WHPA

Salt Creek *E. coli* TMDL

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Contents

1 Introduction **1**

2 Basin Characterization **3**

2.1 Environmental Setting . . . 3

2.2 Hydrologic Setting . . . 14

3 Water-Quality Data **19**

3.1 Data Inventory and Assessment . . . 19

3.2 Data Analysis . . . 26

3.2.1 Magnitude and Temporal Characteristics . . . 29

3.2.2 Spatial Characteristics . . . 36

3.3 Confirmation of Impairment . . . 38

4 Source Characterization **42**

4.1 Point Sources . . . 42

4.1.1 Permitted Discharges . . . 43

4.1.2 Bypass Discharges . . . 43

4.1.3 Combined Sewers . . . 43

4.2 Nonpoint Sources . . . 45

4.2.1 Subwatershed Landuse . . . 49

4.2.2 Livestock . . . 50

4.2.3 Pastureland / Cropland . . . 52

4.2.4 Wildlife . . . 55

4.2.5 Urban / Industrial Lands . . . 58

4.2.6 Septic Systems . . . 58

4.2.7 Illicit Discharges . . . 63

4.3 Uncertainty in Loading Estimates . . . 63

5 Linkage of Sources and Creek Conditions **65**

5.1 Modeling Framework . . . 65

5.2 Modeling Approach . . . 69

5.3 Hydrologic Calibration and Verification . . . 72

5.4 Water Quality Calibration . . . 73

6 Total Maximum Daily Load Analysis 83
6.1 Critical Conditions . . . 83
6.2 Technical Approach . . . 84
6.3 WLA . . . 85
6.4 LA . . . 86
6.5 MOS . . . 87
6.6 Summary of TMDL Components . . . 87
6.7 Post-TMDL Distribution . . . 89

7 Public Participation 90

8 Implementation Activities and Schedule 91
8.1 Implementation Actions . . . 91
8.1.1 Point Source Actions . . . 91
8.1.2 Nonpoint Source Actions . . . 94
8.1.3 List of Projects Conditionally Selected for Funding . . . 97
8.2 Reasonable Assurance . . . 98
8.3 Legal or Regulatory Controls . . . 98

References 99

Appendix A - Supplemental Data 104

Appendix B - WinHSPF Model Input File 184

List of Figures

1 Location of the Salt Creek watershed in northwestern Indiana. 4
2 Major hydrologic features in the Salt Creek watershed [U.S. Geological Survey, 1999b]. 5
3 Population of Porter County and Valparaiso, Indiana from 1940-2000 [City of Valparaiso, 2002, U.S. Census Bureau, 2000]. 6
4 Population density in the Salt Creek basin [U.S.Census Bureau, 2000]. . . . 7
5 Land use and land cover in the Salt Creek basin [U.S. Geological Survey, 2000]. 8
6 Major crop acreage in Porter County, 1950–2001 [Indiana Agricultural Statistics Service, 2002]. 9
7 Livestock population in Porter County, 1975–2001 [Indiana Agricultural Statistics Service, 2002]. 10
8 Physiographic relief in the Salt Creek basin [U.S. Geological Survey, 1999]. 11
9 Generalized glacial geology in the Salt Creek basin [Gray and Walls, 2002]. 12
10 Major soil regions in the Salt Creek basin [U.S. Department of Agriculture, 1994]. 13
11 Mean temperature and precipitation in Valparaiso, Indiana, 1961–1990 [Purdue University, 2002]. 14
12 Location of USGS stream gages. 16
13 Flow–duration curve for Salt Creek. 17
14 Mean monthly flows in Salt Creek. 18
15 Locations of IDEM fixed stations in the Salt Creek basin. 22
16 Locations of sampling sites for IDEM special studies in the Salt Creek basin. 24
17 Locations of sites in the Salt Creek basin sampled for the Lake Michigan Interagency Task Force/Non–point Source Committee. 25
18 Locations of sites in the Salt Creek basin sampled for the Lake Michigan Interagency Task Force/Point Source Committee. 27
19 NPDES effluent-pipe locations in the Salt Creek watershed that are potential sources of *E. coli*. 28
20 *E. coli* concentrations measured at IDEM fixed stations, 1991–2001. 30
21 *E. coli* concentrations measured at IDEM fixed stations, by month, 1991–2001. 31

22 Relationship between daily flow values at USGS McCool gage on Salt Creek and nearby Porter gage on the Little Calumet River, 1970–1991. . . . 32
23 Load–duration curve computed from flow and *E. coli* concentrations measured in Salt Creek. Flow statistics were computed with data from USGS McCool gage, 1970-1991. *E. coli* data from IDEM Fixed Station measurements at U.S. Highway 20 in Portage, IN, 1991–1999. 33
24 Load–duration curve computed from flow and *E. coli* concentrations measured in Salt Creek, organized by season. 34
25 *E. coli* concentrations measured by Lake Michigan Interagency Task Force/ Point Source Committee in 1998. Concentrations are shown for basin outlet (site 208) and Damon Run (site 205) in relation to precipitation and CSO overflow volume recorded at Valparaiso. 39
26 *E. coli* concentrations measured by Lake Michigan Interagency Task Force/ Point Source Committee in 1998. Concentrations are shown for Salt Creek above Valparaiso (site 201) and Squirrel Creek (site 206) in relation to precipitation and CSO overflow volume measured at Valparaiso. 40
27 Five–sample geometric mean concentrations determined by IDEM special studies. 41
28 The five Salt Creek subwatersheds; Upper, Valparaiso, Middle, Damon, and Lower. 49
29 Schematic of the Bacterial Indicator Tool used to calculate *E. coli* nonpoint source accumulation rates and storage limits. 50
30 Number of houses on septic systems in the Salt Creek watershed [U.S. Census Bureau, 1999]. 60
31 Number of people with septic systems in the Salt Creek watershed [U.S. Census Bureau, 1999]. 61
32 Population density of septic systems in the Salt Creek watershed. Derived from [U.S. Census Bureau, 1999]. 62
33 Software and data framework for the Salt Creek *E. coli* TMDL. 66
34 WinHSPF layout of Salt Creek watershed model. 67
35 Scatterplots of observed and simulated daily flow in Salt Creek at McCool. 75
36 Observed and simulated flow-duration curves for Salt Creek at McCool: Calibration and validation periods. 76

37 Observed and simulated daily flows in Salt Creek at McCool for the calibration and verification periods 77
38 Observed and simulated daily concentration in Salt Creek at watershed outlet for the 1998 recreational season. 78
39 Graphical representation of the statistical method used to calculate the E. coli TMDL target and allocations for Salt Creek. 88

List of Tables

1 Water-quality data sets from the Salt Creek watershed. 21
2 NPDES facilities in Salt Creek watershed that are potential sources of *E. coli* and their monitoring requirements. 44
3 Average flow and estimated annual *E. coli* loads to Salt Creek from NPDES facilities. 46
4 Discharge and *E. coli* load information for the CSO in Valparaiso in 2002. . 47
5 Description of the output worksheets provided in the Bacterial Indicator Tool. Modified from [U.S. EPA, 2000a]. 51
6 Land use information for the five subwatersheds in the Salt Creek watershed [USGS, 2000]. 52
7 Livestock sources of *E. coli* in Salt Creek watershed. 53
8 Estimated number of livestock in the Salt Creek subwatersheds. 53
9 The estimated *E. coli* production from livestock in the Salt Creek subwatersheds. 54
10 Wildlife sources of *E. coli* in Salt Creek watershed. 56
11 The estimated number of wildlife in various land uses in the Salt Creek watershed. 57
12 The estimated *E. coli* load from wildlife in the Salt Creek watershed. 57
13 Number of people on septic systems and number of failed septic systems in the subwatersheds. Derived from [U.S. Census Bureau, 1999, NESC, 2001]. 59
14 Data sets used for model implementation. 68
15 Comparison of simulated and observed annual flow at McCool Gage for calibration and verification period. 74
16 Summary statistics from flow calibration and verification. 79
17 Final monthly accumulation rates for each subwatershed/land-use combination (counts/acre-day). 80
18 Final storage limits for each subwatershed/land-use combination (count/acre). 81
19 Final estimated loads used as input in calibrated model. 82
20 Salt Creek TMDL components. 89
21 Entities in Salt Creek watershed required to implement EPA's Phase II stormwater regulations. 93

Appendix A - Supplemental Data

List of Tables

1 Water-quality data from IDEM Fixed-Station Monitoring in the Salt Creek watershed in Porter County, Indiana, 1990-2000. 104

2 Water-quality data in the Salt Creek watershed in Porter County, Indiana from IDEM special studies, 2000. 112

3 Non-point source water-quality data collected by the Interagency Task Force in the Salt Creek watershed, Porter County, Indiana, 1999-2001. 118

4 Point source water-quality data collected by the Interagency Task Force in the Salt Creek watershed in Porter County, Indiana, 1997-1999. 121

5 Volume of combined sewer overflows and inches of precipitation in Valparaiso, Indiana, collected by the Lake Michigan Interagency Task Force, 1998. 126

6 Water-quality data from the discharge monitoring reports of Major NPDES permit facilities, 1989-2002. 127

7 Water-quality data from the discharge monitoring reports of Minor NPDES permit facilities, 1989-2002. 139

8 Water-quality data from the discharge monitoring reports of Semi-public NPDES permit facilities, 1989-2002. 142

9 Volume of combined sewer overflows and inches of precipitation in Valparaiso, Indiana, obtained from NPDES CSO Monitoring Reports, 2001-2002. 174

10 Monthly accumulation values (MON_ACCUM) and the build-up limit (MON-SQOLIM) for Cropland in the Salt Creek subwatersheds. 175

11 Monthly accumulation values (MON_ACCUM) and the build-up limit (MON-SQOLIM) for Pastureland in the Salt Creek subwatersheds. 177

12 *E. coli* loading rates from cattle with direct stream access in the Salt Creek subwatersheds. 179

13 Monthly accumulation values (MON_ACCUM) and the build-up limit (MON-SQOLIM) for Forest in the Salt Creek subwatersheds. 181

14 Monthly accumulation values (MON_ACCUM) and the build-up limit (MON-SQOLIM) for Built-up in the Salt Creek subwatersheds. 181

15 Flow rates from failed septic systems in the Salt Creek subwatersheds. 182

1 Introduction

Section 303(d) of the Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be established for each water body in a state that does not meet the water-quality standards for the water body's designated use. The purpose of creating a TMDL is to establish allowable loads of a pollutant such that the water body will meet water-quality standards. Three basic steps are necessary to achieve this goal: 1) Determine all sources of contamination from the watershed, both point and non-point sources 2) Determine the maximum amount of pollutant load to a water body that will maintain water-quality standards 3) Allocate to each source a portion of the allowable load.

In 1998, the Indiana Department of Environmental Management (IDEM) included Salt Creek on the 303(d) list of impaired waters, which was approved by the U.S. Environmental Protection Agency (USEPA) on February 16, 1999 [IDEM, 2002b]. Each water body on the 303(d) list was determined to be impaired by one or more water-quality parameters and then ranked according to severity of impairment. Salt Creek was listed for *Escherichia coli* (*E. coli*) with a severity ranking of "low" [IDEM, 2002a]. Salt Creek is included on the 2002 303(d) list as a Category 5 waterbody. Category 5 denotes waters impaired or threatened by a pollutant or pollutants such that a TMDL is needed.

The goal of the TMDL program is to reduce the *E. coli* concentrations in Salt Creek to a level that meets its designated-use standard for a full body contact recreational stream. Indiana's water-quality standard for recreational waters is set forth in 327 I.A.C. 2-1-6 and 2-1.5-8(e)(2) [IDEM, 2002b]. The standard reads "*E. coli* bacteria, using membrane filter (MF) shall not exceed one hundred twenty five (125) per one hundred (100) milliliters as a geometric mean based on no less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period."

Escherichia coli is a bacteria found in the intestines of warm-blooded animals. While humans rely upon bacteria for production of important vitamins, such as vitamin K and B-complex vitamins, not all strains of bacteria within the *E. coli* species are beneficial (e. g. *E. coli* O157:H7) [Brown, 1995]. Contact and/or ingestion of these strains of *E. coli* or food and water contaminated with *E. coli* indicates an increased risk of illness in humans. It is not known how many or exactly which bacteria strains cause human illness. Therefore, *E. coli* is used as an indicator species when water is tested. When *E. coli* are present, it is assumed that the water contains harmful bacterial strains and poses a health risk to humans.

In addition, the presence of *E. coli* in water also indicates the potential presence of other pathogens, such as protozoans and viruses, that can also cause disease in humans. So, the presence of *E. coli* indicates contamination which is potentially harmful.

Contamination occurs when water comes in contact with feces from a warm-blooded animal. Water bodies such as lakes, reservoirs, streams, and groundwater can become contaminated from animal or human sources. Feces of wildlife, pets, and livestock (raccoons, deer, geese, cows, dogs, hogs, etc.) can wash off the landscape into nearby water bodies during precipitation events or be directly deposited by the animal into the water. Human sources include, but are not limited to, failed septic systems, illegal discharges, and sewer overflows.

This report shows the development of a TMDL for *E. coli* in the Salt Creek watershed. It describes the environmental and hydrologic setting of the watershed, includes an inventory of existing water-quality data collected in the watershed, and presents the results of the source assessment and modeling analysis.

2 Basin Characterization

2.1 Environmental Setting

Salt Creek is located in northwestern Indiana (IN) in Porter County (Figure 1). The watershed includes the city of Valparaiso as well as portions of Chesterton and Portage. Salt Creek originates south of Valparaiso, flows northwest around the city, and empties into the Little Calumet River just east of Portage, IN (Figure 2). Ultimately, the creek drains into Lake Michigan through Burns Ditch. Over 30 tributaries and several springs contribute to the streamflow of Salt Creek. In addition, several lakes are located within the watershed; lakes with known names include Lake Louise, Loomis, Silver, and Sager's Lake.

The Salt Creek watershed is composed of 49,573 acres, covering 19% of Porter County. Fifty-one percent of the county's population is living in the watershed. Porter County has a population of 146,798 and has grown 12% since 1990. The largest city in the watershed, Valparaiso, accounts for 37% (27,428 people) of the population. Valparaiso has grown 11% since 1990 (Figure 3) [U.S.Census Bureau, 2000]. The majority (70%) of the acreage in Salt Creek's watershed supports only 15% of the population, at a density of less than 500 people per square mile. Much of this land is pasture and farmland. The majority of the watershed population (63%) live in densities of 1,000 - 10,000 people per square mile. These higher population densities are centered around Valparaiso, South Haven, Portage, and Lake Louise (Figure 4).

Until the 1800's, northwestern Indiana was undeveloped marsh lands, hardwood forests, or grasslands [IDNR, 1994]. Currently, agricultural row crops (23%) and pastureland (18%) account for the two largest land use categories in the watershed (Figure 5). The predominant crops grown in the basin are corn and soybeans (42% and 49%, respectively; Figure 6). The production of these crops has increased whereas wheat and hay production has decreased. Corn and soybean acreage has increased 26% and 71%, respectively, since 1950. In contrast, acreage of wheat and hay dropped 86% and 90%, respectively. Livestock numbers show a general downward trend since 1974, although, the data are lacking in more recent years (Figure 7). The number of cattle in the county has dropped 59%, from 12,700 in 1975 to 5,200 in 2001. Chicken production decreased 39% from 1974 to 1985 and the number of hogs decreased 17% from 1974 to 1995. The non-agricultural acreage is primarily forest and populated areas. The residential, dense residential, and commercial properties account for 18% of the watershed, combined. Deciduous forest covers 17% of the watershed.

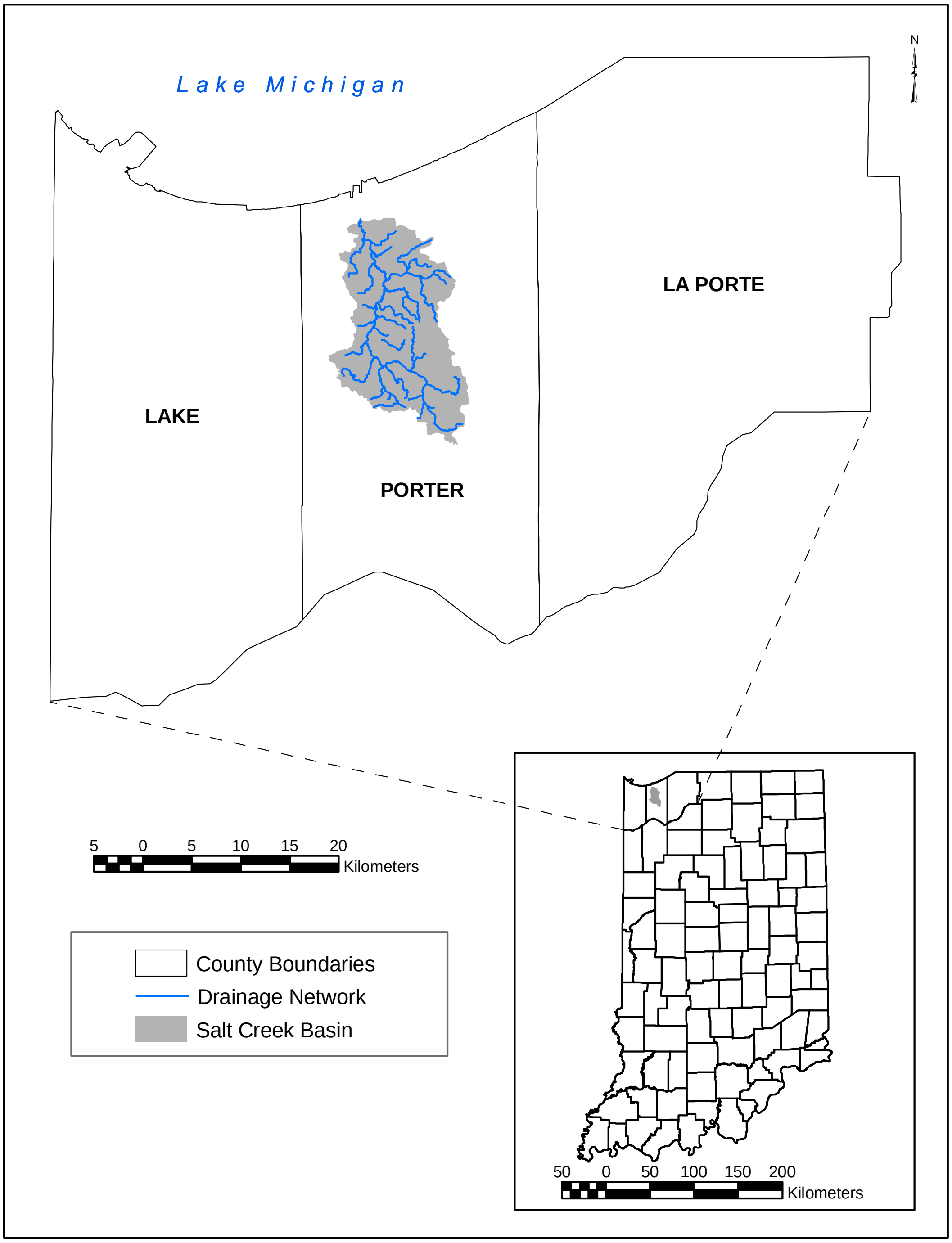


Figure 1: Location of the Salt Creek watershed in northwestern Indiana.

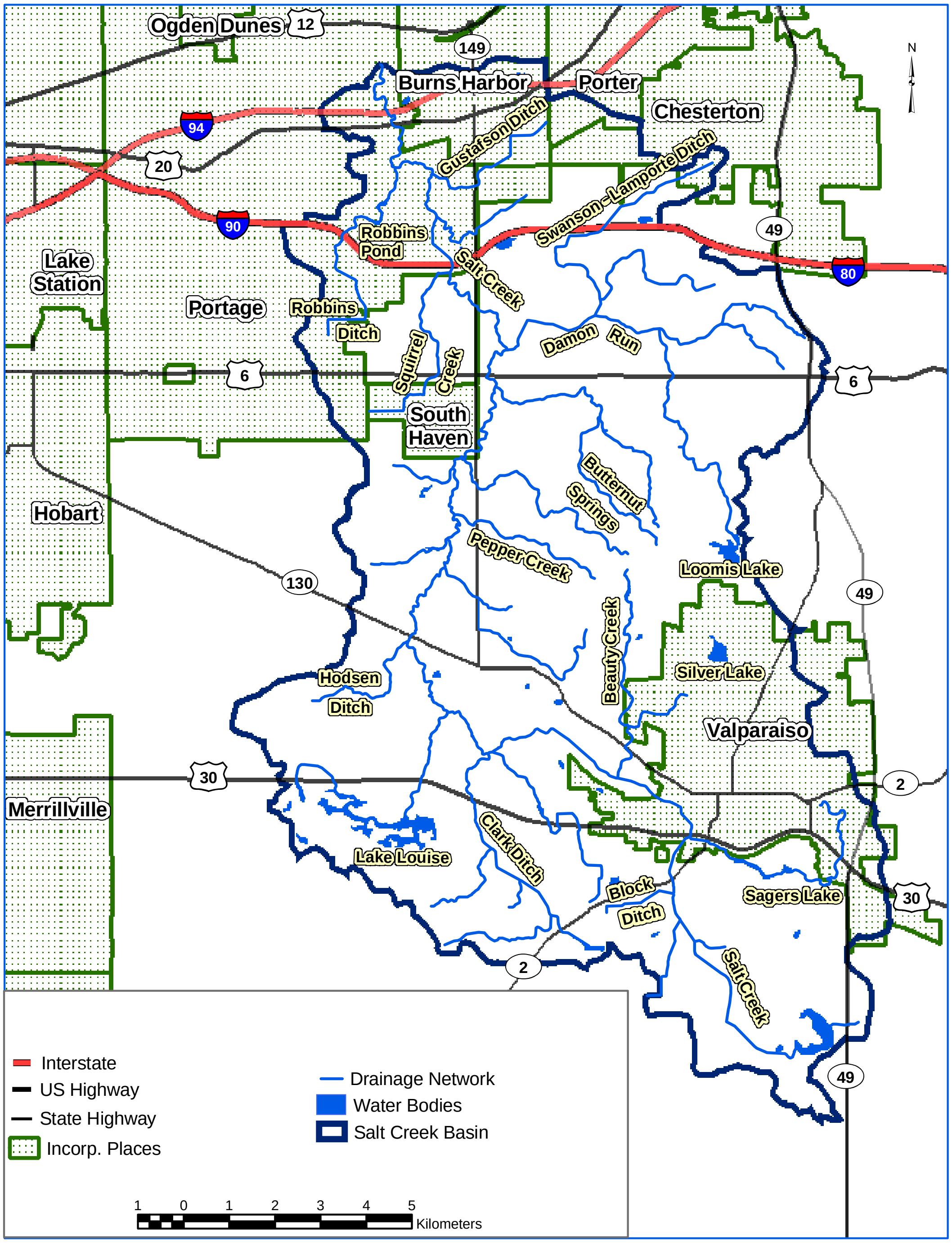


Figure 2: Major hydrologic features in the Salt Creek watershed [U.S. Geological Survey, 1999b].

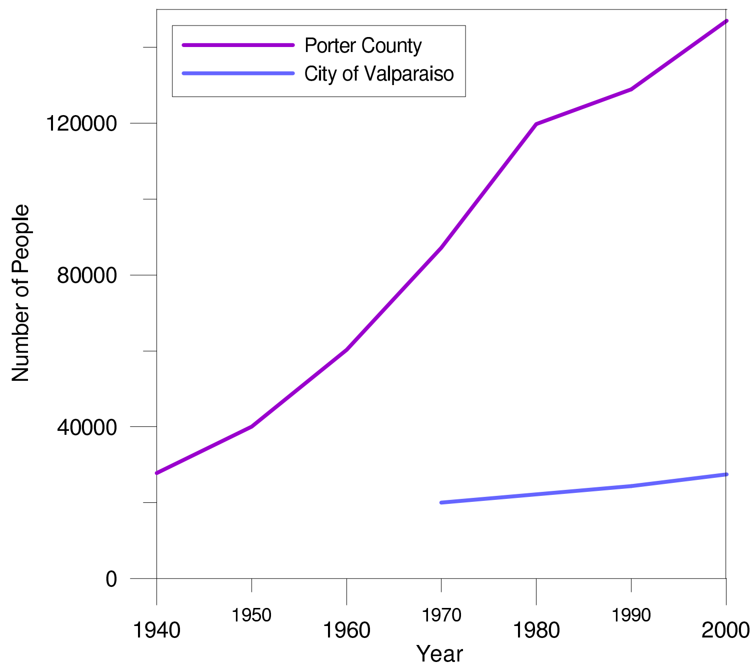


Figure 3: Population of Porter County and Valparaiso, Indiana from 1940-2000 [City of Valparaiso, 2002, U.S. Census Bureau, 2000].

The topography, surficial geology, soil development, and bedrock geology in the region were directly influenced by the advance and retreat of the Lake Michigan lobe of ice during the Wisconsinan glaciation [IDNR, 1994]. The bedrock deposits of the basin are from the Devonian age. These rocks consist of dolomite and limestone overlain by shale [Fenelon et al., 1994]. The unconsolidated deposits above the bedrock range from 150-200 feet thick in the watershed. The deepest unconsolidated unit is a dense, clay-loam till. In most of the watershed glaciofluvial deposits overlie the clay till. The glaciofluvial deposits consist of sand and gravel interbedded with clay [Fenelon et al., 1994]. In the northern portion of the watershed a surficial sand and gravel aquifer unit exists that is primarily recharged directly from precipitation. At higher elevations in the watershed this aquifer is discontinuous, overlain by surficial till, and recharged from the overlying till [Fenelon et al., 1994].

The continuous and discontinuous aquifer systems coincide with the two physiographic

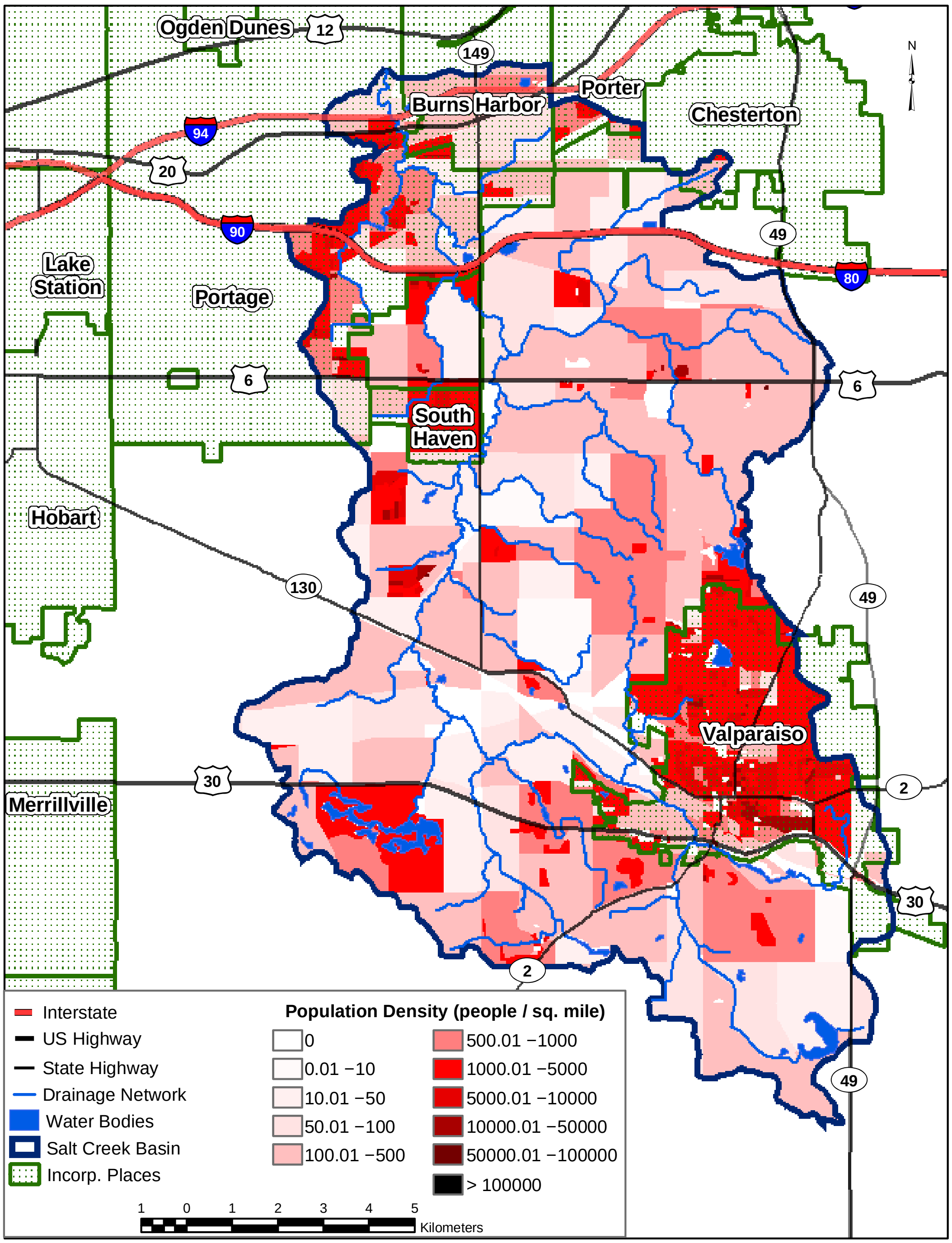


Figure 4: Population density in the Salt Creek basin [U.S.Census Bureau, 2000].

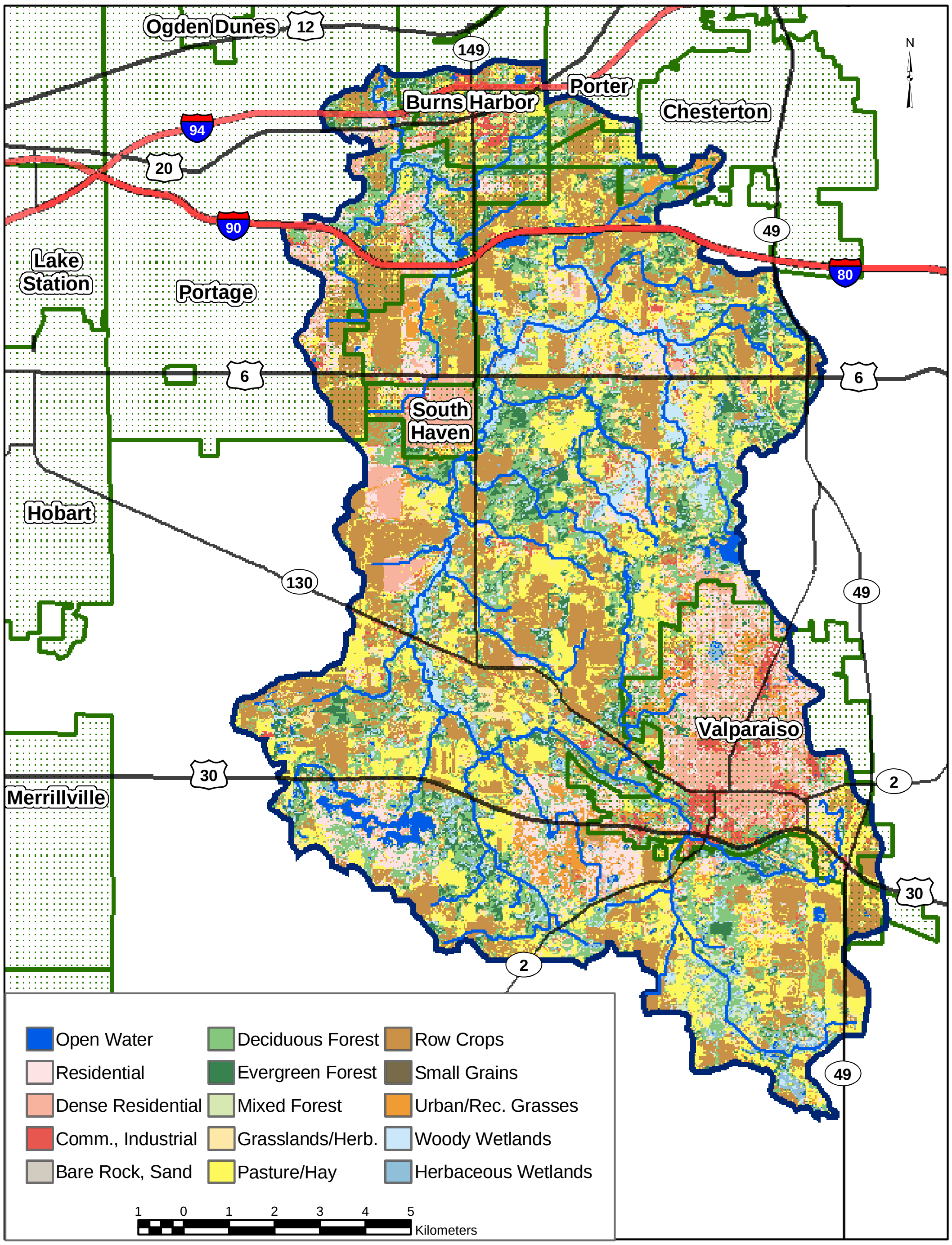


Figure 5: Land use and land cover in the Salt Creek basin [U.S. Geological Survey, 2000].

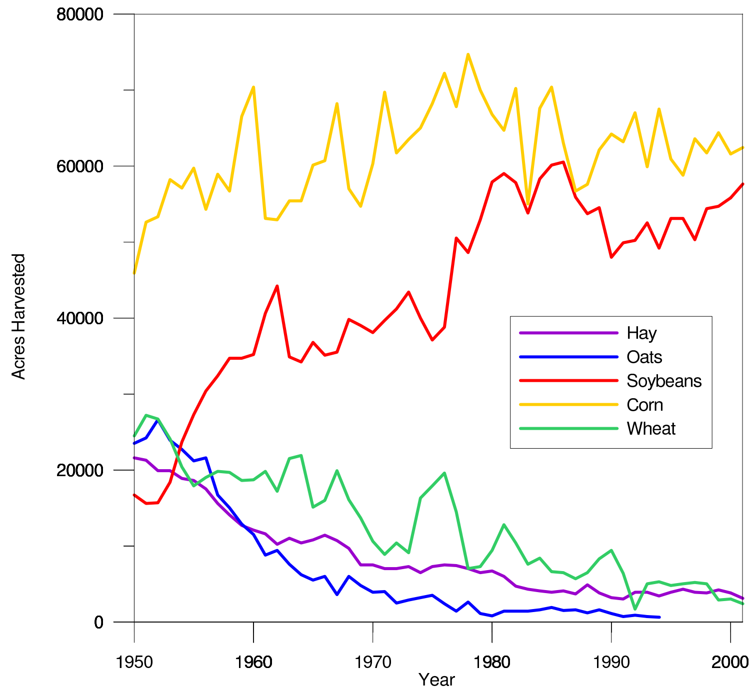


Figure 6: Major crop acreage in Porter County, 1950–2001 [Indiana Agricultural Statistics Service, 2002].

regions of the watershed. The two physiographic regions in the Salt Creek watershed are the Calumet Lacustrine Plain and the Valparaiso Morainal Area. The Valparaiso Moraine is characterized by some of the highest elevations in the watershed, ranging from 220-270 meters above sea-level in the southern section of the watershed near Valparaiso and Lake Louise (Figure 8). The northern, downstream section of the watershed has the lowest elevation (170-190 meters above sea-level). Low elevations are characteristic of the Calumet Lacustrine Plain. The surficial geology of northern Indiana follows regional lines similar to topography due to influence of the Wisconsinan glaciation (Figure 9). The watershed consists predominantly of mixed drift (34%), clay-loam to silt-loam till (31%), clay-loam to silt-loam (10%), and lake sand (10%).

The watershed is comprised of six soil associations, three of which dominate (Figure 10). The Blount-Glynwood-Morley series is the predominant soil association, occupy-

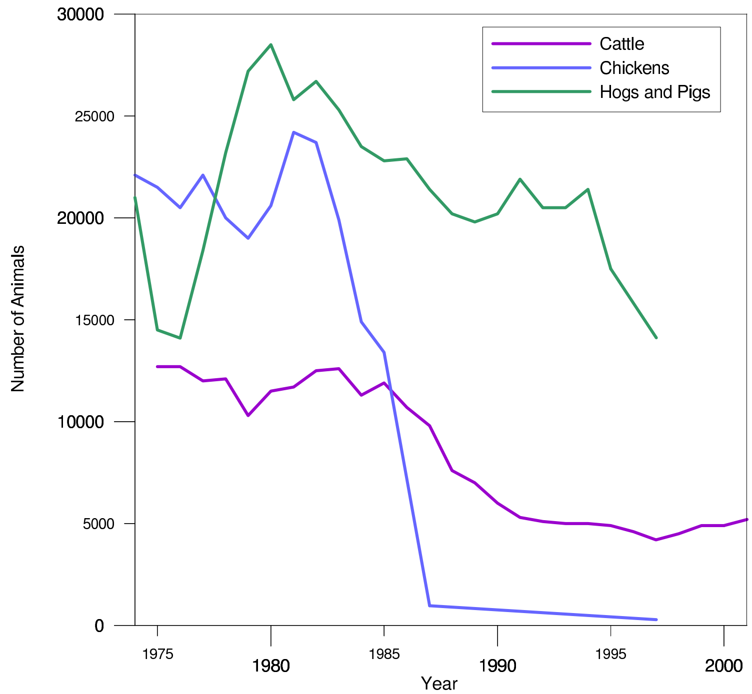


Figure 7: Livestock population in Porter County, 1975–2001 [Indiana Agricultural Statistics Service, 2002].

ing 55% of the watershed. These soils are deep or moderately deep to dense till. They are moderately to poorly drained soils "formed in a thin layer of loess and underlying till." The Blount-Glynwood-Morley soils are typically found on ground moraines and end moraines like that of the Salt Creek watershed [U.S. Department of Agriculture, 2002]. The Rensselaer-Darroch-Whitaker soil series, which is associated with 18% of the watershed, consists of deep, poorly and somewhat poorly drained soils. This association corresponds with the low elevations in the northern section of the watershed. The Rensselaer-Darroch-Whitaker soils are "formed in silty and loamy sediments of lake plains, outwash plains, and till plains" [U.S. Department of Agriculture, 2002]. The Riddles-Elston-Oshtemo soil series is found in 15% of the watershed. This association consists of very deep, well drained soils "formed in loamy and sandy till" and are found south of Valparaiso and western portions of the watershed [U.S. Department of Agriculture, 2002].

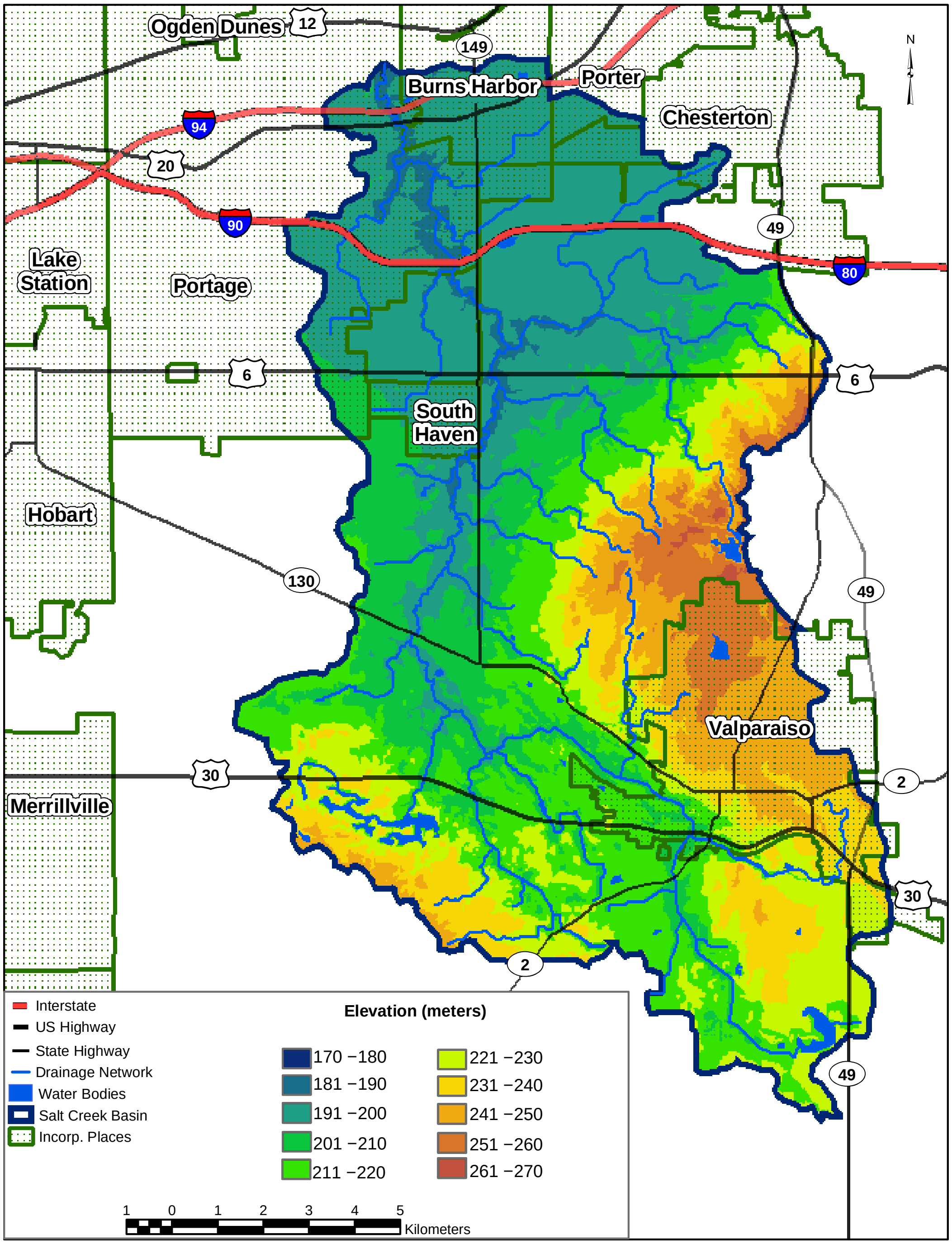


Figure 8: Physiographic relief in the Salt Creek basin [U.S. Geological Survey, 1999].

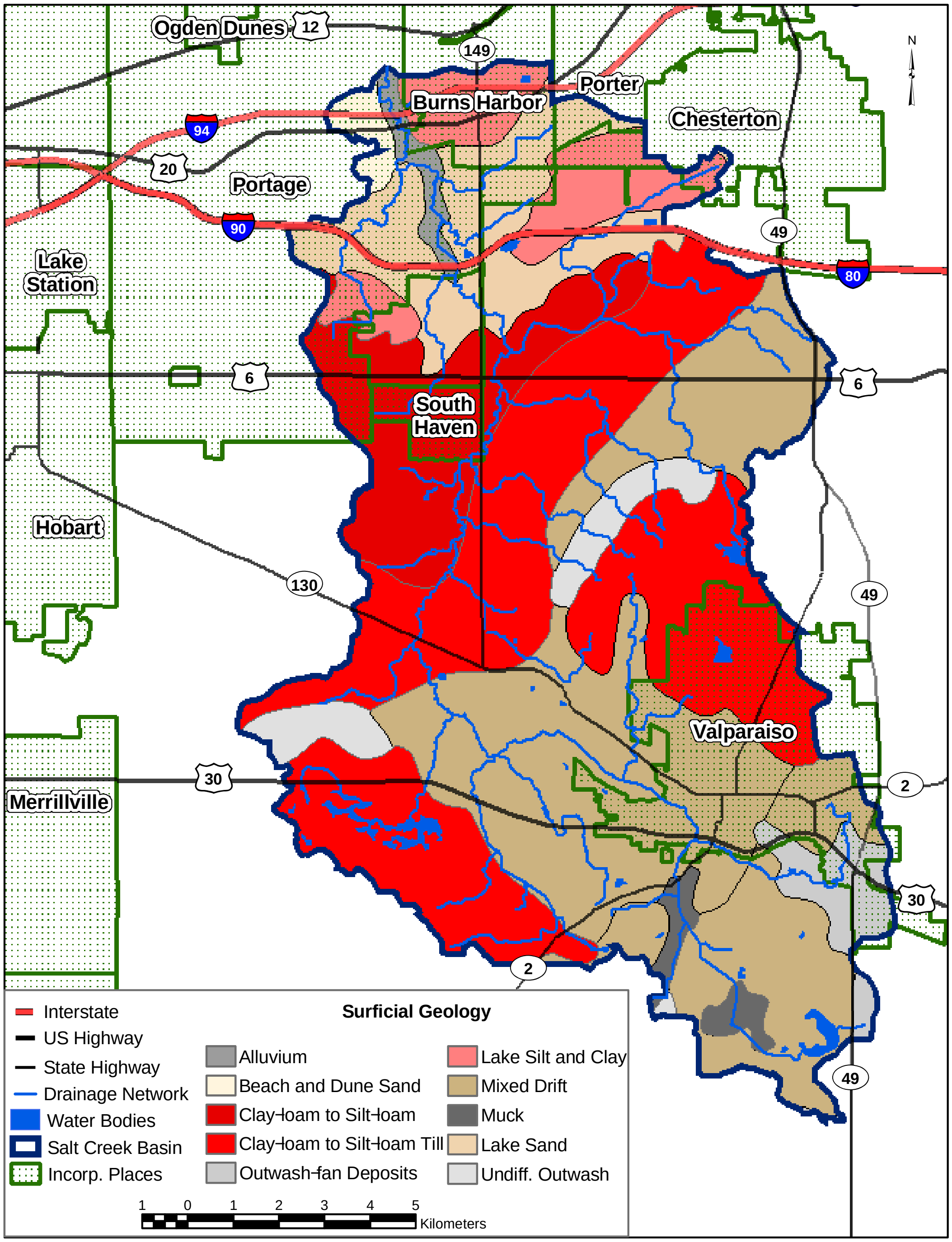


Figure 9: Generalized glacial geology in the Salt Creek basin [Gray and Walls, 2002].

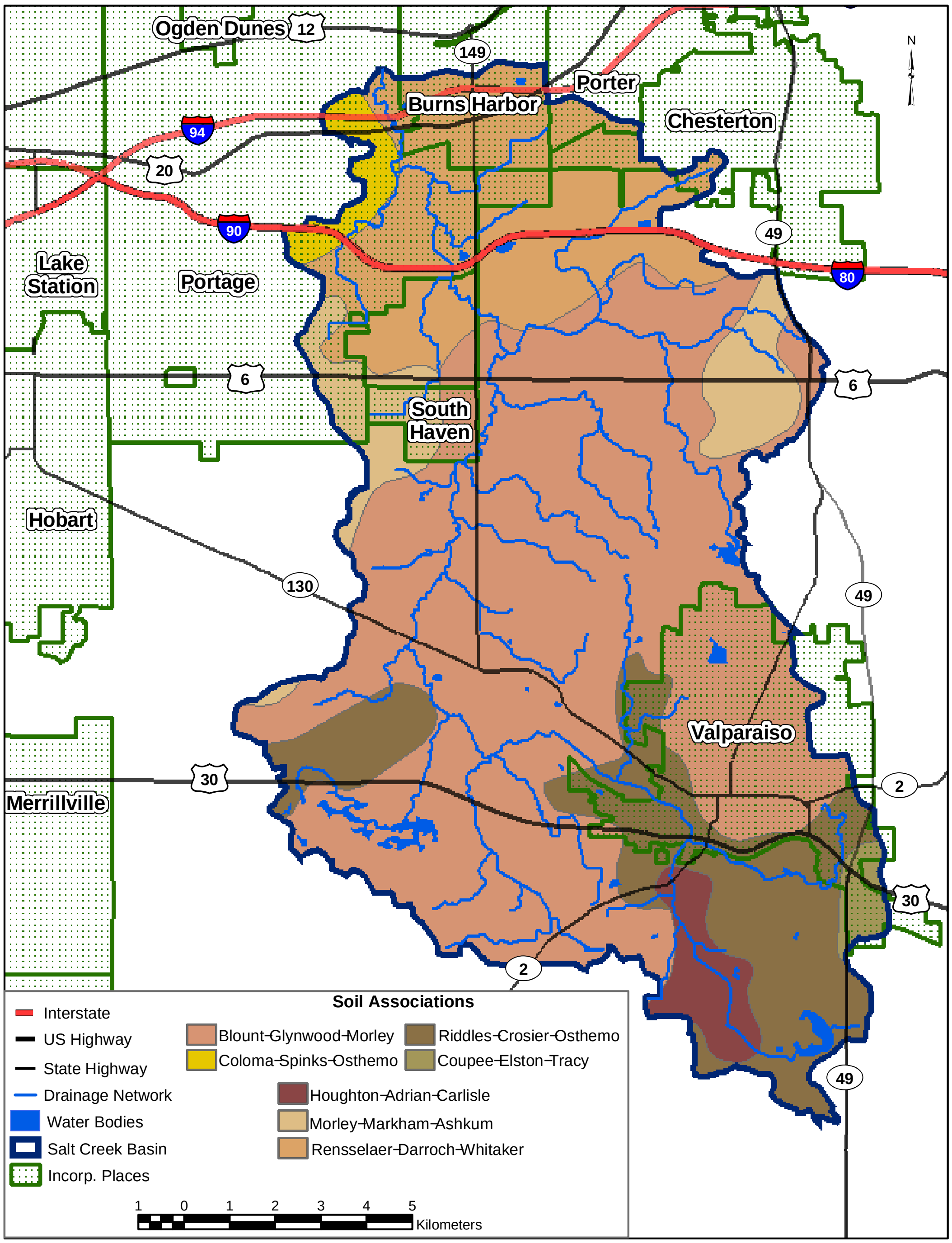


Figure 10: Major soil regions in the Salt Creek basin [U.S. Department of Agriculture, 1994].

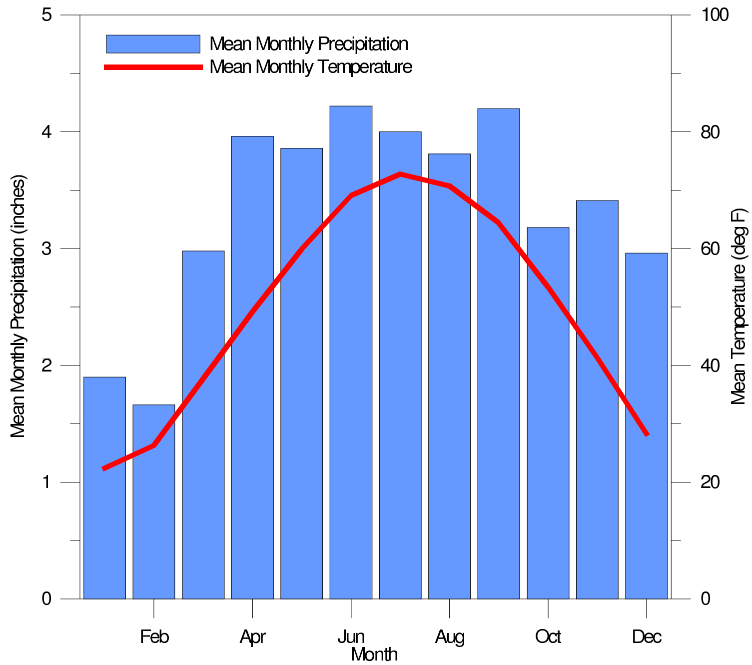


Figure 11: Mean temperature and precipitation in Valparaiso, Indiana, 1961–1990 [Purdue University, 2002].

2.2 Hydrologic Setting

The climate of the Salt Creek region is classified as temperate continental, which describes an area with warm summers and cool winters [IDNR, 1994]. The mean monthly temperature in summer, based on records from 1971-2000, ranges from 69° to 73°F. The mean monthly temperature in winter ranges from 22° to 28° F (Figure 11) [Purdue University, 2002]. The close proximity of Lake Michigan causes the vicinity to have increased amounts of snowfall in winter. The Salt Creek watershed receives approximately 50 inches of snow in an average winter [IDNR, 1994]. The average annual precipitation is 40 inches, with the heaviest rains occurring in the spring and summer months (Figure 11).Approximately 70% of the rainfall is lost to evapotranspiration, leaving about 12 inches of surplus for the watershed's surface water and groundwater supply [IDNR, 1994].

Stream order is a common stream classification system which helps describe a river's size and basin area; the greater the stream order, the greater the size and basin area [Allan, 1995]. Using this system, Salt Creek is a fourth order stream. The USGS maintained a stream gage near McCool, Indiana (Figure 12), from 1945-1991. A flow-duration curve (Figure 13) was developed with daily values from the period of record. A flow-duration curve shows the percent of time that a specified discharge was equaled or exceeded. From the flow-duration curve, the 20-to-90 percent flow-duration ratio can be calculated to indicate streamflow variability. The 20-to-90-percent flow-duration ratio is a numerical index that describes the slope of the middle portion of the flow-duration curve [IDNR, 1994]. It reflects not only flood-attenuating factors, but also the relative component of stream flow due to base flow [IDNR, 1994]. The low 20-to-90 percent flow-duration ratio for Salt Creek, 3.0, indicates that the stream has high base flow. This is indicative of the surficial sand and gravel aquifer in the lower region of the watershed. The aquifer absorbs precipitation in the watershed during wet weather, dampening the high flows, but can also release water to the stream in times of dry weather, maintaining high base flow. This enables Salt Creek and other streams which flow through the Valparaiso Moraine to have some of the highest sustained low flows relative to drainage area in the state [IDNR, 1994]. The average discharge of Salt Creek is $76.6cfs$[1] and the minimum daily discharge is $10cfs$. The lowest 7-day average flow which occurs (on average) once every 10 years (7Q10 flow) is $19cfs$ at the McCool stream gage [Fowler and Wilson, 1996]. The mean monthly flows for Salt Creek are shown in Figure 14. The mean flows show a pattern typical to Midwestern streams; flows are highest in March and April and lowest in August and September.

[1]Cubic feet per second

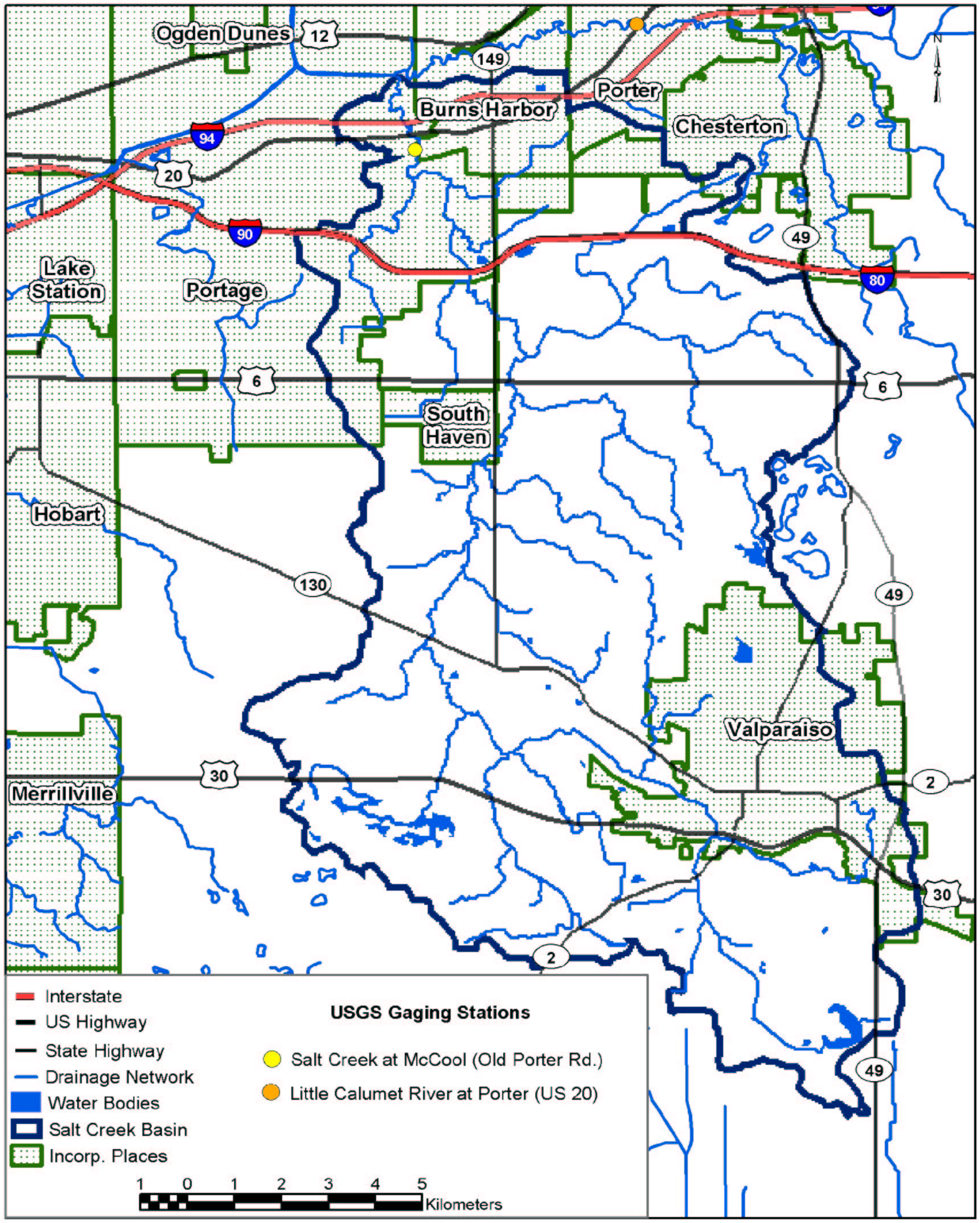


Figure 12: Location of USGS stream gages.

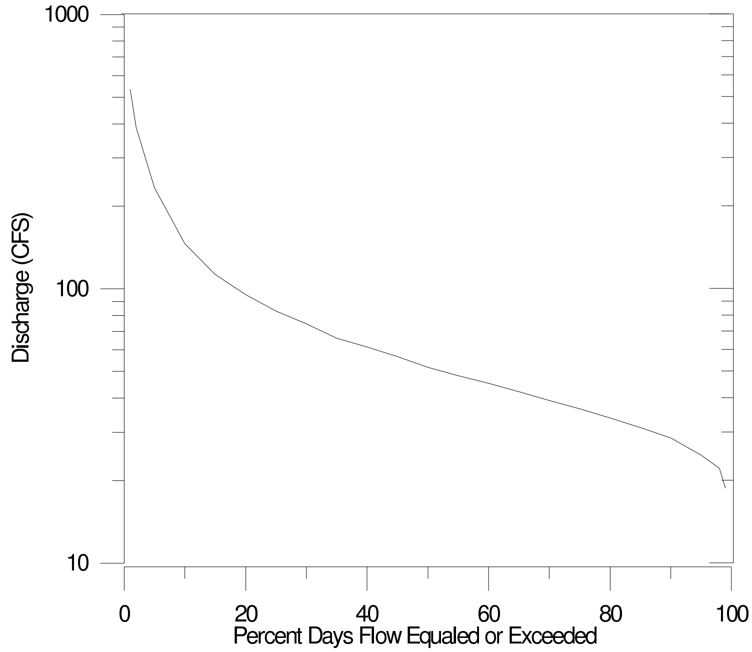


Figure 13: Flow–duration curve for Salt Creek.

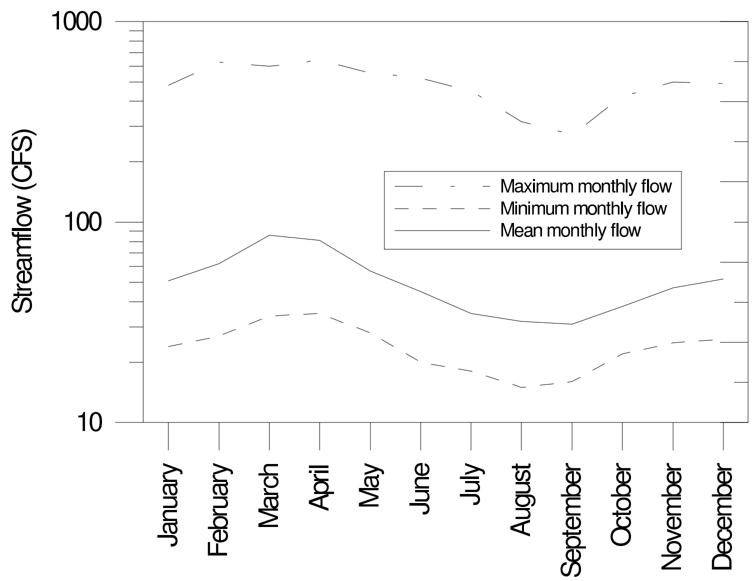


Figure 14: Mean monthly flows in Salt Creek.

3 Water-Quality Data

3.1 Data Inventory and Assessment

Existing water-quality data sets that were potentially relevant to development of a Salt Creek TMDL were identified, compiled, and organized. The data sets were evaluated based on QA/QC pedigree. Data sets that were deemed acceptable were collected and analyzed using the State's Quality Assurance Project Plan (QAPP) [IDEM, 1999]. Data sets were also deemed acceptable if the data was collected and analyzed in a manner comparable to the State's procedures and were approved by the State. The QAPP classifies data into three categories:

1. Enforcement data – All data meet all QC checks. The most stringent category.

2. Acceptable data – Possess scientific and statistical integrity and are suitable for decision making.

3. Estimated data – Are not suitable for enforcement or decision making, but may be appropriate for planning and identifying possible contaminant levels.

Six data sets that included results for *E. coli* measurements in the Salt Creek basin were compiled and evaluated (Table 1). No other data sets with *E. coli* results in the basin were identified. The Porter County Health Department (PCHD) collects bacteria samples for the purpose of evaluating complaints of failed septic systems, but the data are not maintained in a fashion that would make them usable.

The State *E. coli* standards specify concentrations determined specifically by membrane filtration. In short, membrane filtration entails filtering a water sample through a membrane that retains the bacteria. After filtration, the membrane containing the bacteria is placed on a selective medium and incubated. A direct count of *E. coli* in water is determined by the volume of water filtered and the number of colonies that grow on the surface of the membrane [U.S. EPA, 2000c]. In January, 2000, the State approved the use of Method 9223-SM Enzyme Substrate Coliform Test (also known as Colilert) as a method of analysis for *E. coli* to evaluate waters for full contact recreational uses. The Colilert Test does not utilize membrane filtration. Instead, water samples are mixed directly with substrates and incubated. If *E. coli* are present, enzymes produced by the organism react with the substrate and cause the sample to exhibit florescence *[APHA, 1992]*. A sample concentration can be enumerated by traditional serial dilutions or by comparison to standards.

With the exception of one year of data collected by the Non-point Source Monitoring Project, all six data sets were deemed acceptable for use in development of an *E. coli* TMDL for Salt Creek. A brief description of each data set follows.

Fixed Station Monitoring Program

IDEM's Assessment Branch maintains a network of around 160 targeted sampling sites statewide [IDEM, 2001]. The program serves a variety of purposes including NPDES permitting, source-water monitoring, and trend analysis. The sites are located on the main stem of major rivers throughout the state. Sites are sampled once per month for a variety of parameters, depending on the site. The results represent a range of hydrologic conditions. Two active Fixed Stations are located within the Salt Creek basin (Figure 15). Site LMG050-0006 is located at the mouth of the basin, near the confluence with the Little Calumet River. Site LMG050-0007 is located off State Road 130, downstream of the Valparaiso Sewage Treatment Plant. Samples for *E. coli* have been collected at the two Fixed Stations since 1990. Samples collected and analyzed in recent years for the Fixed Station data have followed the State's QAPP. Samples collected in prior years have been deemed acceptable by the State.

Statewide *E. coli* Monitoring Project

The Statewide *E. coli* Monitoring Project is part of the IDEM Assessment Branch Bacteriological Sampling Program [IDEM, 2001]. The project was initiated in the spring of 2000 as part of a USEPA 319 grant. Samples are collected for *E. coli*, coliforms, and physical parameters. The results are used to make comprehensive assessments of surface water-quality in order to determine stream standard attainment for recreational use [Hirschinger, 2002]. Two sites were sampled in the Salt Creek basin (Figure 16). One site coincides with the Fixed Station at the mouth of the basin (LMG050-0006). The other site is located off a county bridge, north of State Road 130 (LMG050-0009). Samples were collected five times within a thirty day period (July and August, 2000) so that a geometric mean could be evaluated against the respective standard. The samples were collected and analyzed according to the State's QAPP and are acceptable.

Table 1: Water-quality data sets from the Salt Creek watershed.

Collecting Organization	Project	Description	Method	QC Category
IDEM	Fixed Station Monitoring Program	Long-term monthly monitoring at two fixed sites, 1990–2001	MF, 1990-2000 Colilert, 2000-2001	Acceptable
IDEM	Statewide *E. coli* Monitoring Project	Sampling to evaluate 5-sample geometric mean at two sites during recreation season in 2000.	Colilert	Acceptable
IDEM	2000 Salt Creek Assessment	Sampling to evaluate 5–sample geometric mean at 24 sites in 2000	Colilert	Acceptable
IDEM/Lake Michigan Interagency Task Force	Non–Point Source Monitoring Project (NPSMP)	Sampling to evaluate non–point source effects at 12 sites during recreational season, 1999-2002	MF, 1999 Colilert, 2000-2002	1999, Estimated 2000-2002, Acceptable
Lake Michigan Interagency Task Force	Point Source Committee	Weekly samples at 8 sites during recreational season, 1997–1999	MF	Valparaiso, Acceptable PCHD, Acceptable
NPDES Facilities	Permit Requirement	Monthly discharge monitoring reports, 1989-2002	Varied	Acceptable

[IDEM, Indiana Department of Environmental Management; MF, Membrane Filtration; NPDES, National Pollution Discharge Elimination System]

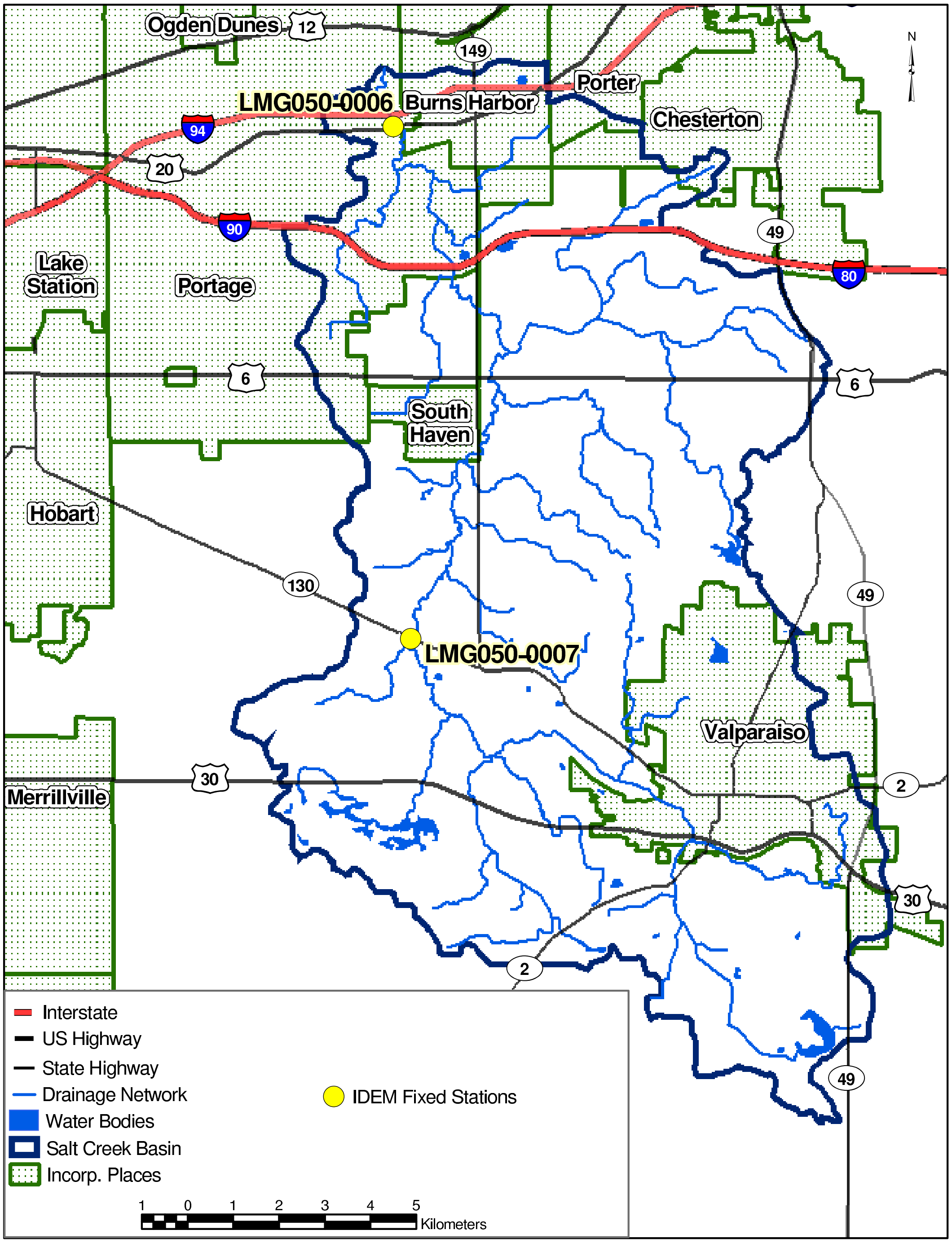


Figure 15: Locations of IDEM fixed stations in the Salt Creek basin.

Salt Creek Assessment for the Development of TMDL

IDEM surveyed Salt Creek in 2000 to reassess the impaired water body and collect data for TMDL modeling purposes. Samples were collected at twenty-four locations (Figure 16) for *E. coli* and physical parameters. The sites are distributed along the length of the main stem and include most of the major tributary creeks. Five samples were collected at each site within a thirty day period between September and October. The samples were collected and analyzed according to the State's QAPP and are acceptable.

Lake Michigan Interagency Task Force/Non-point Source Monitoring Project

The Interagency Task Force on *E. coli* (Task Force) was initiated in 1996 to address the issue of beach closings along Indiana's Lake Michigan shoreline. The Task Force consists of technical experts from state, local, and federal agencies and strives to address the issue with a comprehensive approach. The Non-point Source Committee launched the Monitoring Project (NPSMP) to study bacteria levels in the headwaters of tributaries to Lake Michigan. The project was designed to identify streams affected by non-point sources that may be contributing significant loads of bacteria to the lake. Samples were collected at 12 sites during the recreational season between 1999 and 2002 [Forsness et al., 2001, Clendaniel and Luther, 2001]. Most of the sites are located on tributaries to Salt Creek (Figure 17). Samples were analyzed for *E. coli* and a limited number of physical parameters. With the exception of the 1999, the data were collected and analyzed according to a Quality Assurance Plan that was approved by the U.S. Environmental Protection Agency [Luther, 2000]. The data are acceptable with the exception of data collected in 1999. The 1999 data are considered estimated.

Lake Michigan Interagency Task Force/Point Source Committee

The Task Force initiated the Point Source Committee in 1997 to evaluate the relationships between point source discharges and bacteria levels in Lake Michigan and its Indiana tributaries. Emphasis was placed on researching the conditions that lead to beach closures. The Point Source Committee established a Volunteer Sampling Network comprised of representatives of industry and government. Network members in the Salt Creek watershed include the City of Valparaiso and the Porter County Health Department. In addition to in-stream samples, the work included lake samples, rainfall measurements, and CSO measurements

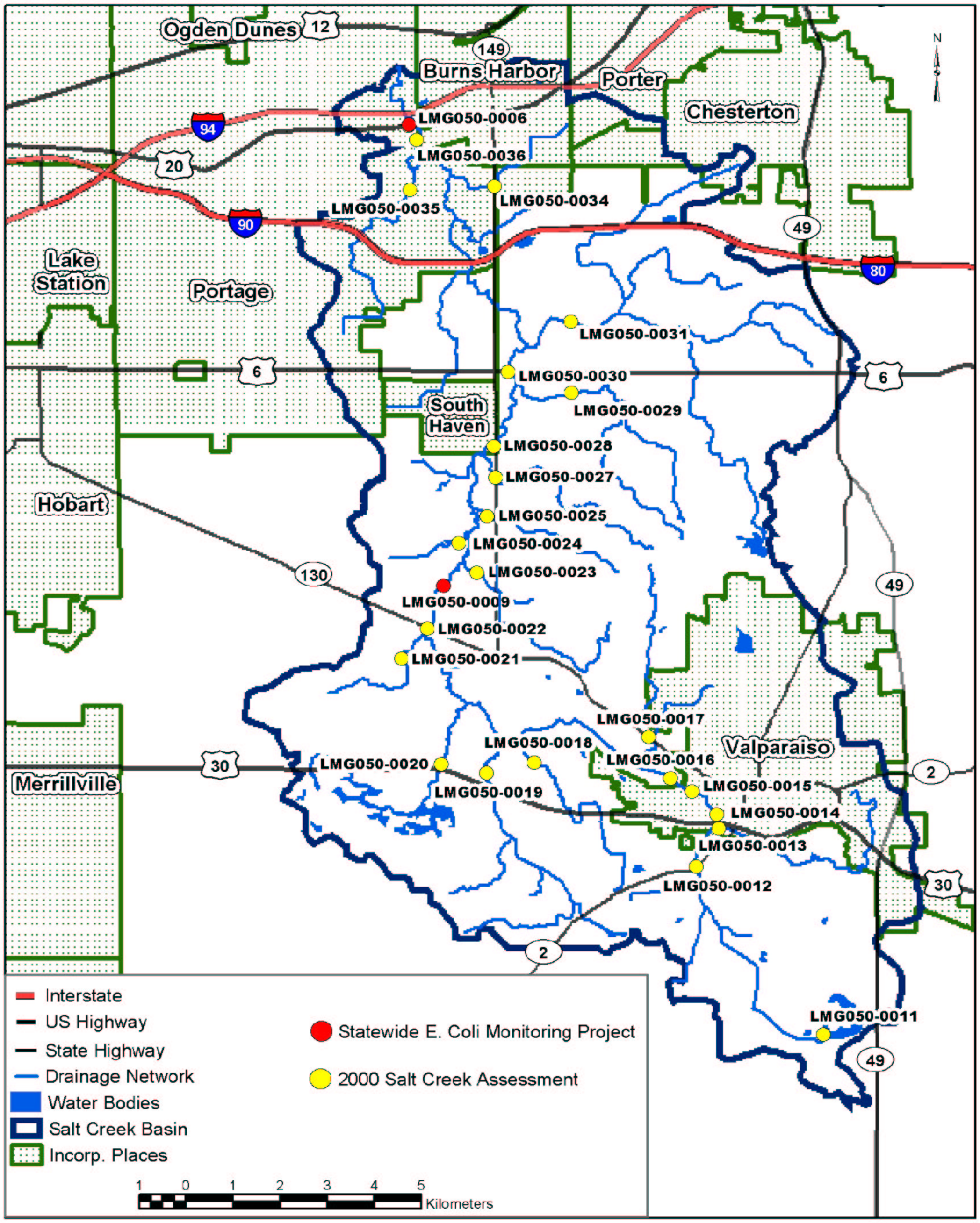


Figure 16: Locations of sampling sites for IDEM special studies in the Salt Creek basin.

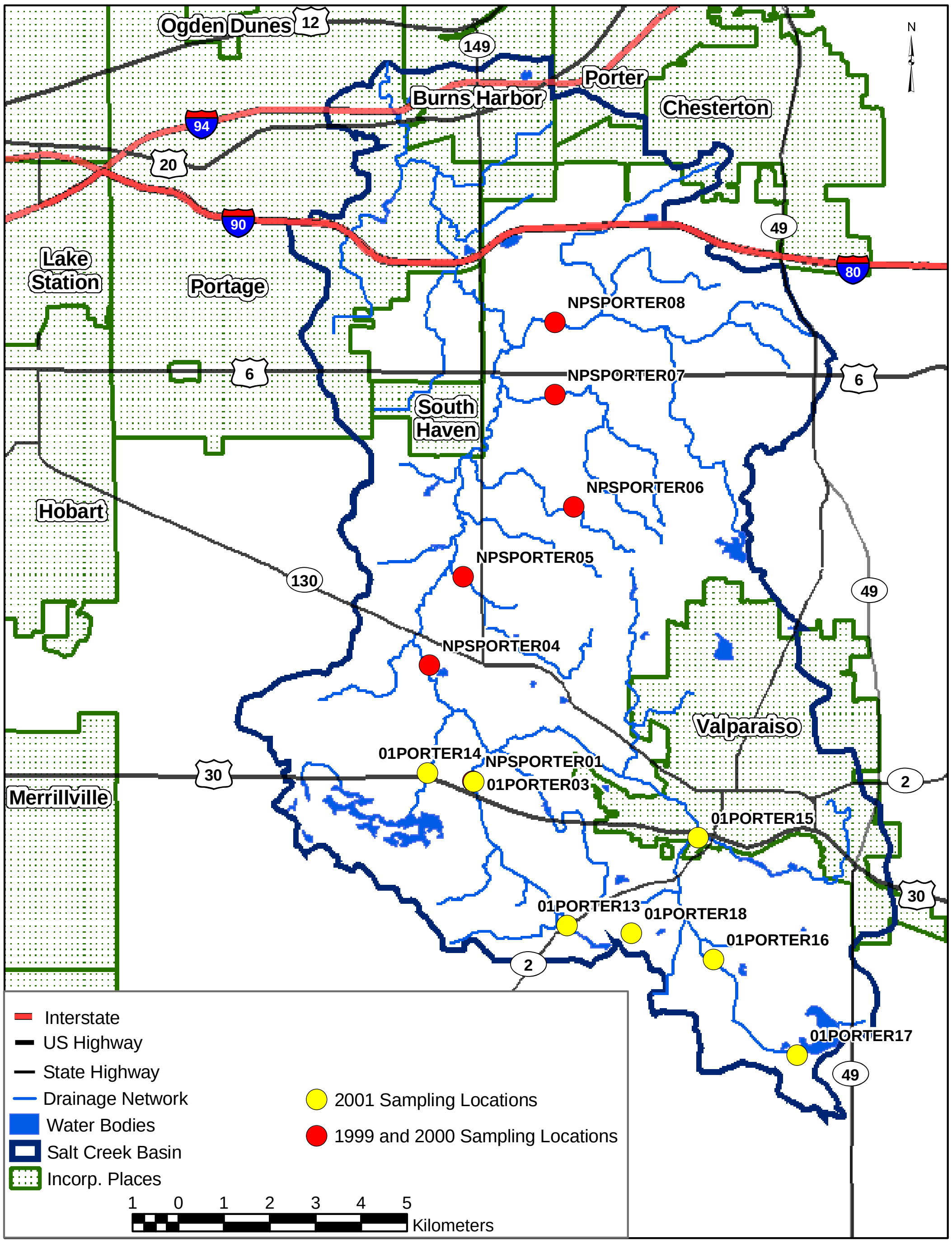


Figure 17: Locations of sites in the Salt Creek basin sampled for the Lake Michigan Interagency Task Force/Non–point Source Committee.

[Kuss, 2001]. Eight sites were located in the Salt Creek basin (Figure 18), mostly along the main stem. Some preliminary sampling was conducted in 1997. However, most of the sampling for this effort was conducted in the Salt Creek basin in 1998 and 1999. Samples were collected on an approximately weekly basis from mid-April to November. The time-series generated from the weekly samples combined with daily rainfall and CSO measurements provide a unique opportunity to examine cause and effect relationships in the watershed.

Early in the sampling program, the Task Force produced a document that established standard operating procedures for the collection and analysis of *E. coli* [ITF, 1999]. The City of Valparaiso collected and analyzed samples in conjunction with their compliance monitoring program. Compliance monitoring data must meet the standards of Enforcement as classified by the State's QAPP. Enforcement data meet the State's most stringent QA/QC standards. The samples collected by the Porter County Health Department were analyzed by the Laporte County Laboratory and were deemed acceptable based on the Lab's response to an IDEM quality control questionnaire.

Discharge Monitoring Reports from NPDES Facilities

Ten facilities with the potential to contribute *E.* coli to the stream are located in Salt Creek watershed (Table 2). IDEM issues permits to each of these facilities and enforces compliance. Some of the facility permits cover multiple outfalls. A total of twelve outfalls in the watershed are potential sources of *E. coli* (Figure 19). The NPDES facilities analyze the required number of samples (Table 2) for each permitted parameter. Because the samples are collected and analyzed for compliance measures, the data meet the State's standards for Enforcement data. Permitted facilities must compile and submit a discharge monitoring report to IDEM every month. Discharge monitoring report data from 1989-2002 for all relevant facilities in the watershed were used in the analysis.

3.2 Data Analysis

The water-quality data sets deemed "acceptable" for the project were analyzed to 1) confirm impairments and 2) determine the nature of *E. coli* loading in the Salt Creek basin. Results from this analysis will help guide the higher level, more complex analyses that will follow. The goal of the analysis was to identify the temporal, spatial, and hydrologic factors associated with the impairment, as well as gain insight into possible sources, relative magnitudes,

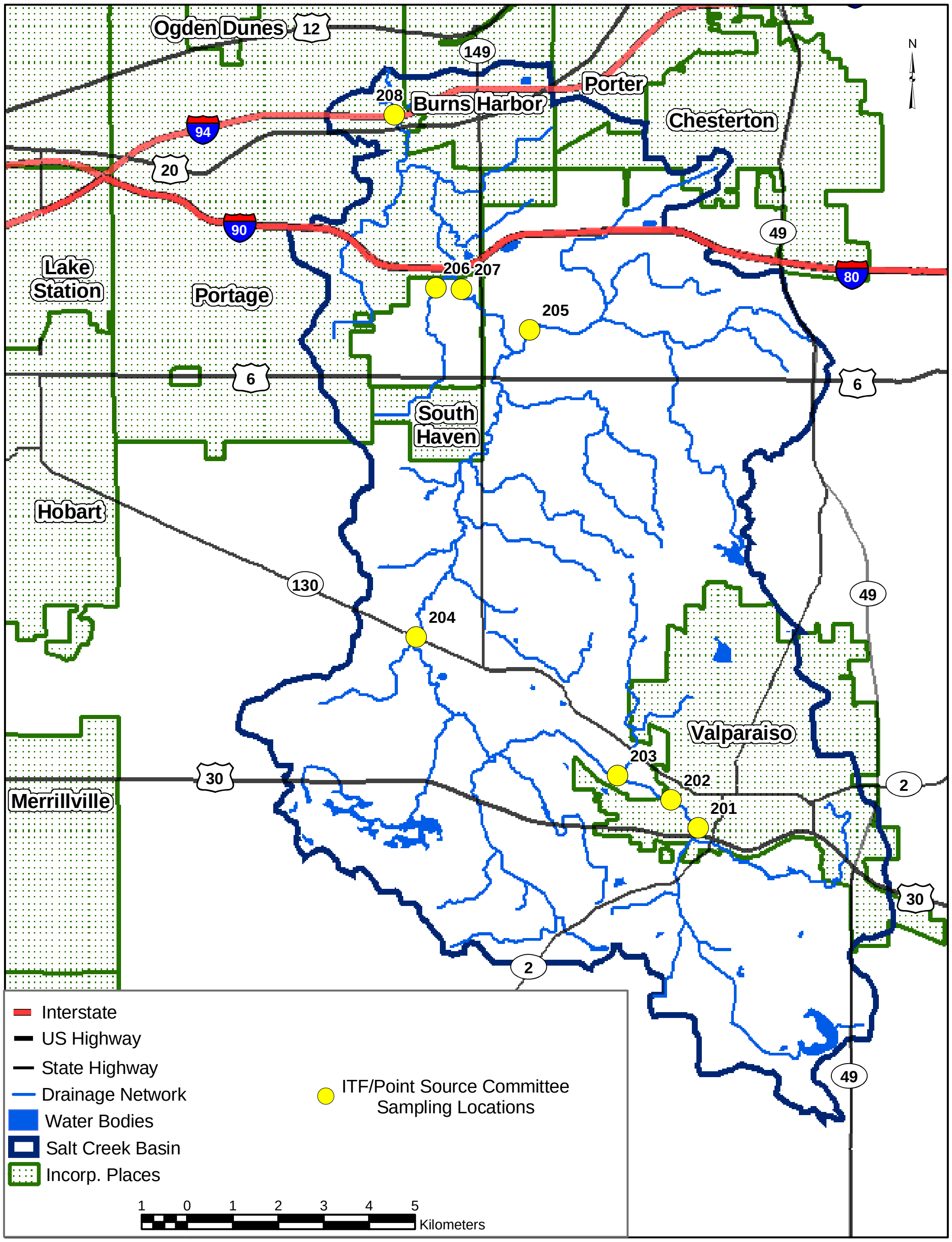


Figure 18: Locations of sites in the Salt Creek basin sampled for the Lake Michigan Interagency Task Force/Point Source Committee.

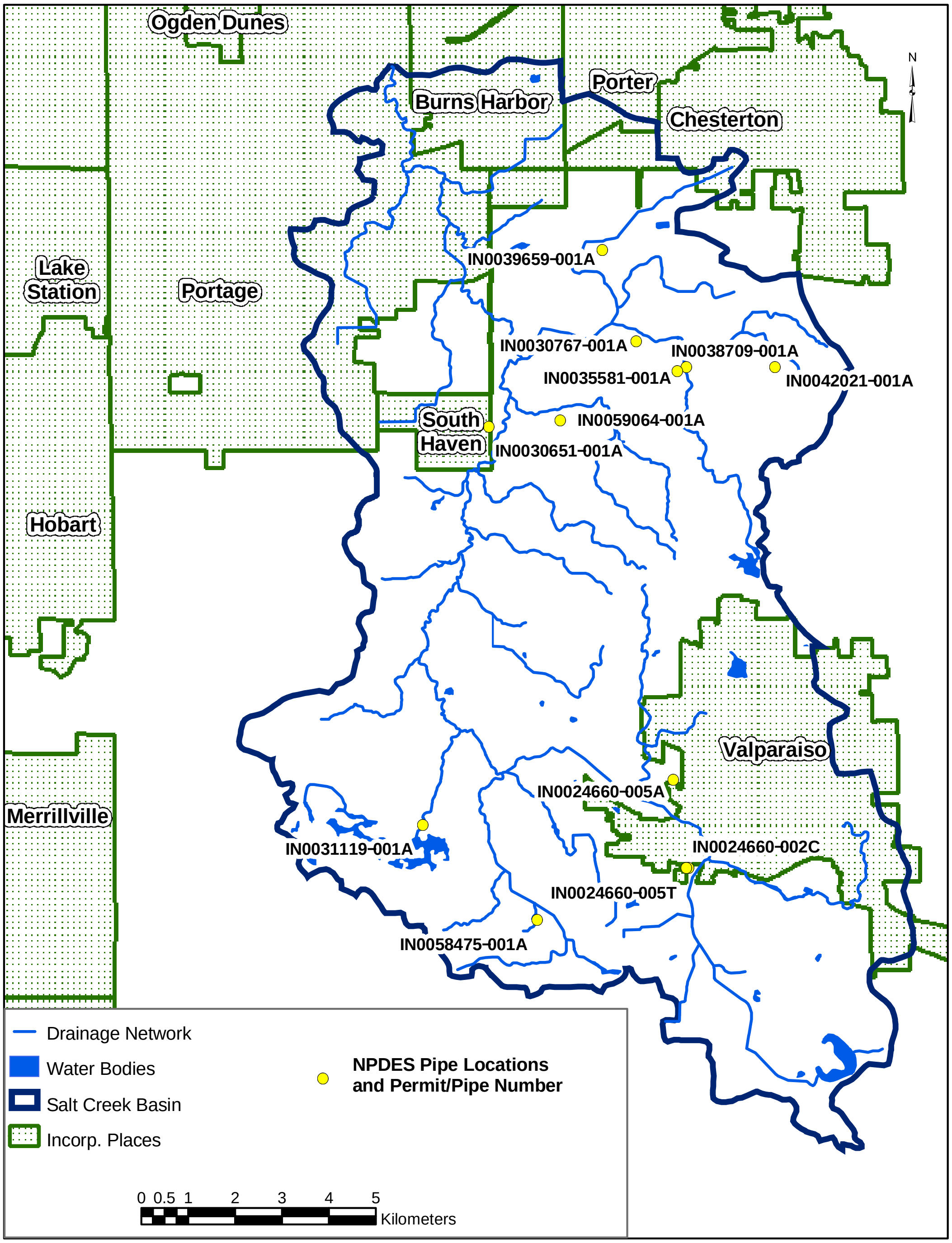


Figure 19: NPDES effluent-pipe locations in the Salt Creek watershed that are potential sources of *E. coli*.

and loading characteristics. By understanding and defining the critical conditions during which the designated use is not supported, we can begin to address the potential causes of impairment and use the information to guide subsequent work toward development of a TMDL for Salt Creek.

3.2.1 Magnitude and Temporal Characteristics

In the early stages of TMDL development it is important to understand when loading occurs and the relative magnitude of impairment. A good understanding of the magnitude and timing of impairment leads to insight about possible sources. The data sets generated by the two Fixed Stations maintained by IDEM (Figure 15) provide valuable information with respect to *E. coli* loading in Salt Creek. The data, collected approximately every month since 1990, supply a long-term record of conditions in the watershed. In addition, the measurements reflect *E. coli* concentrations over a range of climatic and hydrologic conditions in the watershed throughout the year.

Fixed Station Monitoring Data

Figure 20 shows the full record of *E. coli* concentrations measured at the two Fixed Station monitoring sites (Figure 15). The single-sample standard for *E. coli* ($235 CFU/100 ml$[2]) is included on the graph for reference. Many of the samples measured at the two monitoring sites over the period of record exceed the standard. Some of the measurements are well over an order of magnitude higher than the standard. More exceedances were recorded at upstream site LMG050-0007 (74%) than at the basin outlet at site LMG050-0006 (66%). The median concentration of site LMG050-0007 ($500 CFU/100 ml$) was higher than site LMG050-0006 ($430 CFU/100 ml$).

Figure 21 shows the Fixed Station monitoring data by month. Again, the single-sample standard for *E. coli* is included on the graph for reference. The distributions for the two sites are remarkably similar. There is not a strong relationship between exceedances and month; exceedances occur in all months. However, in general, the the lowest percentage of exceedances were observed at both sites in the months of October and April.

[2]Colony forming units per 100 milliliters

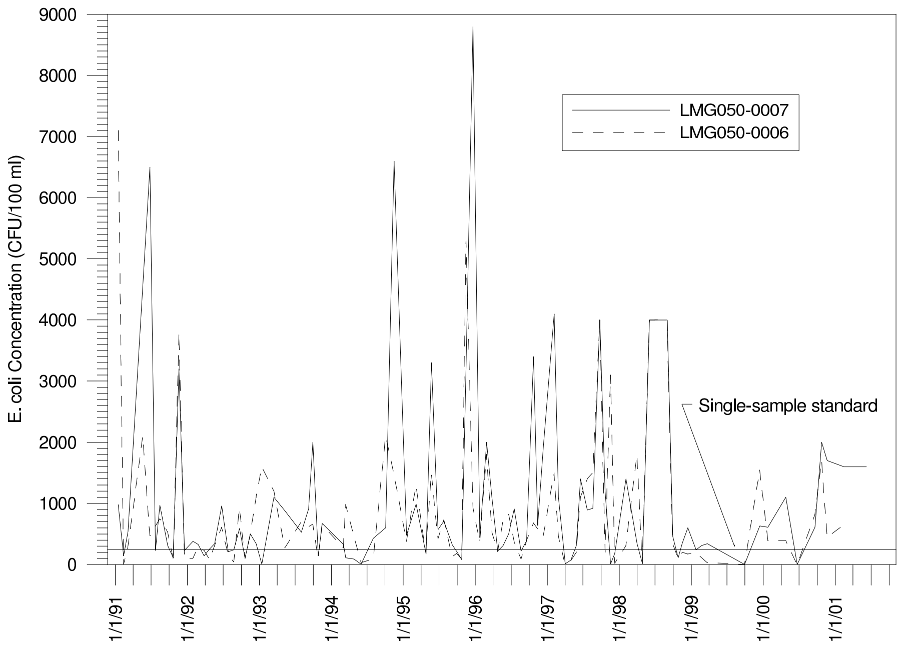


Figure 20: *E. coli* concentrations measured at IDEM fixed stations, 1991–2001.

Kansas Curve Analysis

The Kansas Department of Health and Environment developed a simple methodology for initial evaluation of bacteria impairments [KDHE, 2002]. The Kansas TMDL Curve Method (the Method) was developed to facilitate rapid implementation of phased TMDLs when relatively little data existed and when court imposed time limits did not permit extensive data collection and simulation modeling. While IDEM is not under the same constraints in the Salt Creek basin, the Method can function as an effective tool for exploratory data analysis and can provide direction so that TMDL development is completed in a sound and cost-effective manner.

The method involves transforming the flow-duration curve (Figure 13) into a load-duration curve by multiplying the flow values along the flow-duration curve by the numeric water-quality standard. This simple conversion results in a curve that represents the water-quality standard as a continuum across the flow conditions observed at the gaged site. Instantaneous bacteria loads calculated from in-stream values measured near the gage can be plotted on the load-duration curve with the known flow at the time of the sample.

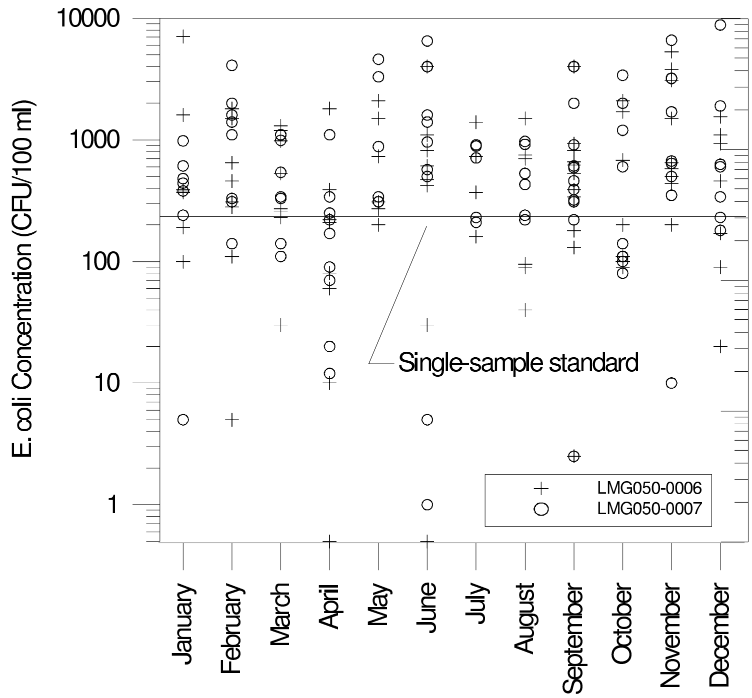


Figure 21: *E. coli* concentrations measured at IDEM fixed stations, by month, 1991–2001.

The long term record of *E. coli* concentrations measured at the Fixed Station site LMG050-0006 (Figure 20) are ideal for the Kansas Curve Method, with one exception: the flow in the creek at the time of sampling is unknown. The USGS gage in McCool was retired in 1991. This shortcoming makes the calculation of an instantaneous load problematic. However, the flow can be estimated in a manner that is acceptable for this cursory level analysis. Site LMG050-0006 is located near the retired USGS stream gage at the mouth of the basin in McCool, Indiana. An active USGS gage is located nearby in Porter on the Little Calumet River (Figure 12). By regressing daily flow values at the McCool gage with daily flow values at the Porter gage for a common period of record (1970-1991), we can establish a relationship between the two gages so that flows can be estimated in Salt Creek for the period of interest. The estimated flows can then be associated with the *E. coli* concentrations measured at site LMG050-0006. Figure 22 shows the relationship between flows at the two gages and the resulting regression line.

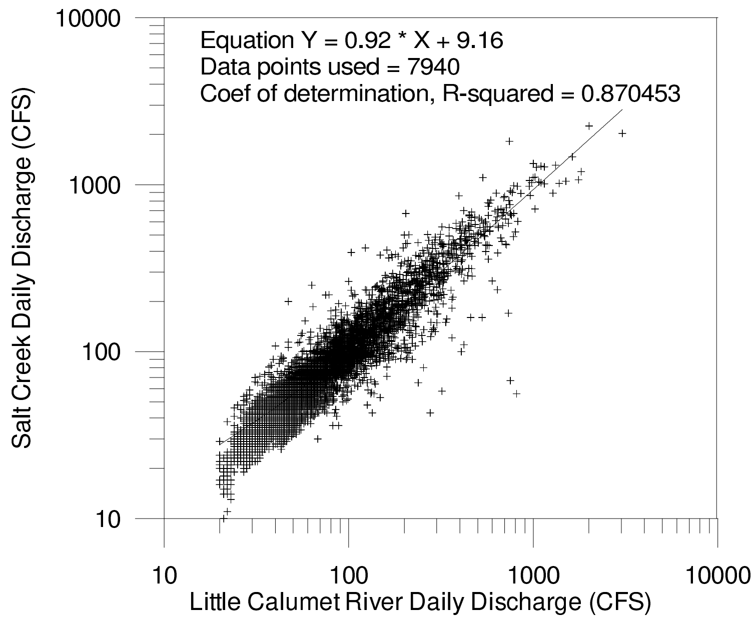


Figure 22: Relationship between daily flow values at USGS McCool gage on Salt Creek and nearby Porter gage on the Little Calumet River, 1970–1991.

Daily flow values estimated from the Porter gage were multiplied by the *E. coli* concentrations measured at site LMG050-0006 to estimate instantaneous loads for the load-duration curve analysis. Figure 23 shows the estimated loads plotted on the load-duration curve for Salt Creek. By plotting *E. coli* loads on the load-duration curve we can visualize the data with respect to the standard, the flow, and the season. In its simplest function, the instantaneous loads plotted on the load-duration curve provide a synopsis of the impairment. Loads plotting above the curve represent exceedances of the standard; loads plotting below the curve represent compliance with the standard. The graph also provides a visual representation for assessing the magnitude, duration and trends in non-compliance.

Figure 23 shows a large percentage of measurements as violations. Sixty-six percent of the *E. coli* samples collected at the site between 1991 and 2001 were above the one-time standard of $235 CFU/100 ml$. The curve also helps identify critical conditions and the nature of the sources contributing to impairment. In addition, the locations of measured bacteria counts on the graph can indicate if water-quality violations are related to specific

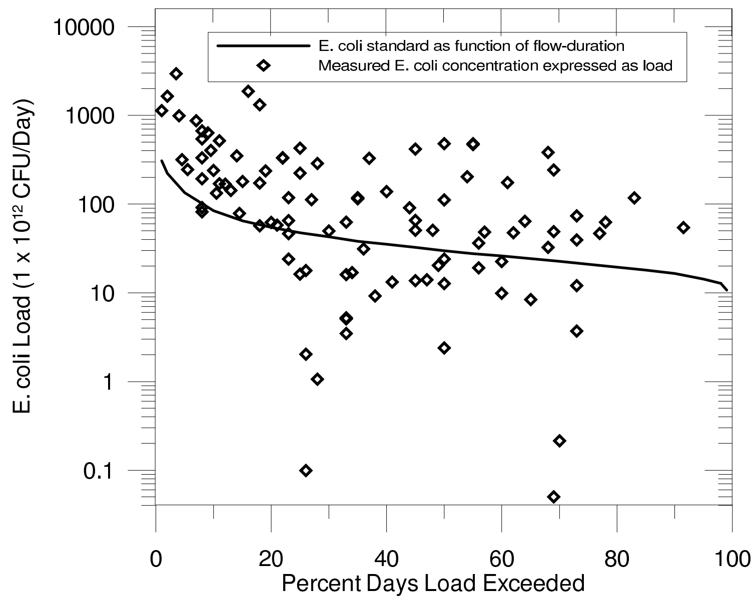


Figure 23: Load–duration curve computed from flow and *E. coli* concentrations measured in Salt Creek. Flow statistics were computed with data from USGS McCool gage, 1970-1991. *E. coli* data from IDEM Fixed Station measurements at U.S. Highway 20 in Portage, IN, 1991–1999.

flow conditions. This concept can be taken one step further, permitting inferences about the sources of critical loading. Point sources generally have the greatest impact when flow is low (i.e., when the dilution capacity of a water body is low). Loads which plot above the curve in the flow regime defined as being 85-99 percent of the time can generally be attributed to point sources. Non-point source loading is generally event-driven and associated with higher flows. Non-point source effects are indicated by loads plotting above the curve in the 10-70 percent load exceedance. A combination of sources is attributed to measured loads at 70-85 percent exceedance. Most of the violations shown in Figure 23 fall in the high to middle range of flows (2-60 percent flow duration), indicating that *E. coli* concentrations above the standard in Salt Creek are likely due to non-point sources or other event-driven inputs such as storm sewer discharges and CSOs.

The load-duration curve can also be constructed with *E. coli* data grouped by season (Figure 24). By segregating the measured bacteria counts by season, seasonal components of critical loading can be discerned. The highest percentage of exceedances occur in the spring, summer, and winter. In addition, most of the spring and winter violations occur at low durations (high flows), whereas summer and fall exceedances are distributed across the flow regime.

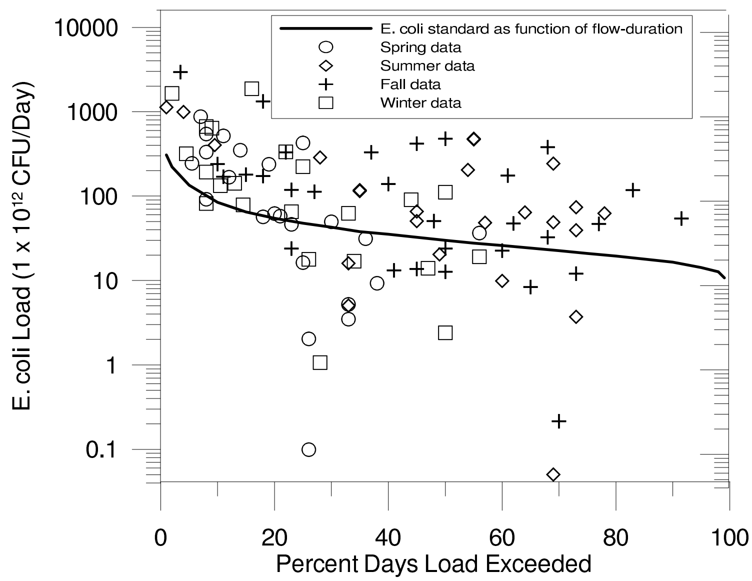


Figure 24: Load–duration curve computed from flow and *E. coli* concentrations measured in Salt Creek, organized by season.

Point Source Monitoring

As of October 2001, the State requires CSO managers to monitor and report overflow volumes. Prior to the new requirement, little information was known about CSO overflow volumes. One exception is the work of the Task Force/Point Source Committee in 1998. The Task Force/Point Source Committee monitored overflow volumes as well as concentrations in Salt Creek and two tributaries.

The Task Force/Point Source Committee concluded that adverse impacts of CSO discharges are most prevalent in the Little Calumet/Burns Waterway system [Kuss, 2001]. The Committee further concludes that the work "clearly and conclusively illustrates that Beach closures/advisories occur only following rainfall events, and do not occur during extended periods of dry weather. Additionally, the results clearly and conclusively illustrate that there is a greater propensity for beach closures/advisories to occur when rainfall amounts are large enough that CSO discharges occur."

The effects of rainfall and CSO overflows on Salt Creek can be seen in the data collected by the Point Source Committee during the 1998 recreational season. Figure 25 shows weekly *E. coli* concentrations measured at the outlet of the basin (site 208, Figure 18). The measured concentrations are shown in relation to precipitation amounts and CSO overflow volumes recorded daily at Valparaiso. Note that the in-stream samples were collected weekly regardless of rainfall or CSO events. The effect is a difference in resolution between the data sets. Sometimes the creek was sampled a day after a CSO overflow and sometimes it was sampled several days after an overflow. Therefore, the concentration measured in the creek does not necessarily represent the peak concentration after a CSO overflow. Despite the difference in resolution between the data sets, we see an increase in *E. coli* concentration at the basin outlet associated with each CSO overflow. The *E. coli* concentration at the basin outlet increased above the standard after rainfall events significant enough to cause a CSO overflow in Valparaiso. The *E. coli* concentration can be elevated even several days after a CSO overflow.

The conclusions drawn by the Point Source Committee for the entire Little Calumet/Burns watershed are congruent with results in Salt Creek. However, the elevated concentrations at the basin outlet are not due entirely to CSO overflows. The work by the Point Source Committee did not specifically consider the effects of non-point source runoff and storm sewer discharges, sources that also can contribute significant loads of *E. coli* to the creek after a rain event. In addition to showing concentrations near the outlet of Salt Creek, Figure 25 shows the concentrations measured in Damon Run near the confluence with Salt Creek (site 205, Figure 18). There is no CSO in the Damon Run watershed, so the concentrations measured in Damon Run do not reflect the effects of a CSO. We can see that the concentrations in Damon Run were comparable to those found at the basin outlet (site 208, Figure 18). Sometimes the concentration was even higher in Damon Run than in Salt Creek. The same effect can be seen at two other sites without a CSO influence (Figure 26). Site 201 (Figure 18) is located on Salt Creek above Valparaiso. Site 206 (Figure 18) is located on Squirrel Creek, a tributary of Salt Creek near the basin outlet (Figure 2). Sites 201 and 206 both exhibit elevated concentrations associated with rain events. In some cases, the concentrations were elevated even though the rain event was not significant enough to cause a CSO overflow at Valparaiso. Clearly, elevated concentrations at the basin outlet are not entirely due to CSO inputs. Thus, non-point sources and other sources that are event-driven impact *E. coli* concentrations in the creek in addition to CSOs.

3.2.2 Spatial Characteristics

The long-term record at the Fixed Stations provides valuable information about concentrations over time. However, the Fixed Station data represent water integrated from large parcels of the watershed over a broad range of conditions. The Fixed Station data do not provide the spatial information that is crucial to solving the problems presented by TMDL development. Understanding where loading occurs is an early step to identifying critical sources. When analyzed together, several of the compiled data sets provide insight into the spatial characteristics of *E. coli* impairment in Salt Creek. The Statewide *E. coli* Monitoring Project, the 2000 Salt Creek Assessment, and the Task Force/NPSMP, all provide a snapshot of conditions in the creek and some of its tributaries during the recreational seasons of recent years.

The Statewide *E. coli* Monitoring Project and the Salt Creek Assessment are grouped together in Figure 16. The two data sets, collected in the same year with the same protocols, provide good spatial coverage of Salt Creek and select tributaries. Samples were collected to allow computation of a five-sample geometric mean. The geometric mean value provides a better representation of general conditions than a single sample. The results show *E. coli* concentrations elevated above the single-sample and the geometric mean standard along the entire length of Salt Creek as well as some of the tributaries (Figure 27). Some of the lowest concentrations were found in water exiting sewer outfalls and water just downstream of the outfalls. Both the Valparaiso (site LMG050-0015) and the South Haven (LMG050-0028) wastewater treatment outfalls had geometric mean concentrations below the respective standard. Most of the samples from the two outfalls also had concentrations less than the single-sample standard. The low *E. coli* concentrations from the outfalls is the result of disinfection activities required by the State during the recreation season (April through October). The lingering effects of disinfection can be seen in results from the sites upstream and downstream of the Valparaiso outfall. *E. coli* concentrations were elevated in the upper reaches of Salt Creek above the Valparaiso wastewater treatment outfall. Concentrations in the creek are still below the geometric mean standard at the site below the outfall. Apparently, the chlorinated water from the outfall is diluting the creek and effectively lowering the concentration of *E. coli* in Salt Creek.

In addition to the wastewater outfalls and the site below Valparaiso, the only other sites where concentrations were below the geometric mean standard were small tributaries. Beauty Creek in Valparaiso, Pepper Creek in the middle of basin, and Robbins Ditch near the basin outlet all exhibited relatively low *E. coli* concentrations. The geometric mean computed from the Pepper Creek samples was below the standard. Results from Robbins Ditch did not allow computation of the geometric mean; however, all four samples were less than the single-sample standard.

The highest concentrations were recorded in Salt Creek and two tributaries. The highest geometric mean recorded at all of the sites was from samples taken below Lake Louise. The second highest geometric mean was computed from samples collected at the Fixed Station site at the basin outlet, LMG050-0006. Other tributaries with geometric mean values greater than the standard include Damon Run, Clark Ditch, Gustafson Ditch, the creek draining Butternut Springs, and several unnamed tributaries (sites LMG050-0021, LMG050-0022, LMG050-0025, and LMG050-0029; Figure 27).

The NPSMP focused on streams potentially affected by non-point sources. The sites include some of the same tributaries sampled for the Salt Creek Assessment. Results from the NPSMP are congruent with most of the results from the Salt Creek Assessment. The NPSMP found elevated *E. coli* concentrations in Damon Run, Clark Ditch, the outlet to Lake Louise, the drainage from Butternut Springs, Parker Ditch in the headwaters of Salt Creek, and the unnamed tributary south of Damon Run (site NPSPORTER06, Figure 17). Contrary to results from the Salt Creek Assessment, the NPSMP found *E. coli* concentrations elevated above the standard in Pepper Creek.

The Task Force/Point Source Committee focused its sampling to evaluate the effects of CSO inputs. However, two of the sites are located on tributaries that are not impacted by a CSO: Squirrel Creek and Damon Run (sites 206 and 205, respectively; Figure 18). Squirrel Creek was not sampled for any of the other studies evaluated here. Therefore, the data are the only results available for Squirrel Creek. Results show elevated *E. coli* concentrations in this small tributary related to rain events. The results for Damon Run confirm findings by the Salt Creek Assessment and the NPSMP. Concentrations of *E. coli* in Damon Run were elevated after rain events, sometimes higher than found at the basin outlet.

3.3 Confirmation of Impairment

Concentrations of *E. coli* measured at IDEM's Fixed Monitoring Stations in Salt Creek indicate that the creek has been frequently impaired with respect to the standard for the entire period of record (1990-2001). Sixty-six percent of the measured concentrations at the basin outlet were greater than the standard; some were over an order of magnitude greater than the standard. Results from four different studies provide good spatial coverage of conditions in Salt Creek. Some tributaries were sampled in more than one of four studies. Results show impaired conditions along the entire length of Salt Creek as well as many of its tributaries. Named tributaries with indications of impairment in more than one study include: Damon Run, Clark Ditch, Parker Ditch, the outlet to Lake Louise, and the drainage of Butternut Springs. Named tributaries with indications of impairment in only one study include: Pepper Creek, Squirrel Creek, Gustafson Ditch, and several unnamed tributaries.

Exceedances have occurred at all times of the year at the basin outlet, but fewer have been observed in April and October than other months. With respect to season, the lowest percentage of violations occurred in fall. Load-duration curve analysis showed that most of the spring and winter exceedances occurred at high flows, whereas summer and fall exceedances were distributed across the flow regime. Load-duration curve analysis further indicated that exceedances in Salt Creek are likely due to non-point sources or other event-driven inputs such as storm sewer discharges and CSOs. Results from monitoring by the Task Force/Point Source Committee confirms this hypothesis. Concentrations at the basin outlet increased above the standard following rainfall events significant enough to cause a CSO overflow in Valparaiso. Results in tributaries unaffected by a CSO showed that concentrations also increased above the standard after rainfall events, even after events not large enough to cause an overflow.

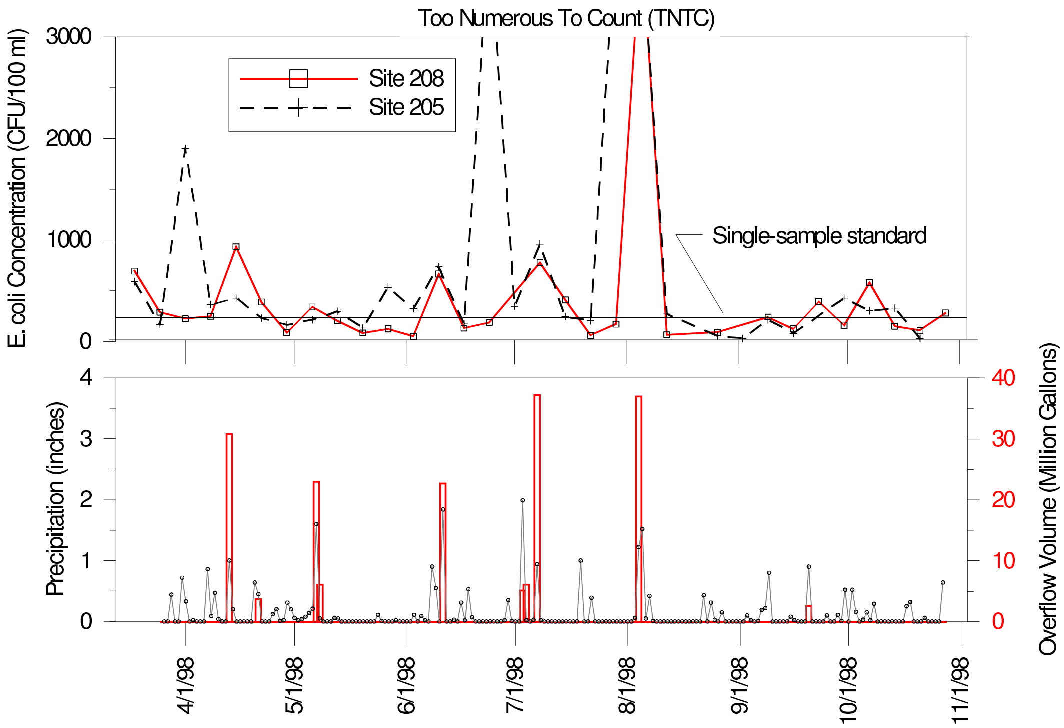


Figure 25: *E. coli* concentrations measured by Lake Michigan Interagency Task Force/ Point Source Committee in 1998. Concentrations are shown for basin outlet (site 208) and Damon Run (site 205) in relation to precipitation and CSO overflow volume recorded at Valparaiso.

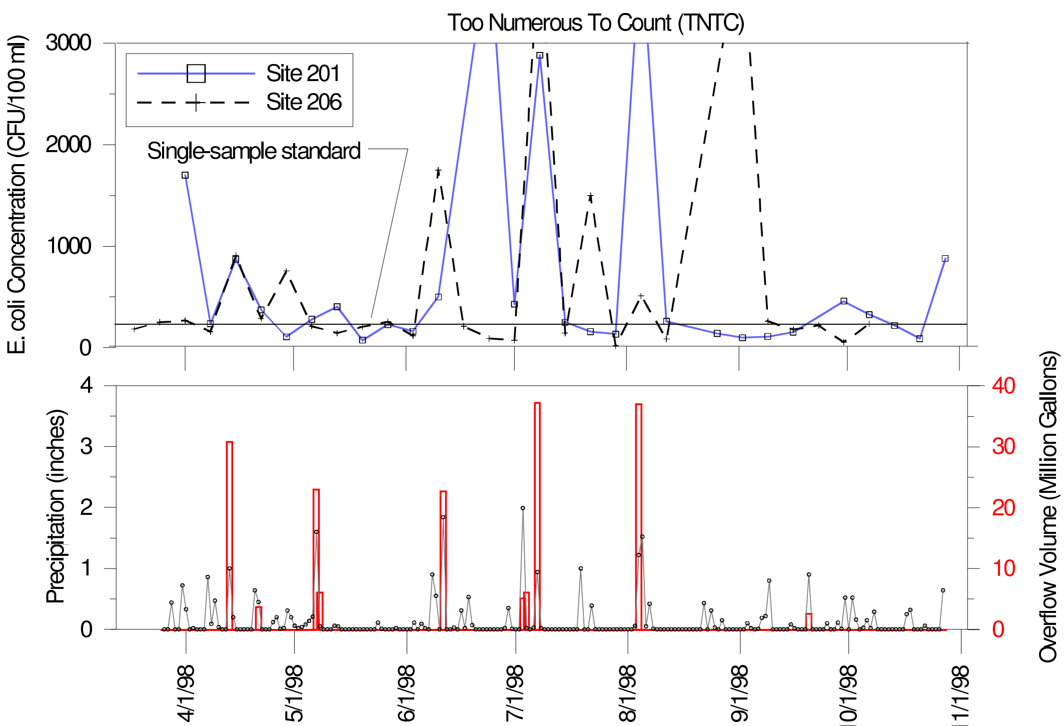


Figure 26: *E. coli* concentrations measured by Lake Michigan Interagency Task Force/ Point Source Committee in 1998. Concentrations are shown for Salt Creek above Valparaiso (site 201) and Squirrel Creek (site 206) in relation to precipitation and CSO overflow volume measured at Valparaiso.

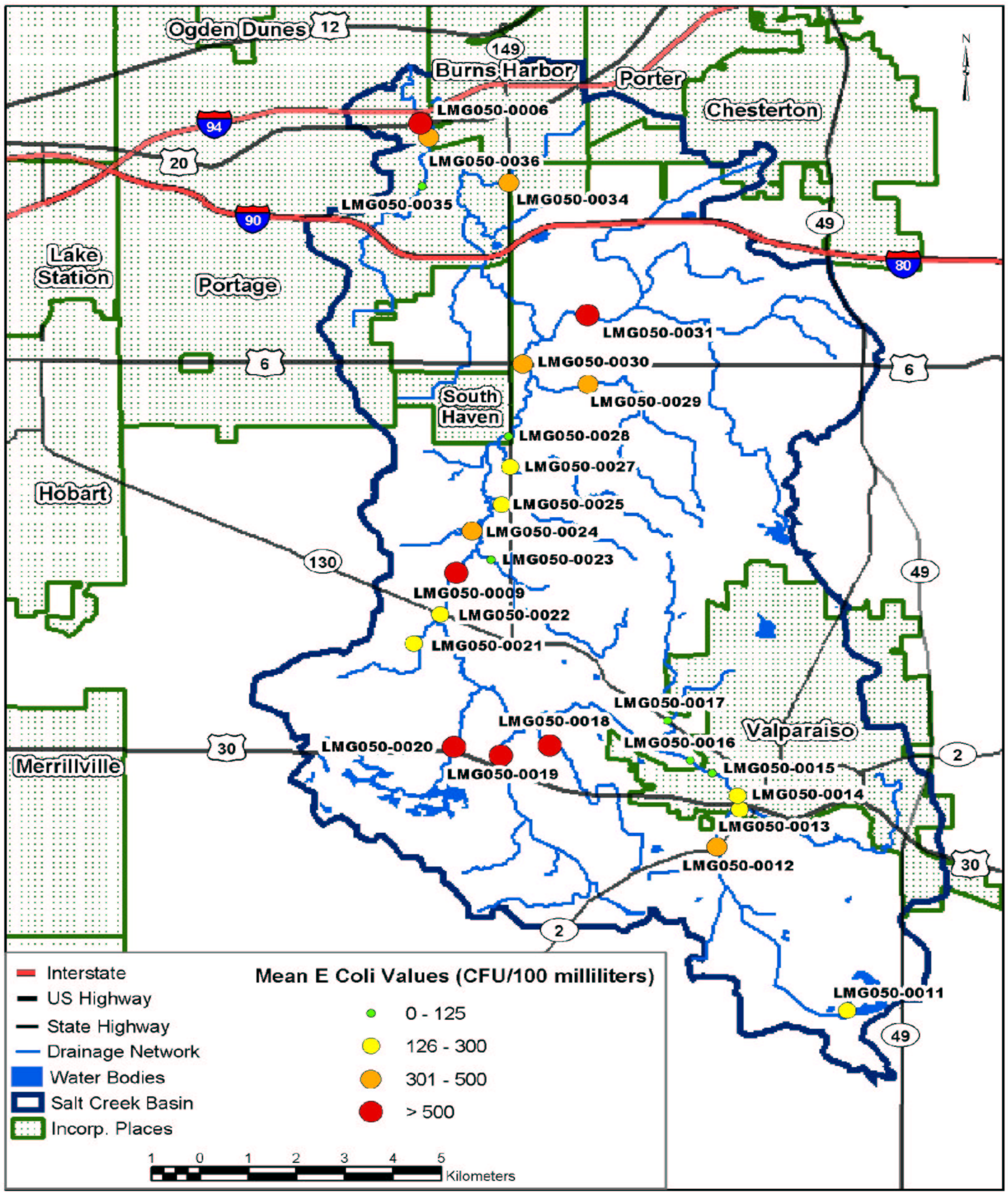


Figure 27: Five–sample geometric mean concentrations determined by IDEM special studies.

4 Source Characterization

The source inventory characterizes the type, magnitude, and location of potential sources of contaminant loading to a waterbody. The assessment characterizes the known and suspected sources of *E. coli* loading to Salt Creek and presents estimates that will be used as a starting point for subsequent modeling activities.

The assessment of contributions from nonpoint sources was aided by use of the Bacterial Indicator Tool (herein referred to as "the Spreadsheet"). The Spreadsheet, distributed with BASINS 3.0, is a spreadsheet that estimates the bacteria contribution from multiple nonpoint sources [U.S. EPA, 2000a]. The Spreadsheet was developed to provide a scientific basis for assigning values to source-loading parameters and has been used successfully for development of TMDLs across the country. The Spreadsheet was written specifically for TMDL development for fecal coliform, but was designed for adaptation for use with nutrients and other fecal indicators. The Spreadsheet was adapted for use with *E. coli* by modifying the amount of bacteria in animal fecal matter from fecal coliform to *E. coli*. For example, the amount of fecal coliform in one gram of cow manure was changed to reflect the amount of the *E. coli* in one gram of cow manure. The Spreadsheet estimates loading rates from livestock, wildlife, and failing septics. In addition, the Spreadsheet estimates the accumulation rate and storage limits of waste buildup on four different land uses (cropland, forest, built-up, and pastureland). Output from the Spreadsheet was designed for use as input to dynamic water quality models such as the Hydrologic Simulation Program-Fortran (HSPF).

4.1 Point Sources

Point source pollution enters a water body at a known location. This type of pollution is regulated by state and federal agencies; permits are required for each pollution source. The concentration of one or more pollutants is monitored at the discharge point to ensure permit compliance. An example is sanitary wastewater discharged via a ditch or pipe. Sanitary wastewater is wastewater originating from toilets, sinks, showers, and kitchen flows. In the Salt Creek watershed there are ten facilities that discharge sanitary wastewater into Salt Creek or one of its tributaries. Each of these facilities has the potential to contribute *E. coli* to the stream(Figure 19). The Indiana Department of Environmental Management (IDEM) issues National Pollution Discharge Elimination System (NPDES) permits to each facility and enforces compliance. The NPDES facilities collect the required number of samples and measure the concentration of each permitted parameter (Table 2). The limits are set at levels protective of both human health and aquatic life in waters that receive the discharge [IDEM, 2002b].

4.1.1 Permitted Discharges

Permitted facilities must compile and submit a Discharge Monitoring Report (DMR) to IDEM every month. The monitoring requirements are variable; some facilities are required to monitor *E. coli* concentrations while others are required to monitor fecal coliform and/or chlorine residuals (Table 2). The average annual loads to Salt Creek from the NPDES facilities are shown in Table 3. The *E. coli* load for facilities that do not monitor *E. coli*, but do monitor fecal coliform, were approximated using the estimation that 40% of the fecal coliform content in raw sewage is *E. coli* [Turner et al., 1997]. Three small facilities monitor only chlorine residual concentrations. Residual chlorine concentrations and *E. coli* concentrations are difficult to correlate due to variable dose and contact time in the disinfection process. For these facilities, the single-sample limit (235 CFU/100mL) was used to estimate the *E. coli* load.

4.1.2 Bypass Discharges

In addition to daily effluent discharged to Salt Creek, facilities may also have 'bypass' discharges. Bypass discharges result when the facility capacity is exceeded due to accidents, such as pumps failing or pipes bursting, wet weather, or other emergency circumstances. Unlike the regular discharges, bypass wastewater has had little or no treatment. The estimated *E. coli* load from bypass discharges is shown in Table 3. The estimated total annual *E. coli* load from NPDES facilities in the Salt Creek watershed, summing daily loads and average bypass loads, is 1.20 x 10^{16} CFU/year.

4.1.3 Combined Sewers

Combined sewer outfalls (CSO) are permitted through the NPDES. CSOs have the potential to contribute significant loads of fecal contamination during wet weather or storm events. Combined sewer systems consist of sanitary sewer pipes connected to stormwater sewer pipes. Normally this water is treated at the wastewater treatment plant (WWTP). How-

Table 2: NPDES facilities in Salt Creek watershed that are potential sources of *E. coli* and their monitoring requirements.

Permit Number	*Facility Classification*	*Facility Owner/Operator*	*CSO*	*E. coli*	*Fecal coliform*	*Chlorine Residuals*	*Ultraviolet Light*
IN0024660	Major	Valparaiso Municipal STP	1	7/week	7/week	7/week	–
IN0030651	Major	South Haven Sewer Works	–	5/week	–	5/week	–
IN0030767	Minor	Liberty Elementary and Middle School	–	1/week	1/week*	2/week	–
IN0031119	Minor	Shorewood Forest Utilities	–	1/week	–	2/99 days**	5/week
IN0035581	Minor	Sands Mobile Home Park	–	–	–	2/week	–
IN0038709	Minor	Liberty Farm Mobile Home Park	–	–	–	5/week	–
IN0039659	Minor	Burns Harbor Estates	–	–	1/week	2/week	–
IN0042021	Minor	Elmwood Mobile Home Park	–	–	1/week	2/week	–
IN0058475	Minor	Nature Works Conservancy District	–	3/week	–	–	5/week
IN0059064	Minor	Mallard's Pointe Condominium	–	–	–	2/week	–

*[Major, ≥ 1 MGD facility; Minor, ≤ 1 MGD facility; STP, ⇒ sewage treatment plant; '#'/week, number of sample measurements per week required by permit; *, parameter monitored from 1983-1998; **, parameter monitored from 1991-1996]*

ever, significant rain events can overwhelm the capacity of combined sewers, causing an overflow. The overflow event discharges both stormwater and sewer water from an outfall into nearby streams. The overflow water contains high concentrations of *E. coli* and other pathogens.

Until 2001, the city of Valparaiso had three CSOs, but two have since been removed. The remaining CSO in the watershed is permitted to the Valparaiso Municipal Sewage Treatment Plant (Table 2). Unlike discharge reports for NPDES facilities, which have been recorded for decades, DMRs for CSOs have been collected only since October 2001. Consequently, the data record is relatively small (Appendix A - Supplemental Data, Table 9A). According to the DMRs, the Valparaiso CSO had 20 overflow events from October 2001 through December 2002. No overflow events occurred from January to April 2003.

The Interagency Task Force (ITF) collected flow and concentration data from the Valparaiso CSO during the recreational season of 1998. The concentration data were not used to calculate loads because the *E. coli* counts during sampled overflow events were not quantifiable (i.e. "too numerous to count") (Appendix A - Supplemental Data, Table 4A and 5A).

Data submitted on the CSO DMRs were used to estimate *E. coli* loading to Salt Creek from the CSO. The average influent flow, the overflow duration, and the total overflow volume were reported on the DMR. The daily flow into the WWTP and the duration were used to estimate the volume of sanitary sewage that was flowing during the overflow event.

$$\text{Influent flow (MGD) X Overflow duration (hrs)} = \text{Sanitary sewage (MG)}$$

The *E. coli* load from sanitary sewage was calculated assuming a concentration of 1×10^6 CFU/100 mL [Turner et al., 1997]. The sanitary sewage volume was subtracted from the total overflow volume to calculate the volume of stormwater, which is assumed to have an *E. coli* concentration of 1×10^4 CFU/100 mL [Marsalek and Rochfort, 2002].

$$\text{Total overflow (MG) - Sanitary sewage (MG)} = \text{Stormwater (MG)}$$

Table 4 shows the estimated 2002 *E. coli* load to Salt Creek due to the CSO.

4.2 Nonpoint Sources

Nonpoint source (NPS) pollution comes from diffuse sources that cannot be identified as entering the water body at a single location. These sources generally involve land activities

Table 3: Average flow and estimated annual *E. coli* loads to Salt Creek from NPDES facilities.

Permit Number	*Data Period*	*Ave. Flow (MG/yr)*	*Ave. E. coli (CFU /100 mL)*	*Load from Effluent (CFU/yr)*	*Ave. Bypass 1994-2001 (no/yr)*	*Ave. Bypass Flow (MG/yr)*	*Load from Bypass* (CFU/yr)*	*Total Load (CFU/yr)*
IN0024660	6/01-4/02	1,803	8	$3.63x10^{11}$	12	126	$4.78x10^{15}$	$4.78x10^{15}$
IN0030651	1/89-4/02	429	17	$2.63x10^{11}$	4	1.13	$4.28x10^{13}$	$4.31x10^{13}$
IN0030767	6/01-4/02	7	58	$3.29x10^{10}$	0.25	0.04	$1.52x10^{12}$	$1.55x10^{12}$
IN0031119	10/91-4/02	75	14	$5.40x10^{10}$	–	–	–	$5.40x10^{10}$
IN0035581	4/89-4/02	5	$235^{\pm}$	$4.45x10^{10}$	0.13	0.003	$1.14x10^{11}$	$1.59x10^{11}$
IN0038709	4/90-4/02	10	$235^{\pm}$	$8.91x10^{10}$	–	–	–	$8.91x10^{10}$
IN0039659	4/89-4/02	18	122**	$4.21x10^{10}$	–	–	–	$4.21x10^{10}$
IN0042021	5/92-10/00	16	390**	$2.73x10^{11}$	0.13	188	$7.13x10^{15}$	$7.13x10^{15}$
IN0058475	9/96-6/01	15	19	$9.45x10^{9}$	–	–	–	$9.45x10^{9}$
IN0059064	6/99-4/02	4	$235^{\pm}$	$3.56x10^{10}$	–	–	–	$3.56x10^{10}$
TOTAL				**1.21x**10^{12}			**1.20x**10^{16}	**1.20x**10^{16}

*[*Assumes concentration in sewage of 1 x* 10^6 *CFU/100mL [Turner et al., 1997]; **, E.coli data not available because facility measures fecal coliform only. Therefore, it was assumed that 40% of the fecal coliform counts consists of E. coli [Turner et al., 1997];* $\pm$*, E. coli and/or fecal data not available because facility measures chlorine only so the single sample limit was used to estimate load (235 CFU/100mL); –, no bypasses reported; ave, average; yr, year; max., maximum; MG, million gallons; no., number; CFU, colony forming units.]*

Table 4: Discharge and *E. coli* load information for the CSO in Valparaiso in 2002.

Overflow Date	Volume of Sanitary Sewer-water (MG)	Volume of Stormwater (MG)	Total Volume of Overflow (MG)	*E. coli* load* (CFU)
1/31/02	6.20	4.30	10.50	2.38×10^{14}
3/08/02	3.90	8.50	12.40	1.51×10^{14}
3/09/02	4.00	16.30	20.30	1.56×10^{14}
4/02/02	0.50	1.45	1.95	2.04×10^{13}
4/08/02	0.70	6.69	7.39	3.00×10^{13}
4/09/02	2.70	4.47	7.17	1.04×10^{14}
4/21/02	1.00	1.54	2.54	3.79×10^{13}
4/27/02	0.20	0.75	0.95	9.58×10^{12}
4/28/02	0.75	0.26	1.01	2.85×10^{13}
5/09/02	0.67	3.00	3.67	2.64×10^{13}
5/11/02	2.78	21.62	24.40	1.13×10^{14}
5/12/02	9.50	86.5	96.00	3.93×10^{14}
5/13/02	1.5	0.88	2.38	5.72×10^{13}
12/18/02	0.59	0	0.59	5.43×10^{13}
TOTAL			191.25	1.42×10^{15}

*[*Assumes stormwater concentration of 1 x* 10^4 *CFU/100mL and sanitary sewer-water concentration of 1 x* 10^6 *CFU/100mL [Marsalek and Rochfort, 2002, Turner et al., 1997]; MG, million gallons; CFU, colony forming units.]*

that contribute pollution to streams during wet weather events. Rain or snow-melt moves over and through the ground where pollutants have accumulated, transports the contaminants, and deposits them into nearby waterbodies. Bacterial NPS pollution is generated by both human and non-human (animal) sources via land use activities. Typical non-point sources of *E. coli* include, but are not limited to:

- Manure application to cropland
- Livestock grazing on pastureland
- Livestock with direct access to streams
- Wildlife
- Urban land activities
- Leaking / failed septic systems

Parameters for each source described above were input into the Spreadsheet. The Spreadsheet allows the watershed to be divided into a maximum of ten subwatersheds. The watershed was divided Salt Creek into five subwatersheds (Figure 28). The subwatersheds were chosen based on the natural topographic divisions within the watershed. Typically the divisions were made at the confluence of major tributaries to Salt Creek. The subwatersheds were delineated with a Geographic Information System (GIS) that allowed for use of best professional judgment. The subwatershed data was then input into the Spreadsheet. The Spreadsheet estimates the monthly accumulation rate and storage limit of bacteria for four land use categories: built-up, cropland, forest, and pastureland (Figure 29). The accumulation rates and storage values are determined for each subwatershed / land use combination. The accumulation rate (ACQOP) and storage limit (SQOLIM) can be used as input for the dynamic water-quality model HSPF as MON-ACCUM (accumulation rate) and MON-SQOLIM (storage limit). The effects of failed septics and cattle with direct access to streams is calculated as a constant monthly load for each subwatershed (Figure 29). The estimated loads can be used as input for modeling. Table 5 summarizes the output sheets in the Spreadsheet. Loading estimates and all output from the Spreadsheet is presented in Appendix A - Supplemental Data.

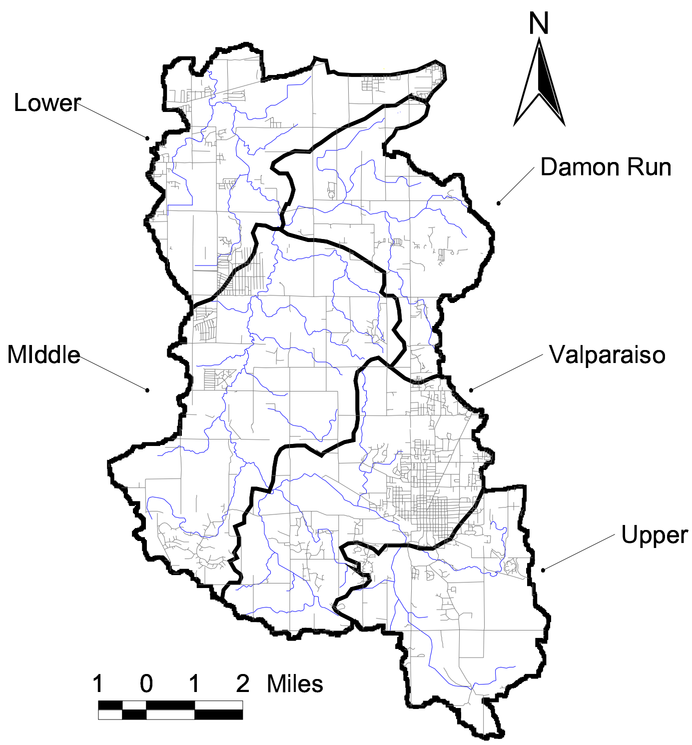


Figure 28: The five Salt Creek subwatersheds; Upper, Valparaiso, Middle, Damon, and Lower.

4.2.1 Subwatershed Landuse

The Salt Creek watershed was divided into five subwatersheds and four land use types (Figure 28 & Table 6). The geographic distribution of land use was modified from the the Indiana Land Cover Dataset [USGS, 2000] presented in the Basin Characterization. The fifteen land use types delineated by the Dataset were appropriately grouped according to the four general land use types recognized by the Bacterial Indicator Tool (cropland, forest, built-up, pasture). The loading for *each* land use is modeled to reflect the practices that occur in that area. The Spreadsheet allows for build-up and wash-off of *E. coli* in conjunction with rain events for each land use type.

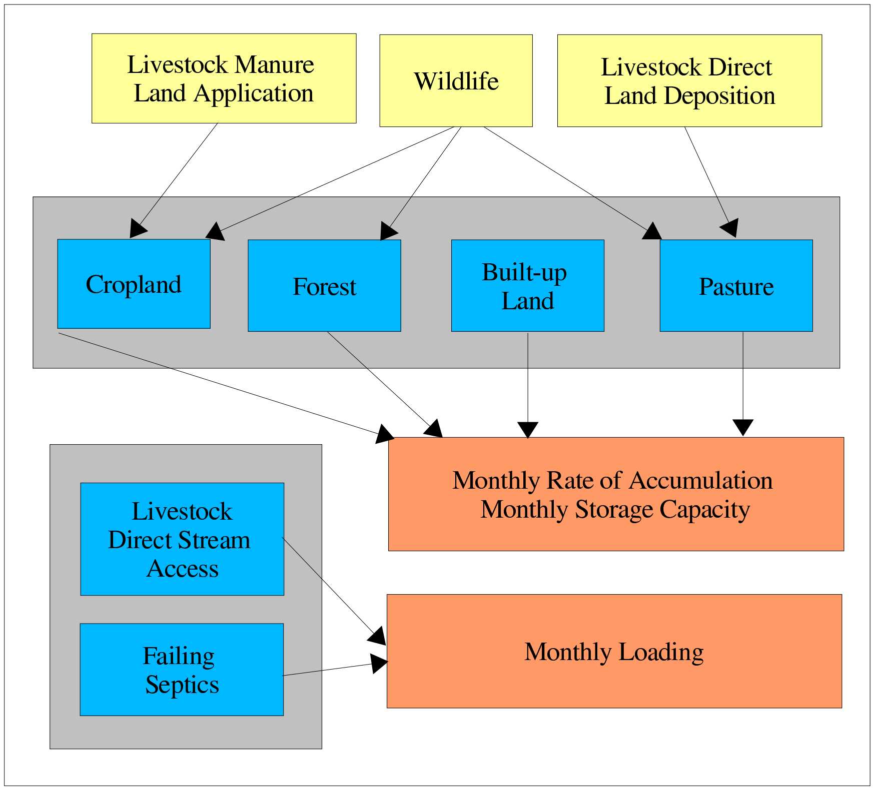


Figure 29: Schematic of the Bacterial Indicator Tool used to calculate *E. coli* nonpoint source accumulation rates and storage limits.

4.2.2 Livestock

Manure from livestock is a potential source of *E. coli* to Salt Creek. The number of animals, the amount of manure produced by each animal, and the concentration of *E. coli* in the manure are used to calculate the impact of livestock on Salt Creek (Table 7 & 8). The *E. coli* concentrations in livestock feces are estimates by researchers who study *E. coli* extensively and have experience with the relevant species. The *E. coli* estimate for chickens was provided by Dr. Mike Jenkins of the Agricultural Research Service [Jenkins, 2003]. The *E. coli* concentration for horse manure was provided by Dr. Robert Atwill of the University of California-Davis [Atwill, 2003]. The *E. coli* concentration for cow manure was provided by a study performed by Jordan and McEwen [Jordan and McEwen, 1997]. The

Table 5: Description of the output worksheets provided in the Bacterial Indicator Tool. Modified from [U.S. EPA, 2000a].

Worksheet Name	Purpose
Cropland	Calculates monthly rate of accumulation and storage limit of *E. coli* on cropland from wildlife, and application of hog, cattle, and poultry manure.
Forest	Calculates monthly rate of accumulation and storage limit of *E. coli* on forestland from wildlife.
Built-up	Calculates monthly rate of accumulation and storage limit of *E. coli* on built-up land from literature values.
Pasture	Calculates monthly rate of accumulation and storage limit of *E. coli* on pastureland from wildlife, cattle, horse, sheep, and other grazing.
Cattle in Streams	Calculates the monthly loading and flow rate of *E. coli* contributed directly to the stream by beef cattle.
Septics	Calculates the monthly loading and flow rate of *E. coli* contributed by failing septics.
ACQOP & SQOLIM	Summarizes the monthly rate of accumulation and storage capacity for *E. coli* for the four land uses. Provides input parameters for HSPF (ACQOP/MON-ACCUM and SQOLIM/MON-SQOLIM)

E. coli concentration number for cow was also verified by Dr. Atwill and Dr. Jeffery Karns [Atwill, 2003, Karns, 2003]. Dr. John Patterson verified that all the livestock estimates for *E. coli* concentrations in fecal matter were reasonable [Patterson, 2003]. The quantity of manure produced from chickens, cows, horses, pigs, and sheep are values provided by the American Society of Agricultural Engineers (ASAE) in the Spreadsheet references [U.S. EPA, 2000a]. The quantity for goats was estimated to be similar to the value provided for white-tailed deer [VADEQ, 2001].

The number and location of livestock was determined by a windshield survey of the watershed. During the windshield survey observations were recorded as every road in the watershed was driven and the livestock were counted. The locations were marked with a Global Position System (GPS). The data were then overlayed on a watershed map and

Table 6: Land use information for the five subwatersheds in the Salt Creek watershed [USGS, 2000].

Subwatersheds	Built-up (%)	Cropland (%)	Forest (%)	Pasture (%)	Total Area (% of total)
Upper Salt Creek	15	29	27	29	16
Valparaiso	44	11	28	17	22
Middle Salt Creek	13	28	33	26	28
Damon Run	12	21	41	26	15
Lower Salt Creek	25	31	29	15	19
Entire Watershed	22	24	32	22	100

clipped to the watershed so as to not include observations outside of the watershed boundaries. Additional information about livestock and verification of the windshield survey data was provided from a meeting on February 6, 2003 with members of the Porter County Natural Resource Conservation Service (NRCS), the Porter County Farm Service Agency, and the Porter County Cooperative Extension Service (Table 8) [Ames et al., 2003]. Based on the survey and the subsequent meeting with local agricultural professionals, no chickens or swine were located within the watershed.

The total estimated production from livestock was calculated by multiplying the number of animals times the estimated amount of *E. coli* produced from each animal (Table 9).

4.2.3 Pastureland / Cropland

In the Salt Creek watershed most cattle and horse owners graze their livestock year round, but 'bed' their animals at night in a barn [Ames, 2003]. While grazing, livestock deposit fecal matter directly onto pastureland and often times directly into streams. Manure deposited onto pastureland is exposed to the environment for a period of time and is available for runoff during storm events. The manure from the barn is collected and applied to croplands. Because of this variation in source type, manure from livestock is treated as three separate sources in the Spreadsheet; originating from pasture grazing, direct input into streams, and manure applied to cropland.

Land application of manure helps reduce or eliminate the need for commercial fertil-

Table 7: Livestock sources of *E. coli* in Salt Creek watershed.

Animals	Estimated *E. coli* in fecal matter (CFU / gram feces)	Estimated amount of fecal matter (grams / day / animal)	Estimated Loading Rate of *E. coli* (CFU / day / animal)
Cattle, Beef[1,2,4,5]	10^6	2.1×10^4	2.1×10^{10}
Cattle, Dairy[1,2,4,5]	10^6	5.5×10^4	5.5×10^{10}
Chicken[1,3]	10^6	1.2×10^2	1.2×10^8
Goats[1]	10^6	7.7×10^2	7.7×10^8
Hogs[1]	10^6	5.0×10^3	5.0×10^9
Horses[1,2]	10^6	2.3×10^4	2.3×10^{10}
Sheep[1]	10^6	9.1×10^2	9.1×10^8

CFU = colony forming units; [1], E. coli concentration provided by [Patterson, 2003];[2], E. coli concentration provided by [Atwill, 2003];[3], E. coli concentration provided by [Jenkins, 2003]; [4], E. coli concentration provided by [Karns, 2003];[5], E. coli concentration provided by [Jordan and McEwen, 1997].

Table 8: Estimated number of livestock in the Salt Creek subwatersheds.

Subwatersheds	Cattle, Beef (number)	Cattle, Dairy (number)	Goats (number)	Horses (number)	Sheep (number)
Upper Salt Creek	65	0	3	4	0
Valparaiso	0	0	0	16	0
Middle Salt Creek	144	0	3	26	11
Damon Run	81	56	23	30	5
Lower Salt Creek	15	0	0	2	0
Total in Watershed	305	56	29	78	16

Table 9: The estimated *E. coli* production from livestock in the Salt Creek subwatersheds.

Subwatersheds	Cattle, Beef (CFU/year)	Cattle, Dairy (CFU/year)	Goats (CFU/year)	Horses (CFU/year)	Sheep (CFU/year)
Upper Salt Creek	5.0×10^{14}	0	8.5×10^{11}	3.3×10^{13}	0
Valparaiso	0	0	0	1.3×10^{14}	0
Middle Salt Creek	1.1×10^{15}	0	8.5×10^{11}	2.2×10^{14}	4.4×10^{12}
Damon Run	6.2×10^{14}	1.1×10^{15}	6.5×10^{12}	2.5×10^{14}	2.0×10^{12}
Lower Salt Creek	1.1×10^{14}	0	0	1.7×10^{13}	0
Total in Watershed	2.3×10^{15}	1.1×10^{15}	8.2×10^{12}	6.5×10^{14}	6.4×10^{12}

CFU = colony forming units

izers. It can be applied in four different ways 1) surface broadcast followed by disking 2) broadcast without incorporation 3) injection under the surface, or 4) irrigation. In Porter County, Indiana, animal manure is generally applied with incorporation in the spring (April - May) and fall (October - November) [Ames, 2003, Sutton, 2003]. It is estimated that livestock farmers only collect and store manure from cattle and horse deposits in their barns where the animals bed at night [Ames, 2003]. It is assumed that livestock usually spend $\frac{1}{3}$ of a typical day indoors. Therefore, the amount of total manure from cattle and horses applied to land was estimated to be $\frac{1}{3}$ of the amount produced by each animal. This fraction of the total for horse and cattle manure is distributed over the four months manure is applied to fields. The Spreadsheet assumes that cattle manure is applied to cropland, horse manure is applied to pastureland, and no manure is applied to forest or built-up areas.

The manure that is not applied by the livestock owners is assumed to all be added directly to the pasture by the animals. The manure deposited directly by the animals onto pastureland ($\frac{2}{3}$ of total) is not incorporated, but remains a source for runoff events. This fraction of the total for horse and cattle manure is distributed over twelve months because the animals are allowed to graze throughout the year.

Access to streams allows livestock to input manure directly into the streams. During the meeting on February 6, 2003, the county agents indicated where livestock have stream access [Ames et al., 2003]. Based on these discussions, 31% of the total cattle in the watershed have access to a stream. It was estimated that these cattle would only spend 10% of grazing time in the stream. It was assumed that most horse owners do not allow their horses access for fear of disease, so no access was input for horses [Ames et al., 2003]. Estimated monthly accumulation rates and storage limits for cropland and pasture are presented in the Appendix A - Supplemental Data, Table 10A and Table 11A. Estimated loading rates from cattle with direct access to streams are presented in Table 12A.

4.2.4 Wildlife

Wildlife also contributes to *E. coli* in streams through runoff of fecal matter. The wildlife assumed to be major contributors in the watershed are coyote, deer, duck, geese, opossum, raccoon, turkey, squirrel, rabbit, and mice. The Indiana Department of Natural Resources surveys wildlife to establish population trends for specific species but does not survey to determine population numbers [Byer, 2003]. Therefore, other resources determined the densities of the wildlife. The deer density was estimated by the Quality Deer Management Association (Table 10) [QDMA, 2002]. The wildlife densities for coyote were estimated by officials at the NRCS (Table 10) [Ames et al., 2003]. The estimates for turkey, opossum, and squirrel were estimated from Indiana DNR harvest numbers [IDNR, 2002b]. The raccoon were estimated from a density range given on the Indiana DNR website [IDNR, 2002b]. The density of geese was estimated using Indiana state-population numbers for geese, historic population data, and the windshield survey [USGS, 1999, IDNR, 2002a]. The density of ducks was estimated from the U.S. Fish and Wildlife Service Adaptive Harvest Management [U.S. Fish and Wildlife Service, 2002]. The wildlife densities were assumed to be similar in all land uses, except built-up. The Spreadsheet assumes no wildlife in the built-up areas of the watershed.

The *E. coli* load in fecal matter for wildlife was based on the work of Dr. Rob Atwill, researcher of *E. coli* and wildlife studies at the University of California - Davis [Atwill, 2003]. The estimated amount of fecal matter produced per animal for deer, geese, and raccoon were provided from an EPA approved TMDL for fecal coliform in Virginia [VADEQ, 2001]. The amount of fecal matter produced by turkey and duck was provided by the ASAE in the Spreadsheet references [U.S. EPA, 2000a]. Opossum values are assumed to be similar to that of a small dog. This value was provided by ASAE [U.S. EPA, 2000a]. The amount of fecal matter from coyote is assumed to be similar to a large dog [VADEQ, 2001, WOW, 2003].

Table 10: Wildlife sources of *E. coli* in Salt Creek watershed.

Animals	Animals in watershed (animal / sq. mile)	*E. coli* content in fecal matter (CFU / gram feces)	Estimated amount of fecal matter (grams / day / animal)	Estimated amount of manure (CFU / day / animal)
Coyote[1]	1	10^6	450	4.5×10^8
Deer[2]	20	10^6	772	7.7×10^8
Duck[3]	5	10^6	125	1.25×10^8
Geese[4]	7	10^6	163	1.6×10^8
Opossum[5]	4.5	10^6	227	2.3×10^8
Raccoon[6]	32	10^6	450	4.5×10^8
Turkey[5]	1	10^6	151	1.5×10^8
Squirrel[5]	41	10^6	50	5.0×10^7
Rabbit[7]	96	10^6	120	1.2×10^8
Mice[7]	320	10^6	3	3.0×10^6

sq. = square; CFU = colony forming units; 1, density from Ames et al., 2003; 2, density from QDMA, 2002; 3, density adapted from US Fish and Wildlife Service; 4, density adapted from IN population numbers, historic populations, and WHPA survey; 5, density estimated from IN DNR harvest numbers (3 times harvest); 6, density from IN DNR website; 7, density from Peterson Field Guide to the Mammals..

The numbers of each type of animal in the land uses were calculated by multiplying their assumed densities with the area of each land use type (Tables 6 & 11). The estimated amount of *E. coli* from wildlife each year was then calculated by multiplying the number of each animal times the amount of manure produced by each (Tables 10 & 12). As Table 12 shows, waste from raccoon, rabbit, and deer produce 86% of the total *E. coli* from wildlife in the watershed. Estimated monthly accumulation rates and storage limits for forestland in each subwatershed are presented in the Appendix A - Supplemental Data, Table 13A.

Table 11: The estimated number of wildlife in various land uses in the Salt Creek watershed.

Animals	Cropland (number)	Forest (number)	Pastureland (number)	Total (number)
Coyote	23	31	22	76
Deer	364	482	343	1,189
Duck	94	124	89	307
Geese	129	171	122	422
Opossum	82	109	77	268
Raccoon	587	1,088	553	2,228
Turkey	24	31	22	77
Squirrel	469	994	708	2,171
Rabbit	1,760	2,331	1,659	5,750
Mice	5,867	5,530	7,769	19,166

Table 12: The estimated *E. coli* load from wildlife in the Salt Creek watershed.

Animals	Cropland (CFU/year)	Forest (CFU/year)	Pastureland (CFU/year)	Total (CFU/year)	% of Total
Coyote	3.78×10^{12}	5.09×10^{12}	3.61×10^{12}	1.25×10^{13}	1
Deer	1.03×10^{14}	1.36×10^{14}	9.67×10^{13}	3.35×10^{14}	30
Duck	5.15×10^{12}	6.79×10^{12}	4.87×10^{12}	1.68×10^{13}	2
Geese	1.06×10^{13}	1.40×10^{13}	1.00×10^{13}	3.47×10^{13}	3
Opossum	6.79×10^{12}	9.03×10^{12}	6.38×10^{12}	2.22×10^{13}	2
Raccoon	9.64×10^{13}	1.79×10^{14}	9.08×10^{13}	3.66×10^{14}	33
Turkey	1.32×10^{12}	1.71×10^{12}	1.21×10^{12}	4.24×10^{12}	0
Squirrel	8.56×10^{12}	1.81×10^{13}	1.29×10^{13}	3.96×10^{13}	4
Rabbit	7.71×10^{13}	1.02×10^{14}	7.27×10^{13}	2.52×10^{14}	23
Mice	6.42×10^{12}	6.06×10^{12}	8.51×10^{12}	2.10×10^{13}	2
Total				1.10×10^{15}	

CFU = colony forming units

4.2.5 Urban / Industrial Lands

Runoff from urban and industrial areas can potentially contribute bacteria to streams and rivers. The bacteria can come from such sources as pet feces, urban wildlife, sanitary sewer cross-connections, and deficient solid waste collection. To assess the impact of the urban runoff, the Spreadsheet divides the built-up areas into four sub-categories and calculates the loading rates for each of these divisions based on published accumulation rates [U.S. EPA, 2000a]. Unfortunately, similar accumulation rates are not available for *E. coli*, so WHPA estimated loading rates for *E. coli* based on the published values for fecal coliform. This estimation assigns the entire built-up area one accumulation rate instead of different rates for each sub-category.

E. coli is a subset of fecal coliform, meaning measurement of fecal coliform includes all measurement of *E. coli*, along with other pathogens. The amount of *E. coli* will be lower than the amount of fecal coliform in manure. Therefore, the low-end of the range for the fecal coliform accumulation rates was used as an estimation for *E. coli*. The accumulation rates for fecal coliform range from 1.8×10^{8}– 2.1×10^{10} count/acre/day [U.S. EPA, 2000a]. The accumulation rate for *E. coli* in urban areas was designated as 1.8×10^{8} count/acre/day. Estimated monthly accumulation rates and storage limits are presented in the Appendix A - Supplemental Data, Table 14A.

4.2.6 Septic Systems

Failing septic systems also contribute pathogen loads to receiving waters. However, specific information regarding the location and nature of failed systems in the watershed is unknown. The distribution of failed septics in the watershed was estimated using available information [U.S. Census Bureau, 1999, NESC, 2001]. The technique used is described briefly in EPA's Protocol for Developing Pathogen TMDLs [U.S. EPA, 2001b] and in more detail in results describing a similar application to nutrient loads [Nizeyimana et al., 1996]. The method uses information from the 1990 census and county level failure rates published by the National Small Flows Clearinghouse (NSFC). Porter County population and housing information was retrieved from the U.S. Census Bureau [U.S. Census Bureau, 1999]. Septic tank use is included in the housing information from the 1990 census. Unfortunately, the same information was not included in the 2000 census. Using data from 1990 may result in underestimating the impact from failing septics. The population of the county increased by

Table 13: Number of people on septic systems and number of failed septic systems in the subwatersheds. Derived from [U.S. Census Bureau, 1999, NESC, 2001].

Subwatersheds	Estimated People with Septics (number)	Estimated People with Failed Septics (number)
Upper Salt Creek	237	3.1
Valparaiso	246	3.2
Middle Salt Creek	252	3.3
Damon Run	84	1.1
Lower Salt Creek	203	2.6

about 20,000 people from 1990 to 2000. However, problems with failed or leaky septics are generally attributed to older homes. The underestimation may derive from the likelihood that some older septics failed in the 10 years that have passed since the NSFC survey.

Figure 30 shows the block group distribution of houses on septic in the watershed. The number of persons per household in each tract was estimated by dividing the number of persons in the tract by the number of houses in the tract. The number of persons on septic in each tract was then estimated by multiplying the estimated number of persons per household by the number of houses on septic in the tract (Figure 31). The population density on septic was then estimated by dividing the number of persons on septic in the tract by the tract area (Figure 32). The population density on septic was then used with GIS software to calculate the number of persons on septic in each of the five subwatersheds (Table 13).

Loads from failing septics in each subwatershed were calculated with the Spreadsheet. The number of persons on septic for each subwatershed was multiplied by the septic failure rate for the area. The septic failure rate was estimated from data collected by the NSFC. The NSFC surveyed local and state public health agencies across the country in the early 1990s regarding the status of on-site systems [NESC, 2001]. Unfortunately, a failure rate for Porter County was not available. We used instead the failure rate published for LaPorte County (1.3 %). The LaPorte County rate is indicative of failure rates for the counties in the region that responded to the survey. This septic failure rate was also confirmed by the Porter

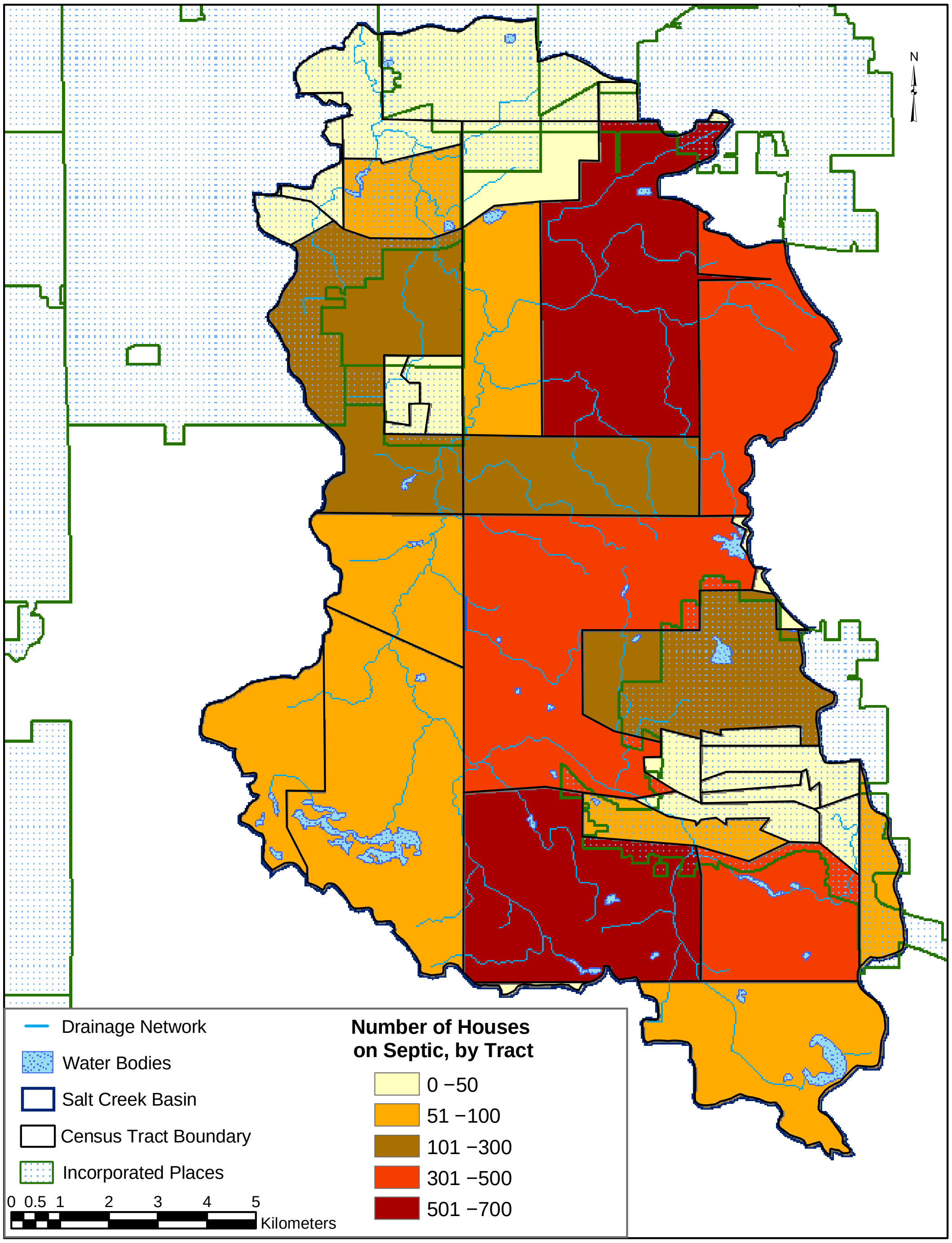


Figure 30: Number of houses on septic systems in the Salt Creek watershed [U.S. Census Bureau, 1999].

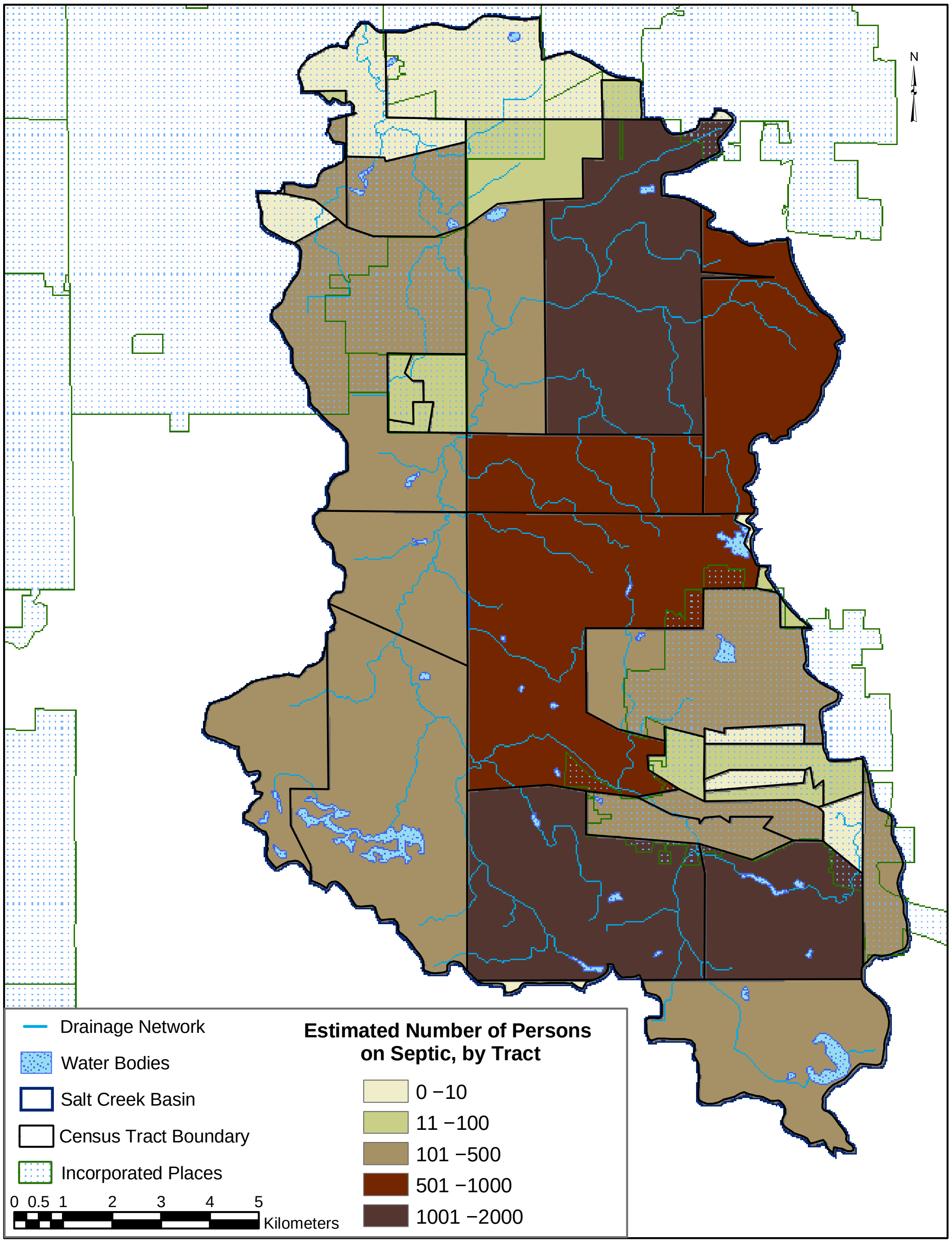


Figure 31: Number of people with septic systems in the Salt Creek watershed [U.S. Census Bureau, 1999].

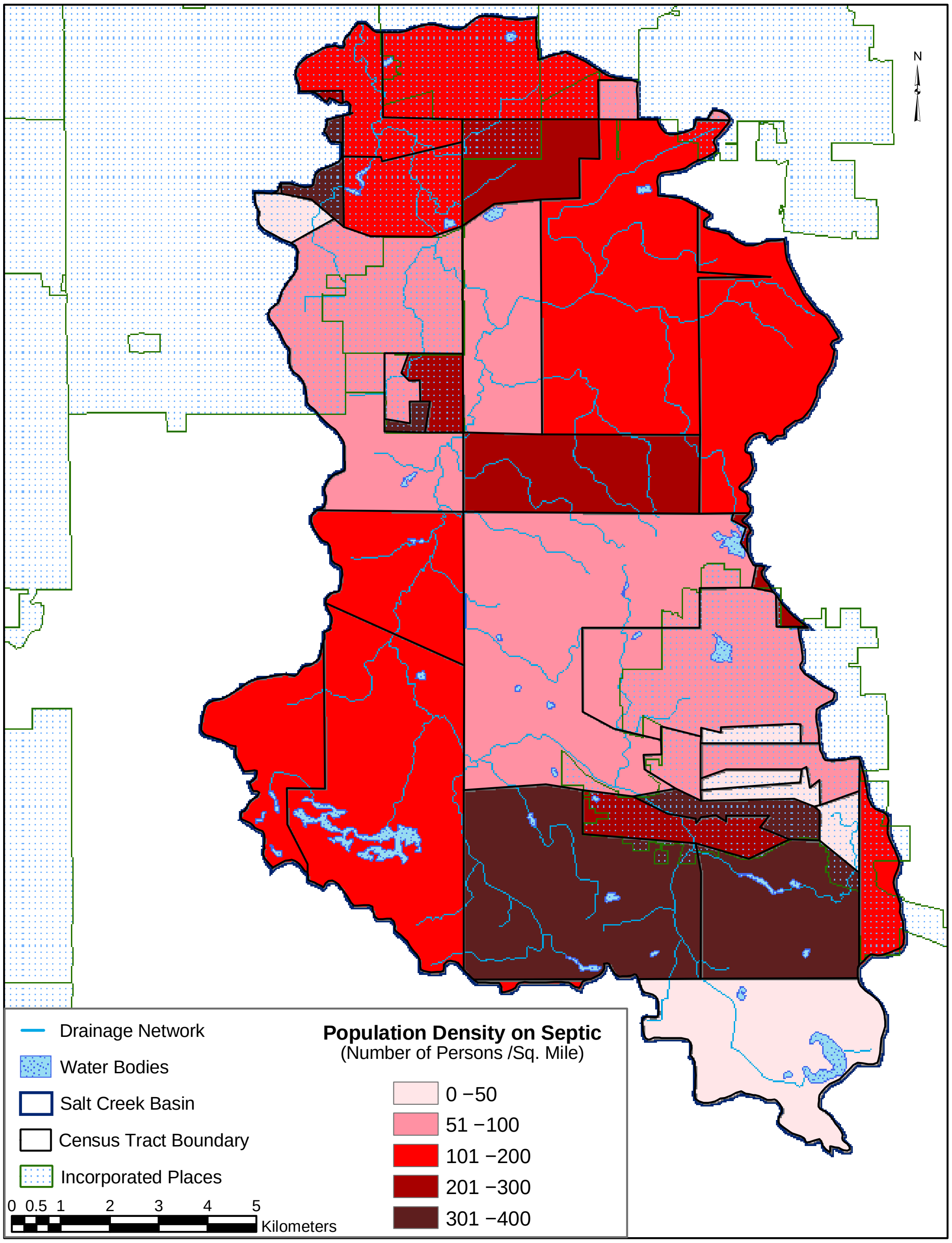


Figure 32: Population density of septic systems in the Salt Creek watershed. Derived from [U.S. Census Bureau, 1999].

County Health Department's numbers of repair permits issued in Porter County in 2002 and an estimation of septic failure [Letta, 2003]. The failure rate was used in conjunction with the number of people on septic systems to calculate the number of failed septics in each subwatershed (Table 13). The subwatershed loading rates were calculated with a typical effluent discharge rate of 70 gallons/person/day and the average *E. coli* concentration of sewage when it reaches the stream [Horsley and Whitten, 1996]. The *E. coli* concentration of septic sewage at the point when it reaches the stream was not available, so the *E. coli* concentration in raw sewage was used (8.8 x 10^6CFU/100mL) [Turner et al., 1997]. This value is most likely an overestimation because the *E. coli* population would probably be reduced from detrimental environmental conditions as it moved from the septic tank to the stream. However, there is evidence that *E. coli* can survive and even reproduce in the natural environment given the right environmental conditions [Turco, 2002]. In addition, the probable underestimation of the septic failure rate may be balanced from this overestimation in *E. coli* concentration. Estimated loading rates from failed septics are presented in Appendix A - Supplemental Data, Table 15A.

4.2.7 Illicit Discharges

Illicit discharges usually involve an illegal or improper connection to a storm drains or a "straight pipe" to receiving waters. Illicit discharge of sewage can derive from domestic and industrial sources. Such sources are difficult to identify; often owners are not even aware of the problem. Programs to identify illicit connections can be resource intensive. However, illicit discharges can be a major source of fecal loading in a watershed. Information about existing or potential illicit discharges in the Salt Creek watershed is not available. Keith Letta of the Porter County Health Department believes that illicit discharges are not a significant problem in the watershed [Letta, 2003]. Due to lack of information, potential loading rates from this source category were not estimated.

4.3 Uncertainty in Loading Estimates

The objective of the source assessment is to estimate the type, magnitude, and location of *E. coli* loading to Salt Creek. These estimates were required in order to begin modeling the effects of the combined loading on water quality in the stream. It is clear that uncertainty exists with respect to some of the loading from the identified potential sources. For instance, illicit discharges of residential sewage to streams or ditches were not identified. It is unlikely that none exist in the watershed. Similarly, there is uncertainty in the density of wildlife and urban loading rates. The estimates presented here are merely a starting point for the modeling process.

5 Linkage of Sources and Creek Conditions

5.1 Modeling Framework

The analytical framework for development of a Salt Creek TMDL is presented in detail in the Modeling Framework Report [WHPA, 2003]. The technical model requirements outlined in the Modeling Framework dictated that the model or models used for TMDL development be capable of simulating 1.) bacteria loading on a watershed scale, 2.) hydrology, and 3.) in-stream processes and *E. coli* transport. It was also essential that the model be able to simulate the above aspects at a time step appropriate for analysis of storm events.

HSPF was chosen as the best choice for development of an *E. coli* TMDL for Salt Creek. The model, as packaged with BASINS 3.0, is very suitable for fulfilling the technical model requirements. HSPF is a comprehensive, dynamic simulation model capable of simulating point and nonpoint source runoff and pollutant loading for a watershed. In addition, the model can simulate flow and water-quality routing in stream reaches [U.S. EPA, 2001a, Bicknell et al., 2001].

HSPF can be accessed in BASINS 3.0 through an interface called WinHSPF [Duda et al., 2001]. Earlier versions of the interface were known as the Nonpoint Source Model. WinHSPF was developed to ease the complexity of building and modifying input files for HSPF to enhance the modeler's ability to understand and represent model output.

The general approach outlined in the Modeling Framework is shown in the schematic in Figure 33. The BASINS platform was used to setup a WinHSPF model of the Salt Creek watershed. Table 14 presents detailed information regarding the various data sets used for model implementation. WinHSPF's integrated design with BASINS 3.0 streamlines the process of setting up an HSPF model. Functions in the BASINS 3.0 GIS interface create a series of input files for initial WinHSPF model setup. The land use/land cover, soils, and topography data (Table 14) were used with BASINS 3.0 to create three setup files for WinHSPF: the watershed file, the reach file, and the channel geometry file. The watershed file provides information to WinHSPF related to land use distributions. The reach file provides information regarding each stream reach and the connections between reaches. The channel geometry file provides information related to channel cross-sections and lengths for each stream reach. The WinHSPF model of Salt Creek was setup with 36 reaches. Figure 34 shows the layout for the model reaches. The figure also shows the relationship between the model reaches and the subwatershed delineations used to estimate

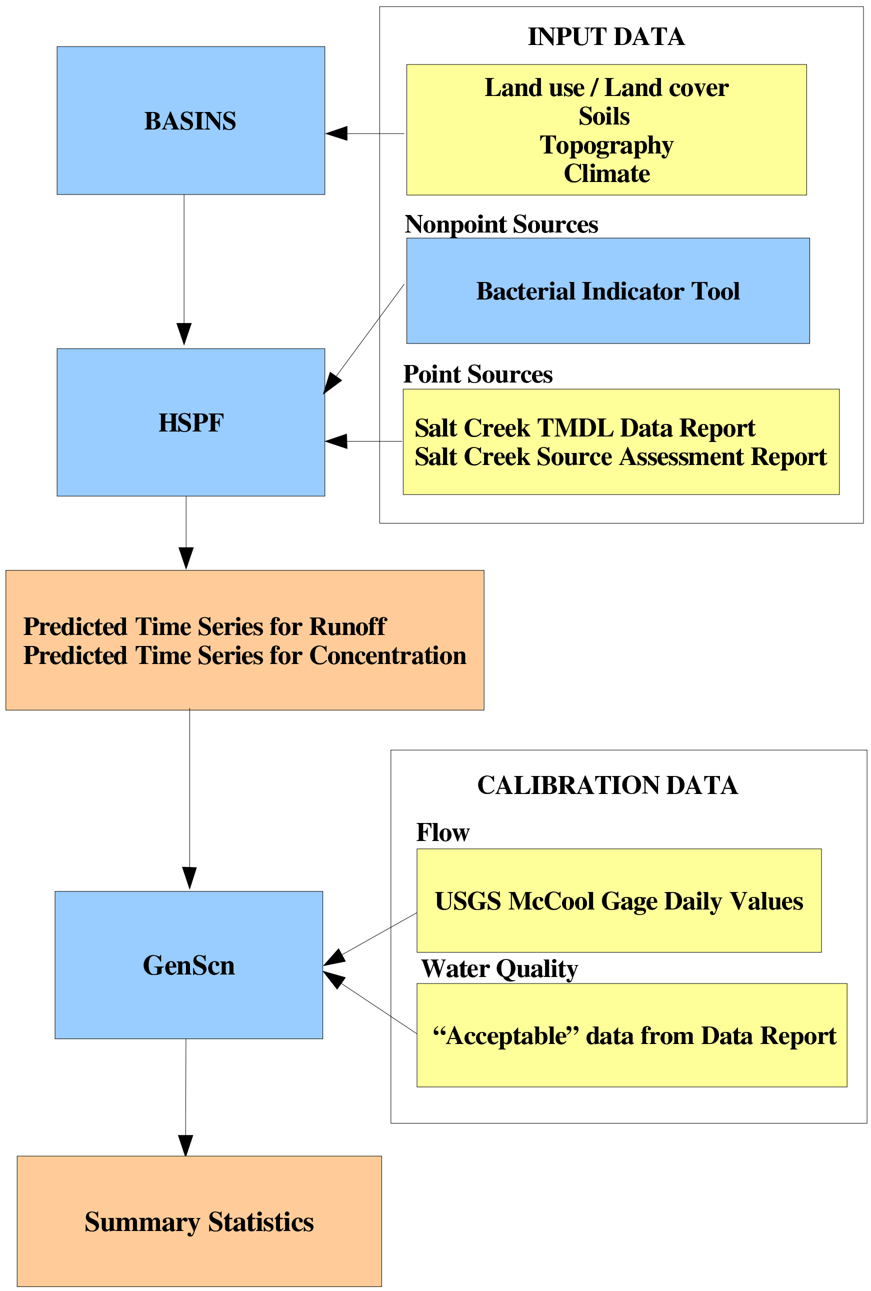


Figure 33: Software and data framework for the Salt Creek *E. coli* TMDL.

(blue=software; yellow=data; orange=output)

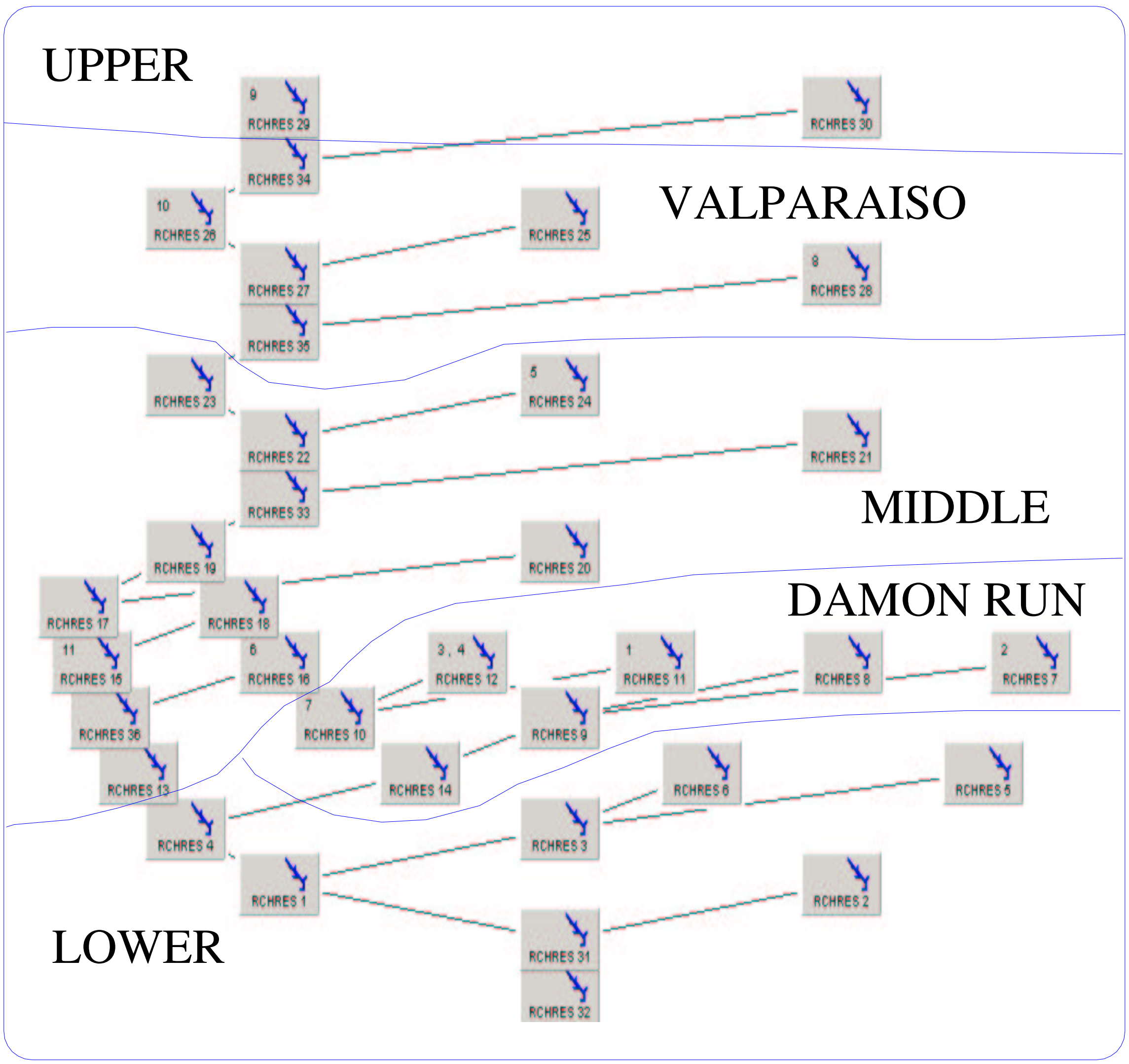


Figure 34: WinHSPF layout of Salt Creek watershed model.

Table 14: Data sets used for model implementation.

Data Type	Use	Source	Description
Land Use/Land Cover	Input	USGS[1]	Land use classifications: 1:24,000 scale
Soils	Input	USDA[2]	Soil physical properties: 1:250,000 scale
Topography	Input	USGS[3]	Digital Elevation Model: 1:24,000 scale
Climate	Input	NCDC[4]	Climate from Valparaiso
Point Sources	Input	IDEM	Flow and contaminant inputs from point sources
Nonpoint Sources	Input	WHPA	Estimated loads from nonpoint sources
Flows	C/V	USGS[5]	Daily Flow Values from McCool Gage
E. coli concentrations	C/V	IDEM	*E. coli* concentrations measured in Salt Creek

USGS=U.S. Geological Survey, USDA=U.S. Department of Agriculture, NCDC=National Climatic Data Center, WHPA=Wittman Hydro Planning Associates, C/V= Calibration/Verification, [1] [USGS, 2000], [2] [U.S. Department of Agriculture, 1994, U.S. Department of Agriculture, 2002], [3] [U.S. Geological Survey, 1999], [4] [NCDC, 2002], [5] NWISWeb Water Data *http://waterdata.usgs.gov/nwis/sw*

nonpoint source loading (Figure 28).

Watershed simulation combines the physical characteristics of the watershed, such as those described above, with climate and source loading data to produce a simulated hydrologic response. Climate data and data regarding point and nonpoint sources were used as input to WinHSPF. Climate data measured in Valparaiso was used to drive the rainfall-runoff component of model. Point source loads were estimated from National Pollution Discharge Elimination System (NPDES) information. Nonpoint source loads were estimated with the Bacterial Indicator Tool for the Source Characterization (Section 4). The Bacterial Indicator Tool, also distributed with BASINS 3.0, is a spreadsheet that estimates the bacteria contribution from multiple sources [U.S. EPA, 2000a]. The Spreadsheet was produced for use with fecal coliform, but was developed with adaptation in mind. The Spreadsheet was adapted for use with *E. coli* by modifying production parameters. The worksheets estimate the loading rate from livestock, wildlife, and failing septics. In addition, output sheets estimate the accumulation rate and buildup limit of fecal waste on four different land uses (cropland, forest, built-up, and pastureland). Output from the Spreadsheets can easily be used as input to WinHSPF and the HSPF watershed loading components.

WinHSPF models watershed dynamics for the four land use groupings utilized by the Spreadsheet (cropland, forest, built-up, and pastureland). WinHSPF also uses an additional land use category called "impervious". Runoff dynamics from impervious surfaces is distinct from the other land use categories. WinHSPf uses a separate module to compute flow and pollutant contributions from impervious land. For modeling purposes, the amount of impervious land was estimated to be 30% of the urban land use.

Typical application of HSPF requires development of parameter values for a large number of physically-based algorithms. Initial parameterization of the model was aided by USEPA guidance [U.S. EPA, 2000b] and HSPFParm [U.S. EPA, 1999], a database of calibrated HSPF parameter values used in watersheds across the Nation. Calibrated parameter values from HSPFParm utilized in a small watershed in the Lake Region of Ohio were used to develop realistic starting values for the parameterization of the Salt Creek WinHSPF model.

5.2 Modeling Approach

Calibration establishes the model's ability to represent watershed processes. Calibration is an iterative procedure in which parameter values are adjusted and refined based on comparison of simulated and observed values. A robust calibration procedure should result in realistic parameter values that provide the best agreement between simulated and observed values. Model calibration and verification were based on methods described in Donigian [2002]. Donigian describes a "weight of evidence" approach that represents current practice in watershed model calibration and validation. The approach includes multiple tests and comparisons to evaluate model performance.

Model verification is an extension of the calibration effort. The purpose of validation is to demonstrate the ability of the model to predict observations for conditions different than the calibration period. This step is typically performed for calibration of flow. Model credibility depends on the ability of the model to represent the entire range of observed data with a single set of input parameters [Donigian, 2002]. In the validation process, the model is operated with the same unique set of input parameters formulated during the calibration process. The results are then compared to a subset of field observations not utilized during calibration. The same procedures used to assess model prediction for calibration are used for verification.

Calibration and verification of flow were accomplished by comparing simulated flows and flows observed at the U.S. Geological Survey stream gage in McCool, Indiana (Figure 12). The site of the gage is located at the mouth of the Salt Creek watershed, just upstream of the creek's confluence with the Little Calumet River. Unfortunately, the McCool gage was retired on September 30, 1991. The lack of recent flow data meant that the hydrologic and water-quality components of the model were calibrated with data with different periods of record. However, it was considered imperative to use data from the watershed to the extent possible.

Flow was calibrated with data from water years 1988-1990 and verified with data from water year 1991. The water year begins October 1 and ends September 30. The water year was used as the annual "accounting unit" for calibration rather than the calender year so that the partial record of McCool gage data in 1991 could be fully utilized.

Calibration was achieved with the hierarchical approach described by Donigian [2002] and by the HSPF application guide [A.S. Donigian, 1984]. The hydrologic calibration preceded calibration of water-quality constituents. General hydrology was calibrated first, followed by nonpoint source loading rates and bacteria dynamics. The hydrologic calibration was accomplished by addressing, in order, four watershed characteristics: 1.) annual water balance, 2.) seasonal and monthly flows, 3.) baseflow, and 4.) storm events. Calibration of each hydrologic characteristic involved methodically adjusting the input parameters and then evaluating model performance. A USEPA technical document provided additional guidance on realistic parameter ranges [U.S. EPA, 2000b]. Calibration was considered done when: 1.) all four hydrologic aspects were addressed, 2.) model performance criteria were acceptable based on criteria outlined by Donigian [2002], and 3.) further improvement in model performance criteria was seen as limited by uncertainties in input and calibration data.

A baseflow separation program was used to estimate characteristics of the ground water flow component in the watershed. The program is described in Arnold and others [1995] and Arnold and others [1999]. Daily values from the period of record at the McCool gage were used as input. The estimated ground water contribution was considered in the first three watershed characteristics addressed in the hydrologic calibration.

Model performance for flow was evaluated by comparing observed and simulated values with graphical and statistical means. Comparisons of simulated and observed flows were performed during the calibration and verification periods for annual, monthly, and daily values. Graphical methods of evaluation included timeseries and scatterplot comparisons of simulated and observed values for flow. Graphical comparisons also included comparison of flow-duration curves based on simulated and observed data. Numerical and statistical means used for evaluation of model performance include mean error, percent mean error, correlation coefficient (R), coefficient of determination (R^2), and Nash-Suttcliffe simulation efficiency. The R^2 value is an indicator of the strength of the relationship between the observed and simulated values. The Nash-Suttcliffe simulation efficiency indicates how well the observed and simulated values fit a 1:1 relationship. Values near 1 for R, R^2, and Nash-Suttcliffe simulation efficiency indicate a good fit of the data, whereas values near 0 indicate a poor fit of the data.

Concentrations of *E. coli* were modeled as a flow-associated constituent. This technique is standard practice for modeling bacteria. Data collected in 1998 by the Point Source Committee of the Interagency Task Force were used for calibration of simulated *E. coli* concentrations (Section 3). This subset of the available data was selected for calibration for two main reasons: 1.) the in-stream samples were collected weekly at multiple locations throughout the entire recreational season, and 2.) CSO volumes from Valparaiso were also recorded. The weekly sampling frequency provided the best opportunity for evaluating a range of conditions in the watershed throughout an entire recreational season. Analysis of the water-quality data (Section 3) and the Source Characterization (Section 4) identified the CSO as an important source of *E. coli* in the watershed. The accompanying CSO data allowed realistic estimates of inputs from that source. The only other existing data regarding CSO volumes in the recreational season are from 2002, for which there is no accompanying water-quality data sets for calibration.

Initial model inputs representing nonpoint and point-source loads were estimated from data compiled for the Basin Characterization (Section 2) and the Source Characterization (Section 4). To estimate nonpoint source loads with the Bacterial Indicator Tool, the watershed was divided into five subwatersheds (Figure 28) as described in the Source Characterization. The in-stream decay rate was estimated from data presented in U.S. EPA [2001]. A temperature correction coefficient was used for the first order decay. The in-stream temperature was estimated from monthly measurements collected by IDEM at two Fixed Station sites in the watershed.

Calibration of the water-quality component of the model was achieved by following general guidelines presented in Donigian [2002] and the HSPF Application Guide [A.S. Donigian, 1984]. Calibration was accomplished in a stepwise fashion; the model components were addressed in the following order: 1.) Nonpoint source loading rates, 2.) Instream parameters, and 3.) Point source loading estimates. Input parameters effecting each model component were adjusted to obtain good agreement between observed and simulated concentrations. Results were evaluated based on graphical methods.

5.3 Hydrologic Calibration and Verification

Calibration of the hydrologic component of the Salt Creek watershed model was a stepwise process as described in the Approach. The four watershed characteristics were addressed sequentially. Each step involved an iterative process of executing the model, interpreting the results as described in the Approach, and adjusting input parameters accordingly. All final, calibrated input parameters were within the published, possible ranges [U.S. EPA, 2000b]. Table 15 presents a comparison of the annual flows observed at the McCool gage with the corresponding annual flows predicted by the calibrated model. The mean annual discharge at the gage from 1947 to 1990 was 14.0 inches. The average annual flow for the calibration period was 15.0 inches. Flow data from 1991 was ideal for the verification period because 1991 was a wetter than average year. The average annual flow for 1991 was 19.3 inches. Calibration with data from a wet year provided the opportunity to evaluate the model under conditions different than the calibration period.

Comparison of observed and simulated values for annual flow and baseflow contribution from the calibrated model were acceptable. Donigian [2002] considers percent mean errors of less than ten percent to be “very good” for monthly and annual flows. The differences between the simulated and observed annual flows were less than ten percent for the calibration and verification periods (Table 15). The annual baseflow component at the McCool gage was estimated to be about 50%, based on 45 complete years of record. The simulated baseflow contribution for the calibration years averaged 52% (Table 15). The simulated baseflow contribution for the verification period was 54%, somewhat lower than the average for the period of record. A lower portion of baseflow contribution is expected in a wetter year.

Table 16 presents statistical results for monthly and daily flows predicted by the calibrated model. The results for the calibration and verification periods show good agreement based on monthly and daily comparisons. The correlation coefficients for the monthly and daily values for the calibration period indicate that the results are "good" as described by Donigian [2002]. By the same standards, results from the verification period indicate that the predictive capacity of the model is "good" for daily flows and categorized as "very good" for monthly flows.

Graphical comparisons of output were also employed to add weight to the evaluation of model performance. Figure 35 shows the scatterplots of observed and predicted daily flows at McCool. The scatterplots for the daily calibration and verification results both show graphically the correlation features of the results. Figure 36 shows observed and predicted flow-duration curves at the same site. The flow-duration curves for both calibration and verification show reasonable representation of the flow distribution. Figure 37 shows a timeseries plot of simulated and observed flows at McCool. Simulated daily flows matched well with observed flows. Some difficulties were encountered in matching exactly the magnitude or timing of storm events. In many cases, the model simulates small storm events that are not reflected in the observed data. Difficulties in matching exactly the timing or magnitude of storm flows can largely be attributed to spatial and temporal uncertainties in the input climate data. Inherent approximations are introduced by using data from only one climate site to represent the entire watershed. There are numerous additional uncertainties in the measured input data and data used for calibration, including: 1.) spatial variability errors in soils and land use data, 2.) errors in flow measurements, and 3.) errors caused by sampling strategies.

5.4 Water Quality Calibration

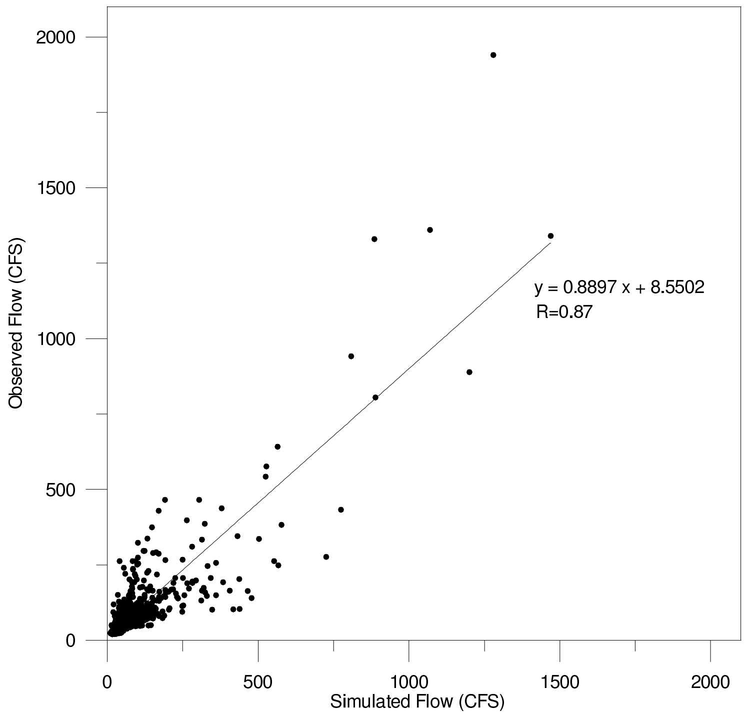
As described in the Approach, calibration of simulated *E. coli* concentrations was accomplished by first addressing nonpoint source loads. Parameters governing nonpoint source loading rates were adjusted based on comparison of simulated and observed values in Upper Salt Creek. This portion of the watershed has no known point sources, a mixture of land use, and afforded comparison with in-stream water quality data collected by the Point Source Committee of the Interagency Task Force (Site 201, Figure 18). Input parameters that were calibrated include the monthly accumulation rates (MON-ACCUM) and storage limit (SQOLIM) for each subwatershed/landuse combination. The washoff coefficient (WSQOP), which relates runoff intensity to pollutant washoff, was also adjusted. Final calibrated values for the monthly accumulation rates are shown in Table 17. Calibrated values for the storage limit are shown in Table 18. Final values for the washoff coefficient were

Table 15: Comparison of simulated and observed annual flow at McCool Gage for calibration and verification period.

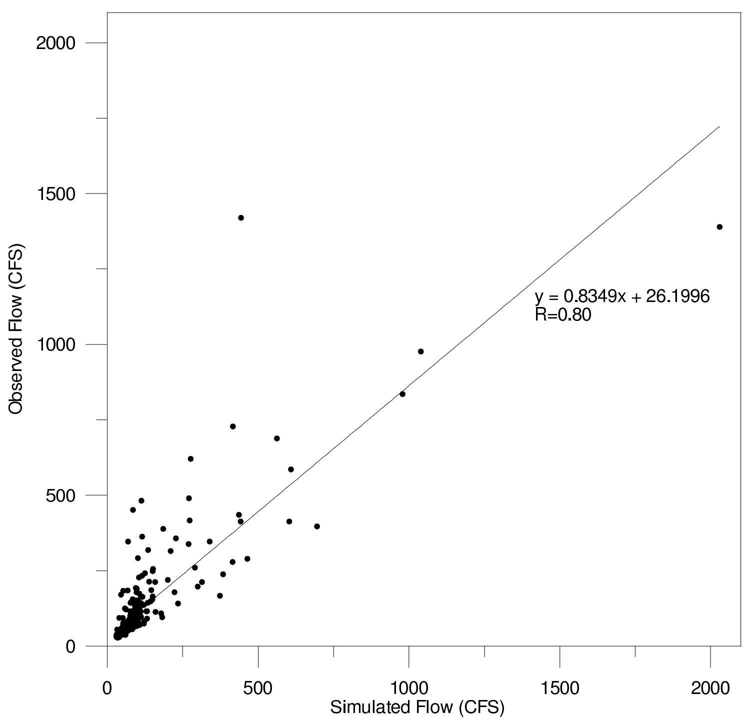
Water Year	Simulated Baseflow (%)	Simulated Flow (inches)	Observed Flow (inches)	Residual (Sim-Obs)	Error (%)
Calibration Period					
1988	59	11.5	12.1	-0.6	-5.2
1989	50	16.3	15.2	1.1	6.7
1990	46	17.0	17	0	0
Average	52	15.0	14.8	0.2	1.3
Validation Period					
1991	54	21.6	19.3	1.3	6.0

0.3 in/hr for Forest and Agricultural land use and 0.1 in/hr for Pasture and Urban land use.

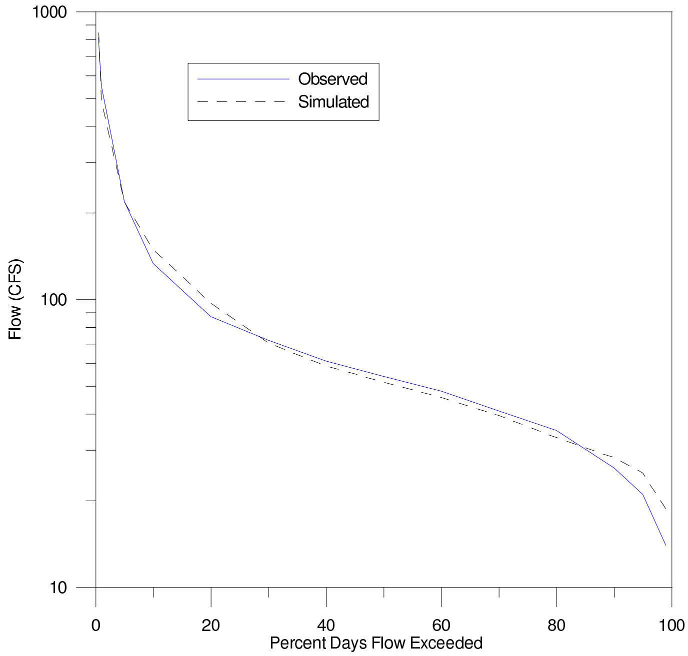
Calibration of the in-stream decay rate and point source loading rates were accomplished by comparing simulated and observed *E. coli* concentrations at the watershed outlet (Site 208, Figure 18). The decay rate (FSTDEC) was adjusted to a final value of 0.4 day^{-1} for all reaches. A value of 1.1 was used as the temperature correction coefficient for first order decay (THFST). Estimated point source loads were adjusted for the final calibration. The final point source loading rates are shown in Table 19. The final calibration for the watershed outlet (Figure 38) provides a good fit to the measured data. The model appears to over predict the peaks caused by CSO inputs. However, the limited spatial scale and quantification limits of the observed data imposes limits on any comparison with predicted values. The input file for the calibrated WinHSPF model is provided in Appendix B - WinHSPF Model Input File.



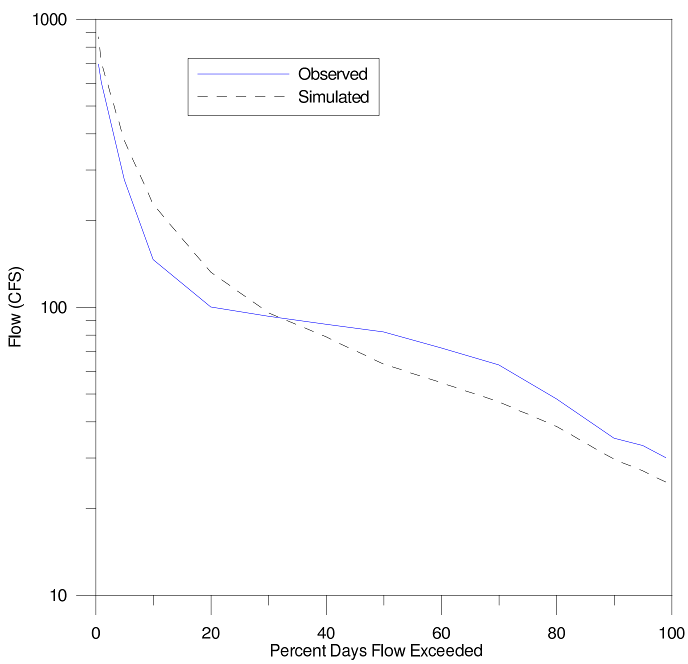
(a) Daily flow for the calibration period at McCool.



(b) Daily flow for the verification period at McCool.



(a) Flow-duration curve for calibration period at McCool.



(b) Flow-duration curve for the validation period at McCool.

Figure 36: Observed and simulated flow-duration curves for Salt Creek at McCool: Calibration and validation periods.

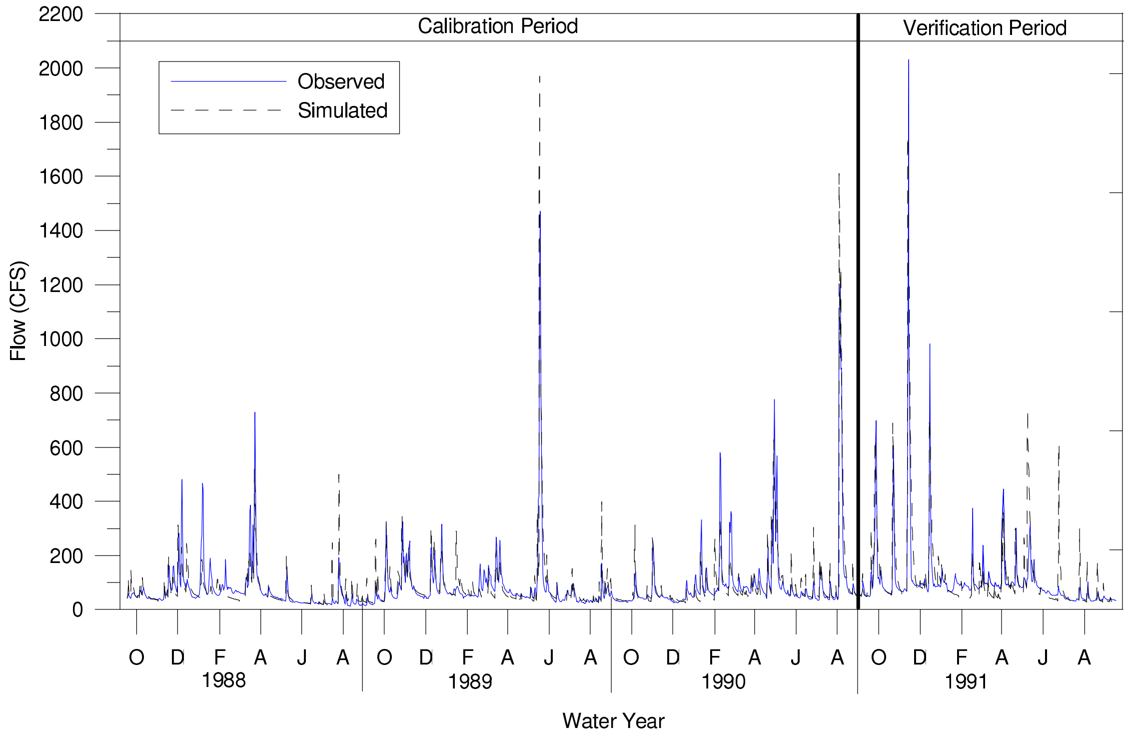


Figure 37: Observed and simulated daily flows in Salt Creek at McCool for the calibration and verification periods

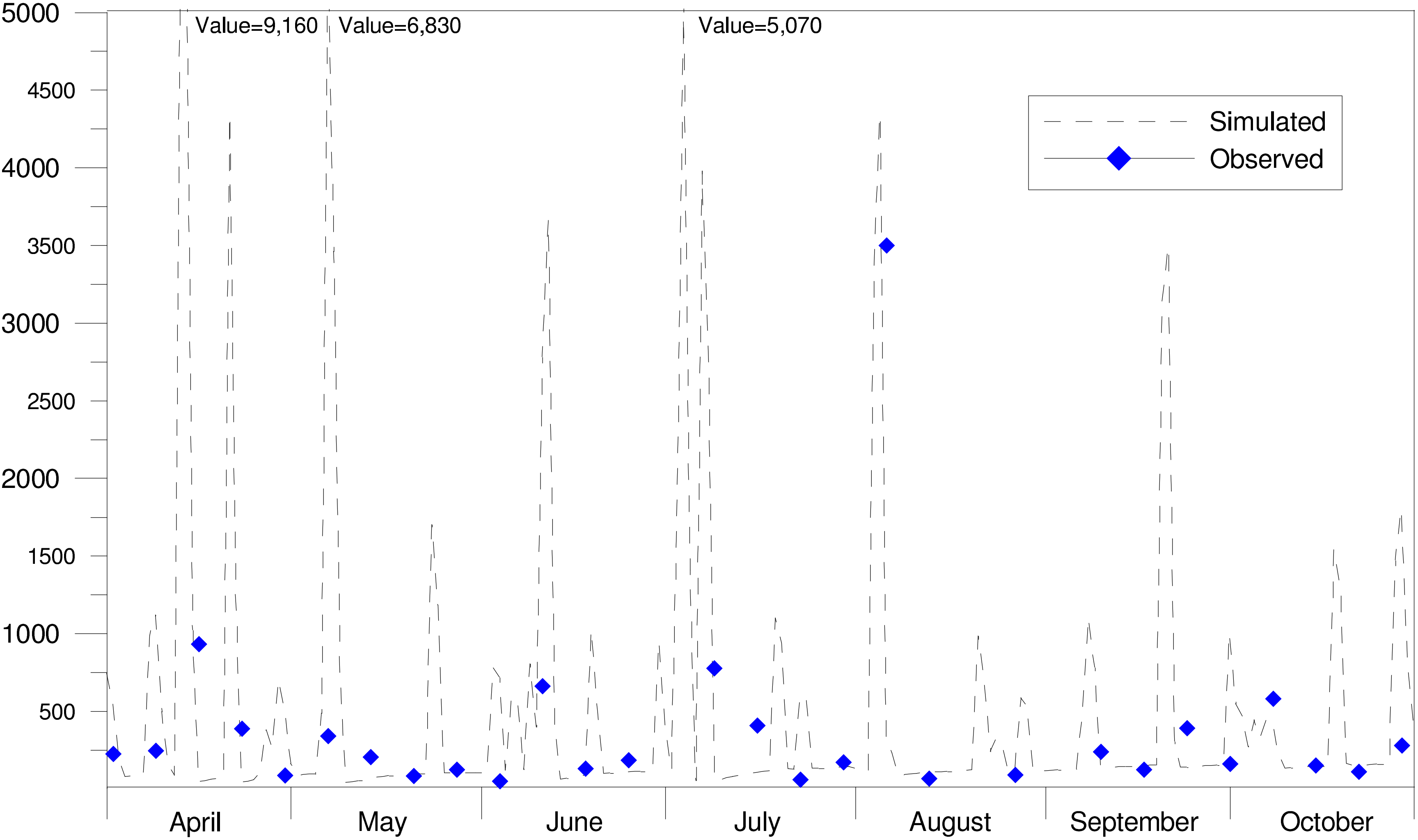


Figure 38: Observed and simulated daily concentration in Salt Creek at watershed outlet for the 1998 recreational season.

Table 16: Summary statistics from flow calibration and verification.

		Correlation Coefficient, R	Coefficient of Determination, R^2	NS Model Fit Efficiency
Calibration:	Average Monthly	0.91	0.83	0.83
Water Years 1988-1990	Average Daily	0.87	0.76	0.76
Verification:	Average Monthly	0.93	0.86	0.80
Water Year 1991	Average Daily	0.80	0.63	0.63

NS= Nash-Suttcliffe

Table 17: Final monthly accumulation rates for each subwatershed/land-use combination (counts/acre-day).

Subwatershed	Land Use	January	February	March	April	May	June	July	August	September	October	November	December
Upper	Forest	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Pasture	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.40E+09	4.30E+09	4.30E+09	4.30E+09	4.30E+09	4.40E+09	4.40E+09	4.40E+09
	Agriculture	1.30E+09	1.30E+09	1.80E+09	1.80E+09	1.80E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.80E+09	1.80E+09	1.30E+09
	Urban	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
	Impervious	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08
Valparaiso	Forest	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Pasture	2.60E+09	2.60E+09	2.60E+09	2.90E+09	2.90E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.90E+09	2.90E+09	2.60E+09
	Agriculture	1.30E+09	1.30E+09	1.40E+09	1.40E+09	1.40E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.40E+09	1.40E+09	1.30E+09
	Urban	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
	Impervious	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08
Middle	Forest	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Pasture	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.30E+09	6.30E+09	6.30E+09	6.30E+09	6.50E+09	6.50E+09	6.50E+09
	Agriculture	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Urban	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
	Impervious	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08
Damon	Forest	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Pasture	7.80E+09	7.80E+09	7.80E+09	8.20E+09	8.10E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	8.10E+09	8.20E+09	7.80E+09
	Agriculture	1.30E+09	1.30E+09	6.70E+09	7.00E+08	6.70E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	6.70E+09	7.00E+08	1.30E+09
	Urban	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
	Impervious	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08
Lower	Forest	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Pasture	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09	2.60E+09
	Agriculture	1.30E+09	1.30E+09	2.00E+08	2.00E+08	2.00E+08	1.30E+09	1.30E+09	1.30E+09	1.30E+09	2.00E+08	2.00E+08	1.30E+09
	Urban	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
	Impervious	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08

Table 18: Final storage limits for each subwatershed/land-use combination (count/acre).

Subwatershed	Land Use	January	February	March	April	May	June	July	August	Sept	Oct	Nov	Dec
	Forest	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10
Upper	Pasture	8.E+10	8.E+10	8.E+10	7.E+10	7.E+10	7.E+10	7.E+10	7.E+10	7.E+10	7.E+10	8.E+10	8.E+10
	Agriculture	3.E+10	3.E+10	4.E+10	3.E+10	3.E+10	2.E+10	2.E+10	2.E+10	2.E+10	4.E+10	4.E+10	3.E+10
	Urban	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07
	Impervious	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10
	Forest	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10
Valparaiso	Pasture	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	4.E+10	4.E+10	4.E+10	4.E+10	6.E+10	6.E+10	6.E+10
	Agriculture	3.E+10	3.E+10	3.E+10	2.E+10	2.E+10	2.E+10	2.E+10	2.E+10	2.E+10	3.E+10	3.E+10	3.E+10
	Urban	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07
	Impervious	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10
	Forest	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10
Middle	Pasture	3.E+11	3.E+11	3.E+11	1.E+10	1.E+10	1.E+10	1.E+10	1.E+10	1.E+10	3.E+11	3.E+11	3.E+11
	Agriculture	3.E+10	3.E+10	4.E+10	3.E+10	3.E+10	2.E+10	2.E+10	2.E+10	2.E+10	4.E+10	4.E+10	3.E+10
	Urban	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07
	Impervious	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10
	Forest	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10
Damon	Pasture	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11	3.E+11
	Agriculture	3.E+10	3.E+10	3.E+11	3.E+11	3.E+11	2.E+10	2.E+10	2.E+10	2.E+10	3.E+11	3.E+11	3.E+10
	Urban	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07
	Impervious	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10
	Forest	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10	3.E+10
Lower	Pasture	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	4.E+10	4.E+10	4.E+10	4.E+10	5.E+10	5.E+10	5.E+10
	Agriculture	3.E+10	3.E+10	3.E+10	3.E+10	2.E+10	2.E+10	2.E+10	2.E+10	2.E+10	3.E+10	3.E+10	3.E+10
	Urban	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07	4.E+07
	Impervious	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10	5.E+10

Table 19: Final estimated loads used as input in calibrated model.

SOURCE CATEGORY		DAILY LOAD (counts/day)
In-stream Cattle and Septic	**Subwatershed**	
	Damon Run	3.08E+10
	Lower	1.28E+10
	Middle	3.82E+10
	Upper	3.59E+10
	Valpo	3.73E+10
NPDES	**Facility**	
	Liberty Schools	4.19E+09
	Shorewood Forest	1.13E+08
	Sands Mobile Home Park	3.12E+08
	Liberty Farm Mobile Home Park	2.44E+08
	Burns Harbor Estates	2.28E+08
	Elmwood Mobile Home Park	6.27E+08
	Nature Works Conservancy District	3.01E+08
	Mallard's Pointe Condominiums	9.75E+07
	Valparaiso Municipal STP	1.49E+09
	South Haven Sewer Works	7.40E+07
Valparaiso Municipal STP By-Pass	**Month**	
	01/98	9.16E+10
	02/98	6.90E+09
	03/98	2.79E+10
	04/98	2.17E+10
	05/98	2.08E+10
	06/98	2.81E+10
	07/98	5.80E+10
	08/98	1.06E+09
	09/98	3.07E+09
	10/98	0.00E+00
Valparaiso Municipal STP CSO	**Day**	
	04/13/98	5.35E+13
	04/21/98	6.40E+12
	05/07/98	4.00E+13
	05/08/98	1.06E+13
	06/11/98	3.95E+13
	07/03/98	8.87E+12
	07/04/98	1.06E+13
	07/17/98	6.47E+13
	08/14/98	6.43E+13
	09/20/98	4.52E+12

6 Total Maximum Daily Load Analysis

A TMDL represents the maximum capacity of a waterbody to assimilate a pollutant while safely meeting the respective water-quality standard. The TMDL for a given waterbody and pollutant is the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background levels [U.S. EPA, 2001b]. The sum of the allocations must not result in the exceedance of the water-quality standard. In addition, a margin of safety (MOS) must be included in the analysis, either implicitly or explicitly. The MOS accounts for any uncertainty in the relationship between loads and conditions in the receiving water and helps to ensure that the water-quality standard is met. These concepts can be expressed conceptually by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

Developing allocations for point and nonpoint sources presents a challenge for bacteria TMDLs. TMDLs are traditionally expressed in terms of loads (mass per unit time). However, mass is not an appropriate unit for pathogens. Concentrations of indicators such as *E. coli* are usually reported in units of “colony forming units per unit volume” or “counts per unit volume.” In addition, the dynamic nature of bacteria loading and the range of critical conditions presented by such diffuse sources makes assignment of fixed loads insufficient for the quantification required by a TMDL. Federal regulations allow TMDLs to be expressed in “other appropriate measures” [40 CFR 130.2 (i)]. It is common for bacteria TMDLs to be expressed as a concentration or as a percent reduction required for attainment of the standard. This TMDL is expressed as a total percent reduction based on a statistical measure of the existing and target conditions. The WLA and LA are expressed as portions of the total reduction, the sum of which equals the reduction necessary to achieve the loading capacity of Salt Creek. An explicit MOS is included in the TMDL.

6.1 Critical Conditions

The goal of the TMDL program is to reduce the *E. coli* concentrations in Salt Creek to a level that meets its designated-use standard for a full body contact recreational stream. Indiana’s water-quality standard for recreational waters is set forth in 327 I.A.C. 2-1-6 and 2-1.5-8(e)(2) [IDEM, 2002b]. The standard reads “*E. coli* bacteria, using membrane filter (MF) shall not exceed one hundred twenty five (125) per one hundred (100) milliliters as a geometric mean based on no less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period."

The analysis of existing water-quality data presented in Section 3 demonstrated that there is no single critical condition associated with violations of the dual *E. coli* standard in Salt Creek. Load-duration curve analysis revealed that exceedances of the single-sample standard occur throughout the flow regime. A higher percentage of exceedances were observed, however, in the high-to-middle range of flows (2-60 percent flow duration), indicating that concentrations above the standard are likely associated with nonpoint sources or other event-driven inputs such as storm sewer discharges and CSOs. Additional analyses presented in the Section 3 confirmed that exceedances in the creek and its tributaries were associated with precipitation events. The modeling analysis presented in Section 5 also confirmed the importance of precipitation events in contributing to elevated concentrations in the creek. The HSPF model of the watershed employed for this analysis was calibrated over an entire recreational season. The calibration period provided a good opportunity for evaluating a range of conditions in the watershed and allowed proper consideration of the the critical conditions of impairment.

6.2 Technical Approach

The TMDL and respective allocations were developed in terms of the percent reductions required for attainment. The needed reductions were calculated by a statistical method that utilizes the frequency distributions of predicted *E. coli* concentrations. The method employed is modeled after concepts presented as Statistical Rollback Theory by Ott [1995]. Frequency distributions of *E. coli* concentrations predicted by the watershed model were analyzed to assess the linkage of sources with in-stream effects and set the TMDL values.

A frequency distribution is an excellent way to graphically represent hydrologic data sets. Figure 39 shows the results of the analysis. Existing conditions were defined as the distribution of concentrations predicted by the calibrated model. The distribution includes the predicted *E. coli* concentration for each day of the calibration period (the 1998 recreational season). By using the distribution of the entire recreational season, the range of conditions that represent the critical conditions is incorporated into the TMDL. The predicted distribution was approximated as lognormal. Distributions of water-quality data are commonly lognormal. The lognormal regression is included on the graph with the resulting correlation coefficient.

A cumulative frequency distribution is constructed by first ranking the data from the smallest value to the largest value. The smallest value is assigned a rank of i=1 and the largest a rank of i=n, where n equals the sample size of the data set. The "plotting position" is plotted on the horizontal axis. The plotting position is a function of the rank i and the sample size n. An advantage of using frequency distributions is that all of the data are displayed and every data point has a distinct position.

Graphical analysis of *E. coli* distributions predicted by the model allows convenient comparison of scenarios with both the single-sample and geometric-mean standard. The 100^{th}percentile of the data set represents the maximum concentration and allows direct comparison with the single-sample standard. The geometric mean of the data set is given by the 50^{th}percentile and allows comparison with the geometric mean standard. For existing conditions, the watershed and regression models predict a 100^{th}percentile value of 1,445 $CFU/100\,ml$ (Figure 39). The WLA and LA were calculated as portions of the total reduction required to achieve the loading capacity. The loading capacity was defined as a distribution with a 100^{th}percentile value equal to the single-sample standard of 235 $CFU/100\,ml$.

6.3 WLA

The WLA represents the portion of the TMDL assigned to point sources. A detailed description of the point sources of *E. coli* in the watershed is presented in Section 4. Ten NPDES facilities in the watershed are point sources of *E. coli*. Discharges from the ten permitted facilities include treated sanitary wastewater. All ten permittees are required to treat the waste stream and to monitor for *E. coli*, fecal coliform, or residual chlorine. Some are required to monitor for a combination of the three parameters. All of the permits are issued with the purpose of meeting the water-quality standard for *E. coli* in the receiving water. It was assumed that those permittees required only to monitor for residual chlorine were meeting the single-sample standard if the permitted residual levels were met. All facilities required to monitor for only residual chlorine will be required by IDEM during the next permit cycle to monitor for *E. coli*.

In addition to treated wastewater from the permitted dischargers, point source contributions include intermittent discharges of untreated sanitary wastewater due to bypasses and CSOs. Load estimates based on 1998 data from Discharge Monitoring Reports showed that inputs due to the CSO at Valparaiso and bypasses from several of the facilities were significantly higher than the combined ambient inputs. Bypasses are defined as "the intentional diversion of waste streams from any portion of an Industrial User's treatment facility" [40 CFR122.41(m)(l)]. Section 402 of the Clean Water Act prohibits bypasses from wastewater treatment facilities unless the bypass does not violate the permit or other specific extenuating circumstances are present. Indiana has in place a CSO Control Strategy to bring the State into compliance with the requirements of the Clean Water Act. The city of Valparaiso's Long Term Control Plan (LTCP) for the CSO was submitted to the State earlier in 2003 and is currently under review. The LTCP will help the city in meeting the water-quality standard for *E. coli*.

The WLA was calculated as the percent reduction achievable by eliminating all bypass flows and reducing the CSO input concentrations to the geometric mean standard of 125 $CFU/100\,ml$. The geometric mean standard was used to calculate the percent reduction achievable by the point-source controls described above, the model inputs were adjusted accordingly, and the resulting distribution of predicted concentrations was fitted to a lognormal model (Figure 39) in the same way as described above for the existing conditions. The model predicts how the distribution of concentrations will change in the post-control state. The post-control distribution is lower, as expected, and tilted more toward the right. Unlike Ott's Statistical Rollback Theory, the analysis presented here does not assume geometric scaling of post-control distributions. The tilt is represented by the lognormal model as a decrease in the slope of the regression line. The tilt is due to the reduction of CSO inputs in the model. CSO inputs are sporadic, but cause very high daily concentrations. Reducing CSO inputs in the model reduces values in the upper end of the distribution, causing the regression line to decrease and tilt more toward the right. The lognormal model of the post-control scenario predicts a distribution with a 100^{th} percentile concentration of 1023 $CFU/100\,ml$. The resulting reduction of 29% represents the WLA of the TMDL (Figure 39). The reduction is achievable by eliminating all bypass flows and reducing the CSO input loads and does not require a reduction in limits for the permitted facilities.

6.4 LA

The LA represents the portion of the TMDL assigned to nonpoint sources. Nonpoint source pollution is derived from diffuse sources that generally involve land activities. A detailed description of the nonpoint sources of *E. coli* in the watershed is presented in Section 4.

The LA was calculated as the percent reduction required to reduce concentrations in addition to the WLA to the loading capacity of the creek. The loading capacity was defined as conditions that yield a 100^{th} percentile concentration equal to the single-sample standard of 235 $CFU/100\,ml$. Specifically, the LA was calculated as the reduction required to reduce the 100^{th} percentile concentration from conditions modeling post-control of the CSO (1023 $CFU/100\,ml$) to the loading capacity (235 $CFU/100\,ml$) (Figure 39). The required reduction for the LA is 55%.

6.5 MOS

The MOS accounts for any uncertainty in the relationship between loads and conditions in the receiving water. Uncertainties in the source assessment and the linkage analysis were identified in Sections 4.3 and 5.3, respectively. An explicit 4% MOS was incorporated into the TMDL by reserving a portion of the loading capacity. A relatively low MOS was chosen because the overall uncertainty was minimized by use of a comprehensive watershed loading model.

The loading capacity was defined as a distribution with a 100^{th} percentile value equal to the single-sample standard of 235 $CFU/100\,ml$. The TMDL must incorporate a MOS that accounts for uncertainty in the analysis linking pollutant loads and conditions in the creek. The MOS was incorporated by defining target conditions as an additional 4 % of the TMDL. The result is a distribution with a 100^{th} percentile equal to 170 $CFU/100\,ml$. The TMDL was calculated as the percent reduction required such that the 100^{th}percentile of the distribution representing existing conditions is equal to that representing the target conditions. The total reduction required is 88%. The MOS portion of the TMDL is relatively low compared to the LA and the WLA. However, the MOS was determined with a 100^{th} percentile value that is 28% lower than the single-sample standard and is considered appropriate given the robust modeling analysis used for linking sources and conditions in the creek.

6.6 Summary of TMDL Components

The TMDL was calculated by determining the total percent reduction required to reduce the 100^{th}percentile of the distribution from existing conditions to the target conditions (Figure 39). Of the total 88% reduction required to meet the target conditions, 29% is the WLA,

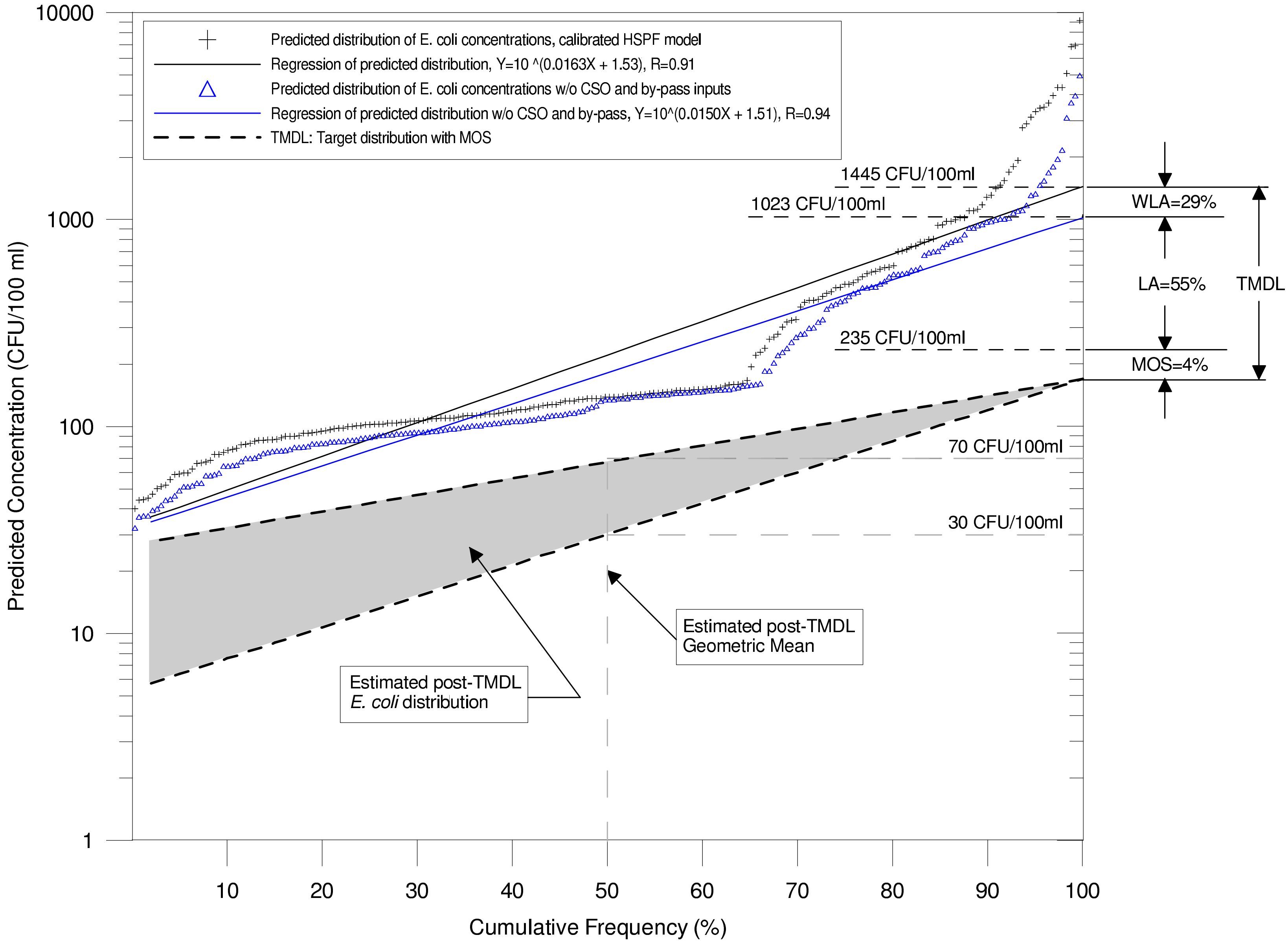


Figure 39: Graphical representation of the statistical method used to calculate the E. coli TMDL target and allocations for Salt Creek.

Table 20: Salt Creek TMDL components.

Pollutant	WLA	LA	MOS	TMDL[1]
E. coli	29%	55%	4%	88%

[1]Expressed as reduction required to reduce the 100thpercentile of the E. coli distribution to the single-sample standard, with MOS

55%, is assigned to the LA, and 4% is the MOS. The TMDL elements are summarized in Table 20.

6.7 Post-TMDL Distribution

The predicted post-TMDL distribution of concentrations is shown in Figure 39. The 100$^{\text{th}}$ percentile of the distribution was defined as necessary for achievement of the TMDL (described above). The slope of the regression was estimated as having a range. The slope was bracketed between the slope of the post-control distribution (upper bound) and the slope of the modeled distributions in the middle frequencies (30%-70% cumulative frequency). Reducing nonpoint source inputs will reduce the slope of the distribution similar to the change in slope seen by reducing CSO inputs. Like the CSO, diffuse sources are episodic, but contribute high daily concentrations. It is assumed that reducing nonpoint source inputs will not decrease the slope of the distribution more than the slope represented by the middle range of concentrations since these concentrations should be unaffected by nonpoint source controls.

The geometric mean of the lognormal distribution is estimated by the 50$^{\text{th}}$percentile. While this value represents the geometric mean of the distribution of concentrations over the entire recreational season and the geometric water-quality standard applies only to a subset of the samples over any 30-day period, it is useful to compare the predicted geometric mean with the geometric standard. Given the assumptions to estimate the slope of the distribution, the geometric mean of the post-TMDL distribution was estimated to be between 30 and 70 $CFU/100\,ml$, values well below the geometric mean standard of 125 $CFU/100\,ml$.

7 Public Participation

IDEM has held four public stakeholder meetings to present the progress of the TMDL program for Salt Creek. Comments from the public have been incorporated into the final draft of the documents. The kickoff meeting, held on July 25, 2002, introduced the stakeholders to WHPA, Inc. and IDEM officials involved in the TMDL process. The second meeting, held on October 22, 2002, presented a summary of the Salt Creek Data Report which described the stream and watershed characteristics, climate, and preliminary analysis of the data. The meeting on June 25, 2003 provided a presentation of the Salt Creek Source Assessment and Modeling Framework. A meeting on December 15, 2003 presented information on the combined modeling framework of the Salt Creek TMDL and concurrent TMDLs being developed in adjacent watersheds. A stakeholder meeting presenting the Draft TMDL is scheduled for January 29, 2004. In addition to the public meetings, a project website with pertinent documents, announcements, and helpful information has been maintained at www.saltcreektmdl.org. Salt Creek project documents are also available for download on IDEM's TMDL website http://www.in.gov/idem/water/assessbr/tmdl/tmdldocs.html.

8 Implementation Activities and Schedule

8.1 Implementation Actions

Reduction of *E. coli* concentrations in Salt Creek must be actively pursued. Implementation actions for point source and nonpoint source reduction are provided, as well as, descriptions of current programs that will help reduce *E. coli* loads to Salt Creek.

8.1.1 Point Source Actions

NPDES permits Only five out of the ten NPDES facilities within the watershed that discharge *E. coli* are required to monitor *E. coli* levels in their effluent. The five that don't monitor *E. coli* monitor either chlorine and/or fecal coliform. *E. coli* measurements from all facilities would help inform the TMDL process. During the next permit renewal, *E. coli* limits and *E. coli* monitoring will be added to the permit requirements for all facilities.

CSO Long Term Control Plan In 1994, the USEPA published the National Combined Sewer Overflow (CSO) Control Policy. In accordance with that policy, IDEM amended Indiana's CSO Strategy to bring Indiana into compliance with the requirements of the Clean Water Act. Phase I of the National CSO Policy requires that "nine minimum controls" be implemented. These controls are 1) proper operational and regular maintenance 2) maximum use of the collection system for storage 3) review and modification of pretreatment programs 4) maximization of flow to the treatment plant 5) prohibition of CSO discharges during dry weather 6) control of solid and floatable materials in CSO discharges 7) pollution prevention programs 8) public notification of CSO occurrences and impacts, and 9) monitoring to effectively characterize CSO impacts. In addition the city must characterize the stream reach and submit a Long Term Control Plan (LTCP) for approval by IDEM. The LTCP will assist Valparaiso in meeting the water-quality standard for *E. coli*.

Valparaiso submitted its LTCP in 2003. It is currently under review by IDEM. Improvements at Elden Kuehl Pollution Control Facility in Valparaiso have already begun with the Upgrade and Expansion Project. The improvements include modifications to the existing CSO tanks, expansion of the headworks facility, conversion of two-stage nitrification system to a single stage nitrification, installation of two new circular clarifiers, replacement of tertiary filter media, a new laboratory building, and other miscellaneous improvements. The LTCP will assist Valparaiso in meeting the water-quality standard for *E. coli*.

Bypasses Bypasses are defined as "the intentional diversion of waste streams from any portion of an Industrial User's treatment facility [40 CFR122.41(m)(l)]." Section 402 of the Clean Water Act prohibits "bypasses" from wastewater treatment facilities unless: (a) It was unavoidable to prevent loss of life, personal injury, or severe property damage. (b) There was no feasible alternative to bypass. (c) The industrial user submitted notices as required under Federal, State, or local regulations. (d) It does not result in any condition which violates the users permit.

Of the bypass exceptions, (b) requiring "no feasible alternative" has been challenged most often. However, in a recent federal case, *United States v. City of Toledo, Ohio,* the Federal Court ruled that "any bypass which occurs because of inadequate plant capacity is unauthorized...to the extent that there are 'feasible alternatives,' including construction or installation of additional treatment capacity [USEPA, 2000]." The ruling emphasizes the importance of communities assessing whether each treatment facility has adequate storage and/or treatment capacity. Ensuring sufficient facility capacity will reduce the occurrence of bypasses in Salt Creek.

Stormwater Program The EPA Phase II stormwater rule, effective October 29, 1999, requires communities with populations under 100,000 to meet permit program conditions aimed at controlling water pollution caused by stormwater runoff. The rule requires communities to implement a municipal stormwater management program that includes a list of six minimum stormwater control measures:

1. Public education and outreach on stormwater impacts: develop and implement a program to educate the public on stormwater discharge impacts to water bodies and the steps necessary to reduce stormwater pollution.

2. Public involvement: develop and implement a public participation program to assist in the implementation of the stormwater management program.

3. Illicit discharge detection and elimination: develop and implement a program that includes ordinances prohibiting illicit connections or discharges (including dumping), create storm sewer maps, and offer public education on the hazards of illicit discharges.

4. Construction site stormwater runoff control: develop, implement, and enforce a program to control stormwater runoff from construction activities on land disturbances of 1 or more acres.

5. Post-construction site stormwater management in new developments and redevelop-

Table 21: Entities in Salt Creek watershed required to implement EPA's Phase II stormwater regulations.

Permit ID	Designated Entity	Type of Designation	Operators Name
INR040149	Aberdeen Property Owner's Assoc.	Residential Population and Location in UA	John R. Marshall
INR040036	Town of Chesterton	Urbanized Area	Michael J. Phipps
INR040090	City of Portage	Urbanized Area	Craig Hendrix
INR040140	Porter County	Urbanized Area	Kevin D. Breitzke
INR040115	Town of Porter	Urbanized Area	Kathryn Kozuszek
unknown	South Haven Census Defined Place	Urbanized Area	unknown
INR040073	City of Valparaiso	Urbanized Area	Matthew J. Kras
INR040073	Valparaiso University	University Enrollment and Location in UA	Matthew J. Kras
INR040103	Valparaiso Lakes Area Conservancy District	Residential Population and Location in UA	Karl Bauer

UA=Urbanized Area

ment: develop, implement, and enforce a program that addresses stormwater runoff from new development and redevelopment, generally using structural and non-structural best management practices (BMPs).

6. Pollution prevention/good housekeeping for municipal operations: develop and implement a program that considers pollution prevention and good housekeeping measures for maintenance activities, street runoff controls, storm sewer waste disposal, and flood control management projects as they relate to municipal operations.

Indiana's Rule 13 meets the guidelines set by the EPA's Phase II stormwater regulations. In August 2003, IDEM sent a letter of notification to the entities which are required to obtain a permit and implement Phase II regulations. The permit applications were due November 4, 2003. In the Salt Creek watershed there are nine entities which are required to implement Phase II stormwater regulations (Table 21).

The The City of Valparaiso has already begun implementing some of the six (6) minimum control measures (MCMs) required by Rule 13:

1. Public Education and Outreach - the information regarding Phase II is on the city website and will be updated regularly.

2. Illicit Discharge Detection and Elimination - the city is currently working on photographing and mapping all outfalls from conveyance systems with a pipe diameter of twelve-inches (12") or larger and open ditches with a two-foot (2’) or larger bottom width.

3. Construction Site Stormwater Runoff Control - the city currently requires erosion control measures, usually silt fencing, at construction sites for the stormwater runoff.

8.1.2 Nonpoint Source Actions

Nonpoint source pollution can be reduced by the implementation of “best management practices" (BMPs). BMPs are structural and management practices which are used in agriculture, forestry, urban land development and industry to reduce the potential for damage to natural resources from human activities [IDEM, 2002b]. A BMP may be structural, that is, something that is built or involves changes in landforms or equipment, or it may be managerial, that is, a specific way of using or handling infrastructure or resources. BMPs should be selected based on the goals of a Watershed Management Plan. BMPs can be implemented by livestock owners, farmers, and urban planners. For reduction of *E. coli* runoff, the following are recommended:

Riparian Area Management Management of riparian areas protects streambanks and river banks with a buffer zone of vegetation, either grasses, legumes, or trees. Riparian areas are along the sides of streams. Management of this area is beneficial for streams near urban areas, cropland, and pastureland. Riparian area buffer zones can trap coliform bacteria, soluble nutrients, and soluble pesticides in runoff water if the runoff moves over the buffer area in a shallow, even flow. The area prevents sediment and other pollutants from reaching those bodies of water as well as provide shade to the water body. They reduce water erosion, slow runoff, trap soil particles, and provide food and nesting cover for wildlife. The effectiveness of riparian buffer zones is increased as the width of the zone is increased.

Manure Collection and Storage Collecting, storing, and handling manure in such a way that nutrients or bacteria do not run off into surface waters or leach down into ground water. Manure is collected each day and stored.

Contour Row Crops Farming with row patterns and field operations aligned at or nearly perpendicular to the slope of the land. Row patterns follow established grades or terraces or diversions, if present. This practice reduces erosion, controls water runoff, and improves water quality. Contours are established at a nearly perpendicular direction to the slope of the land. Contours may be designed with a slight slope on soils which are slowly or very slowly drained to allow for surface drainage. Excess runoff from contours is often directed to field borders, vegetative filter strips, or grassed waterways. Contour farming decreases sheet and rill erosion by creating furrows or small dams, reducing transport and providing opportunities for deposition. Contour farming reduces surface runoff of dissolved nutrients and pesticides by reducing runoff. Contour farming also increases the time between onset of rainfall and initiation of runoff, which helps move some dissolved chemicals below the soil surface and reduces runoff losses. Contour farming is most effective on fields relatively free of gullies and depressions, and where slopes are uniform. Contour farming is often used in combination with other practices, such as terraces or grassed waterways, especially for control of excess runoff.

No-Till Farming No-till is a year-round conservation farming system. In its pure form, no-till does not include any tillage operations either before or after planting. The practice reduces wind and water erosion, catches snow, conserves soil water, protects water quality, and provide wildlife habitat. No-till helps control soil erosion and improve water quality by maintaining maximum residue levels on the soil surface. These plant residues: 1) protect soil particles and applied nutrients and pesticides from detachment by wind and water; 2) increase infiltration; and 3) reduce the speed at which wind and water move over the soil surface.

Manure Nutrient-Testing If manure application is desired, sampling and chemical analysis of manure should be performed to determine nutrient content for establishing the proper manure application rate. Knowing the nutrient content of manure will help reduce the possibility of over application and minimize nutrient runoff or leaching potential. Nutrient content of manure varies widely with animal type, age, and size; feed; manure storage system; and climate. For these reasons, determination of manure nutrient values from sampling and laboratory analysis is preferable to using average values. A sample should be taken from each manure source or storage system. For daily hauling, take many small samples over a representative period. The sample should be taken as close to time of use as possible, allowing time for analysis, interpretation of results, and calibration of the manure spreader. Manure should be re-sampled if changes in management, handling, or feeding occur.

Soil Nutrient-Testing Soils are sampled to a 2-foot depth from 1 to 6 months prior to applying the fertilizer and analyzed for nitrate-nitrogen and sampled to a 6-inch depth for phosphorus. The results are analyzed by a professional agronomist to make fertilizer recommendations. Soil testing evaluates the amount of nitrogen and phosphorus in the soil available for the forthcoming crop, and develop fertilizer recommendations that will match crop needs and yield goals. All homeowners, businesses, and farmers are encouraged to have their soil tested for nutrient content.

Drift Fences Drift fences (short fences or barriers) can be installed to direct livestock movement. The fences manipulate livestock patterns in a way that reduces soil erosion problems and keeps livestock away from surface waters. A drift fence can be used to block a gentle slope where continual trailing of animals is causing gullies. This will force the animals to utilize different areas. A drift fence parallel to a stream keep animals out and prevents direct input of *E. coli* to the stream.

Pet Clean-up / Education Education programs for pet owners can improve water quality of runoff from urban areas. Teaching citizens to pick up and dispose of their pet's feces can reduce the amount of *E. coli* entering the streams through stormwater.

Septic Management Programs for management of septic systems can provide a systematic approach to reducing septic system pollution. One example of such a program is the Community Septic Management Program adopted by Massachusetts. The program is implemented at the local level where each community can decide between two options 1) development of a plan which requires regular inspection of all septic systems at least every 7 years or 2) creation of a local plan to monitor proper maintenance of systems. Both approaches provide some form of funding to homeowners for septic repair and upgrade. Other communities have passed septic management ordinances that require pumping of septic tanks at regular intervals. Although, difficult to enforce, requiring proper maintenance of septic systems can help alleviate pollution.

Public education about septic system maintenance is a good first step to decreasing septic system pollution. Most septic system owners want to maintain their system to help extend the life and effectiveness of their systems as well as benefit the environment.

8.1.3 List of Projects Conditionally Selected for Funding

Other projects in the Salt Creek watershed that may enhance the water quality of the stream are being funded through the Great Lakes Coastal Restoration Grants Program. The Indiana Great Lakes Coastal Restoration Grants Program is a new grants program established in 2001 as a means to distribute Indiana's share of a Congressional award to Great Lakes states. Indiana's funds will be used to restore and protect rivers, streams, lakes, wetlands, and habitat for endangered wildlife in Indiana's Lake Michigan coastal region [IDNR, 2003]. Five of the projects selected for funding will benefit the Salt Creek Watershed. All have been conditionally selected and are currently waiting for federal approval. A description of these projects is provided below [IDNR, 2003].

- *Restore and Enhance Samuelson's Fen and Salt Creek at Imagination Glen Park*. This project will restore and enhance the natural communities associated with Salt Creek, which bisects the 250-acre Imagination Glen Park.

- *Phase 2b: Creekside Park Development*. This project will develop trails and an environmental management plan for a 70-acre undeveloped park. The project will also restore and maintain native upland habitat, wetlands, fens, and Salt Creek corridor (a salmonid stream).

- *Phase 2c: Creekside Park Development*. This project will assist in the development of boardwalks and a bridge crossing for public access and restore 10-40 acres with native vegetation to Creekside Park, a 70-acre undeveloped park.

- *Stimson Drain Stormwater Best Management Practices Management Design Project.* This project will produce a stormwater management design that will promote various best management practices for the 600-acre Stimson Drain Watershed.

- *Porter County Jail Alternative Stormwater Management Demonstration Project.* The newly constructed Porter County Jail is located in the Stimson Drain Watershed, which is undergoing significant commercial development. This on-site demonstration project will reduce and manage the impact of stormwater in the watershed.

8.2 Reasonable Assurance

Reasonable assurance of implementation plan success is supplied by water-quality monitoring and ongoing programs occurring in the watershed. Programs such as the CSO Long Term Control Plan and the Stormwater Program help insure that CSOs and Stormwater will have a reduced impact in the watershed. Monitoring also assures the effectiveness of the implementation plan. The water quality in Salt Creek will continue to be monitored throughout the implementation plan. The following organizations / projects are responsible for the water quality monitoring:

- IDEM fixed station data collection
- The Statewide *E. coli* Monitoring Project
- Lake Michigan Interagency Task Force/Non-point Source Monitoring Project
- Discharge Monitoring Reports from NPDES Facilities

The data collected will be used to show progress towards *E. coli* concentration reduction in the stream. If progress is not shown, changes in the implementation plan will be made.

8.3 Legal or Regulatory Controls

The implementation of the TMDL will be facilitated / controlled by Indiana Department of Environmental Management (IDEM) officials.

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Appendix A - Supplemental Data

Appendix B - WinHSPF Model Input File