EMPIRICAL SEDIMENT AND PHOSPHORUS NONPOINT SOURCE MODEL FOR THE ST. JOSEPH RIVER WATERSHED

Prepared for:

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1.0 Executive Summary

An empirical nonpoint source (NPS) modeling effort of the St. Joseph River Watershed was conducted using loading data calculated near the mouth of the river to estimate NPS loads of phosphorus and sediment from recognized subwatersheds draining to Lake Michigan. Monitoring data were collected by the U.S. Geological Survey (USGS) as a part of the National Stream Quality Assessment Network, and published in a 1997 study on loading of phosphorus and sediment to Lakes Michigan and Superior from major tributaries (Robertson, 1997). This modeling assessment was undertaken to estimate the spatial origin of NPS phosphorus and sediment loads for the development of a Watershed Management Plan. Modeling targeted compilation and utilization of a consistent set of relevant watershed attributes and climatic variables.

NPS modeling in this application used a combination of empirical tools, published literature values for pollutant runoff concentrations and a geographic information system database. The approach integrates: a) high resolution land cover data for the watershed; b) estimated mean concentrations (EMCs) of pollutants in runoff; c) 30-meter resolution digital elevation data, and; d) interpolated rainfall data from existing weather stations to produce a consistent spatial dataset for the entire watershed. Annual sediment and phosphorus loads are calculated for each subwatershed using event mean concentrations, land cover relationships and precipitation data. Published loading data and point source discharge information were used to adjust NPS loading model coefficients.

This NPS modeling effort serves as an initial step to identify critical areas in the St. Joseph Watershed related to common, yet important, pollutants which influence water quality. Critical area identification will lead to prioritization of improvement and protection strategies within the watershed and the recommendations of Best Management Practices (BMPs) to reduce NPS pollution.

The St. Joseph River NPS loading model yielded an estimated load of 288 tons of phosphorus and 134,000 tons of sediment annually associated with runoff from precipitation. The model results were utilized to compare loading among subwatersheds.

The distribution of land cover throughout the watershed, and the corresponding NPS loads derived from this modeling effort, provide important insight into the most significant contributors of sediment and phosphorus to the river. Analyses indicate that 86% and 70% of the NPS sediment and phosphorus loads, respectively, appear attributable to agricultural land covers that comprise 70% of the total land use in the watershed. In highly urbanized reaches of the watershed (which constitute only 1% of the total land use in the watershed), urban stormwater contributions are the dominant contributor of pollutants.

The value of this NPS modeling effort for the St. Joseph River Watershed Management Plan is several fold. Beneficial outcomes of this approach include:

- A contiguous land use/land cover data set for the 1990s.
- Consistent land cover interpretation and breakdown of land uses for the entire watershed and subwatershed areas.
- Distribution of NPS loads by land use and by subwatershed.
- Regional understanding of NPS loads.
- Comprehensive GIS coverage of physical attributes, including soils, slope, elevation and precipitation, that allows for examination of critical watershed areas and attributes.
- Valuable information for future educational use to engage participants and establish new partnerships.

2.0 Introduction

This report presents the results of a NPS modeling analysis that estimates sediment and phosphorus loads from subwatersheds of the St. Joseph River Watershed. This effort was completed by KIESER & ASSOCIATES (K&A) as part of a Clean Water Act Section 319 grant administered by the Michigan Department of Environmental Quality (MDEQ) to the Friends of the St. Joe River Association, Inc. The purpose of the grant is to prepare a Watershed Management Plan for the St. Joseph River Watershed.

The St. Joseph River Watershed drains fifteen counties in Southwestern Michigan and Northeastern Indiana. Its headwaters originate in Hillsdale County, Michigan. The river flows west to Three Rivers, Michigan and then southwest past Elkhart, Mishawaka and South Bend, Indiana. The river then flows northwest past Niles, Michigan and discharges to Lake Michigan at St. Joseph/Benton Harbor, Michigan. The watershed covers 4,685 square miles of largely agricultural land (over 70% of the land cover). According to the 2000 U.S. Census, approximately 1.5 million people live in the 15 counties of the watershed. The most populated county is St. Joseph County, Indiana, where South Bend and Mishawaka are located. The second most populated county is Kalamazoo County, Michigan.

A 2000 Michigan Department of Natural Resources (MDNR) assessment of the St. Joseph River Watershed lists 63 water bodies which do not meet designated uses, based on 1996 Indiana Department of Environmental Management (IDEM) and MDEQ reports. Several water bodies (or stream segments) are listed for multiple stressors. *E. coli* is listed most with 29 water bodies. Twenty-two are impaired by biological degradation, and fifteen are impaired by sedimentation. Two TMDLs are currently being developed for *E. coli*.

The MDEQ 2002 Water Body System Nonattainment survey indicates that fish consumption advisories were issued in 10 water bodies; 1 did not meet the cold water fisheries designated use; 1 was listed for macroinvertebrate communities being rated poor; and 2 were impaired for body contact.

Annual sediment and phosphorus loads to Lake Michigan from the entire St. Joseph River were previously estimated by the U.S. Geological Survey based upon available 1970-1993 concentration and flow data measured at Niles, Michigan (Roberston, 1997). These estimates included all sources of phosphorus and sediments to the river, including permitted point sources (municipal and industrial wastewater) and nonpoint sources (runoff from all land uses plus in-stream erosion processes). Loading of these parameters from regulated point sources was averaged over a 10-year period (1990-1999) and subtracted from the total measured loads from the river. The resulting load was attributed to nonpoint sources (NPS) and utilized to calibrate the model. NPS loads accounted for 98% and 75% of the total loads of sediment and phosphorus, respectively, from the St. Joseph River to Lake Michigan.

Results of this non-point source modeling analysis are provided in the following sections of this report:

- Methods
- Watershed Characterization
- Non-point Source Sediment and Phosphorus Loading
- Conclusions/Recommendations

Information in these sections is supplemented with technical details provided in appendices.

3.0 Methods

Brief descriptions of the methods and datasets used in the St. Joseph River Watershed NPS loading model are provided in this report section. A detailed description of the data preparation steps completed for this modeling effort is included in Appendix A. Calculation methods for storm water runoff and NPS sediment and phosphorus loads and model calibration are presented in Appendix B.

3.1 Subwatershed Boundaries

Existing subwatershed boundaries available from the Michigan Center for Geographic Information were preliminarily used in the Section 319 planning project. However, these boundaries left large subwatersheds in Indiana, including the Pigeon River and Elkhart River Watersheds undelineated. Watershed boundaries for the Indiana portion of the watershed that contain fine-scale delineations of the Pigeon River and Elkhart River Watersheds are available from the USGS. However, this delineation only covers the Indiana portion of the St. Joseph River Watershed. Therefore, digital elevation modeling was conducted to create a single, continuous subwatershed layer across the watershed. The subwatershed boundaries from the MDEQ and USGS were utilized to name the delineated subwatersheds and to assure that any newly delineated subwatersheds were not included in the final product. It was the purpose of the final delineation to only map federally recognized subwatersheds in a single layer.

Figure 1 illustrates the subwatersheds of the St. Joseph River watershed delineated by the MDEQ. Figure 2 illustrates the Indiana subwatersheds available from the USGS. Figure 3 illustrates the final subwatershed delineation. Subwatersheds are numbered, corresponding to the subwatershed designations (or Acodes@) in Table 1.

The final subwatershed delineation for the St. Joseph River Watershed was completed using 30-meter resolution Digital Elevation Model (DEM) topographic information. This approach provided the continuous representation of elevation for the entire area of study as shown in Figure 4. Flow direction, flow accumulation, and finally the subwatershed boundaries for the entire watershed were determined from this fine resolution data. The resulting boundaries delineated with the DEM data aligned well with the existing MDEQ and USGS subwatershed boundaries. However, twelve subwatersheds were delineated in addition to those recognized on the MDEQ and USGS layers. These additional subwatersheds were combined with their appropriate adjacent subwatersheds so that no unrecognized subwatersheds were utilized in the model. Differences in the placement of watershed boundaries were noted among the delineated subwatersheds and the layers available from the MDEQ and USGS. This is presumably due to differences in the resolution of the elevation data utilized for the delineations. The subwatershed delineation conducted by Kieser & Associates was utilized for the NPS model. (See Appendix A for additional details.)

3.2 Land Use/Land Cover

Land use/land cover data for the St. Joseph River Watershed was obtained from the USGS National Land Cover Dataset. These data layers are available as grid files from the Michigan Center for Geographic Information by Michigan counties and from the Indiana Geological Survey (Indiana GIS Atlas) for the entire state of Indiana. The eight Michigan county land cover files were Amosaiced@ together to create one continuous file for the Michigan portion of the watershed. These data layers were provided in the Michigan Georef projection. The Indiana land use layer was provided in the Universal Transverse Mercator (UTM) projection. The Amosaiced@ Michigan layer was reprojected to the UTM projection and then Amosaiced@ with the Indiana layer. The resulting land cover data file was then clipped by the watershed boundaries.

The clipped land cover file was utilized to calculate the areas of each land cover type in each subwatershed and in the St. Joseph River Watershed as a whole. This land cover information was then utilized in the NPS model. Figure 5 represents the land cover layer.

3.3 Precipitation Data

Annual precipitation values were collected from 15 weather stations located within Michigan and Indiana spanning a time period of January 1949 to December 1999 as a part of an NPS modeling effort conducted by Kieser & Associates for the Kalamazoo River Watershed. (The Kalamazoo River Watershed is located adjacent to the St. Joseph River Watershed to the north. Therefore, the weather stations accessed for that study overlapped the geographic area of the St. Joseph River Watershed.) A continuous grid of precipitation values was created using Akriging@, a widely used method of spatial interpolation.

Figure 6 presents the average annual precipitation grid. The interpolated precipitation values within each subwatershed were then averaged to provide a single precipitation value for that subwatershed representative of annual weather patterns.

3.4 Storm Water Runoff

Runoff in the St. Joseph River Watershed NPS model was determined using the approach prescribed in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002). This approach uses fractions of impervious surface based on land use/land cover, areas of different land use/land cover types, and precipitation to generate runoff. Details of this approach are provided in Appendix B.

3.5 Sediment and Phosphorus Loads

Nonpoint source sediment and phosphorus loading to Lake Michigan from the St. Joseph River was determined using the event mean concentration (EMC) approach. In this approach (also prescribed by the Part 30 - Water Quality Trading Rules), sediment and phosphorus loads are calculated from runoff volumes corresponding to annual precipitation depths and pollutant concentrations assigned to each land use/land cover category in each subwatershed. The EMCs used for this characterization are based on those determined from storm water pollutant monitoring conducted during the Nationwide Urban Runoff Program for the Rouge River, Michigan Watershed (as seen in Wayne County, 1998). Average annual sediment and phosphorus loads predicted with the NPS model are presented in Figures 7 and 8, respectively. Loading from each subwatershed is depicted in units of pounds/acre/year to portray the relative loadings among subwatersheds. Appendix B presents a detailed discussion of how these loads were computed.

4.0 Watershed Characterization

This section provides a summary of the information compiled for the land use/land cover. Based on the land cover data obtained from the USGS National Land Cover Dataset, the approximately 3 million acres of the St. Joseph River Watershed are comprised of 17% forest and open areas, 71% agriculture, 3% residential, 1% commercial, industrial and transportation, and 8% open water and wetlands. Table 1 summarizes these land cover types by subwatershed. The urban centers of St. Joseph/Benton Harbor, MI and South Bend, Mishawaka and Elkhart, IN are evident as large clusters of residential, commercial, industrial and transportation related land covers (Figure 5). The remainder of the watershed is primarily agricultural in Indiana and a patchwork of agriculture, forests/open areas, open water and wetlands in Michigan.

The topography of the St. Joseph River Watershed, derived from the 30-meter DEM, is displayed in Figure 4. The region is characterized by gently rolling surfaces resulting from glacial moraines. Elevations range from approximately 180 meters above sea level to just over 380 meters. The highest elevations are observed in Hillsdale County, Michigan in the easternmost portion of the watershed.

Figures 9 to 12 illustrate the percent distribution of land cover types by subwatershed. Figure 9 shows that agricultural lands are typically more prevalent in the southwestern and south-central portions of the watershed. Subwatersheds 206 and 213, both subwatersheds of Turkey Creek (part of the Elkhart River Subwatershed) exhibit the highest percentage of agricultural lands at 95% and greater.

Forested and open areas by subwatershed are displayed in Figure 10. Areas with a greater percentage of these land covers tend to be found in the northern-central portions of the St. Joseph River Watershed. Subwatersheds 2 (North Branch Paw Paw River, located north of Watervliet, MI) and 89 (Mill Creek, located west of Three Rivers, MI) contain the greatest percentage of forest and open land covers at 45% and 36%, respectively.

Wetlands and open water by subwatershed are depicted in Figure 11. Subwatersheds 12 (Gourdneck Creek, located south of Portage, MI), 205 (Turkey Creek at Wawasee Lake) and 51 (Dowagiac Creek), each exhibit over 25% water and wetland areas. Subwatershed 51 contains 7 lakes including Fish Lake, Finch Lake, Saddlebag Lake and Bunker Lake.

Figure 12 displays percent urbanized land cover by subwatershed. Urban areas include residential, commercial, industrial and transportation land covers. The subwatersheds overlapping St. Joseph/Benton Harbor, MI and Mishawaka-South Bend, IN exhibit the highest percentages of these land cover types. Subwatersheds overlapping Goshen and Elkart, IN and Niles, MI also have notably higher urban land covers relative to other subwatersheds. The most intensive urban land uses are adjacent to the St. Joseph River at its middle and downstream sections.

The range and distribution of land slopes in the watershed are illustrated in Figure 13. The steepest areas of the watershed are often observed along the banks of the St. Joseph River floodplain. The ability to locate these steeper areas in combination with other land cover information such as agriculture, begins to illustrate the types of useful analyses that can be completed with these GIS data. This approach thus offers the capability to identify watershed areas where non-point source loadings may be greatest.

5.0 Nonpoint Source Sediment and Phosphorus Loading

The St. Joseph River NPS sediment and phosphorus loading model was calibrated to predict loads of 135,000 and 290 tons, respectively, on an annual basis. NPS sediment and phosphorus loading predictions for each subwatershed are presented in Table 1 and Figures 7 (sediment loads) and 8 (phosphorus loads).

Table 1 indicates that NPS sediment and phosphorus loads from the St. Joseph River Watershed=s 217 identified subwatersheds are primarily from the western end of the watershed. This might suggest that NPS loading is driven by rainfall depths, as the western end of the watershed averages an annual rainfall depth of 36 inches, driven by the effects of Lake Michigan. Conversely, the eastern end of the watershed averages an annual precipitation depth of 30 inches. However, when one examines Figures 7 and 8, it is evident that a NPS strategy with a focus on geographic areas may yield the best opportunities for significant reductions. Clustered drainage areas surrounding the large urban areas of St. Joseph/Benton Harbor, MI and South Bend, IN, for example, suggest that targeted efforts in these areas may be useful for reducing NPS loading. Of interest, in the central portion of the watershed where precipitation depths are moderate, is Subwatershed 121 (Nye Drain) which stands out as an area of high nonpoint source loading compared to the surrounding subwatersheds. This subwatershed overlaps the urban area of Sturgis, MI and is adjoined by subwatersheds exhibiting higher percentages of forested and wetland land covers.

This is not to suggest that watershed improvement efforts in other sections of the watershed do not merit attention, rather watershed management efforts focused on sediment and phosphorus loading may be better served by implementing Best Management Practices (BMPs) in urban areas where investments potentially yield higher returns in terms of loading reductions to the river. Stormwater management efforts in these areas may also yield reductions in pathogen loading to the river, which has been identified as a priority. Pesticide loading to the river has also been identified as a concern. Agricultural areas, comprising 71% of the watershed, are expected to be the largest contributor of pesticides, such as atrazine. However, pesticide use in residential areas has been noted to occur at a high rate, as homeowners tend to over apply these products and are not trained to apply the appropriate levels. Urban watershed education and stormwater management techniques must be an integral component of the Watershed Management Plan.

It is valuable to note that forests, open areas and water/wetlands cover almost one-quarter of the land area in the watershed while representing only about 7% and17% of the sediment and phosphorus loads, respectively. Although this ratio of land cover to load reflects a relatively small contributing proportion of the overall load, these loads can be viewed as the Anatural background@ contributions associated with relatively undisturbed conditions. As such, there will be few opportunities or techniques to reduce NPS contributions from these background sources. Protection, and/or conservation development practices should therefore be promoted as an integral element of the Watershed Management Plan in these areas.

6.0 Conclusions/Recommendations

The NPS modeling effort described herein, provides a first-cut analysis of the relative NPS loads stemming from various land uses/land covers of the St. Joseph River Watershed. The modeling approach used in this effort offers a variety of valuable tools and results previously not utilized in the St. Joseph River Watershed as a whole. Such valuable attributes include:

$ Land use distributions by subwatershed and for the overall St. Joseph River Watershed.
$ Land cover data for the entire watershed derived from a single source (USGS National Land Cover Data Set) and Amosaiced@ into a single raster file.
$ Fine scale resolution of subwatershed characteristics including land use, elevations and other applicable data compiled in a GIS format.
$ Use of rainfall patterns that vary dramatically across the watershed, derived from the NPS modeling efforts for the Kalamazoo River Watershed, to the north of the St. Joseph River Watershed.
$ Annual NPS sediment and phosphorus loading estimates from subwatersheds to identify those areas of the watershed most contributing to the NPS load.
$ Estimated NPS loads by land use categories within each subwatershed allowing for identification of land uses and locations where BMPs should be implemented.
$ An NPS modeling approach that offers a relatively simple, yet reasonable method to estimate annual sediment and phosphorus loads in a manner consistent with the State of Michigan Water Quality Trading Rules.
$ Mapping of sensitive and/or critical watershed areas where protection or restoration may provide the greatest long-term benefits to protect water quality.
$ A valuable tool to integrate with other known characteristics of the watershed to identify critical areas and direct implementation efforts to lead to overall watershed health.

The scope of this modeling effort was not intended to provide a comprehensive analysis that would result in recommendations for specific NPS loading reductions. Rather, it was to serve as one tool to be used in the watershed management planning process. The model does not account for specific Aon-the-ground@ practices which may impact (positively or negatively) water quality. It simply utilizes land cover and precipitation data to predict NPS loading from each subwatershed of the St. Joseph River Watershed to Lake Michigan.

The model also does not account for sediment transport and deposition nor phosphorus uptake within the St. Joseph River and its tributaries. Therefore, it is meant to be capture the loading from land surfaces of each subwatershed to surface waters in the watershed. The model was calibrated to measured concentrations of total phosphorus and total suspended solids. These data incorporate wet weather loads to the St. Joseph River and dry weather baseline conditions. The NPS model was calibrated to these total loads using EMC=s, which are estimates of concentrations of pollutants in wet weather runoff. Therefore, wet weather estimates were utilized to calibrate the NPS loading model to both dry and wet weather loads in the river. However, it is beyond the scope of this modeling effort to segregate wet and dry weather conditions. Nevertheless, the NPS model is valid for comparing subwatersheds and identifying potential areas of high loading. With these caveats in mind, the model is utilized as one tool in the process of the development of the Watershed Management Plan for the St. Joseph River Watershed.

7.0 References

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TABLE 1

Land Use and NPS Loading for Each Delineated Subwatershed

Watershed Number	Water Course	Water + Wetland		Forest + Open Land		Agriculture		Residential	Commercial + Industrial	Urban	Total Acres	TP Load	TSS Load
		acres	percent of subwatershed	acres	percent of subwatershed	acres	percent of subwatershed	acres	acres	percent of subwatershed		pounds/acres	pounds/acre
1	Brandywine Creek	1556.06	7.81	4544.76	22.81	13715.24	68.75	92.29	11.79	0.46	20019.50	0.179	89.8
2	N Br Paw Paw River	2047.77	11.01	8351.63	44.89	7940.21	42.58	230.84	22.24	1.24	18691.18	0.151	65.5
3	N Br Paw Paw River	1202.91	6.63	6056.12	33.35	10742.10	59.04	137.44	16.01	0.75	18253.60	0.162	80.3
4	Mud Lake Drain	975.18	9.93	2152.29	21.89	6648.79	67.47	45.37	1.56	0.46	9922.47	0.193	93.6
5	Paw Paw River	2458.52	14.40	4205.17	24.61	10365.82	60.59	38.25	1.78	0.22	17169.15	0.184	83.1
6	Paw Paw Lake	1471.78	16.39	2637.99	29.33	4391.98	48.67	468.35	8.67	5.16	9073.16	0.215	81.7
7	Portage River	2283.50	11.39	3598.27	17.94	14010.13	69.80	142.55	6.89	0.71	20140.48	0.175	83.2
8	Paw Paw River	1641.02	9.24	4613.04	25.96	11085.70	62.31	271.76	145.89	1.52	17854.91	0.196	91.4
9	Nottawa Creek	2457.41	9.98	5987.85	24.32	16059.23	65.16	55.60	52.26	0.22	24711.81	0.156	75.5
10	Paw Paw River	1214.47	12.24	1938.13	19.51	5625.80	56.52	906.68	237.29	9.06	10010.64	0.270	102.4
11	Gourdneck Creek	1734.86	20.50	1617.66	19.07	4451.58	52.35	580.88	79.17	6.79	8556.07	0.221	78.9
12	Gourdneck Creek	3621.84	28.55	2254.37	17.73	6187.78	48.59	572.65	50.70	4.48	12782.22	0.211	70.1
13	E Br Paw Paw River	1083.48	4.97	7409.81	33.99	12696.91	58.16	378.51	224.84	1.73	21890.67	0.171	82.7
14	Paw Paw River	1148.42	9.59	1958.81	16.35	8430.58	70.26	273.98	161.90	2.27	12069.89	0.224	103.4
15	Nottawa Creek	1197.57	7.56	3536.22	22.32	11017.65	69.43	12.01	74.72	0.08	15937.48	0.156	78.7
16	Pine Creek	968.06	9.99	2940.44	30.32	5761.46	59.22	15.79	3.11	0.16	9788.39	0.152	72.9
17	Eagle Lake Drain	822.84	8.08	1709.29	16.77	7621.97	74.65	28.91	2.67	0.28	10285.18	0.190	96.4
18	Alder Creek	954.94	9.28	3287.59	31.92	6039.89	58.46	8.01	0.00	0.08	10390.09	0.144	69.8
19	Portage River	2738.29	14.15	3719.92	19.21	12682.23	65.43	194.81	13.57	1.00	19447.62	0.177	79.7
20	S Br Paw Paw River	192.81	1.45	4098.20	30.85	8743.71	65.68	169.24	76.72	1.26	13378.67	0.168	89.0
21	Pine Creek	2466.31	13.07	4220.74	22.34	12161.84	64.31	26.02	2.22	0.14	18976.84	0.166	77.0
22	St. Joseph River	115.64	4.93	670.73	28.51	1527.60	64.16	31.36	2.22	1.28	2445.14	0.151	76.6
23	Little Portage Creek	801.72	4.46	3342.08	18.59	13713.90	76.20	105.86	10.90	0.59	18073.70	0.166	88.1
24	Mill Creek	700.08	3.77	2793.66	15.06	14849.43	79.98	108.75	95.18	0.58	18645.92	0.207	109.9
25	Brush Creek	2669.12	9.97	5519.05	20.61	18341.17	68.45	131.21	102.30	0.49	26861.90	0.195	94.2
26	Paw Paw River	1288.53	6.20	5333.13	25.64	13374.98	64.23	535.52	260.42	2.56	20888.64	0.214	100.9
27	St. Joseph River	1329.00	8.14	3530.44	21.61	11238.26	68.70	138.55	93.40	0.84	16428.10	0.161	78.8
28	St. Joseph River	1968.15	18.94	1439.09	13.83	6805.13	65.29	145.89	31.58	1.39	10487.90	0.178	74.9
29	Portage Creek	3076.10	17.67	2031.31	11.66	11456.87	65.72	718.76	121.65	4.11	17499.73	0.211	85.7
30	Portage River	390.29	12.66	261.09	8.44	2430.50	78.31	0.67	0.00	0.02	3181.96	0.186	90.1
31	Flowerfield Creek	892.67	8.67	1143.31	11.09	8041.62	77.94	173.46	47.37	1.67	10396.13	0.196	95.7
32	Paw Paw River	983.19	6.11	3355.42	20.84	6234.93	38.67	4166.48	1355.24	25.78	16160.87	0.408	124.6
33	Flowerfield Creek	2070.67	13.12	2500.11	15.83	11149.08	70.53	57.60	0.89	0.36	15877.83	0.186	87.3
34	Bear Creek	821.51	7.13	2717.16	23.57	7978.69	69.06	4.89	0.00	0.04	11622.01	0.160	82.0
35	Tekonsha Creek	855.76	6.16	3443.49	24.78	9570.11	68.75	4.23	16.23	0.03	13989.50	0.149	77.0
36	St. Joseph River	1144.86	19.19	948.27	15.84	740.56	12.34	2727.61	404.75	45.36	6013.43	0.513	112.1
37	St. Joseph River	688.52	21.25	393.41	12.07	1876.75	57.35	248.85	31.80	7.47	3330.00	0.218	78.3
38	Nottawa Creek	1486.68	8.95	3235.55	19.46	11744.42	70.55	134.55	18.46	0.80	16718.60	0.167	82.2
39	St. Joseph River	432.33	3.54	2269.93	18.58	9411.99	76.90	72.28	30.25	0.59	12315.79	0.161	85.9
40	Bear Creek	1055.46	8.30	2406.93	18.92	9250.76	72.61	0.44	0.00	0.00	12813.42	0.166	84.0
41	Flowerfield Creek	127.43	3.98	775.47	24.17	2134.94	66.04	164.57	2.22	4.99	3298.83	0.184	87.3
42	Dowagiac River	1020.99	3.11	6957.25	21.16	24523.61	74.54	309.57	63.16	0.94	32973.39	0.183	97.3
43	Hog Creek	1022.33	7.19	2396.47	16.85	10740.77	75.42	15.12	42.70	0.11	14316.85	0.162	83.0
44	Flowerfield creek	1053.46	14.10	1019.88	13.62	5271.75	70.28	68.94	59.16	0.91	7571.19	0.195	88.3
45	Silver Creek	2425.39	21.44	1801.14	15.89	6883.64	60.65	181.69	20.68	1.59	11410.52	0.223	89.3
46	Pipestone Creek	215.94	2.78	1634.57	21.06	5745.00	73.80	151.00	13.79	1.92	7857.94	0.206	107.9
47	Portage River	884.45	9.90	1281.41	14.32	6746.87	75.30	21.79	1.56	0.24	9035.59	0.177	87.7
48	Nottawa Creek	329.58	7.34	547.75	12.18	3600.49	79.85	10.01	1.56	0.22	4588.76	0.174	90.3
49	Little Portage Creek	100.52	0.98	1412.40	13.74	8684.77	84.39	64.27	14.01	0.62	10375.09	0.170	95.3
50	Coldwater River	161.68	5.26	590.45	19.17	2322.20	74.93	0.22	0.00	0.01	3173.91	0.157	83.3
51	Dowagiac Creek	3757.72	25.21	2825.91	18.93	8258.23	55.24	61.38	2.45	0.41	15005.07	0.197	75.2
52	Pipestone Creek	1178.00	4.91	4579.90	19.08	18186.39	75.70	53.15	3.56	0.22	24100.68	0.199	105.6
53	Rocky River	3830.00	13.93	6333.00	23.02	17296.38	62.81	37.81	2.45	0.14	27599.39	0.176	80.4
54	St. Joseph River	2233.02	7.96	4373.74	15.59	21363.90	76.09	74.28	8.90	0.26	28153.47	0.167	85.3

55	Dowagiac River	4359.07	12.98	6940.35	20.65	21624.98	64.31	544.63	122.98	1.62	33689.95	0.206	92.6
56	Coldwater River	306.23	4.23	1568.07	21.66	5331.36	73.41	23.35	7.34	0.32	7335.65	0.156	82.9
57	Soap Creek	321.35	3.96	1403.73	17.27	6364.36	78.14	32.25	1.56	0.39	8222.61	0.156	84.0
58	S Br Hog Creek	554.86	6.23	1972.82	22.13	6355.91	71.13	5.11	18.68	0.06	9006.88	0.152	78.8
59	St. Joseph River	1459.10	9.75	2340.21	15.63	11079.47	73.93	70.05	12.45	0.47	15060.60	0.173	85.3
60	St. Joseph River	907.35	9.23	1044.79	10.62	7724.27	78.45	141.44	7.78	1.43	9923.95	0.185	90.8
61	Beebe Creek	1288.31	10.92	2814.12	23.82	7694.92	65.01	4.23	0.00	0.04	11901.32	0.154	73.8
62	St. Joseph River	1272.96	6.41	3730.59	18.77	13911.38	69.92	694.30	260.64	3.48	19964.98	0.179	83.8
63	S Br Hog Creek	755.46	5.06	2367.12	15.83	11594.53	77.48	149.89	77.39	1.00	15042.75	0.166	85.7
64	Big Meadow Drain	353.16	3.57	1589.64	16.07	7363.11	74.34	531.29	48.26	5.32	9979.44	0.237	113.9
65	Portage River	1834.05	7.79	3439.93	14.60	17797.43	75.49	419.21	61.38	1.77	23649.87	0.184	90.7
66	Dowagiac Creek	926.92	9.45	2912.20	29.66	5390.29	54.74	422.76	156.34	4.27	9902.36	0.209	88.8
67	Mud Creek	553.08	4.38	1802.47	14.26	8535.11	67.44	1410.17	335.81	11.08	12722.72	0.223	92.2
68	St. Joseph River	982.52	6.92	2461.86	17.32	10731.21	75.40	28.24	3.56	0.20	14307.02	0.165	85.4
69	St. Joseph River	1030.56	7.65	2191.21	16.25	9605.25	71.15	504.38	144.55	3.72	13570.99	0.237	110.0
70	Rocky River	3691.90	14.61	7112.03	28.12	14268.32	56.35	189.03	15.57	0.74	25375.93	0.173	75.7
71	Beebe Creek	1468.22	9.78	3513.98	23.40	9969.52	66.28	50.93	6.67	0.34	15108.78	0.155	75.3
72	St. Joseph River	1021.44	13.39	1233.15	16.14	5111.86	66.76	203.71	56.93	2.64	7723.38	0.193	84.8
73	Dowagiac Creek	2037.54	8.78	5046.25	21.75	16080.13	69.24	19.79	9.79	0.08	23293.27	0.181	90.1
74	St. Joseph River	1335.01	8.57	3021.39	19.39	10665.60	68.35	413.65	140.77	2.64	15672.73	0.228	106.3
75	Sand Creek	967.62	7.18	3435.93	25.49	9009.46	66.71	54.71	5.78	0.40	13572.87	0.150	75.7
76	Spring Creek	1138.19	5.30	2967.57	13.82	17346.42	80.73	14.68	1.56	0.07	21568.27	0.170	90.9
77	Rocky River	1601.88	9.03	4972.20	28.01	10569.53	59.44	341.15	259.31	1.91	17840.53	0.180	81.6
78	Dowagiac River	2180.31	12.46	3304.94	18.87	11966.14	68.25	35.36	16.01	0.20	17602.33	0.203	95.9
79	E Br Sauk River	393.19	3.74	1660.59	15.79	7893.73	74.94	440.55	125.65	4.15	10608.18	0.184	89.1
80	Coldwater River	2134.28	11.06	3164.16	16.39	13271.12	68.68	592.89	132.32	3.06	19390.91	0.182	81.9
81	Prairie River	219.94	4.65	341.59	7.21	4170.26	87.90	0.89	0.00	0.02	4832.44	0.177	96.3
82	St. Joseph River	638.04	7.68	2030.20	24.41	3819.99	45.79	1455.10	366.28	17.35	8387.48	0.251	84.8
83	Christiana Creek	2106.48	13.76	3368.54	21.99	9736.68	63.46	86.51	8.45	0.56	15405.87	0.182	82.7
84	Little Swan Creek	807.94	3.86	3127.69	14.96	16946.56	80.98	24.69	2.00	0.12	21008.68	0.164	89.1
85	Marble Lake	1195.35	9.67	1882.75	15.22	8997.68	72.63	263.53	24.24	2.11	12461.06	0.172	81.8
86	Paradise lake	1589.87	17.82	2830.14	31.67	4440.02	49.50	50.26	9.56	0.56	9018.83	0.169	69.2
87	Hickory Creek	1163.32	3.61	7075.56	21.98	18729.69	58.14	4695.99	523.06	14.55	32271.35	0.285	110.7
88	Diamond Lake	1390.16	14.83	937.37	9.98	6526.70	69.44	376.95	143.66	3.98	9469.10	0.230	96.8
89	Mill Creek	2656.67	16.81	5757.45	36.39	7319.74	46.16	65.61	3.34	0.41	15902.18	0.158	64.8
90	Pokagon Creek	1069.25	5.03	4741.58	22.28	15389.17	72.25	58.04	15.57	0.27	21373.16	0.183	96.1
91	Prairie River	955.61	5.83	1970.38	12.02	13231.76	80.63	211.05	23.57	1.28	16490.84	0.181	93.3
92	S Br Hog Creek	880.44	4.91	3214.43	17.91	13842.67	77.03	7.56	1.78	0.04	18046.72	0.155	82.9
93	Prairie River	1870.30	15.15	2607.52	21.10	7664.89	61.91	183.03	19.57	1.47	12443.46	0.176	76.8
94	St. Joseph River	1088.15	8.67	2287.50	18.22	8597.60	68.38	422.32	151.23	3.34	12642.07	0.194	88.6
95	Swan Creek	2257.26	13.56	2664.90	16.00	11427.95	68.54	253.08	40.25	1.51	16741.55	0.179	81.0
96	S Br Hog Creek	1067.25	8.24	2175.64	16.80	9460.69	72.94	234.40	6.89	1.80	13042.86	0.166	81.3
97	Dowagiac River	709.65	5.41	2686.69	20.49	9148.46	69.66	437.00	125.65	3.31	13203.01	0.220	105.4
98	St. Joseph River	1401.95	8.81	4278.34	26.87	9534.30	59.78	559.09	139.66	3.49	16008.80	0.223	99.3
99	Prairie River	2130.94	17.51	3240.89	26.60	6753.32	55.30	36.25	6.00	0.30	12266.82	0.164	69.4
100	Swan Creek	2339.77	6.76	5345.81	15.44	26517.78	76.56	388.52	21.13	1.12	34711.77	0.168	85.5
101	Coldwater River	1958.37	13.97	2267.04	16.15	9681.08	68.90	50.26	63.83	0.36	14119.60	0.172	79.2
102	Mudd Lake Exit Drain	677.18	7.80	3024.50	34.83	4935.28	56.60	34.92	4.89	0.40	8776.00	0.165	80.6
103	Christiana Creek	3822.88	14.97	6417.51	25.12	15240.61	59.60	40.47	12.01	0.16	25633.17	0.177	78.7
104	Mill Creek	1089.04	9.01	2921.54	24.14	8076.98	66.62	3.34	0.22	0.03	12190.89	0.165	81.9
105	St. Joseph River	1298.54	5.42	5393.18	22.49	16013.41	66.71	969.62	303.34	4.03	24072.70	0.232	108.2
106	Prairie River	1161.54	6.05	2125.83	11.06	15560.63	80.93	314.90	46.48	1.63	19307.42	0.179	91.2
107	Fawn River	638.70	3.63	2282.17	12.96	14593.90	82.84	74.50	12.01	0.42	17700.71	0.173	93.8
108	Sherman Mill Creek	2182.76	14.35	3062.53	20.11	9692.42	63.57	237.96	37.81	1.55	15311.50	0.177	78.1
109	Fisher Creek	346.26	3.47	1618.33	16.21	8016.05	80.15	0.89	0.44	0.01	10081.80	0.157	85.9
110	St. Joseph River	224.61	4.96	761.69	16.81	1931.01	42.45	1271.85	338.26	27.70	4591.63	0.421	129.5
111	Coldwater Lake	2712.49	21.82	2301.74	18.48	7182.53	57.58	199.71	36.92	1.59	12531.26	0.179	70.2
112	St. Joseph River	945.82	5.57	2688.70	15.82	12957.55	76.19	345.82	48.04	2.02	17083.51	0.181	91.2

113	Christiana Creek	1819.37	13.37	2709.60	19.89	8812.87	64.60	244.63	21.57	1.78	13705.91	0.187	83.5
114	Prairie River	1304.76	7.28	1792.91	10.00	14800.72	82.52	18.90	0.67	0.10	18017.77	0.171	89.4
115	St. Joseph River	240.18	5.00	1519.81	31.59	2387.36	49.29	471.24	188.14	9.63	4892.61	0.269	104.9
116	Prairie River	2028.64	17.84	1465.33	12.87	7849.92	68.86	14.46	11.12	0.13	11469.04	0.176	77.8
117	Tallahassee Drain	809.28	4.34	3323.40	17.80	14480.48	77.49	42.25	9.79	0.23	18764.82	0.158	84.6
118	Himebaugh Drain	825.51	10.66	1034.78	13.34	5882.44	75.71	0.67	2.67	0.01	7845.77	0.170	84.2
119	Fawn River	1181.11	11.02	1852.51	17.27	7648.66	71.20	27.80	4.45	0.26	10814.02	0.168	81.6
120	St. Joseph River	435.66	10.22	1197.13	28.02	2591.96	60.28	32.69	4.45	0.75	4360.40	0.163	76.8
121	Nye Drain	53.60	0.67	593.11	7.40	5334.91	66.52	1364.59	665.84	16.87	8086.63	0.305	115.5
122	Brandywine Creek	818.40	5.40	4039.71	26.65	9353.95	61.61	815.73	123.87	5.35	15245.31	0.210	94.7
123	McCoy Creek	1208.24	8.08	3391.00	22.67	9285.45	61.98	803.50	261.75	5.34	15042.68	0.245	105.6
124	Trout Creek	3379.44	17.28	6435.52	32.88	9528.97	48.60	193.92	17.79	0.99	19654.41	0.166	67.4
125	Crooked Creek	1442.20	18.09	1128.41	14.12	5215.27	65.16	136.77	48.70	1.70	8068.73	0.184	77.3
126	Unnamed Tributary	1096.16	12.40	687.41	7.77	6931.23	78.23	39.14	86.29	0.44	8938.62	0.186	88.1
127	Fawn River	829.74	5.88	1454.65	10.30	11724.40	82.97	16.46	89.85	0.12	14214.24	0.179	94.0
128	St. Joseph River	229.73	1.68	4043.27	29.52	7422.71	54.08	1646.58	352.49	11.95	13780.05	0.255	102.7
129	Fawn River	1643.02	10.92	1982.16	13.17	11236.25	74.58	21.57	158.79	0.14	15140.46	0.179	86.0
130	Fish Lake	2176.98	9.70	3482.41	15.51	16226.69	72.22	298.00	260.20	1.32	22541.69	0.187	88.5
131	Fawn River	1017.43	6.69	1245.16	8.18	12699.14	83.43	42.25	202.15	0.28	15304.45	0.186	95.0
132	VanNatta Ditch	977.40	14.04	775.25	11.12	5162.12	73.90	31.36	13.79	0.44	7058.98	0.182	84.9
133	St. Joseph River	812.61	7.66	2293.73	21.61	7218.78	67.89	161.90	117.20	1.51	10701.39	0.179	85.6
134	Petersbaugh Creek	736.78	7.01	1444.42	13.74	7302.40	69.36	806.39	217.72	7.61	10597.81	0.225	96.5
135	Ryan Ditch	486.81	6.12	839.52	10.55	6610.32	82.99	7.34	4.89	0.09	8048.55	0.168	89.1
136	Christiana Creek	347.15	8.43	590.45	14.31	2107.59	50.92	743.45	328.03	17.74	4190.32	0.320	108.0
137	Snow Lake	2123.82	12.10	3213.09	18.29	11316.76	64.37	461.68	435.88	2.62	17646.00	0.192	82.7
138	Juday Creek	161.23	0.71	2903.08	12.85	15593.99	68.96	3284.03	656.94	14.48	22681.79	0.268	109.6
139	St. Joseph River	321.35	2.16	2088.24	14.04	11834.93	79.47	428.32	203.26	2.86	14971.78	0.194	98.8
140	Cobus Creek	1248.94	5.53	4288.12	19.00	15594.65	69.03	1125.74	308.68	4.97	22659.70	0.206	94.8
141	St. Joseph River	213.05	3.82	1014.32	18.19	4028.15	72.01	260.64	56.04	4.60	5666.22	0.193	92.1
142	Fawn River	668.95	9.01	459.68	6.18	6183.78	83.10	88.07	25.35	1.17	7524.12	0.183	91.1
143	Crooked Creek	2302.63	21.11	2178.31	19.94	6088.82	55.62	218.83	116.75	1.99	11002.01	0.184	71.2
144	Little Elkhart River	851.53	6.71	3054.75	24.07	8592.70	67.58	99.63	85.84	0.78	12782.82	0.167	83.1
145	St. Joseph River	306.90	2.72	1717.30	15.21	6017.87	53.23	2424.27	820.84	21.34	11358.34	0.327	112.8
146	St. Joseph River	377.62	3.17	1036.56	8.69	4815.63	40.35	3687.67	2006.40	30.79	11976.09	0.506	152.9
147	Lake Shipshewana	913.80	7.25	1251.83	9.93	10086.28	79.95	217.28	129.21	1.71	12695.53	0.190	93.6
148	Tamarack Lake Outlet	2670.68	17.44	2102.92	13.72	9889.24	64.45	316.68	332.25	2.06	15407.39	0.198	81.3
149	Pigeon Lake	651.60	6.26	783.04	7.51	8717.47	83.57	213.72	51.37	2.03	10514.53	0.187	94.3
150	St. Joseph River	671.84	5.58	938.93	7.79	4545.87	37.69	3508.65	2383.13	29.00	12099.48	0.466	139.6
151	Pigeon Lake	525.51	3.75	1510.92	10.79	11916.55	85.05	13.79	29.36	0.10	14095.72	0.167	91.2
152	Cline Lake Outlet	2211.45	12.85	3091.89	17.95	11873.40	68.85	32.47	4.45	0.19	17313.30	0.167	78.7
153	Green Lake	1732.64	12.45	2424.72	17.40	9749.80	69.90	6.00	5.56	0.04	14018.47	0.165	78.8
154	Little Elkhart	117.42	1.70	547.97	7.92	6227.81	89.95	8.01	13.12	0.11	7013.89	0.174	98.1
155	Pine Creek	653.60	3.31	2429.17	12.30	16168.42	81.83	381.62	109.19	1.92	19839.45	0.183	95.4
156	Emma Creek	152.11	1.25	664.95	5.48	11292.30	93.09	11.34	3.56	0.09	12224.08	0.174	99.3
157	Buck Creek	719.43	3.68	1558.51	7.97	17259.91	88.19	20.24	0.67	0.10	19658.59	0.173	95.2
158	Otter Lake	613.13	5.79	1425.52	13.45	8513.53	80.24	36.69	2.00	0.34	10690.36	0.165	86.9
159	Mongo Reservoir	913.13	8.07	1749.54	15.44	8651.42	76.25	6.67	1.33	0.06	11421.86	0.164	84.1
160	Yellow Creek	273.98	3.08	957.61	10.78	4675.97	52.57	2155.63	818.40	24.09	8948.02	0.348	115.6
161	E Fly Creek	1530.49	9.44	2205.00	13.59	12440.05	76.60	32.69	8.67	0.20	16316.53	0.170	85.0
162	Baugo Creek	354.04	3.07	854.64	7.40	9935.72	86.03	260.86	133.43	2.24	11635.21	0.201	103.8
163	Mud Creek	749.01	6.05	1248.50	10.08	9731.79	78.50	468.13	184.14	3.75	12476.19	0.194	92.4
164	Hogback Lake	1673.93	13.04	2102.92	16.37	8866.24	68.92	64.72	127.21	0.50	12933.35	0.175	80.5
165	Rock Run Creek	109.86	0.84	882.22	6.77	11970.81	91.85	43.81	18.01	0.33	13124.19	0.176	100.0
166	Fly Creek Headwaters	314.24	2.84	909.35	8.20	9430.00	84.99	342.70	87.62	3.07	11179.95	0.188	96.2
167	St. Joseph River	607.12	2.90	3262.68	15.58	8409.01	40.13	6660.36	1998.62	31.72	20996.40	0.405	121.7
168	Grimes Ditch	206.60	1.65	821.29	6.55	11510.02	91.68	8.01	0.67	0.06	12646.45	0.184	104.5
169	Emma Lake	128.76	1.46	388.52	4.40	8307.60	93.98	9.34	0.00	0.10	8934.05	0.175	99.4
170	Little Elkhart Creek	1432.86	15.21	889.56	9.43	7050.87	74.67	39.14	6.00	0.41	9517.75	0.180	83.3

171	Big Turkey Lake	930.92	8.50	1065.47	9.72	8857.57	80.70	95.41	8.23	0.86	11056.51	0.174	87.6
172	Leedy Ditch	503.94	3.47	1522.26	10.49	10303.33	70.93	1995.51	186.59	13.67	14596.51	0.239	98.3
173	Johnson Ditch	164.57	2.56	233.95	3.63	5840.63	90.65	89.40	108.53	1.37	6533.92	0.191	100.4
174	Pigeon Creek	847.53	8.26	1196.24	11.65	8046.51	78.30	147.00	19.35	1.42	10354.84	0.175	86.7
175	Baugo Creek	173.24	1.63	504.38	4.76	9797.39	92.36	48.48	77.84	0.45	10700.08	0.189	104.7
176	Rock Run Creek	299.11	2.07	878.89	6.08	11504.68	79.54	1011.87	761.02	6.96	14543.26	0.245	109.6
177	Elkhart River	577.99	11.72	382.96	7.75	2028.20	40.96	1486.23	456.79	29.77	4992.59	0.376	108.4
178	Little Elkhorn River	115.87	0.96	371.17	3.08	11270.73	93.36	159.45	151.67	1.31	12166.27	0.191	103.5
179	Little Turkey	1540.50	12.41	1638.57	13.19	9179.15	73.79	49.15	6.67	0.39	12513.42	0.171	81.7
180	Yellow Creek Headwaters	190.14	1.19	1008.32	6.31	14744.90	92.25	28.91	3.78	0.18	16075.80	0.178	101.5
181	Little Elkhart Creek	2538.14	18.20	1466.44	10.50	9625.26	68.88	272.43	43.14	1.94	14042.99	0.188	80.0
182	N Branch Elkhart River	1046.57	11.11	1047.01	11.11	7284.83	77.18	35.14	2.67	0.37	9515.62	0.175	85.4
183	Turkey Creek Headwaters	382.51	3.32	741.67	6.44	10297.99	89.41	69.39	16.01	0.60	11606.75	0.173	94.5
184	Stony Creek	354.71	2.86	638.04	5.14	11222.91	90.39	142.11	49.82	1.14	12505.98	0.183	99.1
185	Rowe Eden Ditch	102.74	0.50	910.91	4.39	19664.84	94.78	27.58	36.03	0.13	20841.76	0.176	101.3
186	Dry Run	252.64	6.62	366.94	9.60	3166.17	82.67	27.13	0.89	0.69	3912.66	0.176	91.6
187	Little Elkhart Creek	859.54	7.07	1610.77	13.24	9586.34	78.69	88.96	16.90	0.73	12261.50	0.168	86.2
188	Baugo Creek	149.00	1.02	590.67	4.06	13372.98	91.86	295.78	143.89	2.02	14649.26	0.197	106.0
189	Middle Branch Elkhart River	1567.63	14.32	1294.75	11.81	7838.80	71.44	170.80	74.50	1.55	11044.05	0.184	82.5
190	Swoveland Ditch	645.82	5.59	602.90	5.22	10030.01	86.80	163.01	102.74	1.40	11642.10	0.193	98.8
191	Dausman Ditch	89.62	1.12	375.17	4.70	7504.77	93.91	13.34	2.45	0.17	8085.09	0.178	101.5
192	Whetten Ditch	924.92	6.74	883.56	6.44	11531.59	83.97	314.90	64.49	2.28	13816.61	0.190	95.1
193	Sparta Lake	285.33	6.92	260.20	6.30	3521.10	85.13	46.26	10.01	1.10	4221.24	0.182	93.3
194	Meyer/Hire Ditch	240.18	2.77	568.65	6.55	7859.48	90.52	4.23	0.89	0.05	8773.27	0.173	96.9
195	Berlin Court Ditch	98.74	0.85	422.32	3.66	10131.64	87.69	609.13	287.77	5.23	11641.80	0.220	107.9
196	Waldron Lake	1939.91	11.49	1413.07	8.37	13366.53	79.11	65.83	91.40	0.39	16975.70	0.180	87.3
197	N Branch Elkhart River	1176.44	6.13	1272.52	6.63	16693.71	86.93	21.13	27.13	0.11	19290.61	0.175	93.0
198	Henderson Lake Ditch	1019.21	8.14	1135.75	9.06	8344.30	66.52	1309.65	718.54	10.38	12611.16	0.254	99.2
199	Kieffler Ditch	363.16	3.33	609.57	5.59	9695.76	88.89	133.88	96.29	1.22	10996.48	0.188	99.7
200	Elkhart River	700.75	4.47	658.72	4.20	13468.61	85.91	592.22	248.19	3.76	15763.07	0.204	100.0
201	Turkey Creek	654.49	4.91	1041.45	7.81	11169.09	83.70	278.43	188.14	2.07	13428.03	0.193	97.0
202	S Branch Elkhart River	519.95	10.28	708.98	13.98	3732.37	73.41	79.84	18.68	1.55	5157.49	0.176	83.7
203	Croft Ditch	872.66	5.51	1284.75	8.10	13356.08	84.20	237.07	97.63	1.49	15945.99	0.180	92.4
204	S Branch Elkhart River	2295.95	13.43	1760.44	10.29	12984.91	75.84	40.03	15.57	0.23	17196.46	0.176	83.8
205	Lake Wawasee	4982.87	25.61	2394.03	12.29	10771.01	55.25	1145.75	163.23	5.86	19550.05	0.214	74.3
206	Omar Neff Ditch	69.39	0.72	232.84	2.42	9315.03	96.83	0.00	0.00	0.00	9717.22	0.178	102.8
207	Dewart Lake Outlet	1199.79	13.10	856.42	9.34	6983.71	76.09	98.07	18.01	1.06	9254.55	0.184	86.2
208	Solomon CreekHeadwaters	242.18	1.57	762.13	4.95	14321.03	92.92	53.37	27.35	0.34	15505.50	0.175	98.5
209	Turkey Creek Headwaters	714.32	7.44	826.62	8.60	8020.05	83.37	38.25	4.89	0.39	9703.54	0.175	90.5
210	Rivir Lake	839.08	7.14	2324.20	19.75	8594.26	72.92	1.33	0.22	0.01	11858.90	0.156	80.6
211	S Branch Elkhart River	1037.89	9.43	1159.99	10.53	8770.39	79.53	34.69	4.45	0.31	11106.91	0.172	86.3
212	Carrol Creek	1185.78	10.48	1108.39	9.78	8925.85	78.72	83.40	14.68	0.73	11417.08	0.176	86.4
213	Coppes Ditch	99.85	0.79	422.76	3.33	12038.19	94.87	107.41	16.90	0.84	12784.11	0.180	101.6
214	Little Elkhart	907.35	7.16	1308.77	10.32	9933.05	78.29	304.23	216.16	2.38	12765.34	0.198	95.2
215	S Br Paw Paw River	1619.44	10.58	3471.51	22.67	9597.02	62.58	404.75	210.16	2.63	15398.71	0.204	90.6
216	St. Joseph River	851.31	6.99	1328.34	10.91	6905.21	56.65	2230.35	856.42	18.21	12246.18	0.314	109.4
217	St. Joseph River	793.49	4.49	2091.80	11.82	11929.89	67.38	2066.45	808.61	11.63	17773.92	0.266	106.9

APPENDIX A

Preparation of Model Inputs

APPENDIX A
Preparation of Model Inputs

1.0 Introduction

This appendix describes the methods used to prepare data within a geographic information system (GIS) used in the nonpoint source (NPS) sediment and phosphorus loading model for the St. Joseph River watershed. This information is presented as follows:

Section 2.0	Subwatershed Boundaries
Section 3.0	Land Use/Land Cover
Section 4.0	Precipitation Data

Calculation methods for storm water runoff and NPS loads, and model calibration are presented in Appendix B.

2.0 Subwatershed Boundaries

Existing subwatershed boundaries available from the Michigan Center for Geographic Information were utilized in early efforts of the watershed management planning process. However, large portions of the Indiana portion of the watershed were left undelineated. Specifically, the Elkhart River and Pigeon River Subwatersheds were not delineated into smaller drainage areas, as other subwatersheds have been.

Subwatershed boundaries for the Indiana portion of the watershed were obtained from the U.S. Geological Survey (USGS). Those boundaries were combined with the Michigan delineation to provide a template for a basin-wide subwatershed boundary delineation using 30-meter Digital Elevation Model (DEM) acquired from the Michigan Department of Natural Resources (for the Michigan portion of the watershed) and the Indiana Geological Survey (for the Indiana portion of the watershed).

The U.S. Environmental Protection Agency's BASINS (Better Assessment Science for Integrating Point and Nonpoint Sources) Version 3.0, a GIS-based platform, was utilized to conduct the delineation. Besides calculating flow diversion and flow accumulation, the delineation process in BASINS 3.0 also used available stream network datasets to improve hydrographic segmentation and determine subwatershed boundaries (USEPA, 2001). The delineation resulted in 229 subwatersheds. So that no unrecognized subwatersheds were delineated for this planning effort, the Michigan and Indiana delineations were used as a guide to compare to the DEM delineated subwatersheds. Twelve additional subwatersheds created with the DEM process were identified and combined with the appropriate adjacent subwatershed. This resulted in the delineation of 217 subwatersheds. The DEM delineation resulted in some variation in the locations of subwatershed boundaries, particularly near the outer (headwater) regions of the watershed. Further, the Michigan delineation contained additional small subwatersheds not delineated by the DEM data. However, the DEM delineation was utilized for the model and associated planning efforts, as it presented a continuous dataset across the watershed.

The subwatershed boundaries used in the NPS model are presented in Figure 3 of this report.

3.0 Land Use/Land Cover

Land Use/Land Cover dataset for the St. Joseph River Watershed was produced from USGS National Land Cover Dataset raster files. Data was available for each Michigan county and for the State of Indiana. Each Michigan county dataset was presented in the Michigan Georef projection. The Indiana data file was available in the Universal Transverse Mercator (UTM) projection.

Each Michigan county file was “mosaiced” together to create one seamless file encompassing the eight Michigan counties in the watershed. That file was then reprojected to the UTM projection. The resulting file was then “mosaiced” with the Indiana land cover file. The resulting land cover dataset was clipped by the St. Joseph River Watershed boundaries.

4.0 Precipitation Data

In 2001, Kieser & Associates conducted a phosphorus NPS modeling effort for the Kalamazoo River Watershed, which lies adjacent to the St. Joseph River Watershed to the north. As a part of that effort, monthly precipitation data spanning from January 1949 to December 1999 were collected from 15 gauges across Michigan and Indiana. The gauge coverage, chosen to lie within 100 miles of the Kalamazoo River Watershed, also encompassed the St. Joseph River Watershed.

The fifty-year dataset was utilized to determine the average annual precipitation depth at each gauge. An estimation method called “kriging” was then utilized in the GIS to spatially interpolate the data from each gauge. A continuous grid of average annual precipitation values resulted. The region of the grid overlapping the St. Joseph River Watershed was utilized to determine the average annual precipitation for each subwatershed. The subwatersheds were mapped with the precipitation grid in the GIS. The average precipitation value that lay within each subwatershed was then determined using the GIS and input into the NPS model.

5.0 References

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Michigan Center for Geographic Information. Geographic Data Library. Source of land cover data for Michigan counties. http://www.mcgi.state.mi.us/mgdl/

APPENDIX B

Nonpoint Source Loading Model

APPENDIX B
Nonpoint Source Sediment and Phosphorus Loading Model

1.0 Introduction

This appendix describes the methods used to generate runoff and nonpoint source (NPS) sediment and phosphorus loads for the St. Joseph River Watershed. This information is presented as follows:

2.0 Data Inputs

Data used in the NPS sediment and phosphorus loading model for the St. Joseph River Watershed are described in detail in Appendix A. The various data sets used in the model are described briefly in the following paragraphs.

2.1 Subwatershed Boundaries

Subwatershed boundaries were delineated using 30-meter Digital Elevation Model (DEM) topographic data. The delineation was conducted using the U.S. Environmental Protection Agency's (USEPA) BASINS program, a GIS-based platform. Existing delineations from the Michigan Department of Environmental Quality (MDEQ) and USGS (for the Indiana portion) were used for comparison to the delineated subwatersheds and to name the subwatersheds by the water course flowing through them.

2.2 Land Use/Land Cover

Land use/land cover information for the watershed was obtained from the USGS National Land Cover Dataset. The data was interpreted from satellite data collected in the 1990s.

2.3 Precipitation Data

Annual average precipitation from a fifty-year dataset was spatially interpolated for the Kalamazoo River Watershed NPS model. Those data overlapped the St. Joseph River Watershed and were, therefore, used in this model. A continuous grid of precipitation values was available (Kieser & Associates, 2001). The average precipitation depth obtained from the grids falling within each subwatershed was utilized as the precipitation depth for that subwatershed in the NPS model.

3.0 Runoff Calculations

Runoff in the St. Joseph River Watershed NPS model was determined using the approach prescribed in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002). Equation 1 describes the runoff calculation for each land use/land cover category in each subwatershed:

$$R_{L,i} = [C_P + (C_I - C_P) DCIA_f * IMP_L] * A_{L,i} * I_i \qquad \textit{Equation 1}$$

Where,

$R_{L,i}$	=	total average annual surface runoff from land use *L* in subwatershed *i* (ac-in/year)
C_P	=	pervious area runoff coefficient
C_I	=	impervious area runoff coefficient
$DCIA_f$	=	fraction of impervious area that is directly contributing
IMP_L	=	fractional imperviousness of land use/land cover *L*
I_i	=	subwatershed precipitation (in/year)
$A_{L,i}$	=	area of land use *L* (acres)

Runoff coefficients C_P, C_I, and $DCIA_f$ selected for the model are discussed in Section 5.0. Values for percent impervious surface in each land use/land cover category are presented in Table B-1.

Table B-1. Percent Impervious Surface in Land Use/Land Cover Categories

Land Use/Land Cover Category	Impervious Surfaces (%)
Forest and Open Space	0.5
Agriculture	0.5
Residential	30
Commercial/Industrial/ Transportation	90
Water and Wetland	100

4.0 Sediment and Phosphorus Load Calculations

NPS sediment and phosphorus loading to Lake Michigan from the St. Joseph River was determined using the event mean concentration (EMC) approach. In this approach (also prescribed by the Part 30 - Water Quality Trading Rules), sediment and phosphorus loads are calculated from runoff volumes corresponding to a certain period of precipitation and pollutant concentrations assigned to each land use/land cover category in each subwatershed. The EMCs used for this characterization are based on those determined from storm water pollutant monitoring conducted during the Nationwide Urban Runoff Program for the Rouge River, Michigan watershed (Wayne County, 1998) and are presented in Table B-2.

Table B-2. Event Mean Concentrations from the Rouge River, Michigan Applied to the St. Joseph River Watershed NPS Loading Model.

Land Use/Land Cover Category	Total Suspended Solid EMC (mg/L)	Total Phosphorus EMC (mg/L)
Forest and Open Space	51	0.11
Agriculture	216	0.37
Residential	79	0.43
Commercial/Industrial/ Transportation	100	0.32
Water and Wetland	6	0.08

The following equation describes the method used to determine the NPS sediment and phosphorus loads from each land use/land cover category in each subwatershed:

$$M_{L,i} = EMC_L * R_{L,i} * K \qquad \textit{Equation 2}$$

Where,

$M_{L,i}$ = annual pollutant load for land use/land cover L in subwatershed i (lbs/year)
EMC_L = event mean concentration of storm water runoff from land use L (mg/l)
$R_{L,i}$ = stormwater runoff from land use/land cover L in subwatershed i (in/year)
K = 0.2266, a unit conversion constant

The total sediment and phosphorus loads from each subwatershed are then determined using Equation 3:

$$M_i = \sum_{L=1}^{m} M_{L,i} \qquad \textit{Equation 3}$$

Where,

M_i = annual pollutant load for subwatershed i (lbs/year)
m = number of land use/land cover categories

The total NPS sediment and phosphorus loads in the St. Joseph River Watershed can be determined from Equation 4:

$$M = \sum_{i=1}^{n} M_i \qquad \textit{Equation 4}$$

Where,

M = annual pollutant load to Lake Michigan (lbs/year)
n = number of subwatersheds in the St. Joseph River Watershed

5.0 Model Calibration

The primary uncertainties in the St. Joseph River Watershed NPS phosphorus loading model are runoff parameters and EMCs. The EMCs (Table B-2) used in the model were developed for a Michigan watershed (Rouge River) and are based on monitoring data. These concentrations represent the best available estimates of pollutant concentrations for various land use/land cover types. Selection of appropriate values for the runoff parameters C_P, C_I, and $DCIA_f$ was the focus of the model calibration. Monitoring data collected by the USGS from 1970 - 1993 at Niles, Michigan was utilized in a published study (Robertson, 1997) to estimate loading of sediment and phosphorus from major tributaries to Lakes Michigan and Superior. Reported point source loads from 1990-1999, available from the Permit Compliance System through BASINS 3.0, in the watershed were averaged annually for sediment and phosphorus loading (USEPA, 2001). These loads were subtracted from the published watershed loads. The average annual loads published in the USGS report for the St. Joseph River minus loading from point sources were the target total loads for the model. Therefore, the model was calibrated to achieve specific published loads. Therefore, the value of the model is to compare subwatersheds relative to one another, but not to determine a total load for the entire watershed.

5.1 Runoff Coefficients

Table B-3 summarizes literature values for the runoff parameters used in the NPS model (see Equation 1). As indicated in the table, values for the coefficients can vary significantly.

To improve model predictions, the published load estimates minus point source contributions for the St. Joseph River were used as a target for the NPS model and values for the runoff parameters C_P, C_I, and $DCIA_f$ were determined using an iterative solution with the minimum values reported in the literature as initial conditions. The values resulting in a best fit to the target load estimate are provided in Table B-3.

Table B-3. Literature Values for Runoff Parameters

Source	C_P	C_I	$DCIA_f$
Generally accepted values[a]	0.20[a]	0.95[a]	0.50[b]
Rouge River (Michigan) National Wet Weather Demonstration Project (Wayne County, 1998b)	0.03 to 0.08[c]	0.90[c]	0.57[d,e]
Lake Allegan/Kalamazoo River NPS Phosphorus Loading Model	0.04	0.89	0.50
St. Joseph River NPS Loading Model	0.068	0.89	0.50

[a]Values recommended in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002)
[b]Wayne County, 1998b
[c]Based on Storm Water Management Model (SWMM) calibration
[d]Value based on field verification and SWMM calibration for individual subwatersheds
[e]Average of all land use/land covers

As indicated in Table B-3, the selected parameter values for the St. Joseph River NPS loading model correspond well with the range of literature values reported for each of the three parameters. The difference in the value selected (0.068) for the pervious area runoff coefficient C_P and that of the generally accepted value (0.20) recommended in the Part 30 - Water Quality Trading Rules is significant. However, given the highly-undeveloped and thereby highly-pervious nature of the St. Joseph River Watershed (88% forest, open space, and agriculture), a lower value for C_P is intuitive. The selected value for the impervious area runoff coefficient C_I is slightly lower than the literature values, while the selected value for the directly contributing impervious area factor $DCIA_f$ is on the low end of the literature values. As with the pervious area runoff parameter, the selected values for C_I and $DCIA_f$ represent the underdeveloped nature of the watershed.

5.2 Model Validation

Published tributary loading data indicate that the St. Joseph River Watershed annually contributes 104 kg/ha and 0.20 kg/ha of total suspended solids and total phosphorus, respectively, to Lake Michigan (Robertson, 1997). Point source loading of total phosphorus accounts for approximately 25% of the total load; total suspended solids loading by point sources is equal to 1.4% of the total load. The average NPS loading rates of each pollutant derived from the NPS model were compared to the published data as a check to the calibrations. Table B-4 illustrates those values and illustrates that the model closely corresponds to the published loading estimates. The NPS load model rates are approximately 2% greater than the published rates. However, Robertson estimates that the watershed area is 2,996,153 acres, while the delineation performed with the 30-meter topographic data yielded a watershed area of 2,970,014 acres. Calibrating the NPS model to a fixed published watershed load with a smaller watershed area resulted in a higher loading rate.

Table B-4. Comparison of published loading rates to NPS model rates.

	Published Loading (kg/ha/year)[a]	Published Loading (lb/acre/year)	Published NPS Loading Accounting for Point Sources (lb/acre/year)	NPS Model Estimate (lb/acre/year)
Total Suspended Solids	102	90.7	89.4[b]	91
Total Phosphorus	0.29	0.259	0.194[b]	0.197

[a] Robertson, 1997

[b] 1.4% of the total suspended solid load is attributable to point sources. NPS loading is equal to 98.6% of 90.7 lb/acre. 25% of the total phosphorus loading is attributable to point sources. NPS loading is equal to 75% of 0.259 lb/acre.

6.0 Sediment and Phosphorus Load Predictions

The St. Joseph River Watershed NPS loading model was calibrated to published annual sediment and phosphorus loads for the river (Robertson, 1997). The model was utilized to compare NPS loading among subwatersheds. NPS sediment and phosphorus loading predictions for each subwatershed are presented in Table 2 and Figures 7 and 8 of this report. The following assumptions are inherent in the model predictions:

- The Robertson load estimates, based on monitoring data from 1970-1993, to Lake Michigan are reasonable and representative.
- St. Joseph River load includes instream (bedload and streambank) contributions.
- Each land use category assumes the same storm water sediment and phosphorus concentrations throughout the watershed.
- Runoff model parameters are held constant throughout the watershed.

7.0 Sensitivity Analysis

For each land use *L* in subwatershed *i*, the model gives the total annual pollutant load as:

$$M_{L,i} = [C_P + (C_I - C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K \qquad \textit{Equation 5}$$

This sensitivity analysis looks at each adjustable term in the equation 5 while holding other terms in constant. A variation factor "=1.2 (a 20% increase of the value) is used for each term to examine the corresponding change of the result from Equation 5 with respect to a specific term. For example, when examining the sensitivity of the pervious area runoff coefficient C_P, we will determine the outcome of the following equation:

$$\frac{M_{L,i,a}}{M_{L,i}} = \frac{[a * C_P + (C_I - a * C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K}{[C_P + (C_I - C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K} \qquad \textit{Eq. 6}$$

where $M_{L,i,}$" is the annual pollutant load for land use *L* in subwatershed *i* with an increased C_P. If Equation 6 has a value greater than "=1.2, the particular adjustable term examined is considered highly sensitive. If this value is between "=1.2 and greater than or equal to 1.1 (10% change), the adjustable term is considered sensitive. If Equation 6 yields a value smaller than 1.1, the adjustable term is considered not sensitive. In addition, this analysis looks at the sensitivity of the adjustable terms with regard to both land use types and subwatersheds, as implied by the subscript of $M_{L,i}$.

1. Subwatershed precipitation depth (I_i):

Equation 5 indicates that I_i has a constant return to scale and a uniform effect on loading from every land use type. A 20% change (increase or decrease) in precipitation will lead to a 20% change in loading from all land use types within any particular subwatershed. Therefore, I_i is a sensitive term.

2. Event Mean Concentration of storm water runoff from land use *L* (EMC_L)

EMC_L has mathematically the same effect on load calculations as precipitation I_i for a particular land use type. Therefore, it is a sensitive term for land use types. However, because EMC_L is a function of land use *L* that changes its distribution pattern from subwatershed to subwatershed, its sensitivity for subwatershed loading will vary among subwatersheds. For example, if we vary EMC_L for agriculture land by 20%, subwatersheds with a substantial agricultural land component will have a higher load change than those composed mostly of urban land uses. On the other hand, if the 20% variation of EMCs is applied to all land use types, then all subwatersheds will have a change of pollutant load of 20%.

3. Pervious area runoff coefficient (C_P)

The rest of the four adjustable terms in Equation 5 are all included in the parentheses [ ]. Within this set of parenthesis, IMP_L varies from land use to land use. The remaining three terms are constants across all land uses and subwatersheds. Therefore, when we consider the sensitivity of these constant terms, we also need to take IMP_L into account because (1) as Table B-1 shows, IMP_L can vary from 0.005 to 1, a span of two orders of magnitude, and (2) IMP_L changes with land use types and causes different sensitivity responses in subwatersheds with different land use distributions.

With the calibrated parameter (term) values, the following table is constructed for C_P sensitivity analysis.

″	IMP_L	$M_{L,i,″}/M_{L,i}$
1.2	0.005	1.19
	0.1	1.12
	0.2	1.08
	0.3	1.06
	0.9	1.02
	1.0	1.01

This table shows that C_P is sensitive only when IMP_L is small (less than 0.2). This is because smaller IMP_L (imperviousness) means higher perviousness. Pervious area runoff coefficient, $C_{P,}$ consequently exerts more influence on the loading results. For a subwatershed that is predominantly agricultural or has large areas of forest and open space (see Table B-1), C_P is a very sensitive model parameter.

4. Impervious area runoff coefficient (C_I)

With the calibrated parameter (term) values, the following table is constructed for C_I sensitivity analysis.

"	IMP_L	$M_{L,i},"/M_{L,i}$
1.2	0.005	1.01
	0.1	1.08
	0.2	1.12
	0.3	1.14
	0.9	1.18
	1.0	1.19

This table shows that C_I is sensitive only when IMP_L is high (greater than or equal to 0.2). This is just the opposite of C_P as higher IMP_L (imperviousness) means lower perviousness. Therefore, C_I is very sensitive in urban subwatersheds or subwatersheds with large areas of water and wetland.

5. Fraction of impervious area that is directly contributing ($DCIA_f$)

With the calibrated parameter (term) values, the following table is constructed for $DCIA_f$ sensitivity analysis.

"	IMP_L	$M_{L,i},"/M_{L,i}$
1.2	0.005	1.01
	0.1	1.07
	0.2	1.11
	0.3	1.13
	0.9	1.17
	1.0	1.17

This table shows that $DCIA_f$ is sensitive only when IMP_L is high (greater than or equal to 0.2). The influence of $DCIA_f$ (fraction of impervious area that is directly contributing) on loading is obviously positively correlated to the imperviousness of a land use type.

6. Fractional imperviousness of land use/land cover L (IMP_L)

Mathematically, IMP_L has the same sensitivity as $DCIA_f$ for each land use type. Therefore, IMP_L itself is sensitive only when its value reaches 0.2.

The most important implication of this sensitivity analysis is that except precipitation depth (I_i), land use distribution is the key factor deciding the sensitivity of these adjustable terms (parameters) on the model-calculated pollutant load from a specific subwatershed. Therefore, on a subwatershed level, sensitivity of model parameters will vary significantly. In terms of the entire St. Joseph River Watershed, because of its high agricultural land use pattern, the pervious area runoff coefficient C_P is a very sensitive parameter. The EMC for agricultural land is also a sensitive parameter at this scale. However, no matter what scale at which we examine the model, precipitation depth I_i is always the most sensitive parameter.

8.0 References

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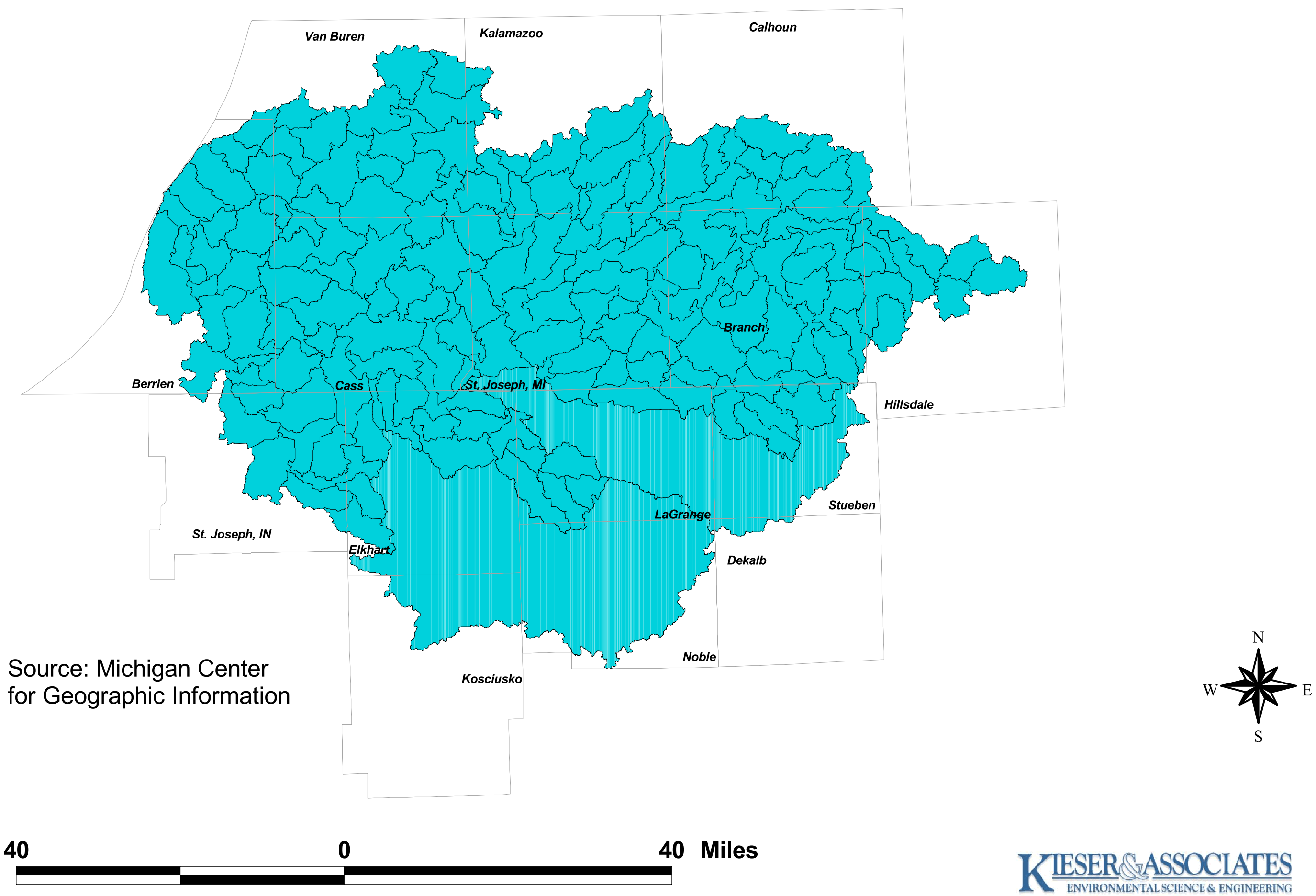
Figure 1. Subwatersheds of the of the St. Joseph River Watershed
Leaving Elkhart River and Pigeon River Subwatersheds Undelineated.



Source: Michigan Center
for Geographic Information

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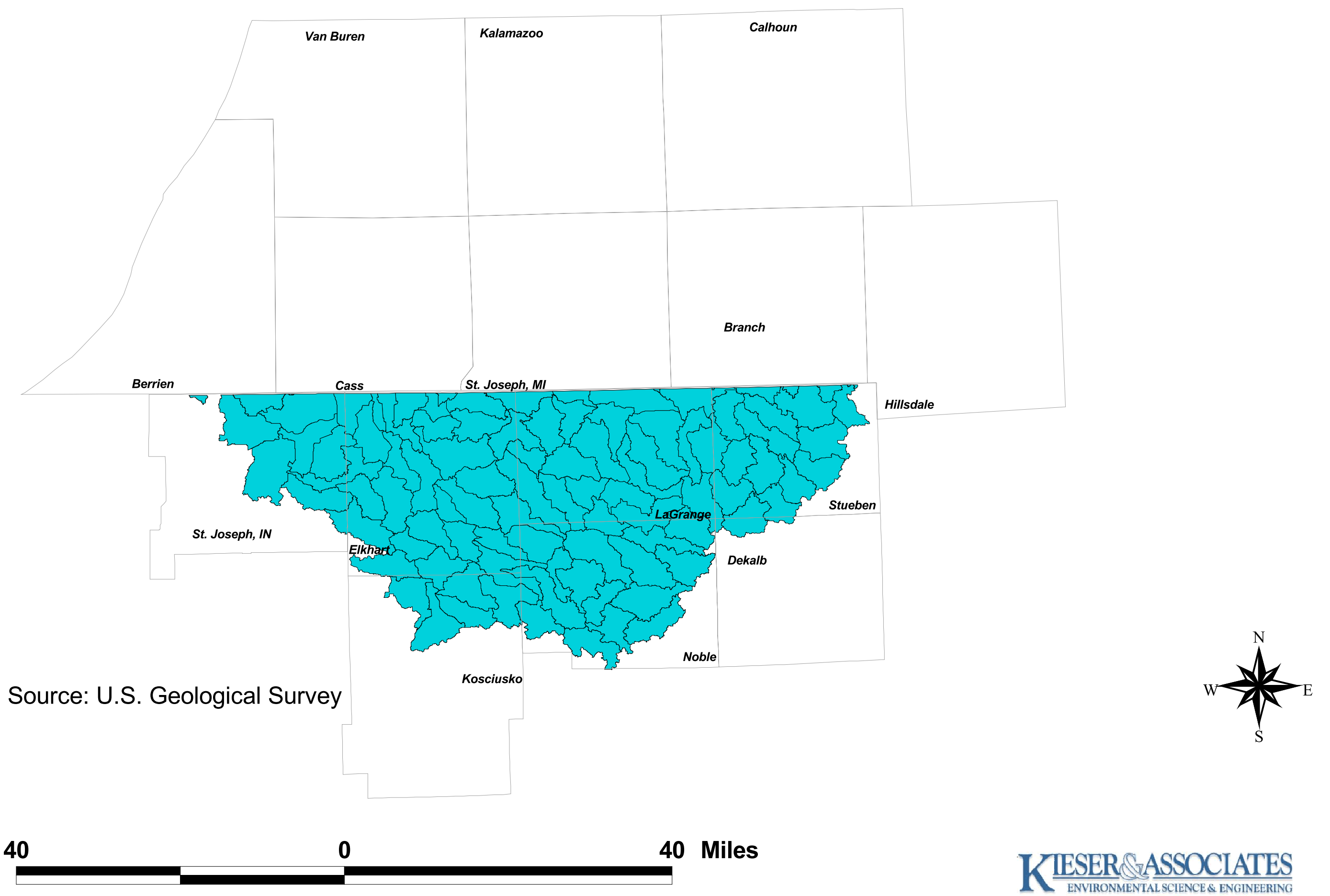
Figure 2. Subwatersheds of the Indiana Portion of the St. Joseph River Watershed



Source: U.S. Geological Survey

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Figure 3. Delineated Subwatersheds of the St. Joseph River Watershed.

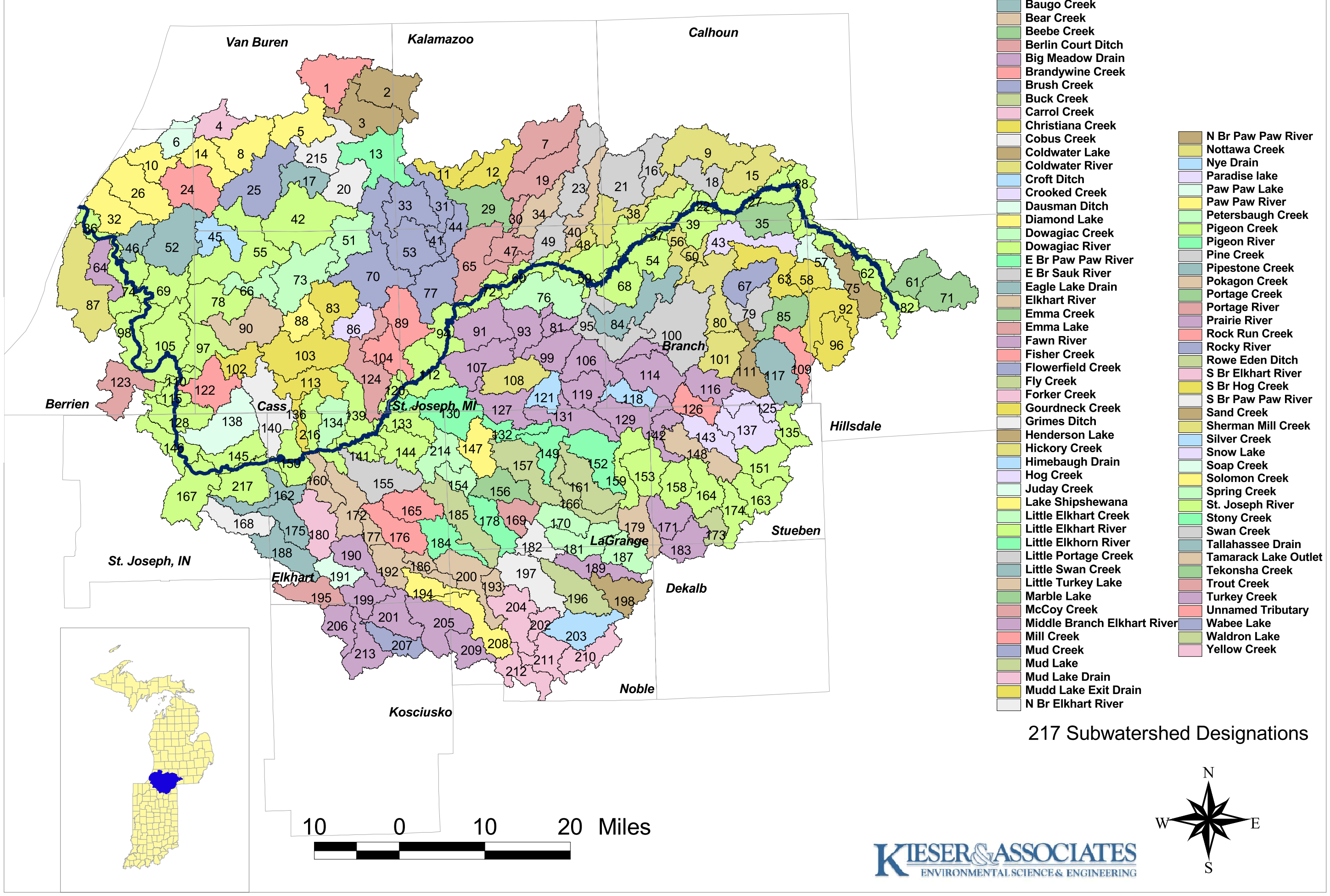

Figure 4. Topography of the St. Joseph River Watershed.

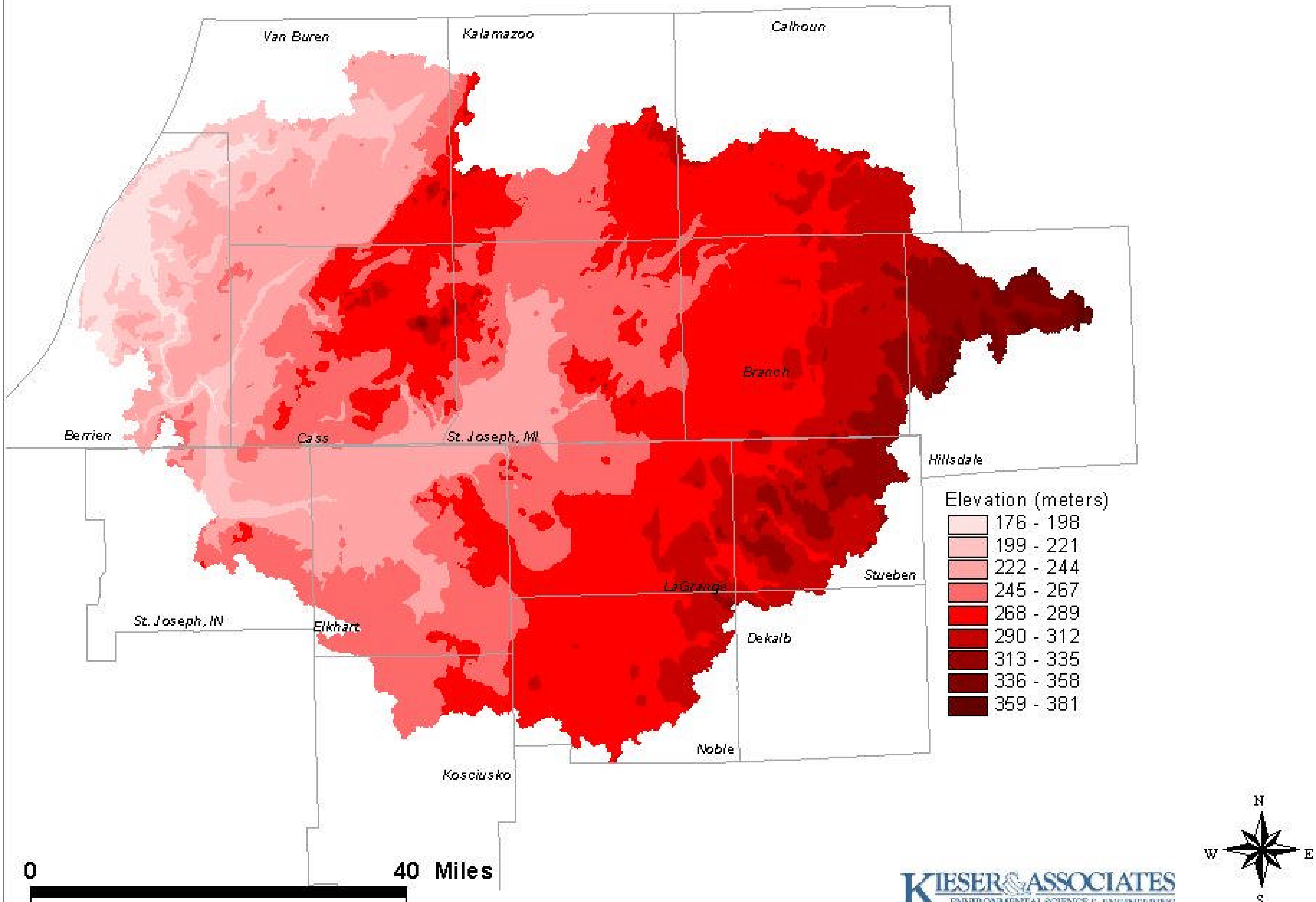

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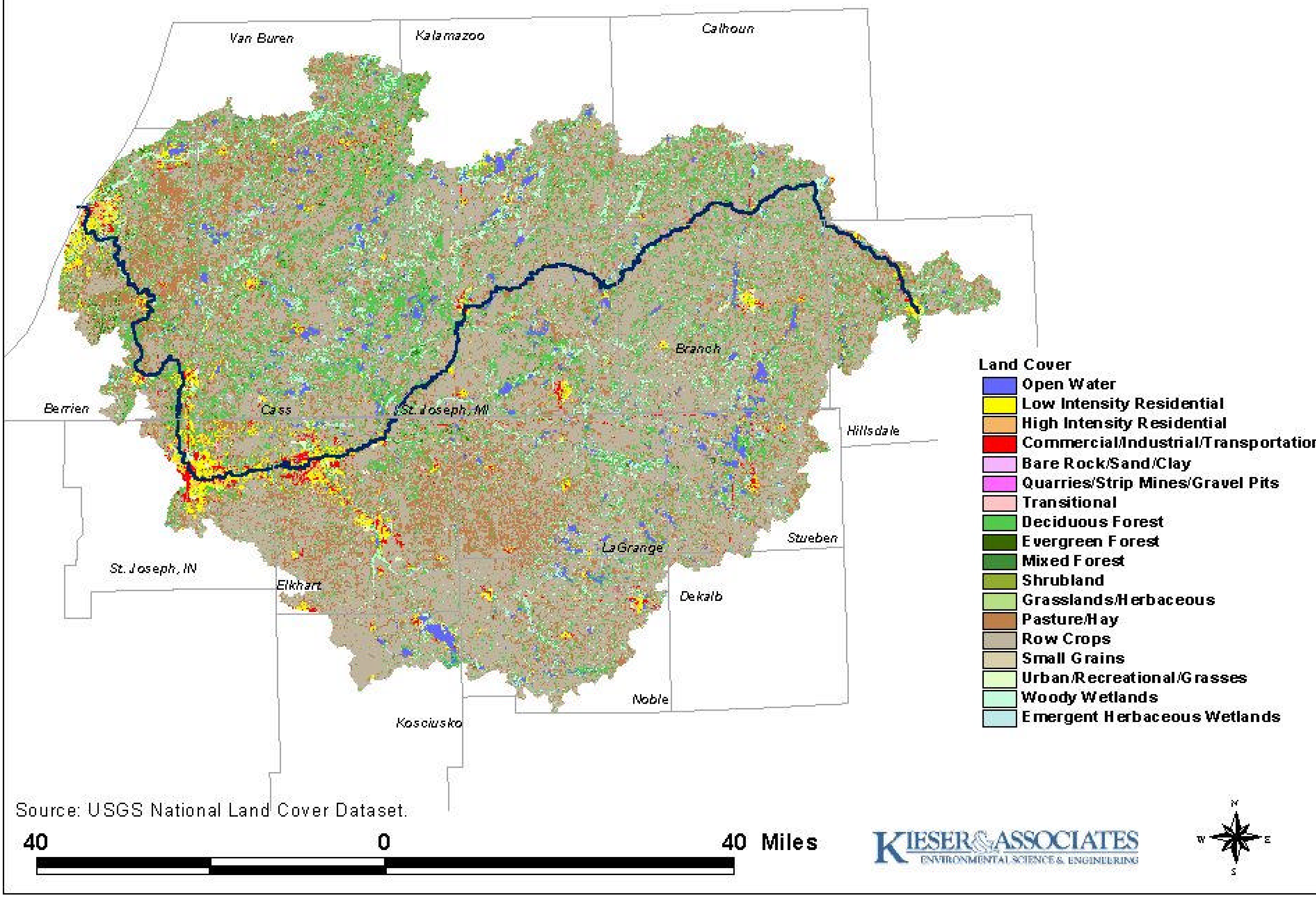
Figure 5. Land Use/Land Cover Data for the St. Joseph River Watershed.



Source: USGS National Land Cover Dataset.

Figure 6. Distribution of Annual Average Precipiation (1950-1999).

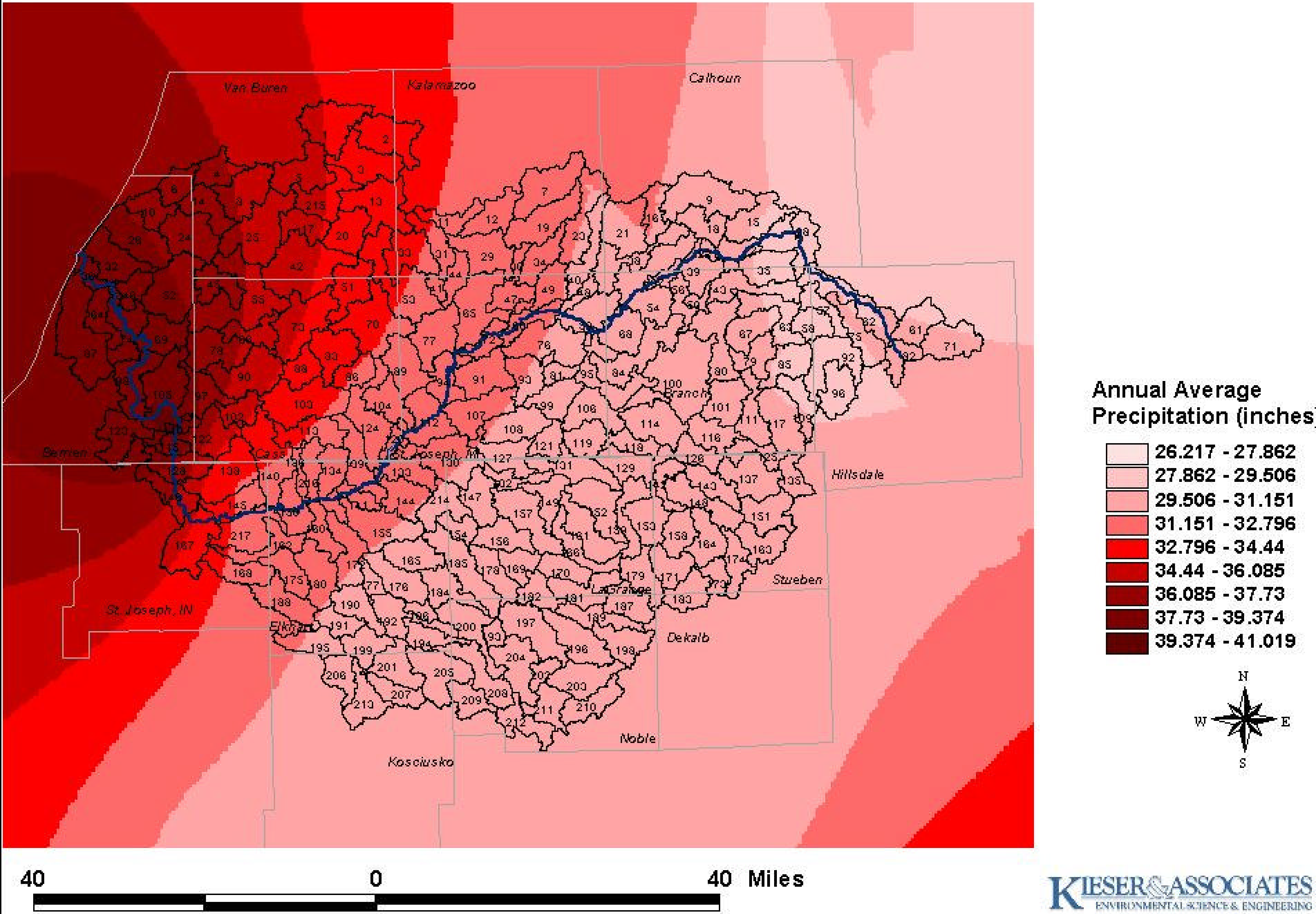


Figure 7. Nonpoint Source Sediment Loading by Subwatershed of the St. Joseph River Watershed

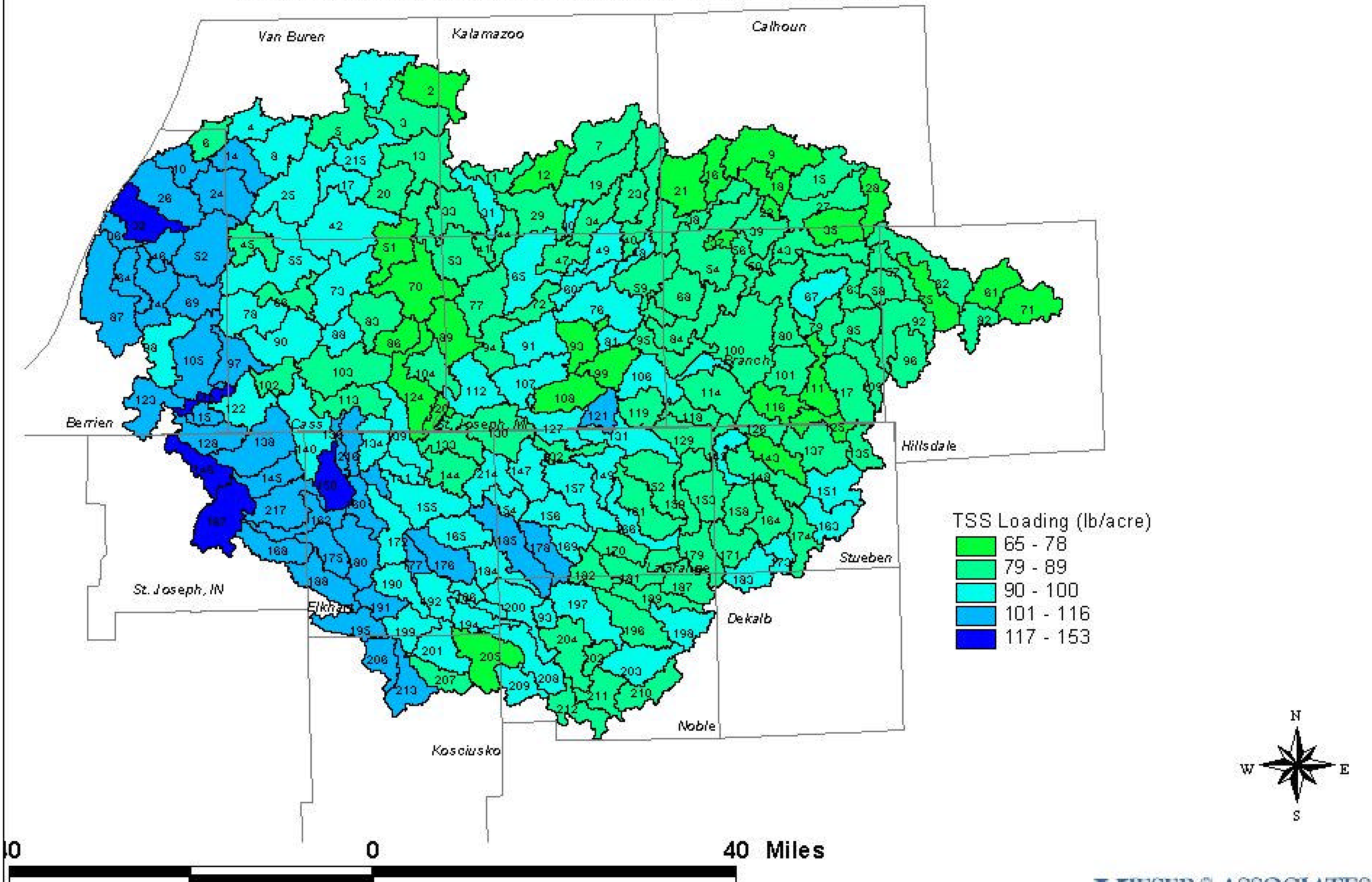


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Figure 8. Nonpoint Source Phosphorus Loading by Subwatershed of the St. Joseph River Watershed

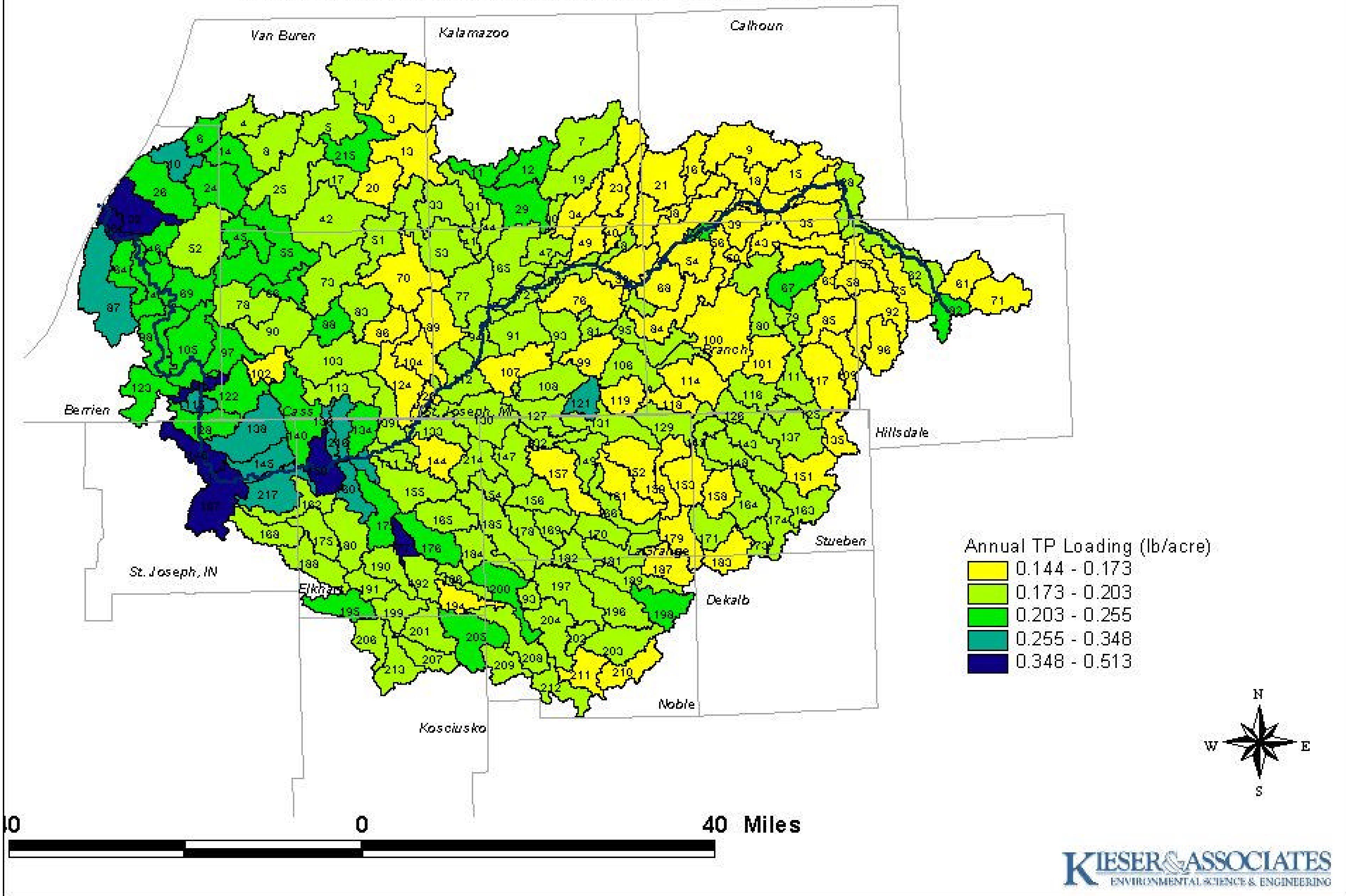

Figure 9. Percent Agricultural Land Cover in each Subwatershed of the St. Joseph River Watershed.

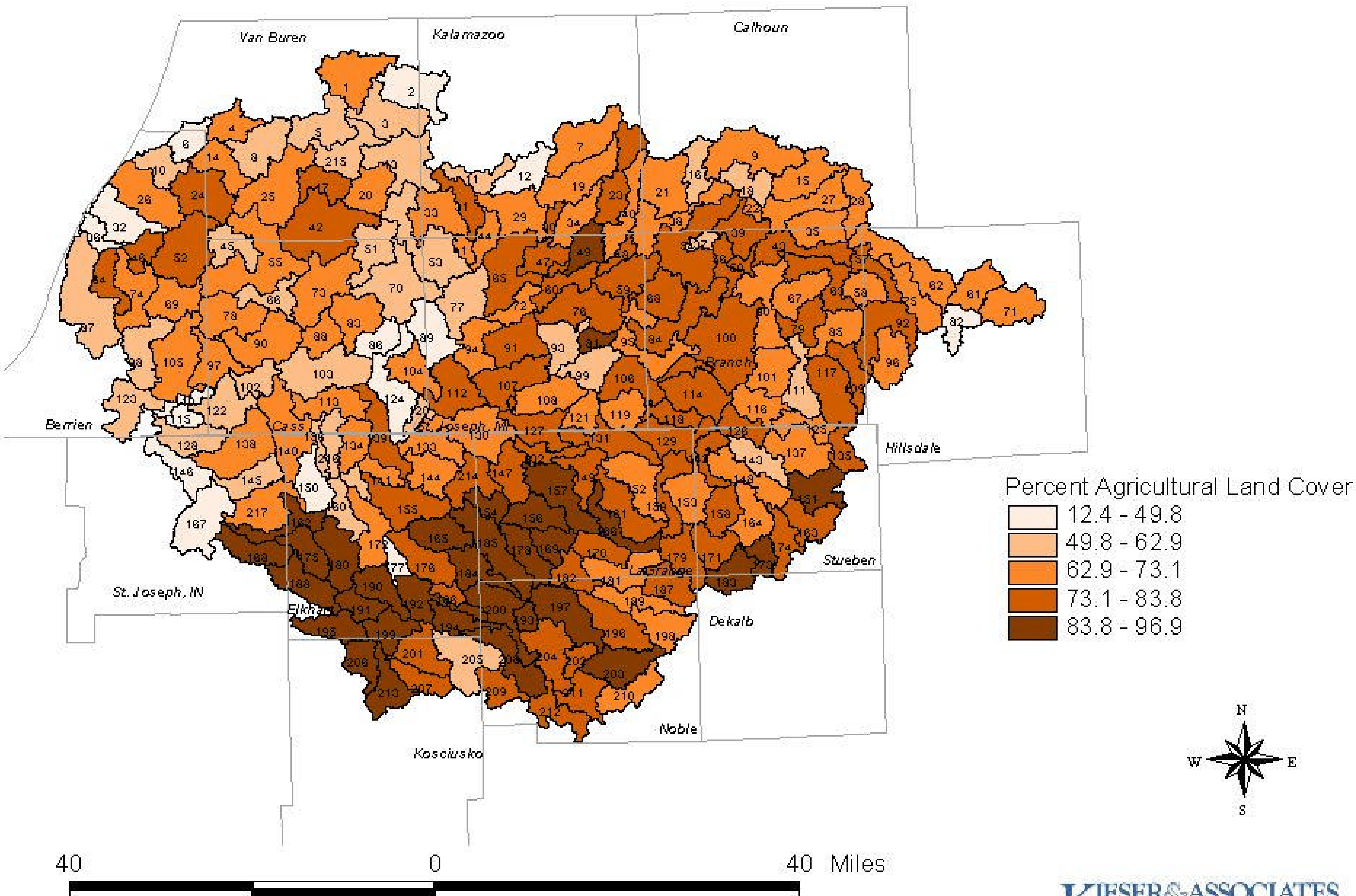

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Figure 10. Percent Open Land/Forest Land Cover in each Subwatershed of the St. Joseph River Watershed.

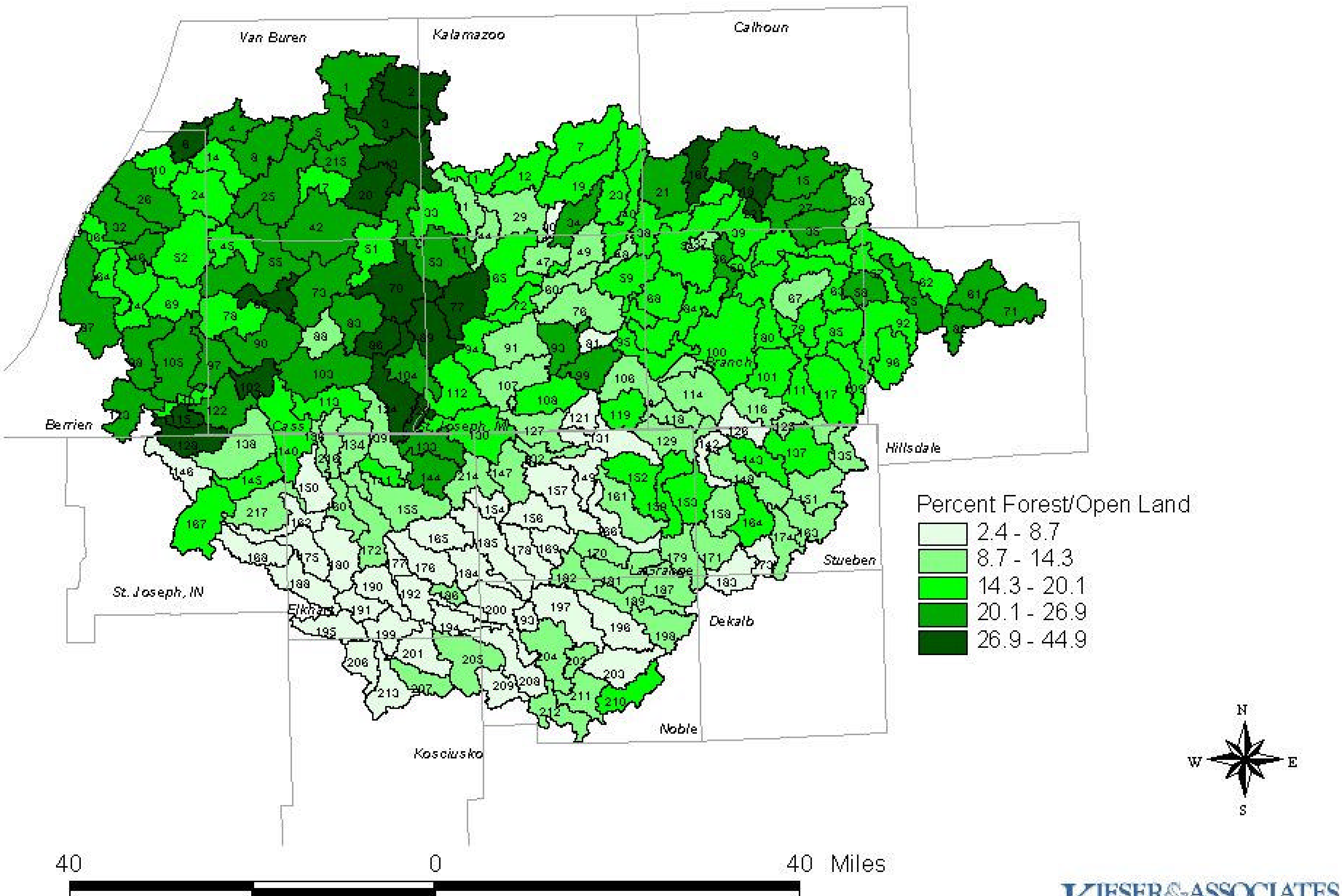

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Figure 11. Percent Open Water/Wetland Land Cover in each Subwatershed of the St. Joseph River Watershed.

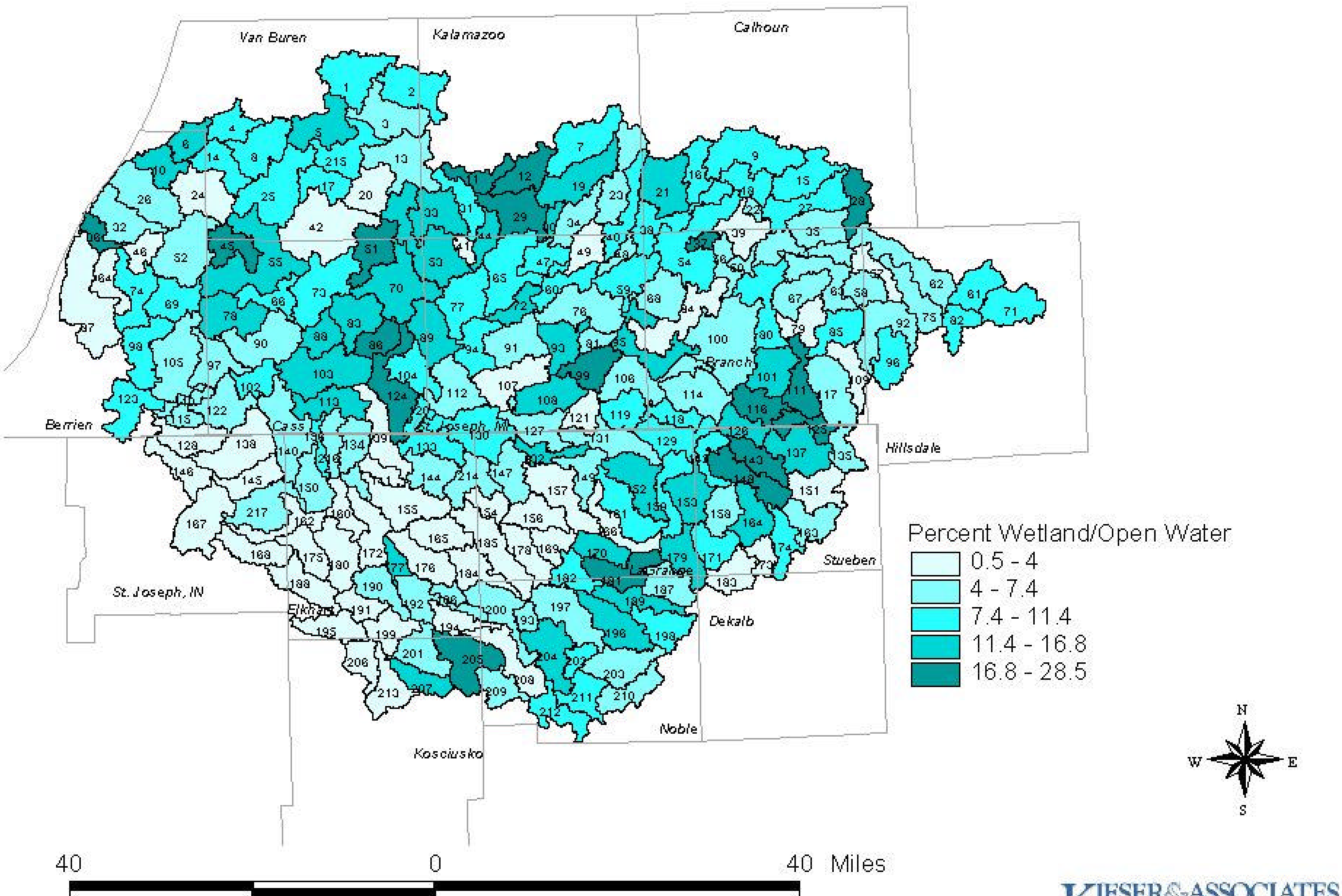

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Figure 12. Percent Urban Land Cover in each Subwatershed of the St. Joseph River Watershed.

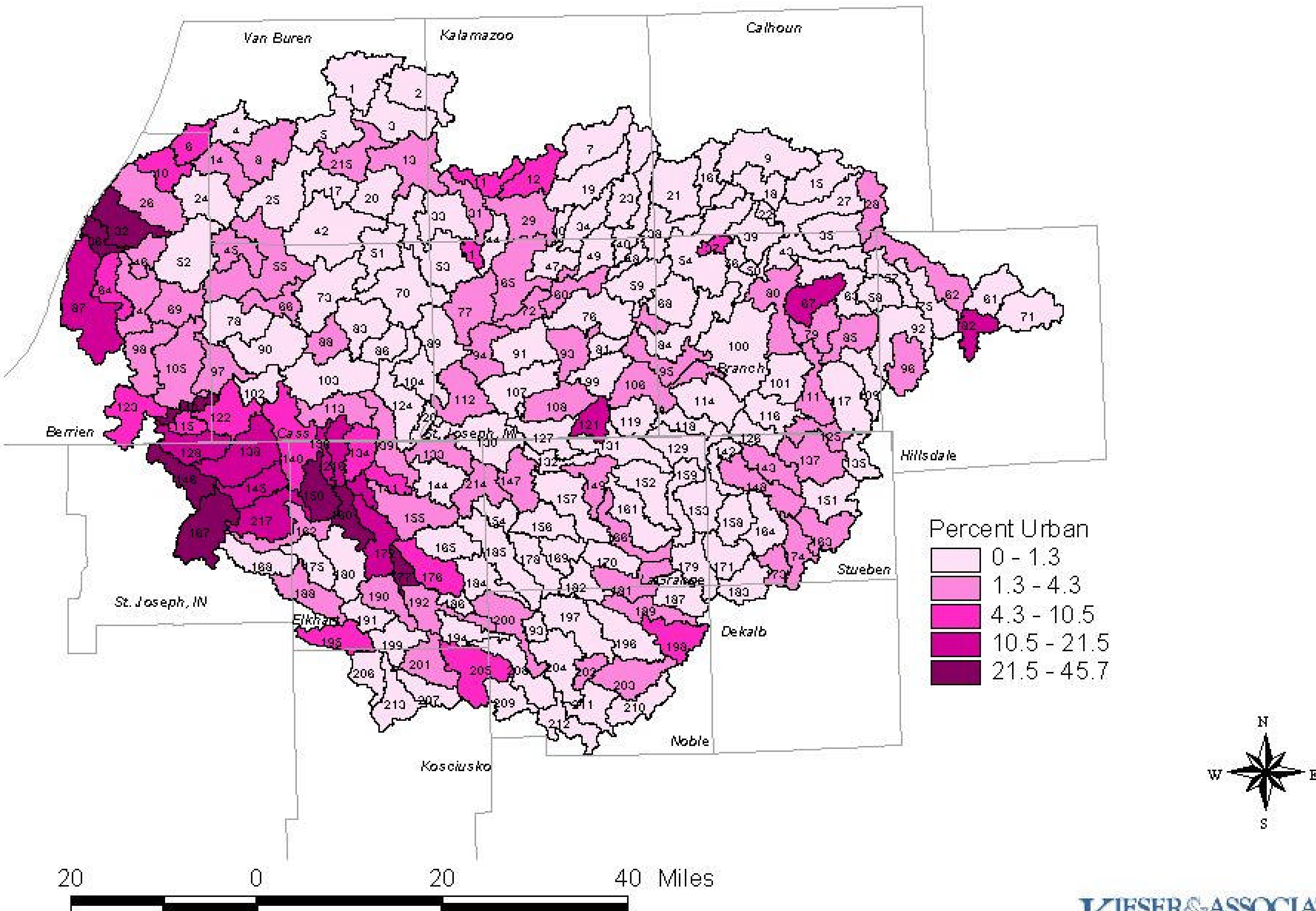

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Figure 13. Slopes of the St. Joseph River Watershed.