Memorandum
To: Joe Grengs
From: Kenneth Dunn and Peter Sotherland
Re: VULNERABILITY ANALYSIS: Socioeconomic vulnerability and flood risk in Milwaukee, Wisconsin.

Summary

As ramifications of global climate change become an increasing concern for municipalities to address (Global Climate Change Impacts in the United States), it is important to identify the spatial distribution of their most vulnerable populations in order to tailor measures for aid and assistance. In this study we attempted to create a model for showing vulnerable populations at the Census Block Group (CBG) level using an adapted method based off of the Cutter, Brouff and Shirley method. The Social Vulnerability Index (SVI) consists of an aggregation of five different demographic characteristic indices: age under 18 and over 65 years, non-white population, female population, population density, and housing value/rent. The method was then used to map vulnerably CBGs in Milwaukee, Wisconsin, St. Joseph/Benton Harbor, Michigan, and Marquette Michigan. The vulnerability data was overlaid by FEMA flood zone information to show how the most vulnerable CBGs might be affected by a major flood event. From this study, some limitations were discovered on how the method addresses certain abnormal issues. It did however create maps that show the vulnerable CBGs in these communities and gave insight into how the population of those CBGs might be affected by flood events.

Introduction to Problem

One of the key techniques for confronting threats from climate change, especially extreme events, is determining where a city's most vulnerable populations are located, and how they are situated compared to potential threats. The goal of this study was to identify the location and distribution of the most vulnerable CBGs within the urbanized areas of Milwaukee, St. Joseph/Benton Harbor, and Marquette, then to compare that distribution to potential threats from flooding as shown by FEMA flood zones. One of the most significant threats to Great Lakes communities from climate change will be an increase in extreme precipitation events leading to an increase in flooding. In order to determine the location of areas under threat from large scale flooding, this study looked at FEMA flood zone maps with the classification of up to a 500 year flood event.

Vulnerability was determined at a CBG level using an index adapted from the Cutter, Brouff, and Shirley method, developed to show county-level social vulnerability to environmental hazards (Cutter, Boruff, & Shirley, 2003). The Social Vulnerability Index (SVI) consists of an aggregation of five different demographic characteristics indices: age under 18 and over 65 years, non-white population, female population, population density, and housing value/rent. Each index is a 0-1 decimal value calculated from the proportion of the total population for every demographic characteristic living in each CBG. The index ranks the proportions in each CBG from smallest to largest and also conveys the magnitude of difference between CBGs. The overall SVI is calculated by summing all of the individual demographic vulnerability indices, and it reflects the aggregation of all variables within a CBG.

The geographic focus of this study is the urbanized areas of Milwaukee (Figure 1), St. Joseph/ Benton Harbor (Figure 2) and Marquette (Figure 3) as delineated by the 2000 U.S. Census. In an attempt to limit the study area to the most urbanized CBGs, the study looks at contiguous CBGs whose centers are located within the urbanized areas of these cities. For Milwaukee, the study includes the entire City of Milwaukee, the City of Waukesha and the area between the two along with portions of Ozaukee and Washington Counties. For the St. Joseph/Benton Harbor urban area, the study area included the communities of St. Joseph, Benton Harbor, Benton Heights, Fair Plain, Shoreham, Stevensville and the block groups that connect these communities. For Marquette urban area this included Marquette, Harvey, Trowbridge, Negaunee, Ishpeming, West Ishpeming and the CBGs that connect the communities.

Methods

All of the demographic data used for this study was downloaded from the census website. The following census data tables were used:

P3 Population (SF3)
P6 Race (SF3)
P8 Sex by age (SF3)
H1 Housing units (SF1)
H 70 Median gross rent as a percentage of household income (SF3)
H 85 Median value for all owner occupied housing units (SF3)

The vulnerability index for female, non-white, under 18 and over 65 population, and population density was calculated using the following method. First the percentage (X) of each variable that falls within each CBG was calculated where (a) is the number of individuals in a CBG and (b) is the total number of individuals in the study area.

$$X=a/b$$

For example, if a CBG has a female population of 500 (a) of a total female population of 10,000 (b) within the study area the X value is calculated as 500/10,000. The social vulnerability (SV) for each variable is then determined by dividing each census block X value by the largest X value CBG within the study area (Xmax).

$$SV=X/Xmax$$

This provides a 0-1 value for each characteristic where 0 is the lowest vulnerability where none of that population characteristic occurs in the CBG and 1 is the CBG that has the maximum number of that population characteristic in the study area.

For example: the CBG with 500 females has an X value of 0.05. The highest female population of any CBG is 600 with an X value of 0.06. Thus the 0-1 vulnerability index for female population in that CBG is 0.05/0.06 or 0.83. This value not only orders each CBG from least to greatest vulnerability but also shows the magnitude of difference between each CBG.

The housing value/rent vulnerability consists of an aggregation of both housing value and median rent as a proportion of income and is then weighted by the proportion of rental and owner occupied units in each CBG. The rent vulnerability index is calculated using the same formula as the other variables; however the housing value is calculated differently.

First the difference between the study area median housing value (c) is calculated and is subtracted from the CBG median housing value (d)

$$A = c-d$$

The absolute value of A is taken to find the difference between the CBG's median value and the study area's median value. The CBG whose value has the largest difference from the median is then added to every CBG's median value to create the B value

$$B=A+|Amax|$$

The B value for each CBG is then divided by the largest B value in the study area to give the 0-1 vulnerability index value.

$$SV=B/Bmax$$

In order to illustrate the housing stock of a CBG, The indices for rent and housing value are weighted off of the proportion of both renter and owner occupied units within the CBG

$$R = (\text{Renter Occupied Units})/(\text{Total Units})$$
$$H = (\text{Owner Occupied Units})/(\text{Total Units})$$

Both the housing value and rent vulnerability indices are multiplied by their respective R and H values to reflect the proportion of the housing stock in each CBG. The SV for each of the variables is then added to create the overall SVI for the entire study area.

Findings and Discussion

The largest concentrations of vulnerable populations within the Milwaukee study area are located in the South Central, Central and Northern sections of the city (Figure 4). While a portion of the most vulnerable population lives outside of the city in more rural areas, the majority of the most vulnerable population lives in the central and northern portions of the City of Milwaukee. The CBGs that register highest on the SVI in Milwaukee are generally areas with high concentrations of minority and low-income populations.

The distribution of Marquette's vulnerable population has no strong spatial pattern (Figure 5). The communities of Ishpeming and Negaunee are generally more vulnerable than Marquette, however, the four most vulnerable CBGs are at least partially located in five of the six communities included in the study area. Only West Ishpeming does not have one of these, though its census blocks are still relatively high. In general the four most vulnerable CBGs have populations with high index numbers for age, female population and population density.

In the St. Joseph/Benton Harbor study area, the distribution of vulnerable CBGs was also somewhat diffuse (Figure 6). The most vulnerable CBGs however, are mainly in the downtown St. Joseph and in Benton Harbor/Benton Heights. The highly vulnerable CBGs in Benton Harbor are mainly vulnerable due to dwelling value, non-white and age demographic characteristics. Alternatively, the vulnerable CBGs in St. Joseph are characterized by population density, female population and age, with very low numbers associated with non-white population and dwelling value.

To assess the potential for these vulnerable populations to be impacted by river flooding FEMA flood zone data were overlaid onto the vulnerability index. It is clear that vulnerable populations tend to live in areas outside of the flood zones. This may be explained by waterfront property generally having higher property values, but that analysis is beyond the scope of this study. While areas of dense social vulnerability generally do not coincide with flood zones in Milwaukee, there are some notable cases where there has been documented surface flooding outside of flood zones within areas of high vulnerability. One of the best examples of an interaction between flood hazards and vulnerable population is the area surrounding 30th Street industrial corridor (Figure 7). The 30th Street area is surrounded by neighborhoods with high vulnerability in the North Central portion of Milwaukee. This area recently experienced surface flooding and sewer overflows following storms of record (Jones, 2010) despite the fact that it is not in a registered FEMA flood zone. The former Eaton Corp building, located on North 27th Street, was an economic anchor within this troubled neighborhood. The building was damaged both in the most recent floods of 2010 and in floods several years earlier and is now leaving the area (Tolan, 2011). This should be an area of focus when looking at flood mitigation strategies.

Another area of concern is in the central portion of Milwaukee, north of the Kinnikinnick River (Figure 8). During the 2010 flood of record, the Kinnikinnick River delta and the surrounding area experienced sewer overflows, sinkholes, and severe surface flooding (Jones, 2010). This is also a concentration of CBGs that ranked high on the SVI. Due to the overlapping of threat, and social vulnerability, this portion of the city should also be an area of priority for flood mitigation strategies.

While flooding and damage was not limited to areas that rate highly on the SVI, it is important to give special attention to those areas that are socially vulnerable. Have a lower adaptive capacity for response to extreme events (Cutter, Boruff, & Shirley, 2003). It is important to identify the most vulnerable areas with at-risk populations and ensure that they these neighborhoods have the proper infrastructure and support to cope and adapt to changing climate and related weather conditions.

Generally in Benton Harbor, the most vulnerable CBGs are not in risk for major flood events (Figure 9). In St. Joseph however, the highly vulnerable population does have some flooding concern. This census block is of special concern because based on the census numbers; this census block is dominated by an elderly population with a high female population. Depending on availability of vehicular transportation this CBG could have serious problems dealing with a flood event.

Due to lack of digital FEMA flood data for the Marquette study area the flood analysis was limited to looking at the impact of 100 year flood events in the City of Marquette only and the accuracy of the data is questionable as it was developed by digitizing the printed FEMA flood maps (Figure 10). From this data however, some information can be drawn. In the event of a 100 year flood, much of the most vulnerable CBGs look to be reasonably safe in the City of Marquette. Some concern is created however in a CBG located in Trowbridge Park directly west of the City of Marquette. Looking at where the 100 year flood boundary is, it appears that parts of this CBG could be impacted by a 100 year flood event and this CBG is determined to be a more vulnerable area.

Limitations of This Analysis and Conclusions

Our primary conclusions were the limitations in using this method on a CBG scale resolving block groups with unusual demographic characteristics and using this method for specifically addressing flood vulnerability.

First, in Marquette, the CBG highlighted in (Figure 11) scored quite high with an overall SVI of 3.18. The CBG had non-white, population density, and female vulnerability index of 1.00, 0.83, and 0.83 respectively. Looking only at the SVI, it can be concluded that this is an area of vulnerability populations. In reality however, this block group is located directly beside Northern Michigan University and is made up primarily of a population of college students as illustrated by the age vulnerability index of 0.05. Generally speaking people would not expect college students to have an overly difficult time dealing with any extreme natural event. Because of this, it is felt that the method created in this study has a problem dealing with such situations.

A second limitation of this method is also exhibited by Marquette. 95% of the population registered as white in the 2000 census. Because of this, it seems that the method we created, which uses non-white as an index, would seem to be over weighted in Marquette. While there is no particular way with census numbers to show levels of vulnerability solely within a race (like white) we know they exist and this method is unable to deal with that.

The third limitation includes the two most vulnerable CBGs in St. Joseph/Benton Harbor (Figure 12). One located in Benton Harbor is vulnerable mainly due to the indices of non-white, age, and dwelling value, while another in St. Joseph is mainly due to the indices of age, female, and population density. Each of these CBGs will be vulnerable in different ways to each extreme event and would need to be addressed separately. However, the maps created by this method do not show this.

A fourth issue is illustrated by a CBG in Milwaukee which is the location of a veterans association. While this CBG has very high age vulnerability, the lack of other key traits: rent/housing value decreases its overall social vulnerability value detracting from an accurate representation of its true social vulnerability.

The size of the study area seems to make some difference. The CBGs of concern raised for St. Joseph/Benton Harbor and Marquette are areas that the planners in those areas should take into consideration; however, no strong patterns are revealed in these areas. Conversely, in Milwaukee a strong pattern emerges showing the vulnerably African-American and Hispanic populations in Milwaukee and the more elderly, female populations along the periphery of the urbanized area. It appears that this method is well suited for vulnerability studies in larger metropolitan areas like Milwaukee but less so for smaller areas like St. Joseph/Benton Harbor and Marquette.

Finally, this method of analyzing census data does not include a way to factor a physical threat into the demographic analysis. While flood zones were overlaid to look at possible convergence between locations of social vulnerability to show where there could be overlap between flood damage and vulnerable populations, we didn't actually factor flood risk into our vulnerability index. This could be a shortfall looking forward as flood risk change due to climate change and other factors and flood plain maps become less accurate.

Work Cited

1. Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. *84* (2).

2. Jones, M. (2010). Line of thunderstorms pounds city, floods streets. *Wisconsin Journal Sentinel* .

3. Tiger Line Data 2000. (n.d.). Retrieved January 2011, from Census: http://arcdata.esri.com/data/tiger2000/tiger_download.cfm

4. Tolan, T. (2011). Departure of Eaton does not quash optimism. *Milwaukee Journal Sentinel* .

5. 2000 US Census. (n.d.). Retrieved January 2011, from census.gov

Figure 1: Background Map Milwaukee: County, city boundaries and with social vulnerability study area.

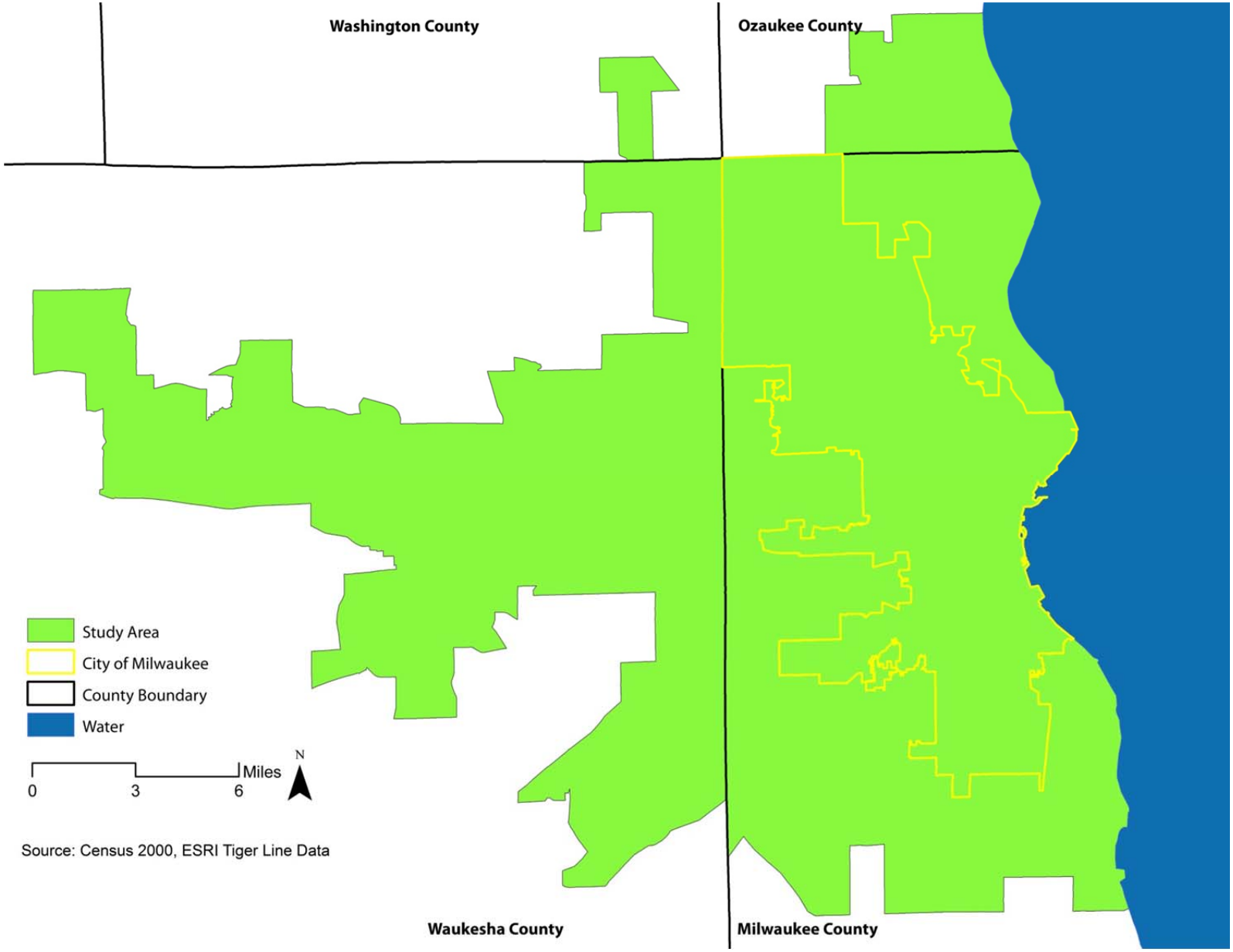


Figure 2: Background Map St. Joseph/Benton Harbo: County, city boundaries and with social vulnerability study area.

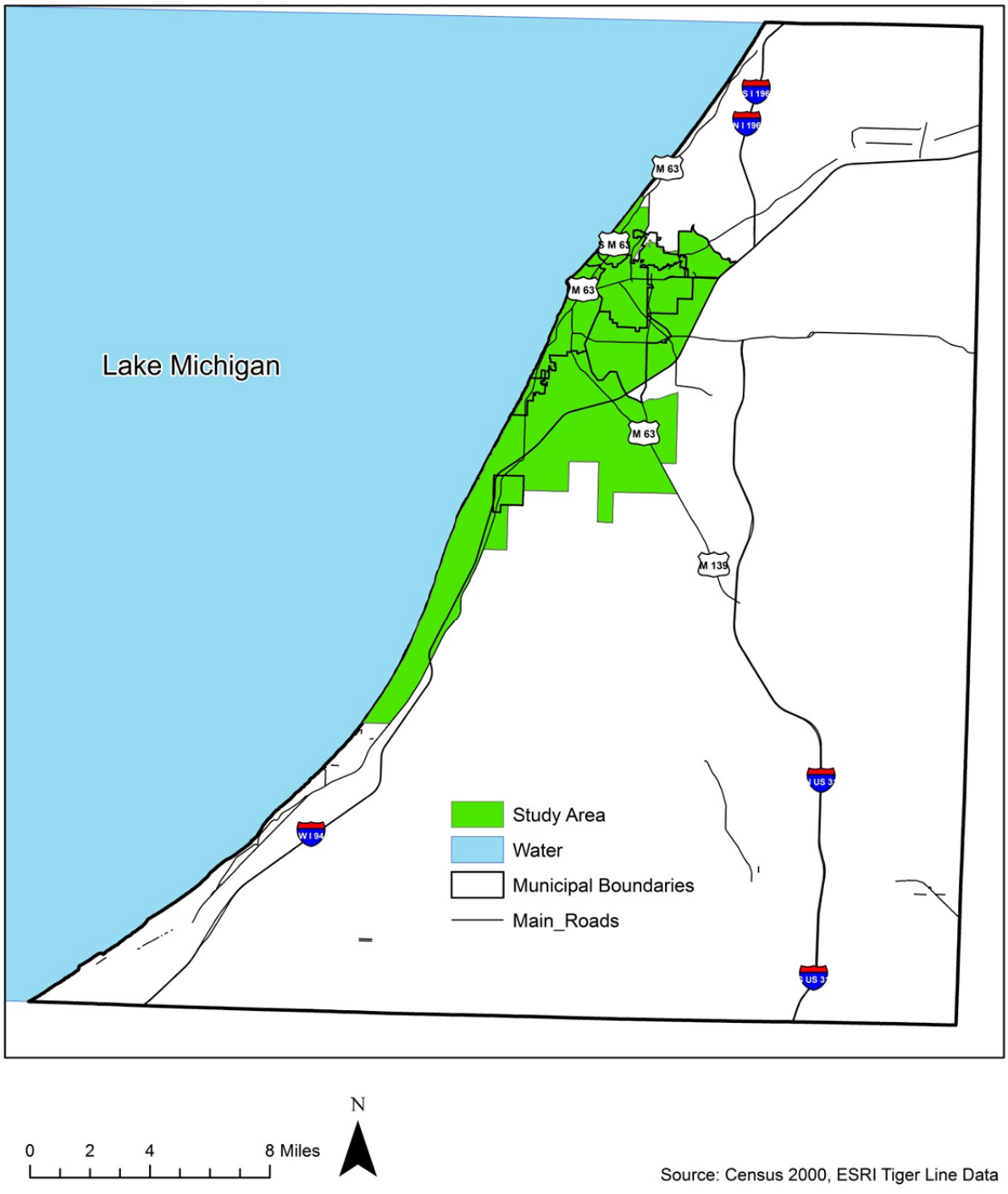


Figure 3: Background Map Marquette: County, city boundaries and with social vulnerability study area.

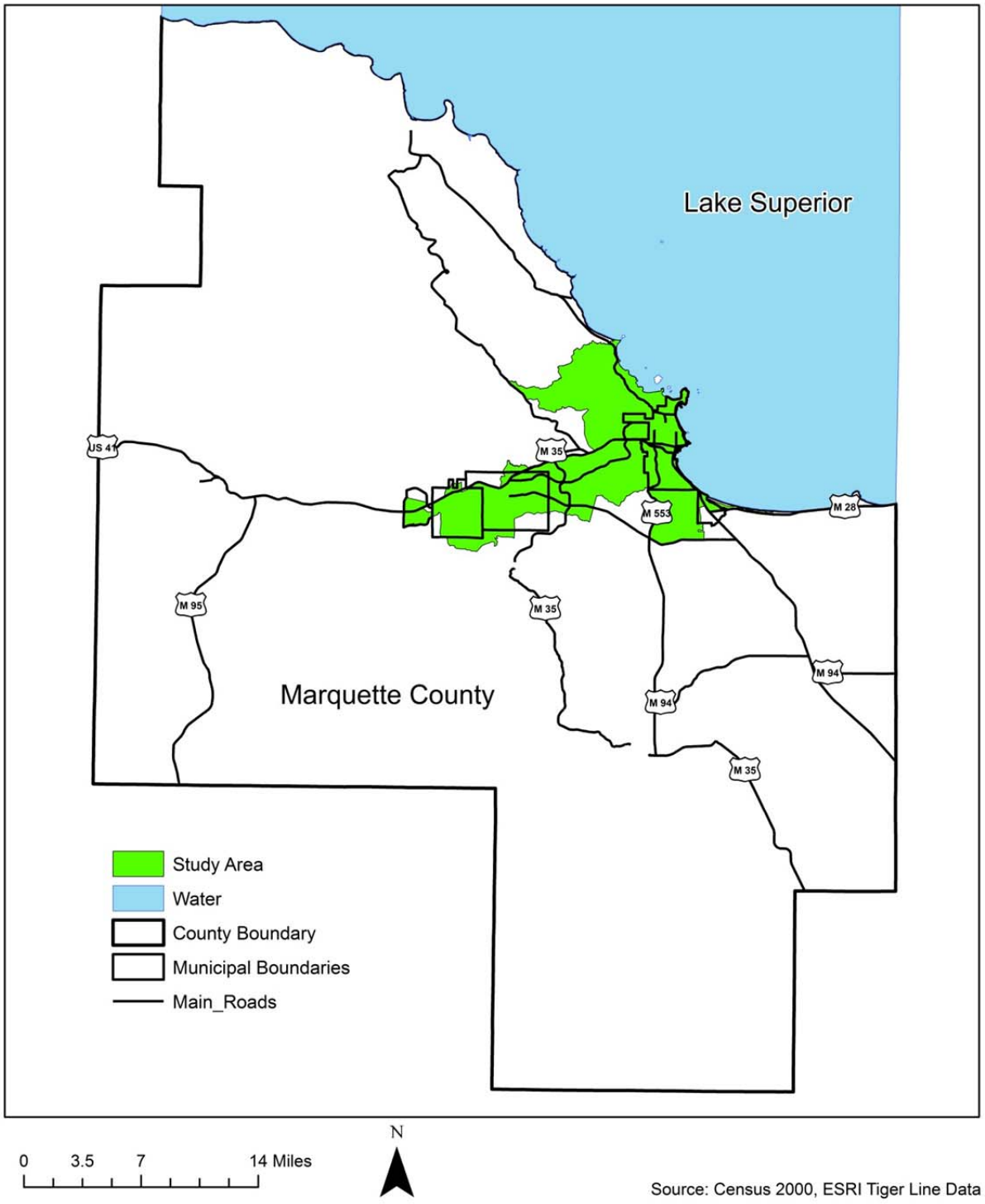
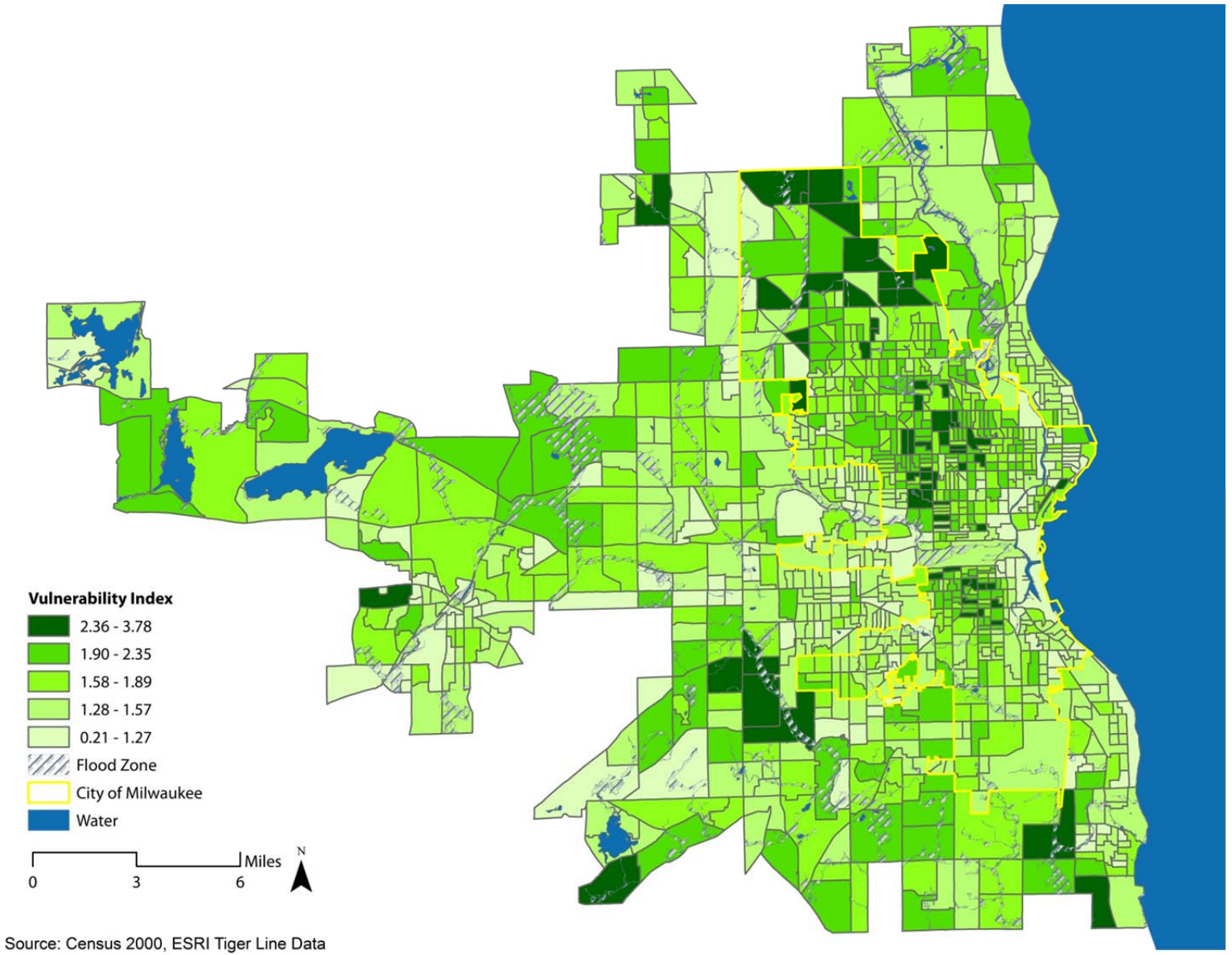


Figure 4: Distribution of Vulnerable Population: Milwaukee, WI Urbanized Area by Census Block Group (2000)



Source: Census 2000, ESRI Tiger Line Data

Figure 5: Distribution of Vulnerable Population: Marquette, WI Urbanized Area by Census Block Group (2000)

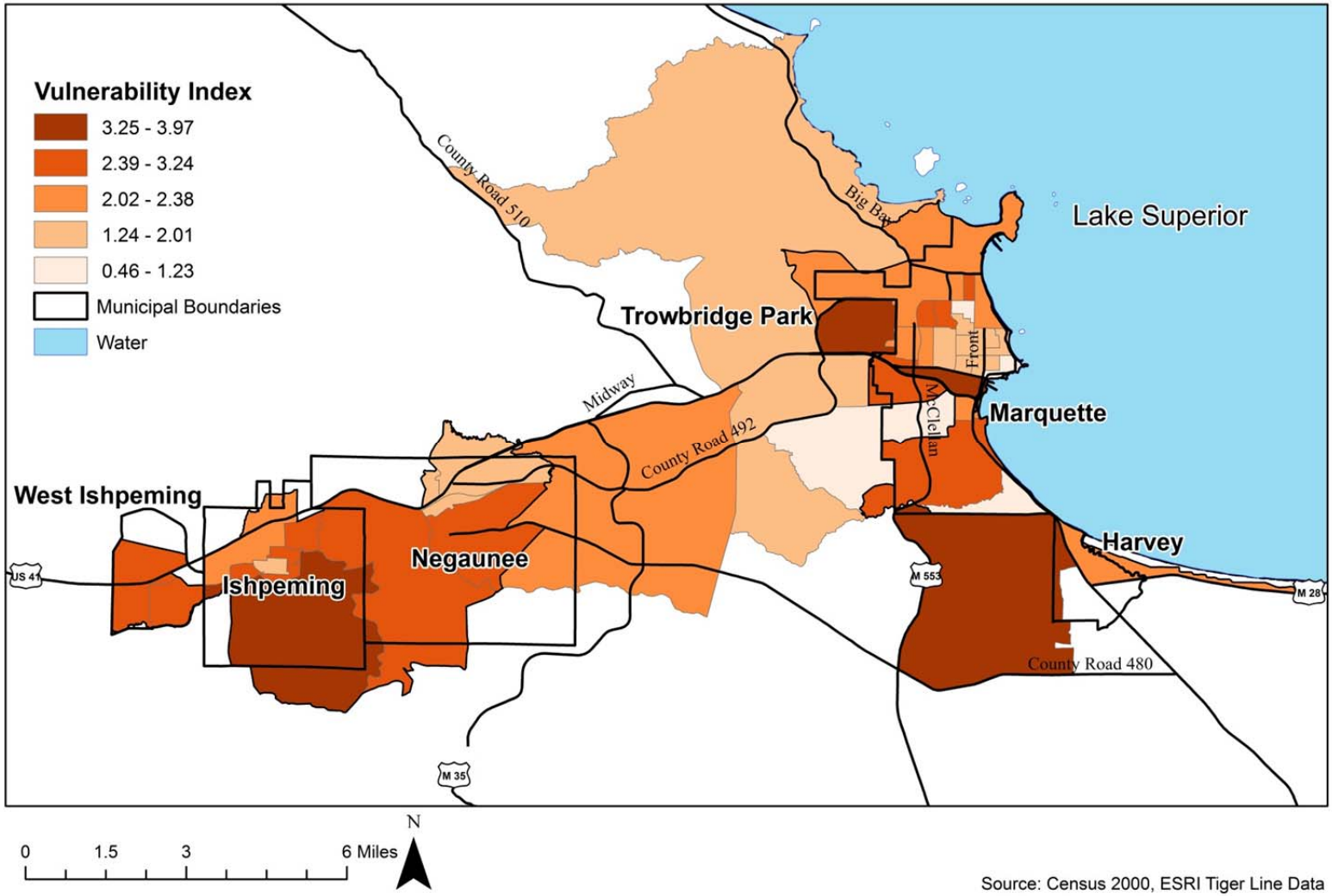


Figure 6: Distribution of Vulnerable Population: St. Joseph/Benton Harbor, MI Urbanized Area by Census Block Group (2000)

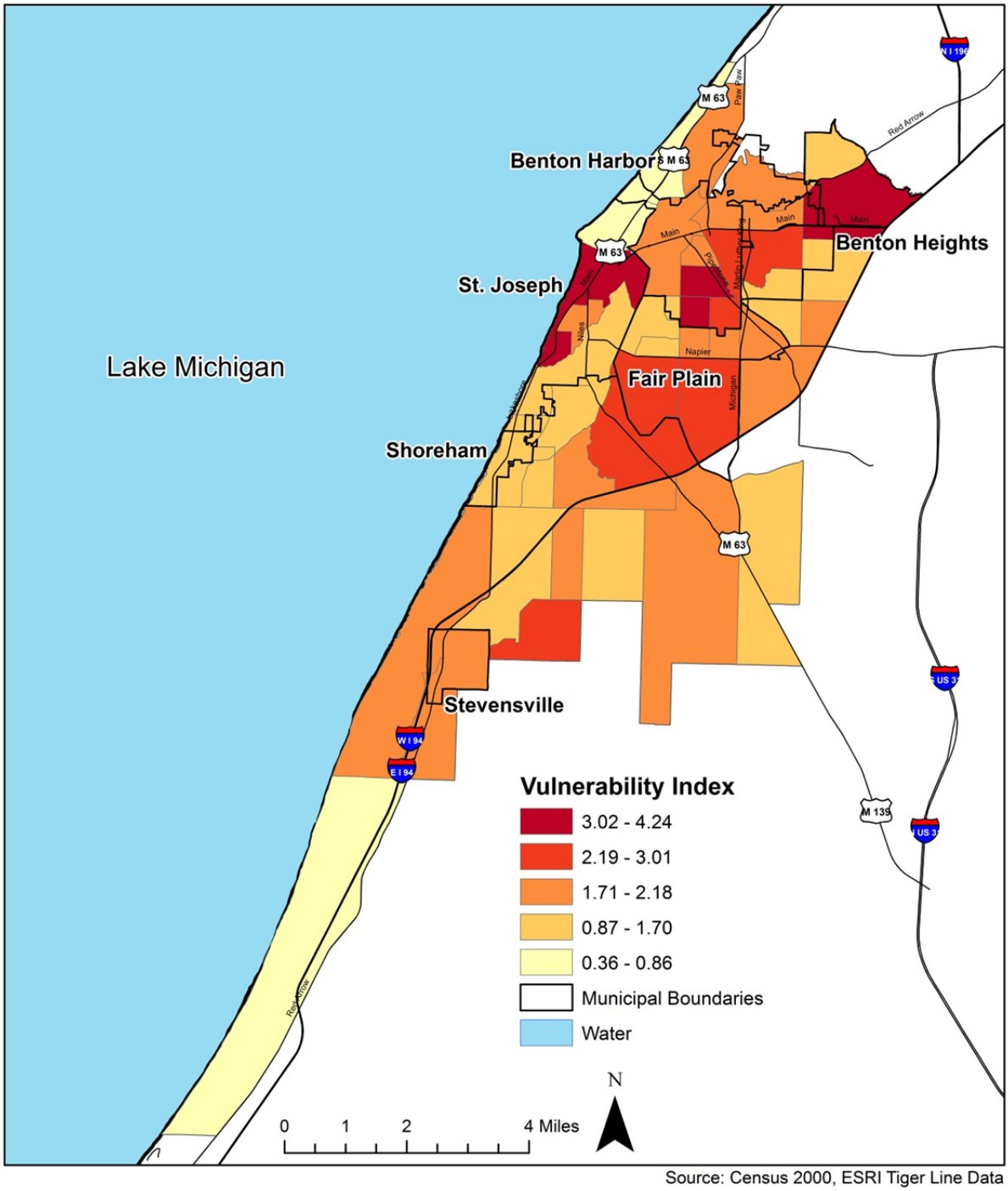


Figure 7: 30th Street Industrial Corridor Vulnerability: Distribution of socially vulnerable census block groups in the 30th Street Industrial Corridor delta area. Highlights areas impacted by flash flooding that fall outside of FEMA flood plains specifically impacting vulnerable populations.

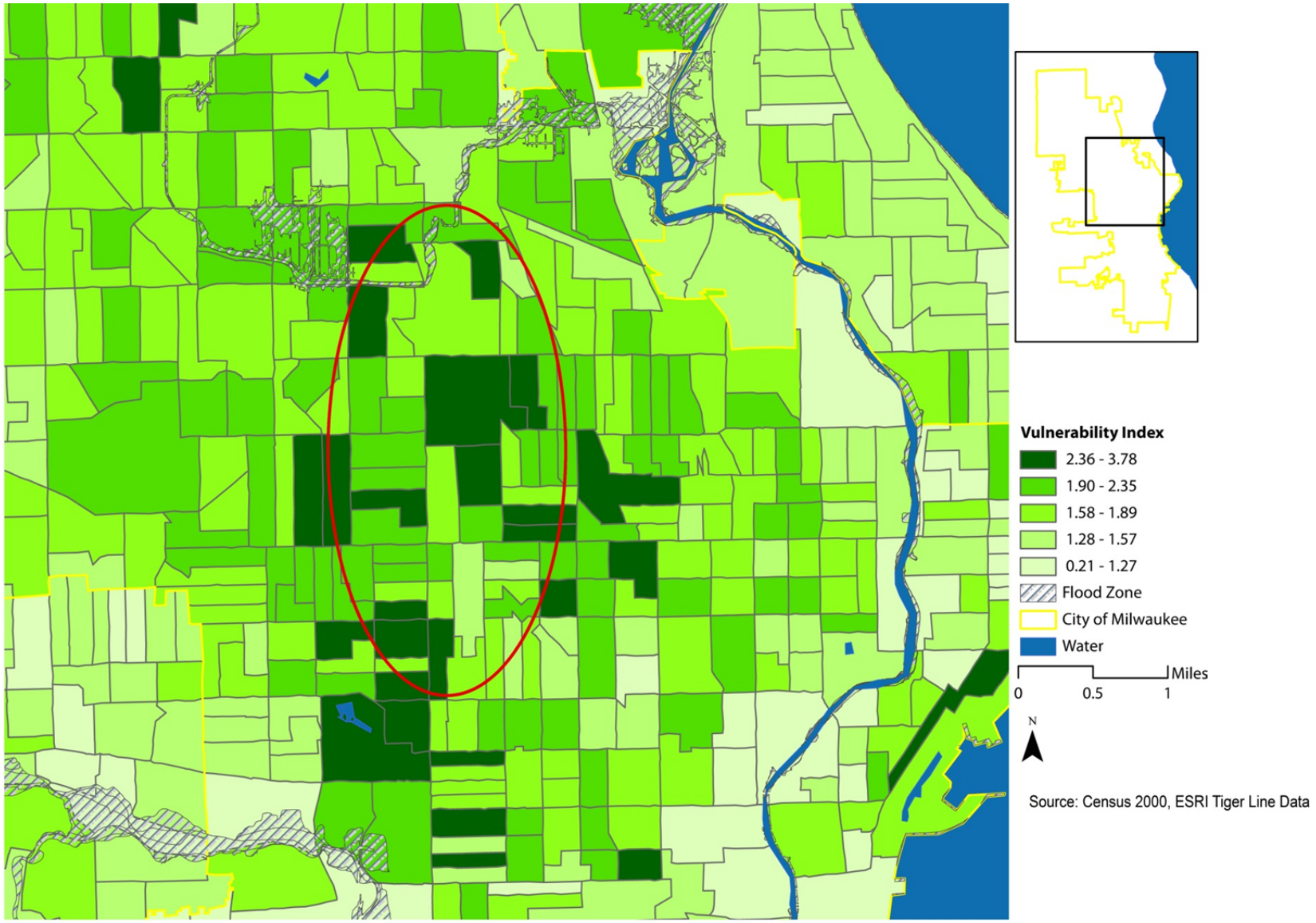


Figure 8: Kinnikinnick River Vulnerability: Distribution of socially vulnerable census block groups in the Kinnikinnick River delta area. Highlights areas impacted by flash flooding that fall outside of FEMA flood plains specifically impacting vulnerable populations.

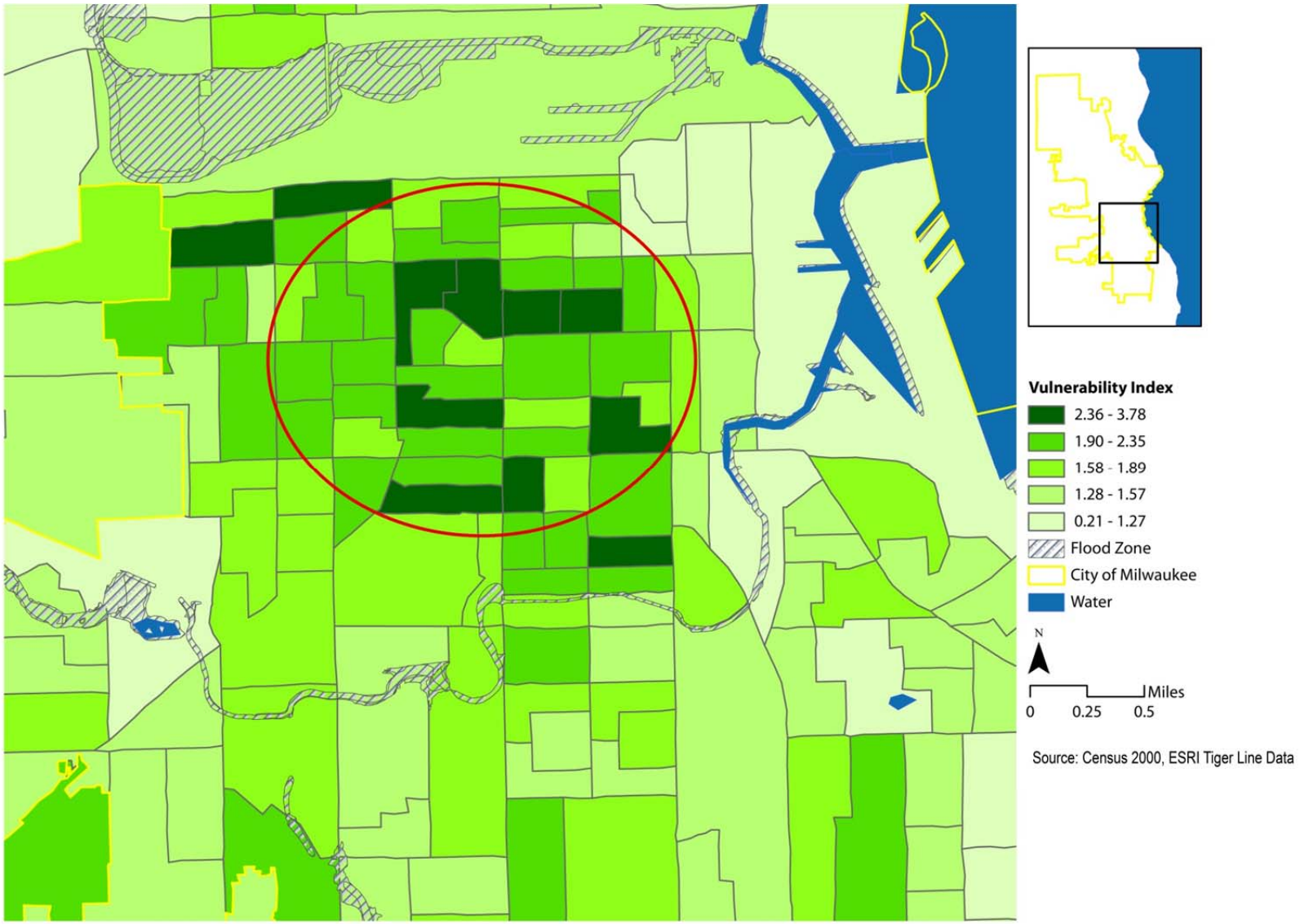


Figure 9: Flood Impacts on Vulnerable Populations, St. Joseph/Benton Harbor, MI Urbanized Area by Census Block Group (2000)

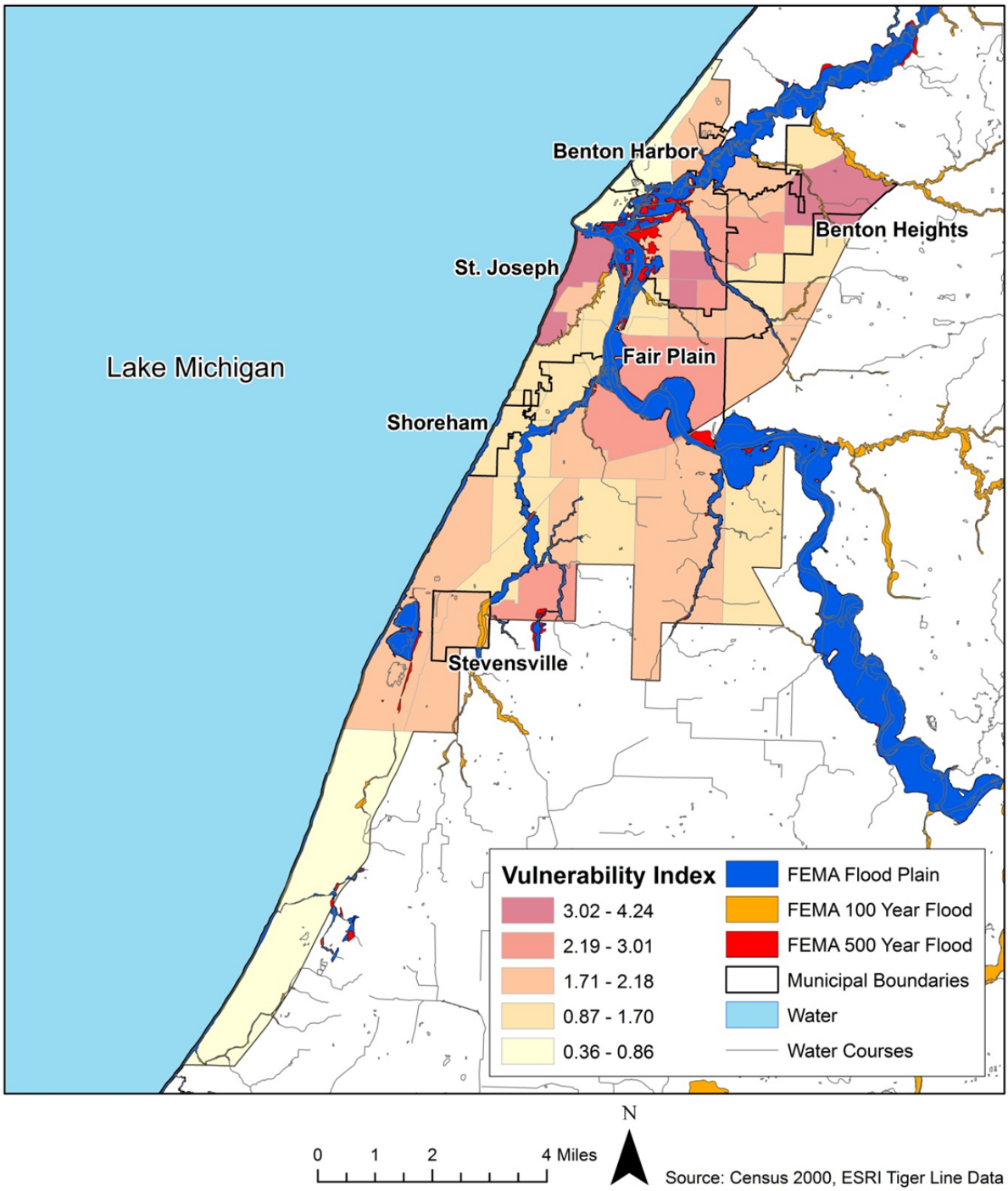
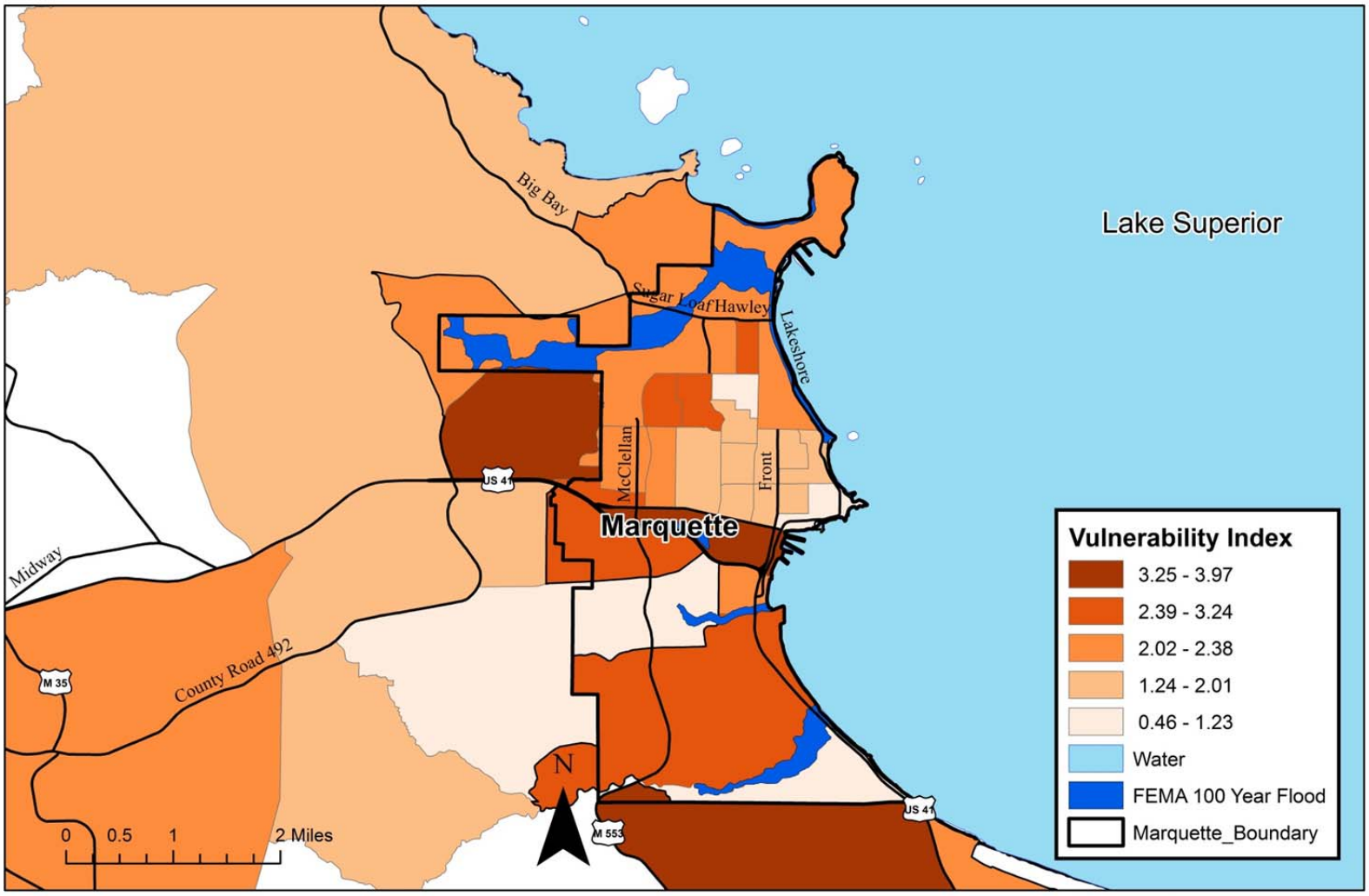


Figure 10: Flood Impacts on Vulnerable Populations, City of Marquette, MI Urbanized Area by Census Block Group (2000)



Source: Census 2000, ESRI Tiger Line Data

Figure 11: Distribution of Vulnerable Population (Block Group of Concern) Marquette/Ishpeming, MI Ubanized Area by Census Block Group (2000)

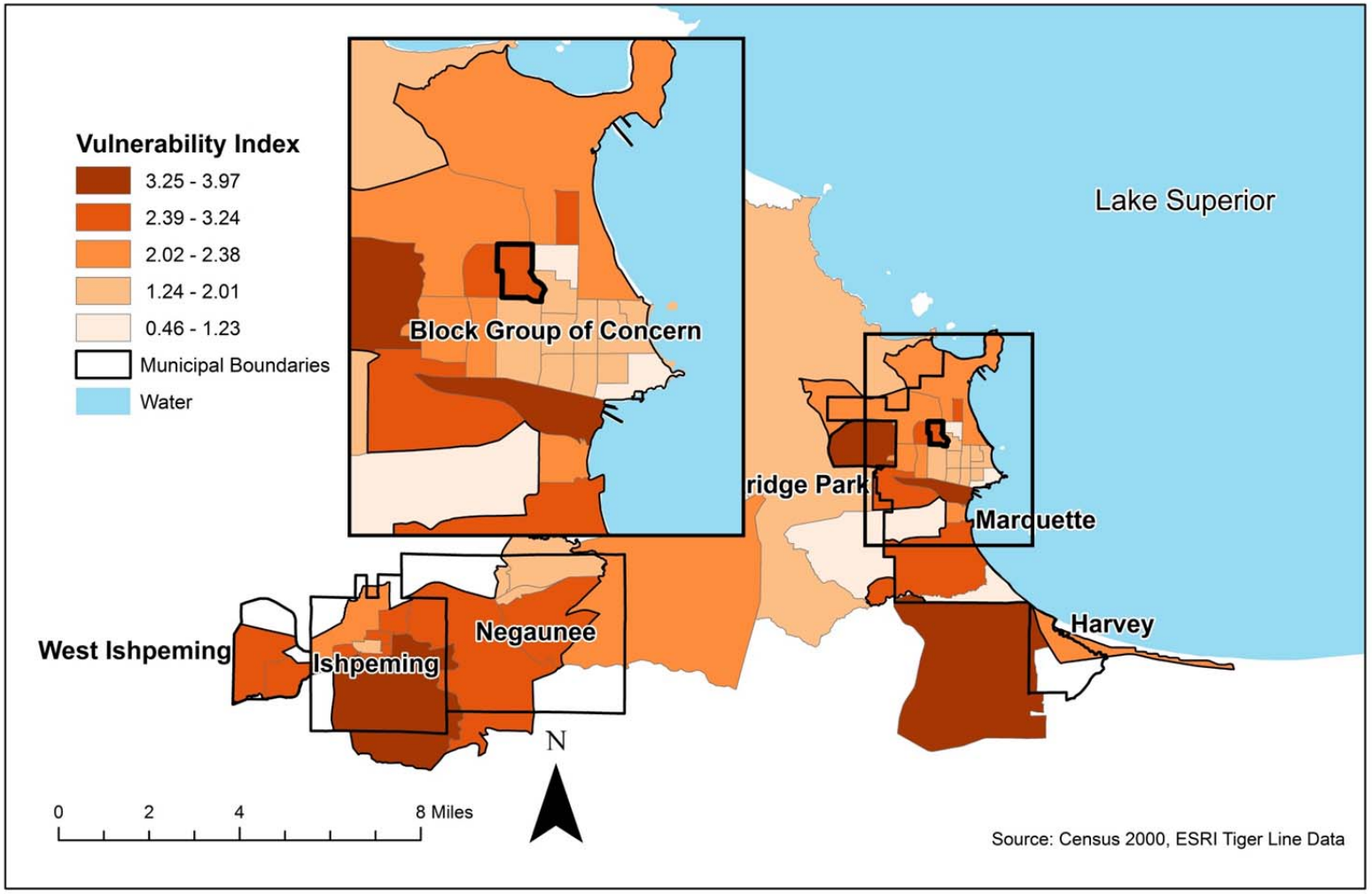
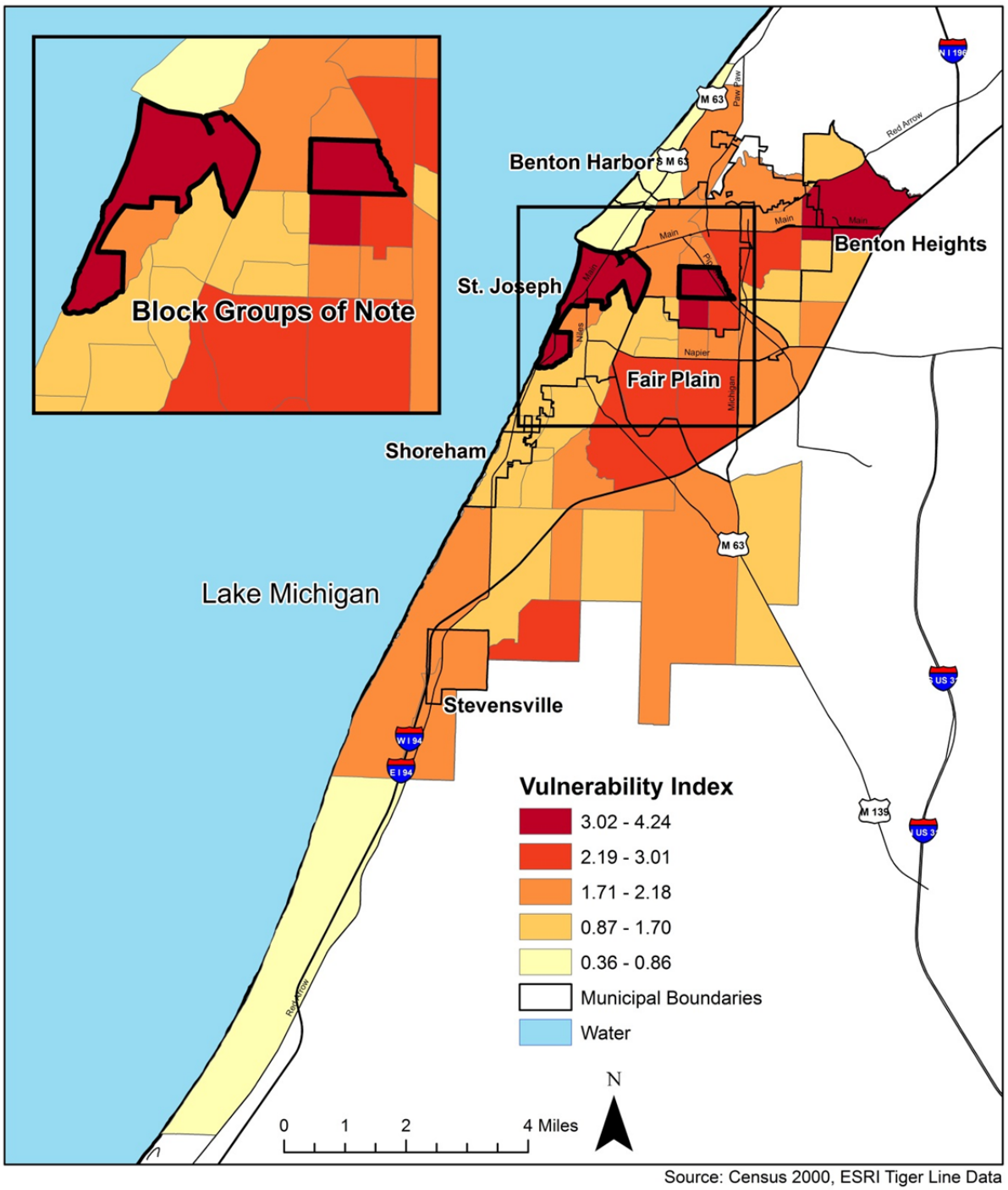
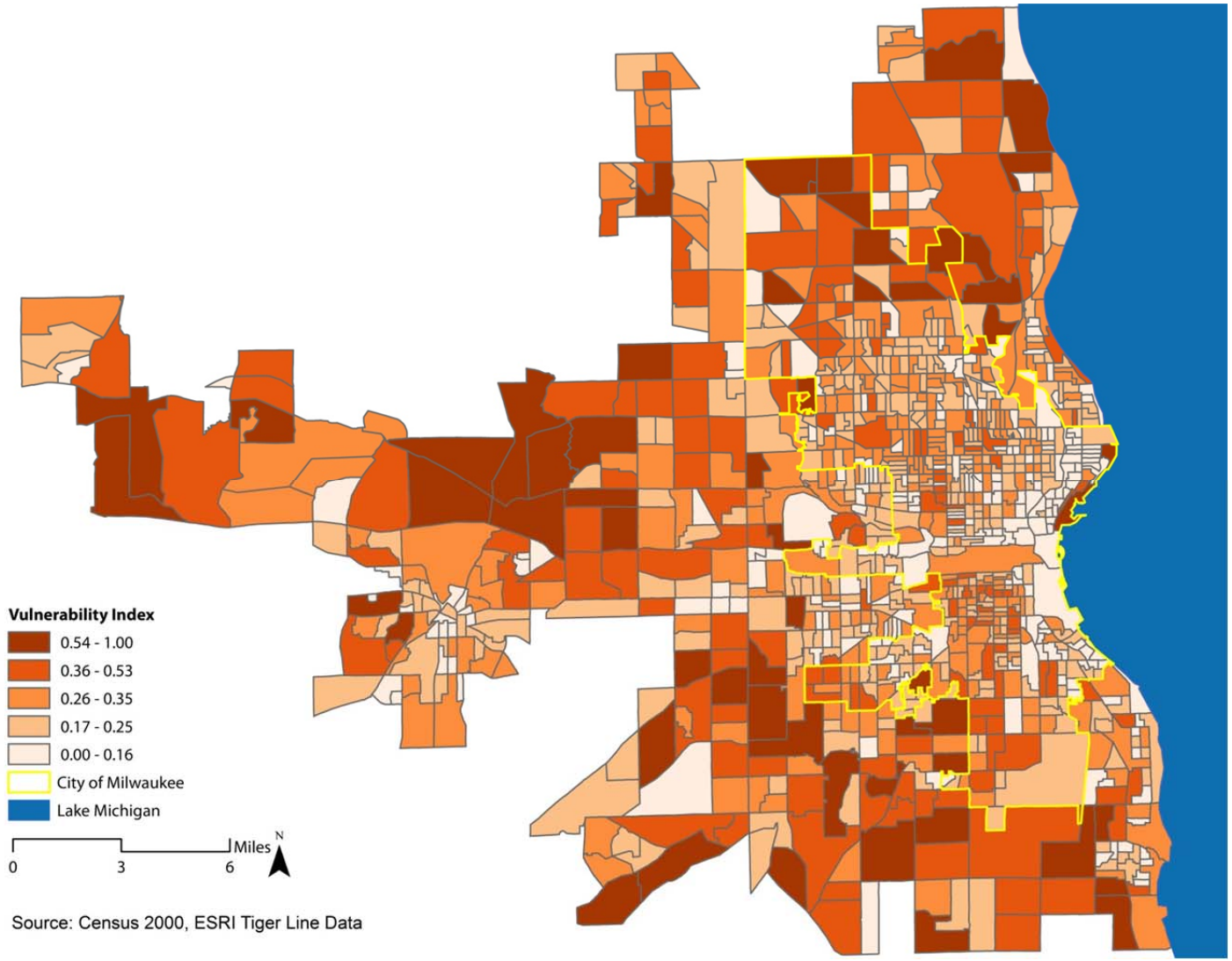


Figure 12: Distribution of Vulnerable Population, (Block Groups of Note) St. Joseph/Benton Harbor, MI Urban Area by Census Block Group (2000)

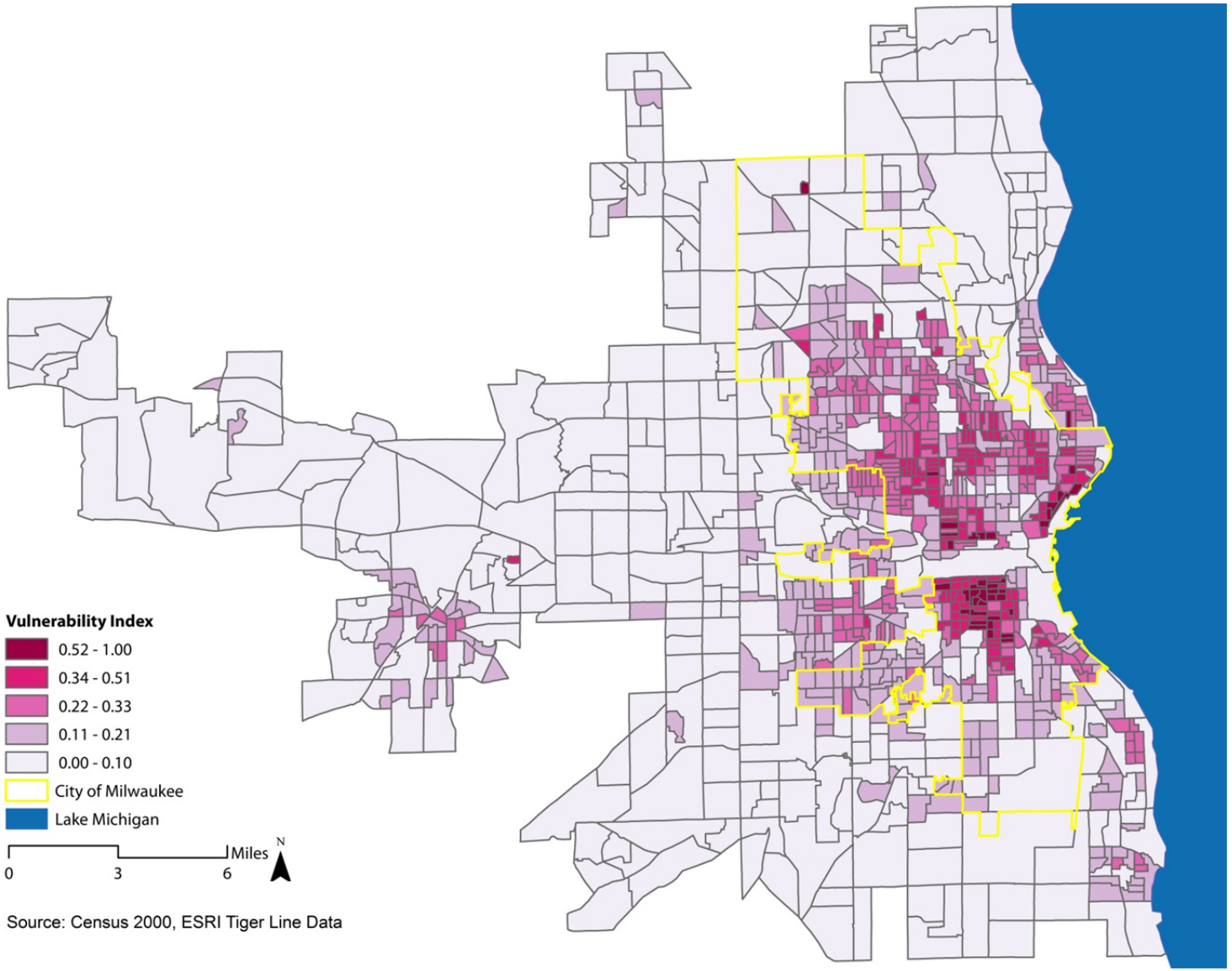


Appendix Maps

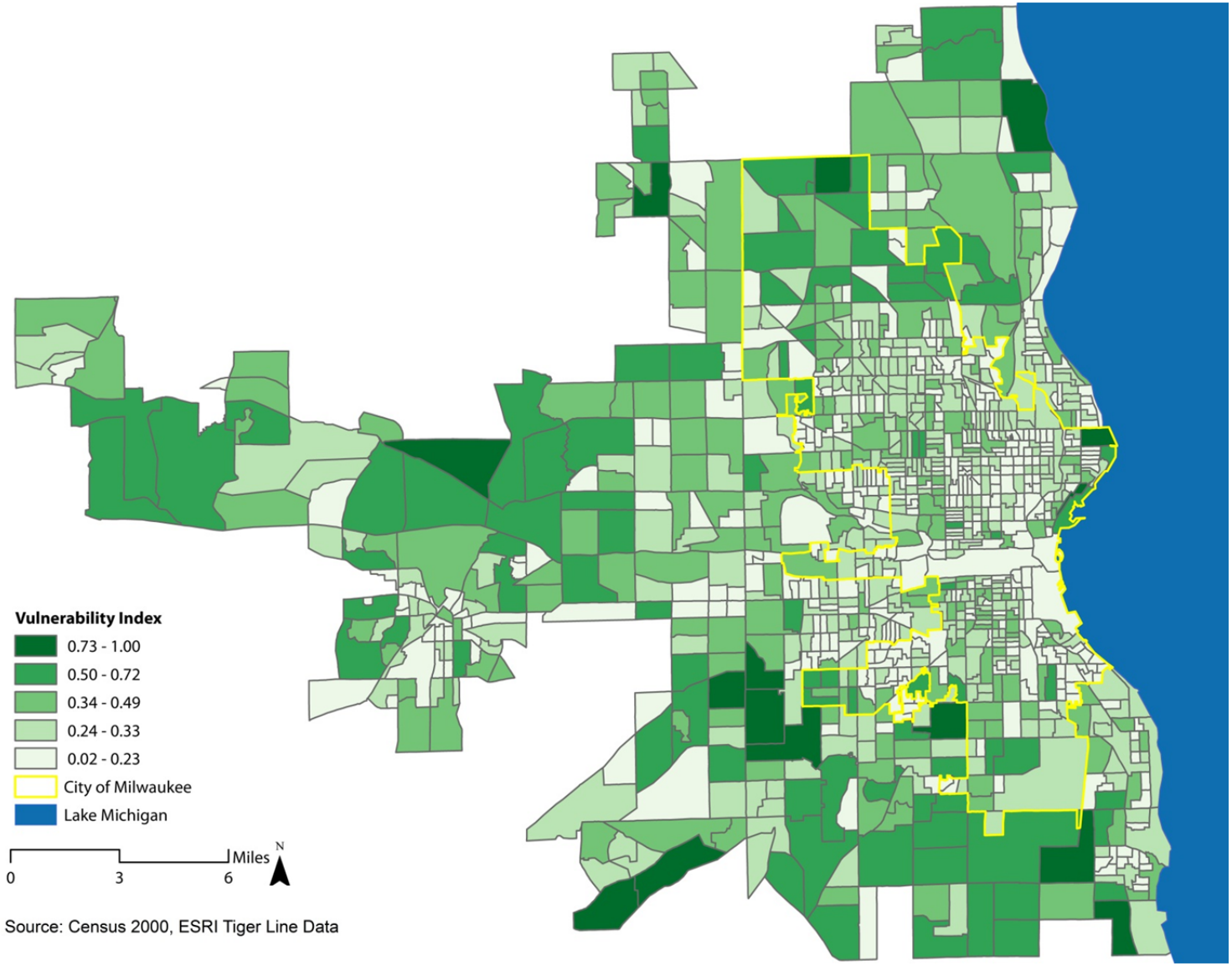
Age Component of Social Vulnerability Index: Milwaukee, WI Urban Area by Census Block Group (2000)



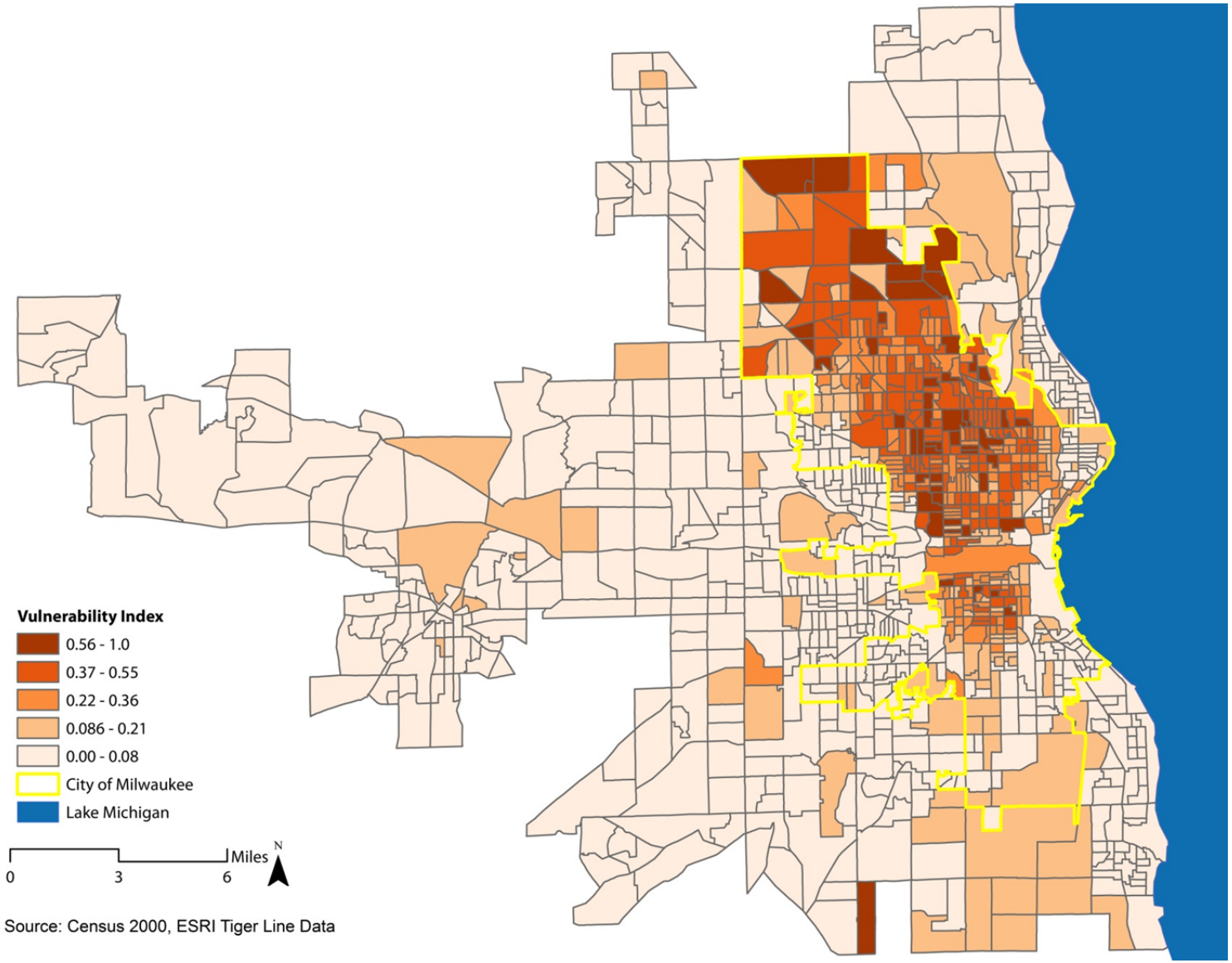
Density Component of Social Vulnerability Index: Milwaukee, WI Urban Area by Census Block Group (2000)



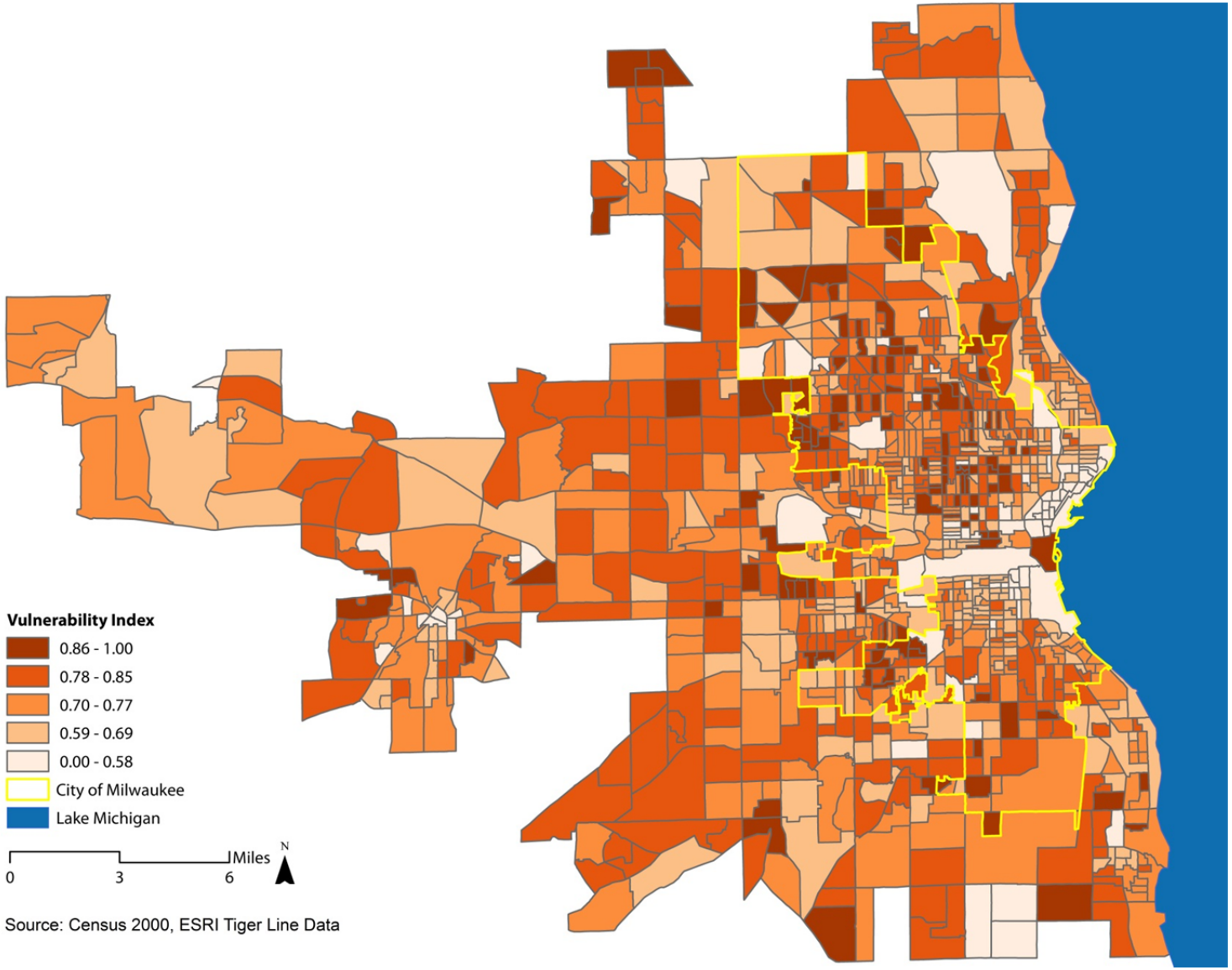
Female Component of Social Vulnerability Index: Milwaukee, WI Urban Area by Census Block Group (2000)



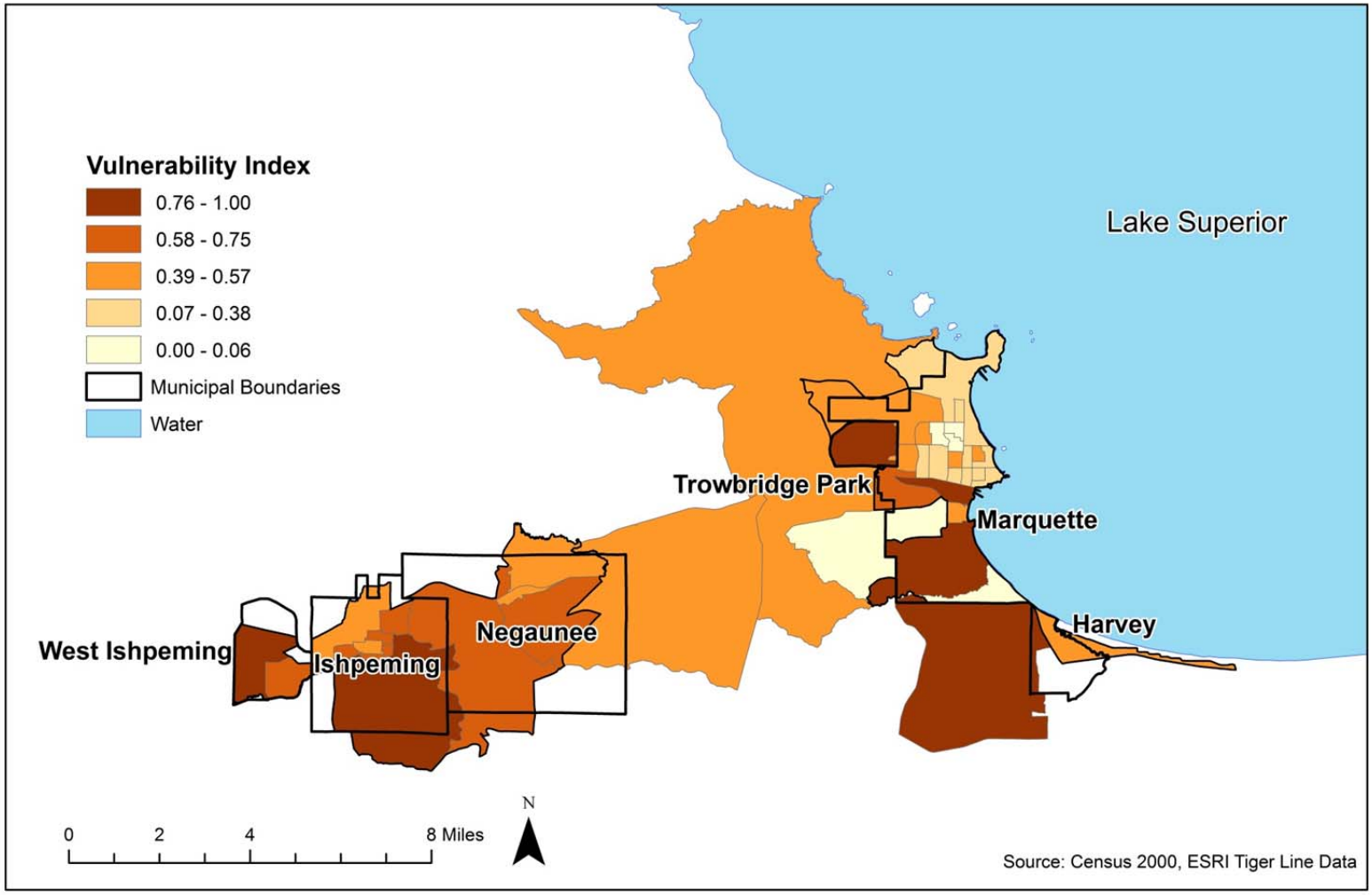
Non-White Component of Social Vulnerability Index: Milwaukee, WI Urban Area by Census Block Group (2000)



Value Component of Social Vulnerability Index: Milwaukee, WI Urban Area by Census Block Group (2000)



Age Component of Social Vulnerability Index: Marquette MI, Urban Area by Census Block Group (2000)



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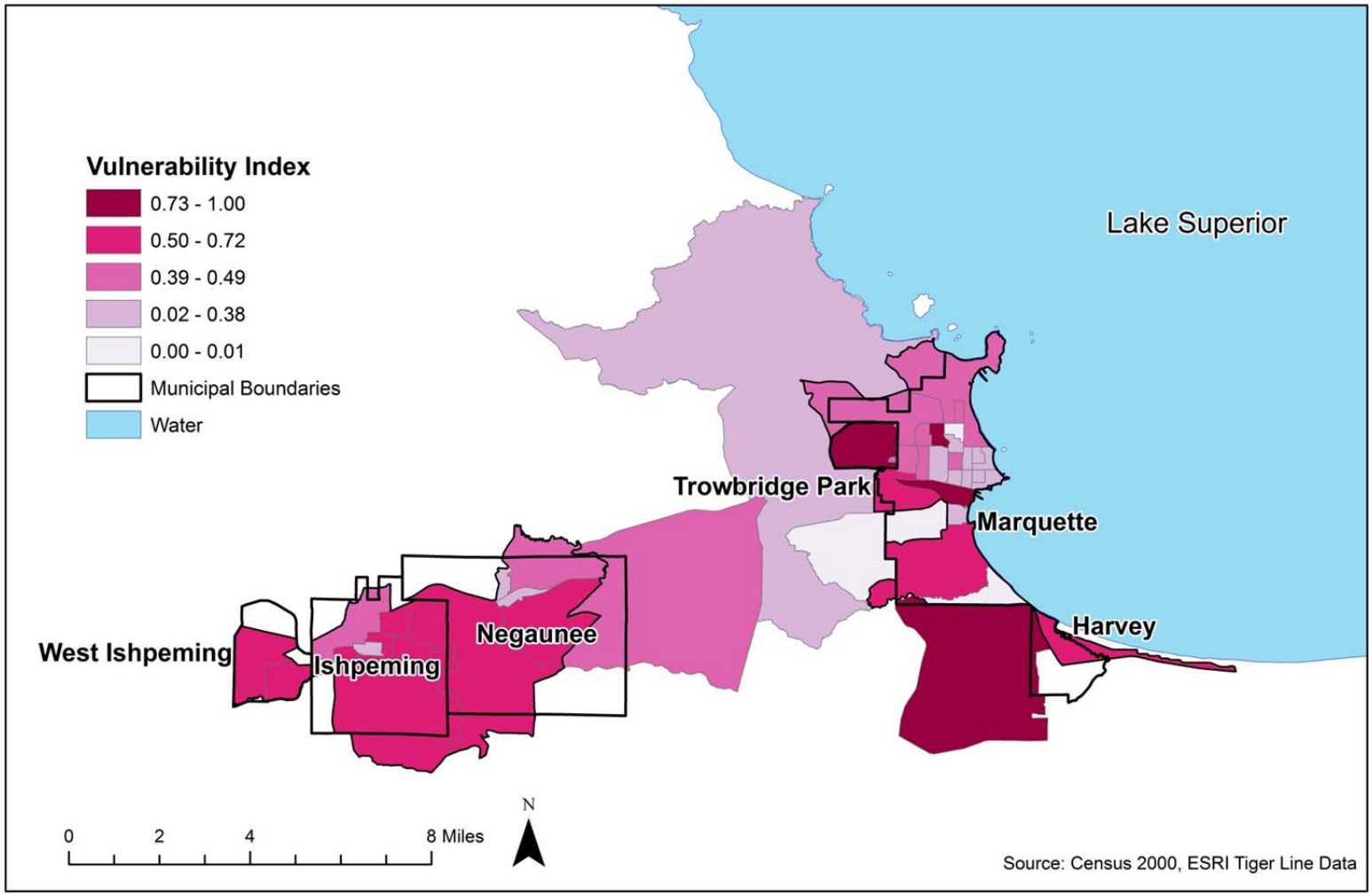

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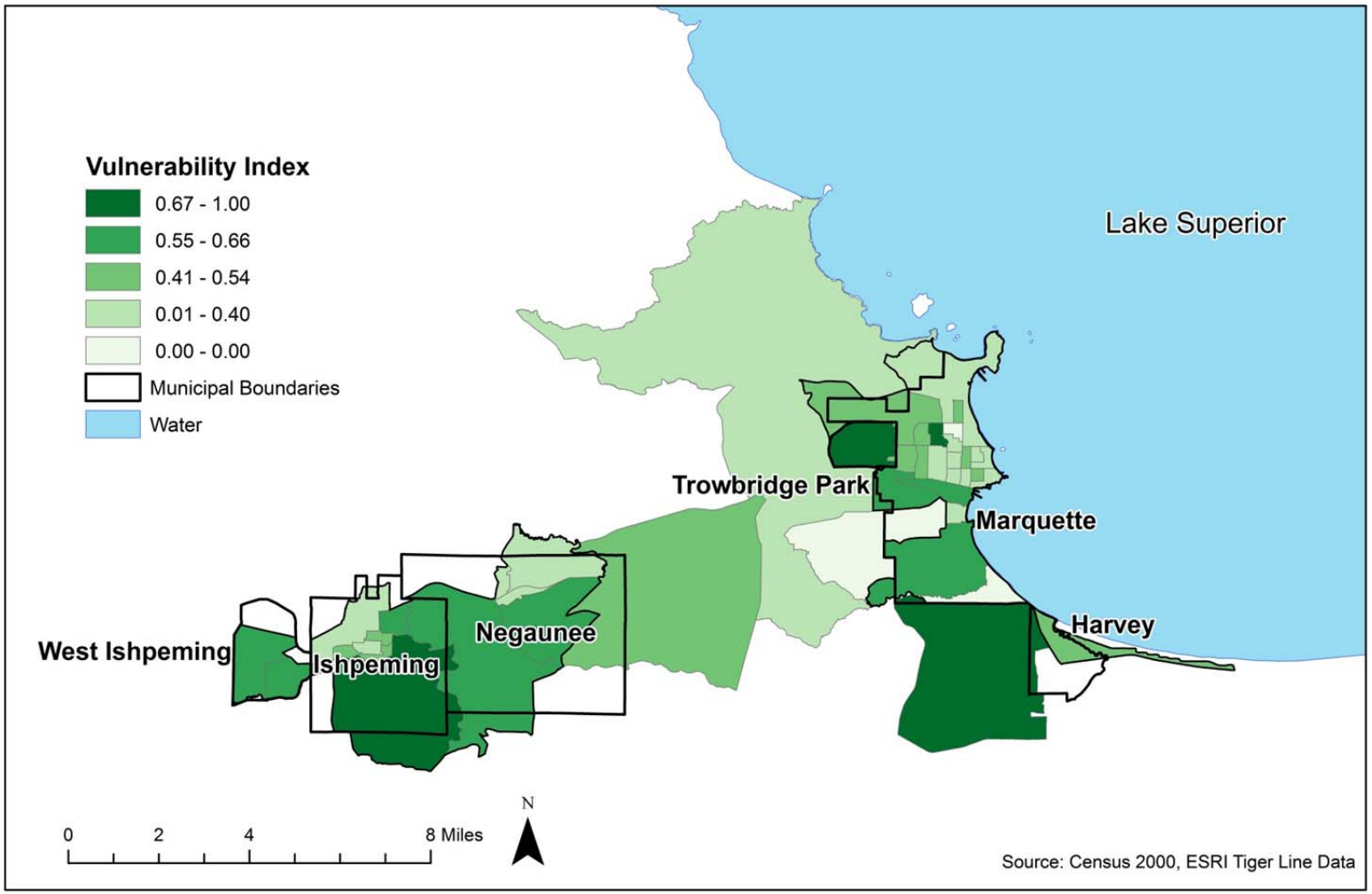

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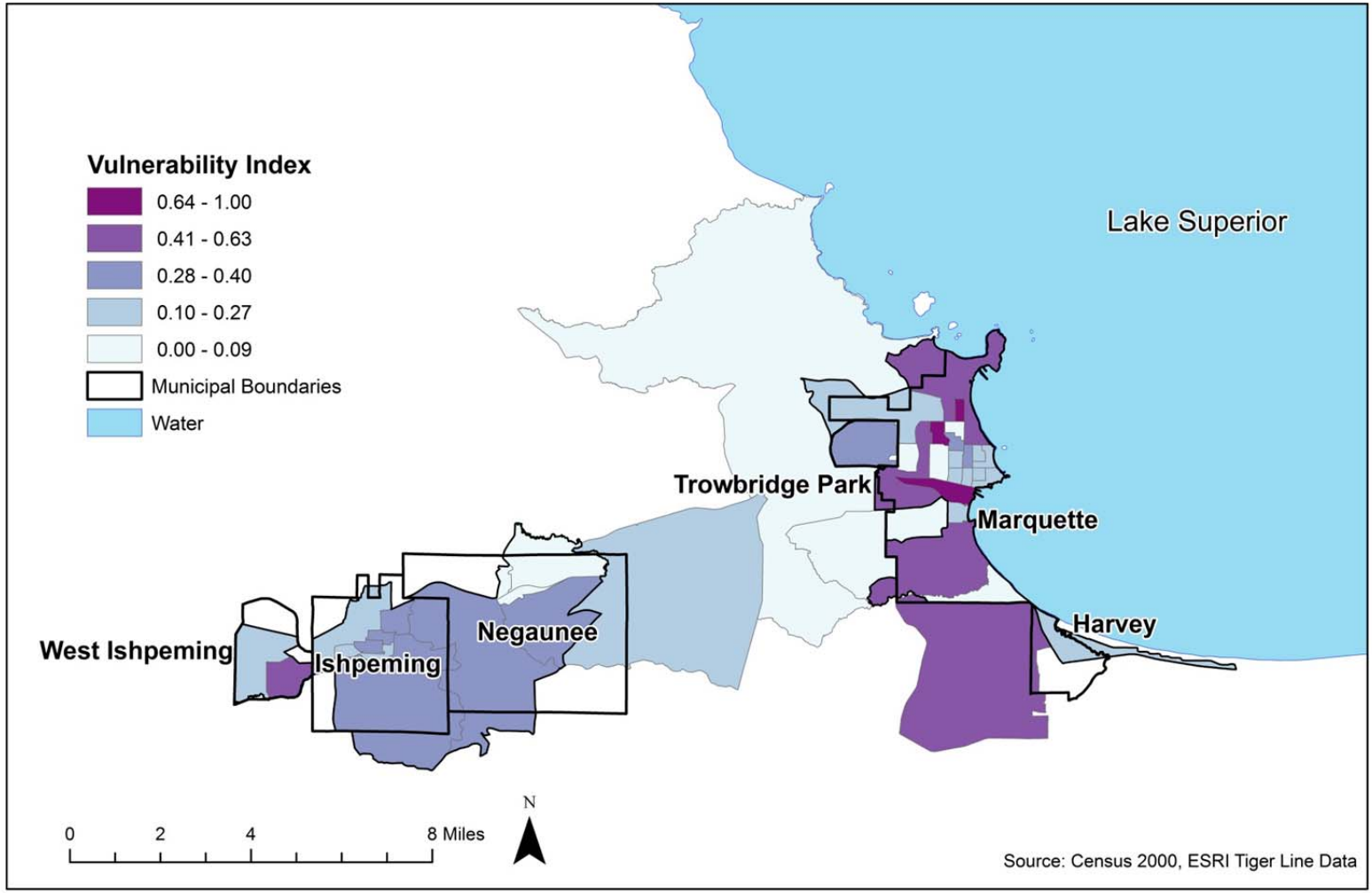

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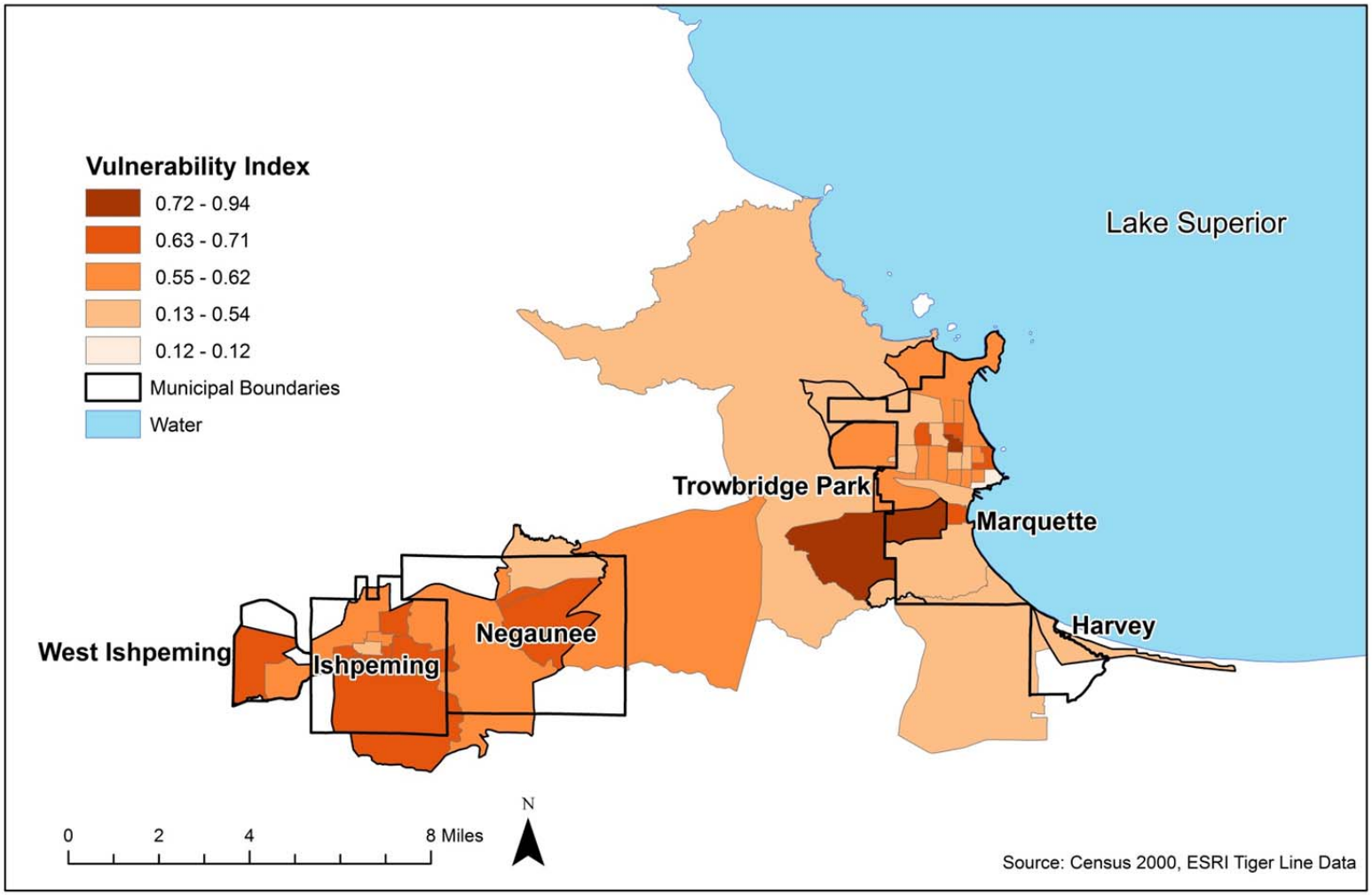

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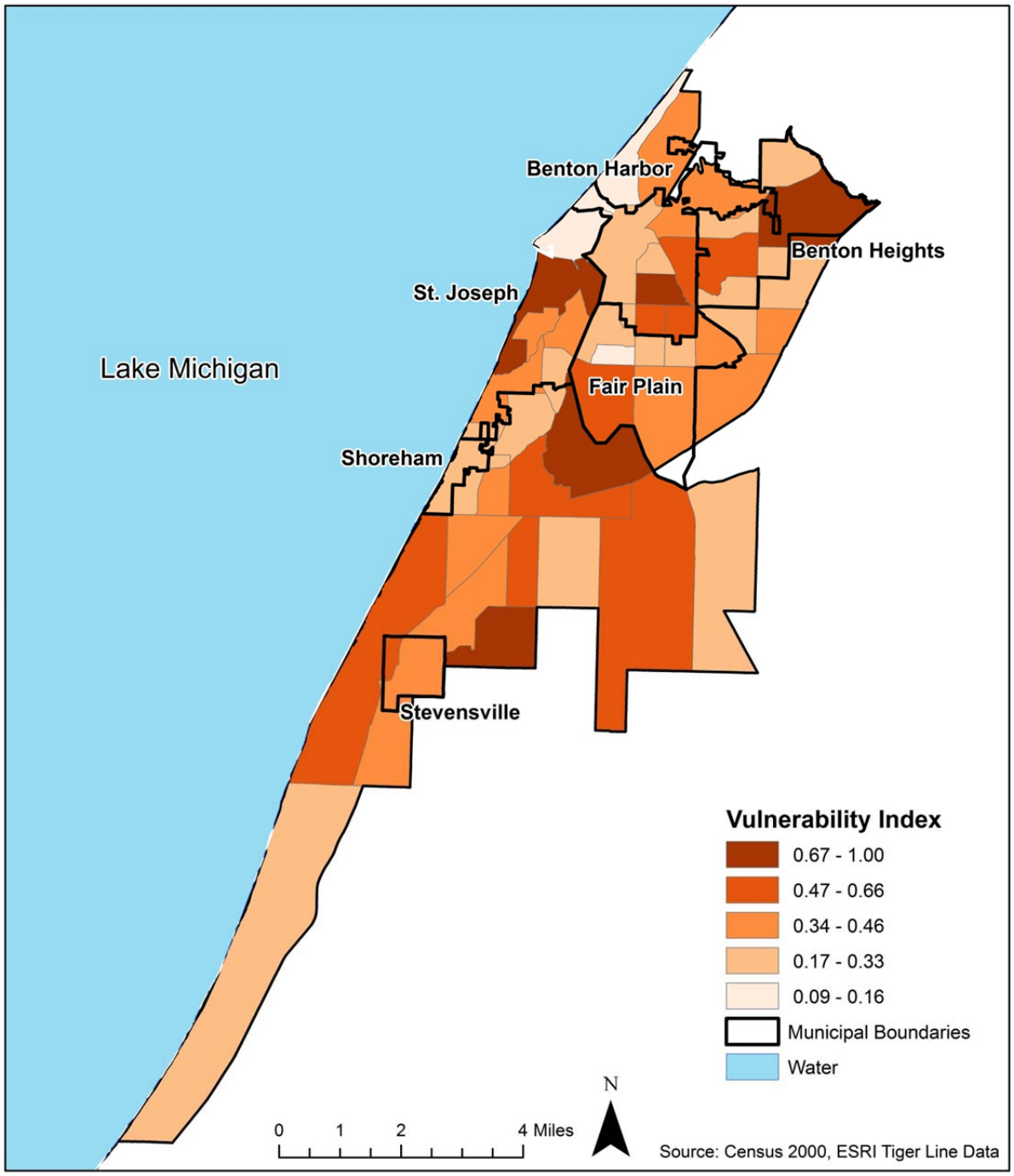

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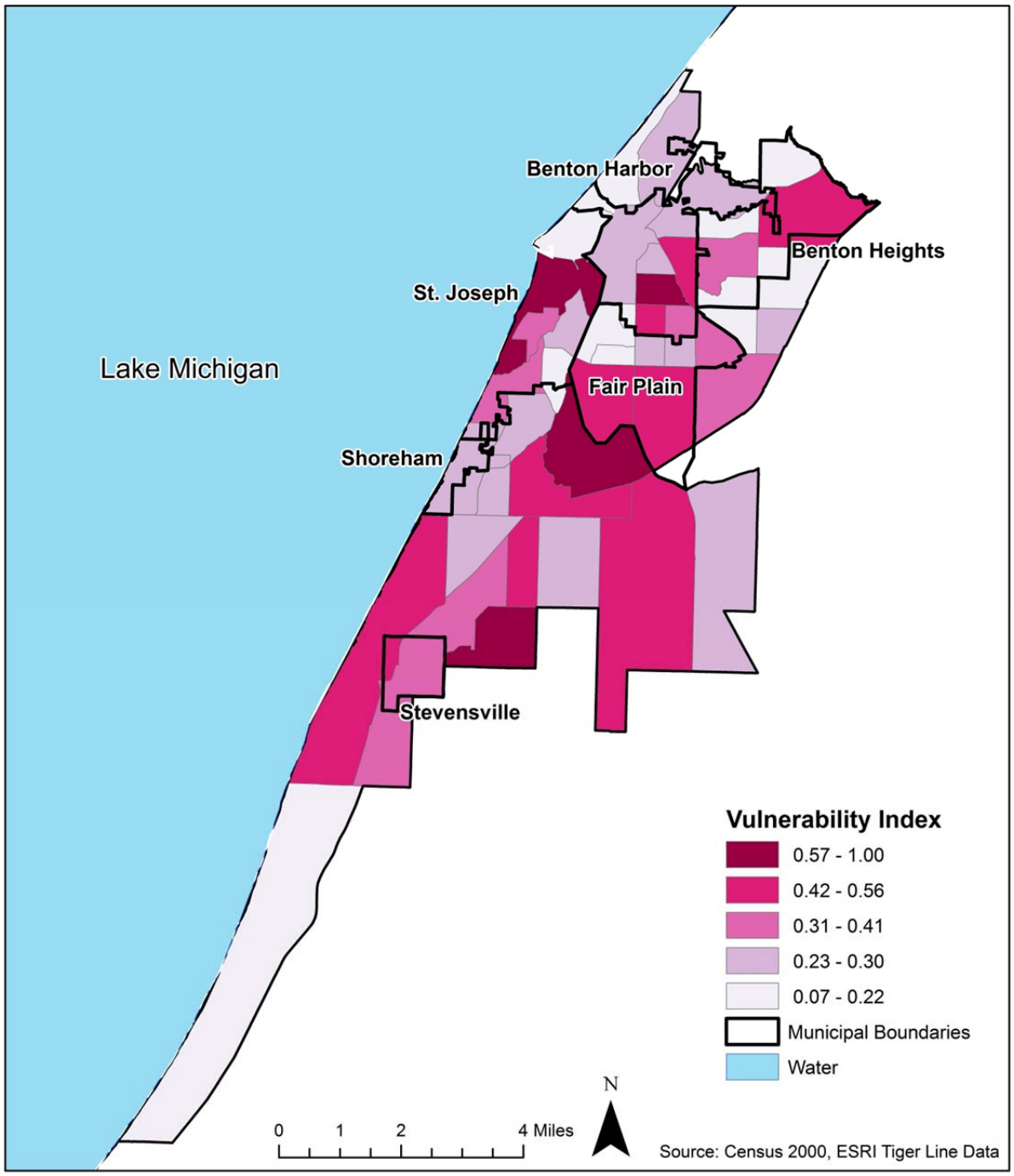
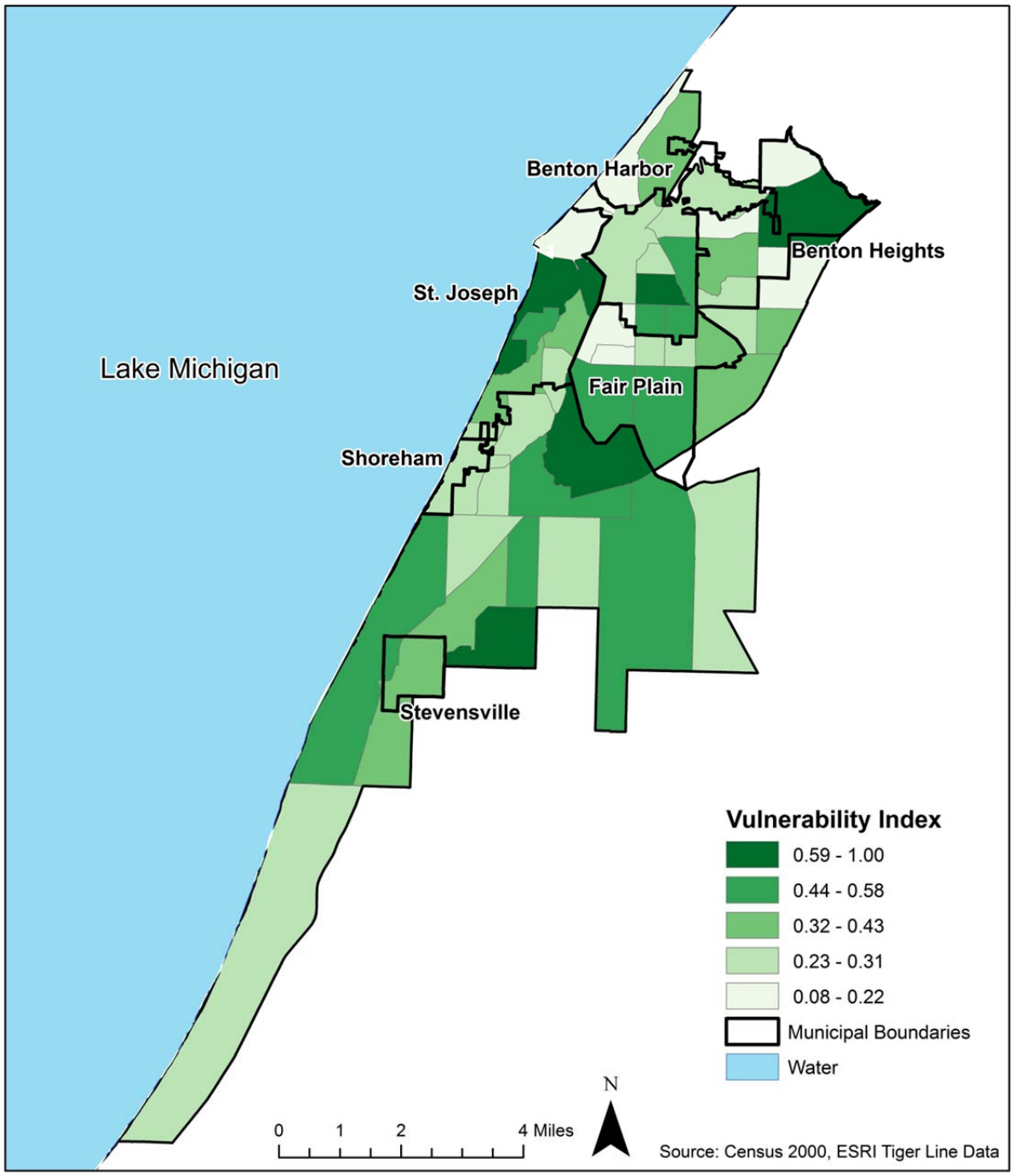


Female Component of Social Vulnerability Index: Marquette MI, WI Urban Area by Census Block Group (2000)



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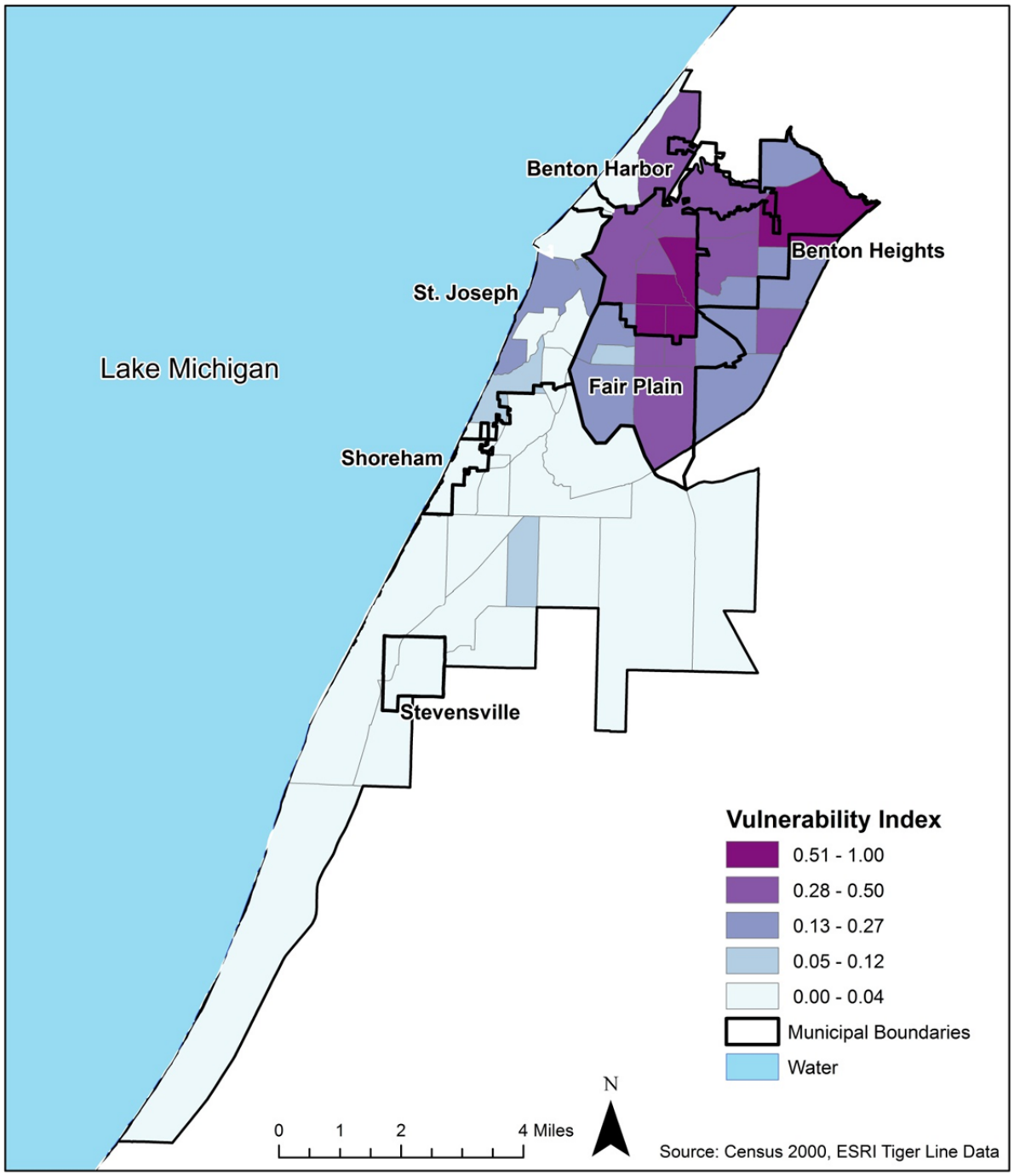

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