Land Protection Priorities in the Macatawa Watershed

Part 1 - Natural Land

Prepared for the

Macatawa Area Coordinating Council

By

John D. Fraser

January 31, 2010

1. INTRODUCTION

1.1 The Macatawa Watershed

The Macatawa River Watershed drains an area of 175 square miles in southern Ottawa and northern Allegan Counties in southwestern Michigan. The Macatawa River and its tributaries flow into Lake Macatawa, an 1808 acre, 5 mile long body of water which empties into Lake Michigan through a short channel. Pine Creek drains the northwestern part of the watershed directly into Lake Macatawa.

The watershed encompasses the cities of Holland and Zeeland and most of the townships of Park, Holland and Zeeland as well as parts of Port Sheldon, Olive, Blendon, Georgetown and Jamestown townships in Ottawa County and parts of Manlius, Overisel, Fillmore and Laketown townships in Allegan County.

The region is relatively flat with a maximum elevation above Lake Michigan of approximately 35 meters. The land has been extensively drained for agriculture and almost 50% of the watershed is characterized as prime farmland soil by the U. S. Department of Agriculture.

1.2 Protection Priority Criteria

The unit of comparison used in this study is the survey quarter-quarter section (see Appendix A for discussion of possible comparison units). Each quarter-quarter section or part quarter-quarter section was assigned a protection score based on the value of each of the criteria used in assessing protection potential. Protection priority was determined by summing the criteria scores and comparing the totals for each comparison unit.

The original datasets used to quantify the criteria are described in the appendices. Most of the original data was extensively modified as described in Part 2 - Data Preparation. The result was the assignment of a numerical measure of protection value for each criterion.

The following is a brief outline of the criteria used:
Land Cover/Use values were based on the percentage area of each cover type in a given quarter-quarter section. (Cover types are described in Appendix B). Note that most quarter-quarter sections are approximately 40 acres (88% are between 35 and 45 acres). Smaller units are generally those around the periphery of the watershed which have been clipped to fit.

Hydro values were based on the length of hydro features in each quarter-quarter section. Hydro features are subdivided into Lake/pond, river/steam and drain categories. Scores are weighted to reflect the relative values of each category.

Biological Rarity Index values (Appendix C) are assigned by the Michigan Natural Features Inventory to each block of an arbitrary 40 acre grid. The survey quarter-quarter section grid used for the model is also comprised mainly of 40 acre blocks but the two grids do not correspond. In order to assign RI values to each quarter-quarter section the area of each part of an MNFI grid unit lying within a quarter-quarter section was multiplied by the MNFI RI value of the grid unit and the products were summed for all MNFI part units lying within each quarter-quarter section. The total obtained for each quarter-quarter section was then divided by the area of the quarter-quarter section to give the project (MAC) RI value for each survey quarter-quarter section.

Development Pressure values were based on difference between the Purdue University Land Transformation Model (Appendix D) predicted urban land cover for each quarter-quarter section in 2015 and the predicted values for 2005. The predicted increase in urbanization was taken as a measure of short-term development pressure.

Proximity to Protected Areas. Protection scores were assigned to quarter-quarter sections which have undeveloped areas adjacent to property parcels which already have some degree of protection from development. Protected areas were identified on property parcel datasets by referring to the websites of state, county and local government organizations and land conservation organizations in the watershed (Appendix E).

Ground Water Recharge. The Mi DNR Darcy Potential Groundwater Movement Model (Appendix F) is a raster dataset showing the input or output of groundwater from each 30 meter grid unit of the model to the nearest surface water body (lake, stream, etc.). Protection values for this study were obtained by averaging recharge over each quarter-quarter section. Areas with higher recharge rates were assigned higher protection scores because they have a greater effect on downstream surface water and thus on the watershed as a whole. Areas with negative recharge rates (surface water flowing into the grid unit ground water) were assigned zero value.

Agricultural Soil Quality. Natural habitat is characterized by having a diverse biota and being self-sustaining, at least if the ecosystem is large enough. Farmland, on the other hand, is generally a monoculture and requires constant human intervention to maintain its character. Thus the criteria used to assess the value of the two land types may be quite different. Because both types of land need protection, *negative* values have been assigned to quarter-quarter sections in this study which have large areas of prime farmland soil as determined by the USDA (Appendix G). This will tend to insure that if natural areas of equal potential are being considered for protection the one that has less prime farmland soil will be preferred.

1.3 Methodology Outline

The procedure for creating the model comprised the following steps:

- Creation of a survey quarter-quarter section ESRI file geodatabase feature class to serve as a base or framework for the model.
- Creation and/or modification of a geodatabase feature class representing each of the protection criteria.
- Establishment of a numerical attribute (area, length, percentage, index or nominal value, etc.) which best represents the contribution each criterion makes to the quality of the landscape.

- Addition of the attribute values for each of the criteria to the framework feature class (model) attribute table.
- Classification (if necessary) of each criterion attribute.
- Weighting (scoring) of each criterion attribute for each quarter-quarter section.
- Computation of a total protection score for each quarter-quarter section by the addition of the scores for each criterion.
- Testing of outcomes against DOQs, parcel data and other digital resources and by ground-truthing.
- Ranking and symbolization of the outcome for display in a map.

2. DATA PREPARATION

2.1 Watershed Boundary

Data Source

Macc_Watershed.shp.

Dataset provided by the Macatawa Area Coordinating Council.

Processing

Macc_Watershed.shp reprojected from:

NAD_1983_Michigan_GeoRef_Meters

to:

NAD_1983_Hotine_Oblique_Mercator_Azimuth_Natural_Origin.

Dataset imported into ESRI file geodatabase as:

MAC2.gdb/MAC_WS_Bound.

2.2 Survey Quarter-Quarter Section Base Feature Class

Data Source

ottawa_quarter_quarter_sections.shp

and

allegan_quarter_quarter_sections.shp

Datasets created by the Michigan Department of Natural Resources and downloaded from the Michigan Geographic Data Library.

Processing

Select by Location from *allegan_quarter_quarter_sections.shp* and *ottawa_quarter_quarter_sections.shp* records which intersect *MAC2.gdb/MAC_WS_Bound*.

Merge (Data Management Tools>General>Merge) selected records.

Clip (Analysis Tools>Extract>Clip) merged dataset with *MAC2.gdb/MAC_WS_Bound*. The resulting dataset has 2950 records (QQs).

Delete fields AREA and PERIMETER from attribute table because they refer to the un-clipped records. New areas and perimeters are given by Shape_Area and Shape_Length.

Delete records less than 1 acre (52 records). 2898 records remain. (The small polygons are slivers along the edges of the boundary).

Add field:

MAC_ID (short integer).

Populate field with sequential values 1 to 2898.

Save dataset as: *MAC2.gdb/MAC_QQ*.

Add field:
MAC_Acres (double)
Populate using Calculate Geometry.

2.3 Land Cover/Land Use

Data Source

Original Dataset: *lu2005.shp* developed by the Michigan Department of Environmental Quality and obtained from the Macatawa Area Coordinating Council. (Total acres = 111677).

In preparing data for the priority model extensive revisions were made to polygons in the Michigan DEQ *lu2005.shp* dataset. Changes were made by comparison to 1998 and 2005 aerial imagery and ground-truthing. Revisions included reclassification and splitting of some polygons. No polygons were re-drawn. During the revision process some farmland areas were reclassified to other cover types and some non-farmland areas were reclassified as farmland. The new classification system is described in Appendix B.

Processing

Define projection as:
NAD_1983_Hotine_Oblique_Mercator_Azimuth_Natural_Origin.prj

Save dataset as MAC2.gdb/MAC_Cover.

Edit features as described above.

Add Fields:
M_Class (text, 5).
M_Type (text, 12).
M_Acres (double).
M_AgClass (text, 5)
M_AgType (text, 15)

Use Calculate Geometry to populate MAC_Acres field.

Use Field Calculator to populate MAC_Class, MAC_Type, MAC_AgClass and MAC_AgType fields with appropriate Class symbol and type designation (see: Appendix B).

2.4 Hydro

Data Source

Ottawa Hydro Framework: *hydro_139v8a.shp*.
Allegan Hydro Framework: *hydro_005v8a.shp*.

These datasets are maintained and distributed by the Michigan Center for Geographic Information and were downloaded from the Michigan Geographic Data Library. (www.mcgi.state.mi.us/mgdl/).

Processing
Select by Location from *hydro_139v8a.shp* and *hydro_005v8a.shp* features that are within *MAC2.gdb/MAC_WS_Bound* . Export selected features to *MAC2.gdb/Hydro_Ottawa* and *MAC2.gdb/Hydro_Allegan*.

Merge (Data Management Tools>General>Merge): *MAC2.gdb/Hydro_Ottawa* and *MAC2.gdb/Hydro_Allegan*. Output:
MAC2.gdb/MAC_Hydro.

Edit features in *MAC2.gdb/MAC_Hydro* to conform more closely to 2005 and 1998 DOQ aerial imagery. DRGs, DEMs and ground-truthing consulted to improve accuracy.

Note: The following two steps were carried out by reference to 1998 and 2005 aerial imagery (DOQs) and Mi DEQ Land Use/Land Cover dataset (*lu2005.shp*).

Remove lake features (FCC = H21) where lake shorelines within a quarter-quarter section are completely developed (built up).

Digitize unrecorded lakes and ponds greater than 5000m^2. Mark FCC = H21 and ver = “jdf”. (85 new features created. 127 total H21 features).

Change FCC class of Lake Macatawa mouth features from H32 (two-bank stream) to H21 (lake shoreline).

2.5 Biological Rarity Index

Original Data
Original data contained in *ottawa_ri.shp* and *allegan_ri.shp* Biological Rarity Index and Probability Value datasets developed by the Michigan Natural Features Inventory (3/31/2006). Each dataset provides a probability model and a biological rarity index model for the appropriate county.
Data downloaded from the Michigan Geographic Data Library.

Processing
ottawa_ri.shp and *allegan_ri.shp* reprojected from:
NAD_1983_Michigan_GeoRef_Meters
to:
NAD_1983_Hotine_Oblique_Mercator_Azimuth_Natural_Origin.

Merge (Data Management Tools>General>Merge) *ottawa_ri.shp* and *allegan_ri.shp* to form *ottawa_allegan_Merge.shp*.

Select by location from *ottawa_allegan_Merge.shp* records that are intersected by *MAC2.gdb/MAC_WS_Bound* .
Export selected records to *MAC2.gdb/MAC_MNFI*.

Add Field:
RI_Area (double).

2.6 Development Pressure

<u>Data Source</u>

Data was in the form of a series of ArcGIS Grid (raster) files representing actual land use in the state of Michigan for the year 2000 and predicted land use for the years 2005, 2010, 2015, 2020, 2025 and 2030.
Data was downloaded from the Purdue University Land Transformation Model web site. (http://ltm.agriculture.purdue.edu/ltm.htm).

<u>Processing</u>

Convert(Conversion Tools>From Raster>Raster to Polygon) raster datasets to polygons (Field = VALUE; uncheck Simplify Polygons).

From new vector datasets Select by Location polygons that intersect *MAC2.gdb/MAC_WS_Bound*.
Export selections to:
MAC2.gdb/MAC_LTM2005.
MAC2.gdb/MAC_LTM2015.

Select urban polygons (gridcode = 11, 12, 13 or 14) and export selections to:
MAC2.gdb/Urban2005. (4290 records).
MAC2.gdb/Urban2015. (5591 records).

Merge (Edit>Merge) output records *within* each feature class.
Delete field: ID
Populate 'GRIDCODE' field with 1.

2.7 Protected Areas

Protected Parcels are property parcels which currently (2009) have some degree of protection from development through their designation as parks, preserves or nature areas or due to the presence of a conservation easement. A few parcels of undeveloped public land (state, county or municipal) are also included.

Protected Areas are protected parcels or groups of protected parcels. Generally, parcels in a protected area will have the same owner but there are some exceptions such as Holland's Outdoor Discovery Center. Also, parcels in a protected area are usually contiguous but not always (Holland City Greenway parcels, Greenway Partnership parcels).

The Macatawa Greenway is a projected natural corridor running along the Macatawa River from downtown Holland to Zeeland Township. Current components of the Greenway comprise both public and private lands. The project is administered by the The Outdoor Discovery Center - Macatawa Greenway Partnership (ODC-MGP), a nonprofit environmental education and conservation organization. Some components of the

Greenway are named parks or preserves and are listed as such under AreaName in the datasets attribute table - otherwise they are listed as 'Macatawa Greenway'.

<u>Processing</u>
Create new polygon feature class *MAC2.gdb/MAC_Protect*.

Add Fields:
AreaName (text, 35)
Location (text, 15)
AcresMAC (double)
Parcels (short integer)
OwnerType (text, 10)
Owner1 (text, 35)
Owner2 (text, 35)
Owner3 (text, 35)
Status (text, 5)
NotesMAC (text, 25)

Append (Data Management Tools>General>Append) protected parcel features from county property parcel layers to *MAC2.gdb/MAC_Protect* (Schema Type = NO TEST).

Merge (Edit>Merge) parcels where there is more than one property parcel in a protected area (see above).

Populate attribute fields of *MAC2.gdb/MAC_Protect* with attribute information from Appendix E.

2.8 Ground Water Recharge
<u>Data Source</u>
Darcy Potential Groundwater Movement Model (Input-Output), Michigan DNR Fisheries Division, Institute for Fisheries Research raster dataset *asciito_darc2.rrd* downloaded from the MI DNR Geographic Data Library.

<u>Processing</u>
Extract (Spatial Analyst>Extract>Extract by Mask) from *asciito_darc2.rrd* using *MAC2.gdb/MAC_WS_Bound* as mask:
Output raster grid: *asciito_ex*.

Convert (Conversion Tools>From Raster>Raster to Polygon) raster dataset *asciito_ex* to vector dataset *MAC2.gdb/MAC_GWR*.

2.9 Soil Quality
<u>Data Source</u>
Allegan County Soil Survey Data (Survey Area Version 8; Tabular Data Version 7; Spatial Data Version 5; (SSURGOV2.1, MD 2.2.3)
and

Ottawa County Soil Survey Data (Survey Area Version 4; Tabular Data Version 4; Spatial Data Version 2; (SSURGOV2.1, MD 2.2.2):

The data is provided in the form of shapefiles (*soilmu_a_mi005.shp* and *soilmu_a_mi139.shp*) which show the spatial extent of soil types in the respective counties. In addition, a set of tabular data which contains attribute information on the soil types is provided, as well as a Microsoft Access template database (*soildb_MI_2002.mdb*). The tabular data can be imported into the Access template and reports created.

All original data was created by United States Department of Agriculture, Natural Resources Conservation Service and downloaded from the Soil Data Mart: http://soildatamart.nrcs.usda.gov/

<u>Processing</u>
soilmu_a_mi005.shp and *soilmu_a_mi139.shp* reprojected from:
NAD_1983_Michigan_GeoRef_Meters
to:
NAD_1983_Hotine_Oblique_Mercator_Azimuth_Natural_Origin.

Select by Location features from *soilmu_a_mi005.shp* and *soilmu_a_mi139* that intersect *MAC2.gdb/MAC_WS_Bound* and output selected data as:
MAC2.gdb/MSoil005 and
MAC2.gdb/MSoil139.

Select by Attributes from *MAC2.gdb/MSoil005* features where MUSYM field attribute equals one of the Map Symbols listed in the Prime and Other Important Farmlands report for Allegan County as 'All areas are prime farmland'. Export selected features.
Output: *MAC2.gdb/MSoil005_prime*.

Select by Attributes from *MAC2.gdb/MSoil005* features where MUSYM field attribute equals one of the Map Symbols listed in the Prime and Other Important Farmlands report for Allegan County as 'Prime farmland if drained'. Export selected features.
Output: *MAC2.gdb/MSoil005_drained*.

Select by Attributes from *MAC2.gdb/MSoil139* features where MUSYM field attribute equals one of the Map Symbols listed in the Prime and Other Important Farmlands report for Ottawa County as 'All areas are prime farmland'. Export selected features.
Output: *MAC2.gdb/MSoil139_prime*.

Select by Attributes from *MAC2.gdb/MSoil139* features where MUSYM field attribute equals one of the Map Symbols listed in the Prime and Other Important Farmlands report for Ottawa County as 'Prime farmland if drained'. Export selected features.
Output: *MAC2.gdb/MSoil139_drained*.

Merge (Data Management Tools>General>Merge) *MAC2.gdb/MSoil005_prime*, *MAC2.gdb/MSoil005_drained*, *MAC2.gdb/MSoil139_prime* and *MAC2.gdb/MSoil139_drained*.
Output: *MAC2.gdb/MAC_PrimeSoil*.

3. MODEL CREATION

<u>Data Sources</u>
Watershed boundary: *MAC2.gdb/MAC_WS_Bound*. (Data Preparation 2.1).
Survey quarter-quarter sections: *MAC2.gdb/MAC_QQ*. (Data Preparation 2.2).
Land Cover/Use: *MAC2.gdb/MAC_Cover*. (Data Preparation 2.3).
Hydro: *MAC2.gdb/MAC_Hydro*. (Data Preparation 2.4).
Biological Rarity: *MAC2.gdb/MAC_MNFI*. (Data Preparation 2.5).
Development Pressure: *MAC2.gdb/Urban2005* and *MAC2.gdb/Urban2015*. (Data Preparation 2.6).
Proximity to Protected Areas: *MAC2.gdb/MAC_Protect*. (Data Preparation 2.7).
Groundwater Recharge: *MAC2.gdb/MAC_GWR*. (Data Preparation 2.8).
Prime Soils: *MAC2.gdb/MAC_PrimeSoil*. (Data Preparation 2.9).

<u>Processing</u>
Delete all fields from *MAC2.gdb/MAC_QQ* except:
OBJECTID
Shape
COUNTY
TOWN
GEO_ID
MAC_ID
Shape_Length
Shape_Area
MAC_Acres

Save result as:
MAC2.gdb/MAC_Model.

Land Cover/Use
To *MAC2.gdb/MAC_Model* add field:
MAC_Built (text, 5)
Quarter-quarter sections with no undeveloped parcel greater than 5 acres were designated 'B' in MAC_Built field. (318 features).
Quarter-quarter sections consisting entirely of water were designated 'L' in MAC_Built field. (22 features).
All other quarter-quarter sections were designated 'S'.

To *MAC2.gdb/MAC_Model* add fields:
M1 (float)
M19 (float)
M2 (float)
M29 (float)
M31 (float)
M32 (float)
M4 (float)

M429 (float)
M5 (float)
M53 (float)
M6 (float)
M7 (float)

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* with *MAC2.gdb/MAC_Cover* (NO FID; Output Type = INPUT).
Output: *MAC2.gdb/Intersect_Cover*.

Select by Attributes from *MAC2.gdb/Intersect_Cover* where M_Class = M19.

Summarize selected records on field MAC_ID for Shape_Area (Sum).
Output Table: *MAC2.gdb/Sum_M19*.

Join table *MAC2.gdb/Sum_M19* to *MAC2.gdb/MAC_Model* based on field MAC_ID.

Use Field Calculator to populate model M19 field [MAC_Model.M19] with percentage of M19 cover in each model feature (quarter-quarter section) using expression:
([Sum_M19.Sum_Shape_Area] / [MAC_Model.Shape_Area]) *100

Remove Join.

Repeat the previous 5 operations for each of the land cover classes M2 to M7.

Comparison of the lan cover dataset and 2005 DOQ imagery revealed significant changes from Water to Wetland cover in some areas, especially near downtown Holland. In order to avoid redrawing polygons in the Cover dataset (because this may not reflect a permanent drop in water level), these changes were reflected by reducing proportion of Water cover and increasing proportion of Wetland cover in a few QQs :
MAC_ID = 1283 (30%), 1341 (30%), 1344 (40%), 1345 (20%).

Hydro
To *MAC2.gdb/MAC_Model* add fields:
MH2 (double)
MH3 (double)
MH4 (double)

Export feature class *MAC2.gdb/MAC_Hydro* to:
MAC2.gdb/MAC_Hydro_Merge.

Delete all two-banked streams (H32) and replace with a single screen digitized H31 feature.

Edit/Merge all features where FCC = H31, H32 or H33 into a single feature where FCC = H3.

Edit/Merge all features where FCC = H41 into a single feature where FCC = H4.

Edit/Merge all features where FCC = H21 into a single feature where FCC = H2.

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* with *MAC2.gdb/MAC_Hydro_Merge* (NO FID; Output Type = INPUT).
Output: *MAC2.gdb/Intersect_Hydro*.

Select by Attributes from *MAC2.gdb/Intersect_Hydro* where FCC = H2.

Summarize selected records on field MAC_ID for Shape_Length (Sum).
Output Table: *MAC2.gdb/Sum_MH2*.

Join table *MAC2.gdb/Sum_MH2* to *MAC2.gdb/MAC_Model* based on field MAC_ID.

Use Field Calculator to populate model MH2 field [MAC_Model.MH2] with length of lake perimeter (H2) in each quarter-quarter section.

Remove Join.

Repeat the previous 5 operations for hydro types H3 and H4.

MNFI Species Rarity Index
To *MAC2.gdb/MAC_Model* add field:
MRI (float)

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* and *MAC2.gdb/MAC_MNFI*.
Output: *MAC2.gdb/Intersect_MNFI*.

Use Field Calculator to populate *MAC2.gdb/Intersect_MNFI* RI_Area field with:
RI x Shape_Area

Summarize on field MAC_ID for field RI_Area (Sum).
Output table: *MAC2.gdb/Sum_RIArea*.

Join *MAC2.gdb/MAC_Model* and *MAC2.gdb/Sum_RIArea* using MAC_ID as join field.

Use Field Calculator to populate model MRI field [MAC_Model.MRI] with project rarity index (RIarea for each QQ/area of QQ) for each QQ using the expression:
[MAC_Model.MRI] = [Sum_RIarea.Sum_RI_Area] / [MAC_Model.Shape_Area]

Remove Join.

Development Pressure
To *MAC2.gdb/MAC_Model* add field:
MDev (double)

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* with *MAC2.gdb/Urban2005* and *MAC2.gdb/Urban2015*.
Output:
MAC2.gdb/Intersect_2005.
MAC2.gdb/Intersect_2015.

To *MAC2.gdb/Intersect_2015* add field:
S_A_2005 (double).

Join *MAC2.gdb/Intersect_2015* and *MAC2.gdb/Intersect_2005* using MAC_ID as the join field.

Using Field Calculator populate *MAC2.gdb/Intersect_2015* S_A_2005 field with values in *MAC2.gdb/Intersect_2005* Shape_Area field.

Select by Attributes records where S_A_2005 field values are 'NULL' and use Field Calculator to populate selected fields with '0'.

Remove Join.

Join *MAC2.gdb/MAC_Model* and *MAC2.gdb/Intersect_2015* using MAC_ID as join field.

Use Field Calculator to populate model MDev field [MAC_Model.MDev] with the difference between the area of 2015 urban records and the area of 2005 urban records (field S_A_2005) using expression:
MAC_Model.MDev = [Intersect_2015.Shape_Area] - [Intersect_2015.S_A_2005].

Remove Join.

Proximity to Protected Areas
To *MAC2.gdb/MAC_Model* add field:
MPrx (short integer).

Select by Location from *MAC2.gdb/MAC_Model* features which intersect *MAC2.gdb/MAC_Protect*.

Export selected features to new feature class:
MAC2.gdb/MAC_Prox.

By reference to *MAC2.gdb/MAC_Cover*, delete features from *MAC2.gdb/MAC_Prox* which have only land cover characterized as M1 or M29 (built up land) in contact with protected land from *MAC2.gdb/MAC_Protect*.

By inspection, populate the MPrx field of the remaining features in *MAC2.gdb/MAC_Prox* with one of 5 values:
1 = QQs which share a border equal to or greater than 50 m with protected features from *MAC2.gdb/MAC_Protect*.
2 = QQs which share a border less than 50 m with protected features from *MAC2.gdb/MAC_Protect*.
3 = QQs which are entirely protected.
4 = QQs which contain some protected land but no other undeveloped land.
5 = QQs which contain some protected land and some adjacent undeveloped land.

Join *MAC2.gdb/MAC_Model* and *MAC2.gdb/MAC_Prox* using MAC_ID as join field.

Using Field Calculator, populate model MPrx field [MAC_Model.MPrx] with values from *MAC2.gdb/MAC_Prox* MPrx field [MAC_Prox.MPrx].

Remove Join.

Groundwater Recharge
To *MAC2.gdb/MAC_Model* add field:
MGw (double).

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* and *MAC2.gdb/MAC_GWR*.
Output: *MAC2.gdb/Intersect_GWR*.

Summarize on field MAC_ID for field GRIDCODE (Mean).
Output table: *MAC2.gdb/Sum_GWR*.

Join *MAC2.gdb/MAC_Model* and table *MAC2.gdb/Sum_GWR* using MAC_ID as join field.

Using Field Calculator, populate model MGw field [MAC_Model.MGw] with values from table Ave_GRIDCODE field [Sum_GWR.Ave_GRIDCODE].

Remove Join.

Soil Quality
To *MAC2.gdb/MAC_Model* add field:
MFm (double).

Intersect (Analysis Tools>Overlay>Intersect) *MAC2.gdb/MAC_Model* and *MAC2.gdb/MAC_PrimeSoil*.

Output: *MAC2.gdb/Intersect_Soil*.

Summarize on field MAC_ID for field Shape_Area (Sum).
Output table: *MAC2.gdb/Sum_Soil*.

Join table *MAC2.gdb/Sum_soil* to *MAC2.gdb/MAC_Model* based on field MAC_ID.

Use Field Calculator to populate model MFm field [MAC_Model.MFm] with percentage of prime soil cover in each QQ section using expression:
([Sum_Soil.Sum_Shape_Area] / [MAC_Model.Shape_Area]) *100

Remove Join.

4. MODEL SCORING

4.1 Scoring Considerations

There are no ‘right’ scores for each of the criteria chosen just as there are no ‘right’ total scores for each of the quarter-quarter sections. The computer cannot decide what weights to assign to each of the criteria because the criteria are of different types: percentage area of forest vs. meters of stream, for example. Humans must decide the comparative value of forest vs. stream. The machine merely crunches the numbers and adds them up. The beauty of the computer model is that the weights can be changed and the model re-run to produce different outcomes. This is vital because in the end the rankings must reflect real-world conditions on the ground as well as the actual preferences of the stakeholders.

In practice a number of factors were taken into account when assigning weights:

- The need to separate the comparison units numerically so they can be effectively ranked. If too many units get the same score the prioritization is less useful.
- The need to ensure that slight differences in the value of a criterion do not result in large differences in score. A unit which has 69.9% of a given value should not score significantly less than a unit which has 70% of the value.
- The limitations of the technology. Some criteria may be represented more accurately than others and that should be reflected in the scores.

4.2 Classification and Weighting

<u>Processing</u>

To *MAC2.gdb/MAC_Model* add fields:

M1_PS (short integer)
M19_PS (short integer)
M2_PS (short integer)
M29_PS (short integer)
M31_PS (short integer)
M32_PS (short integer)
M4_PS (short integer)
M429_PS (short integer)
M5_PS (short integer)
M53_PS (short integer)
M6_PS (short integer)
M7_PS (short integer)
MH2_PS (short integer)
MH3_PS (short integer)
MH4_PS (short integer)
MRI_PS (short integer)
MDev_PS (short integer)
MPrx_PS (short integer)
MGw_PS (short integer)
MFm_PS (short integer)
Total_PS (short integer)

Save *MAC2.gdb/MAC_Model* as:
MAC2.gdb/MAC_Model_B.

Classify protection criteria fields (M1 to MFm) and apply protection scores (M1_PS to MFm_PS) based on values in the Protection Criteria Classification and Weighting Worksheet on the following pages.

Calculate the Total Protection Score for each quarter-quarter section by the adding the scores for each of the criteria (M1_PS to MFm_PS).

4.3 Protection Criteria Classification and Weighting Worksheet.

Criterion	Field	Classification	QQs	Bw2		
				Score		
LandCover						
Built	**M1_PS**			**0**		
(developed land cover).						
Recreation	**M19_PS**	=< 30%	2848	**0**		
(% of recreation land		> 30 - =< 60	26	**2**		
cover in q-q).		> 60%	24	**4**		
Agricultural	**M2_PS**	=< 30%	1213	**0**		
(% of agricultural land		> 30 - =< 60	332	**2**		
cover in q-q).		> 60%	1353	**4**		
Built Ag	**M29_PS**			**0**		
(agricultural structures)						
Open Land	**M31_PS**	< 5%	2421	**0**		
(% of open land cover		=> 5 - < 25	332	**1**		
in q-q).		=> 25 - < 40	77	**2**		
		=> 40 - < 50	32	**6**		
		=> 50 - < 60	14	**10**		
		=> 60 - < 70	9	**14**		
		=> 70 - < 80	7	**18**		
		=> 80%	6	**22**		
Shrubland	**M32_PS**	< 5%	2531	**0**		
(% of shrubland land		=> 5 - < 25	275	**2**		
cover in q-q).		=> 25 - < 40	55	**4**		
		=> 40 - < 50	12	**8**		
		=> 50 - < 60	11	**12**		
		=> 60 - < 70	4	**16**		
		=> 70 - < 80	8	**20**		
		=> 80%	2	**24**		
Forest	**M4**	< 5%	1825	**0**		
(% of forest land cover		=> 5 - < 25	584	**5**		
in q-q).		=> 25 - < 40	191	**9**		
		=> 40 - < 50	87	**13**		
		=> 50 - < 60	72	**17**		
		=> 60 - < 70	44	**21**		
		=> 70 - < 80	35	**25**		
		=> 80%	60	**29**		
Plantation	**M429**	<= 10%	2892	**0**		
(% of plantation land		> 10 - <= 30	2	**3**		
cover in q-q).		> 30 - < = 60	3	**5**		
		=> 60%	1	**7**		

Water	**M5**	<= 10%	2796	**0**		
(% of open water in q-q).		> 10 - <= 30	39	**2**		
		> 30 - < = 60	22	**3**		
		> 60%	41	**4**		
Reservoir	**M53**	<= 25%	2896	**0**		
		> 25%	2	**2**		
Wetland	**M6**	< 1%	2709	**0**		
(% of wetland cover)		=> 1 - < 5	63	**3**		
		=> 5 - < 10	42	**6**		
		=> 10 - < 15	30	**9**		
		=> 15 - < 20	14	**12**		
		=> 20 - < 25	17	**15**		
		=> 25%	23	**19**		
Bare	**M7**	=< 30%	2895	**0**		
(% of bare land cover)		> 30 - =< 60	2	**2**		
		> 60%	1	**3**		
Hydro						
Lakes & Ponds	**MH2**	< 10m	2705	**0**		
(meters of pond perimeter		=> 10 - < 100	11	**2**		
in q-q).		=> 100 - < 300	68	**3**		
		=> 300 - < 500	71	**5**		
		=> 500 - < 650	24	**7**		
		=> 650m	19	**9**		
Rivers	**MH3**	< 10m	2462	**0**		
(meters of rivers in q-q).		=> 10 - < 100	46	**8**		
		=> 100 - < 300	107	**10**		
		=> 300 - < 500	179	**12**		
		=> 500 - < 650	59	**15**		
		=> 650m	45	**18**		
Drains	**MH4**	< 10m	1917	**0**		
(meters of drains in q-q).		=> 10 - < 100	109	**3**		
		=> 100 - < 300	271	**5**		
		=> 300 - < 500	387	**7**		
		=> 500 - < 650	139	**9**		
		=> 650m	75	**11**		
Species Rarity Index	**MRI**	0	1046	**0**		
(index of likelyhood of		> 0 - <= 5	1226	**1**		
rare species in q-q).		> 5 - <= 8	530	**3**		
		> 8 - <= 10	61	**6**		
		>10	35	**9**		

Development Pressure	**MDev**	<= 4047m^2	1647	**0**		
(predicted increase in		> 4047 - <= 24282	566	**1**		
area (m^2) developed).		> 24282 - <= 40470	383	**2**		
		> 40470 - <= 60705	229	**3**		
		> 60705m^2	73	**4**		
Proximity to Protected	**MPrx**	0	2642	**0**		
(index of proximity to		1	110	**10**		
protected land.		2	34	**7**		
See page 17).		3	26	**0**		
		4	10	**0**		
		5	76	**7**		
Ground Water Recharge	**MGw**	<= 0	2088	**0**		
(average positive recharge		> 0 - <= 10	508	**1**		
rate in a q-q).		> 10 - <= 40	225	**3**		
		>40	77	**5**		
Prime Farmland	**MFm**	0%	978	**0**		
(% of q-q with prime		> 0 - <=30	284	**-1**		
farmland soil type).		> 30 - <= 60	333	**-2**		
		> 60 - <= 90	515	**-3**		
		>90%	788	**-4**		

Total QQs = 2898, B = classification version, QQs = # of QQs in class, Bw2 = protection scores for classification B. (Bw2 is also the version number for this model outcome).

5. CONCLUSIONS

The scoring system described in the previous pages resulted in the assignment of a protection score to each of the quarter-quarter section comparison units in the study area. However, there is no single correct outcome for the priority modeling process used in this study. Classification and weighting of the values representing each of the criteria is a matter of judgment. It reflects the modeler's best assessment of the relative importance of each criterion and of the quality of the data used to represent it. As far as possible the results must be tested against real world conditions to determine their accuracy and reliability. One advantage of the modeling process is that scoring can be changed relatively easily if outcomes fail to reflect conditions on the ground or the protection priorities of the stake holders in the area being assessed.

This is not an ecological model designed to identify the best habitat for a particular species or the areas most likely to be self-sustaining. Ecological factors were certainly important but consideration was also given to the needs and desires of a wide range of stakeholders, not just scientists. In short, the model is not meant to produce an ideal protection priority ranking but rather to be a flexible tool which can assist decision makers in applying real-world priorities to land conservation decisions.
(See Appendix J for problems encountered in creating the model).

Appendix A - Choosing Base Units When Prioritizing Land for Protection

Natural Units

These would comprise polygons (or raster cells) representing areas of contiguous land cover type: wetlands, forests, farm fields, etc. Internal barriers whether natural (streams) or man-made (roads) would further delimit the units. Unfortunately it is very difficult to create a digital layer which accurately represents most land cover types at appropriate resolutions. Additionally, the units in such a layer vary widely in size and so are difficult to compare directly for any criterion other than area of land cover. A land cover/use layer of some kind is essential for developing a land protection priority system but is not ideal for use as the base framework in such a system.

Property Parcels

Since identifying property (and landowners) is one of the main purposes of land protection prioritization this would seem to be the ideal unit. However, there are many problems with parcel data. It may not be available for some jurisdictions (counties) and the standards for parcel digitization are variable. The purposes for which counties use the data may not require high accuracy and data integrity but analysis in a GIS is not so tolerant. Because methods and standards are different it may be particularly difficult to reconcile parcel data from more than one county if a study area crosses county lines. Also, parcels are of different sizes. In prioritizing them a choice must be made between average values and absolute values. Assuming you are interested in protecting wetland, would you assign a higher rank to a 10 acre parcel which is 50% wetland or a 100 acre parcel which is 10% wetland? Finally, there are privacy issues which arise when using easily identified property parcels as base units in a map which is publicly available.

Grids

Grids can be created in any size and the cells have the advantage of being identical no matter what the political units involved. On the other hand, such grids have no relation to any real world characteristics, whether natural or political. In order to compare protection potential in different regions a standard grid would have to be adopted.

Survey Quarter-Quarter Sections

These represent a particular kind of grid. Each cell is approximately 40 acres - though there is some variability, especially along the edges of any study area boundary which is not defined by section lines. The big advantage of quarter-quarter sections is that they often correspond to property parcel boundaries, especially in non-urban areas, since boundaries are based on section lines. Also, 40 acres is close to the lower limit of accuracy for the best available land cover data. Finally, a standard quarter-quarter section dataset is freely available from the Michigan Geographic Data Library for every county in the State.

Appendix B - Land Cover Classes

M Class

Class	Type	Acres	Description
M1	Developed	31847	Built up, roads
M19	Recreation	1693	Golf, playground, vacant lot, lawn, etc.
M2	Agriculture	53356	Farmland
M29	Ag Structure	1294	Farmhouses, barns, greenhouses, silos, etc.
M31	Open	4272	Herbaceous open land (meadow, overgrown farmland)
M32	Shrubland	2958	Shrubland, some emergent trees.
M4	Forest	12213	Mature forest
M429	Plantation	119	Christmas trees, pine plantation, etc.
M5	Water	2450	Open water (lakes, large two-bank rivers)
M53	Reservoir	274	Recent, manmade lake/pond, recreational, development.
M6	Wetland	893	Wetland (open or emergent)
M7	Bare	318	Sand, open pit, etc.

M AgClass

Class	Type	Acres	Description
M21	Cropland	50902	Row crops, small grains.
M22	Orchard	1855	Tree and bush fruits, ornamentals.
M24	Pasture	598	Permanent pasture
M29	Structure	1294	Farmhouses, barns, greenhouses, silos, etc.

The original Land Cover/Use dataset used in this study was developed by the Michigan Department of Environmental Quality, Land and Water Management Division, Hydrologic Studies Unit and obtained from the Macatawa Area Coordinating Council.

In preparing data for the priority model extensive revisions were made to polygons in the *lu2005.shp* dataset. Changes were made by comparison to 1998 and 2005 aerial imagery and ground-truthing. Revisions included reclassification and splitting of some polygons. No polygons were re-drawn. During the revision process some farmland areas were reclassified to other cover types and some non-farmland areas were reclassified as farmland.
In this *natural history* model (Part 1) only M Classes were used. M AgClasses were used in the separate model prioritizing *farmland* for protection (Part 2).

New class designations (see tables) used in the MAC study were chosen to reflect those used in the original dataset and also in the Michigan Land Cover/Use Classification System - 2000, which was originally developed by the Michigan Land Use Classification and Referencing Committee and is published by the Michigan Department of Natural Resources.

Appendix C - Biological Rarity Index

The original data used in developing values for this criterion was taken from a probability model and a biological rarity index model developed by the Michigan Natural Features Inventory (MNFI). Both models are based on the MNFI database of known sightings of threatened, endangered, or special concern species and high quality natural communities. The model values are reported on a 40 acre polygon grid for the state of Michigan.

The following is the metadata for the original dataset. (From MNFI metadata: http://web4.msue.msu.edu/mnfi/data/rarityindex/rarity_index_metadata.htm):

Citation:

Citation_Information:
Originator: Michigan Natural Features Inventory
Publication_Date: 20060331
Title: Biological rarity index and probability value - 40 acre grid
Geospatial_Data_Presentation_Form: vector digital data

Description:

Abstract:
Two models, a probability model and a biological rarity index model, are provided in this dataset. Both models are based on the Michigan Natural Features Inventory (MNFI) database of known sightings of threatened, endangered, or special concern species and high quality natural communities. The model values are reported on a 40 acre polygon grid for the state of Michigan, or a subset of MI.

Purpose:
The probability value is designed to highlight those areas with known occurrences of rare species or high quality natural communities. The biological rarity index is designed to help prioritize the known occurrence areas for conservation.

Process_Description:

The first step in the biodiversity and probability models is to group species into general habitat classes. The habitat classes are spatially represented using landcover data, stream lines, and rail corridors. These habitat layers are used to redefine the spatial extent of the rare species locations. Natural community locations are not subset by habitat, because all the communities have a defined spatial extent.

Process_Description:

Each occurrence is assigned a value based on the age of the record. This value is used to represent the probability that the occurrence still exists. Occurrences with a last observed date of no later than 1982 are assigned a value of one, occurrences between 1970 and 1982 are assigned a value of 0.5, and occurrences prior to 1972 are assigned a value of 0.25. All natural community records are assigned a value of one.

Each occurrence is also assigned three other values, one based on the species global status, one based on the species State status, and one based on the occurrence quality rank. The greater the threat of imperilment to the species, the higher the value assigned to the occurrence. In a similar vein, the higher the quality of each occurrence, the higher its assigned value. The rarity index value of each occurrence is then calculated by adding the values for the global status, state status, and the quality ranking, and then multiplying the sum by the probability value.

Process_Description:

To create the probability value for the 40 acre grid, all records in the grid are selected and assigned a "No Status" value. Next the records in the species database with the lowest probability of still existing (value = 0.25) are selected. The 40 acre grid is intersected with the species database and the selected grid records are assigned a value of "Low." Next those records with a moderate likelihood of still existing are selected (value = 0.5). The grid layer is intersected with the species database and the selected grid records are assigned a value of "Moderate." Finally the records in the species database with the highest probability of continued existance (value = 1) are selected. The grid data set is intersected with the species database and the selected sections records are assigned a value of "High." Performing the selections and intersections in this order insures that a higher probability in any section feature will override a lower probability.

To calculate the rarity index value of a given section, all the species occurrences intersecting the section are selected. The rarity index values of the selected species occurrences are summed and attributed to that grid location. The result is a rarity index value for each 40 acre block that is the sum of rarity index values of all occurrences falling within the block.

Entity_and_Attribute_Overview:

Probability represents the likelihood of encountering a rare species or high-quality natural community based on the age of the database record. The rarity index value is the sum of the values assigned to global status, state status, and quality ranking, multiplied by the probability value. These values are added for all occurrences intersecting each polygon grid feature.

Distributor:

Contact_Information:
Contact_Person_Primary:
Contact_Person: Edward Schools
Contact_Organization: Michigan Natural Features Inventory
Contact_Position: Conservation and GIS Manager
Contact_Address:
Address_Type: mailing address
Address: PO Box 30444
City: Lansing
State_or_Province: MI
Postal_Code: 48909
Contact_Voice_Telephone: 517-373-0798
Contact_Electronic_Mail_Address: schoolse@michigan.gov

Appendix D - Development Pressure

The original data for this criterion was downloaded from the Purdue University Land Transformation Model web site. (http://ltm.agriculture.purdue.edu/ltm.htm). Data was in the form of a series of ArcGIS Grid (100 meter raster cell size) files representing actual land use in the state of Michigan for the year 2000 and predicted land use for the years 2005, 2010, 2015, 2020, 2025 and 2030.
The current MAC study compared predicted urban land use in 2005 and 2015 in each quarter-quarter section in the watershed to measure short-term development pressure in that quarter-quarter section.
The following discussion is an extract from the *Technical Users Guide to the Land Transformation Model II*. (The entire guide can be downloaded from the website noted above.):

The Land Transformation Model has been developed to integrate a variety of land use change driving variables, such as population growth, agricultural sustainability, transportation, and farmland preservation policies. The LTM utilizes a set of spatial interaction rules, which are organized into an object class hierarchy. The model is entirely coded within a geographic information system with graphical user interfaces that allow users to change model parameters. Output of the LTM includes a time series of projected land uses in the watershed at user specified time steps.

Land Transformation Model is characterized by change in land use and land cover. Land use describes the anthropogenic uses of land as its affects ecological processes and land value (Veldkamp and Fresco 1996). Land uses that we consider at the most general level are: urban, agriculture/pasture, forest, wetlands, open water, barren and non-forested vegetation.
Land cover characterizes the plant cover of associated land use and is thus not mutually exclusive of land use. Land cover types that are considered include: types of agriculture (row crops versus non-row crops), deciduous and coniferous forests, and non-forested vegetation.

Within each land use, we consider *Intensity Of Use* such as land management practices, resource use and human activities. Intensity of use can be measured as chemical inputs to the land to increase its productivity (e.g., herbicides), chemical inputs as it results from human activities (e.g., salting of roads), and natural resource use (e.g, subsurface water for irrigation, per unit area energy consumption and forest harvesting). Socioeconomics, policy and environmental factors will also drive the intensity of use as well.

Changes in land use and cover, and intensity of use, alter *Processes* (e.g., hydrogeologic and geochemical) *and Distributions* of plants and animals in ecosystems. Processes that we are interested in characterizing include groundwater and surface water flows, chemical and sediment transport across land and through rivers and streams, geochemical interactions and fluxes such as nutrients (nitrogen and phosphorus). Land use and land cover will affect the types and numbers of animals inhabiting areas.

Land use and features (roads, rivers, etc.) in the watershed are characterized in the pilot LTM model as a grid of cells. Each cell is assigned an integer value based on land use (e.g., urban, agriculture, wetlands, forest) or land feature. Driving variable calculations produce land use conversion probabilities for each cell.

In the LTM, we use the GIS to make spatial calculations between drivers of land use change and cells being considered for land transition. The values resulting from these calculations are converted to *relative land transition probabilities.* Relative land transition probabilities that are used range from 1 (lowest probability of undergoing transformation to urban land use) to 10 (greatest chance of being converted to urban land use).

Appendix E - Protected Areas

	Owner/ Easement Holder	Protected Area Name	Size (ac)	Location
1	Land Conservancy of West Michigan	Kuker-VanTil Nature Preserve	45	Park Twp
2		Dune Pines Nature Presrve	13	Laketown Twp
3		Castle Park Reserve	5	Laketown Twp
4		Muzzy Conservation Easement	10	Laketown Twp
5	Michigan Department of Natural Resources	Holland State Park	142	Park Twp
6		Olive Twp State Game Area	245	Olive Twp
7		Blendon Twp State Game Area	40	Blendon Twp
8		unknown	8	Park Twp
9	Hope College	Hope College Nature Preserve	55	Laketown Twp
10	Ottawa County	Upper Macatawa Conservation Area	612	Zeeland Twp
11		12 Park Parcels	58	Park Twp
12		Riley Trails	300	Park Twp
13		Albert C. Keppel Forest Preserve	40	Park Twp
14		Tunnel Park	17	Park Twp
15		Macatawa Greenway	10	Holland Twp
16		unknown	40	Holland Twp
17	Macatawa Greenway Partnership	Macatawa Greenway	65	Holland, Zeeland
18		MG - Buursma Easement	3	Holland Twp
19		MG - Ridge Point Easement	150	Holland Twp
20		MG - Cruiser Easement	21	Holland Twp
21		MG - Dirkse Easement	12	Holland Twp
22	Wildlife Unlimited	Outdoor Discovery Center	100	Fillmore Twp
22	ODC of Wildlife	Outdoor Discovery Center	1	Fillmore Twp
22	ODC Friends	Outdoor Discovery Center	5	Fillmore Twp
23	Park Township	Ransom St. Park	20	Park Twp
24		Pine Creek Trail	37	Park Twp
25		Winstrom Park/Preserve	72	Park Twp
26		Cooper-Van Wieren	66	Park Twp
27		Wendt Fitness Park	17	Park Twp
28		unknown	14	Park Twp
29	Holland Township	Dunton Park	21	Holland Twp
30		Quincy Park	133	Holland Twp
31		Helder Park	159	Holland Twp
32		Macatawa Greenway	19	Holland Twp
33	Zeeland Township	VanZoeren Woods	34	Zeeland Twp
34		Drenthe Grove Park	20	Zeeland Twp
35	Fillmore Township	proposed	20	Fillmore Twp
36		unknown	6	Fillmore Twp

37	Laketown Township	Sanctuary Woods	40	Laketown Twp
38		Wolters Woods	34	Laketown Twp
39		The Huyser Farm	102	Laketown Twp
40		Fairview Nature Park	87	Laketown Twp
41		Kelly Lake	10	Laketown Twp
42		Gilligan Lake	13	Laketown Twp
43	Overisel Township	unknown	50	Overisel Twp
44	City of Holland	Degraff Nature Center	18	Holland City
45		Van Raalte Farm	160	Holland City
46		Windmill Island	70	Holland City
47		Window on the Waterfront	40	Holland City
48		Macatawa Greenway	17	Holland City
49		Macatawa Greenway	55	Holland Twp
50		unknown	8	Holland City
51		Paw Paw Recreation Preserve	48	Holland City
52		Kollen Park	19	Holland City
53		Lakeview Park	3	Holland City
54		Prospect Park	7	Holland City
55		VanBragt Park	4	Holland City
56	City of Zeeland	Huizenga Park	23	Zeeland City

Protected Parcels are property parcels which currently (2009) have some degree of protection from development through their designation as parks, preserves or nature areas or due to the presence of a conservation easement. Parks which have extensive recreational facilities (playgrounds, ballfields, tennis courts, campgrounds etc.) are generally not included unless they have significant areas (>5 acres) of undeveloped forest, wetland or meadow.

Protected Areas are protected parcels or groups of protected parcels. Generally, parcels in a protected area will have the same owner but there are some exceptions such as Holland’s Outdoor Discovery Center. Also, parcels in a protected area are usually contiguous but not always (Holland City Greenway parcels, Greenway Partnership parcels).

The **Macatawa Greenway** is a projected natural corridor running along the Macatawa River from downtown Holland to Zeeland Township. Current components of the Greenway comprise both public and private lands. The project is administered by the The Outdoor Discovery Center - Macatawa Greenway Partnership (ODC-MGP), a nonprofit environmental education and conservation organization. Some components of the Greenway are named parks or preserves and are listed as such in the above table - otherwise they are listed as ‘Macatawa Greenway’.

Protected areas were identified on property parcel datasets by referring to the websites of state, county and local government institutions and land conservation organizations in the watershed.

Appendix F - Groundwater Recharge

The original data was derived from the Darcy Potential Groundwater Movement Model (Input-Output), developed by the Michigan DNR Fisheries Division, Institute for Fisheries Research. Data was in the form of a raster dataset *asciito_darc2.rrd* downloaded from the MI DNR Geographic Data Library.

The following discussion was taken from the metadata (*darcy_io.htm*) for the model (ERDAS raster file *asciito_darc2.rrd*):

GIS-based models of potential groundwater loading in glaciated landscapes: considerations and development in Lower Michigan.
With this model, we implement and validate a simple, terrain-based approach for predicting groundwater delivery to streams and other surface water systems using mapped data within a GIS environment. Model output was calculated in units of m day-1 for every 30 m2 grid cell across Lower Michigan.
The grid values produced by this DARCY model (velocity = length*time-1) represent only the potential groundwater velocities to a surface location. The models contain no information about the actual distribution or transport of water - values should be treated principally as an index of potential groundwater delivery. For visualization purposes, the model output values could be usefully scaled in standard deviations from their mean value across Lower Michigan.
Validation was indirect because these potential velocities were not directly measurable in the field. To the extent that these models successfully identified locations where groundwater loading to surface systems could occur, groundwater-related attributes of the surface water systems could be used to test model predictions of spatial patterning. Likewise, we expected that model predictions should correspond to spatial patterns in statistical summaries of instantaneous groundwater delivery rates. Validation tests of the MRI-DARCY Input Output model (a product of the version 3 model) were more rigorous compared to earlier versions.

Appendix G - Soil Quality

The original data for this criterion was developed by the United States Department of Agriculture, Natural Resources Conservation Service and was obtained from the Soil Data Mart (http://soildatamart.nrcs.usda.gov/).

The data is provided in the form of shapefiles (*soilmu_a_mi005.shp* and *soilmu_a_mi139.shp*) which show the spatial extent of soil types in Allegan County and Ottawa County respectively. In addition, a set of tabular data which contains attribute information on the soil types is provided, as well as a Microsoft Access template database (*soildb_MI_2002.mdb*). The tabular data can then be imported into the Access template and reports created.

Versions used in this study:
Allegan County Soil Survey Data (Survey Area Version 8; Tabular Data Version 7; Spatial Data Version 5; (SSURGOV2.1, MD 2.2.3)
and
Ottawa County Soil Survey Data (Survey Area Version 4; Tabular Data Version 4; Spatial Data Version 2; (SSURGOV2.1, MD 2.2.2).

Reports were created using the Access template database and the tabular data to show the Map Symbols for prime farmland in the respective counties and the symbols were used to identify prime farmland and prime farmland when drained polygons.

Appendix H - Fields in the Model Dataset Attribute Table

Field	Data Type	Values
OBJECTID		Database unique identifier. Maintained by ArcGIS.
Shape		Feature type. Maintained by ArcGIS.
COUNTY	text, 2	County code (from original q-q dataset).
TOWN	text, 3	Township code. (From original q-q dataset).
GEO_ID	text, 12	Town, range, section, quarter and quarter-quarter section. (From original q-q dataset).
MAC_ID	integer	Project unique identifier
Shape_Length	double	(m) Automatically computed for each feature. Maintained by ArcGIS.
Shape_Area	double	(m^2) Automatically computed for each feature. Maintained by ArcGIS.
MAC_Acres	double	(ac) Calculated from Shape_Area
MAC_Built	text, 3	'B', 'L' or 'S' (see Part 3 - Creation of Model Dataset)
M1	float	% of QQ with Urban land cover
M19	float	% of QQ with Recreation land cover
M2	float	% of QQ with Agricultural land cover
M29	float	% of QQ with Built Agricultural land cover
M31	float	% of QQ with Open land cover
M32	float	% of QQ with Shrubland land cover
M4	float	% of QQ with Forest land cover
M429	float	% of QQ with Plantation land cover
M5	float	% of QQ with Water land cover
M53	float	% of QQ with Reservoir land cover
M6	float	% of QQ with Wetland land cover
M7	float	% of QQ with Bare land cover
MH2	double	(m) Length of lake perimeters (H21) in QQ
MH3	double	(m) Length of rivers (H31, H32 and H33) in QQ
MH4	double	(m) Length of drains (H41) in QQ
MRI	float	Project index of species rarity for each QQ. (see DP 5)
MDev	double	(m^2) Difference between 2005 and 2015 projected urban land cover area. (see 2.6).
MPrx	integer	Index of adjacency of QQs to already protected areas (1 - 5). (see 2.7).
MGw	double	Index of groundwater delivery to streams and ponds. (see 2.8).
MFm	double	% of QQ with prime farmland soil type.
****_PS*	integer	A separate protection score field for each of the above criteria fields.
Total_PS	integer	Sum of '***_PS' fields

Appendix I - Protection Criteria Classification and Weighting Worksheet.

Criterion	Field	Classification	QQs	Bw2		
				Score		
LandCover						
Built	**M1_PS**			**0**		
(developed land cover).						
Recreation	**M19_PS**	=< 30%	2848	**0**		
(% of recreation land		> 30 - =< 60	26	**2**		
cover in q-q).		> 60%	24	**4**		
Agricultural	**M2_PS**	=< 30%	1213	**0**		
(% of agricultural land		> 30 - =< 60	332	**2**		
cover in q-q).		> 60%	1353	**4**		
Built Ag	**M29_PS**			**0**		
(agricultural structures)						
Open Land	**M31_PS**	< 5%	2421	**0**		
(% of open land cover		=> 5 - < 25	332	**1**		
in q-q).		=> 25 - < 40	77	**2**		
		=> 40 - < 50	32	**6**		
		=> 50 - < 60	14	**10**		
		=> 60 - < 70	9	**14**		
		=> 70 - < 80	7	**18**		
		=> 80%	6	**22**		
Shrubland	**M32_PS**	< 5%	2531	**0**		
(% of shrubland land		=> 5 - < 25	275	**2**		
cover in q-q).		=> 25 - < 40	55	**4**		
		=> 40 - < 50	12	**8**		
		=> 50 - < 60	11	**12**		
		=> 60 - < 70	4	**16**		
		=> 70 - < 80	8	**20**		
		=> 80%	2	**24**		
Forest	**M4**	< 5%	1825	**0**		
(% of forest land cover		=> 5 - < 25	584	**5**		
in q-q).		=> 25 - < 40	191	**9**		
		=> 40 - < 50	87	**13**		
		=> 50 - < 60	72	**17**		
		=> 60 - < 70	44	**21**		
		=> 70 - < 80	35	**25**		
		=> 80%	60	**29**		
Plantation	**M429**	<= 10%	2892	**0**		
(% of plantation land		> 10 - <= 30	2	**3**		
cover in q-q).		> 30 - < = 60	3	**5**		
		=> 60%	1	**7**		

Water	**M5**	<= 10%	2796	**0**		
(% of open water in q-q).		> 10 - <= 30	39	**2**		
		> 30 - < = 60	22	**3**		
		> 60%	41	**4**		
Reservoir	**M53**	<= 25%	2896	**0**		
		> 25%	2	**2**		
Wetland	**M6**	< 1%	2709	**0**		
(% of wetland cover)		=> 1 - < 5	63	**3**		
		=> 5 - < 10	42	**6**		
		=> 10 - < 15	30	**9**		
		=> 15 - < 20	14	**12**		
		=> 20 - < 25	17	**15**		
		=> 25%	23	**19**		
Bare	**M7**	=< 30%	2895	**0**		
(% of bare land cover)		> 30 - =< 60	2	**2**		
		> 60%	1	**3**		
Hydro						
Lakes & Ponds	**MH2**	< 10m	2705	**0**		
(meters of pond perimeter		=> 10 - < 100	11	**2**		
in q-q).		=> 100 - < 300	68	**3**		
		=> 300 - < 500	71	**5**		
		=> 500 - < 650	24	**7**		
		=> 650m	19	**9**		
Rivers	**MH3**	< 10m	2462	**0**		
(meters of rivers in q-q).		=> 10 - < 100	46	**8**		
		=> 100 - < 300	107	**10**		
		=> 300 - < 500	179	**12**		
		=> 500 - < 650	59	**15**		
		=> 650m	45	**18**		
Drains	**MH4**	< 10m	1917	**0**		
(meters of drains in q-q).		=> 10 - < 100	109	**3**		
		=> 100 - < 300	271	**5**		
		=> 300 - < 500	387	**7**		
		=> 500 - < 650	139	**9**		
		=> 650m	75	**11**		
Species Rarity Index	**MRI**	0	1046	**0**		
(index of likelyhood of		> 0 - <= 5	1226	**1**		
rare species in q-q).		> 5 - <= 8	530	**3**		
		> 8 - <= 10	61	**6**		
		>10	35	**9**		

Development Pressure	**MDev**	<= 4047m^2	1647	**0**		
(predicted increase in		> 4047 - <= 24282	566	**1**		
area (m^2) developed).		> 24282 - <= 40470	383	**2**		
		> 40470 - <= 60705	229	**3**		
		> 60705m^2	73	**4**		
Proximity to Protected	**MPrx**	0	2642	**0**		
(index of proximity to		1	110	**10**		
protected land.		2	34	**7**		
See page 17).		3	26	**0**		
		4	10	**0**		
		5	76	**7**		
Ground Water Recharge	**MGw**	<= 0	2088	**0**		
(average positive recharge		> 0 - <= 10	508	**1**		
rate in a q-q).		> 10 - <= 40	225	**3**		
		>40	77	**5**		
Prime Farmland	**MFm**	0%	978	**0**		
(% of q-q with prime		> 0 - <=30	284	**-1**		
farmland soil type).		> 30 - <= 60	333	**-2**		
		> 60 - <= 90	515	**-3**		
		>90%	788	**-4**		

Total QQs = 2898, B = classification version, QQs = # of QQs in class, Bw2 = protection scores for classification B. (Bw2 is also the version number for this model outcome).

Scores in the worksheet can be changed by changing the numbers in the ***_PS fields in the model. For example, the procedure for changing the maximum score for Recreation land cover from 4 to 6 is as follows:

Start by saving *MAC2.gdb\MAC_Model_A* with a new name (MAC_Model_A2). You might want to create a new file geodatabase and export Model_A to it, changing the name in the process.

In ArcMap, open the attribute table of *MAC2.gdb\MAC_Model_A2*.

From the Menu bar choose Selection>Select by Attributes>Select from MAC_Model_A2 where “M19_PS” = 4

Click OK.

Now the appropriate records are selected in the attribute table. Click the Show Selected button to see them.

Find the M19_PS field (column). Rt-click on the header and choose Field Calculator.

Type 6 in the big box. Click OK and the 4 values will change to 6. Note that this applies to selected records only.
Note that VBA expressions (*.cal) can be used to simplify changing scores for attributes.

Appendix J – Problems Encountered in Creating the Model

There are a number of problems that may result in iterations of the model which do not produce acceptable results. Some problems are inherent in the nature of the data used or in the design of the model. Others are the result of the way the data is classified and weighted.

Problems inherent in the data include the following:
Problems of scale. Groundwater recharge data is accurate to 30 meters. Land Transformation Model values are based on a 100 meter grid. MNFI Biological Rarity values are reported on a 40-acre grid but this grid does not match the 40 acre quarter-quarter section grid.
Inaccurate data. Remote sensing is not able to distinguish land cover types with perfect accuracy; e.g. when imagery is obtained during dry periods, unforested wetland may be confused with farmland. Species rarity determination relies on reports by human observers thus more sightings tend be made in areas where there are more people. Development pressure values are themselves based on a computer model which undoubtedly has its own problems.
Changes in conditions (e.g. land cover) since the latest available data was created.

Problems inherent in model design include:
Quarter-quarter section units in the base layer are not all the same size. The large majority are approximately 40 acres but some quarter-quarter sections along county and watershed borders are considerably smaller. The value of these small quarter-quarter sections may tend to be overestimated.
Land cover is measured by percentage of quarter-quarter section area. Land cover types in a quarter-quarter section are usually in contiguous blocks but where they are divided up (by a large highway, for example) the protection value will actually be less than that indicated by the protection score.
Different systems of classifying the data and weighting the classes will give different outcomes. Outcomes should be tested against aerial imagery, parcel data and other digital resources and by ground truthing wherever possible.

Appendix K – Map Symbology

Symbology determines how the model outcomes will be displayed in a map.

The symbology for a feature class (dataset) is saved in a map (.mxd) document or a layer file (.lyr) – but <u>not</u> with the shapefile or geodatabase feature class that contains the map layer's data.

A particular dataset can be symbolized in many different ways for any of its attributes and each way can be saved in the same map or a different map or as a different layer file. The data remains the same, only the appearance changes.

The following is the procedure for symbolizing the model used in this study based on its Total_PS attribute:

Right-click the model layer name in ArcMap and choose Properties and then the Symbology tab.

In the left pane choose View: Quantities > Graduated Colors.

For Fields choose TOTAL_PS.

Click the Classify button. Set to 6 classes (or however many you want) and choose Manual.

Set the Break Values to correspond to the number of units you want in each class (tier). Click on each break value to show the number of elements in each class (at the bottom of the window). This should correspond to the number of quarter-quarter sections (QQs) for each class in the Worksheet.

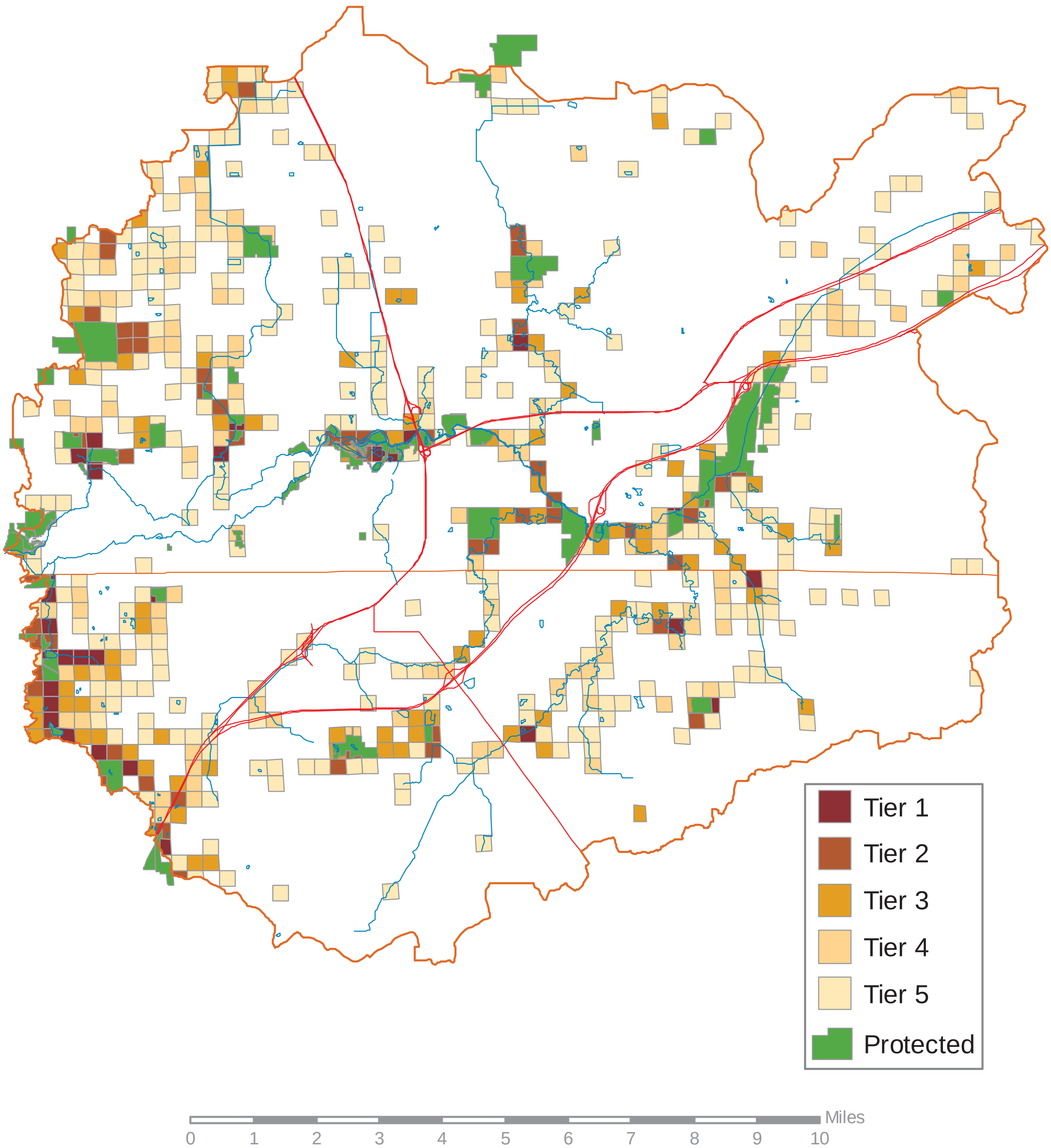
Experiment with number and size of classes until you find a symbology which represents the data in the simplest and most useful way possible.

Note: You can change the colors without changing the classification.

Macatawa Watershed

Land Protection Priority by Quarter-Quarter Section

Version Bw2

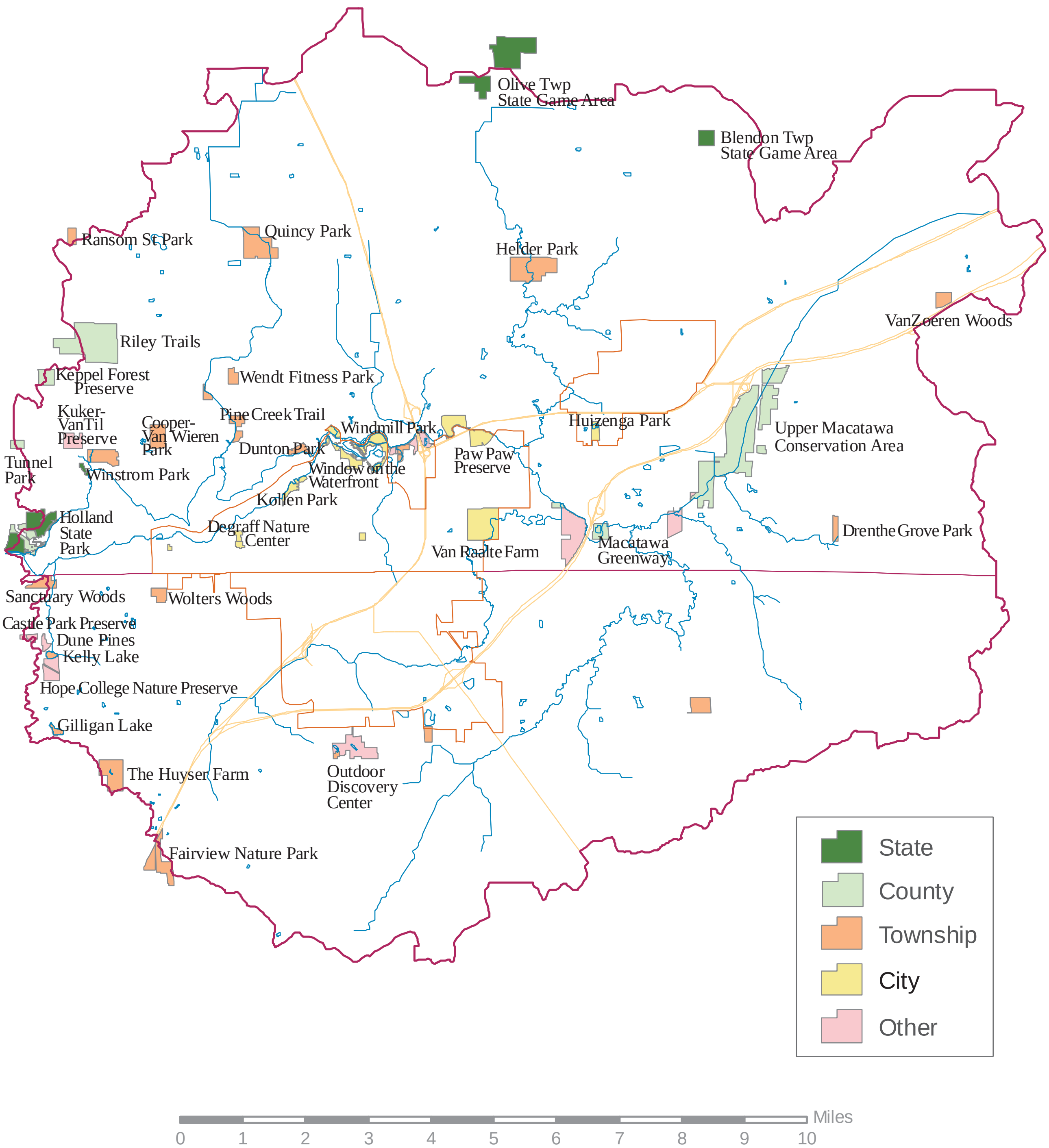


Macatawa Watershed
Political Divisions

Macatawa Area Coordinating Council

01/31/10

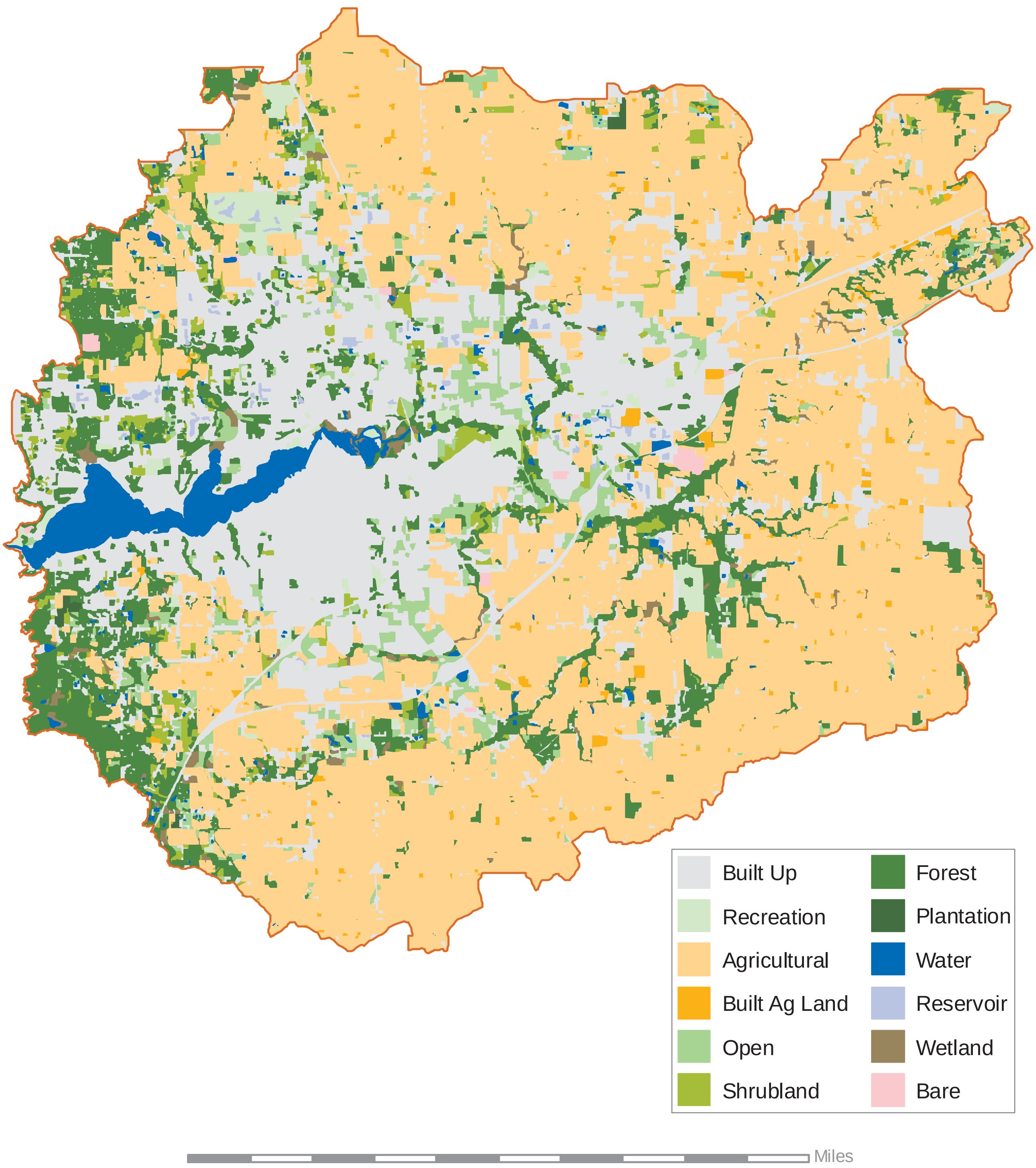
Macatawa Watershed
Protected Areas



Macatawa Area Coordinating Council

01/31/10

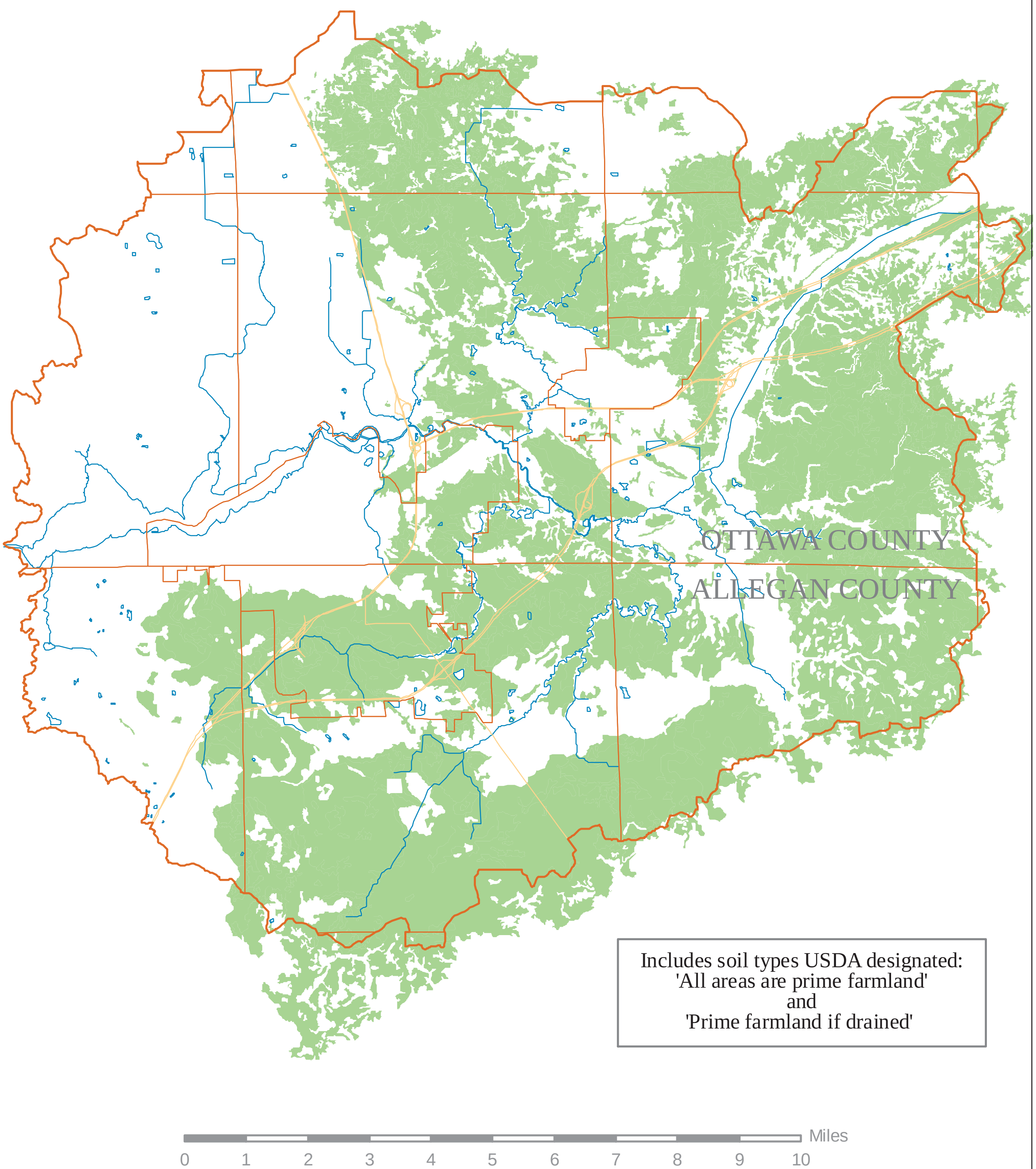
Macatawa Watershed
Land Cover



Macatawa Area Coordinating Council

01/31/10

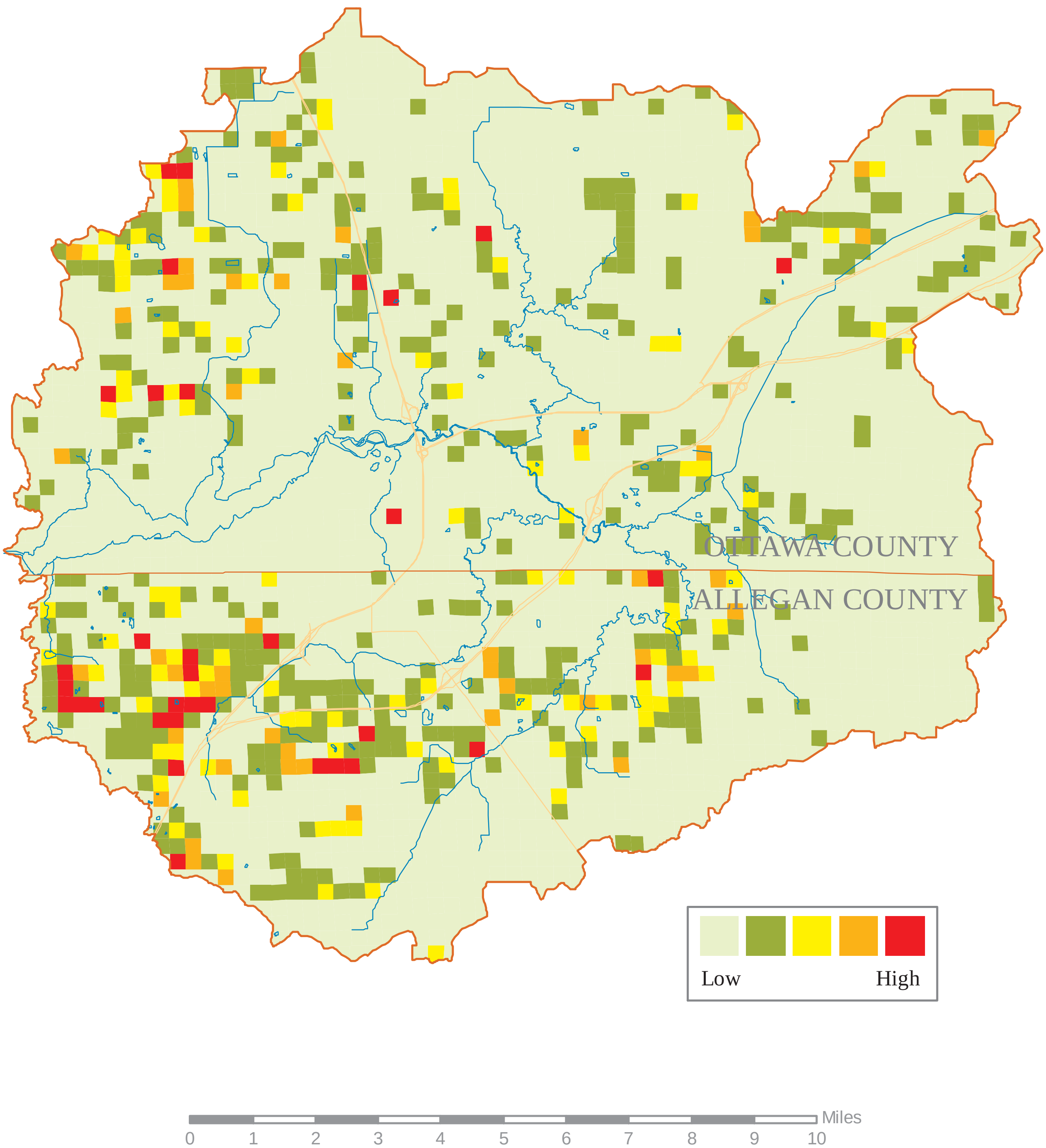
Macatawa Watershed
USDA Prime Farmland Soil



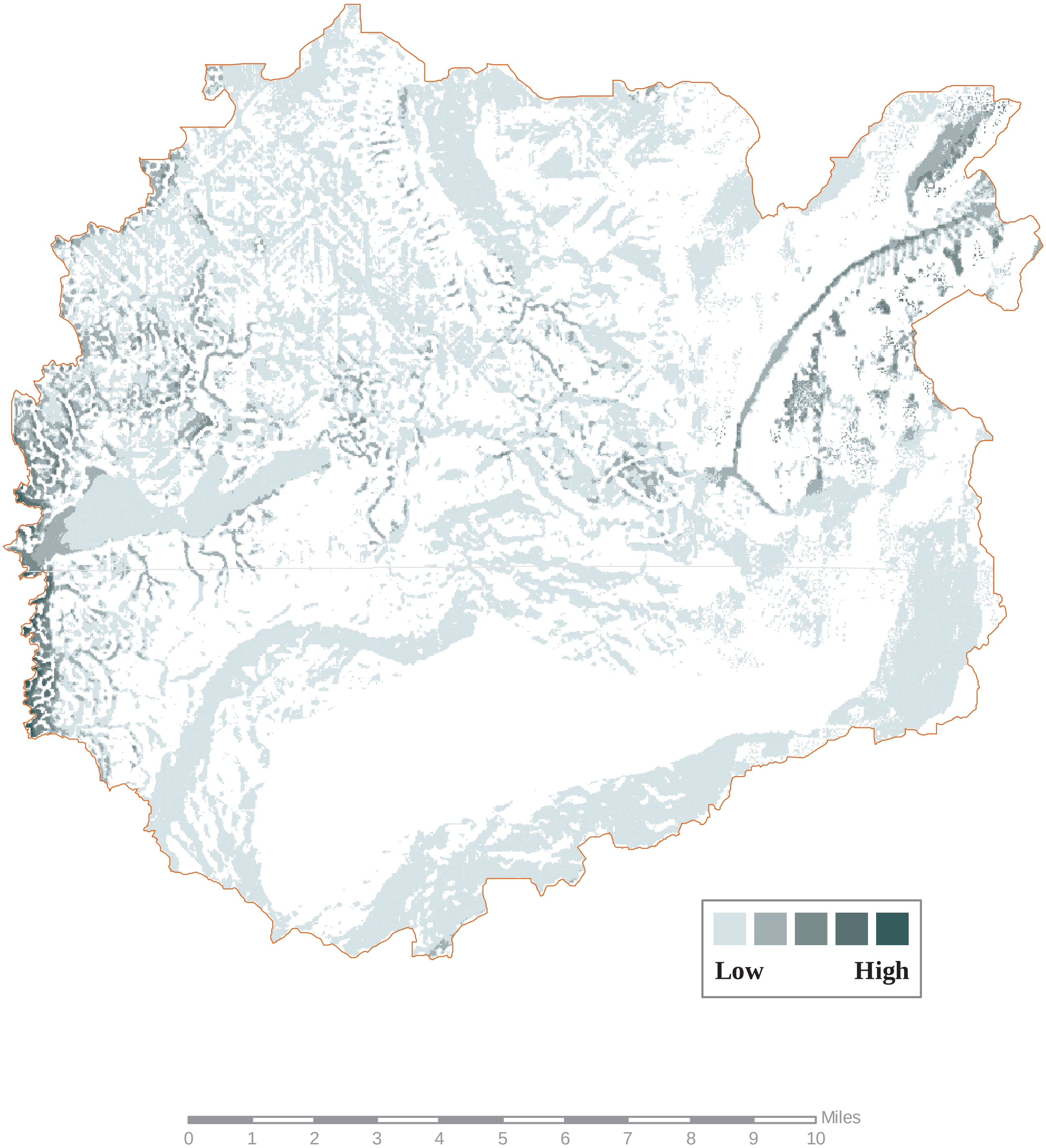
Macatawa Area Coordinating Council

01/31/10

Macatawa Watershed
Development Pressure by Quarter-Quarter Section



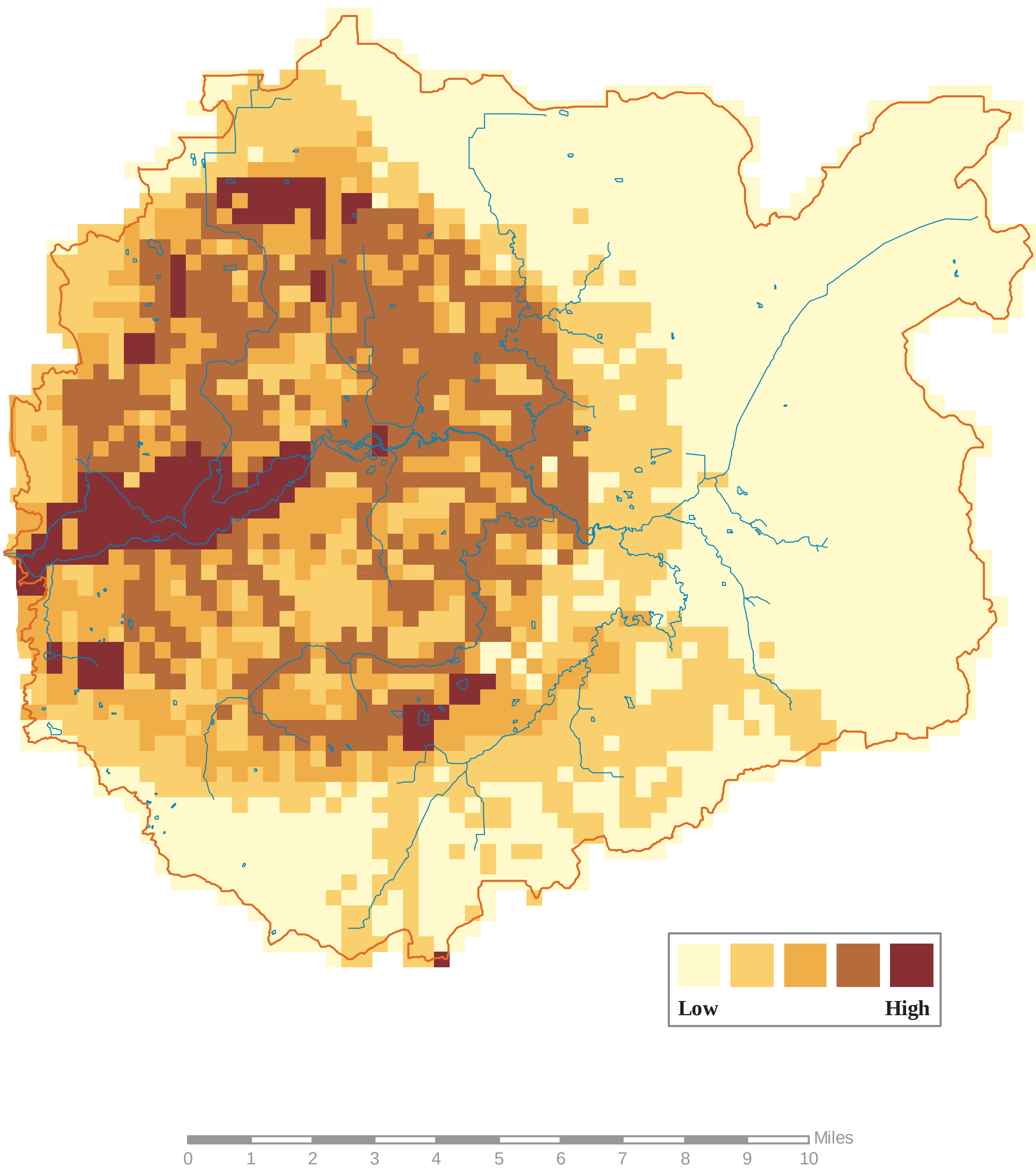
Macatawa Watershed
Positive Ground Water Recharge Rate



Macatawa Area Coordinating Council

01/31/10

Macatawa Watershed
Biological Rarity Index



Macatawa Area Coordinating Council

01/31/10