Appendix B.

Additional Watershed Characterization Information

Contents

B-1 Previous Studies B-4
B-2 Land Use and Land Cover B-12
B-3 Geology and Soils B-14
B-4 Climate B-19
B-5 Hydrology B-25
B-6 Community Profile B-27
B-7 References B-28

Tables

Table B - 1. Level IV ecoregion physiography and geology in the SJRW B-15
Table B - 2. Level IV ecoregion soils in the SJRW B-15
Table B - 3. HSG descriptions B-18
Table B - 4. HSG distribution in the SJRW B-18
Table B - 5. Climate data summary for Angola, IN (station 120200) B-19
Table B - 6. Climate data summary for Montpelier, OH (station 335438) B-20
Table B - 7. Climate data summary for Hillsdale, MI (station 203823) B-22
Table B - 8. USGS sites with field measurements data B-25
Table B - 9. Populations of select counties and municipalities in the SJRW B-27

Figures

Figure B - 1. Cropland in the SJRW. B-12
Figure B - 2. Impervious cover in the SJRW. B-13
Figure B - 3. Level III ecoregions in the SJRW. B-14
Figure B - 4. Level IV ecoregions in the SJRW. B-16
Figure B - 5. Bedrock geology underlying the SJRW. B-17
Figure B - 6. Temperature and precipitation summary at Angola, IN (station 120200). B-19
Figure B - 7. Precipitation intensity at Angola, IN (station 120200). B-20
Figure B - 8. Temperature and precipitation summary at Montpelier, OH (station 335438). B-21
Figure B - 9. Precipitation intensity at Montpelier, OH (station 335438). B-21
Figure B - 10. Temperature and precipitation summary at Hillsdale, MI (station 203823). B-22
Figure B - 11. Precipitation intensity at Hillsdale, MI (station 203823). B-23
Figure B - 12. NCDC climate stations in and near the SJRW. B-24
Figure B - 13. Average daily mean flow for active gages on the St. Joseph River (WY 1994-2013). B-26
Figure B - 14. Flow duration curves for the active gages on the St. Joseph River (WY 1994-2013). B-26

Acronyms and Abbreviations

ALU	aquatic life use
ARS	Agricultural Research Service (U.S. Department of Agriculture)
EBSJR	East Branch St. Joseph River
HSG	hydrologic soil group
HSTS	household sewage treatment system
HUC	hydrologic unit code
IDEM	Indiana Department of Environmental Management
Michigan DEQ	Michigan Department of Environmental Quality
NASS	National Agricultural Statistics Service (U.S. Department of the Interior)
NCDC	National Climactic Data Center (U.S. Department of Commerce)
NRCS	Natural Resources Conservation Service (U.S. Department of Agriculture)
Ohio EPA	Ohio Environmental Protection Agency
OWTS	on-site wastewater treatment systems
RM	river mile
SJR	St. Joseph River
SJRW	St. Joseph River watershed
SJRWI	St. Joseph River watershed Initiative
SWAT	Soil and Water Assessment Tool
USCB	U.S. Census Bureau (U.S. Department of Commerce)
USDA	U.S. Department of Agriculture's
USGS	U.S. Geological Survey (U.S. Department of the Interior)
WBSJR	West Branch St. Joseph River
WFWBSJR	West Fork of the West Branch of the St. Joseph River
WMP	watershed management plan
WQS	water quality standards
WRCC	Western Reserve Climate Center
WWH	warmwater habitat

B-1 Previous Studies

The Indiana Department of Environmental Management (IDEM), Michigan Department of Environmental Protection (Michigan DEQ), Ohio Environmental Protection Agency (Ohio EPA), St. Joseph River Watershed Initiative (SJRWI), Purdue University, and other entities have thoroughly studied the St. Joseph River watershed (SJRW). This section provides a summary of selected previous work. Additional studies regarding specific topics (e.g., SJRWI's conservation tillage study) are referenced throughout this report.

B-1.1 Biological and Water Quality Studies

Michigan DEQ and Ohio EPA published their biological and water quality data collected during various surveys between 1993 and 2015. The published studies include evaluations of their data, watershed characterizations, and source assessments.

B-1.1.1 Biological and Water Quality Study of the St. Joseph River and Selected Tributaries (Ohio EPA 1994)

Ohio EPA sampled the St. Joseph River (SJR), the West Branch St. Joseph River (WBSJR) and Bear, Fish, and Silver creeks in 1992; the Agency also conducted a mini-study in Bear and Fish creeks in 1991. The WBSJR and Silver Creek were in full attainment of their warmwater habitat (WWH) designations while portions of Bear and Fish creeks were in partial attainment of aquatic life use (ALU) designations. In 1992, the entire length of the SJR in Ohio was in partial attainment of its WWH designation. Exceedances of the primary contact recreation criteria occurred in the SJR, WBSJR, and Bear and Silver creeks.

The partial attainment of WWH criteria in the SJR was due to fish community health. "The benthic macroinvertebrate fauna was characterized as good to exceptional," but did show some impacts from siltation and embedding (Ohio EPA 1994, p. 2). Ohio EPA described the fish community health as follows:

> The fish assemblage within the St. Joseph River mainstem was more indicative of marginal habitat quality. Past channel modification, maintenance activities, and low gradient coupled with the delivery of clayey silts from agricultural nonpoint sources has resulted in a heavy bedload of sediment, siltation, and modest channel heterogeneity. As a consequence of the present condition of instream habitats significant components of the fish community were diminished (Ohio EPA 1994, p. 2)

In Fish Creek, fish community health achieved WWH criteria but "the performance of benthic macroinvertebrate fauna was diminished" and was "reflective of moderate nutrient enrichment from agricultural nonpoint sources and modified habitat" (Ohio EPA 1994, p. 6). Poor physical habitat impacted aquatic life in Bear Creek. Agricultural channelization of these streams contributed to poor habitat quality that diminished aquatic community health.

Exceedances of fecal coliform criteria were typically due to agricultural nonpoint sources. Bear Creek exceedances were also caused by home sewage treatment system (HSTS) discharges to storm sewers in the villages of Blakeslee and Edon.

B-1.1.2 Biological Surveys of Tributaries in the Vicinity of Two CAFOs in the St. Joseph and Bean/Tiffin Watersheds (Michigan DEQ 2004)

Michigan DEQ assessed the fish and macroinvertebrate communities' health and habitat in three warmwater tributaries to the SJR in 2003: Nile Ditch, Goose Creek, and Otto Creek. Fish community health was acceptable in each of the streams. Macroinvertebrate community health, as measured by

Procedure 51 at one site on each stream, was acceptable. All three streams' habitat was affected by dredging, canopy removal, and snagging. Habitat was marginal (moderately impaired) in Nile Ditch and Goose Creek and poor (severely impaired) in Otto Creek. Michigan DEQ generally found better macroinvertebrate community health and habitat in streams that were not recently dredged.

B-1.1.3 Bacteria Source Load Tracking (Ross and Loomis 2004)

Antibiotic Resistance Analysis was used to determine the sources of bacteria in the SJRW. Ambient in-stream bacteria data were collected from SJRWI sampling sites in 2002-2005 and certain areas were targeted (e.g., livestock operations, sewer overflows). A database of bacterial strains was created using fecal matter samples from horses, swine, dairy cattle, and beef cattle at 4H and county fairs in Allen (IN), DeKalb (IN), Hillsdale (MI), and Williams (OH) counties, from cats and dogs at animal shelters in Fort Wayne and DeKalb County, and from humans at rest stops along I-69.

The study results show that livestock operations (swine, dairy cattle, and beef cattle) contribute relatively small proportion of bacteria throughout the SJRW. Human sources tended to also contribute relatively low proportions (10 to 15 percent) of the in-stream bacteria, except certain areas. Throughout the watershed, geese tended to contribute a relatively large proportion of the bacteria.

B-1.1.4 Biological and Water Quality Study of Fish Creek (Ohio EPA 2005)

Ohio EPA has thoroughly studied Fish Creek and has issued five reports describing their studies (Ohio EPA 1993, 1994b, 1995, 2003, 2005). Fish Creek supports diverse aquatic communities and has been repeatedly studied due, in part, to a spill of 30,000 gallons of diesel fuel from a pipeline rupture on September 15, 1993. Fish, macroinvertebrate, water column, and sediment data were collected multiple times since the spill by Ohio EPA, Ohio Department of Natural Resources, IDEM, The Nature Conservancy, and U.S. Fish and Wildlife Service.

Macroinvertebrate community health has typically met water quality standards (WQS). Attainment of biological criteria at river miles (RMs) 14.3 and 8.3 has not varied over time, while a decline was observed at RM 7.5 (though criteria are still met). At RM 5.4, the ICI has attained its exceptional warmwater habitat use, except in 1993 following the spill and 1997 for unknown reasons (Ohio EPA 2005, p. 20). At RM 0.3, the ICI has attained the WWH use, and even the exceptional warmwater habitat criteria. IDEM also evaluated macroinvertebrate community health using the macroinvertebrate Index of Biotic Integrity (mIBI) and Helsenhoff Biotic Index (HBI); most sample sites attained criteria.

Fish community health was considerably worse than macroinvertebrate community health. Poor fish communities were identified at the two most upstream sample locations due to high proportions of pollution tolerant species and IBI scores throughout the stream were generally lower than expected (Ohio EPA 2005, p. 28). Multiple surveys identified heavy silt layers that caused extensive embeddedness.

By 2002, only strontium exceeded Ohio's WQS all other constituents in the water column or sediment were at or below standards or targets (Ohio EPA 2005). In 1997, levels of fecal coliform and total phosphorus exceed WQS and targets (Ohio EPA 2003). Also in 1997, seven polycyclic aromatic hydrocarbons were detected at low levels from sediment collected in lower Fish Creek, below the spill; only one polycyclic aromatic hydrocarbon was detected in 2002. Ohio EPA had reported a "moderately strong diesel fuel odor" in bottom sediments in 1994 that was not observed in 1997 (Ohio EPA 2003, p. 14). Additional tests in 1997 showed that fish had "little or no exposure to organic contaminants" (Ohio EPA 2003, p. 6).

B-1.1.5 A Biological Study of the East and West Branches of the St. Joseph River Watershed and Bean Creek Watershed in Southern Lenawee and Hillsdale Counties (Michigan DEQ 2005a)

The East Branch St. Joseph River (EBSJR) and WBSJR in Michigan were sampled in 2000. Habitat was fair (moderately impaired) in the EBSJR subwatershed, except for poor (severely impaired) habitat in Laird Creek due to sedimentation and low flow and slightly impaired habitat at a site on the EBSJR. Macroinvertebrate community health ranged from acceptable to excellent and met the OIALW designated use. Except for zinc in Clear Fork Creek, all water chemistry results in the East Branch subwatershed met Michigan's WQS.

Many streams in the WBSJR subwatershed are maintained as ditches and drains (Michigan DEQ 2005a, p. 4). Habitat ranged from fair to good, and macroinvertebrate community health ranged from acceptable to excellent. Similar to the EBSJR subwatershed, the WBSJR subwatershed also met the OIALW designated use. Mercury was detected in the West Branch and zinc in Silver Creek at levels above their respective WQSs. Phosphorus, ammonia, arsenic, and zinc each exceeded expected ranges at a few sites.

B-1.1.6 Biological Surveys of Tributaries to the Maumee (St. Joseph) River Watershed in Hillsdale and Lenawee Counties, Michigan (Michigan DEQ 2005b)

Michigan DEQ sampled eight sites across EBSJR and WBSJR subwatersheds in 2005. The West Fork of the West Branch of the St. Joseph River (WFWBSJR) had excellent habitat and macroinvertebrate community health in the headwaters and both decreased downstream. Habitat quality decreased due to "a lack of stable substrates […], an increase in hydrologic instability (flashiness), and a loss of buffering capabilities resulting from a diminished riparian zone" (Michigan DEQ 2005b, p. 5). A general increase in nutrient concentrations was observed. Portions of the East Fork of the West Branch of the St. Joseph River (EFWBSJR) were impounded, dredged, and straightened. Habitat was good and macroinvertebrate community health was excellent. Nutrient levels were within expected ranges.

The EBSJR is also dredged and straightened, but the headwaters receives a substation amount of groundwater. Habitat was poor (severely impaired) but macroinvertebrate community health was excellent, though populations had low densities. Silver, Laird, and Bird creeks are tributaries of the East Branch, and Silver and Laird creeks are less channelized. Silver and Laird creeks had good habitat and excellent macroinvertebrate community health; streams were flashy and had expected nutrient levels. Bird Creek had good habitat and macroinvertebrate community health with low nutrient concentrations. All the sites attained Michigan's WQS.

B-1.1.7 Biological and Water Quality Study of the St. Joseph River Basin, 2013 (Ohio EPA 2015)

In 2013, Ohio EPA sampled 24 sites for bacteria, 33 sites for biology, and 35 sites for water chemistry. All 24 sites sampled for *E. coli* resulted in high bacteria concentrations and every site failed to meet the *E. coli* geometric mean criterion (Ohio EPA 2015). All eight the sites on the mainstem of the SJR attained WWH biocriteria and 23 of 25 sites on tributaries to the SJR met their respective biocriteria. Fish and macroinvertebrate communities' health at the eight sites on the SJR ranged from marginally good to exceptional (Ohio EPA 2015, p. 48, 60). Fish community health on the tributaries to the SJR ranged from fair to exceptional, while macroinvertebrate community health ranged from marginally good to exceptional (Ohio EPA 2015, p. 49, 78)

Ohio EPA (2015, p. 1) found that "[t]he biological integrity of the St. Joseph River watershed has improved since the streams were last sampled in 1992". In 1992, all the sites sampled for fish failed to meet WWH biocriteria and the "fish assemblage was dominated by tolerant, omnivorous, or otherwise

generalist species" (Ohio EPA 2015, p. 93). In 2013, all eight sites met biocriteria and Ohio EPA (2015, p. 91) found "a strong and significant statistical difference" between IBIs from 1992 and 2013.

While water quality is generally good throughout the watershed, "[s]ome of the streams in the study area [Ohio's portion of the SJRW] were affected by agricultural runoff, sedimentation, and direct habitat alteration" (Ohio EPA 2015, p. 9).

B-1.2 Soil and Water Assessment Tool Modeling Studies

IDEM, Purdue University, the U.S. Department of Agriculture's Agricultural Research Service (USDA ARS), and the University of Michigan developed Soil and Watershed Assessment Tool (SWAT) models for the SJRW or the Cedar Creek subwatershed. Purdue University's recent SWAT modeling (Chaubey et al. 2014; see Section B-1.2.5) will be used to support SWAT model development for this TMDL project.

B-1.2.1 Cedar Creek Watershed SWAT Modeling (Rice 2005)

IDEM developed a SWAT model for the Cedar Creek subwatershed to evaluate management scenarios for agricultural practices[1]. The SJRWI and Allen, DeKalb, and Noble soil and water conservation districts provided row crop management practices and septic systems information. The SWAT model simulated total suspended solids, total nitrogen, and total phosphorus. Due to the lack of monitoring data, water quality calibration and validation of the model was limited.

IDEM also evaluated *E. coli* in the Cedar Creek watershed. As SWAT does not simulate bacteria, IDEM used load duration curves and the Bacteria Indicator Tool. The load duration curve results showed that runoff-derived source loading contributed the most *E. coli*. Using the Bacteria Indicator Tool, IDEM concluded that failing HSTS contributed relatively low *E. coli* loading as compared to other sources.

B-1.2.2 Atrazine SWAT Modeling (Larose et al. 2007; Heathman et al. 2008; Quansah et al. 2008)

Researchers at Purdue University and USDA ARS developed SWAT models for the SJRW and Cedar Creek subwatershed with various study objectives involving in-stream atrazine levels. Larose et al. (2007) developed a SWAT model for the Cedar Creek subwatershed that was calibrated and validated using USGS flow and atrazine (National Water Quality Assessment Program) data for a site at the mouth of Cedar Creek. Heathman et al. (2008, p. 554) developed un-calibrated SWAT and Annualized Agricultural Non-Point Source (AnnAGNPS) models for the Cedar Creek subwatershed "to test accuracy and applicability of the SWAT2005 and AnnAGNPS models for estimating streamflow and atrazine loss". Quansah et al. (2008) developed a SWAT model for the SJRW to evaluate the impacts of tillage practices on in-stream atrazine levels, which is a concern for public water supplies. This model was calibrated/validated with data from three USGS gages and SJRWI atrazine data. None of the studies evaluated nutrients, sediment, or *E. coli*, and thus, are not further discussed herein.

B-1.2.3 Impact of Watershed Subdivision and Soil Data Resolution on SWAT Model Calibration and Parameter Uncertainty (Kumar and Merwade 2009)

Purdue University researchers developed 24 SWAT models, 12 models each for the SJRW and Cedar Creek subwatershed, using either STATSGO or SSURGO soil data and variously sized critical source areas. They used Purdue's TeraGrid system to autocalibrate 14 parameters using 7 years of daily streamflow data (1993 through 1999). Kumar and Merwade (2009, p. 1185) concluded that "calibration results are different depending on whether [the Nash-Sutcliff efficiency coefficient] or [Model Bias] is used as the performance indicator". They also found that "[v]isual inspection of simulated hydrograph

[1] Row crop inputs for each scenario and inputs hydrologic response units are presented in the appendices of *Water Quality Modeling Analysis for the Cedar Creek Watershed* (Rice 2005).

and manual adjustment of parameters may become necessary to ensure appropriate water balance in a hydrologic model" because autocalibration can yield water balances and parameterization results that are not consistent with the actual watershed (Kumar and Merwade 2009, p. 1192).

B-1.2.4 Impacts of conservation buffers and grasslands on total phosphorus loads using hydrologic modeling and remote sensing techniques (Larose et al. 2011)

Researchers at the University of Michigan and USDA ARS developed a SWAT model for the Cedar Creek subwatershed to evaluate the impacts of vegetated buffers and conservation grasslands on TP loads. Streamflow was calibrated at the USGS gage at Cedarville (04180000) from 1993-2002 and validated for 2006-2008; the F34 stream gage maintained by USDA ARS National Soil Erosion Research Laboratory (NSERL) was also used for validation. TP was calibrated for 2003-2007 using NSERL data. Scenario results indicated that the greatest TP load reductions were associated with the combination of all the simulated conservation practices implemented and that conservation grassland alone resulted in the lowest TP reductions (Larose et al. 2011, p. 128).

B-1.2.5 Cumulative Impacts of BMP Implementation in the Maumee River Basin – BMP Effect Modeling (Chaubey et al. 2014)

Purdue University developed a SWAT model for the SJR, St. Mary's River, and upper Maumee River watersheds, under a grant from the U.S. EPA Great Lakes National Program Office, to support WMP development and BMP implementation. The model was auto-calibrated/validated at multiple sites, including three sites for hydrology and one site for water quality in the SJRW[2]. The hydrological calibration was excellent while the water quality calibration was generally good. The model was run to simulate the years 1993 through 2009. Purdue University evaluated various BMPs through SWAT model scenario development at field-, watershed-, and basin-scales.

The researchers found that "[c]onservation crop rotation and no-till, which were most widely applied conservation practices in the study watershed, provided the greatest sediment load reduction at a watershed scale, while conservation crop rotation and cover crop reduced the greatest amount of nutrients (Chaubey et al. 2014, p. 9). They also found that site-specific, landscape, and topographic factors limited BMP effectiveness. SWAT modeling of BMP effectiveness showed that "conservation practice implementation may not be focused in the areas of the watershed where they are most needed" (Chaubey et al. 2014, p. 89).

B-1.3 Watershed Management Plans

Five watershed management plans (WMPs) were developed by or in coordination with the SJRWI.

B-1.3.1 St. Joseph River Watershed Management Plan (SJRWI 2006)

One of the goals of the 2006 revision of the SJR WMP was to begin managing the *entire* SJRW. The WMP identified sediment, nutrient, bacteria, and pesticide pollutants, their potential sources, and how some entities are addressing these sources. This WMP also seeks to assist stakeholders with developing WMPs for each of the subwatersheds (formerly 11-digit hydrologic unit codes [HUCs]). The additional goals are to reduce levels of alachlor, ammonia, atrazine, bacteria, glyphosate, pH, and total phosphorus to water quality standards or target levels (as appropriate) and the reduction of sediment loads by 30 percent.

[2] The hydrological parameterization was within predefined ranges while the water quality parameterization was at or near the upper and lower limits of the predefined ranges (Chaubey et al. 2014, p. 61)

SJRWI (2006) identified the following critical areas: Bear Creek, Big Run, Cedar Creek watershed including Garrett City Ditch, EBSJR, WBSJR, Nettle Creek, and northern Allen County including Tiernan Ditch. These critical areas were designated based, in part, upon analyses of SJRWI's water quality data that showed elevated concentrations of turbidity, nutrients, *E. coli*, and atrazine.

B-1.3.2 Cedar Creek Watershed Management Plan (Loomis 2008)

SJRWI was awarded a CWA section 319 grant to develop a WMP for the Cedar Creek subwatershed that is composed of two HUs[3]: *Matson Ditch-Cedar Creek* (HUC 04100003 06) and *Cedar Creek* (HUC 04100003 07). The grant was used to replace failing HSTS, plant trees, install two-stage ditches (in lieu of installing buffers and filter strips), and installed rain gardens. A cost-share program funded the installation of 24 HSTS, including 19 conventional systems and five alternative systems[4]. SJRWI also helped to develop an HSTS maintenance DVD.

The grant originally called for restoration activities that were not competitive with programs managed by the Farm Service Agency and U.S. Fish and Wildlife Service. Instead, a two-stage ditch development project was installed along the Van Gorder and Davis-Freeman ditches that are tributary to Little Cedar Creek, which is a critical area for sedimentation. About 1.33 lineal miles of managed drainage ditches were converted to two-stage ditches, with additional support provided by the Maumee River Basin Commission.

SJRWI supported the installation of seven rain gardens, including the installation of four rain gardens as a demonstration project at the Ricke Park lodge. A level spreader that routes parking lot stormwater runoff at the Ricke Park lodge to a swale was also installed. Other projects that demonstrate environmentally friendly landscaping included a pervious concrete installation at an outdoor theater and a buffer with multiple species of grasses planted for bank stabilization.

B-1.3.3 Lower St. Joseph - Bear Creek Watershed Management Plan (SJRWI 2008)

SJRWI developed a WMP for the *St. Joseph River* HU that is presently HUC 04100003 08); the WMP addressed two former 11-digit HUCs: L*ower St. Joseph* (formerly HUC 04100003 100) and *Bear Creek* (formerly HUC 04100003 070). The WMP characterizes the project area; identifies pollutants, targets, and impairments; discusses pollutant loads and potential reductions; recommends future best management practices (BMPs) and other activities; and describes the WMP goals[5]. Stakeholder perceptions and concerns are presented throughout the WMP; stakeholder concerns ranged from drinking water protection and water quality to public access and recreation to preservation, dredging and community involvement (SJRWI 2008).

SJRWI identified and assessed the main sources of water quality issues involving *E. coli* bacteria, nutrients, sediment, and pesticides. The four main sources of bacteria are combined sewer overflows, failing on-site wastewater treatment systems (OWTS)[6] , wildlife, and livestock and domestic pets. Five source areas for bacteria were delineated: (1) combined sewer overflows in Fort Wayne, (2) failing OWTS in urban and suburban Fort Wayne, (3) un-sewered communities in DeKalb County, (4) failing OWTS and animals in the SJR-Cedarville Reservoir and Swartz-Carnahan subwatersheds, and (5)

[3] Loomis (2008) developed the WMP for *Upper Cedar Creek* (HUC 04100003 080) and *Lower Cedar Creek* (HUC 04100003 090). After the 11-digit to 10-digit HUC conversion, these HUs became *Matson Ditch-Cedar Creek* (HUC 04100003 06) and *Cedar Creek* (HUC 04100003 07), respectively.

[4] The five alternative systems are "three Presby systems adjusted to non-standard site and layout specifications; one engineered wetland pre-treatment system, and one secondary pre-treatment peat filter system" (Loomis 2008, p. 4).

[5] SJRWI's (2008, p. 87-88) quantified goals include the reductions of *E. coli* by 95 percent, TSS by 63 percent, atrazine by 50 percent, and total phosphorus by 2.6 percent.

[6] On-site septic systems are essentially equivalent to home sewage treatment systems (HSTS), a common term for such systems in Ohio.

nuisance geese at the Indiana University-Purdue University Fort Wayne (IPFW) campus and other urban areas along the SJR (SJRWI 2008, p. 68-69).

Agriculture, loss of stabilized and vegetated banks, and construction activities were identified by SJRWI as the sources of sediment; SJRWI also identified four source areas: (1) construction and development in northern Allen County, (2) conventional tillage, lack of cover crops, and livestock access to streams (e.g., hoof-shear on the banks) in DeKalb County, (3) agricultural development in the floodplains, and (4) construction of new roads and salt/sand mixture application to roads during the winter (SJRWI 2008, p. 70-71). The sources of pesticides are runoff from crop fields and urban lawns and recreational areas. SJRWI (2008, p. 71-71) identified four source areas for pesticides, which are all urban or agricultural applications of pesticides in floodplains. Similar to sediment and pesticides, SJRWI (2008, p. 72) found the sources of nutrients to be: stormwater runoff from agriculture and urban areas, failing OWTS, CSOs, livestock, domestic animals, wildlife, and dredging operations. The nutrient source areas are: (1) stormwater runoff from agricultural and urban areas and failing OWTS in Swartz-Carnahan Ditch and affect Cedarville Reservoir, (2) stormwater runoff from urban areas, nuisance geese and failing OWTS that affect the St. Joseph Reservoir, (3) agriculture in the floodplains, and (4) ditch management, including periodic maintenance.

B-1.3.4 Middle St. Joseph River Watershed Management Plan (draft; Quandt nd)

SJRWI developed a WMP for the Middle St. Joseph River (the *Sol Shank Ditch-St. Joseph River* HU, which is HUC 04100003 05). The WMP presents stakeholder concerns, summarizes previous studies, and evaluates the project area by subwatershed. Subwatershed sections in various chapters characterize the subwatersheds, describe the land use, identify causes and sources, estimates loads and necessary reductions, and outlines goals for each subwatershed. Eleven major sources of pollutants are identified:

- Permitted point sources
- Butler, IN combined sewers
- Stormwater runoff from industrial areas
- Improperly placed or faulty septic systems that are failing
- Livestock with direct access to streams and operations that are adjacent to or otherwise directly drain to streams
- Land use management on erodible soils
- Row crops that are tiled
- Row crop management that uses conventional tillage
- Lack of functional riparian buffers
- Stream bank erosion
- Quarries

A load reduction analysis found that nitrate plus nitrite loads needed to be reduced throughout the project area but total phosphorus and total dissolved solids loads did not need reductions.

Quandt (nd) classified critical areas into categories based upon water quality, livestock operations, stream buffer widths, subsurface drainage, on-site wastewater treatment, and stormwater from developed areas. The Willow Run subwatershed was the highest prioritized water quality critical area, due to nitrate plus nitrite loads, and was followed by the Bluff and Big runs subwatersheds as the second highest priorities. Willow, Russell, and Bluff runs are critical areas due to in-stream turbidity. All current and future confined feeding operations, any operations where livestock have direct access to streams, and small animal operations within 100 feet of a stream or ditch are considered critical areas. All stream segments with buffer widths of less than 20 feet are considered critical and critical buffer widths were recommended by the adjacent lands' percent slope. Areas with unmanaged tiles and on-site wastewater

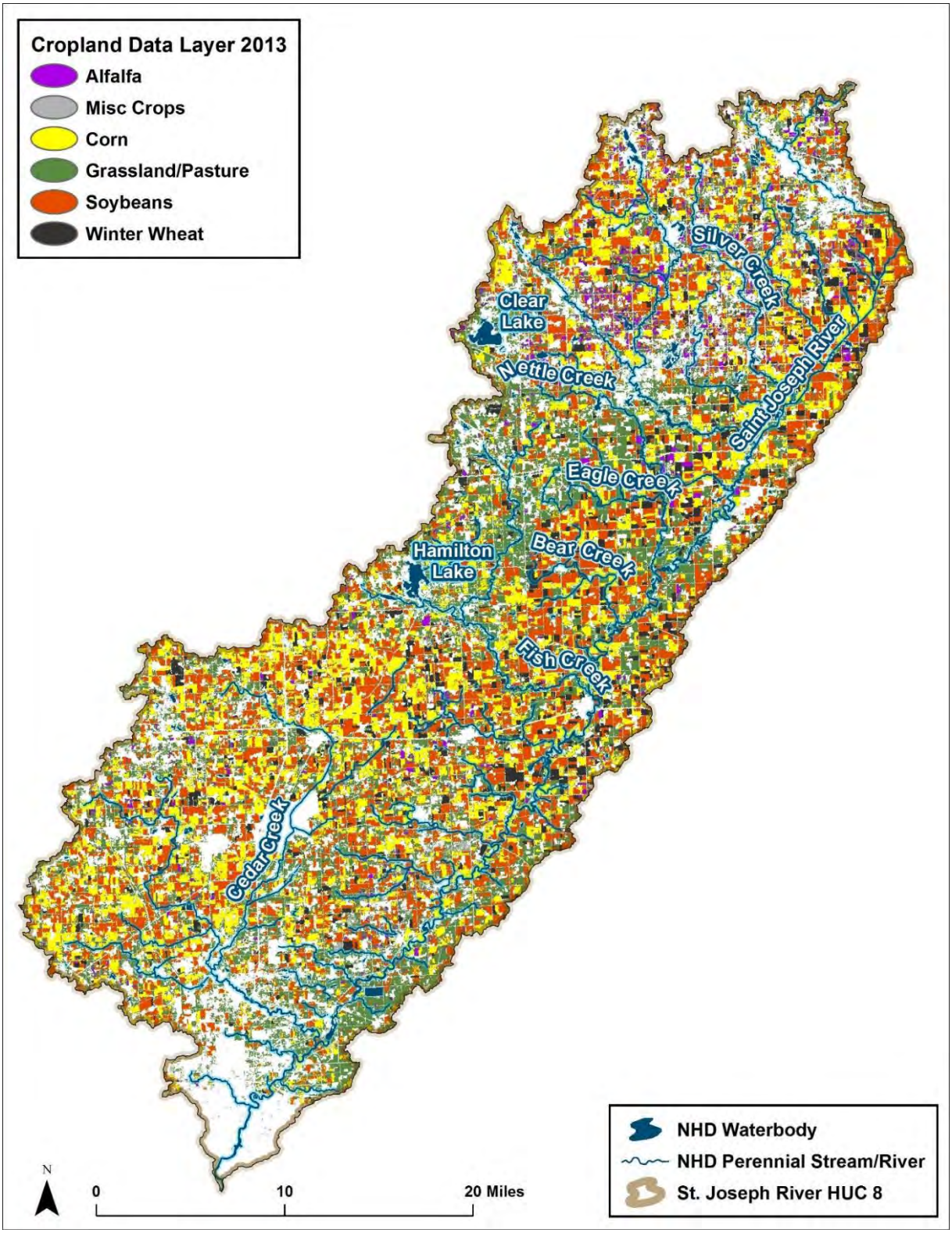
treatment systems that are faulty or failing are both also considered critical areas. Butler, IN and Edgerton, OH, are also critical areas due to storm flow from impervious areas.

B-1.3.5 Upper SJRW Management Plan (Quandt 2015)

SJRWI developed a WMP for the Upper SJR in *East Branch St. Joseph River* (HUC 04100003 01), *West Branch St. Joseph River* (*02), *Nettle Creek-St. Joseph River* (*03), and *Fish Creek* (*04). Like the previous WMP (i.e., Quand [nd]), this WMP presents stakeholder concerns, summarizes previous studies, characterizes the watershed, catalogues sources, and evaluates the project area by subwatershed. Subwatershed sections in various chapters characterize the subwatersheds, describe the land use, identify causes and sources, estimates loads and necessary reductions, and outlines goals for each subwatershed. This WMP also inventories water quality data per subwatershed that was collected by U.S. EPA, IDEM, Michigan DEQ, Ohio EPA, SJRWI, and the Steuben County Lakes Council.

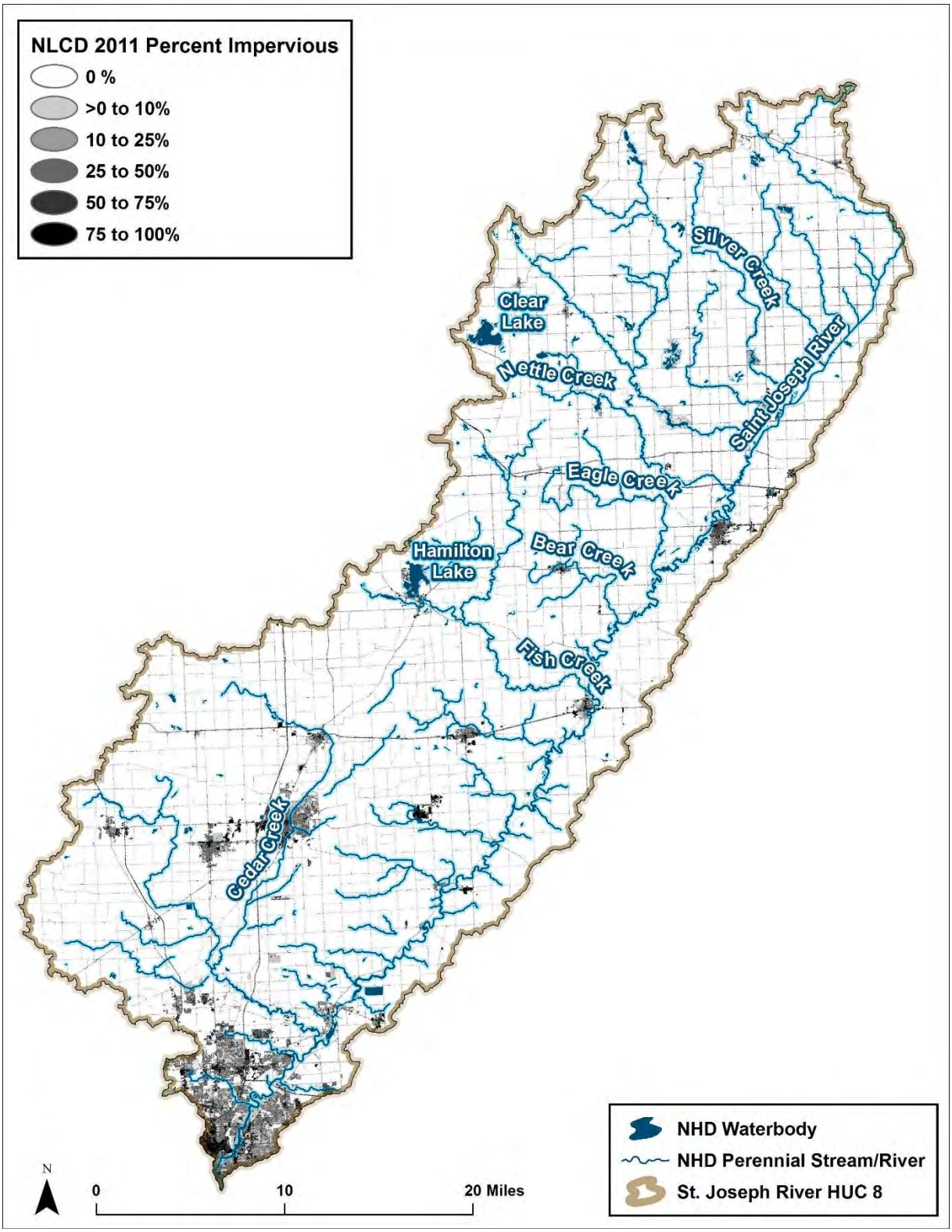
Quandt (2015) identified critical areas in the upper SJRW for pollutant reductions (for TP, turbidity, *E. coli*, dissolved reactive phosphorus), buffer width along headwaters streams and streambank erosion, and urban land use (i.e., Lake Seneca, Pioneer and Montpelier, Ohio, and Clear Lake and Hamilton Lake, Indiana). Goals, indicators (water quality, administrative, and social), and management measures were developed for each critical area.

B-2 Land Use and Land Cover



Source: 2013 Cropland Data Later (NASS 2013).

Figure B - 1. Cropland in the SJRW.



Source: 2011 *Percent Impervious Cover* in the National Land Cover Dataset (Jin et al. 2013).

Figure B - 2. Impervious cover in the SJRW.

B-3 Geology and Soils

Source: Woods et al. 2014a,b

Figure B - 3. Level III ecoregions in the SJRW.

Table B - 1. Level IV ecoregion physiography and geology in the SJRW

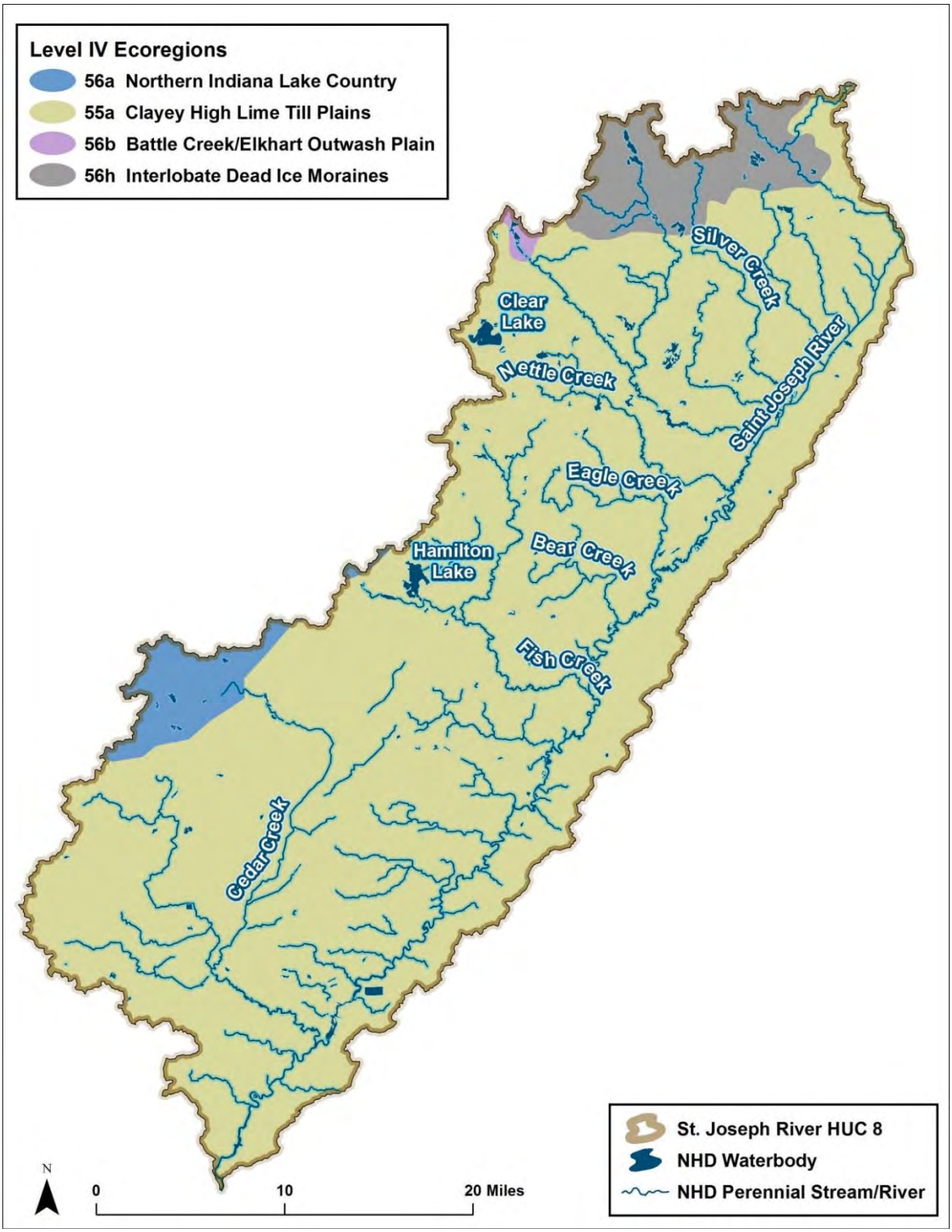
Ecoregion	Physiography	Geology
Clayey, High Lime Till Plains (55a)	Glaciated. Broad nearly level glacial till plain; also basins and end moraines. Low gradient streams.	Clayey, high lime, late-Wisconsinan glacial till, lacustrine deposits, and scattered loess overlie Paleozoic shales, carbonates, and sandstones.
Northern Indiana Lake Country (56a)	Glaciated. Hummocky plain. End moraines with many lakes, ponds, marshes, bogs, kettles, kames, and relict meltwater channels are present. Low to medium gradient streams with sand and gravel bottoms, and low sediment loads.	Late-Wisconsinan drift; also organic material. Deposits overlie Paleozoic shale, limestone, and dolomite.
Battle Creek/ Elkhart Outwash Plain (56b)	Glaciated. Nearly level to rolling drift plain with end moraines, glacial outwash landforms, lacustrine flats, and scattered potholes.	Loamy glacial till; also Quaternary glacial outwash, dune sand, lacustrine deposits, organic material, and alluvium overlie Paleozoic shale, limestone, and dolomite.
Interlobate Dead Ice Moraines (56h)	The Interlobate Dead Ice Moraines ecoregion encompasses a band of coarse-textured end moraines, kames, and outwash sands extending across much of the width of the Lower Peninsula. They consist of ice-contact topography or dead-ice moraine; it formed where ice melted in place within a stalled glacier, leaving numerous kettle ponds in its wake. Lakes also occur in pitted outwash channels.	*not available*

Source: Woods et al. 2014a,b

Table B - 2. Level IV ecoregion soils in the SJRW

Ecoregion	Common soil series
Clayey, High Lime Till Plains (55a)	Widespread: Blount, Pewamo, Glynwood, Morley. In east: Bennington, Cardington. In west: Del Rey, Eel. On lake plains: Nappanee, Milford.
Northern Indiana Lake Country (56a)	Glynwood, Morley, Fox, Oshtemo, Rawson, Houghton, Wawasee, Boyer.
Battle Creek/ Elkhart Outwash Plain (56b)	Riddles, Crosier, Brookston, Metea, Oshtemo, Tyner, Brady, Tracy.
Interlobate Dead Ice Moraines (56h)	Riddles, Hillsdale, Gilford,Spinks,Houghton, Boyer, Miami, Marlette, Lapeer, Oshtemo, Capac.

Source: Woods et al. 2014a,b



Source: Woods et al. 2014a,b

Figure B - 4. Level IV ecoregions in the SJRW.

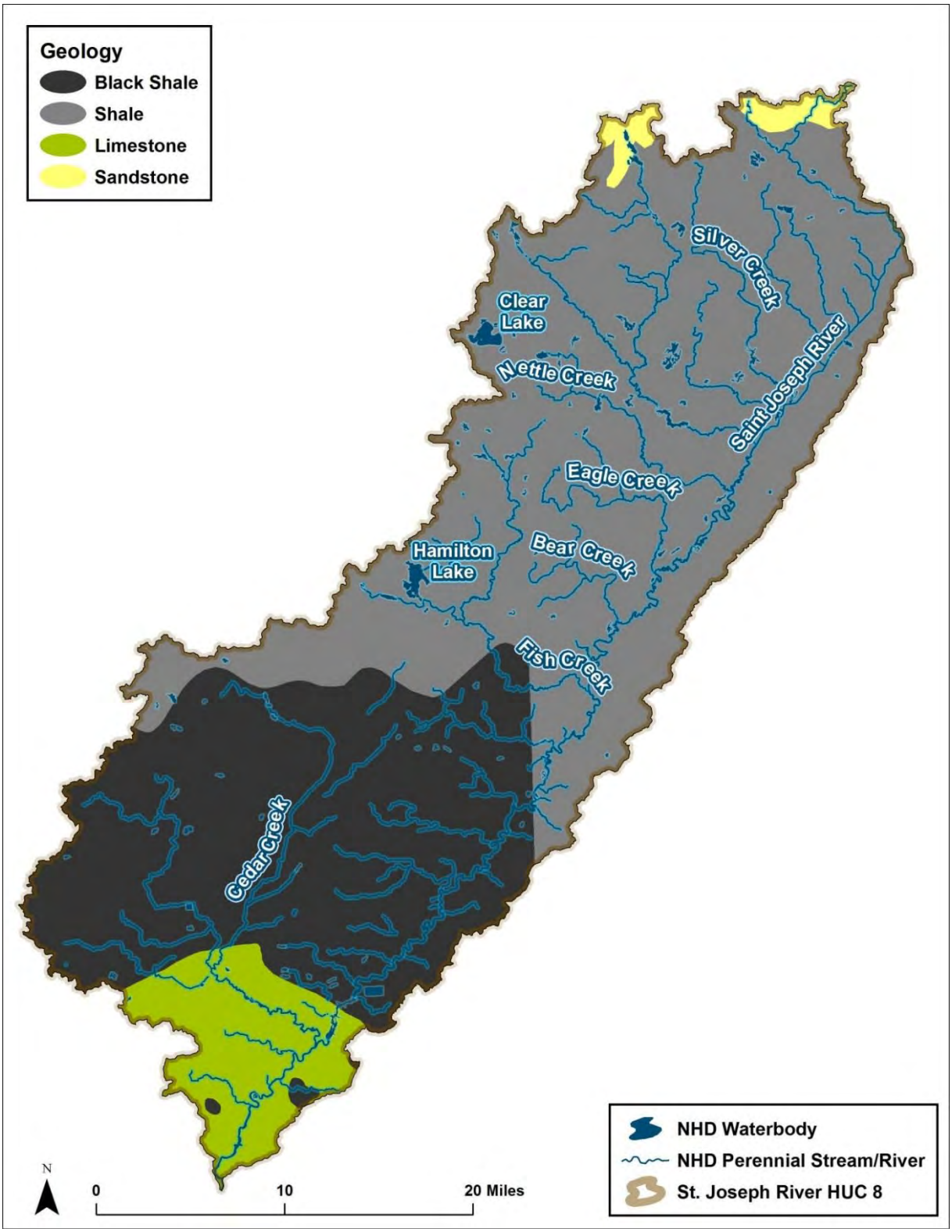


Figure B - 5. Bedrock geology underlying the SJRW.

Table B - 3. HSG descriptions

HSG	Group description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well- to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
A/D B/D C/D	Dual HSGs. Certain wet soils are placed in group D solely on the basis of the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity might be favorable for water transmission. If these soils can be adequately drained, they are assigned to dual HSGs (A/D, B/D, and C/D) according to their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the un-drained condition.

Source: Soil Data Viewer 6.0 (NRCS 2011).

Table B - 4. HSG distribution in the SJRW

HUC 10	Watershed Name	A	B	C	D	A/D	B/D	C/D	NR
01	East Branch Saint Joseph River	4%	9%	**41%**	18%	7%	8%	12%	1%
02	West Branch Saint Joseph River	9%	12%	**29%**	18%	8%	10%	10%	3%
03	Nettle Creek-Saint Joseph River	3%	1%	8%	**51%**	4%	8%	24%	2%
04	Fish Creek	7%	2%	20%	**41%**	4%	7%	16%	3%
05	Sol Shank Ditch-Saint Joseph River	4%	1%	3%	**60%**	3%	5%	23%	1%
06	Matson Ditch-Cedar Creek	6%	8%	7%	**46%**	3%	9%	19%	1%
07	Cedar Creek	4%	3%	12%	**47%**	4%	7%	21%	2%
08	Saint Joseph River	4%	2%	6%	**60%**	1%	3%	22%	2%

Notes
NR = not reported.
Bolded values are the largest percentage per HUC 10.
Values might not sum to 100 percent because of rounding.

B-4 Climate

Table B - 5. Climate data summary for Angola, IN (station 120200)

Parameter [a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	31.0	33.1	43.7	57.4	69.6	78.8	83.0	81.1	74.4	62.2	47.1	34.5
Low	15.8	16.5	25.4	36.4	47.4	57.3	61.3	59.5	52.3	41.3	30.9	20.6
Precipitation	2.2	1.9	2.7	3.4	3.6	3.6	3.5	3.4	3.1	2.7	2.8	2.5
Snowfall	9.2	8.7	5.7	1.8	0.2	0.0	0.0	0.0	0.0	0.3	3.4	7.8

Source: WRCC 2014.
Notes:
Summary of data collected at Angola, IN NCDC station 120200 from January 1, 1893 through October 25, 2014.
a. All four parameters are monthly averages. High and low are in degrees Fahrenheit. Average precipitation is in inches water equivalent. Average snowfall is in inches of snow.

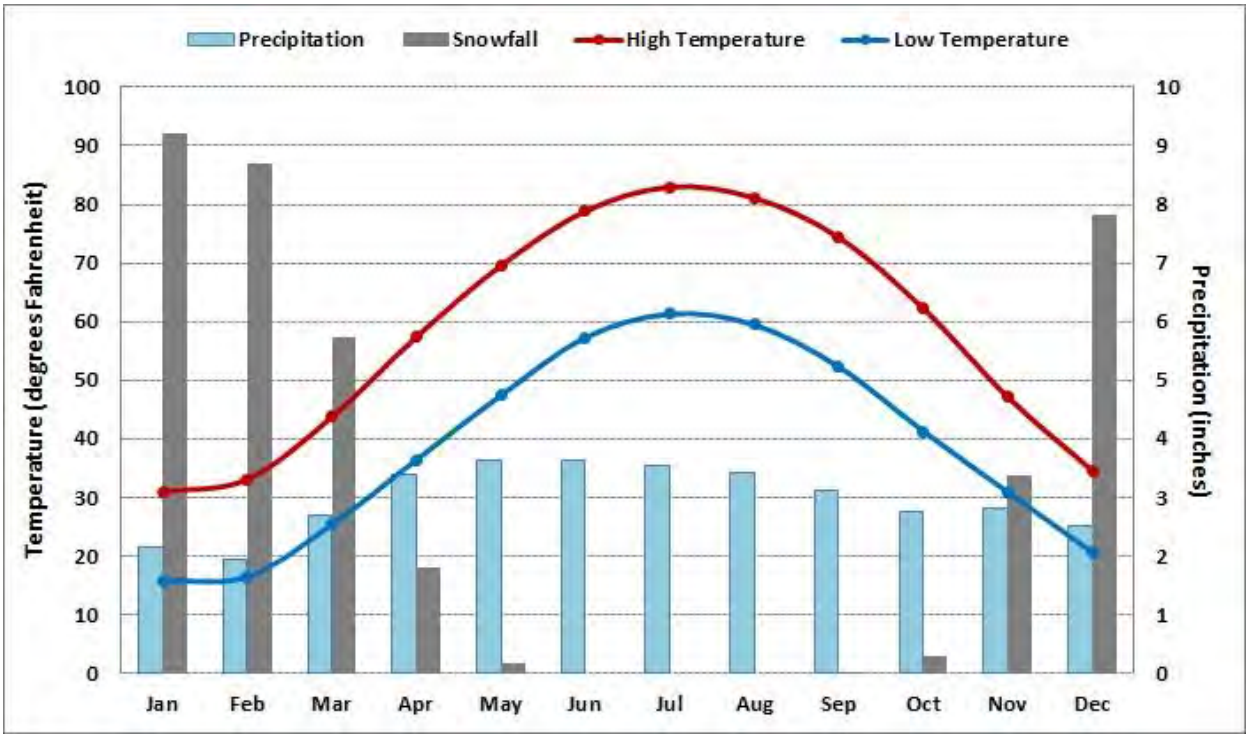


Figure B - 6. Temperature and precipitation summary at Angola, IN (station 120200).

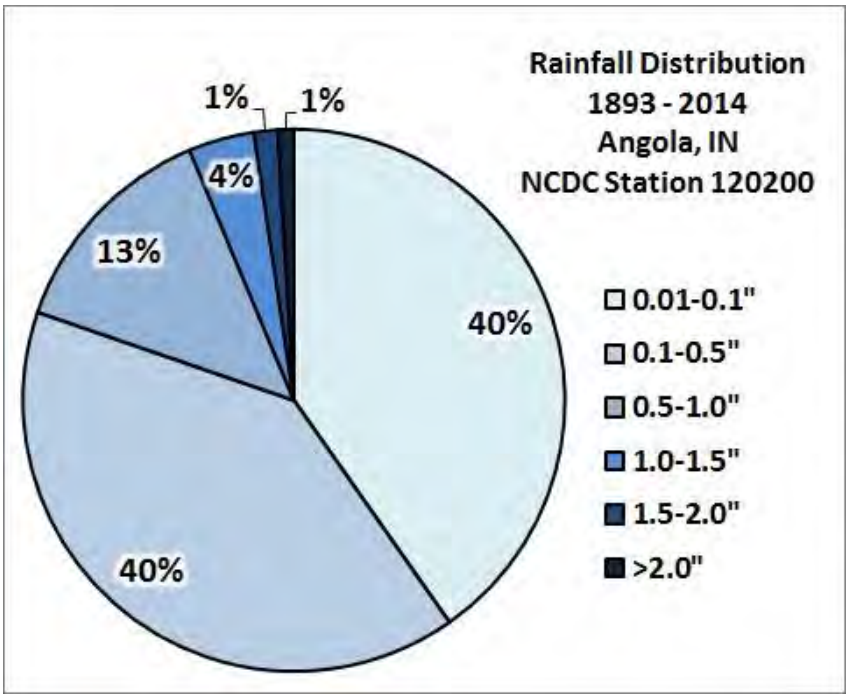


Figure B - 7. Precipitation intensity at Angola, IN (station 120200).

Table B - 6. Climate data summary for Montpelier, OH (station 335438)

Parameter [a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	32.4	34.6	45.9	59.5	71.5	80.9	85.2	83.2	76.3	64.0	48.7	35.9
Low	16.3	17.1	26.2	36.6	46.9	56.5	60.6	58.5	51.3	40.3	30.9	21.0
Precipitation	2.1	2.0	2.7	3.3	3.7	3.5	3.3	3.2	2.9	3.3	2.6	2.3
Snowfall	7.9	7.9	4.5	0.7	0.0	0.0	0.0	0.0	0.0	0.1	2.0	6.6

Source: WRCC 2014.
Notes:
Summary of data collected at Montpelier, OH NCDC station 335438 from June 1, 1893 through October 25, 2014.
a. All four parameters are monthly averages. High and low are in degrees Fahrenheit. Average precipitation is in inches water equivalent. Average snowfall is in inches of snow.

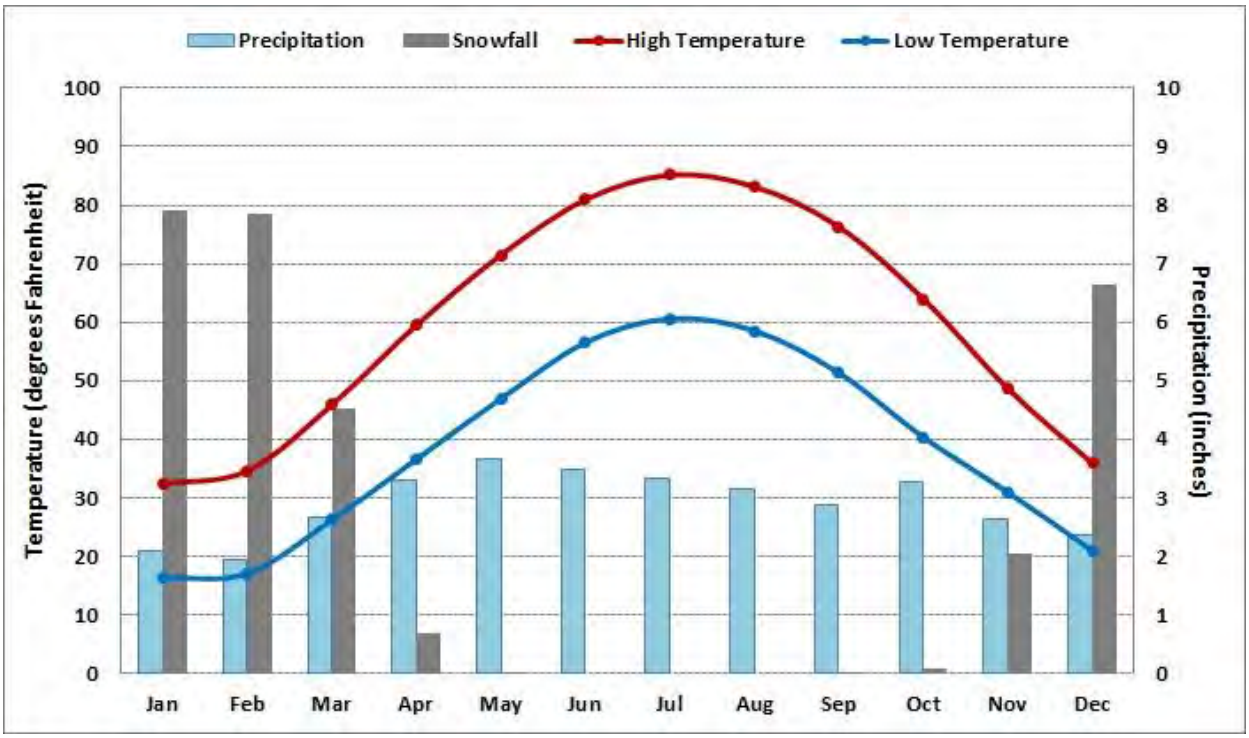


Figure B - 8. Temperature and precipitation summary at Montpelier, OH (station 335438).

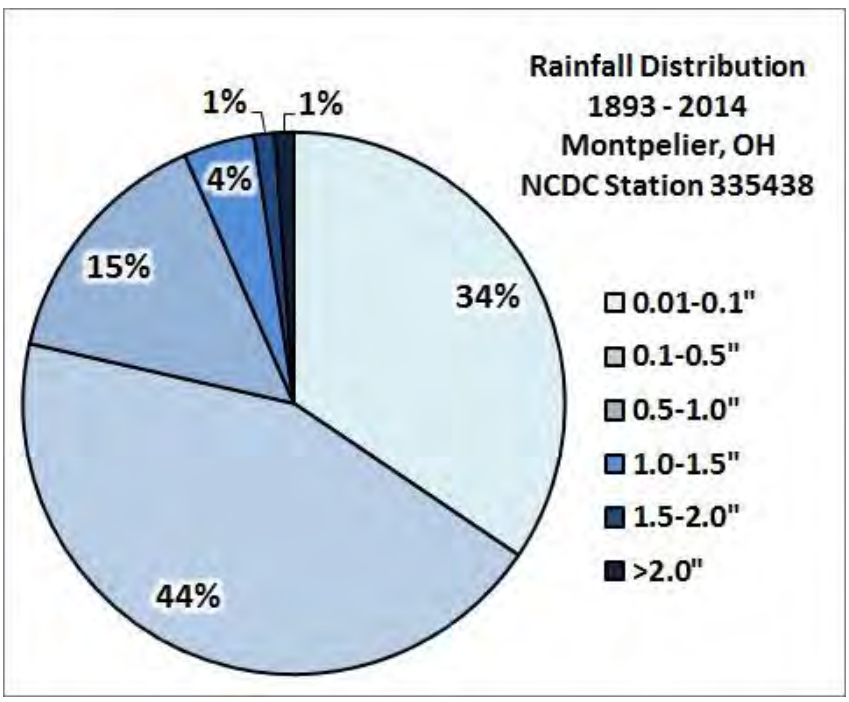


Figure B - 9. Precipitation intensity at Montpelier, OH (station 335438).

Table B - 7. Climate data summary for Hillsdale, MI (station 203823)

Parameter [a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	30.9	33.3	44.0	57.7	69.6	79.0	83.3	81.2	74.2	61.7	46.9	34.4
Low	15.2	16.0	24.9	35.4	46.0	55.6	59.3	57.3	50.6	40.1	30.3	20.0
Precipitation	2.2	2.0	2.7	3.2	3.6	3.8	3.3	3.1	3.2	2.7	2.8	2.5
Snowfall	11.4	10.2	6.7	1.8	0.1	0.0	0.0	0.0	0.0	0.2	3.9	9.9

Source: WRCC 2014.
Notes:
Summary of data collected at Hillsdale, MI NCDC station 203823 from September 1, 1891 through October 25, 2014.
a. All four parameters are monthly averages. High and low are in degrees Fahrenheit. Average precipitation is in inches water equivalent. Average snowfall is in inches of snow.

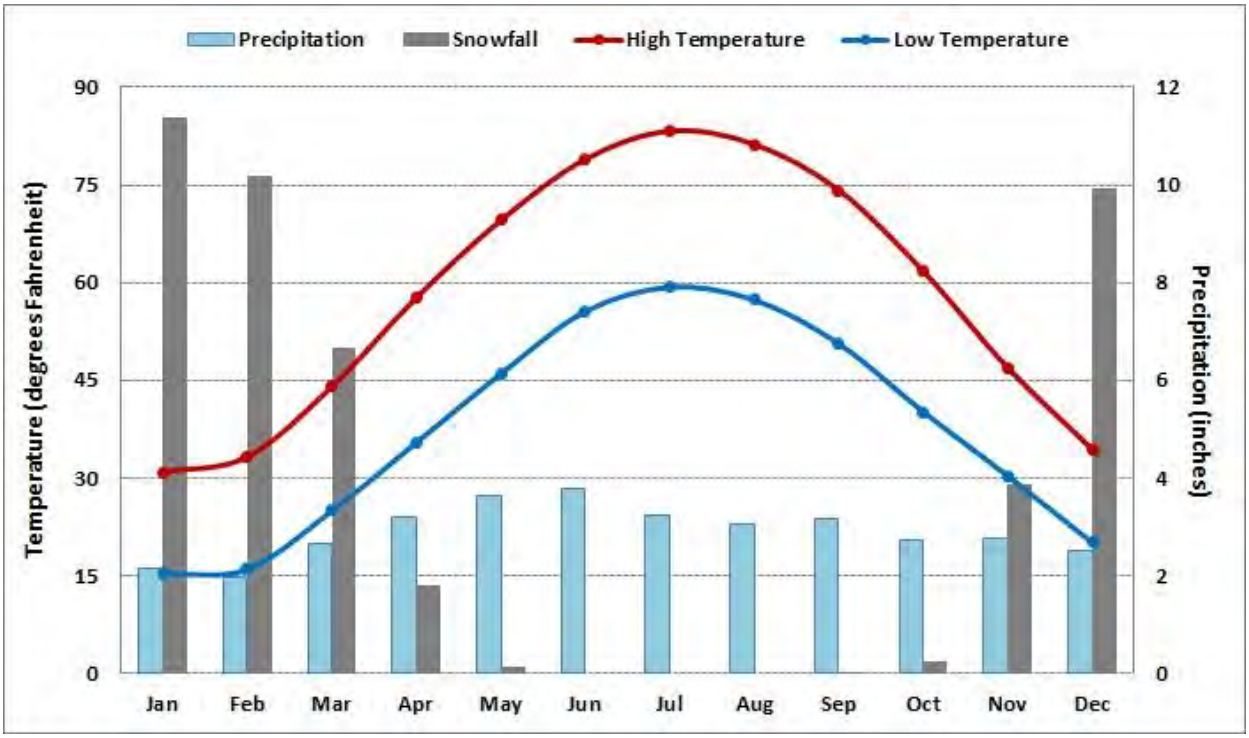


Figure B - 10. Temperature and precipitation summary at Hillsdale, MI (station 203823).

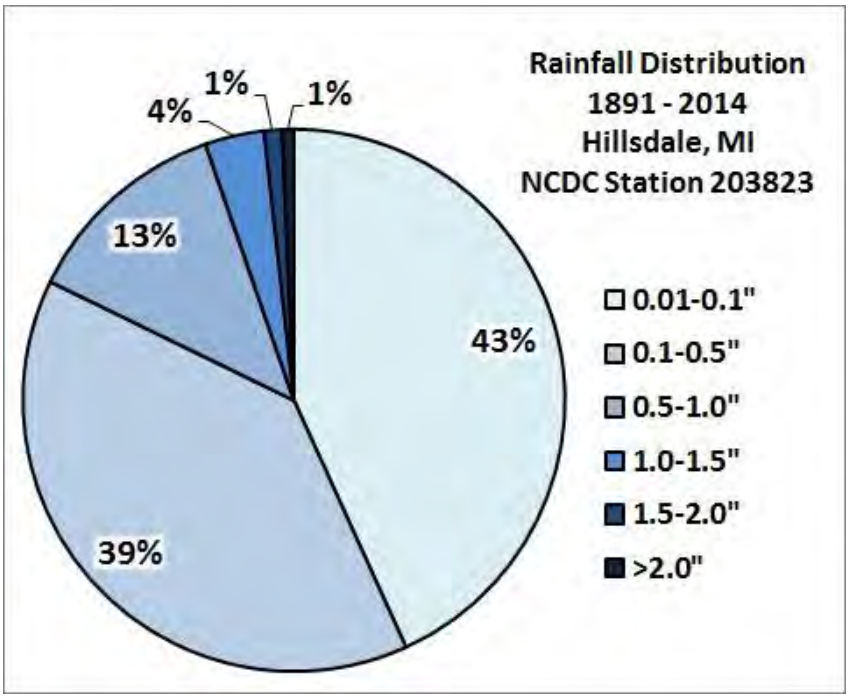


Figure B - 11. Precipitation intensity at Hillsdale, MI (station 203823).

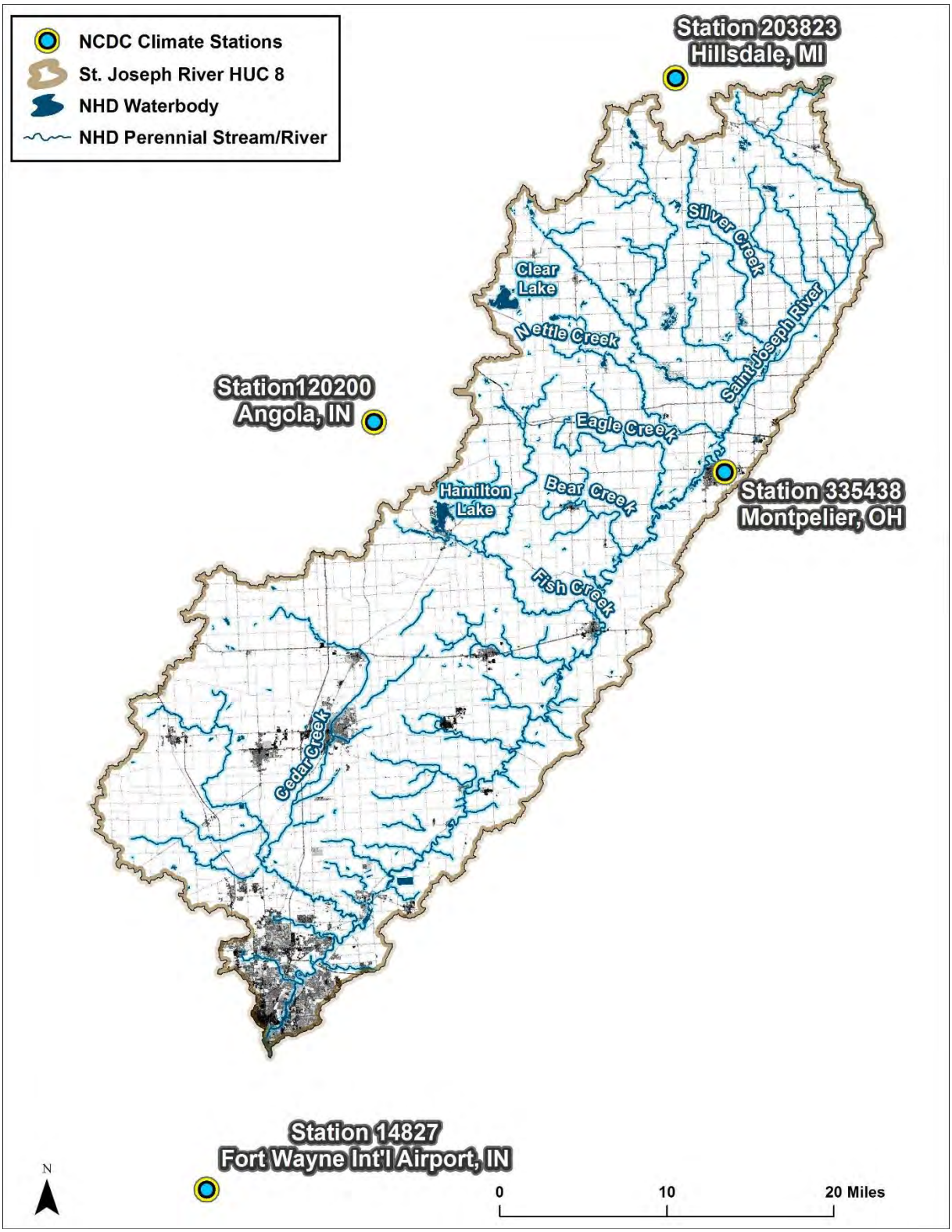


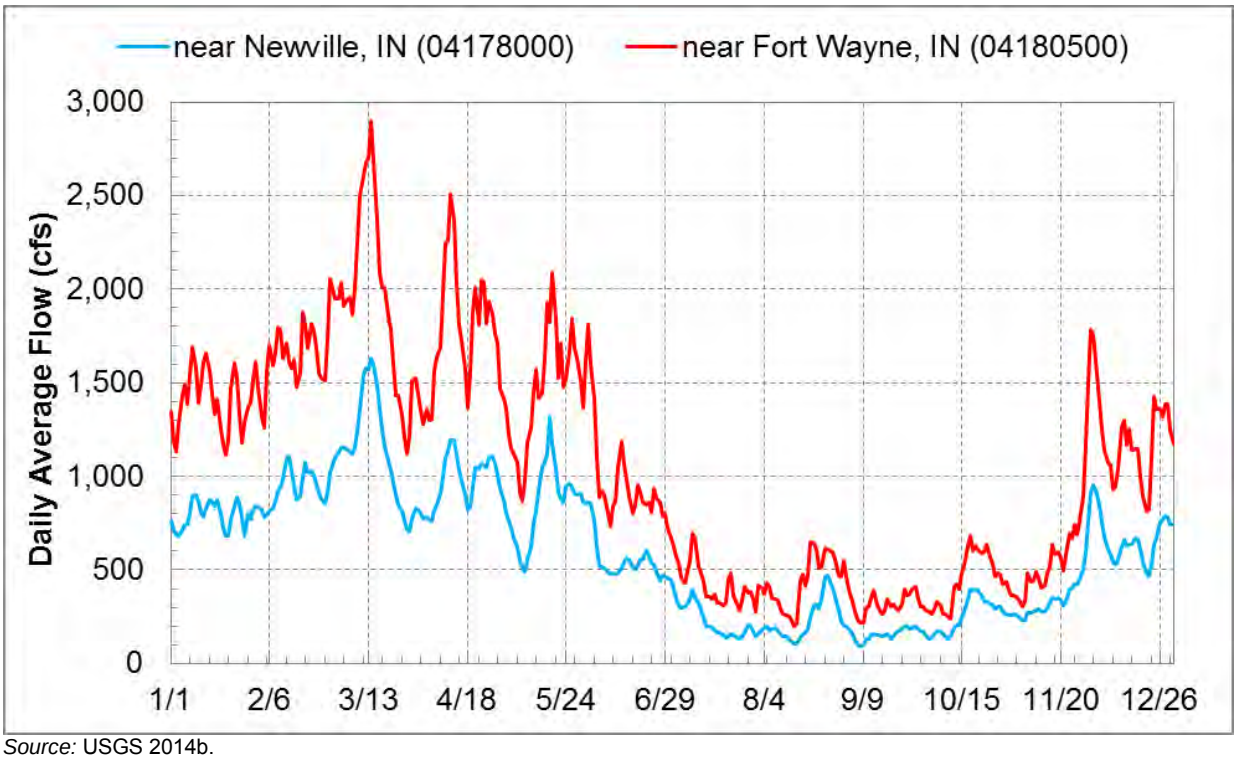
Figure B - 12. NCDC climate stations in and near the SJRW.

B-5 Hydrology

Table B - 8. USGS sites with field measurements data

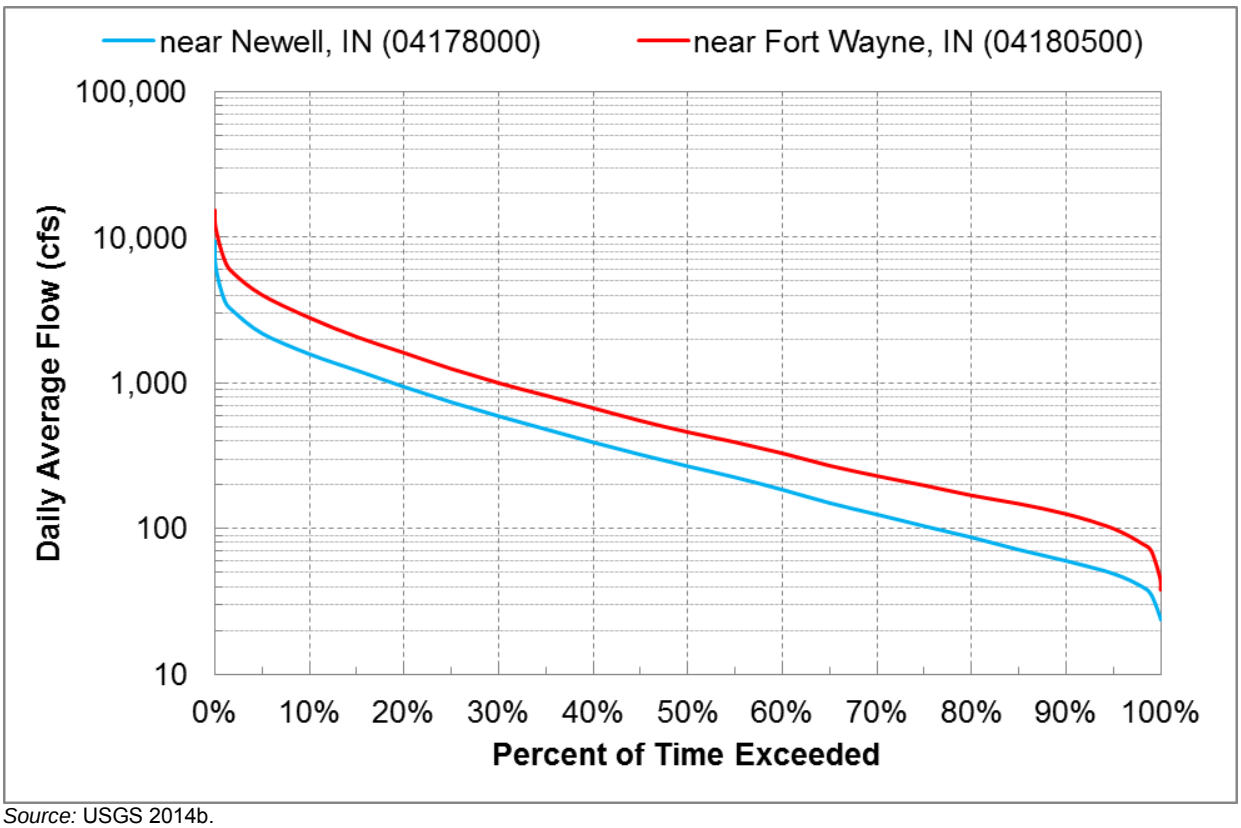
Site ID	Location	Area (mi.^{2})	No. of flows	Period of record (water years)
04177063	East Branch St. Joseph River near Pittsford, MI	22.1	1	1989
04177064	East Branch St. Joseph River near Pittsford, MI	24.2	1	1989
04177067	East Branch St. Joseph River near Pittsford, MI	27.1	1	1989
04177080	East Branch St. Joseph River at Territorial Road near Waldron, MI	70.8	12	1963, 1973 -1975
04177085	Laird Creek near Waldron, MI	16.3	3	1962, 2004
04177094	Clear Fork at Hillsdale Road near Camden, MI	n/a	1	1967
04177220	Clear Lake outlet at Long Lake Road at Montgomery, MI	15.1	1	1963
04177221	Prouty Drain at State Highway M-49 near Reading, MI	n/a	1	1982
04177222	Prouty Drain at Abbott Road near Reading, MI	n/a	3	1982-1984
04177223	Prouty Drain at Brott Road near Reading, MI	n/a	3	1982-1984
04177225	WFWBSJR near Montgomery, MI	32.2	2	1963
04177240	WFWBSJR near Austin, MI	47	3	1963, 1967, 1977
04177250	EFWBSJR near Woodbridge, MI	30.4	2	1963
04177260	EFWBSJR near Austin, MI	50.2	3	1963, 1967, 1977
04177310	Mill Stream Drain at Territorial Road near Camden, MI	11.2	2	1963, 1967
04177720	Fish Creek at Hamilton, IN	37.5	366	1969 - 2014
04177800	Fish Creek near Artic, IN	95.8	15	1968 - 1975
04177810	Fish Creek near Artic, IN	98	73	1998 - 2007
04177900	Big Run at Butler, IN	16.7	15	1968 - 1975
04178000	St. Joseph River near Newille, IN	610	315	1947 - 2014
04178400	Bear Creek near Saint Joe, IN	23.9	12	1972 - 1976
04178500	St. Joseph River at Hursh, IN	734	18	1950 - 1954
04179308	Dibbling Ditch near Waterloo, IN	12.9	9	1976 - 1978
04179310	Cedar Creek near Waterloo, IN	48.8	20	1968 - 1977
04179500	Cedar Creek at Auburn, IN	87.3	69	1946 – 1953 1963 – 1974
04179520	Cedar Creek at 18th Street at Auburn, IN	90.2	95	2001 – 2014
04179560	John Diehl Ditch at Auburn, IN	37.5	4	1988 – 1989
04179800	Little Cedar Creek near Garrett, IN	72.3	17	1972 – 1978
04179900	Willow Creek near Huntertown, IN	19.0	8	1976 - 1978
04180000	Cedar Creek near Cedarville, IN	270	631	1946 – 2014
04180500	St. Joseph River near Fort Wayne, IN	1,060	195	1984 – 2014
04180600	St. Joseph River at Fort Wayne, IN	n/a	9	1988 - 1991
04180610	St. Joseph River at Parnell Avenue at Fort Wayne, IN	1,094	1	2014

Source: USGS 2014a.
Notes
Sites are listed from top to bottom numerically by gage ID.
EFWBSJR = East Fork West Branch St. Joseph River; n/a = not available; WFWBSJR = West Fork West Branch St. Joseph River.



Source: USGS 2014b.

Figure B - 13. Average daily mean flow for active gages on the St. Joseph River (WY 1994-2013).



Source: USGS 2014b.

Figure B - 14. Flow duration curves for the active gages on the St. Joseph River (WY 1994-2013).

B-6 Community Profile

Table B - 9. Populations of select counties and municipalities in the SJRW

Location	Population in 2000	Population in 2010	Population change
Allen County, Indiana	**331,849**	**355,329**	**+7.1%**
Fort Wayne (city)	205,727	253,691	+23.3%
Grabill (town)	1,113	1,053	-5.4%
Huntertown (town)	1,771	4,810	+171.6%
Leo-Cedarville (town)	2,782	3,603	+29.5%
DeKalb County, Indiana	**40,285**	**42,223**	**+4.8%**
Auburn (city)	12,074	13,086	+8.4%
Altona (town)	198	197	-0.5%
Butler (city)	2,725	2,684	-1.5%
Corunna (town)	254	254	0.0%
Garrett (city)	5,803	6,286	+8.3%
Saint Joe (town)	478	460	-3.8%
Waterloo (town)	2,200	2,242	+1.9%
Noble County, Indiana	**46,275**	**47,536**	**+2.7%**
Avilla (town)	2,049	2,401	+17.2%
Steuben County, Indiana	**33,214**	**34,185**	**+2.9%**
Clear Lake (town)	244	339	+38.9%
Branch County, Michigan	**45,787**	**45,248**	**-1.2%**
No populated places [a]	--	--	--
Hillsdale County, Michigan	**46,527**	**46,688**	**+0.3%**
Camden (village)	550	512	-6.9%
Montgomery (village)	386	342	-11.4%
Defiance County, Ohio	**39,500**	**39,037**	**-1.2%**
No populated places [a]	--	--	--
Williams County, Ohio	**39,188**	**37,642**	**-3.9%**
Blakeslee (village)	130	96	-26.2%
Edgerton (village)	2,117	2,012	-5.0%
Edon (village)	898	834	-7.1%
Holiday City (village)	49	52	+6.1%
Montpelier (village)	4,320	4,072	-5.7%
Pioneer (village)	1,460	1,380	-5.5%

Source: USCB 2014.
Notes
Listed populations are for the entire county or municipality and may include portions outside of the St. Joseph River watershed.
a. No incorporated municipalities are in the very small portions of Branch and Defiance counties that are within the St. Joseph River watershed.

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