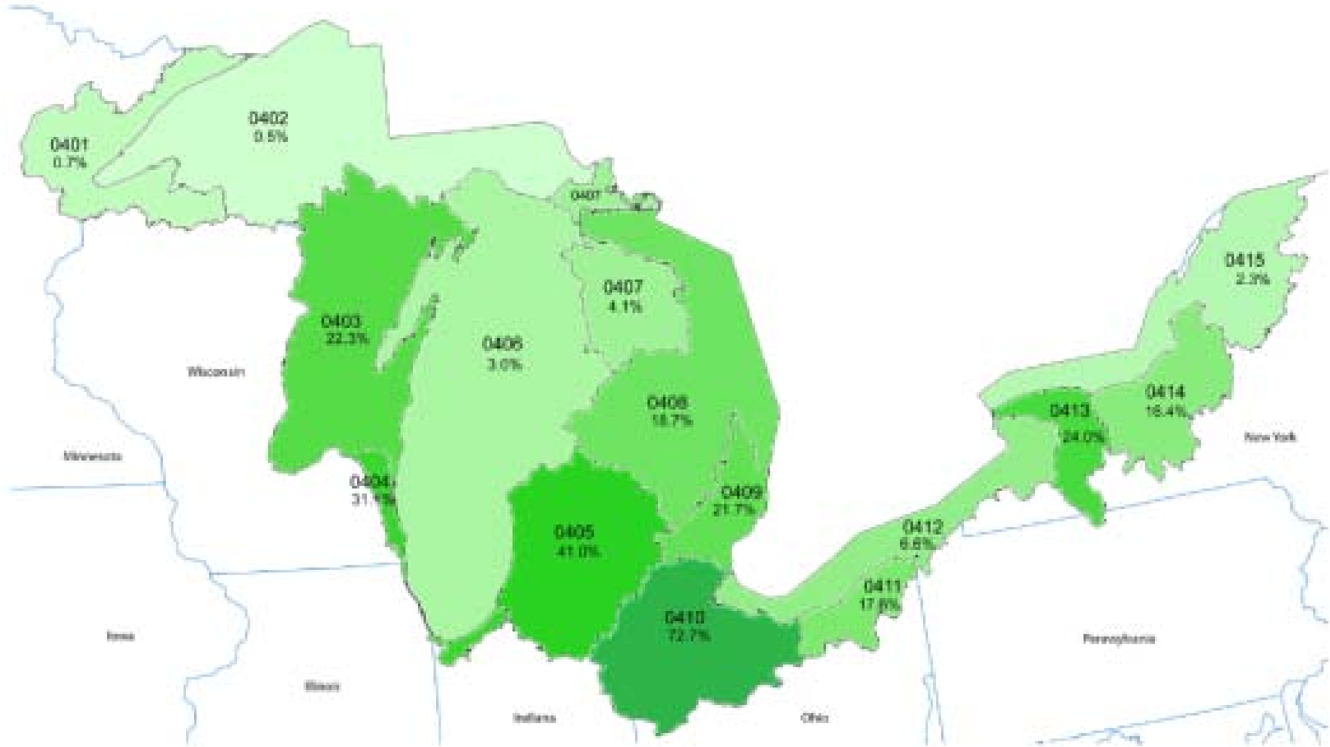

Figure B1. Map showing the entire study Region and 15 subregions used for assessing and reporting on the benefits of NRCS conservation practices by the CEAP Cropland Component for the Great Lakes. The four digit codes represent the USGS 4-digit Hydrologic Unit Codes and the percentages represent the percent of cultivated cropland within each unit.

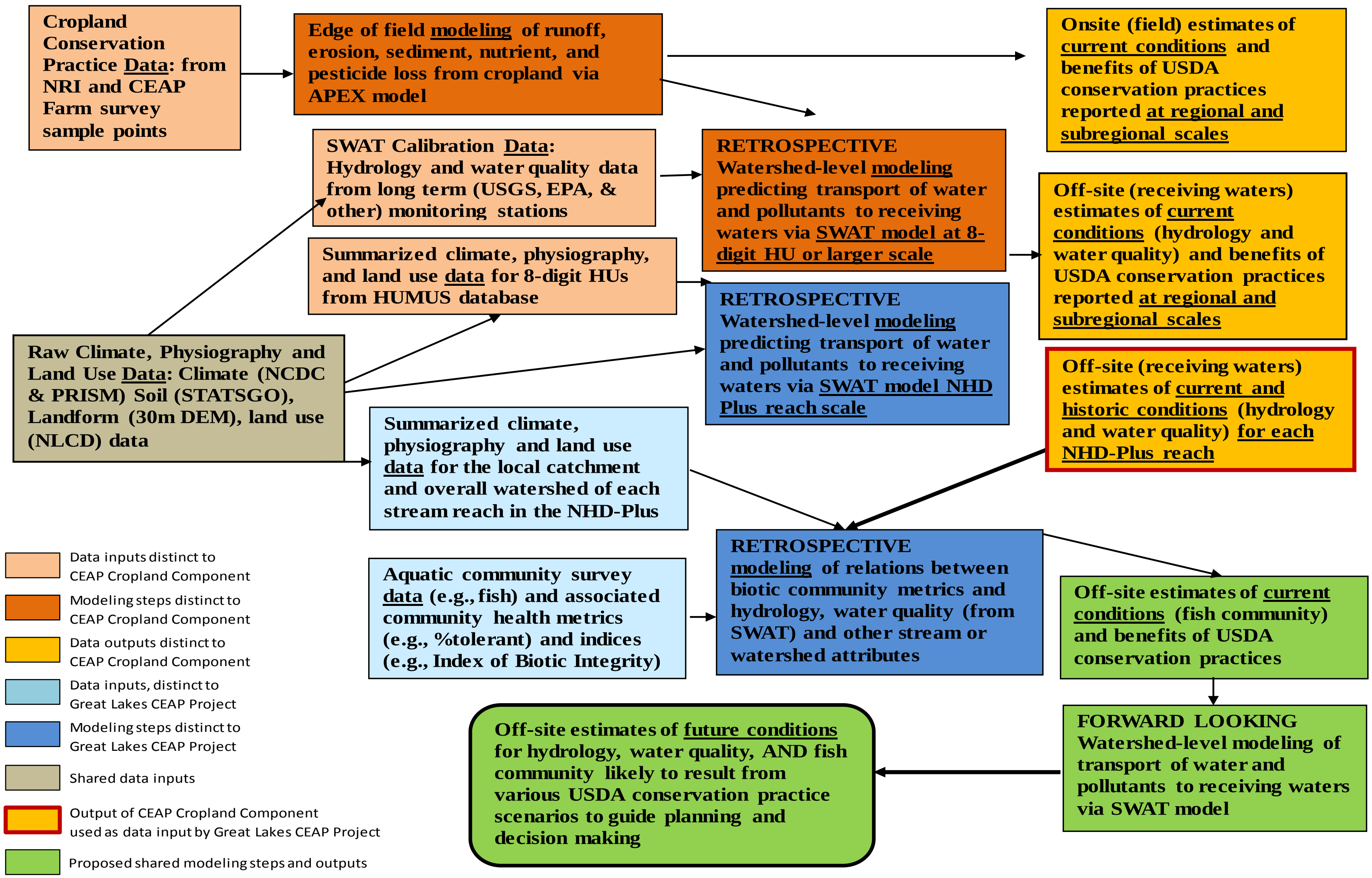

Figure B2. Major data input, modeling, and outputs of the Cropland National Assessment and Great Lakes CEAP project showing the points of integration proposed to be addressed in the WLEB CEAP project.

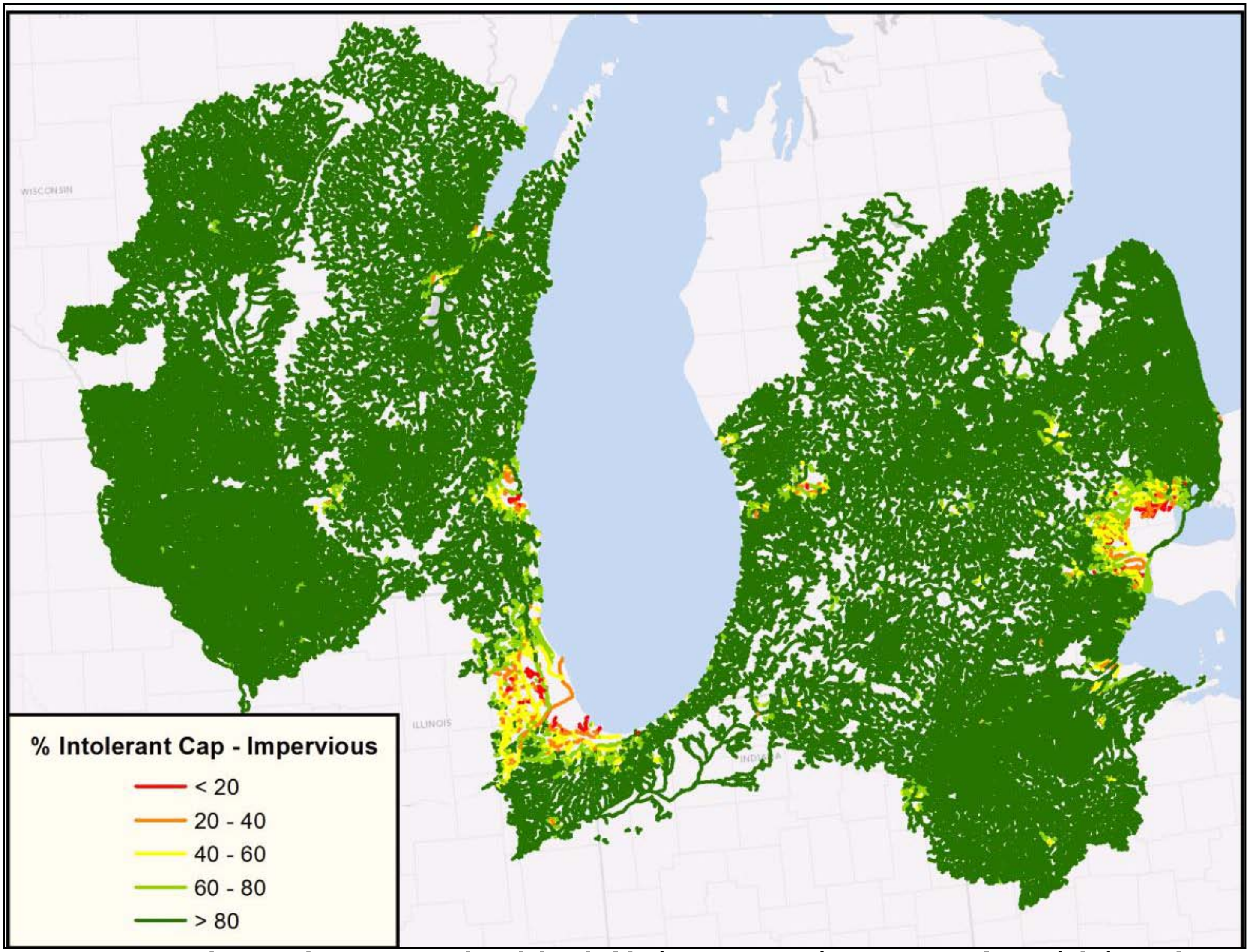

Figure B3. Map showing the current predicted threshold of expectations for percent intolerant fish for each stream reach across southern WI and MI based on relations of this metric with actual watershed percentages of impervious surface.

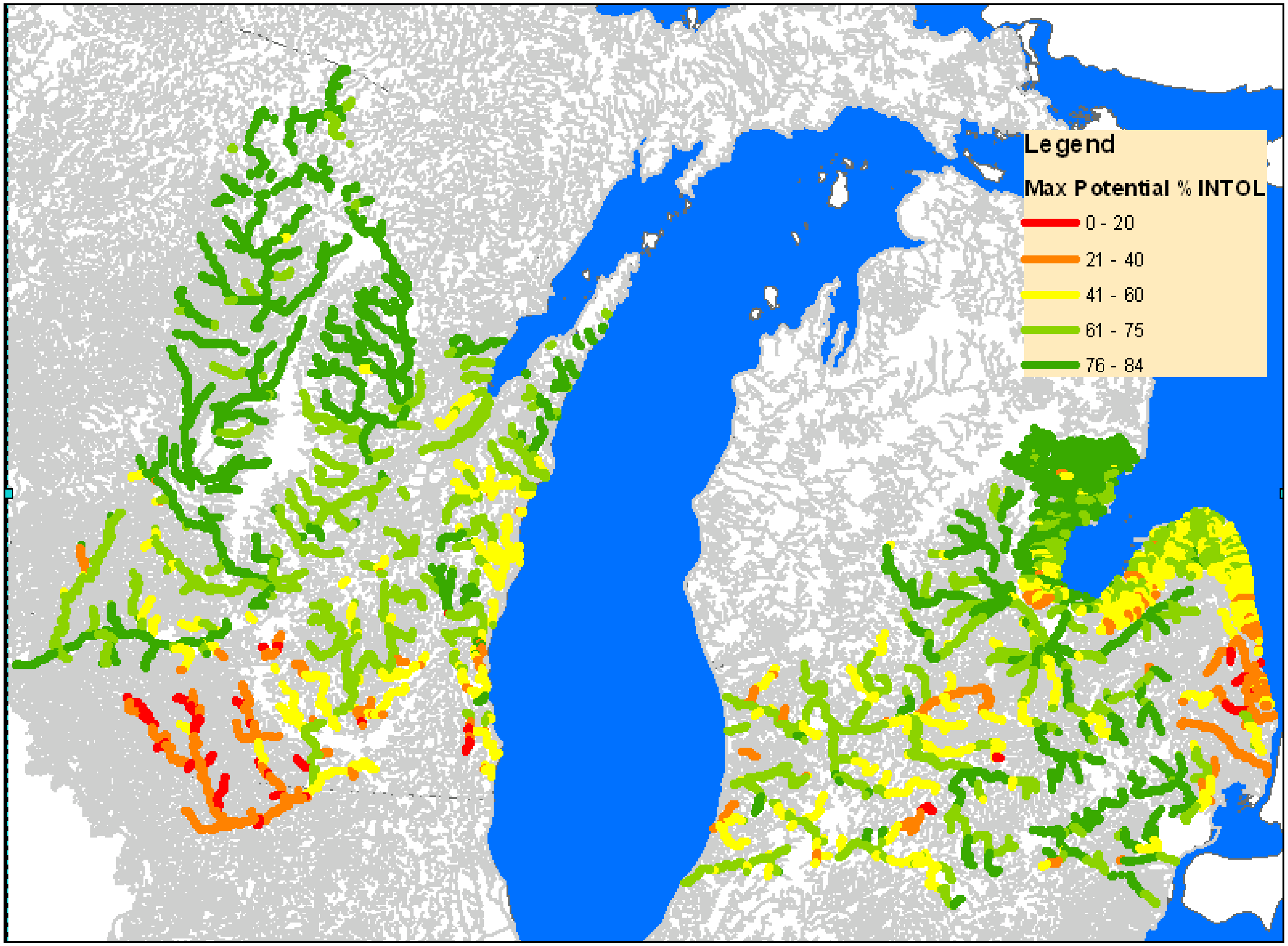

Figure B4. Map showing the predicted current threshold of expectations for percent intolerant fish species for each stream reach across southern WI and MI based on relations of this metric with multiple water quality parameters predicted from SWAT models.