Formatted for Double-Sided Printing

Charleston Side Channel Reservoir Total Maximum Daily Load Report

Coles County, Illinois

Doc. No: IEPA/BOW/03-013

Submitted by:
Illinois Environmental Protection Agency
1021 North Grand Avenue East
Springfield, IL 62794-9276

Prepared by:
Tetra Tech, Inc.
1468 W. 9th Street
Suite 620
Cleveland, OH 44113

August 2003

This page was intentionally left blank for double-sided printing

CONTENTS

APPENDIX

FIGURES

TABLES

Executive Summary

The Charleston Side Channel Reservoir (CSCR) is a water supply and recreational reservoir located in Coles County in east central Illinois. The CSCR is located three kilometers south of the city of Charleston and is the sole drinking water source for the city's approximately 23,000 residents. Many residents and outsiders also use the CSCR for sportfishing and boating activities.

As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency (Illinois EPA) has identified the CSCR as an impaired water. The potential causes of impairment are phosphorus, nitrogen, total suspended solids (TSS), and excessive algal growth/chlorophyll *a* (Illinois EPA, 2001). These impairments result in the CSCR's being in partial support of its primary contact (swimming) and secondary contact (recreation) designated uses and in partial support of its aquatic life designated use. The drinking water supply and fish consumption designated uses of the CSCR are not impaired. It should also be noted that swimming is prohibited in the CSCR due to concerns about safety. The Illinois Pollution Control Board has designated the CSCR with a swimming use, therefore, Illinois EPA monitors this use even though the city of Charleston prohibits swimming in the CSCR.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters on the Section 303(d) lists. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the potential pollutants impairing the CSCR, phosphorus is the only one with a water quality standard for lakes.

Potential sources of phosphorus to the CSCR include pumping from Lake Charleston, runoff from the direct drainage area, shoreline erosion, septic systems, and precipitation. The bottom sediments are also contributing phosphorus loadings during portions of the year. Loads from these sources were estimated using a variety of means, and it was determined that the primary sources are the bottom sediments, pumping, and shoreline erosion. The BATHTUB model was used to determine how much the loads must be reduced so that the phosphorus target is achieved. BATHTUB was determined to be appropriate for the modeling because it addresses the parameter of concern (phosphorus) and has been used previously for reservoir TMDLs in Illinois and elsewhere.

The results of this analysis indicate that phosphorus loads must be reduced approximately 90 percent from their current levels to meet the TMDL target. A draft project implementation plan discusses potential implementation activities to achieve the desired reductions in loading, and presents a range of alternatives along with their expected costs and ability to reduce loads. Additional discussion among key stakeholders must occur to better identify specific actions that can be taken, and to refine the cost analysis.

Phase II Storm Water Regulations were not addressed in this TMDL because municipal separate storm sewer systems (MS4s) were not identified as a contributor to the pollutant for which this TMDL was developed.

Confined Animal Feeding Operations (CAFOs) were not addressed in this TMDL because they were not identified as a contributor to the pollutant for which this TMDL was developed.

This page was intentionally left blank for
double-sided printing

1.0 Introduction

The CSCR is a water supply and recreational reservoir located in Coles County in east central Illinois (Figure 1). The CSCR is located three kilometers south of the city of Charleston, and it is the sole drinking water source for the city's approximately 23,000 residents. Many residents and outsiders also use the CSCR for sportfishing and boating activities. The CSCR was created in 1981 when Lake Charleston, an impoundment on the Embarras River, was divided by the building of a dike. Water from Lake Charleston is now pumped into the CSCR for eventual intake to the Charleston drinking water treatment plant. The land that drains directly into the CSCR is only a few square kilometers in size, is steeply sloped, and is primarily forested.

Since the completion of the CSCR, the names of the resulting waterbodies have created some confusion. Different reports and maps use different names for these waters. Illinois EPA considers the large body of water to the west of the side-channel dike to be the CSCR (Figure 2). The body of the water on the east side of the dike from the Riverview Dam-spillway to the Route 16 bridge is considered Lake Charleston. The name of the river above and below Lake Charleston is the Embarras River.

As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency (EPA) has identified the CSCR as an impaired water (Table 1). The potential causes of impairment are phosphorus, nitrogen, total suspended solids (TSS), and excessive algal growth/chlorophyll *a* (Illinois EPA, 2001). These impairments result in the CSCR's being in partial support of its primary contact (swimming) and secondary contact (recreation) designated uses and in partial support of its aquatic life designated use. The drinking water supply and fish consumption designated uses of the CSCR are not impaired. It should also be noted that swimming is prohibited in the CSCR due to concerns about safety. The Illinois Pollution Control Board has designated the CSCR with a swimming use, therefore, Illinois EPA monitors this use even though the city of Charleston prohibits swimming in the CSCR.

Several segments of the Embarras River upstream of Lake Charleston are also impaired and are identified below:

- Segment BE14 in Douglas County for habitat alteration (other than flow), nutrients, nitrate, and pathogens.
- Segment BE19 in Douglas County for habitat alteration (other than flow), nutrients, and nitrate.
- Segment BE20 in Champaign and Douglas counties for habitat alteration (other than flow), nutrients, and nitrate.

The waterbody known as Lake Charleston generally behaves as a river due to its riverine characteristics. However, at times, it acts like a lake due to the presence of a spillway on its downstream end. These characteristics are evident from the Lake Charleston water levels data recorded daily (Monday-Friday) from 1990 to 1999 by the City of Charleston Water Treatment Plant. These data suggest that in three out of the ten years, there were extended periods of no flow over the spillway; approximately two weeks in 1990, three months in 1991 and three months in 1994 (City of Charleston, 2003). Illinois EPA monitored Lake Charleston in 1976 but no longer monitors Lake Charleston as part of the Ambient Monitoring Program or Clean Lakes Program because of its riverine characteristics. Data that Illinois EPA has for Lake Charleston are not used to determine impairment because the data are more than 15 years old.

The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) lists. Illinois EPA is currently developing TMDLs for pollutants that have water quality standards. Of the pollutants impairing the CSCR, phosphorus is the only one with a water quality standard for lakes. Illinois EPA believes that addressing the phosphorus impairment should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. For example, reducing loads of phosphorus to the CSCR should result in less algal growth and some of the management measures taken to reduce phosphorus loads (e.g., reducing shoreline erosion) should also reduce loads of suspended solids. Also, if phosphorus is reduced the ability of nitrogen to contribute to excessive algal growth should be limited since both nutrients are required.

Table 1. Charleston Side Channel Reservoir Section 303(d) Listing Information.

Rank	29
Watershed Identifier	ILBE09
Waterbody Segment	RBC
Waterbody Name	Charleston Side Channel Reservoir
Size	137 hectares (339 acres)
Designated Uses and Support Status	Fish Consumption (Full), Drinking Water Supply (Full), Overall (Partial), Aquatic Life (Partial), Primary Contact/Swimming (Partial), Secondary Contact/Recreation (Partial)
Causes of Impairment[1]	Nutrients (Phosphorus, Total Ammonia-N), Suspended Solids, Excessive Algae Growth
Potential Sources of Impairment	Agriculture (Crop Related Sources-Non-irrigated Crop Production), Habitat Modification (Streambank Modification/Stabilization), Forest/Grassland/Parkland

[1]Ammonia appeared as a cause in the 2002 Water Quality Report, but was not a cause in the 1998 303(d) List for which the Illinois EPA developed the TMDL. The ammonia cause is being re-evaluated and Illinois EPA plans to monitor the CSCR in 2004.

Source: Illinois EPA, 2002a.

A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The overall goals and objectives in developing the CSCR TMDL have been to:

- Further assess the water quality of the CSCR and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine the maximum load of phosphorus that the CSCR can receive and fully support all of its designated uses. Addressing the phosphorus impairment will also address the other causes of impairment.
- Use the best available science and available data to determine current loads of pollutants to the CSCR.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

Previous reports described the available water quality data, characterized the watershed, and described the modeling tools to be used in developing the TMDLs (Tetra Tech, 2001a, 2001b). This report incorporates all of the information from these previous reports, presents the findings of the modeling analysis, and describes the elements of the TMDL. It also includes a preliminary discussion of how the load reductions might be implemented.

Figure 1. Upper Embarras River Watershed and the Charleston Side Channel Reservoir.

2.0 Description of Waterbody and Associated Watersheds

2.1 Identification and Location of CSCR

The CSCR (watershed identifier ILBE09, waterbody segment RBC) is in Coles County, Illinois (Figure 2). It is adjacent to Lake Charleston, a 62-hectare (153-acre) artificial lake that was formed in 1947 by damming the Embarras River. The CSCR was constructed in 1981 when Lake Charleston (watershed identifier ILBE09, waterbody segment RBH) was separated by a dike (i.e., from 1947 to 1981 the CSCR was part of Lake Charleston). Although the area that surrounds the CSCR and the lake is forested, land use in the watershed that drains to Lake Charleston is predominantly agricultural.

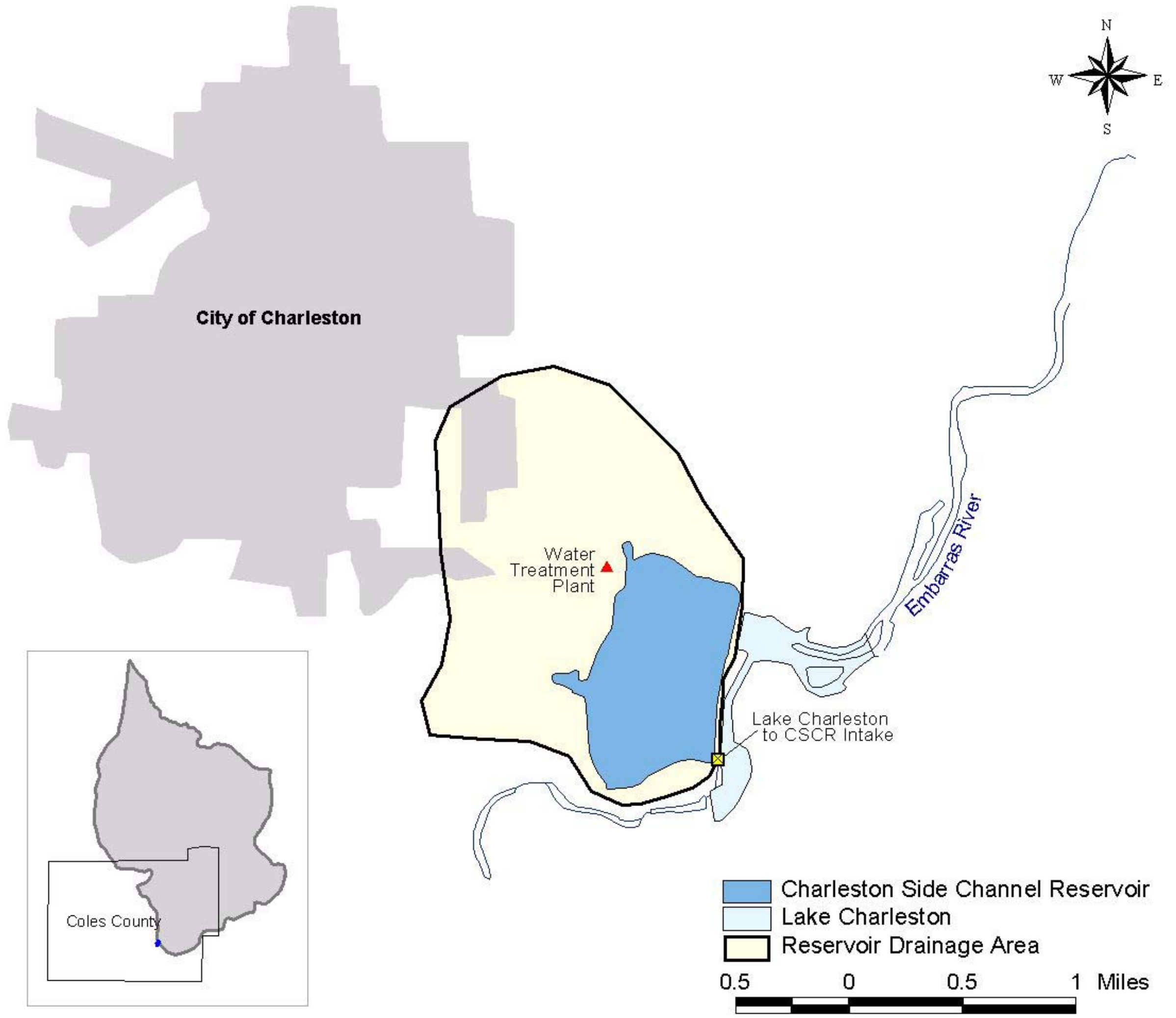
The CSCR is approximately 137 hectares (339 acres) in area. The estimated volume is 3.6 billion liters (923 million gallons). The average depth is 2.6 meters (8.6 feet) with a maximum of 4.6 meters (15 feet) near the water treatment plant (Alford, 2001). The intake from Lake Charleston to the CSCR is at the southeast end of the reservoir, while the output pump that leads from the CSCR to the water treatment plant is at the northwest end. The shoreline length is approximately 4,500 meters (14,800 feet) (City of Charleston, 1992).

The city of Charleston installed an aeration system in the CSCR in 1987 to address taste and odor problems associated with high algal populations. The purpose of an aeration system is to artificially increase dissolved oxygen concentrations to help the aquatic life and make it less likely that phosphorus will be released from the bottom sediments. The city installed the aeration system in the northwest corner of the CSCR, surrounding the raw water intake structure. Several problems were experienced with the initial system and it was replaced in the spring of 1996. The new system has performed better but still is incapable of keeping the entire CSCR from becoming anoxic during summer conditions. This is partly due to the unique hydrologic characteristics of the CSCR, such as the lack of flow associated with a typical reservoir.

The city of Charleston has also treated the CSCR with copper sulfate over the years in an attempt to control algae. The decision to treat with copper sulfate is made based on the results of algal analyses. The CSCR is treated with copper sulfate as many as three times in any one year, usually with some success. However, in some years the application is hampered by high winds that force all the copper sulfate to the north end of the CSCR (Alford, 2002).

The Embarras River upstream of Lake Charleston drains approximately 2,039 square kilometers (787 square miles) of land. The Embarras River begins just south of Champaign and Urbana, Illinois, and includes parts of five counties: Champaign, Edgar, Coles, Douglas, and a small corner of Vermillion. The entire Embarras River watershed (including downstream of Lake Charleston) drains 8,596 square kilometers (3,319 square miles) in 10 counties in east central Illinois.

Figure 2. Charleston Side Channel Reservoir and Lake Charleston.



2.2 Land Use

General land use and land cover data for the CSCR and Upper Embarras River watersheds were extracted from the Multi-Resolution Land Characteristics (MRLC) Consortium database for the state of Illinois. The following federal agencies formed the MRLC to acquire satellite-based remotely sensed data for their environmental monitoring programs: U.S. Geological Survey, EPA, National Oceanic and Atmospheric Administration, Forest Service, National Atmospheric and Space Administration, and the Bureau of Land Management. The land use data are derived from images acquired by Landsat's Thematic Mapper satellite during the early 1990s. These data categorize the land use for each 30-meter by 30-meter pixel of land in the watershed[1]. Each 30-meter by 30-meter pixel contained within the satellite image is classified according to its reflective characteristics. Land use in the area directly draining to the CSCR is

[1] A 1995 land cover database referenced by the Illinois Natural Resources Geospatial Data Clearinghouse is based on similar satellite data and was not available at the time of this report.

a mix of forest, agriculture, and urban areas (Table 2 and Figure 3). Table 3 and Figure 4 present the land use information for the Upper Embarras River watershed.

Table 2. Land Use Distribution in the Area Directly Draining to the Charleston Side Channel Reservoir.

Land Use	Hectares	Percentage
Deciduous Forest	197.4	37.7
Water	139.8	26.7
Pasture/Hay	60.8	11.6
Row Crops	43.4	8.3
Low-Intensity Residential	34.2	6.5
Grasslands/Herbaceous	12.0	2.3
High-Intensity Residential	11.3	2.2
Urban Grasses	8.5	1.6
Wooded Wetlands	8.0	1.5
Commercial/Industrial	2.7	0.5
Evergreen Forest	1.9	0.4
Small Grains	1.6	0.3
Herbaceous Wetlands	1.2	0.2
Bare Rock/Sand/Clay	0.3	0.1
Total	**523.1**	**99.9**

Source: MRLC, 1992.

Figure 3. Land Use in the Charleston Side Channel Reservoir Direct Drainage Area.

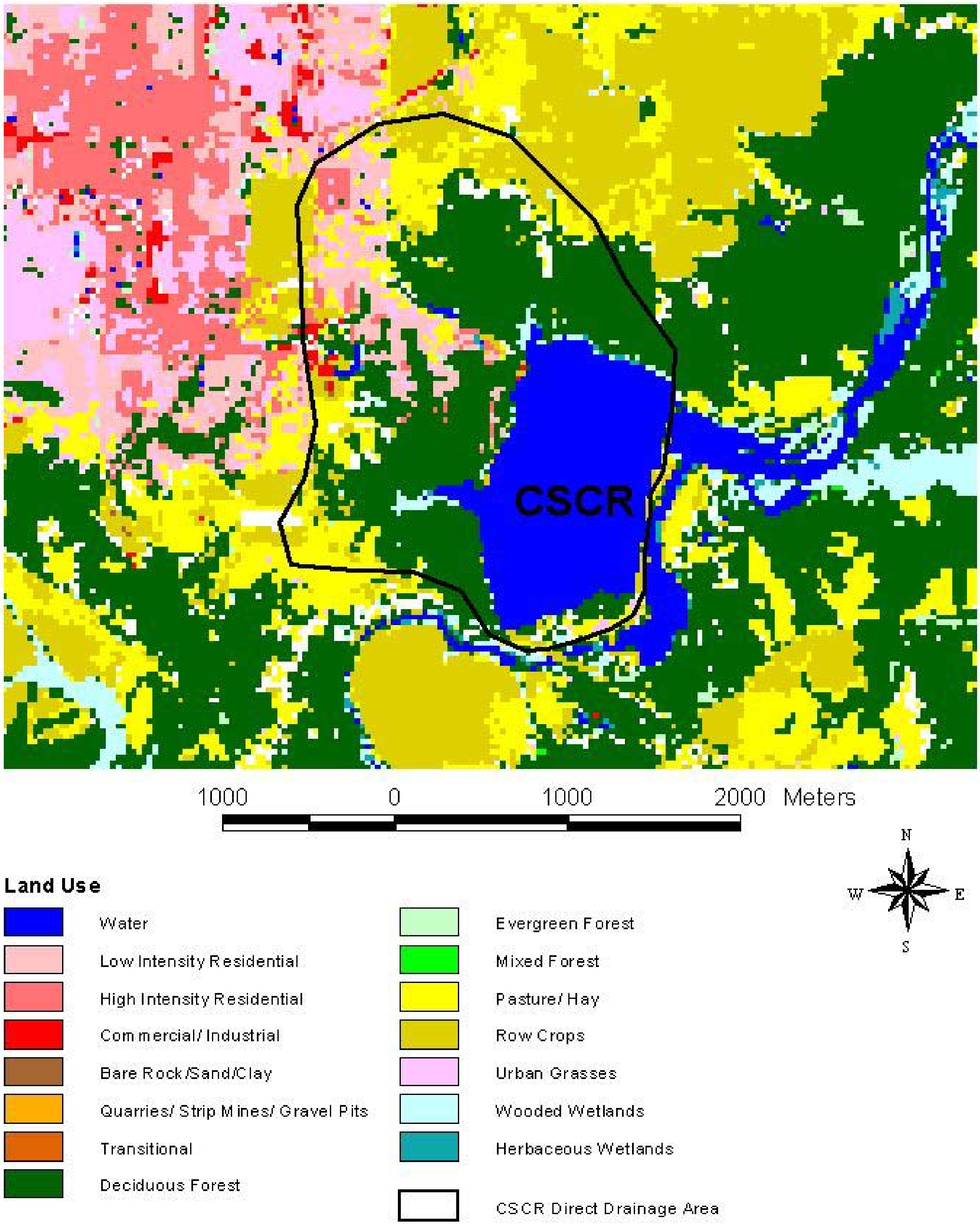
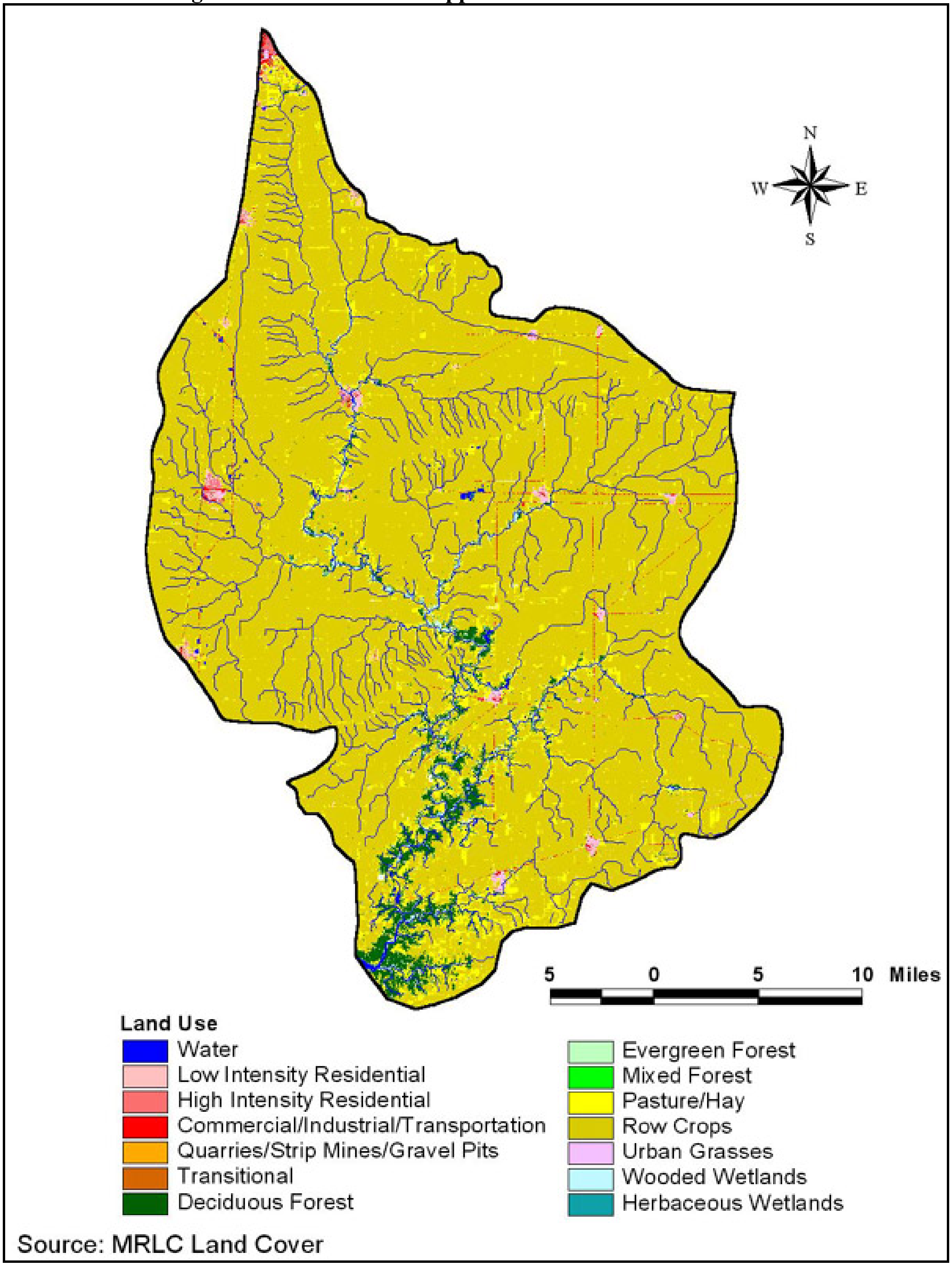


Table 3. Land Use in the Upper Embarras River Watershed.

Land Use	Hectares	Percent
Row Crops	175,442	86.0
Pasture/Hay	15,274	7.5
Deciduous Forest	6,592	3.2
Wooded Wetlands	2,244	1.1
Commercial/Industrial/Transportation	985	0.5
Grasslands/Herbaceous	871	0.4
Low-Intensity Residential	802	0.4
Urban Grasses	635	0.3
High-Intensity Residential	366	0.2
Open Water	373	0.2
Evergreen Forest	112	0.1
Herbaceous Wetlands	103	0.1
Small Grains	83	0.0
Quarries/Strip Mines/Gravel Pits	54	0.0
Bare Rock/Sand/Clay	14	0.0
Mixed Forest	2	0.0
Total	**203,952**	**100.0**

Source: MRLC, 1992.

Figure 4. Land Use in the Upper Embarras River Watershed.



2.3 Topography and Soils

The CSCR is in the Embarras River Valley, which cuts through glacial till and some bedrock. The topography in the CSCR watershed is dominated by ridges and ravines with steep slopes, short lengths, and high-gradient tributaries. The maximum depth of the ravines is 27 meters (89 feet), and the slopes have a characteristic angle of approximately 27 degrees. Land on these slopes is predominantly forested. A portion of the watershed is flat uplands (City of Charleston, 1992).

The Upper Embarras River watershed is part of the Central-Corn Belt Plains Level III Ecoregion. Flat areas with little surface relief characterize this ecoregion. The maximum elevation in the upstream watershed is 244 meters (801 feet), and the minimum elevation is 171 meters (561 feet). The mean elevation is 208 meters (682 feet). Soils in the watershed are primarily Mollisols. Mollisols have a high native fertility making them some of the most important agricultural soils in the world (Brady, 1990).

2.4 Population

The Upper Embarras River watershed encompasses portions of five rural counties with small communities. The biggest cities in the area are Champaign-Urbana, with a population of approximately 170,000, and the city of Charleston, with a population of approximately 23,000 (U.S. Census Bureau, 2000). Nearly half of Charleston's population consists of students at Eastern Illinois University (EIU). The population of only the Upper Embarras River watershed is estimated to be 40,000 based on the 2000 Census data and a geographic information system (GIS) analysis.

Table 4 indicates that population growth in the area has been slow, with an increase of less than two percent for the five-county area between 1990 and 2000 (U.S. Census Bureau, 2000).

Table 4. Population for the Five Counties That Overlap the Upper Embarras River Watershed.

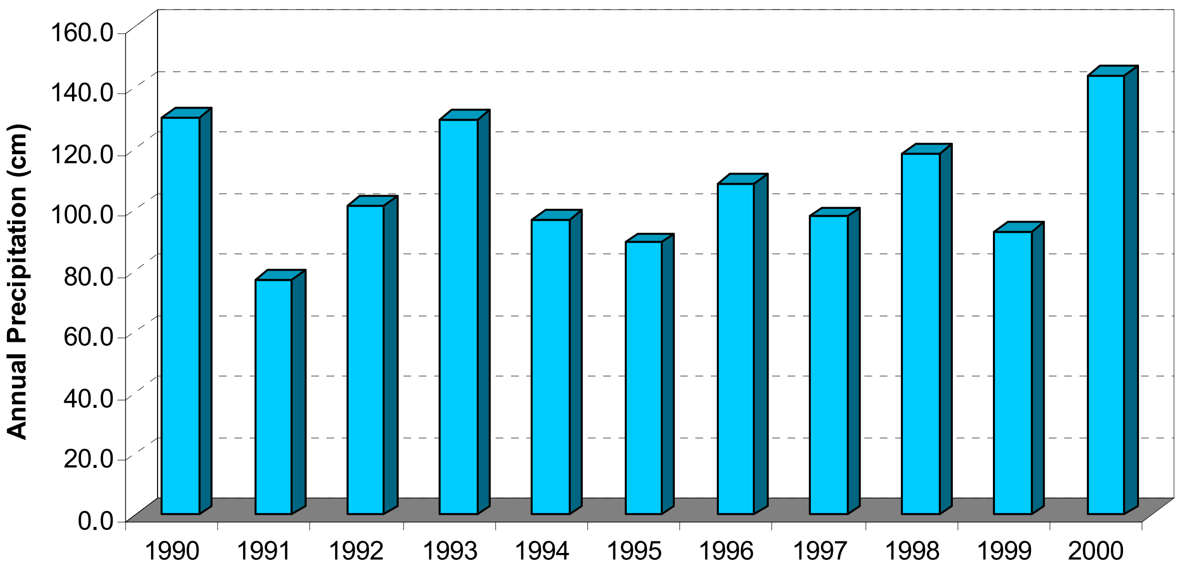
County	1990 Population	2000 Population
Champaign	173,025	179,669
Coles	51,644	53,196
Douglas	19,464	19,922
Edgar	19,595	19,704
Vermilion	88,257	83,919
Total	**351,985**	**356,410**

3.0 Climate and Hydrology

3.1 Climate

East central Illinois has a temperate climate with hot summers and cold, snowy winters. The average long-term annual precipitation is approximately 102 centimeters (40 inches). The maximum annual precipitation is 143.8 centimeters (56.6 inches) (2000); the minimum annual precipitations is 64.5 centimeters (25.4 inches) (1914). On average there are 107 days with precipitation of at least 0.03 centimeter, 26 days with precipitation of at least 1.3 centimeters, and 10 days with precipitation greater than 2.5 centimeters (MCC, 2001). Average snowfall is approximately 56 centimeters (22 inches) per year. The annual precipitation for the period 1990 to 2000 is shown in Figure 5. Average maximum and minimum temperatures in Charleston are 1.4 °C (34.6 °F) and –7.7 °C (18.1 °F), in January, and 30.3 °C (86.5 °F) and 18.9 °C (66.1°F) in July. The growing season typically lasts from April through October.

Figure 5. Annual Precipitation in Charleston, Illinois (1990–2000).



3.2 CSCR Hydrology

Inputs of water to the CSCR include precipitation, the water that the treatment plant pumps from Lake Charleston, direct runoff, and groundwater (including septic systems). A hydrologic budget for 1989 and 1990 (City of Charleston, 1992) showed that, of the contributions that could be accounted for, 51.3 percent of the flow input came from pumping. Pumping was greatest during the months of December and July, and least during May, September, and October (when no pumping occurred). The second largest input was from precipitation, which constituted 41.2 percent of the total input. Approximately 6 percent of the input came from direct runoff and less than 1 percent came from septic systems. Outputs include evaporation, groundwater discharges, and withdrawals for water supply. The water treatment plant withdrew 66.7 percent of the water, evaporation accounted for 31.2 percent, and groundwater loss accounted for the difference. Table 5 shows a comparison of Lake Charleston and CSCR pumping for the years 1981 to 2000.

Table 5. Pumping Records from 1981 to 2000 (million gallons) (City of Charleston, 2002).

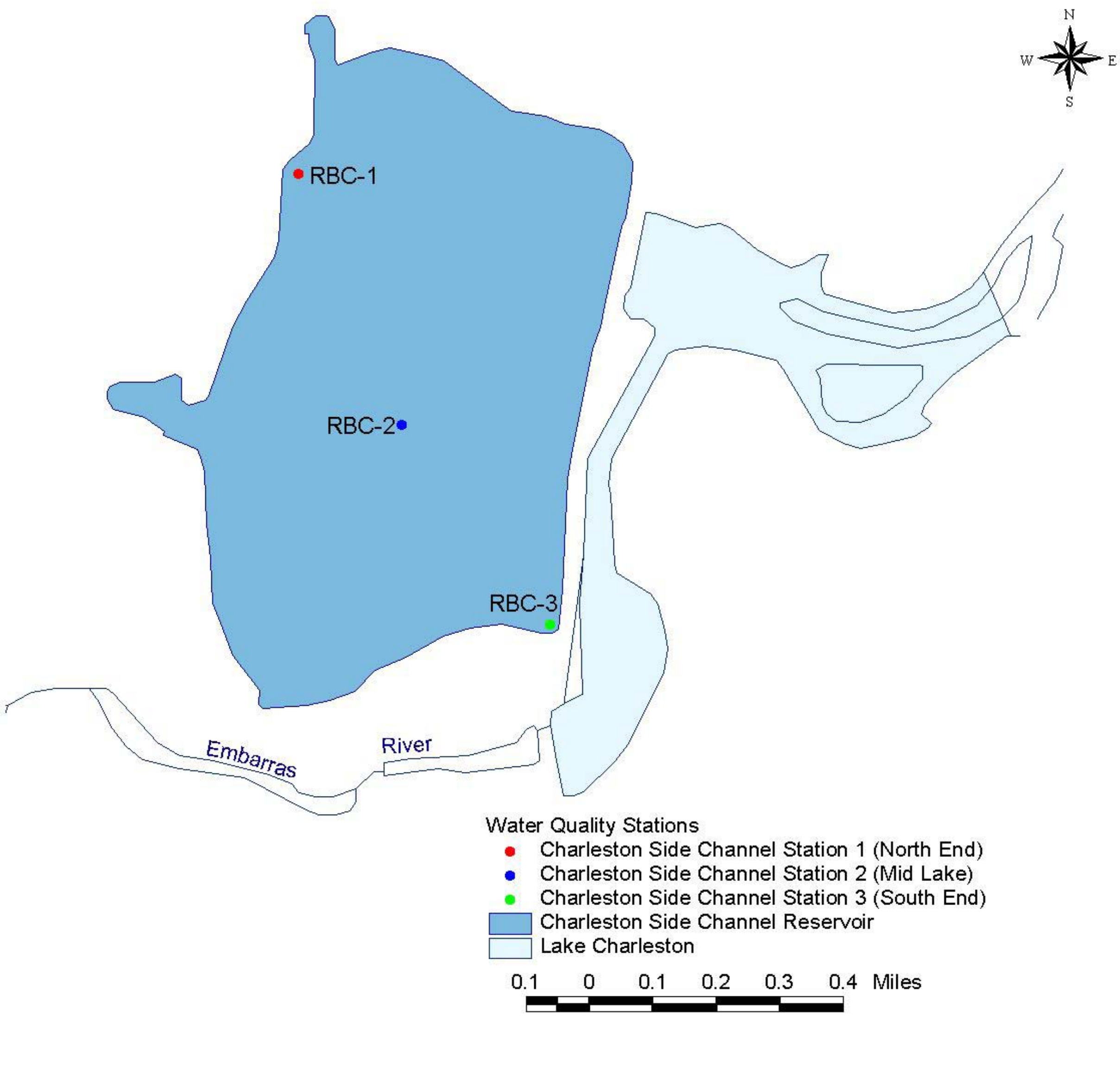
Year	Volume Pumped from Lake Charleston to CSCR	Volume Pumped from CSCR to Treatment Plant	Volume Pumped from Treatment Plant to City
1981	207.4	522.0	488.1
1982	297.3	525.4	560.6
1983	470.4	589.2	594.5
1984	397.5	629.4	614.9
1985	243.7	604.7	602.8
1986	541.3	604.6	606.8
1987	698.3	634.2	588.3
1988	590.4	630.0	601.1
1989	472.2	602.8	501.2
1990	322.6	557.6	489.5
1991	502.3	575.4	512.8
1992	559.5	680.2	577.6
1993	139.5	702.7	655.0
1994	311.9	800.2	691.4
1995	837.8	758.1	667.0
1996	633.7	821.4	673.9
1997	831.0	988.7	801.5
1998	503.1	831.0	705.5
1999	496.8	710.0	642.9
2000	720.8	657.3	609.7
Average	488.9	671.2	609.3

4.0 Water Quality

4.1 Monitoring Data

Illinois EPA has sampled water quality in the CSCR every three years since 1983. The location of the three sampling stations is shown in Figure 6. Parameters sampled include transparency, temperature, dissolved oxygen, nutrients, nonvolatile suspended solids, chlorophyll *a*, pH, and conductivity. Dissolved oxygen and temperature samples are taken at multiple depths in increments of 0.30 meters (1 foot). The results of the sampling for the parameters of interest to this TMDL are shown in Appendix A.

Figure 6. Location of Water Quality Monitoring Stations.



4.2 Water Quality Standards and TMDL Targets

States are responsible for setting water quality standards to protect the physical, biological, and chemical integrity of their waters. The Illinois Pollution Control Board establishes the water quality standards for all waters in the state, including the CSCR. The three components of water quality standards are:

- Designated uses (e.g., drinking water supply, aquatic life, secondary contact (recreation)).
- Narrative and numeric criteria designed to protect these uses.
- An antidegradation policy that provides a method of assessing activities that might affect the integrity of water bodies.

The purpose of the TMDL program is to ensure that waters that are not currently attaining water quality standards will meet them in the future.

Designated uses take into consideration the use and value of the CSCR for public water supply; for propagation of fish, shellfish, and wildlife; and for recreational, agricultural, industrial, and navigational purposes. General use standards protect aquatic life, wildlife, agricultural use, primary contact use (swimming), and secondary contact use (recreation). The public water supply use provides protection of potable water and culinary water. The general use standards are usually the principal restoration targets for water resource management efforts in Illinois.

Full support is achieved when the water body meets the designated use. Partial support means that the water body incompletely attains the designated use. Nonsupport means that the waterbody does not attain the designated use. Full/threatened means the waterbody attains the designated use, but a declining water quality related trend has been evidenced, and if continued, only partial use support may be attained in the future.

The assessment of the overall use support aggregates the support attained for each of the individual uses. The CSCR is currently rated as “partial” for its overall use support. Since the CSCR does not fully support all of its designated uses, it is considered impaired and is listed on the Section 303(d) list. The impaired designated uses are primary contact (swimming), secondary contact (recreation), and aquatic life. The fish consumption and drinking water supply uses are fully supported. This TMDL focuses only on phosphorus because it is the only listed parameter with a numeric water quality standard for lakes. However, Illinois EPA believes that addressing the phosphorus impairment should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. For example, reducing loads of phosphorus to the CSCR should result in less algal growth and some of the management measures taken to reduce phosphorus loads (e.g., reducing shoreline erosion) should also reduce loads of suspended solids. Also, if phosphorus is reduced the ability of nitrogen to contribute to excessive algal growth should be limited since both nutrients are required.

4.3 Evaluation of Water Quality Data in CSCR

The following sections describe the available water quality data in the CSCR related to the phosphorus impairment.

4.3.1 Eutrophication

Since the early part of the 20th century, lakes and reservoirs have been classified according to their trophic state. A eutrophic (“well-nourished”) reservoir has high nutrients and high plant growth. An oligotrophic reservoir has low nutrient concentrations and low plant growth. Mesotrophic reservoirs fall somewhere in between.

Four main factors regulate trophic state:

- Availability of sunlight
- Climate
- Shape of the lake or reservoir
- Rate of nutrient supply

Of these factors, sunlight availability and the rate of nutrient supply are the two that are most temporally sensitive. Sunlight availability varies throughout the year and is one of the reasons algae concentrations are typically at their highest during the summer. Aeration systems such as the one in the CSCR can also stir up sediments and block sunlight from reaching plants attached to the bottom of the CSCR.

When nutrient loading to a reservoir is too high and sunlight is available, plant growth can be excessive and cause problems for the aquatic life, recreationists, and water supply use. For example, excessive algae can be aesthetically unattractive and can deplete dissolved oxygen concentrations. High growths of attached plants can also tangle boat propellers and be a nuisance to swimmers. The following sections of this report provide information on the degree of eutrophication in the CSCR.

4.3.2 Total Nitrogen (TN)-to-Total Phosphorus (TP) Ratio

Either nitrogen or phosphorus typically controls eutrophication in freshwater systems. The limiting nutrient is defined as the nutrient that limits plant growth when it is not available in sufficient quantities. Controlling this nutrient can often slow the rate of eutrophication and improve reservoir conditions.
An initial identification of the limiting nutrient can be made by comparing the levels of nutrients in the waterbody with the quantitative relationship between nutrients in the plant, known as its stoichiometry. The ratio of nitrogen to phosphorus in biomass is approximately 7.2:1. Therefore, a nitrogen:phosphorus ratio in water that is less than 7.2 suggests that nitrogen is limiting. Alternatively, higher ratios suggest that phosphorus is limiting (Chapra, 1997). The average TN-to-TP value for all samples for the CSCR is 16.04. This value was obtained for site RBC-1 using data collected during several years (Table 6). These data indicate that phosphorus is the limiting nutrient in the CSCR.

Table 6. TN:TP Ratios at Station RBC-1.

Year	TN:TP
1983	14.33
1984	10.65
1988	13.59
1989	25.75
1990	16.23
1992	14.88
1995	13.15
1998	19.72
Average	16.04

4.3.3 Total Phosphorus

The applicable water quality standard for TP in Illinois for lakes is 0.05 mg/L. Figure 7 presents the Illinois EPA TP data for 1998 in the CSCR. A review of these data shows that the water quality standard was routinely exceeded during the summer and fall months. The average concentration of TP for 1998 was 0.10 mg/L. All three stations have similar TP concentration values, with the station at the northwest end of the CSCR (RBC-1) presenting higher TP values (in particular during the fall months). For all stations a trend is noted: phosphorus values are least during the spring and increase during the summer reaching a maximum in the fall. No data are available for the months of November to March.

Figure 7. 1998 Total Phosphorus Observations.

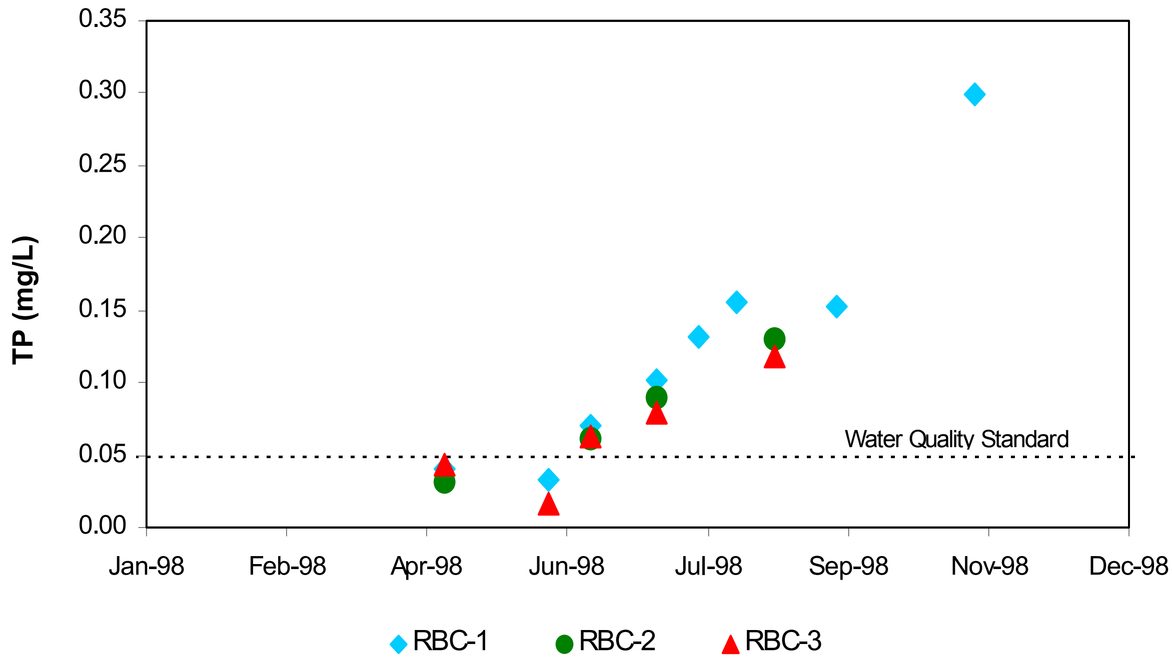
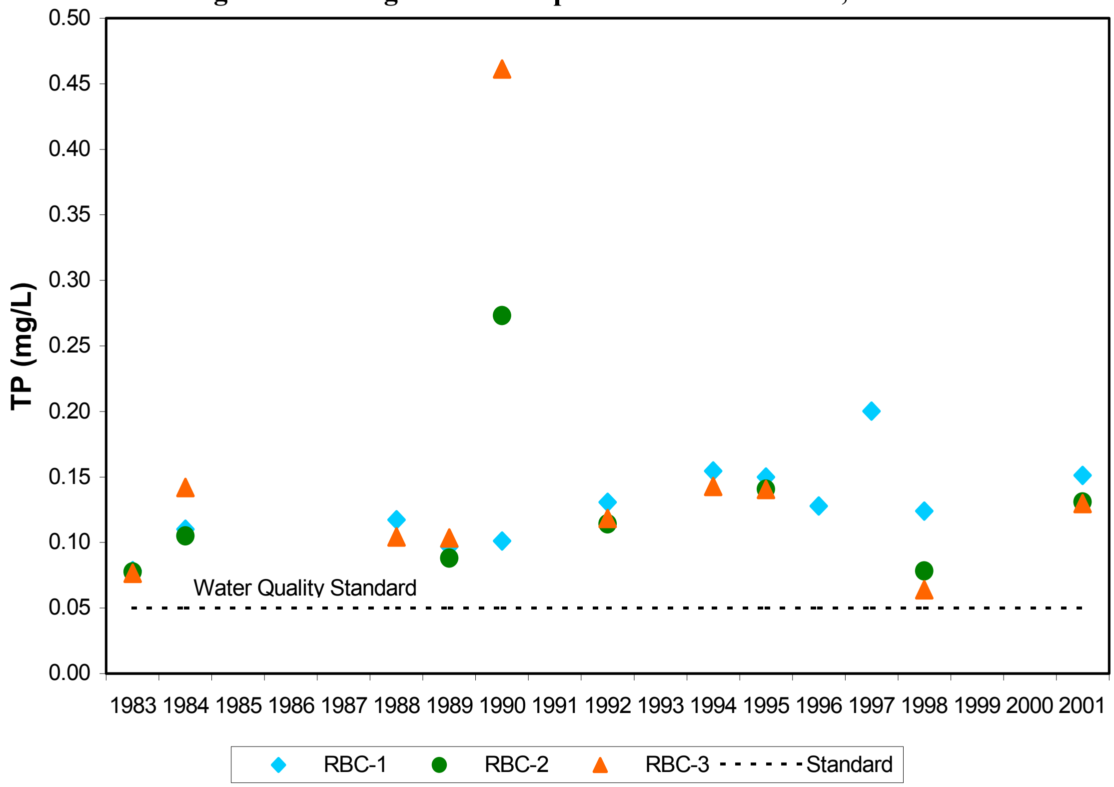


Figure 8 presents the annual averages of TP concentrations for several monitoring years between 1983 and 2001 (Illinois EPA data). Most values fall within the 0.05 to 0.15 mg/L range. The averages for 1990 are particularly notable because they were as high as 0.45 mg/L. A possible explanation might be that 1990 was a relatively wet year and therefore phosphorus loadings from nonpoint sources could have been greater than normal. The long-term average TP concentration for all samples for all dates at all depths is 0.13 mg/L.

Figure 8. Average Total Phosphorus Concentrations, 1983–2001.



4.3.4 Dissolved Phosphorus

The dissolved phosphorus component of TP is the form that is most readily available to plants. It consists of soluble phosphorus that is not bound to particulates. In waterbodies with relatively short residence times (such as fast-flowing streams), dissolved phosphorus is of greater interest than TP because it is the only form that is readily available to support algal growth. However, in lakes and reservoirs, where residence times are much longer, particulate phosphorus can be transformed to dissolved phosphorus through microbial action. TP is therefore considered an adequate estimation of bioavailable phosphorus (USEPA, 1999a).

Dissolved phosphorus concentrations at station RBC-1 averaged 0.025 mg/L for the period 1983 to 2001 (see Appendix A). This is 20 percent of the average TP concentration observed at the same station over the same period and indicates that particulate phosphorus constitutes the large majority of TP in the CSCR.

Table 7 shows the average monthly concentration of dissolved phosphorus and TP at RBC-1 for the period 1983 to 2001. It indicates that the ratio of dissolved phosphorus to TP is greatest in September and the least in April.

Table 7. Average Monthly Concentrations of Dissolved Phosphorus and TP at RBC-1 for the Period 1983 to 2001 (IEPA data).

Month	Average Total Phosphorus (mg/L)	Average Dissolved Phosphorus (mg/L)	Ratio of Dissolved Phosphorus to Total Phosphorus
April	0.06	0.01	0.17
May	0.08	0.02	0.25
June	0.11	0.02	0.18
July	0.14	0.04	0.29
August	0.15	0.03	0.20
September	0.13	0.04	0.31
October	0.17	0.03	0.18

4.3.5 Excessive Algal Growth/chlorophyll *a*

Chlorophyll *a*, the dominant pigment in algal cells, is fairly easy to measure and is a valuable surrogate for algal biomass. Chlorophyll *a* is desirable as an indicator because algae are either the direct (e.g., nuisance algal blooms) or indirect (e.g., high/low dissolved oxygen, pH, and high turbidity) cause of most problems related to excessive nutrient enrichment. Both seasonal mean and instantaneous maximum concentrations can be used to determine impairments. The Illinois water quality standard for general use states that “waters of the state shall be free from algal growth of other than natural origin” (Section 302.203).

Figure 9 depicts the observed chlorophyll *a* concentration values for 1998 (Illinois EPA data) and indicates a trend of increasing values from the spring to late summer and then decreasing values again in the fall. The annual means for sampling years between 1983 and 2001 are presented in Figure 10.

Figure 9. 1998 Observed Chlorophyll *a* Concentrations.

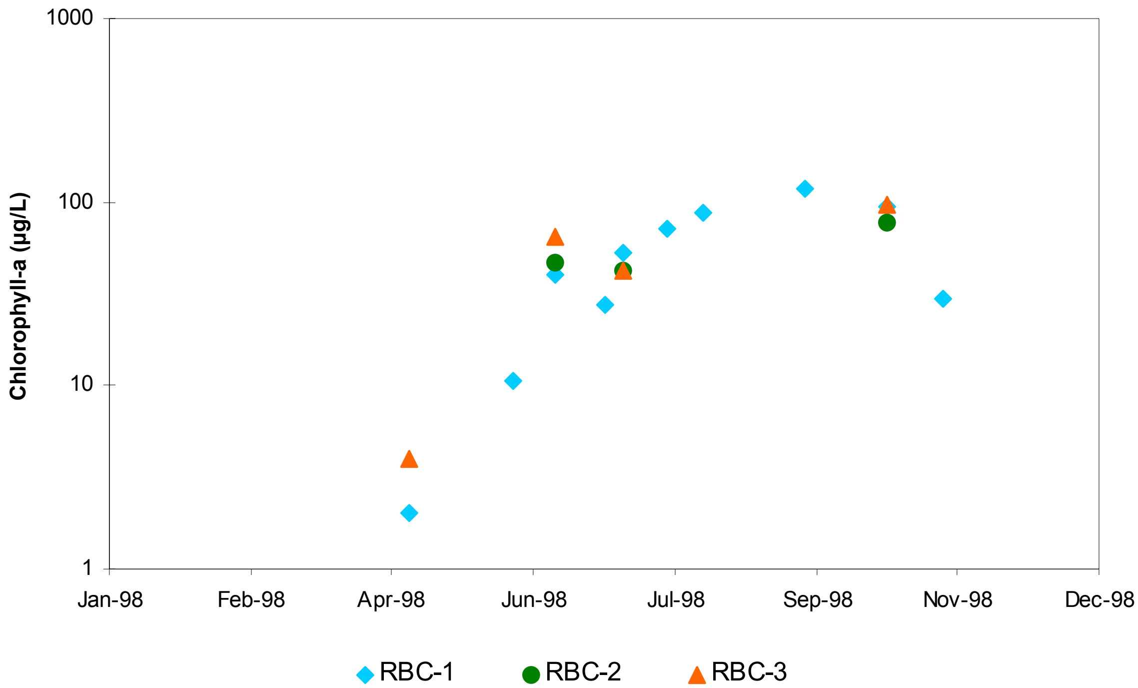
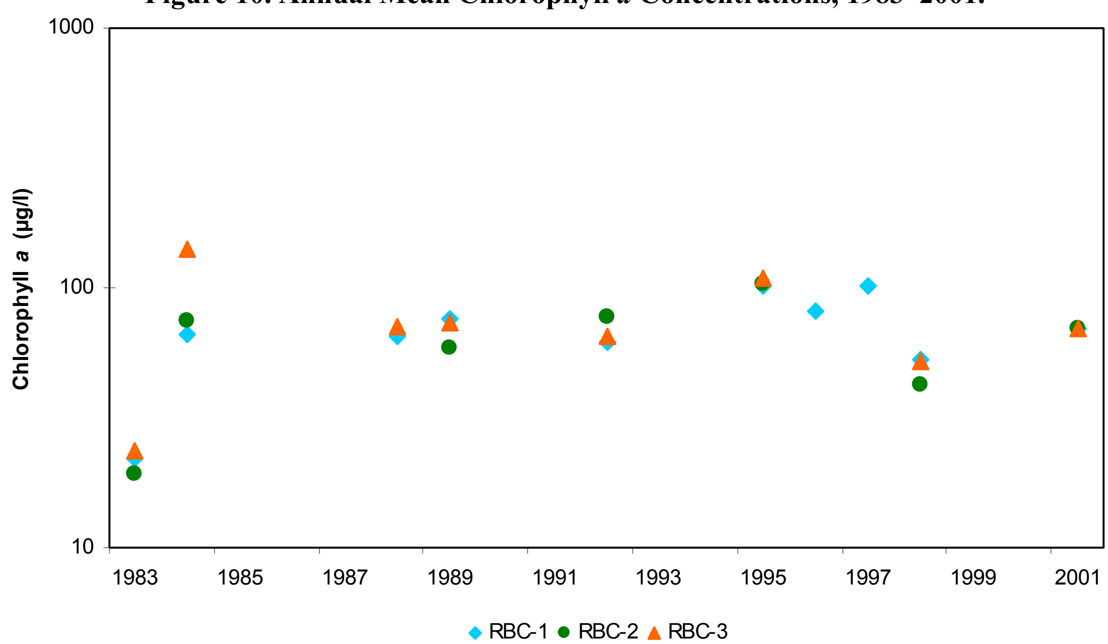


Figure 10. Annual Mean Chlorophyll *a* Concentrations, 1983–2001.



4.3.6 Trophic State

A frequently used biomass-related trophic status index was developed by Carlson in 1977. His trophic status index (TSI) uses Secchi depth (SD), chlorophyll *a* (Chl) and TP, each producing an independent measure of trophic state. Index values range from approximately 0 (ultraoligotrophic) to 100 (hypereutrophic). The index is scaled so that TSI = 0 represents SD transparency of 64 meters. Each halving of transparency represents an increase of 10 TSI units. For example, a TSI of 50 represents a transparency of 2 meters. A TSI is calculated from each of SD, chlorophyll *a* concentration, and TP concentration (Carlson, 1977; Carlson and Simpson, 1996). Each variable is used to estimate algal biomass independently, and the values should not be averaged.

Illinois EPA considers TSI values below 55 to be protective of swimming uses and values below 60 to be protective of aquatic life uses. TSI values above 60 suggest the presence of blue-green algae during the summer, algal scum, and a considerable macrophyte problem. Boating becomes difficult because of weeds and algal scum discourages swimming.

Average TSI values for the CSCR were calculated using available chlorophyll *a*, TP and SD data, and are presented in Table 8. All averages exceed the values Illinois EPA considers protective of swimming and recreational uses.

Table 8. Average Values of the TSI for the Charleston Side Channel Reservoir.

Location	TSI (Chl)	TSI (TP)	TSI (SD)
RBC-1	65.4	70.8	70.5
RBC-2	62.9	65.2	68.1
RBC-3	64.6	61.5	67.9
CSCR Average	64.3	**65.8**	**68.8**

Chl = chlorophyll *a*
TP = total phosphorus
SD = Secchi depth

4.4 Lake Charleston Water Quality Data

Table 9 presents the results of Lake Charleston sampling done by the city of Charleston in 2000. The sampling occurred near the point where water is pumped to the CSCR (Figure 2). It shows an average dissolved phosphorus concentration of 0.19 mg/L and an average TP concentration of 0.30 mg/L. Values fluctuate during the year, with TP concentrations greatest in June and August, and least in March and July. Xue et al. (1998) also report an average dissolved phosphorus concentration of 0.19 mg/L for the Embarras River upstream of Lake Charleston based on weekly or biweekly sampling during the period 1993 to 1996. Xue et al. did not report TP.

Table 9. Phosphorus Concentration in Lake Charleston (Sampling Done by City of Charleston in 2000). [1,2]

Month	Dissolved Phosphorus	Number of samples	Total Phosphorus	Number of Samples
January	0.06	1	0.40	1
February	0.06	4	0.22	2
March	0.13	23	0.04	1
April	0.13	14	0.31	2
May	0.16	4	0.40	2
June	0.49	7	0.46	2
July	0.26	4	0.08	2
August	0.15	2	0.46	1
September	NA	0	NA	0
October	0.21	2	0.23	1
November	NA	0	NA	0
December	0.36	2	0.34	2
Average (weighted)	0.19	NA	0.30	NA

[1]The sampling procedures and laboratory analysis used to collect these data do not meet the same level of quality assurance as data collected by the Illinois EPA. However, since they represent the only current data available for Lake Charleston, and since pumping from Lake Charleston is one of the major sources of nutrients to the CSCR, they were used.

[2]Note that in some cases the monthly values for dissolved phosphorus are greater than those for total phosphorus. This is a nonsensical result for an individual sample because dissolved phosphorus is a part of total phosphorus. However, in some months there were more samples of dissolved phosphorus than total phosphorus and therefore the average dissolved phosphorus could indeed be greater than the average total phosphorus.

5.0 Source Assessment

5.1 Point Sources

No point sources discharge directly to the CSCR. However, there are 12 facilities with National Pollutant Discharge Elimination System (NPDES) permits in the Embarras River watershed upstream of the CSCR (Illinois EPA, 2002b). Table 10 provides information on these facilities along with their annual TP loads for the period March 1998 to March 2002. The loads were estimated based on the reported average flow rates and an assumed discharge concentration of 4.0 mg/L TP (Litke, 1999). The literature value of 4.0 mg/L had to be used for the TP concentration in the effluent because all but one of the facilities do not report this parameter.[1]

5.2 Nonpoint Sources

Potential nonpoint sources of phosphorus to the CSCR include pumping from Lake Charleston, runoff from the direct drainage area, shoreline erosion, septic systems, the bottom sediments, and precipitation. Loads from these sources were measured or estimated by the city of Charleston during its preparation of the 1992 Clean Lakes Program Diagnostic/Feasibility Study (City of Charleston, 1992). These loads were used as the initial basis for estimating current loads to the CSCR but were modified in some cases to reflect new conditions.

5.2.1 Pumping from Lake Charleston

The Water Treatment Plant pumps on average 1.8 billion liters (488.9 million gallons) of water per year from the river to the CSCR (see Table 5). Annual loads of phosphorus from pumping are a function of the volume of water pumped and the concentration of pollutants in the water. A representative annual load of 554.5 kg has been estimated using the average pumping volume, and the 2000 sampling data for Lake Charleston, which indicate an average TP concentration of 0.30 mg/L (Table 9).

TP concentrations in Lake Charleston are a function of flows and loads coming from the Embarras River watershed upstream of Lake Charleston. To further evaluate these upstream loads, the Soil and Water Assessment Tool (SWAT) model was used. SWAT is a watershed model developed by the U.S. Department of Agriculture, Agricultural Research Service. It depicts the effects of land management practices on water, sediment, and agricultural chemical yields in large, complex watersheds. The watershed is divided into subwatersheds to assist in identification of potential sources of phosphorus (Figure 11). For more detailed information on SWAT modeling, refer to Appendix B.

The calibrated SWAT model was run for the 1993 to 2000 time period to determine annual average pollutant transport. The annual average load of TP for this time period was estimated to be 630,000 kg/yr. The majority of this load is attributed to row crop agriculture, which comprises more than 85 percent of the watershed area. Loads from other land uses, such as pasture, are less than 5 percent of the total load.

[1] The only facility to report TP concentrations for its effluent was the Villa Grove Sewage Treatment Plant. The reported value was 0.78 mg/L TP, and this value was used to estimate the average annual loads for this facility. It is not known why this value is so far below those typically reported in the literature.

Figure 11. Upper Embarras River Watershed Modeled Using SWAT2000, Divided into Subwatersheds.

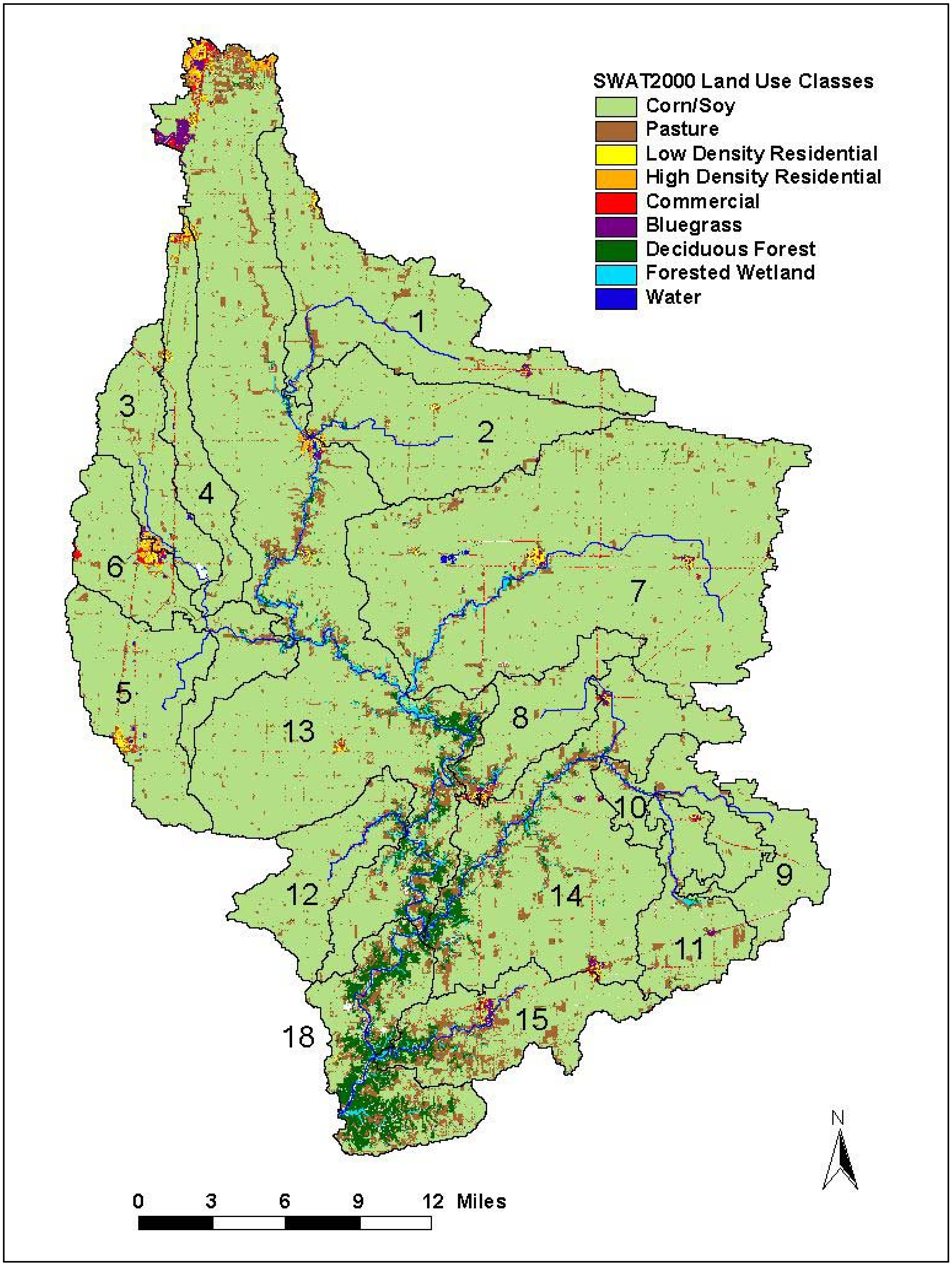


Table 10. NPDES Facilities in the Embarras River Watershed Upstream of the Charleston Side Channel Reservoir and Their Estimated Annual Discharge of Phosphorus (March 1998 to March 2002).

NPDES Permit No.	Facility Name	City	County	Description	Receiving Stream	Average Flow Rate (mgd)	TP (kg/yr)
IL0059005	Villa Grove Sewage Treatment Plant	Villa Grove	Douglas	Sewage Treatment Plant	Embarras River To Wabash River	0.3325	360
IL0027499	Arcola Sewage Treatment Plant	Arcola	Douglas	Sewage Treatment Plant	Unnamed Trib To Scattering Fork	0.4431	2,448
IL0071617	Tuscola Sewage Treatment Plant	Tuscola	Douglas	Sewage Treatment Plant	Hayes Branch	0.8208	4,536
IL0031453	Tolono Sewage Treatment Plant	Tolono	Champaign	Sewage Treatment Plant	Hackett Branch	0.1169	646
IL0055450	Newman Sewage Treatment Plant	Newman	Douglas	Sewage Treatment Plant	Embarras River	0.1220	674
IL0004375	Cabot Corporation	Tuscola	Douglas	Manufacturing	Scattering Fork Creek	0.0704	389
IL0066532	Hydromet Environmental (USA)	Newman	Douglas	Sewage Treatment Plant	Brushy Creek	0.0004	2
IL0042757	Shiloh County Community School	Hume	Edgar	School	Brushy Fork	0.0042	23
IL0055212	Unity High School	Tolono	Champaign	School	Embarras River	0.0012	7
IL0060119	Parkview Mobile Home Park	Tuscola	Douglas	Mobile Home Park	Scattering Fork	0.0100	55
IL0066974	Boxwood Health Care Center	Newman	Douglas	Health Services	Trib To Embarras River	0.0087	48
IL0034916	Rogers Mobile Home Park	Charleston	Coles	Mobile Home Park	Unnamed Trib To Embarras River	0.0059	33
					Total	**1.9361**	**9,221**

For each subbasin, SWAT produces reports that describe the total annual transport by runoff of sediment and associated pollutants into the subbasin stream reach from certain combinations of land use and soil type. Subbasin 7 generates the largest annual average loadings of TP, while Subbasins 13 and 14 contribute the second and third largest pollutant loadings. The large TP delivery from Subbasins 7, 13, and 14 is related to their large size and the dominance of corn/soybean agricultural activities within each subbasin.

The SWAT model does not include a component to estimate TP loads from septic systems. These loads were therefore estimated using the watershed population and assumptions for the performance of the systems (properly functioning systems should contribute very little TP because it will be adsorbed to the soil). Data from the 2000 U.S. Census indicate that the non-urban population of the watershed is approximately 14,000. Assuming that this entire population is served by septic systems with a per capita phosphorus load of 1.5 grams per day (Haith et. al, 1992), and a 15 percent failure rate, the estimated annual load of TP from failing septic systems is 1,150 kg/yr.

5.2.2 Direct Runoff

The only available TP data for tributaries draining directly to the CSCR are from sampling conducted in 1989 and 1990 as part of the Clean Lakes Study (City of Charleston, 1992). Loads were estimated based on monthly flows and observed phosphorus concentrations. Although several efforts have been made to control gully erosion since 1992, the observed loads from the Clean Lakes Study were used as an estimate of current loads in the absence of more current data. Table 11 provides the current estimated loads.

5.2.3 Precipitation

Phosphorus loads from precipitation were estimated using data from the National Atmospheric Deposition Program (NADP). Multiyear averages from three NADP sites were used to produce values for the CSCR. The estimated loads are shown in Table 11.

5.2.4 Shoreline Erosion

Shoreline erosion is another source of TP to the CSCR because phosphorus can be attached to the soil particles that erode. Shoreline erosion in the CSCR occurs when wave activity undercuts poorly consolidated soils and the higher slopes undergo mass movement into the CSCR. Shoreline erosion also occurs when large trees on the edge of the cliffs fall into the CSCR. This causes large masses of soil to be carried into the water and creates a large scar on the shore, which contributes significant sediment (City of Charleston, 1992).

An estimate of the loading from shoreline erosion was developed for the Clean Lakes Study with data supplied by Dr. Vince Gutowski and Dr. Ted Peck. The annual shoreline erosion rate was estimated to be between 944 cubic meters (33,330 cubic feet) and 1,573 cubic meters (55,556 cubic feet) per year based on measuring the eroding cliffs. The average density of the eroded material was estimated to be between 1.35 and 1.40 grams per cubic centimeter and the TP content was 0.45 to 0.91 kilograms (1 to 2 pounds) per short ton (2000 pounds). The most conservative values were used in the nutrient budget and this produced an annual shoreline TP load of 636.6 kg (1,403 lb) (City of Charleston, 1992).
Current loading from shoreline erosion is less than it was in 1992 due to the following (Alford, 2002):

- A 210-meter (700-foot) dike was built along the west shore in 1994 to contain a collapsing shoreline.
- More than 600 meters (2000 feet) of riprap was installed in 1999 and 2000 along the west shoreline.
- Approximately 120 meters (400 feet) of riprap were installed along the south shore.

Current loads were estimated to be approximately 40 percent less than the 1992 loads based on best professional judgment. A significant reduction in shoreline erosion is expected because the management measures focused on some of the most highly erodible areas of the shoreline. Table 11 provides the current estimated loads from shoreline erosion.

5.2.5 Internal Loading

Under certain conditions, bottom sediments can be important sources of phosphorus to the overlying waters of reservoirs, particularly if the reservoir is shallow or has an anaerobic hypolimnium (Chapra, 1997). Phosphorus flux from sediment deposits is strongly affected by sediment composition and oxygen levels in the water column; sediment release can contribute significant nutrient loadings during low-oxygen conditions. Under low-oxygen conditions, phosphorus may be released from the sediment layer, entering the water column and contributing to loading. Indicators of potential nutrient loading from sediment sources might include probable high concentrations of phosphorus in the sediment and known low-oxygen conditions in the waterbody, or evidence of algal blooms following turnover. The estimated internal loading for the CSCR is 944.1 kg/yr based on the results of the BATHTUB modeling. The phosphorus sedimentation term in BATHTUB is net sedimentation–that is, it represents the rate of phosphorus settling minus the rate of resuspension/regeneration from the sediment. The difference between an estimate of phosphorus deposition (1771 kg/yr) based on a phosphorus budget model (Chapra, 1997) and the BATHTUB net sedimentation rate was interpreted as internal loading.

5.2.6 Septic Systems

Several residences in the CSCR direct drainage area treat their household waste using septic systems. Septic systems provide an economically feasible way of disposing of household wastes where other means of waste treatment are unavailable (e.g., public or private treatment facilities). The basis for most septic systems involves the treatment and distribution of household wastes through a series of steps involving the following:

- A sewer line connecting the house to a septic tank
- A septic tank that allows solids to settle out of the effluent
- A distribution system that dispenses the effluent to a leach field
- A leaching system that allows the effluent to enter the soil

Phosphorus loads from properly functioning septic systems should be close to zero because the phosphorus is adsorbed by soil as the effluent passes through. Septic system failure occurs when one or more components of the septic system do not work properly and untreated waste or wastewater leaves the system. The waste may pond in the leach field and ultimately run off into nearby streams or percolate into the groundwater system. Untreated septic system waste is a potential source of nutrients (nitrogen and phosphorus), organic matter, suspended solids, and bacteria. Failure can occur for several reasons, the most common reason being improper maintenance. Other reasons for failure include improper installation, location, and choice of system. Harmful household chemicals can also cause failure by killing the bacteria that digest the waste.

No information is available on the performance of the septic systems in the CSCR direct drainage area. Assuming that 30 persons are served by these systems with a per capita daily phosphorus load of 1.5 g/day (Haith et. al, 1992), and a 15 percent failure rate, the estimated annual load is 2.5 kg/yr.

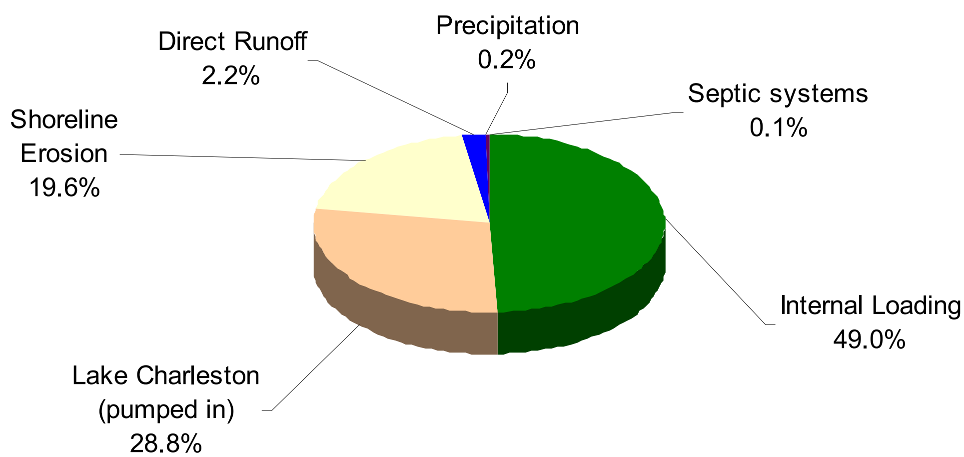
5.3 Source Summary

Table 11 and Figure 12 summarize the estimates of TP loading to the CSCR. They indicate that internal loading, pumping from Lake Charleston, and shoreline erosion are the largest sources of TP.

Table 11. Current Total Phosphorus Loads to the Charleston Side Channel Reservoir.

Source	TP Load (kg/yr)	Percent
Internal Loading	944.1	49.1
Lake Charleston (pumped in)	554.5	28.8
Shoreline Erosion	377.5	19.6
Direct Runoff	41.8	2.2
Precipitation	4.5	0.2
Septic systems	2.5	0.1
Total	1924.9	100.0

Figure 12. Phosphorus Loads to the Charleston Side Channel Reservoir.



6.0 Technical Analysis

Establishing the link between pollutant loads and resulting water quality is one of the most important steps in developing a TMDL. This link can be established through a variety of techniques ranging from simple mass balance analyses to sophisticated computer modeling. The objective of this section of the report is to describe the approach that was used to link the sources of phosphorus with the resulting concentrations in the CSCR.

6.1 Modeling Approach and Model Selection

BATHTUB was selected for modeling water quality in the CSCR. BATHTUB performs steady-state water and phosphorus balance calculations in a spatially segmented hydraulic network, which accounts for advective and diffusive transport, and nutrient sedimentation. In addition, the BATHUB model automatically incorporates internal phosphorus loadings into its calculations. Eutrophication-related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1985). BATHTUB was determined to be appropriate because it addresses the parameter of concern (phosphorus) and has been used previously for reservoir TMDLs in Illinois and elsewhere. USEPA also recommends the use of BATHTUB for phosphorus TMDLs (USEPA, 1999a).

6.2 Data to Support the Modeling Analysis

The BATHTUB model requires the following data to configure and calibrate: tributary flows and concentrations, reservoir bathymetry, in-lake water quality concentrations, and global parameters such as evaporation rates and annual average precipitation. Appendix C provides these values for the CSCR BATHTUB modeling.

The model was segmented into three sections to match the locations of the three sampling stations and to more accurately model the system and better understand the processes affecting water quality. The water quality associated with the station located in each segment was assumed representative of the water quality data of the whole segment. Available contour maps were digitized and used to obtain surface area, average depth, and average length for each segment.

Pumping records from the water treatment plant were used to obtain pumping rates and changes in storage. Average annual evaporation and precipitation values were obtained using the Illinois State Water Survey data for Urbana, Illinois.

The average and coefficients of variation for the sampling stations were determined by analysis of the available Illinois EPA data. These were summarized using statistical tools available with Microsoft Excel and Microsoft Access. Refer to Appendix C for details.

The BATHTUB model can compute average loads over one year or over the growing season. Since the CSCR has a residence time greater than one year, the appropriate averaging period is one year. (Note that the residence time for any one year varies depending on the volume of water pumped from Lake Charleston into the CSCR and the volume of water pumped to the treatment plant).

6.3 Model Calibration

The BATHTUB model was calibrated to observed conditions in 1992 by first checking and adjusting the water balances. The measured inflows and outflows reported in the Clean Lakes report were specified, and the storage term was adjusted to account for unmeasured or un-quantified inflow and outflows (seepage and groundwater contributions). Several of the phosphorus sedimentation routines available within BATHTUB were tested. These included the Canfield and Bachman, Vollenweider, Simple First Order, and Second Order Decay routines. The Second Order Decay routine was selected for the modeling because it provided the best calibration to the observed data. Table 12 shows the results of the calibration period.

Table 12. Results of BATHTUB Modeling (Calibration Period).

Component	Observed Area Weighted Mean	Estimated Area Weighted Mean	Observed vs Estimated Ratio
Total Phosphorus (mg/L)	0.1391	0.1379	1.01
Chlorophyll *a* (μg/L)	65.4	68.1	0.96
Secchi Depth (m)	0.4	0.4	1.00

6.4 Model Validation

The BATHTUB model was next validated to observed conditions in 1998 by adjusting loading and meteorological conditions to represent 1998 conditions and keeping all other model parameters the same. The results of the model validation are shown in Table 13.

Table 13. Results of BATHTUB Modeling (Validation Period).

Component	Observed Area Weighted Mean	Estimated Area Weighted Mean	Observed vs Estimated Ratio
Total Phosphorus (mg/L)	0.1048	0.1082	0.97
Chlorophyll *a* (μg/L)	52.8	52.2	1.01
Secchi Depth (m)	0.6	0.59	1.02

7.0 TMDL

7.1 Loading Capacity

The calibrated BATHTUB model was used to identify the load reductions necessary to achieve a target concentration of 0.05 mg/L phosphorus. An 87 percent reduction in loads is needed to meet the target. This corresponds to a loading capacity of 240.7 kg/yr. Table 14 displays the effect of this reduction.

Table 14. Predicted Impact of 87 Percent Reduction in Phosphorus Loads.

Parameter	Existing Concentration (mg/l)	TMDL Target Concentration (mg/L)	Post-TMDL Concentration (mg/L)
Total Phosphorus	0.1048	0.0500	0.0498
Chlorophyll *a*	0.0528	NA	0.0273

7.2 Allocations

The loading capacity and allocation of loads for the CSCR are summarized in Table 15. The wasteload allocations are 0.4 percent of the loading capacity because it is estimated that point sources currently contribute approximately 0.4 percent of the TP load to the CSCR. (They contribute approximately 1.5 percent of the TP load upstream of Lake Charleston which, in turn via pumping, is 28.8 percent of the load to the CSCR (see Table 11)). The margin of safety is set at ten percent of the loading capacity.

Table 15. TMDL Summary for Charleston Side Channel Reservoir.

Category	Phosphorus (kg/yr)
Existing Load	1924.9
Loading Capacity	240.7
Wasteload Allocation	1.0
Margin of Safety	24.0
Load Allocation	215.7

7.3 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7(c)(1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. For the CSCR, the impact of seasonal and other short-term variability in loading is damped out by the fact that it is the long-term average TP concentrations that drives the biotic response. Since the residence time of the CSCR is greater than one year, the TMDL can be adequately expressed in terms of an annual average load.

7.4 Margin of Safety

Section 303(d) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." Future growth is included in the margin of safety. The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991). A 10 percent explicit margin of safety has been incorporated into the CSCR TMDL by reserving a portion of the loading capacity. A relatively low margin of safety is justified because of the results of the BATHTUB modeling which indicate good representation of the relationship between source loading and water quality response.

Five percent of the margin of safety is for future growth. The relatively small percentage is based on the fact the city of Charleston is experiencing only moderate growth. Charleston's population increased from 20,398 in 1990 to 21,039 in 2000. Similarly, Table 4 shows that the five counties of which the Upper Embarras River watershed is a part grew by less than 2 percent between 1990 and 2000 (U.S. Census Bureau, 2000). The 5 percent will provide for continued growth but emphasizes that the impacts of all future growth must be fully addressed and TP loads minimized.

8.0 Implementation

A draft project implementation plan (Appendix D) discusses potential implementation activities to achieve the desired reductions in phosphorus loading, and a range of alternatives along with their expected costs and benefits. Additional discussion among key stakeholders must occur to better identify specific actions that can be taken.

9.0 Public Participation and Involvement

The public participation process for this TMDL was addressed through the use of a series of public meetings and progress reports made available on the Illinois EPA TMDL Web site <http://www.epa.state.il.us/water/tmdl/>. The Illinois EPA held public meetings to provide information and education on the TMDL process, and to take comments on the draft TMDL. The first meeting was held June 5, 2001, in Springfield, Illinois. A second meeting was held January 17, 2002, at the Charleston High School. The primary purpose of these meetings was to advise the public that a TMDL was being compiled, present the issues to be considered and addressed, and outline the timeframes for developing the TMDL. A final public hearing will be held to discuss and take comments on the draft TMDL.

10.0 References

Alford, A. 2001. City of Charleston. Personal communication, October 25, 2001.

Alford, A. 2002. City of Charleston. Personal communication, May 3, 2002 and December 13, 2002.

Brady, N. 1990. *The nature and property of soils.* MacMillan Publishing Company, New York, NY.

Carlson, R., 1977. A trophic state index for lakes. *Limnology and Oceanography*. 22:361:369.

Carlson, R. and J. Simpson. 1996. *A coordinator's guide to volunteer lake monitoring methods.* North American Lake Management Society and the Educational Foundation of America.

Chapra, S. 1997. *Surface water-quality modeling*. The McGraw-Hill Companies, Inc., Boston, MA.

City of Charleston. 1992. *Clean Lakes Program Phase I Diagnostic Feasibility Study of the Charleston Side Channel Reservoir.* City of Charleston in cooperation with Eastern Illinois University, Illinois EPA, and USEPA, Charleston, IL.

City of Charleston. 2001. Charleston Water Treatment Plant. Monthly Reports of Daily Test River Water. City of Charleston, Charleston, IL.

City of Charleston. 2002. Charleston Water Treatment Plant. Water Production Records. City of Charleston, Charleston, IL.

City of Charleston. 2003. Charleston Water Treatment Plant. Level and Discharge at Charleston Spillway. City of Charleston, Charleston, IL.

Haith, D. A., R. Mandel, and R. S. Wu. 1992 *Generalized watershed loading functions model. Version 2.0. User's Manual*. December 15, 1992.

Illinois EPA (Illinois Environmental Protection Agency). 1998. *Clean Water Act Section 303(d) List - Illinois' Submittal for 1998*. Illinois Environmental Protection Agency, Springfield, IL.

Illinois EPA (Illinois Environmental Protection Agency). 2000. *Illinois Water Quality Report 2000*. Illinois Environmental Protection Agency, Bureau of Water, Springfield, IL.

Illinois EPA (Illinois Environmental Protection Agency). 2001. Attachment 2 to Contract FWN-1305. Revised TMDL Scope of Work for Tetra Tech, Inc.

Illinois EPA (Illinois Environmental Protection Agency). 2002a. *Illinois Water Quality Report 2002*. Illinois EPA/BOW/02-006. Illinois Environmental Protection Agency, Springfield, IL. July 2002.

Illinois EPA (Illinois Environmental Protection Agency). 2002b. Point source discharge information forwarded to Tetra Tech, Inc. by Jennifer Clarke, Illinois Environmental Protection Agency. May 1, 2002.

Litke, D. 1999. Review of Phosphorus Control Measures in the United States. U.S. Geological Survey. Water-Resources Investigations Report 99-4007, Denver, CO.

McConkey, S., and K. P. Singh. 1996. *City of Charleston Public Water Supply: Analysis of Drought Yields from the Charleston Side-Channel Reservoir.* Illinois State Water Survey, Hydrology Division, Champaign, IL.

MCC (Midwestern Climate Center). 2001. Historical climate summaries for station 111436, Charleston, Illinois. Midwestern Climate Center. Available on the Internet at: <http://mcc.sws.uiuc.edu/>.

MRLC (Multi-Resolution Land Characteristics). 1992. Land use data for the Multi-Resolution Land Characteristics Consortium. Multi- Resolution Land Characteristics. Land use data produced mainly from the 1992 Landsat TM meter coverage (30 m resolution).

Tetra Tech, Inc. 2001a. Charleston Side Channel Reservoir TMDL. Report #1. Water Quality Analysis and Watershed Characterization. November 2001.

Tetra Tech, Inc. 2001b. Charleston Side Channel Reservoir TMDL. Report #2. Methodology. November 2001.

U.S. Census Bureau. 2000. *United States Census 2000.* < www.census.gov>. Accessed March 29, 2002 and November 25, 2002.

USEPA (U.S. Environmental Protection Agency). 1980. *Clean Lakes Program Guidance Manual* EPA440/5-81-003. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC.

USEPA. (U.S. Environmental Protection Agency). 1991. *Guidance for water quality-based decisions: The TMDL process.* EPA 440/4-91-001. U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999a. *Protocol for Developing Nutrient TMDLs. First Edition*. EPA 841-B-99-007. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1999b. BASINS Version 2.0. Region 5 Data. U.S. Environmental Protection Agency, Washington, DC.

Walker, W. W. 1985. *Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Model Refinements*. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Xue, Y. 1998. Kinetics and modeling of dissolved phosphorus export from a tile-drained agricultural watershed. *Journal of Environmental Quality*. 27:917-922.

Appendix A

Water Quality Data

Table 1. Results of Total Phosphorus Sampling (mg/L) for Charleston Side Channel Reservoir.

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
5/26/1983	1	0.06	0.06	0.06
5/26/1983	7	0.07		
9/6/1983	1	0.10	0.10	0.09
9/6/1983	5	0.10		
5/14/1984	1	0.08	0.08	0.09
5/14/1984	10	0.09		
8/9/1984	1	0.14	0.13	0.19
8/9/1984	9	0.14		
5/4/1988	1	0.09		0.07
6/20/1988	1	0.12		0.09
7/25/1988	1	0.12		0.12
8/30/1988	1	0.12		0.13
9/23/1988	1	0.13		0.13
10/28/1988	1	0.13		0.08
4/20/1989	1	0.02	0.03	0.04
4/20/1989	8	0.03		
5/15/1989	1	0.06		0.08
5/30/1989	1	0.08		0.08
6/14/1989	1	0.11	0.10	0.14
6/14/1989	11	0.12		
6/28/1989	1	0.06		0.05
7/13/1989	1	0.11	0.10	0.09
7/13/1989	12	0.11		
7/26/1989	1	0.15		0.17
8/10/1989	1	0.11	0.12	0.12
8/10/1989	12	0.11		
8/22/1989	1	0.12		0.18
9/5/1989	1	0.17		0.10
9/19/1989	1	0.05		0.06
10/5/1989	1	0.12	0.12	0.12
10/5/1989	11	0.11		
10/24/1989	1	0.07	0.07	0.08
5/8/1990	1	0.09	0.08	0.08
6/5/1990	1	0.09	0.09	0.10
7/3/1990	1	0.09	0.08	0.07
8/21/1990	1	0.07	0.07	0.08

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
9/4/1990	1	0.15	1.20	2.30
10/2/1990	1	0.12	0.12	0.15
4/23/1992	1	0.09	0.10	0.09
4/23/1992	11	0.09		
6/5/1992	1	0.12	0.11	0.13
6/5/1992	10	0.12		
7/1/1992	1	0.13	0.08	0.09
7/1/1992	10	0.11		
8/24/1992	1	0.19	0.15	0.14
8/24/1992	10	0.16		
10/13/1992	1	0.13	0.13	0.14
10/13/1992	11	0.14		
5/31/1994	1	0.08		0.07
6/21/1994	1	0.10		0.10
7/13/1994	1	0.21		0.22
8/2/1994	1	0.23		0.14
9/28/1994	1	0.16		0.18
4/12/1995	1	0.07	0.08	0.08
4/12/1995	5	0.08		
6/12/1995	1	0.17	0.13	0.12
6/12/1995	9	0.16		
7/13/1995	1	0.18	0.15	0.15
7/13/1995	7	0.17		
8/23/1995	1	0.16	0.19	0.19
8/23/1995	8	0.18		
10/16/1995	1	0.17	0.16	0.16
10/16/1995	7	0.18		
5/22/1996	1	0.07		
6/26/1996	1	0.10		
7/23/1996	1	0.13		
8/20/1996	1	0.17		
9/17/1996	1	0.16		
10/14/1996	1	0.14		
5/27/1997	1	0.10		
6/24/1997	1	0.11		
7/30/1997	1	0.10		

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
8/26/1997	1	0.20		
9/30/1997	1	0.16		
10/28/1997	1	0.55		
4/21/1998	1	0.04	0.03	0.04
4/21/1998	10	0.04		
5/28/1998	1	0.03		0.02
6/12/1998	1	0.07	0.06	0.06
6/12/1998	5	0.08		
7/6/1998	1	0.10	0.09	0.08
7/6/1998	7	0.08		
7/21/1998	1	0.13		
8/3/1998	1	0.16		
8/17/1998	1	0.13	0.13	0.12
8/17/1998	6	0.12		
9/8/1998	1	0.15		
10/27/1998	1	0.30		
5/7/2001	1	0.09	0.10	
5/7/2001	3	0.10		
5/7/2001	5	0.06		
7/2/2001	1	0.16	0.13	0.12
7/2/2001	5	0.23		
7/2/2001	6	0.15		
7/26/2001	1	0.15	0.14	0.13
7/26/2001	3	0.14		
7/26/2001	6	0.14		
8/21/2001	1	0.20	0.16	0.14
8/21/2001	3	0.16		
8/21/2001	6	0.16		
10/15/2001	1	0.16	0.13	0.13
10/15/2001	3	0.13		
10/15/2001	6	0.13		
Average		**0.13**	**0.14**	**0.15**

Table 2. Results of Dissolved Phosphorus Sampling (mg/L) for Charleston Side Channel Reservoir.

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
5/26/1983	1	0.01	0.00	0.01
5/26/1983	7	0.01		
9/6/1983	1	0.04	0.03	0.03
9/6/1983	5	0.04		
5/14/1984	1	0.02	0.02	0.02
5/14/1984	10	0.02		
8/9/1984	1	0.02	0.02	0.02
8/9/1984	9	0.02		
4/20/1989	1	0.01	0.00	0.01
4/20/1989	8	0.01		
6/14/1989	1	0.02	0.02	0.02
6/14/1989	11	0.02		
7/13/1989	1	0.01	0.01	0.00
7/13/1989	12	0.01		
8/10/1989	1	0.01	0.01	0.01
8/10/1989	12	0.02		
10/5/1989	1	0.05	0.05	0.06
10/5/1989	11	0.05		
4/23/1992	1	0.02	0.02	0.02
4/23/1992	11	0.03		
6/5/1992	1	0.02	0.02	0.03
6/5/1992	10	0.02		
7/1/1992	1	0.03	0.02	0.02
7/1/1992	10	0.04		
8/24/1992	1	0.04	0.03	0.03
8/24/1992	10	0.03		
10/13/1992	1	0.02	0.02	0.02
10/13/1992	11	0.02		
4/12/1995	1	0.01	0.01	0.01
4/12/1995	5	0.01		
6/12/1995	1	0.02	0.02	0.02
6/12/1995	9	0.03		
7/13/1995	1	0.01	0.01	0.01
7/13/1995	7	0.01		
8/23/1995	1	0.03	0.05	0.03
8/23/1995	8	0.03		

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
10/16/1995	1	0.02	0.02	0.02
10/16/1995	7	0.02		
4/21/1998	1	0.01	0.01	0.01
4/21/1998	10	0.01		
6/12/1998	1	0.01	0.01	0.01
6/12/1998	5	0.01		
7/6/1998	1	0.01	0.01	0.01
7/6/1998	7	0.01		
8/17/1998	1	0.03	0.02	0.02
8/17/1998	6	0.02		
5/7/2001	1	0.02	0.02	
5/7/2001	3	0.02		
5/7/2001	5	0.02		
7/2/2001	1	0.09	0.04	0.03
7/2/2001	5	0.14		
7/2/2001	6	0.05		
7/26/2001	1	0.04	0.02	0.02
7/26/2001	3	0.04		
7/26/2001	6	0.02		
8/21/2001	1	0.06	0.02	0.02
8/21/2001	3	0.02		
8/21/2001	6	0.02		
10/15/2001	1	0.04	0.04	0.02
10/15/2001	3	0.02		
10/15/2001	6	0.02		
Average		**0.03**	**0.02**	**0.02**

Table 3. Results of Chlorophyll *a* Sampling (µg/L) for Charleston Side Channel Reservoir.

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
5/26/1983	2	22.20	19.32	23.54
5/14/1984	3	47.28	51.78	63.21
8/9/1984	2	84.22	96.75	219.76
7/25/1988	3	64.24		62.53
8/30/1988	2	86.78		105.36
9/23/1988	2	74.17		85.37
10/28/1988	2	34.12		
10/28/1988	3			30.25
4/20/1989	3	100.52	68.23	58.41
6/14/1989	2	49.08		
6/14/1989	3		58.41	78.29
7/13/1989	2	85.05	65.08	
7/13/1989	3			80.10
7/26/1989	2	152.19		135.28
8/10/1989	2	74.76	77.52	91.30
8/22/1989	1	58.74		
8/22/1989	3			48.95
9/12/1989	2	114.81		82.77
9/19/1989	2	76.10		
9/19/1989	3			68.83
10/5/1989	2		39.67	43.07
10/5/1989	3	36.17		
10/24/1989	3	42.72	45.39	37.38
4/23/1992	3		64.25	51.29
4/23/1992	4	55.76		
6/5/1992	2	47.12	87.91	46.34
7/1/1992	3	47.92	43.13	32.42
10/13/1992	2	94.93	115.70	131.93
4/12/1995	3		47.12	38.38
4/12/1995	4	50.86		
6/12/1995	2	136.58	51.96	76.68
7/13/1995	2	160.20	137.32	150.03
8/23/1995	2	61.74	171.64	174.76
10/16/1995	2	100.64	111.66	104.48
5/22/1996	3	53.40		

Start Date	Sample Depth (ft)	RBC-1	RBC-2	RBC-3
6/26/1996	3	48.23		
7/23/1996	2	58.41		
8/20/1996	2	105.40		
9/17/1996	2	154.86		
10/14/1996	2	69.42		
5/27/1997	3	74.30		
6/24/1997	3	97.01		
7/30/1997	3	104.13		
8/26/1997	2	169.36		
9/30/1997	2	106.80		
10/28/1997	4	61.41		
4/21/1998	8		3.34	
4/21/1998	9			4.00
4/21/1998	10	2.00		
5/28/1998	3	10.68		
6/12/1998	2			64.08
6/12/1998	3		46.72	
6/12/1998	4	40.05		
6/29/1998	5	27.46		
7/6/1998	3	53.40	42.70	42.70
7/21/1998	1	70.80		
8/3/1998	1	87.20		
9/8/1998	2	119.00		
10/7/1998	2			96.10
10/7/1998	3	93.50	77.40	
10/27/1998	3	29.40		
5/7/2001	4	15.50	13.30	13.30
7/2/2001	2	66.30		74.50
7/2/2001	3		67.70	
7/26/2001	2	92.30	66.70	74.00
8/21/2001	2	84.30	115.00	118.00
10/15/2001	3	92.10	86.50	70.60
Average		**74.45**	**69.34**	**76.51**

Appendix B

SWAT 2000 Modeling of the Upper Embarras River Watershed, Illinois

The Soil Water Assessment Tool (SWAT), version 2000

The Soil Water Assessment Tool (SWAT) model was developed by the U.S. Department of Agriculture, Agricultural Research Service. The model is intended to predict the impact of land management practices (e.g., vegetative changes, reservoir management groundwater withdrawals and water transfer), on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time. SWAT can analyze large watersheds and river basins (greater than 100 square miles) by subdividing the area into homogenous subwatersheds. The model uses a daily time step, and can perform continuous simulation for a period of one to 100 years. SWAT simulates hydrology, pesticide and nutrient cycling, erosion and sediment transport.

Hydrology

The hydrology component of SWAT is based on the water balance equation. A distributed curve number is generated for the computation of overland flow runoff volume, given by the standard SCS (now the Natural Resources Conservation Service (NRCS)) runoff equation (USDA, 1986). The curve number method is empirically based and relates runoff potential to land use and soil characteristics. The curve number method combines infiltration losses, depression storage, and interception into a potential maximum storage parameter called *S*. Runoff depth is given by the following set of empirical relationships:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

where *Q* is the accumulated runoff depth or rainfall excess (inches), *P* is the accumulated precipitation (inches), and *S* is a maximum soil water retention parameter given by

$$S = \frac{1000}{CN} - 10$$

where *CN* is known as the curve number.

The equation above indicates that precipitation, *P,* must exceed 0.2*S* before any runoff is generated. Furthermore, this equation yields a depth of runoff. To calculate runoff volume, the computed depth must be multiplied by area.

The curve number indicates the runoff potential of an area for the combination of land use characteristics and soil type. Higher curve numbers translate into greater runoff. Curve numbers are a function of hydrologic soil group, vegetation, land use, cultivation practice, and antecedent moisture conditions. The NRCS has classified more than 4000 soils into four hydrologic soil groups according to their minimum infiltration rate for bare soil after prolonged wetting. The characteristics associated with each hydrologic soil group are given in Table 1. The amount of moisture present in the soil is known to affect the volume and the rate of runoff. Consequently, the NRCS developed three antecedent soil moisture conditions: dryer antecedent conditions (Condition I) reflect soils that are dry but not to the wilting point, wetter conditions (Condition III) characterize soils that have experienced heavy rainfall, light rainfall and low temperatures within the last five days, or saturated soils, and Condition II is the average condition. Curve numbers for dryer antecedent conditions (Condition I) and for wetter antecedent conditions (Condition III) are found in Table 3.

Table 1. Characteristics of Hydrologic Soil Groups.

Soil Group	Characteristics	Minimum Infiltration Capacity (in./hr)
A	Sandy, deep, well drained soils; deep loess; aggregated silty soils	0.30-0.45
B	Sandy loams, shallow loess, moderately deep and moderately well drained soils	0.15-0.30
C	Clay loam soils, shallow sandy loams with a low permeability horizon impeding drainage (soils with a high clay content), soils low in organic content	0.05-0.15
D	Heavy clay soils with swelling potential (heavy plastic clays), water-logged soils, certain saline soils, or shallow soils over an impermeable layer	0.00-0.05

Source: NRCS, 1972

Table 2. Seasonal Rainfall Limits for Antecedent Rainfall Conditions.

Antecedent Moisture Condition Class	5-Day Total Antecedent Rainfall (inches)	
	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5-1.1	1.4-2.1
III	Over 1.1	Over 2.1

Source: NRCS, 1972

Table 3. Curve Number Adjustments from Antecedent Moisture Condition II to Antecedent Moisture Conditions I and III.

CN for Antecedent Moisture Condition II	CN for Antecedent Moisture Condition I	CN for Antecedent Moisture Condition III
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
70	51	87
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

Source: NRCS, 1972

Curve numbers are updated daily as a function of initial soil moisture storage. A soil database is used to obtain information on soil type, texture, depth, and hydrologic classification. In SWAT, soil profiles can be divided into 10 layers. Infiltration, defined in SWAT as precipitation minus runoff, moves into the soil profile where it is routed through the soil layers. A storage routing flow coefficient is used to predict flow through each soil layer, with flow occurring when a layer exceeds field capacity. When water percolates past the bottom layer, it enters the shallow aquifer zone (Arnold et al., 1993). Channel transmission loss and pond/reservoir seepage replenish the shallow aquifer while it interacts directly with the stream. Flow to the deep aquifer system is effectively lost and cannot return to the stream (Arnold et al., 1993). The irrigation algorithm developed for SWAT allows irrigation water to be transferred from any reach or reservoir to any other in the watershed. Based on surface runoff calculated using the SCS runoff equation, excess surface runoff not lost to other functions makes its way to the channels where it is routed downstream.

An important consideration in modeling the hydrology of the Embarras River watershed is that agricultural land in the basin is heavily tiled, as many of the soils are naturally poorly drained. The presence of tile drains has altered the natural hydrology of the area. Precipitation is routed to the streams through the tiles, rather than running over the land surface, which results in a shorter time-of-travel and less erosion.

It is not feasible to simulate individual tile drain systems at the large basin scale with currently available watershed scale models. Further, neither the location nor the total density of tile drainage is known throughout the basin: in most areas, only the ditches are documented in spatial coverages, and the extent of private tile drains is known only for limited areas. Furthermore, the SWAT model does not contain any routines for the explicit representation of tile.

To address these factors several model parameters were adjusted to simulate the effects of tiling on watershed hydrology. For example, NRCS curve numbers for tiled soils are lower than for non-tiled soils to simulate the effect of greater infiltration. The storage routing flow coefficient within SWAT was also adjusted during model calibration to address the effects of tiling. These adjustments, in combination with other calibration activities, resulted in acceptable performance of the model as measured by recommended modeling criteria (see below).

Upland Erosion
Another important model parameter obtained from the soils database is the Universal Soil Loss Equation (USLE) erodibility factor, *k*. The erodibility factor is an empirically derived value reflecting a soil's inherent erodibility. The USLE is used in SWAT to estimate initial soil detachment and upland erosion. Sediment yield used for instream transport is determined from the Modified Universal Soil Loss Equation (MUSLE) (Arnold, 1992). For sediment routing in SWAT, deposition calculation is based on fall velocities of various sediment sizes. Rates of channel degradation are determined from Bagnold's (1977) stream power equation. Stream power is a useful index for describing the erosive capacity of streams, and has been related to the shape of the longitudinal profile, channel pattern, the development of bed forms, and sediment transport. As stream slopes become steeper and/or velocities increase, stream power increases as does stream erosivity.

Sediment size is estimated from the primary particle size distribution (Foster et al.,1980) for soils that the SWAT model obtains from the State Soil Geographic (STATSGO)(USDA 1995) database. Stream power is also accounted for in the sediment routing routine, and is used for calculation of re-entrainment of loose and deposited material in the system until all of the material has been removed.

Description of the ArcView-SWAT Interface
An ArcView interface for SWAT (DiLuzio et al., 2001) was employed to efficiently derive and build the input files for SWAT modeling of the Upper Embarras River watershed. The interface requires digital elevation data (DEM), land use/land cover, soils, and meteorological data. Thirty-meter DEM representing 7.5 minute U.S. Geological Survey (USGS) quadrangles were downloaded from GEOCommunity <www.geocomm.com>, the current distribution center for USGS DEM. Watershed and subbasin delineation is based on a DEM of the watershed coupled with a "burn-in" of EPA's Reach File 3 spatial database of stream reaches. This approach ensures that the subbasins conform to topography while requiring that catalogued stream segments connect in the proper order and direction.

The interface allows a user to select multiple subbasin outlets, thereby defining multiple subbasins for modeling analysis purposes. The interface then uses the DEM to calculate the upstream area, defined by the total number of upslope cells, which could contribute flow to each point, thus defining the area of each subbasin. For the Charleston Side Channel watershed, the USGS 14-digit Hydrologic Unit Code (HUC) served as the basis for subbasin definition. This resulted in a total of 20 subbasins as shown in Figure 1.

After computing watershed topographic parameters for each subbasin, the interface uses land cover and soils data in an overlay process to assign soil parameters and SCS curve numbers. The land cover for the watershed area was extracted from the Multi-Resolution Land Characterization database for the state of Illinois (MRLC, 1992). The MRLC land cover data must be reclassified to equal land cover and land use classes used by the SWAT2000 model. Soils information was extracted from the STATSGO soils database for the state of Illinois (USDA, 1995). The user may decide whether or not to use multiple hydrologic response units (HRUs) in the modeling application. An HRU is a combination of land use/land cover and soil characteristics, and represents areas of similar hydrologic response. If multiple HRUs are not employed, the interface will use the dominant land use and soil characteristic for the entire watershed. To model multiple HRUs, the user must determine a threshold level used to eliminate minor land uses in each subbasin. Land uses that cover a percentage of the subbasin area less than the threshold level are eliminated and the area of the land uses is reapportioned so that 100 percent of the land area in the subbasin is included in the simulation. The ArcView SWAT interface user's manual suggests that a 20 percent land use threshold and a 10 percent soil threshold are adequate for most modeling applications. In SWAT, land use and soil thresholds represent cutoff values that reduce the complexity in the simulated watershed. For example, land use areas less than a given percentage of the total land use in the watershed (threshold) are ignored and their respective areas are reapportioned equally to the remaining land use categories. For the Upper Embarras watershed, a 2 percent land use threshold and a 5 percent soil threshold were employed. These threshold values resulted in a highly detailed land use and soil SWAT database, containing many HRUs, which in turn represent a very heterogeneous watershed. Figure 1 shows the SWAT land use distribution in the watershed. Table 4 lists the SCS curve numbers used in the Upper Embarras River watershed. Table 5 lists the respective land use characteristics of each of the subbasins.

Table 4. SCS Curve Numbers (CN-II) for Land Use and Land Cover in the Upper Embarras Watershed.

SWAT Land Use/Land Cover Classification	SCS Curve Numbers for Land Use and Hydrologic Soil Group			
	A	B	C	D
Water	100	100	100	100
Low Density Urban Residential	46	65	77	82
High Density Urban Residential	63	77	85	88
Urban Commercial	89	92	94	96
Deciduous Forest	45	66	77	83
Pasture	49	69	79	84
Corn/Soybean	67	78	85	89
Bluegrass	31	59	72	79
Forested Wetlands	45	66	77	83

Figure 1 and Table 5 show that corn/soybean is by far the most dominant land use in the watershed, representing nearly 82 percent of the total land use. It is assumed that corn and soybean crops are rotated on an annual basis. Pasture is the second largest land use, representing 8.6 percent of the total watershed. Deciduous forest and forested wetlands account for nearly 5 percent, and 1 percent, respectively. All other land use classes each represent less than 1 percent of total land use/land cover in the watershed.

Several USLE parameters are used in AVSWAT, including the K-factor, length-slope factor, C-factor, and the P-factor. *K*-factors and length-slope factors were derived from the STATSGO soils database and topographic data, respectively, and are automatically determined in AVSWAT. For the Upper Embarras watershed, C-factors for corn/soybean and pasture were assumed to be 0.20 and 0.003, respectively, according to recommendations made by the Illinois NRCS. Corn/soybean and pasture were assigned P-factors of 1.0 based on recommendations made by the Illinois NRCS.

Figure 1. Subbasins and Land Use/Land Cover in the Upper Embarras River Watershed.

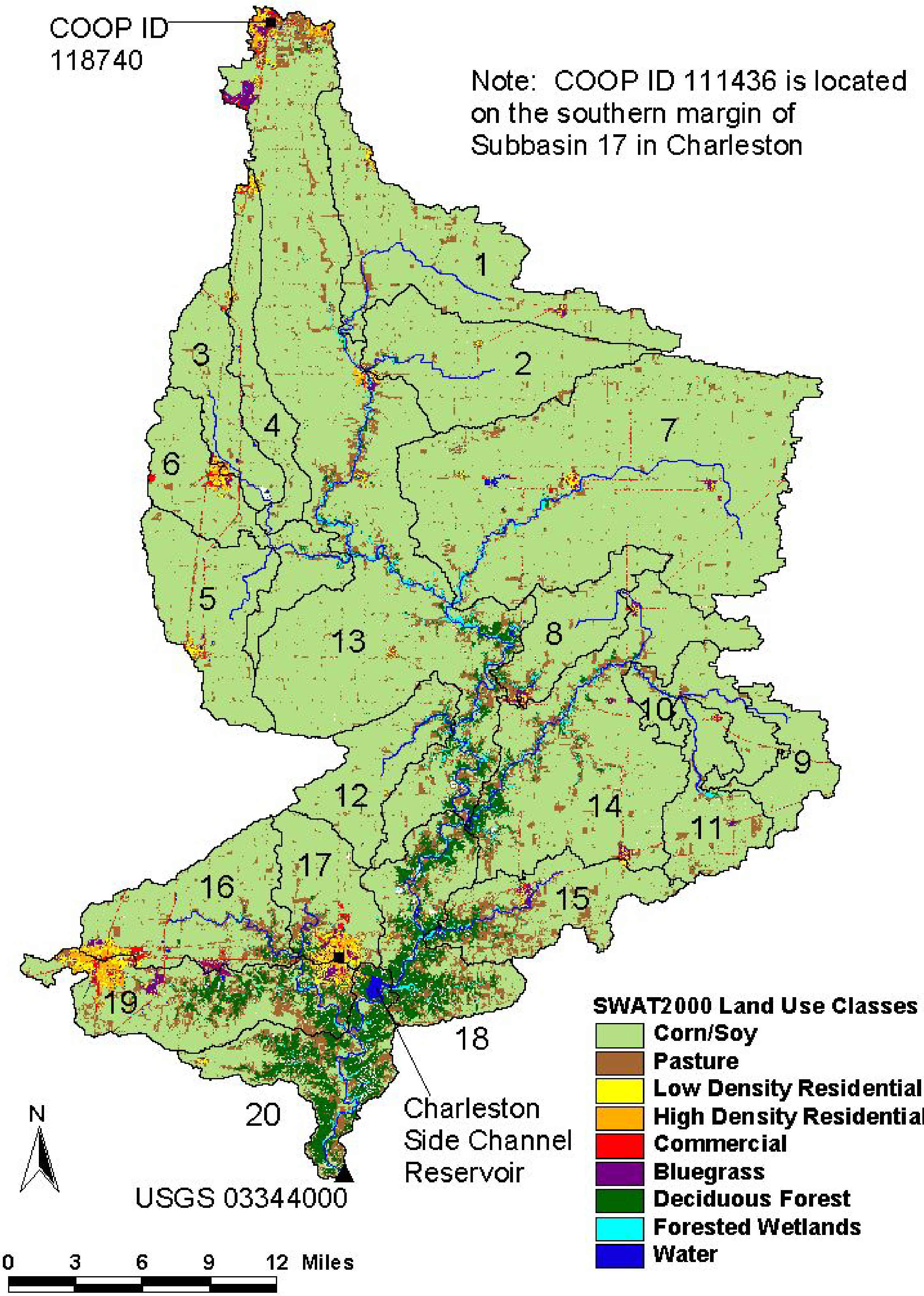


Table 5. Subbasin Land Use Characteristics for the Upper Embarras Watershed.

SUBBASIN 1				
SWAT Land Use	**MRLC Land Use**	**Area (ha)[1]**	**Area (ac)[2]**	**Percent Subbasin**
Corn/Soybean	Row Crops	13,740.3	33,952.3	93.8
Pasture	Pasture/Hay	909.9	22,48.4	6.2
	Total	**14,650.2**	**36,200.6**	**100.0**
SUBBASIN 2				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	10,805.2	26,699.6	96.7
Pasture	Pasture/Hay	374.1	924.4	3.3
	Total	**11,179.3**	**27,624.1**	**100.0**
SUBBASIN 3				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	5,631.8	13,916.2	94.6
Pasture	Pasture/Hay	321.7	794.9	5.4
	Total	**5,953.5**	**14,711.1**	**100.0**
SUBBASIN 4				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	5,245.7	12,962.1	94.7
Pasture	Pasture/Hay	292.6	723.0	5.3
	Total	**5,538.3**	**13,685.1**	**100.0**
SUBBASIN 5				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	8,547.9	21,121.9	96.0
Pasture	Pasture/Hay	359.2	887.6	4.0
	Total	**8,907.1**	**22,009.4**	**100.0**
SUBBASIN 6				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	7,930.4	19,596.0	95.0
Pasture	Pasture/Hay	416.1	1,028.2	5.0
	Total	**8,346.5**	**20,624.2**	**100.0**
SUBBASIN 7				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	36,879.9	91,130.2	95.8
Pasture	Pasture/Hay	1,609.5	3,977.1	4.2
	Total	**38,489.4**	**95,107.3**	**100.0**
SUBBASIN 8				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	5,120.8	12,653.5	91.7
Pasture	Pasture/Hay	461.5	1,140.4	8.3
	Total	**5,582.3**	**13,793.9**	**100.0**
SUBBASIN 9				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	3,917.3	9,679.6	100.0
	Total	**3,917.3**	**9,679.6**	**100.0**
SUBBASIN 10				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**

Corn/Soybean	Row Crops	4,507	11,136.8	93.6
Pasture	Pasture/Hay	309	763.5	6.4
	Total	**4,816**	**11,900.3**	**100.0**
SUBBASIN 11				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	5,444.3	13,452.9	91.2
Pasture	Pasture/Hay	524.1	1,295.1	8.8
	Total	**5,968.4**	**14,747.9**	**100.0**
SUBBASIN 12				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	6,115.5	15,111.4	94.1
Pasture	Pasture/Hay	386.5	955.0	5.9
	Total	**6,502.0**	**16,066.4**	**100.0**
SUBBASIN 13				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	40,973.2	101,244.8	85.1
Deciduous Forest	Deciduous Forest	1,745.3	4,312.6	3.6
Pasture	Pasture/Hay	4,365.4	10,786.9	9.1
Forested Wetland	Woody Wetlands	1,071.7	2,648.2	2.2
	Total	**48,155.6**	**118,992.5**	**100.0**
SUBBASIN 14				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	18,037.2	44,569.9	85.7
Deciduous Forest	Deciduous Forest	953.4	2,355.9	4.5
Pasture	Pasture/Hay	2,054.8	5,077.4	9.8
	Total	**21,045.4**	**52,003.2**	**100.0**
SUBBASIN 15				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	5,838.1	14,425.9	72.5
Deciduous Forest	Deciduous Forest	572.4	1,414.4	7.1
Pasture	Pasture/Hay	1645	4,064.8	20.4
	Total	**8,055.5**	**19,905.1**	**100.0**
SUBBASIN 16				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	8,612.1	21,280.5	83.4
Deciduous Forest	Deciduous Forest	277.3	685.2	2.7
Pasture	Pasture/Hay	1,182.5	2,922.0	11.4
Commercial	Commercial/Industrial/ Transportation	257.2	635.5	2.5
	Total	**10,329.1**	**25,523.2**	**100.0**
SUBBASIN 17				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Bluegrass	Urban/Recreational Grasses	140.5	347.2	2.2
Corn/Soybean	Row Crops	4,722.5	11,669.3	75.3
Deciduous Forest	Deciduous Forest	205.9	508.8	3.3
Pasture	Pasture/Hay	702.7	1,736.4	11.2
High Density Residential	High Intensity Residential	231.2	571.3	3.7
Low Density Residential	Low Intensity Residential	268.2	662.7	4.3
	Total	**6271.0**	**15495.6**	**100.0**

SUBBASIN 18				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	4,411.4	10,900.6	47.9
Deciduous Forest	Deciduous Forest	2,699.7	6,671.0	29.3
Pasture	Pasture/Hay	1,838.2	4,542.2	20.0
Forested Wetland	Woody Wetland	257.8	637.0	2.8
	Total	**9,207.1**	**22,750.7**	**100.0**
SUBBASIN 19				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Bluegrass	Urban/Recreational Grasses	348.2	860.4	3.2
Corn/Soybean	Row Crops	5,818.5	14,377.5	52.8
Deciduous Forest	Deciduous Forest	1,718.2	4,245.7	15.6
Pasture	Pasture/Hay	2,226.0	5,500.4	20.2
High Density Residential	High Intensity Residential	447.2	1,105.0	4.1
Low Density Residential	Low Intensity Residential	459.5	1,135.4	4.2
	Total	**11,017.6**	**27,224.5**	**100.0**
SUBBASIN 20				
SWAT Land Use	**MRLC Land Use**	**Area (ha)**	**Area (ac)**	**Percent Subbasin**
Corn/Soybean	Row Crops	2,843.3	7,025.8	33.2
Deciduous Forest	Deciduous Forest	3,497.1	8,641.3	40.9
Pasture	Pasture/Hay	1,714.0	4,235.3	20.0
Water	Water	257.0	635.0	3.0
Forested Wetland	Woody Wetland	245.3	606.1	2.9
	Total	**8,556.7**	**21,143.6**	**100.0**
	TOTAL WATERSHED AREA	**242,488.3**	**599,188.6**	**100.0**

[1] ha=hectares
[2] ac=acres

Meteorological Data

SWAT2000 requires daily precipitation, temperature, relative humidity, solar radiation, and wind speed data. These parameters may be given in a site-specific, user-specified file, estimated using a climate simulator, or a combination of the two. The interface will search and find the station closest to the mean center of each subbasin, and assign that station's meteorological parameters to the subbasin. Daily precipitation and temperature data were obtained from the National Climatic Data Center (NCDC) for the Charleston (COOP ID 111436) and Urbana (COOP ID 118740) stations (see Figure 1). Daily data are available for both stations from 1948 to present. Relative humidity, solar radiation and wind speed were simulated using a climate simulator available in SWAT2000. The climate simulator uses historical data collected from surrounding National Weather Service sites to estimate parameters. It is believed that these stations are quite adequate for estimating relative humidity, solar radiation, and wind speed for the Upper Embarras River watershed.

Model Simulation Period

SWAT2000 was calibrated for the Upper Embarras River watershed from January 1970 through December 1982. This time period corresponds to the period of record of the nearest USGS stream gage (03344000), which is approximately 8.7 miles downstream of the Charleston Side Channel Reservoir (see Figure 1). Historical stream flow data collected from this gage were used in the hydrologic calibration of the SWAT2000 model. The hydrologic and water quality calibration period was from 1972 to 1982. The earlier beginning time for the SWAT2000 application allows the model to operate through an annual hydrologic cycle, thereby removing the influences of initial boundary conditions. An example of the calibration results is given below for the 1974 water year. Figure 2 shows a comparison of the observed versus the simulated daily stream flow. Figure 3 provides a comparison of the observed versus the simulated monthly and weekly stream flows. Figures 2 and 3 show a high level of agreement between observed and simulated stream flow, as well as the timing of peak storm flow.

Figure 2. Observed Versus Simulated Daily Stream Flow, 1974.

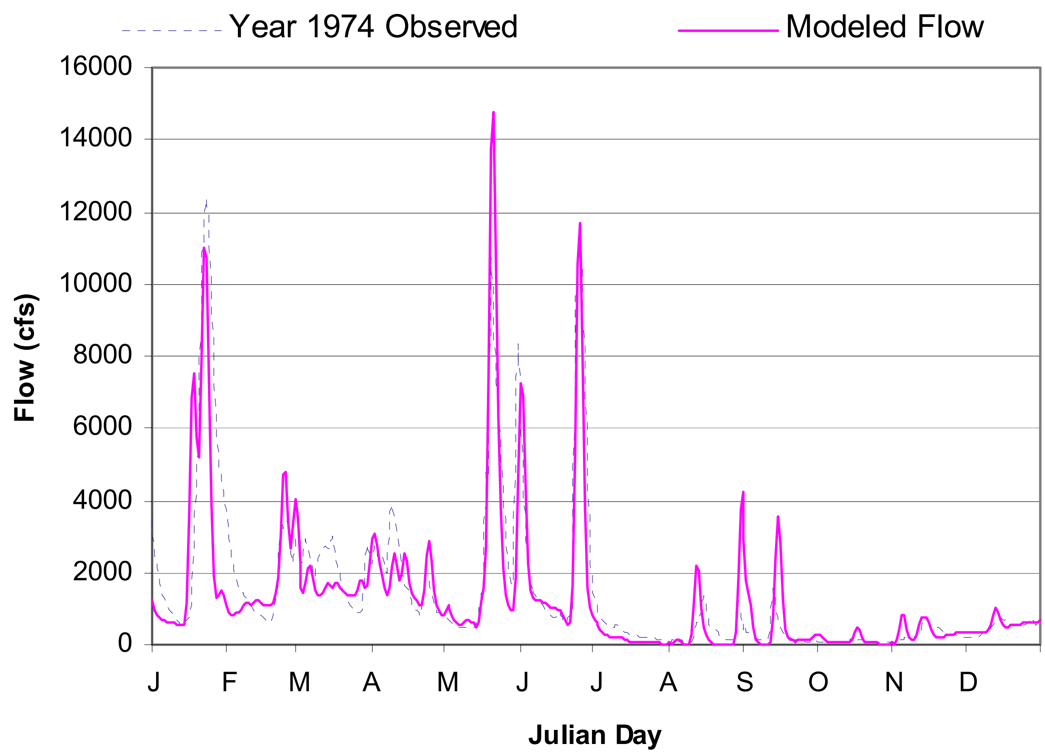
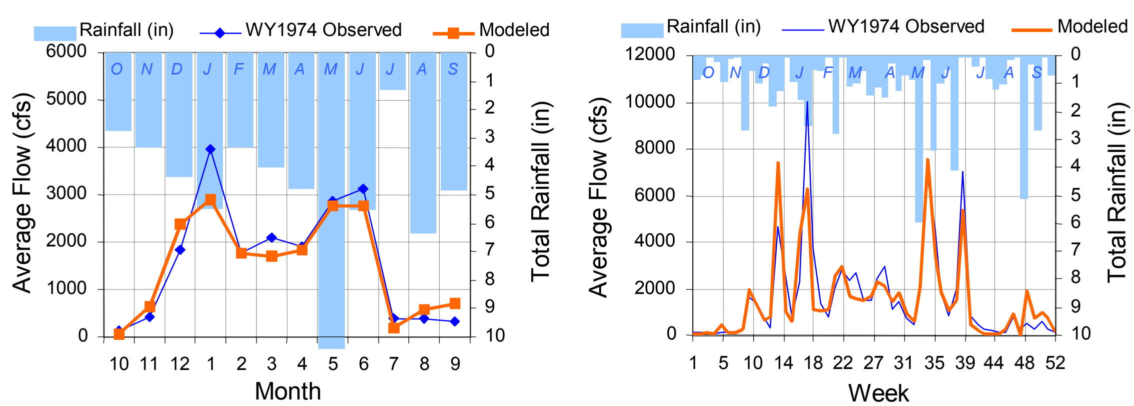
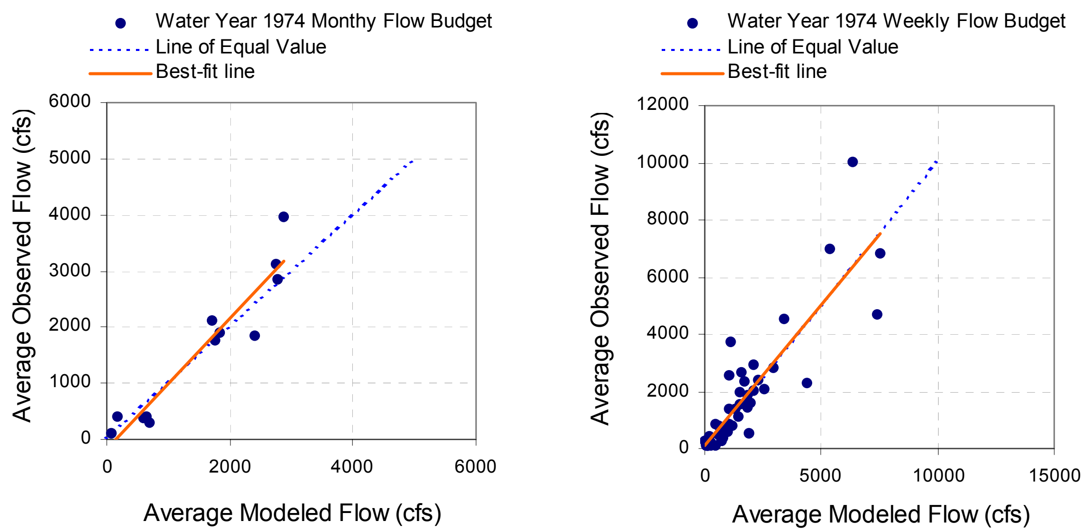


Figure 3. Observed Versus Simulated Monthly and Weekly Stream Flow, 1974.



A quantified description of the level of agreement between observed and simulated stream flow is given in Figure 4 and summarized in Table 6. Figure 4 shows that the level of agreement between monthly observed versus monthly simulated stream flow is very high (R^2 = 0.9075), while the level of correspondence between weekly observed versus weekly simulated stream flow is a bit lower, yet good overall, with an R^2 value of 0.7765.

Figure 4. Statistical Comparison of Observed Versus Simulated Monthly and Weekly Stream Flow, 1974.



Seasonal and annual differences between observed versus simulated stream flow are summarized in Table 6. The table shows that simulated flow for the 1974 water year agrees very well with observed stream flow data. The greatest errors occur in simulated summer storm volumes, yet these errors are within recommended calibration parameters. In general, the hydrologic calibration appears adequate in that it reflects the total water yield, annual variability, and magnitude of individual storm events in the basin.

Table 6. Upper Embarras River Watershed Calibration Results for the 1974 Water Year.

Simulation Name:	USGS Gage 03344000	**Simulation Period:**	
		Watershed Area (ac):	599,188
Selected a Year for Flow Analysis:	**1974**		
Type of Year (1=Calendar, 2=Water Year)	**2**	**Baseflow PERCENTILE:**	2.5
Water Year 1974:		*Usually 1%-5%*	
10/1/1973 to 9/30/1974			
Total Simulated In-stream Flow:	**22.09**	Total Observed In-stream Flow:	**23.19**
Total of highest 10% flows:	**10.54**	Total of Observed highest 10% flows:	**10.59**
Total of lowest 50% flows:	**2.10**	Total of Observed Lowest 50% flows:	**2.19**
Simulated Summer Flow Volume (Months 7-9):	**1.78**	Observed Summer Flow Volume (Months 7-9):	**1.33**
Simulated Fall Flow Volume (Months 10-12):	**3.81**	Observed Fall Flow Volume (Months 10-12):	**2.92**
Simulated Winter Flow Volume (Months 1-3):	**7.61**	Observed Winter Flow Volume (Months 1-3):	**9.45**
Simulated Spring Flow Volume (Months 4-6):	**8.90**	Observed Spring Flow Volume (Months 4-6):	**9.50**
Total Simulated Storm Volume:	**21.73**	Total Observed Storm Volume:	**21.97**
Simulated Summer Storm Volume (Months 7-9):	**1.69**	Observed Summer Storm Volume (Months 7-9):	**1.02**
Errors (Simulated-Observed)		*Recommended Criteria***	Last run
Error in total volume:	**-4.96**	10	
Error in 50% lowest flows:	**-4.62**	10	
Error in 10% highest flows:	**-0.44**	15	
Seasonal volume error - Summer:	**25.31**	30	
Seasonal volume error - Fall:	**23.41**	30	
Seasonal volume error - Winter:	**-24.16**	30	
Seasonal volume error - Spring:	**-6.74**	30	
Error in storm volumes:	**-1.14**	20	
Error in summer storm volumes:	**39.37**	50	

* Months 1–3 = January, February, March
Months 4–6 = April, May, June
Months 7–9 = July, August, September
Months 10–12 = October, November, December
** Source: Lumb, et al., 1994.

A comparison between measured and simulated annual average flows was also performed and the results are presented in Table 7 and Figure 5, and show very good agreement. A more rigorous comparative analysis is provided in Figure 6 and Table 8, which show that measured and simulated annual average monthly flows are in good agreement, and that their differences conform to acceptable error levels (Lumb et al., 1994).

Table 7. Comparison of Measured and Simulated Annual Average Flows.

Water Year	Measured Flow (cubic feet)	Simulated Flow (cubic feet)	Difference (cubic feet)
Oct-70	1107142.3	1437815.6	-330673.4
Oct-71	1188695.8	1586932.2	-398236.5
Oct-72	3716937.4	3949911.9	-232974.4
Oct-73	3910349.8	3725696.8	184653.0
Oct-74	2499341.4	2808214.7	-308873.3
Oct-75	1266381.1	1592248.6	-325867.5
Oct-76	687344.0	1342775.8	-655431.8
Oct-77	2465672.4	2551113.4	-85441.0
Oct-78	2710090.6	2793998.6	-83908.0
Oct-79	1211503.5	1433522.6	-222019.1
Oct-80	1798549.9	1929753.7	-131203.8
Oct-81	3107285.3	2182293.8	924991.5

Figure 5. Statistical Comparison Between Measured and Simulated Annual Average Flows.

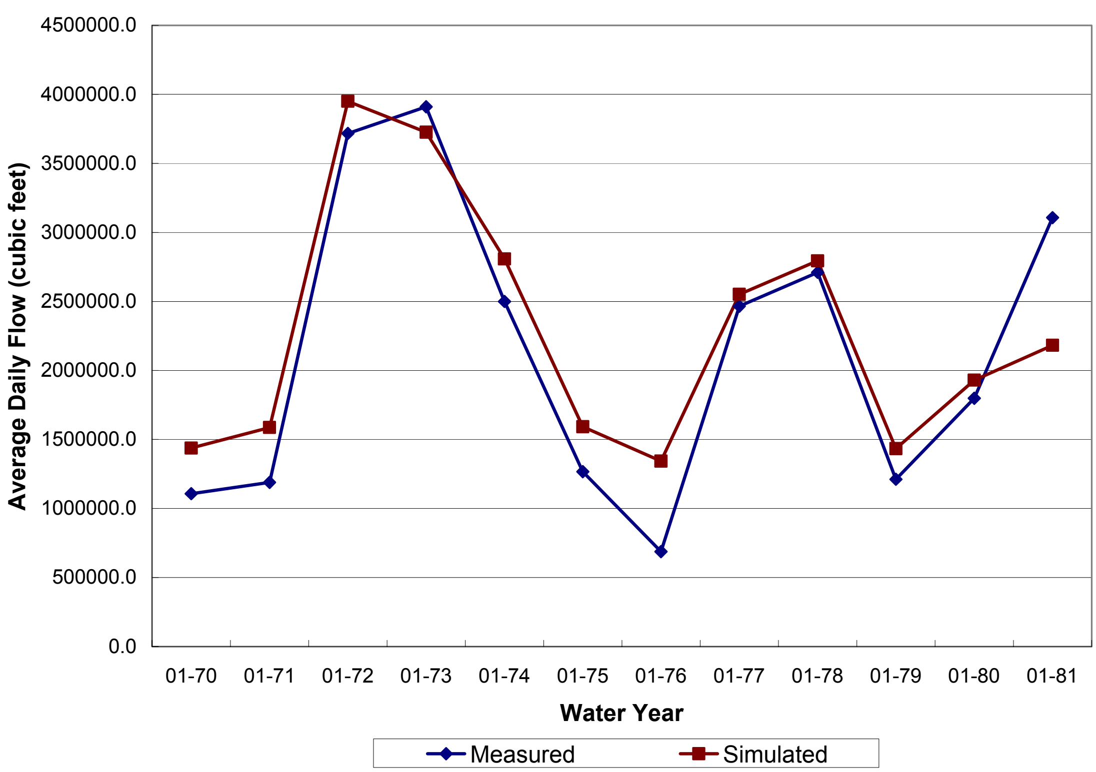
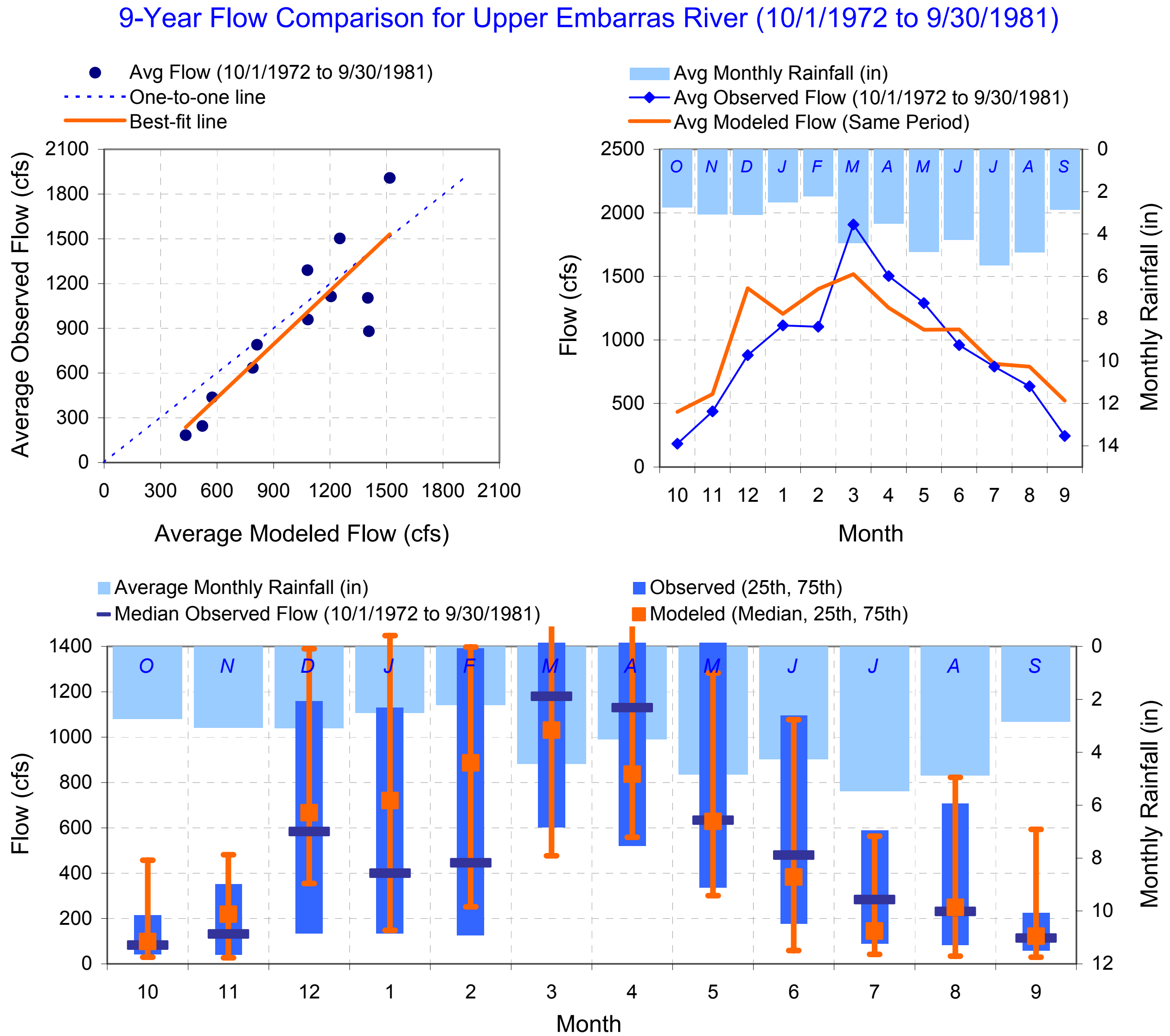


Figure 6. Statistical Comparison Between Measured and Simulated Annual Average Flows.



MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)				VOLUME (IN)		COMPARISON	
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH	DATA	MODEL	DEV	CRITIQUE
OCT	183.28	83.00	43.00	215.50	433.69	98.87	29.52	457.26	2.03	4.81	2.78	OK
NOV	437.42	132.00	40.25	352.50	574.65	219.28	26.95	481.10	4.69	6.16	1.47	OK
DEC	879.74	584.00	135.00	1160.00	1406.90	667.36	354.87	1389.45	9.75	15.59	5.84	OK
JAN	1113.91	400.00	135.00	1130.00	1205.31	720.32	148.13	1447.71	12.35	13.36	1.01	OK
FEB	1103.96	446.00	126.25	1392.50	1401.18	886.28	252.20	1397.39	11.14	14.14	3.00	OK
MAR	1908.04	1180.00	603.00	2620.00	1517.55	1031.05	476.69	1670.16	21.15	16.82	-4.33	OK
APR	1502.88	1130.00	520.00	2017.50	1252.39	836.85	558.78	1612.78	16.12	13.43	-2.69	OK
MAY	1289.95	634.00	336.00	1495.00	1081.10	628.52	301.02	1283.52	14.30	11.98	-2.31	OK
JUN	958.65	479.50	176.00	1095.00	1082.50	383.11	58.97	1076.96	10.28	11.61	1.33	OK
JUL	789.77	284.00	88.50	588.50	812.37	145.12	42.37	563.19	8.75	9.00	0.25	OK
AUG	635.19	231.00	84.00	708.50	789.78	249.29	34.32	822.72	7.04	8.75	1.71	OK
SEP	244.43	114.00	58.00	225.25	522.30	122.53	29.78	593.21	2.62	5.60	2.98	OK

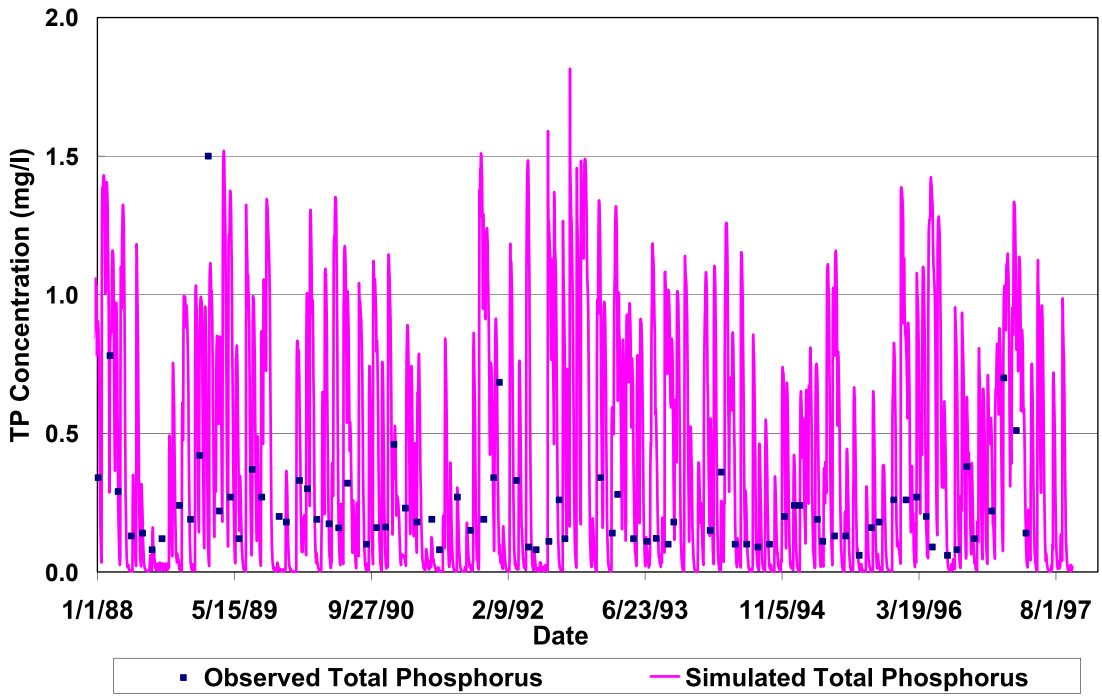
Table 8. Comparison of Measured and Simulated Monthly Average Flows.

Simulation Name:	Upper Embarras	**Simulation Period:**	
		Watershed Area (ac):	599,188
Period for Flow Analysis			
Begin Date: 10-01-72	**10-01-72**	**Baseflow PERCENTILE:**	2.5
End Date: 09-30-82	**09-30-82**	*Usually 1%-5%*	
Total Simulated In-stream Flow:	**121.56**	Total Observed In-stream Flow:	**110.96**
Total of highest 10% flows:	**60.56**	Total of Observed highest 10% flows:	**54.70**
Total of lowest 50% flows:	**8.96**	Total of Observed Lowest 50% flows:	**8.04**
Simulated Summer Flow Volume (Months 7-9):	**18.12**	Observed Summer Flow Volume (Months 7-9):	**14.48**
Simulated Fall Flow Volume (Months 10-12):	**26.56**	Observed Fall Flow Volume (Months 10-12):	**16.47**
Simulated Winter Flow Volume (Months 1-3):	**44.31**	Observed Winter Flow Volume (Months 1-3):	**44.63**
Simulated Spring Flow Volume (Months 4-6):	**32.57**	Observed Spring Flow Volume (Months 4-6):	**35.38**
Total Simulated Storm Volume:	**119.85**	Total Observed Storm Volume:	**109.76**
Simulated Summer Storm Volume (Months 7-9):	**17.71**	Observed Summer Storm Volume (Months 7-9):	**14.19**
Errors (Simulated-Observed)		*Recommended Criteria***	Last run
Error in total volume:	**8.72**	10	
Error in 50% lowest flows:	**10.29**	10	
Error in 10% highest flows:	**9.69**	15	
Seasonal volume error - Summer:	**20.09**	30	
Seasonal volume error - Fall:	**37.98**	30	
Seasonal volume error - Winter:	**-0.71**	30	
Seasonal volume error - Spring:	**-8.65**	30	
Error in storm volumes:	**8.42**	20	
Error in summer storm volumes:	**19.86**	50	

* Months 1–3 = January, February, March
Months 4–6 = April, May, June
Months 7–9 = July, August, September
Months 10–12 = October, November, December
** Source: Lumb, et al., 1994.

A comparison between measured and simulated total phosphorus is presented below in Figure 7. The figure shows good agreement between measured and simulated concentrations. IEPA (1999) summarized water quality data collected by the Illinois EPA Ambient Water Quality Monitoring Network (AWQMN) from 1980 to 1996. One of these sites in the network, Station BE 09, is located at the study watershed outlet (USGS Station 03344000). IEPA (1999) estimated the median total phosphorus concentration over the period of record to be 0.19 mg/l. Simulated median total phosphorus concentration from 1988 to 1997 at the watershed outlet was 0.26 mg/l. Additionally, IEPA (1999) reported the estimated annual average unit area loading of total phosphorus at Station BE 09 to be 0.77 kg/ha/year, and the estimated average daily load to be 511 kg/day. Modeling results suggest annual average unit area total phosphorus loading of 1.28 kg/ha/year, and an average daily total phosphorus loading of 851.2 kg/day.

Figure 7. Comparison of Observed and Simulated (TP) Concentrations from 1988 through 1997.



Estimated Subbasin Nonpoint Source Loadings

The SWAT2000 model produces HRU reports that describe the annual contribution of runoff, sediment, and associated pollutants from individual HRUs to subbasin stream reaches. These HRU data may be used to provide information about the source area contribution to the overall pollutant loading from the watershed. The outlets for subbasins 16, 17, 19, and 20 are located below the Charleston Side Channel Reservoir and are therefore not included in the nonpoint source loadings analysis.

Annual Average Subbasin Pollutant Transport to Stream Reaches

The calibrated SWAT2000 model was run for the 1993 to 2000 time period to determine annual average pollutant transport. For each subbasin, SWAT2000 produces reports that describe the total annual transport by runoff of sediment and associated pollutants into the subbasin stream reach from unique combinations of land use and soil type. Table 9 summarizes annual average subbasin pollutant loadings according to land cover and land use. Table 9 shows that corn/soybean land uses generate the largest annual average and unit area loadings within the Upper Embarras River watershed. Total annual average pollutant loading by subbasin is summarized in Table 10. On a subwatershed basis, Subbasin 7 generates the largest annual average loadings of total phosphorus (316,123 lbs), while Subbasins 13 and 14 contribute the second and third largest pollutant loadings, with annual average total loads of 313,063 lbs. and 135,046 lbs, respectively. The large total phosphorus delivery from Subbasins 7, 13, and 14 is related to their large size and the dominance of corn/soybean agricultural activities within each subwatershed (see Table 5).

On a unit area basis, Subbasins 18 and 11 produced the greatest unit area total phosphorus loads, both associated with corn/soybean land use activities. Subbasin 18 generated a total phosphorus unit load of 3.8 lbs/acre (4.3 kg/ha), while Subbasin 11 generated 3.7 lbs/acre (4.1 kg/ha). These relatively large unit area loading estimates are a result of topographic and soil characteristics within each subbasin. For example, mean slope in Subbasin 18 is 3.77 percent, while the rest of the watershed above the Lake Charleston has an average slope of 0.98 percent. Figure 8 shows the slopes throughout the watershed. Additionally, the mean USLE K-factor for Subbasin 18 is 0.36, while the average K-factor for the other subbasins is 0.28. The combination of these two factors in relation to the MUSLE yields greater estimates of sediment erosion and consequently greater estimates of phosphorus delivery.

Figure 8. Average Land Slope within the Upper Embarras River Watershed.

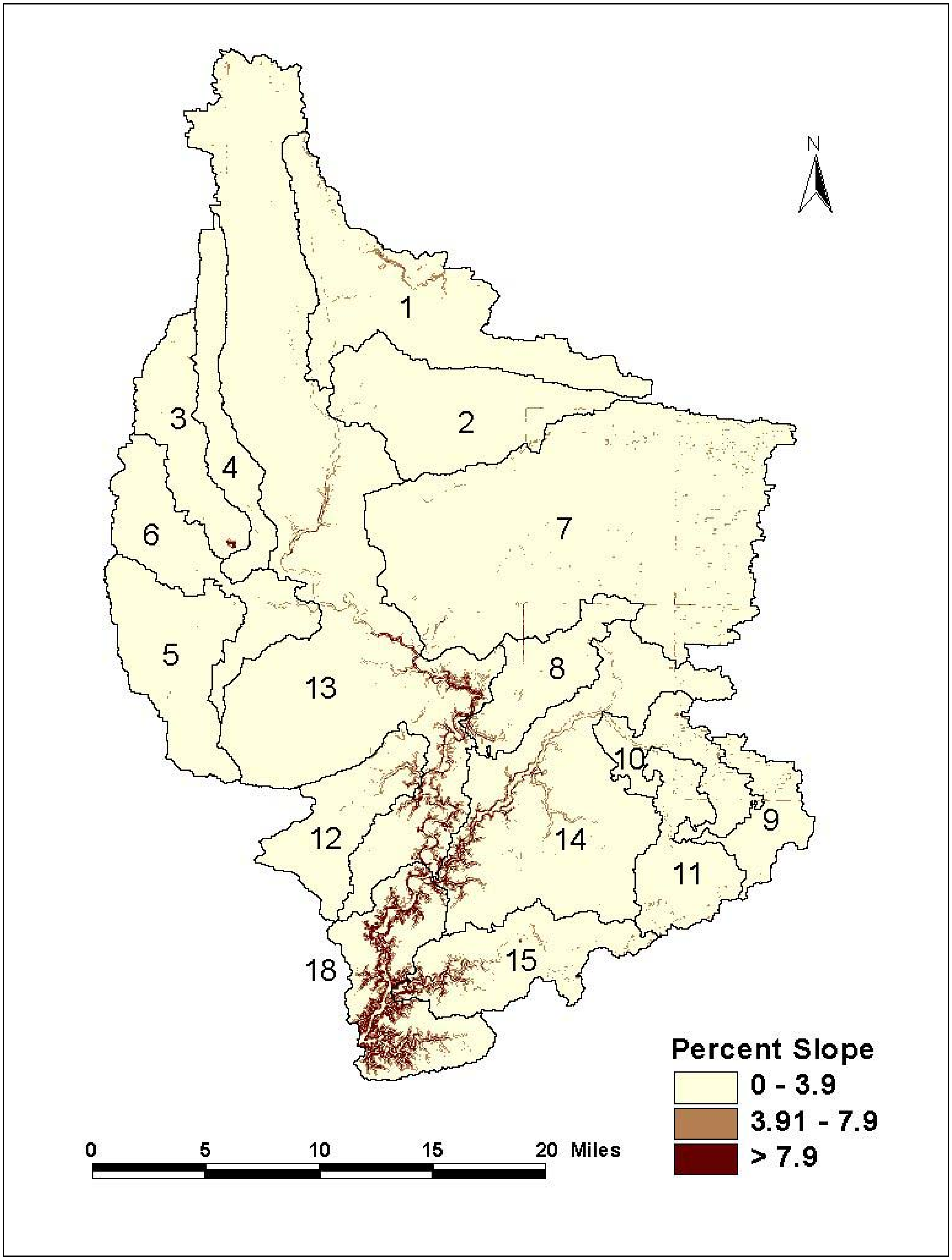


Table 9. Simulated Annual Average Subbasin TP Pollutant Loadings for the Upper Embarras Watershed.

SUBBASIN 1					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	13,740.3	33,952.3	3.3	2.9	99,835.9
Pasture	909.9	2,248.4	0.5	0.4	924.6
				Total Subbasin Load	**100,760.5**
SUBBASIN 2					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	10,805.2	26,699.6	3.1	2.8	73,644.1
Pasture	374.1	924.4	0.4	0.3	311.9
				Total Subbasin Load	**73,956.0**
SUBBASIN 3					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	5,631.8	13,916.2	2.7	2.4	32,985.7
Pasture	321.7	794.9	0.4	0.4	303.8
				Total Subbasin Load	**33,289.5**
SUBBASIN 4					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	5,245.7	12,962.1	2.6	2.4	30,538.1
Pasture	292.6	723.0	0.4	0.4	289.1
				Total Subbasin Load	**30,827.2**
SUBBASIN 5					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	8,547.9	21,121.9	2.8	2.5	59,923.5
Pasture	359.2	887.6	0.4	0.4	343.6
				Total Subbasin Load	**60,267.1**
SUBBASIN 6					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	7,930.4	19,596.0	2.4	2.1	41,190.8
Pasture	416.1	1,028.2	0.4	0.4	360.3
				Total Subbasin Load	**41,551.1**
SUBBASIN 7					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	36,879.9	91,130.2	3.9	3.5	315,089.2
Pasture	1,609.5	3,977.1	0.4	0.4	1,033.4
				Total Subbasin Load	**316,122.6**
SUBBASIN 8					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	5,120.8	12,653.5	3.5	3.2	40,018.9
Pasture	461.5	1,140.4	0.4	0.3	374.2
				Total Subbasin Load	**40,393.1**
SUBBASIN 9					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	3,917.3	9,679.6	3.8	3.4	32,893.0
				Total Subbasin Load	**32,893.0**

SUBBASIN 10					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	4,507	11,136.8	3.1	2.8	30,810.4
Pasture	309	763.5	0.4	0.3	266.7
				Total Subbasin Load	**31,077.1**
SUBBASIN 11					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	5,444.3	13,452.9	4.1	3.7	49,142.2
Pasture	524.1	1,295.1	0.4	0.4	504.0
				Total Subbasin Load	**49,646.2**
SUBBASIN 12					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	6,115.5	15,111.4	3.2	2.9	43,299.8
Pasture	386.5	955.0	0.4	0.4	335.6
				Total Subbasin Load	**43,635.4**
SUBBASIN 13					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	40,973.2	101,244.8	3.4	3.0	308,716.9
Deciduous Forest	1,745.3	4,312.6	< 0.1	< 0.1	122.0
Pasture	4,365.4	10,786.9	0.4	0.4	4,149.0
Forested Wetland	1,071.7	2,648.2	< 0.1	< 0.1	75.3
				Total Subbasin Load	**313,063.2**
SUBBASIN 14					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	1,8037.2	44,569.9	3.4	3.0	133,267.3
Deciduous Forest	953.4	2,355.9	< 0.1	< 0.1	57.4
Pasture	2,054.8	5,077.4	0.4	0.3	1,721.5
				Total Subbasin Load	**135,046.2**
SUBBASIN 15					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	5,838.1	14,425.9	3.9	3.5	50,424.3
Deciduous Forest	572.4	1,414.4	< 0.1	< 0.1	32.0
Pasture	1,645	4,064.8	0.4	0.4	1,459.4
				Total Subbasin Load	**51,915.7**
SUBBASIN 18					
SWAT Land Use	**Area (ha)**	**Area (ac)**	**TP (kg/ha)**	**TP (lb/ac)**	**TP (lbs)**
Corn/Soybean	4,411.4	10,900.6	4.3	3.8	41,538.9
Deciduous Forest	2,699.7	6,671.0	< 0.1	< 0.1	256.0
Pasture	1,838.2	4,542.2	0.5	0.5	2,177.3
Forested Wetland	257.8	637.0	< 0.1	< 0.1	24.6
				Total Subbasin Load	**43,996.8**
				TOTAL WATERSHED LOAD (lbs)	**1,398,440.7**

Table 10. Summary of Simulated Annual Average Total Phosphorus Pollutant Loadings in the Upper Embarras Watershed.

SUBBASIN ID	TOTAL PHOSPHORUS (LBS)	TOTAL PHOSPHORUS (KGS)
1	100,761	45,704
2	73,956	33,546
3	33,290	15,100
4	30,827	13,983
5	60,267	27,337
6	41,551	18,847
7	316,123	143,390
8	40,393	18,322
9	32,893	14,920
10	31,077	14,096
11	49,646	22,519
12	43,635	19,793
13	313,063	142,002
14	135,046	61,256
15	51,916	23,548
18	43,997	19,957
Total Watershed Loading	**1,398,441**	**634,320**

REFERENCES

Arnold, J.G., J.R. Williams, A.D. Nicks, and N.B. Sammons. 1990. SWRRB, a Basin Scale Simulation Model for Soil and Water Resources Management. Texas A&M Press.

Arnold, J.G.. 1992. Spatial Scale Variability in Model Development and Parameterization. Ph.D. Dissertation., Purdue University, West Lafayette, IN.

Arnold, J.G., P.M. Allen, and G.T. Bernhardt. 1993. A Comprehensive Surface-Groundwater Flow Model. *Journal of Hydrology*, V. 142, p. 47-69.

Bagnold, R.A.. 1977. Bedload Transport in Natural Rivers: Water Resources Research, v. 13, no. 2.

DiLuzio, M., R. Srinivasan, and J. Arnold. 2001. ArcView Interface for SWAT2000: User's Guide. Blackland Research Center, Texas Agricultural Experiment Station, Temple, Texas.

Foster, G.R., L.J. Lane, J.D. Nowlin, L.M. Laflen, and R.A. Young. 1980. A Model to Estimate the Sediment Yield from Field-sized Areas: Development of model. In "CREAMS-A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems," Vol. I, "Model Documentation", Chap. 3, USDA-SEA Conservation Report No. 26, p 36-64.

IEPA (Illinois Environmental Protection Agency), 1999. *Baseline Loadings of Nitrogen, Phosphorus, and Sediments from Illinois Watersheds.* Illinois Environmental Protection Agency, Bureau of Water, Springfield, IL.

Lumb, A.M., R.B. McCammon, and J.L. Kittle, Jr. 1994. Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrological Simulation Program–Fortran. U.S. Geologic Survey. Water-Resources Investigations Report 94-4168, Reston, VA, 1994.

MRLC (Multi- Resolution Land Characteristics). 1992. Land use data available for the Multi-Resolution Land Characteristics Consortium. Land use data produced mainly from the 1992 Landsat TM meter coverage (30 m resolution).

NRCS (Natural Resources Conservation Service). 1972. *Hydrology Guide for Use in Watershed Planning.* Soil Conservation Service (now the NRCS) National Engineering Handbook, Section 4: Hydrology, Supplement A. U.S. Department of Agriculture, Natural Resources Conservation Service. Washington, D.C.

NRCS (Natural Resources Conservation Service). 1994. State Soil and Geographic Database (STATSGO). U.S. Department of Agriculture, Washington, DC.

USDA (U.S. Department of Agriculture). 1986. Technical Release 55, Urban Hydrology for Small Watershed. U.S. Department of Agriculture. Soil Conservation Service, National Technical Information Service, Springfield, VA.

USDA (U.S. Department of Agriculture). 1995. *State Soil Geographic (STATSGO) Data Base Data Use Information* Miscellaneous Publication Number 1492. U.S. Department of Agriculture, Natural Resources Conservation Service. Fort Worth, TX.

Appendix C

BATHTUB Modeling of the Charleston Side Channel Reservoir, Illinois

This page was intentionally left blank for double-sided printing

Description of BATHTUB
BATHTUB is an empirical eutrophication model that performs water and nutrient balance calculations in a steady-state, spatially segmented hydrologic network. It accounts for advective transport, diffusive transport, and nutrient sedimentation. Eutrophication-related water quality conditions are predicted using empirical relationships previously developed and tested for reservoir applications.

Data to Support the Modeling Analysis
Compared to other reservoir models, the BATHTUB model requires a moderate amount of site-specific data to configure and calibrate. Input data include atmospheric loads of nutrients, tributary flows and concentrations, in-lake water quality concentrations, and global parameters such as evaporation rates and annual average precipitation. Tables 1 to 8 show the actual values used in the modeling and the source of the data. The average and coefficients of variation for the sampling stations were determined by analysis of Illinois EPA sampling data. These were summarized using statistical tools available with Microsoft Excel and Microsoft Access.

Table 1. Average Annual Atmospheric Loads used in CSCR BATHTUB Modeling.

Atmospheric Loads (kg/km^2-yr)	
Total Phosphorus	3.23
Orthophosphorus	1.5

Source: National Atmospheric Deposition Program

Table 2. Evaporation Rates and Precipitation used for 1998 CSCR BATHTUB Modeling.

Parameter	Mean	CV
Precipitation (m)	1	0.13
Evaporation (m)	1.45	0.3
Change in storage (m) [a]	-0.5	0.3

Source: Illinois State Water Survey Data for Urbana, Illinois

Table 3. Tributary Drainage Areas, Flows and 1998 Concentrations.

Segment Number	Name	Drainage Area (km^2)	Mean Flow (Million L/yr)	Total Phosphorus (mg/L)
3	Lake Charleston	0	1,850[a]	0.300
2	Overland Flow	3.83	200[b]	0.212
1	Outflow	0	2,260[a]	0.134
1	Overflow	0	70[b]	0.101

[a] City of Charleston (2001).
[b] Clean Lakes Study estimate (1992).

Table 4. In-Lake 1998 Concentrations for Segment 1 (RBC 1).

Constituent	Mean	CV
Nonalgal Turbidity (1/M)	0.93	0.67
Total Phosphorus (mg/L)	0.125	0.63
Total Nitrogen (mg/L)	1.278	0.33
Chlorophyll-*a* (mg/L)	0.053	0.72
Secchi Depth (m)	0.51	0.58
Organic Nitrogen (mg/L)	0.608	0.66
Total P - Ortho P (mg/L)	0.072	0.14

Table 5. In-lake 1998 Concentrations for Segment 2 (RBC-2).

Constituent	Mean	CV
Nonalgal Turbidity (1/M)	0.93	0.67
Total Phosphorus (mg/L)	0.125	0.63
Total Nitrogen (mg/L)	1.463	0.29
Chlorophyll-*a* (mg/L)	0.053	0.72
Secchi Depth (m)	0.51	0.58
Organic Nitrogen (mg/L)	0.608	0.66
Total P - Ortho P (mg/L)	0.072	0.14

Table 6. In-Lake 1998 Concentrations for Segment 3 (RBC 3).

Constituent	Mean	CV
Nonalgal Turbidity (1/M)	0.72	0.48
Total Phosphorus (mg/L)	0.064	0.59
Total Nitrogen (mg/L)	1.382	0.45
Chlorophyll-*a* (mg/L)	0.052	0.75
Secchi Depth (m)	0.65	0.56
Organic Nitrogen (mg/L)	0.730	0.78
Total P - Ortho P (mg/L)	0.064	0.47

The model was segmented into three sections to match the locations of the three sampling stations and to more accurately model the system and understand the processes affecting water quality. The water quality data associated with the station in each segment was assumed representative of the water quality data of the whole segment. Please refer to Appendix A for the raw water quality data. Available contour maps were digitized and used to obtain surface area, average depth, and the average length for each segment (Figure 1 and Table 7).

Figure 1. Map of Reservoir Depths for Charleston Side Channel Reservoir (City of Charleston, 1992).

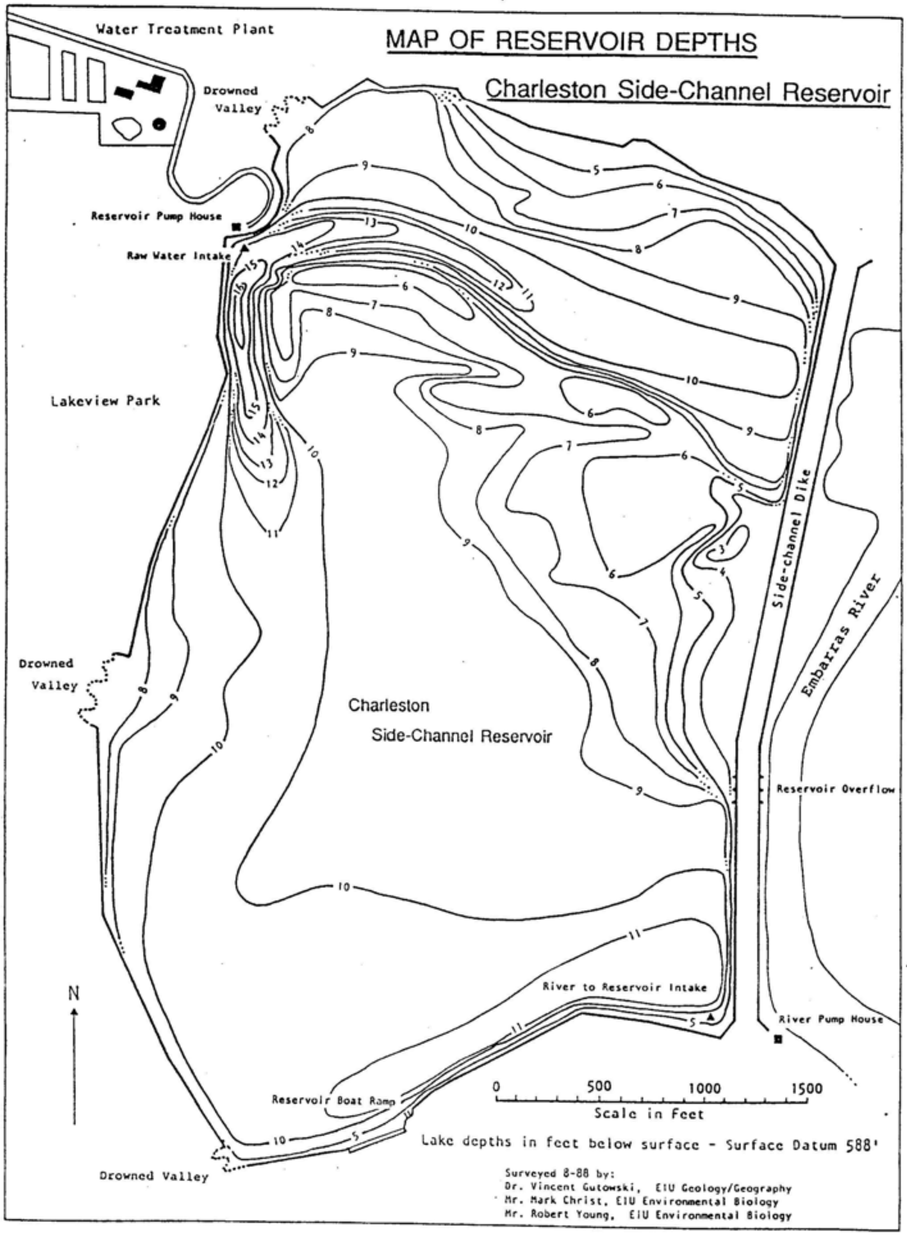


Table 7. Morphologic Characteristics of CSCR.

Total Shoreline Length	4511.04 m
Total Area	1,252,878 m^2
Total Volume	3,379,814.7 m^3
Mean Depth	2.62 m

Table 8. Morphologic Characteristics of Each Segment used in BATHTUB Modeling.

Segment	Depth (m)	Area (m^2)	Mixed Layer Depth (m)	Hypolimnetic Depth (m)
1	4.05	417,626	0.05	0.19
2	2.63	417,626	0.06	0.17
3	2.96	417,626	0.08	0.19

Model Calibration

The calibration of the BATHTUB model was accomplished by adjusting the predicted water balance to observed conditions in 1992. The measured inflows and outflows were specified and the storage term was adjusted to account for un-quantified inflows and outflows (seepage and groundwater contributions). After testing several nutrient sedimentation routines the dispersion rates were calibrated to match the observed nutrient concentrations. The second order decay rate function empirical sedimentation routine was selected to best represent phosphorous sedimentation within the CSCR. The calibration results are shown in Table 9.

Table 9. Results of BATHTUB Calibration.

Component	Observed Area Weighted Mean	Estimated Area Weighted Mean	Observed vs Estimated Ratio
Total Phosphorus (mg/L)	0.139	0.138	1.01
Chlorophyll *a* (μg/L)	65.4	68.1	0.96
Secchi Depth (m)	0.4	0.4	1.00

Model Validation

The BATHTUB model was validated by adjusting the loading and meteorological conditions to represent the observed conditions of 1998 while keeping all other model parameters the same. The validation results are shown in Table 10.

Table 10. Results of BATHTUB Validation.

Component	Observed Area Weighted Mean	Estimated Area Weighted Mean	Observed vs Estimated Ratio
Total Phosphorus (mg/L)	0.1048	0.1082	0.97
Chlorophyll *a* (μg/L)	52.9	52.2	1.01
Secchi Depth (m)	0.6	0.59	1.02

Appendix D

Charleston Side Channel Reservoir TMDL
Draft Project Implementation Plan

This page was intentionally left blank for double-sided printing

1.0 Introduction

The Charleston Side Channel Reservoir (CSCR) is a water supply and recreational reservoir located southeast of the city of Charleston in Coles County in east central Illinois (Figure 1). As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency (Illinois EPA) identified the CSCR as an impaired water. The potential causes of impairment are total phosphorus (TP), nitrogen, total suspended solids (TSS), and excessive algal growth/chlorophyll *a* (Illinois EPA, 2001). These impairments result in the CSCR being in partial support of its primary contact (swimming) and secondary contact (recreation) designated uses and in partial support of its aquatic life designated use. The drinking water supply and fish consumption designated uses of the CSCR are not impaired.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters on the Section 303(d) lists. Illinois EPA is currently developing TMDLs for pollutants that have water quality standards. Of the pollutants impairing the CSCR, phosphorus is the only one with a water quality standard for lakes. Illinois EPA believes that addressing the phosphorus impairment will lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants.

Potential sources of TP to the CSCR include pumping from Lake Charleston, runoff from the direct drainage area, shoreline erosion, septic systems, and precipitation. The bottom sediments are also contributing TP loadings during portions of the year. Loads from these sources were estimated using a variety of means as part of the TMDL analysis, and it was determined that the primary sources are bottom sediments, pumping, and shoreline erosion. The BATHTUB model was used to determine how much the loads must be reduced so that the TP standard for lakes of 0.05 mg/L is achieved and the results indicate that loads must be reduced approximately 90 percent. Please refer to the full TMDL report for details regarding the analysis.

The purpose of this implementation plan is to identify and describe activities that can be taken to achieve reduction in TP loads. The description includes cost estimates, the likely effectiveness of each activity, their advantages/disadvantages, and an identification of responsible parties. Since there are multiple options for meeting the TP load reduction, this plan does not provide a specific list of steps that must be taken. Instead, the different alternatives should be discussed and agreed upon by the key stakeholders.

The CSCR TMDL will use a nonregulatory approach to TMDL implementation and watershed projects will be started incrementally as they are funded. Many efforts to improve water quality in the CSCR and to reduce TP loads in the watershed upstream of Lake Charleston are already under way. A concerted locally driven effort will be needed to effectively implement the additional needed changes and the approaches outlined in this plan are therefore subject to change based on additional local input. The process is likely to take many years and will require a commitment from a number of people and organizations. This implementation plan is therefore intended to be a living document that will continuously be revised to help guide watershed protection efforts until water quality standards are met. More details, including a schedule, interim milestones, and specific responsibilities, should be added to this draft implementation plan once they have been determined.

The activities that can be taken to achieve the desired load reductions are organized in this document according to the controllable sources:

- Internal loads
- Pumping from Lake Charleston
- Shoreline erosion
- Direct runoff
- Septic systems

Figure 1. Upper Embarras River Watershed and the Charleston Side Channel Reservoir.

2.0 Internal Loads

The results of the TMDL analysis indicate that internal loading from the bottom sediments is the largest current source of TP in the CSCR. Internal loadings are caused by the slow release of TP from the sediment in the lake bottom during low oxygen conditions. To combat this problem the city of Charleston installed an aeration system in the CSCR to artificially increase dissolved oxygen concentrations. However, the system has had difficulty keeping the entire CSCR from becoming anoxic during summer conditions. This is partly due to the unique hydrologic characteristics of the CSCR, such as the lack of flow associated with a typical reservoir. The Clean Lakes Study concluded that installing an aeration system large enough to keep the entire CSCR from going anoxic would require prohibiting boating because of potential entanglement associated with air lines and platforms (City of Charleston, 1992).

Another option to reduce internal TP loading is to chemically treat the water in the CSCR. An aluminum hydroxide floc would be mixed with CSCR water so that a chemical reaction would inactive the TP. The Clean Lakes report estimated this cost at $148,500 in 1992, or $191,900 in current dollars (U.S. Department of Labor, 2002). Potential disadvantages associated with chemical treatment include damaging effects to the aquatic life through the possible formation of toxic aluminum (III). Chemical treatment also might be difficult because high wind and wave action typically associated with the CSCR might break up the floc blanket before it has time to take complete effect.

Internal loading of TP could also be addressed through dredging of the sediment. Table 1 shows information for two lakes in Illinois that have been dredged within the past 15 years. The two upper arms of Lake Springfield were dredged from 1987 to 1990 at a cost of $7,800,500 ($10,820,300 in current dollars (U.S. Department of Labor, 2002)). West Lake, in Edgar County, was dredged from 1995 to 1996 at a cost of $722,000 ($834,300 in current dollars). The average cost per cubic yard removed for these two projects is $3.17. The Clean Lakes study estimated that approximately 1.3 million cubic yards of sediment would need to be removed to limit phosphorus recycling in the CSCR. The estimated cost to dredge the CSCR is therefore $4,121,000 (1.3 million cubic yards multiplied by $3.17 per cubic yard). An added benefit of dredging would be deepening of the CSCR. However, a potential problem is locating an appropriate site for the spoils.

Table 1. Previous dredging projects in Illinois.

Lake Name	Lake Size (acres)	Watershed Size (acres)	Sediment Removal (cubic yards)	Cost (2002 Dollars)
Lake Springfield	4300	170,000	3,222,835	$10,820,300
West Lake	56.7	12,826	452,000	$834,300

3.0 Pumping from Lake Charleston

Loading of TP to the CSCR is a result of pumping from Lake Charleston. Annual loads from pumping are a function of the volume of water pumped and the concentration of pollutants in the water. An annual average load of 554 kg has been estimated using the average pumping volume and the most recent TP data for Lake Charleston that indicates an average concentration of 0.30 mg/L.

Since reducing the volume of water pumped to the CSCR is not a viable option because it could affect the city’s water supply, efforts to reduce loadings must focus on reducing the average TP concentration of the intake water. This could be accomplished in several ways. First, pumping could be avoided during periods with extremely high TP concentrations. For example, pumping during periods when the average

TP is 0.15 mg/L would reduce loadings by 50 percent. Periods of high TP are likely to be during and shortly after upstream wet weather events. Sampling in other agricultural watersheds has shown that TP concentrations during wet weather events can be as much as 60 to 70 percent greater than ambient conditions (Tetra Tech, 2001). The other period when TP concentrations are likely high is during the late summer when anoxic conditions in Lake Charleston probably result in internal loading from its sediment.

Avoiding pumping during periods with high TP concentrations is relatively inexpensive compared to some of the other options identified. However, several challenges would need to be overcome. First, the practice would only be feasible for short periods of time because the city of Charleston would not be able to jeopardize its water supply. An intensive monitoring program would also be needed prior to implementing this practice to obtain a full understanding of TP dynamics in Lake Charleston to know the best time to avoid pumping. Weekly sampling of Lake Charleston would be needed for at least one year.

Another option is to treat the water pumped from Lake Charleston. This could be done by adding alum to the Lake Charleston pump water. The alum would produce an aluminum hydroxide floc that would sorb phosphorus and precipitate solids. This option does not prevent the introduction of the phosphorus but it does remove it from the water column. The Clean Lakes Study estimated the cost at approximately $3000 per year ($4000 in current dollars).

Another option is to build a plant to treat the Lake Charleston pump water. The city of Charleston estimated this cost at $400,000 ($517,000 in current dollars (U.S. Department of Labor, 2002)). However, the effectiveness of building a treatment plant to reduce TP concentrations below the current levels observed in Lake Charleston is unknown because these plants are typically designed to reduce much higher TP concentrations (e.g., typical reductions are from 7 or 8 mg/L TP to 1 mg/L). Costs to reduce TP concentrations below 0.30 mg/L would likely be prohibitive.

Another option for reducing the TP concentrations in Lake Charleston is to reduce the loadings from upstream sources. The analysis conducted for the TMDL indicates that row crop agriculture is the largest current source of upstream TP (refer to Appendix B) and efforts should therefore start with this source.

There are several possible best management practices (BMPs) that can be implemented to reduce TP loadings from row crop agriculture and a great deal of effort has already been made to implement these in the watershed above Lake Charleston. For example, the Champaign County NRCS estimates that 50 percent of producers already only apply nitrogen and phosphate at levels to meet crop needs (Wendte, 2002). Numerous acres of vegetated filter strips have also been planted in Champaign, Coles, Douglas, Edgar, and Vermillion Counties to catch sediment and TP before they enter streams. Many acres are also already cultivated using conservation tillage practices which greatly reduce erosion rates.

Both the Illinois EPA and the Illinois Department of Agriculture have made funds available in the current fiscal year to reduce TP loads in the Upper Embarras River watershed. The Illinois EPA is targeting the award of Section 319 monies to projects that will reduce TP in watersheds where TMDLs are being developed. Maximum funding by Illinois EPA is 60 percent of the total project; the remaining 40 percent is the responsibility of the applicant. Illinois EPA made available more than $2.1 million statewide for Section 319 projects this fiscal year

The Illinois Department of Agriculture, Division of Natural Resources, has also made available more than $275,000 in Champaign, Coles, Douglas, Edgar, and Vermilion counties for nutrient management plans and traditional erosion control practices in the current fiscal year. These funds are designated for incentive payments to landowners/operators within the watershed to promote the use of management practices that reduce the movement of sediment and TP. The dollar amount allocated to each eligible soil and water conservation district is based on its portion of the total number of cropland acres in the watershed. Landowners/operators are paid for each acre of land that follows a nutrient management plan (typically $5 per acre) and there has been tremendous response from landowners/operators in the watershed. Several of the counties have already allocated all of their funds.

The discussion below provides a brief summary of two practices that are eligible for the funding made available by the Illinois EPA and the Illinois Department of Agriculture.

3.1 Nutrient Management Plans

Nutrient management plans are often implemented to help maximize crop yields while using nutrient resources in the most efficient, environmentally sound manner. The plans help guide landowners by analyzing agricultural practices and suggesting appropriate nutrient reduction techniques. This is often done by managing the amount and timing of nutrient fertilizers on agricultural land in the watershed. Nutrient management plans are tailored for specific fields and crops. Because of this, they require site specific sampling and planning. USEPA (1993) suggests that the nutrient management plan include:

- Maps and data regarding the farm size and type of crops grown
- Realistic yield expectations based on soils and past crop yields
- Summary of the nutrient resources available
- An evaluation of field limitations and hazards
- Use of the limiting nutrient concept to apply nutrients based on realistic crop expectations
- Specific timing and application data for nutrients
- Provisions for proper calibration and operation of nutrient application equipment
- Annual reviews and monitoring

Using these plans, a landowner can apply fertilizers based on the limiting nutrient in the soils and realistic crop yields.

Limited information is available on the effectiveness of nutrient management plans to reduce loads of TP. The effectiveness will vary a great deal depending on the application rate prior to implementation of the plan and site-specific factors such as crop types and soil characteristics. The U.S. Department of Agriculture found in a study of 340 nutrient management plans in Pennsylvania that the average reduction in applied phosphorus was 14 percent (USDA-ASCS, 1992).

The Illinois Department of Agriculture is promoting the use of nutrient management plans in the Upper Embarras River watershed as part of the TMDL. Landowners/operators should contact their local soil and water conservation district to obtain information about obtaining funding. One important point to note is that the producer must use Certified Crop Advisors (CCAs) or other approved third party vendors for the development of nutrient management plans.

3.2 Vegetated Filter Strips

Vegetated filter strips are used to reduce the amount of nutrients and sediments that enter a waterbody, reduce erosion around a stream channel, and protect a waterbody from encroachment. Targeted placement of vegetated filter strips can play an important role in reducing TP in the Upper Embarras River watershed even though soil erosion is not considered a significant problem due to the flat topography, extensive use of tile drainage, and conservation tillage practices.

If vegetated buffers are designed correctly, they can prevent suspended solids, nitrogen, and TP from entering a stream. The ability of the buffer to uptake TP depends on the filter strip design, residence time of the water, and slope of the land. Suspended solids (which can transport TP) are more easily removed by vegetated buffers through settling.

Pennsylvania State University (1992) estimates that the preferred filter strip width for phosphorus will remove 50–75 percent of TP. Local NRCS personnel and soil and water conservation districts should be consulted to determine the most appropriate design criteria and placement of filter strips in the Upper Embarras River watershed.

4.0 Shoreline Erosion

Shoreline erosion in the CSCR occurs when wave activity undercuts poorly consolidated soils and the higher slopes undergo mass movement into the reservoir. Another method of shoreline erosion occurs when large trees on the edge of the cliffs fall into the CSCR. This causes large masses of soil to be carried into the water and creates a larger scar on the shore which contributes to significant sediment.

A number of steps have been taken to reduce shoreline erosion to the CSCR. These include:

- A 700-foot dike built along the west shore in 1994 to contain a collapsing shoreline
- More than 2000 feet of riprap installed in 1999 and 2000 along the west shore
- Approximately 400 feet of riprap installed along the south shore

Additional options for reducing shoreline erosion include tree cutting and maintaining reduced water levels. Tree cutting refers to cutting those trees that are on the verge of falling. If the trees on the edge of cliffs were removed, these large scale inputs could be slowed. Maintaining lower water levels would also help reduce shoreline erosion. When water levels in the CSCR are lower, a natural bench or ledge can be observed. This bench is made up of gravel, rock, and shale which is less erodible than the poorly consolidated materials located above it. It also has a lower TP content. By maintaining lower water levels the waves will break on this ledge and lose their energy. This reduces the undercutting that leads to shoreline erosion. The Clean Lakes Report includes some guidelines for how this activity could be implemented.

5.0 Direct Runoff

Direct runoff is not considered a significant source of TP to the CSCR when compared to other sources (less than 3 percent). However, an effort should still be made to reduce loadings from this source wherever feasible.

Residential land can be a source of a wide range of pollutants from cars, lawns, and construction sites. Residential areas also tend to increase the imperviousness in a watershed, which reduces the amount of water infiltration, and increases the amount of stormwater that flows into surface waterbodies. When water is allowed to run off paved areas, it can transport various pollutants including metals, grease and oil, nutrients, and sediment to surface waters. Stormwater flows and volumes are often higher in these streams. The Center for Watershed Protection (CWP) has estimated that watersheds with 11 to 25 percent impervious cover have affected stream quality, and watersheds with more than 25 percent impervious cover have nonsupporting stream quality (CWP, 1998).

Outreach programs are used to educate the public about watershed concerns, stormwater runoff issues, and alternative construction practices (such as open space planning). These programs can also teach the community about individual practices that can reduce TP loadings. For example, lawn fertilization and animal wastes may be a source of nutrient pollution in streams in residential areas. Instruction in proper fertilization practices could help reduce nutrient loadings from individual residential lots. Other individual homeowner practices include using nonphosphorus-containing detergents and reducing overall water use. Studies have found that newspapers and television are more effective outreach programs than brochures and meetings (Tetra Tech, 2001).

The main goal of structural BMPs is to increase the amount of water infiltration and reduce the amount of runoff. By doing this, stormwater, and pollutants carried by stormwater, are prevented from directly entering a stream. Some common structural residential BMPs are listed below:

- Infiltration basin
- Infiltration trench
- Dry or wet ponds
- Porous pavement
- Constructed wetlands

The premise of each of these BMPs is to route stormwater to a holding basin so that more water can infiltrate and suspended solids can settle out of the water. The effectiveness of each of these BMPs depends on the retention time, size (volume of the basin), flow, and type of soils.

6.0 Septic Systems

Septic systems are not considered a significant source of TP to the CSCR. Nevertheless, an effort should be made to ensure that the systems surrounding the reservoir are not contributing to the problem.

Septic systems provide an economically feasible way of disposing of household wastes where other means of waste treatment are unavailable (e.g., public or private treatment facilities). The basis for most septic systems involves the treatment and distribution of household wastes through a series of steps involving the following:

- A sewer line connecting the house to a septic tank
- A septic tank that allows solids to settle out of the effluent
- A distribution system that dispenses the effluent to a leach field
- A leaching system that allows the effluent to enter the soil

Septic system failure occurs when one or more components of the septic system do not work properly and untreated waste or wastewater leaves the system. The waste may pond in the leach field and ultimately run off into nearby streams or percolate into the groundwater system. Untreated septic system waste is a potential source of nutrients (nitrogen and TP), organic matter, suspended solids, and bacteria. The most common reason for failure is improper maintenance. Other reasons include improper installation, location, and choice of system. Harmful household chemicals can also cause failure by killing the bacteria that digest the waste.

Many homeowners do not realize they have a failing septic system, whereas others may know, but choose not to remedy the problem because of cost. One recommendation is to initiate an outreach program to educate residents about septic systems, and, in some cases, provide funding to help fix or replace failing systems. The components of an example outreach program are illustrated below:

- Make homeowners aware of the age, location, type, capacity, and condition of their septic system.
- Teach homeowners to recognize a failing septic system.
- Teach homeowners about proper septic system maintenance.

- Provide information about different types of septic systems, and their costs, advantages, and disadvantages.
- Provide consultation and inspection services to homeowners.
- Teach homeowners about water quality concerns in their watershed.

In addition to conducting a public outreach campaign, an effort should be made to identify and repair failing systems. In some cases extremely old systems might need to be replaced. Systems located in close proximity to the reservoir or reservoir tributaries should be targeted first. This effort should be coordinated by the Coles County Health Department.

Finally, an effort needs to be made to ensure that septic systems are properly maintained. Homeowners should be required to pump out or inspect their septic tanks on a regular schedule. Septic tanks should be pumped when the solids in the tank accumulate to a point where the effluent no longer has enough time to settle and clarify. The timing of the pump-out depends on the tank and household size.

REFERENCES

Barker, J.C., and B.A.Young. 1984. *Evaluation of a Vegetative Filter for Dairy Wastewater in Southern Appalachia*. Water Resource Research Institute, North Carolina State University, Raleigh, NC.

City of Charleston. 1992. *Clean Lakes Program Phase I Diagnostic Feasibility Study of the Charleston Side Channel Reservoir.* City of Charleston in cooperation with Eastern Illinois University, Illinois EPA, and USEPA, Charleston, IL.

CWP (Center for Watershed Protection). 1998. *Rapid Watershed Planning Handbook.* Center for Watershed Protection, Ellicott City, MD.

Dillaha, T.A., R.B. Renear, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. *Transactions of the American Society of Agricultural Engineers*, 32(2):513–519.

Doyle, R.C., G.C. Stanton, and D.C. Wolf. 1977. *Effectiveness of Forest and Grass Buffer Filters in Improving the Water Quality of Manure Polluted Runoff.* American Society of Agricultural Engineers Paper No. 77-2501. St. Joseph, MI.

Glasoe, S., and M. Tompkins. 1996. *Sanitary surveys in Mason County*. Puget Sound Water Quality Authority, Puget Sound Notes. Number 39. June 1996.

Lowrance, R.R., R.L. Todd, and L.E. Asmussen. 1983. Waterborne nutrient budgets for the riparian zone of an agricultural watershed. *Agriculture, Ecosystems, and Environment* 10:371–384.

Pennsylvania State University. 1992. Nonpoint Source Database. Pennsylvania State University. Department of Agricultural and Biological Engineering. University Park, Pennsylvania.

Tetra Tech, Inc. 2001. 2000 Water Quality Report. Supplement to the East Fork Little Miami River Water Quality Assessment Report for Clermont County, Ohio. Final Report. May 8, 2001. Tetra Tech, Inc. Cleveland, Ohio.

URI (University of Rhode Island). 2002. University of Rhode Island. Cooperative Extension Water Quality Program. www.uri.edu/ce/wq/owtc/bighp/matrix.html

USDA-ASCS. (U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service). 1992. Conestoga Headwaters Project Pennsylvania Rural Clean Water Program 10-Year Report. U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. Harrisburg, Pennsylvania.

U.S. Department of Labor. 2002. Bureau of Labor Statistics. Consumer Price Index Inflation Calculator Available at http://www.bls.gov/cpi/. Accessed December 2, 2002.

USEPA (U.S. Environmental Protection Agency). 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA 840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (U.S. Environmental Protection Agency). *Technical Guidance Manual for Developing Total Maximum Daily Loads. Book 2. Streams and Rivers. Part 1. Biochemical Oxygen Demand/Dissolved*

Oxygen and Nutrients/Eutrophication. EPA 823-B-97-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Wendte, L. 2002. Natural Resources Conservation Service. Champaign County. Personal communications. March 5, 2002.

Appendix E

Charleston Side Channel Reservoir TMDL Responsiveness Summary

RESPONSIVENESS SUMMARY

This responsiveness summary responds to substantive questions and comments received during the public comment period from May 20, 2003, through July 5, 2003 (postmarked), including those from the June 19 public meeting discussed below.

WHAT IS A TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Charleston Side Channel Reservoir (CSCR) TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the CSCR and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and the regulations thereunder.

BACKGROUND

The 339-acre CSCR is a water supply reservoir for the city of Charleston. It is listed as impaired for primary contact (swimming), secondary contact (recreation) and aquatic life designated uses. The potential causes of impairment are phosphorus, nitrogen, total suspended solids and excessive algae growth/chlorophyll a. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) Lists. Illinois EPA is currently developing TMDLs for pollutants that have water quality standards. Of the pollutants impairing the CSCR, phosphorus is the only one with a water quality standard for lakes. Illinois EPA believes that addressing the phosphorus impairment should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. The Illinois EPA contracted with Tetra Tech Inc. of Fairfax, Virginia, to prepare a TMDL report for this water body.

PUBLIC MEETINGS

Public meetings were held in the city of Springfield on June 5, 2001, and in the city of Charleston on January 17, 2002 and June 19, 2003. The Illinois EPA provided public notice for the June 19 meeting by placing display ads in the Charleston Times-Courier, Philo Southern Champaign County Today, Villa Grove News and Oakland County Crossroads on May 20, 2003. This notice gave the date, time, location and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 350 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review in the reference area of the Charleston Carnegie Library and also at the Agency's TMDL web page at http://www.epa.state.il.us/water/tmdl/ .

The final public meeting started at 6:30 P.M. on Thursday, June 19, 2003. It was attended by approximately 20 people and concluded at 8:30 P.M. with the meeting record remaining open until midnight July 5, 2003.

QUESTIONS AND COMMENTS

1. The Lake Charleston phosphorus data provided by the city of Charleston should not have been used in the model because they are not quality assured like the Agency data are. The phosphorus data are much too high.

   Response: The only data available for Lake Charleston were provided by the city of Charleston. The Charleston Water Treatment Plant did the sampling and Illinois EPA believes that their data are valid. As for their value of phosphorus in Lake Charleston, the most extensive study that we have found, which was done by Xue et al.*, states that the Embarras River's dissolved phosphorus concentration is 0.19 mg/L. Lake Charleston is part of the Embarras River (please refer to page 1 in the TMDL). The city's data for Lake Charleston is 0.30 mg/L total phosphorus and 0.19 mg/L dissolved phosphorus. Xue et al did not report total phosphorus but the dissolved phosphorus seemed to match the city's data.

   *** Xue, Yuan, M. B. David, L. E. Gentry, and D. A. Kovacic. 1998. Kinetics and Modeling of Dissolved Phosphorus Export from a Tile-Drained Agricultural Watershed. *Journal of Environmental Quality* 27: 917-922.**

2. Illinois EPA should discuss with stakeholders the data, type of analyses, level of detail, and assumptions that are appropriate for a particular TMDL model prior to TMDL development. Discussion of these issues early in the process will save everybody time in the long run by reducing the number and intensity of disagreements between stakeholders and IEPA regarding the modeling.

   Response: Illinois EPA held three public meetings: one at the beginning of the project, one in the middle, and one at the end. These are intended to keep the public involved with the TMDL. We have two draft reports that come out before the final and these are sent to the Department of Agriculture and the Natural Resources Conservation Service for recommendations. Illinois EPA will work on improving communication with the stakeholders for future TMDLs.

3. I have a hard time understanding the partitioning between the dissolved and solid phases of phosphorus in the CSCR. If phosphorus in the influent water is 0.30 mg/L and the average in the reservoir is 0.15 mg/L, we must be getting adsorption of the phosphorus on to the sediment to remove it from the water column. However, if the model is saying that desorption of phosphorus from sediments is taking place, then the inflow from the river must be lower to achieve an inlake concentration of 0.15 mg/L.

   Response: The BATHTUB model is indicating that both adsorption and desorption of phosphorus to the bottom sediments of the CSCR is taking place. Settling of soil particles (and associated phosphorus) is taking place throughout the year and desorption occurs during periods of low oxygen. The explanation for the difference between the influent pumping concentrations (0.30 mg/L) and the inlake concentrations (0.15 mg/L) is explained by the fact that pumping accounts for only about 50 percent of the water in the CSCR. Approximately 40 percent of the water balance is due to precipitation which is expected to have a very low phosphorus content and serves to dilute the inlake concentrations.

4. The Soil Water Assessment Tool (SWAT) model should not have been used because it does not take tile drainage into account.

   Response: The SWAT model was developed by the U.S. Department of Agriculture, Agricultural Research Service. The model is intended to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions. The SWAT model, like most other watershed models, unfortunately does not currently have the ability to directly simulate the effects of large-scale tiling. Several model parameters were therefore adjusted to simulate the effects of tiling on watershed hydrology. For example, NRCS curve numbers for tiled soils were adjusted to be lower than they otherwise would be to simulate the effect of greater and quicker infiltration. The storage routing flow coefficient within SWAT was also adjusted during model calibration to address the effects of tiling so that water reached the stream more quickly. These adjustments, in combination with other calibration activities, resulted in acceptable performance of the model as measured by recommended modeling criteria.

5. Does the agency have plans to conduct follow-up monitoring on Lake Charleston? Sounds like these data are lacking. Based on the data from the city, it sounds like this lake does not meet Illinois EPA lake standards.

   Response: Lake Charleston is part of the Embarras River and is not considered a lake due to its riverine characteristics (please refer to page 1 in the TMDL). The Embarras River is monitored, but not at the exact location of Lake Charleston. There is ongoing dialogue between the Illinois EPA volunteer program and the water treatment plant staff to have monitoring done. The Charleston Water Treatment Plant staff will be monitoring as part of the volunteer program as of this year. This monitoring may help answer some of the questions brought up on phosphorus. As for Lake Charleston not meeting standards, there is no phosphorus standard for rivers and therefore Lake Charleston would not be considered impaired for phosphorus. The phosphorus standard for streams is in development at this time and once a standard is formally adopted, Lake Charleston will be assessed relative to the new standard.

6. Although Lake Charleston is not defined as a lake by IEPA and therefore not currently subject to the numeric standard for phosphorus, area residents have indicated that excessive algal blooms occur in the impoundment. Therefore, the impoundment is likely violating the narrative water quality standard regarding offensive conditions and the numeric standard for dissolved oxygen. Because reducing loads to the Embarras River would eventually alleviate both the problem in Lake Charleston and the problem in the CSCR, these reductions should be a priority.

   Response: While we have no data or information on algae blooms in Lake Charleston, we agree that many of the nutrient controlling best management practices (BMPs) cited in the implementation plan will improve conditions in both Lake Charleston and the CSCR.

7. Does the CSCR have a nitrate problem?

   Response: Nitrate is not a cause of impairment in the CSCR. The City has said there has never been a nitrate problem.

8. I know we are targeting phosphorus in this TMDL, but if we only address phosphorus in the implementation activities, are we going to have a nitrogen problem arise. Did anyone look at this?

   Response: Targeting the TMDL to reduce phosphorus instead of nitrogen should not lead to a nitrogen eutrophication issue. Phosphorus is already the limiting nutrient in the CSCR (see section 4.3.2 of the report). This means that there is plenty of nitrogen for the algae and therefore their growth is controlled by phosphorus. This condition will remain the same if phosphorus concentrations are reduced with little to no corresponding change in the nitrogen concentrations.

9. The TMDL document indicates that phosphorus does not adversely impact the drinking water use that is an important function of the reservoir. However, excess phosphorus can lead to excess organic matter in the water. When water with high dissolved organic matter content is chlorinated, there is potential for the formation of disinfection byproducts, such as trihalomethanes (THMs), that have adverse impacts on human health. The potential for these byproducts to form following treatment at the water supply plant should be assessed as part of this study to assure citizens that this problem does not pose human health threats.

   Response: The TMDL recommends a reduction in phosphorus that should result in reductions in dissolved organic matter in the CSCR. This in turn should reduce the potential for THM precursors. Historically, the CSCR has not had a problem with either total trihalomethanes or haloacetic acids. If it becomes a problem, there are remedies that a treatment facility can implement such as changing disinfectants, the location of disinfectant application, or modifying their disinfection procedures.

10. Concerning other implementation activities, you brought up controlled pumping. Obviously that has an effect on lake fluctuation. Have you looked at the net effect of lake level fluctuation on the erosion issue.

    Response: Controlled pumping is now being done by the Charleston Water Treatment Plant and there has not been an erosion problem as a result. The treatment plant staff says that, at most, the fluctuation of the side channel reservoir is 6 feet. There are times when the water level is static for months at a time.

11. The document indicates that because residence time of the CSCR is greater than one year, seasonal considerations are not significant. However, because water from the river is pumped to the reservoir at variable rates throughout the year and phosphorus levels in the river can vary substantially, seasonality is important. The ratio of point source contributions to nonpoint source contributions can be quite variable depending on the time of year and flow in the stream. Therefore, appropriate load and wasteload allocations must be considered in conjunction with the seasonally dependent pumping schedule.

    Response: It is true that because of pumping and hydrologic factors the ratio of point source to nonpoint source contributions of total phosphorus (TP) is likely variable throughout the year. However, we still feel it is appropriate to base the TMDL on the total annual loads of TP because, due to the long residence time of the CSCR, the system is responsive to any load of TP regardless of when it occurs. Furthermore, historical pumping patterns indicate that large

volumes of water are pumped in during periods when nonpoint sources would be expected to dominate the TP load (December), as well as during periods when point sources would be more significant (July).

12. You also mentioned tree cutting in the implementation plan. This seems counterintuitive to some of us that feel that trees will reduce the sediment to the reservoir because their roots add to soil stability.

    Response: Part of the CSCR shores have bluffs and steep hillsides. Wave action is undermining the slopes. Large trees on the edge of the shore fall into the CSCR, which causes large masses of soil to be carried into the water. Tree cutting was one of the methods for erosion control in the 1992 Phase I Clean Lakes Study. This recommendation focuses only on those trees on the verge of falling into the water and would therefore slow down sediment input.

13. I would be bothered if we spent more time and money doing detailed analysis to come up with fairly obvious implementations. I would encourage the Agency to have dialogue with the stakeholders about what kind of analysis needs to be done for specific TMDLs. I know that a valid reason for doing detailed analysis is to defend NPDES permits requiring reductions.

    Response: We are required to set load allocations and do the analysis to back up these load allocations. We have spent funds on the CSCR in the past. In 1996, 319 funds were used for shoreline erosion control and an educational brochure. In 1999, a Priority Lake Watershed Implementation Project constructed additional shoreline erosion control. Also, we are currently using 319 TMDL Implementation Funds for an in-lake sediment basin. We will continue to make funds available to local groups for projects, consistent with the TMDL implementation plan.

14. Are reductions going to be made for the point sources in the watershed? It is not very clear in the TMDL.

    Response: The wasteload allocation is 1 kg/yr and the load allocation is 215.7 kg/yr. Point sources currently contribute only a very small portion of the total phosphorus load, approximately 0.4 percent to the CSCR. Therefore, any significant reductions in the phosphorus loading to the CSCR will have to be achieved through reductions in the nonpoint loadings. At this time phosphorus standards for streams are being developed. When those standards are adopted, the Agency will implement them through the NPDES permitting program, including appropriate limitations on point sources when needed.

15. The analysis that came out of the SWAT model and the loads you have are from the entire watershed. But not all of the load from the upper watershed is coming into the CSCR. I have a recommendation to make it more clear how those watersheds need to make reductions.

    Response: The TMDL used the SWAT model and broke up the upper watershed into subwatersheds. Then it computed phosphorus loads from each of these subwatersheds based on a variety of parameters such as slope, soil, and land use. Appendix B contains the details of the modeling and gives the phosphorus loads for each of the subwatersheds. One can see the specific subwatersheds that have larger phosphorus loads. This should allow the Agency, watershed groups and others to implement phosphorus-controlling activities in these areas.

16. What is the internal phosphorus load in the CSCR? Shouldn't you focus on fixing this load? I think the focus should be on the CSCR.

    Response: Almost half the phosphorus load is from internal loading. Even if we correct the problem in the reservoir itself, we are still going to have to go up into the watershed because that is where most of the phosphorus came from in the first place. If we do nothing about the upper watershed, we will continuously be getting phosphorus loads into the CSCR, which will have to be removed continuously.

17. What can we do about the sediment problem besides dredging and how often would this need to be done?

    Response: We looked at other alternatives to control the internal load in the implementation plan. Among those were aeration, which would slow the release of total phosphorus from sediment in low oxygen conditions. The CSCR does have an aeration system in place, but it does not keep the entire lake from going anoxic. The problem with putting more systems in place is that the aeration units could interfere with boating. Another option is an aluminum hydroxide floc that would be mixed with the CSCR water to inactivate phosphorus. This can damage the aquatic life through the possible formation of toxic aluminum (III). The formation of a settleable floc can also be disturbed if there is wave action, which is typical at the CSCR.

18. I have a question on BATHTUB and the parameters used. Does the model consider aeration? There is aeration in the CSCR.

    Response: BATHTUB is an empirical model that is built with data from a large number of reservoirs. It derives an estimate of loading. Aeration was indirectly incorporated through the dissolved oxygen concentration, which the model tracks.

19. The CSCR was built as a public water supply and that is not an impaired use, so why are you doing a TMDL on it. This seems to be another report to hand in to the government. You spend all this money on the TMDL and then you come back and tell us we have to take care of the problem. The investment for the reservoir was for water, not for recreation.

    Response: The TMDL is required by federal law. The CSCR has the designated uses of drinking water supply, aquatic life, and primary contact (swimming) and secondary contact (recreation). The local government can tell the community not to swim in the water, but it still maintains the uses designated by the state of Illinois. Federal regulations say that if those uses designated by the state are impaired, we must do a TMDL on the water. IEPA believes that aquatic life should be protected and it is known that the CSCR is used recreationally. As for IEPA not coming to Charleston and telling them exactly what they have to do to take care of the problem, we cannot do that lawfully and do not believe it would be accepted by the public. The bottom line is that with point sources, we can reduce their allowable discharges because the law says we have the obligation and the authority to do so. With nonpoint sources, we have no control over this through a regulatory mechanism. It is voluntary only. We believe local stockholder's need to decide what they can and cannot do for implementation activities.

20. How often are you required to do a TMDL on the CSCR?

    Response: One time. After we do the TMDL, we will focus on the implementation activities. Unless there are newer causes that show up in the next assessment, we will not be doing another TMDL on the CSCR.

21. Does the entire 87% reduction in phosphorus need to be made in the upper Embarrass watershed? Obviously the nutrient management plans are a good idea, but it would not reduce it 87%. Are you going to suggest other ways?

    Response: The implementation plan recommends activities for both upstream and in-lake. We already have nutrient management plans in place for this watershed. We have done past projects for the CSCR (refer to response 13) and we are looking for additional projects. We don't expect this problem to be taken care of overnight and nobody else should either. We have just allotted funds to go towards TMDL watersheds for 319 projects. If you have any ideas for 319 projects, the application deadline is August 1st of every year.

22. Another note to the upper Embarrass problem. You can argue that even if you had distilled water coming into the CSCR, it would not meet standards because of the internal phosphorus. This may be true, but let us think why the CSCR was built in the first place and where the sediment in there came from. The city of Charleston built the reservoir because of sediment problems in Lake Charleston which came from the Upper Embarras. We should not make the city solve all of the problem, when it was from an upstream source.

    Response: We do not intend to have the city solve this impairment. Much of the source of the problem is the upper Embarras watershed.

23. We question the data that has been used to develop the TMDL. It appears that some of the information on which the TMDL was based was collected thirteen years ago. This is too old and many things have changed in the watershed in that time. Programs of the state and the USDA have been implemented that improve water quality and old data will not take these improvements into consideration.

    Response: We agree that it would be desirable to have more recent data. Unfortunately, the collection of new data was not in the scope of our contract. We would like to point out several factors that made us more comfortable using the available data:

    - **Historical water quality data for the CSCR (1983 to 2001) indicate that TP conditions have remained fairly similar over time (see Figure 8 in the report).**
    - **The water quality data used in the BATHTUB modeling are from 1998.**
    - **The water quality data used in the SWAT calibration include those from 1997.**
    - **The data used to estimate the most significant sources of TP, internal loading and pumping, are more recent (1998 and 2000, respectively) than are the data used to estimate less significant sources such as shoreline erosion and direct runoff (1992).**

24. Some of the data points used for the TMDL development had spikes that were not explained. This data should be discarded. It seems that the agency would then want to collect additional data to substantiate the information on which water goals are being developed.

    Response: Out of the 103 days that were sampled, one day measured high phosphorus values. The average phosphorus concentration in the CSCR including those values is 0.14 mg/L. If we did discard those values, it would change to 0.12 mg/L. The standard for phosphorus in lakes is 0.05 mg/L. There were only five days out of the 103 days sampled that the standard was not exceeded.

25. Nutrient Management Plans should at least be a three-year program and would be much better as a five-year program. We are asking farmers to change and that takes time, not just one year. You have to understand that the farmer's income depends on what he can produce. When you start to limit his inputs, that helps him produce yields that might in his mind limit his income. Therefore it will take time for us to prove to the farmer that we are in fact not limiting his income. Another reason one year programs do not work on the farm is too many uncontrolled factors, like weather.

    Response: The nutrient management plans contain the information necessary for the next four years. A producer must commit to following this four-year plan before they can begin. A one-time payment will be made after the producer begins implementing the plan. NRCS requires that records to document plan implementation be maintained for five years. Based on the results in other watersheds thus far for this program, producers have accepted a two-year "demonstration" period. We are now reviewing this program to determine how and if it should be modified.

26. Vegetated filtered strips are great, however, they should be expanded in the implementation plan to include field borders.

    Response: Vegetated filter strips are situated between a pollutant source area and a water body and field borders are a separate BMP that can be constructed along a field regardless if there is a water body next to it. The implementation plan is a guide to help get stakeholders started. There are other BMPs that can be used in the watershed and funding sources are available to support many of these. Information on these sources is available from the U.S. EPA publication titled *Catalog of Federal Funding Sources for Watershed Protection* (EPA 841-B-99-003). The publication presents information on federal funding sources that may be used for a variety of watershed protection projects. There is also a catalog database at http://cfpub.epa.gov/fedfund/. One of the funding sources is the U.S. EPA 319 Program, administered by the Illinois EPA, that provides grants to states for implementation of approved nonpoint source management programs. Funding under these nonpoint source program implementation grants has been used in Illinois to finance projects that demonstrate cost-effective solutions to nonpoint source problems and that promote the public's knowledge and awareness of nonpoint source pollution. Another funding source is the Conservation Reserve Program (CRP), which is through the U.S. Department of Agriculture and the Farm Service Association. It is a voluntary program that offers long-term rental payments and cost-share assistance to establish long-term resource conserving cover on environmentally sensitive cropland. The protective cover reduces soil erosion, improves water quality, and enhances or establishes wildlife habitat.

27. I suggest adding no-till farming to help keep phosphorus out of the CSCR. When you look at the total phosphorus loss potential, it is much higher when conventional tillage is used. Also, the sediment with attached phosphorus will be deposited in the river and the CSCR, much like we find now when conventional tillage is used. No-till is the only farming method that stops erosion before it starts.

    Response: Although conservation tilling is recommended, there are some problems with the no-till practice when dealing with phosphorus. No-till reduces the sediment loss which then reduces the phosphorus attached to the soil particles that make their way to surface waters. But no-till can also increase the soluble phosphorus if phosphorus is concentrated in the surface layer of the soil. There are other conservation tillage practices, such as ridge-till and mulch-till and other conservation practices, such as crop residue management that can be used effectively.

28. The current incentive programs help with implementation activities, but funds are also needed to educate those people in the watershed that the practices we are supporting are both environmentally sound and in their best economic interest. An overall education effort is needed so people continue with the practices after the incentives are removed.

    Response: The Catalog of Federal Funding Sources for Watershed Protection, which was mentioned in question 26, contains grants for education. The U.S. Department of Agriculture has a Sustainable Agriculture Research and Education Grant and the U.S. EPA has an Environmental Education Grants Program and a Nonpoint Source Implementation Grant (319 Program). These are just a few of the federal sources of assistance. Once implementation begins, local stakeholders may plan education projects with the help of these sources or with other sources.

Appendix E

Charleston Side Channel Reservoir TMDL
Responsiveness Summary

RESPONSIVENESS SUMMARY

This responsiveness summary responds to substantive questions and comments received during the public comment period from May 20, 2003, through July 5, 2003 (postmarked), including those from the June 19 public meeting discussed below.

WHAT IS A TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Charleston Side Channel Reservoir (CSCR) TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the CSCR and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and the regulations thereunder.

BACKGROUND

The 339-acre CSCR is a water supply reservoir for the city of Charleston. It is listed as impaired for primary contact (swimming), secondary contact (recreation) and aquatic life designated uses. The potential causes of impairment are phosphorus, nitrogen, total suspended solids and excessive algae growth/chlorophyll a. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) Lists. Illinois EPA is currently developing TMDLs for pollutants that have water quality standards. Of the pollutants impairing the CSCR, phosphorus is the only one with a water quality standard for lakes. Illinois EPA believes that addressing the phosphorus impairment should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. The Illinois EPA contracted with Tetra Tech Inc. of Fairfax, Virginia, to prepare a TMDL report for this water body.

PUBLIC MEETINGS

Public meetings were held in the city of Springfield on June 5, 2001, and in the city of Charleston on January 17, 2002 and June 19, 2003. The Illinois EPA provided public notice for the June 19 meeting by placing display ads in the Charleston Times-Courier, Philo Southern Champaign County Today, Villa Grove News and Oakland County Crossroads on May 20, 2003. This notice gave the date, time, location and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 350 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review in the reference area of the Charleston Carnegie Library and also at the Agency's TMDL web page at http://www.epa.state.il.us/water/tmdl/ .

The final public meeting started at 6:30 P.M. on Thursday, June 19, 2003. It was attended by approximately 20 people and concluded at 8:30 P.M. with the meeting record remaining open until midnight July 5, 2003.

QUESTIONS AND COMMENTS

1. The Lake Charleston phosphorus data provided by the city of Charleston should not have been used in the model because they are not quality assured like the Agency data are. The phosphorus data are much too high.

   Response: The only data available for Lake Charleston were provided by the city of Charleston. The Charleston Water Treatment Plant did the sampling and Illinois EPA believes that their data are valid. As for their value of phosphorus in Lake Charleston, the most extensive study that we have found, which was done by Xue et al.*, states that the Embarras River's dissolved phosphorus concentration is 0.19 mg/L. Lake Charleston is part of the Embarras River (please refer to page 1 in the TMDL). The city's data for Lake Charleston is 0.30 mg/L total phosphorus and 0.19 mg/L dissolved phosphorus. Xue et al did not report total phosphorus but the dissolved phosphorus seemed to match the city's data.

   *** Xue, Yuan, M. B. David, L. E. Gentry, and D. A. Kovacic. 1998. Kinetics and Modeling of Dissolved Phosphorus Export from a Tile-Drained Agricultural Watershed. *Journal of Environmental Quality* 27: 917-922.**

2. Illinois EPA should discuss with stakeholders the data, type of analyses, level of detail, and assumptions that are appropriate for a particular TMDL model prior to TMDL development. Discussion of these issues early in the process will save everybody time in the long run by reducing the number and intensity of disagreements between stakeholders and IEPA regarding the modeling.

   Response: Illinois EPA held three public meetings: one at the beginning of the project, one in the middle, and one at the end. These are intended to keep the public involved with the TMDL. We have two draft reports that come out before the final and these are sent to the Department of Agriculture and the Natural Resources Conservation Service for recommendations. Illinois EPA will work on improving communication with the stakeholders for future TMDLs.

3. I have a hard time understanding the partitioning between the dissolved and solid phases of phosphorus in the CSCR. If phosphorus in the influent water is 0.30 mg/L and the average in the reservoir is 0.15 mg/L, we must be getting adsorption of the phosphorus on to the sediment to remove it from the water column. However, if the model is saying that desorption of phosphorus from sediments is taking place, then the inflow from the river must be lower to achieve an inlake concentration of 0.15 mg/L.

   Response: The BATHTUB model is indicating that both adsorption and desorption of phosphorus to the bottom sediments of the CSCR is taking place. Settling of soil particles (and associated phosphorus) is taking place throughout the year and desorption occurs during periods of low oxygen. The explanation for the difference between the influent pumping concentrations (0.30 mg/L) and the inlake concentrations (0.15 mg/L) is explained by the fact that pumping accounts for only about 50 percent of the water in the CSCR. Approximately 40 percent of the water balance is due to precipitation which is expected to have a very low phosphorus content and serves to dilute the inlake concentrations.

4. The Soil Water Assessment Tool (SWAT) model should not have been used because it does not take tile drainage into account.

   Response: The SWAT model was developed by the U.S. Department of Agriculture, Agricultural Research Service. The model is intended to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use, and management conditions. The SWAT model, like most other watershed models, unfortunately does not currently have the ability to directly simulate the effects of large-scale tiling. Several model parameters were therefore adjusted to simulate the effects of tiling on watershed hydrology. For example, NRCS curve numbers for tiled soils were adjusted to be lower than they otherwise would be to simulate the effect of greater and quicker infiltration. The storage routing flow coefficient within SWAT was also adjusted during model calibration to address the effects of tiling so that water reached the stream more quickly. These adjustments, in combination with other calibration activities, resulted in acceptable performance of the model as measured by recommended modeling criteria.

5. Does the agency have plans to conduct follow-up monitoring on Lake Charleston? Sounds like these data are lacking. Based on the data from the city, it sounds like this lake does not meet Illinois EPA lake standards.

   Response: Lake Charleston is part of the Embarras River and is not considered a lake due to its riverine characteristics (please refer to page 1 in the TMDL). The Embarras River is monitored, but not at the exact location of Lake Charleston. There is ongoing dialogue between the Illinois EPA volunteer program and the water treatment plant staff to have monitoring done. The Charleston Water Treatment Plant staff will be monitoring as part of the volunteer program as of this year. This monitoring may help answer some of the questions brought up on phosphorus. As for Lake Charleston not meeting standards, there is no phosphorus standard for rivers and therefore Lake Charleston would not be considered impaired for phosphorus. The phosphorus standard for streams is in development at this time and once a standard is formally adopted, Lake Charleston will be assessed relative to the new standard.

6. Although Lake Charleston is not defined as a lake by IEPA and therefore not currently subject to the numeric standard for phosphorus, area residents have indicated that excessive algal blooms occur in the impoundment. Therefore, the impoundment is likely violating the narrative water quality standard regarding offensive conditions and the numeric standard for dissolved oxygen. Because reducing loads to the Embarras River would eventually alleviate both the problem in Lake Charleston and the problem in the CSCR, these reductions should be a priority.

   Response: While we have no data or information on algae blooms in Lake Charleston, we agree that many of the nutrient controlling best management practices (BMPs) cited in the implementation plan will improve conditions in both Lake Charleston and the CSCR.

7. Does the CSCR have a nitrate problem?

   Response: Nitrate is not a cause of impairment in the CSCR. The City has said there has never been a nitrate problem.

8. I know we are targeting phosphorus in this TMDL, but if we only address phosphorus in the implementation activities, are we going to have a nitrogen problem arise. Did anyone look at this?

   Response: Targeting the TMDL to reduce phosphorus instead of nitrogen should not lead to a nitrogen eutrophication issue. Phosphorus is already the limiting nutrient in the CSCR (see section 4.3.2 of the report). This means that there is plenty of nitrogen for the algae and therefore their growth is controlled by phosphorus. This condition will remain the same if phosphorus concentrations are reduced with little to no corresponding change in the nitrogen concentrations.

9. The TMDL document indicates that phosphorus does not adversely impact the drinking water use that is an important function of the reservoir. However, excess phosphorus can lead to excess organic matter in the water. When water with high dissolved organic matter content is chlorinated, there is potential for the formation of disinfection byproducts, such as trihalomethanes (THMs), that have adverse impacts on human health. The potential for these byproducts to form following treatment at the water supply plant should be assessed as part of this study to assure citizens that this problem does not pose human health threats.

   Response: The TMDL recommends a reduction in phosphorus that should result in reductions in dissolved organic matter in the CSCR. This in turn should reduce the potential for THM precursors. Historically, the CSCR has not had a problem with either total trihalomethanes or haloacetic acids. If it becomes a problem, there are remedies that a treatment facility can implement such as changing disinfectants, the location of disinfectant application, or modifying their disinfection procedures.

10. Concerning other implementation activities, you brought up controlled pumping. Obviously that has an effect on lake fluctuation. Have you looked at the net effect of lake level fluctuation on the erosion issue.

    Response: Controlled pumping is now being done by the Charleston Water Treatment Plant and there has not been an erosion problem as a result. The treatment plant staff says that, at most, the fluctuation of the side channel reservoir is 6 feet. There are times when the water level is static for months at a time.

11. The document indicates that because residence time of the CSCR is greater than one year, seasonal considerations are not significant. However, because water from the river is pumped to the reservoir at variable rates throughout the year and phosphorus levels in the river can vary substantially, seasonality is important. The ratio of point source contributions to nonpoint source contributions can be quite variable depending on the time of year and flow in the stream. Therefore, appropriate load and wasteload allocations must be considered in conjunction with the seasonally dependent pumping schedule.

    Response: It is true that because of pumping and hydrologic factors the ratio of point source to nonpoint source contributions of total phosphorus (TP) is likely variable throughout the year. However, we still feel it is appropriate to base the TMDL on the total annual loads of TP because, due to the long residence time of the CSCR, the system is responsive to any load of TP regardless of when it occurs. Furthermore, historical pumping patterns indicate that large

volumes of water are pumped in during periods when nonpoint sources would be expected to dominate the TP load (December), as well as during periods when point sources would be more significant (July).

12. You also mentioned tree cutting in the implementation plan. This seems counterintuitive to some of us that feel that trees will reduce the sediment to the reservoir because their roots add to soil stability.

    Response: Part of the CSCR shores have bluffs and steep hillsides. Wave action is undermining the slopes. Large trees on the edge of the shore fall into the CSCR, which causes large masses of soil to be carried into the water. Tree cutting was one of the methods for erosion control in the 1992 Phase I Clean Lakes Study. This recommendation focuses only on those trees on the verge of falling into the water and would therefore slow down sediment input.

13. I would be bothered if we spent more time and money doing detailed analysis to come up with fairly obvious implementations. I would encourage the Agency to have dialogue with the stakeholders about what kind of analysis needs to be done for specific TMDLs. I know that a valid reason for doing detailed analysis is to defend NPDES permits requiring reductions.

    Response: We are required to set load allocations and do the analysis to back up these load allocations. We have spent funds on the CSCR in the past. In 1996, 319 funds were used for shoreline erosion control and an educational brochure. In 1999, a Priority Lake Watershed Implementation Project constructed additional shoreline erosion control. Also, we are currently using 319 TMDL Implementation Funds for an in-lake sediment basin. We will continue to make funds available to local groups for projects, consistent with the TMDL implementation plan.

14. Are reductions going to be made for the point sources in the watershed? It is not very clear in the TMDL.

    Response: The wasteload allocation is 1 kg/yr and the load allocation is 215.7 kg/yr. Point sources currently contribute only a very small portion of the total phosphorus load, approximately 0.4 percent to the CSCR. Therefore, any significant reductions in the phosphorus loading to the CSCR will have to be achieved through reductions in the nonpoint loadings. At this time phosphorus standards for streams are being developed. When those standards are adopted, the Agency will implement them through the NPDES permitting program, including appropriate limitations on point sources when needed.

15. The analysis that came out of the SWAT model and the loads you have are from the entire watershed. But not all of the load from the upper watershed is coming into the CSCR. I have a recommendation to make it more clear how those watersheds need to make reductions.

    Response: The TMDL used the SWAT model and broke up the upper watershed into subwatersheds. Then it computed phosphorus loads from each of these subwatersheds based on a variety of parameters such as slope, soil, and land use. Appendix B contains the details of the modeling and gives the phosphorus loads for each of the subwatersheds. One can see the specific subwatersheds that have larger phosphorus loads. This should allow the Agency, watershed groups and others to implement phosphorus-controlling activities in these areas.

16. What is the internal phosphorus load in the CSCR? Shouldn't you focus on fixing this load? I think the focus should be on the CSCR.

    Response: Almost half the phosphorus load is from internal loading. Even if we correct the problem in the reservoir itself, we are still going to have to go up into the watershed because that is where most of the phosphorus came from in the first place. If we do nothing about the upper watershed, we will continuously be getting phosphorus loads into the CSCR, which will have to be removed continuously.

17. What can we do about the sediment problem besides dredging and how often would this need to be done?

    Response: We looked at other alternatives to control the internal load in the implementation plan. Among those were aeration, which would slow the release of total phosphorus from sediment in low oxygen conditions. The CSCR does have an aeration system in place, but it does not keep the entire lake from going anoxic. The problem with putting more systems in place is that the aeration units could interfere with boating. Another option is an aluminum hydroxide floc that would be mixed with the CSCR water to inactivate phosphorus. This can damage the aquatic life through the possible formation of toxic aluminum (III). The formation of a settleable floc can also be disturbed if there is wave action, which is typical at the CSCR.

18. I have a question on BATHTUB and the parameters used. Does the model consider aeration? There is aeration in the CSCR.

    Response: BATHTUB is an empirical model that is built with data from a large number of reservoirs. It derives an estimate of loading. Aeration was indirectly incorporated through the dissolved oxygen concentration, which the model tracks.

19. The CSCR was built as a public water supply and that is not an impaired use, so why are you doing a TMDL on it. This seems to be another report to hand in to the government. You spend all this money on the TMDL and then you come back and tell us we have to take care of the problem. The investment for the reservoir was for water, not for recreation.

    Response: The TMDL is required by federal law. The CSCR has the designated uses of drinking water supply, aquatic life, and primary contact (swimming) and secondary contact (recreation). The local government can tell the community not to swim in the water, but it still maintains the uses designated by the state of Illinois. Federal regulations say that if those uses designated by the state are impaired, we must do a TMDL on the water. IEPA believes that aquatic life should be protected and it is known that the CSCR is used recreationally. As for IEPA not coming to Charleston and telling them exactly what they have to do to take care of the problem, we cannot do that lawfully and do not believe it would be accepted by the public. The bottom line is that with point sources, we can reduce their allowable discharges because the law says we have the obligation and the authority to do so. With nonpoint sources, we have no control over this through a regulatory mechanism. It is voluntary only. We believe local stockholder's need to decide what they can and cannot do for implementation activities.

20. How often are you required to do a TMDL on the CSCR?

    Response: One time. After we do the TMDL, we will focus on the implementation activities. Unless there are newer causes that show up in the next assessment, we will not be doing another TMDL on the CSCR.

21. Does the entire 87% reduction in phosphorus need to be made in the upper Embarrass watershed? Obviously the nutrient management plans are a good idea, but it would not reduce it 87%. Are you going to suggest other ways?

    Response: The implementation plan recommends activities for both upstream and in-lake. We already have nutrient management plans in place for this watershed. We have done past projects for the CSCR (refer to response 13) and we are looking for additional projects. We don't expect this problem to be taken care of overnight and nobody else should either. We have just allotted funds to go towards TMDL watersheds for 319 projects. If you have any ideas for 319 projects, the application deadline is August 1st of every year.

22. Another note to the upper Embarrass problem. You can argue that even if you had distilled water coming into the CSCR, it would not meet standards because of the internal phosphorus. This may be true, but let us think why the CSCR was built in the first place and where the sediment in there came from. The city of Charleston built the reservoir because of sediment problems in Lake Charleston which came from the Upper Embarras. We should not make the city solve all of the problem, when it was from an upstream source.

    Response: We do not intend to have the city solve this impairment. Much of the source of the problem is the upper Embarras watershed.

23. We question the data that has been used to develop the TMDL. It appears that some of the information on which the TMDL was based was collected thirteen years ago. This is too old and many things have changed in the watershed in that time. Programs of the state and the USDA have been implemented that improve water quality and old data will not take these improvements into consideration.

    Response: We agree that it would be desirable to have more recent data. Unfortunately, the collection of new data was not in the scope of our contract. We would like to point out several factors that made us more comfortable using the available data:

    - **Historical water quality data for the CSCR (1983 to 2001) indicate that TP conditions have remained fairly similar over time (see Figure 8 in the report).**
    - **The water quality data used in the BATHTUB modeling are from 1998.**
    - **The water quality data used in the SWAT calibration include those from 1997.**
    - **The data used to estimate the most significant sources of TP, internal loading and pumping, are more recent (1998 and 2000, respectively) than are the data used to estimate less significant sources such as shoreline erosion and direct runoff (1992).**

24. Some of the data points used for the TMDL development had spikes that were not explained. This data should be discarded. It seems that the agency would then want to collect additional data to substantiate the information on which water goals are being developed.

    Response: Out of the 103 days that were sampled, one day measured high phosphorus values. The average phosphorus concentration in the CSCR including those values is 0.14 mg/L. If we did discard those values, it would change to 0.12 mg/L. The standard for phosphorus in lakes is 0.05 mg/L. There were only five days out of the 103 days sampled that the standard was not exceeded.

25. Nutrient Management Plans should at least be a three-year program and would be much better as a five-year program. We are asking farmers to change and that takes time, not just one year. You have to understand that the farmer's income depends on what he can produce. When you start to limit his inputs, that helps him produce yields that might in his mind limit his income. Therefore it will take time for us to prove to the farmer that we are in fact not limiting his income. Another reason one year programs do not work on the farm is too many uncontrolled factors, like weather.

    Response: The nutrient management plans contain the information necessary for the next four years. A producer must commit to following this four-year plan before they can begin. A one-time payment will be made after the producer begins implementing the plan. NRCS requires that records to document plan implementation be maintained for five years. Based on the results in other watersheds thus far for this program, producers have accepted a two-year "demonstration" period. We are now reviewing this program to determine how and if it should be modified.

26. Vegetated filtered strips are great, however, they should be expanded in the implementation plan to include field borders.

    Response: Vegetated filter strips are situated between a pollutant source area and a water body and field borders are a separate BMP that can be constructed along a field regardless if there is a water body next to it. The implementation plan is a guide to help get stakeholders started. There are other BMPs that can be used in the watershed and funding sources are available to support many of these. Information on these sources is available from the U.S. EPA publication titled *Catalog of Federal Funding Sources for Watershed Protection* (EPA 841-B-99-003). The publication presents information on federal funding sources that may be used for a variety of watershed protection projects. There is also a catalog database at http://cfpub.epa.gov/fedfund/. One of the funding sources is the U.S. EPA 319 Program, administered by the Illinois EPA, that provides grants to states for implementation of approved nonpoint source management programs. Funding under these nonpoint source program implementation grants has been used in Illinois to finance projects that demonstrate cost-effective solutions to nonpoint source problems and that promote the public's knowledge and awareness of nonpoint source pollution. Another funding source is the Conservation Reserve Program (CRP), which is through the U.S. Department of Agriculture and the Farm Service Association. It is a voluntary program that offers long-term rental payments and cost-share assistance to establish long-term resource conserving cover on environmentally sensitive cropland. The protective cover reduces soil erosion, improves water quality, and enhances or establishes wildlife habitat.

27. I suggest adding no-till farming to help keep phosphorus out of the CSCR. When you look at the total phosphorus loss potential, it is much higher when conventional tillage is used. Also, the sediment with attached phosphorus will be deposited in the river and the CSCR, much like we find now when conventional tillage is used. No-till is the only farming method that stops erosion before it starts.

    Response: Although conservation tilling is recommended, there are some problems with the no-till practice when dealing with phosphorus. No-till reduces the sediment loss which then reduces the phosphorus attached to the soil particles that make their way to surface waters. But no-till can also increase the soluble phosphorus if phosphorus is concentrated in the surface layer of the soil. There are other conservation tillage practices, such as ridge-till and mulch-till and other conservation practices, such as crop residue management that can be used effectively.

28. The current incentive programs help with implementation activities, but funds are also needed to educate those people in the watershed that the practices we are supporting are both environmentally sound and in their best economic interest. An overall education effort is needed so people continue with the practices after the incentives are removed.

    Response: The Catalog of Federal Funding Sources for Watershed Protection, which was mentioned in question 26, contains grants for education. The U.S. Department of Agriculture has a Sustainable Agriculture Research and Education Grant and the U.S. EPA has an Environmental Education Grants Program and a Nonpoint Source Implementation Grant (319 Program). These are just a few of the federal sources of assistance. Once implementation begins, local stakeholders may plan education projects with the help of these sources or with other sources.