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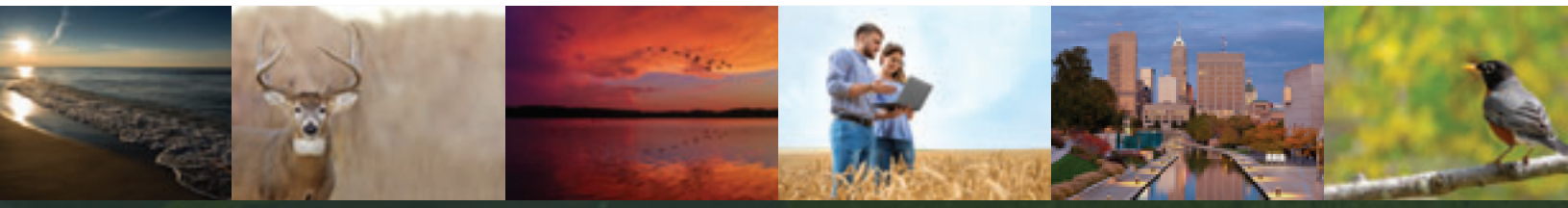
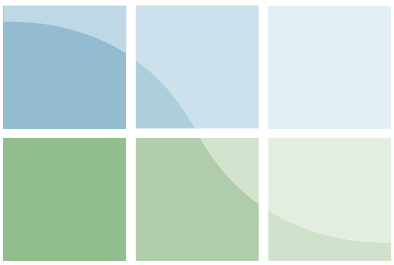


# TIPPING POINT PLANNER

## Supporting Sustainable Communities in Great Lakes States

http://tippingpointplanner.org/



# TIPPING POINT PLANNER

Supporting Sustainable Communities in Great Lakes States

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EXPERT REVIEWED

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# Tipping Point Planner Toolkit



### Session 1: Planning Meeting(s) with Local Leads

## Measurement and Evaluation

# Tipping Point Planner

Community leaders throughout the Great Lakes Basin make long term management decisions that can have a substantial impact on the environmental health of local resources as well as on quality of life.

Protecting natural resources while enhancing community resiliency requires:

- Understanding of human-induced ecological stress
- Identification of indicators for natural resource conditions
- Determination of tipping points that trigger rapid, sometimes irreversible, shifts in ecosystem functions.

Through Tipping Point Planner (http://www.tippingpointplanner.org), communities in Great Lakes states can plan for a sustainable future by directly linking data to local decision making-process.

As an example, the Tipping Point Planner decision support tool allows participants to evaluate how proposed land use changes may affect water quality or coastal ecosystems. They select critical action goals to sustain water quality and ecosystem integrity, such as reducing runoff, and action strategies that meet their goals, which can include limiting or mitigating impervious surfaces.

The Tipping Point Planner Program is designed to serve as a road-map for communities as they tackle complex land use and water resources management challenges. Trained facilitators enable both professional and civic participation in land-use planning and management, including maintaining projects using a HUC 12 watershed scale.

Participants in the Tipping Point Planner Program will:

- Examine past and predicted land-use changes
- Identify environmental threats
- Define natural resource assets in need of protection or restoration
- Explore land-use strategies and policies that enhance local values
- Gain the framework to define a community's priorities through:
    - Visualization dashboards
    - Paint tools
    - Interactive community visioning exercises

Through this program, local leadership and community groups identify issues of concern. Local leads then convene a working group to meet with trained Sea Grant and Extension facilitators over the course of approximately four meetings. Facilitators support community visioning, share innovative management strategies, and coach action plan development. The result is a local or regional action plan and implementation strategies for projects that may support the development of county or municipal comprehensive plan updates or watershed management plans.

## Target Audiences

This curriculum is designed for use by decision makers who have oversight and management of ecological and land-use services, including:

- local leaders
- government officials and their staffs
- representatives from nongovernmental organizations
- residents who want to participate in decisions concerning local natural resources

## Program Outcomes

The end result of this program's facilitated process is an action plan that includes:

- An overview of the community's status
- Potential environmental tipping points. and proximity to them
- Customized implementation steps to improve conditions/steer clear of tipping points, such as:
    - Planning options
    - Example policies
    - Sample ordinances
    - Educational programs
    - Local government best management practices

To learn more about the models associated with the decision support tool, visit the model resources website below. Click on the model of interest to access videos about the research, published papers, and screenshots of what the research looks like in the decision support system.

http://www.tippingpointplanner.org/resources/model-resources

# Planning Tools for Land Use and Natural Resource Management

Guiding and managing land use is integral to natural resource management. Most land use guidance is created, updated, and enforced at the county or municipal government level. In counties or municipalities that have a plan commission, comprehensive plans are the primary policy document used to guide land use decisions. This section provides an overview of the planning tools that may be available in your community to manage land use and the agencies that administer land use planning.

## Watershed Planning and the Watershed Planning Process

According to the U.S. Environmental Protection Agency (EPA), a watershed plan is a geographic approach to addressing water quality problems within the boundaries of a specific watershed. Watershed boundaries often extend across multiple local government jurisdictions and state lines. Progress on watershed issues requires partnerships both among and between private landowners and government entities. Therefore, state agencies and the EPA have developed funding programs, guidance documents, and criteria for determining nonpoint source pollution problems in watersheds. The EPA's Clean Water Act Section 319 is the major funding mechanism for nonpoint source pollution reduction. The EPA provides the following guidance for watershed plans.

The watershed planning process has the following six steps:

1. Build Partnerships
2. Characterize the Watershed
3. Set Goals/Identify Solutions
4. Design an Implementation Program
5. Implement the Plan
6. Measure Progress and Make Adjustments

(EPA, 2008)

Watershed groups can arise based on common interests or issues among community members, non-profit groups, businesses, and state or local government agencies. Partnering with other groups is one method for expanding the resources available to the effort. Once a watershed group forms and determines its geographic focus,

the next step is to characterize the watershed through a watershed inventory. A basic inventory can be started by accessing online publicly available data from a variety of sources such as Google Earth and state/local GIS platforms. Other aspects of this step include identifying sources and causes of pollution, estimating quantities of pollutants, and use of modeling tools (EPA, 2008).

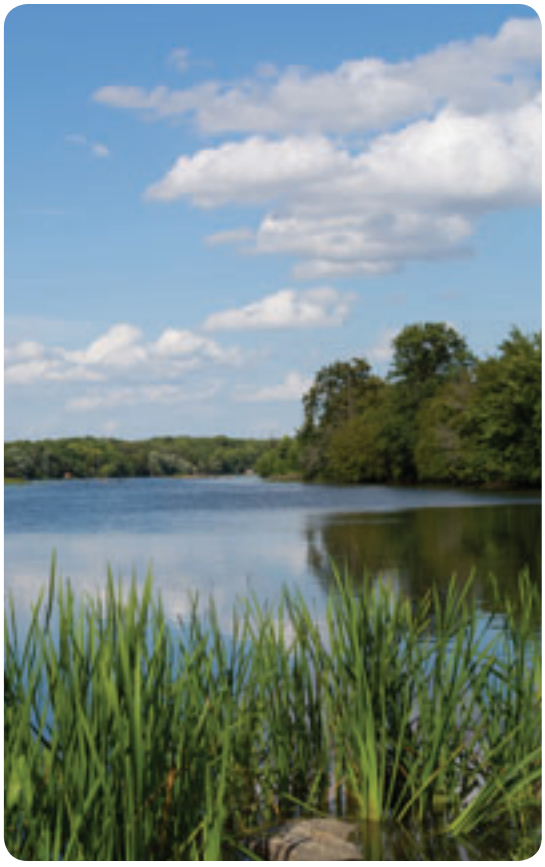
Once the group has characterized the watershed, it can move on to finalizing goals and identifying solutions. For example, a group that has identified sediment reduction as a goal based on its characterization of the watershed may identify critical areas of steep slope or exposed riverbanks as key sources of sediment. It would then need to develop a sediment reduction goal, and a set of actions that would reduce the amount of erosion from these areas.

Next, the group would develop an implementation program with several components including monitoring, metrics for evaluation, education, and technical and financial assistance required (EPA 2008). This is sometimes called an action plan. It contains details on implementation, measurement, evaluation, technical and financial assistance required, and lists who is responsible for which actions (EPA 2008).

Once the implementation program is developed, the group would begin the process of following it. In this step may include education activities, water quality monitoring, and execution of BMPs to address critical areas in the watershed.

The group's final task would be to measure the progress it has made toward reducing sediment and determine if the strategies it used were effective. If the group's goals were not realized, the group would evaluate its efforts and determine if adjustments were needed.

*Above: the Tipping Point Planner Watershed Planning Process*



*Morning on the Dupage River*

## Comprehensive Plans

Cities, smaller communities, and counties across Indiana undertake the comprehensive planning process to establish a vision for land use and community needs. Communities that choose this path commonly develop plans that contain the following: 1) objectives for future development 2) a statement of policy for the land use development of the jurisdiction, and 3) a statement of policy for development of roads, public places, public lands, public structures, and public utilities. Most comprehensive plans focus on how the community will change in the next 20 years. This prevents the plan from becoming overly detailed or technical and provides adaptability. The list below shows some common elements:

- Land use (existing and projected)
- Transportation
- Housing
- Natural resources and open space
- Demographics
- Utilities and public services

Land use planning is integral to the comprehensive plan and natural resource management. Most land use planning occurs at the municipal or county level through the comprehensive planning process. The comprehensive planning process is led by plan commissioners or their staff or through a contracted planning consultancy. Often, at least one public hearing is required before any plan is approved by the legislative body. Consult your jurisdiction's codes and laws related to planning enablement. A high-quality public input process is critical to receiving buy-in on the plan's policies, goals, and strategies from the public and elected officials. Often, plan commission staff members or a consultant conducts a series of open houses or focus group feedback sessions. Each meeting may focus on a certain element of the comprehensive plan. Though none of these efforts are required in some locations, they are part of a public engagement strategy that supports comprehensive plan development. Through this process, communities are able to take account of their natural resources and consider how to manage, develop, and conserve them in the best interest of residents and businesses. This process allows the plan commission to develop a plan that reflects community values, interests, and concerns.

The jurisdiction's legislative body must approve the plan via resolution for it to become an official policy document. Comprehensive plans are the primary policy document adopted by local government to guide land use decisions.

Land use planning for natural resources includes doing an inventory of the municipality or county's existing natural resources and developing land use policies, goals, and objectives. The inventory, such as maps, text, and tables that describe existing conditions, is often included as an independent element of the comprehensive plan. In addition, natural resources can be addressed, in part, by other elements of the comprehensive plan, such as land use or recreation. This information forms the foundation for land use policy that can reduce the impact of development on the community's natural resources.

Monroe County, Indiana provides a prime example. Its comprehensive plan includes an inventory of natural resources and characteristics including Karst areas[1], wetlands, soils, floodplains, waterbodies, watersheds, contiguous forest canopy, steep slopes, and endangered series of environmental conservation goals and strategies. One strategy is to establish riparian buffers on both sides of perennial or intermittent streams. Chapter 825 of the Monroe County zoning ordinance, titled Environmental Constraints Overlay Zone, states that "riparian buffer zones, measured from the stream/vegetation interface line, shall be established to a distance of 100 feet from each side of all intermittent and perennial streams" (Monroe County, Indiana, 2008). This is a clear example of a natural resource inventory linked to policy that affects land use.

Another important aspect of the comprehensive plan is that it lays out the community's needs for capital projects, such as providing water and sewer service. Typically, Indiana communities develop Capital Improvement Programs (CIPs) that are approved by the jurisdiction's legislative body. These programs prioritize infrastructure investments and should align with the comprehensive plan's policies for land use and future development. Often, public investments in infrastructure have more impact on the form and location of development than land use regulations (Kelly and Becker, 2000). Due to their significant and long-lasting impact, it is critical that decisions regarding CIP projects consider natural resource assets within the community.

*[1]Karst areas are areas where water infiltrates into the ground rapidly due to subsurface cavities in limestone bedrock. This has implications for groundwater quality and surface soil stability.*

## Zoning Ordinance/Subdivision Control Ordinance

Zoning ordinances and subdivision control ordinances are two tools used by Indiana local governments to regulate land use for public objectives. Zoning has been accepted as a legal exercise of government police power since the Supreme Court upheld its constitutionality in the 1926 Euclid v. Ambler Realty Company decision. Later, the Standard State Zoning Enabling Act was passed, which expanded the option to use zoning to all states. Together, zoning ordinances and subdivision control ordinances establish definitions, regulations, and procedures for how land may be divided and its purposes. Zoning classifications and restrictions are the product of each community's public planning process and differ between planning jurisdictions, but must all have a rational connection to a legitimate public purpose (typically related to protecting the health, safety, welfare, and morals of the community). Throughout the history of zoning implementation, separation of land use—and particularly the separation of conflicting land uses—has been standard practice. Residential, commercial, and industrial uses are separated geographically. The zoning ordinance also regulates density, bulk, parking, signage, landscaping requirements, and home-based businesses (Higginbotham, 2017).

Zoning ordinances may require a broad range of BMPs for conservation, such as permeable pavers, bicycle parking, green space, and impervious surface maximums. The plan commission can decide to develop and recommend the adoption of a zoning ordinance that implements best practice for conservation. This is by no means a simple process, as the commission has many stakeholders throughout the community.

A plan commission that has developed a plan with robust public engagement will be able to demonstrate that the plan represents the community's vision,

*1926 Euclid v. Ambler Realty*

*Zoning ordinances regulate land use for public objectives*

rather than the vision of any number of its members. A plan commission may also develop an ordinance that attempts to balance the environmental impact of development with the financial impact to developers.

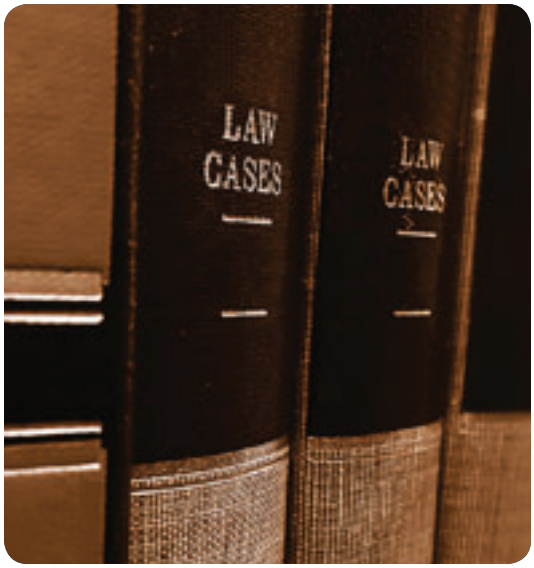
The following are examples of zoning tools that can be used to reduce the environmental impact of development:

1. **Performance Zoning** – This type of zoning regulates characteristics of use, rather than use itself. Criteria for performance can include trip generation, odor, surface water runoff, hours of operation, and noise generation. As a result, a wider variety of land uses can occur, as long as the use meets specific performance criteria (Ottensmann, 2000).

2. **Mixed-Use Zoning** – Mixed-use zoning enables higher-density, multi-level commercial or residential development in urban areas where it is identified as desirable. Mixed-use zones are focused on integrating residential and office or retail uses, although in some cases light industrial uses are considered compatible (Atlanta Regional Commission, n.d.). A reduction in environmental impact occurs when density in already-developed areas is increased. Vehicular travel is reduced as distances between commercial and residential use are shortened.

3. **Overlay Districts** – Overlay districts protect natural resources by applying land use regulations in addition to existing regulations that are in the base classification of the zoning ordinance. For example, the City of Richmond has established an Aquifer Protection Overlay District to prevent contamination by restricting land uses that negatively affect ground water quality. Porter County has also used overlay districts in its comprehensive plan to protect its water resources. The county instituted overlay districts divided into different zones according to distance from a stream or waterbody (Thompson, 2013).

Plan commissions are responsible for approving subdivisions. The Subdivision Control Ordinance regulates the division of land and sets standards for physical development of infrastructure and buildings. The ordinance can also include requirements for recreation facilities, conservation of naturally-sensitive lands, and landscaping (Luzier, Isaacs, and Schweitzer, 2017). The Subdivision Control Ordinance is used by the plan commission staff during the subdivision review process to recom-



mend the approval or denial of subdivision applications to the plan commission. One purpose of the Tippecanoe County Unified Subdivision ordinance is natural resource preservation and protection. It states the following as purposes of the ordinance:

(10) To prevent the pollution of air, streams, and ponds, to assure the adequacy of drainage facilities, to safeguard the water table, and to encourage the wise use and management of natural resources throughout the participating jurisdictions in order to preserve the integrity, stability, and beauty of the community and the value of the land.

(11) To preserve the natural beauty and topography of the participating jurisdictions and to insure appropriate development with regard to these natural features.

## Other Tools and Strategies for Natural Resource Management through Land Use

1. **Conservation Easement** – A conservation easement is "[a] policy… to preserve lands indefinitely, not only for recreation, maintenance of wildlife, and scenic value, but also for maintenance of agriculture and of a way of life" (Harrison & Richardson, n.d.).

2. **Transfer of Development Rights** – This program establishes a base density and allows some landowners to transfer their development rights to other areas, thus compensating them for agreeing not to develop their land. Conservation can be achieved through the designation of these donor areas. Properties that receive additional development rights may be developed at densities greater than would otherwise be allowed. Donor land may not be developed after development right transfer occurs (Higginbotham 2017).

3. **Purchase of Development Rights** – Communities establish this program to preserve naturally sensitive areas and forbid development. The value of the right to develop land is appraised and purchased, and then the land is placed in a conservation easement (Higginbotham, 2017).

4. **Conservation Subdivision Ordinance** – Development takes place using subdivision cluster, suburban-style dwellings to preserve open spaces and natural features such as topography, water features, or other significant natural features of a site. Open spaces are never developed and are maintained by a homeowners' association (Luzier, Isaacs, and Schweitzer, 2017). According to the Hendricks County zoning ordinance, key purposes for planning for this type of subdivision are to encourage efficient use of land, preserve habitat, and to minimize the street and utility network. (Hendricks County, et al., 2008) See the resources section for example documents and handbooks for conservation subdivisions.

5. **Stormwater Management/Control Ordinance** – The stormwater management ordinance regulates how stormwater is treated in a jurisdiction. It describes required practices at construction sites to reduce sediment runoff.

6. **Riparian and Wetland Setbacks** – Riparian setbacks or buffers are zones of vegetation that allow sediment and other waterborne pollutants to settle or filter out before reaching a stream or other waterbody. They can also serve to moderate water temperature and provide additional species habitat. Setbacks can be required via the zoning ordinance or adopted by individual landowners (Castelle, Johnson, and Connolly, 1994).

7. **The Ohio Balanced Growth Toolkit and Model Ordinances website** – Contains information on a range of land use planning tools that can be used for natural resource management including meadow protection, steep slope protection, compact growth, agricultural land protection, scenic protection, and woodlands protection. This resource can be found at: http://balancedgrowth.ohio.gov/BestLocalLandUsePractices/ToolkitModelOrdinances2004.aspx.

8. **Tipping Point Planner Dashboard Tools** – Several dashboard tools are available in the Tipping Point Planner Decision Support System. These tools provide information on factors that influence environmental quality. Information on stream health, nutrient sources and quantities, and impervious surfaces can be found in the resources section of the Tipping Point Planner Decision Support System, these resources are available at: http://tippingpointplanner.org/resources/regional-planning/.

*Tippecanoe County Courthouse*

## Land Use Planning Agencies

### Plan Commissions

The main function of the plan commission is to adopt the comprehensive plan, zoning ordinance, and subdivision control ordinance. Plan commissions also make recommendations to legislative bodies on land use issues including annexation, text amendments to the zoning ordinance, or subdivision control ordinance, and changes to the zoning map. Plan commissions also approve development plans and subdivisions (Reitz and Ternet, 2017).

### City Council/County Commissioners

City councils or county commissioners, as legislative bodies, are responsible for adopting the comprehensive plan and regulatory tools to implement it. These bodies should refer to the comprehensive plan for guidance when making decisions. Local legislative officials consider issues including zoning, infrastructure, annexation, and funding capital projects in the community.

### Board of Zoning Appeals

The Board of Zoning Appeals (BZA) is a quasi-judicial body that can grant zoning variances or special exceptions to petitioners. While zoning is an effective tool for land use management, it cannot strictly address all circumstances without becoming cumbersome to administer, enforce, or comply with. Variances and special exceptions are a relief valve for landowners that are caused what is termed impractical difficulty in use of their property by the application of the zoning ordinance. A variance allows a landowner to circumvent certain requirements of the zoning ordinance. Special exceptions are uses permitted in the zoning ordinance only if the application meets clearly defined conditions of the ordinance. The BZA's job is to judge the facts of each case and determine whether granting a variance or special exception is justified.

### State and Regional Resources for Land Use, Conservation, and Policy

**State Departments** – There are many state agencies that regulate natural resources. State agencies administer federal programs related to conservation such as the Forest Legacy Program from the U.S. Forest Service and Environmental Protection Agency's programs related to the Clean Water Act. Visit your state's environmental agency websites to learn more about programs, and potential sources of funding, for conservation efforts.

**State-appointed Land Use Groups** – These groups assist local and state decision makers with land use tools and policies. They are composed of public officials as well as experts in land development, the environment, and agriculture.

**State Chapters of the American Planning Association** – State chapters hold annual meetings and serve as a resource for citizens and practicing planners alike. Various workshops and inter-state chapter meetings are held throughout the year, mainly targeted at practicing public, private, academic, or non-profit planners. Find your state's chapter of the APA at: http://www.planning.org.

**University Academic Departments** – Faculty often teach courses that seek com-

munity partners for design charrettes, studies, surveys, and other projects.

**State Cooperative Extension** – At land grant universities in all 50 states, extension educators and specialists work to provide training and education programs in agriculture, community development, the environment, and many other areas of focus. Wisconsin's Center for land use education (https://www.uwsp.edu/cnr-ap/clue/Pages/default.aspx) and the Purdue University Land Use Team (https://www.cdext.purdue.edu/collaborative-projects/land-use/) are two examples of Extension affiliated land use resources available to communities. Find more information about your state's Extension programs by visiting the website of your local land grant university.

**The Nature Conservancy** – The Nature Conservancy works nationally to shape policy, restore lands, and protect water. The Nature Conservancy's National website can be found at https://www.nature.org/en-us/.

## Additional Resources

Richmond, Indiana's Aquifer Protection Overlay District: https://www.richmondindiana.gov/docs/aquifer-protection-overlay.

A comprehensive list of state and regional land trusts and conservation organization land trusts: https://www.findalandtrust.org/.

North Carolina State University Conservation Subdivision Handbook: https://content.ces.ncsu.edu/conservation-subdivision-handbook.

National Wildlife Federation: https://www.nwf.org/.

Conservation Easement/Purchase of Conservation Easement (Purchase of Development Rights) – Example Laporte County Comprehensive Plan: http://www.laportecounty.org/Resources/Planner/LaPorteCountyLandDevPlan.pdf.

Atlanta Regional Commission. Quality Growth Toolkit Mixed-Use Development. Retrieved from: https://www.dekalbcountyga.gov/sites/default/files/user18/mixed_use_development.pdf.

The Environmental Protection Agency's Resources for Watershed Planning: https://www.epa.gov/nps/resources-watershed-planning

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# Tipping Point Planner Modules

## Community Overview

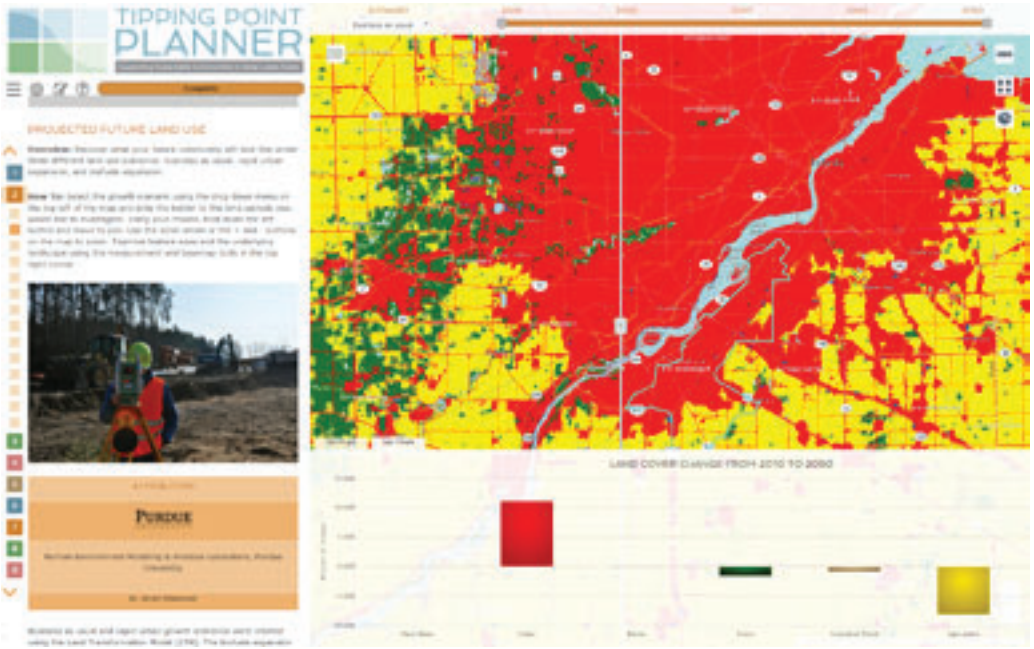
Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants, and animals. Land use information can be used to develop solutions for natural resource management issues such as salinity and water quality. For instance, water bodies in a region that has been deforested or having erosion will have different water quality than those in areas that are forested. Forest gardening, a plant-based food production system, is believed to be the oldest form of land use in the world.

The community overview module provides a comprehensive review of land use, natural resource assets, and environmental threats in the selected watersheds using models, maps, graphs, and resources from multiple reference sources consolidated into one easy-to-digest section.

### Past and Future Land Use

How have the natural resources in our community changed over time? The past land use feature allows users to examine how the natural resources in the selected watershed(s) have changed between 2001, 2006, and 2011. Users can select land cover statistics to compare by sliding button-bars to the time period they would like to investigate.

The future land use feature uses the Land Transformation Model (LTM) to predict what the land uses in the selected watershed(s) might look like in the next 10-50 years. The model uses population growth as well as past land use trends to project future land uses under three well-described land use scenarios: business as usual, rapid urban expansion, and biofuels expansion.



## Natural Resource Assets

The natural resource assets feature allows users to explore existing natural resource assets for open space, ground water, water quality, and prime farmland in their selected watershed(s).

- Open Space—The open space map displays land cover classes as identified in the National Land Cover (NLCD) dataset as land that supports wildlife. Specific land cover types displayed include forest, shrub land, grassland, and wetland. These cover types are often critical for maximizing biodiversity and can have a major influence on water quality and water quantity.
- Ground Water Resources—The map in this section shows aquifers as identified by the Ground Water Atlas of the United States.
- Prime Farmlands—Prime farmland is designated as land that has the best combination of both physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is also available for these production land uses. The map in this section displays U.S. Department of Agriculture prime farmland types to allow planners and communities to prioritize areas for farmland preservation when it aligns with the goals and objectives of the group.
- Major Crop Types—Major crop types displayed are designated by the USDA National Agricultural Statistics Service and include cereal grains, fruit, vegetable, other edible, and non-edible.

### Existing Environmental Concerns

Determine whether there are existing areas of environmental concern by examining impervious surfaces, National Pollutant Discharge Elimination System (NPDES) sites, and impaired waterbodies within your watershed.

- Impervious Surfaces—Impervious surfaces reduce the amount of water that can infiltrate into the ground, which increases storm water runoff, pollutants, and sediment loads leading to degraded water quality. The impervious surfaces map and resources provide comparison, and review, of the percent of impervious surface area at different scales and changes in impervious surface area over time. Water quality impairments can occur with as little as 10% impervious surface area and greatly increase when impervious surface areas exceed 20% of land cover in a watershed.
- Existing National Pollutant Discharge Elimination System (NPDES) Sites—As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources include pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. The map shows the location of National Pollutant Discharge Elimination System (NPDES) permitted sites.
- Impaired Waterbodies—Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters too polluted, or otherwise degraded, to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop a Total Maximum Daily Load (TMDL) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. The impaired waterbodies map displays water bodies with 305b and 303d water quality reports.

## Tipping Points

The term "tipping point" refers to the threshold(s) of human-induced ecological stress and indicators of natural resource condition that can indicate change in how aquatic ecosystems function. The Tipping Points module uses digital tools and research data to identify land use limits and identify critical areas requiring protection or restoration to improve ecosystem health in a watershed.

### Stream Health – Land Use and Invertebrate Health

Because invertebrate organisms are an important food source and are sensitive to pollution and habitat modification, the health of benthic communities is a strong indicator of overall stream health. The stream health model helps users to determine how close a watershed is to an ecological tipping point by examining the health of organisms living in its streams.

- Current Stream Health—The purpose of the stream health model is to understand the current health of individual streams within the Great Lakes basin by using three land use stressors as indicators of stream health. These three stressors include: percent urban land cover, percent suburban land cover, and percent agricultural land within a 150 meter buffer of streams. The model uses Index of Biotic Integrity (IBI) scores to determine the health and status of organisms living in the stream. The three land use stressors are then correlated to the IBI scores to allow land use planners to determine at what level land use decisions begin to negatively impact the health of organisms in that stream.
- Future Stream Health—The future stream health model incorporates the Land Transformation Model (discussed earlier) to project future land use trends to be used as the land use stressors for the stream health model. The integration of both models allows users to understand how future changes to the land may affect the health of organisms in the stream.

## Nutrients and Nutrient Loading

The Nutrients and Nutrient Loading module provides a comprehensive view of nitrogen and phosphorus quantities including their sources within the watershed(s).

- Spatially Explicit Nutrient Sources (SENS) Map—The Spatially Explicit Nutrient Sources (SENS) map and model seek to describe how much Nitrogen (N) and Phosphorus (P) is applied to the landscape within each 12 digit watershed in the Great Lakes basin. The model identifies seven distinct nutrient sources and accounts for these nutrients through four approaches: interpolated measurements (atmospheric

deposition), regulated locations (point sources, confined animal feeding operations (CAFOs)), "population"-based loading (septic systems, non-CAFO manure, golf course fertilizers, nitrogen fixation), and by distributing county-level data (chemical agricultural fertilizers, non-agricultural fertilizers). Annual applied loads are displayed at the HUC 12 watershed scale, and pie charts show the percent contribution of each nutrient source.

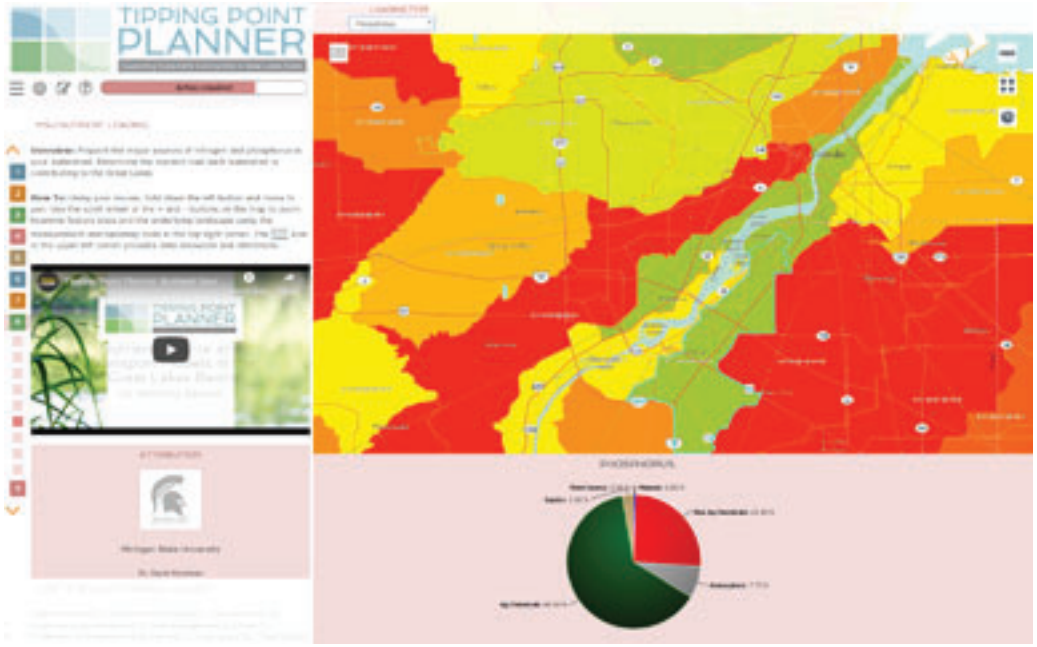
The model is driven by widely-available data sources. Some examples of these sources include:

| State |
|---|
| Drinking well locations |
| Regulated CAFO inventories |

| National |
|---|
| U.S. Census |
| Ag Census |
| Incorporated area boundaries |
| Cropland data layers |
| National Land Cover Dataset |
| Soil survey (SSURGO) |
| Atmospheric deposition data |
| NPDES point source discharges |

| Literature |
|---|
| Atmospheric deposition data |
| Per-person septic loading |
| Per-head animal excretion |
| Per-animal manure N:P ratio |
| Manure recovery rates |
| N-fixation equations |

| Original Datasets |
|---|
| Golf course boundaries |
| Wastewater treatment/service area refinement |



More information about the SENS model, including a short video, can be found here: http://tippingpointplanner.org/resources-3/model-resources/49-uncategorised/185-spatially-explicit-nutrient-sources-model.

- SPARROW Phosphorus Loading Model – Current and Future—The U.S. Geological Survey developed a nutrient loading model that combines water quality monitoring data with information about the landscape to predict nutrient loading levels transported by rivers and streams. The SPARROW (SPAtially Referenced Regression On Watershed attributes) model relates measured Phosphorus (P) loads to known sources on the landscape to model nutrient loading to surface waters. The model considers landscape factors (climate, soils, topography, drainage density) as well as transport and fate properties at the stream segment catchment level. As nutrients from significant sources travel through a stream network, they remain in flux depending on stream/reservoir characteristics. Stream monitoring data from USGS is used to calibrate the SPARROW model. Mean-annual nutrient load is predicted for each stream segment catchment and then aggregated at larger scales by following stream networks (i.e., by connecting upstream outlets and downstream catchment inlets).

  The SPARROW model used for the Tipping Point Planner identifies six significant sources of P at the catchment level: point sources, urban land uses, manure from confined and unconfined animals, farm fertilizers, and forested land uses. Because

SPARROW modeling depends on transport and fate processes (how nutrients are gained and lost due to new inputs, settling out, etc.), data at the stream segment catchment level do not provide the most accurate representation of P loads. Therefore, P loads (kg) are shown on the map at the HUC 8 watershed scale.

For future P input predictions, P sources are linked to the Land Transformation Model (LTM; Pijanowski et al. 2002) land use maps for 2010 and 2040.

- Long-Term Hydrologic Impact Assessment (L-THIA) Model—The Long-Term Hydrologic Impact Assessment (L-THIA) model estimates the impact of land use change on surface runoff and non-point source pollution. The model is based on the Curve Number method for estimating changes in discharge as a watershed undergoes urbanization. It uses annual average runoff data from the past 30 years compared to the land use configuration for a given area.

  The "Paints" tool in the Tipping Point Planner allows users to draw new land cover types, and the model calculates, in real-time, what impacts these land use changes might have on pollutant loading. This allows users to investigate multiple "what-if" scenarios and model how planned changes to the landscape could impact water quality. The output gauges display the increase or decrease of six pollutants: Nitrogen (N), Phosphorus (P), Suspended Solids, Lead, Copper, and Zinc—all common non-point source pollutants from urban areas that impact water quality.

More information about the L-THIA model, including a short video, can be found here: http://tippingpointplanner.org/resources/action-strategies/183-lthia.

### Food Webs

Changes in nutrient loading levels can have a major impact on the coastal food webs – particularly sport fish, invasive species, and forage species – in the Great Lakes.

- Food Web Model—The purpose of the food web model is to examine the impact of increased nutrient loads on the food web of Saginaw Bay. Users can view changes in the biomass of walleye, yellow perch, aquatic plants, and harmful blue-green algae in the Bay when Phosphorus (P) concentration is increased or decreased. At a certain point, increased P causes a decrease in the biomass of yellow perch and aquatic plants, while the biomass of blue-green algae and walleyes will continue to increase.

  For more information about the Food Web Model, including a short video, can be found here: http://tippingpointplanner.org/resources/action-strategies/182-food-web-model.

## Research Literature

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