Illinois
Environmental
Protection Agency

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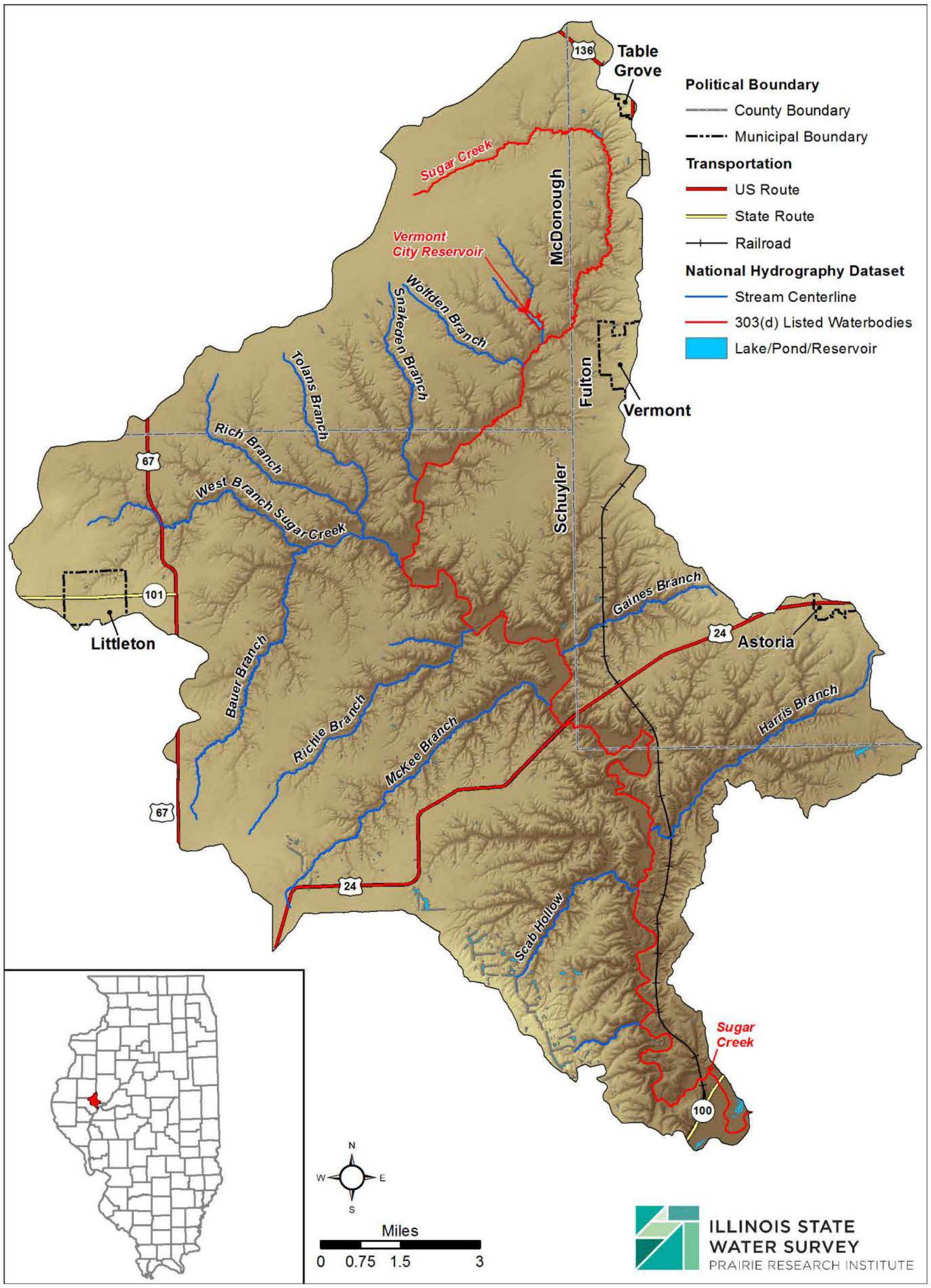
April 2019

IEPA/BOW/IL-2019-002

Sugar Creek/Vermont City Reservoir Watershed TMDL Report



Sugar Creek watershed

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TMDL Development for the Sugar Creek/Vermont City Reservoir Watershed, Illinois

This file contains the following documents:

1) U.S. EPA Approval letter and Decision Document for the Final TMDL Report
2) Phase I TMDL Development
3) Phase II TMDL Development

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

APR 3 0 2019

REPLY TO THE ATTENTION OF

WW-16J

Sanjay Sofat, Chief
Bureau of Water
Illinois Environmental Protection Agency
P.O. Box 19276
Springfield, Illinois 62794-9276

Dear Mr. Sofat:

The U.S. Environmental Protection Agency has conducted a complete review of the final Total Maximum Daily Loads (TMDLs) for fecal coliform, atrazine, and phosphorus for the Sugar Creek/Vermont City Reservoir watershed, including supporting documentation and follow up information. The waterbodies are located in southcentral Illinois. The TMDLs submitted by the Illinois Environmental Protection Agency address the impaired Aesthetic Quality, Primary Contact, and Public and food Processing Water Supply Uses for the waterbodies.

The TMDLs meet the requirements of Section 303(d) of the Clean Water Act and EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, EPA hereby approves Illinois's three TMDLs for fecal coliform, atrazine, and phosphorus as noted in the enclosed decision document. The statutory and regulatory requirements, and EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in submitting these TMDLs and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. David Pfeifer, Acting Chief of the Watersheds and Wetlands Branch, at 312-353-9024.

Sincerely,

Joan M. Tanaka

Joan M. Tanaka
Acting Director, Water Division

Enclosure

cc: Abel Haile, IEPA

TMDL: Sugar Creek and Vermont City Reservoir Watershed, McDonough, Fulton, and Schuyler Counties, Illinois
Date:

DECISION DOCUMENT FOR THE APPROVAL OF THE SUGAR CREEK/VERMONT CITY RESERVOIR, IL TMDL

Section 303(d) of the Clean Water Act (CWA) and EPA's implementing regulations at 40 C.F.R. Part 130 describe the statutory and regulatory requirements for approvable TMDLs. Additional information is generally necessary for EPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations, and should be included in the submittal package. Use of the verb "must" below denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable. These TMDL review guidelines are not themselves regulations. They are an attempt to summarize and provide guidance regarding currently effective statutory and regulatory requirements relating to TMDLs. Any differences between these guidelines and EPA's TMDL regulations should be resolved in favor of the regulations themselves.

1. Identification of Waterbody, Pollutant of Concern, Pollutant Sources, and Priority Ranking

The TMDL submittal should identify the waterbody as it appears on the State's/Tribe's 303(d) list. The waterbody should be identified/georeferenced using the National Hydrography Dataset (NHD), and the TMDL should clearly identify the pollutant for which the TMDL is being established. In addition, the TMDL should identify the priority ranking of the waterbody and specify the link between the pollutant of concern and the water quality standard (see Section 2 below).

The TMDL submittal should include an identification of the point and nonpoint sources of the pollutant of concern, including location of the source(s) and the quantity of the loading, e.g., lbs/per day. The TMDL should provide the identification numbers of the NPDES permits within the waterbody. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of the natural background. This information is necessary for EPA's review of the load and wasteload allocations, which are required by regulation.

The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as:

(1) the spatial extent of the watershed in which the impaired waterbody is located;
(2) the assumed distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) population characteristics, wildlife resources, and other relevant information affecting the characterization of the pollutant of concern and its allocation to sources;
(4) present and future growth trends, if taken into consideration in preparing the TMDL (e.g., the TMDL could include the design capacity of a wastewater treatment facility); and

(5) an explanation and analytical basis for expressing the TMDL through *surrogate measures*, if applicable. *Surrogate measures* are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

Comment:
Location Description: The Illinois Environmental Protection Agency (IEPA) developed TMDLs for fecal coliform, atrazine, and phosphorus for impaired waters in the Sugar Creek/Vermont City Reservoir (SCVR) watershed in west-central Illinois (Table 1 of this Decision Document). The SCVR watershed begins in McDonough County southeast of Macomb, Illinois, and flows south into the Illinois River near Beardstown, Illinois (Figure 2-2 of the TMDL). Table 1 of this Decision Document is from Table 1-1 in the TMDL and lists the waterbodies addressed by this TMDL.

The Vermont City Reservoir is an impounded tributary to Sugar Creek. The reservoir was built in 1942 to provide a water supply to the City of Vermont (Section 2.9.1 of the TMDL). The reservoir has a surface area of 38.5 acres, and the drainage area is approximately 38 times larger than the surface area (2.3 square miles). The maximum depth is 11 feet, and the retention time is approximately 2 months. The reservoir is also listed as impaired for total suspended solids, but IEPA has determined that the phosphorus TMDL will address the total suspended solids impairment (Section 8 of the TMDL).

Table 1: TMDLs in the SCVR watershed

Segment Name	Segment ID	Designated use	Pollutant Addressed
Vermont City Reservoir	**IL_RDM**	**Public Water Supply**	**Atrazine**
		Aesthetic Quality	**Phosphorus**
Sugar Creek	**IL_DH-01**	**Primary Contact Recreation**	**Fecal coliform**

Distribution of land use: The SCVR watershed is approximately 161 square miles in size, and the Vermont City Reservoir watershed is approximately 2.3 square miles in size. The land use for SCVR watershed is mainly agricultural and forest in nature, with most of the agricultural land use in row crop (mainly corn/soybean). Urban and open space makes up a very small portion of the watershed (Section 2.2 and Table 2-1 of the TMDL). Table 2 of this Decision Document contains a summary of the land use for the SCVR watershed.

Table 2: Land use in the SCVR Watershed

Land Use	Sugar Creek	Vermont City Reservoir
	%	%
Agricultural	64.15	80
Forest	30.98	15
Developed	1.22	0
Wetland	2.96	2
Other	0.69	3
Total	100	100

Problem Identification:
The impaired waterbodies in the SCVR watershed were added to the Section 303(d) list for impairments due to high levels of fecal coliform, atrazine, and phosphorus. Sugar Creek exceeded the bacteria standards numerous times, and to varying degrees (Section 5.3.6 of the TMDL). In the Vermont City Reservoir, atrazine exceeded the criteria several times in the historical sampling, although IEPA noted that the magnitude of the exceedences as diminished in the last several years (Section 5.3.1 of the TMDL). The reservoir exceeded the lake phosphorus standard for virtually every sample in the last twenty years (Section 5.3.4 of the TMDL).

Pollutant:
Fecal coliform: Bacteria exceedances can negatively impact recreational uses (fishing, swimming, wading, boating, etc.) and public health. At elevated levels, bacteria may cause illness within humans who have contact with or ingest bacteria-laden water. Recreation-based contact can lead to ear, nose, and throat infections, and stomach illness.

Atrazine: Atrazine is a widely used herbicide, used on corn to control broadleaf and grassy weeds. It is sprayed on crops during the spring and summer months, where it is absorbed into weeds and stops photosynthesis. It generally breaks down in soil, but moisture delays the degradation. The half-life of atrazine in soils is about 146 days. In water, atrazine has a half-life of 742 days. Although there are strict requirements for usage, atrazine can still wash off the plants and soil during rain events and enter local waterbodies. This runoff can be exacerbated by agricultural drainage tiles. Research into the health effects of atrazine is ongoing, but atrazine is a regulated contaminant under the Safe Drinking Water Act. IEPA determined that the source of atrazine in the Vermont City Reservoir is nonpoint runoff from agricultural fields, and that none of the point sources in the watersheds are a source of atrazine.

Total phosphorus: While TP is an essential nutrient for aquatic life, elevated concentrations of TP can lead to nuisance algal blooms that negatively impact aquatic life and recreation (swimming, boating, fishing, etc.). Algal decomposition depletes oxygen levels which stresses benthic macroinvertebrates and fish. Excess algae can shade the water column which limits the distribution of aquatic vegetation. Aquatic vegetation stabilizes bottom sediments, and also is an important habitat for macroinvertebrates and fish. Furthermore, depletion of oxygen can cause phosphorus release from bottom sediments (i.e. internal loading).

Degradations in aquatic habitats or water quality (ex. low dissolved oxygen) can negatively impact aquatic life use. Increased algal growth, brought on by elevated levels of nutrients within the water column, can reduce dissolved oxygen in the water column, and cause large shifts in dissolved oxygen and pH throughout the day. Shifting chemical conditions within the water column may stress aquatic biota (fish and macroinvertebrate species). In some instances, degradations in aquatic habitats or water quality have reduced fish populations or altered fish communities from those communities supporting sport fish species to communities which support more tolerant rough fish species.

Priority Ranking:
The watershed was given priority for TMDL development due to the impairment impacts on the public value of the impaired water resource, and the timing as part of the Illinois River Basin monitoring process.

Source Identification (point and nonpoint sources):
Point Source Identification:
Fecal coliform: IEPA identified two individual point sources located in the Sugar Creek watershed (Table 16 of the TMDL). These are two small wastewater treatment facilities. No other point sources (Confined Animal Feeding Operations (CAFOs), Municipal Storm Sewer Systems (MS4s), etc.) were identified in the watershed.

Phosphorus and Atrazine: No point source dischargers were identified in the Vermont City Reservoir watershed that could discharge atrazine or phosphorus (Section 8 of the TMDL).

Nonpoint Source Identification: The potential nonpoint sources for the SCVR watershed TMDLs are described below.

Fecal coliform
Stormwater runoff from agricultural land use practices: Non-regulated stormwater runoff can add fecal coliform to the impaired waters. The sources of bacteria in stormwater include animal/pet wastes, and wildlife. Manure spread onto fields is a source of bacteria, and can be exacerbated by tile drainage lines, which channelize the stormwater. Tile-drained fields and channelized ditches enable particles to move more efficiently into surface waters.

Animal Operations: Runoff from agricultural/animal lands may contain significant amounts of bacteria which may lead to impairments in the SCVR watershed. Manure spread onto fields is often a source of bacteria, and can be exacerbated by tile drainage lines, which channelize the stormwater. Tile-drained fields and channelized ditches enable bacteria to move more efficiently into surface waters. Furthermore, livestock with direct access to a waterway can directly deposit nutrients via animal wastes into a waterbody, which may result in very high localized bacteria concentrations.

Failing septic systems: IEPA noted that failing septic systems, where waste material can pond at the surface and eventually flow into surface waters or be washed in during precipitation events, are potential sources of bacteria. IEPA noted that much of the watershed is serviced by septic systems, but that the newer systems are usually aerated systems, which include a disinfection tank to reduce bacteria.

Phosphorus
Stormwater runoff from agricultural land use practices: Runoff from agricultural lands may contain significant amounts of nutrients, organic material and organic-rich sediment which may lead to impairments in the lake watershed. Manure spread onto fields is often a source of phosphorus, and can be exacerbated by tile drainage lines, which channelize the stormwater. Tile lined fields and channelized ditches enable particles to move more efficiently into surface waters. Phosphorus, organic material and organic-rich sediment may be added via surface runoff from upland areas, grasslands, and agricultural lands used for growing hay or other

crops. Stormwater runoff may contribute nutrients and organic-rich sediment to surface waters from livestock manure, fertilizers, vegetation and erodible soils.

Failing septic systems: IEPA noted that failing septic systems, where waste material can pond at the surface and eventually flow into the waterbodies or be washed in during precipitation events, are potential sources of phosphorus.

Internal loading: The release of phosphorus from lake sediments via physical disturbance from benthic fish (rough fish, ex. carp) and from wind mixing the water column may all contribute internal phosphorus loading to the lake. Phosphorus may build up in the bottom waters of the lake and may be resuspended or mixed into the water column when the thermocline decreases and the lake water mixes.

Atrazine:
Agricultural runoff: As noted above, atrazine is used as an herbicide on cultivated crops. IEPA determined that the source of atrazine for the Vermont City Reservoir is nonpoint runoff from agricultural fields.

Population and future growth trends
The population in the watershed is fairly small (2,547). IEPA did not account for any future growth in the watershed.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this first element.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the antidegradation policy. (40 C.F.R. §130.7(c)(1)). EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

The TMDL submittal must identify a numeric water quality target(s) - a quantitative value used to measure whether or not the applicable water quality standard is attained. Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. The TMDL expresses the relationship between any necessary reduction of the pollutant of concern and the attainment of the numeric water quality target. Occasionally, the pollutant of concern is different from the pollutant that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as Dissolved Oxygen (DO) criteria). In such cases, the TMDL submittal should explain the linkage between the pollutant of concern and the chosen numeric water quality target.

Comment:

Fecal coliform and phosphorus:

Designated Use/Standards: Section 4.3 of the TMDL states that the SCVR is not meeting the General Use designation. The applicable water quality standards (WQS) for these waterbodies are established in Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards, Subpart B for General Use Water Quality Standards. The portions of the WQS that apply to SCVR are the Aesthetic Quality Use (phosphorus), and Primary Contact Use (fecal coliform)(Section 4.3 of the TMDL).

Atrazine:

Designated Use/Standards: Section 4.3 of the TMDL states that the Vermont City Reservoir is a designated drinking water source and is not meeting the Public and Food Processing Water Supplies designation. The applicable water quality standards (WQS) for this waterbody is established in Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards, Subpart C for Public and Food Processing Water Supplies.

IEPA does not have an in-stream criterion for atrazine. The Maximum Contaminant Level (MCL) for atrazine is 3 μg/L. The MCL applies to finished water (i.e., water that has been treated and is ready for consumption) and is based upon a rolling 4-quarter average. Since there is only limited removal of atrazine from raw water, IEPA uses an assessment guideline for raw water to determine impairment of the Public and Food Processing Water Supplies use. Since atrazine is used in the spring and summer months, the rolling averages were analyzed, and showed the atrazine exceedences were occuring during the spring/summer quarters, which is consistent with the application times of atrazine (Section 5.3.1 of the TMDL).

Criteria: The applicable criteria are found in Table 3 of this Decision Document.

Table 3: WQSs for the SCVR TMDLs

Pollutant	Units	Criteria
Phosphorus	mg/L	0.05
Atrazine	μg/L	3***
Fecal coliform	Count/100 mL	200*, 400** May through October

* - geometric mean based upon a minimum of 5 samples in a 30-day period

** - not to be exceed by more than 10% of the samples in a 30-day period

*** - rolling 4-quarter average

Target: The water quality targets for these TMDLs are the WQSs for the waters. For fecal coliform, IEPA used the 200 counts per 100 mL monthly geometric mean portion of the standard to calculate loads in the SCVR. IEPA stated that while the TMDL will focus on the geometric mean portion of the water quality standard, both parts of the water quality standard must be met. For phosphorus, the water quality target is the criterion of 0.05 mg/L. For atrazine, the water quality target is the acute criterion of 3 μg/L, either the finished water (end of pipe) or as a quarterly average for raw water (Section 8.2 of the TMDL).

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this second element.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

The pollutant loadings may be expressed as either mass-per-time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)). If the TMDL is expressed in terms other than a daily load, e.g., an annual load, the submittal should explain why it is appropriate to express the TMDL in the unit of measurement chosen. The TMDL submittal should describe the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

The TMDL submittal should contain documentation supporting the TMDL analysis, including the basis for any assumptions; a discussion of strengths and weaknesses in the analytical process; and results from any water quality modeling. EPA needs this information to review the loading capacity determination, and load and wasteload allocations, which are required by regulation.

TMDLs must take into account *critical conditions* for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable *critical conditions* and describe their approach to estimating both point and nonpoint source loadings under such *critical conditions*. In particular, the TMDL should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

Comment:
The approaches utilized by the IEPA to calculate the loading capacity for the fecal coliform, atrazine, and phosphorus TMDLs are described in Section 7 of the TMDL.

Fecal coliform and phosphorus: For the bacteria and phosphorus TMDLs, IEPA used a two-step approach. To determine the watershed runoff and loading to the two impaired waters, IEPA utilized the Generalized Watershed Loading Function (GWLF) loading model.

GWLF is a monthly time-step model used to predict runoff, sediment, and nutrients from watersheds with mixed land uses. GWLF can be used for both sediment and phosphorus TMDLs. The runoff is simulated using daily precipitation, the runoff curve number and antecedent moisture. GWLF typically is used to model sediment run-off but was adapted to model bacteria runoff using the same basic process as used for sediment modeling (using the Universal Soil Loss Equation). Dissolved nutrients including phosphorus are also simulated using event mean concentrations. The loads generated by individual sources are simply aggregated to produce the total loads.

The watershed was subdivided into smaller subbasins for modeling purposes. The Sugar Creek watershed was divided into 19 subbasins, while the Vermont City Reservoir was subdivided into

17 subbasins. Precipitation, flow, land use, soils, flow lines, and other data were input into the model to determine the runoff and corresponding pollutant loading. See Section 7.2.1 of the TMDL for more detailed information on the GWLF modeling effort. The results were calibrated based upon sampling data in the watershed, as well as flow data from nearby gages (Section 7.2.1.2 of the TMDL). Model results showed generally good calibration with sampling data.

Phosphorus: IEPA used the CE-QUAL-W2 (W2) to determine phosphorus impacts in the Vermont City Reservoir. W2 is a laterally averaged, two-dimensional (longitudinal and vertical) hydrodynamic and water quality model. It is best suited for relatively long and narrow water bodies. The hydrodynamic component of the model predicts water surface elevations, velocities, and temperatures, while the water quality component simulates 21 constituents, including nutrients, phytoplankton, and DO interactions. W2 models basic eutrophication processes, such as relationships among temperature, nutrients, algae, dissolved oxygen, organic matter, and sediment in stratified or non-stratified systems. The W2 model used inputs from the GWLF model to simulate the impacts of loads on total phosphorus (and sediment) in the Vermont City Reservoir.

The reservoir was divided into 15 segments (Figure 3 of the TMDL). The phosphorus loads determined from GWLF were input into the W2 model, and the model was run to determine the impacts on phosphorus concentrations, dissolved oxygen, and algal growth. The model endpoint was the WQS of 0.05 mg/L phosphorus. The model was calibrated to compare the results to water quality sampling data at the water supply intake and sampling points in the waterbody (Section 7.2.2.9 of the TMDL). Model results showed generally good calibration with sampling data. Detailed information on the W2 model is found in Appendix D of the TMDL.

The impacts of internal loading of phosphorus were explored during the modeling process (Section 8.3 of the TMDL). The results indicate that internal loading of phosphorus is a very minor component of the phosphorus loading, less than 0.06%, and therefore IEPA determined that a separate allocation for internal loading is not needed.

Table 4 of this Decision Document contains a summary of the TMDL results.

Table 4: Phosphorus TMDL summary for Vermont City Reservoir (IL_RDM)

LC lb/day	WLA lb/day	LA lb/day	MOS lb/day	Current Load lb/day	Reductions lb/day	Percent Reduction
1.56	0	1.29	0.27	5.2	3.64	70%

Fecal Coliform: IEPA used the QUAL2K model to determine the loadings of fecal coliform in Sugar Creek. QUAL2K is one-dimensional river and stream water quality model intended to represent a well-mixed channel both vertically and laterally with steady state hydraulics, non-uniform steady flow, diel heat budget and water quality kinetics. The QUAL2K model used run-off loading inputs from the GWLF modeling to simulate the impacts of loads of fecal coliform in Sugar Creek. Fecal coliform concentrations are determined as functions of temperature, light, settling and decay.

The main stem of Sugar Creek was divided into 16 reaches, and the Sugar Creek tributaries were divided into 60 reaches (Section 7.2.3.2 of the TMDL). The flows and bacteria loads from three point sources (only two discharge bacteria) were input into the model. The model was calibrated to compare model results to sampling results in the watershed. Model results showed generally good calibration with sampling data.

The model results generated daily loading capacities per month, from May to October. Table 5 of this Decision Document contains a summary of the TMDL results for fecal coliform for Sugar Creek. Results of the modeling indicate that there is significant variation in flow in the watershed. May-June-July have a higher monthly average flow that the months of August-September-October. IEPA calculated the WLAs based upon two facility flow rates. The WLAs for the higher flow months (May-June-July) were determined using the design maximum flow, while WLAs for the lower flow months (August-September-October) were determined using the design average flow (Section 5 of this Decision Document).

Table 5: Fecal coliform TMDL summary for Sugar Creek (IL_DH-01)

Month	Flow (m^3/s)	Load Capacity*	LA*	WLA*	MOS	Actual Load*	Percent Reduction
May	4.18	722,084	715,364	6,720	implicit	490,950	0.0%
June	11.74	20,280,545	20,273,825	6,720	implicit	41,687,657	51%
July	1.83	3,161,277	3,154,557	6,720	implicit	2,664,640	0.0%
August	0.07	121,120	118,432	2,688	implicit	385,484	69%
September	0.03	51,476	48,788	2,688	implicit	62,443	21%
October	0.03	51,476	48,788	2,688	implicit	21,974	0.0%

* - millions of colonies/day

IEPA stated that while the bacteria TMDL will focus on the geometric mean portion of the water quality standard (i.e., the chronic WQS of 200 cfu/100mL), attainment of the WQS involves the water body meeting both the chronic (200 cfu/100 mL) and acute (400 cfu/100 mL) portions of the water quality standard. EPA finds these assumptions to be reasonable.

Atrazine: IEPA used a simple mass-balance approach to determine the loading capacity of atrazine for Vermont City Reservoir (Section 8.3.2 of the TMDL). The volume of the reservoir was determined (86 million gallons (MG)), and the target concentration of 3 ug/L for atrazine multiplied by the appropriate conversion factors results in a loading capacity of

$$86.113\ \text{MG} * 3\ \mu\text{g/L} * 0.0022\ \text{lb}/\mu\text{g} * 3.785\ \text{L/gallon} = \text{LC} = 2.15\ \text{lbs /day}$$

Table 6: Atrazine TMDL Summary for Vermont City Reservoir (IL_RDM)

LC lb/day	WLA lb/day	LA lb/day	MOS	Current Load lb/day	Reductions lb/day	Percent Reduction
2.15	0	2.15	implicit	11.89	9.74	82%

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this third element.

4. Load Allocations (LAs)

EPA regulations require that a TMDL include LAs, which identify the portion of the loading capacity attributed to existing and future nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Where possible, load allocations should be described separately for natural background and nonpoint sources.

Comment:
The LAs for the waterbodies are found in Tables 4-6 of this Decision Document. The nonpoint sources of fecal coliform, atrazine, and phosphorus in the watershed are nonpoint source runoff from row crop agricultural fields, failing septics, and animal operations. As discussed in Sections 8 and 10 of this Decision Document, IEPA provided further analysis of how reductions from the various pollutant sources could be attained.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this fourth element.

5. Wasteload Allocations (WLAs)

EPA regulations require that a TMDL include WLAs, which identify the portion of the loading capacity allocated to individual existing and future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit.

The individual WLAs may take the form of uniform percentage reductions or individual mass based limitations for dischargers where it can be shown that this solution meets WQSs and does not result in localized impairments. These individual WLAs may be adjusted during the NPDES permitting process. If the WLAs are adjusted, the individual effluent limits for each permit issued to a discharger on the impaired water must be consistent with the assumptions and requirements of the adjusted WLAs in the TMDL. If the WLAs are not adjusted, effluent limits contained in the permit must be consistent with the individual WLAs specified in the TMDL. If a draft permit provides for a higher load for a discharger than the corresponding individual WLA in the TMDL, the State/Tribe must demonstrate that the total WLA in the TMDL will be achieved through reductions in the remaining individual WLAs and that localized impairments will not result. All permittees should be notified of any deviations from the initial individual WLAs contained in the TMDL. EPA does not require the establishment of a new TMDL to reflect these revised allocations as long as the total WLA, as expressed in the TMDL, remains the same or decreases, and there is no reallocation between the total WLA and the total LA.

Comment:
Fecal coliform: IEPA determined loads for fecal coliform for the two dischargers in the SCVR watershed (Table 7 of this Decision Document). The WLAs are based upon the design average flow or the design maximum flow of the facilities (Section 8.3.3.4 of the TMDL). Design average flow is the flow based upon normal plant operation and average precipitation, while the design maximum flow is the highest expected average flow under wet-weather conditions. IEPA utilized the design maximum flow for each facility for the higher-flow months of May-June-July, and the design average flow for the months of August-September-October. The appropriate flow was multiplied by the WQS of 200 cfu/100 mL for the facilities. Both of the facilities have been granted disinfection exemptions by IEPA; the WLA is applicable at the downstream point where

the disinfection exemption ends (Section 8.3.3.4 of the TMDL). No other point sources were identified discharging fecal coliform in the SCVR watershed.

Table 7: Fecal coliform WLAs in the SCVR TMDL

Permit Number	Facility Name	Design Average Flow (MGD)	WLA* - Average flow	Design Maximum Flow (MGD)	WLA* – Maximum flow
ILG0025364	Village of Astoria WWTP	0.28	2,120	0.70	5,300
ILG580040	Village of Table Grove	0.075	568	0.1875	1,420
Total			2,688		6,720

* - million colonies/day

Atrazine: No point sources discharging atrazine were identified in the Vermont City Reservoir watershed. The WLA = 0.

Phosphorus: No point sources discharging phosphorus were identified in the Vermont City Reservoir watershed. The WLA = 0.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this fifth element.

6. Margin of Safety (MOS)

The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

Comment:

Fecal coliform: The SCVR TMDL incorporates an implicit MOS in the TMDL (Section 6.2.5 of the TMDL). The WLA is based upon the 200 cfu/100 mL as a 30-day geometric mean portion of the WQS to determine the daily load. This essentially sets the monthly geometric mean portion of the WQS as a daily not-to-exceed value (i.e., no averaging), significantly overestimating the bacteria reductions needed to attain WQSs in the SCVR watershed.

An additional conservative assumption is that IEPA did not use a rate of decay, or die-off rate of pathogen species, in the TMDL. Bacteria have a limited capability of surviving outside their hosts, and normally a rate of decay would be incorporated. IEPA determined that it was more conservative to use the WQS (200 cfu/100 mL) and not to apply a rate of decay, which could result in a discharge limit greater than the WQS.

As stated in *EPA's Protocol for Developing Pathogen TMDLs* (EPA 841-R-00-002), many different factors affect the survival of pathogens, including the physical condition of the water. These factors include, but are not limited to sunlight, temperature, salinity, and nutrient deficiencies. These factors vary depending on the environmental condition/circumstances of the water, and therefore it would be difficult to assert that the rate of decay caused by any given combination of these environmental variables was sufficient to meet the WQS of 200 cfu/100 mL. Thus, it is more conservative to apply the State's WQS as the MOS, because this standard must be met at all times under all environmental conditions.

Atrazine: The SCVR TMDL incorporates an implicit MOS in the TMDL (Section 8.3 of the TMDL; Table 6 of this Decision Document). IEPA calculated the loading capacity as a daily load of atrazine designed to not exceed the 3 ug/L atrazine target. IEPA noted that the drinking water target is actually a rolling annual average of quarterly samples, and therefore overestimates the reductions needed to attain the atrazine target.

Phosphorus: The Vermont City Reservoir phosphorus TMDL incorporates an explicit MOS of 17% of the total loading capacity. The MOS reserved 17% of the loading capacity and allocated the remaining loads to point and nonpoint sources (Table 4 of this Decision Document). IEPA calculated the MOS based upon the difference between the average phosphorus monitored value in the reservoir (0.114 mg/L) and the simulated phosphorus value based upon the modeling effort (0.133 mg/L). This represents a 17% difference (Section 8.2 of the TMDL).

EPA finds that the TMDL document submitted by IEPA has an appropriate MOS satisfying all requirements concerning this sixth element.

7. Seasonal Variation

The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variations. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Comment:

The modeling process accounts for seasonal variation by utilizing streamflows over a wide range. For all fecal coliform and phosphorus, GWLF was used to determine pollutant run-off into the waterbodies. GWLF uses meteorological data as part of the modeling effort, accounting for seasonal changes in weather and loading. The CE-QUAL-W2 model also utilizes meteorological data over a multi-year timeframe, accounting for seasonal variation in pollutant impacts in the reservoir.

For atrazine, herbicide application is typically in the spring and early summer when weeds are sprouting. The limited data set appears to indicate that exceedences occur in the spring and early summer, when atrazine is applied.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this seventh element.

8. Reasonable Assurances

When a TMDL is developed for waters impaired by point sources only, the issuance of a National Pollutant Discharge Elimination System (NPDES) permit(s) provides the reasonable assurance that the wasteload allocations contained in the TMDL will be achieved. This is because 40 C.F.R. 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with "the assumptions and requirements of any available wasteload allocation" in an approved TMDL.

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, EPA's 1991 TMDL Guidance states that the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for EPA to determine that the TMDL, including the load and wasteload allocations, has been established at a level necessary to implement water quality standards.

EPA's August 1997 TMDL Guidance also directs Regions to work with States to achieve TMDL load allocations in waters impaired only by nonpoint sources. However, EPA cannot disapprove a TMDL for nonpoint source-only impaired waters, which do not have a demonstration of reasonable assurance that LAs will be achieved, because such a showing is not required by current regulations.

Comment:
Section 9 of the TMDL discusses the implementation efforts that will be pursued by IEPA as part of the TMDL for SCVR. IEPA provided information on controls of fecal coliform, atrazine, and phosphorus, and what practices will be targeted in the watershed.

Reasonable assurances that the WLAs will be implemented are through the NPDES program. IEPA listed two Wastewater Treatment Plants (WWTPs) that discharge fecal coliform in the SCVR watershed. Section 8.3.3 of the TMDL addresses the discharges of fecal coliform from permitted facilities. No point sources of phosphorus or atrazine were identified in the TMDL.

Section 9 of the TMDL discusses various BMPs that, when implemented, will significantly reduce pollutant loadings to attain WQS. For most of these BMPs, IEPA provided some watershed analysis on the impacts these BMPs may have on pollutant loads. This discussion included the impacts of waterbody buffers, conservation tillage, and nutrient management plans on the transport of pollutants into the waterbodies. For atrazine, IEPA also noted the impacts of changing application practices for atrazine (such as applying post-emergent to reduce volume) as well as mixing atrazine with other herbicides could reduce the volume of atrazine use while maintaining weed control.

IEPA also identified critical areas for fecal coliform and phosphorus reductions, as noted in Section 9.2.1.2 of the TMDL. These have been identified as highly-erodible lands (HEL) and potentially highly-erodible lands (PHEL), where BMPs need to be targeted to reduce pollutant loads. IEPA also identified estimated costs for BMPs in the watershed (Section 9.4.2 and Table 19 of the TMDL), as well as potential funding sources.

EPA finds that this criterion has been adequately addressed.

9. Monitoring Plan to Track TMDL Effectiveness

EPA's 1991 document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA 440/4-91-001), recommends a monitoring plan to track the effectiveness of a TMDL, particularly when a TMDL involves both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur. Such a TMDL should provide assurances that nonpoint source controls will achieve expected load reductions and, such TMDL should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring and leading to attainment of water quality standards.

Comment:
The TMDL contains discussion on future monitoring (Section 9.5 of the TMDL). There are several monitoring sites used to gather data for the SCVR, one site on Sugar Creek and three sites on the Vermont City Reservoir (Section 5 of the TMDL). The reservoir sites are part of the Illinois Ambient Lake Monitoring Program and the site on Sugar Creek is part of the Ambient Water Quality Monitoring System. These sites will continue to be monitored. IEPA also performs intensive basin surveys every five years using a rotating basins process. Detailed monitoring of the SCVR and associated tributaries will be performed during these surveys. In addition, since Vermont City Reservoir is a public water supply, water quality monitoring will continue for the reservoir.

EPA finds that this criterion has been adequately addressed.

10. Implementation

EPA policy encourages Regions to work in partnership with States/Tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired by nonpoint sources. Regions may assist States/Tribes in developing implementation plans that include reasonable assurances that nonpoint source LAs established in TMDLs for waters impaired solely or primarily by nonpoint sources will in fact be achieved. In addition, EPA policy recognizes that other relevant watershed management processes may be used in the TMDL process. EPA is not required to and does not approve TMDL implementation plans.

Comment:
Numerous implementation options are discussed in Section 9 of the TMDL. These options are directed for reductions in fecal coliform, atrazine, total phosphorus, as well as sediment.

The potential BMPs are:

- Cover crops
- No-till/strip till
- Grassed waterways
- Filter strip, grass conversion, and field borders
- Streambank stabilization
- Shoreline stabilization

- Detention basin/pond
- Septic Systems
- Nutrient management

For most of these BMPs, IEPA provided some watershed analysis on the impacts these BMPs may have on the pollutants addressed in these.

EPA reviews, but does not approve, implementation plans. EPA finds that this criterion has been adequately addressed.

11. Public Participation

EPA policy is that there should be full and meaningful public participation in the TMDL development process. The TMDL regulations require that each State/Tribe must subject calculations to establish TMDLs to public review consistent with its own continuing planning process (40 C.F.R. §130.7(c)(1)(ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval should describe the State's/Tribe's public participation process, including a summary of significant comments and the State's/Tribe's responses to those comments. When EPA establishes a TMDL, EPA regulations require EPA to publish a notice seeking public comment (40 C.F.R. §130.7(d)(2)).

Provision of inadequate public participation may be a basis for disapproving a TMDL. If EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the State/Tribe or by EPA.

Comment:
An initial public meeting was held on December 12, 2012, to describe the watershed plan and TMDL process. The public comment period for the draft TMDL opened on February 9, 2019 and closed on March 8, 2019. A public meeting was not held.

The public notices were published in the local newspaper and interested individuals and organizations received copies of the public notice. A hard copy of the TMDL was made available at the Vermont Public Library and Astoria Town Hall. The draft TMDL was also made available at the website https://www2.illinois.gov/epa/public-notices/Pages/default.aspx . No public comments were received.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this eleventh element.

12. Submittal Letter

A submittal letter should be included with the TMDL submittal, and should specify whether the TMDL is being submitted for a *technical review* or *final review and approval*. Each final TMDL submitted to EPA should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute. The submittal letter, whether for technical review or final review and approval, should contain such identifying information as the name and location of the waterbody, and the pollutant(s) of concern.

Comment:
On April 4, 2019, EPA received the SCVR watershed TMDL, and a submittal letter from Sanjay Sofat, IEPA, to Joan Tanaka, EPA. In the submittal letter, IEPA stated it was submitting the TMDL report for EPA's final approval. The submittal letter included the name and location of the waterbodies and the pollutants of concern.

EPA finds that the TMDL document submitted by IEPA satisfies all requirements concerning this twelfth element.

Conclusion
After a full and complete review, EPA finds that the TMDLs for the SCVR watershed satisfy all of the elements of an approvable TMDL. This approval is for three TMDLs; one for fecal coliform, one for atrazine, and one for phosphorus, as noted in Table 1 of this Decision Document.

EPA's approval of this TMDL does not extend to those waters that are within Indian Country, as defined in 18 U.S.C. Section 1151. EPA is taking no action to approve or disapprove TMDLs for those waters at this time. EPA, or eligible Indian Tribes, as appropriate, will retain responsibilities under the CWA Section 303(d) for those waters.

Sugar Creek and Vermont City Reservoir TMDL Development
Phase I Report

FINAL

December 2018

Prepared for
Illinois Environmental Protection Agency

Prepared by
Illinois State Water Survey

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Table of Contents

Page

Figures

Tables

1. Goals and Objectives for Sugar Creek and Vermont City Reservoir Watershed

1.1 Total Maximum Daily Load (TMDL) Overview

Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency (U.S. EPA) Water Quality Planning and Management Regulations (40CFR Part 130) require states to identify water bodies that do not meet water quality standards and to determine the Total Maximum Daily Load (TMDL) for pollutants causing impairment.

The term TMDL has several connotations. First, it is a numerical value establishing the maximum amount of a pollutant that can be received by a water body without violating water quality standards and designated uses. Second, the process of establishing this numerical value is often called a TMDL. Third, TMDL is also used to describe the program that drives the process.

Under the Clean Water Act Section 303(d), the State of Illinois is required to biannually produce a list of waters in which water quality standards are not met. Such waters are designated as impaired with respect to its designated uses and are often referred to as the 303(d) listed waters. TMDL studies are required by the Clean Water Act for all waters that are designated as impaired, addressing each constituent identified as a cause of the impairment.

For each constituent, the TMDL is determined using the following general formula:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS} + \text{RC}$$

where WLA is Waste Load Allocation and refers to a load discharged to a water body by point sources, LA is Load Allocation and refers to a load that enters the water body from non-point sources and natural background, MOS is Margin of Safety that accounts for uncertainty, and RC is Reserve Capacity that allows for future growth.

The Illinois Environmental Protection Agency (IEPA) has traditionally utilized a three-stage approach to TMDL development. Stage 1 provides for watershed characterization, data analyses, and methodology development. Stage 2, if determined to be necessary during Stage 1, consists of monitoring and data collection. Stage 3 includes TMDL calculation, typically using computer simulation models, and the development of TMDL scenarios and an implementation plan. For those constituents that contribute to the impairment but do not have a numeric water quality standard, the IEPA utilizes the development of Load Reduction Strategies (LRS). Development of a LRS follows the same general assessment and evaluation methods as a TMDL. However, it does not allocate TMDL to individual point and nonpoint sources as WLA and LA, respectively.

This project includes activities normally associated with Stage 1 and Stage 2. This approach represents a joint endeavor of the IEPA and the Illinois State Water Survey (ISWS) to conduct scientifically-based TMDLs using data adequate for load calculation, water quality assessment, source tracking, and model calibration. For this TMDL, Stage 1 and Stage 2 are being carried out simultaneously, collecting one year of stream water quality and discharge data for analyses and modeling approach recommendations and an additional six months of data for model development and verification of stream conditions. The integrated monitoring effort is essential to enable realistic TMDL determination and to support credible recommendations.

1.2 TMDL Goals and Objectives for Sugar Creek and Vermont City Reservoir Watershed

The overall goals and objectives of the TMDL study for Sugar Creek and Vermont City Reservoir are:

- Collect intensive water quality and discharge data to describe pollutant loadings to the impaired water body
- Gather and analyze data describing the watershed draining to the impaired water body
- Assess water quality of the impaired water body and its tributaries
- Identify potential pollutant sources and key issues associated with the impairments
- Determine current load allocations to pollutant sources within the contributing watershed
- Determine the load reductions necessary to meet water quality standards
- Develop an implementation plan that will accomplish needed load reductions
- Inform and involve the stakeholders during all stages of TMDL development

The draft IEPA Integrated Water Quality Report (IEPA, 2010) presents a detailed assessment of Illinois streams and lakes. Sugar Creek is listed as impaired for Fecal Coliform bacteria. Vermont City Reservoir is listed as impaired for total phosphorus, total suspended solids, manganese, aquatic algae, and atrazine (Table 1-1). This report will address all listed constituents with respect to the above stated overall goals. Algae impairment is addressed indirectly through total phosphorus as the surrogate parameter.

Table 1-1. Causes of impairment for Sugar Creek and Vermont City Reservoir (from IEPA, 2010)

Water body	IEPA Segment ID	Impaired Use	Causes of Impairment
Vermont City Reservoir	RDM	Public Water Supply	Atrazine, Manganese
		Aesthetic Quality	Total Suspended Solids, Total Phosphorus, Aquatic Algae
Sugar Creek	IL_DH-01	Primary Contact	Total Fecal Coliform

The newly released 2012 draft IEPA Integrated Water Quality Report (IEPA, 2012) lists new causes of impairment (ammonia and dissolved oxygen) for Vermont City Reservoir in addition to those listed in Table 1-1 and removes atrazine as a cause of impairment.

1.3 Report Overview

This section provides an overview of the remaining sections of this report:

Section 2. Sugar Creek and Vermont City Reservoir Watershed Characterization describes watershed characteristics such as land use, soils, topography, population, and climate data. This section also includes stream and reservoir data and information on known point sources in the watershed.

Section 3. Public Participation and Involvement discusses and provides a schedule of the events planned to provide for public participation and involvement throughout the TMDL development process.

Section 4. Sugar Creek and Vermont City Reservoir Water Quality Standards defines water quality standards applicable to Sugar Creek and Vermont City Reservoir based on their respective designated uses.

Section 5. Water Quality Conditions presents water quality data available for the Vermont City Reservoir and Sugar Creek watersheds. Historical data as well as data collected during this project are presented. This section also includes discussion on point and non-point source contributions.

Section 6. TMDL Approach summarizes observations and conclusions from previous sections, discusses a recommended approach for modeling potential causes of impairment during Stage 3 of TMDL development for Vermont City Reservoir and Sugar Creek.

2. Sugar Creek and Vermont City Reservoir Watershed Characterization

2.1 Sugar Creek and Vermont City Reservoir Watershed Location

The Sugar Creek watershed is located in McDonough, Fulton, and Schuyler counties in western Illinois (Figure 2-1 and Figure 2-2). The headwaters of Sugar Creek are located in southeast McDonough County. Sugar Creek flows in a northeasterly direction as it enters Fulton County, but gradually swings to the southwest over the next 5 miles and passes through McDonough County and into Schuyler County until its confluence with the West Branch of Sugar Creek. After the West Branch joins the mainstem, Sugar Creek continues in a general southeasterly direction until its confluence with the Illinois River. Total drainage area for the Sugar Creek watershed (HUC 10 code: 0713000310) is approximately 161 square miles.

Figure 2-1. Sugar Creek at U.S. Route 24, looking downstream

Vermont City Reservoir, also known as Vermont New Lake, is located on an unnamed tributary to Sugar Creek in southeast McDonough County (Figure 2-2 and Figure 2-3). The reservoir spillway is located approximately 0.3 river miles above the mouth of the unnamed tributary. The Vermont City Reservoir watershed has a total drainage area of approximately 2.3 square miles.

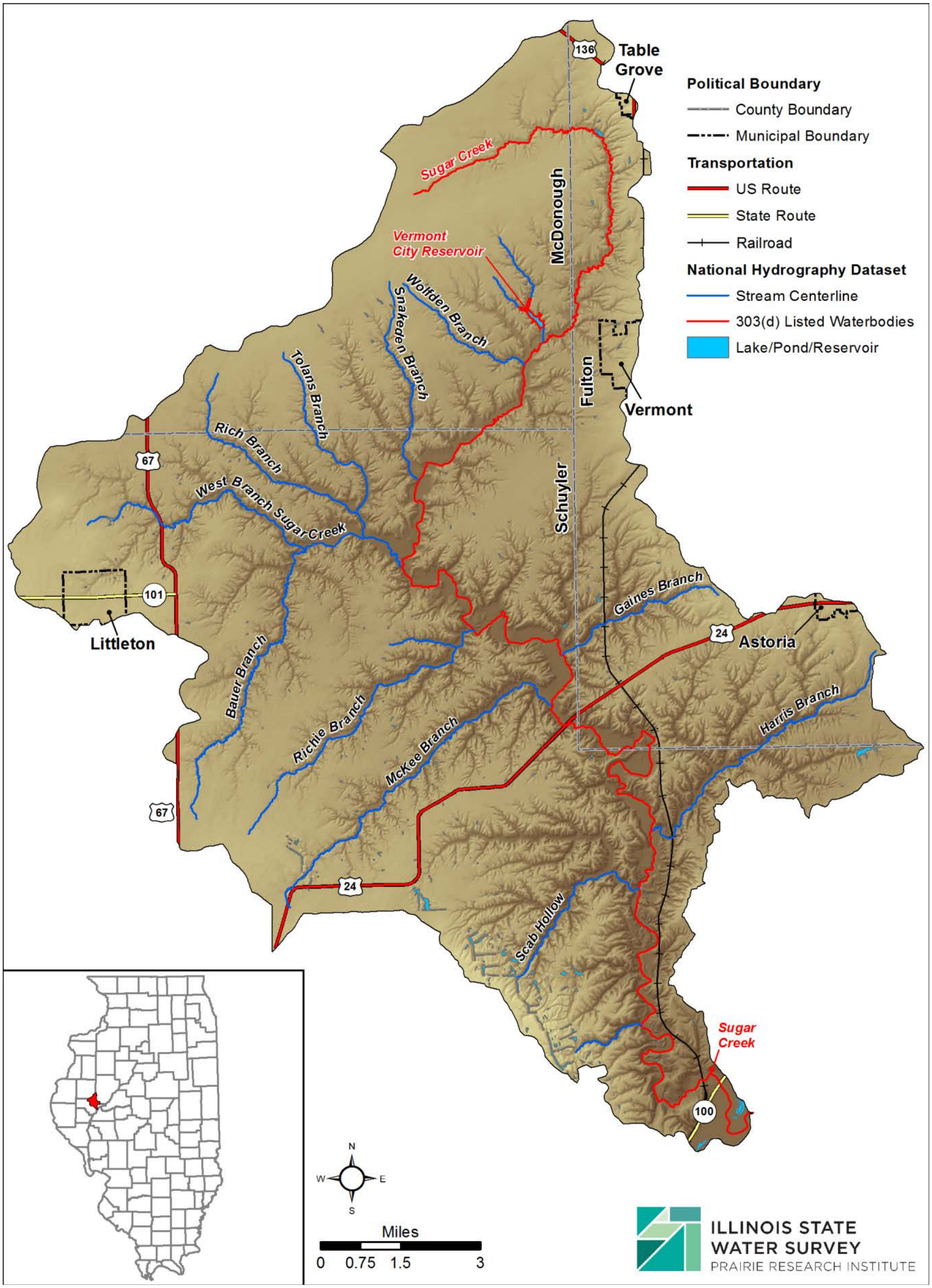

Figure 2-2. Sugar Creek watershed

Figure 2-3. Vermont City Reservoir

2.2 Land Use

Land use/land cover data were obtained from the U.S. Department of Agriculture, National Agricultural Statistics Service, Illinois Cropland Data Layer (USDA, NASS, 2017). The Illinois Cropland Data Layer (CDL) "is a raster, geo-referenced, crop-specific land cover data layer. The 2017 CDL has a ground resolution of 30 meters. The CDL is produced using satellite imagery from the Landsat 8 OLI/TIRS sensor, the Disaster Monitoring Constellation (DMC) DEIMOS-1 and UK2, the ISRO ResourceSat-2 LISS-3, and the ESA SENTINEL-2 sensors collected during the current growing season." (USDA, NASS, 2017)

The 2017 land cover data (Table 2-1, Figure 2-4) show that approximately half of the Sugar Creek watershed is dedicated to agriculture. During the time of imagery acquisition, corn and soybeans were the prevalent crop in the area. The second highest major land cover category in the watershed is forested land. The 2017 land cover data estimate more than 41% of the watershed is forested. The majority of forested areas are located near Sugar Creek and its tributaries. A small percentage of the Sugar Creek watershed is classified as urban/developed. The Vermont City Reservoir watershed is composed of the following land cover categories: 69% agricultural, 24% forested, 0.02% wetland, and 3% water.

Table 2-1. 2017 Land cover in the Sugar Creek and Vermont City Reservoir watersheds

Land Use Type	**Sugar Creek % Area**	**Vermont City Reservoir % Area**
Corn	22.34	43.32
Soybeans	20.60	16.54
Rural Grassland	8.14	7.52
Small Grains	0.53	1.25
Other Agriculture	0.01	--
Deciduous Forest	41.90	23.52
Developed Land	5.51	5.46
Wetlands	0.60	0.02
Open Water	0.35	2.37
Shrubland	0.02	--

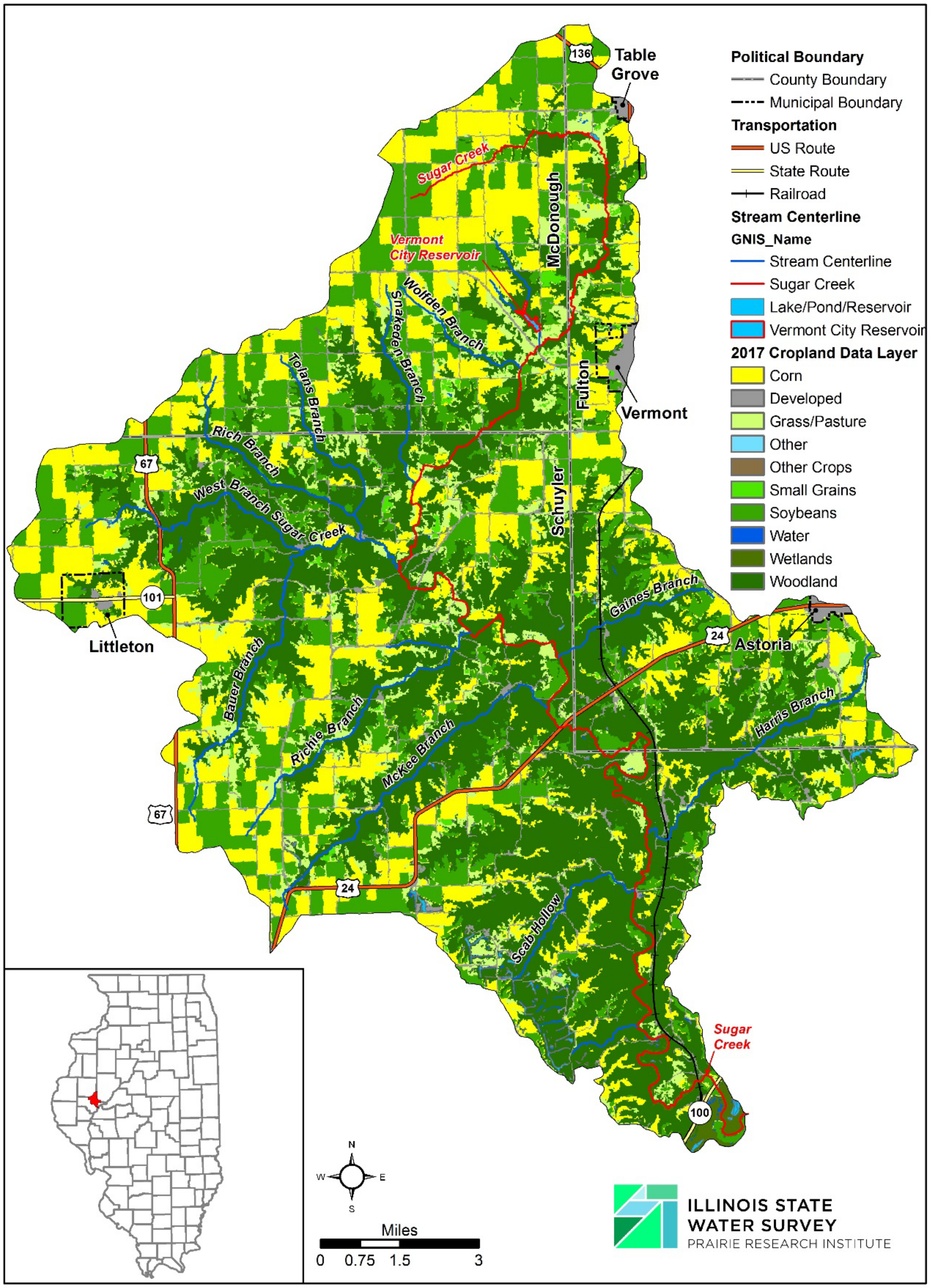

Figure 2-4. 2017 Land cover in the Sugar Creek watershed

2.3 Soils

The most detailed soil information available was obtained in electronic form from the Soil Survey Geographic (SSURGO) database for Illinois, produced by the Natural Resources Conservation Service (NRCS, 2010). SSURGO datasets are completed on a county scale, and their level of mapping detail matches the original printed county soil surveys. SSURGO maps delineate map units or areas with similar soil components that exhibit similar characteristics. These map units are linked to an attribute database which provides information on individual soil characteristics as well as aggregated information for entire map units.

Soils are mostly classified as silt loam or silty clay loam (USDA, 2001, 2003, and 2005). Many of the soils present in the Sugar Creek and Vermont City Reservoir watersheds contain manganese in at least some of their layers (USDA, 2001, 2003, and 2005). This presence is described either as manganese concretions (39% of the Vermont City watershed area) or masses of manganese (56% of the Vermont City watershed area).

The drainage class of soils within the Sugar Creek watershed are summarized in Table 2-2 and displayed by the map unit in Figure 2-5. More than one-third of the watershed is classified as somewhat poorly drained or poorly drained. Approximately 50% of the Vermont City Reservoir watershed is classified as poorly drained or somewhat poorly drained, while 45% is considered well drained.

Table 2-2. Drainage class of soils in the Sugar Creek watershed

Drainage Class	Percent Coverage
Well drained	53%
Moderately well drained	9%
Somewhat poorly drained	34%
Poorly drained	4%
Very poorly drained	<0.1%
Water	1%

Soils that are classified as poorly drained can often be converted into productive agricultural land with the installation of agricultural drain tiles. These drainage tiles provide rapid and consistent removal of excess water from the farm fields. Subsequently, these tiles also transport dissolved constituents to the stream network. Unfortunately, the extent of tile drainage in individual Illinois counties is difficult to quantify. The World Resources Institute prepared county-level estimates of tile drainage for several states across the U.S. based on GIS analysis of soils data and land cover data (Sugg, 2007). Based on their estimates of tile drainage in Fulton, McDonough, and Schuyler counties, 14% to 26% of the Sugar Creek watershed contains subsurface agricultural drain tiles.

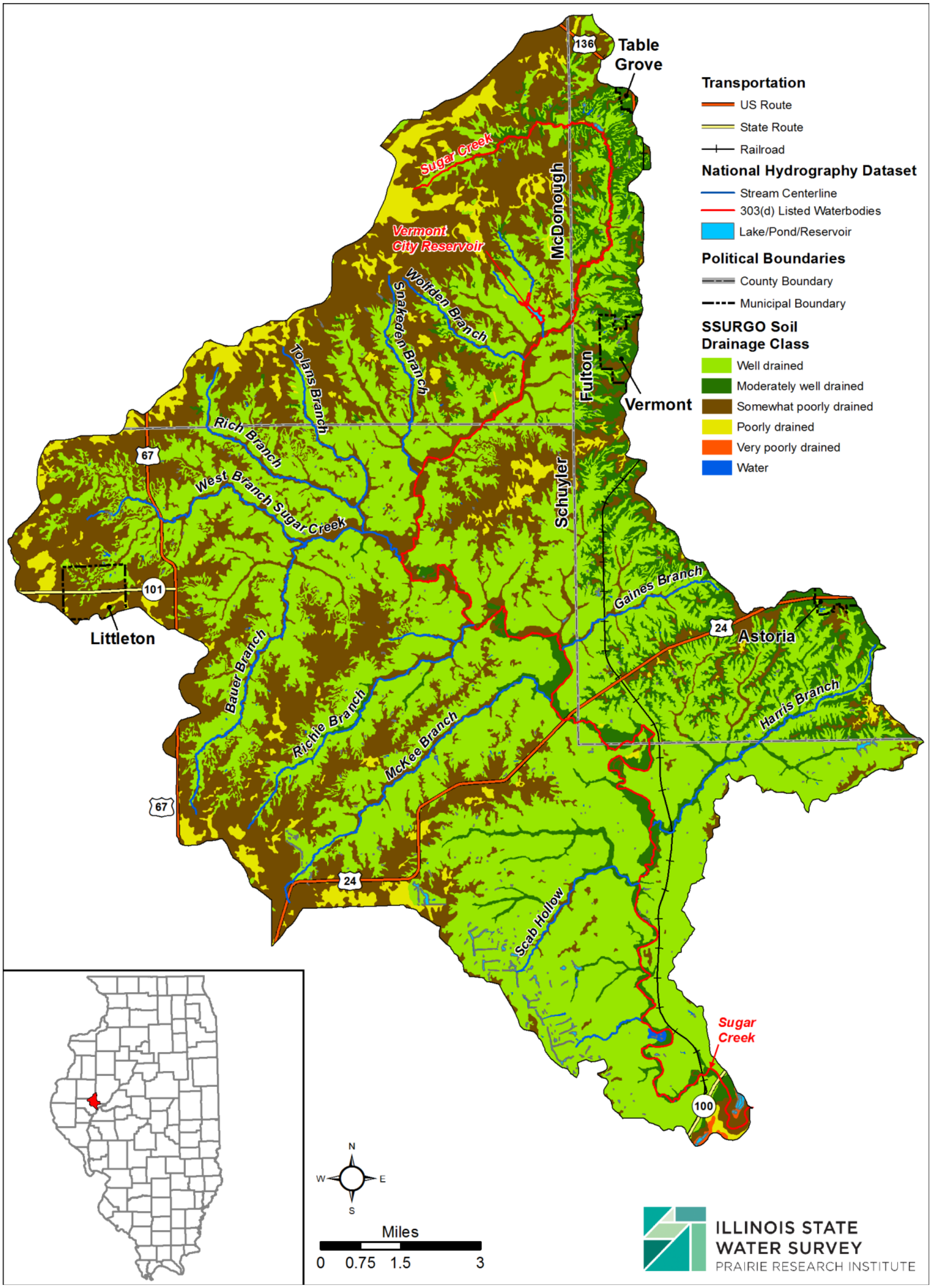

Figure 2-5. Sugar Creek watershed soil drainage classes

Hydrologic soil groups in conjunction with land use, land management practices, and hydrologic conditions determine the runoff curve number for a location (NRCS, 2009). In hydrologic models, runoff curve numbers can be used to estimate direct runoff from rainfall. Table 2-3 and Figure 2-6 show the distribution of hydrologic soil groups based on the properties of the major soil in each map unit within the Sugar Creek watershed. The majority of soils (70%) fall into hydrologic soil group B, where the potential for runoff is moderately low for saturated soils, and water transmission through the soil is unimpeded. Group C soils compose 22% of the watershed and describe soils with moderately high runoff potential when saturated. Group D soils have a high runoff potential when saturated and are extremely rare in this watershed. Soils designated by the NRCS as B/D are those which would be classified as Group D without the presence of tile drains; when drained, the soils behave more like Group B soils. Similarly, soils designated by the NRCS as C/D are those which would be classified as Group D without the presence of tile drains; when drained, the soils behave more like Group C soils.

The distribution of hydrologic soil groups in the Vermont City Reservoir watershed is similar to the percentages for the entire Sugar Creek watershed.

Soil erosion is common on steeper slopes near streams and can seriously impact aquatic life by altering channel capacity and geometry. Quiet-water pools along streams are in particular danger of sediment accumulation through erosion as well as accumulation of pesticides and other chemicals adsorbed to the eroded soils (IDNR, 2001).

The Natural Resources Conservation Service maintains records of lands considered highly erodible. Highly erodible land (HEL) determinations are made using 1990 soils information and soil map units. The soils information used is always the information that was available in January 1990 for the county, which provides a level playing field for participants of farm programs that rely on HEL determinations. A soil map unit is considered highly erodible if the predominant soil type is highly susceptible to erosion. Potential highly erodible land (PHEL) is an area that cannot be determined to be either HEL or non-HEL (NHEL) using the available 1990 data alone and requires a field survey to classify it (USDA NRCS, 2011).

HEL composes 34% of the Sugar Creek watershed, while 29% of the watershed is classified as non-HEL, and 35% is not classified as either HEL or NHEL (Table 2-4). The remaining 2% is classified as PHEL. McDonough County was the only county in the Sugar Creek watershed that used the PHEL classification. McDonough County also had more land not classified than Schuyler or Fulton counties, which is reflected in the Vermont City Reservoir HEL percentage. HEL areas for the entire watershed typically occur near stream channels, and NHEL/PHEL areas are typically located in upland areas with gentler slopes (Figure 2-7).

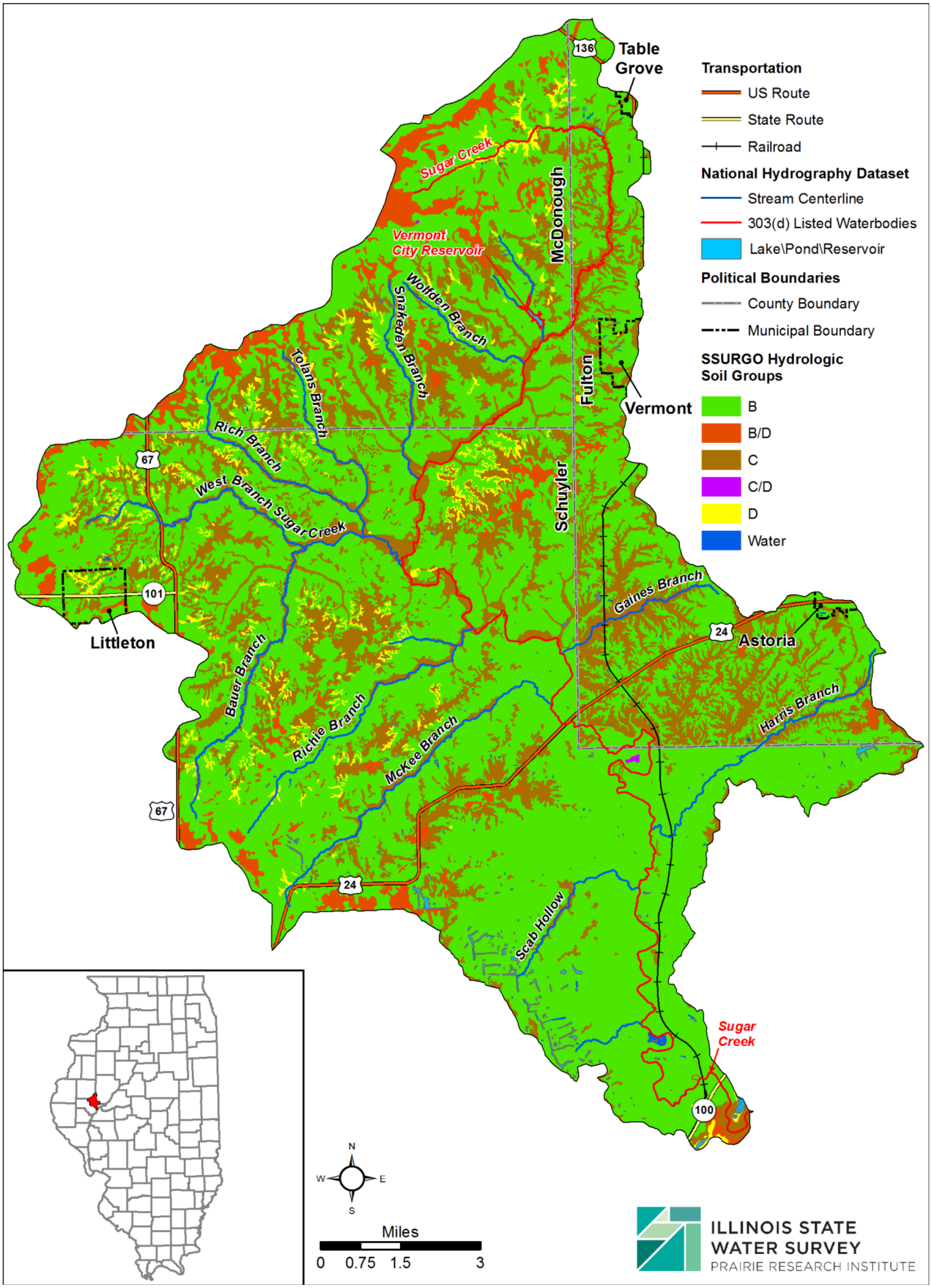

Figure 2-6. Sugar Creek watershed hydrologic soil groups

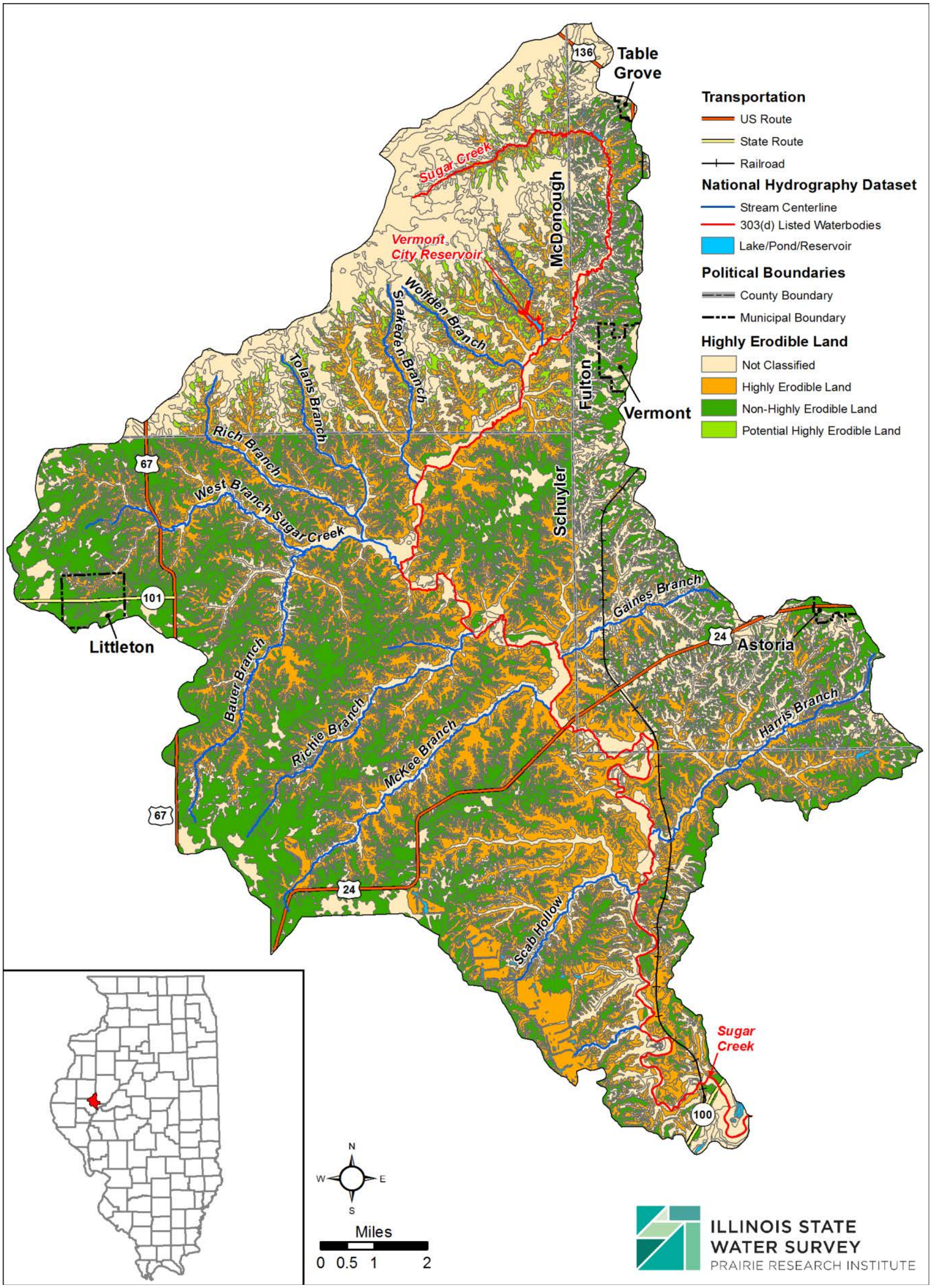

Figure 2-7. Sugar Creek watershed erodible lands

Table 2-3. Hydrologic soil groups in the Sugar Creek watershed

Group	Percent Coverage
B	70%
B/D	4%
C	22%
C/D	<0.1%
D	2%
Water	1%

Table 2-4. Highly erodible land in the Sugar Creek and Vermont City Reservoir watersheds

Group	Sugar Creek Watershed Percent Coverage	Vermont City Reservoir Watershed Percent Coverage
Highly Erodible Land	34%	32%
Non Highly Erodible Land	29%	--
Potential Highly Erodible Land	2%	13%
Not Classified	35%	55%

2.4 Topography

Topographic information was obtained from the U.S. Geological Survey (USGS). The USGS (2018) distributes a seamless layer online via The National Map. The digital elevation data obtained were at a resolution of 10 meters (1/3 Arc Second). All elevations presented are in North American Vertical Datum of 1988 (NAVD 88). Land surface elevations in the Sugar Creek watershed range from 745 feet in the southwest corner of the watershed near Scab Hollow to 437 feet near the mouth of Sugar Creek (Figure 2-8).

Land surface elevations in the Vermont City Reservoir watershed range from 680 feet along the northern edge of the watershed to approximately 587 feet near the lake shoreline.

2.5 Geology

Bedrock geology data were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse (ISGS, 2005). The data were provided at a scale of 1:500,000 and are in North American Datum of 1983 (NAD 83). The geology of the study area consists of Carbondale bedrock throughout, Tradewater bedrock near the Sugar Creek stream channel, and a small area of Shelburn-Patoka bedrock on the southwest border of the watershed (Figure 2-9).

Loess thickness data were obtained from the Illinois State Geological Survey (ISGS, 1997). The data were provided at a scale of 1:500,000 and are in NAD 83. Loess deposits in the Sugar Creek watershed range from 0 to 20 feet and generally decrease in thickness from east to west (Figure 2-10). This is typical of the region and for areas near the Illinois River (IDNR, 2001).

Glacial drift data were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse (ISGS, 1994). The data were provided at a nominal scale of 1:500,000 and are in NAD 83. Glacial drift thickness in the Sugar Creek watershed ranges from less than 25 feet to between 50 and 100 feet (Figure 2-11). This is a relatively thin deposit when compared to nearby regions in Illinois which can reach over 500 feet (IDNR, 2001).

2.6 Aquifer

Aquifer data were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse (ISGS, unpublished). The data were provided at a scale of 1:500,000 and are in NAD 83. This data source defines potable water as water containing less than 2,500 milligrams per liter (mg/L) total dissolved solids (TDS). The Sugar Creek watershed rests above a potable aquifer at a depth less than 500 feet and located generally below the Sugar Creek floodplain. The entire watershed also rests above a non-potable aquifer at a depth greater than 500 feet that yields water containing from 2,500 to 10,000 mg/L of TDS (Figure 2-12).

2.7 Population

Maps delineating census blocks from the 2000 U.S. Census were obtained as Geographic Information System (GIS) shapefiles from the U.S. Census TIGER website (U.S. Census Bureau, 2010b). Data on population by block were obtained from the U.S. Census American FactFinder website (U.S. Census Bureau, 2010a). Population densities within the Sugar Creek watershed were estimated by dividing the population in each block by that block’s area. The census blocks were then clipped to the Sugar Creek watershed boundary, and the total watershed population was estimated based on the percentage of area located within the watershed.

The total estimated population within the Sugar Creek watershed is 2,547 persons. The population density within the watershed is relatively low, with most areas containing fewer than 40 persons per square mile. The areas of densest population are within four municipalities: Vermont, Table Grove, Littleton, and Astoria, which reside partially or wholly within the watershed.

The total estimated population within the Vermont City Reservoir watershed is 7 persons.

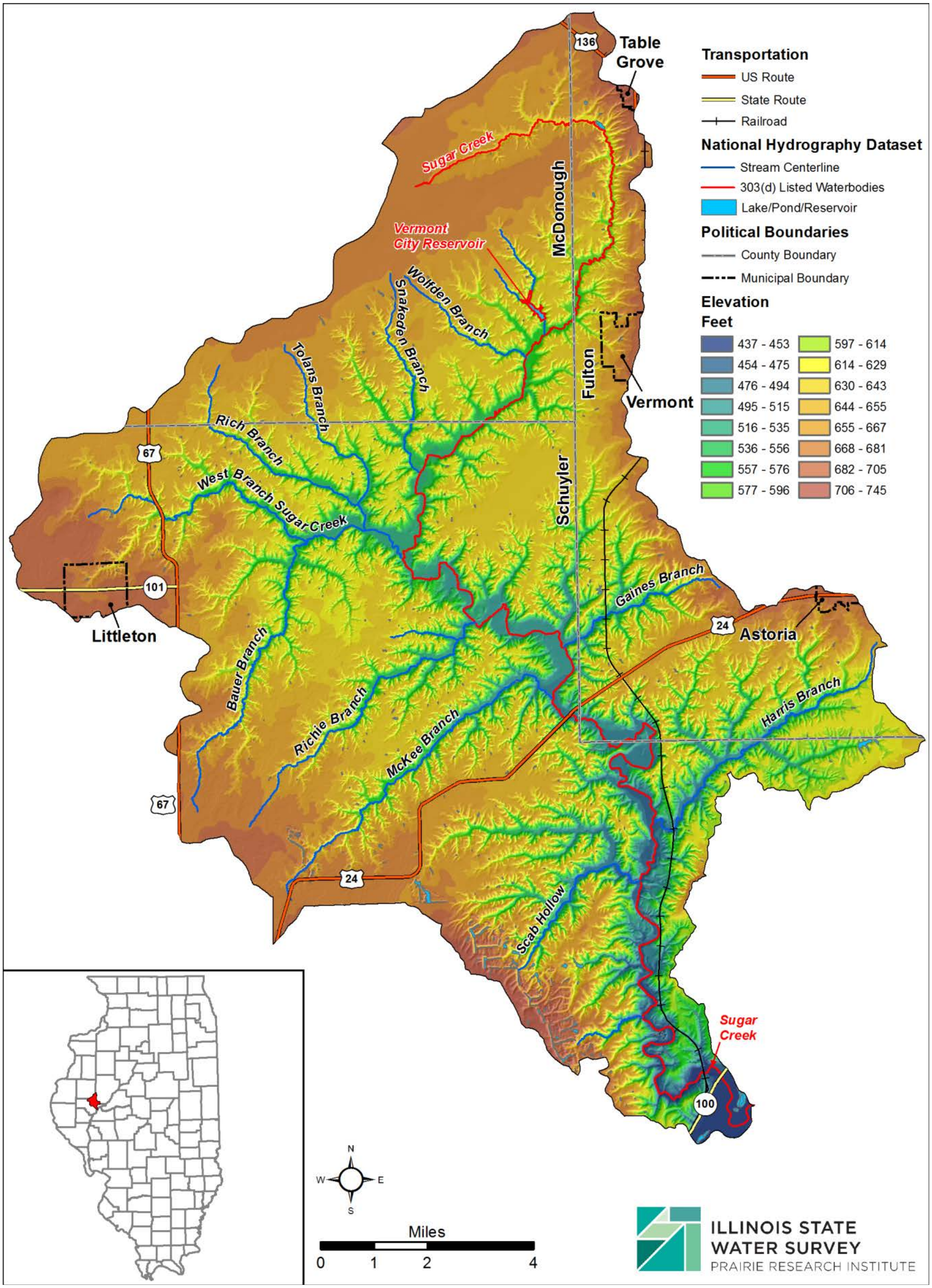

Figure 2-8. Sugar Creek and Vermont City Reservoir watershed elevation

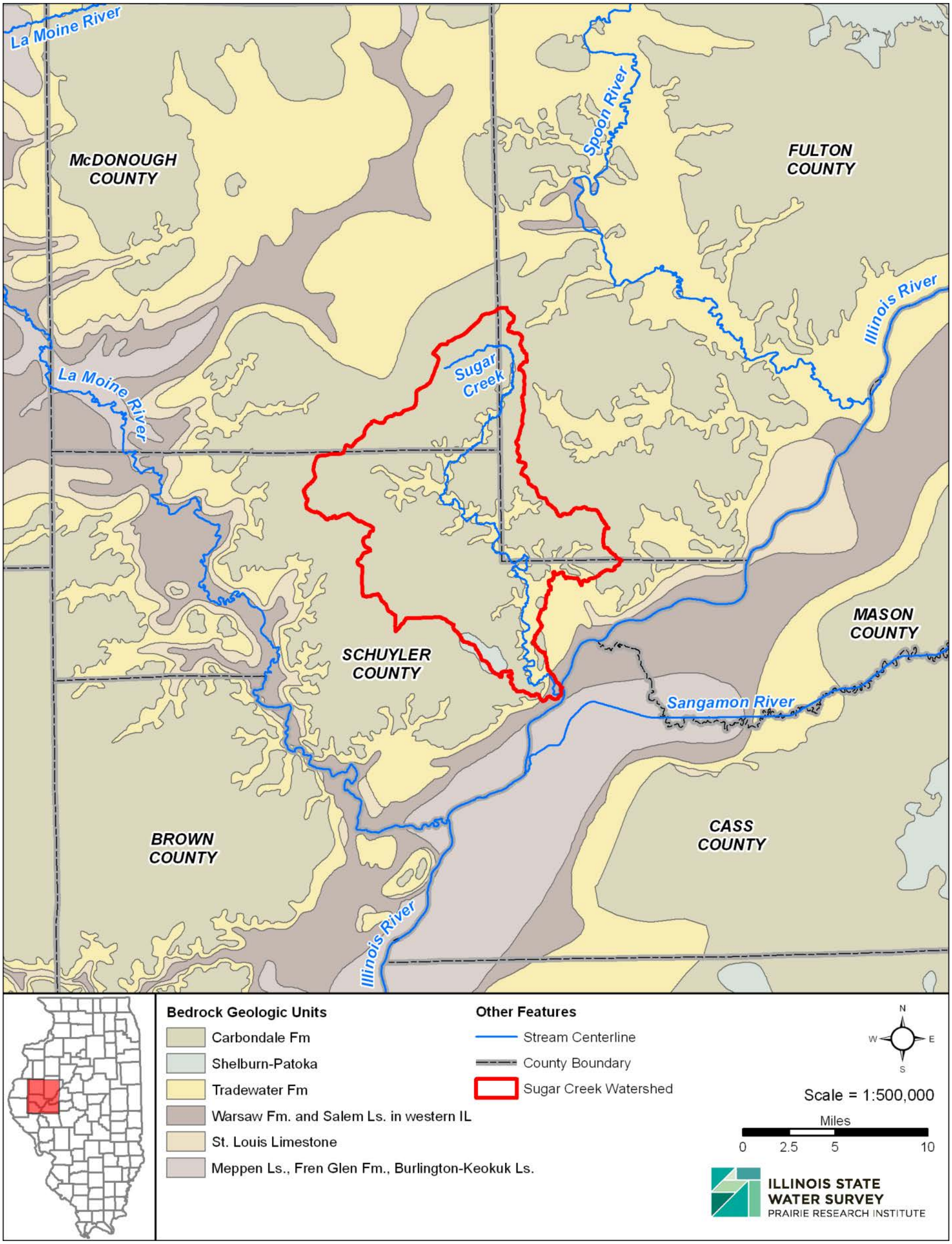

Figure 2-9. Bedrock geology of the Sugar Creek watershed

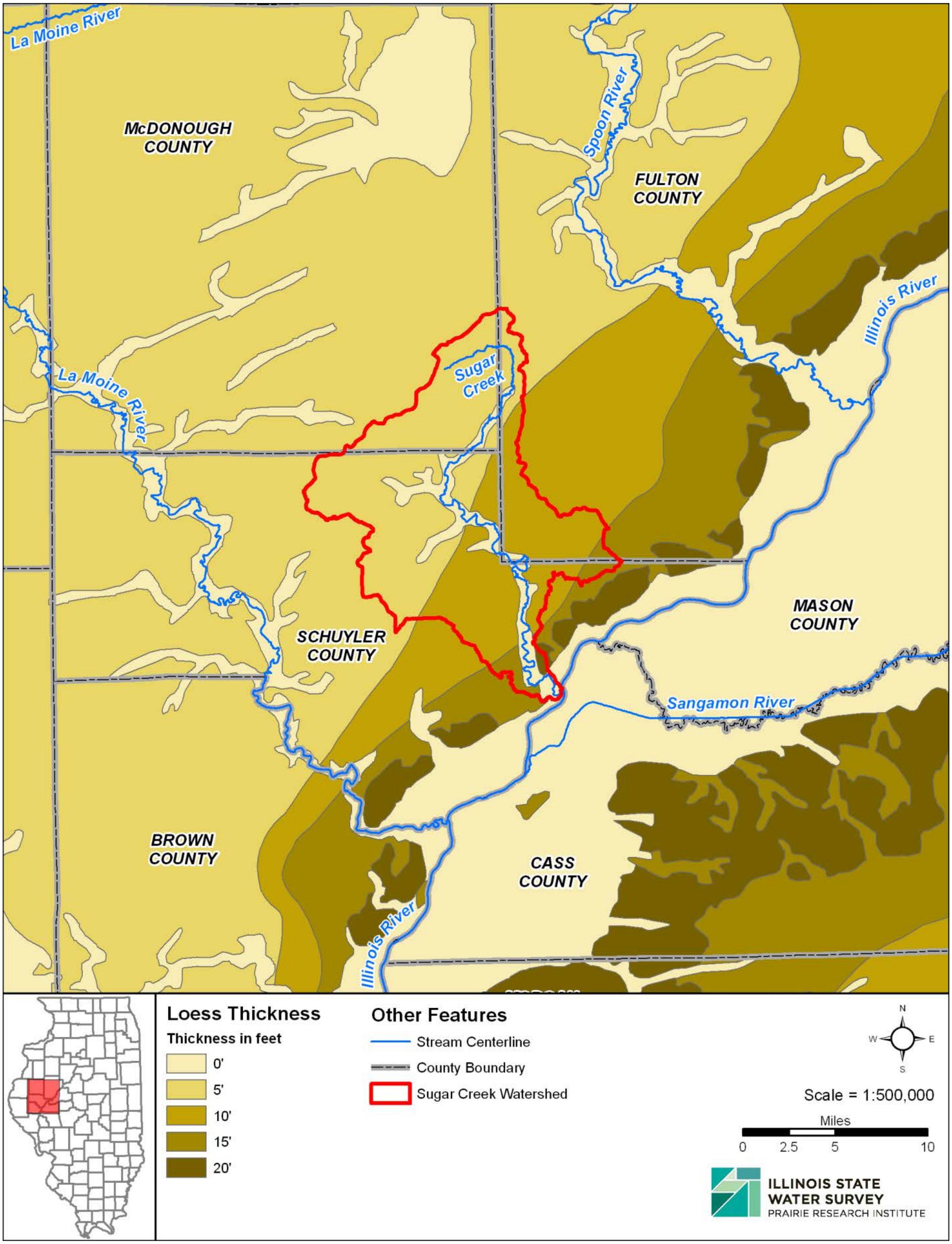

Figure 2-10. Loess thickness in the Sugar Creek watershed

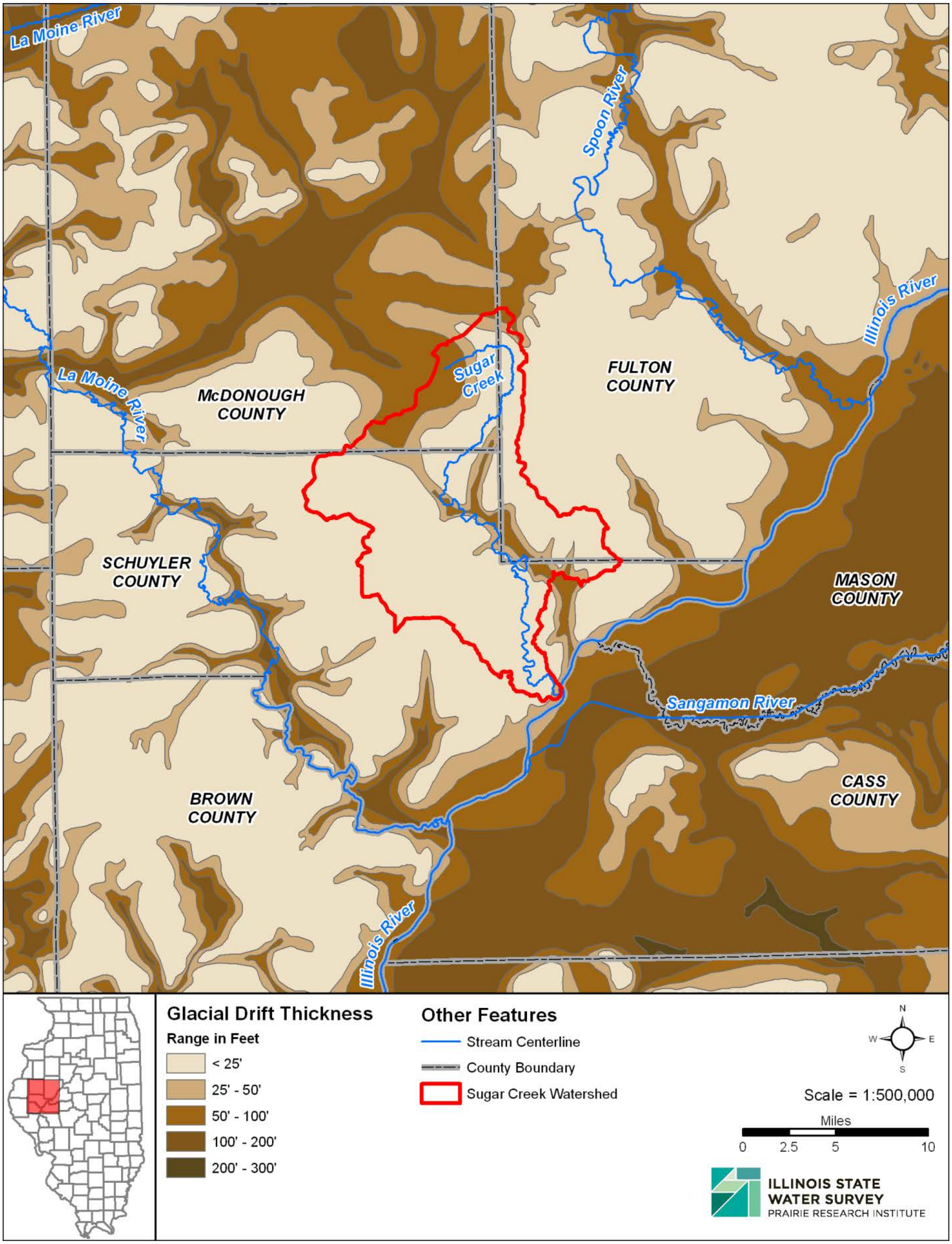

Figure 2-11. Glacial drift thickness in the Sugar Creek watershed

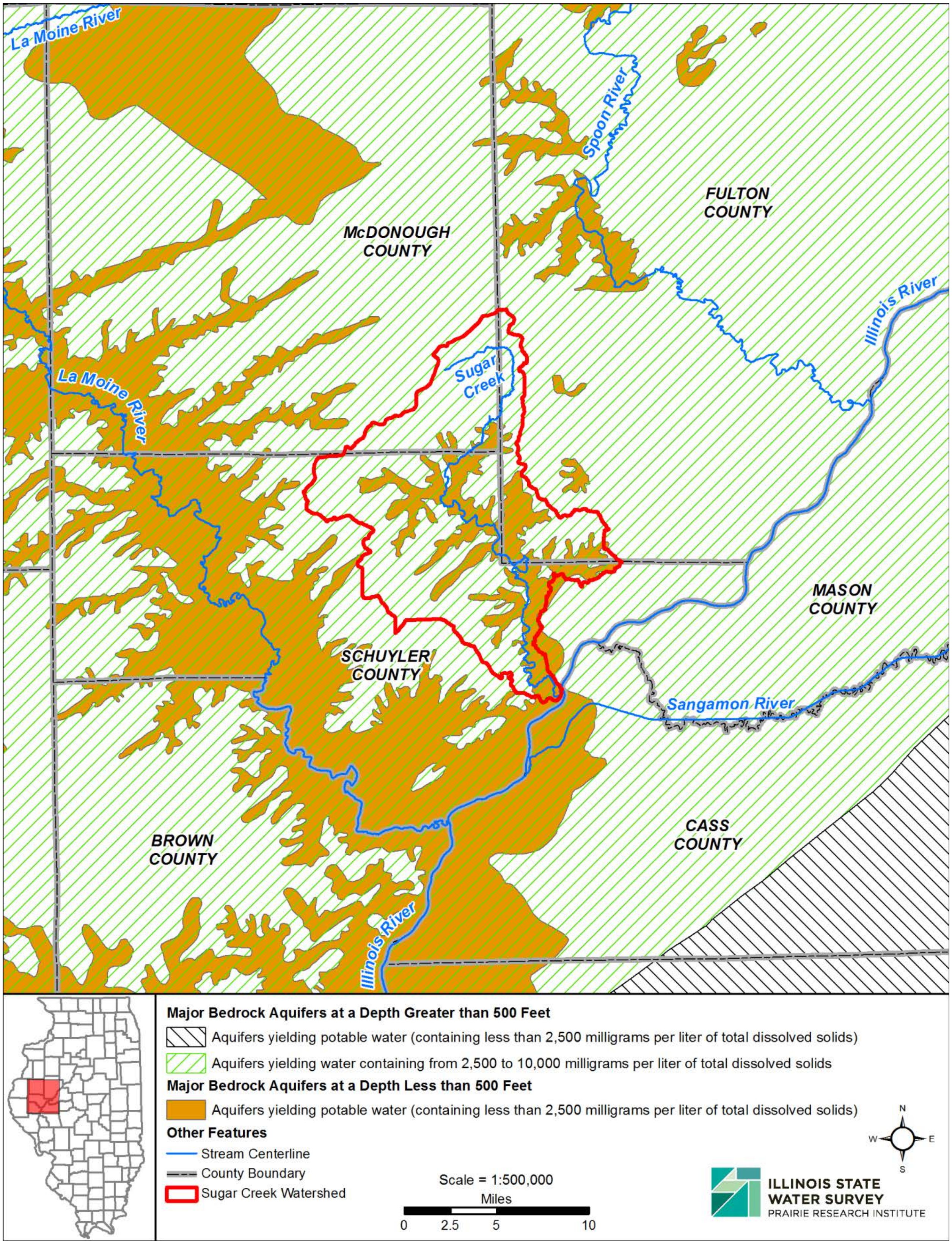

Figure 2-12. Major bedrock aquifers in the Sugar Creek watershed

2.8 Climate Data

The climate of this area is continental, defined as changeable weather with warm summers and cold winters (IDNR, 1998). The temperature and precipitation data presented in this report were obtained from the Midwest Regional Climate Center (MRCC, 2010). In order to provide temperature and precipitation values that are representative of recent climatic conditions, some of the climate data presented are climate “normals”, a 30-year average computed by the National Climatic Data Center every 10 years (NCDC, 2005). The climate normals computed for the period 1971-2000 are the most recent data available.

2.8.1 Temperature

Temperature data were obtained from the MRCC for Rushville, IL (Station ID 117551). The city of Rushville is located less than a mile from the watershed boundary (Figure 2-13). The average maximum and minimum temperatures for Rushville are displayed by month in Figure 2-14. A summary of temperature data for Rushville is presented in Table 2-5. The maximum and minimum temperatures presented are the normal temperatures from 1971 to 2000, and the extreme temperatures presented are from anytime during Rushville’s period of record (1890-2011). With an average high temperature of 87° F, the warmest month in Rushville is July. The lowest temperatures occur in December, January, and February when both maximum and minimum values average less than 40° F. The warmest day on record at Rushville occurred July 15, 1936 when temperatures reached 113° F. The low on February 13, 1905 of -26° F is the lowest temperature on record at Rushville.

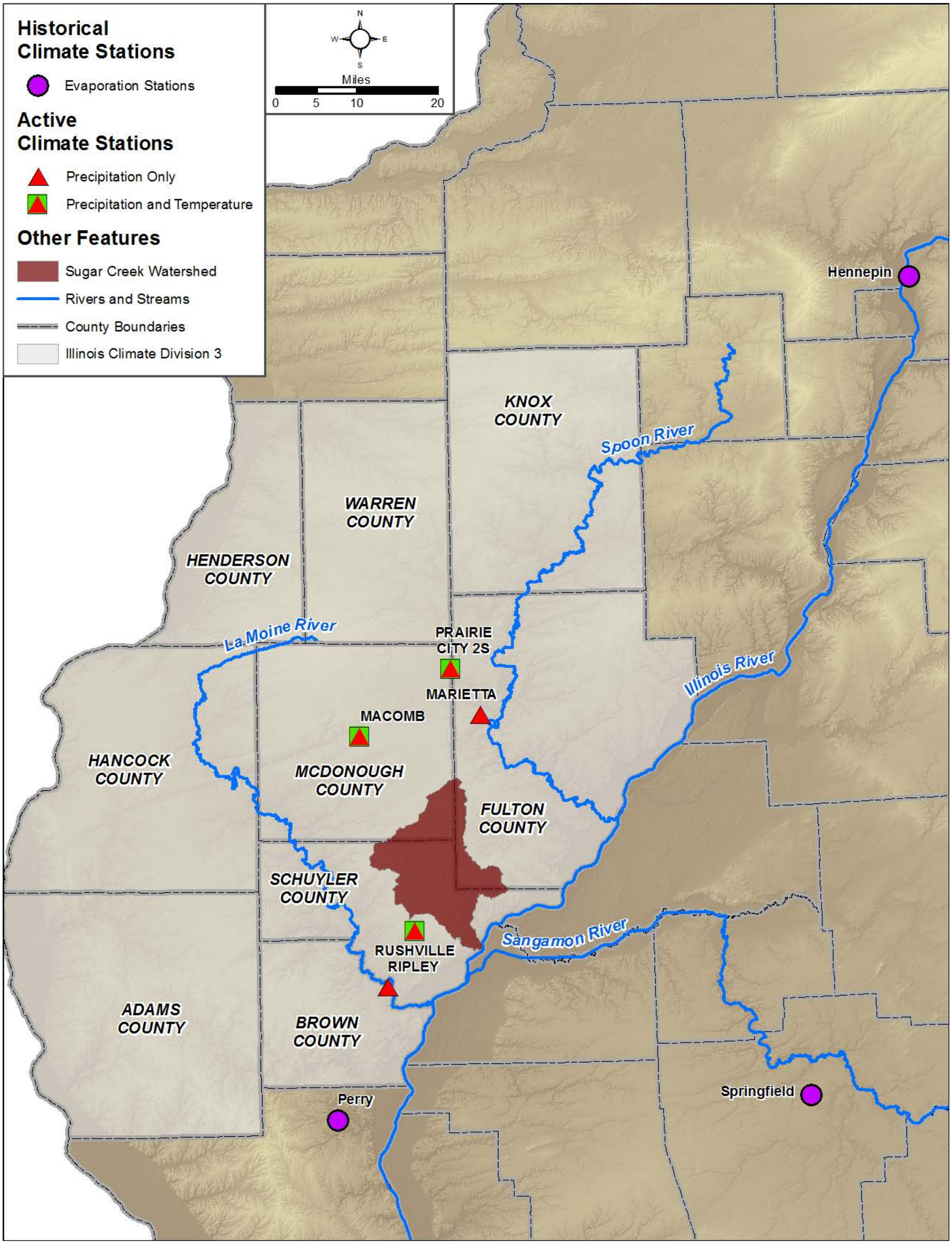

Figure 2-13. Climate stations near the Sugar Creek study area

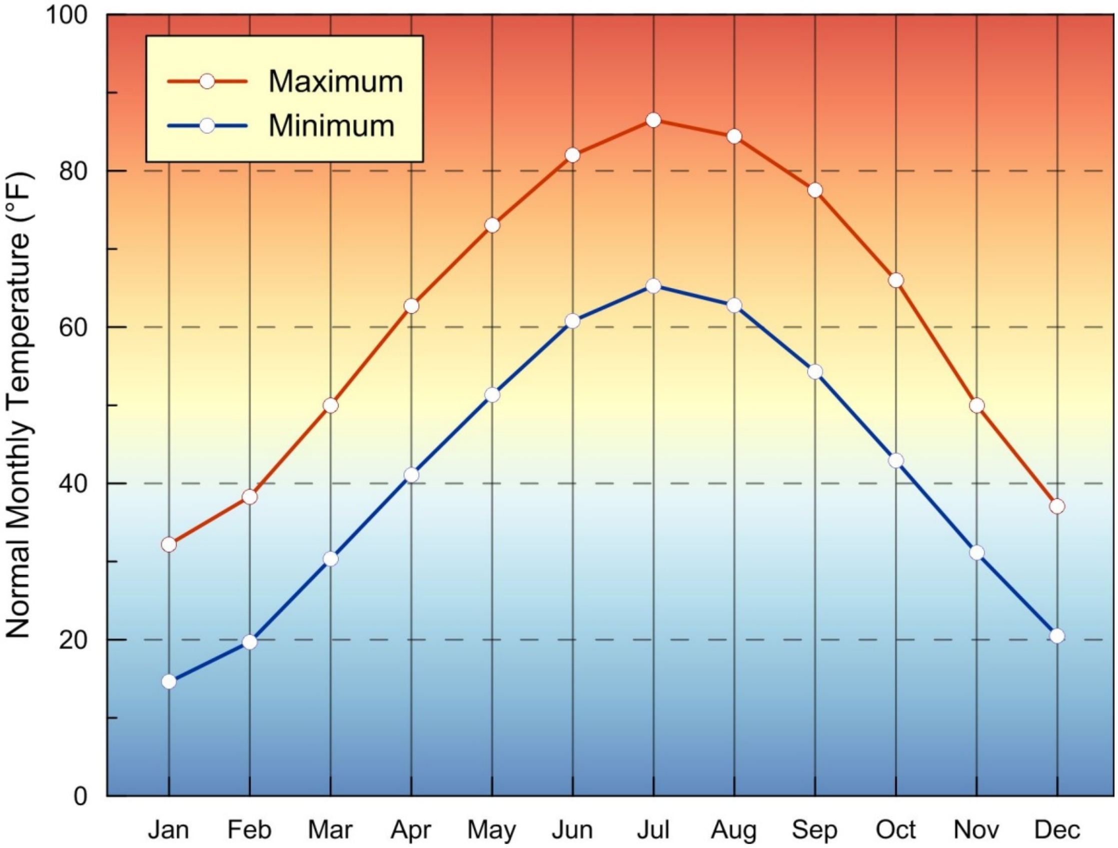

Figure 2-14. Normal monthly temperatures at Rushville, IL, 1971-2000

Table 2-5. Temperature summary for Rushville, IL (°F)

	Temperature, F			
	Average High	**Average Low**	**Record High (Year)**	**Record Low (Year)**
January	32.2	14.6	74 (1909)	-21 (1918)
February	38.3	19.7	78 (1932)	-26 (1905)
March	50.0	30.3	90 (1907)	-11 (1960)
April	62.7	41.1	95 (1894)	9 (1920)
May	73.0	51.3	105 (1934)	22 (2002)
June	82.0	60.8	104 (1934)	39 (1903)
July	86.5	65.3	113 (1936)	46 (1904)
August	84.4	62.8	111 (1934)	41 (1934)
September	77.5	54.3	103 (1913)	26 (1942)
October	66.0	42.9	93 (1922)	4 (1925)
November	50.0	31.1	84 (1950)	-8 (1964)
December	37.1	20.5	76 (1970)	-22 (1924)

2.8.2 Precipitation

Precipitation data for Rushville, IL were available from MACS from 1890 to 2011.

The normal monthly variation in precipitation at Rushville is displayed in Figure 2-15 and Table 2-6. Annual average precipitation at Rushville is approximately 39 inches. More rain falls in the late spring and early summer than at other times during the year. The month of May averaged 5.14 inches from 1971 to 2000; however, the wettest month on record is September, when a total of 14.65 inches of precipitation was measured in 1911.

Snowfall at Rushville can be expected from November to April, though it is most common from December to March. The month of January historically has the highest amount of total snowfall, averaging 5.8 inches from 1971 to 2000.

In addition to the seasonal variation in precipitation, there can also be considerable variability in the annual totals. Precipitation data for the Western Illinois climate division (CD 3) is presented in Figure 2-16. The wettest year on record for this nine-county region was 1973 (54.57 inches), which was 16.63 inches above normal. The driest year on record was 1988 (22.14 inches), 15.8 inches below normal.

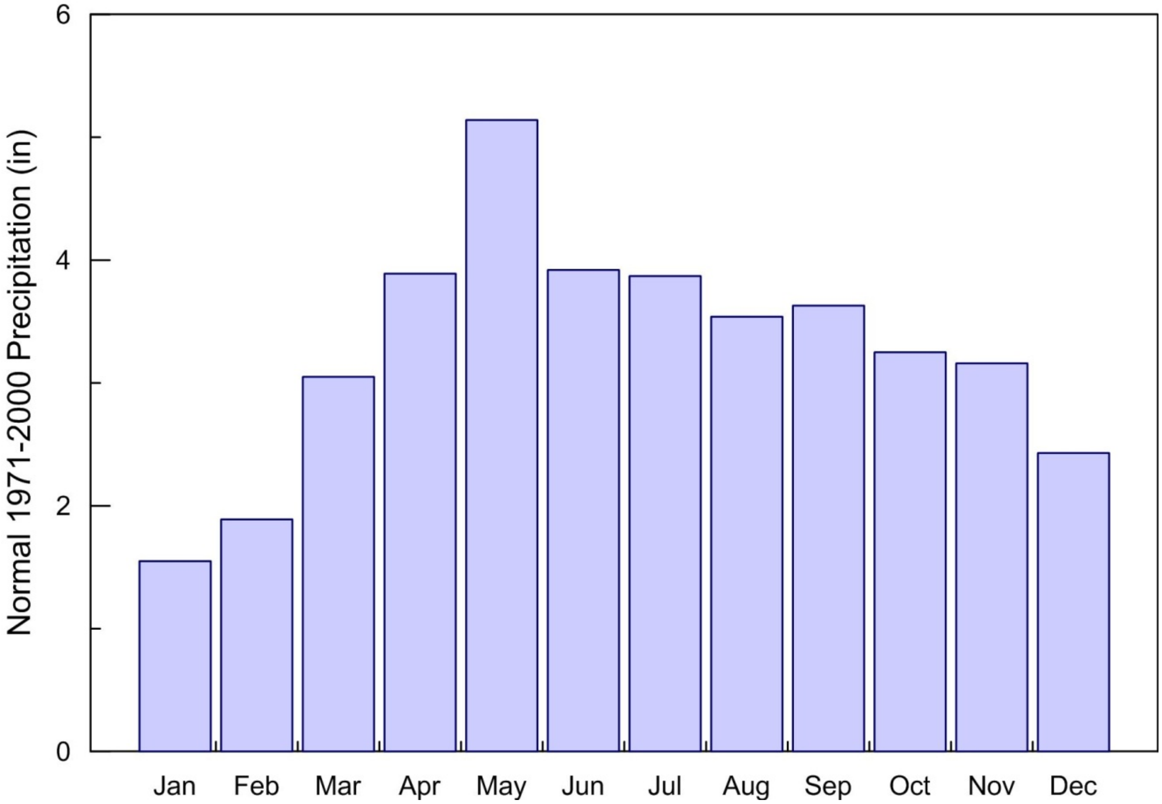

Figure 2-15. Normal monthly precipitation at Rushville, IL

Table 2-6. Monthly distribution of precipitation at Rushville, IL (inches)

	Average	*Record High (Year)*	*Record Low (Year)*
January	1.55	6.17 (1965)	0.05 (1919)
February	1.89	4.63 (1990)	0.10 (1917)
March	3.05	10.43 (1973)	0.12 (1910)
April	3.89	9.10 (1893)	0.36 (1932)
May	5.14	14.26 (1996)	0.29 (1934)
June	3.92	13.21 (1947)	0.41 (1991)
July	3.87	11.30 (1981)	0.25 (1936)
August	3.54	8.56 (1940)	0 (1909)
September	3.63	14.65 (1911)	0 (1956)
October	3.25	10.83 (1991)	0.15 (1964)
November	3.16	10.36 (1985)	0 (1914)
December	2.43	6.38 (1982)	0.10 (1919)
Annual	39.32	57.16 (1990)	23.54 (1913)

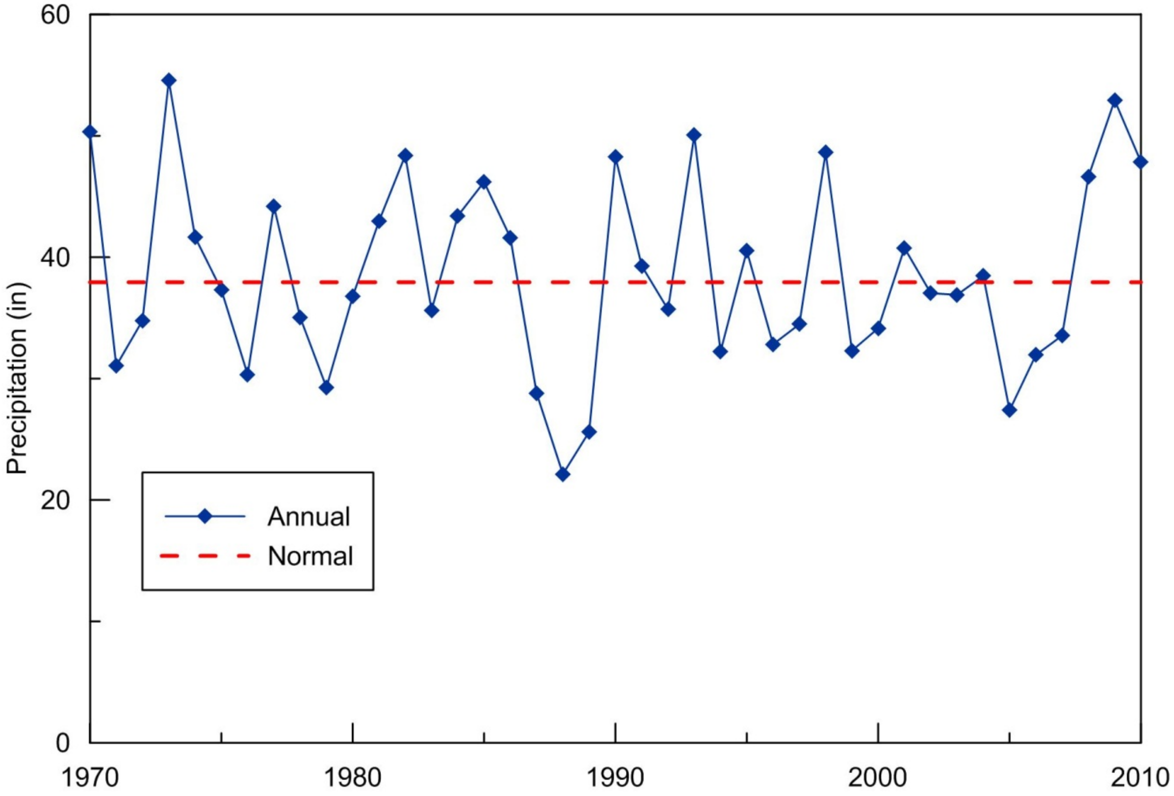

Figure 2-16. Annual and normal precipitation in Illinois climate division 3

2.8.3 Evaporation

Evaporative losses can be a significant component of the water budget for a reservoir. Because there can be considerable spatial and temporal variation in evaporation rates across Illinois, observed data for the period of interest should be used whenever possible. Pan evaporation data are available from the State Climatologist Office website at the Illinois State Water Survey (ISWS, 2011a). The ISWS website provides pan evaporation data for the warm season for nine sites across Illinois. Data from Springfield, Perry, and Hennepin were selected because of their proximity to the watershed (Figure 2-13) and their ranges in period of record (Table 2-7).

Table 2-7. Selected pan evaporation stations in Illinois

Station	Period of Record	
Perry	Apr-Sep	1996-2002
Springfield	Apr-Oct	1980-1990
Hennepin	May-Oct	1980-2005

Table 2-8 shows average pan evaporation at each station for their respective periods of record. Evaporation is typically highest in the summer months, May-August, during which time a loss of 7-9 inches/month can be expected. The highest evaporation rate measured was nearly 12 inches at Springfield in June 1988; Hennepin did not report data from May-June 1988. Evaporation measured at Hennepin is lower than at Perry and Springfield. While the average evaporation rates presented for Springfield are higher than that measured at Perry, that difference appears to be due to the differing periods of record rather than a directional variation. The average evaporation May-September at Perry, Springfield, and Hennepin is 36.6, 38.6, and 33.3 inches respectively. To estimate the evaporation rate from a natural body of water, pan evaporation data should be multiplied by a correction factor of 0.75 (ISWS, 2011a).

Table 2-8. Average pan evaporation data (inches/month)

Station	Apr	May	Jun	Jul	Aug	Sep	Oct
Perry	5.56	7.12	7.70	8.41	7.44	5.92	
Springfield	6.03	7.72	8.64	8.82	7.49	5.96	4.51
Hennepin		6.64	7.16	7.57	6.90	5.00	4.60

2.9 Surface Water Data

When investigating the water quality of an impounding reservoir, three types of surface water quantity information are critical: (1) the capacity of the reservoir, (2) inflow to the reservoir, and (3) outflow from the reservoir.

2.9.1 Reservoir Data

Vermont City Reservoir (IEPA Waterbody ID: IL_RDM) is an impounding reservoir created by damming an unnamed tributary to Sugar Creek in 1942. The reservoir was constructed to serve as the water supply for the City of Vermont. The chronology of original construction and subsequent surveys to measure its capacity are outlined in Table 2-9.

Table 2-9. Vermont City Reservoir historical capacity information

Year	Event	Measured Capacity	
		(MG)	(ac-ft)
1942	Reservoir built	119	366
1962	Illinois State Water Survey Sedimentation Survey	95	292
1980	Illinois State Water Survey Sedimentation Survey	73	223

According to the IEPA (2012), Vermont City Reservoir has a surface area of 38.5 acres. Vermont City Reservoir's drainage area is approximately 38 times larger than its surface area. Generally lakes with high ratios of watershed area to lake area are prone to poorer water quality than those lakes with lower ratios. Based on ratios computed for all of the lakes in the Illinois Natural History Survey's *Compendium of 143 Illinois Lakes* (Austen et al., 1993), the mean and median ratios of watershed to surface area for lakes in Illinois are 33 and 16, respectively.

2.9.2 Streamflow Data

To understand the hydrology of a watershed it is important to have long-term streamgage records. Unfortunately, there are no active USGS streamgages in the Sugar Creek watershed, nor has there ever been an active USGS streamgage in the watershed. The location of USGS streamgages near the Sugar Creek watershed are listed in Table 2-10 and presented in Figure 2-17.

Table 2-10. Selected USGS streamgages near the Sugar Creek watershed

USGS ID	Station Name	Drainage Area (mi^2)	Period of Record
05568800	Indian Creek near Wyoming, IL	62.7	1960-Present
05569500	Spoon River at London Mills, IL	1072.0	1943-Present
05570000	Spoon River at Seville, IL	1636.0	1914-Present
05584400	Drowning Fork at Bushnell, IL	26.3	1960-1983
05584500	La Moine River at Colmar, IL	655.0	1945-Present
05585000	La Moine River at Ripley, IL	1293.0	1921-Present

As part of the monitoring being conducted for this Phase 1 study, two streamgages have been installed in the Vermont City Reservoir watershed, and four streamgages have been installed on Sugar Creek. While having 18 months of streamflow information at these six sites will be extremely valuable to this study, there can be significant variation in streamflows both within a year and from year to year, so it is also important to understand how this 18-month record compares to the long-term annual and seasonal streamflows for this region.

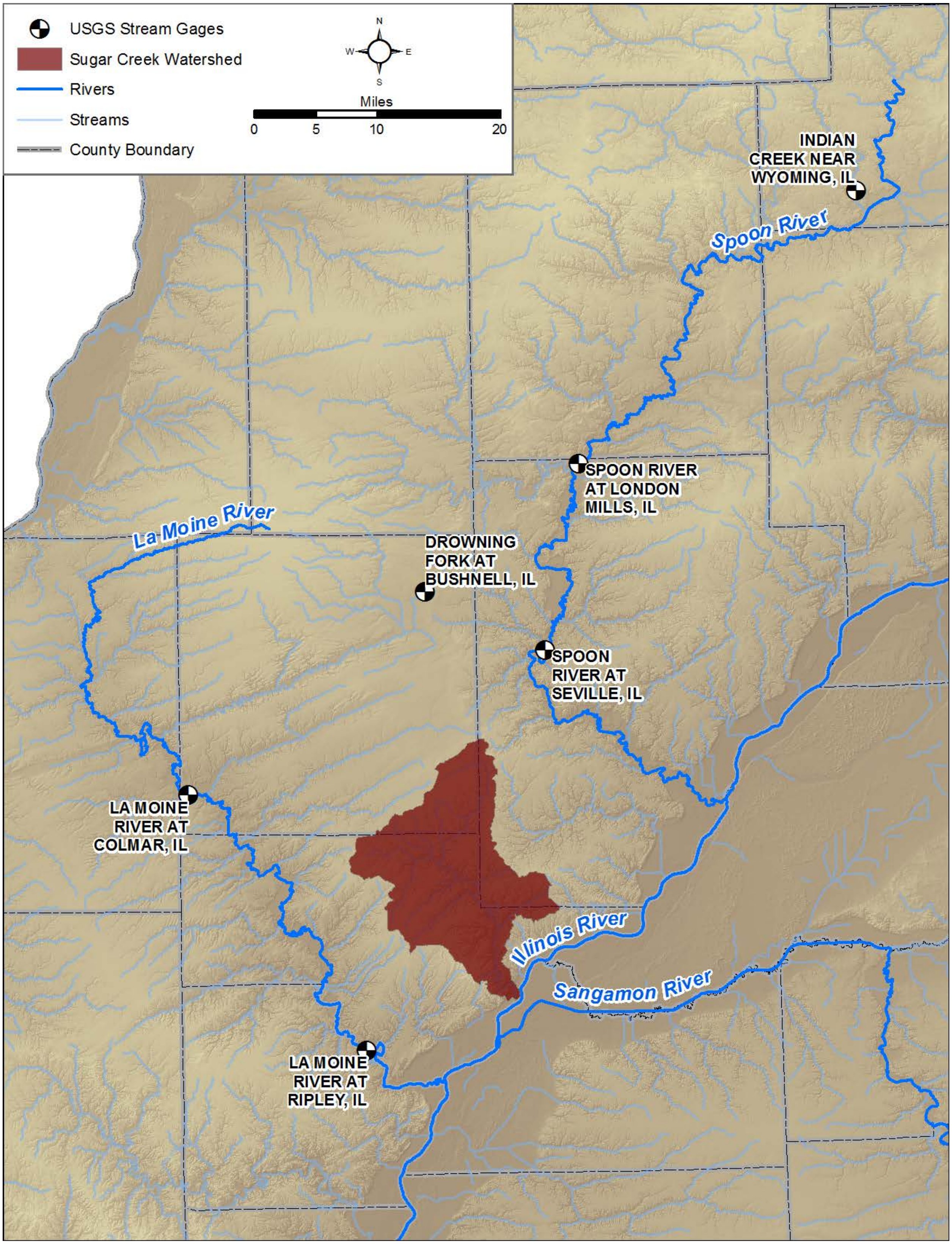

Figure 2-17. Selected USGS streamgages near the Sugar Creek watershed

Annual Flow Variability. Precipitation is the largest driver in the annual variation of streamflow for a given site. While the magnitude of annual flows measured at the nearby USGS sites will vary dramatically due to their range in drainage areas, streamflow can be normalized as inches of runoff for each watershed. Displaying the streamflow as runoff illustrates the similar annual flows for gaged streams in this area of the state, despite their differences in drainage area (Figure 2-18). When compared to the annual precipitation for west central Illinois (Figure 2-16), the relationship between precipitation and streamflow is especially evident in the years during and immediately following extreme precipitation deficits and/or surpluses. During the past 40 years, the greatest runoff at the two Spoon River sites and the two La Moine River sites occurred in 1993 and 2010, respectively. The annual runoff ranged from 25 to 30 inches at all five active gages in 1993 and exceeded 30 inches at the two La Moine River gages in 2010. During the past 40 years, the drought of 1988-1989 was the driest two-year period at these sites; annual runoff totaled less than 5 inches in 1989 at all five active gages. Due to this large range in possible flows, it will be important to determine whether the 18 months of streamflow data collected for this study are representative of wet, dry, or average conditions.

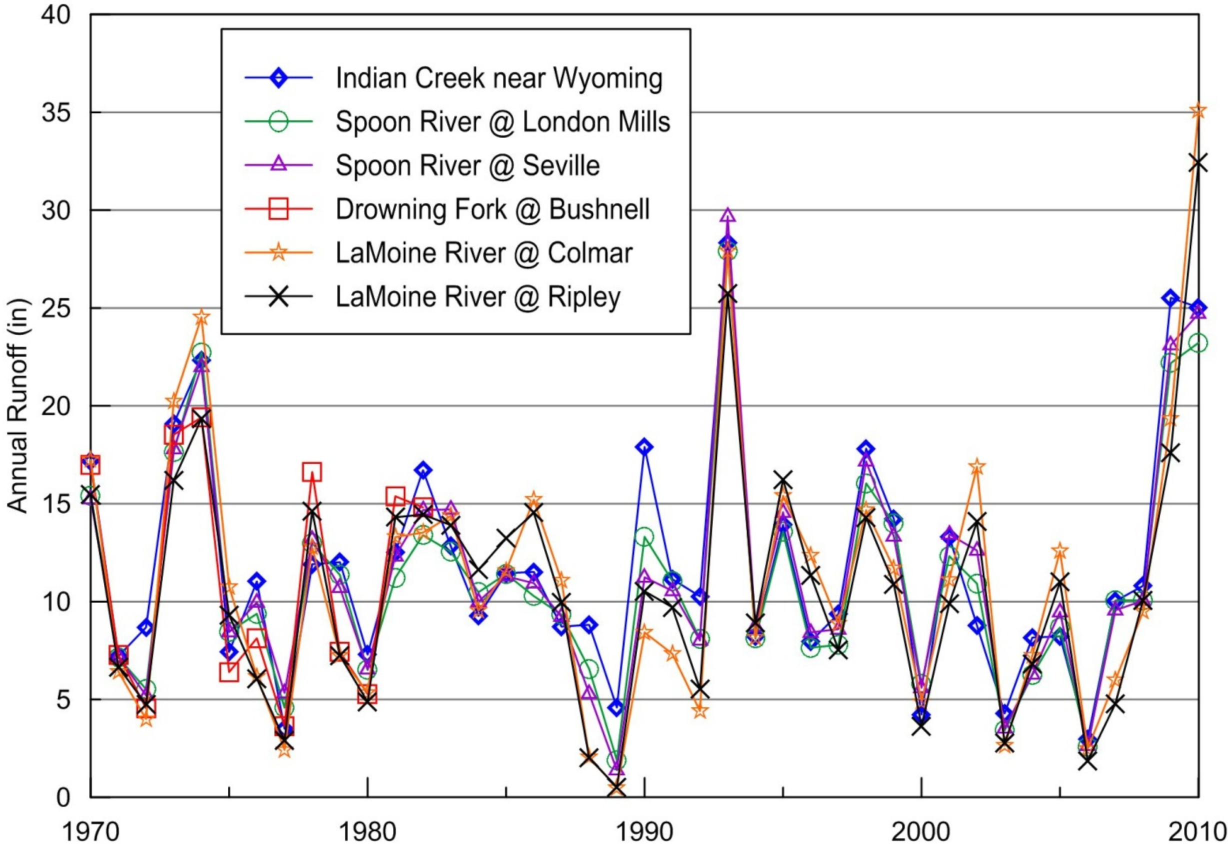

Figure 2-18. Annual runoff for selected USGS streamgages, 1970-2010

Seasonal Flow Variability. Even though the Indian Creek gage is located outside of the Sugar Creek watershed, it is still suitable for describing seasonal variation in flows as it is located in the Spoon River basin, a nearby watershed with similar characteristics. This gage is one of the few active streamgages in western Illinois with a drainage area less than 100 square miles. The

Indian Creek gage is located downstream of the Toulon Sewage Treatment Plant (STP), so the contributions of this point source would need to be accounted for if this gage is used as part of any regional regressions to estimate flows in the Sugar Creek watershed. While the magnitude of flows will differ, its record is still useful for describing the monthly variations in flow typical for small streams in this region.

Mean daily flow values for each month were averaged to determine the monthly average streamflow for that month/year. The monthly average streamflow was computed in this manner for each month of Indian Creek's 50-year record and ranked. The maximum, mean, and minimum of these monthly streamflow values are presented in Figure 2-19. Flows tend to be greatest during the spring through early summer months, March-June, and flows are typically at their lowest during late summer and fall, August-October.

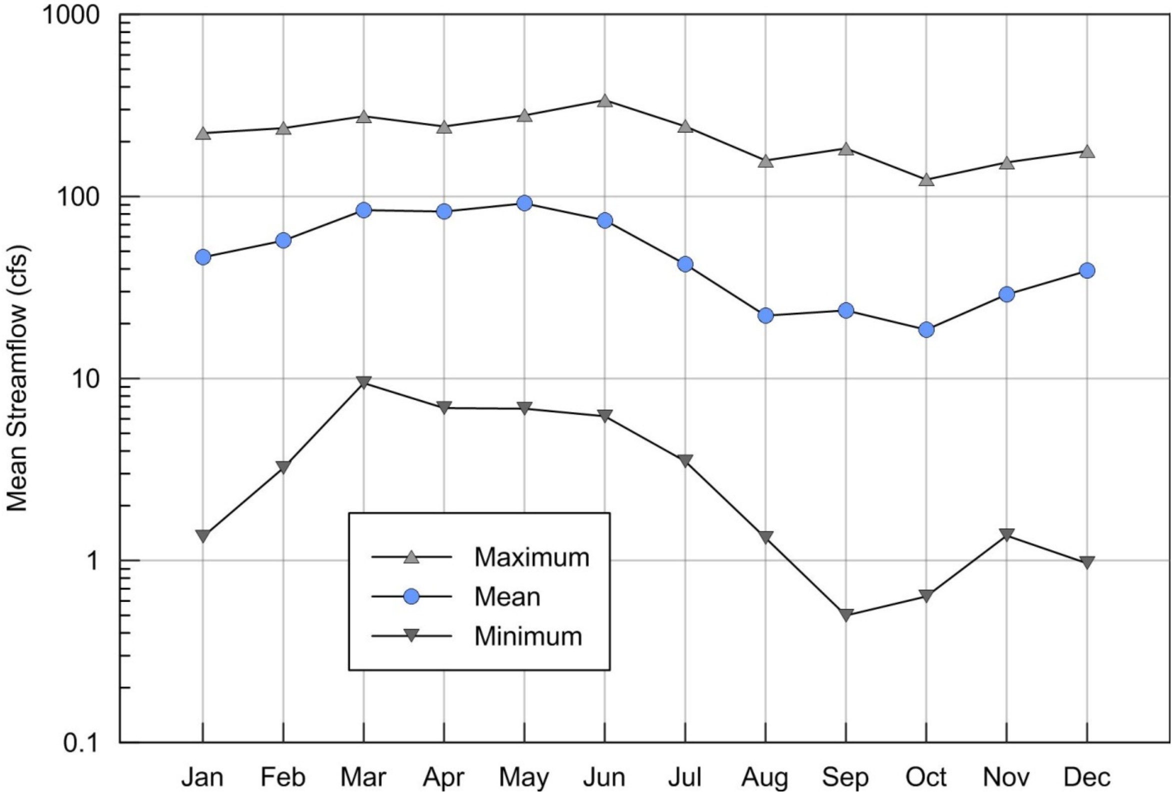

Figure 2-19. Monthly average streamflow for Indian Creek near Wyoming, IL (USGS Gage 05568800), 1960-2010

3. Public Participation and Involvement

3.1 Vermont City Reservoir and Sugar Creek Watershed Public Participation and Involvement

The general public living within a proposed TMDL watershed has an important role in the design, development, and successful implementation of any TMDL impacting that watershed. Local citizens often have unique information and perspectives concerning historic and current activities within a watershed that improve our understanding. In addition, the local citizenry will be integral to the acceptance and successful implementation of the different watershed practices that may be proposed as a result of the TMDL process. The early establishment of an open dialogue with the public also helps alleviate any concerns the local citizenry have about the purpose and extent of any regulatory impacts associated with the TMDL.

To meet these objectives, the ISWS, along with the IEPA, held a public meeting at the City Building in Vermont, IL on December 4, 2012. This meeting was an opportunity for the public to receive information and comment on the draft Stage 1 report. There were 26 attendees at this public meeting. A similar meeting will be held following completion of the draft Stage 3 report. This section will be updated after the Stage 3 public meeting occurs.

ISWS staff have met and/or contacted the manager of the City of Vermont Water Department, Road Commissioner for El Dorado Township in McDonough Co., the Road Commissioner for Oakland Township in Schuyler County and Illinois Department of Transportation (IDOT) Region 4. In addition, project staff have met with operators from both the Astoria and Table Grove wastewater treatment facilities. All departments and individuals contacted have been extremely helpful and supportive. Staff at Vermont Water Dept., Astoria STP, and the Table Grove STP have been especially helpful to this project by providing access to their facilities for sampling purposes and their continued willingness to share their expertise and institutional knowledge.

4. Sugar Creek and Vermont City Reservoir Water Quality Standards

This section of the report provides information on the water quality standards and designated uses as they apply to Sugar Creek and Vermont City Reservoir. The water quality standards are set by the Illinois Pollution Control Board (IPCB) to protect designated beneficial uses of surface waters, including aquatic life, indigenous aquatic life, primary contact (swimming), public and food processing water supply (drinking water), secondary contact, aesthetic quality, and fish consumption.

A detailed description of the assessment process can be found in the IEPA Integrated Water Quality Report (IEPA, 2010 and 2012) for each designated beneficial use. First, the designated use attainment is determined by analyzing various types of information, including biological, physicochemical, physical habitat, and toxicity data. If the water body is determined to be impaired, additional information is analyzed to determine potential causes and sources of impairment.

4.1 Designated Uses for Sugar Creek and Vermont City Reservoir

In Illinois, all streams and inland lakes are designated as general use waters unless there is a specific designation for these waters. The general use standards “protect the State's water for aquatic life …, wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the State's aquatic environment. Primary contact uses are protected for all General Use waters whose physical configuration permits such use.” (Ill. Adm. Code 302.202). Waters designated for multiple uses must meet the most stringent requirements. Table 4-1 summarizes designated uses and applicable water quality standards in Illinois.

Sugar Creek comes under the category of general use and does not have any other designated uses or standards associated with it. Vermont City Reservoir provides potable water to Vermont. Thus, public and food processing water supply use is one of the designated uses and all standards associated with it must be met in addition to any requirements associated with aquatic life, primary and secondary contact, aesthetic quality, and fish consumption uses.

4.2 Causes of Impairment

The 2010 Draft Illinois Integrated Water Quality Report (IEPA, 2010) lists Vermont City Reservoir as impaired with respect to aesthetic quality and public water supply use. Sugar Creek is listed as impaired with respect to primary contact recreation. Table 4-2 lists causes of impairment for the impaired designated uses as determined by the IEPA since 2006. The newly released 2012 draft IEPA Integrated Water Quality Report (IEPA, 2012) lists new causes of impairment (ammonia and dissolved oxygen) for Vermont City Reservoir in addition to those listed in Table 4-2 and removes atrazine as a cause of impairment.

Table 4-1. Designated uses and water quality standards applicable to Vermont City Reservoir and Sugar Creek

Illinois Waters	**Designated Use**	**Applicable Water Quality Standards**
All streams and inland lakes unless specified otherwise	Aquatic Life	General Use
	Fish Consumption	
	Primary Contact*	
	Secondary Contact	
All streams and inland lakes where water is withdrawn for human consumption**	Public and Food Processing Water Supply	Public and Food Processing
All inland lakes**	Aesthetic Quality	General Use

Notes: *Primary contact use is protected for all general use waters whose configuration permits such use.
** Vermont City Reservoir only

Table 4-2. Causes of impairment for Sugar Creek and Vermont City Reservoir by designated use (IEPA, 2012, 2010, 2008, 2006)

Waterbody	***Vermont City Reservoir***			***Sugar Creek***
Assessment Cycle	**Public Water Supply**	**Aesthetic Quality**	**Aquatic Life Use**	**Primary Contact Recreation**
2012	Manganese	Total Suspended Solids Phosphorus (Total) Cause Unknown Aquatic Algae	Ammonia (Total) Dissolved Oxygen	Fecal Coliform
2010	Manganese Atrazine	Total Suspended Solids Phosphorus (Total) Cause Unknown		Fecal Coliform
2008	Manganese	Total Suspended Solids Phosphorus (Total)		Fecal Coliform
2006	Manganese	Total Suspended Solids Phosphorus (Total) Aquatic algae		Fecal Coliform

4.3 Applicable Water Quality Standards

In Illinois, all waters must meet water quality standards for general use unless site specific standards are defined. All general use standards are applicable to Sugar Creek and Vermont City Reservoir, as specified in Title 35 Ill. Adm. Code, Part 302, Sections 302.100–302.213. In addition, all public and food processing water supply use standards are applicable to Vermont City Reservoir, as specified in Title 35 Ill. Adm. Code, Part 302, Sections 302.301–302.307. Table 4-3 lists numerical values for water quality standards and guidelines for water quality constituents identified as causes of impairment.

Table 4-3. Numerical water quality standards for impairment causes

Impairment Cause	Water Quality Standard	Type	Season	Evaluated statistic
Fecal Coliform	200 cfu/100 ml	PC	May-October	Geometric mean of 5 or more samples taken over 30-day period
	400 cfu/100 ml	PC	May-October	90th percentile of 5 or more samples taken over 30-day period
Phosphorus, Total	0.05 mg/l	AQ[*]	At all times	Individual values
Manganese	1 mg/l	ALU	At all times	Individual values
	0.15 mg/l	PWS	At all times	Individual values
Atrazine	82 µg/l	ALU (A)[+]	At all times	Individual values
	9 µg/l	ALU (C)[+]	At all times	Arithmetic average of at least four consecutive samples collected over a period of at least four days
	3 µg/l[1]	PWS[#]	At all times	Quarterly arithmetic average, Running annual average
	12 µg/l[2]	PWS[#]	At all times	Individual values

Notes: PC=Primary Contact, AQ = Aesthetic Quality, PWS = Public and food processing water supply, ALU = Aquatic Life Use

* Applicable for lakes and reservoirs with a surface area of 8.1 hectares (20 acres) or more, and any stream at the point where it enters any such reservoir or lake

\+ Derived criteria specified in IEPA (2011) for aquatic life protection (A = acute and C= chronic toxicity values)

[#] Specified in Title 35 Ill. Adm. Code, Part 611, Section 310 for untreated water

[1] Maximum Contaminant Level

[2] Specified as 4 times the Maximum Contaminant Level to assess Public Water Supply Use

The State of Illinois does not have a numerical standard for Total Suspended Solids. The narrative water quality criterion requires the waters of the State of Illinois to be free from "sludge or bottom deposits, floating debris, visible oil, odor, plant or algal growth, color or turbidity of other than natural origin" (Ill. Adm. Code, Section 302.203). The value listed in Table 4-3 is used by the IEPA as guidance in their water resources assessment process to help identify when Total Suspended Solids should be included as a cause of impairment for a specific water body. IEPA utilizes a Load Reduction Strategy (LRS) approach for those constituents that potentially contribute to the impairment but do not have a numeric water quality standard.

Changes in assessment methodology were implemented in the 2012 assessments, removing total suspended solids as a possible cause of Aesthetic Quality Use impairment. The IEPA now uses Aesthetic Quality Index (AQI) to help evaluate whether the designated use is being met (IEPA, 2012). AQI is determined using median Trophic State Index (calculated from total phosphorus, chlorophyll a, and Secchi disk transparency), macrophyte coverage, and median non-volatile suspended solids concentration.

Water quality standards for atrazine are not specified directly in the Ill. Adm. Code. A separate water criteria list was developed by the IEPA (2009) to provide water quality criteria for aquatic life use protection. The criteria are specified separately for acute and chronic effects. In addition, Primary Drinking Water Standards in Ill. Adm. Code Section 310 specify criteria for untreated water.

5. Water Quality Conditions

This section reviews water quality data available in the watershed and discusses potential point and nonpoint sources and associated causes of impairment. Historical data were collected from the IEPA database as well as downloaded from Legacy STORET and the STORET Data Warehouse. Additional historical data were identified via a search of ISWS publications. Results of the 12-month monitoring effort conducted as a part of this study are also summarized.

5.1 Data Sources

Historical data as well as data collected in this project are presented to further characterize Vermont City Reservoir and Sugar Creek watersheds. Water quality data from Vermont City Reservoir are directly relevant in determining the impairments for the studied lake segment. Additional data from the tributary contributing to the lake can aid in identification of sources of impairment and in Stage 3 TMDL development.

5.1.1 IEPA Data

There are three historical water quality sites in Vermont City Reservoir and one in Sugar Creek (Table 5-1). The site locations are displayed in Figure 5-1. Historical water quality data analyzed in this study were collected as parts of various IEPA monitoring efforts. The Ambient Lake Monitoring Program (ALMP) and Volunteer Lake Monitoring Program (VLMP) collect water quality and sediment samples and record field observations of lake conditions. Together these programs produced the bulk of the historical data available for Vermont City Reservoir. Data collection at the Sugar Creek site was conducted as part of the Ambient Water Quality Monitoring Network (AWQMN). Data collection was conducted during the years listed in Table 5-2.

Table 5-1. Historical water quality sites, IEPA data

Station Code	Location	Waterbody	Agency
RDM-1	VERMONT CITY L SITE 1	Vermont City Reservoir	IEPA
RDM-2	VERMONT CITY L SITE 2	Vermont City Reservoir	IEPA
RDM-3	VERMONT CITY L SITE 3	Vermont City Reservoir	IEPA
DH-01	Sugar Creek near Frederick, IL	Sugar Creek	IEPA

Table 5-2. IEPA historical water quality data availability

Station Code	**Site Type**	**Constituent**	**Year Sampled**
RDM-1	Lake	TP, TSS, VSS	1977, 1989, 2001, 2005, 2009, 2010, 2011
		Atrazine, Chl, Mn	2001, 2005, 2009, 2010, 2011
RDM-2	Lake	TP, TSS, VSS	1977, 2001, 2005
		Chl	2001, 2005
RDM-3	Lake	TP, TSS, VSS	1977, 2001
		Chl	2001
DH-01	Stream	Fecal Coliform	1981-2006

Notes: TP = total phosphorus, TSS = total suspended solids, VSS = volatile suspended solids, Chl = chlorophyll a, Mn = manganese.

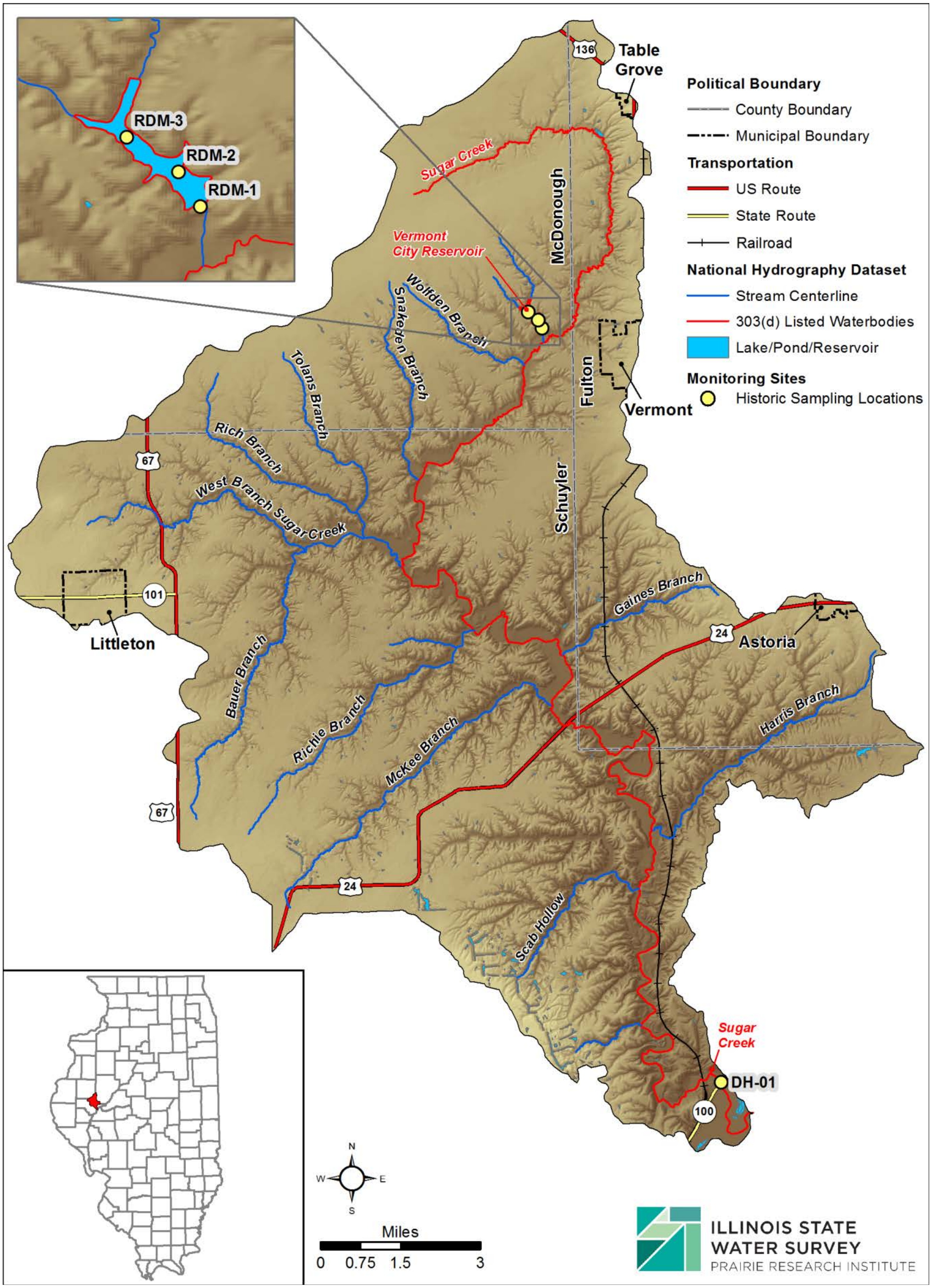

Figure 5-1. Location of historical water quality stations, Sugar Creek

5.1.2 Syngenta Data

Raw water collected from the intake at Vermont City Reservoir is analyzed by Syngenta (Table 5-3). Samples are collected weekly from April to July and bi-weekly from August to March. Raw water is pumped from the intake structure to the treatment plant, approximately 200 feet downstream. Samples are collected from within the treatment plant.

Table 5-3. Historical water quality sites, Syngenta data

Station Code	Location	Waterbody	Agency
VCR	Raw water intake	Vermont City Reservoir	Syngenta

5.1.3 ISWS Historical Data

Vermont City Reservoir was included in a study the ISWS conducted, which assessed bottom conditions for several water supply impoundments in Illinois (Lin and Raman, 1990). Samples for Vermont City Reservoir were collected from a single site located at the deepest portion of the lake (8 feet) on July 18, 1989.

Water samples were collected 1 foot below the surface and 1 foot above the lake bottom. These samples were analyzed by the IEPA for turbidity, total suspended solids, volatile suspended solids, ammonia-N, nitrate-N, Kjeldahl-N, total and dissolved phosphorus, and chemical oxygen demand. Surface water samples were collected for algal identification and enumeration. Instantaneous in-situ measurements of secchi disk depth, dissolved oxygen, and temperature were taken at the same site at 2-foot intervals.

The constituents of interest for this study, total phosphorus and total suspended solids, are incorporated into the IEPA database. The location corresponds to site RDM-1 (Table 5-4). The results are presented together with the other IEPA data for this site in the subsequent parts of the report.

Table 5-4. ISWS historical water quality station

Station Code	Location	Waterbody	Agency
RDM-1	Vermont City Reservoir, deepest point	Vermont City Reservoir	ISWS

5.1.4 Project-Related Monitoring

New data were collected at 19 water quality sites starting in March 2011. Two sites were located in the Vermont City Reservoir watershed. Seventeen sites were located on Sugar Creek or its major tributaries. The monitoring continued through October 2012; however, only data collected between March 1, 2011 and February 29, 2012 are presented in this report. After completing all QA reviews, the additional eight months of data will be provided to the IEPA in order to be available for future modeling efforts associated with Stage 3. Watershed monitoring activities carried out during this project are described in detail in the project Quality Assurance Project Plan (QAPP) and summarized below (ISWS, 2011b).

5.1.4.1 Vermont City Reservoir Monitoring

Data collection for Stage 1 TMDL Development for Vermont City Reservoir (McDonough County, IL) included monitoring of Vermont City Reservoir and its major tributary. The monitoring is designed to quantify current loads and to identify contributions from different sources and locations.

The monitoring sites for Vermont City Reservoir are listed in Table 5-5, along with the constituents to be sampled. A map of sampling sites for Vermont City Reservoir is provided in Figure 5-2. One site is located on a tributary draining to Vermont City Reservoir and one at the Vermont City Reservoir outfall.

Table 5-5. Sampling locations for Vermont City Reservoir TMDLs

Station Code	*Stream & Location*	*ISWS Data*		*WQ Sampling*		
		Stage Record	Streamflow Record	TP, TSS, VSS, Mn	Atrazine	Chlorophyll
DHZC-01	Vermont City Reservoir spillway	X	X	X	X	X
DHZC-02	Inflow to Vermont City Reservoir	X	X	X	X	

Sampling consisted of routine weekly sampling with additional storm sampling. Both sites were equipped with gaging equipment (15-min. gage record). At both sites discharge measurements were performed throughout the range of water levels experienced in order to develop a continuous record of streamflow. Automated pump samplers were installed at both locations to ensure samples are obtained during runoff events. These samplers were slaved to the stage sensor, allowing sample frequency to be driven by changes in stage. This sampling strategy, when conducted at a gaged site, provides representative samples from across the entire stage record so that accurate constituent loadings delivered to and retained in the reservoir can be determined. The Vermont City Reservoir spillway site is shown in Figure 5-3.

Water quality samples were analyzed for Total Phosphorus (TP), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Manganese (Mn), and Atrazine. VSS values help determine the mineral and organic portion of TSS loads delivered and provide useful information to help guide proposed remediation actions. Atrazine samples were collected weekly (and during storm events) from April to July and biweekly from August to March. Biweekly samples taken during the summer period (June-September) at the Vermont City outfall were also analyzed for chlorophyll a. The sampling timeline is provided in Table 5-6.

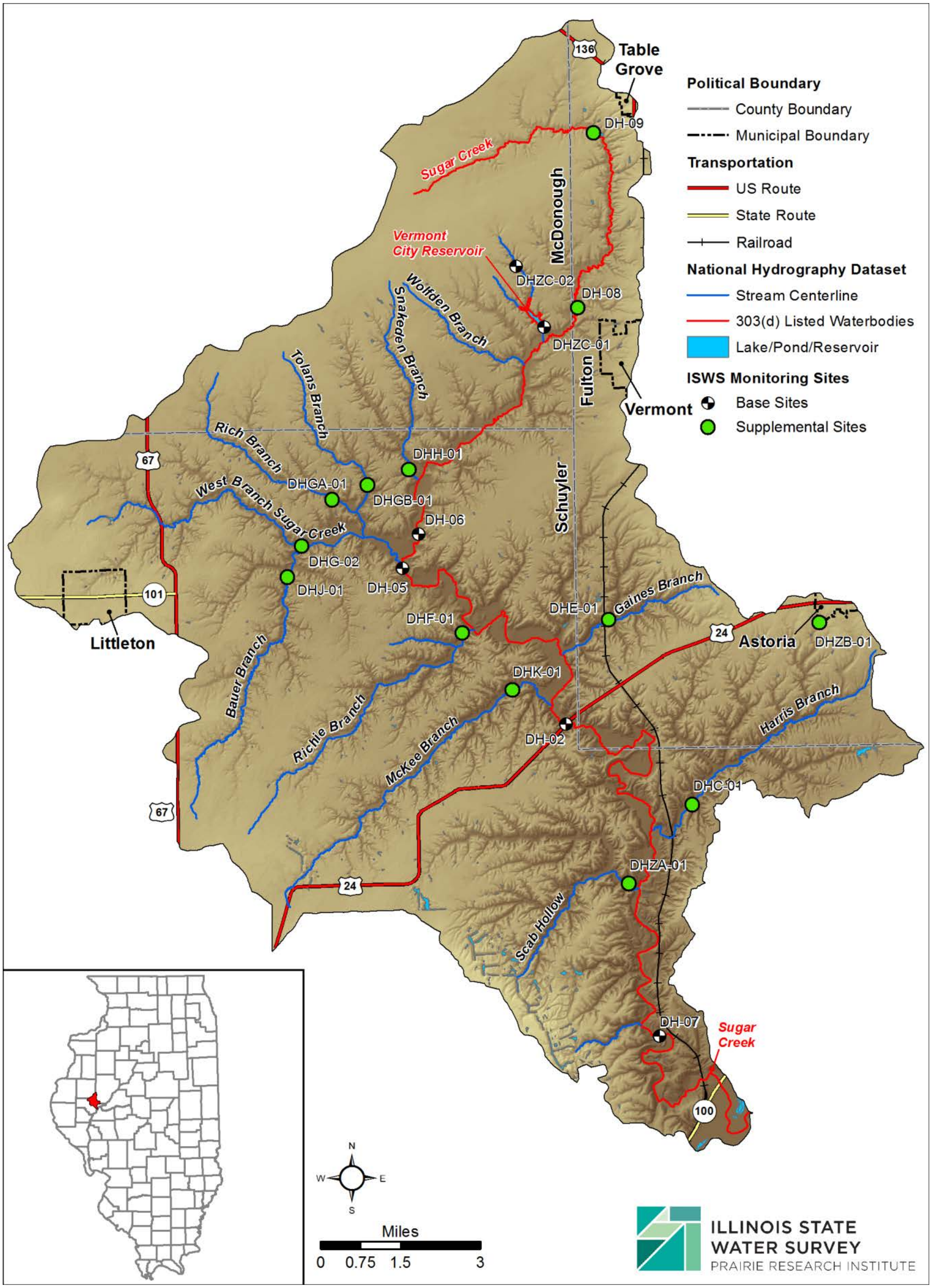

Figure 5-2. Location of ISWS monitoring sites within the Sugar Creek watershed


Figure 5-3. Vermont City Reservoir spillway

Table 5-6. Sampling timeline for TMDL monitoring project

		2011										2012									
Monitoring Activity		**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**
Vermont City Reservoir TMDL Sites																					
2 Base Sites	Streamgaging	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
2 Base Sites	Water Quality Sampling - TP, TSS, VSS, Mn	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S	W+S		
2 Base Sites	Water Quality Sampling - Atrazine	BW	W+S	W+S	W+S	W+S	BW	BW	BW	BW	BW	BW	BW	BW	W+S	W+S	W+S	W+S	BW		
Outflow Base Site Only	Water Quality Sampling - Chlorophyll				BW	BW	BW	BW									BW	BW	BW	BW	
Sugar Creek TMDL Sites																					
4 Base Sites	Streamgaging	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
4 Base Sites	Water Quality Sampling - Fecal Coliform			6/mo	6/mo	6/mo	6/mo	6/mo	6/mo							6/mo	6/mo	6/mo	6/mo	6/mo	6/mo
13 Supplemental Sites	Discharge Measurements			6/mo	6/mo	6/mo	6/mo	6/mo	6/mo							6/mo	6/mo	6/mo	6/mo	6/mo	6/mo
13 Supplemental Sites	Water Quality Sampling - Fecal Coliform			6/mo	6/mo	6/mo	6/mo	6/mo	6/mo							6/mo	6/mo	6/mo	6/mo	6/mo	6/mo

Note: W + S = Weekly + Storm sampling, BW = Bi-weekly sampling, 6/mo = A set of 6 samples collected within a 30-day period

Table 5-7 shows statistics for instantaneous discharge at the time of sampling. While continuous discharge data are available for both samples sites, the statistics presented here focus on conditions during water quality sample collection. Additional flow analysis can be found in Section 5.2 Flow Data Analysis (page 49).

Both sites went dry with zero discharge at some point during water quality sampling. In those cases a sample was collected from a pool, if present. Vermont City Reservoir spillway (station DHZC-01) was always sampled regardless of whether there was an outflow or not. Samples were marked as “zero discharge” samples.

It is important to note that higher discharges were sampled at the inflow site than at the spillway site. This is due to a difference between a stream response and lake response to storms and also due to lake levels being below the spillway during a substantial portion of the sampling period.

Table 5-7. Discharges during water quality sampling in Vermont City Reservoir watershed, project data (cfs)

Station Code	Start Date	End Date	Number Measurements	Minimum	Average	Maximum	Number Zero Discharges
DHZC-01*	3/1/2011	2/29/2012	79	0	9.11	94	44 (56%)
DHZC-02*	3/1/2011	2/29/2012	58	0	10.4	130	7 (12%)

Note: * Continuous gage data available, statistics shown only for times when water quality samples were collected

5.1.4.2 Sugar Creek Monitoring

Data collection for Phase 1 TMDL Development for Sugar Creek included monitoring of Sugar Creek and its major tributaries. The monitoring is designed to identify problematic reaches or sub watersheds (source monitoring) that contribute significantly to the fecal coliform levels found in Sugar Creek. While monitoring sites were identified as base sites or supplemental sites, the distinction between these sites for Sugar Creek is only a reference to whether the site is gaged. The sampling frequency at base sites and supplemental sites was identical.

The Sugar Creek TMDL monitoring sites are listed in Table 5-8, along with the data collected at each site. The location of the sampling sites is shown in Figure 5-2. Six sites were located directly on Sugar Creek and 11 sites were located on tributaries to Sugar Creek.

Table 5-8. Sampling locations for Sugar Creek TMDLs

Figure ID	*Stream & Location*	*Site Type*	*ISWS Data*			
			Stage Record	Streamflow Record	Instantaneous Discharge	Fecal Coliform Sampling
DH-06	Sugar Creek, above West Branch	B	X	X		X
DH-05	Sugar Creek, below West Branch	B	X	X		X
DH-02	Sugar Creek, below McKee Branch (Rte 24)	B	X	X		X
DH-07	Sugar Creek	B	X	X		X
DH-08*	Sugar Creek, U/S of Vermont City Reservoir	S			X	X
DHH-01	Snakeden Branch	S			X	X
DHGB-01	Tolans Branch	S			X	X
DHGA-01	Rich Branch	S			X	X
DHG-02	West Branch	S			X	X
DHJ-01	Bauer Branch	S			X	X
DHF-01	Richie Branch	S			X	X
DHE-01	Gaines Branch	S			X	X
DHK-01	McKee Branch	S			X	X
DHC-01*	Harris Branch	S			X	X
DHZA-01	Unnamed tributary in Scab Hollow	S			X	X
DH-09*	Sugar Creek, below Table Grove STP outfall	S			X	X
DHZB-01*	Unnamed tributary, below Astoria STP outfall	S			X	X

Note: U/S = upstream; B = Base site; S = Supplemental site; STP = Sewage treatment plant; * = site located on a stream with disinfection exemption

Base sites were equipped with gaging equipment (15-min. gage record). At each base site discharge measurements were performed throughout the range of water levels experienced in order to develop a continuous record of streamflow. Supplemental sites did not have stage continuously monitored. Discharge measurements were performed at supplemental sites only at the time of sample collection.

Fecal coliform sampling at all sites consisted of a set of 6 samples collected within a 30-day period during each month from May to October. A stratified random sampling approach was utilized for scheduling fecal coliform sampling in the Sugar Creek watershed. In the planned sampling design, two field research specialists visited a subset of the Sugar Creek sites up to three days per week every week until six samples were collected at all 17 sites that month. In an effort to minimize travel times for field staff and lab couriers in order to meet short hold times associated with fecal coliform samples, the following guidelines were developed when randomly determining the sampling dates for each site.

- Sugar Creek monitoring sites were assigned to one of two regions: upstream or downstream. The nine upstream sites were those located at or above the confluence of Sugar Creek and West Branch Sugar Creek. The eight downstream sites were located below West Branch Sugar Creek.
- At least twelve sites were selected each day (typically 6 upstream, 6 downstream).
- All 17 sites were eligible for drawing every day.
- A site was visited only once per day.
- Once a site had been visited and sampled six times, it was no longer included in the daily drawings for that month.

The fecal coliform sampling routine can be summarized as follows:

- On the first day of sampling each month, sites from the downstream region were randomly selected and divided between the field staff. After sampling these sites, the field staff relinquished samples to the lab courier in the field. The randomly selected upstream sites were then sampled in the afternoon. At the end of the field day the lab courier returned to the Sugar Creek watershed for a second pick-up of samples from these upstream sites.
- The following sampling day, randomly selected upstream sites were sampled in the morning, while the randomly selected downstream sites were sampled in the afternoon.
- The starting region for the watershed was alternated in this manner every morning until all 17 sites were visited six times within 30 days.

Table 5-9 shows statistics for instantaneous discharge at the time of sampling. While continuous discharge data are available for the four base sites, the statistics presented here focus on conditions during water quality sample collection. Additional flow analysis can be found in Section 5.2 Flow Data Analysis (page 49).

Almost all sites were found dry with zero discharge at some point during water quality sampling. In those cases a sample was collected from a pool, if present, and marked as “zero discharge” samples.

It is important to note that there is significant variation in the maximum discharge sampled at the individual sites. This is due to the inherent differences between watersheds, such as slope and area draining to the individual sites. The randomized sampling protocol utilized to determine when individual sites were visited would also influence this statistic.

Table 5-9. Discharges during water quality sampling in Sugar Creek watershed, project data (cfs)

Station Code	Start Date	End Date	Number Measurements	Minimum	Average	Maximum	Number Zero Discharges
Sugar Creek							
DH-02*	5/4/2011	10/27/2011	36	0	58.0	521	1 (3%)
DH-05*	5/3/2011	10/25/2011	36	0	72.7	1,412	12 (33%)
DH-06*	5/4/2011	10/20/2011	36	0	17.8	131	13 (36%)
DH-07*	5/3/2011	10/27/2011	36	0.11	241	3,792	0 (0%)
DH-08	5/3/2011	10/27/2011	36	0	18.3	360	11 (31%)
DH-09	5/3/2011	10/27/2011	36	0	5.8	38.5	1 (3%)
Tributaries							
DHC-01	5/3/2011	10/25/2011	36	0.05	9.9	145	0 (0%)
DHE-01	5/3/2011	10/27/2011	36	0	3.0	51.5	15 (42%)
DHF-01	5/3/2011	10/27/2011	36	0	3.7	45.8	13 (36%)
DHG-02	5/3/2011	10/27/2011	36	0	5.0	37.1	15 (42%)
DHGA-01	5/3/2011	10/20/2011	36	0	2.2	18	15 (42%)
DHGB-01	5/3/2011	10/27/2011	36	0	1.0	7.1	16 (44%)
DHH-01	5/10/2011	9/29/2011	30	0	5.7	99.4	11 (37%)
DHJ-01	5/4/2011	10/25/2011	36	0	3.2	31.8	17 (47%)
DHK-01	5/3/2011	10/27/2011	36	0	6.8	62.3	12 (33%)
DHZA-01	5/3/2011	10/25/2011	36	0.01	6.9	58.9	0 (0%)
DHZB-01	5/4/2011	10/27/2011	36	0	0.3	2.0	10 (28%)

Note: * Continuous gage data available, statistics shown only for times when water quality samples were collected

5.1.5 ISWS Groundwater Data

The ISWS historical well database contains only one record with water quality information for a well located within the Vermont City Reservoir watershed (Table 5-10). Well location is specified using Public Land Survey System (Townships, Ranges, Sections, and Plot numbers) and is displayed in Figure 5-4. The well is 405 feet deep. The sample was analyzed only for total dissolved solids and total phosphate.

Table 5-10. Records in ISWS historical well database for Vermont City Reservoir watershed

Record ID	Township	Range	Section	Plot	Date	Depth
12109	04N	01W	23	1A	6/19/1974	405

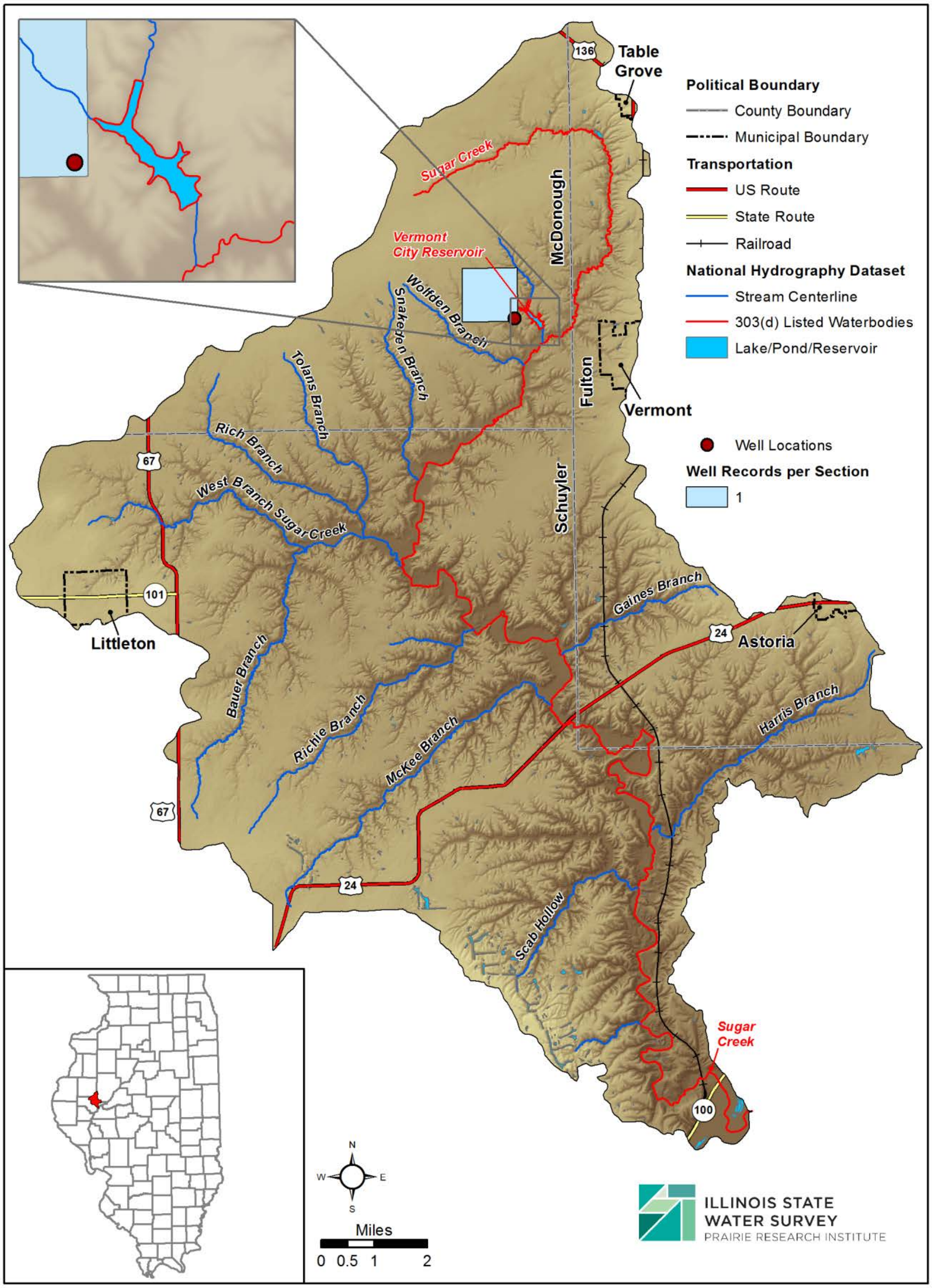

Figure 5-4. Location of wells in ISWS historical well database

5.2 Flow Data Analysis

Historical and current USGS streamflow data as well as data collected during this project are presented to characterize flows in the Sugar Creek watershed.

5.2.1 Climate Conditions during Project Monitoring

Monthly precipitation totals at Rushville, IL during the first year of project monitoring (March 2011-February 2012) are presented in Figure 5-5. Normal monthly precipitation totals typically vary 2-6 inches per month. From March 2011 to February 2012 monthly precipitation varied from less than 0.5 inches in August to nearly 10 inches in June. The monthly precipitation departure from normal is presented in Figure 5-6. March-June had above average rainfall, but seven of the next eight months experienced a precipitation deficit. The total rainfall at Rushville during the first project year was 37.25 inches, nearly 3 inches below normal.

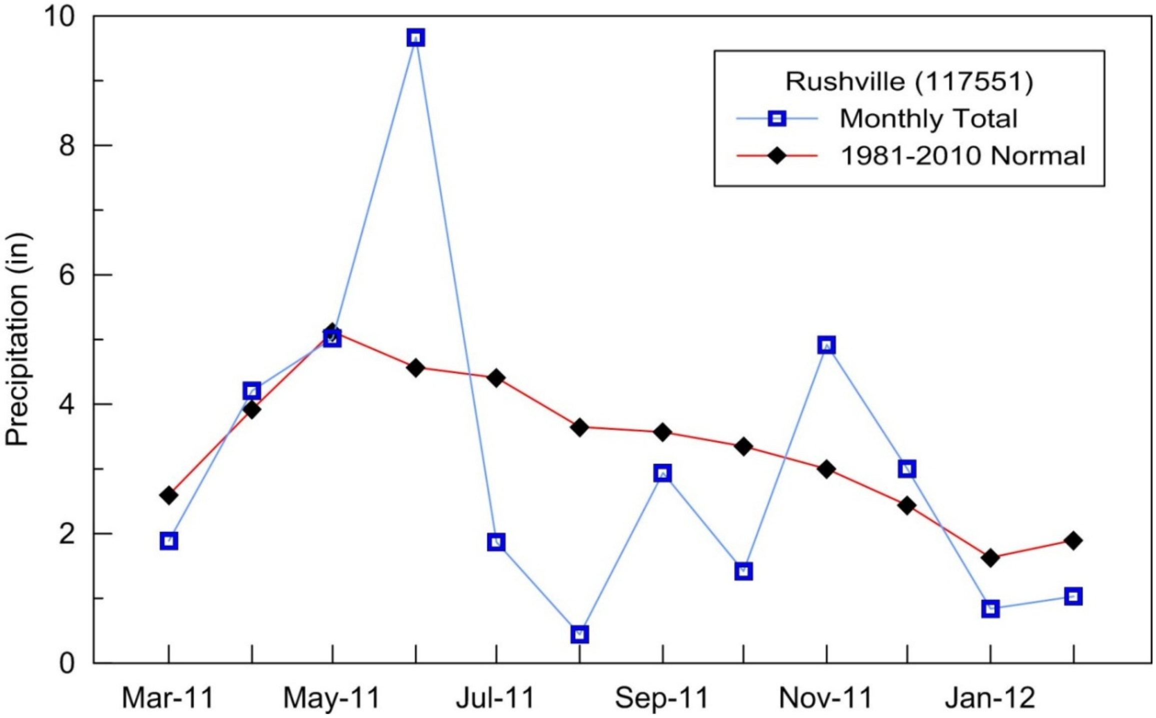

Figure 5-5. Monthly precipitation totals at Rushville, IL during study period (March 2011-February 2012), as compared to normal conditions (1981-2010)

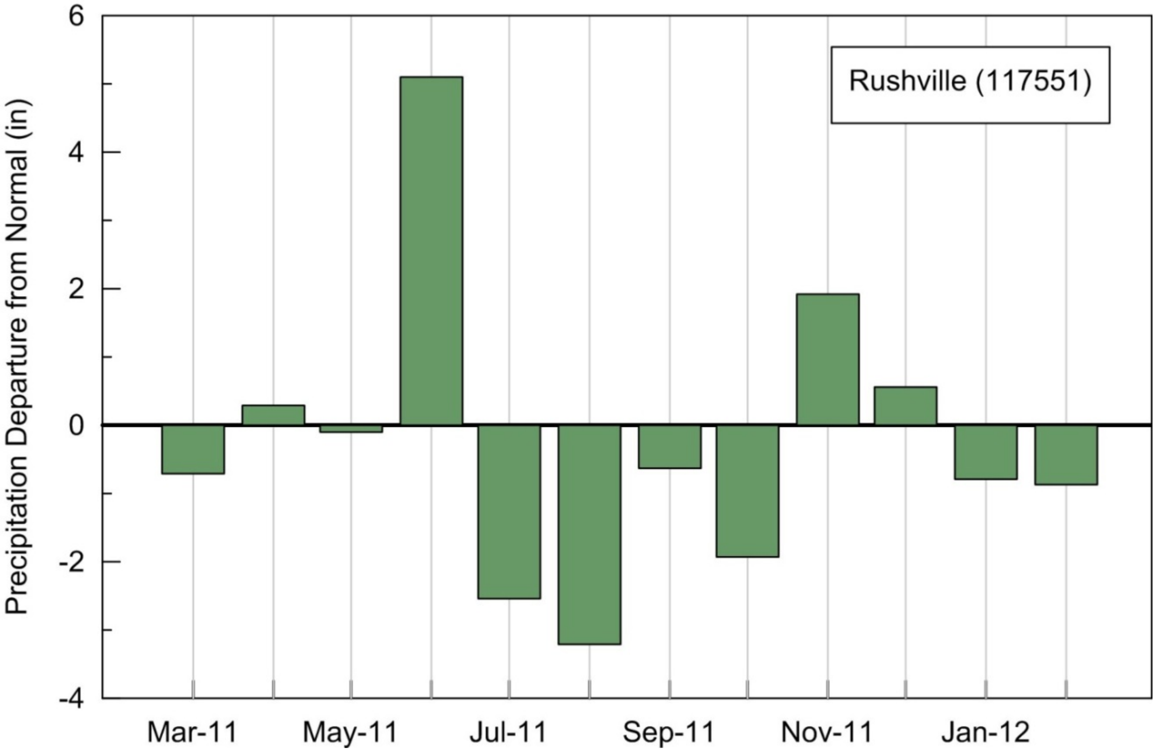

Figure 5-6. Monthly precipitation departures from normal at Rushville, IL during study period (March 2011-February 2012)

Average maximum and minimum temperatures at Rushville, IL for the first year of project monitoring are presented in Figure 5-7. Temperature ranges during the first few months of the study were normal. July, however, was warmer than normal. August was slightly warmer than normal, and September was cooler than normal. In October, the average maximum temperature was warmer than normal, while the average minimum temperature was cooler than normal. The remainder of the monitoring year (Nov-Feb) sustained above average temperatures.

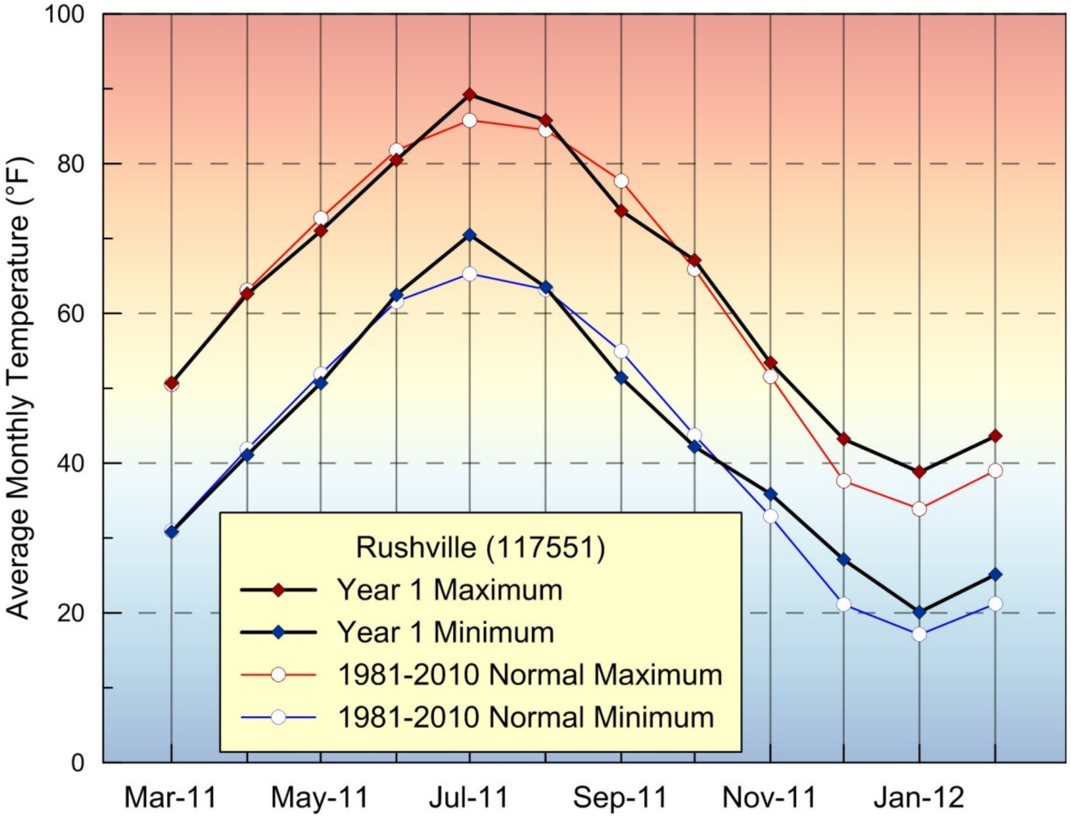

Figure 5-7. Monthly temperatures at Rushville, IL during study period (March 2011-February 2012), as compared to normal conditions (1981-2010)

5.2.2 Gaging Stations

To understand the hydrology of a watershed it is important to have long-term streamgage records. Unfortunately, there are no active or discontinued USGS streamgages in the Sugar Creek watershed. Active USGS streamgages near the Sugar Creek watershed are listed in Table 5-11 and presented in Figure 2-17.

Table 5-11. Active USGS streamgages near the Sugar Creek watershed

USGS ID	Station Name	Drainage Area (mi^2)	Period of Record
05568800	Indian Creek near Wyoming, IL	62.7	1960-Present
05569500	Spoon River at London Mills, IL	1072.0	1943-Present
05570000	Spoon River at Seville, IL	1636.0	1914-Present
05584500	La Moine River at Colmar, IL	655.0	1945-Present
05585000	La Moine River at Ripley, IL	1293.0	1921-Present

As part of the monitoring conducted for this study, six streamgages (Table 5-12) were installed in the Sugar Creek watershed. Because there can be significant variation in streamflows both within a year and from year to year, it is critical to understand how the short-term project streamflow records compare to long-term annual and seasonal streamflows for the region.

Table 5-12. ISWS project streamgages installed in the Sugar Creek watershed

Station ID	Station Description	Drainage Area (mi^2)	Start of Record
DHZC-02	Unnamed tributary to Sugar Creek (Inflow to Vermont City Reservoir)	1.06	3/24/2011
DHZC-01	Vermont City Reservoir spillway	2.22	3/24/2011
DH-06	Sugar Creek at Sugar Creek Road	41.7	3/31/2011
DH-05	Sugar Creek below West Branch	80.2	3/28/2011
DH-02	Sugar Creek at Rte 24	118	3/31/2011
DH-07	Sugar Creek at Rock Quarry Road	158	3/31/2011

Depending on the methodology selected for Stage 3 TMDL calculation, the ISWS project streamgages may be used for calibration and validation of watershed loading models. If determination of flow statistics within Sugar Creek watershed is necessary, then the long-term USGS streamgage records such as those listed in Table 5-11 would be used to provide additional information for these calculations. One of two approaches will be used to compute tributary flow statistics: application of regional regression equations previously developed for the Illinois Streamflow Assessment Model (ILSAM) or application of a record-extension method to adjust the project flow duration curves using an appropriate index station.

5.2.3 Annual Flow Variability

Annual flows at the six ISWS gages are summarized in Table 5-13. Data from the USGS gages for the same time period will be used to characterize the first year's flows. At the time of this report, USGS data had only been finalized through the end of Water Year 2011 (September 30, 2011), so the USGS data presented from Oct 2011 to Feb 2012 are provisional and subject to change. Annual flows at the selected USGS gages are summarized in Table 5-14.

Table 5-13. Annual flow statistics for ISWS gages, Project Year 1 (March 2011* - February 2012)

Station ID	Total Flow (cfs)	Mean Flow (cfs)	Total Runoff (in)
DHZC-02	212	0.62	7.4
DHZC-01	435	1.27	7.3
DH-06	7,621	23	6.8
DH-05	16,494	49	7.7
DH-02	29,224	87	9.2
DH-07	42,990	128	10.1

*Note: March 2011 is only a partial month.

Table 5-14. Annual flow statistics for USGS gages, Project Year 1 (March 2011 - February 2012)

Station ID	**Total Flow (cfs)**	**Mean Flow (cfs)**	**Total Runoff (in)**
05568800	24,150	66	14.3
05569500	362,193	990	12.6
05570000	539,319	1,474	12.3
05584500	245,555	671	13.9
05585000	430,340	1,176	12.4

Figure 5-8 presents the annual flows at the USGS stations within the bordering La Moine River watershed as compared to each gage's long-term average flow, computed using the common period 1960–2011. Water Year 2011 is defined as the period October 1, 2010–September 30, 2011, so this represents only a portion of the project's first year of data collection. Water Year 2011 was the third consecutive year of above average annual flows. Annual flows in Water Year 2010 were more than triple the long-term average.

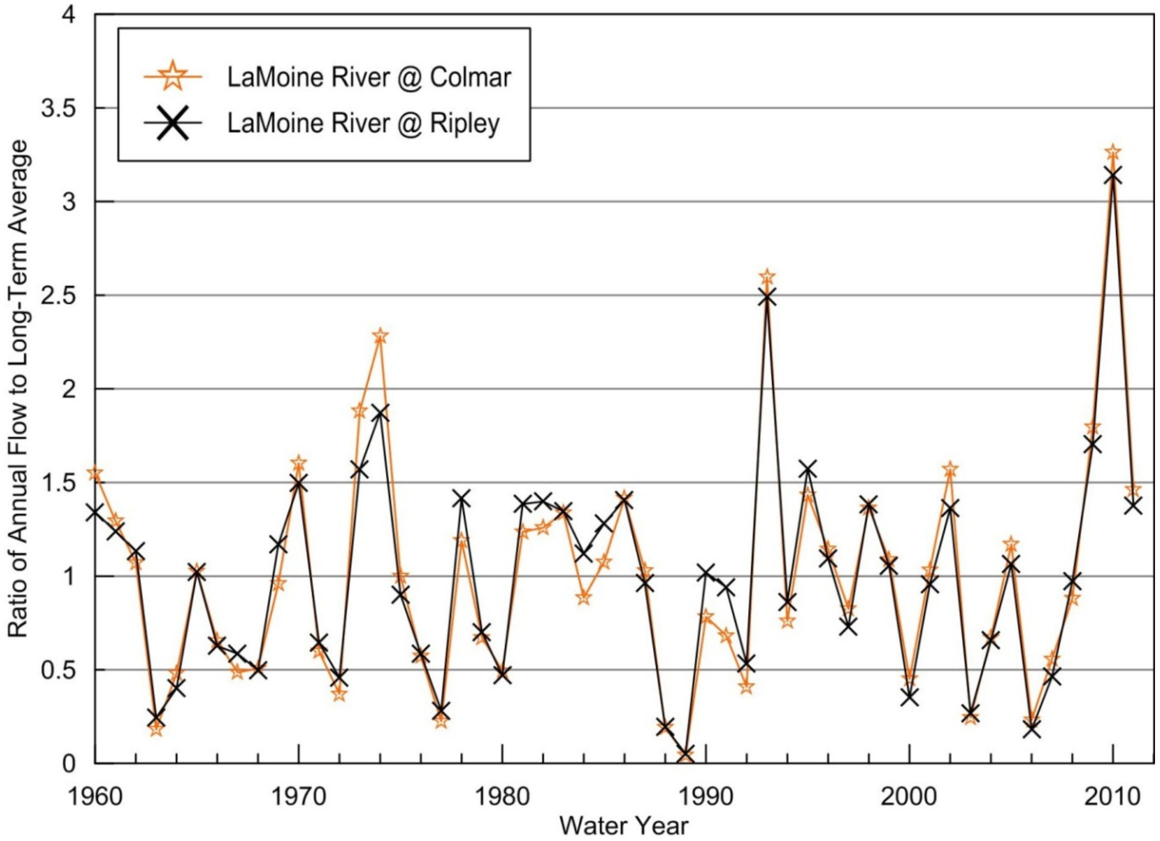

Figure 5-8. Annual flows at selected USGS stations as compared to each gage's long-term (1960-2011) average

5.2.4 Seasonal Flow Variability

While overall flows in 2011 were above average, there can be considerable variation in the monthly and seasonal flows. To explore this variability, monthly streamflows at Indian Creek from March 2011 to February 2012 are compared to its monthly streamflow statistics in Figure 5-9. Similar to the precipitation fluctuations, Indian Creek's flows in March-July 2011 were higher than median monthly flows (50th percentile), while August 2011-February 2012 flows were much closer to median streamflows. To determine how far above or below normal these 2011-2012 flows were, monthly flow values for each USGS gage's period of record were sorted, ranked, and assigned a flow percentile. These monthly streamflow percentiles are presented in Figure 5-10. The differences between the Spoon gages' and the La Moine gages' monthly flow percentiles reflect the spatial variation in rainfall and runoff events. At Spoon River watershed streamgages, summer flows, while less than median flows (50th percentile), were still mostly in the range of normal flows. La Moine River streamgages dipped into the below normal range of flows August-October 2011 and again in February 2012. At the Colmar and Ripley gages on the La Moine River, it was the second and third wettest Junes on record, respectively.

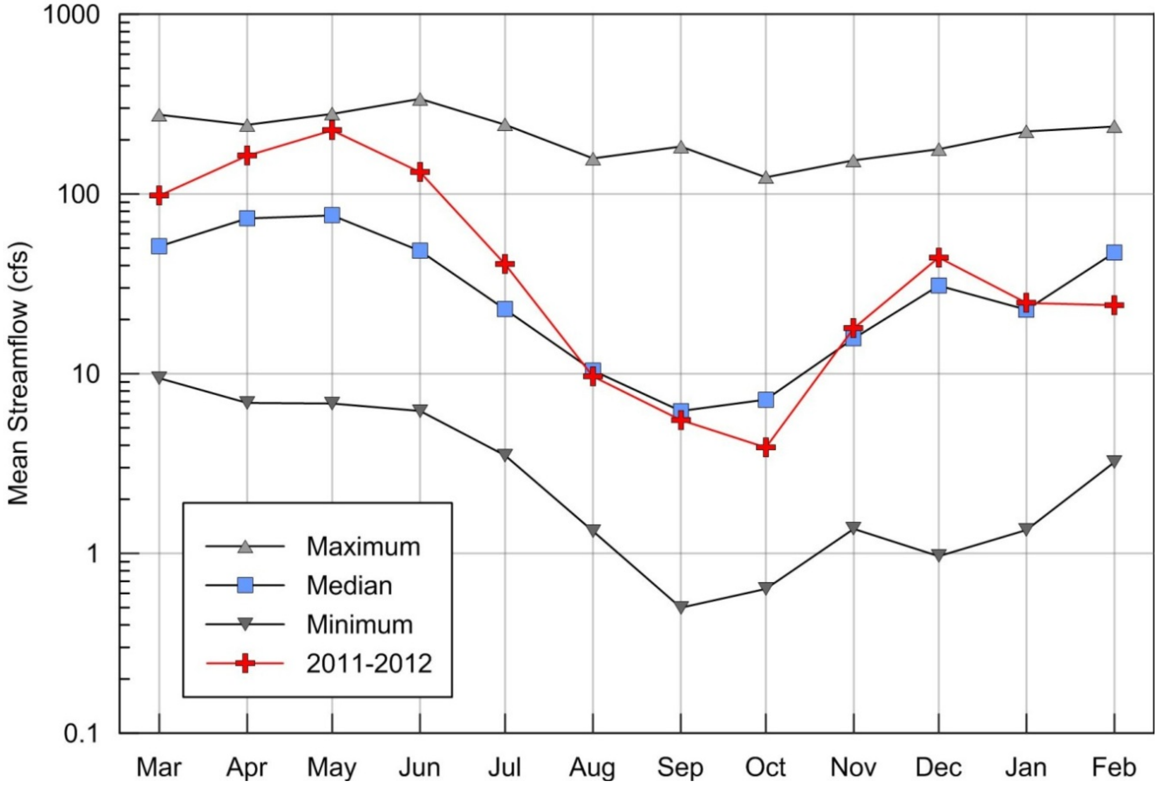

Figure 5-9. Monthly average streamflow during study period for Indian Creek near Wyoming, IL (USGS Gage 05568800) as compared to long-term monthly streamflow statistics (1960-2010)

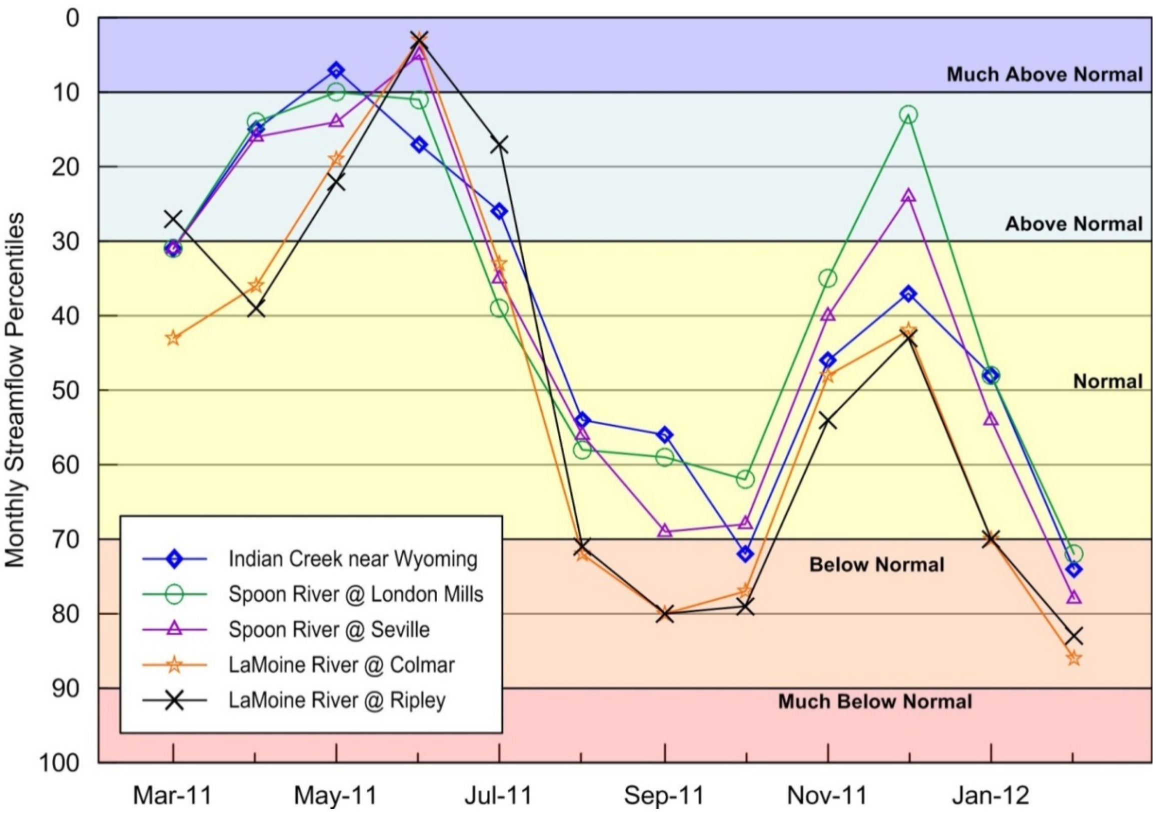

Figure 5-10. Monthly streamflow percentiles during study period (March 2011-February 2012) for selected USGS streamgages

5.2.5 Stream Flashiness

Stream flashiness refers to the rate of change in streamflow and the frequency of these changes. Differences in stream flashiness can be attributed to slope, soils, geology, land use, drainage area, and presence of point sources. An index developed by Baker et al. (2004) quantifies the flashiness of a stream by summing the absolute values of changes in streamflow and then dividing by the total of all mean daily discharges during the period of interest. This index is most commonly computed using mean daily streamflow records, but can be used with records of any regular time-step. The Richards-Baker Index (RBI) of flashiness was computed for ISWS gaging stations using mean daily, hourly, and 15-minute records of streamflow (Table 5-15). On streams of this size, using mean daily flow to characterize flashiness or stream response does not capture the rapidity of changes in the stream hydrographs. The streamflow response at DHZC-02 was the flashiest of all study sites. Due to its small drainage area, many of the runoff events at this site were measured in hours.

Table 5-15. Stream flashiness at ISWS stations during study period (unitless)

Station ID	Drainage Area (mi^2)	RBI Based on Mean Daily Flows	RBI Based on Hourly Flows	RBI Based on 15-minute Flows	Ratio of 15-min/Hourly	Ratio of 15-min/Daily
DHZC-02	1.06	0.712	5.662	7.560	1.34	10.62
DHZC-01	2.22	0.798	2.986	3.781	1.27	4.75
DH-06	41.7	0.745	1.944	2.122	1.09	2.85
DH-05	80.2	0.912	2.288	2.308	1.01	2.53
DH-02	118	0.923	1.817	1.931	1.06	2.09
DH-07	158	0.800	1.583	1.617	1.02	2.02

Typically the larger watersheds have much slower responses to storm events. For comparison, RBI values were computed for USGS gaging stations in the Spoon River and La Moine watersheds for the first year of project monitoring (Table 5-16).

Table 5-16. Stream flashiness at USGS stations during study period (unitless)

Station ID	Drainage Area (mi^2)	RBI Based on Mean Daily Flows	RBI Based on 15-minute Flows	Ratio of 15-min/Daily
05568800	62.7	0.271	0.665	2.46
05569500	1072	0.193	0.382	1.98
05570000	1636	0.177	0.267	1.51
05584500	655	0.430	0.586	1.36
05585000	1293	0.188	0.264	1.41

Stream flashiness is an important flow characteristic to take into consideration, because many water quality constituents experience rapid changes in concentration during these periods of rapid changes in streamflow, specifically during the rising limb of an event. For many small rural streams, the loadings of particulate constituents during these large flow events of short duration can comprise a majority of the annual load. In *A Study of Measurement and Analysis of Sediment Loads in Streams*, the Federal Interagency Sedimentation Project (FISP, 1940) investigated the suspended sediment loading characteristics of small streams and found that for 11 small streams in the Midwest, the 1-day maximum load experienced during a 15-month monitoring period represented 8 to 36% of the total load. While conservation tillage has increased and fertilizer usage has decreased since this early study, more recent studies still support the finding that a few high flow events can account for the overwhelming majority of non-point source loadings of particulate constituents such as TSS and TP (Markus and Demissie, 2006; Royer et al., 2006; Haggard et al., 2003; Richards et al., 2001).

5.2.6 High Flows

Instantaneous peak discharges and high flow statistics for the six ISWS gages are summarized in Table 5-17. The high flow statistics presented are the largest average flows experienced for the duration indicated during the study period. High flow statistics for the USGS gages are presented in Table 5-18, and their corresponding flow percentiles are presented in Figure 5-11.

The peak discharges and one-day high flows experienced at the Spoon watershed gages during the first year of study were normal. However, the longer duration high flows were above normal for these gages. The La Moine River at Colmar gage experienced much above normal high flows during the study year. In general, the high flows experienced during individual storm events were normal, but the average flows sustained for two to three months were unusually high for these gages.

Table 5-17. High flows at ISWS stations during study period, March 2011*-February 2012 (cfs)

Station	Peak Discharge	1-day	7-day	15-day	31-day	61-day	91-day
DHZC-02	153	19	6.5	4	3.2	2.4	2.2
DHZC-01	94	40	12.9	11.2	7.1	5.5	4.7
DH-06	1090	671	208	163	115	85	77
DH-05	3070	1850	456	380	284	203	170
DH-02	4010	3340	814	717	489	351	298
DH-07	4960	3700	1140	1020	705	501	429

*Note: March 2011 is only a partial month.

Table 5-18. High flows at USGS stations during study period, March 2011-February 2012 (cfs)

Station	Peak Discharge	1-day	7-day	15-day	31-day	61-day	91-day
05568800	1710	1400	597	358	246	216	175
05569500	8940	8820	7544	4937	3493	3119	2575
05570000	12600	12200	11167	7598	5675	4666	3991
05584500	20700	19300	9521	7040	4267	2868	2271
05585000	12100	11800	9420	9205	6474	4539	3742

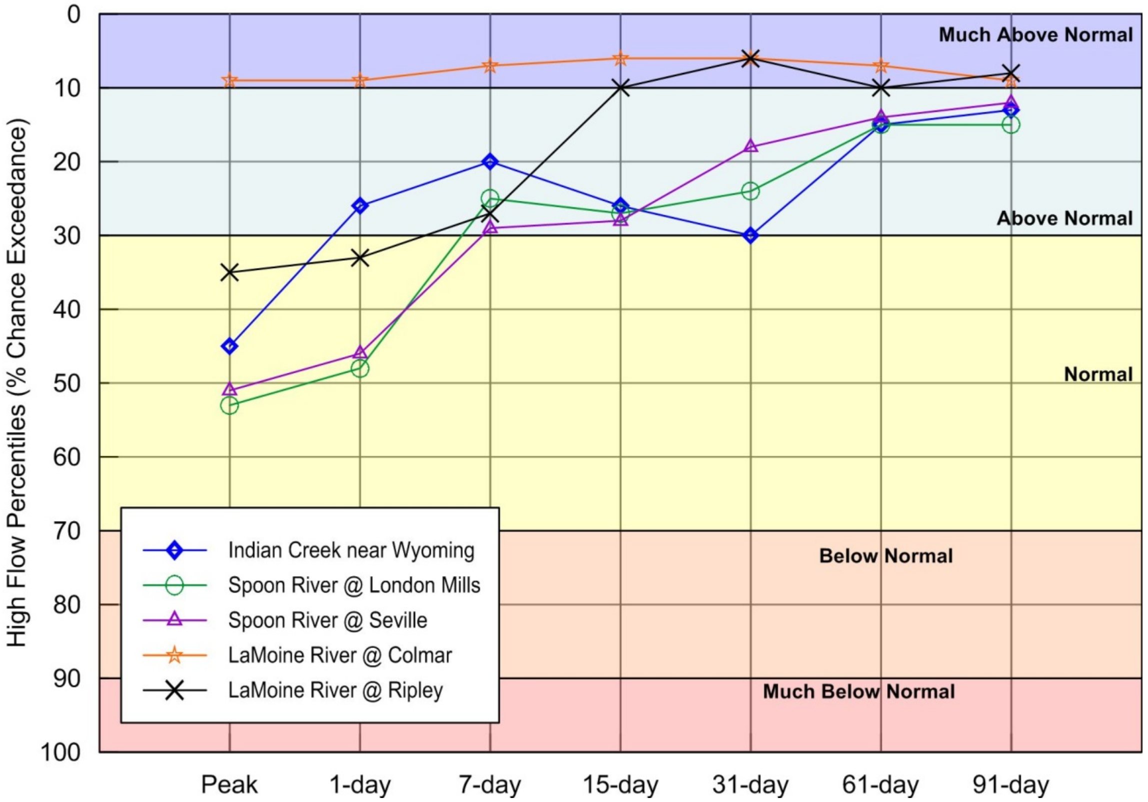

Figure 5-11. High flow percentiles during study period (March 2011-February 2012) for selected USGS streamgages

5.2.7 Low Flows

Low flow statistics for the six ISWS gages are summarized in Table 5-19. The low flow statistics presented are the lowest average flows experienced for the duration indicated during the study period. Low flow statistics for the USGS gages are presented in Table 5-20, and their corresponding flow percentiles are presented in Figure 5-12.

The low flows experienced at the USGS gages during the first year of study were mostly normal. All of the ISWS gages, except the most downstream station on Sugar Creek (DH-07), went dry during the study period, which is expected for streams of this size in this region of the state during most summers and extended dry periods. As mentioned previously, the Indian Creek gage is located downstream of the Toulon STP and would not be expected to reach zero flow due to the presence of this point source. The other USGS gages have much larger drainage areas and would not be expected to reach zero flow even during extended dry periods. Their low flows were all normal to above normal during the first year of monitoring, with the exception of the Colmar gage’s 91-day low flow, which was slightly below normal.

Table 5-19. Low flows at ISWS stations during study period, March 2011*-February 2012 (cfs)

Station	1-day	7-day	15-day	31-day	61-day	91-day
DHZC-02	0	0	0	0	0	0
DHZC-01	0	0	0	0	0	0
DH-06	0	0	0	0	0.01	0.03
DH-05	0	0	0	0	0	0.07
DH-02	0	0.01	0.02	0.06	0.15	0.42
DH-07	0.10	0.11	0.37	1.10	1.66	2.56

*Note: March 2011 is only a partial month.

Table 5-20. Low flows at USGS stations during study period, March 2011-February 2012 (cfs)

Station	1-day	7-day	15-day	31-day	61-day	91-day
05568800	3.4	3.7	3.7	3.9	4.6	5.9
05569500	59	65	67	74	81	98
05570000	87	89	98	101	115	142
05584500	8.1	9.0	11	13	15	19
05585000	25	29	30	33	37	45

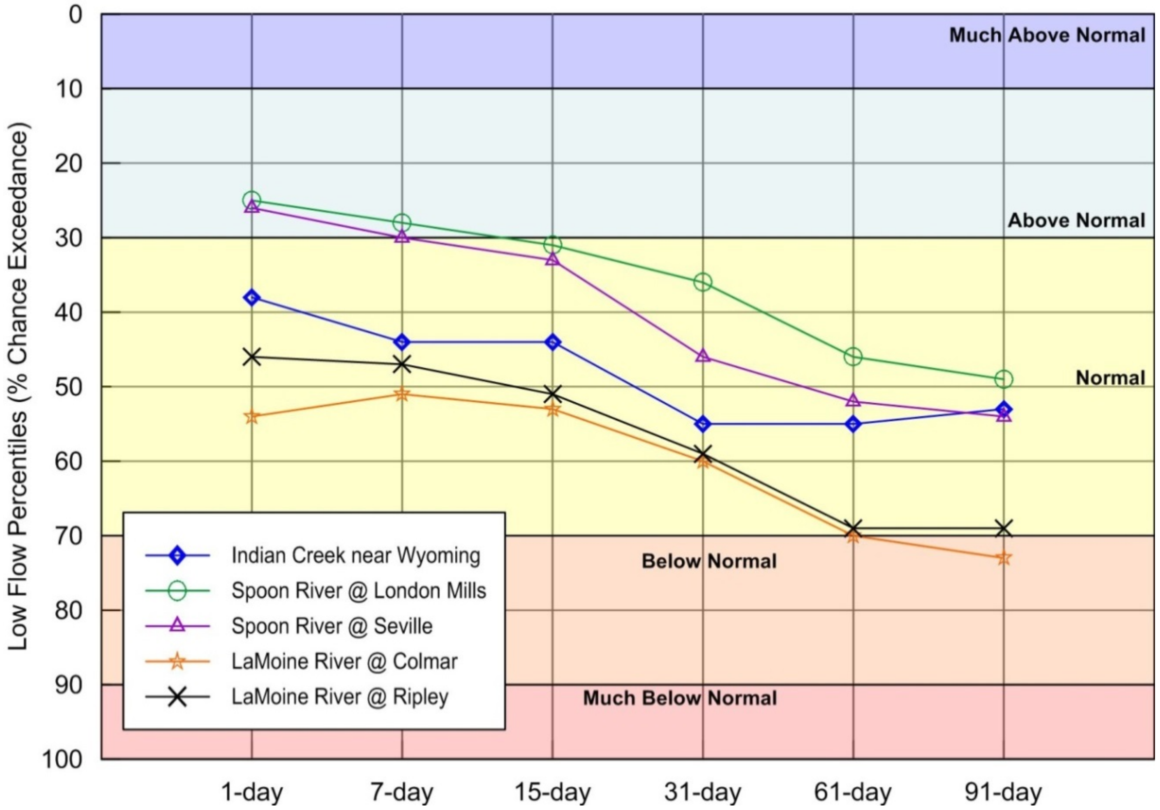

Figure 5-12. Low flow percentiles during study period (March 2011-February 2012) for selected USGS streamgages

5.2.8 Reservoir Levels

At the end of the first TMDL monitoring year, the Vermont City Reservoir level was more than 1 foot below the spillway (Figure 5-13).

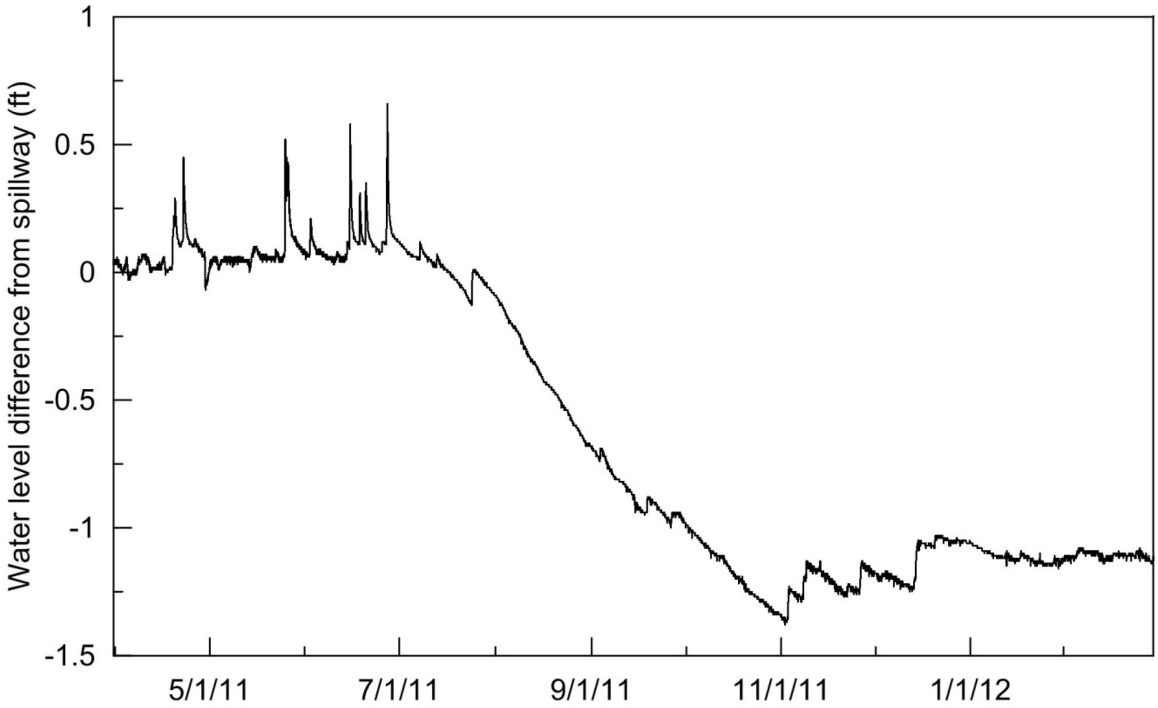

Figure 5-13. Vermont City Reservoir water level during study period

5.2.9 Reservoir Water Budget Analysis

The water budget analysis performed for the first year of monitoring estimates the gains and losses in Vermont City Reservoir's capacity from March 2011 to February 2012. The equation used for this analysis can be summarized as simply:

Storage Change = Inflow – Outflow

The main sources of inflow are tributary inflows and direct precipitation on the lake surface. The main sources of outflow are flow over the spillway, evaporation from the surface of the lake, and direct withdrawals from the lake by Vermont Water Treatment Plant (WTP). In Illinois, measures of seepage from the dam and groundwater inflows are typically considered to balance out, so these influences were not accounted for in this analysis.

The water budget is presented in Table 5-21 with monthly values presented for all inputs.

- Lake storage
- Tributary inflows
- Direct precipitation on the lake
- Evaporation
- Outflow from the lake as spillage
- Withdrawals by the Vermont WTP

A detailed explanation of the inputs and assumptions follows.

Lake storage was determined from the continuous monitoring of lake levels at ISWS station DHZC-01. In order to determine the volume of lake storage this level represents, the relationship between level and volume (stage-storage curve) is needed. No stage-storage curve for Vermont City Reservoir was available in the ISWS files. In order to estimate storage, a quadratic equation was developed relating relative depth to relative volume for Waverly Lake, another water supply reservoir in a predominantly agricultural watershed in western Illinois. In addition to having similar land use and topography, this lake was also selected because the ISWS conducted a detailed bathymetric survey of this reservoir in 2009 which produced a stage-storage curve at 1-foot intervals. This quadratic equation was applied to Vermont City Reservoir after all lake levels were converted to relative depths (using a total depth of 11 feet) to determine a corresponding relative volume. This was then converted to an estimated volume using Vermont City Reservoir's 2010 estimated capacity of 194.7 ac-ft [https://www.isws.illinois.edu/data/ilcws/drought.asp?id=05790950].

Tributary inflows were directly measured at ISWS gage DHZC-02, which represents 1.06 sq miles, of the 2.22 sq miles total lake drainage area. This leaves 1.16 sq miles of ungaged tributary inflows to the lake. These inflows were estimated as a ratio of the total gaged contributions at DHZC-02.

Precipitation values used in the analysis are those measured at Rushville. They were converted to a volume by multiplying the rainfall depth by the surface area of the lake (38.5 ac).

Pan evaporation data for the first year of monitoring was not yet available on the ISWS website. Monthly evaporation estimates for Peoria, IL were obtained from *Lake Evaporation in Illinois* (Roberts and Stall, 1967). Evaporation estimates were also converted to a volume by multiplying by the surface area of the lake.

Outflow from the lake was directly measured at ISWS DHZC-01.

Direct withdrawals from the lake are composed mostly of pumpage for water supply purposes. Typically once per year, an additional withdrawal is made from the lake during the annual opening of the mudgate for maintenance purposes. Monthly pumpage information was obtained from the Vermont WTP, and the volume of flow released via the mudgate was directly measured by ISWS personnel on April 29, 2011.

The last column in Table 5-21 represents the residual or unaccounted for volume in the water budget. The largest discrepancies occur during the months when the lake is spilling (March-July), which may suggest an error in the inflow estimates. Application of a drainage area-ratio may be problematic considering the extremely small size of the other contributing tributaries to the lake. Furthermore, any potential errors in these estimates will be amplified considering the ungaged portion of the watershed is larger than the gaged portion.

There appears to be good agreement in the water budget during periods when the lake is below spillway. However, a detailed bathymetric survey would greatly reduce the uncertainty in these water budget calculations and improve confidence in the results.

From March to July the overwhelming majority of inflow to the lake was in the form of tributary streamflow (Table 5-22). From August to December, most of the inflow was in the form of direct precipitation. In fact, no tributary inflow was estimated during September and October. During January, the primary inflow source was once again tributary streamflow, but the ice cover in February resulted in reduced streamflows so precipitation was once again the largest inflow source.

The lake was at capacity when monitoring began on 3/25/2011, so the majority of outflow for the first four full months of record (April-July) was discharge over the spillway (Table 5-23). Once the lake stopped spilling in July, the majority of outflow shifted to lake evaporation from August to October, but during the fall and winter, the majority of outflow from the lake was direct pumpage.

Table 5-21. Water budget for Vermont City Reservoir, March 2011* - February 2012

	Lake Storage ac-ft	Gaged Inflow ac-ft	Ungaged Inflow ac-ft	Direct Precip. ac-ft	**Total Inflow ac-ft**	DHZC-01 Discharge ac-ft	WTP Pumpage ac-ft	WTP Mudgate ac-ft	Lake Evap. ac-ft	**Total Outflow ac-ft**	**Residual ac-ft**
Mar-11*	**1.1**	5.9	6.5	0.0	**12.5**	5.9	1.5	0.0	1.3	**8.7**	**-2.7**
Apr-11	**-0.8**	99.4	108.7	13.5	**221.6**	177.7	5.6	6.7	10.6	**200.6**	**-21.7**
May-11	**-0.4**	130.9	143.3	16.1	**290.3**	219.8	6.2	0.0	15.5	**241.5**	**-49.2**
Jun-11	**1.5**	158.9	173.9	31.0	**363.9**	411.0	5.7	0.0	18.3	**435.0**	**72.6**
Jul-11	**-6.6**	19.8	21.7	6.0	**47.5**	47.7	6.0	0.0	20.6	**74.2**	**20.2**
Aug-11	**-19.7**	0.5	0.5	1.4	**2.4**	0.0	6.2	0.0	16.7	**22.8**	**0.8**
Sep-11	**-9.8**	0.0	0.0	9.4	**9.4**	0.0	5.4	0.0	11.5	**16.9**	**-2.3**
Oct-11	**-10.7**	0.0	0.0	4.6	**4.6**	0.0	5.8	0.0	7.3	**13.1**	**-2.2**
Nov-11	**5.5**	0.9	1.0	15.8	**17.7**	0.0	4.6	0.0	3.3	**7.9**	**-4.3**
Dec-11	**4.2**	1.2	1.4	9.6	**12.2**	0.0	4.7	0.0	1.4	**6.2**	**-1.8**
Jan-12	**-2.0**	2.2	2.4	2.7	**7.3**	0.0	4.9	0.0	1.4	**6.3**	**-2.9**
Feb-12	**0.3**	0.8	0.8	3.3	**4.9**	0.0	4.2	0.0	2.3	**6.5**	**2.0**
Annual	**-37.3**	420.5	460.2	113.5	**994.1**	862.1	60.8	6.7	110.1	**1039.7**	**8.4**

*Note: Partial month. Analysis began on 3/25/2011

Table 5-22. Monthly distribution of inflows, March 2011* - February 2012

	Gaged Inflow	**Ungaged Inflow**	**Direct Precipitation**
Mar-11 *	48%	52%	0%
Apr-11	45%	49%	6%
May-11	45%	49%	6%
Jun-11	44%	48%	9%
Jul-11	42%	46%	13%
Aug-11	19%	21%	60%
Sep-11	0%	0%	100%
Oct-11	0%	0%	100%
Nov-11	5%	6%	89%
Dec-11	10%	11%	79%
Jan-12	30%	33%	37%
Feb-12	15%	17%	68%
Average Annual	25%	28%	47%

*Note: Partial month. Analysis began on 3/25/2011

Table 5-23. Monthly distribution of outflows, March 2011* - February 2012

	Spillway Discharge	**Mudgate Operation**	**WTP Withdrawals**	**Lake Evaporation**
Mar-11 *	68%	0%	17%	15%
Apr-11	89%	3%	3%	5%
May-11	91%	0%	3%	6%
Jun-11	94%	0%	1%	4%
Jul-11	64%	0%	8%	28%
Aug-11	0%	0%	27%	73%
Sep-11	0%	0%	32%	68%
Oct-11	0%	0%	44%	56%
Nov-11	0%	0%	58%	42%
Dec-11	0%	0%	77%	23%
Jan-12	0%	0%	78%	22%
Feb-12	0%	0%	65%	35%
Average Annual	34%	0.3%	34%	31%

*Note: Partial month. Analysis began on 3/25/2011

5.2.10 Reservoir Retention Time

The average residence time of a reservoir is the volume of the water body divided by the annual inflow. The mean annual inflow to Vermont City Reservoir was estimated following the approach utilized by the Illinois Streamflow Assessment Model (ILSAM) for ungaged streams unimpacted by effluent discharges. The ILSAM was initially developed in 1985 (Knapp et al.,

1985) and has continued to be updated and expanded to 11 watersheds throughout Illinois (http://www.isws.illinois.edu/data/ilsam/). The following equation was most recently presented in Knapp and Russell (2004a):

$$Q_{mean}=0.0738\ DA\ (P–ET)$$

Where Q_{mean} (cfs) is the annual mean flow at the location of interest; DA (mi^2) is the drainage area of the watershed; P is the average annual precipitation (inches) and ET is the average annual evapotranspiration (inches). The term (P-ET) is defined as the average annual net precipitation, and was determined by Knapp and Russell (2004b) to be 9.4 inches for streams in the Galesburg Plain region of Illinois for the base period of 1940-2002.

Using this approach, the annual mean flow into Vermont City Reservoir is 1.54 cfs (1115 ac-ft/yr), and the average residence time for Vermont City Reservoir is 0.17 years, or more than 2 months.

5.3 Water Quality Data

5.3.1 Atrazine

A summary of historical and project data for atrazine data collected in Vermont City Reservoir is presented in Table 5-24 and Table 5-25 for historical and current project data, respectively. Samples taken at the intake depth are considered by the IEPA for water body assessments of Public Water Supply Use and assignment of impairment causes. However, water quality samples collected at all depths were analyzed in this section in order to provide a comprehensive discussion of lake water quality. Less than 10% of historical samples were flagged as at or below detection limit. However, most samples collected during the current project did not have detectable concentrations of atrazine (87-100% samples). The method detection limit was 0.09 µg/l.

Figure 5-14 shows data collected by Syngenta and ISWS from March 2011 to February 2012. The contracted laboratory, Prairie Analytical Systems (PAS) has a reporting limit (RL) of 5 µg /l for atrazine. Therefore any results reported below the RL, but down to the MDL are considered less reliable and would carry a "J" qualifier designation. When comparing Syngenta's data to the current project data (Figure 5-14), it appears that PAS may have been reporting false negatives (i.e., atrazine was not being detected by the lab at concentrations between the RL and the MDL). The EPA method SW 8270C (M) (Semivolatile Organic Compounds by Gas Chromatography/ Mass Spectrometry, GC/MS) was used by the PAS to detect atrazine. Syngenta utilized a Liquid Chromatography / Mass Spectrometry method for atrazine analysis. Additional efforts are planned for the final six months of data collection, which should help explain the differences between project and Syngenta atrazine data. These sampling efforts will focus on determining whether the differences can be explained by the different sampling locations and/or sampling methodology or whether differences in analytical procedures best explain the significant variation in the two atrazine data sets.

Table 5-24. Atrazine data summary, historical data (µg /l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number ND Samples
RDM-1	5/1/2001	10/18/2011	35	ND	1.9*	11	3 (9%)
SYNGENTA	1/13/2003	5/12/2011	298	0.03**	2.0**	44.7	22 (7%)**$

Notes: ND = analyte not detected in a sample
* value affected by a presence of non-detects
** detection limit not specified
$ the number of samples at or below 0.09 µg/l is shown

Table 5-25. Atrazine data summary, project data (µg /l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number ND Samples
DHZC-01	3/8/2011	2/29/2012	50	ND	ND*	6.81	45 (90%)
Mudgate	4/29/2011	4/29/2011	5	ND	ND	ND	5 (100%)
DHZC-02	3/8/2011	2/29/2012	46	ND	ND*	36.7	40 (87%)

Notes: ND = analyte not detected in a sample (detection limit 0.09 µg/l, reporting limit 5 µg/l)
* value could not be calculated due a large number of non-detects

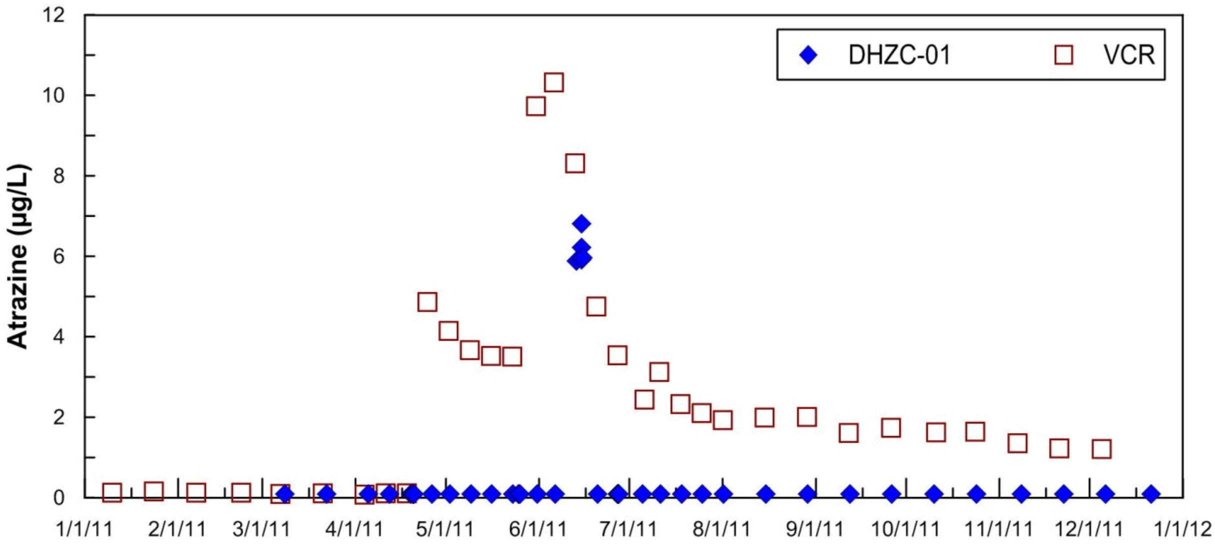

Figure 5-14. Comparison of atrazine data analyzed by Syngenta (VCR) and PAS (DHZC-01) during 2011

Title 35 Illinois Administrative Code, Part 611, Section 310, specifies atrazine standards for untreated water used as a source for public water supply. The Maximum Contaminant Level (MCL) is 3 µg/l. This value should not be exceeded by quarterly arithmetic average as well as running annual average. In addition, no observation should exceed four times the MCL (12 µg/l) in order for the water body to qualify as fully supporting the Public Water Supply Use with respect to atrazine. Aquatic life use is protected using derived criteria (IEPA, 2011). The acute toxicity standard for atrazine is 82 µg /l and should not be exceeded at any time. The chronic toxicity standard for atrazine is 9 µg/l. The chronic standard is compared to an average of four consecutive measurements collected over at least four days.

Compliance with water quality standards is summarized in Table 5-26. The acute toxicity standard was not exceeded at any site at any given time. The chronic toxicity standard was exceeded at 3% of independent sets of four consecutive observations at the SYNGENTA site. The maximum concentration for untreated water was exceeded at 1% samples collected at the SYNGENTA site. Quarterly average was exceeded at 7% and 17% of quarters at sites RDM-1 and SYNGENTA, respectively. The running annual average was exceeded at 11% and 12% of evaluation periods (four consecutive quarters) at sites RDM-1 and SYNGENTA, respectively. Quarterly average values exceeded 3 µg/l at the SYNGENTA site in the second quarters of the last three years (2009-2011). All four instances in which the running annual average exceeded 3 µg/l at the SYNGENTA site occurred during the past three years. The average of values collected at site RDM-1 during 2011 is also greater than 3 µg/l. The current project data at the spillway site do not confirm the impairment of aquatic life use or public water supply use. However, the issues regarding Reporting Limit and Method Detection Limit discussed previously affect the evaluation.

The Public Water Supply water quality standard does not apply to Vermont City Reservoir tributaries; however, it is useful to evaluate exceedances of the standard value to evaluate individual tributaries and their contribution to the overall concentrations found in the lake. Data collected at the inflow site show an impairment of aquatic life use with the chronic toxicity standard exceeded in 17% of independent sets of four consecutive observations.

Table 5-26. Compliance with atrazine water quality standard

	Aquatic Life Use			**Untreated Water**			
	Acute	**Chronic**	*****	**Quarterly average**[$]	**Running annual average**	*****	**Maximum**
Station Code	**82 µg/l**	**9 µg/l**	**9 µg/l**	**3 µg/l**	**3 µg/l**	**3 µg/l**	**12 µg/l**
Historic data							
RDM-1	0 (0%)	0 (0%)	1 (3%)	1 (7%)	1 (11%)	2 (6%)	0 (0%)
SYNGENTA	0 (0%)	2 (3%)	8 (3%)	6 (17%)	4 (12%)	59 (20%)	3 (1%)
Project data							
DHZC-01	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (10%)	0 (0%)
Mudgate	0 (0%)	0 (0%)[$]	0 (0%)	0 (0%)[$]	0 (0%)[$]	0 (0%)	0 (0%)
DHZC-02	0 (0%)	2 (17%)	4 (9%)	1 (20%)	2 (100%)	6 (13%)	4 (9%)

Notes: *individual exceedances of the value are shown for comparison only and do not represent a violation of water quality standard

[$] data insufficient to calculate required statistic

Figure 5-15 and Figure 5-16 show atrazine concentrations plotted in time for historical and current project data, respectively. Discharge for the two current project sites with a stream gage is also shown. The gaps in the discharge plot show dry periods of zero flow (i.e., there were no missing streamflow data from the gage installation). Only one site at the reservoir itself has historical data available, RDM-1. The highest individual atrazine concentrations for this site occurred the last three years of data, 2009-2011. There are no historical data on stream sites.

SYNGENTA's data on raw water intake concentrations show large variations from year to year (Figure 5-17). Odd years have higher mean concentrations than even years, likely reflecting the prevalent corn-soybean rotation in the watershed. There is also a significant monthly pattern in atrazine concentrations collected during odd years (Figure 5-18). The low concentrations at the beginning of a year (January-March) significantly increase during April (transitional month) to high concentrations in late spring (May-June) and then slowly decline through the end of the year, again reflecting activities tied to the planting/growing season for agricultural land use.

Figure 5-19 presents the observed atrazine concentrations plotted versus their corresponding instantaneous discharge for the current project data. Concentrations measured at zero discharge conditions are plotted on the y-axis for comparison. No discharge data were available for the historical data set. The highest atrazine concentrations were measured at the highest flows for the site located at the inflow. The Vermont City Reservoir spillway (site DHZC-01) shows no significant relationship between atrazine concentration and discharge, although the significant number of non-detects may also influence this evaluation.

Figure 5-20 compares distributions of atrazine concentrations at the project monitoring sites. The Vermont City Reservoir spillway (site DHZC-01) shows a smaller variation and lower mean than the inflow site. Again, the significant number of non-detects may also influence this evaluation.

A statistical comparison of means[1] was carried out using samples collected at non-zero discharges during dates common across the two sites. This was necessary because of the relationship between atrazine concentrations and discharge and a higher number of samples collected during high flow regime at the inflow site (DHZC-02). The difference in mean atrazine concentrations between the two sites cannot be statistically confirmed. The lack of values below the Reporting Limit (5 µg/l) affects the evaluation.

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. In spite of the low concentrations, the Vermont City Reservoir spillway site (DHZC-01) carried higher mean atrazine loadings (Figure 5-21). Any difference in mean atrazine loadings among the sites cannot be statistically confirmed. The lack of values below the Reporting Limit (5 µg/l) affects the evaluation.

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[1] Statistical significance was determined using 95% confidence level.

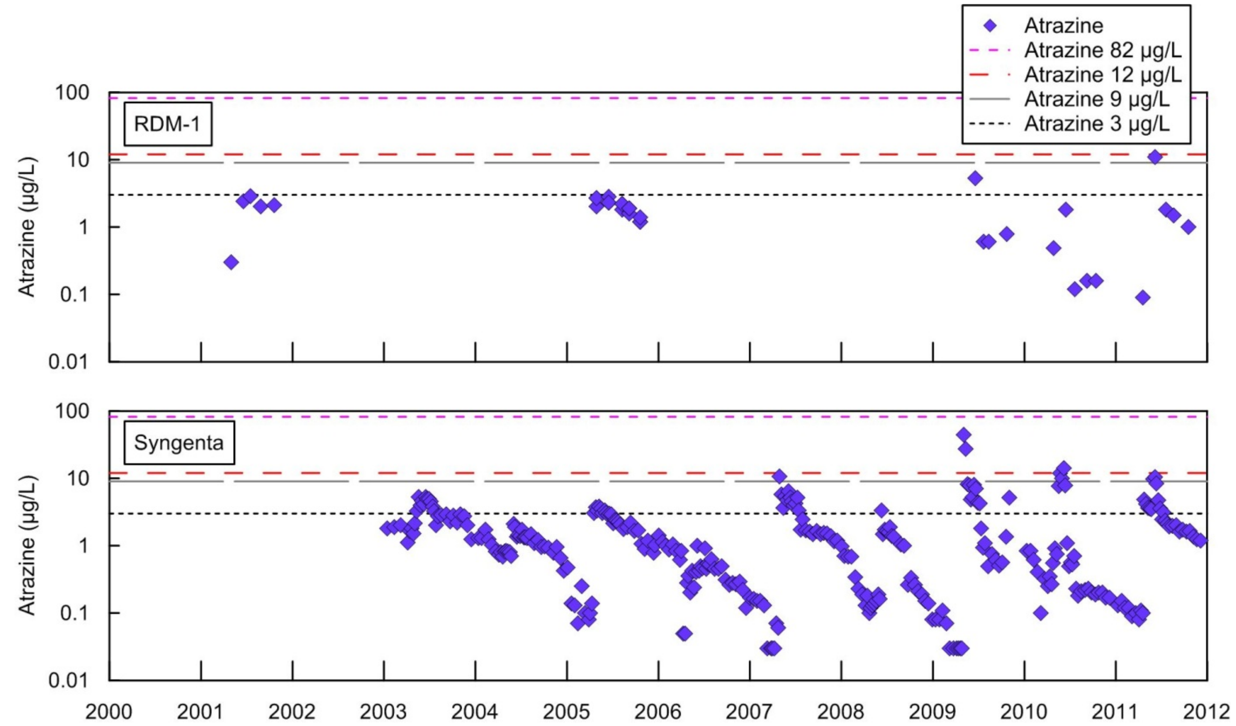

Figure 5-15 Atrazine concentrations, historical data

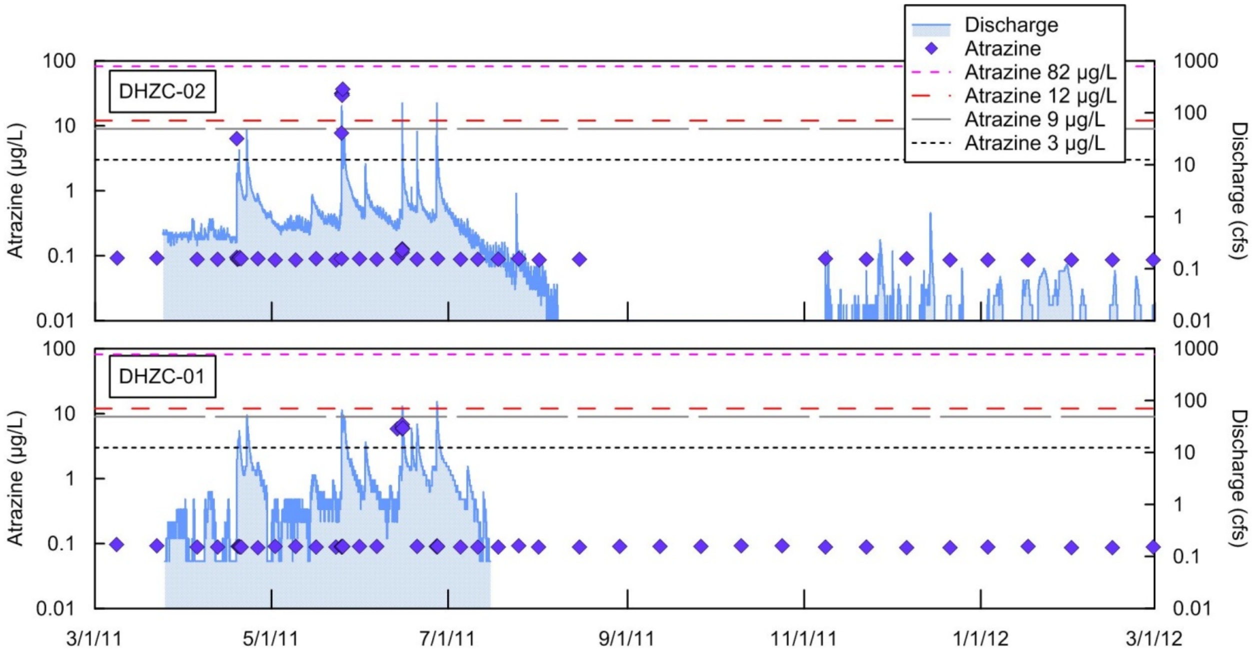

Figure 5-16. Atrazine concentrations, project data

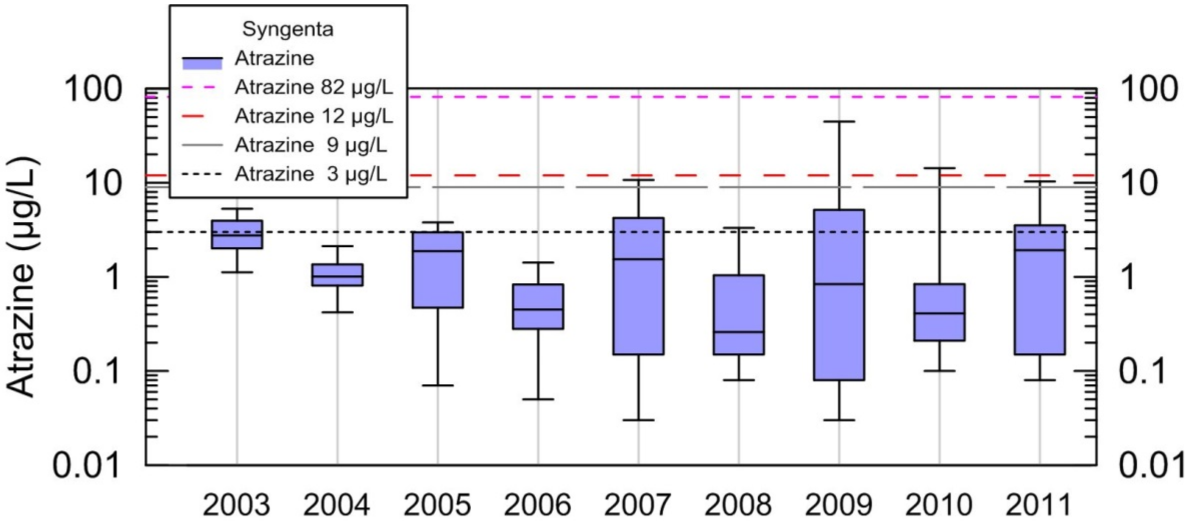

Figure 5-17. Annual variation in atrazine concentration, SYNGENTA data

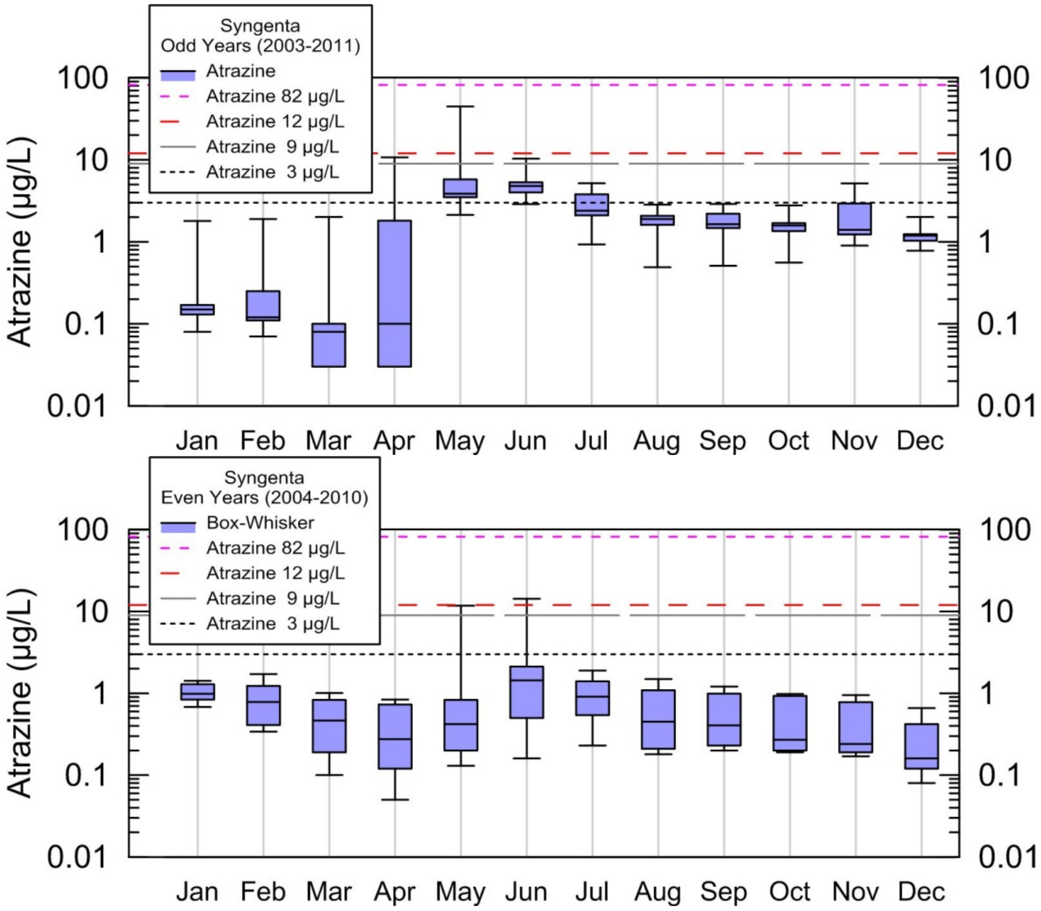

Figure 5-18. Monthly variation in atrazine concentration, SYNGENTA data

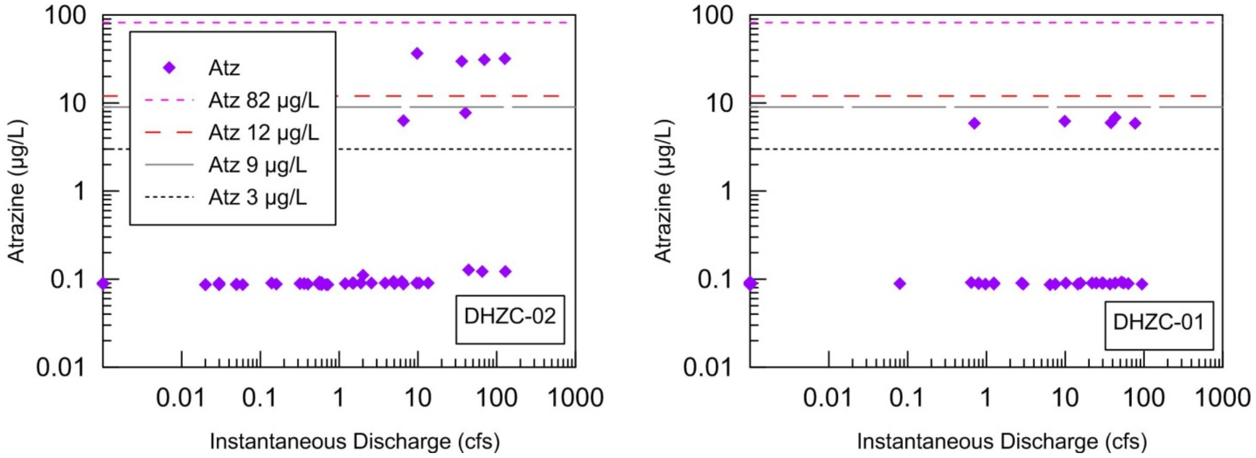

Figure 5-19. Relationship between atrazine concentration and discharge, project data

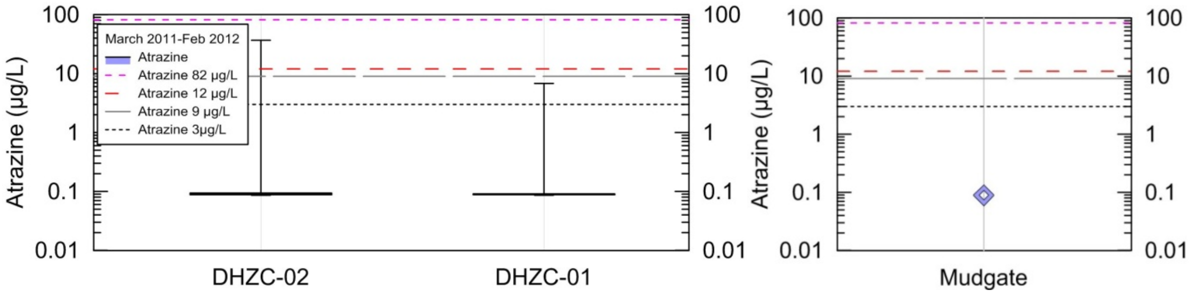

Figure 5-20. Box-whisker plots of atrazine concentrations, project data

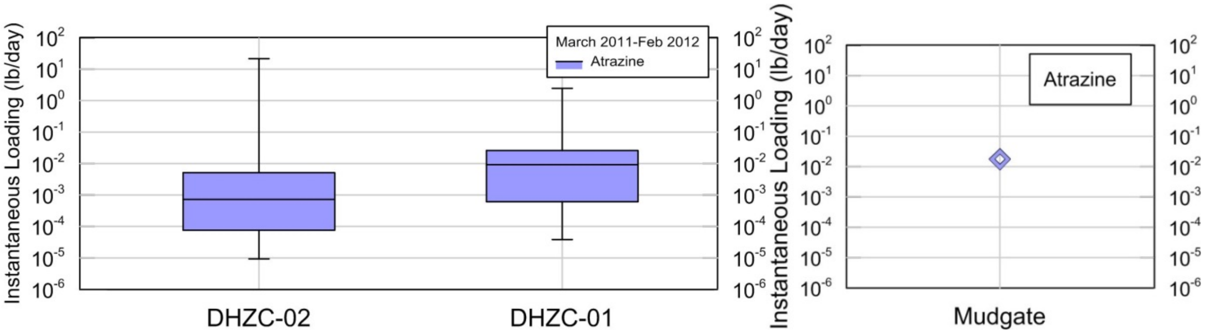

Figure 5-21. Box-whisker plots of atrazine instantaneous loadings, project data

Table 5-27 shows annual atrazine loads calculated from the project monitoring data. The outflow at the spillway site (DHZC-01) represents only a small fraction of the total load incoming to the reservoir. The sampled tributary (DHZC-02) represents 48% of the drainage area contributing to Vermont City Reservoir. Due to a large presence of samples at or below the detection limit and the possibility of false negatives reported by the laboratory, the annual atrazine load was estimated as a minimum and maximum load, using the detection limit and 5 mg/l (PAS reporting limit) for samples flagged as non-detects, respectively. The maxima calculated using the PAS reporting limit are expected to be higher than actual atrazine loads. However, for comparison purposes, atrazine loads at the spillway site were also computed using Syngenta's concentration data with DHZC-01's streamflow record. The annual load computed using Syngenta's data (12.2 lbs) was approximately equal to the maxima calculated using the PAS reporting limit. Annual atrazine load from the ungaged area was estimated using the annual yield of the gaged tributary (Table 5-27) to get a rough estimate of the total loading that entered the lake between March 2011 and February 2012. The load withdrawn through the Water Treatment Plant (WTP) intake was estimated from monthly pumped volumes and average monthly concentrations at the water intake analyzed by Syngenta. These numbers represent only preliminary estimates for the sampled time period and should not be interpreted as final or average loads. The uncertainty about observed concentrations is reflected in the large range of load estimates. The estimated range of load at the outflow is lower than the estimated range of load at the inflow, but the ranges overlap. Detailed analyses are necessary to show whether the atrazine load remains in the lake storage, for how long, and what degradation occurs in the reservoir.

Table 5-27. Annual atrazine loads, project data

Station Code	**Type**	**Annual Load**	**Annual Yield**
		lbs	lbs/ac
DHZC-02	Inflow	5.36 – 10.9$^{\$}$	0.0079 – 0.0161$^{\$}$
Ungaged area	Inflow	5.87 – 12.0*$^{\$}$	0.0079 - 0.0161*$^{\$}$
Total estimated inflow		*11.2 -22.9* $^{\$}$	
DHZC-01	Outflow	1.52 – 12.0$^{\$}$	
Mudgate	Outflow	0.002 – 0.09$^{\$}$	
WTP Pumpage**	Outflow	0.40	
Total estimated outflow		*1.92 -12.4* $^{\$}$	*0.0014 -0.0088* $^{\$}$

Notes: * Based on average annual yield
** Estimated from average monthly concentrations at DHZC-01
$^{\$}$ Minimum and maximum estimate provided due to a large presence of non-detects

Table 5-28 summarizes historical data for atrazine in sediment. All reported concentrations are below the detection limit (50 mg/kg). Atrazine has moderate water solubility and does not adsorb strongly to sediments. Its chemical properties favor movement in the dissolved state (Giddings et al., 2005, Basta et al., 1997, and others).

Table 5-28. Atrazine data in sediment, historical data (mg/kg)

Station Code	**Start Date**	**End Date**	**Number Samples**	**Minimum**	**Average**	**Maximum**
RDM-1	7/17/2001	7/20/2010	5	ND	ND	ND
RDM-2	8/9/2005	8/9/2005	2	ND	ND	ND
RDM-3	7/17/2001	7/17/2001	1	ND	ND	ND

Notes: ND = analyte not detected, value below detection limit

5.3.2 Manganese

A summary of historical and project data for manganese data collected in Vermont City Reservoir is presented in Table 5-29 and in Table 5-30, respectively. The water quality standard (0.15 mg/l) for manganese is applicable to Vermont City Reservoir as a source for public water supply. Samples taken at the intake depth are considered by the IEPA for water body assessments for Public Water Supply Use and assignment of impairment causes. However, water quality samples collected at all depths were analyzed in this section in order to provide a comprehensive discussion of lake water quality. The water quality standard was exceeded in 68% of samples collected in site RDM-1. The current project data confirm the impairment with 53% of samples collected at Vermont City Reservoir spillway (site DHZC-01) violating the standard.

Table 5-29. Manganese data summary, historical data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number Exceedances
RDM-1	5/1/2001	10/18/2011	25	0.092	0.201	0.383	17 (68%)

Table 5-30. Manganese data summary, project data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number Exceedances
DHZC-01	3/1/2011	2/29/2012	72	0.0295	0.157	0.321	38 (53%)
Mudgate	4/29/2011	4/29/2011	5	0.204	0.755	2.4	5 (100%)
DHZC-02	3/1/2011	2/29/2012	60	0.0276	0.857	8.54	35 (58%)

While the water quality standard does not apply to Vermont City Reservoir tributaries, it is useful to evaluate exceedances of the standard value to evaluate individual tributaries and their contribution to the overall concentrations found in the lake. The value of 0.15 mg/l is often exceeded in the inflow to Vermont City Reservoir (58% samples, Table 5-30). Note that manganese concentrations at the inflow site also exceed the general use standard (1 mg/l) applicable to Illinois streams for 22% of samples (Table 5-31).

Table 5-31. Compliance with general use water quality standard (1 mg/l) for stream sites, project data

Station Code	Number Exceedances	Percent Samples
DHZC-02	13	22%

Figure 5-22 shows the change in manganese concentration with depth. Typically, samples were collected at the depth of the drinking water intake. The highest values appear at depths below 6 feet. However, the lack of samples collected at the surface does not allow determination of whether there is any significant increase in manganese concentrations that would indicate a substantial anoxic zone at the bottom. The deepest sample was collected from a 7-foot depth.

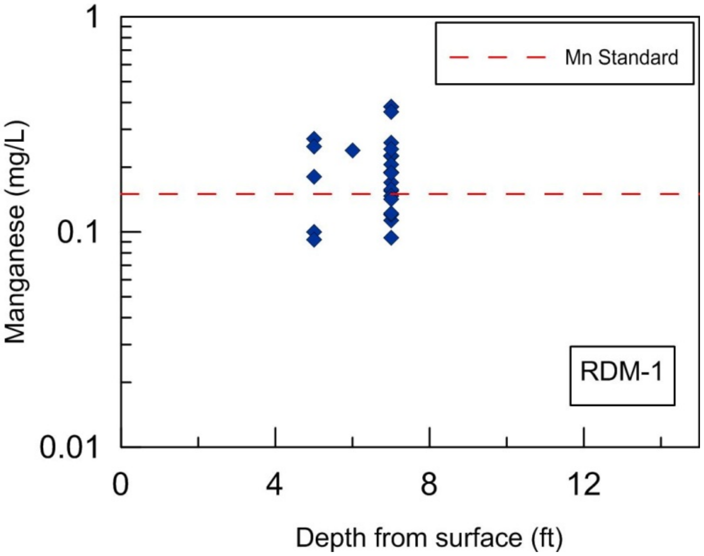

Figure 5-22. Effect of sampling depth on manganese concentration, historical data

Figure 5-23 and Figure 5-24 show manganese concentrations plotted in time for historical and current project data, respectively. Discharge for the two current project sites with a stream gage is also shown. The gaps in the discharge plot show dry periods of zero flow (i.e., there were no missing streamflow data from the gage installation). Only one lake site has historical data available, RDM-1. The highest manganese concentrations for this site occurred the last three years of data, 2009-2011. There are no historical data from the tributaries to Vermont City Reservoir.

Figure 5-25 shows a relationship between the observed manganese concentrations and instantaneous discharge for the current project data. Concentrations measured at zero discharge conditions are plotted on the y-axis for comparison. No discharge data were available for the historical data set. The highest manganese concentrations were measured at the highest flows as well as at the lowest flows for the site located at the inflow. It should be noted though that as discussed in Section 5.2.5 Stream Flashiness (page 55), the rate of change in stream discharge can be as important as overall discharge when considering the impacts on specific constituent loadings. The lowest concentrations were found in the middle range of flows. The Vermont City Reservoir spillway (site DHZC-01) shows no significant relationship between manganese concentration and discharge. Note that concentrations above the standard were found also during zero flow at both sites.

Figure 5-26 compares distributions of manganese concentrations at the project monitoring sites. The Vermont City Reservoir spillway (site DHZC-01) shows a smaller variation and lower mean than the inflow site.

A statistical comparison of means[2] was carried out using samples collected at non-zero discharges during dates common across the two sites. This was necessary because of the relationship between manganese concentrations and discharge and a higher number of samples collected during high flow regime at the inflow site (DHZC-02). The difference in mean manganese concentrations between the two sites cannot be statistically confirmed. A relatively small number of samples were available for this comparison due to no flow over the spillway during a significant portion of the sampling period. This resulted in large ranges for statistically estimated means and a corresponding increase in the uncertainty in the analysis.

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. In spite of the low concentrations, the Vermont City Reservoir spillway site (DHZC-01) carried higher mean manganese loadings (Figure 5-27). Any difference in mean manganese loadings among the sites cannot be statistically confirmed. A relatively small number of samples were available for this comparison due to no flow over the spillway during a significant portion of the sampling period. This resulted in large ranges for statistically estimated means and a corresponding increase in the uncertainty in the analysis.

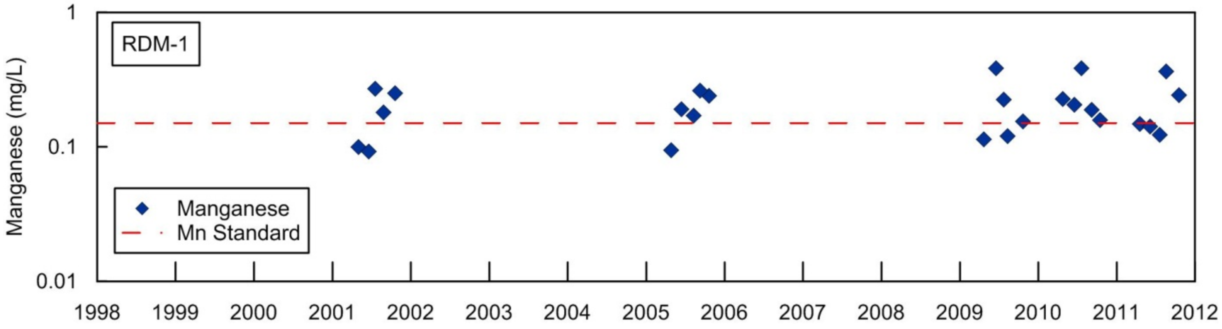

Figure 5-23 Manganese concentrations, historical data

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[2] Statistical significance was determined using 95% confidence level.

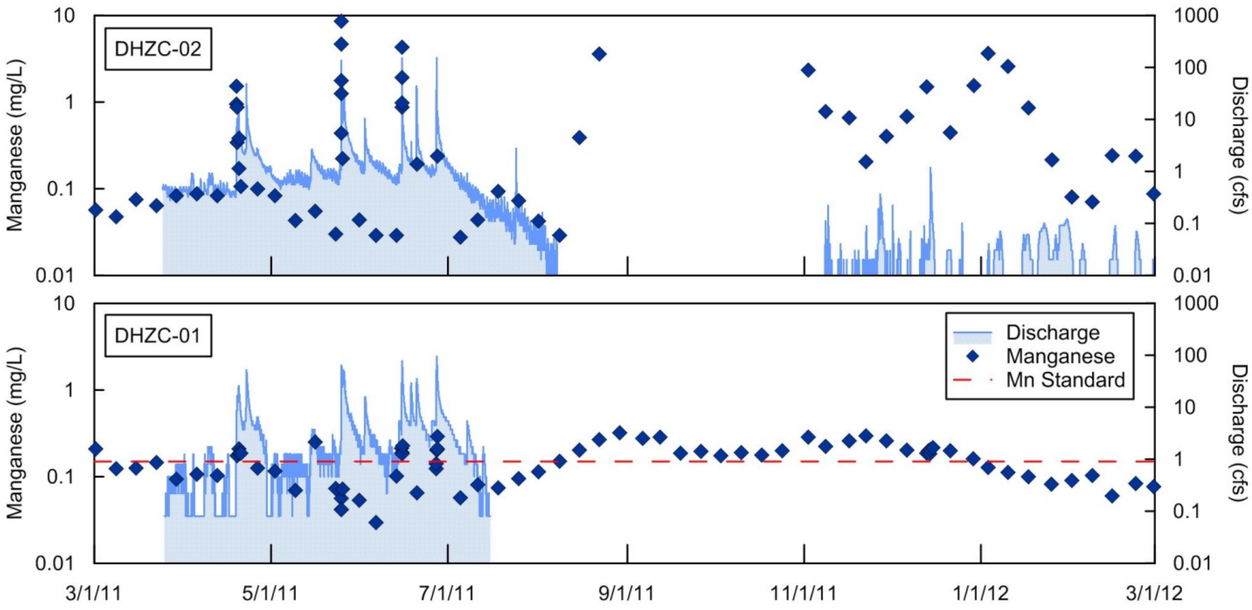

Figure 5-24. Manganese concentrations, project data

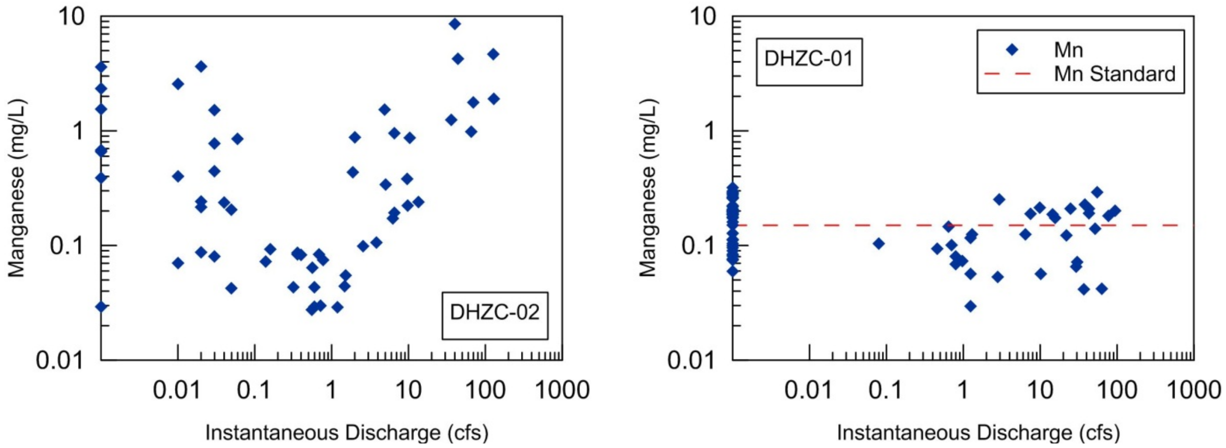

Figure 5-25. Relationship between manganese concentration and discharge, project data

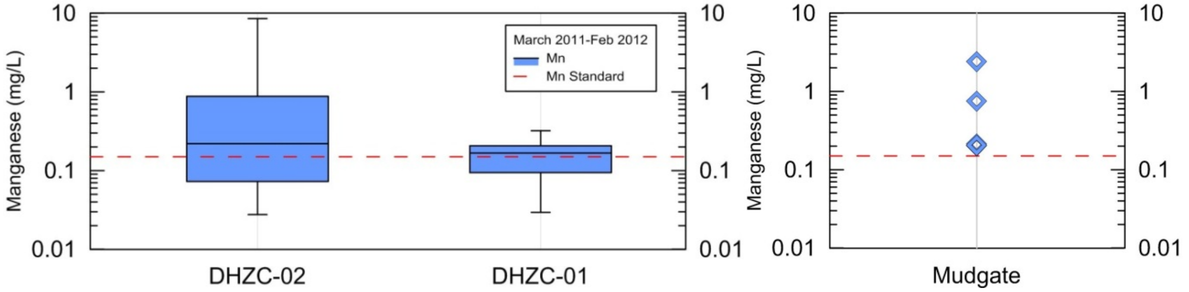

Figure 5-26. Box-whisker plots of manganese concentrations, project data

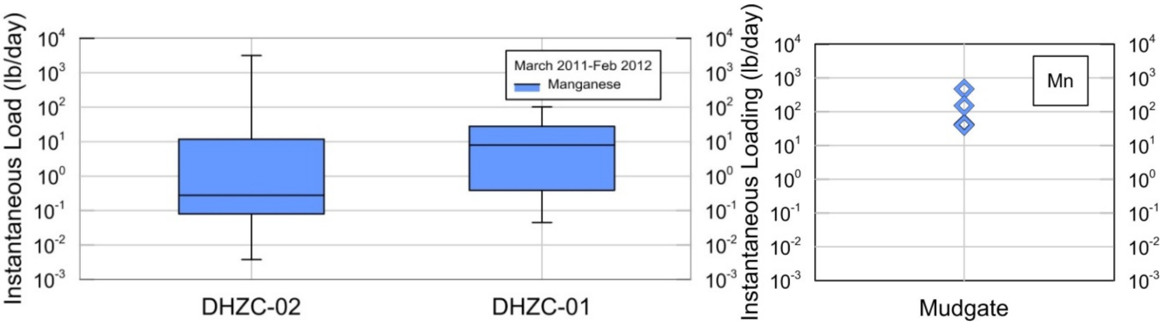

Figure 5-27. Box-whisker plots of manganese instantaneous loadings, project data

Table 5-32 shows annual manganese loads calculated from the project monitoring data. The outflow at the spillway site (DHZC-01) represents only a small fraction of the total load incoming to the reservoir. The sampled tributary (DHZC-02) represents 48% of the drainage area contributing to Vermont City Reservoir. Annual manganese load from the ungaged area was estimated using the annual yield of the gaged tributary (Table 5-32) to get a rough estimate of the total loading that entered the lake between March 2011 and February 2012. The load withdrawn through the Water Treatment Plant (WTP) intake was estimated from monthly pumped volumes and average monthly concentrations at DHZC-01. These numbers represent only preliminary estimates for the sampled time period and should not be interpreted as final or average loads. This preliminary estimate indicates that a majority (80%) of the manganese load that entered Vermont City Reservoir between March 2011 and February 2012 remained in the lake storage. The manganese that was released from the reservoir while the mudgate was opened represents only 4% of the total manganese load that left the reservoir and less than 1% of the manganese load that entered the reservoir during this time period.

Table 5-32. Annual manganese loads, project data

Station Code	**Type**	**Annual Load**	**Annual Yield**
		lbs	lbs/ac
DHZC-02	Inflow	761	1.12
Ungaged area	Inflow	832*	1.12*
Total estimated inflow		*1,593*	
DHZC-01	Outflow	287	
Mudgate	Outflow	14	
WTP Pumpage**	Outflow	26	
Total estimated outflow		*327*	*0.23*

Notes: * Based on average annual yield
** Estimated from average monthly concentrations at DHZC-01

Table 5-33 summarizes historical data for manganese in sediment. Short (1997) analyzed sediment data for Illinois between 1982 and 1995. Concentrations at or above 1,100 mg/kg were determined to be “elevated,” and concentrations at or above 2,300 mg/kg were determined to be “highly elevated.” “Elevated” and “highly elevated” refer to those concentrations of a particular constituent that equal or exceed the 85th and 98th percentiles, respectively, (along the normal distribution curve) of the samples included in the study by Short (1997). All data collected at station RDM-1 are considered elevated (four samples). The two highest concentrations were found in the two most recent samples (Figure 5-28). Only one sample was collected at site RDM-2 and RDM-3 each. Concentrations at these two sites are below these thresholds.

Table 5-33. Manganese data in sediment, historical data (mg/kg)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
RDM-1	7/18/1989	7/20/2010	4	1100	1330	1810
RDM-2	10/20/2005	10/20/2005	1	930	930	930
RDM-3	7/17/2001	7/17/2001	1	460	460	460

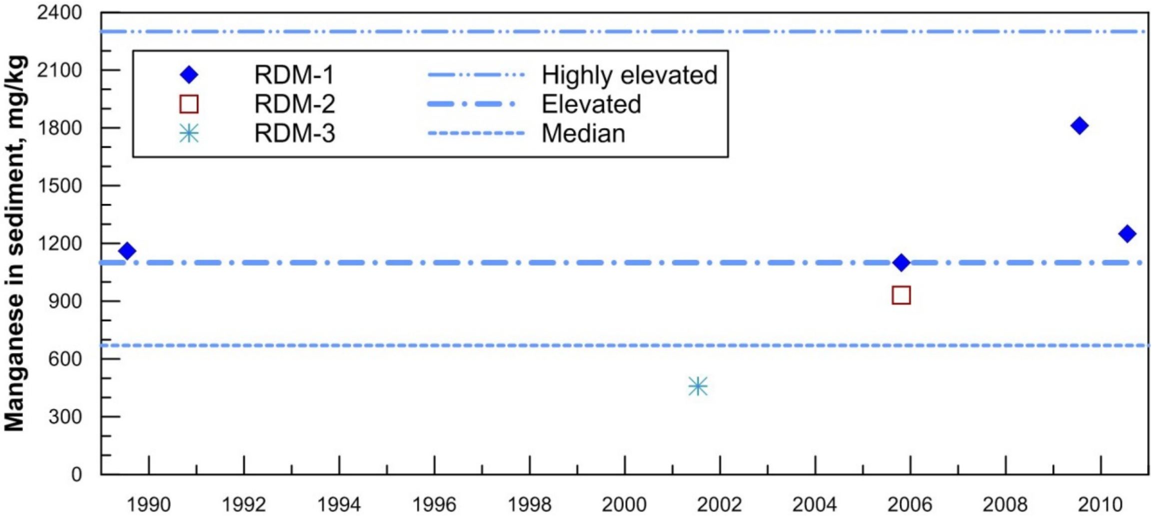

Figure 5-28. Manganese concentration in sediment, historical data

Manganese concentrations were not sampled in the single well located in the Vermont City Reservoir watershed. However, the ISWS well database contains information for a well located outside the watershed but within the same Township and Range as the reservoir. The well located in Section 09, approximately 4 miles northwest of the reservoir, had a manganese concentration of 0.04 mg/l on 3/1/2011.

5.3.3 Total Suspended Solids

A summary of historical and project data for total suspended solids data collected in Vermont City Reservoir is presented in Table 5-34 and Table 5-35, respectively. Other constituents such as total phosphorus and manganese are associated with sediment and carried to receiving waters via soil erosion. Total suspended solids data are thus relevant to TMDL development for total phosphorus and manganese.

There is no water quality standard for total suspended solids. Since 2012 the determination of listing for Aesthetic Use impairment is based on non-volatile suspended solids (IEPA, 2012). Detail evaluation of Aesthetic Use is presented in Section 5.3.5 Algae (page 92).

Average and maximum total suspended solids concentrations observed in lake sites are much lower than those observed at the inflow to the lake or after release from the mudgate (Table 5-34 and Table 5-35). Slower velocities in the lake allow for significant settling of suspended particles. The mudgate releases water from the bottom of the lake. Disturbing the sediment as water is directed to flow towards the bottom enriches the release with total suspended solids.

Table 5-34. Total suspended solids data summary, lake data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
Historical data						
RDM-1	8/18/1977	10/18/2011	69	3	30	160
RDM-2	8/18/1977	10/20/2005	11	5	19	32
RDM-3	8/18/1977	10/19/2011	5	18	29	34
Project data						
DHZC-01	3/1/2011	2/29/2012	72	ND	19*	51.5

Notes: ND = analyte not detected, value below detection limit
* value is affected by a presence of values below detection limit (ND)

Table 5-35. Total suspended solids data summary, stream data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
Project data						
Mudgate	4/29/2011	4/29/2011	5	54	550	2020
DHZC-02	3/1/2011	2/29/2012	60	ND	625*	8940

Notes: ND = analyte not detected, value below detection limit
* value is affected by a presence of values below detection limit (ND)

Figure 5-29 shows the change in total suspended solids concentration with depth. The highest values appear at depths below 6 feet. However, there is no significant increase in total suspended solids concentrations. The deepest sample was collected at a depth of 10 feet.

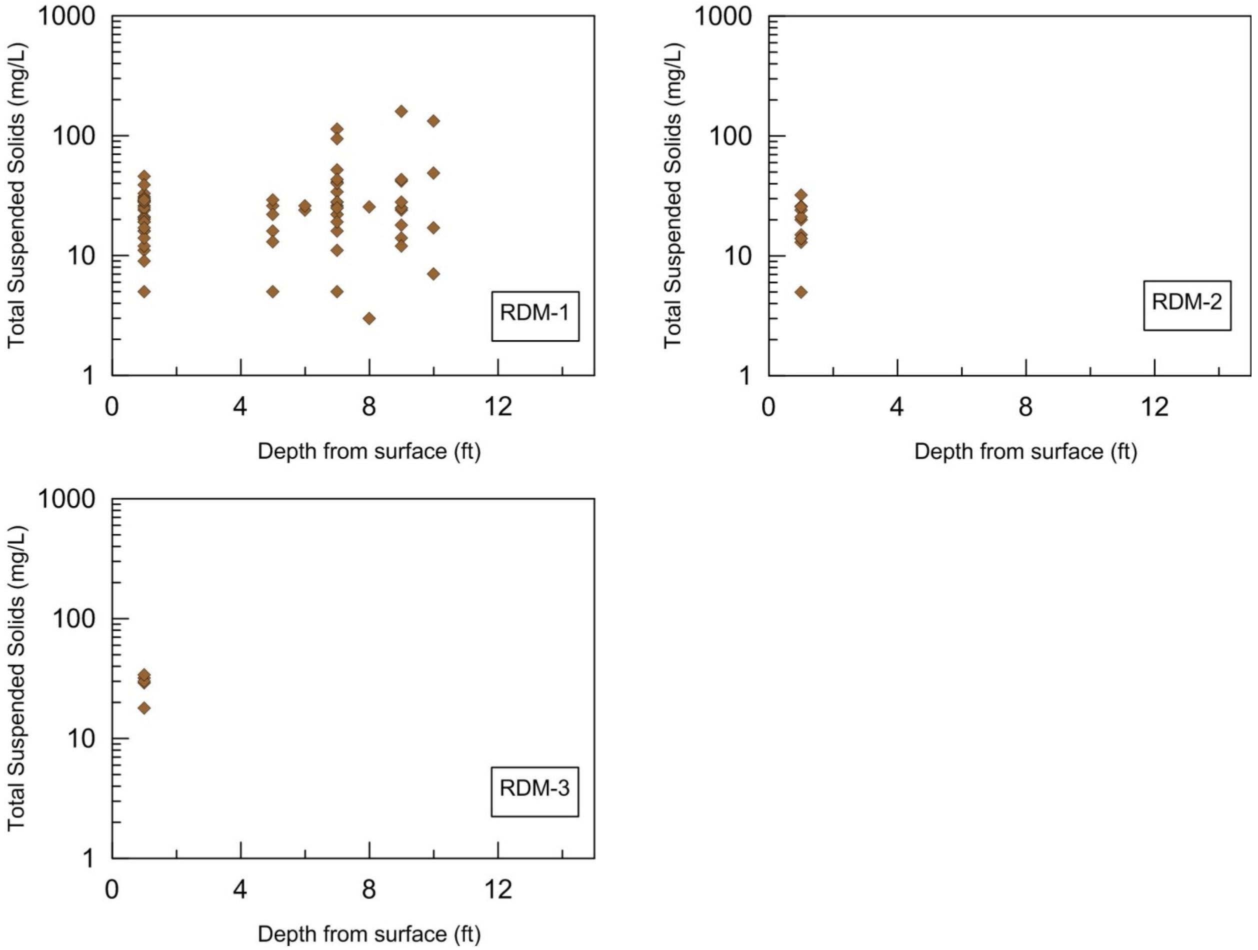

Figure 5-29. Effect of sampling depth on total suspended solids concentration, historical data

Figure 5-30 and Figure 5-31 show total suspended solids concentrations plotted in time for historical and current project data, respectively. Discharge for the two current project sites with a stream gage is also shown. Gaps in the discharge plot show dry periods of zero flow (i.e., there were no missing streamflow data from the gage installation). Historical data are not available for any stream sites. The highest total suspended solids concentrations for this site occurred during 2009-2010. Figure 5-31 also shows volatile suspended solids concentrations analyzed for the same samples.

Figure 5-32 shows a relationship between the observed total suspended solids concentrations and instantaneous discharge for the current project data. Concentrations measured at zero discharge conditions are plotted at the y-axis for each site. No discharge data were available for the historical data set. The highest total suspended solids concentrations were measured at the highest flows as well as for the lowest flows for the inflow site (DHZC-02). The reservoir with its lower water velocities and longer residence time allows for a significant fraction of the total suspended solids to settle out. The Vermont City Reservoir spillway (site DHZC-01) shows no significant relationship between total suspended solids concentration and discharge.

Figure 5-33 compares distributions of total suspended solids concentrations at the project monitoring sites. The Vermont City Reservoir spillway (site DHZC-01) shows much smaller variation in observed concentrations than the inflow site (DHZC-02).

A statistical comparison of means[3] was carried out using samples collected at non-zero discharges during dates common across the sites. This was necessary because of the relationship between total suspended solids concentrations and discharge and a higher number of samples collected during high flow regimes at the inflow site. The mean total suspended solids concentration at the spillway site (DHZC-01) is lower than mean total suspended solids concentration at the inflow site (DHZC-02).

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. Any difference in mean total suspended solids loadings cannot be statistically confirmed between the two sites (Figure 5-34). A relatively small number of samples were available for this comparison due to no flow over the spillway during a significant portion of the sampling period. This resulted in large ranges for statistically estimated means and a corresponding increase in the uncertainty in the analysis.

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[3] Statistical significance was determined using 95% confidence level.

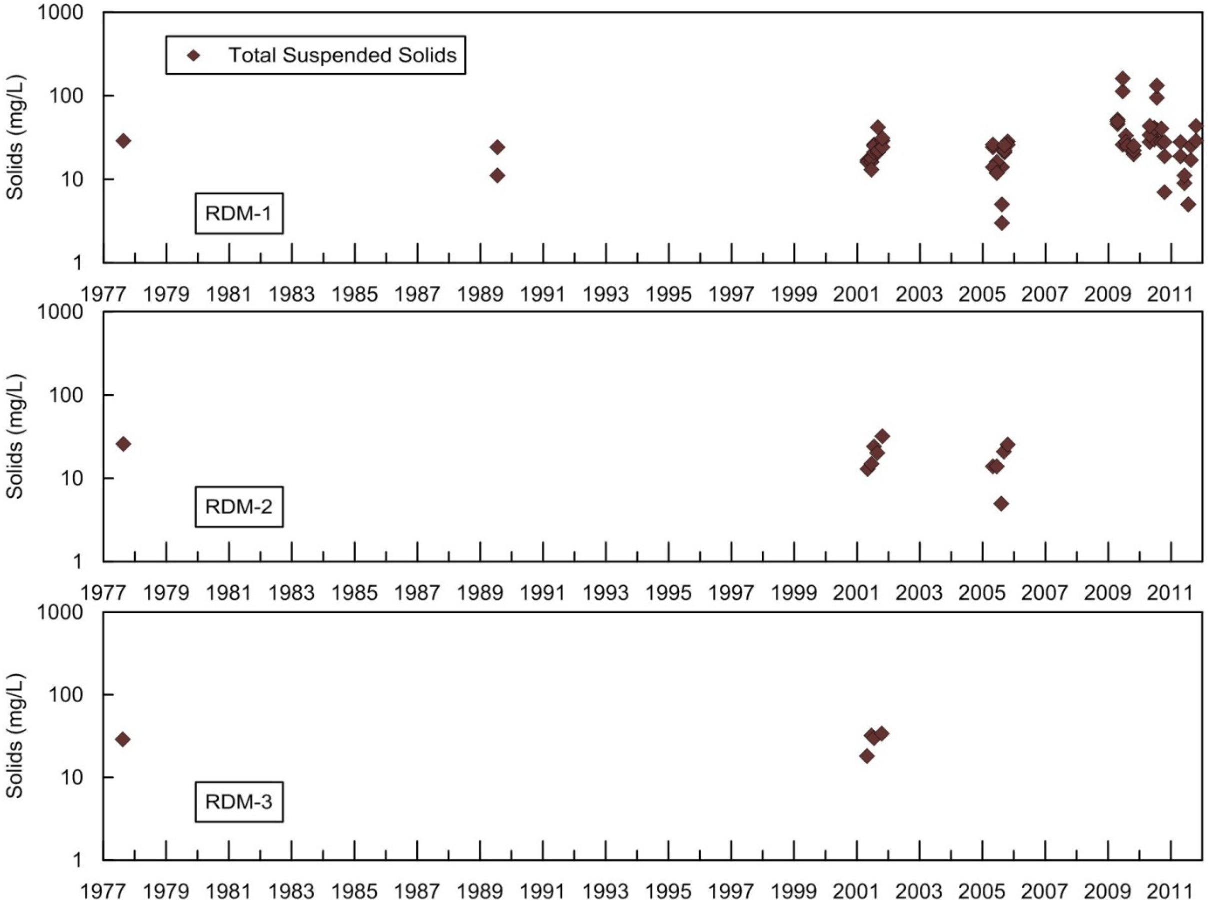

Figure 5-30. Total suspended solids concentrations, historical data

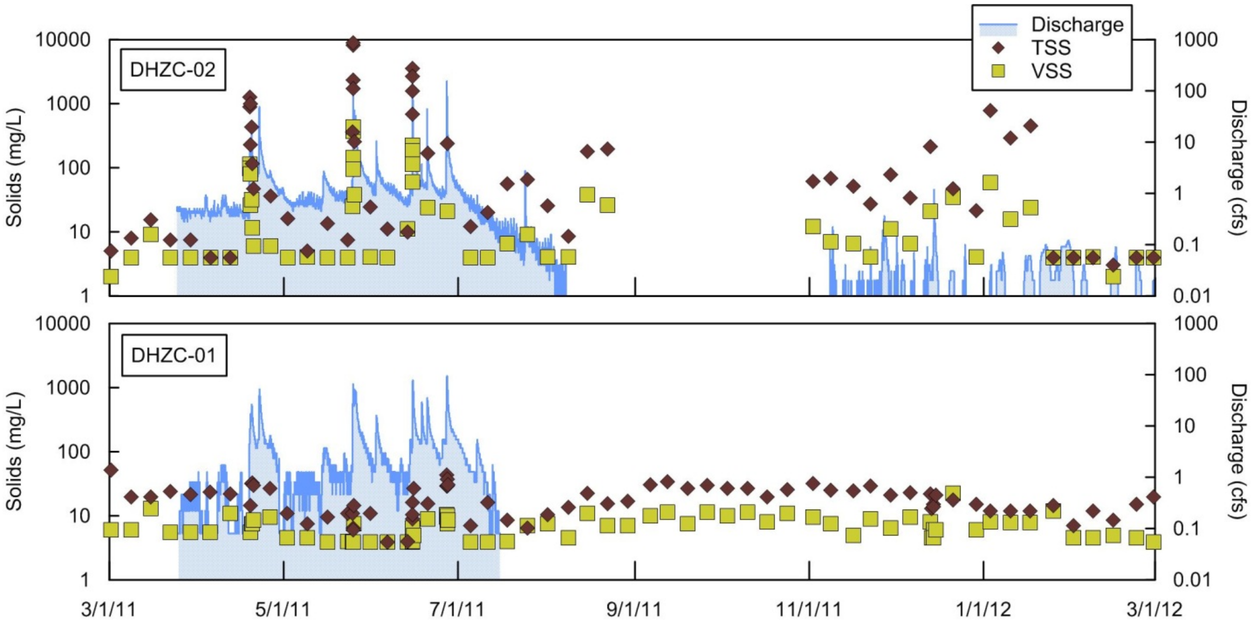

Figure 5-31. Total suspended solids concentrations, project data

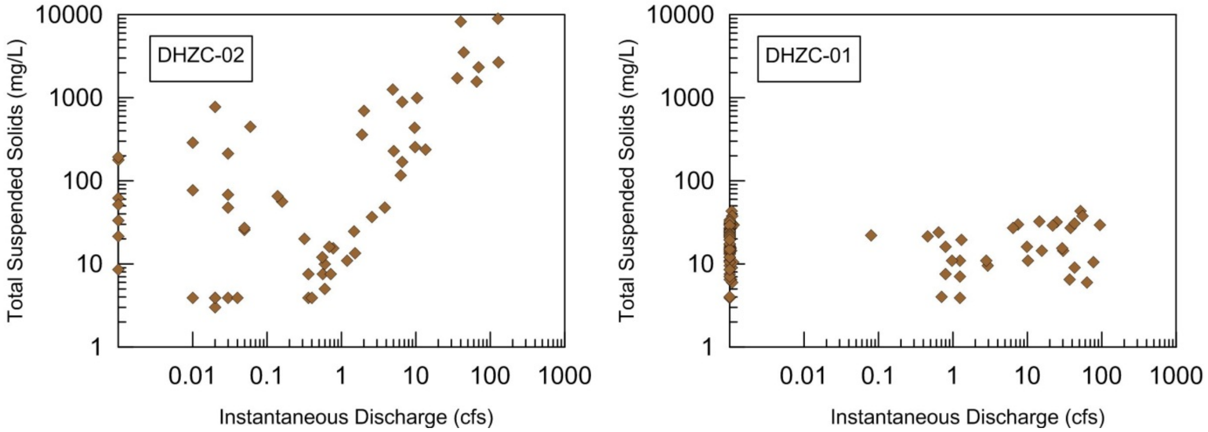

Figure 5-32. Relationship between total suspended solids concentration and discharge, project data

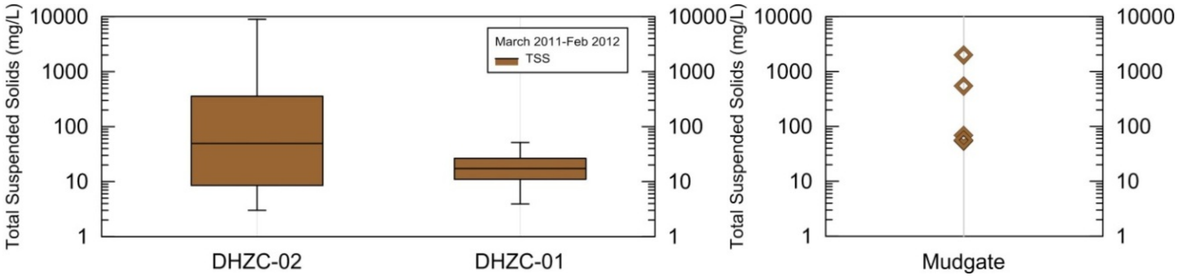

Figure 5-33. Box-whisker plots of total suspended solids concentrations, project data

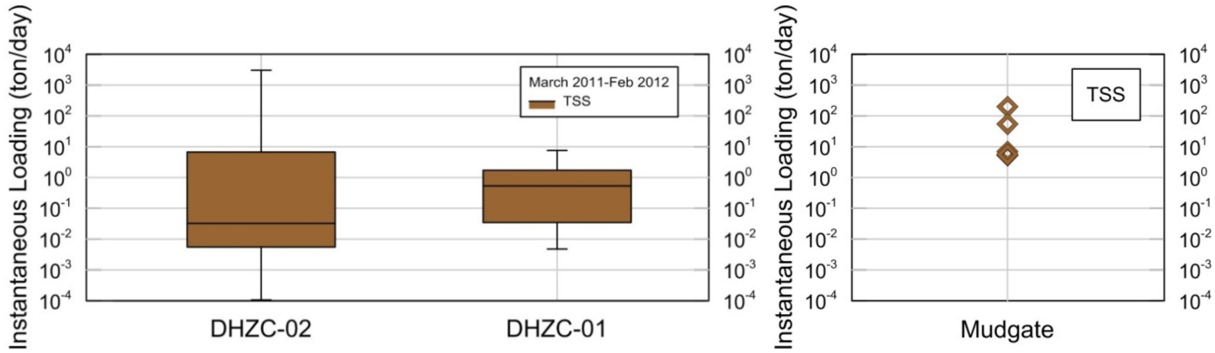

Figure 5-34. Box-whisker plots of total suspended solids instantaneous loadings, project data

Volatile suspended solids data were available for historical as well as current project sites. Table 5-36 and Table 5-37 show summary information for the ratio of volatile suspended solids to total suspended solids for historical and current project sites, respectively. Theoretically, the ratio would always be between zero and one (inclusively). However, due to inherent inaccuracies in analytical procedures, several calculated ratios are larger than one. The ratios of volatile to total suspended solids at the mudgate are lower than at all other sites (Figure 5-35).

Table 5-36. Ratio of volatile suspended solids to total suspended solids, historical data (unitless)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
RDM-1	8/18/1977	10/18/2011	69	0.156	0.418	1.00
RDM-2	8/18/1977	10/20/2005	11	0.154	0.451	1.00
RDM-3	8/18/1977	10/19/2011	5	0.241	0.326	0.444

Table 5-37. Ratio of volatile suspended solids to total suspended solids, project data (unitless)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
DHZC-01	3/1/2011	2/29/2012	71	0.117*	0.427*	1.29*
Mudgate	4/29/2011	4/29/2011	5	0.062	0.086	0.124
DHZC-02	3/1/2011	2/29/2012	53	0.045*	0.233*	1.10*

Notes: * values below detection limit (ND) were removed from calculation

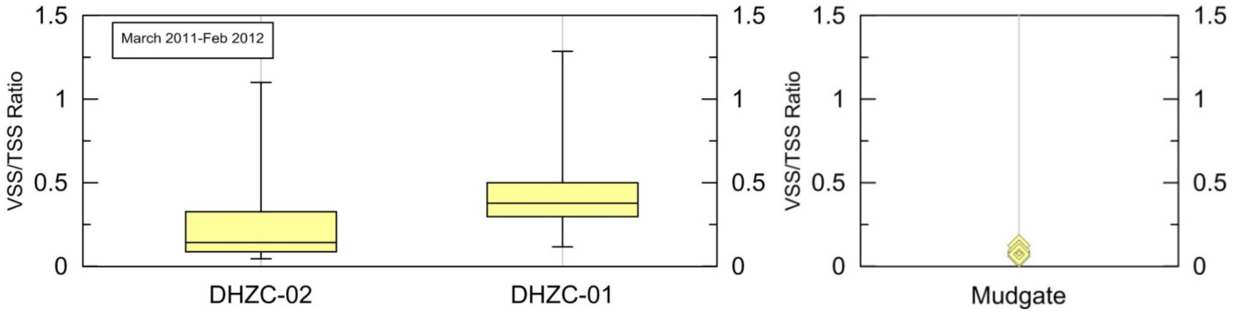

Figure 5-35. Box-whisker plots of ratio of volatile to total suspended solids concentration, project data

Table 5-38 and Table 5-39 show annual total and volatile suspended solids loads, respectively, calculated from the project monitoring data. The outflow at the spillway site (DHZC-01) represents only a small fraction of the total load incoming to the reservoir. The sampled tributary (DHZC-02) represents 48% of the drainage area contributing to Vermont City Reservoir. Annual total and volatile suspended solids load from the ungaged area was estimated using the average annual yield (Table 5-38 and Table 5-39) to get a rough estimate of the total loading that entered the lake between March 2011 and February 2012. The load withdrawn through the Water Treatment Plant (WTP) intake was estimated from monthly pumped volumes and average monthly concentrations at DHZC-01. These numbers represent only preliminary estimates for the sampled time period and should not be interpreted as final or average loads. This preliminary estimate indicates that a majority (97%) of the total suspended solids load that entered Vermont City Reservoir between March 2011 and February 2012 remained in the lake storage. The total suspended solids released while the mudgate was open represents 18% of the total suspended solids load that left the reservoir but less than 1% of the total suspended solids load that entered the reservoir during this time period.

The ratio of volatile to total suspended solids at the inflow site was typically low during higher flows; i.e., a higher proportion of the total suspended solids transported during storm events is inorganic (sediment). No relationship with discharge was found for the spillway site (DHZC-01) but the highest ratios were found at zero discharge. Volatile suspended solids constitute about 6% and 36% of the total suspended solids found in the inflow and outflow, respectively. A relatively low proportion of volatile suspended solids (8%) was found at the outflow through the mudgate. Volatile suspended solids can undergo decomposition over time in addition to settling. However, the presence of algae, which is facilitated by low water velocities, increases volatile suspended solids. This preliminary estimate indicates that a majority (85%) of the volatile suspended solids load that entered Vermont City Reservoir between March 2011 and February 2012 remained within the lake.

Table 5-38. Annual total suspended solids loads, project data

Station Code	Type	Annual Load	Annual Yield
		tons	tons/ac
DHZC-02	Inflow	467	0.688
Ungaged area	Inflow	511*	0.688*
Total estimated inflow		*978*	
DHZC-01	Outflow	21.7	
Mudgate	Outflow	5.0	
WTP Pumpage**	Outflow	1.6	
Total estimated outflow		*28.3*	*0.020*

Notes: * Based on average annual yield

** Estimated from average monthly concentrations at DHZC-01

Table 5-39. Annual volatile suspended solids loads, project data

Station Code	Type	Annual Load	Annual Yield
		tons	tons/ac
DHZC-02	Inflow	29.2	0.043
Ungaged area	Inflow	31.9*	0.043*
Total estimated inflow		*61.1*	
DHZC-01	Outflow	7.9	
Mudgate	Outflow	0.4	
WTP Pumpage**	Outflow	0.6	
Total estimated outflow		*8.9*	*0.006*

Notes: * Based on average annual yield

** Estimated from average monthly concentrations at DHZC-01

5.3.4 Total Phosphorus

A summary of historical and project data for total phosphorus data collected in Vermont City Reservoir is presented in Table 5-40 and Table 5-41, respectively. Total phosphorus water quality standard (0.05 mg/l) is applicable to lakes with a surface area of 20 acres or greater. Only samples taken at 1 foot of depth are considered by the IEPA for water body assessments and assignment of impairment causes. However, water quality samples collected at all depths were analyzed in this section in order to provide a comprehensive discussion of lake water quality. The water quality standard was exceeded in all historical samples collected in Vermont City Reservoir. The current project data collected in Vermont City Reservoir (site DHZC-01) confirm the impairment with 100% of samples exceeding the standard.

Table 5-40. Total phosphorus data summary, historical data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number Exceedances
RDM-1	8/18/1977	10/18/2011	69	0.059	0.133	0.381	69 (100%)
RDM-2	8/18/1977	10/20/2005	11	0.061	0.101	0.13	11 (100%)
RDM-3	8/18/1977	10/19/2001	6	0.097	0.121	0.137	6 (100%)

Table 5-41. Total phosphorus data summary, project data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Number Exceedances
DHZC-01	3/1/2011	3/14/2012	74	0.0651	0.133	0.434	74 (100%)
Mudgate	4/29/2011	4/29/2011	5	0.22	0.982	3.13	5 (100%)$^{\$}$
DHZC-02	3/1/2011	3/14/2012	62	0.0274	0.653	6.02	57 (92%)$^{\$}$

Notes: $^{\$}$ = water quality standard is not directly applicable, exceedances shown only for comparison purposes

While the water quality standard does not apply to Vermont City Reservoir tributaries, it is useful to evaluate exceedances of the standard value to evaluate individual tributaries and their contribution to the overall concentrations found in the lake. The value 0.05 mg/l is also often exceeded in the inflow site (92% samples) and in the outflow from the mudgate (100%, Table 5-41). Note that the total phosphorus concentrations at the Vermont City Reservoir spillway are generally lower than concentrations in the inflow site or the mudgate. Total phosphorus can be associated (adsorbed) with sediment that can settle out at slower velocities found in the reservoir.

Figure 5-36 shows the change in total phosphorus concentration with depth. The highest values appear at depths below 6 feet. However, there is no significant increase in total phosphorus concentrations that would indicate a substantial anoxic zone at the bottom. The deepest sample was collected at a depth of 10 feet.

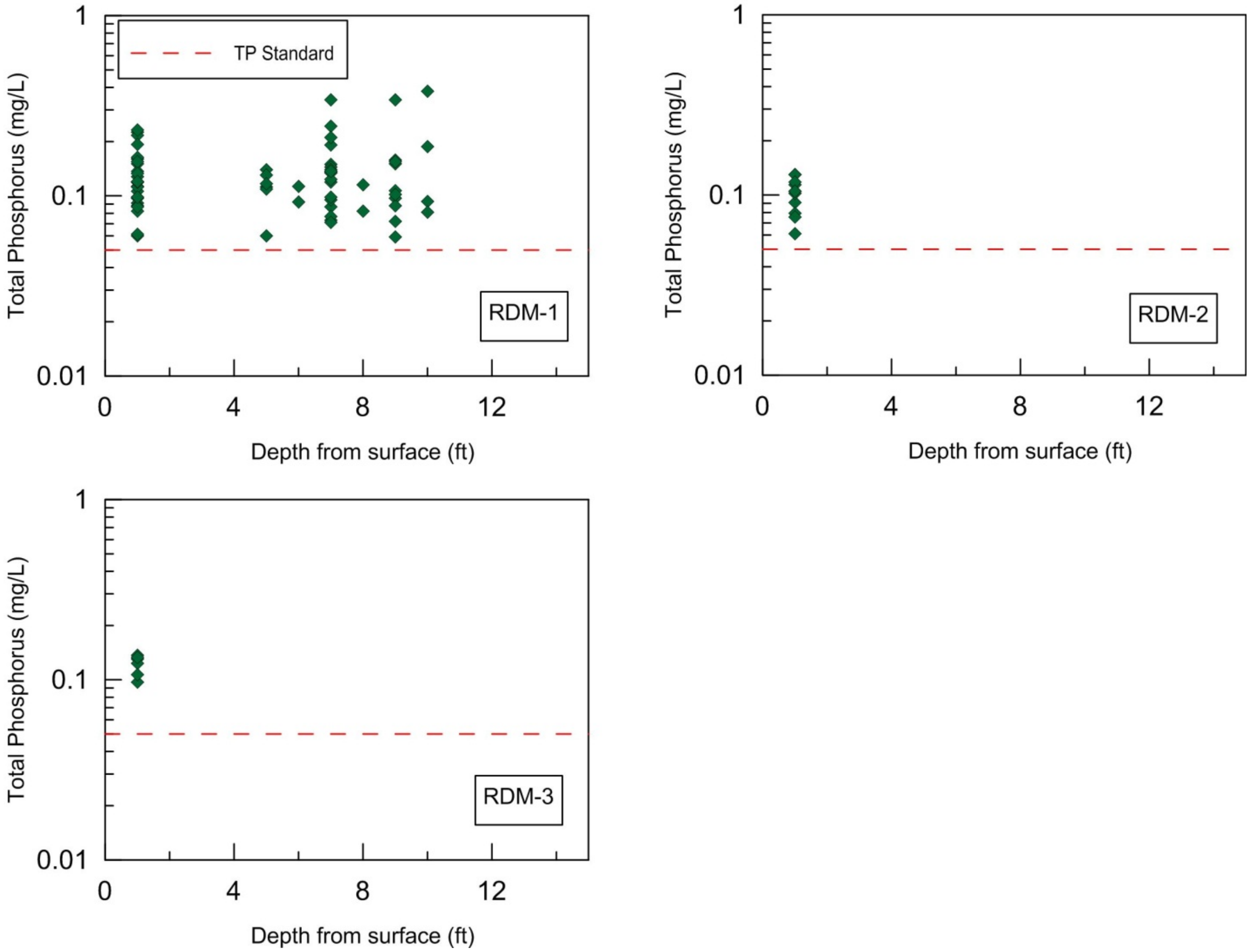

Figure 5-36. Effect of sampling depth on total phosphorus concentration, historical data

Figure 5-37 and Figure 5-38 show total phosphorus concentrations plotted in time for historical and current project data, respectively. Discharge for the three current project sites with a stream gage is also shown. The gaps in the discharge plot show dry periods of zero flow (i.e., there were no missing streamflow data from the gage installation). The highest values in the historical dataset were observed in recent years (2009-2010). Historical data are not available for any tributaries to Vermont City Reservoir.

Figure 5-39 shows a relationship between the observed total phosphorus concentrations and instantaneous discharge for the current project data. Concentrations measured at zero discharge conditions are plotted against a discharge on the y-axis for each site. No discharge data were available for the historical data set. The highest total phosphorus concentrations were measured at the highest flows for the inflow site (DHZC-02). The Vermont City Reservoir spillway site (DHZC-01) shows no significant relationship between total phosphorus concentration and discharge.

Figure 5-40 compares distributions of total phosphorus concentrations at the project monitoring sites. The Vermont City Reservoir spillway site (DHZC-01) shows the smallest variation and the lowest mean. The inflow site (DHZC-02) has a much larger variation in observed concentrations.

A statistical comparison of means[4] was carried out using samples collected at non-zero discharges during dates common across the sites. This was necessary because of the relationship between total phosphorus concentrations and discharge and a higher number of samples collected during high flow regimes at the inflow site. The mean total phosphorus concentration at the spillway site (DHZC-01) is lower than mean total phosphorus concentration at the inflow site (DHZC-02).

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. Any difference in mean total phosphorus loadings cannot be statistically confirmed between the two sites (Figure 5-41). A relatively small number of samples were available for this comparison due to no flow over the spillway during a significant portion of the sampling period. This resulted in large ranges for statistically estimated means and a corresponding increase in the uncertainty in the analysis.

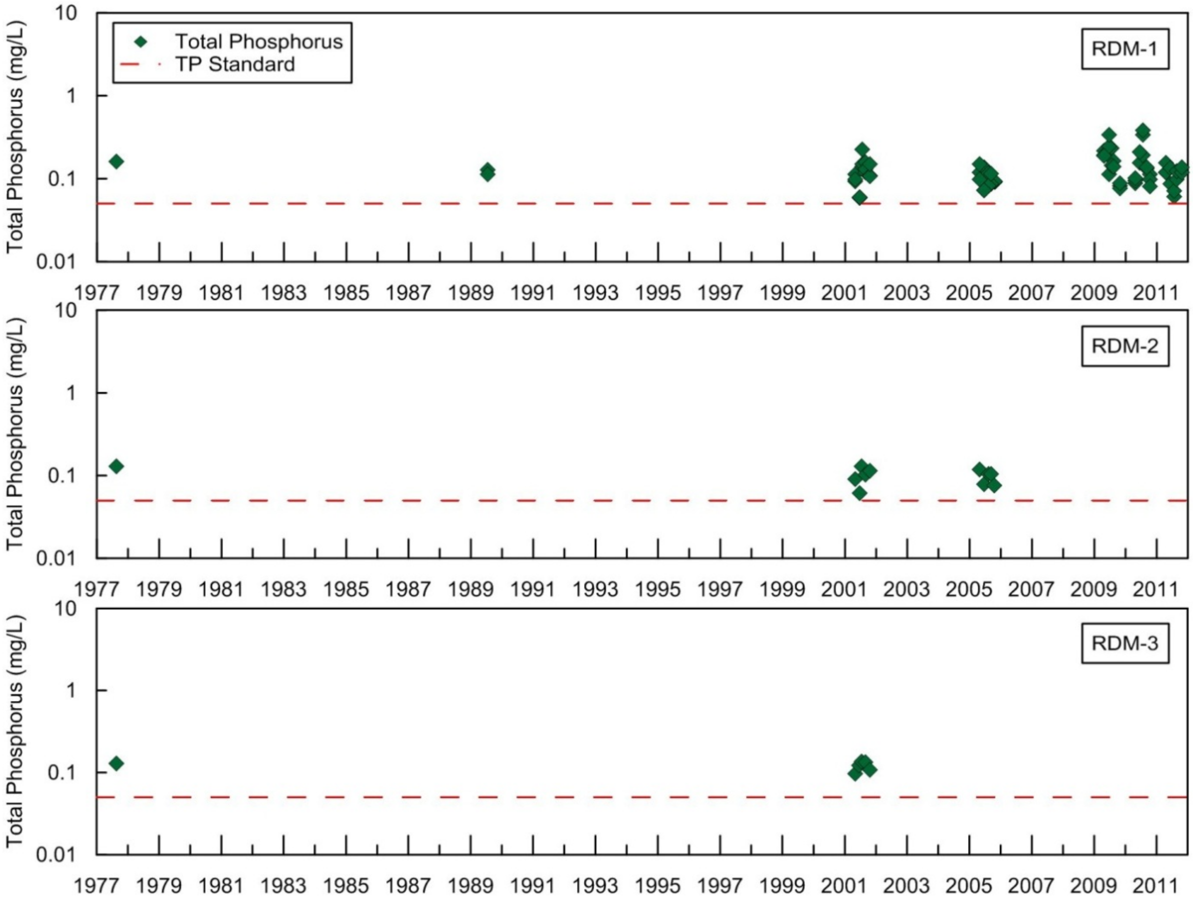

Figure 5-37. Total phosphorus concentrations, historical data

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[4] Statistical significance was determined using 95% confidence level.

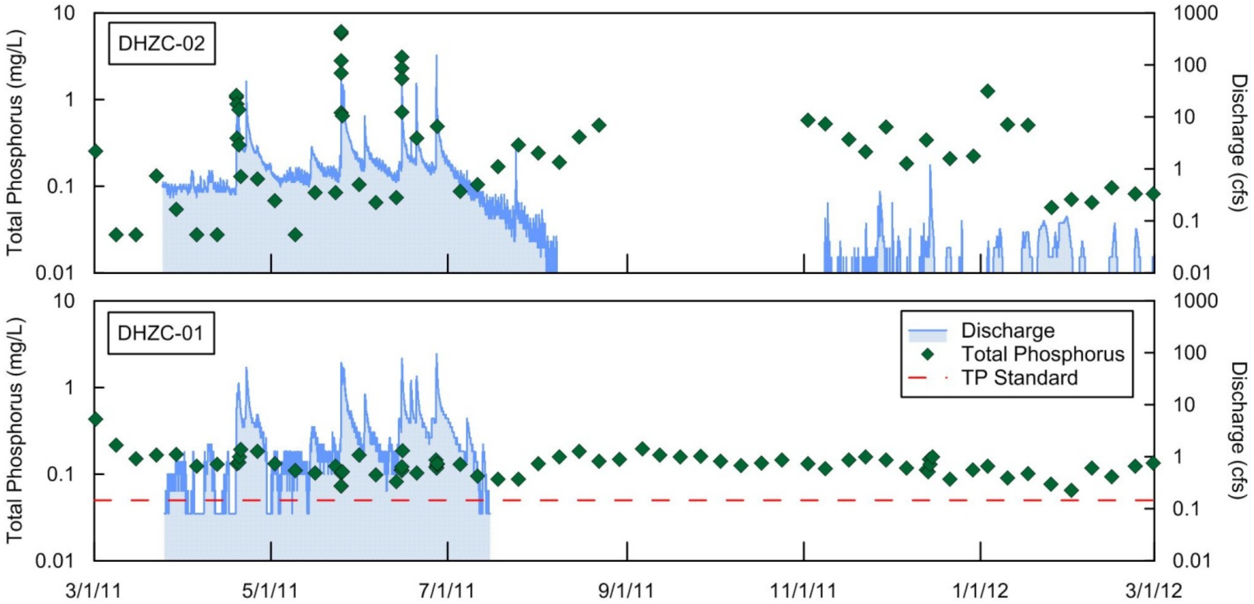

Figure 5-38. Total phosphorus concentrations, project data

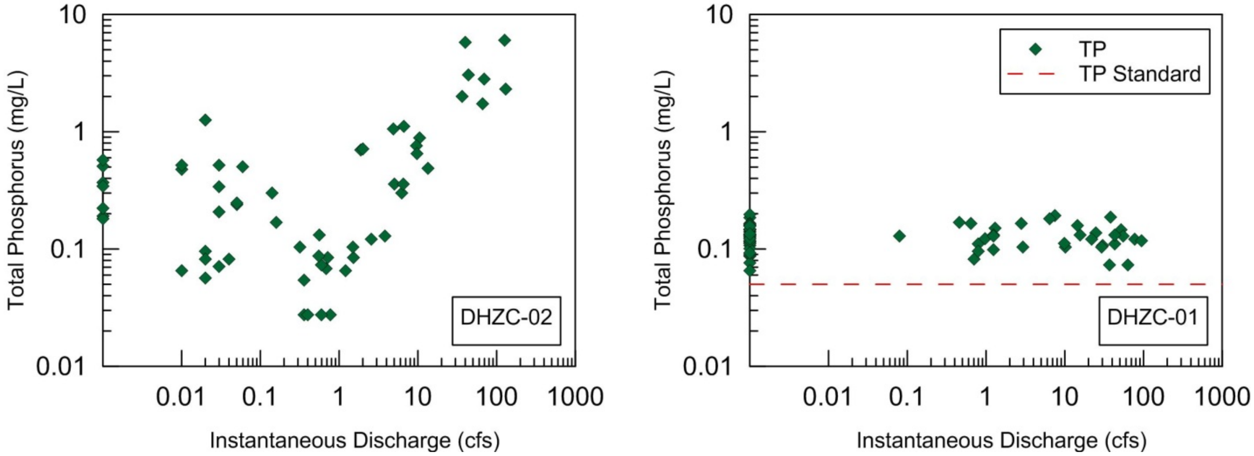

Figure 5-39. Relationship between total phosphorus concentration and discharge, project data

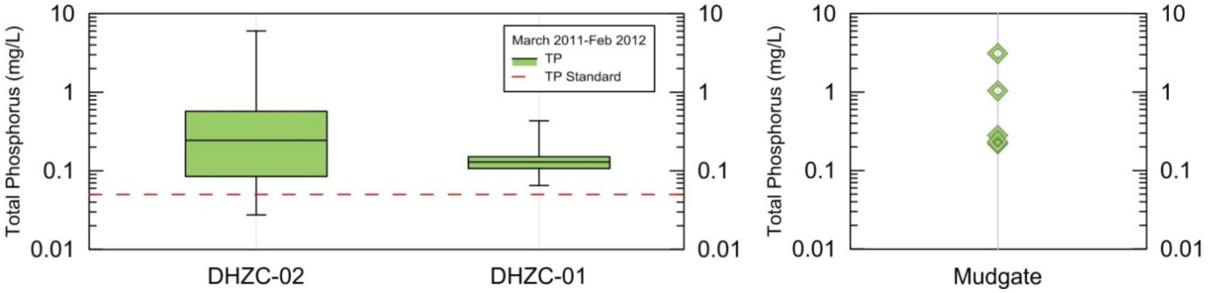

Figure 5-40. Box-whisker plots of total phosphorus concentrations, project data

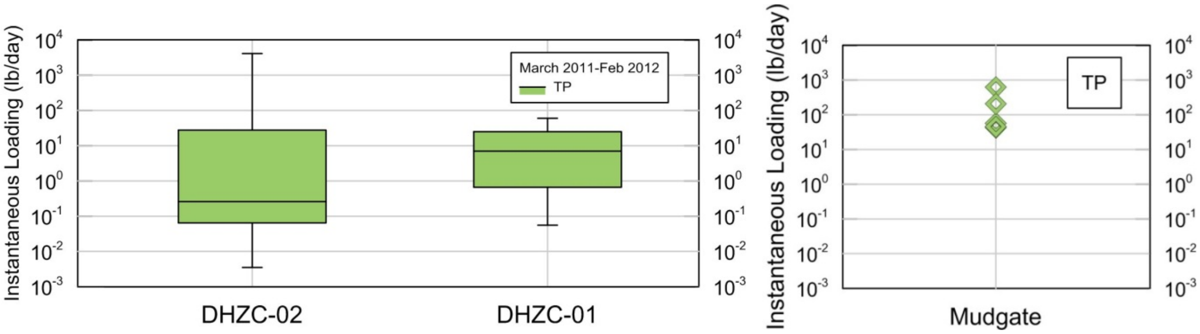

Figure 5-41. Box-whisker plots of total phosphorus instantaneous loadings, project data

Table 5-42 shows annual total phosphorus loads calculated from the project monitoring data. The outflow at the spillway site (DHZC-01) represents only a small fraction of the total load incoming to the reservoir. The sampled tributary (DHZC-02) represents 48% of the drainage area contributing to Vermont City Reservoir. Annual total phosphorus load from the ungaged area was estimated using the average annual yield (Table 5-42) to get a rough estimate of the total loading that entered the lake between March 2011 and February 2012. The load withdrawn through the Water Treatment Plant (WTP) intake was estimated from monthly pumped volumes and average monthly concentrations at DHZC-01. These numbers represent only preliminary estimates for the sampled time period and should not be interpreted as final or average loads. This preliminary estimate indicates that a majority (81%) of the total phosphorus load that entered Vermont City Reservoir between March 2011 and February 2012 remained in the lake storage. The total phosphorus released while the mudgate was open represents only 5% of the total phosphorus load that left the reservoir and less than 1% of total phosphorus load that entered the reservoir during this time period.

Table 5-42. Annual total phosphorus loads, project data

Station Code	**Type**	**Annual Load** lbs	**Annual Yield** lbs/ac
DHZC-02	Inflow	875	1.29
Ungaged area	Inflow	957*	1.29*
Total estimated inflow		*1,832*	
DHZC-01	Outflow	316	
Mudgate	Outflow	18	
WTP Pumpage**	Outflow	22	
Total estimated outflow		*356*	*0.25*

Notes: * Based on average annual yield
** Estimated from average monthly concentrations at DHZC-01

Dissolved phosphorus data were available for historical water quality sites. Table 5-43 shows summary information for ratio of dissolved phosphorus to total phosphorus. Only some samples were analyzed for both dissolved and total phosphorus concentrations as shown by the number of samples. The mean ratios of dissolved phosphorus to total phosphorus at three IEPA sites with historical data are comparable. The smallest variation was found at site RDM-3

(Figure 5-42). This is also the site with the least number of samples available for analyses. A high ratio of dissolved to total phosphorus would indicate a higher proportion of phosphorus in a form readily available for uptake by aquatic plants. A low ratio would indicate most phosphorus is bound to sediment and not readily available for uptake. Typically, municipal effluent would contain mostly dissolved phosphorus while runoff from non-point sources would include a significant proportion of sediment-bound phosphorus.

Table 5-43. Ratio of dissolved phosphorus to total phosphorus, historical data (unitless)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
RDM-1	7/18/1989	10/18/2011	64	0.061*	0.265*	0.876*
RDM-2	5/1/2001	10/20/2005	10	0.136	0.320	0.574
RDM-3	5/1/2001	10/19/2001	5	0.128	0.221	0.263

Notes: * concentrations below detection limit (ND) were removed to calculate the ratio

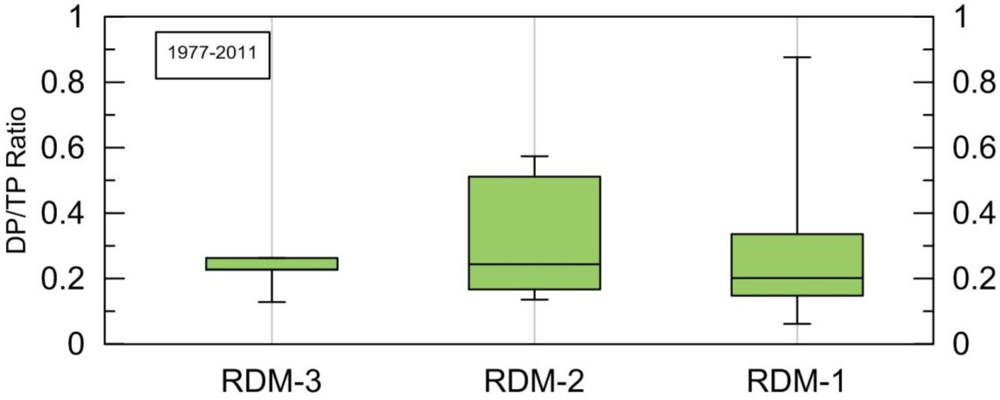

Figure 5-42. Box-whisker plots of ratio of dissolved to total phosphorus, historical data

Table 5-44 summarizes historical data for total phosphorus in sediment. Short (1997) analyzed sediment data for Illinois between 1982 and 1995. Concentrations at or above 1,000 mg/kg were determined to be “elevated,” and concentrations at or above 2,800 mg/kg were determined to be “highly elevated.” “Elevated” and “highly elevated” refer to those concentrations of a particular constituent that equal or exceed the 85th and 98th percentiles, respectively, (along the normal distribution curve) of the samples included in the study by Short (1997). One of four samples at site RDM-1 is found above the elevated value. The highest value at this site was observed in 2010 (Figure 5-43). No samples at the sites RDM-2 and RDM-3 (one sample each) are found above the elevated value.

Table 5-44. Total phosphorus data in sediment, historical data (mg/kg)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum
RDM-1	7/18/1989	7/20/2010	4	887	1034	1340
RDM-2	10/20/2005	10/20/2005	1	765	765	765
RDM-3	7/17/2001	7/17/2001	1	356	356	356

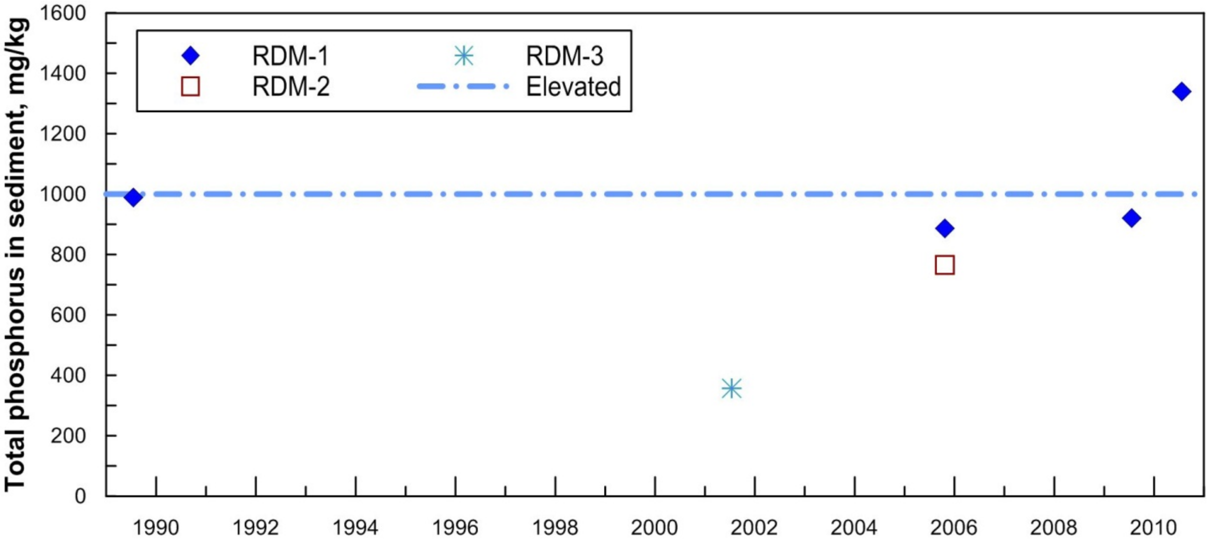

Figure 5-43. Total phosphorus concentration in sediment, historical data

Phosphate data (PO₄ as P) were collected in one well in the Vermont City Reservoir watershed in 1974. The analyzed sample was below detection limit. A summary of groundwater total phosphate concentrations from the one Vermont City Reservoir watershed well contained in ISWS groundwater database is in Table 5-45.

Table 5-45. Total phosphate data summary, groundwater data (mg/l as P)

TRS	Start Date	End Date	Number Samples	Minimum	Average	Maximum
04N01E23	8/14/1979	8/14/1979	1	ND	ND	ND

Notes: TRS = Township, Range, Section; ND = analyte not detected, value below detection limit

5.3.5 Algae

A summary of historical and project data for algae data collected in Vermont City Reservoir is presented in Table 5-46 and Table 5-47, respectively. The actual TMDL will not be developed for algae directly. Rather, the chlorophyll data will be used for modeling purposes and as an indicator of eutrophication due to nutrients such as total phosphorus.

Chlorophylls, the greenish pigments present in algae that enable photosynthesis, are a measure of the algae found in a water body. Often chlorophyll concentrations are determined separately for sestonic algae, those algae suspended in the water column, and benthic algae, which are algae that are attached to solid substrates within the water body. Chlorophyll a is present in all algae, plants, and cyanobacteria. Chlorophyll b occurs only in the "green algae" and chlorophyll c occurs only in brown algae. Pheophytin is a degradation product that is used to measure decay/death in algae. Its presence can lead to overestimation of chlorophyll a using the "uncorrected" indicator. Total algae counts provide information on the concentration of algal cells within the water column and can help indicate when algal blooms occur. Algal counts can exceed 100,000 cells/ml under bloom conditions and have significant impacts on the water quality and biota of a water body. Discussion in this section focuses mostly on chlorophyll a (corrected for pheophytin).

Table 5-46. Algae data summary, historical data (µg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Median
Chlorophyll a, corrected for pheophytin							
RDM-1	5/1/2001	10/18/2011	24	1.62	63.8	243	46.9
RDM-2	5/1/2001	10/20/2005	10	24.2	50.5	123	40.7
RDM-3	5/1/2001	10/19/2001	5	29.9	42.7	57.8	42
Chlorophyll-b							
RDM-1	5/1/2001	10/18/2011	24	0.5	2.9	13.6	1.1
RDM-2	5/1/2001	10/20/2005	10	1	3.4	6.87	3.1
RDM-3	5/1/2001	10/19/2011	5	1	5.048	12.9	3.8
Chlorophyll-c							
RDM-1	5/1/2001	10/18/2011	24	0.5	6.8	20.8	5.0
RDM-2	5/1/2001	10/20/2005	10	0.5	4.0	12	2.3
RDM-3	5/1/2001	10/19/2001	5	1	4.3	12.4	2.2
Pheophytin-a							
RDM-1	5/1/2001	10/18/2011	24	0.5	4.8	17.1	4.1
RDM-2	5/1/2001	10/20/2005	10	0.5	3.4	17.8	1.2
RDM-3	5/1/2001	10/19/2001	5	1	4.8	17.7	1.4
Total Algae (cells/ml)							
RDM-1	8/18/1977	8/18/1977	1	453	453	453	453
RDM-2	8/18/1977	8/18/1977	1	471	471	471	471
RDM-3	8/18/1977	8/18/1977	1	419	419	419	419

Table 5-47. Algae data summary, project data (µg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Maximum	Median
DHZC-01	6/6/2011	9/26/2011	9	2.44	29.0	110	22

Figure 5-44 and Figure 5-45 show chlorophyll a concentrations (corrected for pheophytin) plotted in time for historical and current project data, respectively. Discharge for the current project site at the spillway with a stream gage is also shown. The gaps in the discharge plot show dry periods of zero flow (i.e., there were no missing streamflow data from the gage installation). Two lake sites have historical data available for multiple years, RDM-1 and RDM-2. The highest chlorophyll a concentration occurred at site RDM-1 in 2005. The current project data show a gradual increase in chlorophyll a (corrected for pheophytin) throughout the season with a peak concentration (110 µg/l) observed on August 15, 2011. Subsequent observations were significantly lower (less than 40 µg/l).

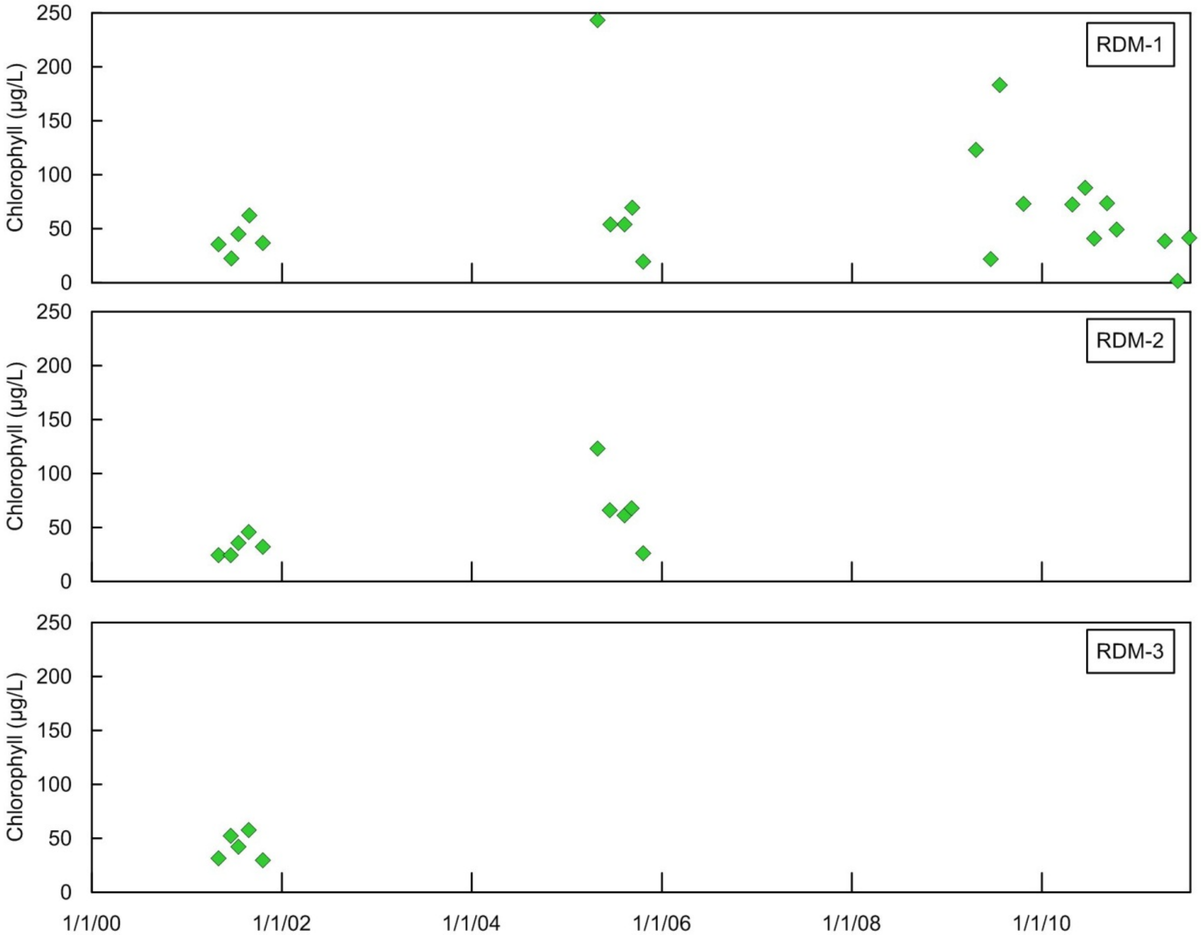

Figure 5-44. Chlorophyll a (corrected) concentrations, historical data

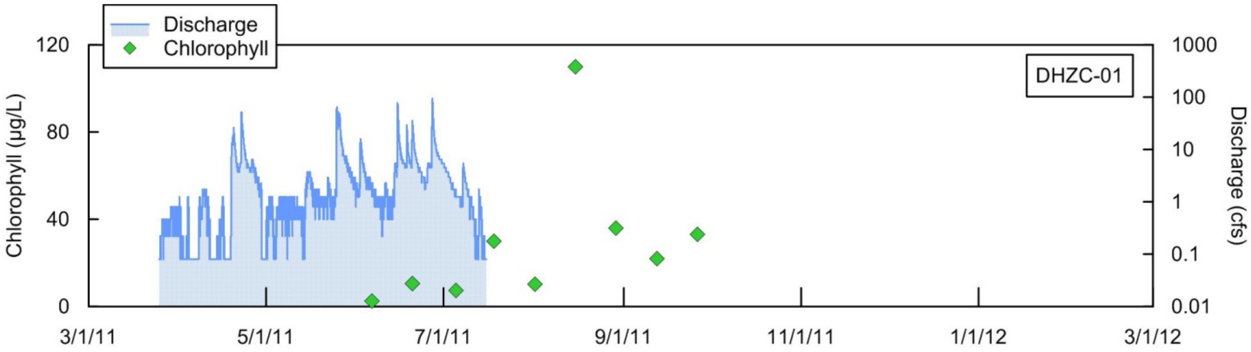

Figure 5-45. Chlorophyll a (corrected) concentrations, project data

There is no numeric standard for algae. The IEPA uses Aesthetic Quality Index (AQI) and Aquatic Life Use Index (ALI) to help evaluate whether designated uses are being met (IEPA, 2012). The AQI and ALI incorporate the Trophic State Index (TSI, Carlson, 1977), the percent-surface-area macrophyte coverage during the peak growing season (June through August), and the median concentration of nonvolatile suspended solids. TSI is calculated from median chlorophyll a values, median total phosphorus, and median Secchi disk transparency values using the following equations, respectively:

$$TSI = 9.81 \ln (Ch\_a) + 30.6$$
$$TSI = 14.42 \ln (TP) + 4.15$$
$$TSI = 60 - 14.41 \ln (S)$$

where S is Secchi disc depth in meters, Ch_a is chlorophyll a in µg/L, and TP is total phosphorus in µg/L. Rigorous data requirements are in place for the algae data collection used in lake assessments. Data are collected a minimum of five times per year (April through October) from one or more established lake sites. Data are considered usable for assessments if meeting the following minimum requirements (IEPA, 2012):

1) at least four out of seven months (April through October) of data are available;
2) at least two of these months occur during the peak growing season of June through August (this requirement does not apply to NVSS); and
3) usable data are available from at least half of all lake sites within any given lake each month.

Table 5-48 shows TSI calculated from chlorophyll a (corrected for pheophytin) and total phosphorus in samples collected at 1-foot depth and Secchi disc transparency. Chlorophyll-based TSI values range from 60.9 (site DHZC-01 in 2011) to 75.6 (site RDM-1 in 2009). Phosphorus-based TSI values range from 70.3 (site RDM-1 in 2011) to 77.6 (site RDM-1 in 2009). Secchi-based TSI values range from 69.1 (site RDM-1 in 2011) to 79.7 (site RDM-1 in 2010).

Table 5-48. Trophic State Index calculated for Vermont City Reservoir

		Chlorophyll a, corrected		**Total phosphorus**		**Secchi disc transparency**		**Median TSI**
Station Code	**Year**	**Median (µg/l)**	**TSI**	**Median (mg/l)**	**TSI**	**Median (in)**	**TSI**	
RDM-1	2001	36.5	65.9	0.119	73.1	14.0	74.9	73.1
	2005	54.2	69.8	0.106	71.4	13.0	76.0	71.4
	2009	98.0	75.6	0.163	77.6	18.0	71.3	75.6
	2010	72.1	72.6	0.133	74.7	10.0	79.7	74.7
	2011	41.3	67.1	0.098	70.3	21.0*	69.1*	68.7
RDM-2	2001	31.8	64.5	0.102	70.8	15.0	73.9	70.8
	2005	65.9	71.7	0.105	71.3	18.0*	71.3*	71.5
RDM-3	2001	42.0	67.3	0.123	73.5	12.0	77.1	73.5
DHZC-01	2011	22.0	60.9	0.129	74.2	14.4	74.5	74.2

Note: * less than 5 samples were collected (4 for RDM-1 in 2011 and 3 for RDM-2 in 2005)

ALI and AQI are calculated as a sum of points assigned based on three factors. Points, or weights, are assigned based on the range of calculated TSI (Table 5-49). All TSI values calculated for Vermont City Reservoir are consistently between 60 and 85 (2nd category for ALI), regardless of the factor used. Non-volatile suspended solids concentrations were calculated as a difference between total suspended solids and volatile suspended solids. Summer median concentrations for non-volatile suspended solids are shown in Table 5-50. Table 5-51 summarizes the points assigned to ALI and AQI. Additional points should be assigned based on macrophyte coverage. However, macrophyte data were not available for evaluation. An expected range is shown for total index values using the full extent (0-15 points) possible.

Aquatic life use is supported if total ALI is less than 75. This is true for all stations and years except site RMD-3 in 2001 where the threshold could possibly be exceeded if there was high macrophyte coverage. Aesthetic quality use is supported if total AQI is less than 60. All AQI points based on TSI already exceed this threshold. The minimum total AQI ranges from 77 to 90. The current project data confirm the aesthetic quality use impairment.

Table 5-49. Weights assigned to TSI (IEPA, 2012)

TSI Range	Aquatic Life Use Index Points	Aesthetic Quality Index Points
<60	40	Actual Median TSI value
60-85	50	
85-90	60	
≥ 90	70	

Table 5-50. Non-volatile suspended solids, 1-foot depth samples (mg/l)

Station Code	Year	Number Samples	Median
RDM-1	2001	5	12
	2005	5	10
	2009	5	14
	2010	5	15
	2011	5	9
RDM-2	2001	5	12
	2005	5	5
RDM-3	2001	4	20.5
DHZC-01	2011	35*	14.5*

Notes: * values below detection limit were removed from calculation

Table 5-51. Aquatic Life Use Index and Aesthetic Quality Index

Station		Aquatic Life Use Index			Aesthetic Quality Index		
Code	Year	TSI	NVSS	Total*	TSI	NVSS	Total*
RDM-1	2001	50	5	55-70	73	10	83-98
	2005	50	5	55-70	71	10	81-96
	2009	50	5	55-70	76	10	86-101
	2010	50	10	60-70	75	15	90-105
	2011	50	0	50-65	69	10	79-94
RDM-2	2001	50	5	55-70	71	10	81-96
	2005	50	0	50-65	72	5	77-92
RDM-3	2001	50	15	65-80	74	15	89-104
DHZC-01	2011	50	5	55-70	74	10	84-99

Notes: * the index varies depending on the actual macrophyte coverage; a range of possible values is presented; NVSS = non-volatile suspended solids

5.3.6 Fecal Coliforms

A summary of historical and project data for fecal coliform bacteria collected in Sugar Creek watershed is presented in Table 5-52 and Table 5-53, respectively. Several samples collected at site DH-01 (historical dataset) were flagged for quality, mostly due to colony counts outside the method acceptable range (110 samples). Eleven samples were reported at or below detection limit. The detection limit for fecal coliforms varied between 2 cfu/100 ml and 100 cfu/100 ml due to different dilutions of samples in the laboratory. Only one sample was reported at or below detection limit for the current project data (site DH-09_STP, detection limit 100 cfu/100 ml).

Table 5-52. Fecal coliform data summary, historical data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Median	Maximum
DH-01	9/8/1981	9/21/2006	192	2$	1,996*$	155*$	72,000$

Notes: * value affected by a presence of non-detects

$ value affected by a presence of quality flags

Table 5-53. Fecal coliform data summary, project data (mg/l)

Station Code	Start Date	End Date	Number Samples	Minimum	Average	Median	Maximum
Sugar Creek							
DH-02	5/4/2011	10/27/2011	36	100	4,953	2,100	58,400
DH-05	5/3/2011	10/25/2011	36	90	4,707	2,520	43,800
DH-06	5/4/2011	10/20/2011	36	184	6,113	3,670	27,000
DH-07	5/3/2011	10/27/2011	36	46	7,694	2,550	131,000
DH-08+	5/3/2011	10/27/2011	36	84	11,903	5,000	117,000
DH-09+	5/3/2011	10/27/2011	36	61	9,779	4,800	41,000
Tributaries							
DHC-01+	5/3/2011	10/25/2011	36	62	4,398	3,270	33,000
DHE-01	5/3/2011	10/27/2011	36	67	2,931	2,205	9,100
DHF-01	5/3/2011	10/27/2011	36	84	6,129	3,350	87,600
DHG-02	5/3/2011	10/27/2011	36	92	3,249	1,790	14,400
DHGA-01	5/3/2011	10/20/2011	36	85	3,440	2,100	26,300
DHGB-01	5/3/2011	10/27/2011	36	207	4,911	2,410	32,100
DHH-01	5/10/2011	9/29/2011	30	40	8,474	4,250	44,000
DHJ-01	5/4/2011	10/25/2011	36	22	3,661	2,830	12,900
DHK-01	5/3/2011	10/27/2011	36	48	2,371	1,540	12,800
DHZA-01	5/3/2011	10/25/2011	36	20	4,206	1,800	36,500
DHZB-01+	5/4/2011	10/27/2011	36	236	7,759	4,450	43,800
End of Pipe							
DH-09_STP	5/5/2011	10/27/2011	12	ND	22,583*	9,750	175,000
DHZB-01_STP	5/17/2011	10/27/2011	11	270	5,249	2,920	16,100
DrainTile01	6/2/2011	6/2/2011	1	91,600	91,600	91,600	91,600

Notes: ND = analyte not detected in a sample

* value affected by a presence of non-detects

+ site located on a stream with disinfection exemption

General use fecal coliform water quality standards for the protection of Primary Contact Use are applicable to Sugar Creek from May to October during any given year. The geometric mean of five or more samples taken over a 30-day period should not exceed 200 cfu/100 ml. The 90th percentile of five or more samples taken over a 30-day period should not exceed 400 cfu/100 ml. Historical data were not collected in frequencies needed to calculate the required statistics. Individual exceedances are thus also evaluated as if the standard was required at all times. A large number of historical samples exceeded 200 cfu/100 ml and 400 cfu/100 ml values; 46% and 29%, respectively (Table 5-54). Both number of samples and percentage of samples exceeding 200 cfu/100 ml and 400 cfu/100 ml values are shown.

To assess primary contact use, Illinois EPA uses all fecal coliform bacteria from water samples collected in May through October over the most recent five-year period (i.e., 2006 through 2010 for this report). Based on these water samples, geometric means and individual measurements of fecal coliform bacteria are compared to the concentration thresholds. To apply the guidelines, the geometric mean of fecal coliform bacteria concentration is calculated from the entire set of May through October water samples, across the five years. No more than 10% of all the samples may exceed 400/100 ml for a water body to be considered fully supporting.

Six samples were collected each month from May 2011 to October 2011 as a part of the current project to evaluate compliance with the water quality standards for fecal coliforms. The results are presented in Table 5-55. Both number of 30-day evaluation periods and percent of evaluation periods exceeding 200 cfu/100 ml and 400 cfu/100 ml values are shown. Individual exceedances of 200 cfu/100 ml and 400 cfu/100 ml values (total number of samples and percent samples) are shown for comparison only and do not necessarily represent a violation of water quality standard. Note that four of the sites are located on a stream reach with a disinfection exemption: sites DH-08 and DH-09 are downstream of the Table Grove STP and sites DHZB-01 and DHC-01 are below the Astoria STP (Figure 5-52). This means the fecal coliform water quality standard is not applicable at these sites. These sites were monitored to assess their contribution of fecal coliform bacteria to Sugar Creek impairment.

The geometric mean exceeded 200 cfu/100 ml every month at every site on Sugar Creek monitored during this project except one month (May 2011) at site DH-07. The 90th percentile exceeded 400 cfu/100 ml every month at every site on Sugar Creek. Geometric means exceeded 200 cfu/100 ml every month at three sites on Sugar Creek tributaries and five out of six months at eight tributary sites. The 90th percentile exceeded 400 cfu/100 ml every month at four sites on Sugar Creek tributaries and five out of six months at seven tributary sites. Seven and eight tributary sites were in compliance with the geometric mean standard and the 90th percentile standard, respectively, during one month, May 2011.

Table 5-54. Number of exceedances of fecal coliform water quality standard, historic data. Number of assessment periods/samples not in compliance with the water quality standard with percent of assessment periods/samples not in compliance in parenthesis.

Station Code	200 cfu/100 ml		400 cfu/100 ml	
	30-day Periods Geometric Mean	Individual Samples*	30-day Periods 90th Percentile	Individual Samples*
DH 01	$	89 (46%)	$	57 (29%)

Notes: *individual exceedances of the value are shown for comparison only and do not necessarily represent a violation of water quality standard

$ data insufficient to calculate required statistic

Table 5-55. Number of exceedances of fecal coliform water quality standard, project data. Number of assessment periods/samples not in compliance with the water quality standard with percent of assessment periods/samples not in compliance in parenthesis.

Station Code	200 cfu/100 ml		400 cfu/100 ml	
	30-day Periods Geometric Mean	Individual Samples*	30-day Periods 90th Percentile	Individual Samples*
Sugar Creek				
DH-02	6 (100%)	33 (91%)	6 (100%)	29 (80%)
DH-05	6 (100%)	35 (97%)	6 (100%)	33 (91%)
DH-06	6 (100%)	35 (97%)	6 (100%)	35 (97%)
DH-07	5 (83%)	32 (88%)	6 (100%)	31 (86%)
DH-08+	6 (100%)	35 (97%)	6 (100%)	34 (94%)
DH-09+	6 (100%)	35 (97%)	6 (100%)	30 (83%)
Tributaries				
DHC-01+	5 (83%)	33 (91%)	5 (83%)	31 (86%)
DHE-01	5 (83%)	32 (88%)	5 (83%)	29 (80%)
DHF-01	6 (100%)	35 (97%)	6 (100%)	33 (91%)
DHG-02	5 (83%)	32 (88%)	5 (83%)	30 (83%)
DHGA-01	5 (83%)	31 (86%)	5 (83%)	29 (80%)
DHGB-01	6 (100%)	36 (100%)	6 (100%)	33 (91%)
DHH-01	5 (100%)	28 (93%)	5 (100%)	24 (80%)
DHJ-01	5 (83%)	31 (86%)	5 (83%)	29 (80%)
DHK-01	5 (83%)	34 (94%)	5 (83%)	29 (80%)
DHZA-01	5 (83%)	30 (83%)	6 (100%)	30 (83%)
DHZB-01+	6 (100%)	36 (100%)	6 (100%)	33 (91%)

Notes: *individual exceedances of the value are shown for comparison only and do not necessarily represent a violation of water quality standard

+ site located on a stream with disinfection exemption, exceedances do not represent a violation of the standard

Figure 5-46 shows month-to-month changes in fecal coliform bacteria in Sugar Creek and its tributaries. Statistical comparison of means[5] across the months was carried out for each site. The mean May fecal coliform bacteria counts were confirmed to be lower for all sites than in any other remaining month. Generally, the differences in mean fecal coliform bacteria cannot be statistically confirmed among the remaining months though there are some exceptions. The August and September means at site DH-09 are higher than the means at all other months at this site. The August mean at site DHGA-01 is higher than the means at the remaining months at this site. The August mean at site DHGB-01 is also higher than the means at the remaining months at this site with the exception of the July mean. Differences at other sites are not as pronounced and the groups often overlap.

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[5] Statistical significance was determined using 95% confidence level.

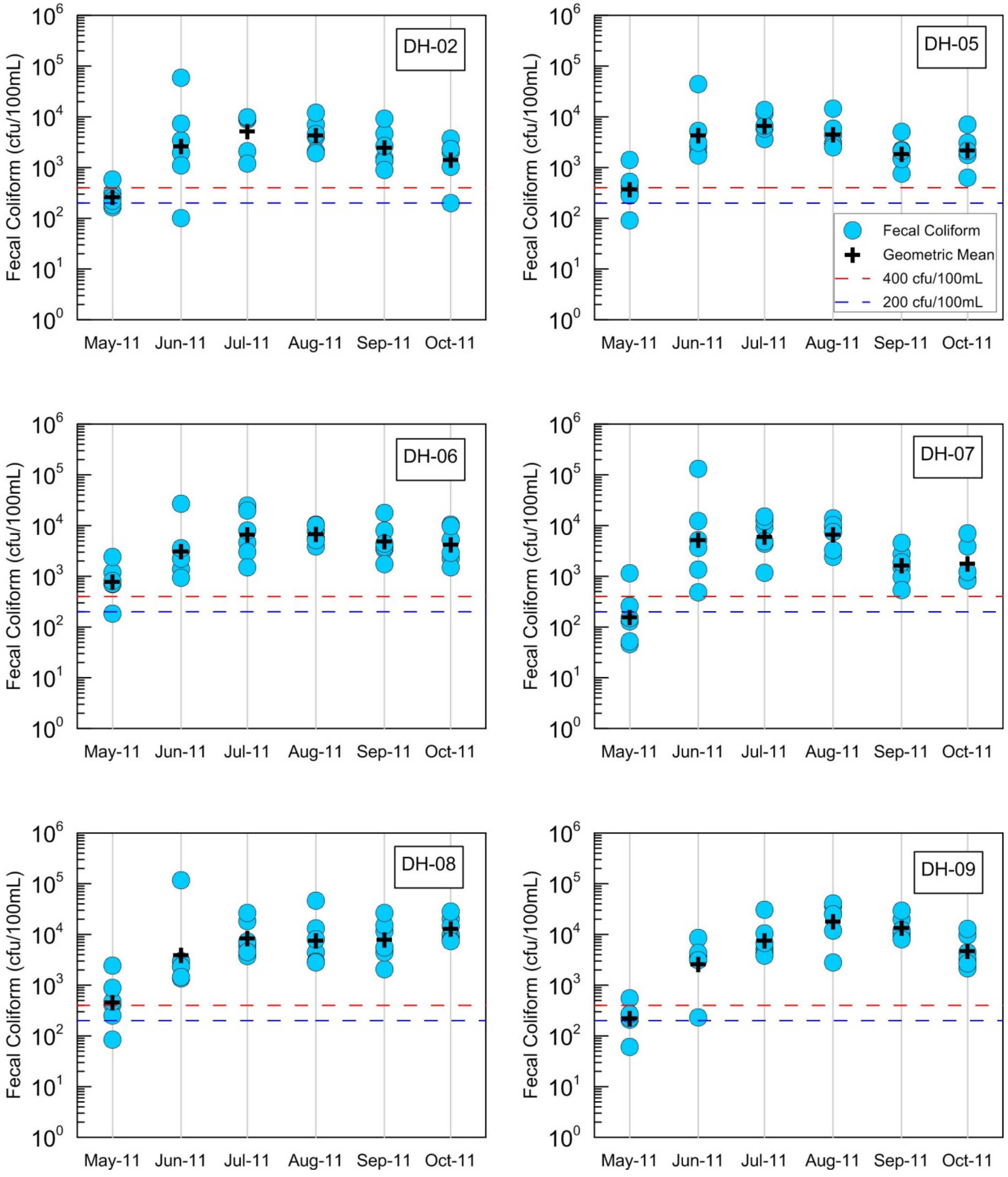

Figure 5-46. Fecal coliform bacteria counts and monthly geometric means, project data. The blue dashed line represents the geometric mean standard (200 cfu/100ml); the red dashed line represents the 90th percentile standard (400 cfu/100 ml).

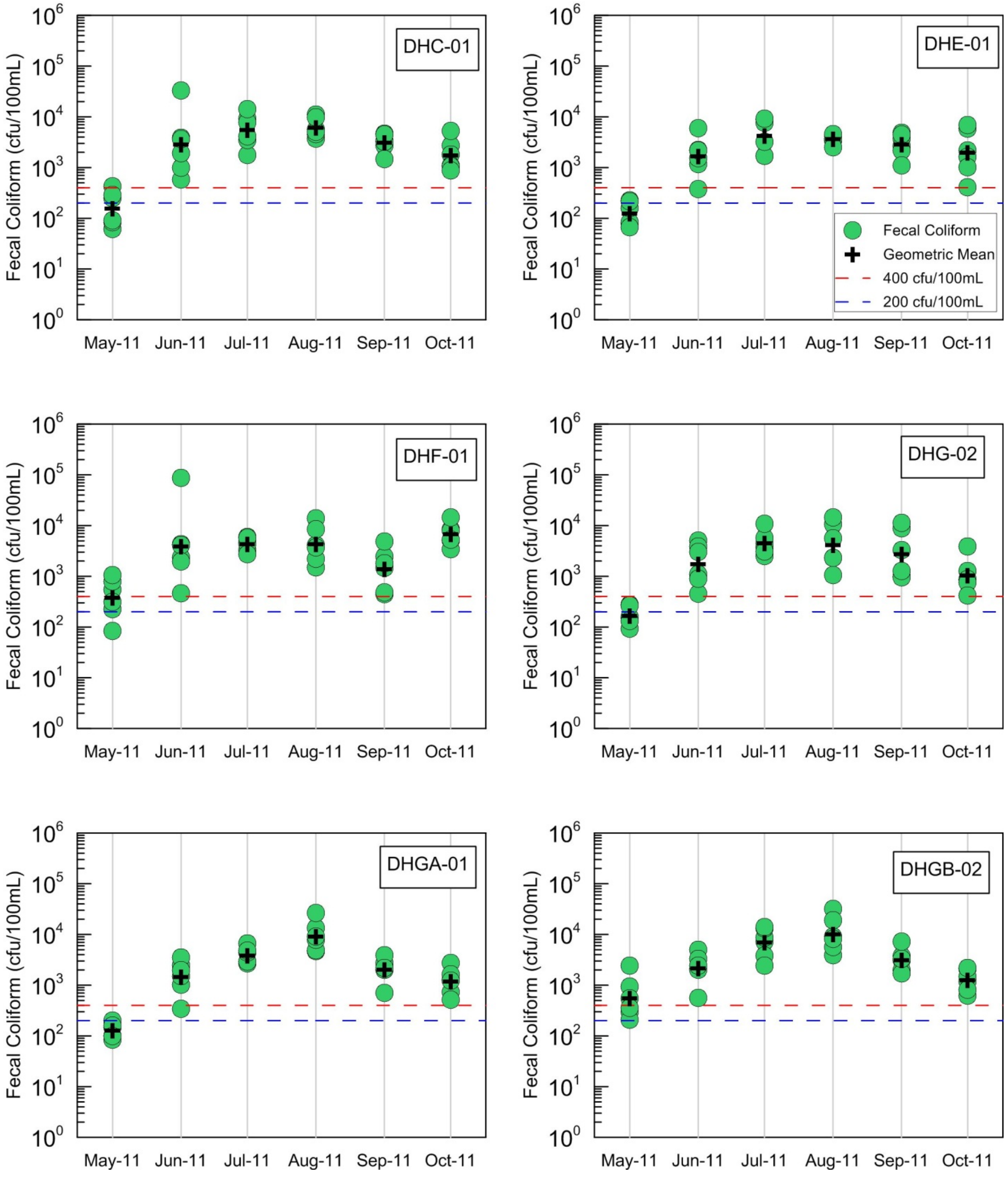

Figure 5-46 (continued)

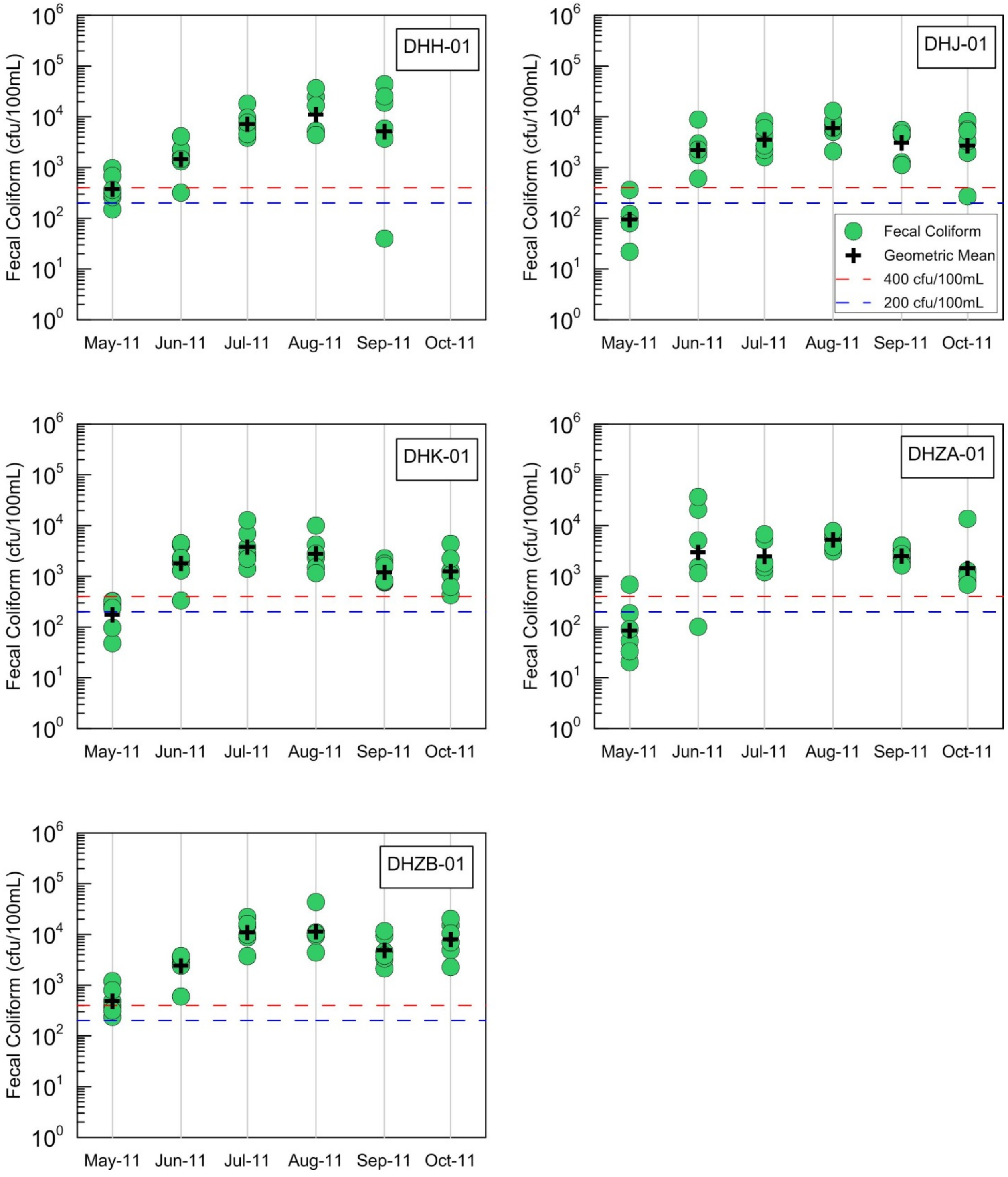

Figure 5-46 (continued)

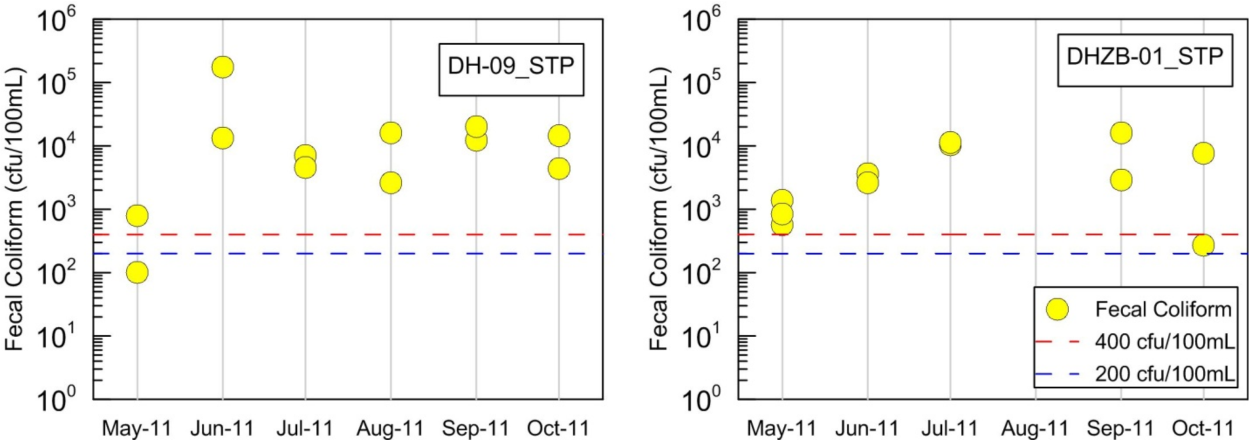

Figure 5-46 (concluded)

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. Figure 5-47 shows month-to-month changes in instantaneous loads of fecal coliform bacteria in Sugar Creek and its tributaries. A statistical comparison of means[6] across the months was carried out for each site. Generally, the mean June fecal coliform bacteria loads were the highest with the mean July loads following. While the mean September and October concentrations were relatively high, the mean loads were among the lowest. Several sites had zero discharge during September-October so loads were also zero, despite observable concentrations collected at remaining pools when present.

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[6] Statistical significance was determined using 95% confidence level.

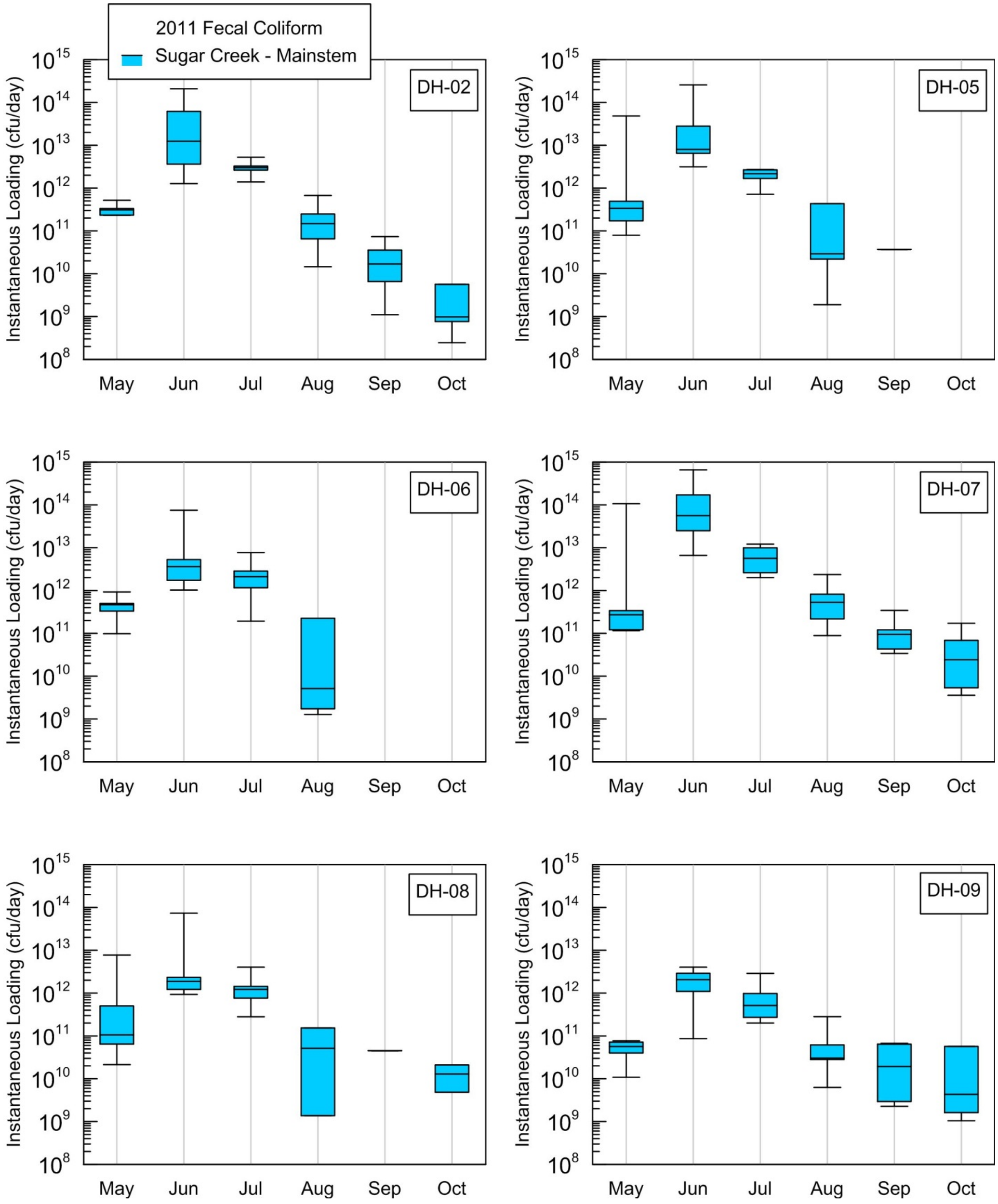

Figure 5-47. Monthly box-whisker plots of fecal coliform bacteria loads, project data

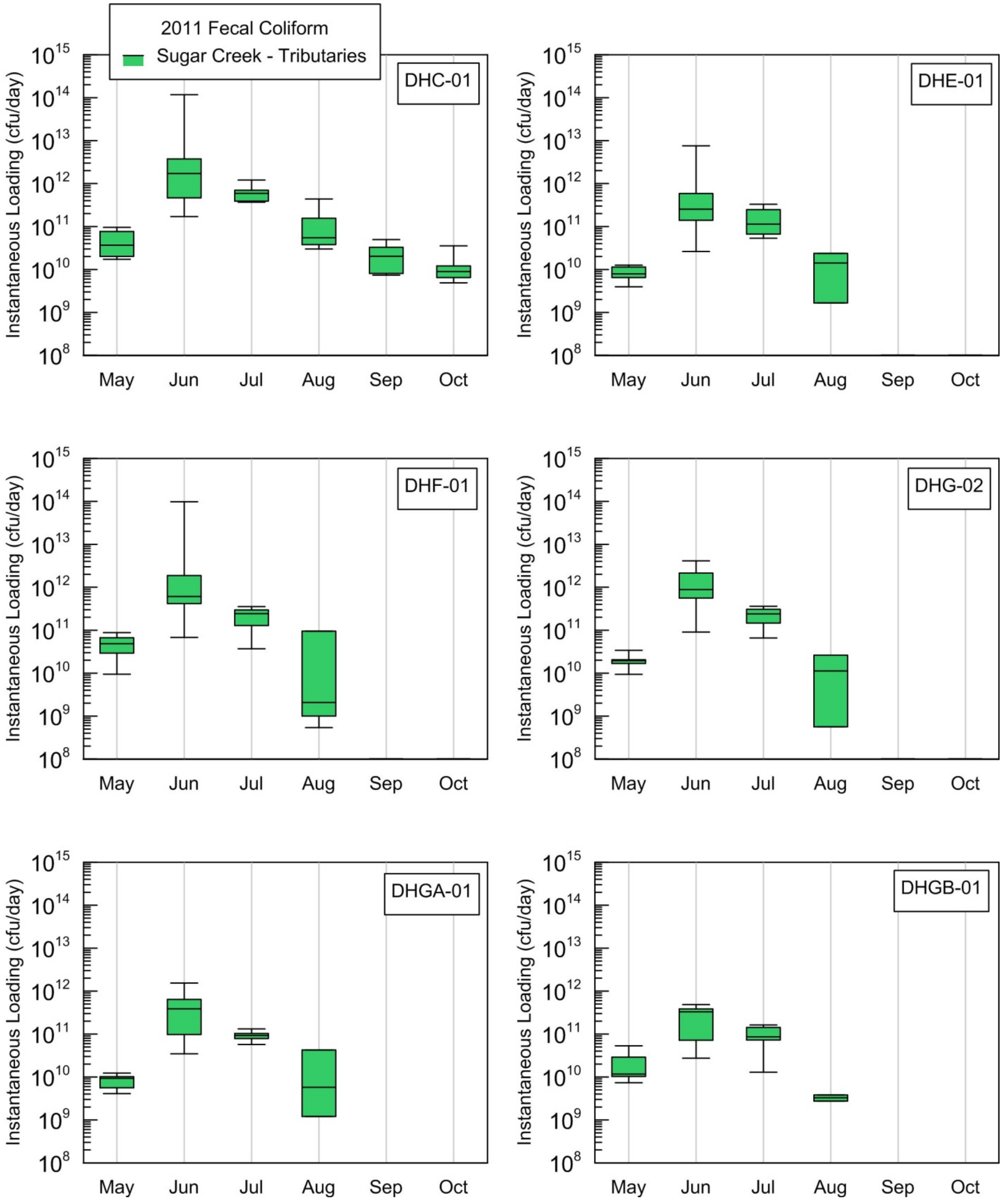

Figure 5-47 (continued)

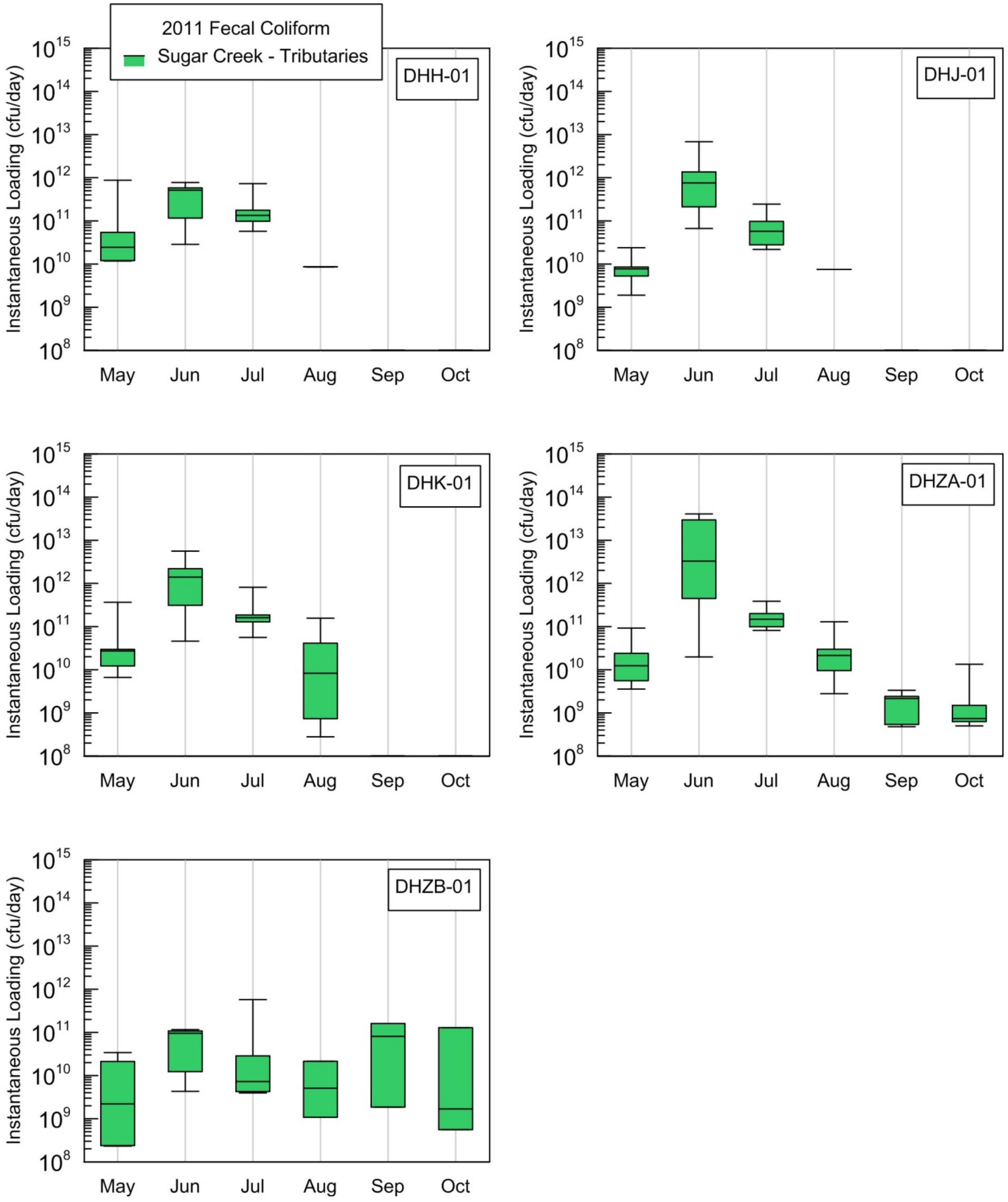

Figure 5-47 (concluded)

Figure 5-48 shows a relationship between the observed fecal coliform counts and instantaneous discharge for the current project data. Concentrations measured at zero discharge conditions are plotted against a discharge on the y-axis for each site. No discharge data were available for the historical data set. There is no apparent or statistically significant relationship between fecal coliform counts and discharges at any site.

Figure 5-49 compares distributions of fecal coliform bacteria at the project monitoring sites. Statistical comparison of means[7] was carried out using samples collected at the project monitoring sites. Sites DH-08 and DH-09_STP have the highest mean. However, the ranges in the estimated mean for these sites (the mean is estimated within certain confidence limits) overlap with the ranges of the estimated means for seven other sites (DHZB-01, DH-09, DH-06, DHH-01, DHZB-01_STP, DHGB-01, and DHF-01, in the descending order of mean fecal coliform concentrations). The means for the remaining 10 sites were lower than the means at sites DH-08 and DH-09_STP but not lower than the means at the seven remaining sites.

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[7] Statistical significance was determined using 95% confidence level.

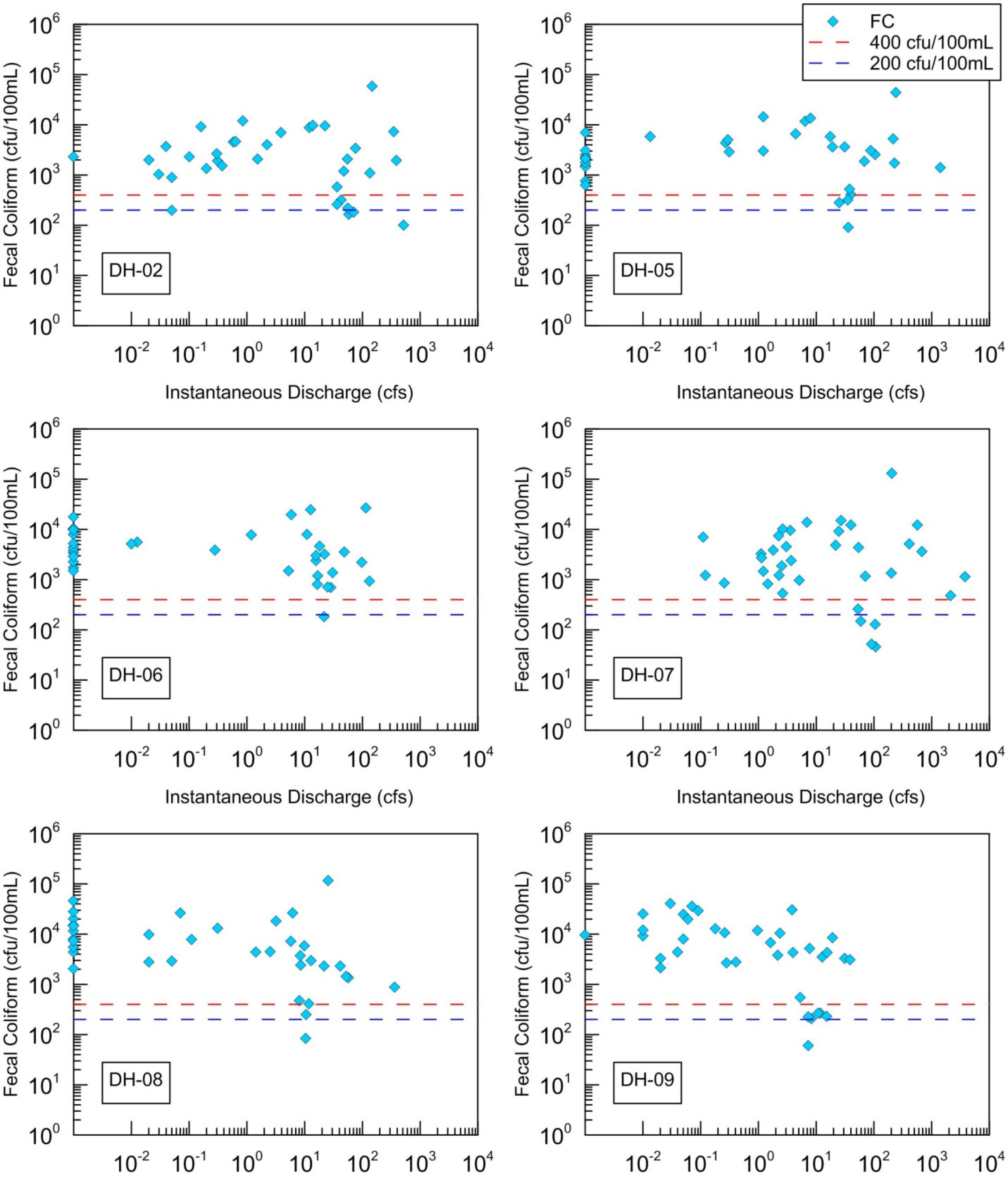

Figure 5-48. Relationship between fecal coliform bacteria counts and discharge, project data. The blue dashed line represents the geometric mean standard (200 cfu/100ml); the red dashed line represents the 90th percentile standard (400 cfu/100 ml).

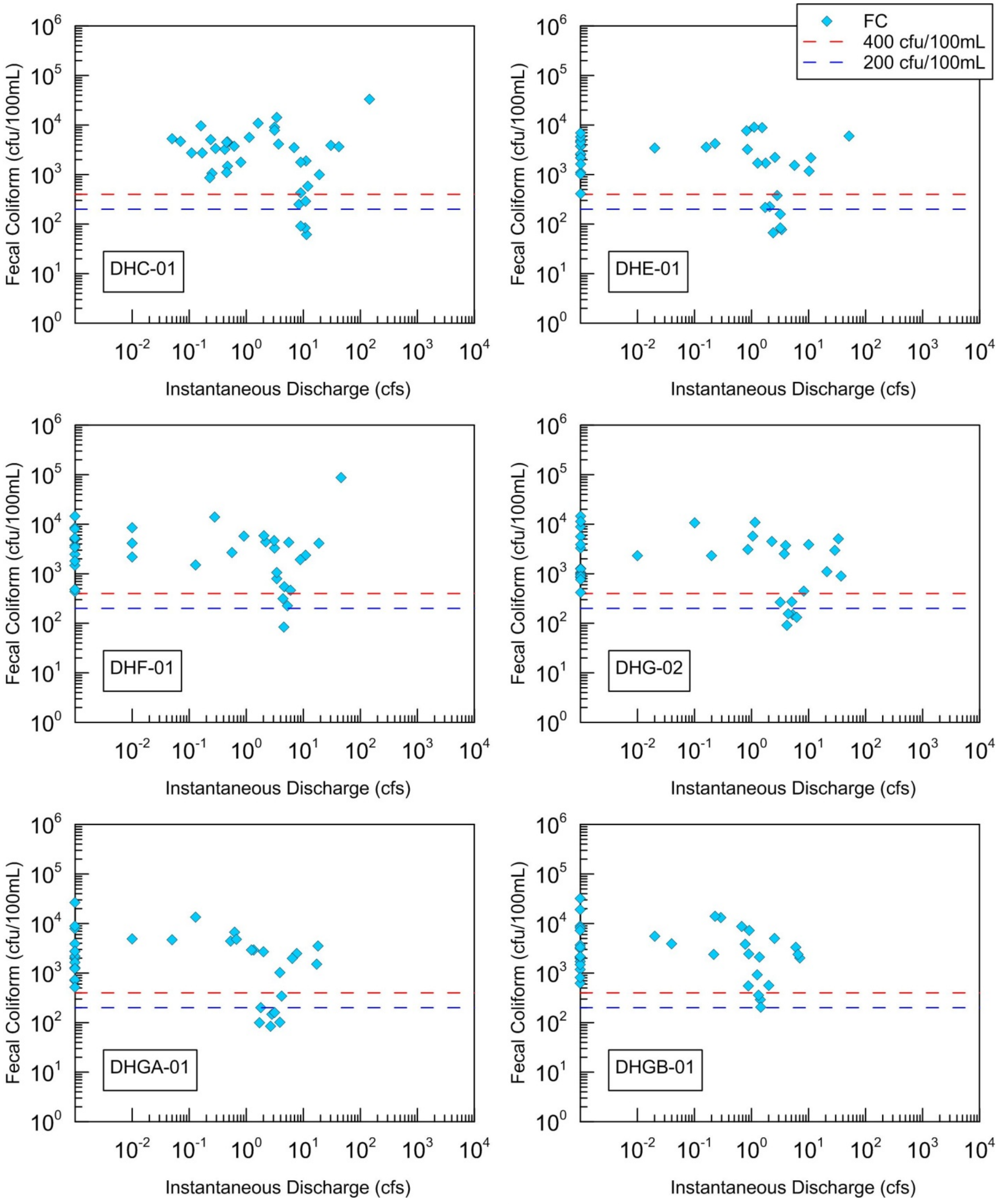

Figure 5-48. (continued)

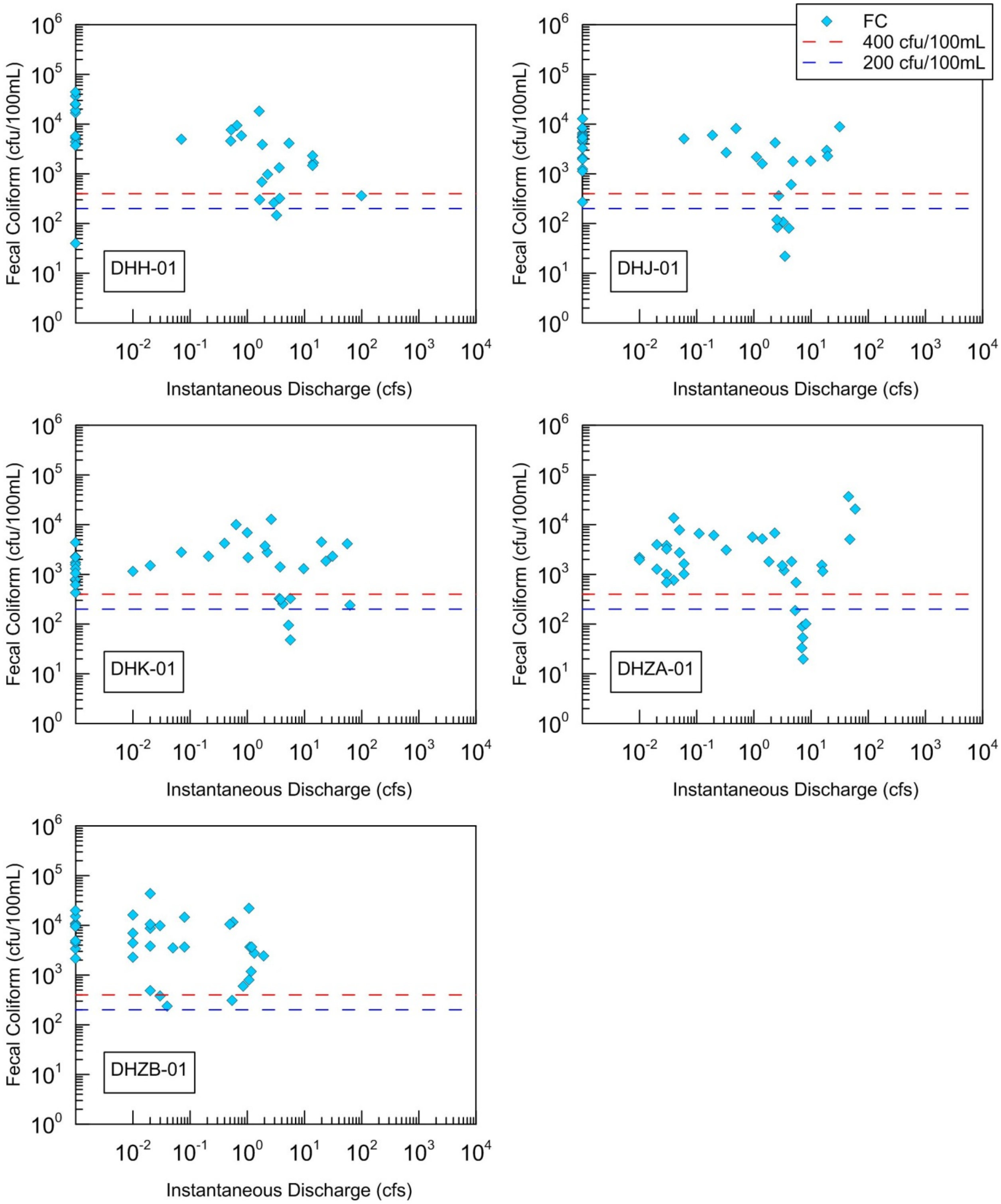

Figure 5-48 (concluded)

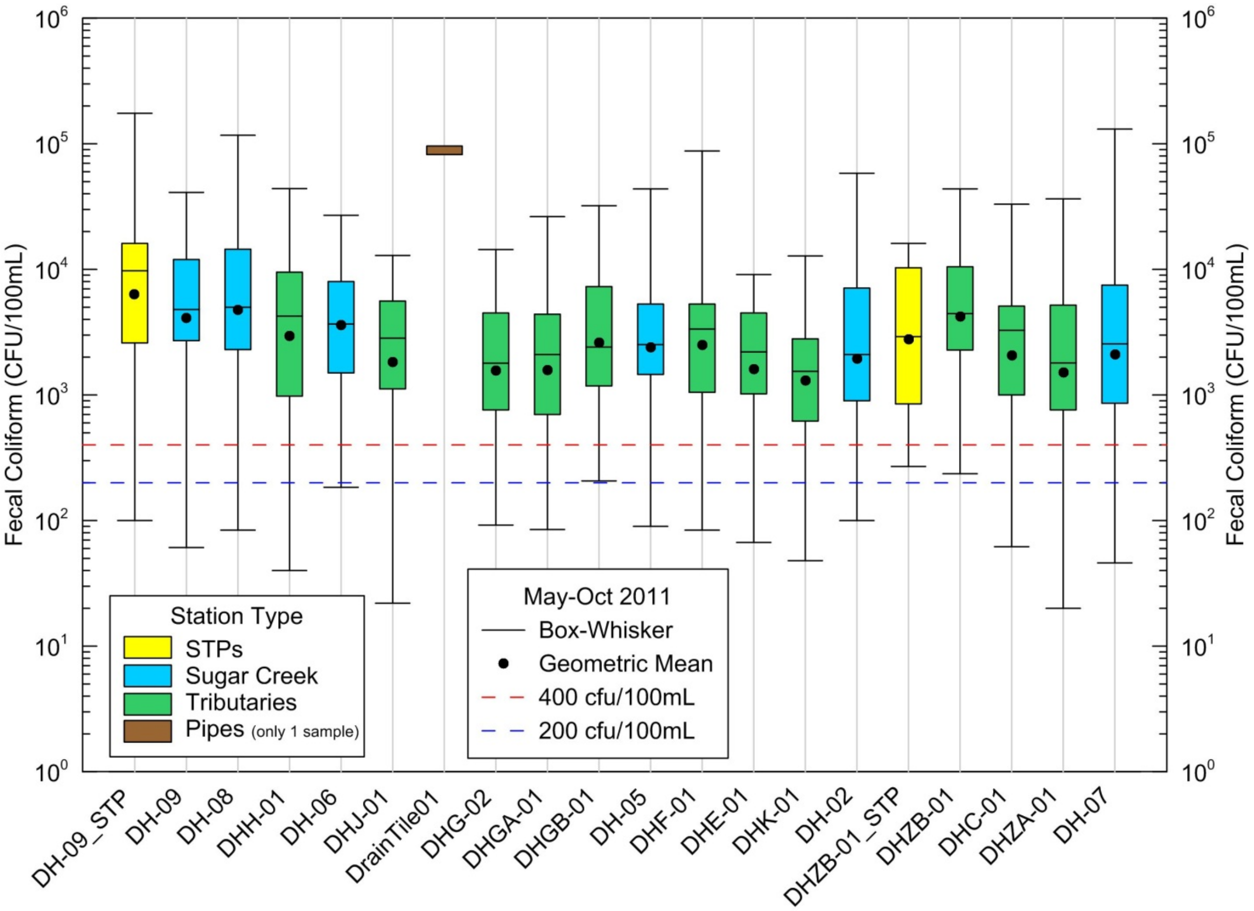

Figure 5-49. Box-whisker plots of fecal coliform bacteria counts, project data

Instantaneous loadings were calculated as a product of observed concentration, discharge, and appropriate conversion factor. Figure 5-50 and Figure 5-51 compare distributions of fecal coliform bacteria instantaneous loadings and yields (loading divided by a watershed area) at the project monitoring sites. Statistical comparison of means[8] was carried out using samples collected at the project monitoring sites. Two sites had the lowest mean fecal coliform loadings, DHZB-01 and DHZA-01. In spite of the similar mean loadings, these two sites are very different in other aspects. Site DHZB-01 had relatively higher mean fecal coliform counts and a very high mean fecal coliform yield. Site DHZA-01 had relatively lower mean fecal coliform counts and a very low mean fecal coliform yield.

The difference in mean fecal coliform loadings cannot be statistically confirmed among the sites with the exception of four sites. Sites DH-05, DH-07, and DH-06 have a mean fecal coliform loading higher than all other sites with the exception of sites DH-08 and DH-02. Site DHZB-01 has a mean fecal coliform loading lower than all other sites with the exception of site DHZA-01.

The difference in mean fecal coliform yields cannot be statistically confirmed among the sites with the exception of three sites. Sites DH-02 and DHZA-01 have a mean fecal coliform yield

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[8] Statistical significance was determined using 95% confidence level.

lower than all other sites. Site DHZB-01 has a mean fecal coliform yield higher than all other sites.

Site DHZA-01 has the second lowest proportion of agriculture land, the highest proportion of forested land, and only minimal urban land. Site DHZB-01 has the highest proportion of urban land and the lowest proportion or agriculture and forest land. Despite the large differences in fecal coliform yields in sites DHZA-01 and DHZB-01, instantaneous loads at these sites are very similar due to large differences in watershed areas. Watershed area contributing to site DHZB-01 is about 1% of the watershed area contributing to site DHZA-01.

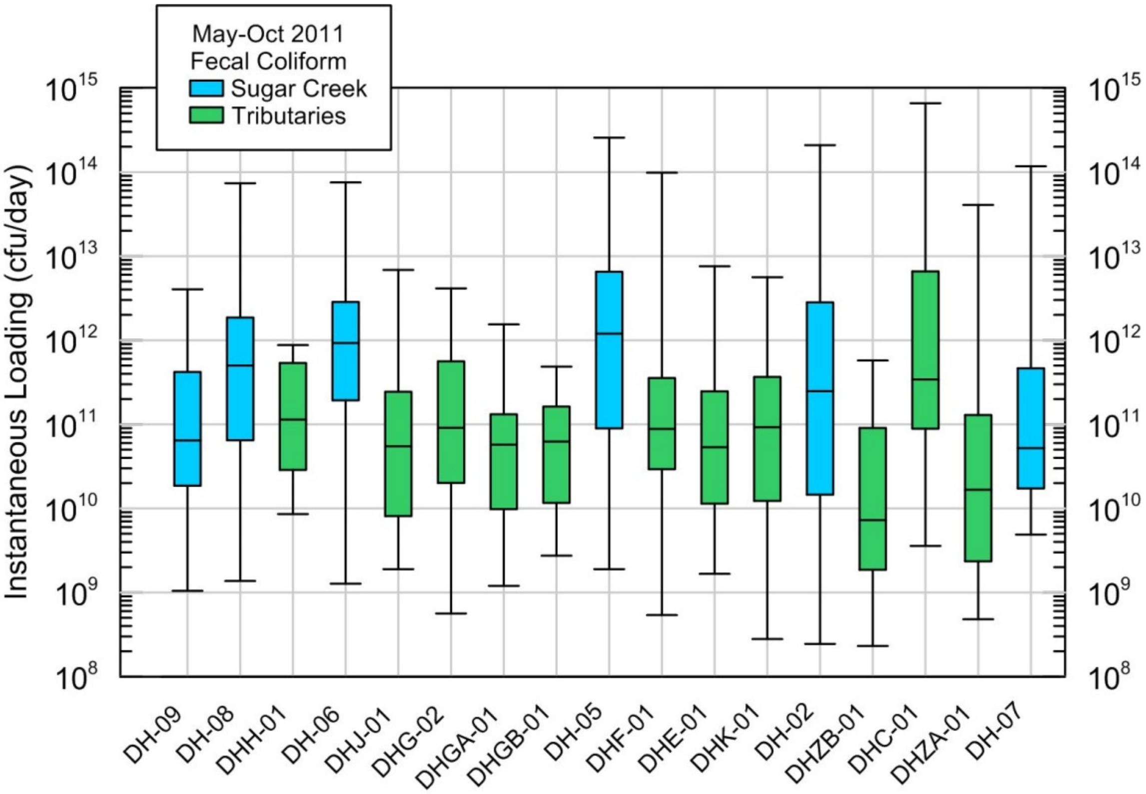

Figure 5-50. Box-whisker plots of fecal coliform bacteria loads, project data

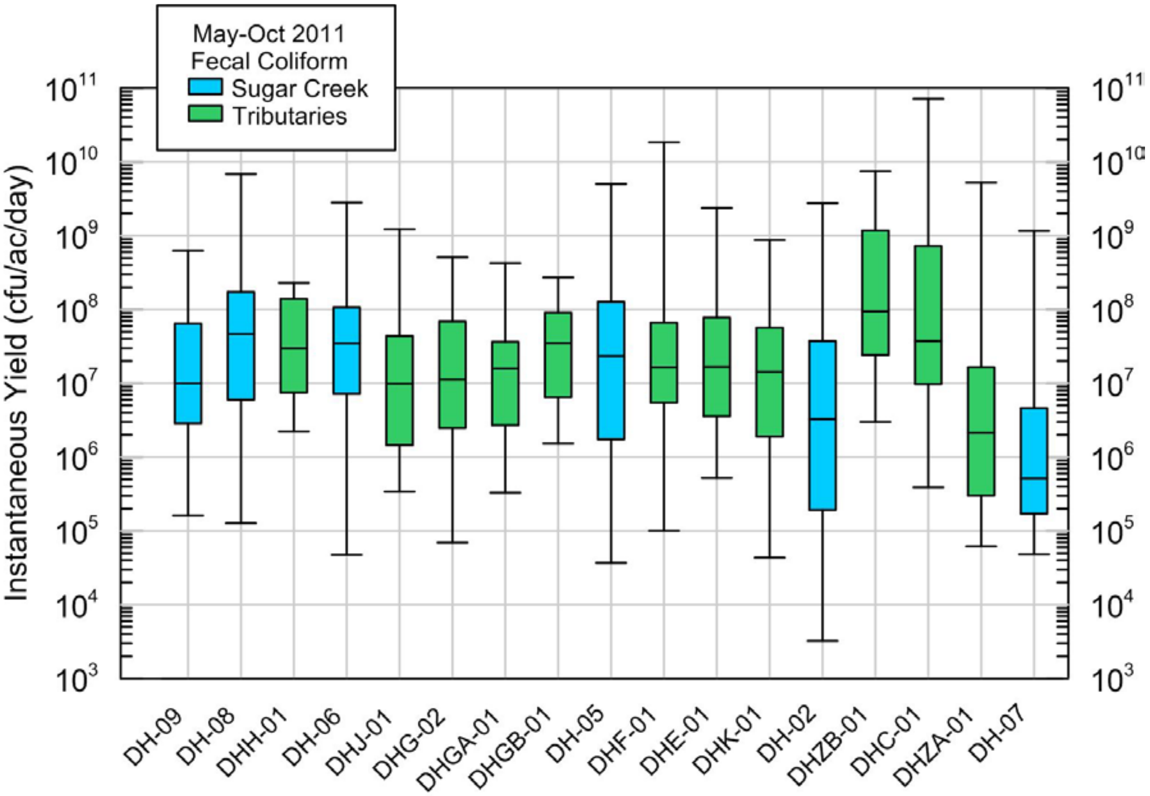

Figure 5-51. Box-whisker plots of fecal coliform bacteria yields, project data

5.4 Potential Sources of Impairment

This section addresses potential sources of impairment as they relate to the constituents of concern (causes of impairment) for Vermont City Reservoir and Sugar Creek. The potential sources listed in the IEPA Integrated Water Quality Reports for Vermont City Reservoir are listed in Table 5-56 for years 2006, 2008, 2010 (Draft), and 2012 (Draft). The list of potential sources is based on best professional judgment and is not exclusive of other potential causes of impairment. In addition to the potential sources listed in Table 5-56, other sources are also discussed based on watershed characteristics.

Table 5-56. Potential sources of impairment for Vermont City Reservoir (IEPA, 2006, 2008, 2010, 2012)

Potential Source of Impairment	2012	2010	2008	2006
Agriculture	Y			
Contaminated sediments	Y	Y	Y	
Crop Production (Crop Land or Dry Land)	Y	Y	Y	Y
Lithoral/shore area modifications	Y	Y	Y	
Livestock (Grazing or Feeding Operations)	Y	Y	Y	Y
Natural sources	Y			
Runoff from forest/grassland/parkland	Y	Y	Y	Y
Unknown sources	Y	Y	Y	Y

The IEPA does not list any specific sources other than “source unknown” for Sugar Creek (IEPA, 2006, 2008, 2010, and 2012). The individual potential sources are discussed below in more detail, including any permitted discharges present in the watershed.

5.4.1 Point Sources

Information on National Pollutant Discharge Elimination System (NPDES) permit holders in the vicinity of the Sugar Creek watershed was obtained from the Environmental Protection Agency Permit Compliance System (USEPA, 2011). Three NPDES permit holders are located within the Sugar Creek watershed: The Village of Astoria sewage treatment plant (STP), the Village of Table Grove STP, and the Village of Vermont water treatment plant (WTP). There are no NPDES permit holders within the Vermont City Reservoir watershed. Discharge monitoring report (DMR) data for relevant NPDES permits were obtained from the Illinois Environmental Protection Agency historic DMR search page (IEPA, 2010). Table 5-57 provides a summary of available information for these facilities.

The Village of Astoria STP discharges into an unnamed tributary of Harris Branch, which is a tributary of Sugar Creek. The parameters currently reported for the Astoria STP main outfall are pH, TSS, flow, chlorine, CBOD5, and Dissolved Oxygen (DO). The parameters currently reported for the Astoria STP excess flow outfall are pH, TSS, flow, chlorine, BOD5, and fecal coliform. Monthly data were downloaded for the period July 2001–April 2012. The Design Average Flow is 0.28 mgd and Design Maximum Flow is 0.70 mgd.

The Village of Table Grove STP discharges into Sugar Creek. The parameters currently monitored at the Table Grove STP are pH, TSS, flow, chlorine, and CBOD5. Monthly data were downloaded for the period April 2003–April 2012. The Design Average Flow is 0.075 mgd and Design Maximum Flow is 0.1875 mgd.

The Village of Vermont WTP discharges into a tributary to Sugar Creek. The parameters currently monitored at the Vermont WTP are pH, TSS, flow, and chlorine. Monthly data were downloaded for the period April 2000-April 2012.

The Astoria and Table Grove STPs both have disinfection exemptions for their main STP outfalls. A disinfection exemption may be granted if a facility discharges to a water body that is unsuitable for primary contact activities (swimming) and is not utilized for public or food processing water supply. A disinfection exemption waives the requirement to test for fecal coliform bacteria, and the receiving water body is not subject to fecal coliform water quality standards (Ill. Adm. Code, Section 378.101). Figure 5-52 shows a map of the facilities and streams with disinfection exemptions in the Sugar Creek watershed.

Table 5-57. NPDES permits and constituents monitored within the Sugar Creek watershed

NPDES permit holder	NPDES ID	Constituents Monitored
ASTORIA STP, VILLAGE OF	IL0025364	
STP Outfall		pH, TSS, flow, chlorine, CBOD5, DO
Excess Flow Outfall		pH, TSS, flow, chlorine, BOD5, coliform
TABLE GROVE STP, VILLAGE OF	ILG580040	
STP outfall		pH, TSS, flow, chlorine, CBOD5
VERMONT WTP, VILLAGE OF	ILG640188	
Iron filter backwash wastewater		pH, TSS, flow, chlorine

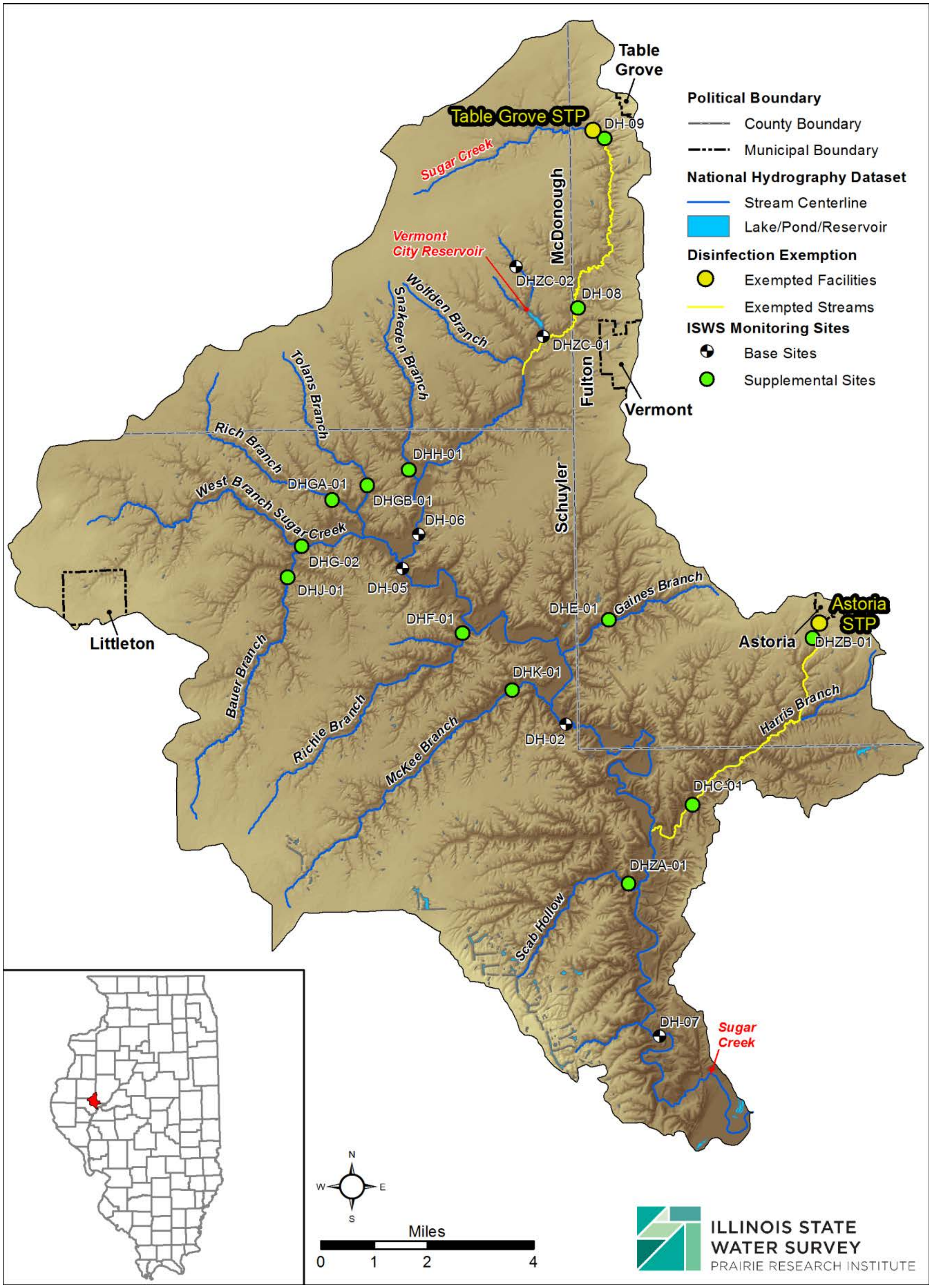

Figure 5-52. Disinfection exemptions in the Sugar Creek watershed

5.4.1.1 Astoria STP

Average monthly discharges for Astoria STP are shown in Figure 5-53. Table 5-58 shows basic statistics for monthly average discharge using only months with non-zero discharges. The excess flow was reported only for one month, September 2008. Total flow reported for Excess Flow Outfall in millions of gallons per month (2.1 mg/month) was recalculated to a monthly average equivalent in millions of gallons per day (0.070 mgd). Discharged volume for Excess Flow Outfall is only reported starting in July 2006. However, concentrations were reported for May 2002, indicating excess flow occurred that month. Maximum daily discharges were also available for the STP Outfall (Figure 5-54 and Table 5-59).

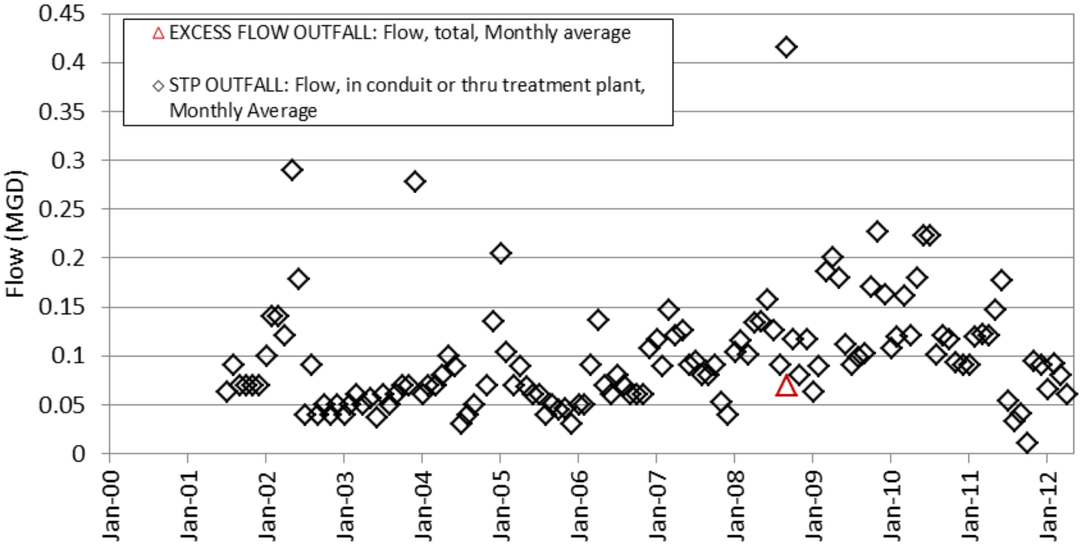

Figure 5-53. Monthly average discharges from Astoria STP (mgd)

Table 5-58. Average monthly discharges summary from Astoria STP (mgd)

Outflow Name	**Start Date**	**End Date**	**Non-zero Months**	**Minimum**	**Non-Zero Average**	**Maximum**
STP Outfall	7/2001	4/2012*	129	0.011	0.098	0.416
Excess Flow Outfall**	7/2006	4/2012*	1	0.070	0.070	0.070

Note: * Last month available at the time of the report preparation
** Discharge value 2.1 mg/month was recalculated into a monthly average equivalent

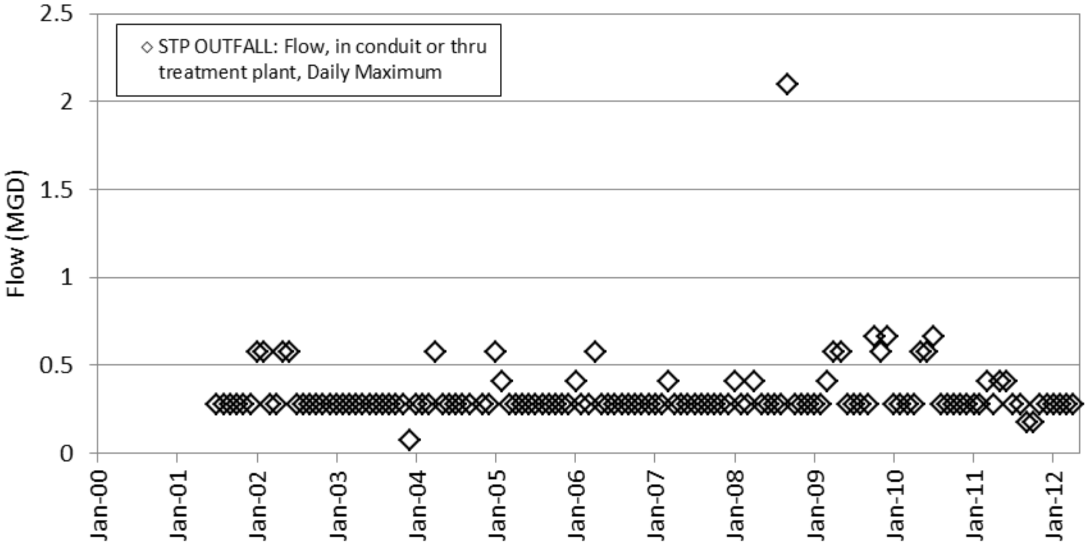

Figure 5-54. Maximum daily discharges from Astoria STP (mgd)

Table 5-59. Maximum daily discharges summary from Astoria STP (mgd)

Outflow Name	**Start Date**	**End Date**	**Non-zero Months**	**Minimum**	**Non-Zero Average**	**Maximum**
STP Outfall	7/2001	4/2012*	129	0.070	0.334	2.1

Note: * Last month available at the time of the report preparation

5.4.1.2 Table Grove STP

The Table Grove STP has only one outfall. Average monthly and daily maximum discharges for Table Grove STP are shown in Figure 5-55. Table 5-60 shows basic statistics for monthly average and daily maximum discharges using only months with non-zero discharges. Reported maximum daily discharges are identical to average monthly discharges with only several exceptions. All seven exceptions occurred on or before February 2006.

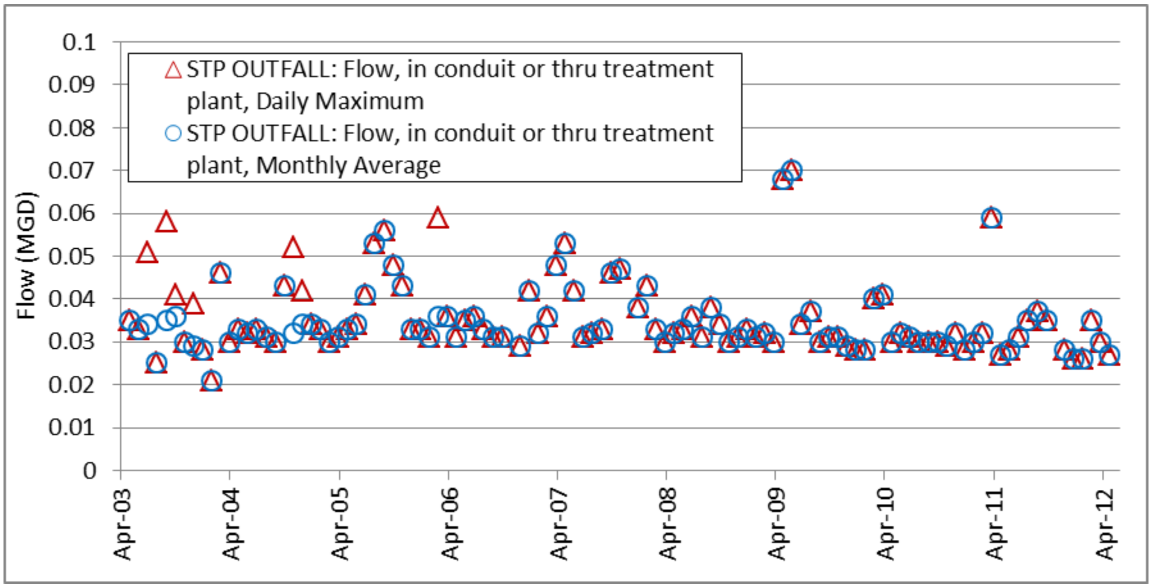

Figure 5-55. Monthly average and daily maximum discharges from Table Grove STP (mgd)

Table 5-60. Average monthly and daily maximum discharges summary from Table Grove STP (mgd)

Reported Value	**Start Date**	**End Date**	**Non-zero Months**	**Minimum**	**Non-Zero Average**	**Maximum**
Average monthly	4/2003	4/2012*	106	0.21	0.036	0.07
Daily maximum	4/2003	4/2012*	106	0.21	0.035	0.07

Note: * Last month available at the time of the report preparation

5.4.2.3 Vermont WTP

Average monthly discharges for Vermont WTP are shown in Figure 5-56. Table 5-61 shows basic statistics for monthly average discharge using only months with non-zero discharges. The DMR database has data for two outfalls at Vermont WTP, one labeled as “IRON FILTER BACKWASH WASTEWTR” and another as “UNTREATED FILTER BACKWASH”. However, only one outfall was operational at any given time, switching on February 2007. Unusually high discharges were reported in November 2004 (0.12 mgd) and November 2008 (0.054 mgd).

Maximum daily discharges were also available (Figure 5-57 and Table 5-62). An unusually high maximum daily discharge was reported in February 2005 (18 mgd). Statistics are reported both with and without this record.

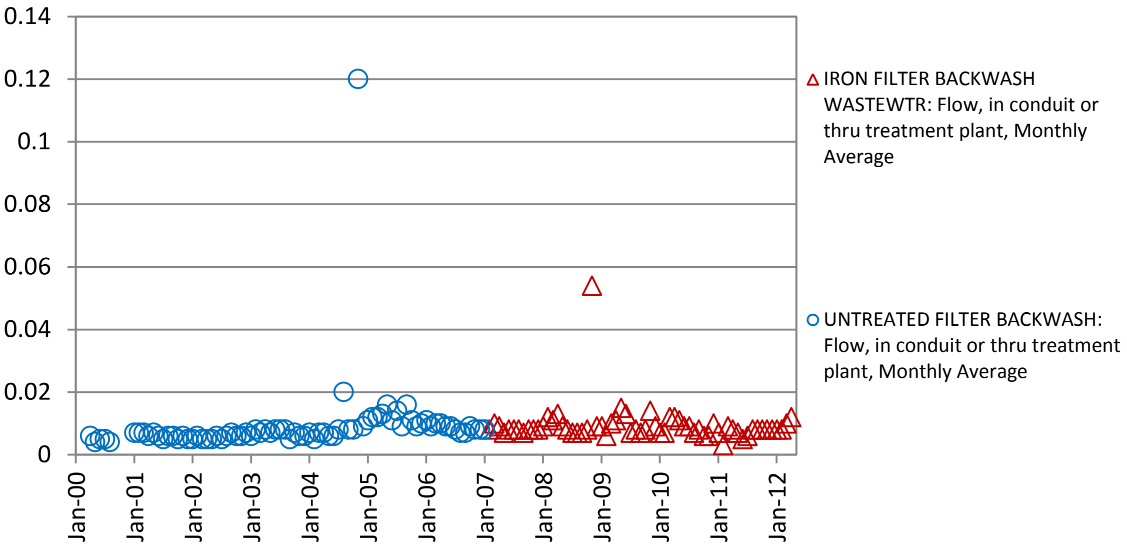

Figure 5-56. Monthly average discharges from Vermont WTP (mgd)

Table 5-61. Average monthly discharges summary from Vermont WTP (mgd)

Outflow Name	**Start Date**	**End Date**	**Non-zero Months**	**Minimum**	**Non-Zero Average**	**Maximum**
UNTREATED FILTER BACKWASH	4/2000	1/2007	78	0.004	0.009	0.12
IRON FILTER BACKWASH WASTEWTR	2/2007	4/2012*	63	0.003	0.009	0.054

Note: * Last month available at the time of the report preparation

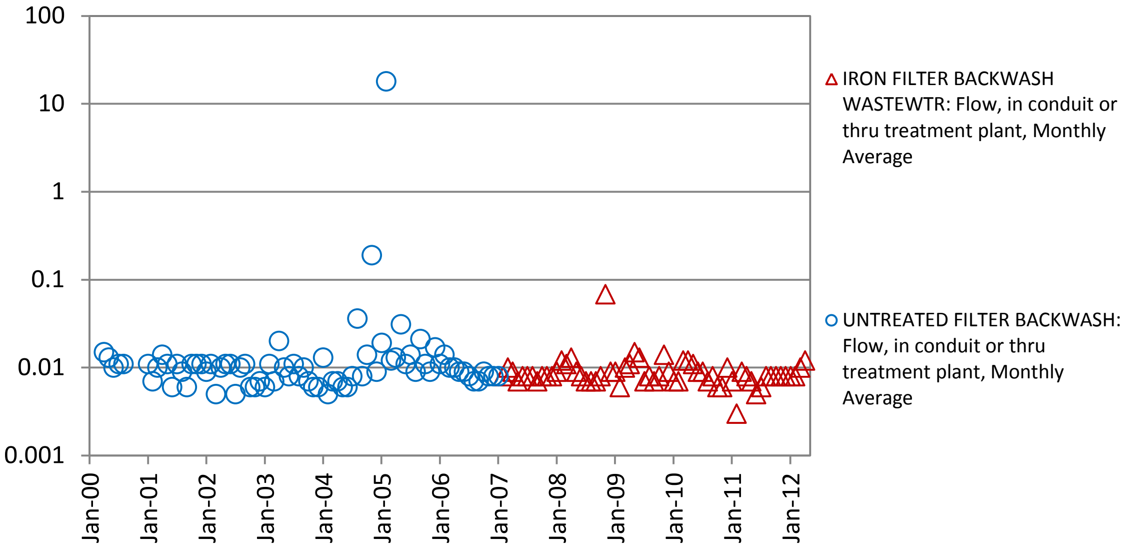

Figure 5-57. Maximum daily discharges from Vermont WTP (mgd)

Table 5-62. Maximum daily discharges summary from Vermont WTP (mgd)

Outflow Name	Start Date	End Date	Non-zero Months	Minimum	Non-Zero Average	Maximum
UNTREATED FILTER BACKWASH	4/2000	1/2007	78	0.005	0.243 (0.013)**	18 (0.19)**
IRON FILTER BACKWASH WASTEWTR	2/2007	4/2012*	63	0.03	0.010	0.068

Note: * Last month available at the time of the report preparation
** The statistic excluding the atypical value for maximum discharge is listed in parenthesis

5.4.2 Nonpoint Sources

Non-point sources discussed here are considered potential sources of impairment at this stage of TMDL development. It is also important to note that the adoption of recommended land use practices to help reduce pollutant loads from non-point sources is voluntary.

The Sugar Creek watershed is dominated by agriculture land uses. The 1999-2000 land cover dataset shows 64.15% watershed was classified as agriculture land (Table 2-1). The 1999-2000 land cover dataset shows 80.19% of the Vermont City Reservoir watershed was classified as agricultural land. Visual comparison of aerial photography from 1999 and 2009 does not confirm any significant development in the watershed. Existing urban development and agricultural practices can adversely impact water quality.

5.4.2.1 Row-Crop Agriculture

Agriculture practices may impact water quality in the Sugar Creek and Vermont City Reservoir watersheds. Tillage and residue management can affect erosion rates and consequently the transport of sediment and nutrients to receiving waters. Fertilizer application rates and timing affect nutrient storage and transport to receiving waters as well. Timing and intensity of rain events play a large role in the export of nutrients from agriculture.

Information on fertilizer usage within Fulton, McDonough, and Schuyler counties was obtained from the 2002 and 2007 USDA Census of Agriculture (USDA, 2008, 2009). The number of acres treated with fertilizer in Fulton (Table 5-63) and McDonough (Table 5-64) counties increased by over 30% between 2002 and 2007, while fertilizer use in Schuyler County (Table 5-65) decreased slightly over the same time period. All three counties treated fewer acres with manure in 2002 than in 2007, and treated significantly fewer acres with manure than with commercial fertilizers, lime, or soil conditioners. Use of commercial fertilizers, lime, and soil conditioners increased from 2002 to 2007 in Fulton and McDonough counties, but decreased slightly in Schuyler County.

Table 5-63. Change in fertilizer use in Fulton County from 2002-2007

	Acres treated		
	2002	**2007**	**Percent Change**
Commercial fertilizers, lime, soil conditioners	96,782	139,214	44%
Manure	13,191	10,834	-18%
Total	109,973	150,048	36%

Table 5-64. Change in fertilizer use in McDonough County from 2002-2007

	Acres treated		
	2002	**2007**	**Percent Change**
Commercial fertilizers, lime, soil conditioners	155,493	213,147	37%
Manure	6,512	3,240	-50%
Total	162,005	216,387	34%

Table 5-65. Change in fertilizer use in Schuyler County from 2002-2007

	Acres treated		
	2002	**2007**	**Percent Change**
Commercial fertilizers, lime, soil conditioners	99,978	99,015	-1%
Manure	3,267	2,813	-14%
Total	103,245	101,828	-1%

Data on tillage practices in Fulton (Table 5-66), McDonough (Table 5-67), and Schuyler (Table 5-68) counties were obtained from the Illinois Department of Agriculture 2006 and 2011 Illinois Soil Conservation and Transect Survey Summary (IDOA, 2006, 2011). The transect survey tracks conservation tillage practices in Illinois for different crops. Results show the majority of soybean and small grain producers use mulch-till or no-till methods, which greatly reduce soil erosion. Corn producers are more varied, slightly favoring conventional or reduced tillage over conservation methods.

Table 5-66. Tillage practices in Fulton County in 2006 and 2011

	Corn		**Soybeans**		**Small Grain**	
	2006	2011	2006	2011	2006	2011
Conventional	10 %	28 %	1 %	8 %	0 %	0 %
Reduced-till	45 %	49 %	4 %	23 %	0 %	0 %
Mulch-till	30 %	18 %	24 %	22 %	0 %	0 %
No-till	15 %	5 %	71 %	47 %	100 %	100 %

Table 5-67. Tillage practices in McDonough County in 2006 and 2011

	Corn		Soybeans		Small Grain	
	2006	2011	2006	2011	2006	2011
Conventional	36 %	66 %	7 %	9 %	0 %	0 %
Reduced-till	32 %	25 %	23 %	31 %	14 %	0 %
Mulch-till	20 %	2 %	28 %	10 %	86 %	0 %
No-till	13 %	6 %	42 %	50 %	0 %	100 %

Table 5-68. Tillage practices in Schuyler County in 2006 and 2011

	Corn		Soybeans		Small Grain	
	2006	2011	2006	2011	2006	2011
Conventional	38 %	14 %	4 %	12 %	0 %	10 %
Reduced-till	27 %	63 %	9 %	43 %	0 %	30 %
Mulch-till	24 %	11 %	40 %	26 %	100 %	60 %
No-till	10 %	11 %	46 %	19 %	0 %	0 %

5.4.2.2 Animal Operations

Confined animal facilities as well as livestock grazing can also contribute pathogens, nutrients, and sediment directly when animals are allowed to enter the stream or lake corridor, through runoff from facilities, or indirectly through land application of manure and increased erosion.

Data on animal populations within Fulton (Table 5-69), McDonough (Table 5-70), and Schuyler (Table 5-71) counties were obtained from the 2002 and 2007 USDA Census of Agriculture (USDA, 2008, 2009). In all three counties the most common farm animals are hogs/pigs and cattle/calves. Poultry, sheep/lambs, and horses/ponies all had much smaller populations of less than 2,000 animals per county in 2007. All three counties show a decrease in numbers of cattle/calves and sheep/lambs between 2002 and 2007. In contrast, poultry increased significantly in population during the same period. Fulton County contains the highest animal population of the three, with over 93,000 total animals in 2007. Management of livestock operations can have significant impacts on local water resources. Increased stream bank erosion as well as higher nutrient and fecal coliform loads can be expected when animals have a direct access to streams. Cattle and horses were commonly seen by the field sampling personnel in the upstream portion of the Sugar Creek watershed (Figure 5-58).

Table 5-69. Change in animal population in Fulton County from 2002 to 2007

	2002	2007	Percent Change
Cattle and Calves	27,368	25,431	-7%
Beef	Not Disclosed	10,421	N/A
Dairy	Not Disclosed	31	N/A
Hogs and Pigs	74,006	54,292	-27%
Poultry	959	1,555	62%
Sheep and Lambs	1,453	1,086	-25%
Horses and Ponies	681	1,058	55%

Table 5-70. Change in animal population in McDonough County from 2002 to 2007

	2002	**2007**	**Percent Change**
Cattle and Calves	19,377	17,545	-9%
Beef	8,780	Not Disclosed	N/A
Dairy	450	Not Disclosed	N/A
Hogs and Pigs	17,062	10,198	-40%
Poultry	344	584	70%
Sheep and Lambs	1,743	1,020	-41%
Horses and Ponies	621	647	4%

Table 5-71. Change in animal population in Schuyler County from 2002 to 2007

	2002	**2007**	**Percent Change**
Cattle and Calves	11,260	9,348	-17%
Beef	Not Disclosed	6,242	N/A
Dairy	Not Disclosed	0	N/A
Hogs and Pigs	42,137	47,919	14%
Poultry	214	450	110%
Sheep and Lambs	242	71	-71%
Horses and Ponies	314	247	-21%

Figure 5-58. Cows crossing a tributary to Sugar Creek downstream of Vermont City Reservoir, April 11, 2011

Impacts from existing animal facilities will be discussed further in the Stage 3 report.

5.4.2.3 Urban Areas

Urban development can contribute to the deterioration of surface waters in ways other than the point source discharges and combined sewer overflows addressed in 5.4.1 Point Sources (page 116). Impervious surfaces present in urban areas affect watershed hydrology by intercepting rain water and limiting infiltration. Urban streams typically have lower base flows and higher peak flow rates and volumes than natural streams.

Human activities in urban areas affect the type and amount of pollutants transported to receiving waters. Fertilizers applied on lawns and gardens are potential sources of nutrients. Pet waste represents an increased nutrient load and a source of pathogens.

Construction itself can contribute to water quality impairments through increased erosion due to soil destabilization. However, construction activities probably have not recently impacted Vermont City Reservoir as no significant new development was found to have occurred in the Sugar Creek and Vermont City Reservoir watersheds since 1999-2000.

5.4.2.4 Septic Systems

Failing or poorly functioning septic systems contribute nutrients and pathogens and can provide a pathway for household chemicals to enter surface waters. The 1990 U.S. Census provides estimates of the number of septic systems by PLSS township and census block. This census information on septic systems was obtained using the U.S. Census Factfinder website (U.S. Census Bureau, 2010a), with GIS data of the 1990 Census township and block boundaries downloaded from the Census Bureau TIGER website (U.S. Census Bureau, 2010b). Densities of septic systems per census block and township were calculated and used to compute area-weighted estimates of 495 and 644 septic systems, respectively, in the Sugar Creek watershed in 1990.

The number of septic installations since 1990 was estimated based on permit data maintained by county public health departments. Permit counts were available from McDonough and Schuyler counties by township. Permit counts from Fulton County were not available. Densities of septic installations by township were calculated and used to compute an area-weighted estimate of septic tank installations. In total, there have been an estimated 94 septic tank installations within the Sugar Creek watershed since 1990.

In total, we estimate there are between 589 and 738 septic systems presently located within the Sugar Creek watershed and 7 septic systems in the Vermont City Reservoir watershed.

5.4.2.5 Wildlife

Wildlife populations can have an adverse impact on water quality. Studies have shown that fecal coliform bacteria enter streams more often from nonpoint sources during storms when fecal material from human and nonhuman sources is washed off the land and into streams (Gregory and Frick, 2000). Alderisio and DeLuca (1999) reported that roosting populations of Canadian geese and Ring-billed gulls impacted Kensico Reservoir by elevating fecal coliform concentrations. A report prepared by the Maryland Department of the Environment (2004) contained estimates that wildlife contributed over 31 percent of the total fecal coliform load for St. Inigoes Creek.

Wildlife populations in the Sugar Creek watershed are considered healthy. Common large game animals include deer and turkey, while small and upland game found in this area of Illinois includes rabbits, squirrel, pheasant, and quail. Furbearers are composed primarily of muskrat, raccoon, coyote, and beaver. Waterfowl populations are primarily composed of ducks and geese. Information on wildlife populations within the Sugar Creek watershed were obtained from annual hunter harvest and trapping reports from the Illinois Department of Natural Resources website (http://www.dnr.illinois.gov/hunting/Pages/IDNRHarvestQuery.aspx).

During 2005-2010, the deer harvest in Fulton, McDonough, and Schuyler counties was typically 50 to 60% higher than the statewide average of 134 deer/100 km^2. Small game populations are similar to the statewide average of 2000 animals/100 km^2. Waterfowl populations are approximately 10% less than the statewide average.

5.4.2.6 Internal Loading

There is no evidence that Vermont City Reservoir becomes stratified during the summer months. Since Vermont City Reservoir is relatively shallow (about 11 feet deep at its deepest point), extended stratification is not expected. However, temporal anoxic conditions at the bottom due to decomposition of organic matter were confirmed using historical dissolved oxygen data.

Very low oxygen levels often occur at the bottom of the lake (Figure 5-59). Dissolved oxygen concentrations below 2 mg/l were found at site RDM-1 (15% of samples) and site RDM-2 (6% of samples). All concentrations below 2 mg/l occurred at or below a depth of 5 feet (29% samples at or below 5 ft depth). Dissolved oxygen concentrations show strong seasonal variation with the lowest values occurring from May to September (Figure 5-60). Figure 5-61 shows a dissolved oxygen profile at site RDM-1 during 2009, 2010, and 2011. Dissolved oxygen concentrations are shown relative to the size of the circle plotted in time at the observed depth. Very low dissolved oxygen values were found near the bottom during each year, although there is some variation in the extent of the hypoxic zone among years.

Under anoxic conditions, phosphorus, manganese, and other constituents become more soluble and are released from the sediments to the overlying waters. Once these constituents become dissolved, they can be transported to other lake layers when mixing or partial mixing occurs. This typically occurs during fall turnover for thermally stratified lakes when air temperatures decline. As the top lake layer cools, water temperature and densities of the individual layers come closer, allowing the layers to mix more readily through wind, inflows, density currents, or other mechanisms. Oxygen, nutrients, and other dissolved constituents are then distributed through the water column more evenly. Partial mixing can sometimes occur in shallower lakes under certain conditions even in summer (high winds, passing of a cold front, etc.)

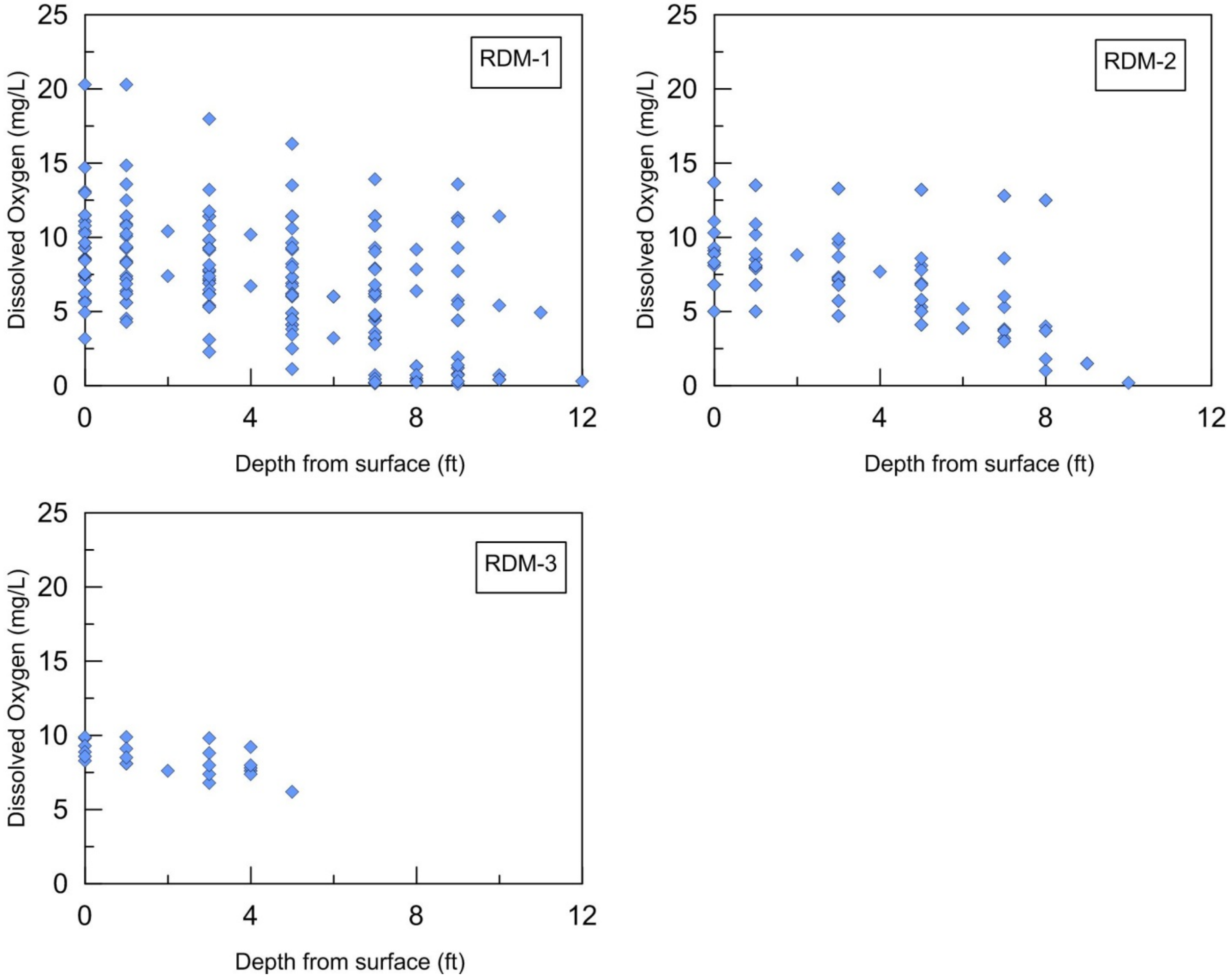

Figure 5-59. Effect of sampling depth on dissolved oxygen concentration (mg/l)

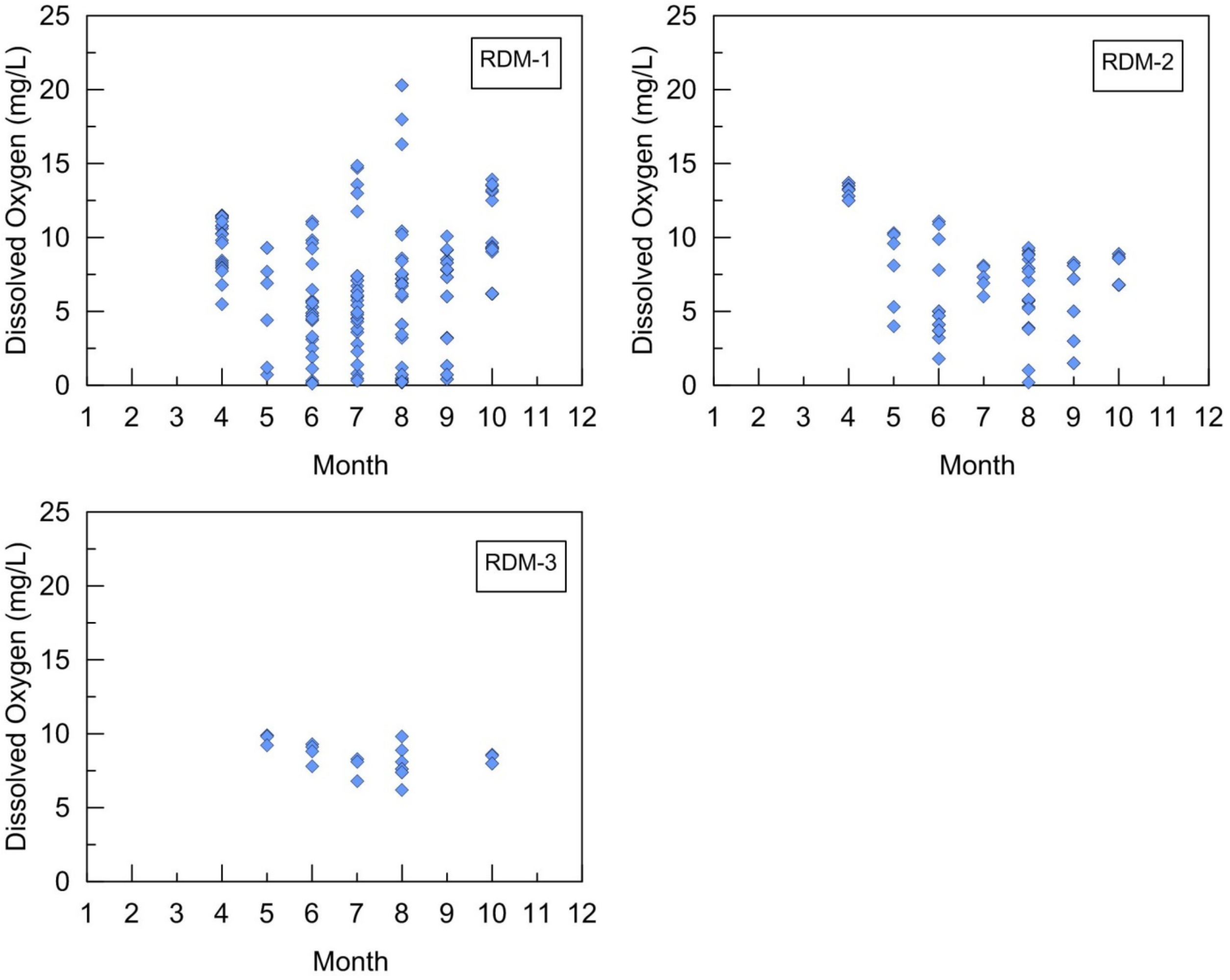

Figure 5-60. Monthly variation in dissolved oxygen concentrations (mg/l)

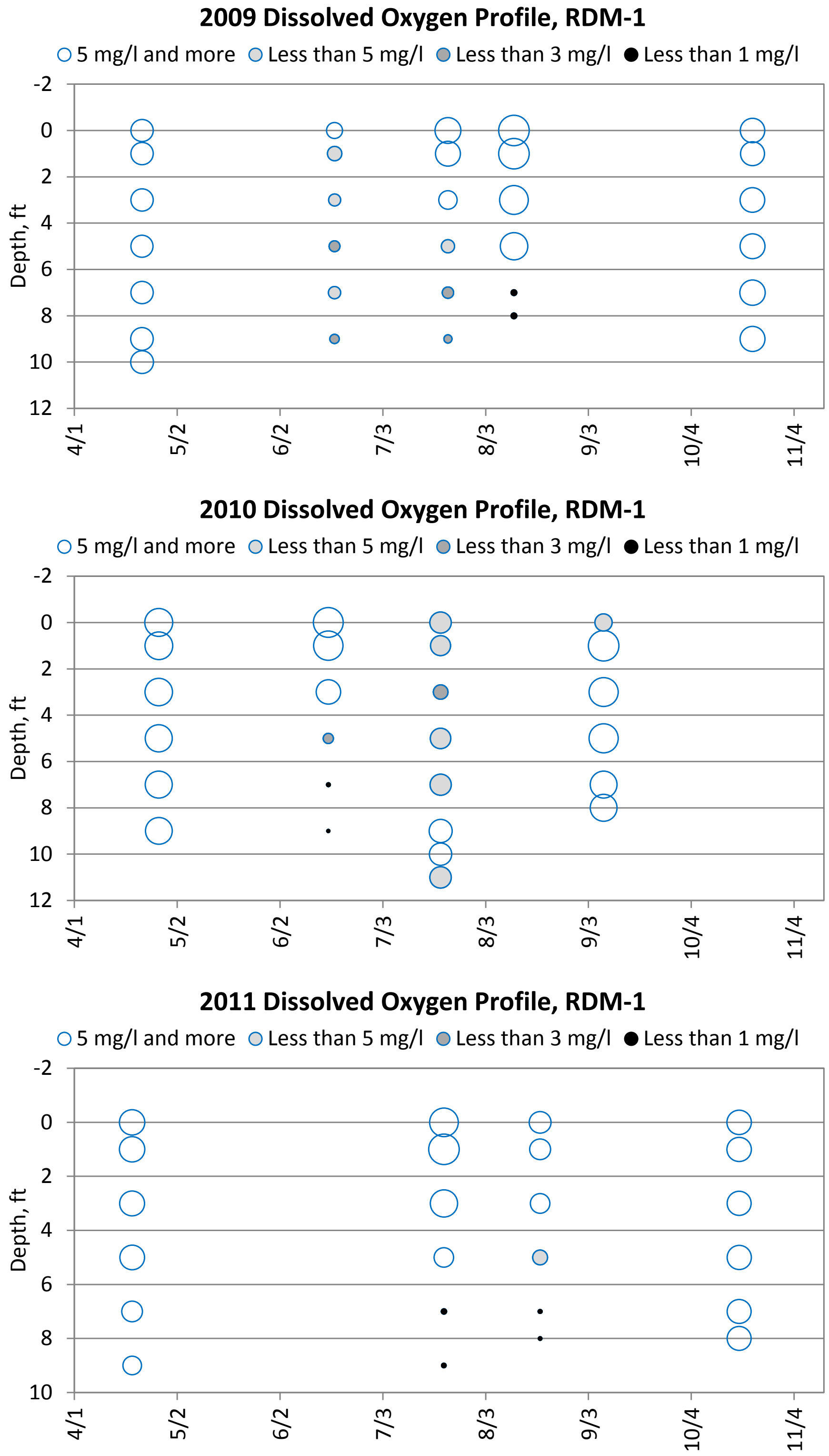

Figure 5-61. Dissolved Oxygen Profile at site RDM-1 during 2009-2011.
The size of the circle increases with increasing observed dissolved oxygen concentration.

5.4.2.7 Runoff from forest/grassland/parkland

Forested lands and grasslands are generally considered beneficial for watershed health by serving as natural filters, retaining nutrients and sediment (TCF, 2006). However poor grazing practices and lack of management of forested lands can be detrimental to water quality. Forested land is the second highest major land cover category (15%) in the Vermont City Reservoir watershed, and runoff from these areas can be a source of total suspended solids and total phosphorus as well as potentially manganese. As most of the forested areas within the watershed are found along stream corridors, streambank erosion can also be a significant source of TSS.

5.4.2.8 Littoral/Shore Area Modifications

Changing water levels as well as waves generated from winds or boating activities can contribute to increased bank erosion within a water body. Sediment delivered to the water body from these erosional processes contributes to increased loadings of total suspended solids and total phosphorus as well as potentially manganese. Previous studies assessing the extent of shoreline erosion at Vermont City Reservoir were not identified and no field reconnaissance of shoreline erosion was conducted as part of this monitoring effort.

6. TMDL Approach

This section summarizes observations and conclusions for each potential cause of impairment investigated. The following constituents are addressed for the Vermont City Reservoir: atrazine, manganese, total suspended solids, total phosphorus, and algae. Fecal coliform contamination is addressed for Sugar Creek and its tributaries.

A recommended approach for subsequent Stage 3 modeling efforts is also presented. In general, any proposed modeling approach must adequately address the following aspects of transport and transformation: generation of loads from point and non-point sources, transport and transformation of pollutants in tributaries, and transport and transformation of pollutants in the final receiving body. Data collected during this project has helped identify the essential processes affecting transport and transformation of monitored pollutants and will be an integral part of the TMDL development. Specific requirements are presented for each listed pollutant as the processes vary with pollutant characteristics.

6.1 Summary of Water Quality Analyses

6.1.1 Atrazine

Atrazine has been removed as a cause of impairment in the draft 2012 assessment (IEPA, 2012). However, more recent data collected by the IEPA and Syngenta confirm the impairment. Atrazine concentrations in Vermont City Reservoir often exceed the Illinois water quality standard for lakes. Analysis of water quality data can be summarized as follows:

- Lake sediments do not have a high atrazine content;
- Data were found insufficient to determine whether the lake is stratified with respect to atrazine concentrations;
- Preliminary analyses of atrazine loadings were inconclusive with respect to atrazine storage in the lake;
- High atrazine concentrations in tributaries are associated with storm events;
- Atrazine concentrations vary significantly on a bi-annual and monthly scale.

The inflow to the lake is characterized by higher flows in spring (storm runoff) and relatively lower flows during the summer and fall. Non-point sources dominate the atrazine loading delivered to the lake through sampled tributaries. When water levels in the lake fall below the spillway, as often happens, all tributary loadings stay within the lake at least until the reservoir is replenished unless the chemical undergoes degradation. Atrazine is an herbicide widely used in Illinois to control weeds in corn crops. It is applied in spring or early summer prior to, during, or after planting a crop or after crop emergence. Atrazine is known to degrade through both biotic and abiotic processes. Biodegradation is much more likely to occur in a soil matrix rather than in surface waters (Rygwelski, 2008). Degradation in surface waters is typically dominated by photolysis (Rygwelski, 2008; Solomon et al., 1996). Due to the high uncertainty in estimated loads and possible degradation of atrazine, a simple mass balance evaluation was insufficient to determine importance of lake storage.

Considering the above observations, the final TMDL approach needs to include the following processes affecting atrazine concentrations and loadings in Vermont City Reservoir:

- Seasonality, including application timing and rates;
- Degradation pathways;
- Possible internal storage;
- Runoff from agriculture and other areas.

6.1.2 Manganese

Manganese concentrations in Vermont City Reservoir often exceed the Illinois water quality standard for lakes. Analysis of water quality data can be summarized as follows:

- Lake sediments have a high manganese content;
- Data were found insufficient to determine whether the lake is stratified with respect to manganese concentrations;
- Very low dissolved oxygen concentrations were found at depths 5 feet and below;
- A significant portion of the manganese loading entering Vermont City Reservoir remains in the lake;
- High concentrations in tributary flows are associated with storm events as well as low flows;
- No groundwater data were found for wells directly in the Vermont City Reservoir watershed, but high concentrations were reported for a well located within the same Township and Range.

The inflow to the lake is characterized by higher flows in spring (storm runoff) and lower flows during the summer and fall. Non-point sources as well as background sources (higher manganese levels in soils and groundwater) are important contributors to high manganese concentrations delivered to the lake through sampled tributaries. There are no data indicating Vermont City Reservoir becomes thermally stratified but data indicate dissolved oxygen gets depleted near bottom sediments, which is likely to facilitate the transfer of manganese from sediments to overlying waters. When water levels in the lake fall below the spillway, as often happens, all loadings stay within the lake at least until the reservoir is replenished.

Considering the above observations, the final TMDL approach needs to include the following processes affecting manganese concentrations and loadings in Vermont City Reservoir:

- Internal loading;
- Runoff from urban, agriculture, and other areas, including abandoned mines;
- Baseflow contribution;
- Variation of dissolved oxygen with depth.

6.1.3 Total Suspended Solids

Total suspended solids in tributary streams as well as in Vermont City Reservoir are important in TMDL development for total phosphorus and manganese. Analysis of water quality data can be summarized as follows:

- Total suspended solids concentration above the IEPA guideline are found in tributaries but not in Vermont City Reservoir;
- High concentrations in tributaries are associated with storm events;
- A significant portion of the total suspended solids loading entering Vermont City Reservoir remain in the lake;
- A lower ratio of volatile to total suspended solids at streams during storm events;
- A higher ratio of volatile to total suspended solids at the lake site than at tributaries.

The inflow to the lake is characterized by higher flows in spring (storm runoff) and lower flows during the summer and fall. Non-point sources dominate the total suspended solids loading delivered to the lake through sampled tributaries. Most total suspended solids transported by the local tributaries during storm runoff are inorganic. When water levels in the lake fall below the spillway, as often happens, all loadings stay within the lake at least until the reservoir is replenished.

Considering the above observations, the final modeling effort needs to include the following processes affecting total suspended solids concentrations and loadings in Vermont City Reservoir:

- Runoff from agriculture and other areas;
- Stream bank and lake shore erosion;
- Re-suspension of lake sediments
- Sediment storage in stream channels.

6.1.4 Total Phosphorus

Total phosphorus concentrations in Vermont City Reservoir often exceed the Illinois water quality standard for lakes. Analysis of water quality data can be summarized as follows:

- Lake sediments have a high phosphorus content (recent data);
- Data were found insufficient to determine whether the lake is stratified with respect to total phosphorus concentration;
- Very low dissolved oxygen concentrations were found at depths 5 feet and below;
- A significant portion of the total phosphorus loading entering Vermont City Reservoir remains trapped in the lake;
- High total phosphorus concentrations in tributaries are associated with storm events.

The inflow to the lake is characterized by higher flows in spring (storm runoff) and relatively lower flows during the summer and fall. Non-point sources dominate the phosphorus loading delivered to the lake through sampled tributaries. There are no data indicating Vermont City

Reservoir becomes thermally stratified but data indicate dissolved oxygen gets depleted near bottom sediments, which is likely to facilitate the transfer of manganese from sediments to overlying waters. When water levels in the lake fall below the spillway, as often happens, all tributary loadings stay within the lake at least until the reservoir is replenished.

Considering the above observations, the final TMDL approach needs to include the following processes affecting total phosphorus concentrations and loadings in Vermont City Reservoir:

- Internal loading;
- Runoff from agriculture and other areas, including septic systems;
- Variation of dissolved oxygen with depth.

6.1.5 Algae

Algae concentrations in Vermont City Reservoir often exceed the requirements for aesthetic quality in lakes. Algae growth is controlled by available nutrients, sunlight, water temperature, turbidity, and water velocity. A surrogate parameter controlling the algae growth such as total phosphorus is recommended to establish TMDL for algae.

The final TMDL approach needs to include the following processes affecting algae concentrations and loadings in Vermont City Reservoir:

- Seasonality;
- Internal nutrient loading;
- Nutrient runoff from urban, agriculture, and other areas, including septic systems.

6.1.6 Fecal Coliforms

Fecal coliform counts in Sugar Creek and its tributaries often exceed the Illinois water quality standard for streams. Analysis of water quality data can be summarized as follows:

- A significant seasonal variation was found for fecal coliform counts as well as loads;
- High fecal coliform counts are found throughout the full range of flows;
- Fecal coliform counts vary significantly at all sites (several orders of magnitude);
- The smallest fecal coliform yield was found at a site with the smallest proportion of agriculture and urban lands;
- Fecal coliform bacteria are directly deposited in streams by animals with unrestricted access.

The flow in Sugar Creek and its tributaries is characterized by higher flows in spring (storm runoff) and relatively lower flows during the summer and fall. Non-point as well as point sources contribute fecal coliform loads to the impaired waters. Key parameters that affect survival of fecal coliform bacteria are sunlight, temperature, turbidity, salinity, sedimentation and resuspension, and pH (Wilkinson et al., 1995; Manache et al., 2007, and others).

Considering the above observations, the final TMDL approach needs to include the following processes affecting fecal coliform counts and loadings in Sugar Creek:

- Seasonal variation;
- Direct deposition to streams;
- Runoff from urban, agriculture, and other areas, including septic systems;
- Contributions from wildlife.

6.2 Methodology

This section discussed methodologies used in TMDL development and their applicability to the Vermont City Reservoir TMDL. A variety of approaches have been used in Illinois and other states to develop TMDLs. The methodologies range from simple empirical relationships to sophisticated physically based computer models. However, all approaches are a simplification of the physical reality. Each approach has limitations and inherent assumptions that affect its application and predictive accuracies. Thus, it is critical to use a methodology appropriate for the modeled situation and to develop suitable applications. The methodologies or their application can also vary in time and spatial scales. The loads can be developed as a long-term average, on an annual or shorter time scale, or even based on individual storm events. Data needs can increase substantially with a smaller time steps and higher spatial resolution. IEPA once relied on watershed models when developing TMDLs, but over the past several years has relied solely on water quality models. IEPA is considering using watershed models to help prioritize TMDL implementation.

6.2.1 Statistical Models

6.2.1.1 Load Duration Curve

Load Duration Curve represents a simple approach to TMDL development (USEPA, 2007). An underlying assumption of this approach is a correlation of water quality impairments to flow conditions. The method compares the stream loading capacity obtained using a water quality standard and stream flow statistics with the observed loads measured across a range of flows. The method can account for seasonal variations.

Long-term flow and concentration data are needed for the impaired reach to properly develop the load duration curve and to account for all variations. The method is severely limited in its ability to track individual sources and link them with allocated loads. Generally, the application of this method is limited to streams and other water bodies where other processes beside flow are negligible. Long residence time and the need to address internal loadings in Vermont City Reservoir means this method is not appropriate to use. The Load Duration Curve could possibly be used for the tributaries to Vermont City Reservoir for preliminary assessment of load reductions if reliable flow statistics can be obtained. Its applicability for fecal coliform bacteria is severely limited in Sugar Creek due to no correlation between flow and fecal coliform counts.

The lack of correlation together with large variations in concentrations could result in large uncertainties in TMDL recommendations.

6.2.1.2. Mass Balance

The Mass Balance method involves balancing loads entering the stream from point and non-point sources with loads in receiving waters. It is typically used for pathogens although theoretically it can be used for any constituent. There are several tools that can be used to estimate the bacteria load generated in the watershed by animals (livestock, wildlife, and pets) as well humans (waste water treatment plant effluents, combined sewer overflows, sanitary sewer overflows, and septic systems). The loading tools such as the two examples described below provide an estimate of the average loading expected without considering any temporal variations. The routing, die-off, and other in-stream processes are typically not accounted for, only the production of bacteria. These tools can possibly be modified to simulate a range of conditions rather than an average loading, providing means to assess the uncertainty in the model inputs.

The Bacteria Indicator Tool (BIT) has been developed by the U.S. EPA to estimate the monthly accumulation rate of fecal coliform bacteria on four land uses (cropland, forest, built-up, and pastureland), as well as the limit for that accumulation should no wash off occur. The tool estimates the direct inputs of fecal coliform bacteria to streams, from such sources as grazing agricultural animals and failing septic systems. The BIT was developed to provide starting values for model input; however, a thorough calibration of the model is still recommended (U.S. EPA, 2000). The BIT does not calculate loads in receiving streams.

The Bacteria Source Load Calculator (BSLC) from the Center for TMDL and Watershed Studies at Virginia Tech University (2007) is another Excel-based tool designed to simplify determination of bacterial loadings. The BSLC can also be used to develop allocation scenarios. The BSLC characterizes how the bacterial loads are spatially and temporally distributed. It can be used to calculate monthly land loadings and hourly stream loadings. The tool application follows several steps: 1) inventory of bacterial sources, 2) estimation of loads generated from these sources, 3) distribution of estimated loads to streams and land, as a function of source type and land use, and if desired 4) generation of bacterial load input parameters for watershed-scale simulation models such as HSPF. The BSLC does not calculate loads in receiving streams.

6.2.2 Loading Models

Watershed loading models provide a linkage between sources of pollution and loads generated in the contributing watershed and delivered to the impaired reach. Watershed loading models can be categorized as simple, mid-ranged, and detailed (U.S. EPA, 1997). Simple methods provide rapid assessment with minimal effort and data requirements using empirical relationships between watershed characteristics and pollutant export. These methods provide a rough estimate of pollutant loads and have limited predictive capabilities. Loads are determined from export coefficients, as a function of sediment yield, or from statistical relationships developed from past monitoring information in similar watersheds. Mid-range models use simplified relationships for the generation and transport of pollutants while retaining responsiveness to management actions. They allow assessment of seasonal or inter-annual loads. Detailed models use storm events or continuous simulation to predict flows and pollutant concentrations for a range of conditions (U.S. EPA, 1997) by simulating the physical processes of infiltration, runoff, pollutant accumulation, instream effects, etc.

6.2.2.1 Land-Use Based Export Coefficients

The premise of this method is that the amount of pollutants delivered to impaired water bodies is driven by land use. The method multiplies individual land use areas and “average expected” loading rates (yields or land-use based export coefficients) to obtain an average annual load. The method is very simple. However, it doesn’t account for any temporal variation due to precipitation or impacts of different soil types and/or activities associated with land use practices such as fertilizer application rate. Caution must be exercised in selecting the loading rates to represent current conditions in the assessed watershed.

Long-term or annual estimates determined from this method may be sufficient to estimate loadings to water bodies with large residence time. Application is often limited to pre-planning or screening activities. Export coefficients could be tested and adjusted for Vermont City Reservoir against the loads documented through the current project monitoring. The relatively short-term availability of this detailed data could bias the estimates for conditions encountered during the 18 months of monitoring.

6.2.2.2 Sediment Yield –Based Models

This group of models uses the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) or its modifications to predict erosion. Concentrations for dissolved and particulate pollutants are then associated with flow volumes and sediment loads, respectively. The Spreadsheet Tool for the Estimation of Pollutant Load (STEPL) and the Generalized Watershed Loading Functions (GWLF) models are two examples of sediment-yield based mode (Haith and Shoemaker, 1987; Haith et al., 1992).

STEPL calculates annual sediment, nutrients, and organic matter loads from different land uses and load reductions that would result from the implementation of various Best Management Practices (Tetra-Tech, 2011). For each watershed, average annual nutrient loadings are calculated from the runoff volume and pollutant concentrations in the runoff that can vary with land use and management practices. The annual sediment load is calculated based on the USLE and the sediment delivery ratio. Streambank and gully erosion can be estimated also from their size. The sediment and pollutant load reductions are computed using the known BMP efficiencies. Atrazine, manganese, and fecal coliform bacteria are not included in STEPL. However, the spreadsheet could be easily modified to estimate manganese loads by including average manganese concentration in soil and groundwater. The practical implications and requirements of such a modification would need to be thoroughly investigated with respect to processes relevant for each constituent before this approach should be used.

GWLF is a daily time-step model used to predict runoff, sediment, and nutrients from watersheds with mixed land uses. GWLF can be used for both sediment and phosphorus TMDLs. The runoff is simulated using the runoff curve number and antecedent moisture. The sediment load is estimated with USLE. Dissolved nutrients are simulated using event mean concentrations. The loads generated by individual sources are simply aggregated to produce total load. While the model is simulated at a daily time step, the outputs should be evaluated on a monthly or longer time step due to methods implemented in the model. This simple model has been used in several TMDLs. It requires a relatively small amount of input data. It does not require calibration, although calibration is helpful where monitored data are available. GWLF assumes no re-deposition within the watershed; all the sediment generated within a given year flows out of the watershed during the same year (Borah et al., 2006). Also, loads for manganese are not calculated. The model could be calibrated and validated using the current project monitoring data and then used to estimate total suspended solids and total phosphorus loads to Vermont City Reservoir. Atrazine, manganese, and fecal coliform bacteria are not simulated by GWLF. The modification of the spreadsheet version to include additional constituents seems possible. The practical implications and requirements of such a modification would need to be thoroughly investigated with respect to processes relevant for each constituent before this approach should be used.

6.2.2.3 Watershed Models

There are several watershed models that simulate detailed hydrology together with pollutant generation and transport. The implementation of in-stream transport and processes varies within the models but usually it is simpler than in a receiving stream water quality model. These models are flexible and can be used in TMDL development. However, due to the large data requirements, they are best suited for watersheds with long-term flow and water quality data for model calibration and validation.

The Agricultural NonPoint Source (AGNPS) model is a single-storm event model (Young et al., 1987). It simulates surface runoff, soil erosion, and transport of sediment, N, P, chemical oxygen demand (COD), and pesticides from nonpoint and point sources resulting from a single rainfall event. The simulated watershed is divided into uniform square areas (grid cells). The model generates total or average responses for a storm event considering the storm duration as one time step. AGNPS computes runoff volume using the runoff curve number method. Computation of soil erosion due to rainfall is based on USLE. It is considered a mid-range model by the U.S. EPA (1997).

The Hydrological Simulation Program FORTRAN version 12 (HSPF) simulates watershed loading, and the generation and transport of loads from point and nonpoint sources of pollution from a watershed (Bicknell et al., 2001). HSPF is well suited for watersheds with mixed urban and agriculture land uses. HSPF uses a comprehensive, physically based water budgeting algorithm with interaction among the various storages and processes. Erosion and transport of pollutants from pervious and impervious surfaces are modeled using empirical relationships for soil detachment, detached sediment wash-off, and gully erosion. The simulated watershed is divided into homogeneous areas with respect to runoff and pollutant generation. HSPF typically utilizes an hourly time step with results summarized at a daily or longer time step. It is intended for long-term impact analyses as well as storm event analyses. The HSPF model can simulate the following constituents: streamflow (as a sum of surface runoff, interflow, and baseflow) sediment loading, inorganic suspended sediment, pathogens, organic matter, DO, pH, pesticide chemicals, inorganic nitrogen, nitrite, ammonia, nitrate, orthophosphate, phosphorus, phosphate, inorganic phosphorus, tracers (chloride, bromide, dyes, etc.), carbon dioxide, inorganic carbon, zooplankton, phytoplankton, benthic algae, organic carbon, fecal coliform bacteria, pH, and alkalinity (Bicknell et al., 2001).

The SWAT model was developed for agricultural watersheds. It predicts 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 over long periods of time. The SWAT model is ideally suited to rural areas dominated by agriculture and requires a great amount of data for vegetative changes and agricultural practices. The simulated watershed is typically divided into homogeneous areas with respect to runoff and pollutant generation. The SWAT model uses a daily time step for simulations with results presented at a daily or longer time step. It is intended for long-term impact analyses (Neitsch et al., 2002). The following constituents can be simulated: water flow, sediment loading, organic nitrogen, organic phosphorus, nitrate, mineral (soluble) phosphorus, ammonium, nitrite, algae as chlorophyll a, conservative metals (aluminum, antimony, arsenic, cadmium, etc.), bacteria, organic matter, dissolved oxygen, and pesticides (Neitsch et al., 2002). SWAT uses runoff curve numbers to calculate surface runoff. Erosion and sediment yield are estimated with the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975).

6.2.3 Receiving Water Quality Models

Receiving water quality models simulate the impacts of pollutant loadings on stream or lake water quality. The watershed loading models described in the previous section provide inputs to the receiving water quality models. As with watershed loading models, receiving water quality models range in complexities and details. Receiving water quality models discussed in this section are limited to those that can simulate (i) vertical distribution of water quality constituents (stratification) and (ii) release of pollutants from sediment when anoxic conditions occur.

6.2.3.1 BATHTUB

The BATHTUB model performs steady-state water and pollutant balance calculations in a spatially segmented hydraulic network. The model relies on empirical relationships to predict lake trophic conditions and subsequent DO conditions as functions of total phosphorus and nitrogen loads, residence time, and mean depth (U.S. EPA, 1997). Empirical relationships have been calibrated and tested for reservoir applications (Walker, 1985, 1986). The basic simulated constituents are total phosphorus, total nitrogen, chlorophyll a, Secchi depth (transparency), organic nitrogen, and ortho-phosphorus. Atrazine, manganese, fecal coliform bacteria, and total suspended solids or sediment are not simulated. BATHTUB can simulate the lake or reservoir as a continuously stirred, mixed reactor, or it can predict longitudinal gradients for trophic state variables in a reservoir or narrow lake.

6.2.3.2 CE-QUAL-W2

CE-QUAL-W2 (Cole and Wells, 2003) is a laterally averaged, two-dimensional (longitudinal and vertical) hydrodynamic and water quality model. It is best suited for relatively long and narrow water bodies. The hydrodynamic component of the model predicts water surface elevations, velocities, and temperatures, while the water quality component simulates 21 constituents, including nutrients, phytoplankton, and DO interactions during anoxic conditions. CE-QUAL-W2 models basic eutrophication processes such as relationships among temperature, nutrients, algae, dissolved oxygen, organic matter, and sediment in stratified or non-stratified systems. A predominant feature of the model is its ability to compute the two-dimensional velocity field for narrow systems that stratify. In contrast with many reservoir models that are zero-dimensional with regards to hydrodynamics, the ability to accurately simulate transport can be as important as the water column kinetics in accurately simulating water quality. Fecal coliform bacteria are simulated using the first-order decay algorithm. Atrazine and manganese are not explicitly included. However, from preliminary review it appears that manganese can be simulated with routines set for iron (only adsorbtion, settling, and anaerobic release are simulated). A simple first-order decay option is also available. The practical implications and requirements of these options would need to be thoroughly investigated with respect to processes relevant for each constituent before this approach should be used.

6.2.3.3 WASP

WASP, which has been greatly enhanced over the past several years, is a detailed and versatile state-of-the-art receiving water quality model with dynamic one-, two-, or three-dimensional spatial simulation capabilities simulating both eutrophication, nutrient, and dissolved oxygen, as well as metals, toxics, and sediment. When run in other than the one-dimensional state, the hydraulics component needs to be simulated by an outside multi-dimensional hydraulic model such as EFDC. A body of water is represented in WASP as a series of discrete computational elements or segments. Environmental properties and chemical concentrations are modeled as spatially constant within segments. Each variable is advected and dispersed among water segments, and exchanged with surficial benthic segments by diffusive mixing. Sorbed or particulate fractions may settle through water column segments and deposit to or erode from surficial benthic segments. Within the bed, dissolved variables may migrate downward or upward through net sedimentation or erosion. Atrazine and manganese can be simulated; however, the simulation is not part of the same module as eutrophication processes. Fecal coliform bacteria can be simulated using the first-order decay algorithm.

6.2.3.4 AQUATOX Release 3

The AQUATOX model is a general ecological risk assessment model that represents combined environmental fate and effects of conventional pollutants, such as nutrients and sediments, and toxic chemicals in aquatic ecosystems (U.S. EPA, 2009). AQUATOX can simulate stratification and sediment diagenesis in a single-segment lake as well as in linked segments. It considers several trophic levels, including attached and planktonic algae and submerged aquatic vegetation, invertebrates, and forage, bottom-feeding, and game fish; it also represents associated organic toxicants. It can be implemented as a simple model (indeed, it has been used to simulate an abiotic flask) or as a truly complex food-web model. The ecosystem model AQUATOX is one of the few general ecological risk models that represents the combined environmental fate and effects of toxic chemicals. The model also represents conventional pollutants, such as nutrients and sediments. Uncertainty analyses built into the model can be used to assess sources of uncertainty, including sensitivity to key parameters (U.S. EPA, 2009). Fecal coliform bacteria are not directly simulated by AQUATOX.

AQUATOX is also one of the few models capable of simulating macrophytes, one of the newly listed causes of impairments. AQUATOX can be applied as a screening level model with readily available data but it can also be used for more detailed analyses when calibrated to site specific conditions. AQUATOX does not simulate hydrodynamic conditions, although it can be coupled with a hydrodynamic model if necessary. AQUATOX is one of the models included in BASINS. It can be linked directly to a SWAT or HSPF model that would provide loadings to the water body. Manganese is not explicitly included; however, from preliminary review it appears that it can be simulated with routines set for silica or possibly other constituents with slight modifications.

6.2.3.5 QUAL2K

QUAL2K is a river and stream water quality model that is an updated version of the QUAL2E model (Brown and Barnwell 1987). QUAL2K is one-dimensional steady-state model capable of simulating diurnal changes in water quality constituents due to changes in meteorology (mainly temperature and sunlight). QUAL2K is typically used to simulate the dissolved oxygen regime in streams. It includes detailed procedures for the simulation of dissolved oxygen, sediment oxygen demand and sediment nutrient fluxes, suspended algae, benthic algae, and a generic pathogen. Pathogen removal is determined as a function of temperature, light, and settling (Chapra et al., 2007). QUAL2K is not appropriate to use in lake systems. It could be used to simulate transport and die-off of fecal coliform bacteria in Sugar Creek.

6.3 Recommendations

The recommended approach includes two steps. First, a method to estimate pollutant loads will be developed using a loading model. Second, the impact of estimated loads will be simulated with a receiving stream model. The final methodology will be determined with consultation with the IEPA based on the requirements of a defensible and approvable TMDL, data and fund availability, stakeholders interest and public acceptance, the ability of the models to evaluate

BMPs, and the complexity of the transport and transformation processes. The level of detail implemented in the model impacts the study complexity, accuracy of the results, and the time and funds necessary to complete the study. Simpler methods are faster, less expensive, require less data, but also provide less accurate results and often do not provide direct linkages between the individual sources of pollution and a water quality response. More sophisticated modeling approaches require more time and higher funding but also provide direct linkages disregarded by simpler methods.

The inherent characteristics of the Vermont City Reservoir watershed will affect the choice of the modeling approach. There is a discrepancy in the temporal resolution needed at the tributary level where flows and pollutant concentrations change rapidly on a sub-hourly scale and at the lake level where flows (or stages) and pollutant concentrations change more slowly (daily or longer time scale). The lake typically falls below the spillway level for a substantial time period each year. Preliminary analyses show lake sediments to be important in total phosphorus and manganese cycling. It is critical that the final approach that is chosen will evaluate their impacts on Vermont City Reservoir impairment.

The final approach to TMDL development for atrazine should consider crop rotation, timing of the atrazine application, atrazine biodegradation in soils, and photolytic degradation of atrazine in surface waters. A simple approach could use land-use based export coefficients or, more conservatively, atrazine application rates to estimate loading to Vermont City Reservoir. A more detailed approach could use SWAT, HSPF, or modified GWLF to simulate temporal variability in incoming pollutant loads. Considering the application occurs consistently in spring or early summer, precipitation events of selected frequency and duration (design rains) can be simulated using an event-based model. A simple approach could use a steady state model simulating conditions during the critical time after the atrazine was applied in fields. A more detailed approach could simulate temporal variation and possible degradation of atrazine by photolysis in the lake. AQUATOX and WASP models include routines capable of simulating the degradation.

Total phosphorus and manganese should be evaluated within the context of lake sediments and the anoxic conditions occurring in the deeper areas of the reservoir. A simple approach could use land-use based export coefficients or one of the sediment yield based models to generate average annual pollutant loads and the BATHTUB model to simulate impacts on total phosphorus concentration in Vermont City Reservoir. A more detailed approach could use GWLF, SWAT, or HSPF to simulate temporal variability in incoming pollutant loads. CE-QUAL-W2 could then be used to simulate the impacts of loads on total phosphorus, sediment, and manganese concentrations in Vermont City Reservoir. AQUATOX can be used to simulate water quality in Vermont City Reservoir in either a simple or a more detailed approach. Dissolved oxygen and temperature profiles would help to establish the current extent of the anoxic conditions.

Total suspended solids do not exceed the IEPA guideline in the lake itself. Thus developing TMDL for total suspended solids in Vermont City Reservoir is not required. However, the incoming load of total suspended solids contributes to lake sedimentation, which decreases the capacity of the reservoir, impacts habitats, and brings associated nutrients and other pollutants including total phosphorus and manganese. A bathymetric survey is recommended to determine current depths and the current capacity of Vermont City Reservoir as well as the extent of sedimentation. A survey of stream bank and lake shore erosion would help to quantify the potential contribution of pollutants from these sources. Simulating total suspended solids would be beneficial for total phosphorus and manganese TMDLs.

Algae should be simulated with the same model as phosphorus. TMDL for algae will not establish actual daily loads of algae. Surrogate constituents such as phosphorus will be used to determine conditions that would reduce algae growth in Vermont City Reservoir to acceptable levels.

The selected approach for estimating fecal coliform bacteria loads should take into account the high variability and uncertainty in observed fecal coliform concentrations. Different pathways from the source to receiving waters should be considered, including direct deposition, land surface transport, and subsurface transport. Fecal coliform bacteria are an indicator of fecal matter in receiving waters. However, without additional analyses it is not possible to differentiate between fecal coliform bacteria from wildlife, livestock animals, and humans. Bacteria source tracking, a powerful tool in identification of fecal coliform sources, animal or human, can be used to identify prevalent sources of fecal coliform bacteria. Mass balance tools can be enhanced to provide ranges of estimates rather than a single long-term average and combined with receiving stream models. A simple approach would use a receiving stream model capable of simulating first-order decay. A more detailed approach would use a receiving stream model that incorporates effects of sunlight, turbidity, temperature, pH, sedimentation, and resuspension. Steady-state modeling of various flows could be used to help understand the impacts of fecal coliform sources on receiving stream water quality under different flow conditions. Hydro-dynamic modeling would be appropriate where detailed data are available to calibrate the model.

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Appendix A – Streamflow Data

Table A-1. Mean Daily Discharge for Vermont City Reservoir Spillway (DHZC-01), Year 1 (March 2011-February 2012)
Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		0.41	0.42	1.6	4.6	0	0	0	0	0	0	0	1
2		0.07	0.94	8.4	3.4	0	0	0	0	0	0	0	2
3		0.06	0.48	4.8	2.4	0	0	0	0	0	0	0	3
4		0.37	0.37	2.6	1.8	0	0	0	0	0	0	0	4
5		0	0.84	2.4	1.3	0	0	0	0	0	0	0	5
6		0	0.97	1.8	1.2	0	0	0	0	0	0	0	6
7		0.08	0.79	1.4	2.1	0	0	0	0	0	0	0	7
8		0.72	0.63	1.1	2.9	0	0	0	0	0	0	0	8
9		1.4	0.77	0.84	1.5	0	0	0	0	0	0	0	9
10		1.0	0.82	0.93	0.91	0	0	0	0	0	0	0	10
11		0.38	0.64	1.6	0.52	0	0	0	0	0	0	0	11
12		0.06	0.61	0.96	0.18	0	0	0	0	0	0	0	12
13		0.07	0.39	0.97	0.93	0	0	0	0	0	0	0	13
14		0.12	1.2	3.9	0.24	0	0	0	0	0	0	0	14
15		0.34	3.0	33	0.06	0	0	0	0	0	0	0	15
16		0.42	2.4	7.9	0	0	0	0	0	0	0	0	16
17		0	1.5	5.1	0	0	0	0	0	0	0	0	17
18		0.12	1.3	13	0	0	0	0	0	0	0	0	18
19		14	1.1	5.8	0	0	0	0	0	0	0	0	19
20		9.5	1.0	18	0	0	0	0	0	0	0	0	20
21		4.3	1.1	7.3	0	0	0	0	0	0	0	0	21
22		23	1.7	4.5	0	0	0	0	0	0	0	0	22
23		12	0.94	3.3	0	0	0	0	0	0	0	0	23
24		5.4	1.0	2.5	0	0	0	0	0	0	0	0	24
25	0.10	4.4	33	3.8	0	0	0	0	0	0	0	0	25
26	0.27	5.2	28	5.8	0	0	0	0	0	0	0	0	26
27	0.43	3.4	9.3	40	0	0	0	0	0	0	0	0	27
28	0.40	2.1	6.2	11	0	0	0	0	0	0	0	0	28
29	0.55	0.68	4.3	7.2	0	0	0	0	0	0	0	0	29
30	0.62	0.01	2.9	5.7	0	0	0	0	0	0	0		30
31	0.61		2.2		0	0		0		0	0		31
TOTAL	2.98	89.61	110.81	207.2	24.04	0	0	0	0	0	0	0	TOTAL
MAX	0.62	23	33	40	4.6	0	0	0	0	0	0	0	MAX
MIN	0.10	0	0.37	0.84	0	0	0	0	0	0	0	0	MIN
AVERAGE	0.40	3.0	3.6	6.9	0.80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AVERAGE

Table A-2. Mean Daily Discharge for Unnamed Tributary to Vermont City Reservoir @ CR 300 N (DHZC-02), Year 1 (March 2011-February 2012) Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		0.43	0.80	1.2	1.2	0.06	0	0	0	0.02	0 e	0.02 e	1
2		0.41	0.71	3.5	1.0	0.06	0	0	0	0.01	0 e	0.01 e	2
3		0.63	0.62	2.3	0.81	0.04	0	0	0	0.03	0.02 e	0.01 e	3
4		0.49	0.57	1.7	0.71	0.02	0	0	0	0.01	0 e	0.02 e	4
5		0.39	0.64	1.4	0.63	0.02	0	0	0	0	0.02 e	0.03 e	5
6		0.46	0.70	1.3	0.57	0.02	0	0	0	0	0.04 e	0.01 e	6
7		0.41	0.77	1.2	0.51	0.01	0	0	0	0.01	0.04 e	0.01 e	7
8		0.43	0.65	1.1	0.40	0	0	0	0.01	0	0.02 e	0.01 e	8
9		0.65	0.75	0.96	0.35	0	0	0	0.05	0	0.01 e	0.01 e	9
10		0.70	0.81	0.89	0.34	0	0	0	0.01	0 e	0.01 e	0.01 e	10
11		0.46	0.67	0.75	0.31	0	0	0	0	0.02 e	0.01 e	0 e	11
12		0.42	0.65	0.68	0.26	0	0	0	0	0.02 e	0.01 e	0 e	12
13		0.45	0.59	0.66	0.23	0	0	0	0.01	0.03 e	0.01 e	0 e	13
14		0.43	1.0	1.1	0.19	0	0	0	0	0.33 e	0.01 e	0.01 e	14
15		0.44	2.0	15	0.18	0	0	0	0	0.08 e	0.04 e	0.03 e	15
16		0.39	1.5	2.7	0.17	0	0	0	0	0 e	0.05 e	0.05 e	16
17		0.37	1.1	1.7	0.17	0	0	0	0	0 e	0.05 e	0.01 e	17
18		0.43	0.98	1.6	0.17	0	0	0	0.01	0 e	0.02 e	0.01 e	18
19		7.2	0.83	1.4	0.17	0	0	0	0.01	0 e	0.01 e	0 e	19
20		4.0	0.88	6.2	0.15	0	0	0	0	0.03 e	0.02 e	0 e	20
21		2.3	0.86	2.1	0.13	0	0	0	0.01	0.02 e	0.07 e	0 e	21
22		11	0.89	1.4	0.11	0	0	0	0.02	0 e	0.09 e	0 e	22
23		5.1	0.76	1.1	0.10	0	0	0	0.01	0 e	0.07 e	0.04 e	23
24		2.8	0.87	0.99	0.47	0	0	0	0.01	0 e	0.03 e	0.03 e	24
25	0.49	2.1	19	0.99	0.15	0	0	0	0.02	0.02 e	0.02 e	0.01 e	25
26	0.43	2.2	13	2.7	0.12	0	0	0	0.07	0 e	0.04 e	0.01 e	26
27	0.40	1.6	4.8	17	0.10	0	0	0	0.18	0 e	0.03 e	0.01 e	27
28	0.41	1.2	3.2	3.3	0.09	0	0	0	0.04	0 e	0.09 e	0.01 e	28
29	0.40	1.1	2.2	1.8	0.07	0	0	0	0.01	0 e	0.09 e	0.02 e	29
30	0.43	1.1	1.8	1.4	0.06	0	0	0	0	0 e	0.11 e		30
31	0.43		1.4		0.06	0		0		0 e	0.07 e		31
TOTAL	2.99	50.09	66	80.12	9.98	0.23	0	0	0.47	0.63	1.1	0.38	TOTAL
MAX	0.49	11	19	17	1.2	0.06	0	0	0.18	0.33	0.11	0.05	MAX
MIN	0.40	0.37	0.57	0.66	0.06	0	0	0	0	0	0	0	MIN
AVERAGE	0.40	1.7	2.1	2.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	AVERAGE

e = Estimated

Table A-3. Mean Daily Discharge for Sugar Creek @ Rte. 24 (DH-02), Year 1 (March 2011-February 2012)

Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		35	78	85	110	6.3	0.35	0.09	0.05 e	2.5	5.8	14	1
2		32	69	272	89	5.2	0.31	0.09	0.04 e	1.9	4.7	12	2
3		30	62	180	76	4.2	0.44	0.10	2.6 e	1.9	4.8	9.9	3
4		57	57	149	68	3.4	0.94	0.07 e	1.9	2.3	3.9	12	4
5		36	56	1320	59	2.8	0.28	0.07 e	1.3	2.0	4.1	19	5
6		30	59	278	53	2.8	0.15	0.05 e	1.9	1.9	4.9	16	6
7		29	52	136	68	2.9	0.08	0.04 e	1.8	1.8	5.3	12	7
8		46	46	95	112	2.5	0.14	0.01 e	3.9	1.6	5.7	10	8
9		46	42	73	52	2.0	0.15	0.01 e	17	1.6 e	4.3	9.5	9
10		43	42	366	43	1.7	0.15	0.02 e	10	1.5 e	4.2	9.6	10
11		44	36	494	44	1.4	0.17	0.03 e	4.4	0.98 e	4.2	9.2	11
12		32	35	121	35	1.3	0.15	0.01 e	2.1	0.98 e	3.8 e	6.9	12
13		28	32	81	44	1.2	0.13	0.02 e	1.5	1.2 e	3.2 e	6.0	13
14		27	54	229	33	1.1	0.08	0.01 e	0.96	201	3.7 e	6.9	14
15		29	105	2900	27	1.0	0.04	0.01 e	0.76	102	3.4 e	8.3	15
16		46	97	446	23	1.1	0.05	0.01 e	0.49	26	5.3 e	12	16
17		32	68	207	20	0.89	0.07	0 e	0.41	14	20 e	11	17
18		31	56	515	18	0.96	0.29	0.02 e	0.49	9.4	21	9.2	18
19		804	48	263	15	0.88	1.0	0.05 e	0.55	8.5	11 e	7.0	19
20		606	42	963	13	0.84	0.58	0.04 e	0.57	13	4.5 e	6.8	20
21		202	39	402	11	0.62	0.32	0.04 e	0.51	18	2.6 e	7.3	21
22		1360	63	215	9.4	0.55	0.2	0.06 e	1.4	14	4.7 e	7.0	22
23		799	51	135	8.0	0.61	0.14	0.04 e	2.2	11	11	7.3	23
24		272	36	104	113	0.62	0.12	0.05 e	2.1	8.6	8.8 e	7.8	24
25		195	1950	118	60	0.57	0.14	0.07 e	1.8	7.9	7.5 e	6.8	25
26		199	2080	277	21	0.29	0.13	0.19 e	6.2	7.3	9.0	5.0	26
27		155	421	3340	16	0.24	0.20	0.09 e	42	9.4	9.0	5.4	27
28		122	241	646	12	0.31	0.30	0.07 e	14	8.2	9.2	5.4	28
29		101	182	211	8.8	0.35	0.22	0.29 e	5.9	7.5	8.9	7.9	29
30		88	138	144	7.8	0.35	0.16	0.23 e	3.3	6.9	8.8		30
31			106		7.3	0.39		0.13 e		6.6	12		31
TOTAL	N/A	5556	6443	14765	1276.3	49.37	7.48	2.01	132.13	501.46	219.3	267.2	TOTAL
MAX	N/A	1360	2080	3340	113	6.3	1.0	0.29	42	201	21	19	MAX
MIN	N/A	27	32	73	7.3	0.24	0.04	0	0.04	0.98	2.6	5.0	MIN
AVERAGE	N/A	185.2	207.8	492.2	41.2	1.6	0.20	0.10	4.4	16.2	7.1	9.2	AVERAGE

e = Estimated

Table A-4. Mean Daily Discharge for Sugar Creek 5.6 Mi. E. Littleton (DH-05), Year 1 (March 2011-February 2012)
Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		22	48	64	80	2.6	0	0	0	1.4	3.8	7.5	1
2		20	43	180	67	2.3	0	0	0	1.2	2.4	5.3	2
3		20	39	120	58	1.9	0.04	0	0	1.3	2.0	4.7	3
4		30	36	90	51	1.4	0.02	0	0.59	1.7	2.2	6.0	4
5		20	37	865	41	1.2	0	0	0.25	1.4	2.5	7.6	5
6		19	36	166	35	0.98	0	0	0.01	1.4	3.2	6.4	6
7		18	33	102	69 e	0.89	0	0	0	1.3	3.9	5.3	7
8		25	30	79	49 e	0.77	0	0	0.77	1.1	2.6	5.2	8
9		26	28	66	31 e	1.0	0	0	6.4	0.9	2.3	4.7	9
10		24	28	106	30 e	0.89	0	0	4.2	0.76	2.3	4.6	10
11		21	25	235	25 e	0.70	0	0	2.0	0.61	2.9 e	3.7	11
12		18	25	85	19	0.46	0	0	1.2	0.66	2.6 e	2.6	12
13		16	23	68	27	0.41	0.16	0	0.64	1.1	2.6 e	2.2	13
14		16	37	142	17	0.36	0	0	0.41	59	2.8 e	3.3	14
15		19	70	1420	14	0.35	0	0	0.32	42	2.8 e	4.7	15
16		27	60	220	11	0.27	0	0	0.32	10	3.5 e	6.7	16
17		18	44	132	9.9	0.31	0	0	0.06	7.4	9.6 e	6.2	17
18		18	37	270	8.3	0.33	0	0	0.05	6.2	7.0 e	5.1	18
19		382	32	143	6.4	0.13	0.01	0	0.05	5.5	4.2 e	4.2	19
20		253	29	596	5.4	0.10	0	0	0.10	6.8	2.5 e	3.7	20
21		113	28	194	4.3	0.10	0	0	0.11	8.4	2.0 e	4.5	21
22		746	39	118	3.7	0.08	0	0	0.67	6.9	3.8 e	4.4	22
23		352	30	87	3.2	0.03	0	0	1.2	5.4	7.5 e	4.8	23
24		156	25	70	51	0.02	0	0	0.84	4.9	6.8 e	4.8	24
25		117	1470	80	26	0.01	0	0	0.85	4.6	3.9 e	3.5	25
26		122	989	139	7.8	0	0	0	4.0	4.6	5.1 e	3.1	26
27		93	260	1850	8.6	0	0	0	18	5.3	5.4 e	3.3	27
28		73	166	242	4.5	0	0	0	4.3	4.7	5.0 e	4.0	28
29	21	61	128	135	3.3	0	0	0	2.6	4.7	5.3	5.3	29
30	21	53	100	100	3.2	0	0	0	1.4	4.6	5.3		30
31	22		79		3.0	0		0		4.5	7.2		31
TOTAL	64	2898	4054	8164	772.6	17.59	0.23	0	51.34	210.33	125	137.4	TOTAL
MAX	22	746	1470	1850	80	2.6	0.16	0	18	59	9.6	7.6	MAX
MIN	21	16	23	64	3.0	0	0	0	0	0.61	2.0	2.2	MIN
AVERAGE	21.3	96.6	130.8	272.1	24.9	0.60	0.0	0.0	1.7	6.8	4.0	4.7	AVERAGE

e = Estimated

Table A-5. Mean Daily Discharge for Sugar Creek @ Sugar Cr. Rd. (DH-06), Year 1 (March 2011-February 2012)
Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		23	30	35	39	2.8	0	0	0	0.69	1.5	4.1	1
2		19	26	115	32	2.3	0	0	0	0.40	0.41 e	2.7	2
3		17	25	81	26	1.8	0.02	0	0	0.45	0.41 e	2.0	3
4		23	22	50	23	1.4	0	0	0.12 e	0.82	0.45 e	2.8	4
5		14	23	114	19	1.2	0	0	0.04 e	0.71	0.87 e	3.5	5
6		13	22	37	17	1.1	0	0	0 e	0.36	1.4	2.8	6
7		13	20	30	51	0.99	0	0	0 e	0.19	1.5	2.2	7
8		17	18	25	30	0.80	0	0	0.85 e	0.12	1.3	2.0	8
9		18	17	21	17	0.60	0	0	2.6 e	0.11	1.3	2.4	9
10		16	17	26	14	0.36	0	0	1.3 e	0.05	0.94	1.8	10
11		15	15	32	13	0.27	0	0	0.21 e	0.06	1.0	0.97	11
12		11	15	19	12	0.18	0	0	0.08 e	0.03	0.83	0.39	12
13		10	14	17	15	0.17	0	0	0.08 e	0.05 e	1.1 e	0.53	13
14		10	25	42	10	0.13	0	0	0.06 e	37 e	1.1 e	1.7	14
15		12	49	548	8.4	0.07	0	0	0.03 e	19 e	0.94 e	2.2	15
16		17	39	114	7.5	0.05	0	0	0.01 e	7.0	1.4 e	3.5	16
17		11	29	65	6.8	0.01	0	0	0 e	3.9	2.7 e	3.0	17
18		11	24	149	6.0	0.10	0	0	0.01 e	3.0	2.0 e	2.2	18
19		228	21	67	5.2	0	0	0	0.01 e	2.7	1.5 e	1.7	19
20		166	19	268	4.5	0	0	0	0.02 e	3.6	0.83 e	1.6	20
21		82	18	116	3.8	0.05	0	0	0.01 e	4.7	1.2 e	1.9	21
22		375	27	67	3.2	0	0	0	0.57 e	3.7	2.0 e	1.9	22
23		213	20	47	2.6	0	0	0	0.90	2.6 e	4.0 e	2.0	23
24		105	17	36	22	0	0	0	0.64	2.1 e	3.6 e	2.1	24
25		76	540	37	15	0	0	0	0.61	2.0	2.1 e	1.5	25
26		82	475	46	7.3	0	0	0	2.9	1.9 e	2.9 e	1.2	26
27		61	155	671	9.2	0	0	0	11	2.7	3.0 e	1.1	27
28		47	105	130	5.7	0	0	0	3.4	2.3	3.0 e	1.1	28
29		40	79	76	4.4	0	0	0	1.4	2.1	3.2 e	2.0	29
30		32	58	52	4.1	0	0	0	0.89	1.8	3.6 e		30
31			44		3.5	0		0		1.9	4.0		31
TOTAL	N/A	1777	2008	3133	437.2	14.38	0.02	0	27.74	108.04	56.08	58.89	TOTAL
MAX	N/A	375	540	671	51	2.8	0.02	0	11	37	4.0	4.1	MAX
MIN	N/A	10	14	17	2.6	0	0	0	0	0.03	0.41	0.39	MIN
AVERAGE	N/A	59.2	64.8	104.4	14.1	0.5	0.0	0.0	0.9	3.5	1.8	2.0	AVERAGE

e = Estimated

Table A-6. Mean Daily Discharge for Sugar Creek @ Rock Quarry Rd. (DH-07), Year 1 (March 2011-February 2012)
Discharge, in Cubic Feet per Second, for indicated date

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	DAY
1		55	112	106	169	13	2.0	2.2 e	1.3 e	9.7	13	24	1
2		52	110	341	130	11	1.8	2.1 e	1.3 e	7.6	9.7	19	2
3		50	108	297	107	10	1.7	1.9 e	23 e	6.2	9.2	16	3
4		79	102	201	93	8.9	4.7	1.7 e	25	7.6	8.2	21	4
5		63	93	1560	80	8.1	2.8	0.92 e	13	6.4	8.3	32	5
6		51	88	699	70	7.8	2.3 e	0.51 e	9.9	5.5	9.5	28	6
7		48	75	201	76	7.6	1.4 e	0.30 e	7.8	5.7	9.8	23	7
8		67	67	129	144	8.3	1.2 e	0.17 e	19	5.7	9.2	20	8
9		66	60	98	73	7.2	1.2 e	0.11 e	41	5.3	9.7	17	9
10		68	58	462	59	6.2	1.2 e	0.11 e	38	4.0	8.2	17	10
11		67	55	1340	56	5.6	1.1 e	0.11 e	19	3.3	8.5	18	11
12		54	52	211	52	5.3	1.1 e	0.10 e	12	3.2	9.4	16	12
13		48	49	125	53	5.6	1.1 e	0.12 e	7.5	4.0	7.1	11	13
14		46	65	343	52	5.1	1.1 e	0.12 e	5.3	296	8.0	12	14
15		46	120	3310	42	4.1	1.1 e	0.11 e	4.9	235	7.3	14	15
16		61	121	1270	37	3.6	1.2 e	0.10 e	4.5	58	9.0	18	16
17		53	89	304	34	3.9	1.4 e	0.10 e	4.2	34	22	20	17
18		46	72	713	31	4.2	1.7 e	1.0 e	3.9	25	25	18	18
19		695	63	536	28	4.0	7.4 e	1.8 e	3.4	20	22	15	19
20		1190	57	1130	25	4.2	4.9 e	1.5 e	3.0	30	13	13	20
21		304	53	718	22	4.6	3.7 e	1.4 e	2.8	38	9.7	13	21
22		1630	69	411	20	3.8	3.1 e	1.3 e	5.5	31	9.6	14	22
23		1680	73	203	18	2.9	2.7 e	1.3 e	9.4	23	14	14	23
24		455	53	151	95	2.5	2.4 e	1.3 e	7.6	17	16	15	24
25		283	1970	165	119	2.1	2.2 e	1.4 e	6.9	16	15	14	25
26		265	3300	433	39	1.8	2.1 e	4.9 e	19	14	15	12	26
27		215	738	3700	26	1.8	2.7 e	2.3 e	71	19	15	11	27
28		166	348	1890	23	1.8	2.6 e	2.0 e	43	18	18	11	28
29		131	243	369	19	1.7	2.5 e	1.7 e	22	16	15	17	29
30		119	180	234	16	1.4	2.3 e	1.6 e	14	16	15		30
31			132		15	2.0		1.4 e		15	20		31
TOTAL	N/A	8153	8775	21650	1823	160.1	68.7	35.68	448.2	995.2	388.4	493	TOTAL
MAX	N/A	1680	3300	3700	169	13	7.4	4.9	71	296	25	32	MAX
MIN	N/A	46	49	98	15	1.4	1.1	0.10	1.3	3.2	7.1	11	MIN
AVERAGE	N/A	271.8	283.1	721.7	58.8	5.2	2.3	1.2	14.9	32.1	12.5	17.0	AVERAGE

e = Estimated

Appendix B – Water Quality Data

Table B-1. Water Quality Results for Vermont City Reservoir Spillway (DHZC-01), Year 1

Date/Time (CST)	*Atrazine µg/L*	*Manganese mg/L*	*TP mg/L*	*TSS mg/L*	*VSS mg/L*	*Chlorophyll µg/L*
3/1/2011 11:28		0.208	0.434	51.5	6	
3/8/2011 14:21	ND 0.097	0.124	0.218	19.5	6	
3/15/2011 10:25		0.125	0.151	19.5	13	
3/22/2011 9:18	ND 0.0918	0.146	0.165	24	5.5	
3/29/2011 9:29		0.0942	0.168	21.5	5.5	
4/5/2011 8:31	ND 0.0889	0.106	0.123	23.5	5.5	
4/12/2011 8:41	ND 0.0889	0.104	0.129	22	11	
4/19/2011 8:53	ND 0.0898	0.174	0.132	14.5	5.5	
4/19/2011 21:29	ND 0.0898	0.21	0.137	32	7.5	
4/20/2011 3:02	ND 0.0879	0.187	0.159	32.5	7.5	
4/20/2011 12:02	ND 0.0879	0.188	0.193	30	8.5	
4/26/2011 7:53	ND 0.087	0.125	0.182	27	9.5	
5/2/2011 7:39	ND 0.0908	0.116	0.132	11	4.5	
5/9/2011 7:45	ND 0.0908	0.069	0.11	7.5	4.5	
5/16/2011 8:21	ND 0.0879	0.252	0.104	9.5	ND 3.92	
5/23/2011 7:36	ND 0.0879	0.0735	0.123	11	4	
5/25/2011 4:31	ND 0.0908	0.0563	0.104	11	ND 3.92	
5/25/2011 6:01	ND 0.0879	0.0417	0.0735	6.5	ND 3.92	
5/25/2011 7:31	ND 0.0889	0.0419	0.0735	6	ND 3.92	
5/25/2011 13:48	ND 0.0898	0.072	0.107	14.5	7.5	
5/31/2011 8:33	ND 0.0898	0.0532	0.165	11	ND 3.92	
6/6/2011 7:20	ND 0.0908	0.0295	0.0984	ND 3.92	ND 3.92	
6/6/2011 7:34						2.44
6/13/2011 8:26	5.88	0.101	0.0818	4	ND 3.92	
6/15/2011 1:45	6.22	0.214	0.112	16	6.5	
6/15/2011 3:00	6.81	0.19	0.11	9	ND 3.92	
6/15/2011 4:45	5.91	0.182	0.121	10.5	4	
6/15/2011 10:45	5.96	0.228	0.187	27	5	
6/20/2011 9:12	ND 0.0898	0.0652	0.104	15.5	9	
6/20/2011 9:25						10.6
6/26/2011 23:30	ND 0.0908	0.123	0.121	29	10.5	
6/27/2011 2:30	ND 0.0928	0.14	0.146	43.5	9.5	
6/27/2011 4:45	ND 0.0879	0.201	0.118	29.5	7.5	
6/27/2011 8:30	ND 0.0898	0.292	0.129	37.5	10	
6/27/2011 10:27	ND 0.0908	0.21	0.132	30.5	8.5	
7/5/2011 8:18	ND 0.0879	0.0566	0.129	7	ND 3.92	
7/5/2011 8:34						7.26
7/11/2011 8:13	ND 0.0889	0.0802	0.0957	16	ND 3.92	
7/18/2011 8:27	ND 0.0889	0.0746	0.0873	8.5	4	

Table B-1. continued

Date/Time (CST)	*Atrazine µg/L*	*Manganese mg/L*	*TP mg/L*	*TSS mg/L*	*VSS mg/L*	*Chlorophyll µg/L*
7/18/2011 8:42						29.9
7/25/2011 8:36	ND 0.0918	0.0953	0.0873	6.5	7	
8/1/2011 8:25	ND 0.0889	0.113	0.132	10.5	7.5	
8/1/2011 8:45						10.2
8/8/2011 14:55		0.15	0.159	13.5	4.5	
8/15/2011 8:18	ND 0.0889	0.201	0.184	22.5	11	
8/15/2011 8:30						110
8/22/2011 6:41		0.266	0.14	15.5	7	
8/29/2011 8:32	ND 0.0898	0.321	0.148	17	7	
8/29/2011 8:46						36
9/6/2011 7:12		0.277	0.196	30.5	10	
9/12/2011 7:16	ND 0.0898	0.288	0.165	34	11.5	
9/12/2011 7:49						22
9/19/2011 9:35		0.186	0.159	26.5	7.5	
9/26/2011 7:06	ND 0.0898	0.195	0.162	30	11.5	
9/26/2011 7:21						33
10/3/2011 7:21		0.174	0.14	26.5	10	
10/10/2011 7:48	ND 0.0928	0.19	0.126	27	11.5	
10/17/2011 6:16		0.177	0.134	19.5	8	
10/24/2011 8:39	ND 0.0928	0.198	0.146	25.5	11	
11/2/2011 8:01		0.285	0.132	32	9.5	
11/8/2011 9:52	ND 0.0889	0.224	0.115	25	7.5	
11/16/2011 10:33		0.258	0.146	24.5	5	
11/22/2011 9:25	ND 0.0879	0.296	0.157	29	9	
11/29/2011 9:00		0.259	0.146	21	6.5	
12/6/2011 8:53	ND 0.087	0.203	0.118	23	9.5	
12/13/2011 8:53		0.187	0.112	22	8	
12/13/2011 21:15		0.199	0.107	13	4.5	
12/14/2011 9:15		0.184	0.148	15	6	
12/14/2011 11:45		0.207	0.129	14	4.5	
12/15/2011 8:45		0.218	0.157	21	6	
12/21/2011 9:08	ND 0.0861	0.199	0.0873	17.5	22.5	
12/29/2011 10:40		0.16	0.112	15	6	
1/3/2012 9:26	ND 0.0879	0.128	0.123	12	8	
1/10/2012 9:12		0.112	0.0901	12	ND 7.84	
1/17/2012 8:59	ND 0.0898	0.0992	0.101	12	ND 7.84	
1/25/2012 9:49		0.0813	0.0762	14.5	12	
2/1/2012 9:49	ND 0.087	0.09	0.0651	7	4.5	
2/8/2012 9:04		0.104	0.118	12	4.5	

Table B-1. concluded

Date/Time (CST)	*Atrazine µg/L*	*Manganese mg/L*	*TP mg/L*	*TSS mg/L*	*VSS mg/L*	*Chlorophyll µg/L*
2/23/2012 10:03		0.0838	0.123	15	4.5	
2/29/2012 13:03	ND 0.0879	0.0766	0.134	19.5	ND 3.92	
Minimium	0.09	0.03	0.07	3.92	3.92	2.44
Maximum	6.81	0.32	0.43	51.50	22.50	110
Mean	0.70	0.16	0.13	19.20	7.12	29.04
Median	0.09	0.17	0.13	17.25	6.75	22
Samples Below MDL	45	0	0	1	13	0
Samples Below RL	0	0	0	0	0	0
Total Samples	50	72	72	72	72	9

ND = Not Detected

Table B-2. Water Quality Results for Unnamed Tributary to VCR @ CR 300N (DHZC-02), Year 1

Date/Time (CST)	*Atrazine µg/L*	*Manganese mg/L*	*TP mg/L*	*TSS mg/L*	*VSS mg/L*	*Chlorophyll µg/L*
3/1/2011 12:01		0.0564	0.254	5	2	
3/8/2011 13:55	ND 0.0928	0.0471	ND 0.0274	8	ND 3.92	
3/15/2011 8:50		0.0749	ND 0.0274	15.5	9	
3/22/2011 7:53	ND 0.0928	0.064	0.132	7.5	ND 3.92	
3/29/2011 8:05		0.0834	0.054	7.5	ND 3.92	
4/5/2011 7:32	ND 0.0889	0.0866	ND 0.0274	ND 3.92	ND 3.92	
4/12/2011 7:12	ND 0.0879	0.0828	ND 0.0274	ND 3.92	ND 3.92	
4/19/2011 0:00	ND 0.0938	1.53	1.06	1250	114	
4/19/2011 1:00	6.34	0.953	1.11	890	96	
4/19/2011 5:12	ND 0.0889	0.339	0.356	228	26	
4/19/2011 7:43	ND 0.0908	0.866	0.889	990	80	
4/19/2011 19:48	ND 0.0908	0.382	0.759	434	32	
4/19/2011 23:00	ND 0.0938	0.172	0.301	116	11.5	
4/20/2011 11:44	ND 0.0898	0.106	0.129	47.5	6	
4/26/2011 6:33	ND 0.0898	0.0987	0.121	36.5	6	
5/2/2011 7:02	ND 0.087	0.0834	0.0679	16	ND 3.92	
5/9/2011 7:04	ND 0.087	0.0432	ND 0.0274	5	4	
5/16/2011 6:59	ND 0.0898	0.0547	0.0846	13.5	ND 3.92	
5/23/2011 7:00	ND 0.0861	0.03	0.0846	7.5	ND 3.92	
5/25/2011 3:29	ND 0.0908	0.437	0.7	358	25	
5/25/2011 4:44	7.73	8.54	5.81	8200	370	
5/25/2011 4:59	31.7	4.64	6.02	8940	430	
5/25/2011 5:59	31.1	1.77	2.82	2330	145	
5/25/2011 6:43	29.7	1.25	2	1720	95	
5/25/2011 14:20	36.7	0.224	0.648	254	38	
5/31/2011 7:07	ND 0.0898	0.044	0.104	24.5	4	
6/6/2011 6:22	ND 0.0889	0.0288	0.0651	11	ND 3.92	
6/13/2011 7:15	ND 0.0918	0.0291	0.0735	10	11	
6/15/2011 1:30	ND 0.111	0.878	0.717	690	60	
6/15/2011 2:00	ND 0.128	4.26	3.07	3520	225	
6/15/2011 2:45	ND 0.122	1.91	2.31	2680	185	
6/15/2011 3:15	ND 0.122	0.979	1.73	1570	112	
6/20/2011 7:55	ND 0.0879	0.193	0.359	169	24	
6/27/2011 7:03	ND 0.0898	0.239	0.487	237	21	
7/5/2011 7:32	ND 0.0879	0.0276	0.0873	12	ND 3.92	
7/11/2011 7:04	ND 0.0889	0.0433	0.104	20	ND 3.92	
7/18/2011 7:11	ND 0.0879	0.0926	0.168	56.5	6.5	
7/25/2011 7:05	ND 0.0898	0.0728	0.301	65.5	9	
8/1/2011 7:48	ND 0.087	0.0424	0.24	25.5	4	

Table B-2. concluded

Date/Time (CST)	*Atrazine µg/L*	*Manganese mg/L*	*TP mg/L*	*TSS mg/L*	*VSS mg/L*	*Chlorophyll µg/L*
8/15/2011 7:37	ND 0.0879	0.388	0.368	178	38	
8/22/2011 6:04		3.61	0.509	194	26	
11/2/2011 7:06		2.34	0.573	61.5	12	
11/8/2011 8:16	ND 0.0898	0.773	0.52	68	7	
11/16/2011 10:02		0.66	0.345	51.5	6.5	
11/22/2011 8:00	ND 0.0879	0.206	0.248	27	4	
11/29/2011 8:18		0.401	0.478	77	11	
12/6/2011 8:04	ND 0.0898	0.68	0.182	33.5	6.5	
12/13/2011 8:04		1.51	0.34	212	21	
12/21/2011 8:18	ND 0.0861	0.444	0.207	47.5	34.5	
12/29/2011 10:00		1.54	0.223	21.5	4	
1/3/2012 8:32	ND 0.087	3.63	1.26	770	58	
1/10/2012 8:40		2.57	0.517	288	ND 15.7	
1/17/2012 8:12	ND 0.087	0.854	0.503	446	24	
1/25/2012 8:55		0.216	0.0568	ND 3.92	ND 3.92	
2/1/2012 8:19	ND 0.0861	0.0803	0.0707	ND 3.92	ND 3.92	
2/8/2012 8:09		0.0701	0.0651	ND 3.92	4	
2/15/2012 7:54	ND 0.0861	0.241	0.0957	3	2	
2/23/2012 8:44		0.237	0.0818	ND 3.92	ND 3.92	
2/29/2012 12:16	ND 0.0861	0.0874	0.0818	ND 3.92	ND 3.92	
Minimum	0.0861	0.0276	0.0274	3	2	
Maximum	36.7	8.54	6.02	8940	430	
Mean	3.19	0.85	0.67	624.75	41.47	
Median	0.0898	0.2305	0.251	49.5	8	
Samples Below MDL	40	0	5	7	16	
Samples Below RL	0	0	0	0	0	
Total Samples	46	60	60	60	60	

ND = Not Detected

Appendix C – Fecal Coliform Data

Table C-1. Fecal Coliform Results for Sugar Creek below McKee Branch (DH-02), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/04/2011 08:15	165	58
05/10/2011 07:30	319	43
05/11/2011 09:56	260	36
05/17/2011 07:44	183	70
05/18/2011 11:58	219	56
05/24/2011 07:33	580	36
06/07/2011 07:27	58400	146
06/09/2011 11:25	3400	76
06/16/2011 12:13	1960	387
06/21/2011 07:08	7300	347
06/23/2011 12:08	1100	135
06/28/2011 07:38	100	521
07/06/2011 12:22	2100	55
07/07/2011 08:53	1200	47
07/20/2011 07:41	9500	14
07/21/2011 09:28	8900	12
07/26/2011 07:21	9500	23
07/27/2011 08:27	9700	14
08/04/2011 11:12	7100	3.9
08/09/2011 08:58	4000	2.2
08/11/2011 11:44	2100	1.5
08/16/2011 08:16	11900	0.85
08/23/2011 08:43	4600	0.58
08/30/2011 07:23	1920	0.31
09/01/2011 08:36	1540	0.37
09/08/2011 09:03	1340	0.20
09/15/2011 11:42	900	0.05
09/20/2011 10:26	4700	0.64
09/22/2011 11:43	2680	0.30
09/27/2011 07:23	9100	0.16
10/04/2011 08:26	3700	0.04
10/11/2011 07:55	1040	0.03
10/13/2011 11:05	2000	0.02
10/18/2011 09:53	2300	0
10/25/2011 09:46	200	0.05
10/27/2011 12:14	2310	0.10

Table C-2. Fecal Coliform Results for Sugar Creek below West Branch (DH-05), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 10:04	407	40
05/04/2011 11:55	90	36
05/05/2011 09:05	320	35
05/18/2011 09:17	528	38
05/24/2011 13:04	280	25
05/26/2011 09:28	1400	1412
06/07/2011 10:31	2540	105
06/09/2011 09:13	1880	68
06/14/2011 12:09	5300	215
06/16/2011 09:50	1720	225
06/23/2011 09:32	3060	88
06/28/2011 10:55	43800	240
07/07/2011 13:06	3600	31
07/12/2011 06:59	3600	19
07/14/2011 12:09	5800	18
07/19/2011 08:28	11700	6.4
07/21/2011 08:44	6600	4.4
07/26/2011 12:12	13600	8.0
08/04/2011 07:16	14600	1.2
08/09/2011 11:16	3000	1.2
08/16/2011 10:12	4400	0.27
08/17/2011 08:26	2900	0.31
08/25/2011 08:31	5800	0.01
08/30/2011 10:24	2500	0
09/01/2011 06:44	1540	0
09/07/2011 10:04	760	0
09/13/2011 09:06	5100	0.30
09/15/2011 08:57	1460	0
09/20/2011 13:01	2200	0
09/27/2011 09:31	2120	0
10/04/2011 10:54	630	0
10/06/2011 07:09	1760	0
10/11/2011 11:06	3100	0
10/13/2011 08:01	7100	0
10/18/2011 12:32	2120	0
10/25/2011 10:50	2130	0

Table C-3. Fecal Coliform Results for Sugar Creek above West Branch (DH-06), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/04/2011 10:03	184	22
05/10/2011 13:07	1200	17
05/11/2011 09:22	2410	16
05/17/2011 12:05	700	28
05/18/2011 08:52	718	25
05/24/2011 10:50	810	17
06/02/2011 09:07	27000	114
06/07/2011 12:06	1380	30
06/09/2011 08:53	3240	22
06/21/2011 12:54	2200	98
06/23/2011 07:24	3540	49
06/28/2011 10:31	940	131
07/06/2011 09:40	4700	18
07/07/2011 09:38	3000	16
07/12/2011 08:15	24600	13
07/14/2011 11:55	8000	11
07/19/2011 09:50	19700	5.9
07/20/2011 10:45	1500	5.3
08/04/2011 06:52	7800	1.2
08/11/2011 08:59	3900	0.28
08/16/2011 11:49	5600	0.01
08/17/2011 08:04	5200	0.01
08/25/2011 07:15	10500	0
08/30/2011 10:07	10200	0
09/08/2011 07:42	3400	0
09/13/2011 09:59	3800	0
09/20/2011 13:15	8000	0
09/22/2011 07:38	4400	0
09/27/2011 09:44	17700	0
09/29/2011 07:52	1720	0
10/04/2011 12:11	5300	0
10/06/2011 07:50	10300	0
10/11/2011 11:38	2260	0
10/13/2011 06:57	1490	0
10/18/2011 11:34	2870	0
10/20/2011 07:26	9800	0

Table C-4. Fecal Coliform Results for Sugar Creek (DH-07), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 12:03	46	108
05/04/2011 06:50	128	105
05/05/2011 12:15	52	91
05/10/2011 07:44	149	59
05/24/2011 08:44	260	53
05/26/2011 11:38	1150	3792
06/02/2011 13:14	5200	407
06/14/2011 07:24	131000	206
06/16/2011 12:26	3660	679
06/21/2011 09:03	12400	565
06/23/2011 11:39	1340	201
06/28/2011 08:10	480	2128
07/06/2011 12:01	1160	70
07/14/2011 07:54	4400	54
07/20/2011 08:50	9100	25
07/21/2011 09:47	4900	22
07/26/2011 08:02	12400	40
07/27/2011 06:48	15100	27
08/09/2011 07:16	13900	6.9
08/16/2011 08:49	9500	3.5
08/17/2011 10:05	2400	3.7
08/23/2011 09:00	10200	2.6
08/25/2011 10:08	7500	2.2
08/30/2011 08:34	3300	1.1
09/08/2011 09:49	1460	1.2
09/13/2011 08:21	2700	1.1
09/20/2011 07:46	970	5.1
09/22/2011 12:19	4600	3.0
09/27/2011 06:49	530	2.6
09/29/2011 09:21	1860	2.5
10/04/2011 08:43	3900	1.8
10/11/2011 07:53	7100	0.11
10/13/2011 10:18	1220	0.12
10/18/2011 08:02	860	0.25
10/20/2011 12:21	820	1.5
10/27/2011 11:08	1230	2.3

Table C-5. Fecal Coliform Results for Sugar Creek upstream of Vermont City Reservoir (DH-08), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 07:15	408	11.7
05/04/2011 13:05	84	10.4
05/05/2011 08:28	251	10.5
05/10/2011 11:00	2400	8.53
05/24/2011 10:56	480	8.06
05/26/2011 07:28	880	360
06/09/2011 07:21	2960	12.9
06/14/2011 11:12	117000	25.7
06/16/2011 08:09	1360	57.1
06/21/2011 12:25	2300	41.5
06/23/2011 08:59	2300	21.7
06/28/2011 12:36	1460	52.1
07/06/2011 08:46	5900	9.86
07/07/2011 11:09	3700	8.46
07/12/2011 07:13	7300	5.74
07/19/2011 09:16	4500	2.55
07/26/2011 12:00	18300	3.21
07/27/2011 08:10	26400	6.24
08/02/2011 11:19	4400	1.43
08/11/2011 07:19	13100	0.31
08/16/2011 10:38	8000	0
08/17/2011 07:25	2900	0.05
08/23/2011 10:49	46000	0
08/30/2011 11:04	2800	0.02
09/07/2011 10:53	2040	0
09/08/2011 07:20	11700	0
09/15/2011 07:57	4400	0
09/22/2011 09:01	15300	0
09/27/2011 08:55	26300	0.07
09/29/2011 07:10	5500	0
10/04/2011 11:48	9900	0.02
10/06/2011 09:52	7800	0.11
10/11/2011 11:36	20400	0
10/13/2011 08:44	14500	0
10/25/2011 11:35	7400	0
10/27/2011 06:37	28100	0

Table C-6. Fecal Coliform Results for Sugar Creek below Table Grove STP Outfall (DH-09), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 08:50	209	8.35
05/04/2011 12:31	61	7.25
05/05/2011 07:14	225	7.26
05/11/2011 07:28	548	5.26
05/17/2011 10:54	268	11.8
05/18/2011 07:57	269	10.9
06/01/2011 11:39	230	15.3
06/02/2011 08:32	8600	19.2
06/14/2011 12:39	3500	12.8
06/21/2011 11:12	3300	30.9
06/23/2011 07:52	4300	15.5
06/28/2011 12:02	3080	38.5
07/06/2011 09:44	5200	7.71
07/14/2011 10:29	4300	3.98
07/20/2011 11:51	3800	2.15
07/21/2011 07:19	6800	1.63
07/26/2011 11:06	10500	2.38
07/27/2011 07:08	30800	3.84
08/02/2011 10:19	11900	0.97
08/09/2011 13:12	2800	0.41
08/16/2011 11:39	25600	0.01
08/23/2011 11:18	36000	0.07
08/25/2011 07:15	41000	0.03
08/30/2011 10:32	24800	0.05
09/01/2011 07:11	19700	0.06
09/07/2011 09:52	29200	0.09
09/13/2011 08:53	10600	0.26
09/15/2011 07:04	9300	0.01
09/20/2011 12:28	12000	0.01
09/27/2011 09:49	8000	0.05
10/04/2011 10:40	4400	0.04
10/11/2011 10:46	2140	0.02
10/13/2011 07:34	9700	0
10/20/2011 08:29	3300	0.02
10/25/2011 11:58	2710	0.28
10/27/2011 07:39	12900	0.18

Table C-7. Fecal Coliform Results for Harris Branch (DHC-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 14:15	62	11.4
05/05/2011 12:40	84	10.7
05/10/2011 09:13	429	9.09
05/11/2011 12:24	249	8.43
05/17/2011 08:32	288	10.9
05/18/2011 11:58	91	9.04
06/01/2011 08:34	580	12
06/02/2011 11:59	33000	145
06/07/2011 08:15	1000	19
06/09/2011 10:54	1900	11.1
06/21/2011 08:32	3900	30.6
06/28/2011 08:53	3650	42
07/06/2011 13:16	1780	8.95
07/12/2011 10:43	3500	6.83
07/19/2011 12:23	4100	3.67
07/20/2011 07:14	9100	3.14
07/21/2011 11:45	7800	3.14
07/26/2011 07:53	14300	3.45
08/02/2011 08:50	11000	1.62
08/04/2011 10:35	5600	1.14
08/11/2011 11:42	3700	0.62
08/17/2011 08:57	4600	0.47
08/23/2011 07:34	5100	0.24
08/25/2011 11:01	9700	0.16
09/01/2011 09:24	3340	0.29
09/07/2011 07:34	4700	0.07
09/08/2011 08:38	2740	0.11
09/15/2011 10:18	3200	0.42
09/20/2011 09:37	4500	0.45
09/22/2011 10:42	1460	0.47
10/04/2011 07:19	2740	0.17
10/11/2011 09:08	5300	0.05
10/13/2011 11:22	1790	0.81
10/18/2011 09:00	1100	0.45
10/20/2011 09:40	1060	0.25
10/25/2011 07:06	870	0.23

Table C-8. Fecal Coliform Results for Gaines Branch (DHE-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 11:11	78	3.4
05/04/2011 09:18	84	3.2
05/05/2011 10:10	160	3.22
05/11/2011 11:09	225	2.07
05/18/2011 12:17	67	2.41
05/24/2011 07:04	216	1.73
06/01/2011 09:09	380	2.82
06/09/2011 11:45	2220	2.57
06/14/2011 07:21	6000	51.5
06/16/2011 11:43	1180	10.2
06/23/2011 13:41	1540	5.65
06/28/2011 08:29	2180	11
07/07/2011 08:49	1700	1.77
07/12/2011 11:40	1700	1.28
07/14/2011 07:08	8800	1.53
07/19/2011 11:07	3200	0.85
07/20/2011 07:16	7700	0.82
07/26/2011 08:43	9100	1.11
08/04/2011 09:25	4200	0.23
08/09/2011 09:55	3600	0.16
08/16/2011 07:30	3400	0.02
08/23/2011 07:56	3700	0
08/25/2011 10:10	4600	0
08/30/2011 08:39	2520	0
09/07/2011 07:09	3720	0
09/08/2011 09:33	2640	0
09/13/2011 07:12	4900	0
09/15/2011 12:05	4500	0
09/22/2011 11:01	2190	0
09/29/2011 09:55	1100	0
10/04/2011 07:23	5800	0
10/11/2011 06:42	2160	0
10/13/2011 09:05	1640	0
10/20/2011 08:55	410	0
10/25/2011 08:46	6900	0
10/27/2011 12:26	1020	0

Table C-9. Fecal Coliform Results for Richie Branch (DHF-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 13:20	84	4.61
05/05/2011 12:12	550	4.68
05/10/2011 09:18	796	3.43
05/17/2011 08:50	226	5.29
05/18/2011 11:23	311	4.44
05/24/2011 09:19	1050	3.43
06/01/2011 07:23	460	6.02
06/07/2011 08:38	2360	10.9
06/09/2011 10:53	4300	5.61
06/14/2011 08:25	87600	45.8
06/21/2011 09:00	4100	18.7
06/23/2011 11:02	1940	8.82
07/06/2011 11:14	3300	3.11
07/07/2011 07:33	4700	3.09
07/12/2011 09:58	4400	2.18
07/14/2011 08:02	5900	2.05
07/20/2011 08:31	5700	0.92
07/21/2011 11:20	2700	0.56
08/02/2011 07:32	13900	0.28
08/04/2011 09:28	1500	0.13
08/11/2011 10:39	4100	0.01
08/16/2011 08:47	8500	0.01
08/17/2011 09:13	2200	0.01
08/25/2011 10:34	3700	0
09/01/2011 08:13	2460	0
09/07/2011 07:31	440	0
09/08/2011 08:01	1480	0
09/15/2011 09:14	480	0
09/20/2011 10:00	4900	0
09/27/2011 08:01	1820	0
10/04/2011 08:48	5100	0
10/11/2011 07:00	8500	0
10/13/2011 10:43	8000	0
10/18/2011 10:14	14400	0
10/20/2011 10:28	3400	0
10/27/2011 11:42	5300	0

Table C-10. Fecal Coliform Results for West Branch (DHG-02), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 07:36	149	5.25
05/05/2011 08:15	92	4.16
05/10/2011 13:26	157	4.38
05/17/2011 11:13	132	6.2
05/18/2011 08:40	274	5.07
05/24/2011 11:42	264	3.17
06/01/2011 12:08	450	8.24
06/02/2011 10:05	5100	33.1
06/07/2011 12:57	1100	20.8
06/09/2011 08:02	3880	10.1
06/16/2011 08:13	900	37.1
06/21/2011 13:08	3000	29.2
07/06/2011 08:30	3700	4
07/07/2011 12:16	2500	3.74
07/14/2011 11:41	4500	2.29
07/20/2011 10:53	5700	1.05
07/21/2011 08:53	3100	0.87
07/26/2011 10:49	10900	1.15
08/02/2011 12:45	2300	0.2
08/04/2011 08:29	10700	0.1
08/11/2011 08:21	2300	0.01
08/17/2011 07:37	1050	0
08/23/2011 09:58	5600	0
08/25/2011 07:58	14400	0
09/01/2011 07:30	1000	0
09/08/2011 07:13	960	0
09/13/2011 09:47	1280	0
09/20/2011 13:38	8800	0
09/22/2011 07:03	11300	0
09/27/2011 09:58	3300	0
10/04/2011 11:30	3900	0
10/11/2011 10:31	840	0
10/13/2011 07:27	1260	0
10/18/2011 12:00	880	0
10/20/2011 06:57	760	0
10/27/2011 08:21	420	0

Table C-11. Fecal Coliform Results for Rich Branch (DHGA-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 08:43	146	2.84
05/04/2011 10:16	85	2.69
05/11/2011 08:09	201	1.79
05/17/2011 12:06	102	3.92
05/18/2011 07:51	160	3.14
05/24/2011 12:38	99	1.69
06/01/2011 12:57	340	4.15
06/07/2011 10:21	2460	7.62
06/09/2011 07:17	1020	3.91
06/14/2011 11:36	3500	18
06/16/2011 07:22	1520	17.2
06/23/2011 08:22	1980	6.46
07/07/2011 11:24	2700	1.99
07/12/2011 08:52	2900	1.36
07/14/2011 10:45	2900	1.24
07/19/2011 08:14	6700	0.63
07/20/2011 11:41	4400	0.53
07/26/2011 11:42	4800	0.67
08/02/2011 11:58	13400	0.13
08/04/2011 07:43	4700	0.05
08/11/2011 07:32	4900	0.01
08/16/2011 10:59	7800	0
08/23/2011 10:14	26300	0
08/25/2011 07:44	9000	0
09/01/2011 07:43	2760	0
09/07/2011 10:50	1990	0
09/08/2011 07:26	700	0
09/13/2011 09:59	3900	0
09/20/2011 13:26	2010	0
09/22/2011 07:15	2190	0
10/04/2011 11:41	740	0
10/06/2011 08:14	1280	0
10/11/2011 10:45	2740	0
10/13/2011 07:16	1640	0
10/18/2011 11:42	1240	0
10/20/2011 07:09	520	0

Table C-12. Fecal Coliform Results for Tolans Branch (DHGB-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 09:40	294	1.43
05/05/2011 07:10	928	1.27
05/10/2011 12:24	548	0.88
05/11/2011 08:58	2420	0.9
05/17/2011 13:08	207	1.45
05/18/2011 09:32	355	1.34
06/01/2011 13:23	560	2
06/07/2011 11:09	5000	2.52
06/09/2011 08:28	2120	1.38
06/14/2011 13:27	3300	6.01
06/16/2011 10:08	2000	7.08
06/21/2011 12:05	2400	6.56
07/06/2011 09:26	7300	0.91
07/07/2011 12:03	3800	0.78
07/14/2011 11:35	8700	0.67
07/19/2011 07:24	13100	0.29
07/20/2011 12:41	14100	0.23
07/21/2011 08:04	2400	0.22
08/02/2011 12:35	3900	0.04
08/04/2011 08:06	5600	0.02
08/11/2011 08:41	32100	0
08/16/2011 10:37	9000	0
08/23/2011 11:04	8200	0
08/30/2011 09:48	19000	0
09/01/2011 07:54	3120	0
09/07/2011 11:12	1960	0
09/13/2011 09:41	3700	0
09/15/2011 08:27	7300	0
09/20/2011 13:53	1700	0
09/22/2011 07:57	3300	0
10/04/2011 11:59	2110	0
10/11/2011 10:12	1180	0
10/13/2011 08:21	1480	0
10/18/2011 12:15	620	0
10/25/2011 11:06	2170	0
10/27/2011 08:37	810	0

Table C-13. Fecal Coliform Results for Snakeden Branch (DHH-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*	*Date/Time (CST)*	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/10/2011 11:27	980	2.26	08/02/2011 12:16	5000	0.07
05/11/2011 07:16	687	1.79	08/04/2011 08:23	5300	0
05/17/2011 13:24	148	3.23	08/11/2011 07:56	24800	0
05/18/2011 09:35	259	2.94	08/16/2011 12:12	16800	0
05/24/2011 11:53	300	1.64	08/17/2011 07:47	4400	0
05/26/2011 09:07	360	99.4	08/30/2011 09:34	36500	0
06/01/2011 12:28	320	3.66	09/01/2011 07:41	44000	0
06/07/2011 11:52	1320	3.59	09/08/2011 07:42	5800	0
06/16/2011 09:19	1660	14.3	09/15/2011 08:17	3700	0
06/21/2011 11:19	2300	13.8	09/22/2011 08:06	18900	0
06/23/2011 09:21	4100	5.35	09/27/2011 09:10	25200	0
06/28/2011 12:18	1460	13.8	09/29/2011 07:34	40	0
07/06/2011 07:36	3900	1.85			
07/12/2011 08:36	18300	1.63			
07/19/2011 09:45	5900	0.79			
07/21/2011 07:23	4600	0.51			
07/26/2011 09:53	9500	0.66			
07/27/2011 09:04	7700	0.52			

Table C-14. Fecal Coliform Results for Bauer Branch (DHJ-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*	*Date/Time (CST)*	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/04/2011 12:56	22	3.52	08/02/2011 11:01	5100	0.06
05/05/2011 09:22	108	3.23	08/09/2011 11:43	2100	0
05/10/2011 12:06	84	2.57	08/11/2011 08:46	6600	0
05/11/2011 08:51	120	2.51	08/17/2011 08:06	6100	0
05/17/2011 13:05	80	4.13	08/23/2011 10:43	8100	0
05/24/2011 12:45	360	2.7	08/25/2011 08:26	12900	0
06/01/2011 11:14	610	4.47	09/01/2011 07:07	1260	0
06/07/2011 11:28	1800	9.88	09/07/2011 10:24	4400	0
06/09/2011 08:59	1780	4.85	09/08/2011 06:49	1120	0
06/14/2011 13:22	8800	31.8	09/13/2011 09:26	5400	0
06/16/2011 09:26	2960	18.9	09/15/2011 08:44	5500	0
06/28/2011 11:56	2260	19.5	09/22/2011 06:42	4700	0
07/06/2011 07:26	4200	2.37	10/04/2011 11:11	1950	0
07/12/2011 07:52	1600	1.4	10/06/2011 07:31	8300	0
07/14/2011 12:28	2200	1.11	10/11/2011 11:19	3300	0
07/19/2011 07:26	8100	0.49	10/13/2011 07:47	5600	0
07/20/2011 10:19	2700	0.33	10/20/2011 06:39	270	0
07/21/2011 08:28	6000	0.19	10/25/2011 10:34	5300	0

Table C-15. Fecal Coliform Results for McKee Branch (DHK-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 12:21	48	5.66
05/04/2011 07:10	96	5.22
05/10/2011 08:24	256	4.15
05/11/2011 09:32	326	3.59
05/24/2011 08:31	317	3.81
05/26/2011 11:05	240	62.3
06/01/2011 08:16	330	5.69
06/14/2011 09:39	4100	56
06/16/2011 11:49	1840	23.6
06/21/2011 08:08	4500	19.9
06/23/2011 11:50	1300	9.78
06/28/2011 07:08	2300	30.9
07/07/2011 08:28	1400	3.74
07/12/2011 10:45	2800	2.23
07/14/2011 08:18	3700	2.05
07/19/2011 12:02	2200	1.04
07/20/2011 08:47	6900	1
07/26/2011 09:10	12800	2.6
08/02/2011 08:21	10000	0.64
08/04/2011 10:14	4200	0.4
08/09/2011 08:45	2300	0.21
08/17/2011 10:00	2800	0.07
08/23/2011 07:28	1500	0.02
08/30/2011 08:16	1140	0.01
09/07/2011 08:12	760	0
09/08/2011 08:12	780	0
09/13/2011 06:52	2260	0
09/22/2011 09:29	1750	0
09/27/2011 07:49	1580	0
09/29/2011 08:07	800	0
10/04/2011 09:02	4400	0
10/11/2011 07:11	430	0
10/13/2011 10:33	1300	0
10/20/2011 10:17	1060	0
10/25/2011 09:01	2220	0
10/27/2011 11:55	620	0

Table C-16. Fecal Coliform Results for Unnamed Tributary in Scab Hollow (DHZA-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/03/2011 12:40	20	7.27
05/04/2011 07:33	53	7.11
05/05/2011 13:28	33	6.89
05/10/2011 08:55	186	5.27
05/11/2011 11:40	687	5.49
05/17/2011 07:34	90	7.04
06/01/2011 09:29	100	8.08
06/02/2011 12:46	5100	47.8
06/07/2011 07:16	1540	15.5
06/14/2011 08:56	20500	58.9
06/23/2011 13:13	1140	16.1
06/28/2011 07:32	36500	45.6
07/07/2011 08:26	1800	4.54
07/12/2011 11:38	1200	3.37
07/14/2011 08:54	1500	3.12
07/19/2011 12:04	1800	1.85
07/21/2011 10:50	5200	1.41
07/27/2011 07:55	6800	2.32
08/02/2011 07:57	5600	0.94
08/11/2011 11:26	3100	0.33
08/17/2011 09:39	6100	0.2
08/23/2011 08:26	6600	0.11
08/25/2011 11:06	7800	0.05
08/30/2011 07:26	3800	0.03
09/01/2011 08:52	3200	0.03
09/07/2011 08:23	2200	0.01
09/13/2011 07:16	4000	0.02
09/15/2011 10:55	1960	0.01
09/20/2011 08:48	2740	0.05
09/27/2011 07:57	1640	0.06
10/04/2011 09:45	1280	0.02
10/11/2011 08:55	1000	0.03
10/13/2011 09:52	760	0.04
10/18/2011 07:34	1020	0.06
10/20/2011 11:12	680	0.03
10/25/2011 07:48	13700	0.04

Table C-17. Fecal Coliform Results for Unnamed Tributary below Astoria STP outfall (DHZB-01), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*	*Instantaneous Discharge (cfs)*
05/04/2011 09:06	236	0.04
05/05/2011 11:08	378	0.03
05/11/2011 11:46	488	0.02
05/17/2011 09:36	1192	1.17
05/18/2011 10:56	312	0.54
05/26/2011 12:45	800	1.08
06/01/2011 07:19	600	0.84
06/07/2011 09:16	3650	1.11
06/09/2011 09:57	3520	0.05
06/14/2011 09:29	2760	1.34
06/16/2011 12:44	2440	1.95
06/21/2011 07:18	3700	1.19
07/06/2011 12:54	14600	0.08
07/07/2011 07:21	3700	0.08
07/12/2011 12:33	21900	1.07
07/19/2011 11:05	8700	0.02
07/21/2011 10:19	9900	0.03
07/26/2011 06:56	16100	0.01
08/02/2011 09:06	10400	0.02
08/04/2011 11:19	43800	0.02
08/11/2011 10:30	4400	0.01
08/16/2011 07:20	11000	0
08/17/2011 10:30	9500	0
08/25/2011 09:51	10200	0
09/01/2011 09:18	9500	0
09/07/2011 09:23	2160	0
09/13/2011 07:35	3400	0
09/15/2011 12:20	4500	0
09/20/2011 11:21	11700	0.56
09/27/2011 08:42	3800	0.02
10/04/2011 06:59	15300	0
10/11/2011 08:44	4900	0
10/13/2011 09:59	6900	0.01
10/18/2011 11:10	2280	0.01
10/25/2011 08:29	20100	0
10/27/2011 13:14	10500	0.5

Table C-18. Fecal Coliform Results for Table Grove STP outfall (DH-09_STP), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*
05/05/2011 07:27	100
05/18/2011 08:09	790
06/14/2011 12:51	175000
06/28/2011 12:13	13200
07/20/2011 12:03	7100
07/27/2011 07:18	4600
08/16/2011 11:52	16100
08/30/2011 10:46	2600
09/13/2011 09:05	12400
09/27/2011 09:59	20100
10/13/2011 07:45	4400
10/27/2011 07:47	14600

Table C-19. Fecal Coliform Results for Astoria STP outfall (DHZB-01_STP), Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*
05/17/2011 09:21	1380
05/18/2011 11:04	567
05/26/2011 12:54	850
06/01/2011 07:30	3650
06/14/2011 09:40	2600
07/06/2011 13:33	10300
07/21/2011 10:27	11400
09/20/2011 11:26	16100
09/27/2011 08:49	2920
10/13/2011 10:06	270
10/27/2011 13:19	7700

Table C-20. Fecal Coliform Results for DrainTile01, Year 1

Date/Time (CST)	*Fecal Coliform (cfu/100mL)*
06/02/2011 10:09	91600

Sugar Creek and Vermont City Reservoir
TMDL Development
Phase II Report

FINAL

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Prepared by
Illinois State Water Survey

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Table of Contents

Figures

Tables

7.0 Methodology Development for the Sugar Creek and Vermont City Reservoir Watersheds

7.1 Methodology Overview

The modeling approach used in this project included two steps for total phosphorus in Vermont City Reservoir and fecal coliform in Sugar Creek. First, the total phosphorus and fecal coliform loads from both watersheds were estimated using the GWLF loading model. Second, the impact of the estimated loads on Vermont City Reservoir water quality was simulated with the CE-QUAL-W2 lake model, and for the Sugar Creek watershed water quality was simulated using the QUAL2K model. This combination of models was chosen to take advantage of the strengths of each, and the model selection process is discussed in the Phase I Report.

A mass balance approach was used to determine atrazine loads in Vermont City Reservoir. In this approach, the daily loading capacity for atrazine was determined from its maximum contaminant level (3 μg/L) and the maximum capacity of Vermont City Reservoir, and the current daily loading was determined from the atrazine concentration which exceeded 95% of the observed atrazine concentrations that exceeded the maximum contaminant level.

7.1.1 GWLF Overview

GWLF is a monthly time-step model used to predict runoff, sediment, nutrients, and other contaminants from watersheds with mixed land uses. GWLF can be used for both sediment and phosphorus TMDLs. The runoff is simulated using daily precipitation, the runoff curve number and antecedent moisture. The sediment load is estimated with USLE. Dissolved nutrients are simulated using event mean concentrations. The loads generated by individual sources are simply aggregated to produce total loads (Haith and Shoemaker, 1987; Haith et al., 1992).

GWLF also produces flows, loads, and concentrations at a daily step. However, daily loads and concentrations in the current model version produce erroneous results, inconsistent with monthly loads and concentrations. Thus, only daily flows were used in the calibration. Loads and concentrations were calibrated using monthly data. This is described in more detail in section 7.2.1 below.

The GWLF model was calibrated and validated using the current project monitoring data and then used to estimate total suspended solids and total phosphorus loads to Vermont City Reservoir, and fecal coliform loads to Sugar Creek.

7.1.2 CE-QUAL-W2 Overview

CE-QUAL-W2 (Cole and Wells, 2003) is a laterally averaged, two-dimensional (longitudinal and vertical) hydrodynamic and water quality model. It is best suited for relatively long and narrow water bodies. The hydrodynamic component of the model predicts water surface elevations, velocities, and temperatures, while the water quality component simulates 21 constituents, including nutrients, phytoplankton, and DO interactions. CE-QUAL-W2 models basic eutrophication processes such as relationships among temperature, nutrients, algae, dissolved oxygen, organic matter, and sediment in stratified or non-stratified systems. A predominant feature of the model is its ability to compute the two-dimensional velocity field for narrow systems that stratify. In contrast with many reservoir models that are zero-dimensional with regards to hydrodynamics, the ability to accurately simulate transport can be as important as the water column kinetics in accurately simulating water quality.

The CE-QUAL-W2 model used inputs from the GWLF model to simulate the impacts of loads on total phosphorus and sediment in Vermont City Reservoir. The use of these two separate models plays to the strengths of each. That is, GWLF is better suited to simulate watershed loading processes, and CE-QUAL-W2 is better suited to simulate water quality processes within lakes and reservoirs.

7.1.3 QUAL2K Overview

QUAL2K is one-dimensional river and stream water quality model intended to represent a well-mixed channel both vertically and laterally with steady state hydraulics, non-uniform steady flow, and diel heat budget and water quality kinetics.

The QUAL2K model used loading inputs from the GWLF modeling to simulate the impacts of loads on fecal coliform in Sugar Creek. Fecal coliform concentrations are determined as functions of temperature, light, settling and decay. The use of these two separate models plays to the strengths of each. That is, GWLF is better suited to simulate watershed loading processes, and QUAL2K is better suited to simulate water quality processes within streams.

7.2 Model Development

7.2.1 GWLF Development

GWLF requires geo-spatial data characterizing the watershed and meteorological data. Geo-spatial data were processed in MapShed, a geospatial software component that is a part of GWLF. MapShed creates text files with land use, soils, and stream characteristics for the watershed that can be directly used as GWLF input files. Individual inputs are described in the following sections.

The GWLF outputs were compared with the observed flows and loads. The model parameters were adjusted during the calibration process until a sufficient agreement between the simulated and observed data was achieved.

Input Files

GWLF model input consists of a set of Geographic Information System (GIS) files and a set of 2 or more weather data files. The inputs are: watershed delineations, elevation, land use, soils, streams, weather, and flow lines.

Land Use

Land use data were downloaded from the Illinois Gap Analysis Project (IL-GAP) (http://www.agr.state.il.us/gis/pass/gapdata/), clipped to the rectangular extent of the watershed, and reclassified to the categories required by the GWLF model. For example, IL-GAP classifies corn, soybeans, and winter wheat as 11, 12, and 13, respectively. GWLF classifies all three of these crops as 5 for row crops.

Soils

Soils input data were downloaded from the SSURGO Soil Survey Geographic Database available from the USDA NRCS Soil Data Mart (http://soildatamart.nrcs.usda.gov). Next, the soils data were clipped to the extent of the watershed and intersected with the watershed delineation sub-basins. Water holding capacity, soil erodibility (K factor), and the dominant soil groups were then determined for each map unit.

Streams

The streams input file contains the location and length of stream segments in the watershed. Sugar Creek and Vermont City Reservoir GIS data were downloaded from the National Hydrography Dataset (NHD) (http://nhd.usgs.gov/). The high-resolution data were then clipped to the watershed boundary.

Weather

Climate data input consists of daily data for only three parameters: precipitation, maximum temperature, and minimum temperature. The climate data were estimated using two nearby stations: Rushville and Havana. Data at these two stations were downloaded from the Midwest Regional Climate Center (MRCC) cli-MATE data portal (http://mrcc.isws.illinois.edu/CLIMATE/). Daily precipitation and Daily minimum and maximum temperatures data were calculated as the average from two stations. The resulting data set was associated with a faux weather station created in GIS and located in the geographic centroid of both the Sugar Creek and the Vermont City Reservoir watersheds.

Flow Lines

The flow line layer in GWLF depicts pathways a stream particle might take as it moves from a sub-area to the outlet of a larger watershed. Flow lines are used by the GWLF model to estimate travel distance to the outlet of each sub-area and thus to attenuate nutrient and sediment loads based on travel time.

The Sugar Creek and Vermont City Reservoir watershed flow line shapefile were created by following established stream lines from the high resolution NHD when available. In areas where NHD streams were not available, the flowlines were digitized along downhill paths using the 30-meter DEM.

Elevation

Vermont City Reservoir watershed elevation input file was created from LiDAR data. LiDAR data used during the lake model development to get a higher accuracy. Meanwhile LiDAR data were not available for the whole Sugar Creek watershed. A 30-meter USGS digital elevation model (DEM) was used for Sugar Creek watershed elevation input file. DEM has sufficient accuracy to determine watershed delineation and is more time-efficient to process. Elevation input file created from clipping each elevation data to the rectangular extent of the respective watershed.

Watershed Delineations

GWLF allows modeling to be performed on a single basin or a selected subset of adjoining basins. The watershed delineation file sets the location and shape of the watershed and its sub-basins and therefore determines which areas of the watershed may be modeled separately or together.

The Vermont City Reservoir watershed was divided into 17 sub-basins and the Sugar Creek watershed was divided into 39 sub-basins based on the respective elevation data (LiDAR and DEM) and locations of branches using the Better Assessment Science Integrating point & Non-point Sources (BASINS) framework. The outside boundary was then adjusted to match HUC12 boundaries in the undeveloped areas. The watershed delineations for the Sugar Creek watershed are depicted in Figure 1, and those for Vermont City Reservoir watershed are depicted in Figure 2.

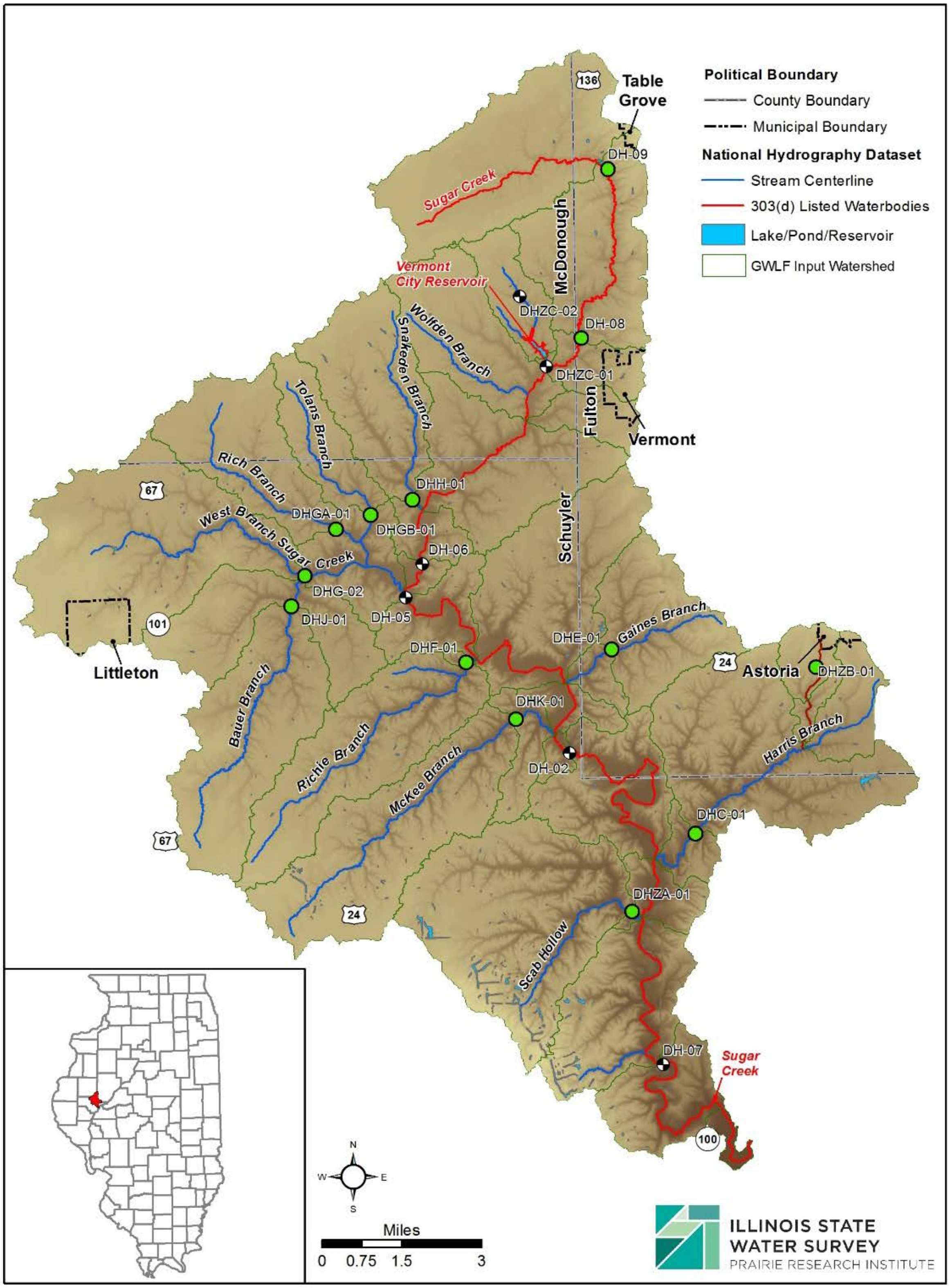


Figure 1. Subwatershed delineations (green lines) for the Sugar Creek watershed

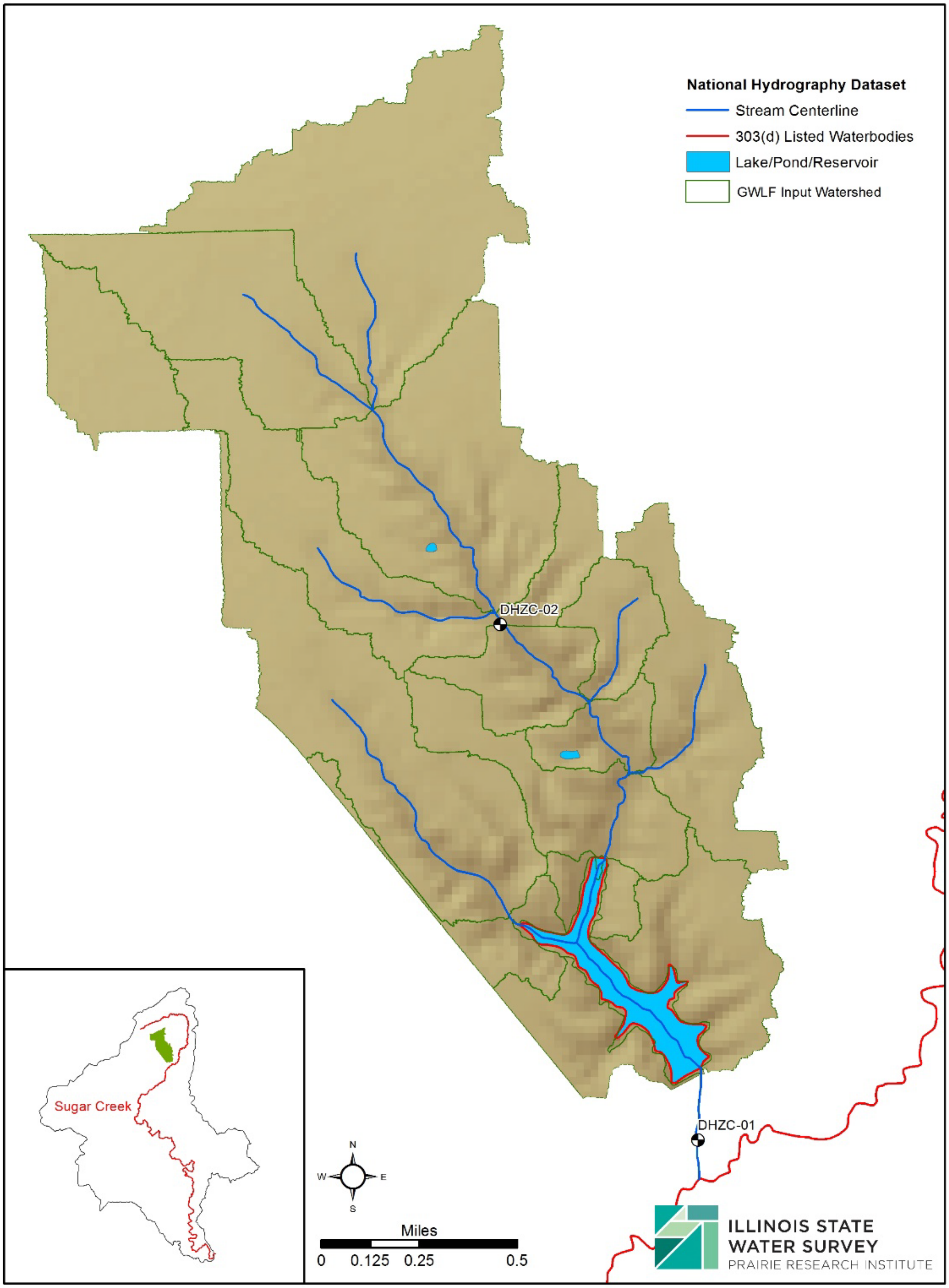


Figure 2. Subwatershed delineations (green lines) for the Vermont City Reservoir watershed

Flow Calibration

Daily discharge data collected at DHZC-02 (Vermont City Reservoir station) and DH-06, DH-05, DH-02, and DH07 (Sugar Creek stations) during the Year 1 monitoring were used to calibrate the flow parameters. Groundwater parameters were adjusted first to achieve the best match with the observed rate of recession. Then, Curve Numbers were adjusted to achieve the best match with the observed peak flows.

Additional corrections to precipitation records that affected the flow calibration were applied during the sediment load calibration due to the unrealistically low sediment loads in April 2011 as simulated with the original precipitation amounts recorded at the rain gages. NEXRAD data for each precipitation event during the ISWS monitoring were analyzed to identify a ratio between the precipitation recorded in the rain gages and the precipitation over the calibration watersheds. These ratios were generally greater than one in April 2011 which resulted in increased precipitation amounts and consequently higher and more realistic sediment loads for that month.

Table 1 shows how model performance was determined based on the goodness-of-fit statistics. For the DHZC-02 site, the GWLF model performed well during the calibration period (Table 2 & 3) when evaluated on weekly or monthly steps. Goodness-of-fit statistics indicate a statistically reliable fit. Weekly and monthly statistics show very good fit in all indicators except volume difference. The volume difference indicates a good fit. The overestimation of total volume can potentially be attributed to two causes: overestimated April flows as discussed above and overestimated flows during high precipitation events that occur during the extended dry periods when the simulated flow is zero.

Volume difference indicates a satisfactory fit for the full simulation period. When simulated flows are adjusted for outliers identified during dry periods, the model performance increases significantly to very good. The Nash-Sutcliffe efficiency (NSE) and Root Mean Square Error – Observations Standard Deviation Ratio (RSR) statistics indicate a very good fit for weekly and monthly flows regardless of whether the outliers were removed. However, the flows adjusted for outliers show a significantly better fit, especially for weekly flows.

Table 1. Goodness-of-fit statistics as indicators of the model performance (after Moriasi et al, 2007)

	Volume/load difference				
Model performance	Streamflow	Sediment	Phosphorus	NSE	RSR
Very good	<±10%	<±15%	<±25%	>0.75	<0.50
Good	±10 - ±15%	±15 - ±30%	±25 - ±40%	0.65 - 0.75	0.50 - 0.60
Satisfactory	±15 - ±25%	±30 - ±55%	±40 - ±70%	0.50 - 0.65	0.60 - 0.70
Unsatisfactory	>±25%	>±55%	>±70%	<0.50	>0.70

Table 2. Vermont City Reservoir watershed flow calibration statistics

Site	Period	Volume difference, %	Time step	NSE	RSR	R^2
DHZC-02	4/2011-7/2011	1%	Daily	0.68	0.56	0.72
			Weekly	0.95	0.22	0.95
			Monthly	0.97	0.15	0.97
	4/2011-2/2012	12%	Daily	0.61	0.62	0.69
			Weekly	0.89	0.32	0.90
			Monthly	0.95	0.21	0.96
	4/2011-10/2012	56%	Daily	0.19	0.90	0.51
			Weekly	0.61	0.62	0.71
			Monthly	0.77	0.47	0.84
	4/2011-10/2012*	21%	Daily	0.69	0.55	0.74
			Weekly	0.92	0.29	0.92
			Monthly	0.94	0.24	0.95

Notes: NSE ranges from 1 (perfect fit) to minus infinity, RSR ranges from 0 (perfect fit) to 1, and R^2 ranges from 1 (perfect fit) to 0.

* Statistics calculated for the simulated flow adjusted for outliers identified during dry periods

Table 3. Sugar Creek watershed flow calibration statistics

Site	Period	Volume difference, %	Time step	NSE	RSR	R^2
DH-06	4/2011-7/2011	1%	Daily	0.75	0.50	0.76
			Weekly	0.92	0.28	0.93
			Monthly	0.98	0.13	0.99
	4/2011-2/2012	6%	Daily	0.73	0.52	0.76
			Weekly	0.92	0.28	0.93
			Monthly	0.98	0.14	0.98
	4/2011-11/2012	25%	Daily	0.55	0.67	0.65
			Weekly	0.82	0.35	0.85
			Monthly	0.93	0.26	0.95
	4/2011-11/2012*	4%	Daily	0.79	0.46	0.80
			Weekly	0.95	0.22	0.96
			Monthly	0.99	0.10	0.99
DH-05	4/2011-7/2011	2%	Daily	0.78	0.46	0.78
			Weekly	0.94	0.24	0.94
			Monthly	0.97	0.14	0.97
	4/2011-2/2012	9%	Daily	0.76	0.49	0.76
			Weekly	0.94	0.24	0.94
			Monthly	0.97	0.16	0.97
	4/2011-11/2012	49%	Daily	0.22	0.88	0.48
			Weekly	0.62	0.61	0.72
			Monthly	0.83	0.40	0.87
	4/2011-11/2012*	0%	Daily	0.82	0.43	0.82
			Weekly	0.98	0.13	0.98
			Monthly	0.99	0.10	0.99

Table 3. Sugar Creek watershed flow calibration statistics (concluded)

Site	Period	Volume difference, %	Time step	NSE	RSR	R^2
DH-02	4/2011-7/2011	0%	Daily	0.85	0.38	0.85
			Weekly	0.95	0.22	0.95
			Monthly	0.99	0.07	0.99
	4/2011-2/2012	6%	Daily	0.83	0.41	0.83
			Weekly	0.95	0.22	0.95
			Monthly	0.98	0.12	0.99
	4/2011-11/2012	33%	Daily	0.35	0.80	0.54
			Weekly	0.70	0.27	0.75
			Monthly	0.88	0.33	0.90
	4/2011-11/2012*	2%	Daily	0.87	0.36	0.87
			Weekly	0.98	0.14	0.98
			Monthly	0.99	0.09	0.99
DH-07	4/2011-7/2011	2%	Daily	0.84	0.40	0.84
			Weekly	0.96	0.19	0.96
			Monthly	0.99	0.07	0.99
	4/2011-2/2012	4%	Daily	0.82	0.42	0.83
			Weekly	0.96	0.19	0.96
			Monthly	0.99	0.10	0.99
	4/2011-11/2012	28%	Daily	0.28	0.85	0.54
			Weekly	0.73	0.24	0.77
			Monthly	0.90	0.31	0.91
	4/2011-11/2012*	1%	Daily	0.86	0.38	0.86
			Weekly	0.98	0.14	0.98
			Monthly	0.99	0.10	0.99

Notes: NSE ranges from 1 (perfect fit) to minus infinity, RSR ranges from 0 (perfect fit) to 1, and R^2 ranges from 1 (perfect fit) to 0.

* Statistics calculated for the simulated flow adjusted for outliers identified during dry periods

TSS Calibration

Vermont City Reservoir watershed daily loads determined from observed daily flows and TSS concentrations were summarized to calculate monthly loads during the Year 1 monitoring. Monthly TSS loads were used to calibrate GWLF. Daily outputs from GWLF were found unreliable due to an internal model error.

Monthly goodness-of-fit statistics are listed in Table 4. Vermont City Reservoir watershed site sediment calibration statistics.Due to the errors in the model's daily output files, daily and weekly goodness-of-fit statistics cannot be calculated. The model simulates monthly sediment loads during wet period very well. The overall model performance is affected by the model's inability to accurately simulate low flows during dry periods. When the model output is adjusted for the outliers during dry periods, the overall model performance can be classified as very good.

Almost in its entirety, the relatively high load difference for DHZC-02 can be attributed to differences between the observed and simulated sediment loads for the month of April. The final calibration for flow and sediment is a compromise between overestimating flows in April 2011 and underestimating sediment load that same month. Any adjustment of the calibration parameters leads to an overall increase of sediment loads throughout the year.

Table 4. Vermont City Reservoir watershed site sediment calibration statistics.

Site	Period	Load difference, %	Time step	NSE	RSR	R^2
DHZC-02	4/2011-7/2011	1%	Monthly	0.97	0.15	0.99
	4/2011-2/2012	85%	Monthly	0.13	0.89	0.55
	4/2011-2/2012*	10%	Monthly	0.97	0.15	0.98

Notes: NSE ranges from 1 (perfect fit) to minus infinity, RSR ranges from 0 (perfect fit) to 1, and R^2 ranges from 1 (perfect fit) to 0.

* Statistics calculated for the simulated flow adjusted for outliers identified during dry periods

TP Calibration

Vermont City Reservoir watershed monthly TP loads were also calculated from the concentrations and stream flows observed during Year 1 monitoring. This observed monthly load was used to calibrate the GWLF model.

Monthly goodness-of-fit statistics are listed in Table 5. The overall model performance is affected by the model's inability to accurately simulate low flows during dry periods. When the model output is adjusted for the outliers during dry periods, the overall model performance can be classified as very good.

Table 5. Vermont City Reservoir watershed site TP calibration statistics.

Site	Period	Load difference, %	Time step	NSE	RSR	R^2
DHZC-02	4/2011-7/2011	-5%	Monthly	0.83	0.36	0.89
	4/2011-2/2012	63%	Monthly	0.19	0.86	0.53
	4/2011-2/2012*	3%	Monthly	0.90	0.30	0.91

Notes: NSE ranges from 1 (perfect fit) to minus infinity, RSR ranges from 0 (perfect fit) to 1, and R^2 ranges from 1 (perfect fit) to 0.

* Statistics calculated for the simulated flow adjusted for outliers identified during dry periods

Similarly to TSS loads, the relatively high load difference for DHZC-02 can be attributed to differences between the observed and simulated sediment loads for the month of April. The final calibration for flow and sediment is a compromise between overestimating flows in April 2011 and underestimating sediment load that same month. Any adjustment of the calibration parameters leads to an overall increase in TP loads throughout the year.

FC Calibration

Sugar Creek watershed monthly FC loads were also calculated from the concentrations and stream flows observed during Year 1 monitoring. This observed monthly load was used to calibrate the GWLF model.

Monthly goodness-of-fit statistics are listed in Table 6. The overall model performance is affected by the model's inability to accurately simulate low flows during dry periods. When the model output is adjusted for the outliers during dry periods, the overall model performance can be classified as very good.

The relatively high load difference for all Sugar Creek stations (DH06, DH05, DH-02, and DH07) can also be attributed to differences between the observed and simulated sediment loads for the month of April.

The final calibration for flow and fecal coliform is a compromise between overestimating flows in April 2011 and underestimating fecal coliform load that same month. Any adjustment of the calibration parameters leads to an overall increase in FC loads throughout the year.

Table 6. Statistics for FC calibration at Sugar Creek watershed sites.

Site	Period	Load difference, %	Time step	NSE	RSR	R^2
DH-06	5/2011-7/2011	2%	Monthly	0.99	0.06	0.99
	5/2011-2/2012	-37%	Monthly	0.99	0.05	0.99
	5/2011-2/2012*	2%	Monthly	0.99	0.05	0.99
DH-05	5/2011-7/2011	2%	Monthly	0.99	0.02	0.99
	5/2011-2/2012	-43%	Monthly	0.99	0.02	0.99
	5/2011-2/2012*	2%	Monthly	0.99	0.02	0.99
DH-02	5/2011-7/2011	0%	Monthly	0.99	0.03	0.99
	5/2011-2/2012	-28%	Monthly	0.99	0.03	0.99
	5/2011-2/2012*	0%	Monthly	0.99	0.03	0.99
DH-07	5/2011-7/2011	1%	Monthly	0.99	0.01	0.99
	5/2011-2/2012	2%	Monthly	0.99	0.01	0.99
	5/2011-2/2012*	1%	Monthly	0.99	0.01	0.99

Notes: NSE ranges from 1 (perfect fit) to minus infinity, RSR ranges from 0 (perfect fit) to 1, and R^2 ranges from 1 (perfect fit) to 0.

* Statistics calculated for the simulated flow adjusted for outliers identified during dry periods

7.2.2 CE-QUAL-W2 Development

The CE-QUAL-W2 lake model inputs are in the form of a series of fixed format text files which define model inflows and withdrawals, meteorological data, and reservoir bathymetry. These input text files are referenced by an input "control file" which also specifies all input variables and runtime settings, such as the date range of the simulation and which water quality parameters are modelled.

Bathymetry

Bathymetric surveying was conducted by ISWS staff on June 12th 2013 using a combination of acoustic depth sounding of the reservoir bottom surface and physical depth measurements. An Odom EchoTrac DF3200 MKII Precision Survey Echo Sounder mounted on an 18 foot pontoon boat was used to perform the acoustic depth soundings. These bathymetric survey data were processed, in conjunction with 2012 McDonough County LiDAR data, into model input data and evaluated to identify the optimum vertical layer thickness to be modeled.

Model Segmentation

The model allows for segmentation into multiple waterbodies and branches. Planimetric model segmentation of the lake was evaluated to identify an appropriate balance between accurate hydrodynamics and computational efficiency. The segmentation scenario adopted for Vermont City Reservoir is a 1-waterbody, 17-segment model with 2 branches (Figure 3 and Figure 4). Note that segment 1 is actually empty boundary cell which is required for the CE-QUAL-W2 model. Hence, it is not visible in Figure 2, but is visible in the gridded representation (Figure 4).

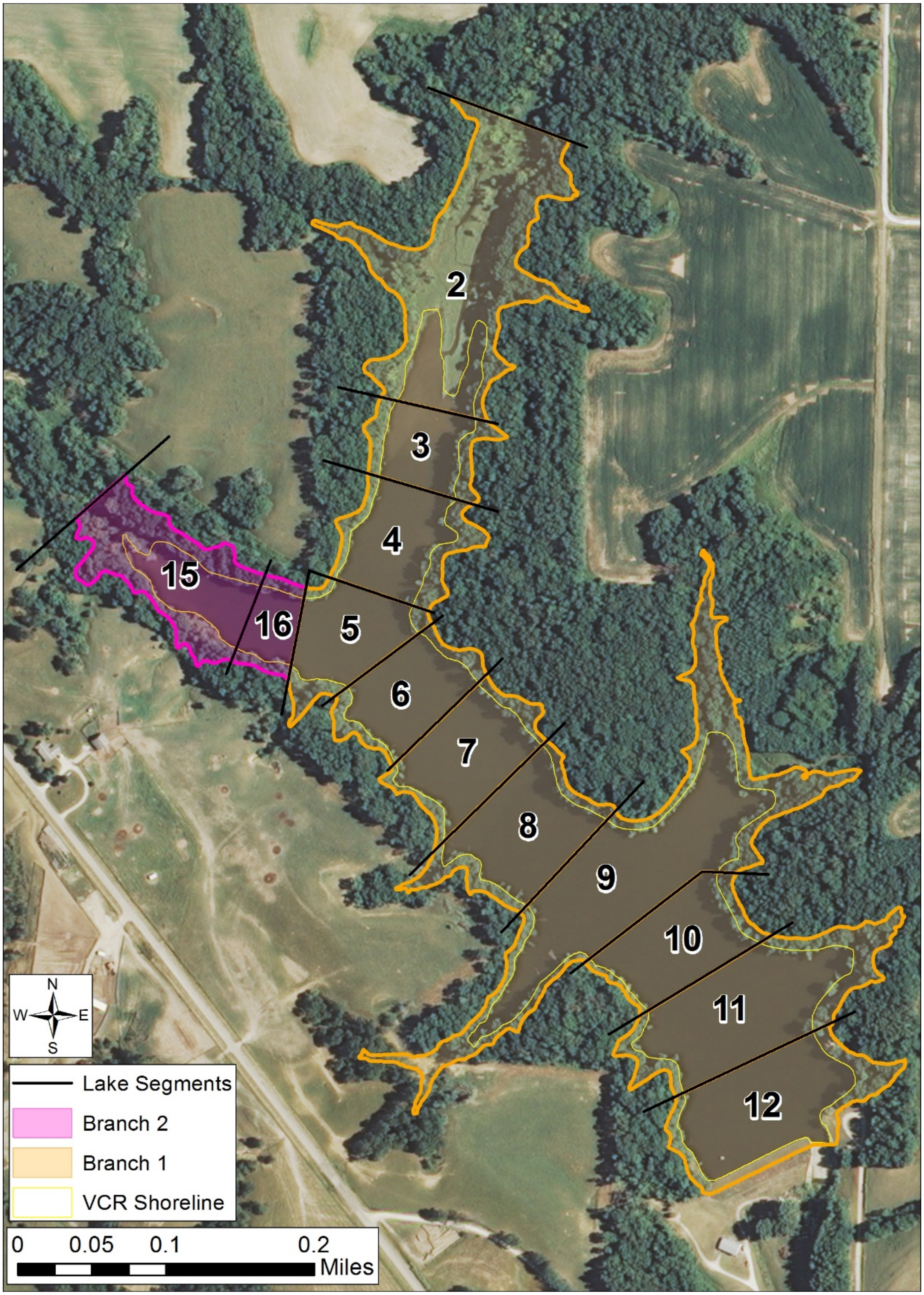


Figure 3. Segmentation for a 2-branch, 17-segment CE-QUAL-W2 model of Vermont City Reservoir.

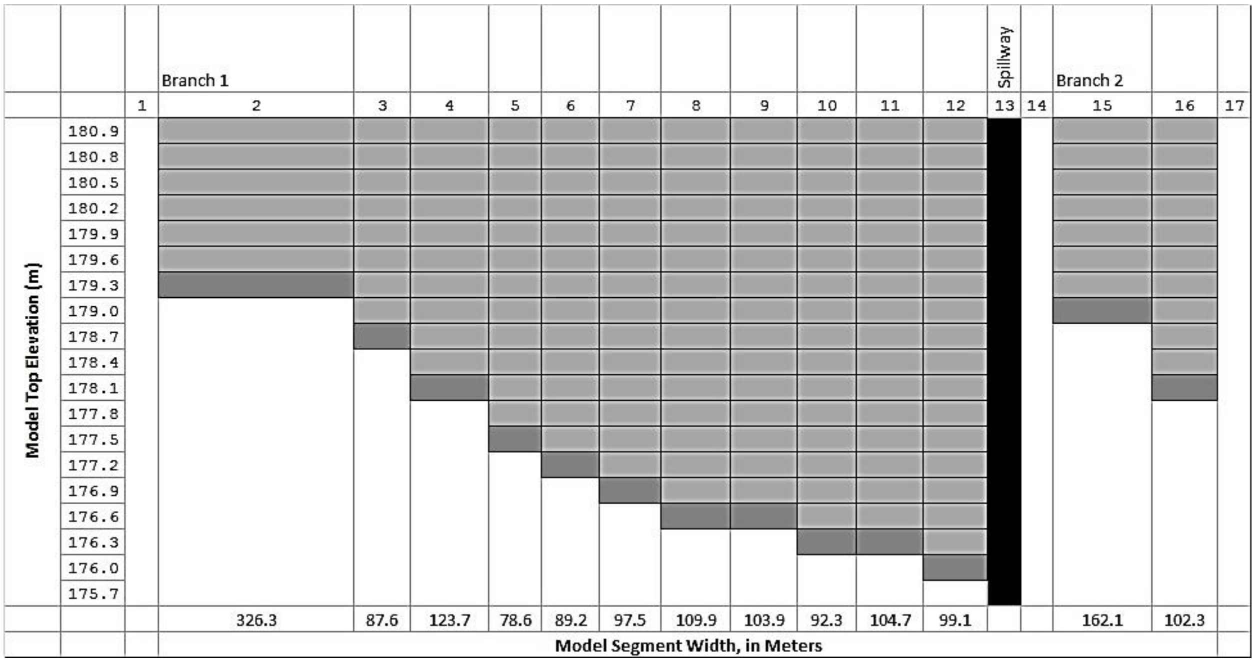


Figure 4. Cross-section view of the grid used to represent Vermont City Reservoir showing where branches enter the lake

Inflows and Boundary Conditions

Inflow data for the lake model includes not only flow volumes, but temperature and constituent concentrations for the inflows as well. While ISWS gage data was used during pre-calibration evaluations, the calibrated GWLF flows were used as the inflows to the lake model. GWLF simulates flows and loads (from which concentrations are derived) for each modeled sub-basin. Due to the confirmed inaccuracies of GWLF daily outputs, monthly data was used to derive daily concentrations for the inflows to the lake model. Subwatersheds simulated with the calibrated GWLF model as tributary inputs to Vermont City Reservoir are shown in Figure 5.

Simulated flows from the GWLF model required additional processing prior to being input to the CE-QUAL-W2 model. This processing corrects known issues with GWLF results and includes identification and removal of outliers that occur during dry periods, as well as adjustment of simulated zero flow values that are known to be greater than zero based on observed data at nearby locations. The method selected replaces outliers with a linear adjustment developed from the observed data during the calibration period. Periods of zero flows are evaluated based on flow similarities with the ISWS Conservation Reserve Enhancement Program (CREP) sites. The CREP monitoring program collects hydrologic, sediment, and nutrient data for selected watersheds within the Illinois River watershed to assist in the evaluation of the effectiveness of the CREP program. The CREP sites used consist of 5 stations located in the Court and Panther Creek watersheds in West-central Illinois. These five stations have been continuously operated since 2000. Routine streamgaging as well as weekly sampling for sediments and nutrients is done at all 5 sites. In addition, these sites are also sampled during storm events. A constant value was substituted for periods where the method identified non-zero flow should be simulated.

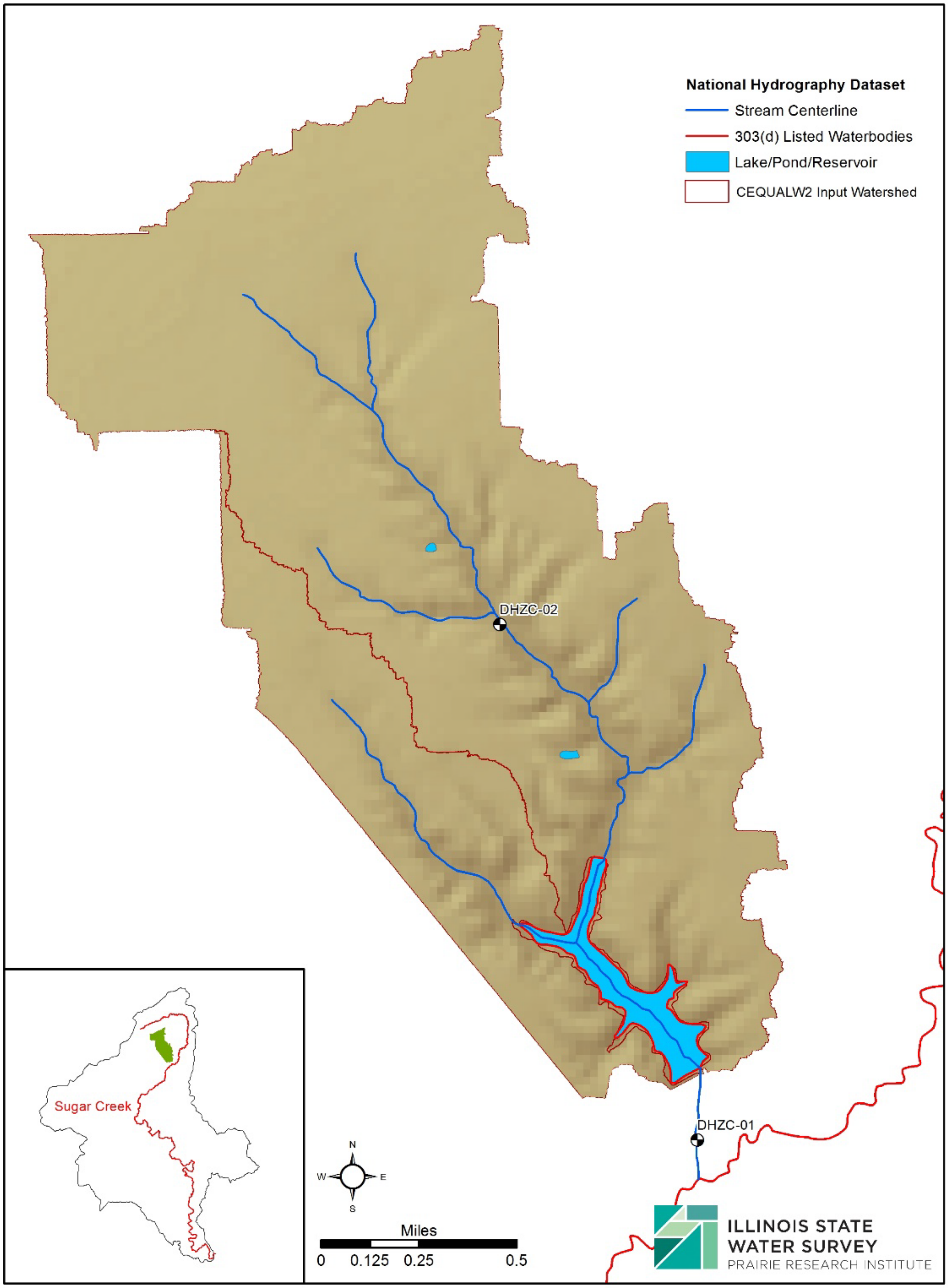


Figure 5. Tributary watersheds used as inflows to Vermont City Reservoir

To estimate the temperature of these inflows, stream temperatures from CREP were evaluated against the spot measurements taken during the Sugar Creek and Vermont City Reservoir watershed monitoring period. The ISWS CREP gaging station on North Creek was the most highly correlated to observed stream temperatures for the tributaries feeding Vermont City Reservoir and was thus selected as a surrogate record.

The same ISWS stations were also analyzed to determine the relationships between the monthly loads, daily loads, and daily flows for sediment and TP. A method to convert the GWLF-simulated monthly loads to daily loads needed for the CE-QUAL-W2 input files was developed and tested. First, daily concentrations were calculated from daily stream flows adjusted for outliers and non-zero flows and a daily load was calculated. Then, monthly loads from these estimated concentrations were compared to the monthly loads simulated by the GWLF model (also adjusted for outliers and non-zero flows). The daily concentrations were then proportionately adjusted, resulting in daily concentrations that when summed, matched the simulated monthly loads from the calibrated GWLF model.

The CE-QUAL-W2 model requires numerical values for additional constituents to simulate the full nutrient cycle with algae and dissolved oxygen, including nitrogen forms and organic matter. The GWLF model was developed only for constituents where data were available for calibration: flow, total suspended solids, and total phosphorus. Daily concentrations for the remaining constituents were derived either from the ISWS CREP stations, the ISWS and IEPA monitoring in the Sugar Creek and Vermont City Reservoir watersheds, ISWS gaging stations in western Illinois, estimated from literature values, or set to values expected for similar streams. The impact of selecting the numerical values for these constituents was evaluated with sensitivity analyses on the preliminary model. The final selected methods are listed in Appendix A.

Precipitation

The precipitation input files include three components: rainfall amounts, rainfall temperature, and constituent concentrations occurring in the rainfall. The precipitation input files are used only to compute the amount of precipitation falling directly onto the lake. Rainfall data consistent with the GWLF model inputs have been prepared.

Wet bulb temperature data were used as a surrogate for precipitation temperature. The equations used for calculation of wet bulb temperature were derived using best fit polynomials of dry bulb vs. wet bulb temperatures at Peoria from 2005-2013. The temperature data at Macomb were downloaded from the QCLCD website (http://cdo.ncdc.noaa.gov/qclcd/QCLCD?prior=N). Wet bulb data for the period of simulation were then calculated as a function of the mean daily dry bulb temperature record used in the GWLF modeling effort.

Meteorological

The CE-QUAL-W2 model uses multiple meteorological parameters for input including: air temperature, dew point temperature, wind speed, wind direction, and cloud cover. The weather station in Rushville, Illinois was selected as the best representative station near the watershed which had all the needed parameters available. Rushville climate data were available from two NCDC website: Unedited Local Climatological Data [https://www.ncdc.noaa.gov/cdo-web/] for data from 2000-2004 and Quality Controlled Local Climatological Data (QCLCD) [https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd] for data from 2005-2013.

All gaps in wind speed, wind direction, and cloud cover data were linearly interpolated. Gaps in air temperature and dew point temperature were linearly interpolated if they were less than 2 hours in length; otherwise, the data were estimated using Macomb climate data downloaded from the same sources.

Additionally, further processing was needed to reduce the density of available data. The original data set contained a variable time step with some measurements as little as 1 or 2 minutes apart. Data this dense caused extremely slow run times in the CE-QUAL-W2 lake model; therefore, the data were thinned to a minimum time-step of 15 minutes.

Withdrawals and Spillway Information

Vermont City Reservoir daily raw water withdrawals and historical outlet works construction documents were provided by the Vermont City Reservoir Water Treatment Plant (WTP).

Initial Concentrations

Initial concentrations must be provided for all simulated constituents for the first day of simulation, June 1, 2000. Initial concentrations were determined from several sources (in the listed order of preference): intake analyses provided by the Vermont City Reservoir WTP, historical data collected in Vermont City Reservoir, and literature values for similar lakes. The selected concentrations are listed in Appendix B.

Uniform in-lake concentrations were assumed at the beginning of the simulation. This is a rough approximation because concentrations of most water quality constituents would rarely be uniform throughout Vermont City Reservoir. Therefore, to eliminate the impact of this assumption, the first 4 months of simulation results were excluded from further analysis.

Water Level Calibration

Figure 6 and Table 7 show results for water level calibration for Vermont City Reservoir. Only ISWS monitored levels are available for calibration. Simulated water levels match the observed data adequately although the CE-QUAL-W2 model tended to under predict lake water levels during periods when the observed lake level stabilizes following the seasonal decline and prior to the seasonal increase. With GWLF inflows to the lake being in general agreement with observed discharges during periods of ISWS monitoring, the source of this volume discrepancy was not thought to originate from watershed contributions.

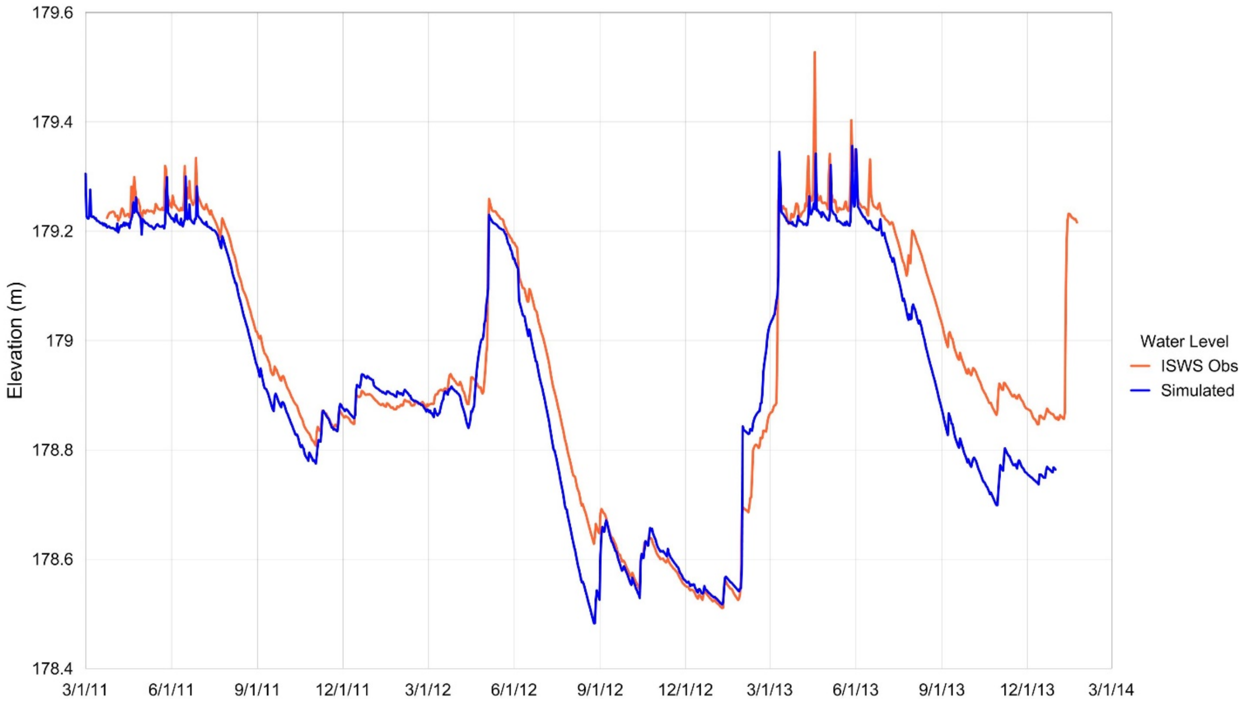


Figure 6. Observed and simulated water levels for Vermont City Reservoir

Table 7. Statistics for Vermont City Reservoir water level calibration

	ISWS observed data			
Statistics	Daily	Weekly	Monthly	Yearly
R^2 [a]	0.92	0.93	0.93	0.98
NSE	0.89	0.90	0.90	0.86
PBIAS [b]	0.02	0.02	0.02	0.02
RSR	0.33	0.32	0.31	0.31

[a] R^2 = Pearson's coefficient of determination. [b] PBIAS = Percent bias.

Water Quality Calibration

Model coefficients were adjusted in an iterative process where the simulated values were compared to the observed concentrations collected at the water supply intake, the ISWS monitoring site RDM-1 by the spillway, and several IEPA historical sampling sites with concentrations collected at several different depths (Figure 7).

The ISWS monitoring data collected at RDM-1 and the ISWS and IEPA sites with profile data were the primary calibration focus. Water supply intake data were used to evaluate long-term trends only. The intake data were found to show larger discrepancy than the primary data sources, possibly due to the water samples being collected at the treatment plant rather than in the lake itself.

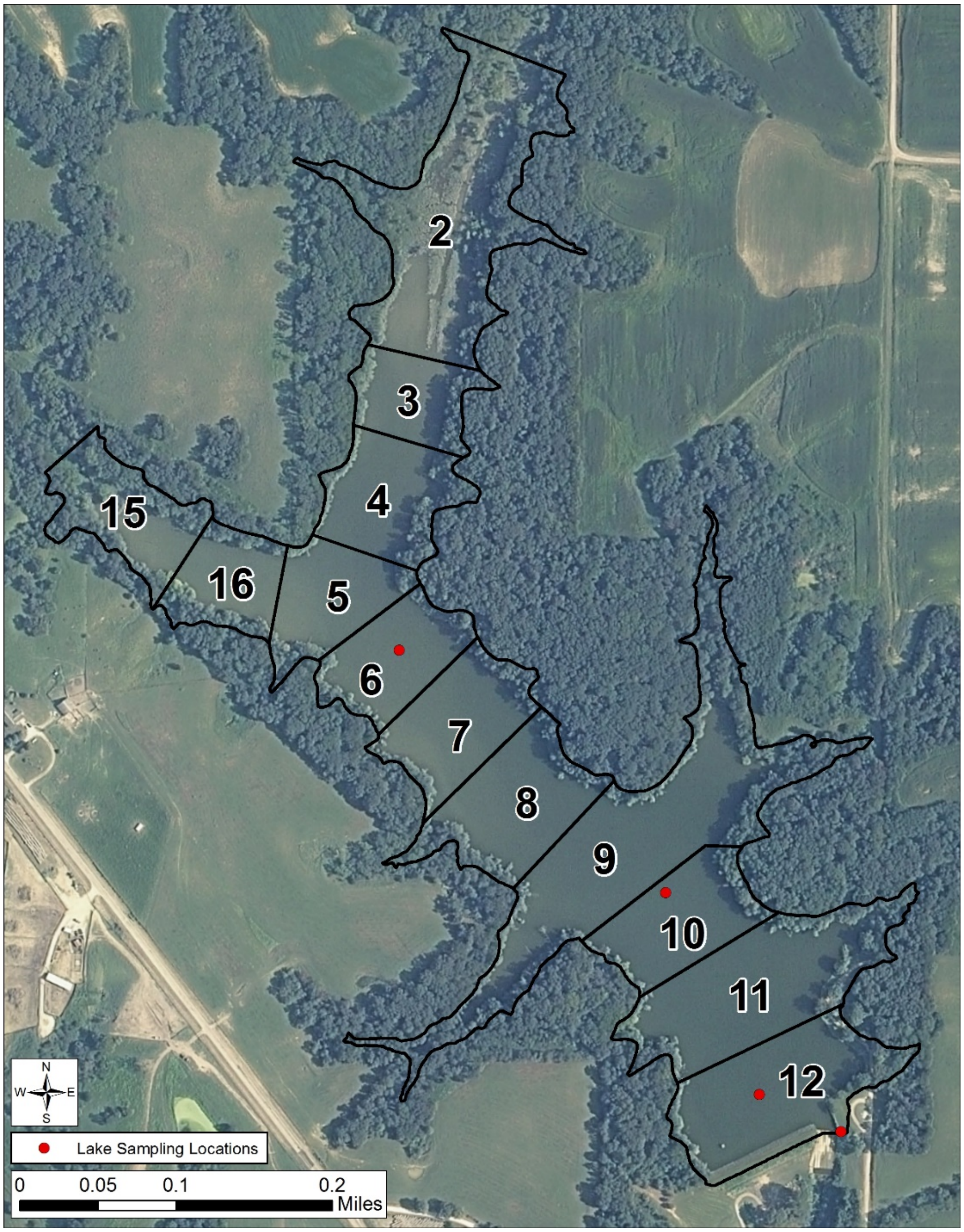


Figure 7. Vermont City Reservoir water quality sampling locations

The model calibration progressed from water level to temperature first, and then to other water quality constituents. While the calibration focused on total phosphorus concentrations in Vermont City Reservoir, full nutrient cycling, including algae and dissolved oxygen were simulated and evaluated. Appendix C shows final values of the model kinetic coefficients as calibrated.

The observed and simulated temperatures at RDM-1 and at the Vermont City Reservoir intake match rather well (Figure 8 and Table 8). The temperature observed at the intake in general matches the simulated temperature. The simulated temperatures tend to be slightly colder during the winter months and slightly warmer during the summer months. This may be due to the temperature readings taking place within the treatment plant rather than at the intake location in the lake itself.

Table 8. Goodness-of-fit statistics for Vermont City Reservoir water quality calibration

Statistics	Temperature, °C		TP, mg/l	DO, mg/l	DP, mg/l	Chlorophyll a, µg/l
	Intake	RDM-1	RDM-1	RDM-1	RDM-1	RDM-1
R2	0.92	-	-	-	-	-
NSE	0.80	-	-	-	-	-
PBIAS	6.55	-	-	-	-	-
RSR	0.44	-	-	-	-	-
S-O	-0.97	0.167	0.055	1.43	-0.019	-8.50

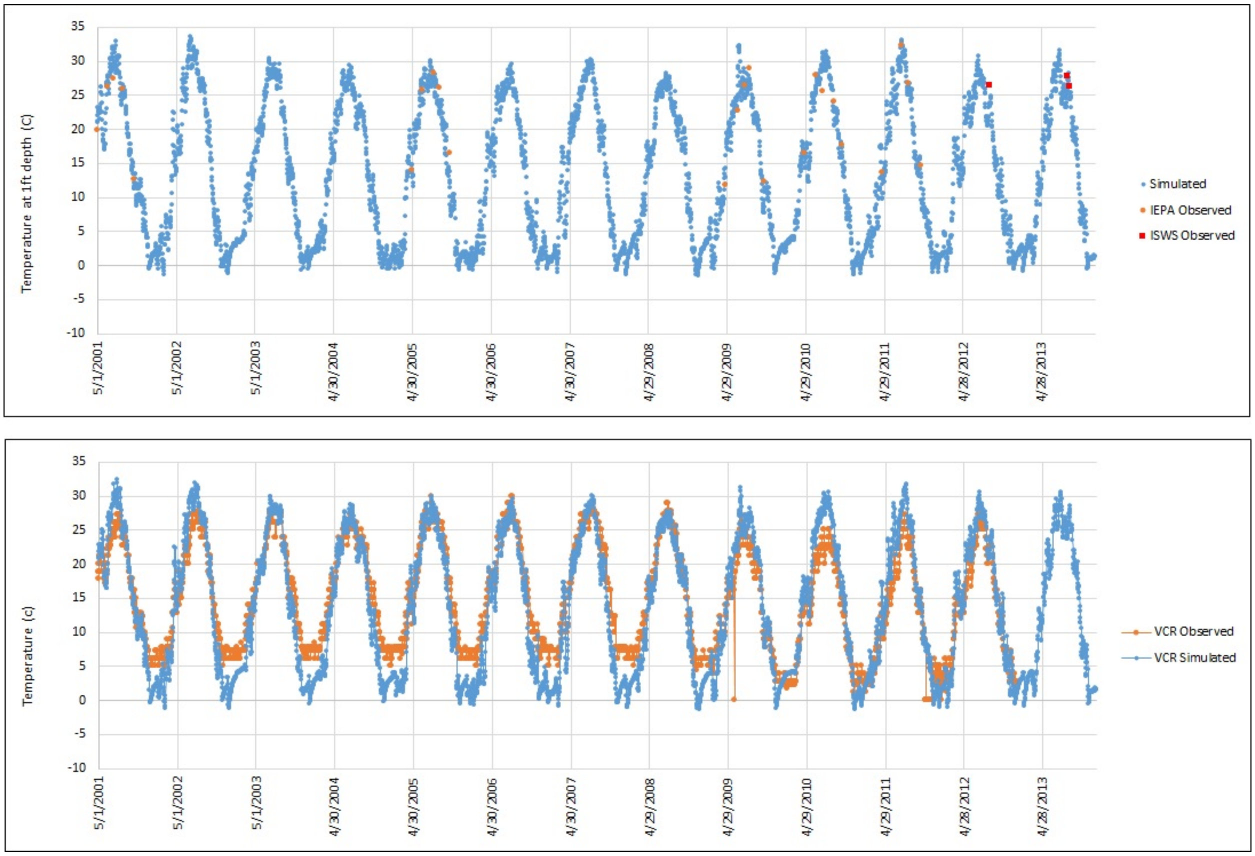


Figure 8. Observed and simulated temperatures at RDM-1 (upper plot) and Vermont City Reservoir intake (lower plot).

The model simulates total phosphorus concentrations fairly well (Table 8) with average differences in simulated and observed concentrations at 0.055 mg/l for RDM-1 (2011-2012). Goodness-of-fit statistics for average differences between simulated and observed concentrations are also shown for dissolved oxygen, dissolved phosphorus, and chlorophyll a in Table 8.

Figure 9 shows individual depth profiles of total phosphorus concentrations collected between September 2010 and September 2013. Full set of results for all profiles and constituents are attached in Appendix D.

While for most days the model describes the observed data adequately, there are several days where the model either overestimates or underestimates total phosphorus concentrations. Figure 10 shows observed and simulated total phosphorus data at RDM-1. The observed data are generally simulated well.

Considering the computer time required to execute the model (30 minutes for one simulation) and the time required to process and analyze the results, additional resources would be needed to improve the model calibration. In addition, the calibration process was affected (1) by the uncertainty in estimating daily concentrations of TP from the simulated monthly loads, (2) by the uncertainty in estimating input concentrations from the lake branches for constituents other than total phosphorus, and (3) by the uncertainty in simulating 13 years of total phosphorus loads with a model calibrated and validated with 1.5 years of data collected during years with low precipitation totals. The model inaccuracies were considered during the selection of the Margin of Safety (MOS) for TMDL determination.

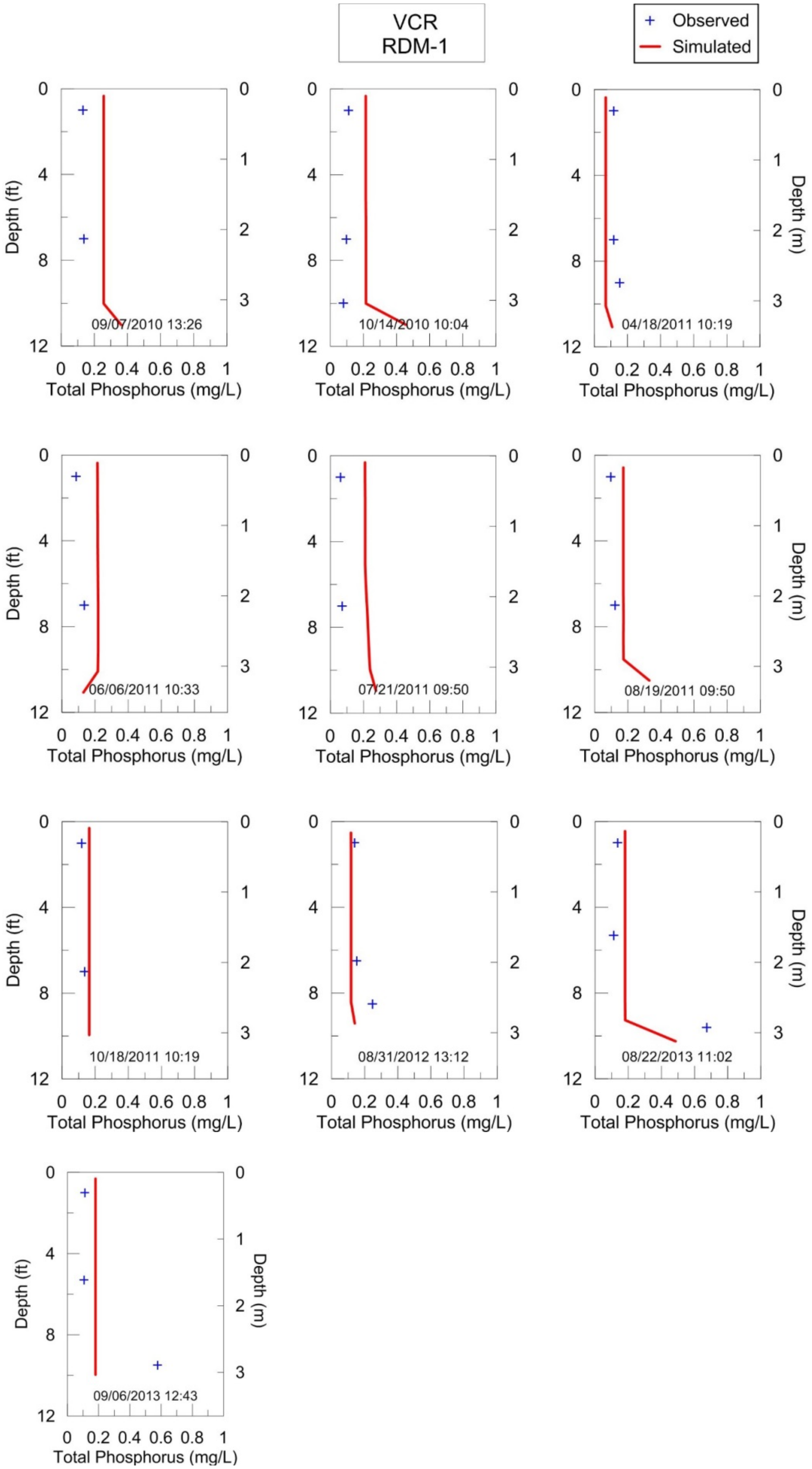


Figure 9. Observed and simulated total phosphorus collected at RDM-1 in 2011-2013; depth profiles

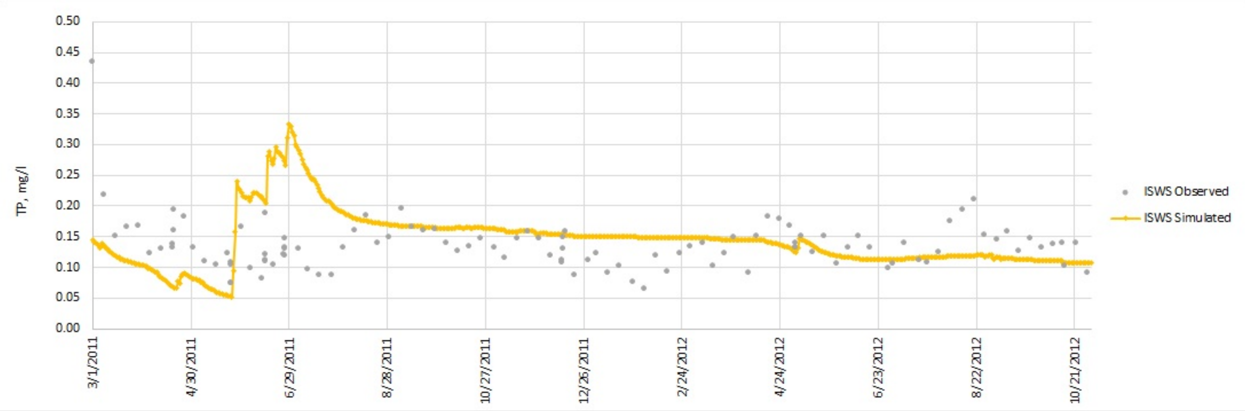


Figure 10. Observed and simulated total phosphorus at RDM-1

7.2.3 QUAL2K Development

The QUAL2K model is a steady-state one-dimensional in-stream water quality model intended to represent a well-mixed channel both vertically and laterally with steady state hydraulics, non-uniform steady flow, and diel heat budget and water-quality kinetics (Chapra et al, 2012). It represents a stream or river by a series of reaches, for which each reach displays similar hydraulic characteristics. A reach can be further subdivided into elements of equal lengths. Given flows at headwaters and various locations along the river, the model conducts a flow balance at each element. Using the discharge at an element, the model calculates element velocity and depth in one of three ways: weir equation, rating curves, or Manning's equation.

Streams were segmented into reaches based upon constant hydraulic characteristics. Sinuosity and slope were the main determinants of where reaches should begin and end. These characteristics often rely on physical attributes of the stream, such as land use.

QUAL2K Inputs

Data that are required for the QUAL2K models along with the source of data used to analyze fecal coliform impairment in the Sugar Creek watershed are shown in Table 9 below. Empirical data amassed during Phase I of TMDL development were used to build the QUAL2K models.

Table 9. Sugar Creek QUAL2K data inputs

Input Category	Data Source
Stream segmentation	GIS data
Hydraulic characteristics	GIS; ISWS data
Headwater conditions	ISWS data
Meteorological conditions	National Climatic Data Center and Midwest Regional Climate Center
Point source contribution	ISWS; Astoria STP; Table Groove STP data
Fecal coliform concentration	ISWS data

Reach Determination

After initial reach delineations were determined, an additional reach with a length of 0.2 km was added at all dams and junctions. A smaller reach at each dam and river junction stabilizes the model and allows a more accurate description of observed stream characteristics during low and medium flows. Each reach was subdivided into several elements for which the average element length was 0.25 km.

The Sugar Creek watershed's streams were divided into 60 reaches and 638 elements for QUAL2K model inputs. The mainstem of Sugar Creek was divided into 16 reaches as shown in Figure 11 below.

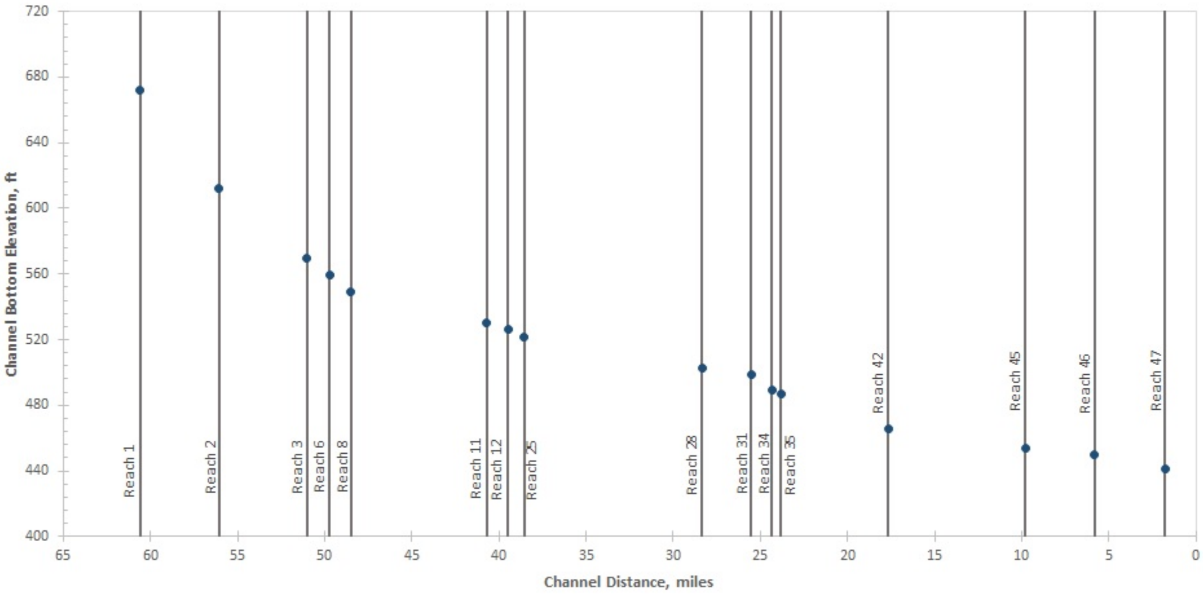


Figure 11. Sugar Creek mainstem slopes (points) and reaches (vertical lines)

Hydraulic Options

The QUAL2K model software has three options for calculating velocity and depth in an element given discharge: rating curves, weir equation, and Manning's equation. The option chosen for the Sugar Creek QUAL2K model was the rating curve method. The rating curves were developed from continuous stream flow data collected by ISWS.

Headwater Conditions

The model was constructed with 14 headwaters:

1. Sugar Creek mainstem
2. Vermont City Reservoir
3. Wolfden Branch
4. Snakeden Branch
5. Tolans Branch
6. Rich Branch
7. West Branch Sugar Creek
8. Bauer Branch
9. Richie Branch
10. Gaines Branch
11. McKee Branch
12. Harris Branch
13. Scab Hollow
14. Mill Creek

The stream flow at the headwaters was estimated for the sampling data using the area ratio method. The headwater flow was estimated to be 10% of the stream flow, and ranged from 0.01 to 0.1 cubic feet per second. These flows rates are representative of the low flow conditions present at the time of monitoring and were entered into the QUAL2K model.

Diffuse Flow

Diffuse flow was estimated about 90% of the stream flow.

Climate

Temperature and wind speed data were obtained from NCDC and MRCC in the same manner as presented above for Vermont City reservoir.

Point Sources

There were three point sources to consider for the QUAL2K model:

- Table Grove Sewage Treatment Plant
- Village of Astoria Sewage Treatment Plant
- Vermont City Water Treatment Plant

Both of the Sewage Treatment Plants have a disinfection exemption, which means that the fecal coliform water quality standard is not applicable for these sources. But, their contributions to fecal coliform bacteria loading to Sugar Creek were calculated in the model as described in Section 8.3.3.4 below.

FC Calibration

QUAL2K model coefficients were adjusted in iterative fashion until the best overall match between the observed and simulated fecal coliform concentrations for the Sugar Creek watershed for the months of May through October together was obtained. The final parameters chosen are given in Appendix F, and Appendix G presents plots of observed vs. simulated fecal coliform concentrations, as well as observed vs. simulated temperatures, and flows along the mainstem of Sugar Creek.

Fecal Coliform simulated and observed geometric mean concentrations and associated standard deviations (SD) for the Sugar Creek watershed are given in Table 10. The agreement is rather good for May through August (within a factor of 1.5), but poorer in September and October when observed concentrations exceed those simulated between 4 and 13 times. Nonetheless, the observed and simulated concentrations for each month are within one standard deviation of each other except for October.

Table 10. Simulated and observed monthly geometric mean decal coliform concentrations (cfu/100 mL) and associated standard deviation ranges (SD range) for the Sugar Creek watershed

	May	SD range	June	SD range	July	SD range	Aug.	SD range	Sept.	SD range	Oct.	SD range
Simulated	235	138-400	3650	2744-4855	4877	3039-7803	4705	2764-7999	866	367-2044	197	44-881
Observed	275	107-707	2774	699-11013	5437	2567-11907	6339	2780-14453	3203	764-9225	2498	835-7469

7.2.4 Manganese

Since the completion of the Phase I Report, the listing of manganese as a cause of impairment for the Public and Food Processing Water Supply Use for Vermont City Reservoir was removed during the 2014 assessment process. This was due to a change in the quality standard for untreated water which was approved in 2013. The previous water quality standard was 0.15 mg/L total manganese. The new water quality standard is now 1.0 mg/L.. The finished water Maximum Contaminant Level standard remains at 0.15 mg/L. Therefore, a TMDL was not completed for manganese.

8.0 Total Maximum Daily Loads for the Sugar Creek and Vermont City Reservoir Watershed

8.1 TMDL Endpoints

The TMDL endpoints for total phosphorus (TP) and atrazine for Vermont City Reservoir and fecal coliform for Sugar Creek are summarized in Table 11. Total phosphorus concentration for lakes and reservoirs with a surface area of 8.1 hectares (20 acres) or more, or in any stream at the point where it enters any such reservoir or lake shall not exceed 0.05 mg/l at any time. The Illinois Pollution Control Board (IPCB) has set a Maximum Contaminant Level (MCL) for atrazine at 3µg/L for waters such as Vermont City Reservoir which serve as public and/or food processing water supplies. The 3 µg/L limit applies to treated water at all times (IEPA, 2016). The general use water quality standard for fecal coliform bacteria specifies that during the months of May through October, based on a minimum of five samples taken over not more than a 30-day period, fecal coliform bacteria counts shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of the samples during any 30-day period exceed 400/100 ml (35 Ill. Adm. Code 302.209). The TMDL endpoint chosen for fecal coliform in Sugar Creek will be not to exceed 200 cfu/100 ml as a conservative endpoint. However, while that is the fecal coliform TMDL endpoint, both portions of fecal coliform water quality standard apply.

Table 11. TMDL Endpoints for Impaired Constituents in Vermont City Reservoir and Sugar Creek Watersheds

Watershed	Parameter	Usage	TMDL Endpoint
Vermont City Reservoir	Total Phosphorus	General use water quality standard	0.05 mg/l at all times
	Atrazine	Public and food processing water supplies	3 µg/l (Maximum Contaminant Level)[1]
Sugar Creek	Fecal Coliform	General use water quality standard	200 cfu/100 ml (geometric mean of 5 or more samples over a 30-day period from May through October)[2]

[1] The MCL is from 35 Ill. Adm. Code 611, Subpart F.

[2] From 35 Ill. Adm. Code 302.209.

Total phosphorus and atrazine concentrations in Vermont City Reservoir, and fecal coliform concentrations in Sugar Creek sometimes exceeded the respective water quality standards as presented in the Phase I report, and these exceedances were the basis for TMDL development.

8.2 Pollutant Source and Linkages

Pollutant sources and linkages were described in the Phase I Report. The watersheds for both Vermont City Reservoir and Sugar Creek are dominated by agricultural land uses, particularly row crop agriculture. Hence, total phosphorus and atrazine loading to Vermont City Reservoir is predominately from non-point sources. Similarly, fecal coliform loading to the Sugar Creek watershed is predominately from non-point sources including livestock and wildlife through both direct (access to streams) and indirect (overland and subsurface runoff, resuspension) contact, as well as failing septic systems. However, there are also three permitted waste water dischargers in the watershed, although only two are wastewater treatment plants.

8.3 Allocation

As explained in Section 1.1 of the Phase I report, a TMDL for a particular pollutant is determined using the following general formula:

TMDL = WLA + LA + MOS + RC

where WLA is Waste Load Allocation and refers to a load discharged to a water body by point sources; LA is Load Allocation and refers to a load that enters the water body from non-point sources and natural background; MOS is Margin of Safety that accounts for uncertainty; and RC is Reserve Capacity that allows for future growth.

8.3.1 Total Phosphorus TMDL

Vermont City Reservoir Total Phosphorus TMDL was established using the CE-QUAL-W2 model. The existing load to the lake was reduced in 10% increments. For each incremental reduction, the CE-QUAL-W2 model was executed and the TP concentrations in the lake were analyzed. Then, the reduction needed to achieve water quality standards was determined.

Existing Total Phosphorus Loads

TP loads during the project monitoring period were calculated directly from the observed flows and concentrations. The calibrated GWLF model was used to produce a long-term series of TP loads generated in the Vermont City Reservoir watershed. These annual watershed TP loads are shown in Figure 12 and given in Table 12. Weather conditions during the monitoring period affected the magnitude of the loads. After a relatively normal spring in 2011 when monitoring was initiated, dry conditions occurred from July 2011 to the end of the monitoring period in October 2012 resulting in lower loads being observed when compared to those periods where average run off occurs. Over the course of the calibration period, the annual average TP load in was 5.2 lbs/day, ranging from 0.2 lbs/day (2006) to 14.2 lbs/day (2009) depending on the weather conditions. Years with higher precipitation also have higher TP loads.

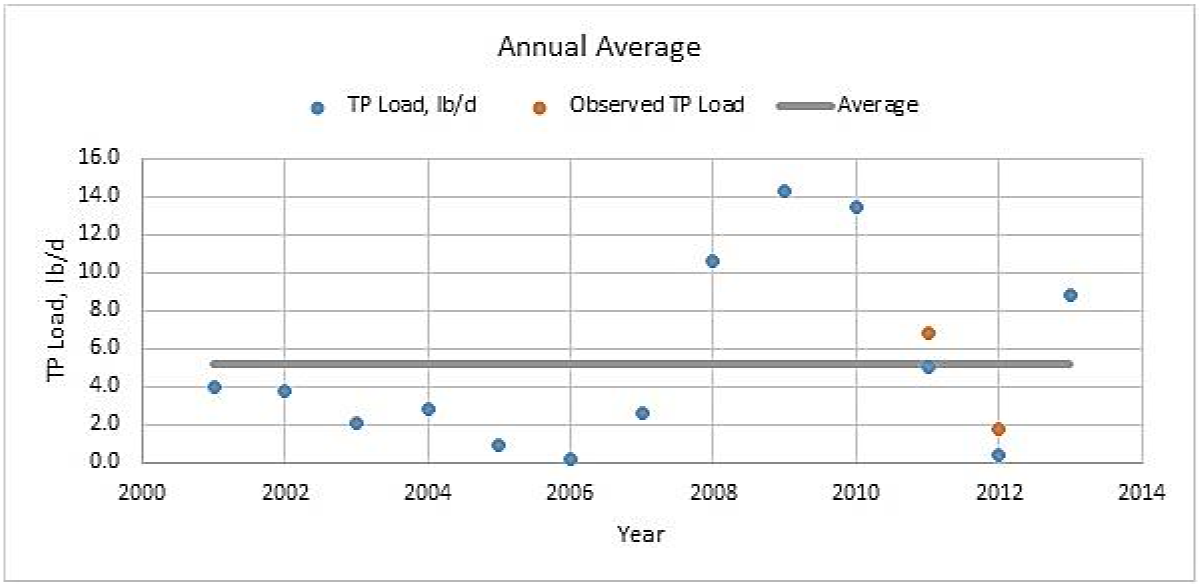


Figure 12. Annual average TP load in lbs/day

Table 12. Annual average TP load during 2001-2013

Year	TP Load, lbs/day	Observed TP Load, lbs/day*
2001	4.0	-
2002	3.8	-
2003	2.1	-
2004	2.8	-
2005	0.9	-
2006	0.2	-
2007	2.7	-
2008	10.6	-
2009	14.2	-
2010	13.5	-
2011	5.0	6.8**
2012	0.4	1.8
2013	8.8	-
Average	5.2	-

Notes: *Estimated from the average loading rates observed at DHZC-02
**TP was not monitored during January-March 2011. Daily average load was assumed to be equal to the average observed daily load during April-December 2011.

Internal P Loading

Internal loading of P can also be an important nonpoint source, especially during drier summer periods in the deeper portions of Vermont City Reservoir. As noted in Section 5.4.2.6 of the Phase I Report, dissolved oxygen concentrations can become depleted in the deeper portions of Vermont City Reservoir which can then enhance the release of dissolved phosphorus from the bottom sediments. This can been seen in the historical data summarized in the Phase I Report, which show that the highest phosphorus concentrations occur below 6 feet in depth.

Our CE-QUAL-W2 model runs simulated P release from bottom sediments under oxygen-depleted conditions, and this effect is noticeable at the deepest Vermont City Reservoir water quality sampling station RDM-1. During the summer months, some of the simulated TP and dissolved P profiles presented in Appendix D noticeably increase near the bottom at RDM-1. Additionally, the corresponding dissolved oxygen profiles show that dissolved oxygen has been depleted.

Our CE-QUAL-W2 model simulations also allowed us to estimate the areal extent and duration of oxygen depleted conditions in Vermont City Reservoir over the 13 year simulation period. As might be expected, drier summer periods resulted in both greater areal extents and durations of dissolved oxygen depletion. Simulated depleted oxygen conditions occurred during every summer season of the simulation period, and ranged from 15 days in 2001 to 2 days in 2005, 2007, 2011, and 2013. Similarly, the areal extent of simulated depleted oxygen conditions was also variable, from the bottom 2 meters of Vermont City Reservoir in 2009, to only the deepest 0.25 meter in 2007 and 2013.

The P release rate from sediments overlain by oxygen depleted water is set by adjusting the variable "PO_4R" in the model, and for our simulations that value was set to 0.001 (Appendix C, below) which equates to a sediment release rate of 1 mg P/m^2/day. That value, combined with the duration and areal extent of oxygen depleted conditions, can be used to estimate the internal P loading, which can then be compared to the external loading from tributaries. In relation to the annual tributary P loading over the simulation period, the internal load ranges from a high of 0.058% of the tributary load in 2012, to a low of 0.0007% in 2010. The mean value is 0.017%, indicating that internal P loading is a very small fraction of the external loading from tributaries. Thus, it does not need a separate Load Allocation.

Loading Capacity

Loading capacity was determined from a series of simulations where the TP load from tributaries was reduced in 10 percent increments from the original TP load and the corresponding in-lake concentration was determined for each load reduction scenario by conducting simulations with the calibrated CE-Qual-W2 model. Figure 13 shows how Vermont City Reservoir TP concentrations are expected to decrease for different percent reductions simulated. The load reduction curve shows that 70% reduction is needed to achieve 0.05 mg/l TP in Vermont City Reservoir. The corresponding loading capacity (LC) was determined to be 1.56 lbs/day on an annual average.

Figure 14 shows percent time the simulated TP concentrations were exceeded in Vermont City Reservoir during 2001-2013. The lake water quality standard (0.05 mg/l) was exceeded 90% time when current TP loading from tributaries was assumed. In addition, the high TP concentrations associated with high-precipitation storm events will cause temporary increases in Vermont City Reservoir TP concentrations above 0.05 mg/L even after the recommended 70% load reduction. However, these higher concentrations would occur only temporarily during and immediately following high flow events.

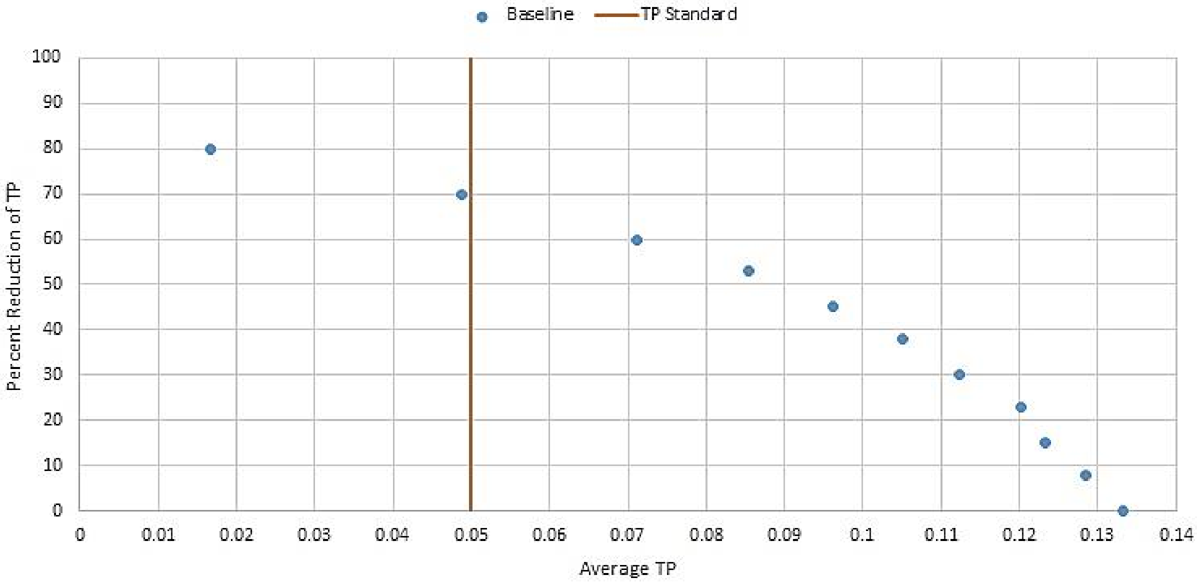


Figure 13. Effect of percent reduction in TP load on TP concentration in Vermont City Reservoir

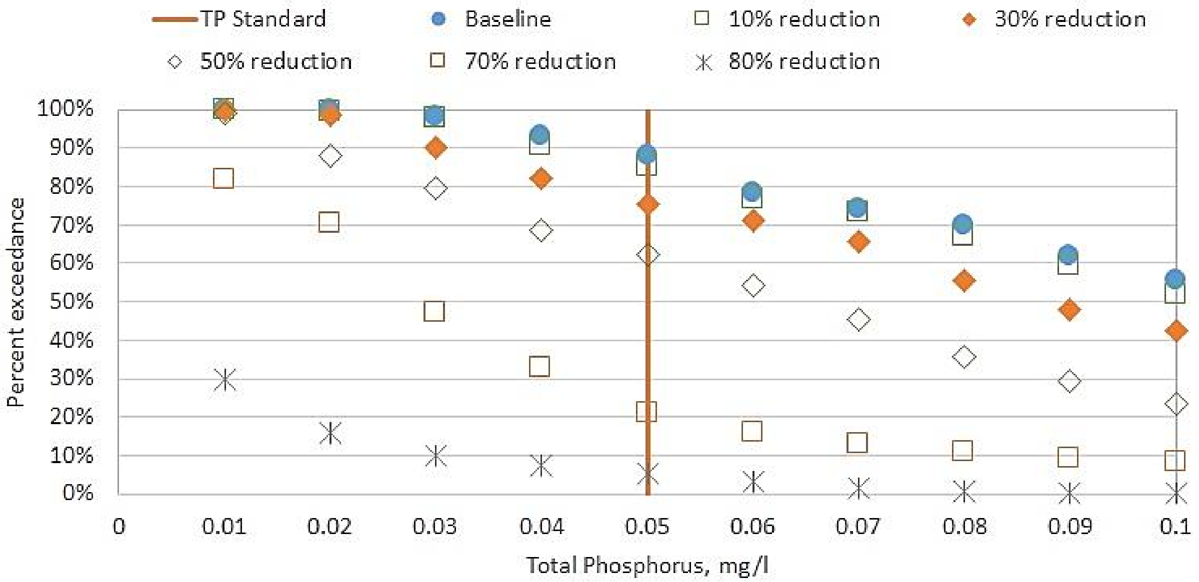


Figure 14. Percent time TP concentration is exceeded in Vermont City Reservoir, 2001-2013

Seasonal Variation

Seasonal variation is explicitly included in this TMDL because conditions were modeled over an annual basis for a 13 year period which included substantial seasonal variations. In addition, the observed data upon which both the watershed GWLF and in-lake CE-QUAL-W2 models were calibrated were collected throughout multiple years. Hence, seasonal variation, including the most critical growing season period is adequately represented in this TMDL.

Margin of Safety

The MOS can be incorporated into a TMDL in two ways: it can be implicitly included in the analyses through the use of conservative assumptions or it can be explicitly defined as a portion of loadings. MOS was defined explicitly in this study as 17% of the Loading Capacity. The selected percentage reflects the uncertainty associated with the model calibration and the difference between the observed and calibrated values.

The average TP concentration calculated from the TP data collected in Vermont City Reservoir during the 2011-2012 project monitoring period is 0.114 mg/l. The average TP concentration simulated by the CE-QUAL-W2 model is 0.133 mg/l. This represents 17% difference between the observed and simulated TP concentrations which is equal to the explicitly defined MOS.

MOS = 0.17 LC = 0.17 x 1.56 lbs/day = 0.27 lbs/day

Reserve Capacity

There has only been a limited development in the Vermont City Reservoir watershed from 2000 to 2009. Reserve capacity has been set to zero since little additional future development is anticipated.

RC = 0 lbs/day

Waste Load Allocation

There are no point sources of total phosphorus in the Vermont City Reservoir watershed. Therefore, WLA is set to zero.

WLA = 0 lbs/day

Load Allocation

Load allocation was determined from Loading Capacity, Margin of Safety, Reserve Capacity, and Waste Load Allocation:

LA = LC – MOS – RC – WLA = 1.56 lbs/day – 0.27 lbs/day - 0 lbs/day – 0 lbs/day = 1.29 lbs/day

Pollutant Load Reductions

Current average daily TP load to Vermont City Reservoir is 5.2 lbs/day. The recommended Loading Capacity of 1.56 lbs/day represents an effective 70% reduction of total phosphorus load from the watershed to Vermont City Reservoir. Table 13 summarizes the TMDL.

Table 13. Total Phosphorus TMDL Summary for Vermont City Reservoir

LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Current Load (lb/day)	Reduction (lb/day)	Percent Reduction
1.56	0	1.29	0.27	5.2	3.64	70%

8.3.2 Atrazine TMDL for Vermont City Reservoir

The Vermont City Reservoir atrazine TMDL was based on the maximum contaminant level of 3 µg/L, the maximum storage capacity of the reservoir from the bathymetric survey conducted in June, 2013 (264.27 ac-ft or 86.113 million gallons), and the atrazine data collected by SYNGENTA between February, 2002 and April, 2012 at the raw water intake location. These data are presented in Appendix E. This mass balance approach was adopted because as explained in the Phase I report, atrazine loading to Vermont City Reservoir could not be determined from project monitoring data. Of the 304 atrazine measurements, 63 exceeded the maximum contaminant level of 3 µg/L. The maximum exceedance was 44.67 µg/L, the median exceedance value was 4.75 µg/L, and 95% of the exceedances were below 16.58 µg/L. Exceedance values and % exceedances are given in Appendix E.

Loading Capacity

The loading capacity (LC) of the waterbody is the amount of atrazine that can be allowed in the lake and still meet the water quality standard of 3 µg/L atrazine. Given the maximum storage capacity of 86 million gallons (MG) and other conversion factors, the LC is calculated as follows,

86 MG * 3 µg/L *0.0022 lb/µg * 3.785 L/gallon = LC = 2.15 lbs /day

Seasonal Variation

All of the exceedances of the atrazine MCL of 3 µg/L occurred between mid-April and mid-July over the entire 2002 to 2012 SYNGENTA monitoring period, and the highest concentrations were found in May and early June. This is to be expected and reflects crop planting/early growing season activities, including applications of herbicides. Consequently, seasonal variation is adequately represented in this TMDL.

Margin of Safety

The MOS can be incorporated into a TMDL in two ways: it can be implicitly included in the analyses through the use of conservative assumptions or it can be explicitly defined as a portion of loadings. The MOS for the Vermont City Reservoir atrazine TMDL is implicit. The load reduction is based on exceedances during the critical planting and early growing season when runoff of atrazine is most likely to occur. The exceedance level was set at 95%, which is commonly used to gage statistical significance.

An additional MOS is provided by how the TMDL is calculated. The loading capacity is calculated as the reservoir volume multiplied by the MCL of 3 µg/L which results in a daily load of atrazine. However, the public water supply assessment process uses a rolling annual average of quarterly samples for raw water (as does the EPA for finished water compliance). Use of an average will by definition have some values above the mean. By using a daily load calculation, the TMDL loading capacity is more protective.

Reserve Capacity

There has only been a limited development in the Vermont City Reservoir watershed from 2000 to the present, and little additional development is expected for the foreseeable future. Therefore, the Reserve capacity for the atrazine TMDL has been set to zero.

Wasteload Allocation

There are no point sources within the Vermont City Reservoir watershed that discharge atrazine. Therefore, the waste load allocations (WLA) were set to zero for point sources.

Load Allocation

Load allocation was determined from Loading Capacity, Margin of Safety, Reserve Capacity, and Waste Load Allocation:

LA = LC – MOS – RC – WLA = 2.15 lbs/day – 0 lbs/day - 0 lbs/day – 0 lbs/day = 2.15 lbs/day

Pollutant Load Reduction

The current daily load of atrazine was calculated using the 95% exceedance value of 16.58 µg/L from the 2002-2012 SYNGENTA data (Appendix E),

86.113 MG * 16.58 µg/L *0.0022 lb/µg * 3.785 L/gallon = Current Load = 11.89 lbs atrazine

Therefore, an 82 percent reduction in the current atrazine load to Vermont City Reservoir is necessary to meet the TMDL. This is summarized in Table 14.

Table 14. Atrazine TMDL Summary for Vermont City Reservoir

LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Current Load (lb/day)	Reduction (lb/day)	Percent Reduction
2.15	0	2.15	implicit	11.89	9.74	82%

8.3.3 Fecal Coliform TMDL for Sugar Creek Segment DH-01

The Sugar Creek segment DH-01 Fecal Coliform TMDL was established using fecal coliform concentration and flow data collected during the Phase I part of this study for May through October, 2011. The existing loads to the mainstem were reduced by 50%, 70%, 90%, 95%, and 99%. For each reduction, the QUAL2K model was executed and the fecal coliform loads in the mainstem of Sugar Creek were calculated. Then, the reduction needed to achieve the 200 cfu/100 ml geometric mean water quality standard was determined. These modeling results are summarized in Figure 15.

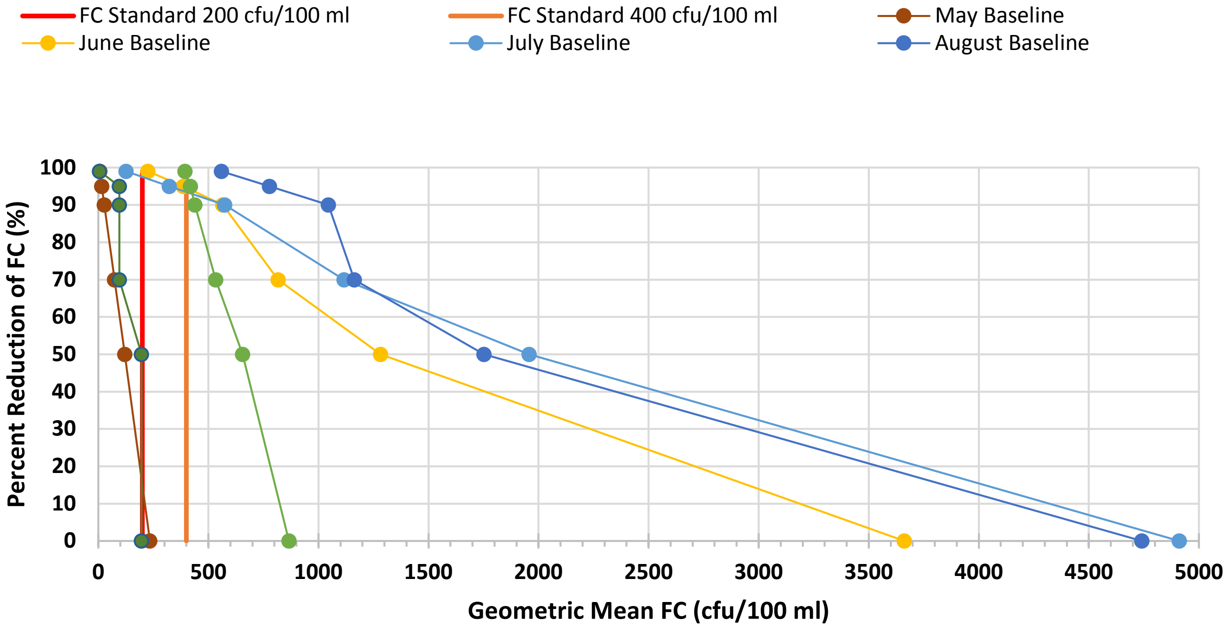


Figure 15. Monthly fecal coliform load reduction scenarios

Loading Capacity

The loading capacity is the maximum amount of fecal coliform that Sugar Creek can receive and still maintain compliance with the 200 cfu/100 mL geometric mean water quality standard. The loading capacity is directly related to flow, and Table 15 presents fecal coliform loading capacity for a range of flows which encompass those observed for Sugar Creek.

Table 15. Fecal Coliform Loading Capacity for Sugar Creek

Estimated mean daily flow (cfs)	Estimated mean daily flow (m^3)	Load Capacity (mil. col/day)
1	0.0283	4,893
5	0.1416	24,466
10	0.2832	48,931
20	0.5663	97,863
50	1.4158	244,657
100	2.8317	489,315
200	5.6634	978,629
500	14.1584	2,446,573
1000	28.3168	4,893,146

Seasonal Variation

Consideration of seasonality is inherent in the load duration analysis. Because the load duration analysis represents the range of expected stream flows, the TMDL has been calculated to meet the standard during all flow conditions. In addition, seasonality is addressed because the TMDL has been calculated to address loading only when the seasonal standard is applicable (May-October).

For the fecal coliform TMDLs, the critical period for fecal coliform is the primary contact recreation season which is May through October each year. The fecal coliform standard must be met under all flow scenarios and standard exceedances have occurred during the majority of flow scenarios.

Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The MOS for the Sugar Creek TMDL is implicit as the analysis compares individual sample results to the 200 cfu/100ml geometric mean component of the WQS. Illinois EPA considered this conservative as the standard is based upon a geometric mean of five samples taken over a 30 day period. Moreover, the QUAL2K model used to simulate fecal coliform includes a rate of decay. This, in effect increases the reductions needed to meet the standard.

Waste Load Allocation

There are three small municipal treatment facilities with NPDES permitted discharges within the Sugar Creek watershed and each of these facilities is expected to meet 200 cfu/100 ml concentration at the end of their respective exempted stream reaches. The location of these facilities is shown in Figure 5-52 of the Phase I report. Specific fecal coliform data were not available for all of these facilities; therefore the fecal coliform standard (200 cfu/100ml) and each facility's design average flow (DAF) values were used to set the WLA for low and moderate flow levels. At high flow levels, the facilities' design maximum flows (DMF) were used to calculate the WLA allocations. Using the conservative fecal coliform standard to calculate the WLA for the watershed ensures that point sources will not be contributing to fecal coliform exceedances instream. The WLA for the STPs was determined to be 2,688 million colonies/day using the design average flows, and 6,720 million colonies/day when calculated for each facility's design maximum flow. WLAs for each facility are shown in Table 16. These facilities may be required to monitor for fecal coliform in the future.

Table 16. WLAs for Permitted Discharges in the Sugar Creek watershed

Facility	**NPDES Permit Number**	**Design Average Flow (MGD)**	**WLA – low to moderate flows (mil. col/day)**	**Design Maximum Flow (MGD)**	**WLA - moderate to high flows (mil. col/day)**
Village of Astoria STP*	IL0025364	0.28	2,120	0.70	5,300
Village of Table Grove STP*	ILG580040	0.075	568	0.1875	1,420
Village of Vermont WTP	ILG640188	-	-	-	-
TOTAL			**2,688**		**6,720**

*The WLAs for facilities with Year-round Disinfection Exemption will apply at the end of their respective disinfection exempted waterbody segments. These facilities through future NPDES Permit renewal applications will be required to provide Illinois EPA with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption re-evaluated through future NPDES permitting actions if the WQS is not met at the end of the exempted waterbody segment.

Load Allocation and TMDL Summary

Table 17 shows a monthly summary (May-October) of the fecal coliform TMDL for Sugar Creek for all flow conditions. To provide a more conservative TMDL load allocation, the 200 cfu/100ml (geometric mean) fecal coliform water quality standard was used for each wastewater treatment facility's design maximum flows (DMF) to calculate the WLA at higher stream flow conditions, while the design average flow (DAF) was used for mid-range to low stream flow conditions. A summary of the DAF and DMF WLAs for each wastewater treatment facility in the watershed is presented in Table 16 above. The stream flows and the fecal coliform Actual Load used in developing the load capacity analysis is available in Appendix H: Sugar Creek Mainstem Fecal Coliform Monthly Loads.

Table 17. Fecal Coliform TMDL for Sugar Creek watershed-average monthly flows

Month	Flow	Q	LC	WLA	LA	MOS	Actual Load (mil. col/day)	Percent reduction needed (%)
		m3/s	(mil. col/day)	(mil. col/day)	(mil. col/day)			
May	High Flows	4.18	722,084	6,720[a]	715,364	Implicit	490,950	0.0%
Jun	High Flows	11.74	20,280,545	6,720[a]	20,273,825	Implicit	41,687,657	51%
Jul	High Flows	1.83	3,161,277	6,720[a]	3,154,557	Implicit	2,664,640	0.0%
Aug	Mid-Range Flow	0.07	121,120	2,688[b]	118,432	implicit	385,484	69 %
Sep	Dry Conditions	0.03	51,476	2,688[b]	48,788	Implicit	62,443	21%
Oct	Low Flow	0.03	51,476	2,688[b]	48,788	Implicit	21,974	0.0%

[a] WLA based on DMF

[b] WLA based on DAF

9.0 Implementation Plan for the Sugar Creek and Vermont City Reservoir Watershed

9.1 Adaptive Management

An adaptive management or phased approach is recommended for the implementation of management practices needed to meet the TMDLs developed for the Sugar Creek and Vermont City Reservoir Watershed. Adaptive management as outlined by USEPA guidelines, is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the beneficial characteristics of adaptive management include:

- Acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue
- Thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle)
- Careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking
- Monitoring of key response indicators
- Analysis of the management outcomes in consideration of the original objectives and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000)

Implementation actions, point source controls, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of point source controls and BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed (Osmond et al. 1995).

To assist in development of an adaptive management program; implementation actions, management measures, available assistance programs, and recommended continued monitoring are all discussed throughout the remainder of this section. The point source controls described below are generally required through the NPDES program administered by Illinois EPA and typically already being implemented although some modifications may be appropriate. Illinois EPA will work with dischargers in the watershed as NPDES permits come up for renewal. The nonpoint source BMPs are entirely voluntary based on the landowner’s preference.

9.2 Implementation Actions and Management Measures of TP and Atrazine for Vermont City Reservoir Watershed

9.2.1 Total Phosphorus (TP)

Total phosphorus concentrations in Vermont City Reservoir have exceeded the Illinois water quality standard for lakes (0.05 mg/L). Analysis of water quality data can be summarized as follows:

- High total phosphorus concentrations in tributaries are associated with high runoff events
- Lake sediments have a high phosphorus content
- The bottom layer of the lake often has a higher proportion of dissolved phosphorus than top layers
- A significant portion of the total phosphorus loading entering Vermont City Reservoir remains trapped in the lake (internal loading)

The inflow to the lake is characterized by higher flows in spring (storm runoff) and relatively lower flows during the summer and fall. Non-point sources dominate the phosphorus loading delivered to the lake through sampled tributaries. The phosphorus concentration increase near the bottom of the lake. However, data indicates that the lake does not undergo stratification in summer. Also, when water levels in the lake fall below the spillway, as often happens, all tributary loadings stay within the lake at least until the reservoir is replenished.

Considering the above observations, the final TMDL approach needs to include the following to affect total phosphorus concentrations and loadings in Vermont City Reservoir:

- Runoff from urban, agriculture, and other areas, including septic systems.

9.2.1.1 Point Sources of TP

There are no point sources of TP in the Vermont City Reservoir watershed, and the associated WLA is therefore set to zero.

9.2.1.2 Nonpoint Sources of TP and available BMPs for Management

Potential sources of nonpoint source phosphorus pollution to Vermont City Reservoir are dominated by runoff from watershed upland agricultural areas, with more minor potential contributions from other runoff sources including septic systems. Therefore, BMPs which focus on those that reduce TP entering Vermont City Reservoir from upland agricultural areas are discussed in Section 9.4.1 below.

Conservation Tillage

Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks) on fields before and after planting the next crop, to reduce soil erosion and runoff. To provide these conservation benefits, at least 30% of the soil surface must be covered with residue after planting the next crop. Some conservation tillage methods forego traditional tillage entirely and leave 70% residue or more. Conservation tillage is especially suitable for erosion-prone cropland.

Conservation tillage methods include no-till, strip-till, ridge-till and mulch-till. Each method requires different types of specialized or modified equipment and adaptations in management. No-till and strip-till involve planting crops directly into residue that either hasn't been tilled at all (no-till) or has been tilled only in narrow strips with the rest of the field left untilled (strip-till). Ridge-till involves planting row crops on permanent ridges about 4-6 inches high. The previous crop's residue is cleared off ridge-tops into adjacent furrows to make way for the new crop being planted on ridges. Maintaining the ridges is essential and requires modified or specialized equipment. Mulch-till is any other reduced tillage system that leaves at least one third of the soil surface covered with crop residue.

When tillage is reduced or eliminated, particulate phosphorus loss in surface runoff usually declines, but dissolved P losses may increase if phosphorus becomes more concentrated near the soil surface unless P fertilizers or manure are injected or incorporated into the soil (Czapar et al. 2008). However, it should be kept in mind that TP reductions from conservation tillage or other BMP measures have been highly variable in published studies. For conservation tillage in particular, a recent review of the literature found particulate P reductions from -33 to 96%, and dissolved P reductions from -308 to -40 %, meaning dissolved P runoff has been observed to increase under conservation tillage alone, compared to conventional tillage (Dodd and Sharpley, 2016). In Illinois, it is estimated that converting from conventional to conservation tillage practices on soils eroding at greater than the soil tolerance rate (T) will reduce total P runoff from those soils 50% (IEPA, 2015). And, fewer trips across the fields save time and money (lowers fuel, labor and machinery maintenance costs) and reduces soil compaction that can interfere with plant growth.

To achieve TMDL load allocations, conservation tillage practices already in place should be continued, and practices should be assessed and improved upon for all agricultural areas in the watershed. According to the 2017 Transect Survey Report for Fulton, McDonough and Schuyler Counties from the Illinois Dept. of Agriculture (https://www2.illinois.gov/sites/agr/Resources/LandWater/Pages/Illinois-Soil-Conservation-Transect-Survey-Reports.aspx) there has already been a shifts toward more conservation tillage in Fulton and McDonough Counties (Table 18) as compared to 2011. The Vermont City Reservoir watershed is in McDonough County where 51% of corn acres are in conservation tillage practices, an improvement from 34% in 2011. Also, 95% of soybean acreage improved slightly from the 91% in 2011. The increases in percent corn acreage to conservation tillage practices shows a good start to improve nonpoint source runoff. The decreases in Schuyler County conservation tillage between 2011 and 2017 show need for more acreage should be converted to any conservation tillage practice (especially for corn), and targeted toward highly erodible land (HEL) and potential highly erodible land (PHEL) areas of the watershed.

The known HEL/PHEL areas of the Sugar Creek and Vermont City Reservoir watershed are shown in Figure 16. This figure indicates that known HEL areas are primarily located near stream corridors, and when compared to figure 2-4 of the Stage 1 report, that a large portion of the HEL areas are also cropland. In the Vermont City Reservoir watershed, of the 662 watershed acres which have been classified as HEL/PHEL, 241 of those acres or 36% are in cropland (corn, soybeans and small grains). It should be noted that 45% of the land in the Vermont City Reservoir watershed has been classified as HEL/PHEL and 55% is not classified. Consequently, there is likely much more HEL in the watershed. In any case, since HEL areas are typically nearer stream channels and/or on greater slopes, these areas should be the focus of conservation tillage and other BMP practices in the watershed.

Table 18. Tillage practices in Fulton, McDonough and Schuyler Counties in 2006, 2011, and 2017 (Illinois Dept. of Agriculture, 2017).

	Fulton County								
	Corn			Soybeans			Small Grains		
	2006	2011	2017	2006	2011	2017	2006	2011	2017
Conventional	10	28	2	1	8	1	0	0	0
Reduced-till	45	49	78	4	23	20	0	0	0
Mulch-till	30	18	14	24	22	26	0	0	0
No-till	15	5	6	71	47	53	100	100	100
	McDonough County								
Conventional	36	66	49	7	9	5	0	0	100
Reduced-till	32	25	37	23	31	18	14	0	0
Mulch-till	20	2	9	28	10	36	86	0	0
No-till	13	6	5	42	50	41	0	100	0
	Schuyler County								
Conventional	38	14	93	4	12	37	0	10	0
Reduced-till	27	63	3	9	43	21	0	30	0
Mulch-till	24	11	0	40	26	9	100	60	0
No-till	10	11	4	46	19	33	0	0	100

Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment to Vermont City Reservoir. Filter strips implemented along stream segments and around waterbodies slow and filter nutrients and sediment out of runoff and provide bank stabilization decreasing erosion and deposition. Strictly speaking, however, filter strips can be placed between crop or grazing land and any environmentally sensitive land, and not necessarily only adjacent to stream segments and waterbodies (IL-NRCS, 2003).

Grass and riparian filter strips filter out nutrients and organic matter associated with sediment loads to a water body. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settle sediment out of runoff and providing vegetation to filter nutrients out of overland flow. For the purposes of filtering contaminants, permanent filter strip vegetative plantings shall be harvested as appropriate to encourage dense growth, maintain an upright growth habit and remove nutrients and other contaminants that are contained in the plant tissue (NRCS, 2013). Additionally, filter strip areas should be periodically re-graded and re-established when sediment deposition at the filter strip-field interface jeopardizes its function.

According to guidance published by the Illinois NRCS, the minimum and maximum flow through times for filter strips should be increased with slope (IL-NRCS, 2003). Recommended minimum flow through times (for a ½ inch depth flow) range from 36 minutes for 0.5% slope source areas, to 117 minutes for 5.0% (or greater) slope source areas. Similarly, maximum flow through times (above which filter strip effectiveness will likely not increase) range from 72 to 234 minutes for 0.5% and 5.0 % (or greater) slope source areas, respectively. Filter strip widths greater than that needed to achieve a 30 minute flow through time at 1/2 inch depth will not likely improve the effectiveness of the strip in addressing most water quality concerns, whereas a minimum of 15 minute flow through times are necessary for substantial water quality benefits (IL-NRCS,2003). Flow into filter strips should be primarily sheet flow, and concentrated flow should be dispersed.

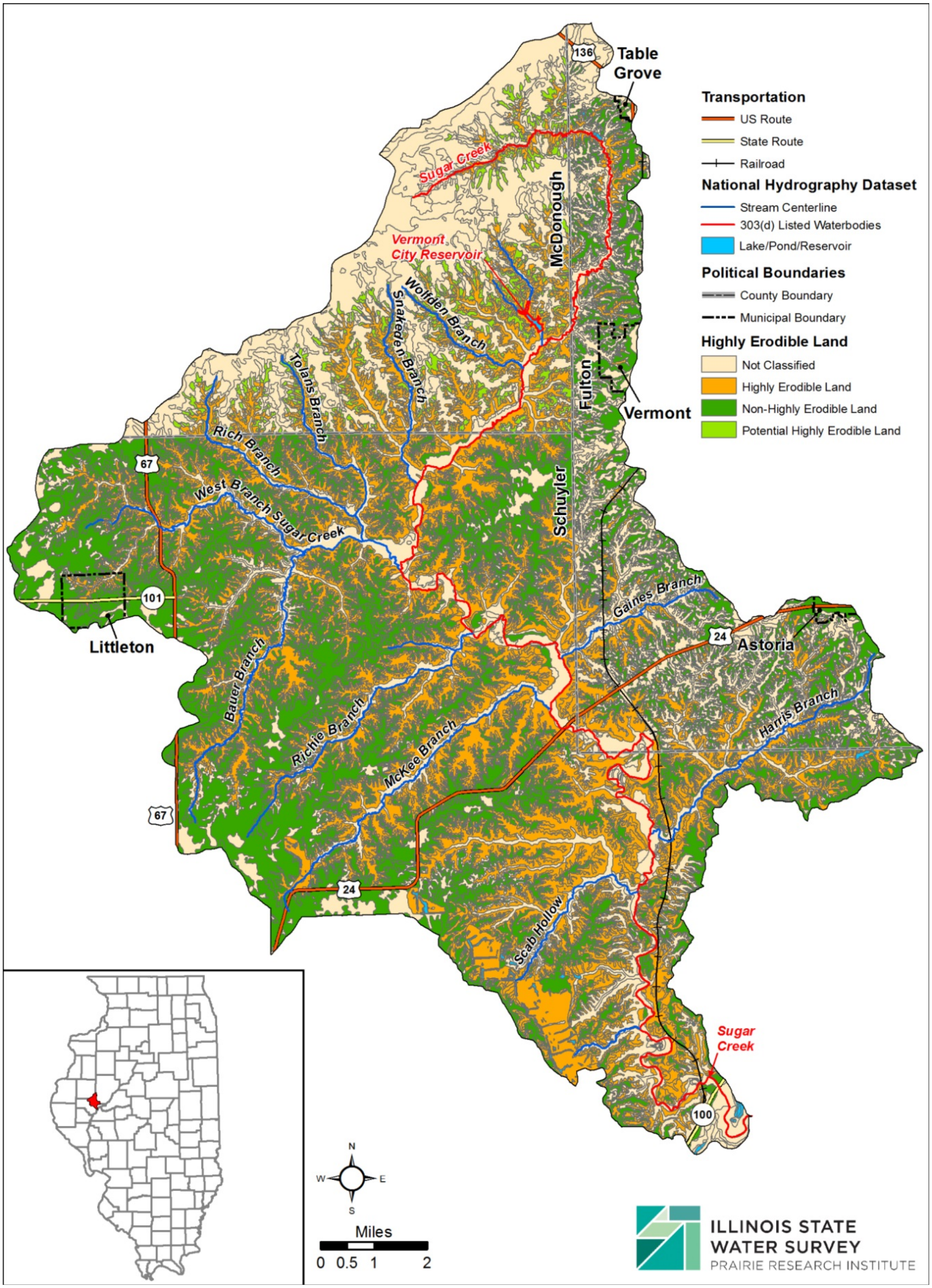


Figure 16. Sugar Creek watershed showing classified HEL areas

Riparian Buffers

A riparian buffer is a newly established area along a stream, of either grass or trees, which is managed to maintain the integrity of stream channels and shorelines and reduce the impacts of upstream land uses such as nutrient and sediment runoff. The root structure of the vegetation in a buffer enhances infiltration of runoff and subsequent trapping of nonpoint source pollutants. However, the buffers are only effective in this manner when the runoff enters the buffer as a slow moving, shallow "sheet", where concentrated flow in a ditch or gully will quickly pass through the buffer offering minimal opportunity for retention and uptake of pollutants. Similarly, riparian buffers are ineffective in tile-drained areas. Even more important than the filtering capacity of the buffers is the protection they provide to streambanks. The rooting systems of the vegetation serve as reinforcements in streambank soils, which help to hold streambank material in place and minimize erosion.

Minimum buffer widths are required for water quality benefits. These minimum widths are different for forest and herbaceous riparian buffers, as described in Illinois NRCS publications (IL-NRCS, 2013; IL-NCRS, 2014). For herbaceous cover buffers, minimum widths should be 2.5 times the bank-full width for streams, and 35 feet for other water bodies. Minimum forest buffer widths vary according to stream order, and should consist of at least 2 zones. For first- and second-order streams the minimum zone 1 and zone 2 widths are both 25 feet, while for third-order and higher streams the minimum zone 1 and zone 2 widths are 25 and 75 feet, respectively.

Phosphorus removal rates of approximately 25 to 30 percent for 30 ft wide buffers and 70 to 80 percent for 60 to 90 ft wide buffers have been documented (NCSU, 2002). Within Illinois, a TP runoff reduction from crop land of 25 to 50% can be expected from riparian buffers according to the Illinois Nutrient Loss Reduction Strategy (IEPA, 2015). However, the effectiveness of riparian buffers can be even more highly variable, ranging from -258 to 88% for dissolved P, and 35-96% for particulate P in published studies (Dodd and Sharpley, 2016). One factor reducing riparian buffer effectiveness are concentrated flow paths, and in one field survey in Southern Illinois, 82.5-100% of the drainage leaving agricultural fields was along concentrated flow paths (Pankau, et. al, 2012). Minimizing concentrated flow paths requires up gradient control measures such as regrading.

Sediment Control Basins

A sediment control basin is a basin constructed with an engineered outlet formed by an excavation or embankment or a combination of the two, to capture sediment laden runoff and trap it in the basin (IL-NRCS 2012a). Also known as Water and Sediment Control Basins (WASCOBs), sediment basins should be located so that they intercept as much of the runoff as possible from disturbed areas of watersheds. Locations should be chosen that minimize the number of entry points for runoff into the basin and interference with construction or farming activities. Sediment basins should not be located in perennial streams. Vegetation should be established on the embankment and side slopes of the basin immediately after construction. Because the sediment storage capacity of a basin is finite, locations should be chosen that allow access for sediment removal when the storage capacity is full.

Sediment control basins should be designed to hold a minimum of 900 ft^3 of sediment per acre of disturbed area, and 3600 ft^3 of total storage per acre of drainage area. According to the Illinois Nutrient Loss Reduction Strategy sediment control basins have been shown to trap about 90 % of the entering sediment (IEPA, 2015). Inspection of available imagery indicates that Sugar Creek watershed has many sediment control basins already. Therefore, continuation of sediment control basin programs is recommended.

Cover Crops

Cover crops can be grasses, legumes, or forbs planted for seasonal vegetative cover (IL-NRCS, 2015a). Water quality benefits of cover crops come from three processes. The first is the literal cover that the crop provides to the soil, reducing erosion from raindrop impact when other production crops are not present. The second is the potential for the cover crop to take up nutrients that would otherwise be lost from the field through surface or drainage water and the third is increasing soil infiltration. Other environmental benefits are enhanced biodiversity, create wildlife habitat and attract honey bees and beneficial insects. Cover crops are recommended for fields where no-till is currently being practiced or where willing landowners express an interest. A switch from conventional tillage to no-till is often a prerequisite for the installation of cover crops and, therefore, is recommended for all fields in the watershed where conventional or reduced tillage is occurring.

Cover crops should be established as soon as practical prior to or after harvest of the production crop. (i.e. before or after harvest). Cover crop species should be selected for their ability to effectively utilize nutrients. Terminate the cover crop as late as practical to maximize plant biomass production and nutrient uptake. Practical considerations for the termination date may include crop insurance criteria, the amount of time needed to prepare the field for planting the next crop, weather conditions, and cover crop effects on soil moisture and nutrient availability to the following crop. If the cover crop will be harvested for feed (hay/balage/etc.), choose species that are suitable for the planned livestock, and capable of removing the excess nutrients present.

Total phosphorus runoff can be reduced 50% with cover crops planted on highly erodible Illinois soils currently in reduced mulch or no-till according to the Illinois Nutrient Reduction Strategy (IEPA, 2015). The Midwest Cover Crop Council (http://mccc.msu.edu/) maintains a decision support tool (http://mccc.msu.edu/covercroptool/covercroptool.php) and mobile app (http://mccc.msu.edu/midwest-cover-crops-field-guide-mobile-app/) to help select cover crops according to crop, soil drainage characteristics, and desired goals. For Fulton County, representative cover crops rated as excellent for minimizing erosion on moderately well drained soils include winter rye and wheat, ryegrass, and a 50:50 mixture of hairy vetch and oats.

Researchers at the University of Illinois, Department of Agricultural and Consumer Economics recently provided some examples on the cover crop costs and benefits, *Cost and Benefits of Cover Crops: An example with Cereal Rye* (http://farmdocdaily.illinois.edu/2016/07/costs-and-benefits-of-cover-crops-example.html) where their estimate to establish 30 pounds of cereal at $0.25 per pound costs $20.60 per acre. Further information on using cover crops in corn-soybean rotations can be found in a publication by Kladivko (2015) titled *Managing Cover Crops: An Introduction to Integrating Cover Crops into a Corn-Soybean Rotation.*

Nutrient Management

Nutrient management is defined as managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments (IL-NRCS, 2015b). The Illinois Fertilizer and Chemical Associations (https://ifca.com/) 4R nutrient stewardship program (https://ifca.com/4R/Code) promulgates nutrient management education and outreach under the slogan, "*Right Source, Right Rate, Right Time, and Right Place*". The right source refers to matching the type of fertilizer to crop needs, the right rate to matching the amount applied to crop needs, the right time to making nutrients available when crops need them, and right place to keeping nutrients where plants can use them. The tool is a combination of agronomics of nitrogen-rate research and the realities of economic variability by providing a customized nitrogen rate. Chapters 8 and 9 of the *Illinois*

Agronomy Handbook (http://extension.cropsciences.illinois.edu/handbook/pdfs/chapter08.pdf & http://extension.cropsciences.illinois.edu/handbook/pdfs/chapter09.pdf) provide guidelines for nutrient management and fertilizer application rates based on the inherent properties of the soil (typical regional soil phosphorus concentrations, root penetration, pH, etc.), the starting soil test phosphorus concentration for the field, and the crop type and expected yield. The handbook notes that Fulton, McDonough and Schuyler Counties lay in the "high sub-soil phosphorus supplying power region of Illinois, which means that less P fertilizer is required for optimal crop yields than elsewhere in the State. Near-maximal corn and soybean yields are obtained if available phosphorous levels are maintained at 40 lbs/acre, while considerably higher levels, about 60 lbs/acre, are required for maximum wheat and oat yields. If available phosphorus levels are above 60 lbs/acre then there is no agronomic advantage to applying phosphorus fertilizer. In fact, Illinois studies have shown that if available P is at 60 lbs/acre or greater, yields are maintained for at least 4 years without any phosphorus application. If available phosphorus levels are between 40 and 60 lbs/acre, phosphorus fertilizer should be applied only in amounts necessary to replace amounts removed by the crop, which are 0.43, and 0.85 lbs/bushel (as P_2O_5) for corn and soybeans, respectively. This is termed maintenance fertilization. If available phosphorus levels are below 40 lbs/acre, then levels must be built back up to the desired level, and to replace what the crop will remove. Consult figures 8.4 and 8.5 in the Illinois Agronomy Handbook for a graphical representation of the above information.

Available phosphorus levels can also vary spatially within a given field in which case variable rate application can be used to place more or less phosphorus as needed to build-up or maintain adequate levels. Studies have also shown that subsurface placement of phosphorus fertilizer reduces phosphorus runoff, and can increase crop yields, as compared to surface broadcast treatment. In one recent Illinois study, phosphorus uptake rates for corn were 24% greater with strip-till subsurface phosphorus application, relative to no-till broadcast application (Fernandez and White, 2012). The overall goal of phosphorus reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with outputs in crops and grasslands as well as managing the level of phosphorus in the soil. Reducing phosphorus loss in runoff may be brought about by source and transport control measures, such as filter strips or riparian buffers (discussed above).

Nutrient management plans must account for all inputs and outputs of phosphorus to determine reductions. Included should be a statement that the plan was developed based on requirements of the current standard and any applicable Federal, state, or local regulations, policies, or programs, which may include the implementation of other practices and/or management activities. Changes in any of these requirements may necessitate a revision of the plan. The following components shall be included in the nutrient management plan:

- Review of aerial photography and soil maps
- Regular soil testing (the IAH recommends soil testing every four years)
- Review of current and/or planned crop rotation practices
- Yield goals and associated nutrient application rates
- Nutrient budgets with the right rate, place, time and source of application
- Identification of sensitive areas and restrictions on application when land is snow covered, frozen or saturated

Streambank and Shoreline Erosion

Since much of the classified HEL acreage in the Sugar Creek watershed is located near stream corridors (Figure 16), streambank erosion is likely a contributor of TP. Hence, BMP efforts should address this source as well. These efforts can be broadly defined as treatments to stabilize and protect banks of streams or constructed channels and shorelines of lakes or reservoirs (IL-NRCS, 2012b). Streambank erosion is a natural process. However, in agricultural areas increased runoff from croplands and/or channelization result in increased flows and correspondingly increased sediment loads, resulting in severe erosion. Such severely eroding streambanks can contribute 30-50 per cent of the sediment entering waterbodies from all sources (IEPA, 2015).

Before selecting a specific BMP it is first necessary to identify the cause of the erosion problem. Otherwise, a given BMP could actually increase erosion. Additionally, consideration must be given to the velocity of the stream, depth of the stream at the BMP placement site, slope and height of the bank, and the soils contained in the bank (Iowa DNR, 2006). The channel evolution model of Schumm, Harvey, and Watson (1984) can be used to help determine the most appropriate BMPs for streambank erosion. In this model there are 5 stages of evolution a stream channel will go through if it is disturbed. Stage I is the initial channel condition, stage II is deepening of the channel through increased bed erosion, stage III is widening of the channel through increased bank erosion, stage IV is the building of a new floodplain and the onset of stabilization, and stage V is the return to a new stable condition. If a channel is in a stage I or V condition, minimally invasive BMPs such as planting of willow posts or other types of vegetation along with erosion netting may be sufficient. Effective stage II BMPs to mitigate channel bed erosion includes the placement of rock riffles to slow water velocity and “stair step” water down steeper grades. Effective stage III channel BMPs include bendway weirs, which are in stream low rock structures placed at angles upstream of outside bends. A well placed series of bendway weirs direct water away from eroding streambanks. Stream barbs are another type of low rock structures which act to direct flow away from erodible streambanks. Stage IV channel BMPs should be directed toward the establishment of vegetation to prevent excessive widening of the floodplain. One such practice is stone toe protection which involves the placement of stone structures which are peaked toward the bank thus stabilizing the bank and aiding the establishment of bankside vegetation. A good source of understanding and information about streambank restoration practices is the *Federal Stream Corridor Restoration Handbook* (NEH-653) located on the USDA-Natural Resources Conservation Service webpage (FISRWG, 1998):
https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043244 .

9.2.2 Atrazine

Atrazine is applied to agricultural land, specifically for corn in the watershed. Surface runoff to tributaries, tile drainage and atmospheric deposition are the dominant nonpoint sources that deliver atrazine to lakes. Some nonpoint source BMPs, presented in Section 9.2.3, that could be utilized are careful pesticide application practices and controlling runoff. Fields closer to surface water bodies can be prioritized for BMP adoption.

9.2.2.1 Application and Best Management Practices for Atrazine

Pesticide Application Practices

Pesticides are most susceptible to runoff during the first several hours after application. Therefore delaying of herbicide application if heavy rain is forecast is important. Applications should be delayed as long as the soils are saturated and more rain is predicted (Purdue 2004). Atrazine should not be applied within 50 feet of abandoned/current wells, drainage wells or sinkholes. This applies to drinking water wells, irrigation wells, livestock water wells, abandoned wells and agricultural drainage wells. Atrazine should not be applied within 66 feet of the points where field surface water runoff enters streams or rivers. This applies to both perennial and intermittent streams. The USGS maps show perennial streams as solid blue lines and intermittent streams as dashed blue lines (https://viewer.nationalmap.gov/advanced-viewer/). You should not apply within 200 feet around a lake or reservoir. Filter strips are recommended around lakes. Atrazine should not be mixed or loaded within 50 feet of any waterbody. Also, atrazine cannot be applied within 66 feet of a tile inlet in terraced fields unless atrazine is incorporated and or greater than 30 percent residue is present. A 66 foot filter strip is recommended around the outlet.

For pre-emergent application in highly erodible soils, a maximum of 2 pounds per acre of atrazine can be sprayed on fields with 30 percent or more of plant residue or 1.6 pounds where there is less than 30 percent plant residue. For pre-emergent application on soils not highly erodible, a maximum of 2 pounds of atrazine can be used. For post-emergent application, if there was no pre-application, a maximum of 2 pounds can be used per acre. The total amount of atrazine applied to a field may not exceed 2.0 pounds of active ingredient in a single pre- or post-emerge application or 2.5 pounds (pre- and post-emergence combined) per acre per calendar year. Applying post emergent can reduce rates up to 75 percent (McKenna and Czapar 2009). Atrazine rates are reduced 30 to 75 percent if application is delayed until the weeds emerge because the herbicide can be placed directly on the weed foliage, which is preferable to relying on uptake from the soil (Purdue 2004). Because there is a narrower window of opportunity for application, fields with greatest runoff potential can be targeted for post emergence application. For additional information on atrazine application information, refer to:

- *Recommended Atrazine Best Management Practices for Surface Water Quality, NRCS* (http://www.nda.nebraska.gov/pesticide/atrazine_bmp_handout.pdf *)*
- *Water Quality Best Management Practices for Atrazine,* (https://mda.state.mn.us/sites/default/files/inline-files/bmpsforatrazine.pdf)
- *Managing to Minimize Atrazine Runoff* (https://www.coffey.k-state.edu/crops-livestock/crops/conservation/Managing%20to%20Minimize%20Atrazine%20Runoff.pdf)

Controlling Runoff

Leaving crop residue on the fields and no-till agriculture can reduce pesticide runoff over conventional tillage. The residue slows the movement of water across the field and can increase infiltration. According to county wide statistics, almost half of the corn acres are farmed conventionally. Other watershed plans in Illinois (i.e. Spring Lake and Lake Carlinville) estimate that changing from conventional to no- till will have the largest reduction in phosphorus for the watershed. So this practice could not only reduce phosphorus and total suspended solids, but atrazine also. This practice has the lowest costs of any practice in the watershed. Other practices to control runoff are terraces, contour farming and grade stabilization. Also allowing soils to dry before tilling or other operations can help reduce compaction and allow better infiltration.

Conservation practices such as buffers and riparian corridors can be used to control runoff. The ground has the filtering capacity to drain water and adsorb atrazine. Buffers implemented along stream segments and around waterbodies slow and filter nutrients, pesticides and sediment out of runoff. Greater biological activity in a soil improves its ability to effectively deal with pesticides and pollutants, and that is more prevalent in a soil rich in plant roots and organisms (Grismer 2006). A recent study in

Iowa indicated a 28 to 35 percent removal for the pesticide atrazine for a 15-foot long filter, compared to a 51 to 60 percent removal for a 30-foot filter (Lee et al, 1998).

Riparian buffers, including both the stream channel and adjacent land areas, are important components of watershed ecology. Preserving natural vegetation along stream corridors and around waterbodies can effectively reduce water quality degradation associated with development. The root structure of the vegetation in a buffer enhances infiltration of runoff and subsequent trapping of nonpoint source pollutants. However, the buffers are only effective in this manner when the runoff enters the buffer as a slow moving, shallow "sheet;" concentrated flow in a ditch or gully will quickly pass through the buffer offering minimal opportunity for retention and uptake of pollutants.

Table 19. Filter Strip Flow Lengths Based on Land Slope

Percent Slope	**0.5%**	**1.0%**	**2.0%**	**3.0%**	**4.0%**	**5.0% or greater**
Minimum (feet)	36	54	72	90	108	117
Maximum (feet)	72	108	144	180	216	234

Table 19 above outlines the guidance for filter strip flow length by slope (NRCS 1999). There are areas within the watershed that could be converted to buffer strips. Landowners and property managers should evaluate the land near tributaries and surrounding the lake and consider installation of filter strips according to the NRCS guidance. Programs available to fund the construction of these filter strips are discussed in Section 9.4.2 and 9.4.3. According to the atrazine label, atrazine should not be applied within 66 feet of where field surface water runoff enters streams or rivers or within 50 feet of a waterbody. Using GIS, a buffer can be geoprocessed around the stream shapefile. This buffer area could be used as a filter strip or riparian corridor.

The following information and photos are taken from the Pesticide Environmental Stewardship website- *Using Buffers to Reduce Pesticide Runoff and Water Erosion* (https://pesticidestewardship.org/water/using-buffers-to-reduce-runoff , compiled by Cornell University Cooperative Extension:

Grassed waterway—*a natural or constructed vegetated channel that is shaped and graded to carry surface water at a non-erosive velocity to a stable outlet. Because of concentrated flow that normally occurs in waterways, sediment trapping and water infiltration can be minimal with large runoff events, but substantial with smaller events. Waterways are most effective in trapping sediment and dissolved chemicals when designed to spread concentrated water-flow over a vegetated filter adjacent to streams.*

Contour buffer strips—*strips of perennial vegetation alternated with wider cultivated strips that are farmed on the contour. Buffers are most effective in trapping pesticides when runoff enters uniformly as sheet-flow. Contour buffer strips are one of the most effective buffers to trap pesticides. There is less chance for concentrated flow and smaller areas of cultivated field deliver runoff directly to each strip within a relatively short distance compared to some edge-of-field buffers.*

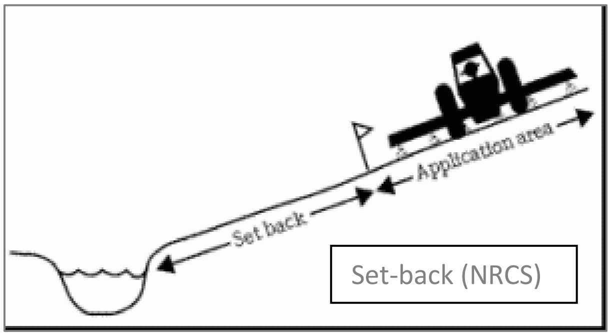
Vegetative barriers—*narrow, permanent strips of stiff stemmed, erect, tall, dense, perennial vegetation established in parallel rows and perpendicular to the dominant slope of the field. These barriers function similar to contour buffer strips and may be especially effective in dispersing concentrated flow, thus increasing sediment trapping and water infiltration.*

EDGE-OF-FIELD WATER BUFFERS:

Field borders—*a band or strip of perennial vegetation established on the edge of a cropland field. This buffer reduces pesticide runoff only when runoff flows over the strip. Even when no water flows over the strip, some water quality benefit may be gained because spraying operations are physically separated from adjacent areas, reducing drift and direct application to riparian areas.*

Filter strips—*areas of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants in runoff and to maintain or improve water quality. Filter strips are located between crop fields and water bodies. More pesticides can be removed by encouraging as much sheet-flow as possible across the strip and minimizing concentrated flow. This may be accomplished by combining filter strips with other conservation practices that control concentrated flow, such as vegetative barriers, level spreaders, or water bars.*

***Setbacks**—untreated areas where surface runoff enters streams. Some herbicide labels describe leaving these areas untreated. Seeding these areas to perennial grass improves herbicide trapping compared to trapping with untreated row crop.*



Set-back (NRCS)

***Riparian forest buffer**—an area of trees and shrubs located adjacent to streams, lakes, ponds, and wetlands. Forest buffers are often combined with perennial grass buffers. Woody vegetation provides food, and cover for wildlife, helps lower water temperatures by shading the water body, contributes energy sources to aquatic communities, protects stream banks, and slows out-of-bank flood flows. Deep tree roots may intercept nitrate, entering streams, in shallow subsurface flow and provide soil carbon for microbial energy. Microbes can degrade pesticides and denitrify nitrate (IL-NRCS, 2014).*

Buffers also provide streambank protection along with their filtering capacity. The rooting systems of the vegetation serve as reinforcements in streambank soils, which help to hold streambank material in place and minimize erosion. Due to the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during stormflow events. Thus, preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to streambank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that passes through the buffer. The increased organic matter in these corridors should increase adsorption of atrazine.

Converting land adjacent to waterbodies for the creation of riparian buffers will provide stream bank stabilization, stream shading, and nutrient uptake and trapping from adjacent areas. Minimum buffer widths of 25 feet are required for water quality benefits. Higher removal rates are provided with greater buffer widths. Riparian corridors typically treat a maximum of 300 feet of adjacent land before runoff forms small channels that short circuit treatment. In addition to the treated area, any land converted from agricultural land has the potential to reduce the amount of atrazine needed.

Treatment Plant Upgrade

The City of Vermont water treatment plant has not had a MCL violation for the last 20 years. Their water is obtained from Vermont City Reservoir (75.77 MG impoundment reservoir; original volume was 117 MG), fed potassium permanganate, flows by gravity (or can be pumped if lake is low) to WTP, fed polymer, discharged to the floculators, fed activated lime, carbon, and alum, flocculated, clarified (with tube settlers), filtered, discharged into a 100,000 gallon clear well, chlorinated, fluoridated and is pumped (via 2 HSPs which alternate), and discharged to the distribution system and 50,000 gallon elevated storage tank. Production Rates: low service pump - 350 gpm @ 20 feet TDH; total filter capacity is 350 gpm; high service pumps - 200 gpm @300 feet TDH each; backwash water pump - 630 gpm @ 46 feet TDH. The treatment is provided with 2 package plants operated in parallel. There are not recommendations for upgrades of the City of Vermont WTP plant.

Atrazine Reduction Success Stories

Following high atrazine levels in 1994, the local watershed committee for Lake Springfield encouraged practices such as buffer zones of plants and vegetation along stream banks, taking farmland out of production, rotating corn and soybeans and improved chemical- application practices. The treatment plant spent more than $600,000 on powdered activated carbon from 1994 to 2003 to reduce atrazine. The yearly amount for treatment has decreased since atrazine levels in the watershed have decreased. The Lake Springfield Watershed Resources Planning Committee is made up of water treatment plant staff, farmers, conservation and environmental advocates, business people and lake residents.

Atrazine Settlement Fund

On May 30, 2012, District Judge J. Phil Gilbert of the United States District Court for the Southern District of Illinois approved a $105 million class-action settlement the City of Greenville brought against Syngenta Crop Protection, Inc., and Syngenta AG (collectively, Syngenta) for the alleged contamination of community water supplies with atrazine. Information from the settlement is available in the court order: http://www.ilsd.uscourts.gov/opinions/ilsd_live.3.10.cv.188.2065985.0.pdf. Through the agreement between the parties, a Settlement Fund was created to allocate a fixed payment to the 2,000 U.S. Community Water Systems and then allocates the remainder of the Settlement Fund on a *pro-rata* basis based on evidence of the significance of the history of atrazine detection, size, and the age of each claim. The settlement ensures that each class member receives a portion of the settlement, while providing a proportionally larger share to those who are most affected by the presence of atrazine. The Settlement Fund is intended to be used to cover the costs associated with the purchase and operation of appropriate filtration systems to properly treat atrazine. Illinois' 143 water supplies that were part of the class-action settlement received a total of $15 million. The $15 million was not allocated to all Illinois water supplies to share, but that the total of each Illinois public water supply claim added up to $15 million, per the settlement agreement. The settlement does not interfere with the jurisdiction of any regulatory agency, and it preserves any claims from future point- source contamination and off-label use. Syngenta acknowledges no liability and continues to stand by the safety of atrazine. Settlement funds have been used for water treatment plant upgrades to reduce atrazine. In one small community, the funds were used to install a water pipe to a nearby non-impaired source, which was more cost effective than a plant upgrade.

9.3 Implementation Actions and Management Measures for Fecal Coliform in Sugar Creek

Section 5 of this report discussed fecal coliform data in the watershed. As indicated in Table 5-39, results for approximately 46% of the fecal coliform single samples were greater than the 200 cfu per 100 mL geometric mean water quality standard (compared for reference) and approximately 29% of the samples exceeded the 400 cfu per 100 mL maximum standard. The TMDL analyses performed for fecal coliform bacteria in Sugar Creek segment DH-01 (discussed in Section 8.3.3) show that exceedances have been reported for average monthly flows. Elevated fecal coliform concentrations reported during higher flow conditions are likely a result of stormwater runoff and re-suspension of instream fecal material. Elevated fecal coliform concentrations occurring under low flow conditions are likely a result of point source contributions, failed septic systems, livestock and other animals, and/or groundwater inputs.

9.3.1 NPDES Permitted Point Sources of Fecal Coliform

There are three NPDES permitted point sources in Sugar Creek watershed: Village of Astoria sewage treatment plant (STP), Village of Table Grove STP, and Village of Vermont water treatment plant (WTP). Table 5-42 shows the NPDES identification number and associated constituents monitored for these facilities. The Astoria and Table Grove STPs both have disinfection exemptions for their main STP outfalls. The facilities are located both on tributaries of the impaired segment and, in some cases, directly discharge effluent to the impaired stream segment.

Sewage from treatment plants treating domestic and/or municipal waste without disinfection processes contains fecal coliform. In Illinois, many of municipal treatment plants have applied for and received a disinfection exemption allowing the facility to discharge wastewater without disinfection. These treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use could occur in the receiving water, or where the water flows into a fecal coliform impaired segment. The extent of the receiving water segment is illustrated in Figure 5-52 for both facilities.

Facilities with year-round disinfection exemptions are now required to monitor and report fecal coliform counts from May to October to Illinois EPA. In addition, facilities directly discharging into a segment whose recreational use is impaired by fecal coliform may have their year-round disinfection exemption re-evaluated through future NPDES permitting actions.

Average discharge for permitted sewage treatment plants discharging into Sugar Creek watershed are shown in Table 16. WLAs for fecal coliform were calculated for each facility based on the 200 cfs/100mL geometric mean water quality standard and the facility's DAF and DMF. The TMDL uses the WLA calculated using the DMFs for moderate to high flow conditions and DAFs under low to moderate flow conditions. The WLA's are also shown in Table 16.

9.3.2 Nonpoint Sources of Fecal Coliform

Several TMDL approaches were identified in Section 6.1.6 to affect processes contributing to fecal coliform counts: season variation, direct deposition to streams, runoff from urban, agricultural and septic systems, and contributions from wildlife. To help reduce fecal coliform counts in the impaired segment of Sugar Creek (DH-01) management options will focus on the most likely sources of fecal coliform, such as agricultural runoff, septic systems, and livestock, and include the following:

Filter Strips

As mentioned in Section 9.2.3, filter strips can be used as a control to reduce both pollutant loads from runoff and sedimentation to impaired waterbodies. Filter strips have a similar benefit in reducing fecal coliform loads from nonpoint sources in the watershed. A 77 percent average reduction in fecal coliform concentration has been measured for feedlots (Mankin, et al., 2006).

Private Septic System Inspection and Maintenance Program

As indicated in Section 2.2, approximately 1 percent of the Sugar Creek watershed consists of developed or urbanized land. Many businesses, residences, and other structures in developed areas are served by a municipal sewer district and septic systems are uncommon in these areas. However, many households in rural areas of Illinois, as well as in some smaller townships, that are not connected to municipal sewers make use of onsite sewage disposal systems, or septic systems. It is estimated that there are between 589 and 738 septic systems within the Sugar Creek watershed and 7 in the Vermont City Reservoir watershed. The degree of nutrient removal in these systems is limited by soils and system upkeep and maintenance.

Failing or leaking septic systems can be a significant source of fecal coliform pollution. A program that actively manages functioning systems and addresses non-functioning systems could be implemented to reduce the potential bacteria loads from septic systems in the watershed. The USEPA has developed guidance for managing septic systems, which includes assessing the functionality of systems, public health, and environmental risks (USEPA 2005). It also introduces procedures for selecting and implementing a management plan.

To reduce the discharge of excessive amounts of contaminants from a faulty septic system, a scheduled maintenance plan that includes regular pumping and maintenance of the septic system should be followed. The majority of failures originate from excessive suspended solids, nutrients, and BOD loading to the septic system. Reduction of solids entering the tank can be achieved by limiting the use of garbage disposals.

Septic system management practices can extend the life, and maintain the efficiency, of a septic system. Water conservation practices, such as limiting daily water use or using low flow toilets and faucets, are the most effective methods to maintain a properly functioning septic system. Additionally, septic systems should not be used for the disposal of solids, such as cigarette butts, cat litter, cotton swabs, coffee grounds, disposable diapers, etc. Physical damage to the drain field can be prevented by:
Maintaining a vegetative cover over the drain field to prevent erosion
Avoiding construction over the system
Protecting the area down slope of the system from excavation
Landscape the area to divert surface flow away from the drain field (Johnson 1998)

The cost of each management measure is highly variable and site-specific data on septic systems and management practices do not exist for the watershed; therefore, homeowners with septic systems should contact their county health department for septic system management costs.

Current protocols for addressing failing septic systems in the rural areas noted above should adhere to the Illinois Private Sewage Disposal Licensing Act and Code "to prevent the transmission of disease organisms, environmental contamination and nuisances resulting from improper handling, storage, transportation and disposal from private sewage disposal systems". Any new, replaced, or renovated system must be installed by a licensed contractor or the homeowner and permitted through the county health department. The department must receive both an application for permit and the appropriate fee from the contractor/homeowner. Once reviewed and approved, a permit is issued and an inspection of the system is conducted during and after construction. The county health department also investigates private sewage disposal system complaints.

A long-range solution to failing septic systems is connection to a municipal sanitary sewer system. Connection to a sanitary sewer line would reduce existing fecal coliform sources by replacing failing septic systems with municipal treatment and will allow communities to develop without further contribution of pathogens. Costs for the installation are generally paid over a period of several years (average of 20 years) and help to avoid forcing homeowners to shoulder the entire initial cost of installing a new septic system. In addition, costs are sometimes shared between the community and the utility responsible for treating the wastewater generated from replacing the septic tanks. The planning process is involved and requires participation from townships, cities, counties, businesses, and citizens.

Animal Feeding Operations (AFOs)

In Illinois, an AFO is defined as a lot or facility (other than an aquatic animal production facility) where the following conditions are met:

- Animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and
- Crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

AFOs that do not meet the definition of a Concentrated Animal Feeding Operation (CAFO) are considered nonpoint sources by U.S. EPA and are not required to obtain NDPES permit coverage. However, they are subject to state livestock waste regulations and may be inspected by the Illinois EPA, either in response to complaints or as part of the Agency's field inspection responsibilities to determine compliance by facilities subject to water pollution and livestock waste regulations

The animals raised in AFOs produce manure that is stored in pits, lagoons, tanks and other storage devices. The manure is then applied to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. AFOs, however, can pose environmental concerns, including the following:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or ground water.
- Manure over application can adversely impact soil productivity.

Bacteria and nutrients are typically found in AFO discharges.

Restrict Livestock Access

Livestock are potential sources of bacteria and nutrients to streams, particularly when direct access is not restricted and/or where feeding structures are located adjacent to riparian areas. Watershed specific data are not available for livestock populations. However, county wide data available from the USDA-National Agricultural Statistics Service, Census of Agriculture (USDA-NASS 2007, 2012) were downloaded for the three counties (Fulton, McDonough, and Schuyler) in the Sugar Creek watershed (Tables 5-54, 5-55, 5-56) and are presented only as an estimated representation of the watershed. As discussed in Section 5.4.2.2 animal population has fluctuated between 2002 and 2007. Over the three counties, cattle/calve and poultry population has decreased. However, large dairy increases occurred in Fulton County (349%) and hogs and pigs increased in McDonough County (419%).

It is unknown to what extent livestock have access to Sugar Creek or its tributaries. Cattle and horses on pasture or feedlots were commonly observed by project field personnel in the upstream portion of the Sugar Creek watershed. Reduction of livestock access to streams, however, is recommended to reduce bacteria loads and limit damage to streambanks. Access of livestock and other animals to streams can increase bank erosion, trample filter strips and riparian buffers causing short circuiting of pollutant treatment, and provide direct input of manure to the waterbody. Exclusion or restricting pet, livestock, and wildlife access to streams with fencing helps reduce pollutant loads. The USEPA found that livestock exclusion from waterways and other grazing management measures were successful in reducing fecal coliform counts by 29 to 46 percent (2003).

Fencing, stream crossings, and alternate watering systems are effective ways to restrict livestock from streams; however, fencing emplacement is not always feasible from either a cost or animal management viewpoint. If used, fencing should be placed outside of the filter strip/riparian area to prevent manure from being entrained during flooding. Another option is to limit access of people to areas of the waterbody; this indirectly keeps a large percentage of waste at a distance from the waterbody. Waterfowl are an issue for phosphorus and fecal coliform loading at lakes and slow moving streams. Acoustic devices and other repellants can be used to stress nuisance waterfowl so they avoid congregating in select areas.

9.4 Reasonable Assurance

Reasonable assurance means that a demonstration is given that nonpoint source reductions in the Sugar Creek and Vermont City Reservoir watershed will be implemented. It should be noted that all programs discussed above are voluntary and some may currently be in practice in the watershed. The discussion in Section 9.2 provides information on available BMPs for reducing phosphorus and atrazine loads from nonpoint sources in Vermont City Reservoir watershed. Section 9.3 provides information on available management measures for reducing fecal coliform in Sugar Creek watershed. The remainder of this section presents an estimate of costs for implementing nonpoint source management practices, and programs available to assist with funding those BMPs.

9.4.1 Cost Estimate of BMPs

Cost-share and incentive programs at the state and federal level are available to landowners, homeowners, and farmers to help offset costs of implementing many of the BMPs recommended in this report. Some of these programs are discussed below. When reviewing the programs, it should be noted that some of the programs are only meant to provide incentives to encourage operators or landowners to try the practice. These incentive programs are not intended to cover the entire cost associated with implementing a practice. Additionally, some practices have many variables to consider that will affect both the cost of the program and the incentive or cost-share amount to be received.

Most of the State of Illinois (Section 9.3.3) and Federal (Section 9.3.4) BMP program information summarized below is taken from the *Illinois Nutrient Loss Reduction Strategy* document (IEPA, 2015), which is available at, (https://www2.illinois.gov/epa/topics/water-quality/watershed-management/excess-nutrients/Pages/nutrient-loss-reduction-strategy.aspx).

9.4.2 State BMP Cost Share Programs

The FY2019 Soil and Water Conservation District (SWCD) Partners for Conservation (PFC), Practice Component List is presented in Table 20 and covers many of the nonpoint source BMPs recommended in previous sections. The Partners for Conservation is a long-term, state-supported initiative to protect natural resources and enhance outdoor recreational opportunities in Illinois. The PFC provides funding for agriculture-related programs in the form of cost share assistance for construction of projects that promote soil conservation and protect water quality, reduce soil erosion and improve water quality. Inquire at your county Soil and Water Conservation District on available PFC programs and opportunities. In general, the PFC program lists an average cost per unit for each BMP practice and SWCDs generally offer a 75% maximum payment on the average cost total of a practice. For example, the grassed waterway practice (412) lists an average cost of $3,525.73 with the 75% cost share of $2,439.55, and payment would not exceed this amount.

Table 20. FY2019 SWCD PFC Practice Component List with Average Costs

PFC Practice Component List FY 2019

Reference Page in Illinois Scenarios pdf	Practice	Component	Unit	Avg Cost
		SWCD PFC Practice Component List FY2019		7/10/2018
109	329A	No-till	AC	$20.81
109	329C	Strip-till	AC	$20.81
102	327	Conservation Cover (Pollinator) Scenario 5 Monarch Species Mix	AC	$511.67
121	340A	Cover Crops	AC	$85.24
124	340	Cover crops -Winter kill species (new)	AC	$48.24
126	342	Critical Area Planting	AC	$184.95
130	345	Mulch-till	AC	N/A
133	351A	Well Decommissioning (hand dug)	FT	$69.01
134	351A	Well Decommissioning (drilled)	FT	$8.12
136	356	Dike	CU/YD	$4.97
142	362	Diversions <2 CY/FT	FT	$3.61
216	393	Filter Strip	AC	$176.23
226	410	Pipe Drop, Smooth steel or CMP	SQ/FT	$13.93
229	410	Open Flow Drop Spillway (metal or reinforced concrete)	SQ/FT	$163.06
230	410	Rock Rip Rap	CU/YD	$75.30
232	410	Concrete Block Chute	SQ/FT	$10.75
233	412	Grassed Waterway	AC	$3,252.73
239	412	Grassed Waterway with checks	AC	$4,296.76
275	484	Mulching (Erosion Control Blanket)	AC	$8,045.52
292	512	Pasture+Hayland Planting(Applys to land not in pasture or hayland within the past 5 year	AC	$392.92
327	554	Drainage Water Management	AC	$9.55
338	570	Rain Gardens	SQ/FT	$10.00
351	587	Structure for Water Control	Each	$2,707.62
358	590A	Nutrient Management Plan	AC	$4.00
358	590B	Nutrient Management Plan Implementation	AC	$12.00
381	600	Terrace, Narrowbase <=9% Slopes, with Topsoiling	FT	$3.89
384	600	Terrace, Narrowbase >9% Slopes, with Topsoiling	FT	$4.22
388	604	Saturated Buffer	FT	$6.22
389	605	Denitrifying Bioreactor	CU/YD	$47.16
393	606	Sub-Surface Drain <=5 inch CPP	FT	$2.15
394	606	Sub-Surface Drain 6 inch CPP	FT	$2.59
395	606	Sub-Surface Drain 8 inch CPP	FT	$6.04
396	606	Sub-Surface Drain 10 inch CPP	FT	$7.98
397	606	Sub-Surface Drain 12 inch CPP	FT	$8.97
398	606	Sub-Surface Drain >=15 inch CPP	FT	$11.49
419	620	Underground Outlet 6in Diameter Pipe with Risers	FT	$3.59
420	620	Underground Outlet 8in Diameter Pipe with Risers	FT	$6.41
421	620	Underground Outlet 10in Diameter Pipe with Risers	FT	$9.33
422	620	Underground Outlet >=12in Diameter Pipe with Risers	FT	$12.10
423	620	Underground Outlet - Blind inlet	FT	$61.46
447	638	Water & Sediment Control Basin - Narrow Base	FT	$2.51
446	638	Water & Sediment Control Basin - Farmable	FT	$6.14
482	656	Constructed Wetland	AC	$10,225.89
	*	"Maintain Soil below T"	AC	N/A
	NOTE: * Applies to multiple practices			

Section 319

Section 319 is a grant program under the Clean Water Act (33 U.S.C. 1329) that disburses funds to states with approved non-point source management plans. States in turn can competitively award grants to qualified applicants to support non-point source pollution control.

Through technical and financial assistance, and to facilitate the planning process, the Illinois Environmental Protection Agency encourages the development of watershed-based plans consistent with current watershed planning principles.

The long-term goals of the Program as listed in the latest State of Illinois Section 319 Biannual Report (IEPA, 2018) are: 1) The restoration and protection of all beneficial uses of Illinois' surface and groundwater resources from non-point source pollution. This goal will be achieved through watershed based assessment, planning, implementation, and education activities carried out as part of an effective and efficient process that employs both regulatory and non-regulatory programs, agencies, authorities, and stakeholders, 2) The prioritization and targeting of impaired waterbodies for the selection and implementations of non-point pollution control measures so as to efficiently and expeditiously restore and protect the full support of their designated uses, 3) Effective communication, coordination, collaboration, and education among all partners and stakeholders involved in NPS pollution control, 4) The refinement and development of monitoring and assessment tools to better determine NPS pollution impairments, including nutrient impacts on Illinois waters.

IEPA receives federal funds through section 319(h) of the Clean Water Act to help implement Illinois' Nonpoint Source Pollution Management Program. The purpose of the program is to work cooperatively with local units of government and other organizations toward the mutual goal of protecting the quality of water in Illinois by controlling nonpoint source pollution. The program emphasizes funding for implementing cost-effective corrective and preventative BMPs on a watershed scale; funding is also available for BMPs on a non-watershed scale and the development of information/education nonpoint source pollution control programs.

The maximum federal funding available is 60 percent, with the remaining 40 percent coming from local match. The program period is two years unless otherwise approved. This is a reimbursement program. Funding is directed toward activities that result in the implementation of appropriate BMPs for the control of nonpoint source pollution or to enhance the public's awareness of nonpoint source pollution. Priorities include the development of watershed-based plans and implementation of those plans. Approximately $3,000,000 is available in this program per year Applications are accepted June 1 through August 1 of each year (https://www2.illinois.gov/epa/topics/water-quality/watershed-management/nonpoint-sources/Pages/grants.aspx).

State Revolving Fund

Funding for non-point source pollution control projects, including agricultural sources, is available through the State Revolving Fund loan program as a result of recent eligibility expansions under the Clean Water Initiative (Public Act 98-0782) designed to address stormwater runoff, which can contribute to nutrient loading in Illinois waters (https://www2.illinois.gov/epa/topics/grants-loans/state-revolving-fund/Pages/default.aspx).

Conservation Reserve Enhancement Program

The Illinois Conservation Reserve Enhancement Program (CREP) is a state incentive program tied to the U.S. Department of Agriculture (USDA) Federal Conservation Reserve Program (CRP). CREP achieves long-term environmental benefits by allowing acres of eligible environmentally-sensitive land within the Illinois and Kaskaskia River watersheds to be restored, enhanced, and protected over periods ranging from 15 years to perpetuity. The Sugar Creek and Vermont City Reservoir watershed lies within the Illinois River watershed and hence watershed landowners are eligible for this program. CREP is driven by locally-led conservation efforts, as evidenced by increased landowner support, and employs a variety of BMPs to protect and restore riparian corridors. This program is a prime example of how partnerships between landowners, governmental entities, and non-governmental organizations can work to address watershed quality concerns.

CREP is one of many tools used by the Illinois Department of Natural Resources (INDR) and its conservation partners to implement the Illinois Comprehensive Wildlife Action Plan, which provides a framework for restoring critical habitats, increasing plant diversity, and expanding habitats for species in greatest need of conservation in a predominately agricultural landscape. More information about the program can be found at: https://www.dnr.illinois.gov/conservation/CREP/Pages/default.aspx.

Partners for Conservation Cost-Share

The Illinois Department of Agriculture (IDOA) administers several initiatives promoting advanced nutrient management, conservation tillage, and the use of cover crops (https://www2.illinois.gov/sites/agr/Resources/Conservation/Pages/default.aspx). "The Partners For Conservation Program provides funding for the following agriculture-related programs: the sustainable agriculture grant program, the conservation practices cost-share program, the stream bank stabilization and restoration program, and the soil and water conservation district grants program." These programs reduce soil erosion, sedimentation, and nutrient runoff, leading to improved water quality. IDOA's Partners for Conservation (PFC) cost-share program provides funding for the implementation of cultural (e.g., no-till and cover crops) and structural (e.g., grassed waterways and terraces) conservation practices. The program provides financial assistance to Illinois soil and water conservation districts (SWCDs) to provide technical assistance to eligible landowners carrying out BMPs that will benefit the environment.

The 97 local SWCDs throughout Illinois play a key role in fostering locally-led conservation work in rural and urban areas. They conduct outreach to increase public awareness of the importance of natural resource conservation. In addition, they hold landowner signups to build conservation projects and prioritize project proposals for funding based on the environmental benefits. Their technical staff provides landowners conservation practice design and construction oversight. The SWCDs are a very important asset in the delivery of IDOA's soil and water conservation programs to rural and urban customers. They also assist the USDA Natural Resources Conservation Service (NRCS) in the construction of conservation projects through various programs authorized by the U.S. Farm Bill.

Conservation practices eligible for cost-share assistance through PFC include terraces, grassed waterways, filter strips, water and sediment control basins, grade stabilization structures, crop residue management, cover crops, and nutrient management plans. A total of 6,733 PFC projects were completed by landowners from 2006-2012. Although the state's portion of the cost of these projects totaled almost $17 million, this amounts to approximately 50 percent of the cost of construction, with a little less than half of the cost contributed by landowners. These projects reduced soil erosion on 68,088 acres of cropland.

Streambank Stabilization and Restoration Program

In an effort to stabilize and restore severely eroding stream banks that would otherwise contribute sediment to the state's rivers and tributaries, IDOA with, assistance from SWCDs, administers the Streambank Stabilization and Restoration Program (SSRP) under the Partners for Conservation Program (https://www2.illinois.gov/sites/agr/Resources/Conservation/Pages/default.aspx). This cost-share program provides up to 75% of the construction cost for eligible and approved projects. The program has 3 primary objectives:

1. Provide funding to construct effective, low-cost practices, such as rock riffles, stream barbs or stone toe protection at suitable locations.
2. Provide technical assistance to landowners interested in stabilizing an eroding streambank.
3. Distribute education materials on the effects of streambank erosion along with the practices available to stabilize the erosion through SSRP.

Severely eroding stream banks can contribute as much as 30-50 percent of the sediment entering waterways from all sources. The SSRP, funded under PFC, provides funds to construct low-cost techniques to stabilize eroding stream banks. During 2004-2012, 58 miles of eroding stream banks were stabilized, resulting in a 61,389 ton reduction in sediment delivery. Loading of nitrate-nitrogen was also reduced by 107,214 lb and total phosphorus by 57,308 lb (IEPA, 2015).

9.4.3 Federal Cost Share BMP Programs

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary cost share program originally authorized under the 1996 Farm Bill (Pub. L. 104-127) and re-authorized in the 2014 Farm Bill (Pub. L. 113- 79). The 2018 Farm Bill is currently in the process of re-authorization. Sixty per cent of EQIP funds must be used for livestock practices. Eligible program participants receive financial and technical assistance to implement conservation practices or activities such as conservation planning that address natural resource concerns on their land. NRCS staff works with applicants to develop an EQIP plan of operations that identifies the appropriate conservation practices needed to address identified natural resource concerns. The following national priorities, consistent with statutory resources concerns that include soil, water, wildlife, air quality, and related natural resource concerns, may be used in EQIP implementation:

1. Reductions of nonpoint source pollution, such as nutrients, sediment, pesticides, or excess salinity in impaired watersheds consistent with total maximum daily loads (TMDL) where available; the reduction of surface and groundwater contamination; and the reduction of contamination from agricultural sources, such as animal feeding operations
2. Conservation of ground and surface water resources
3. Reduction of emissions, such as particulate matter, nitrogen oxides, volatile organic compounds, and ozone precursors and depleters that contribute to air quality impairment violations of National Ambient Air Quality Standards
4. Reduction in soil erosion and sedimentation from unacceptable levels on agricultural land
5. Promotion of at-risk species habitat conservation including development and improvement of wildlife habitat
6. Energy conservation to help save fuel, improve efficiency of water use, maintain production, and protect soil and water resources by more efficiently using fertilizers and pesticides and
7. Biological carbon storage and sequestration

In addition, Illinois has identified the following priorities:

1. Improve soil health by adding organic matter, reducing compaction, and promoting soil organisms.
2. Reduce soil erosion by managing water runoff and increasing plant residue.
3. Improve water quality by reducing the sediments, nutrients and other contaminates from entering Illinois waterways.

Applications for EQIP are accepted on a continuous basis, and NRCS establishes submission deadlines for evaluation and ranking of eligible applications. Applications are ranked based on a number of factors, including the environmental benefits and cost effectiveness of the proposal. Payments are made to participants after the conservation practices and activities identified in the plan are implemented. Contracts can last up to 10 years.

Environmental Quality Incentives Program (EQIP) payment rates applicable to Illinois for fencing to restrict livestock from streams noted in Section 9.3.2-*Nonpoint Sources of Fecal Coliform* range from $0.80-$1.89 per foot. Information on practices available for funding in Illinois can be found at, https://www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/financial/eqip/.

Conservation Stewardship Program

The Conservation Stewardship Program (CSP) helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.

The types of practices eligible for payments which enhance water quality or minimize soil erosion include: applying phosphorus fertilizer below the soil surface, applying fertilizer no more than 30 days prior to planting, variable rate application of fertilizers, applying enhanced efficiency fertilizers, intensive no-till practices, use of cover crop mixes, and intensive cover cropping.

Through CSP, participants can take additional steps to improve soil health, air and habitat quality, water quality and quantity, and energy conservation on their land. CSP provides two types of payments through five-year contracts: annual payments for installing new conservation activities and maintaining existing practices and supplemental payments for adopting a resource-conserving crop rotation. Producers may be able to renew a contract if they have successfully fulfilled the initial contract and agree to achieve additional conservation objectives. A person or legal entity may not receive more than$200,000 during fiscal years 2014 through 2018.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/financial/csp/

Conservation Reserve Program

The Conservation Reserve Program (CRP) is a voluntary land conservation program administered by the Farm Service Agency (FSA). In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in CRP are 10-15 years in length. The long- term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat. Enrollment is continuous and information about the CRP program is available at, (https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index)

A particularly relevant initiative for the Vermont City Reservoir watershed within the CRP program concerns HELs. In the Highly Erodible Lands Initiative, participating farmers and landowners will receive 10 years of annual rental payments, and 50% cost share for establishing grass or tree cover on HELs. As estimated in Section 9.2.1.2 above, approximately 241 acres of cropland within the Vermont City Reservoir watershed is HEL/PHEL and may qualify for this initiative.

CRP protects millions of acres of American topsoil from erosion and is designed to safeguard natural resources. By reducing water runoff and sedimentation, CRP protects groundwater and helps improve the condition of lakes, rivers, ponds, and streams. Acreage enrolled in the CRP is planted to resource-conserving vegetative covers, making the program a major contributor to increased wildlife populations in many parts of the country.

The Farm Service Agency (FSA) administers CRP, while technical support functions are provided by NRCS, USDA's Cooperative State Research, Education, and Extension Service, State forestry agencies, local soil and water conservation districts, and private sector providers of technical assistance. Producers can offer land for CRP general sign-up enrollment only during designated sign-up periods. Environmentally desirable land devoted to certain conservation practices may be enrolled at any time under CRP continuous sign-up. Certain eligibility requirements still apply, but offers are not subject to competitive bidding. Further information on CRP continuous sign-up is available in the FSA fact sheet "Conservation Reserve Program Continuous Sign-up" at https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index. It includes further producer, land and practice eligibility and payment information.

Conservation practices eligible for CRP funding which are recommended BMPs for this watershed TMDL include but are not limited to filter strips, grass waterways, and riparian buffers.

Easement Programs

NRCS offers voluntary easement programs to landowners who want to maintain or enhance their land in ways that are beneficial to the environment. The 2014 Farm Bill authorized the Agricultural Conservation Easement Program (ACEP) and the Healthy Forests Reserve Program (HFRP). ACEP provides financial and technical assistance to help conserve agricultural lands and related benefits. ACEP consolidates programs authorized by previous Farm Bills, including the Grassland Reserve Program and Farm and Ranch Lands Protection Program. Under ACEP, NRCS helps Indian tribes, state and local governments, and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. The easement component of HFRP helps landowners restore, enhance, and protect forestland resources on private lands through easements and financial assistance. Through HRFP, landowners can promote the recovery of endangered or threatened species, improve plant and animal biodiversity, and enhance carbon sequestration. https://www.nrcs.usda.gov/wps/portal/nrcs/il/programs/easements/acep/STELPRDB1247822/

Regional Conservation Partnership Program

This program, which competitively awards funds to conservation projects designed by local partners specifically for their region, was authorized in the 2014 Farm Bill. The Regional Conservation Partnership Program (RCPP) provides assistance to producers through partnership agreements and program contracts or easements. RCPP encourages partners to join in conservation efforts by leveraging RCPP funding for conservation activities in select project areas. Illinois has set priorities for water quality, soil health, and soil erosion for funding proposals. Additional RCPP information is available at, http://www.nrcs.usda.gov/wps/portal/nrcs/main/il/programs/farmbill/rcpp/

9.4.4 Local Program Information

Specific information related to the BMP programs available in Fulton, McDonough and Schuyler Counties may be obtained from the contacts given in Table 21 below.

Table 21. Fulton, McDonough and Schuyler County Contacts

Contact	Address	Phone
Fulton County SWCD Office		
Andrew Karrick	13118 North US Highway 24 Lewistown, IL 61542	(309)547-2215, Ext 3
McDonough County SWCD Office		
Cindy Moon	1607 W. Jackson St. Macomb, IL 61455	(309)833-1711, Ext. 3
Schuyler County SWCD office		
Jamie Kelly	10793 Old Macomb Rd. Rushville, IL 62681	(217)322-3359, Ext. 3

9.5 Monitoring Plan

The purpose of a monitoring plan is to assess the overall effectiveness of implementing the BMPs outlined in this chapter. This can be accomplished by the continued monitoring and future tracking of BMPs and other management actions implemented in the Vermont City Reservoir and Sugar Creek watersheds as well as the tributaries. This can be accomplished by conducting the monitoring programs designed to:

- Track implementation of BMPs in the watershed
- Estimate effectiveness of BMPs
- Further monitor point source discharges in the watershed
- Continued monitoring of impaired stream segments and tributaries
- Monitor storm-based high flow events, including atrazine
- Low flow monitoring of total phosphorus and fecal coliform in impaired streams

Tracking the implementation of management measures can be used to:

- Determine the extent to which management measures and practices have been implemented compared to action needed to meet the TMDL endpoints
- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
- Measure the extent of voluntary implementation efforts
- Support work-load and costing analysis for assistance or regulatory programs
- Determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be accomplished by monitoring before and after the BMP is incorporated into the watershed. For example, additional monitoring could be conducted on specific structural systems such as sediment control basins or riparian buffers. Inflow and outflow measurements could be conducted to determine site-specific TP removal efficiency.

The IEPA should also continue to monitor water quality at their stations within Vermont City Reservoir watershed and Sugar Creek watershed. The IEPA *Illinois Water Monitoring Strategy 2015-2020* (https://www2.illinois.gov/epa/Documents/epa.state.il.us/water/water-quality/monitoring-strategy/monitoring-strategy-2015-2020.pdf) presents their monitoring objectives and design for all their water quality monitoring programs along with the environmental indicators that will be used for assessing attainment of uses, identifying impairments, and determine how to restore impaired waters through 2020. This will provide needed information on the effectiveness of implemented management actions in the watersheds.

Illinois EPA conducts Intensive Basin Surveys every 5 years. Additionally, select ambient sites are monitored nine times a year. Continuation of this state monitoring program will assess lake and stream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the impaired segments are being attained.

9.6 Implementation Time Line

Implementing the actions outlined in this section for the Vermont City Reservoir and Sugar Creek Watersheds should occur in phases and the effectiveness of the management actions should be continually assessed as improvements are made. However, BMPs should begin to be implemented as soon as willing landowners are identified. Moreover, for many of the specific programs outlined above, enrollment is on a continuous basis, so interested landowners can begin implementation immediately.

In the case of TP, even if TP loading to Vermont City Reservoir was reduced by the TMDL endpoint of 70% instantaneously through effective BMP measures, it could take several decades for their full effect to be realized. This is because legacy phosphorus stores in the soils and stream courses of the watershed and bottom sediments of the reservoir itself can continue as phosphorus sources and hence delay water quality improvements (Sharpley et. al., 2013). Consequently, it will be important to document reductions in total phosphorus loading from tributaries over time, which should be more immediately observable as more BMP practices are implemented and maintained in the watershed, and distinguish those from in-lake water quality improvements, which may be slower to achieve.

10.0 References

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Appendix A: Methods to determine water quality concentrations for Vermont City Reservoir

Constituent Name	Concentration	Source or Method
TDS or Salinity	TDS = sqrt(66507.5 - 11180.3*ln(Qdaily_cm))	Relationship developed from CREP site 302
Suspended solids	TSS-VSS	Constituent/chemical balance
Phosphate	TP<1: 0.2199*TP^0.727 TP>1: 0.2111*TP^(-0.724)	Relationship developed from CREP site 302
Ammonium	0.06	median for 202 (mg/l)
Nitrate-Nitrite	43.5799 + 4.14261*ln(flow in cfs per ha)	Relationship developed from CREP site 302
Dissolved silica	dis silica = 2.75 + 2.5 exp (-flow in cm/day /1.1)	Estimate from literature values/other similar lakes
Particulate silica	25% TSS	Estimate from literature values/other similar lakes
Labile DOM	25% DOM	Estimate from literature values/other similar lakes
Refractory DOM	75% DOM	Estimate from literature values/other similar lakes
Labile POM	25% POM	Estimate from literature values/other similar lakes
Refractory POM	75% POM	Estimate from literature values/other similar lakes
Algae Group 1	2	Estimate from literature values/other similar lakes
Algae Group 2	2	Estimate from literature values/other similar lakes
Algae Group 3	2	Estimate from literature values/other similar lakes
Dissolved oxygen		100% saturation concentration at daily temperature
Inorganic Carbon	alkalinity * 12 / 50	Constituent/chemical balance
Alkalinity	intake data	Daily intake concentrations
Labile DOM-P	50% DOM-P	Estimate from literature values/other similar lakes
Refractory DOM-P	50% DOM-P	Estimate from literature values/other similar lakes
Labile POM-P	30% POM-P	Estimate from literature values/other similar lakes
Refractory POM-P	70% POM-P	Estimate from literature values/other similar lakes
Labile DOM-N	50% DOM-N	Estimate from literature values/other similar lakes

Refractory DOM-N	50% DOM-N	Estimate from literature values/other similar lakes
Constituent Name	**Concentration**	**Source or Method**
Labile POM-N	30% POM-N	Estimate from literature values/other similar lakes
Refractory POM-N	70% POM-N	Estimate from literature values/other similar lakes
POM	VSS - algae biomass	Constituent/chemical balance
DOM	2*POM	Constituent/chemical balance
temperature		Values developed from CREP site 302
TP		GWLF TP (monthly loads converted to daily)
TN	21.1848 + 1.81115*ln(flow in cfs per ha)	relationship developed for 202
TSS		GWLF TSS (monthly loads converted to daily)
VSS	0.5*TSS*MIN(IF(TSS>30,(0.280369 + 3.6829/TSS)^2,1/(0.271932 + 0.209574*TSS)),1)	Relationship developed from RDD-T2 site
OM-P	TP - Phosphate - P in algae	Constituent/chemical balance
DOM-P	0.016 * TP^(-0.935)	Relationship developed from CREP site 302
POM-P	OM-P - DOM-P	Constituent/chemical balance
OM-N	TN - NH4 - NO23 - N in algae	Constituent/chemical balance
DOM-N	Assume DOM-N/OM-N = DOM-P/OM-P	Constituent/chemical balance
POM-N	OM-N - DOM-N	Constituent/chemical balance

Appendix B: Methods to determine initial water quality concentrations in Vermont City Reservoir on 6/1/2000

Constituent Name	Initial Concentration	Data Source or Method
TDS or Salinity	284	Average of June 2000 intake concentrations
Suspended solids	11	Median of June lake concentrations, IEPA data
Phosphate	0.034	Median of June lake concentrations, IEPA data
Ammonium	0.217	Median of June lake concentrations, IEPA data
Nitrate-Nitrite	1.985	Median of June lake concentrations, IEPA data
Dissolved silica	5	Estimate from literature values/other similar lakes
Particulate silica	4.5	Estimate from literature values/other similar lakes
Labile DOM	3	25% DOM
Refractory DOM	9	75% DOM
Labile POM	3	50% POM
Refractory POM	3	50% POM
Algae Group 1	4.5	Estimate from literature values/other similar lakes, as chlorophyll a
Algae Group 2	10	Estimate from literature values/other similar lakes, as chlorophyll a
Algae Group 3	4.5	Estimate from literature values/other similar lakes, as chlorophyll a
Dissolved oxygen	8.72	100% saturation concentration at 22C
Inorganic Carbon	33.6	
Alkalinity	140	Average of June 2000 intake concentrations
Labile DOM-P	0.0099	50% DOM-P
Refractory DOM-P	0.0099	50% DOM-P
Labile POM-P	0.0049	30% POM-P
Refractory POM-P	0.0114	70% POM-P
Labile DOM-N	0.135	50% DOM-N
Refractory DOM-N	0.135	50% DOM-N
Labile POM-N	0.067	30% POM-N
Refractory POM-N	0.157	70% POM-N
POM	6	Median of June lake concentrations, IEPA data
DOM	12	2 x POM
temperature	22	Average of June 2000 intake temperatures
TP	0.108	Median of June lake concentrations, IEPA data
TN	3.305	Median of June lake concentrations, IEPA data
OM-P	0.036	TP-Phosphate-P in algae
DOM-P	0.020	Relationship developed from CREP site 302: 0.016 * TP^(-0.935)
POM-P	0.016	OM-P - DOM-P

OM-N	0.495	TN - NH4 - NO23 - N in algae
Constituent Name	**Initial Concentration**	**Data Source or Method**
DOM-N	0.271	Assume DOM-N/OM-N = DOM-P/OM-P
POM-N	0.224	OM-N - DOM-N

APPENDIX C: MAJOR COEFFICIENTS AND CONSTANTS USED IN THE CE-QUAL-W2 MODEL FOR VERMONT CITY RESERVOIR

Default values and/or representative example values provided by Cole and Wells (2002) are listed for comparison. NA= Not Applicable.

MODEL GRID SETUP; INFLOW/OUTFLOW STRUCTURES

Model Symbol	Description	Value	Default Value
NWB	Number of water bodies	1	NA
NBR	Number of branches	2	NA
IMX	Number of segments in the computational grid	17	NA
KMX	Number of layers in the computational grid	19	NA
NTR	Number of tributaries (minor tributaries are treated as distributed	0	NA
NSTR	Number structures (a single discharge structure at the dam)	0	NA
NWD	Number of withdrawals (a single drinking water withdrawal)	2	NA

TIME FACTORS

Model Symbol	Description	Value	Default Value
TMSTRT	Start time (1 Jun 2000)	153	NA
TMEND	End time (31 Dec 2013)	5144	NA
DLTMAX	Maximum time step (seconds)	3600	NA

HEAT EXCHANGE/ICE COVER

Model Symbol	Description	Value	Default Value
SLHTC	Equilibrium temperature computation (ET) for surface exchange	ET	NA
AFW	Intercept for wind-driven heat exchange function	9.2	9.2
BFW	Slope for wind-driven heat exchange function	0.46	0.46
CFW	Exponent of wind-driven heat exchange function	2.0	2.0
WINDH	Height of wind speed measurement (m)	10.0	NA
SLTRC	Transport solution scheme; ULTIMATE algorithm eliminates physically unrealistic over/undershoots due to longitudinal transport	ULTIMATE	ULTIMATE
THETA	Time-weighting for vertical advection	0.5	0.55
ICEC	Ice Cover Algorithm	ON	NA
ALBEDO	Albedo (Reflection/Incident)	0.25	0.25
HWICE	Coefficient of water-ice heat exchange	10.0	10.0
BICE	Fraction radiation absorbed by ice	0.6	0.6
GICE	Solar radiation extinction coefficient (m^{-1})	0.07	0.07
ICEMIN	Minimum ice thickness before ice formation (m)	0.05	0.03
ICET2	Temperature above which ice does not form (^{o}C)	3	3

HYDRAULICS

Model Symbol	Description	Value	Default Value
AX	Longitudinal Eddy Viscosity (m^2 sec^{-1})	1	1
DX	Longitudinal Eddy Diffusivity (m^2 sec^{-1})	1	1
CBHE	Coefficient of bottom heat exchange (W m^{-2} sec^{-1})	0.3	0.3
TSED	Temperature of the sediment (^oC)	14	10.0
FI	Interfacial friction factor	0	0.015
TSEDF	Heat from sediments added back to water	0	0-1
FRICC	Bottom friction	CHEZY	MANN
AZC	Form of vertical turbulence closure algorithm	W2	W2
AZSLC	Implicit (IMP) or Explicit (EXP) treatment of vertical eddy Viscosity	EXP	N/A
AZMAX	Maximum value for vertical eddy viscosity, (m^2sec^{-1})	1E-4	1E-3

HYDRAULIC STRUCTURE CHARACTERISTICS

Model Symbol	Description	Value	Default Value
KTSTR	Top water layer above which selective withdrawal will not occur through the intake structure of the power house draft tubes	NA	NA
KBSTR	Bottom layer below which selective withdrawal will not occur through the intake structure of the power house draft tubes	NA	NA
SINKC	Selective withdrawal algorithm for the intake structure of the power house draft tubes	NA	NA
ESTR	Centerline elevation of intake structure for the power house draft tubes (m)	NA	NA
IWD	Drinking water withdrawal structure; lake segment number	12	NA
EWD	Drinking water withdrawal structure centerline elevation (m)	177 & 176	NA
KTWD	Top water layer above which withdrawal will not occur through the drinking water intake structure	2	NA
KBWD	Bottom water layer below withdrawal will not occur through the drinking water intake structure	18	NA

LIGHT EXTINCTION and SUSPENDED SOLIDS

Model Symbol	Description	Value	Default Value
EXH2O	Extinction for pure water (m^{-1})	0.25	0.25 or 0.45
EXSS	Extinction due to inorganic suspended solids, (m^{-1}/gm^{-3})	0.1	0.1
EXOM	Extinction due to organic suspended solids, (m^{-1}/gm^{-3})	0.1	0.1
BETA	Fraction of solar radiation absorbed at water surface	0.45	0.45
EXA1	Extinction due to algal biomass#1, (m^{-1}/gm^{-3})	0.2	0.2
EXA2	Extinction due to algal biomass#2, (m^{-1}/gm^{-3})	0.2	0.2
EXA3	Extinction due to algal biomass#3, (m^{-1}/gm^{-3})	0.2	0.2
SSS	Suspended Solids Settling rate (m d^{-1})	2	1.0
SEDRC	Sediment resuspension control	OFF	OFF

ALGAL METABOLISM

Model Symbol	Description	Group 1 Diatoms	Group 2 Greens	Group 3 Cyano-bact.	Default Value
AG	Maximum Growth Rate (d^{-1})	1.0	1.0	1.0	2.0
AR	Respiration (d^{-1})	0.04	0.04	0.04	0.04
AE	Excretion (d^{-1})	0.04	0.04	0.04	0.04
AM	Mortality (d^{-1})	0.1	0.1	0.1	0.1
AS	Sinking Rate (m d^{-1})	0.1	0.05	0.02	0.1
AHSP	Half-saturation constant for P (mg/L)	0.004	0.004	0.004	0.003
AHSN	Half-saturation constant for N (mg/L)	0.014	0.035	0.001	0.014
AHSSI	Half-saturation constant for Si (mg/L)	0.002	0.002	0.002	0
ASAT	Light Saturation (W m^{-2})	150	125	145	75
Temperature					
AT1	Min temperature for growth (^{o}C)	0	10	15	5
AT2	Lower temp for max growth (^{o}C)	10	20	20	25
AT3	Upper temp for max growth (^{o}C)	20	30	30	35
AT4	Max temp for growth (^{o}C)	30	40	40	40
AK1	Fraction of algal growth rate at AT1	0.1	0.1	0.1	0.1
AK2	Fraction of max. algal growth rate at AT2	0.99	0.99	0.99	0.99
AK3	Fraction of max. algal growth rate at AT3	0.99	0.99	0.99	0.99
AK4	Fraction of algal growth rate at AT4	0.1	0.1	0.1	0.1
Stoichiometry					
ALGP	Algal P: Biomass ratio	0.005	0.005	0.005	0.005
ALGN	Algal N: Biomass ratio	0.08	0.07	0.08	0.08
ALGC	Algal C: Biomass ratio	0.45	0.50	0.45	0.45
ALGSI	Algal Si: Biomass ratio	0.18	0	0	0.18
ACHLA	Algal Biomass: Chlorophyll ratio	0.05	0.05	0.05	0.05
ALPOM	Fraction of biomass mortality converted to particulate organic matters	0.8	0.8	0.8	0.8
ANEQN	Ammonium preference factor**	2	2	2	2
ANPR	Half-saturation preference for Ammonia-Nitrate	0.001	0.001	0.001	0.001

ORGANIC MATTER PROCESSING

Model Symbol	Description	Value	Default Value
LDOMDK	Labile dissolved organic matter decay rate (d^{-1}	0.1	0.1
RDOMDK	Refractory dissolved organic matter decay rate(d^{-1})	0.001	0.001
LRDDK	Labile to refractory DOM decay rate (d^{-1})	0.005	0.01
LPOMDK	Labile particulate organic matter decay rate (d^{-1})	0.08	0.08
RPOMDK	Refractory particulate organic matter decay rate (d^{-1})	0.01	0.001
LRPDK	Labile to refractory POM decay rate (d^{-1})	0.001	0.01
POMS	Particulate organic matter settling rate (m d^{-1})	1	0.1
ORGP	P:OrgMatt ratio for labile organic matter	0.005	0.005
ORGN	N:OrgMatt ratio for labile organic matter	0.08	0.08
ORGC	C:OrgMatt ratio for dissolved and particulate organic matter	0.45	0.45
ORGSI	Si:OrgMatt ratio for dissolved and particulate organic matter	0.18	0.18
OMT1	Lower temperature for organic matter decay (^{o}C)	4	4
OMT2	Upper temperature for organic matter decay (^{o}C)	30	25
OMK1	Fraction of organic matter decay rate at OMT1	0.1	0.1
OMK2	Fraction of organic matter decay rate at OMT2	0.99	0.99

NUTRIENT CYCLING

Model Symbol	Description	Value	Default Value
PO4R	Phosphorus release from anaerobic sediments (fraction of SOD)	0.001	0.001
NH4R	Ammonium release from anaerobic sediments (fraction of SOD)	0.001	0.001
NH4DK	Ammonium decay rate (d^{-1})	0.12	0.12
NH4T1	Lower temperature for ammonia decay (^oC)	5.0	5.0
NH4T2	Lower temperature for maximum ammonia decay (^oC)	20.0	25.0
NH4K1	Fraction of nitrification rate at NH4T1	0.1	0.1
NH4K2	Fraction of nitrification rate at NH4T2	0.99	0.99
NO3DK	Nitrate decay rate	0.03	0.03
NO3S	Nitrate loss to sediments due to sediment denitrification (m d^{-1})	0.001	1.0
NO3T1	Lower temperature for nitrate decay (^oC)	5.0	5.0
NO3T2	Lower temperature for maximum nitrate decay (^oC)	25.0	25.0
NO3K1	Fraction of denitrification rate at NO3T1	0.1	0.1
NO3K2	Fraction of denitrification rate at NO3T2	0.99	0.99
DSIR	Dissolved silica sediment release rate, fraction of SOD	0.1	0.1
PSIS	Particulate Si settling rate (m d^{-1})	1.0	1.0
PSIDK	Particulate Si decay rate	0.3	0.3
PARTSI	Dissolved Si partitioning coefficient	0.0	0.0
FER	Fe release from anaerobic sediments (fraction of SOD)	NA	0.5
FES	Fe settling velocity (m d^{-1})	NA	2.0

CARBON DIOXIDE AND OXYGEN

Model Symbol	Description	Value	Default Value
CO2R	CO2 release from sediments (fraction of SOD)	1.2	0.1
O2NH4	Oxygen stoichiometry for nitrification	4.57	4.57
O2OM	Oxygen stoichiometry organic matter decay	1.4	1.4
O2AR	Oxygen stoichiometry for algal respiration	1.1	1.1
O2AG	Oxygen stoichiometry for algal primary production	1.6	1.4
O2LIM	O2 concentration below which anaerobic processes begin	0.1	0.1

SEDIMENT DYNAMICS

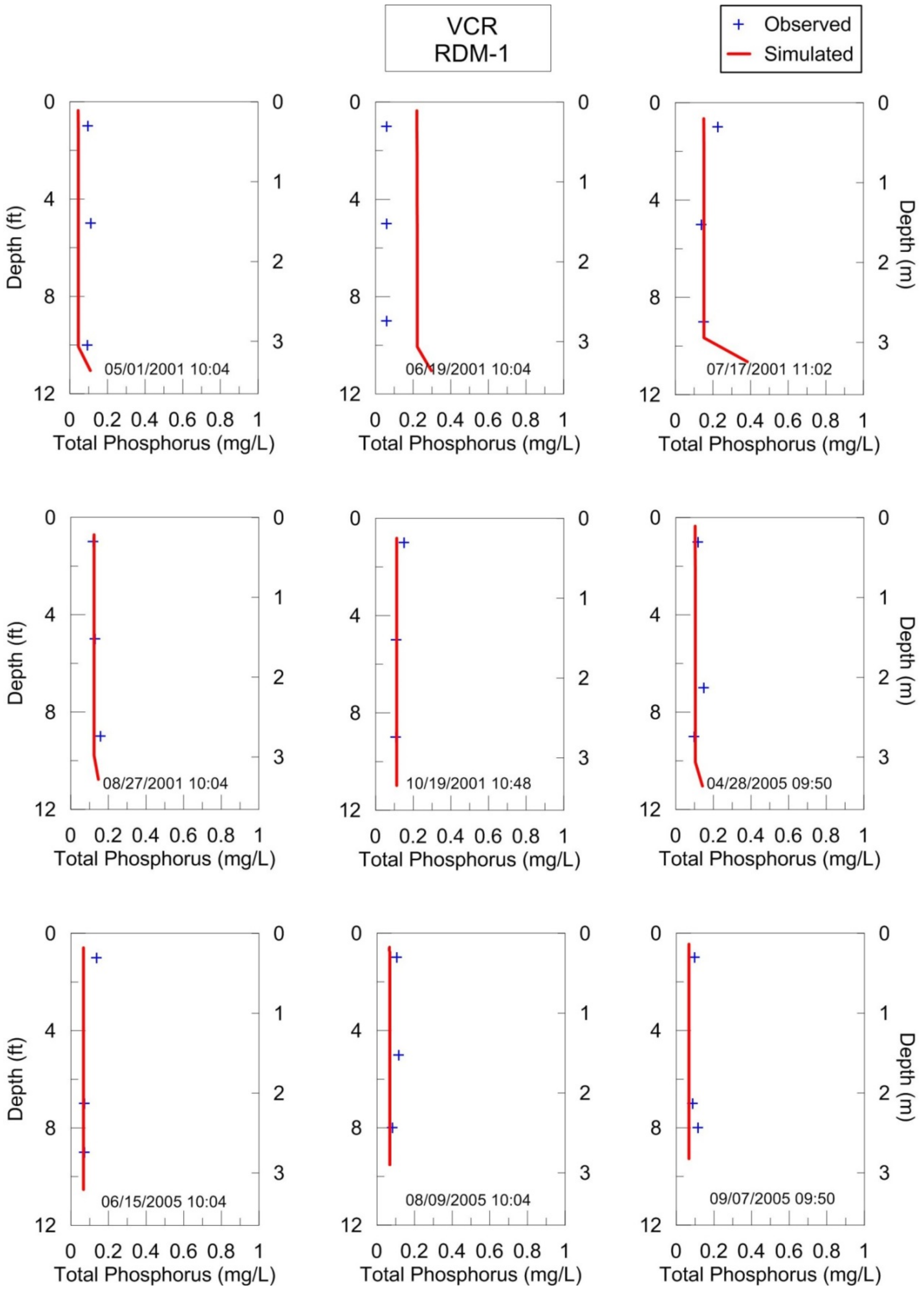
Model Symbol	Description	Value	Default Value
SEDC	Implements 1st-order sediment organic matter decay	OFF	
SEDCI	Initial sediment organic matter concentration (g m^{-2})	0.0	0.0
SEDS	Sediment settling or focusing velocity (m d^{-1})	0.1	0.1
SEDK	Sediment organic matter decay rate (d^{-1})	0.05	0.1
FSOD	Fraction of the zero-order SOD rate used	1.0	1.0
FSED	Fraction of the first-order sediment rate used	1.0	1.0
SODT1	Lower temperature for sediment organic matter decay (^oC)	4.0	4.0
SODT2	Upper temperature for sediment organic matter decay (^oC)	25.0	25.0
SODK1	Fraction of sediment organic matter decay rate at SODT1	0.1	0.1
SODK2	Fraction of sediment organic matter decay rate at SODT2	0.99	0.99
SEDBR	Sediment burial rate (d-1)	0.01	0.01
DYNSEDK	Dynamic sediment K	OFF	OFF

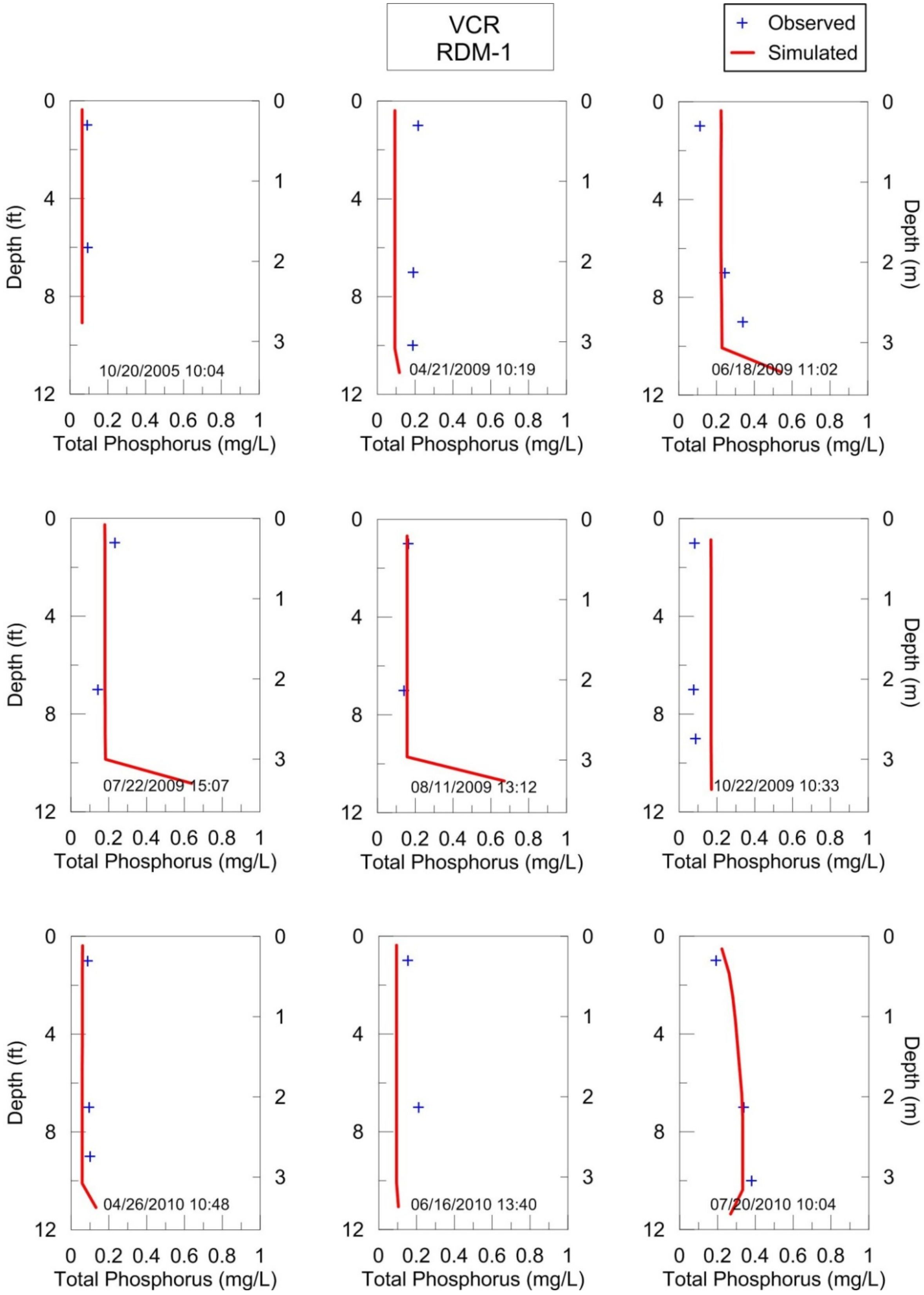
REAERATION

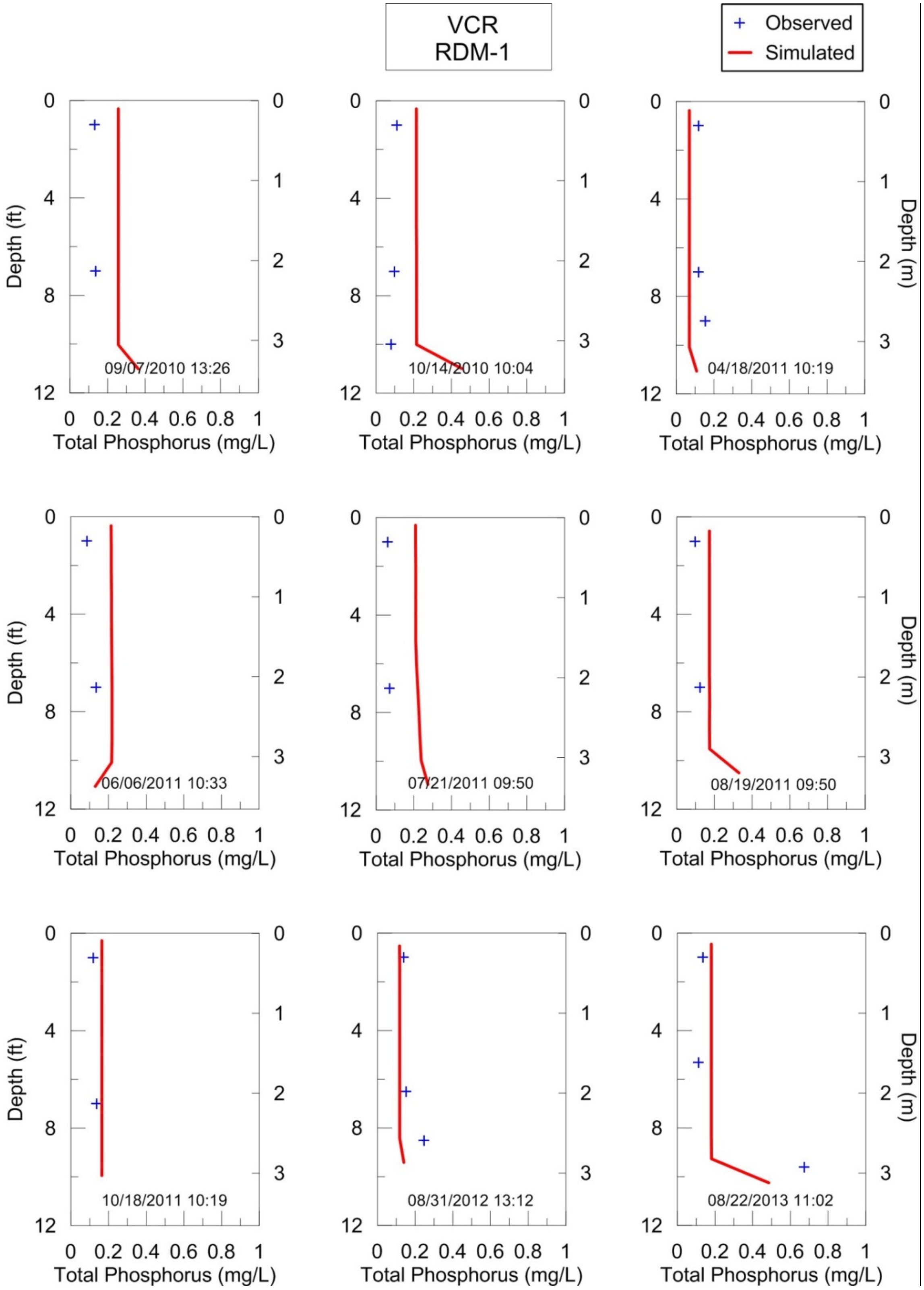
Model Symbol	Description	Value	Default Value
TYPE	RIVER, LAKE, OR ESTUARY	LAKE	NA
EQN#	$Ka = 7.62U/H^{1.33}$ (Langbien and Durum 1967)	6	NA

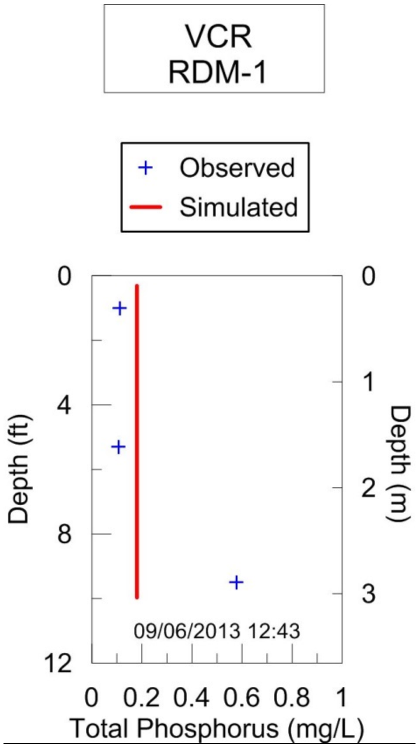
Appendix D: CE-QUAL-W2 Model Results

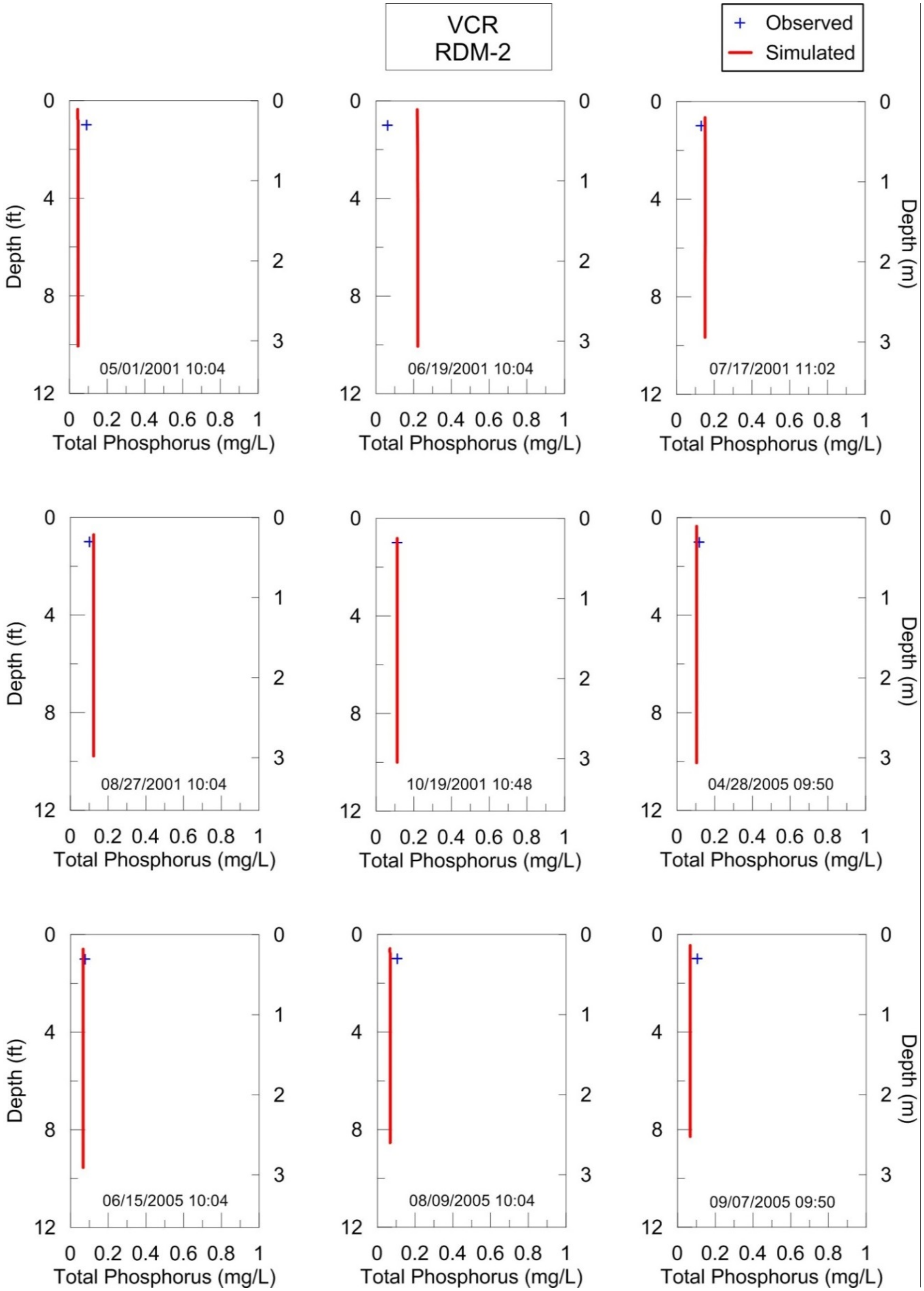
Total Phosphorus

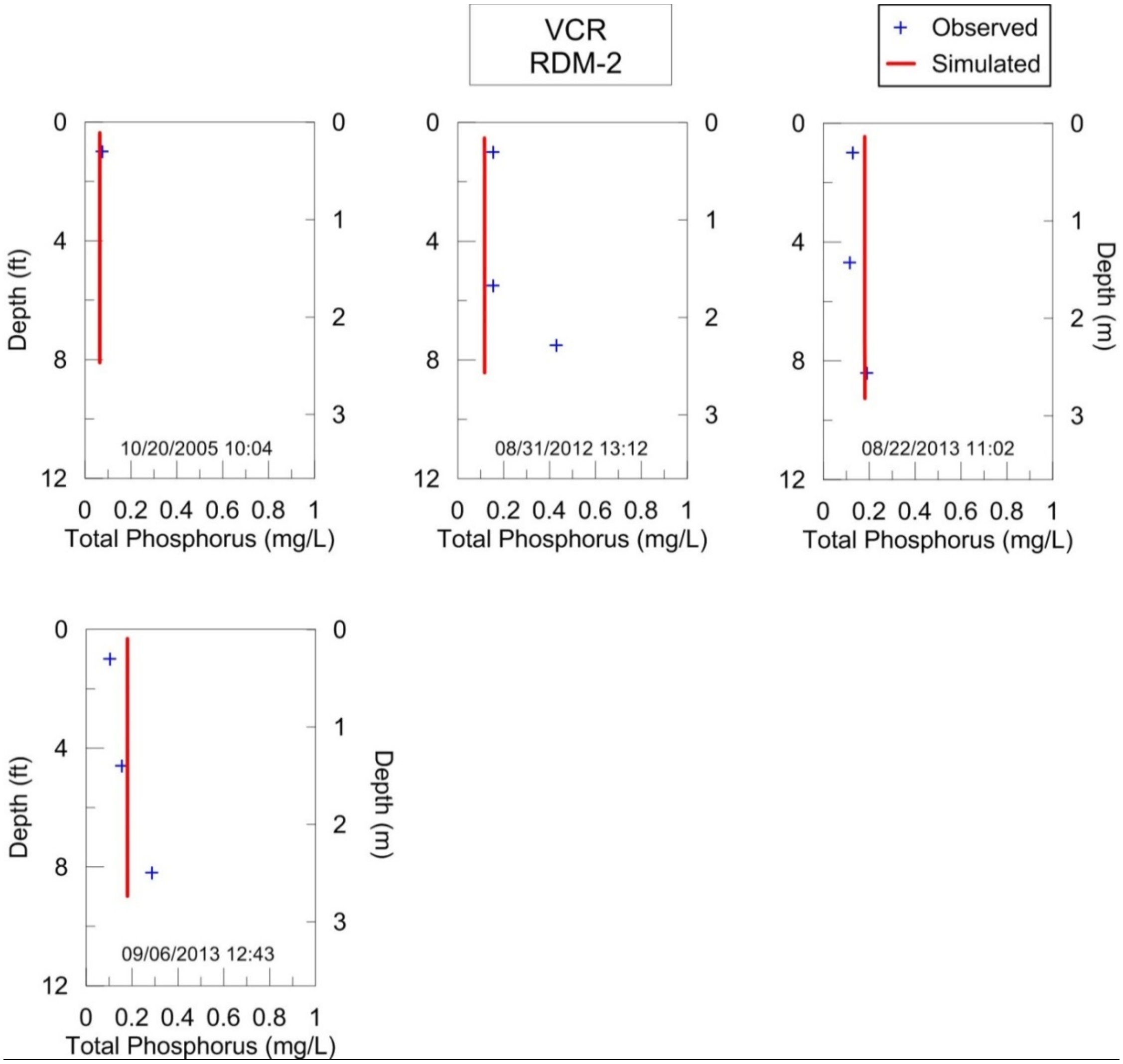


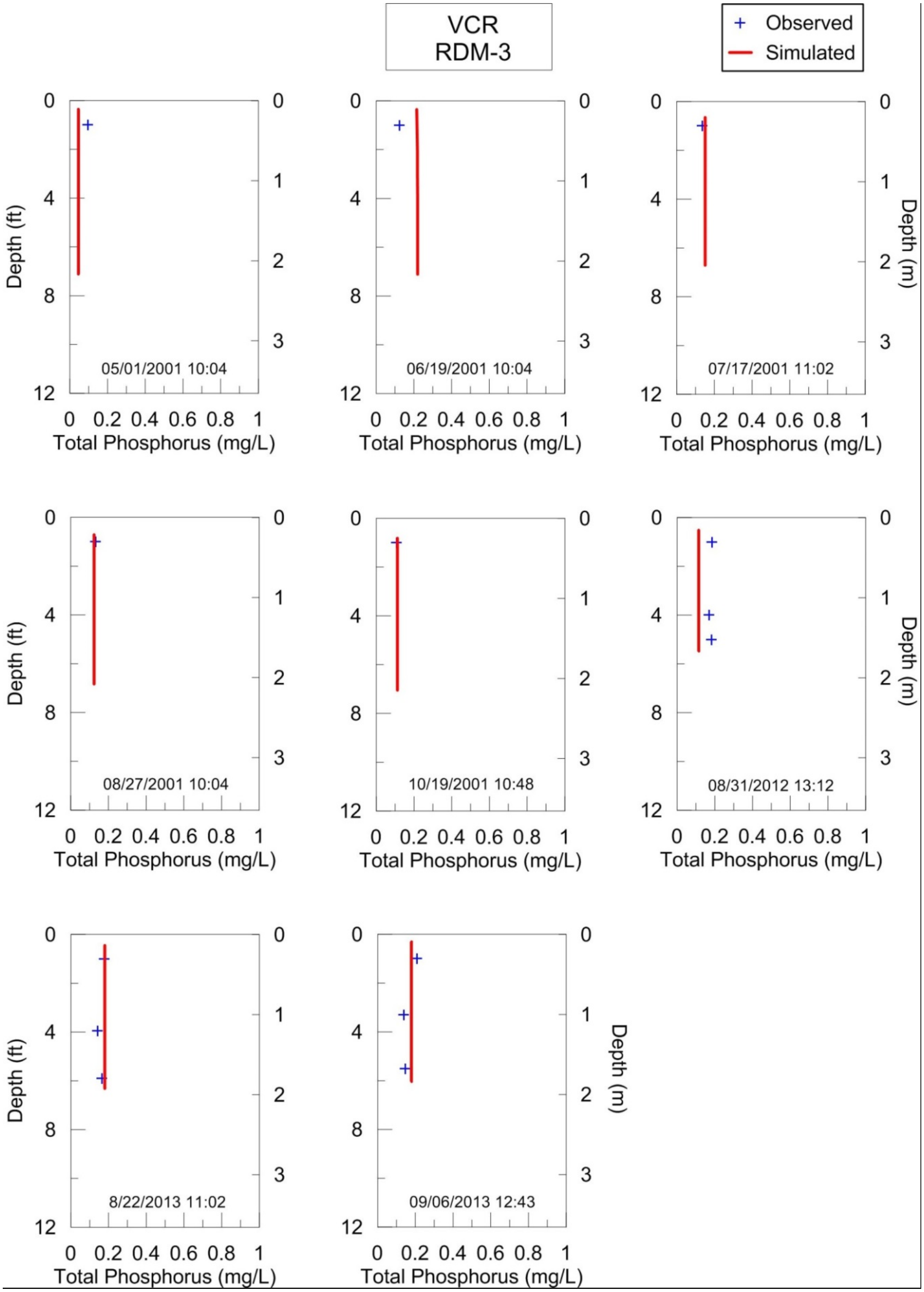

VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Total Phosphorus (mg/L)
0
4
8
12
0
1
2
3
0
0.2
0.4
0.6
0.8
1
10/20/2005 10:04
04/21/2009 10:19
06/18/2009 11:02
07/22/2009 15:07
08/11/2009 13:12
10/22/2009 10:33
04/26/2010 10:48
06/16/2010 13:40
07/20/2010 10:04


VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Total Phosphorus (mg/L)
0
4
8
12
0
1
2
3
0
0.2
0.4
0.6
0.8
1
09/07/2010 13:26
10/14/2010 10:04
04/18/2011 10:19
06/06/2011 10:33
07/21/2011 09:50
08/19/2011 09:50
10/18/2011 10:19
08/31/2012 13:12
08/22/2013 11:02

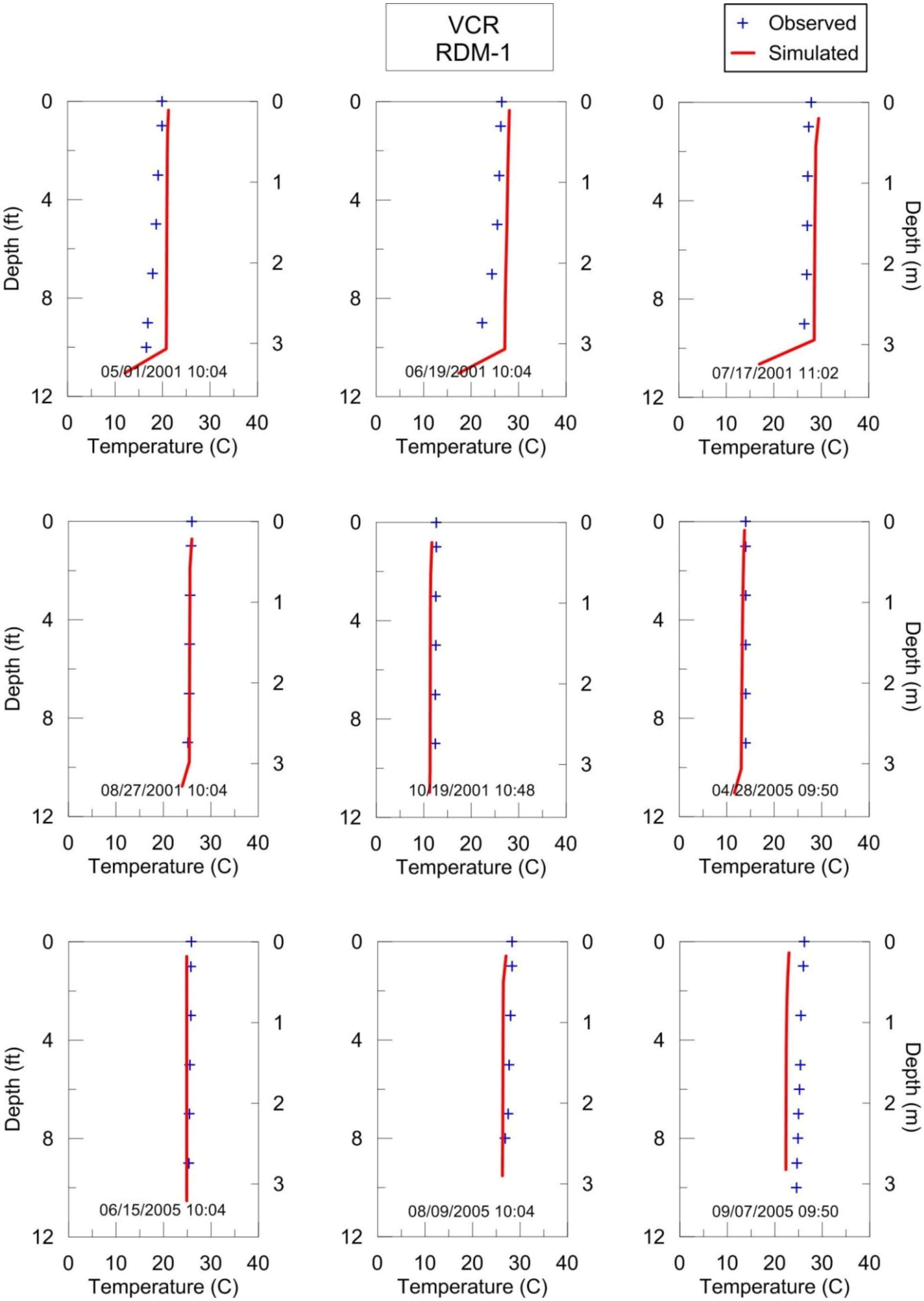

VCR
RDM-1
+ Observed
Simulated
0
4
8
12
Depth (ft)
0
1
2
3
Depth (m)
09/06/2013 12:43
0
0.2
0.4
0.6
0.8
1
Total Phosphorus (mg/L)

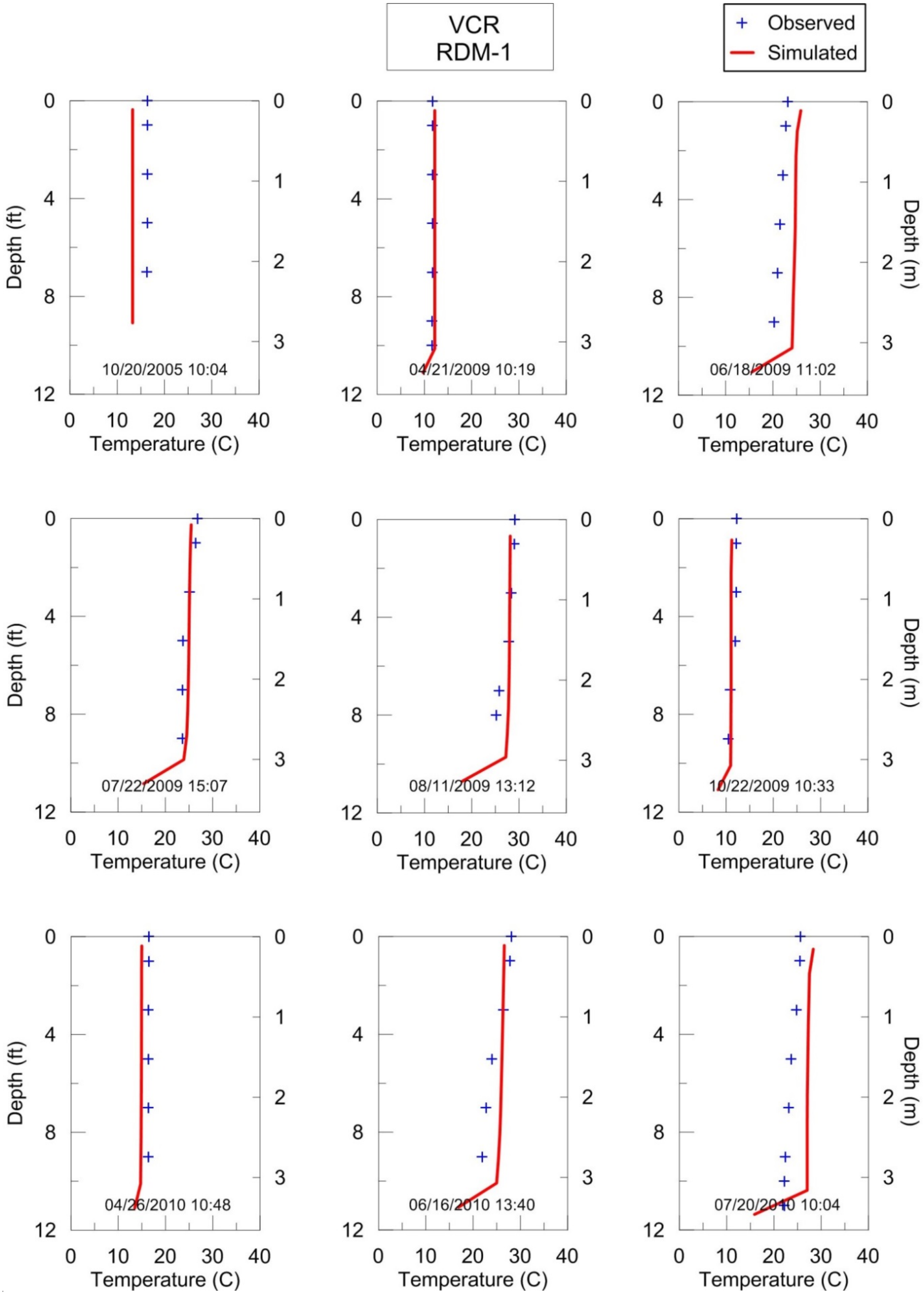

VCR
RDM-2
+ Observed
Simulated
Depth (ft)
Depth (m)
Total Phosphorus (mg/L)
0
4
8
12
0
1
2
3
0 0.2 0.4 0.6 0.8 1
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
04/28/2005 09:50
06/15/2005 10:04
08/09/2005 10:04
09/07/2005 09:50

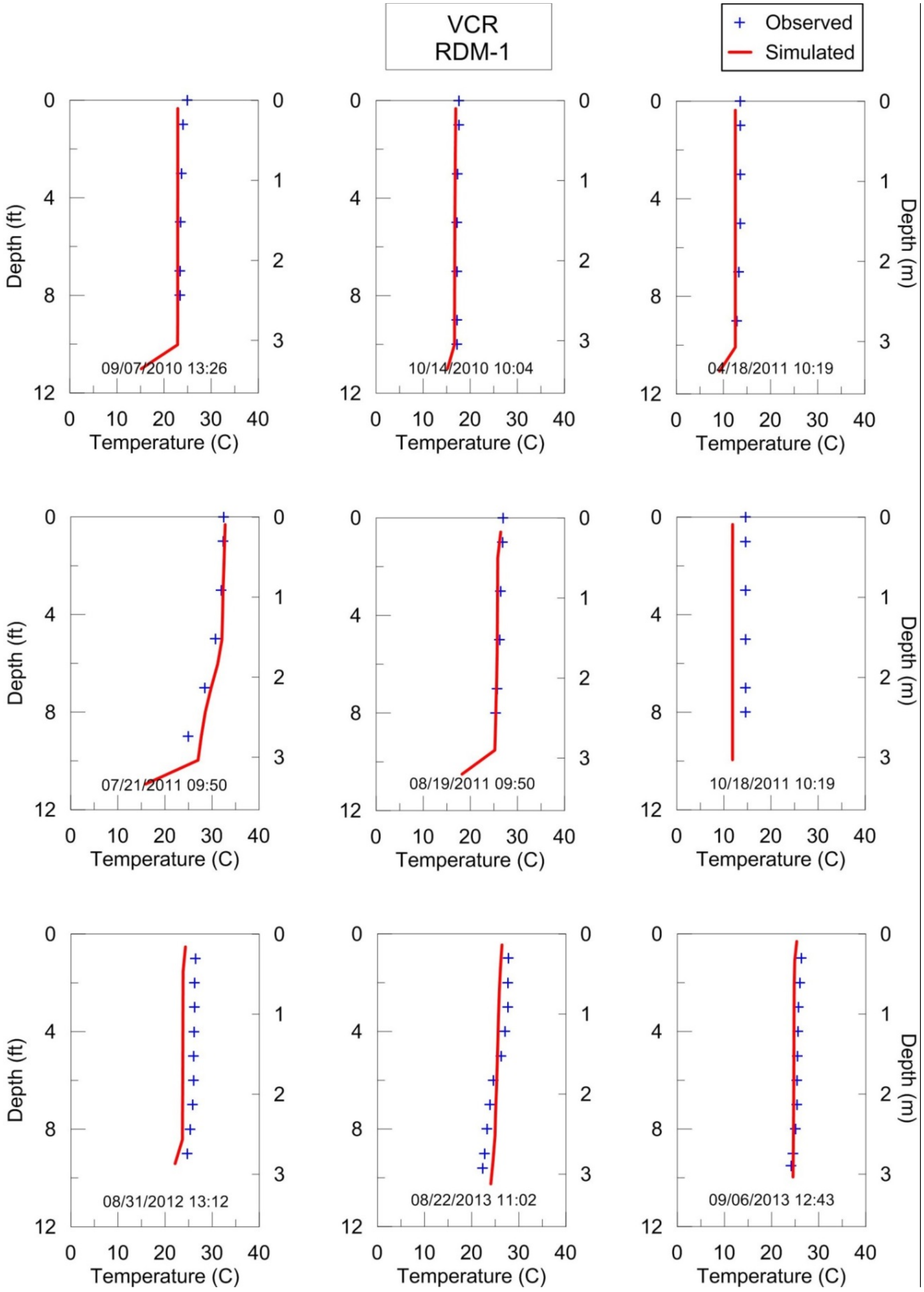

VCR
RDM-2
+ Observed
Simulated
Depth (ft)
Depth (m)
0
4
8
12
0
1
2
3
0 0.2 0.4 0.6 0.8 1
Total Phosphorus (mg/L)
10/20/2005 10:04
08/31/2012 13:12
08/22/2013 11:02
09/06/2013 12:43

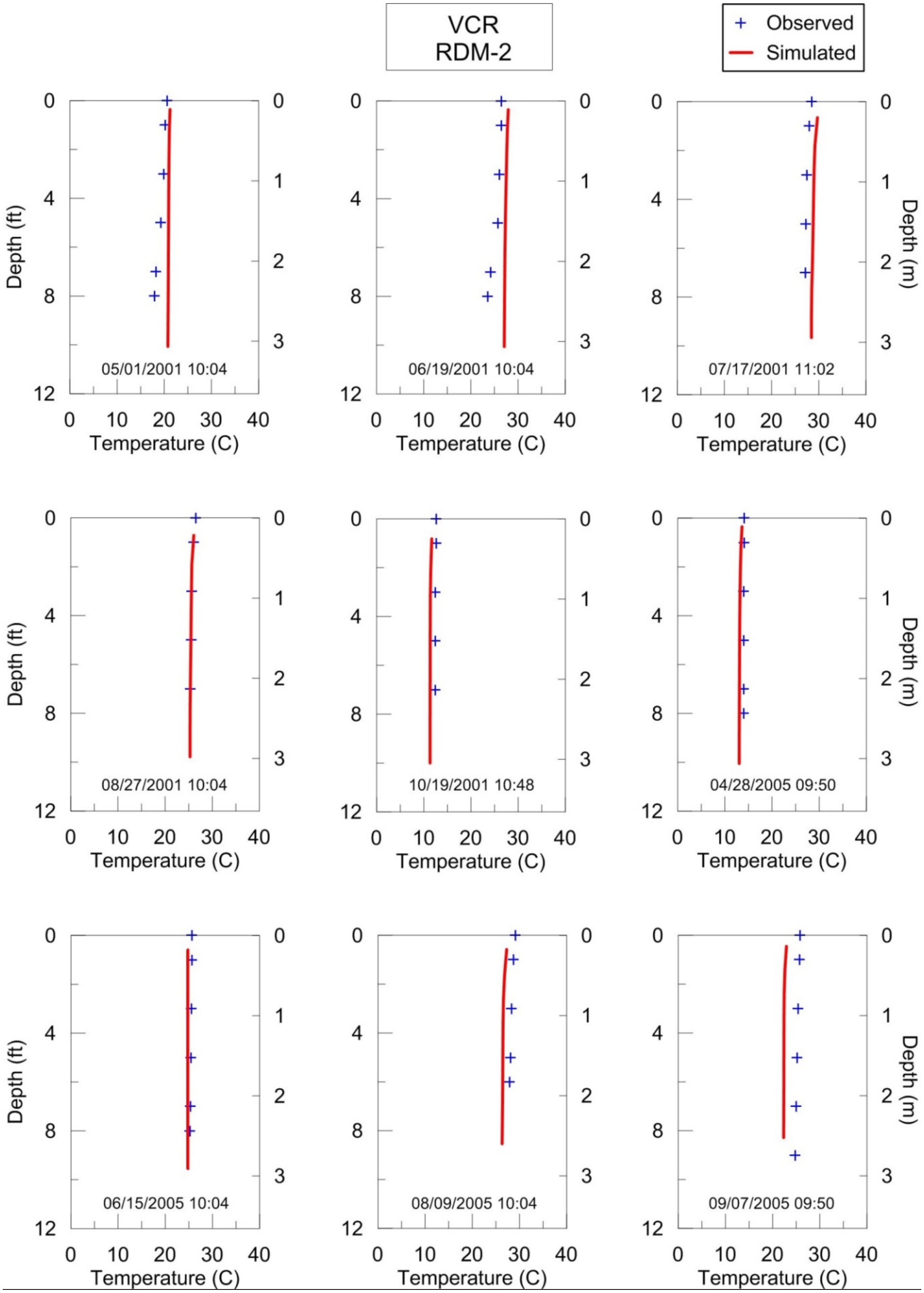

VCR
RDM-3
+ Observed
Simulated
Depth (ft)
Depth (m)
Total Phosphorus (mg/L)
0
4
8
12
0
1
2
3
0 0.2 0.4 0.6 0.8 1
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
08/31/2012 13:12
8/22/2013 11:02
09/06/2013 12:43

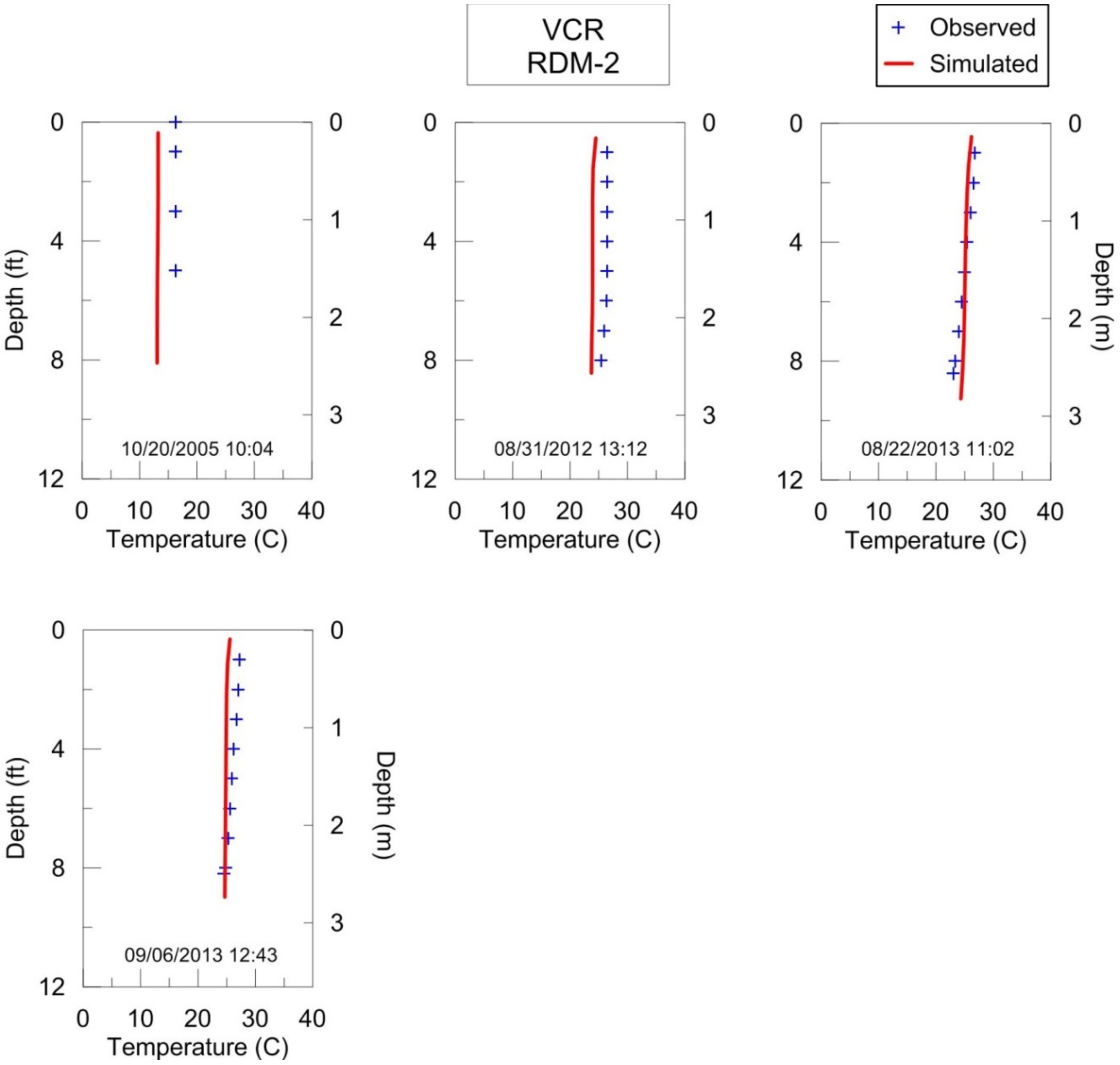
Temperature

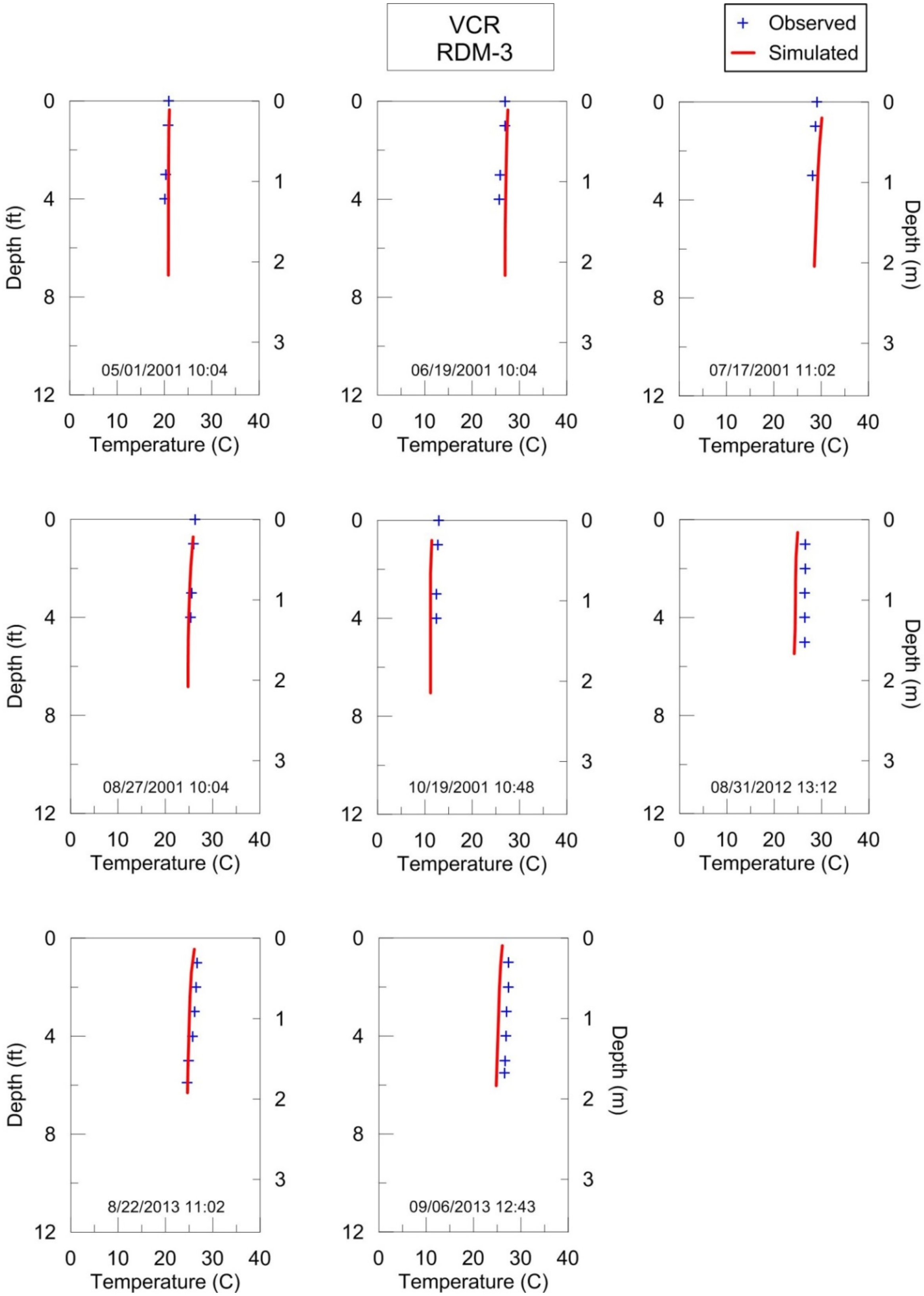



VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Temperature (C)
0
4
8
12
0
1
2
3
0
10
20
30
40
10/20/2005 10:04
04/21/2009 10:19
06/18/2009 11:02
07/22/2009 15:07
08/11/2009 13:12
10/22/2009 10:33
04/26/2010 10:48
06/16/2010 13:40
07/20/2010 10:04

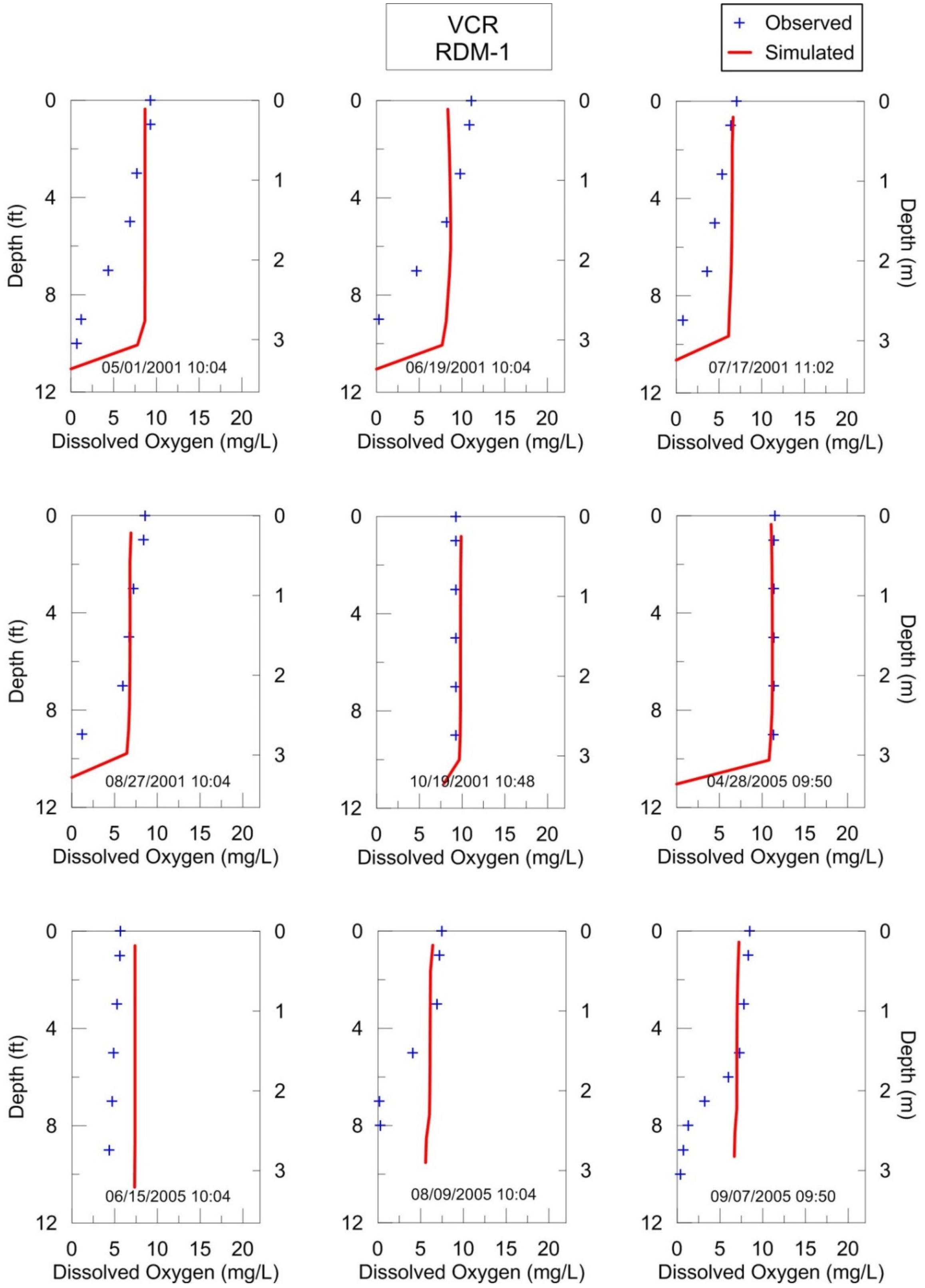

VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Temperature (C)
0
4
8
12
0
1
2
3
0
10
20
30
40
09/07/2010 13:26
10/14/2010 10:04
04/18/2011 10:19
07/21/2011 09:50
08/19/2011 09:50
10/18/2011 10:19
08/31/2012 13:12
08/22/2013 11:02
09/06/2013 12:43

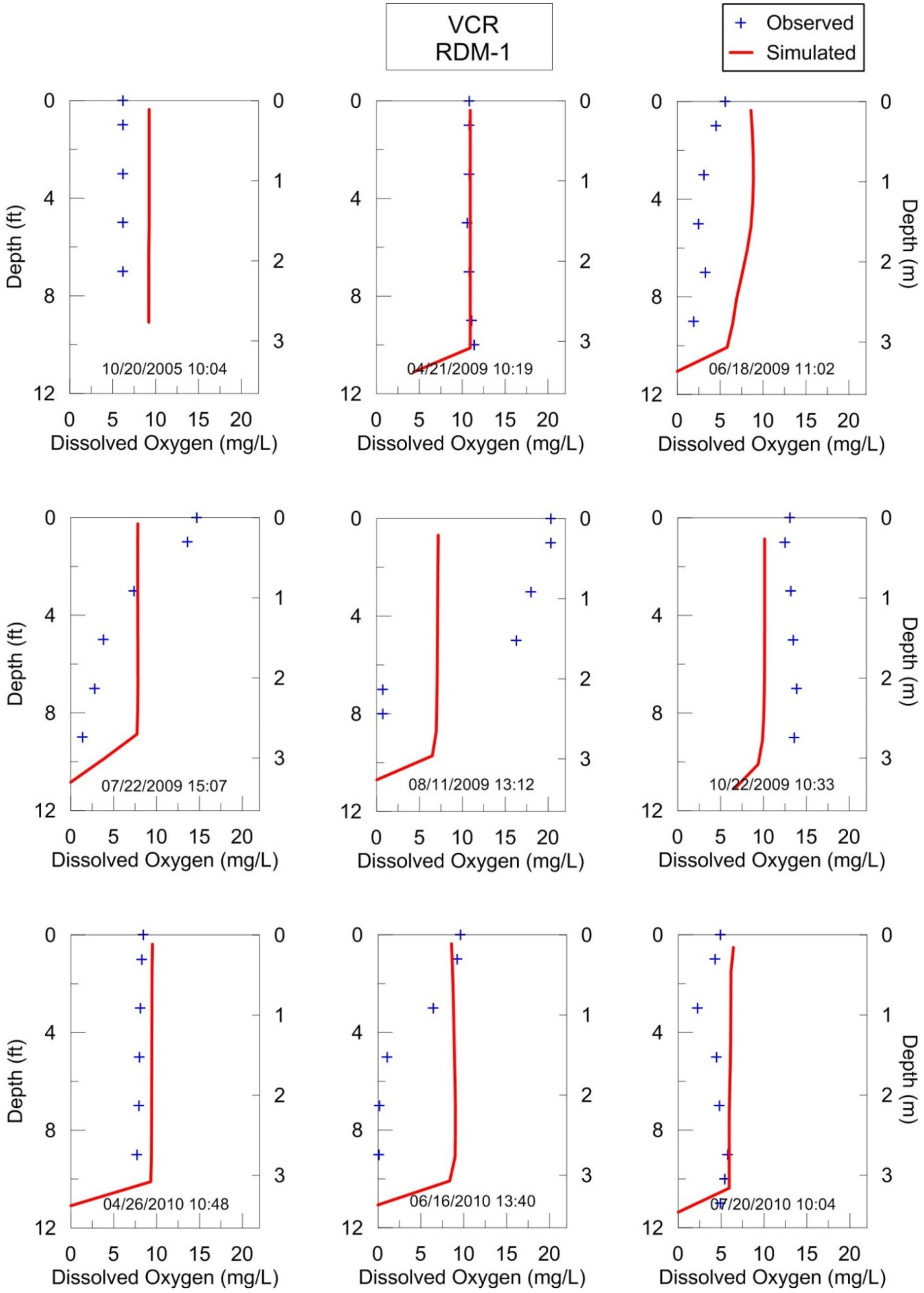

VCR
RDM-2
+ Observed
Simulated
Depth (ft)
Depth (m)
Temperature (C)
0
4
8
12
0
1
2
3
0
10
20
30
40
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
04/28/2005 09:50
06/15/2005 10:04
08/09/2005 10:04
09/07/2005 09:50

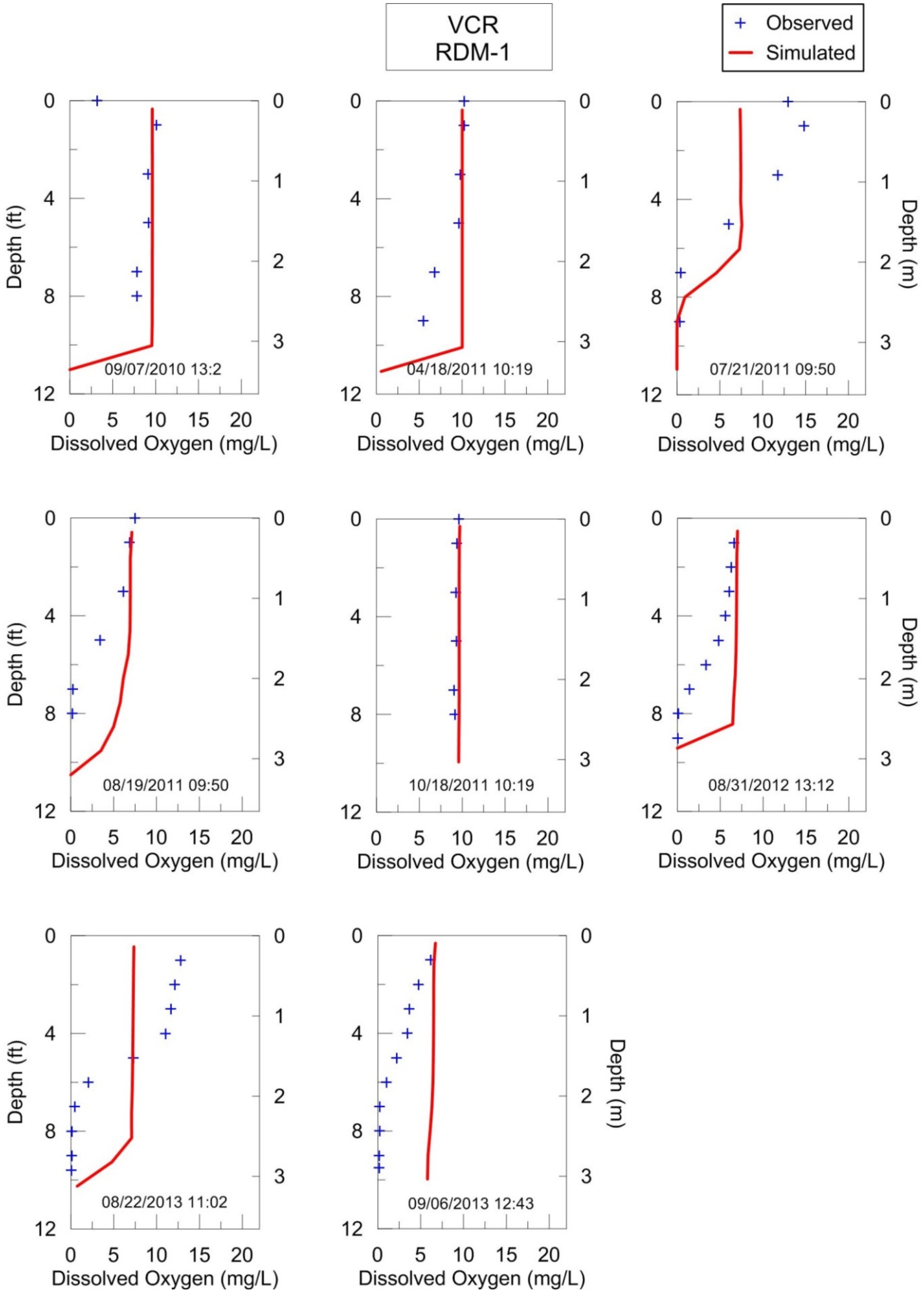

VCR
RDM-2
Observed
Simulated
10/20/2005 10:04
08/31/2012 13:12
08/22/2013 11:02
09/06/2013 12:43
Depth (ft)
Depth (m)
Temperature (C)
0
4
8
12
0
1
2
3
0
10
20
30
40

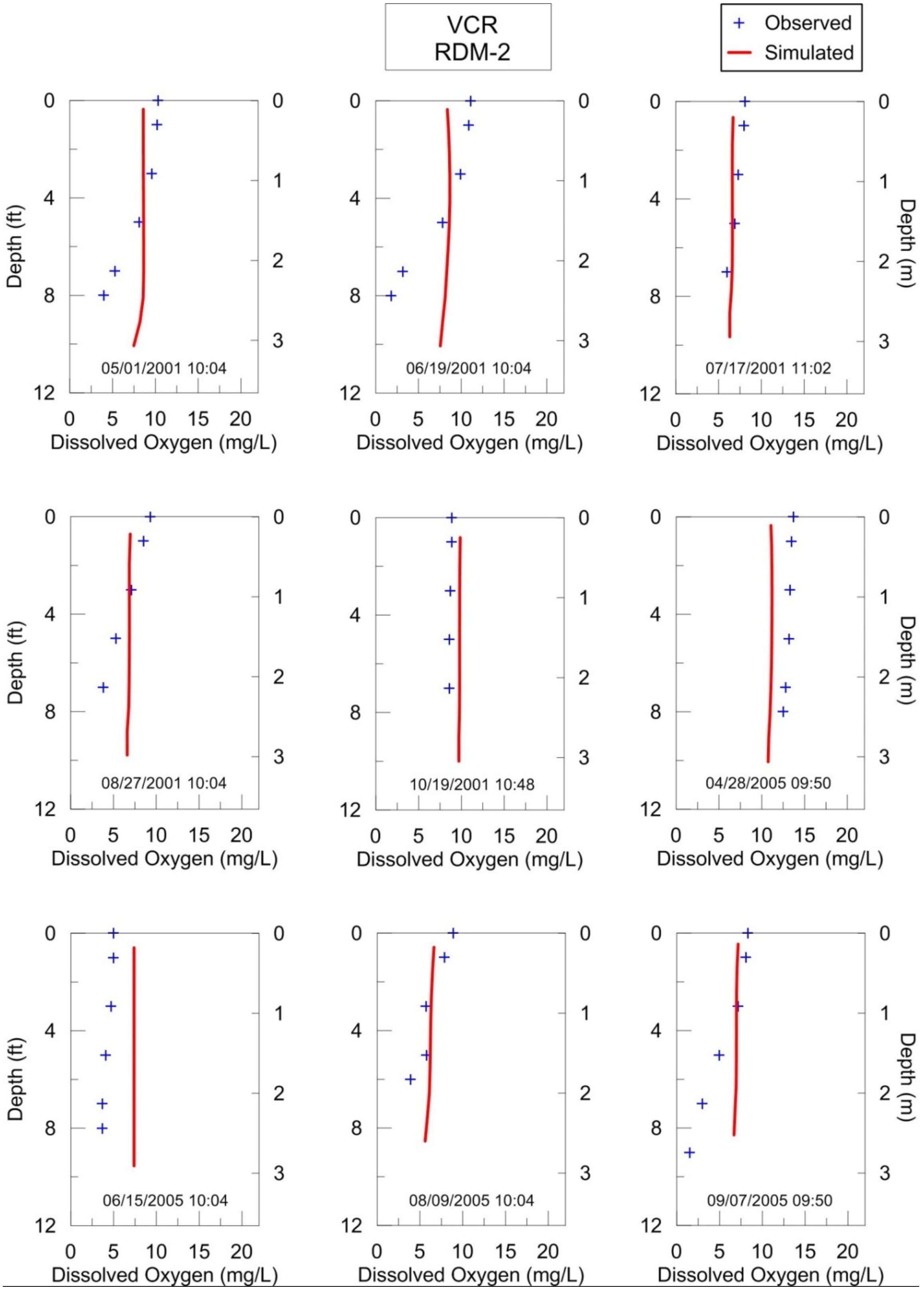

VCR
RDM-3
+ Observed
Simulated
Depth (ft)
Depth (m)
Temperature (C)
0
4
8
12
0
1
2
3
0
10
20
30
40
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
08/31/2012 13:12
8/22/2013 11:02
09/06/2013 12:43

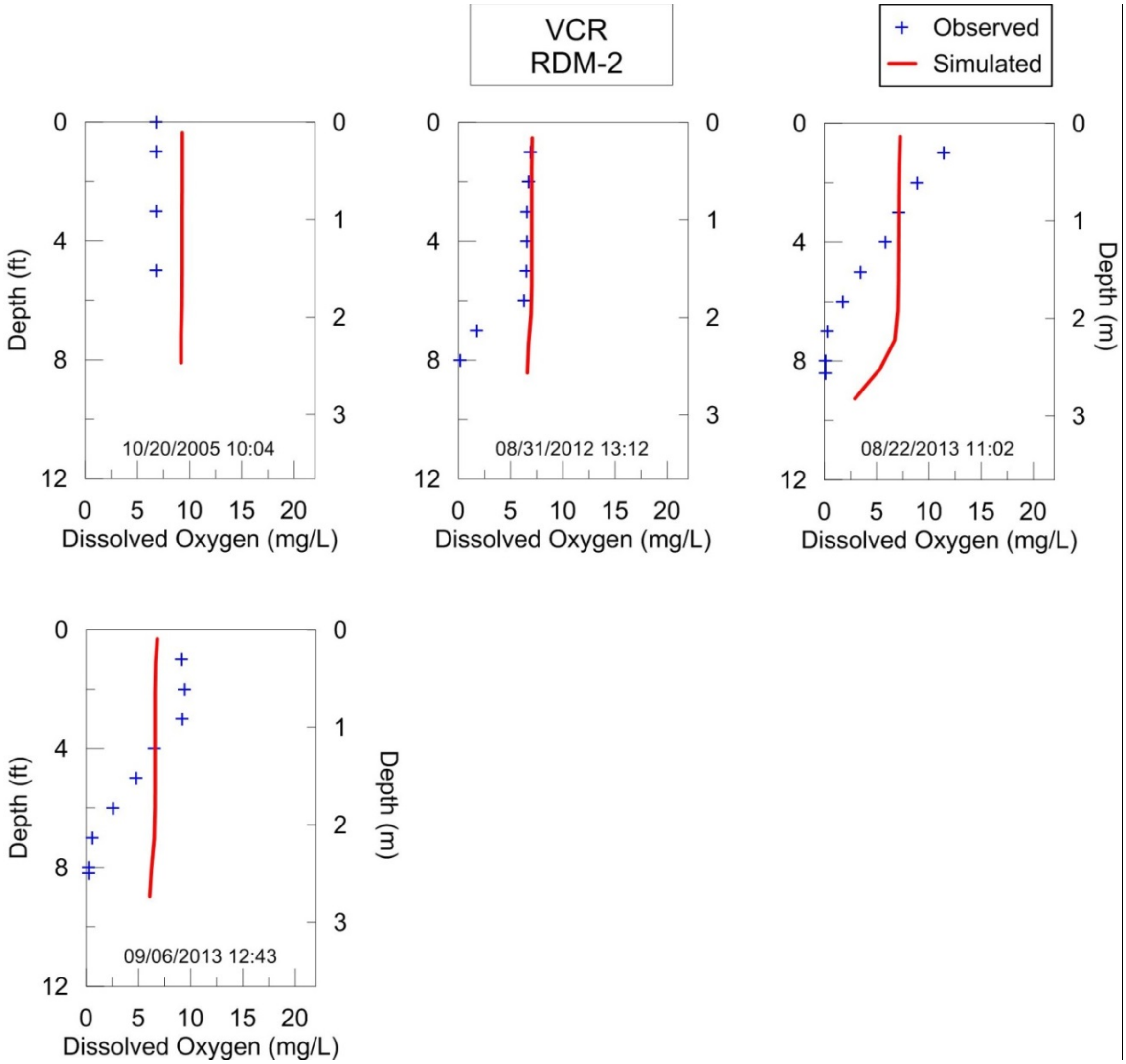
Dissolved Oxygen



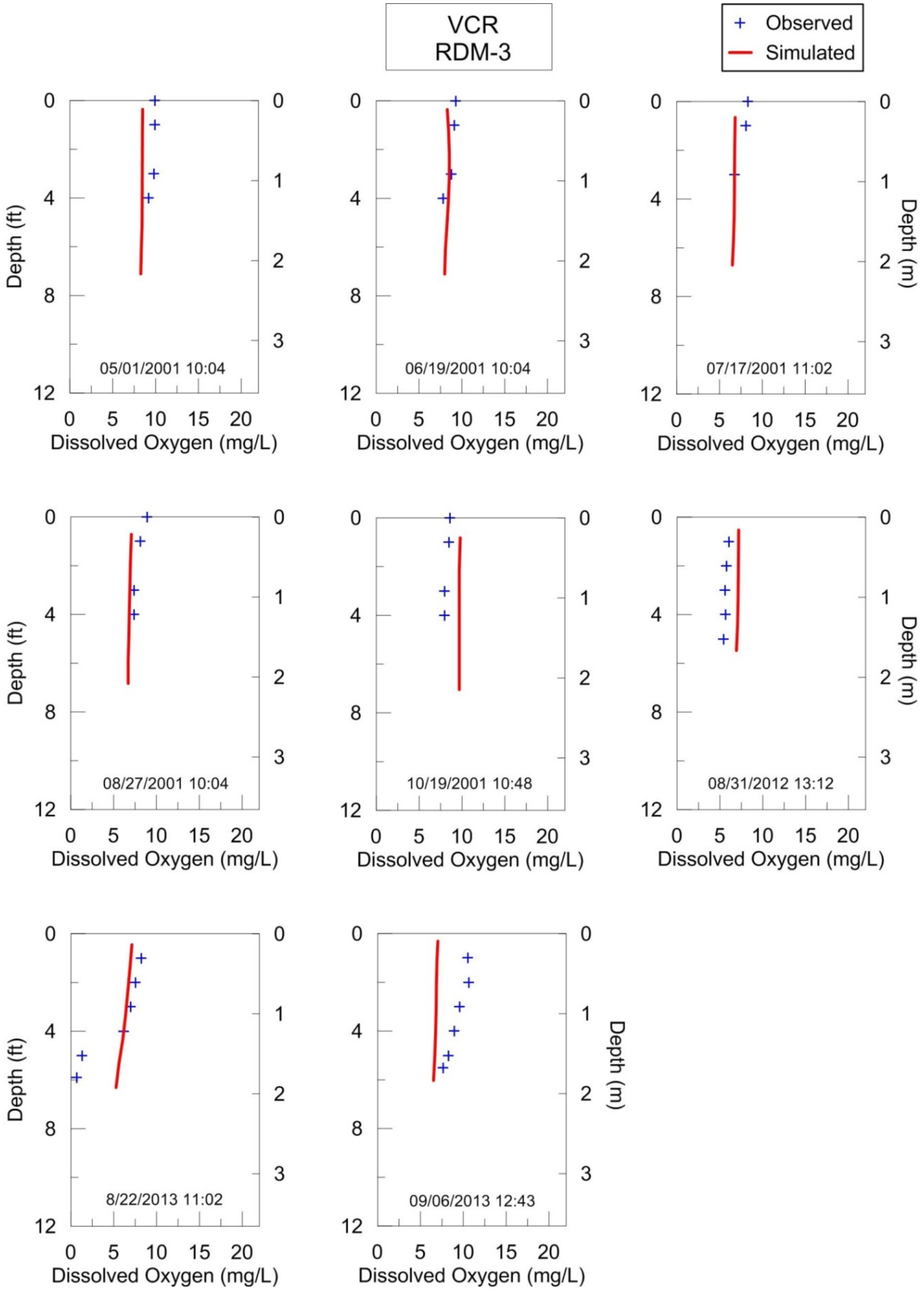

VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Dissolved Oxygen (mg/L)
0
4
8
12
0
1
2
3
0
5
10
15
20
10/20/2005 10:04
04/21/2009 10:19
06/18/2009 11:02
07/22/2009 15:07
08/11/2009 13:12
10/22/2009 10:33
04/26/2010 10:48
06/16/2010 13:40
07/20/2010 10:04


VCR
RDM-1
Observed
Simulated
09/07/2010 13:2
04/18/2011 10:19
07/21/2011 09:50
08/19/2011 09:50
10/18/2011 10:19
08/31/2012 13:12
08/22/2013 11:02
09/06/2013 12:43
Depth (ft)
Depth (m)
Dissolved Oxygen (mg/L)
0
4
8
12
0
1
2
3
0
5
10
15
20

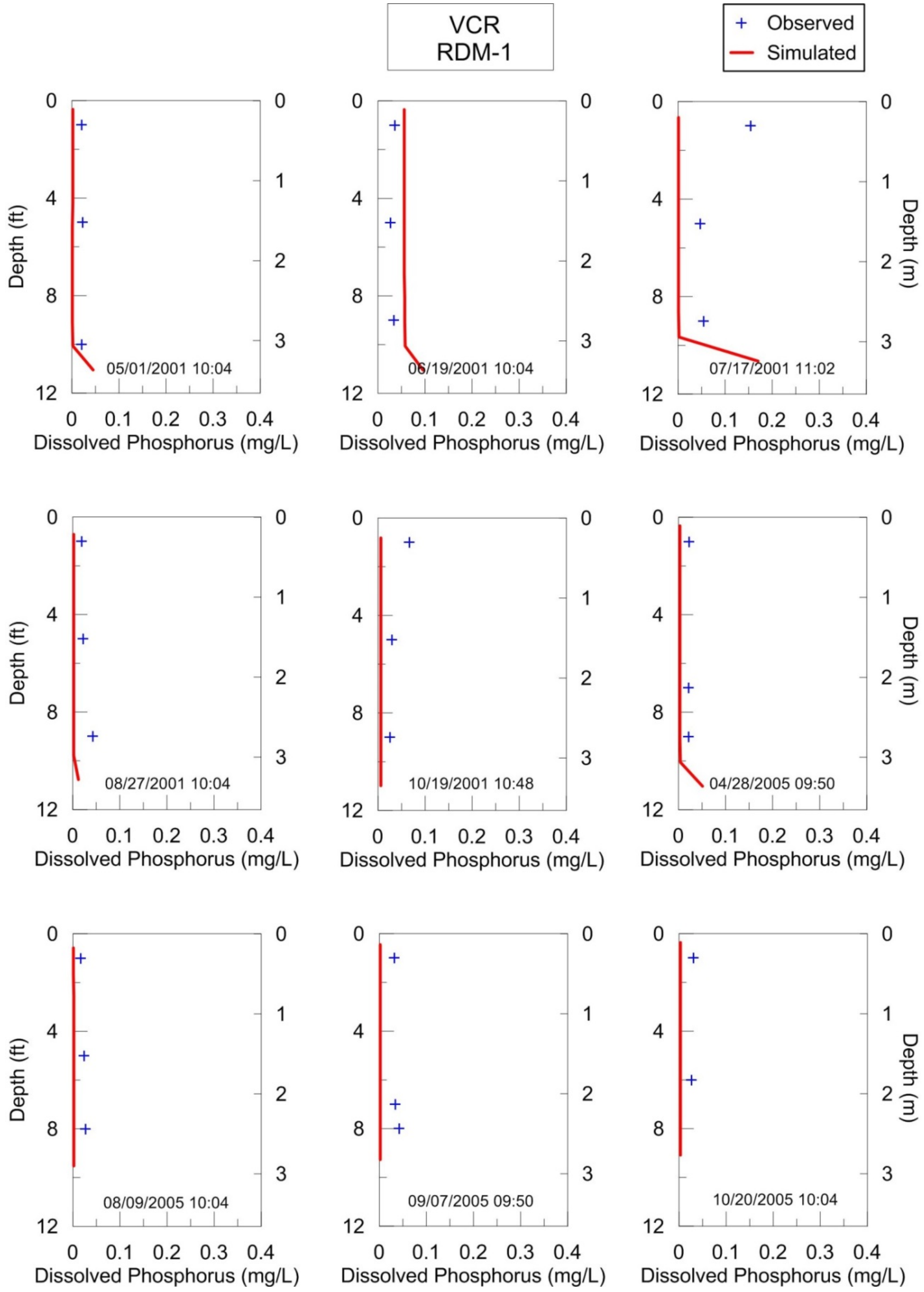

VCR
RDM-2
+ Observed
Simulated
Depth (ft)
Depth (m)
Dissolved Oxygen (mg/L)
0
4
8
12
0
1
2
3
0
5
10
15
20
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
04/28/2005 09:50
06/15/2005 10:04
08/09/2005 10:04
09/07/2005 09:50

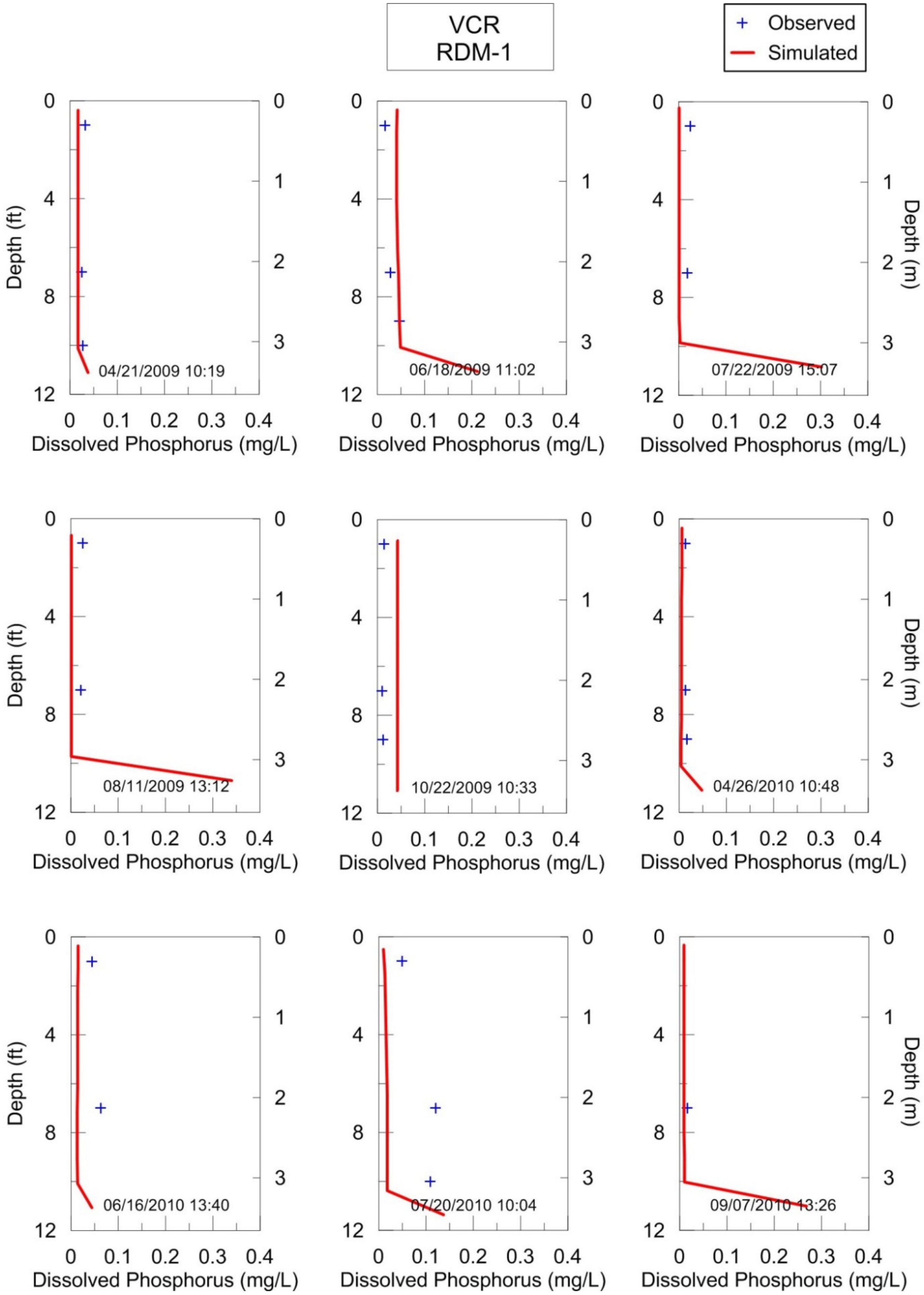


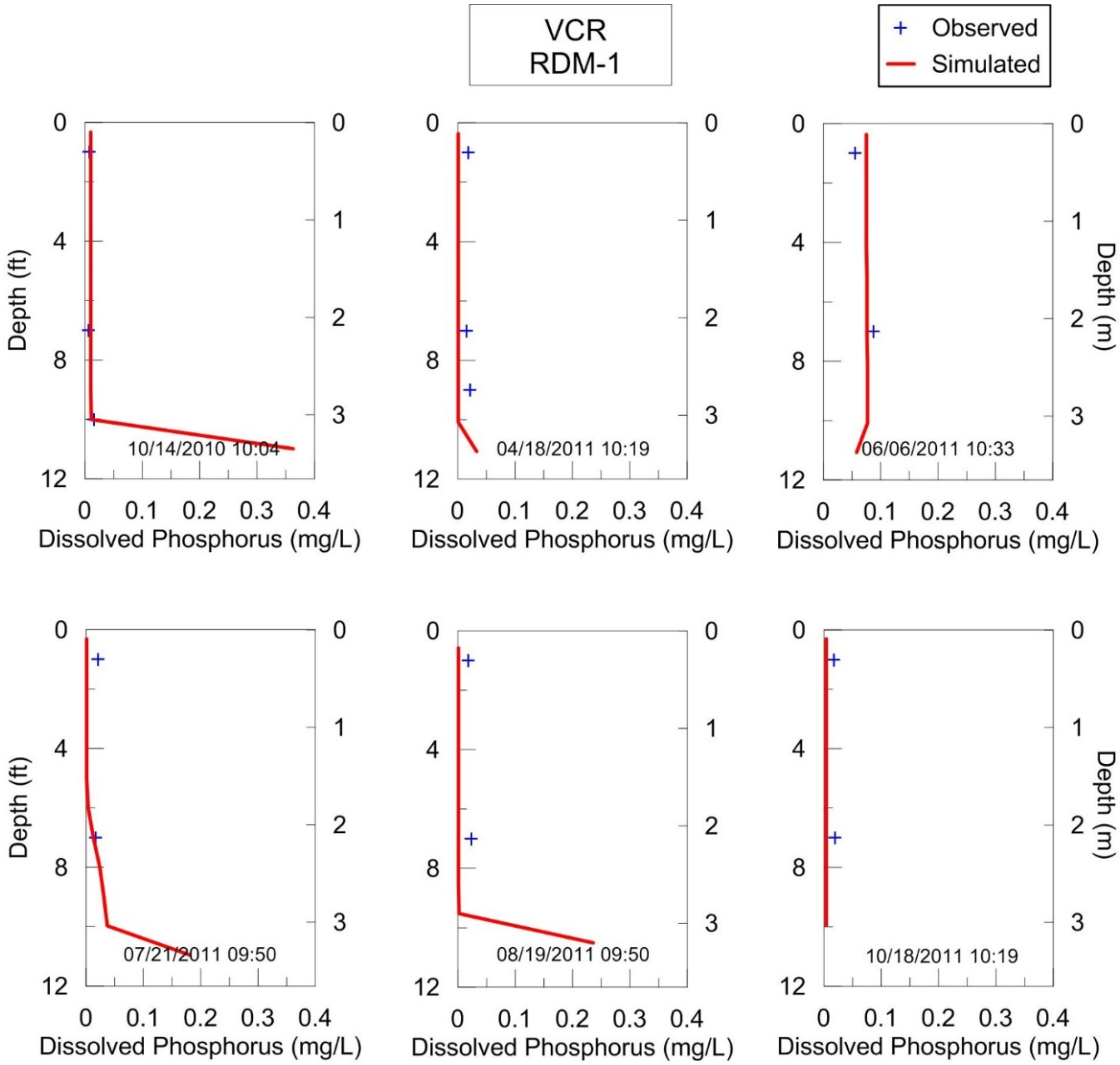
VCR
RDM-2
Observed
Simulated
Depth (ft)
Depth (m)
Dissolved Oxygen (mg/L)
0
4
8
12
0
1
2
3
0
5
10
15
20
10/20/2005 10:04
08/31/2012 13:12
08/22/2013 11:02
09/06/2013 12:43

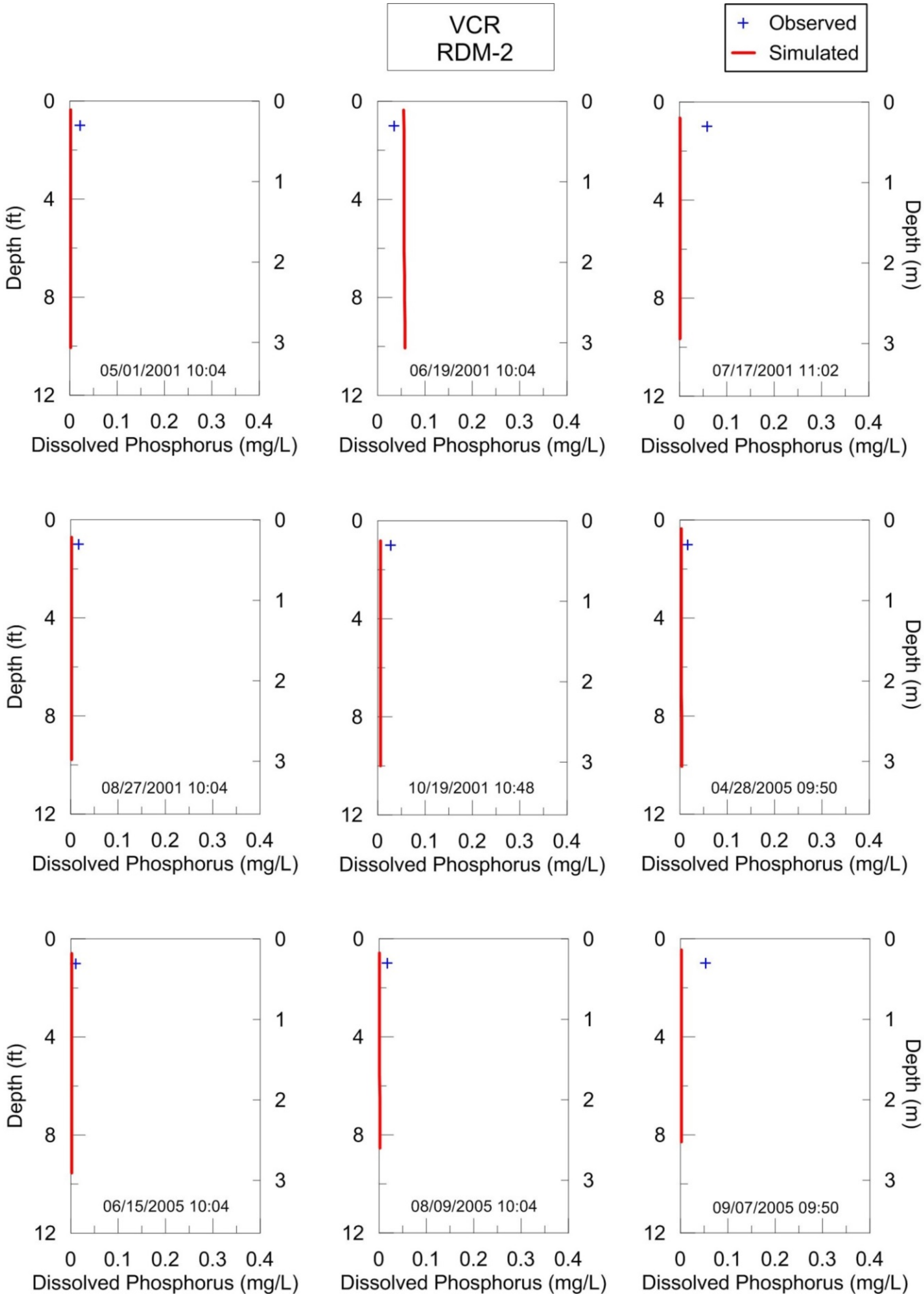

VCR
RDM-3
Observed
Simulated
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
08/31/2012 13:12
8/22/2013 11:02
09/06/2013 12:43
Depth (ft)
Depth (m)
Dissolved Oxygen (mg/L)
0
4
8
12
0
1
2
3
0
5
10
15
20

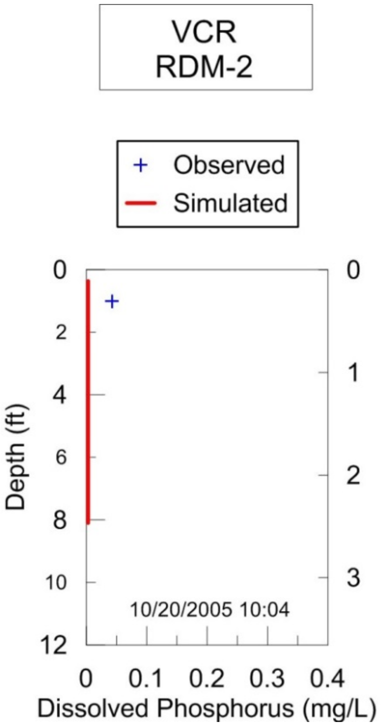
Dissolved Phosphorus

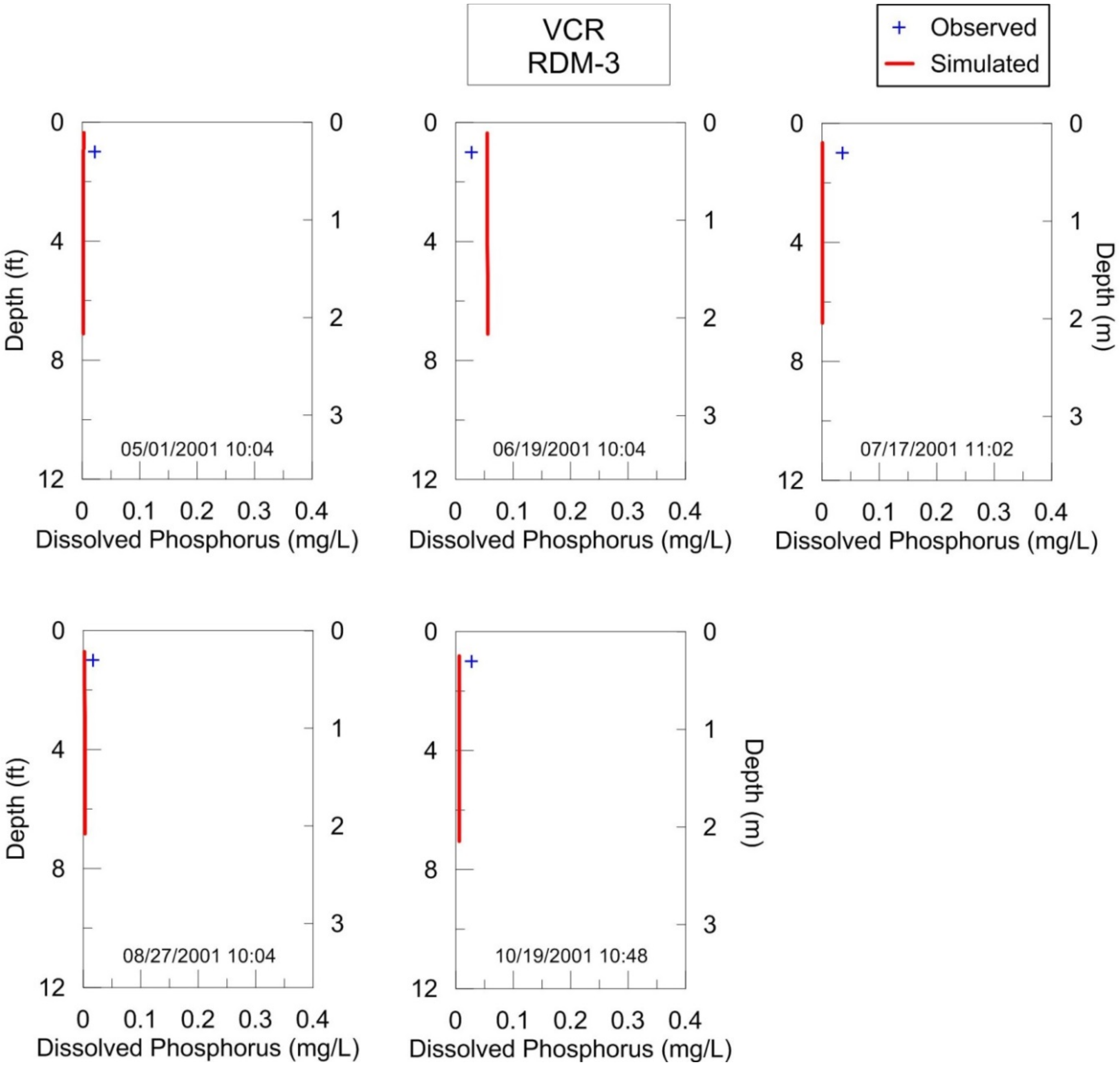



VCR
RDM-1
Observed
Simulated
Depth (ft)
Depth (m)
Dissolved Phosphorus (mg/L)
0
4
8
12
0
1
2
3
0
0.1
0.2
0.3
0.4
04/21/2009 10:19
06/18/2009 11:02
07/22/2009 15:07
08/11/2009 13:12
10/22/2009 10:33
04/26/2010 10:48
06/16/2010 13:40
07/20/2010 10:04
09/07/2010 13:26

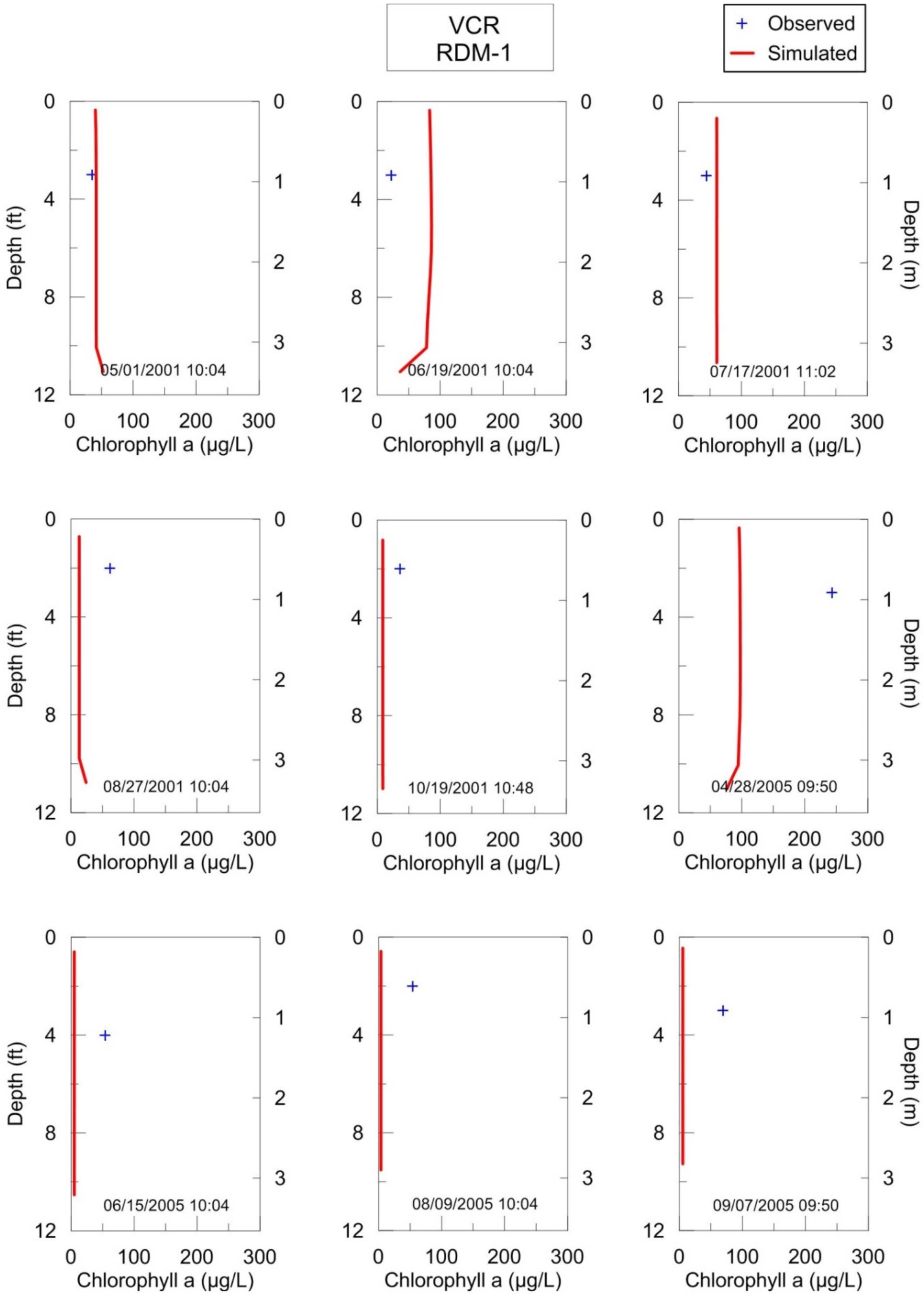

VCR
RDM-1
+ Observed
Simulated
Depth (ft)
Depth (m)
0
4
8
12
0
1
2
3
0
0.1
0.2
0.3
0.4
Dissolved Phosphorus (mg/L)
10/14/2010 10:04
04/18/2011 10:19
06/06/2011 10:33
07/21/2011 09:50
08/19/2011 09:50
10/18/2011 10:19

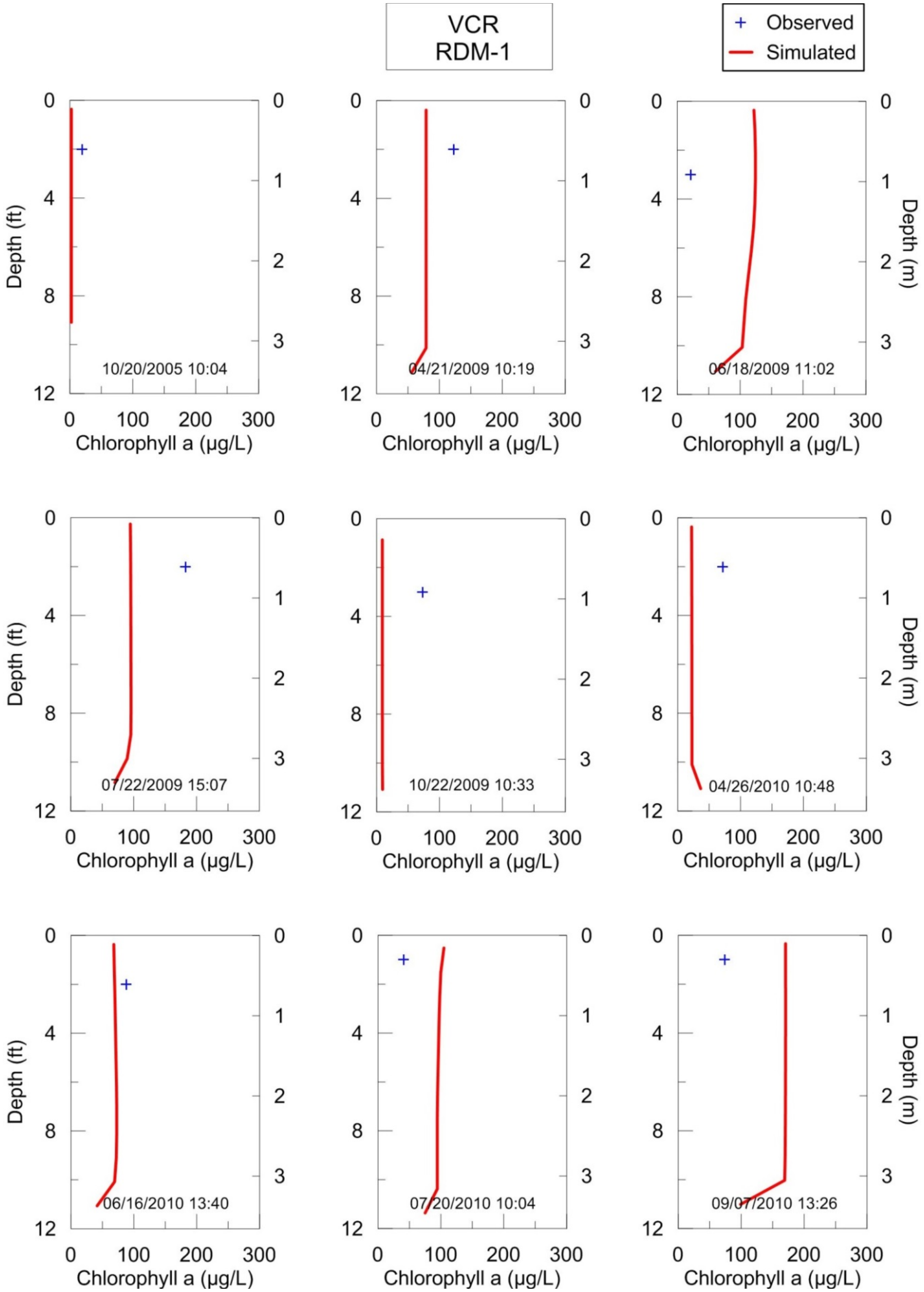

VCR
RDM-2
+ Observed
— Simulated
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
04/28/2005 09:50
06/15/2005 10:04
08/09/2005 10:04
09/07/2005 09:50
Depth (ft)
0
4
8
12
Depth (m)
0
1
2
3
Dissolved Phosphorus (mg/L)
0
0.1
0.2
0.3
0.4

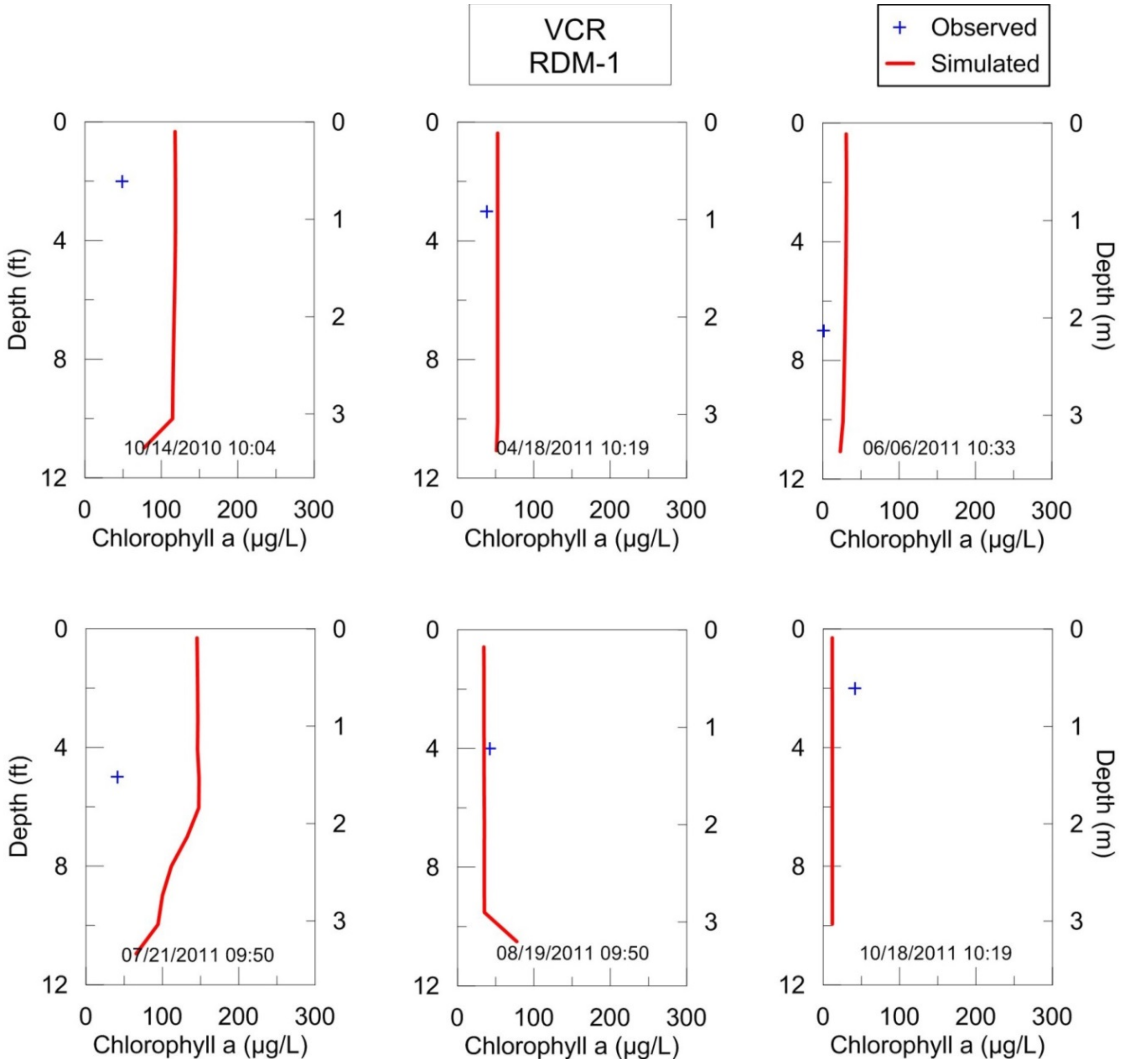

VCR
RDM-2
+ Observed
Simulated
0
2
4
6
8
10
12
Depth (ft)
0
1
2
3
Depth (m)
10/20/2005 10:04
0
0.1
0.2
0.3
0.4
Dissolved Phosphorus (mg/L)

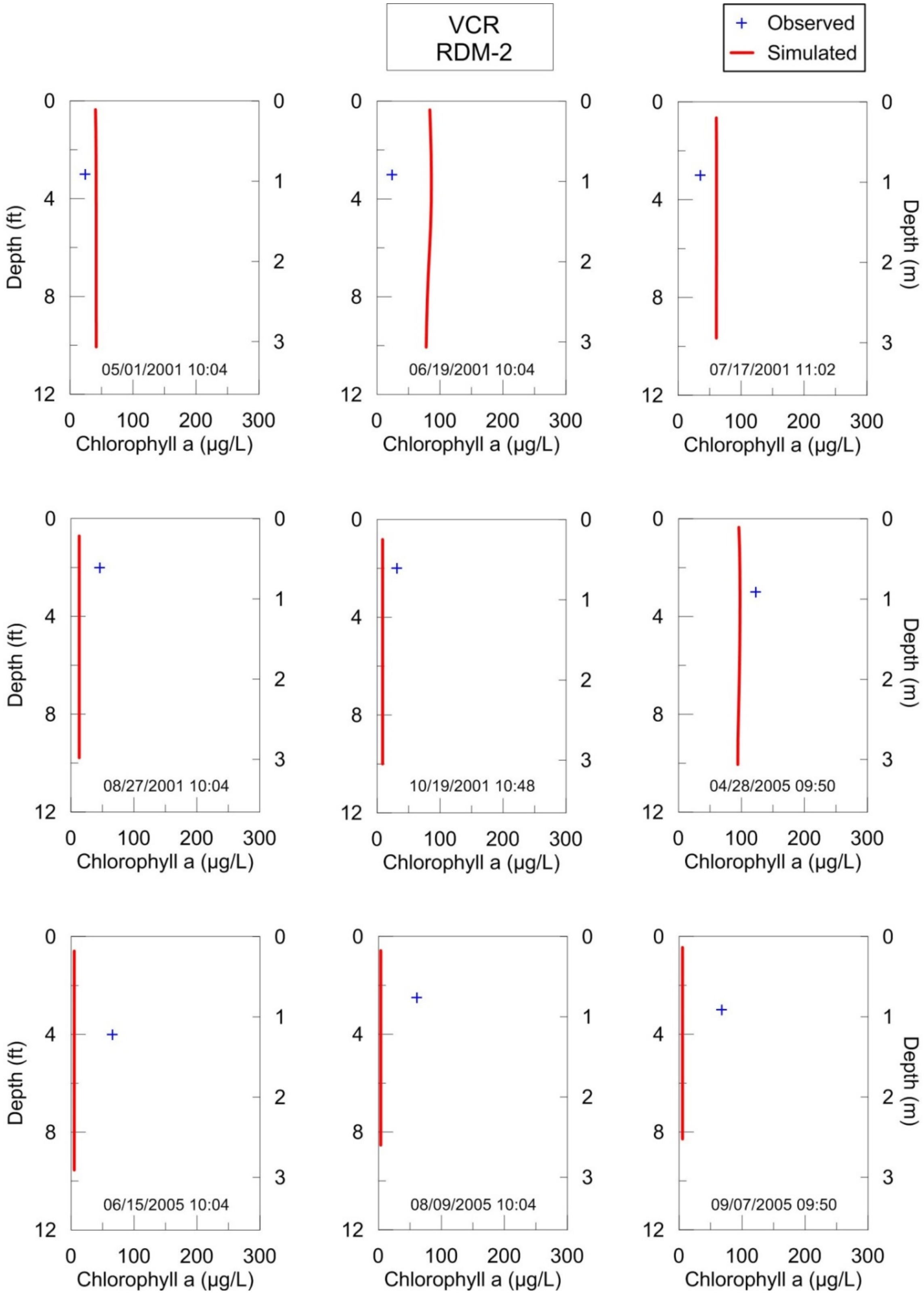

VCR
RDM-3
+ Observed
Simulated
Depth (ft)
Depth (m)
0
4
8
12
0
1
2
3
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
0 0.1 0.2 0.3 0.4
Dissolved Phosphorus (mg/L)

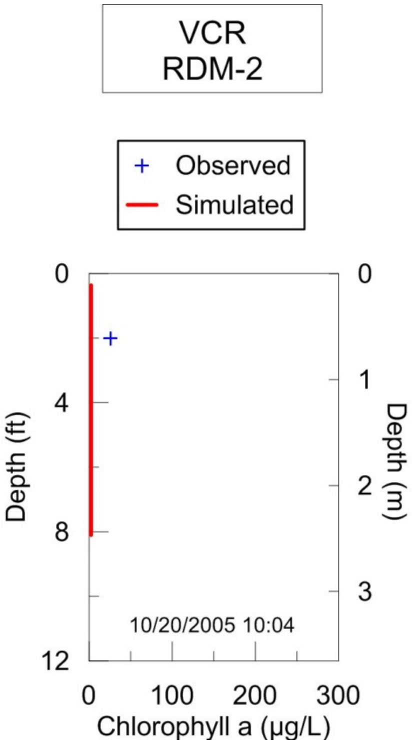
Chlorophyll *a*

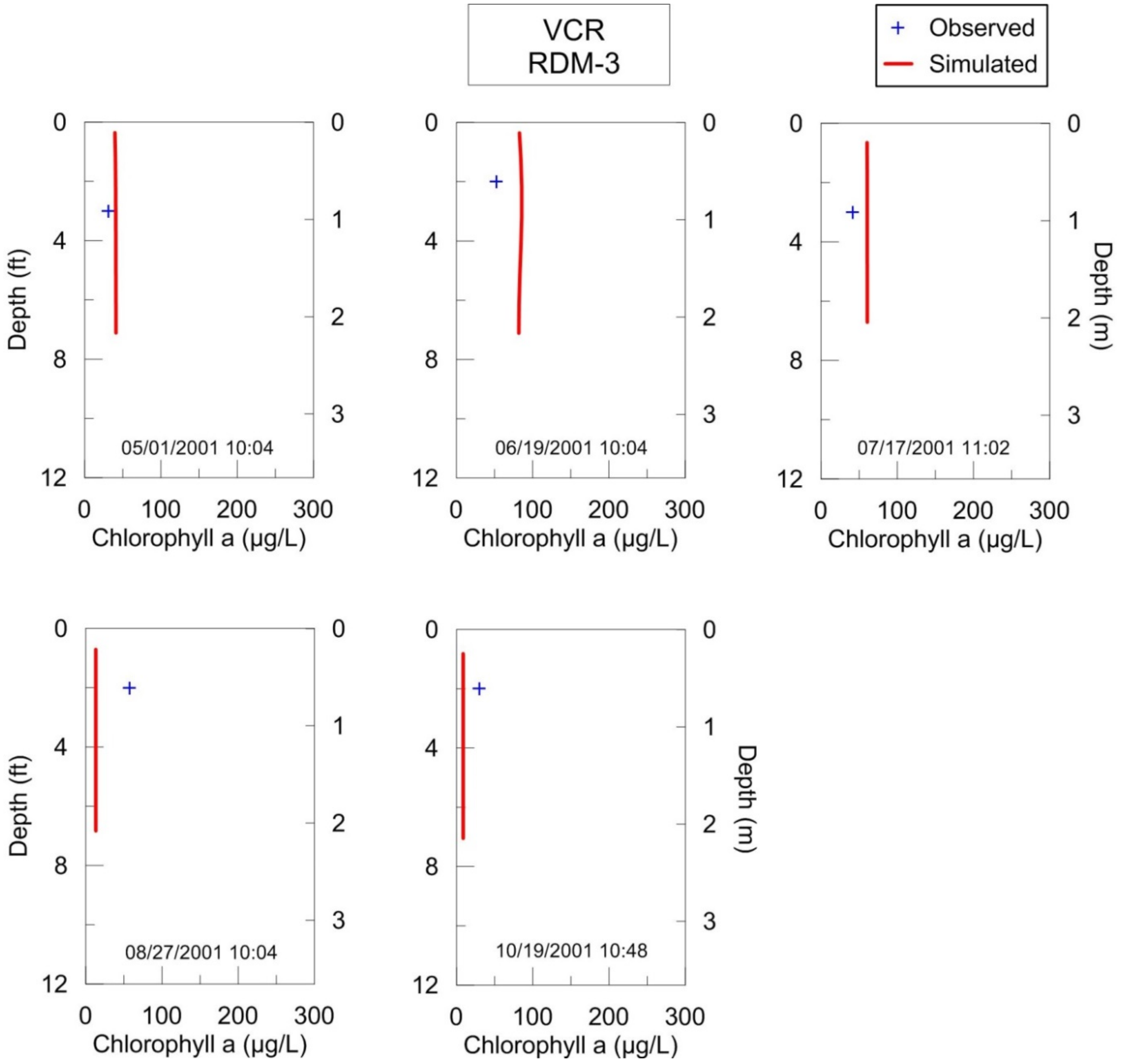



VCR
RDM-1
+ Observed
Simulated
Depth (ft)
Depth (m)
Chlorophyll a (µg/L)
0
4
8
12
0
1
2
3
0
100
200
300
10/20/2005 10:04
04/21/2009 10:19
06/18/2009 11:02
07/22/2009 15:07
10/22/2009 10:33
04/26/2010 10:48
06/16/2010 13:40
07/20/2010 10:04
09/07/2010 13:26


VCR
RDM-1
+ Observed
Simulated
Depth (ft)
Depth (m)
Chlorophyll a (µg/L)
0
4
8
12
0
1
2
3
0
100
200
300
10/14/2010 10:04
04/18/2011 10:19
06/06/2011 10:33
07/21/2011 09:50
08/19/2011 09:50
10/18/2011 10:19


VCR
RDM-2
+ Observed
Simulated
Depth (ft)
Depth (m)
Chlorophyll a (µg/L)
0
4
8
12
0
1
2
3
0
100
200
300
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48
04/28/2005 09:50
06/15/2005 10:04
08/09/2005 10:04
09/07/2005 09:50


VCR
RDM-2
+ Observed
Simulated
0
4
8
12
Depth (ft)
0
1
2
3
Depth (m)
10/20/2005 10:04
0
100
200
300
Chlorophyll a (µg/L)


VCR
RDM-3
Observed
Simulated
Depth (ft)
Depth (m)
Chlorophyll a (µg/L)
0
4
8
12
0
1
2
3
0
100
200
300
05/01/2001 10:04
06/19/2001 10:04
07/17/2001 11:02
08/27/2001 10:04
10/19/2001 10:48

Appendix E: Vermont City Reservoir Raw Water Atrazine Concentrations and Exceedance Values and % Exceedance

Concentrations (2002-2012)

Date	Atrazine (μg/L)	Date	Atrazine (μg/L)	Date	Atrazine (μg/L)	Date	Atrazine (μg/L)	Date	Atrazine (μg/L)
1/31/2002	1.09	6/14/2004	1.36	4/10/2006	0.05	3/10/2008	0.23	4/26/2010	0.55
2/11/2002	0.91	6/21/2004	1.44	4/17/2006	0.05	3/24/2008	0.19	5/3/2010	0.91
3/4/2002	1.15	6/28/2004	1.38	4/24/2006	0.28	4/7/2008	0.13	5/10/2010	0.75
4/8/2002	0.36	7/6/2004	1.73	5/1/2006	0.36	4/14/2008	0.18	5/17/2010	7.74
4/22/2002	0.52	7/12/2004	1.34	5/8/2006	0.2	4/21/2008	0.1	5/24/2010	11.77
5/6/2002	1.08	7/19/2004	1.32	5/15/2006	0.42	4/28/2008	0.12	6/1/2010	10.05
5/20/2002	16.93	7/26/2004	1.29	5/22/2006	0.24	5/5/2008	0.13	6/7/2010	14.33
6/3/2002	16.58	8/9/2004	1.49	5/30/2006	0.41	5/12/2008	0.14	6/14/2010	7.86
6/17/2002	5.01	8/23/2004	1.09	6/5/2006	0.99	5/19/2008	0.15	6/21/2010	1.1
7/8/2002	2.7	9/7/2004	1.21	6/13/2006	0.42	5/27/2008	0.19	6/28/2010	0.5
7/22/2002	3.12	9/20/2004	0.96	6/19/2006	0.49	6/2/2008	0.16	7/6/2010	0.56
8/5/2002	2.38	10/4/2004	0.98	6/26/2006	0.46	6/10/2008	3.31	7/12/2010	0.53
9/9/2002	2.48	10/18/2004	0.93	7/5/2006	0.91	6/16/2008	1.48	7/19/2010	0.7
11/4/2002	2.32	11/8/2004	0.78	7/10/2006	0.45	6/23/2008	1.74	7/26/2010	0.23
12/9/2002	2.44	11/22/2004	0.95	7/17/2006	0.54	6/30/2008	1.67	8/2/2010	0.19
2/10/2003	1.9	12/7/2004	0.66	7/24/2006	0.53	7/8/2008	1.57	8/16/2010	0.21
3/10/2003	2.01	12/20/2004	0.42	7/31/2006	0.63	7/14/2008	1.9	8/30/2010	0.22
4/7/2003	1.12	1/3/2005	0.47	8/14/2006	0.45	7/21/2008	1.4	9/13/2010	0.23
4/14/2003	1.66	1/18/2005	0.14	8/28/2006	0.45	7/28/2008	1.37	9/27/2010	0.2
4/21/2003	1.81	1/31/2005	0.13	9/11/2006	0.5	8/25/2008	1.04	10/12/2010	0.19
4/28/2003	1.51	2/14/2005	0.07	9/25/2006	0.31	9/8/2008	0.99	10/25/2010	0.2
5/5/2003	2.13	2/28/2005	0.25	10/10/2006	0.26	9/22/2008	0.26	11/8/2010	0.2
5/12/2003	3.25	3/14/2005	0.1	10/23/2006	0.28	1/12/2009	0.08	11/22/2010	0.17
5/19/2003	5.3	3/28/2005	0.08	11/6/2006	0.27	1/26/2009	0.08	12/6/2010	0.17
5/27/2003	3.95	4/4/2005	0.1	11/20/2006	0.29	2/9/2009	0.11	1/10/2011	0.13
6/2/2003	4.65	4/11/2005	0.14	1/2/2007	0.17	2/23/2009	0.07	1/24/2011	0.15
6/9/2003	4.18	4/18/2005	3.08	1/16/2007	0.16	3/9/2009	0.03	2/7/2011	0.12
6/16/2003	5.26	4/25/2005	3.72	1/29/2007	0.15	3/23/2009	0.03	2/22/2011	0.12
6/23/2003	4.93	5/2/2005	3.33	2/12/2007	0.15	4/6/2009	0.03	3/7/2011	0.09
6/30/2003	4.98	5/9/2005	3.79	2/26/2007	0.13	4/13/2009	0.03	3/21/2011	0.1
7/7/2003	4.58	5/16/2005	3.54	3/12/2007	0.03	4/20/2009	0.03	4/4/2011	0.08
7/14/2003	3.8	5/23/2005	3.08	3/26/2007	0.03	4/27/2009	0.03	4/11/2011	0.11
7/21/2003	3.28	5/31/2005	3.36	4/2/2007	0.03	5/4/2009	44.67	4/18/2011	0.1
7/28/2003	2.02	6/6/2005	3.05	4/9/2007	0.03	5/11/2009	27.22	4/25/2011	4.86
8/4/2003	2.74	6/13/2005	2.89	4/16/2007	0.07	5/18/2009	8.14	5/2/2011	4.15
8/18/2003	2.84	6/20/2005	2.98	4/23/2007	0.06	5/26/2009	7.78	5/9/2011	3.66
9/8/2003	2.9	6/27/2005	2.94	4/30/2007	10.72	6/1/2009	4.86	5/16/2011	3.52
9/22/2003	2.32	7/5/2005	2.17	5/7/2007	5.78	6/8/2009	5.33	5/23/2011	3.5
10/6/2003	2.78	7/12/2005	2.4	5/14/2007	3.66	6/15/2009	8.06	5/31/2011	9.73
10/20/2003	2.18	7/18/2005	2.33	5/21/2007	5.38	6/22/2009	7.01	6/6/2011	10.32
11/3/2003	2.94	7/25/2005	2.26	5/29/2007	4.72	6/29/2009	4.36	6/13/2011	8.31
11/18/2003	2.72	8/1/2005	2.08	6/4/2007	6.39	7/6/2009	4.26	6/20/2011	4.75
12/1/2003	2.01	8/15/2005	1.76	6/11/2007	5.17	7/13/2009	1.8	6/27/2011	3.53
12/15/2003	1.24	8/29/2005	1.88	6/18/2007	4.52	7/20/2009	0.93	7/6/2011	2.43
1/12/2004	1.29	9/12/2005	2.2	6/25/2007	4.01	7/27/2009	1.09	7/11/2011	3.12
1/26/2004	1.29	9/26/2005	1.65	7/2/2007	4.23	8/10/2009	0.46	7/18/2011	2.33
2/9/2004	1.72	10/11/2005	1.69	7/9/2007	5.18	8/24/2009	0.75	7/25/2011	2.1
2/23/2004	1.23	10/24/2005	1.07	7/16/2007	3.35	9/8/2009	0.61	8/1/2011	1.92
3/8/2004	1.01	11/7/2005	0.9	7/23/2007	1.74	9/21/2009	0.51	8/15/2011	1.99
3/22/2004	0.82	11/21/2005	1.18	7/30/2007	2.47	10/5/2009	0.56	8/29/2011	2
4/5/2004	0.73	12/12/2005	0.78	8/13/2007	1.69	10/19/2009	1.35	9/12/2011	1.6
4/12/2004	0.8	12/19/2005	1.03	8/27/2007	1.61	11/2/2009	5.16	9/26/2011	1.73
4/19/2004	0.68	1/3/2006	1.42	9/10/2007	1.47	1/11/2010	0.84	10/11/2011	1.63
4/26/2004	0.81	1/17/2006	1.15	9/24/2007	1.64	1/25/2010	0.84	10/24/2011	1.64
5/3/2004	0.83	1/30/2006	1	10/9/2007	1.47	2/8/2010	0.62	11/7/2011	1.36
5/10/2004	0.82	2/13/2006	0.88	1/2/2008	0.97	2/22/2010	0.41	11/21/2011	1.23
5/17/2004	0.8	2/27/2006	1.04	1/14/2008	0.71	3/8/2010	0.1	12/5/2011	1.2
5/24/2004	0.71	3/13/2006	0.83	1/28/2008	0.68	3/22/2010	0.32	1/9/2012	1.13
6/1/2004	2.12	3/27/2006	0.61	2/11/2008	0.69	4/5/2010	0.25	1/23/2012	1.07
6/7/2004	1.87	4/3/2006	0.84	2/25/2008	0.34	4/12/2010	0.35	2/6/2012	1.09
						4/19/2010	0.27	3/5/2012	1
								3/19/2012	0.98
								4/2/2012	0.83

Exceedance Values and % Exceedance

Date	Exceedance Concentrations (µg/L)	% Exceedance
6/6/2005	3.05	0.98814
4/18/2005	3.08	2.56917
5/23/2005	3.08	4.1502
7/22/2002	3.12	5.73123
7/11/2011	3.12	7.31225
5/12/2003	3.25	8.89328
7/21/2003	3.28	10.47431
6/10/2008	3.31	12.05534
5/2/2005	3.33	13.63636
7/16/2007	3.35	15.21739
5/31/2005	3.36	16.79842
5/23/2011	3.5	18.37945
5/16/2011	3.52	19.96047
6/27/2011	3.53	21.5415
5/16/2005	3.54	23.12253
5/14/2007	3.66	24.70356
5/9/2011	3.66	26.28458
4/25/2005	3.72	27.86561
5/9/2005	3.79	29.44664
7/14/2003	3.8	31.02767
5/27/2003	3.95	32.6087
6/25/2007	4.01	34.18972
5/2/2011	4.15	35.77075
6/9/2003	4.18	37.35178
7/2/2007	4.23	38.93281
7/6/2009	4.26	40.51383
6/29/2009	4.36	42.09486
6/18/2007	4.52	43.67589
7/7/2003	4.58	45.25692
6/2/2003	4.65	46.83794
5/29/2007	4.72	48.41897
6/20/2011	4.75	50
6/1/2009	4.86	51.58103
4/25/2011	4.86	53.16206
6/23/2003	4.93	54.74308
6/30/2003	4.98	56.32411
6/17/2002	5.01	57.90514
11/2/2009	5.16	59.48617
6/11/2007	5.17	61.06719
7/9/2007	5.18	62.64822
6/16/2003	5.26	64.22925
5/19/2003	5.3	65.81028
6/8/2009	5.33	67.3913
5/21/2007	5.38	68.97233
5/7/2007	5.78	70.55336
6/4/2007	6.39	72.13439
6/22/2009	7.01	73.71542
5/17/2010	7.74	75.29644
5/26/2009	7.78	76.87747
6/14/2010	7.86	78.4585
6/15/2009	8.06	80.03953
5/18/2009	8.14	81.62055
6/13/2011	8.31	83.20158
5/31/2011	9.73	84.78261
6/1/2010	10.05	86.36364
6/6/2011	10.32	87.94466
4/30/2007	10.72	89.52569
5/24/2010	11.77	91.10672
6/7/2010	14.33	92.68775
6/3/2002	16.58	94.26877
5/20/2002	16.93	95.8498
5/11/2009	27.22	97.43083
5/4/2009	44.67	99.01186

Appendix F: Major coefficients and constants used in the QUAL2K Model of Sugar Creek

PATHOGENS

Model Symbol	Description	Default Value	Value	Units
k_{dx}	Decay rate	0.50	0.10	*/d*
θ_{dx}	Temperature correction	1.07	1.07	NA
v_x	Settling velocity	0	0	*m/d*
α_{path}	Light efficiency factor	1.00	0.03	NA

LIGHT AND HEAT

Solar Shortwave Radiation Model

Model Symbol	Description	Default Value	Value	Units
NA	Atmospheric attenuation model for solar	Bras	Bras	NA
n_{fac}	Bras solar atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	2	2	NA

Downwelling Atmospheric Longwave IR Radiation

Model Symbol	Description	Default Value	Value	Units
NA	Atmospheric longwave emissivity model	Brunt	Brunt	NA

Evaporation and Air Convection/Conduction

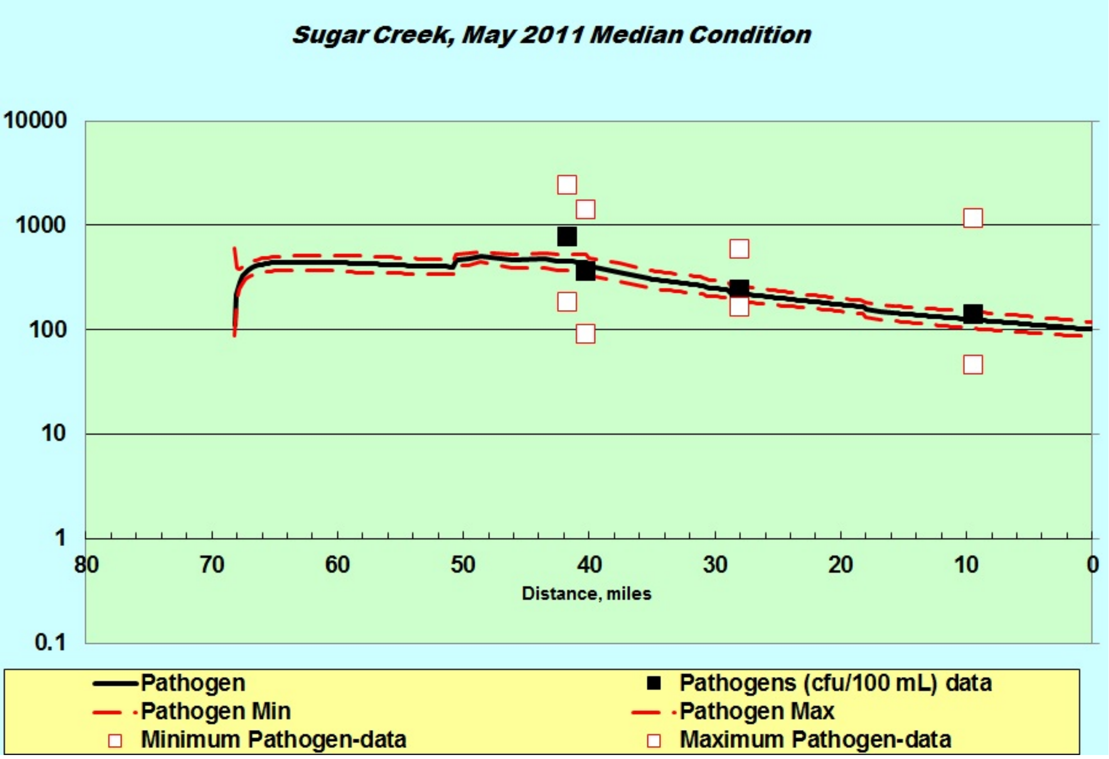
Model Symbol	Description	Default Value	Value	Units
NA	Wind speed function for evaporation and air convection/conduction	Adams 1	Adams 1	NA

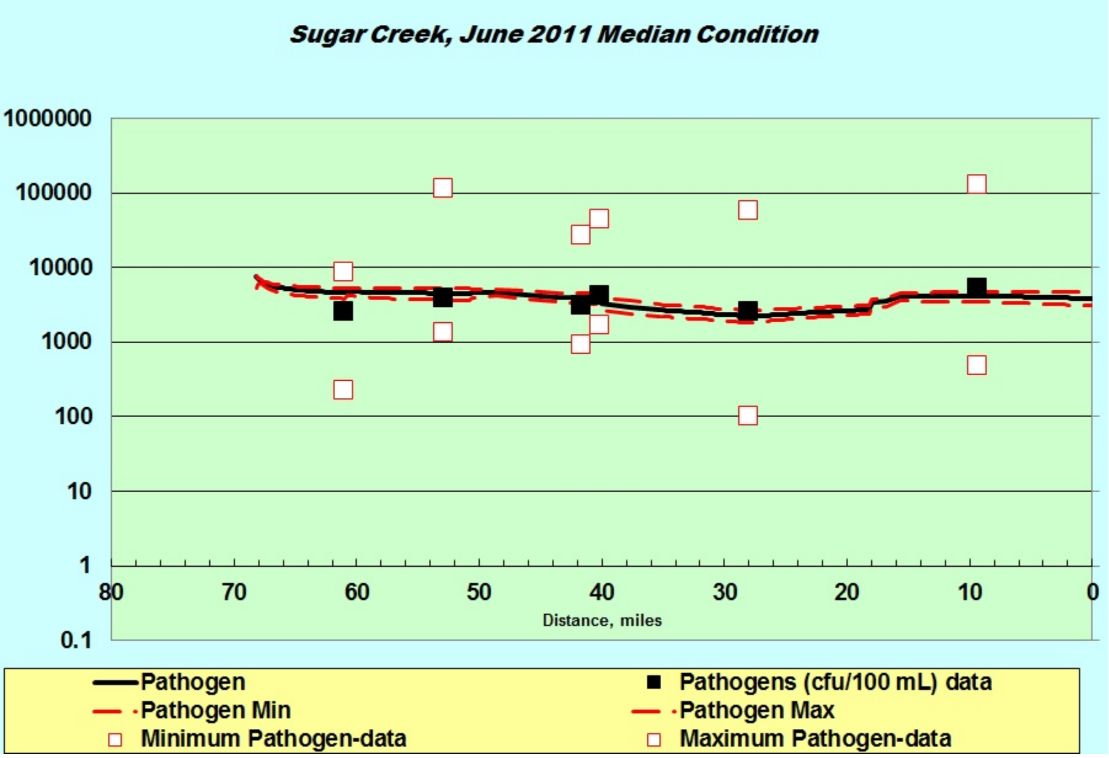
Sediment Heat Parameters

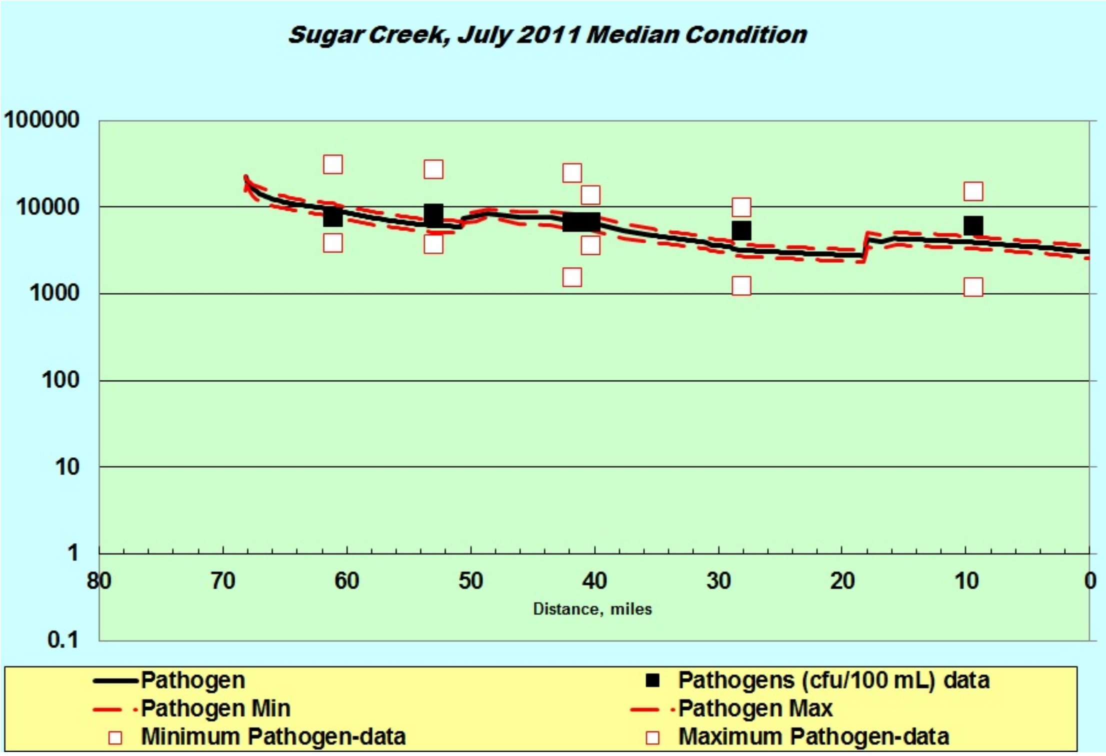
Model Symbol	Description	Default Value	Value	Units
H_s	Sediment thermal thickness	15	15	*cm*
α_s	Sediment thermal diffusivity	0.0064	0.0064	cm^2/s
ρ_s	Sediment density	1.6	1.6	g/cm^3
C_{ps}	Sediment heat capacity	0.4	0.4	*cal/(g °C)*

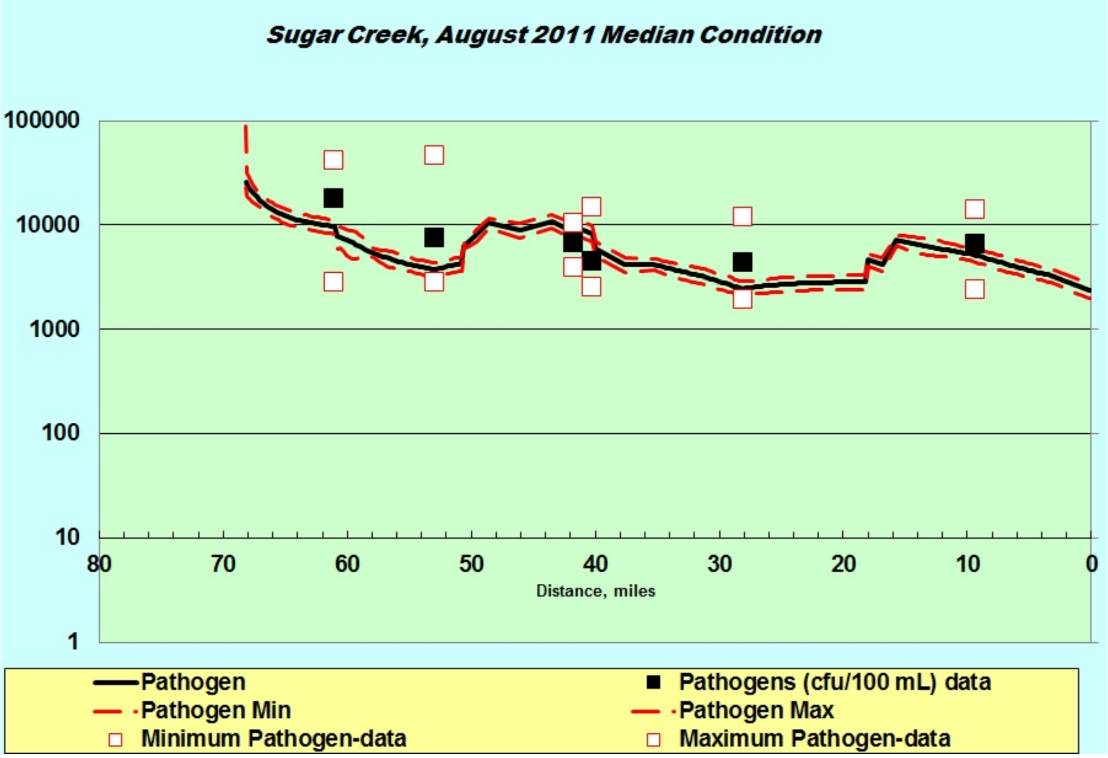
Appendix G: Sugar Creek Mainstem QUAL2K Model Results

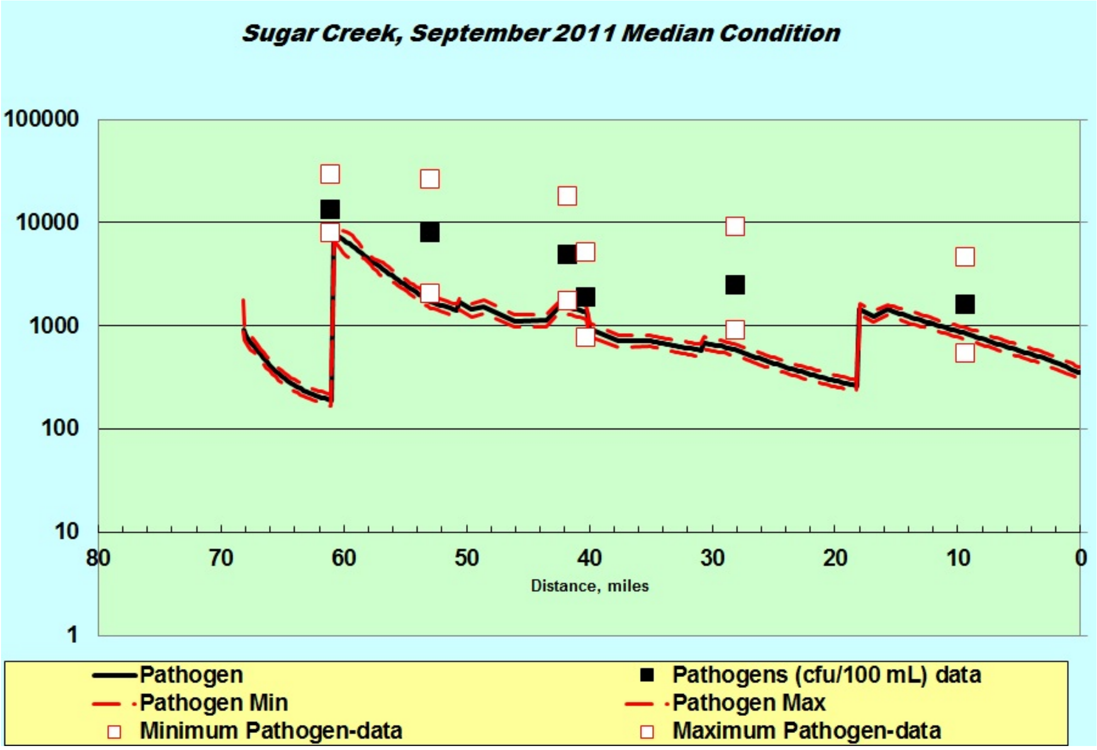
Fecal Coliform

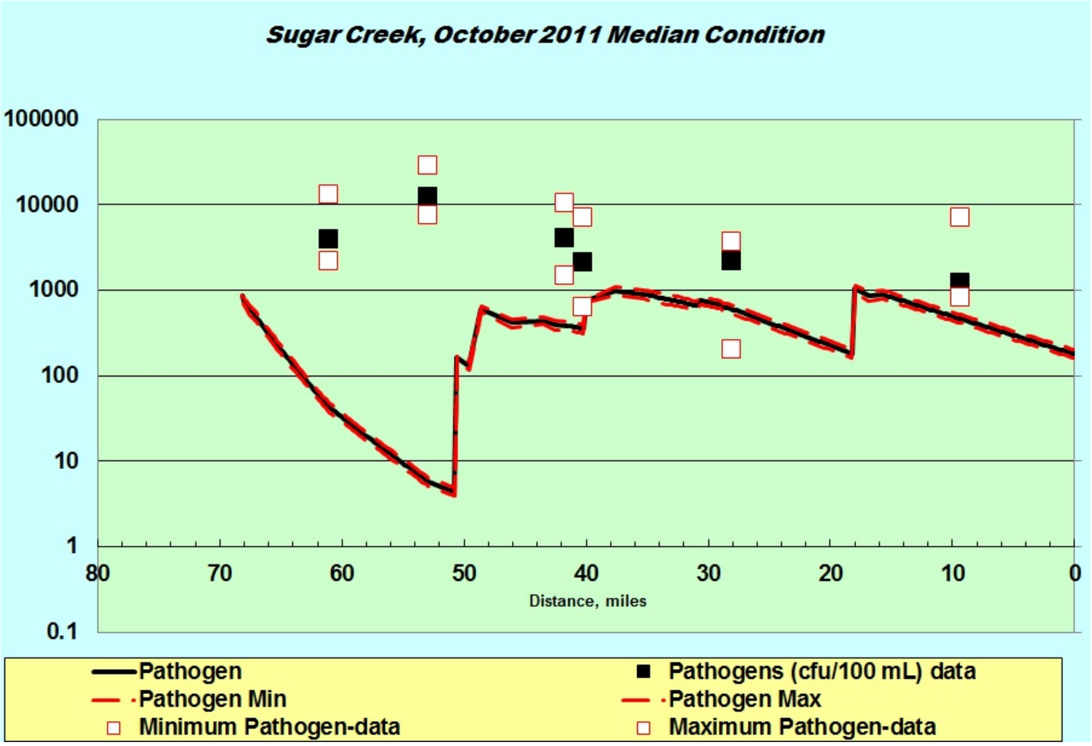




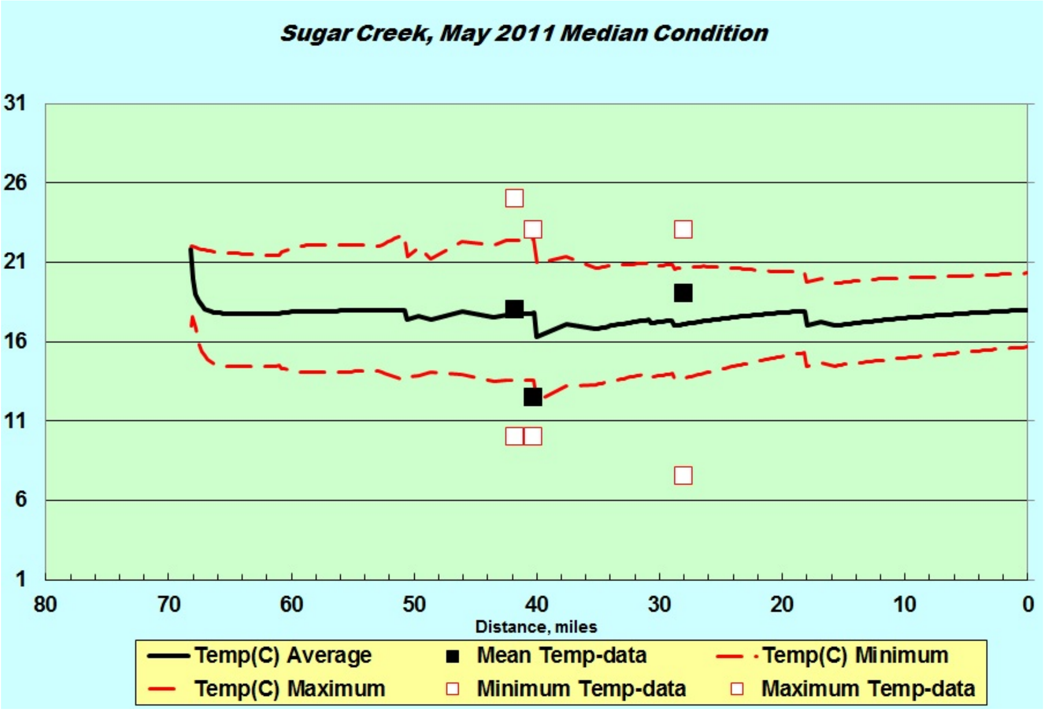

Sugar Creek, July 2011 Median Condition
100000
10000
1000
100
10
1
0.1
80
70
60
50
40
30
20
10
0
Distance, miles
Pathogen
Pathogens (cfu/100 mL) data
Pathogen Min
Pathogen Max
Minimum Pathogen-data
Maximum Pathogen-data

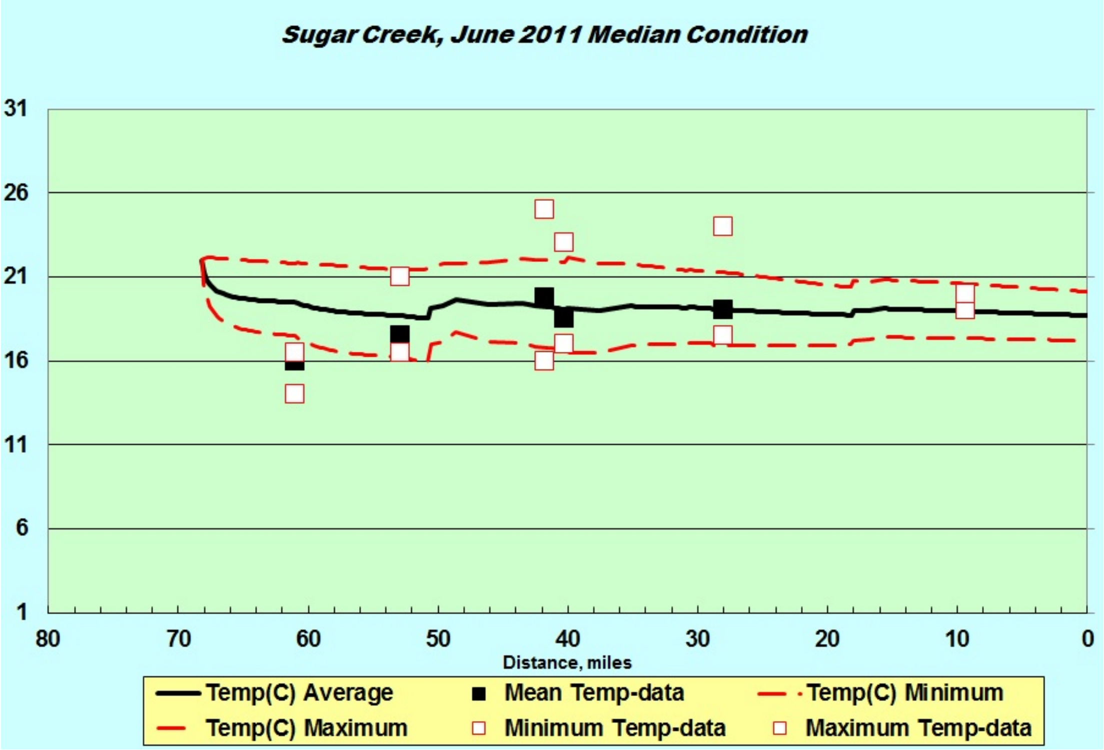

Sugar Creek, August 2011 Median Condition
100000
10000
1000
100
10
1
80
70
60
50
40
30
20
10
0
Distance, miles
Pathogen
Pathogens (cfu/100 mL) data
Pathogen Min
Pathogen Max
Minimum Pathogen-data
Maximum Pathogen-data

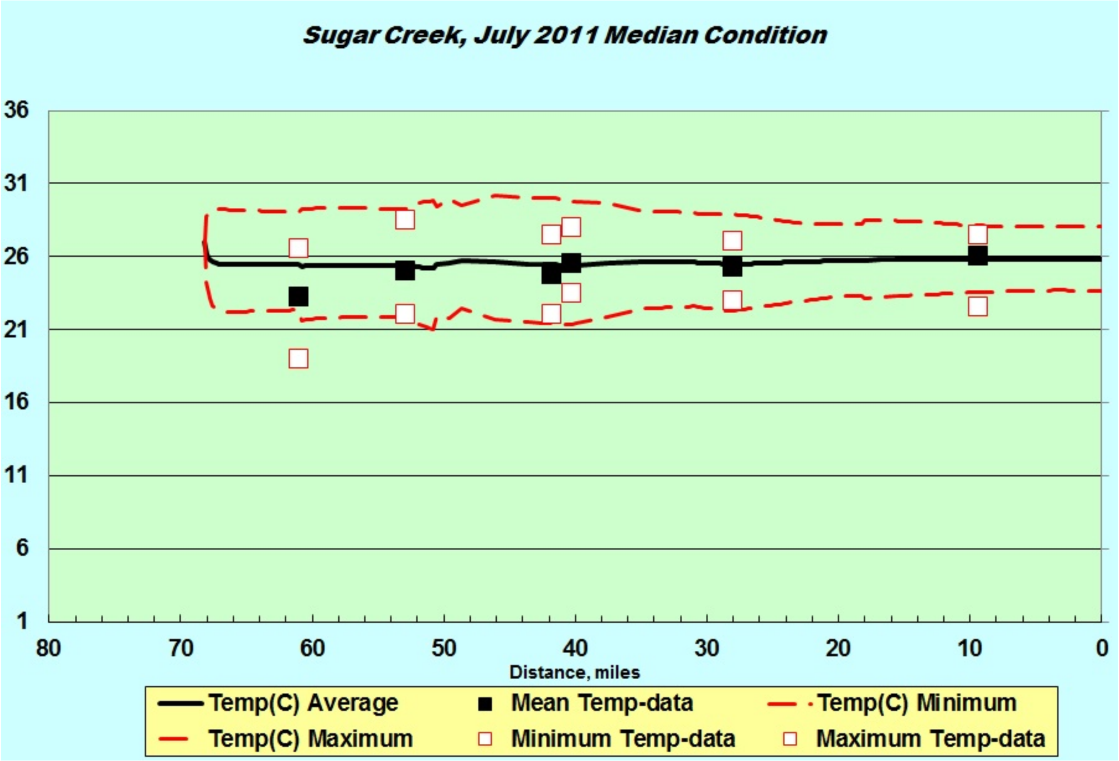

Sugar Creek, September 2011 Median Condition
100000
10000
1000
100
10
1
80
70
60
50
40
30
20
10
0
Distance, miles
Pathogen
Pathogen Min
Minimum Pathogen-data
Pathogens (cfu/100 mL) data
Pathogen Max
Maximum Pathogen-data


Sugar Creek, October 2011 Median Condition
100000
10000
1000
100
10
1
0.1
80
70
60
50
40
30
20
10
0
Distance, miles
Pathogen
Pathogen Min
Minimum Pathogen-data
Pathogens (cfu/100 mL) data
Pathogen Max
Maximum Pathogen-data

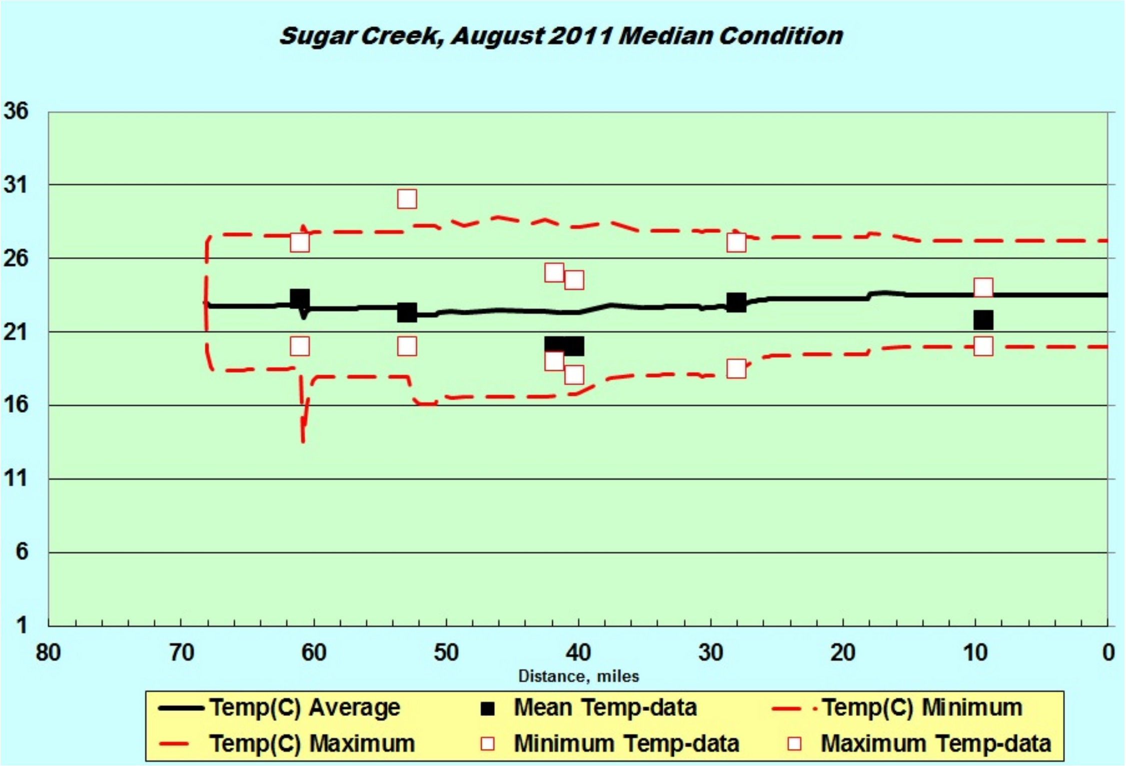
Temperature



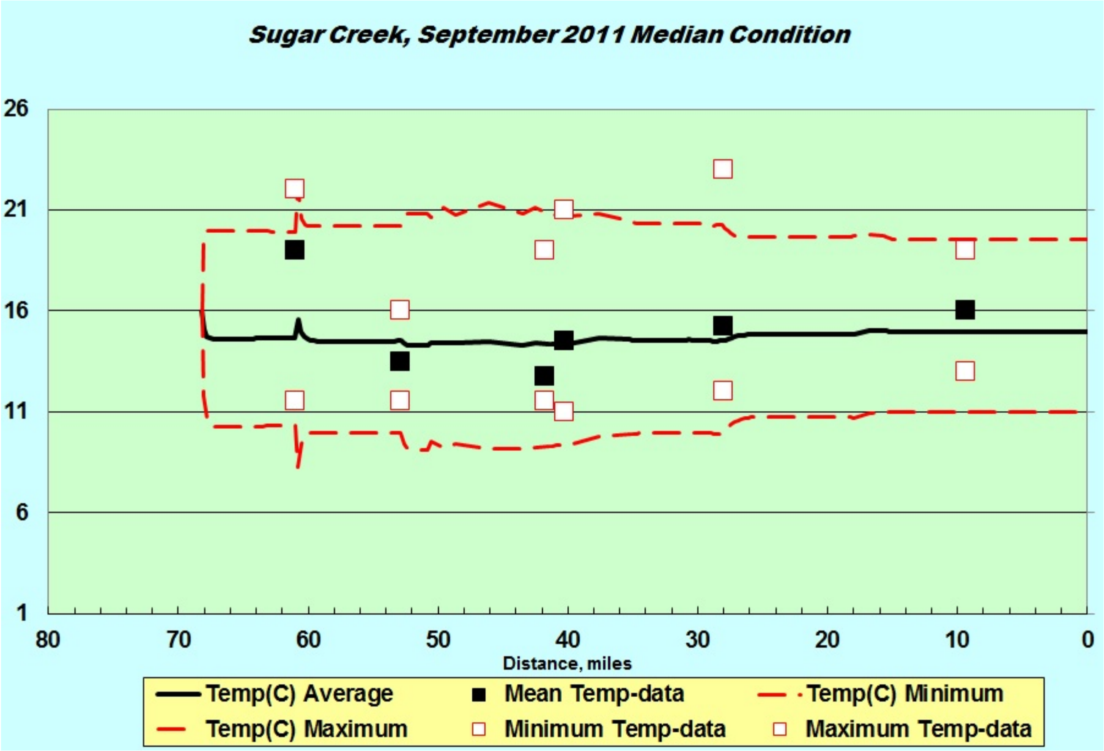




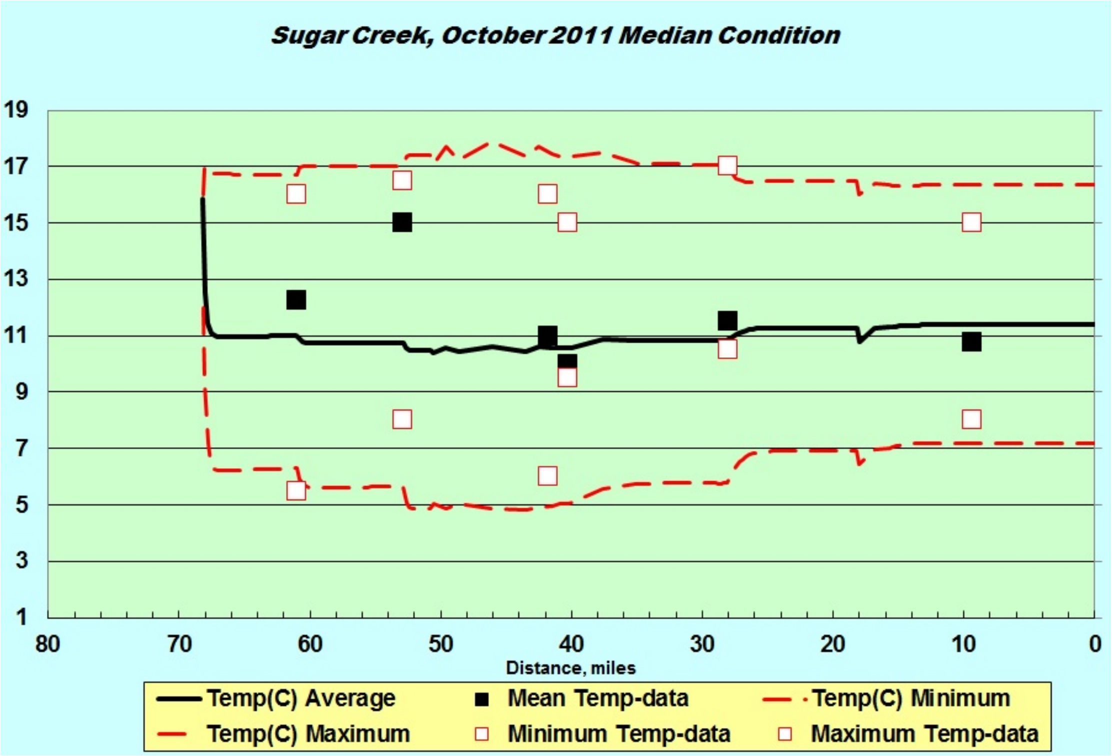
Sugar Creek, July 2011 Median Condition
36
31
26
21
16
11
6
1
80
70
60
50
40
30
20
10
0
Distance, miles
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data



Sugar Creek, August 2011 Median Condition
36
31
26
21
16
11
6
1
80
70
60
50
40
30
20
10
0
Distance, miles
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data

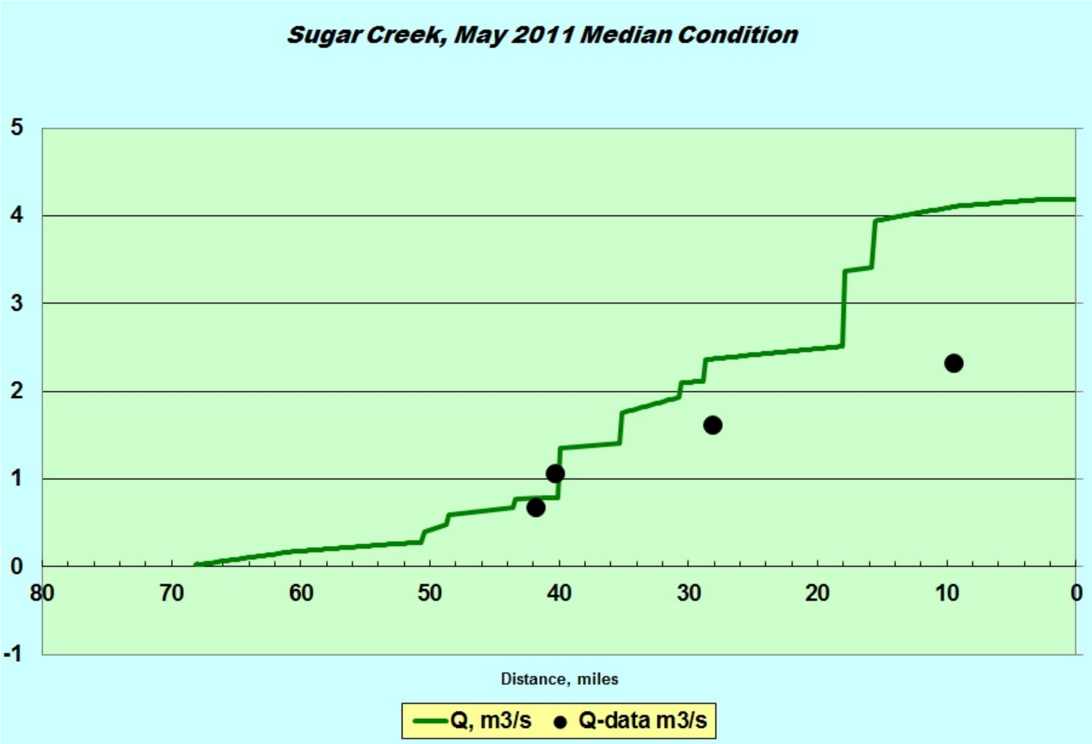


Sugar Creek, September 2011 Median Condition
26
21
16
11
6
1
80
70
60
50
40
30
20
10
0
Distance, miles
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data

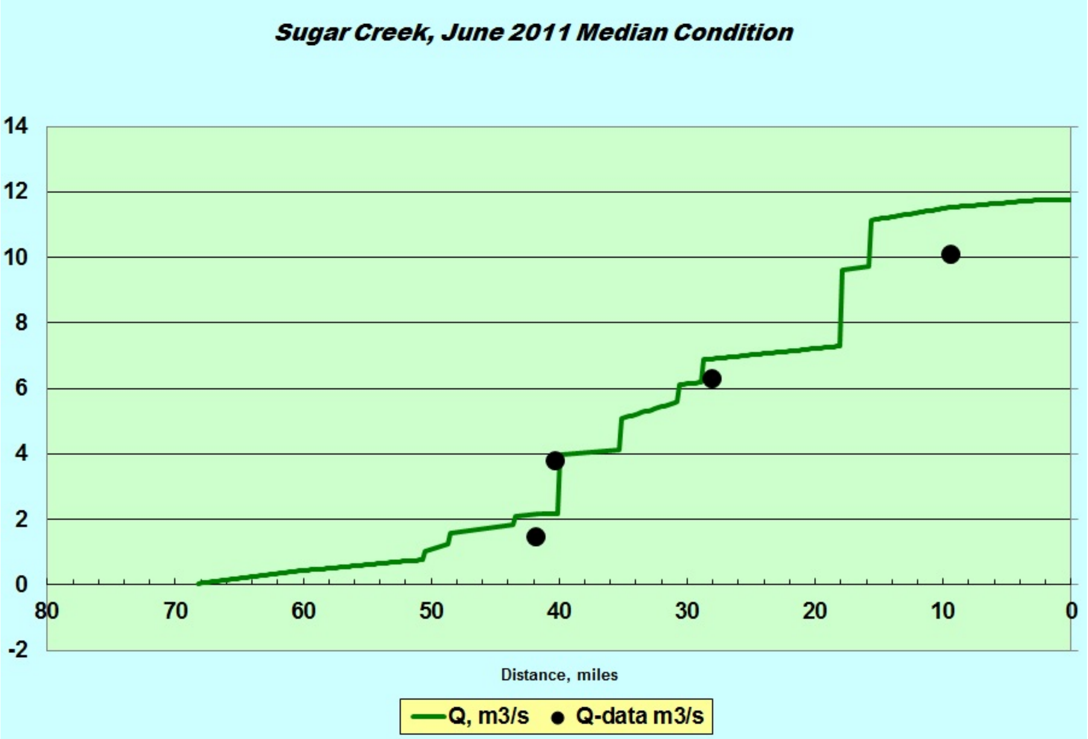


Sugar Creek, October 2011 Median Condition
19
17
15
13
11
9
7
5
3
1
80
70
60
50
40
30
20
10
0
Distance, miles
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data

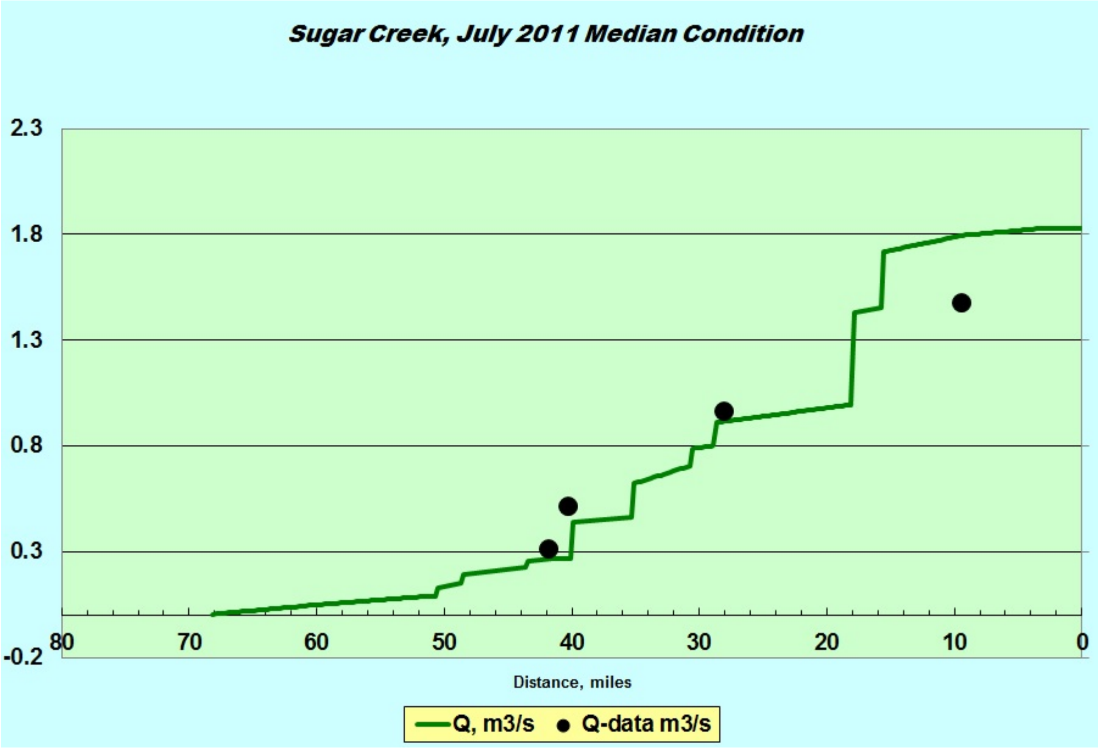
Flow

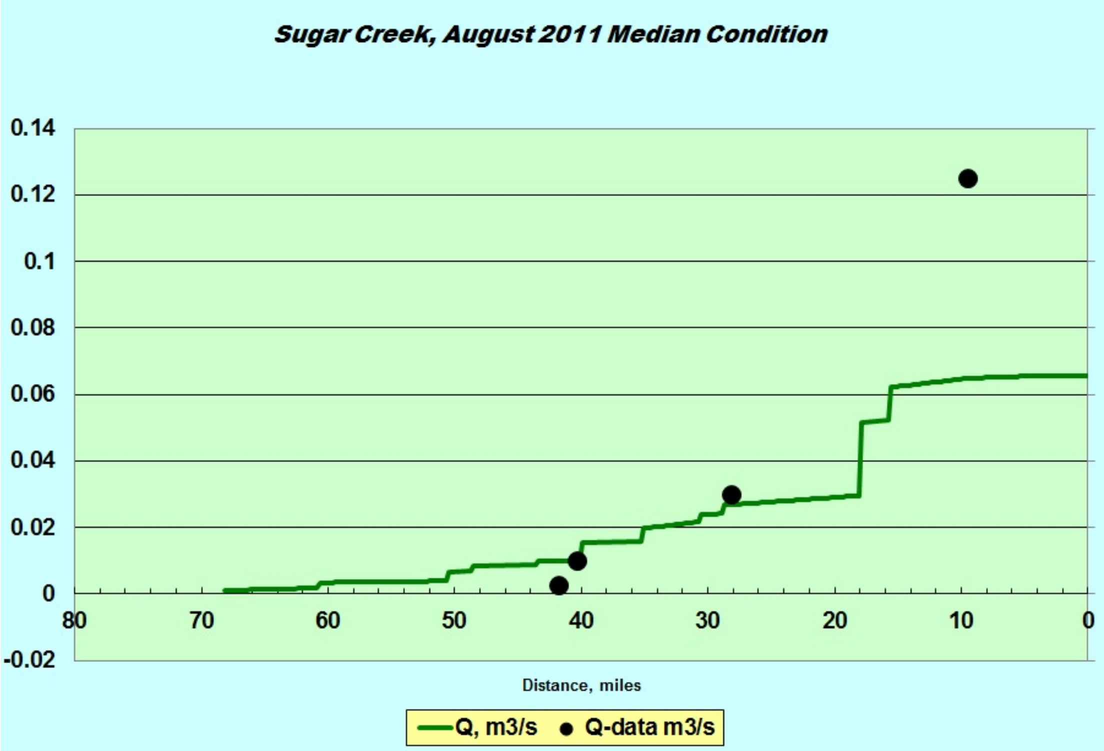


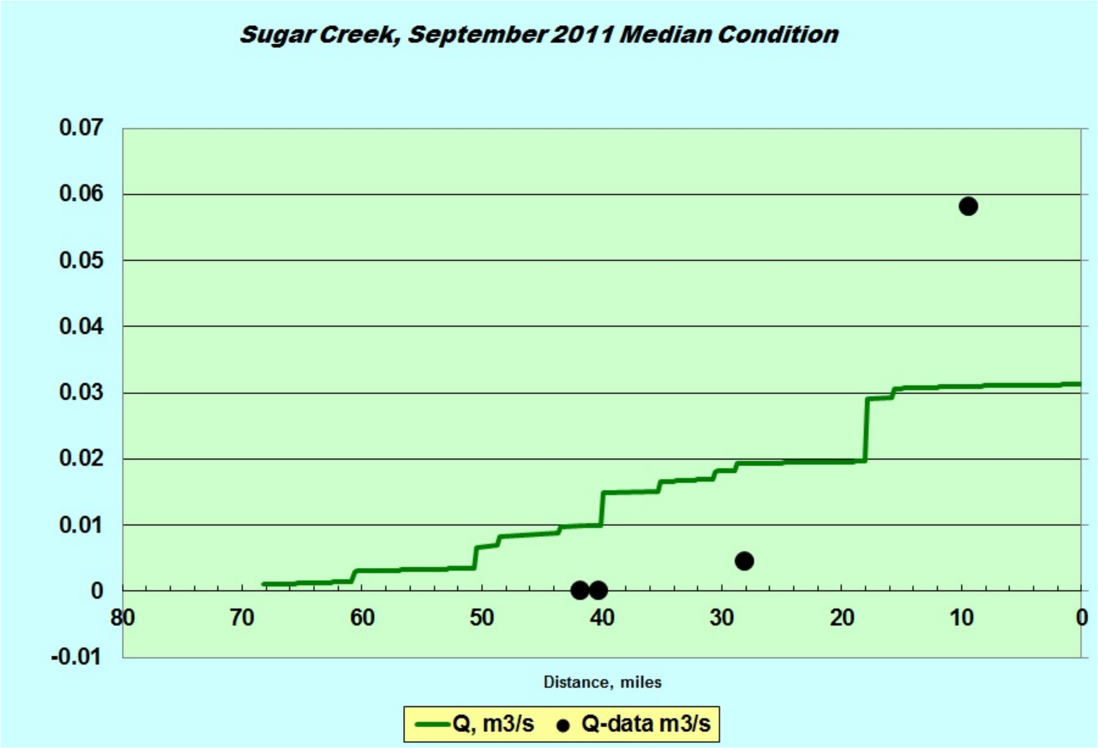
Sugar Creek, May 2011 Median Condition
5
4
3
2
1
0
-1
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s

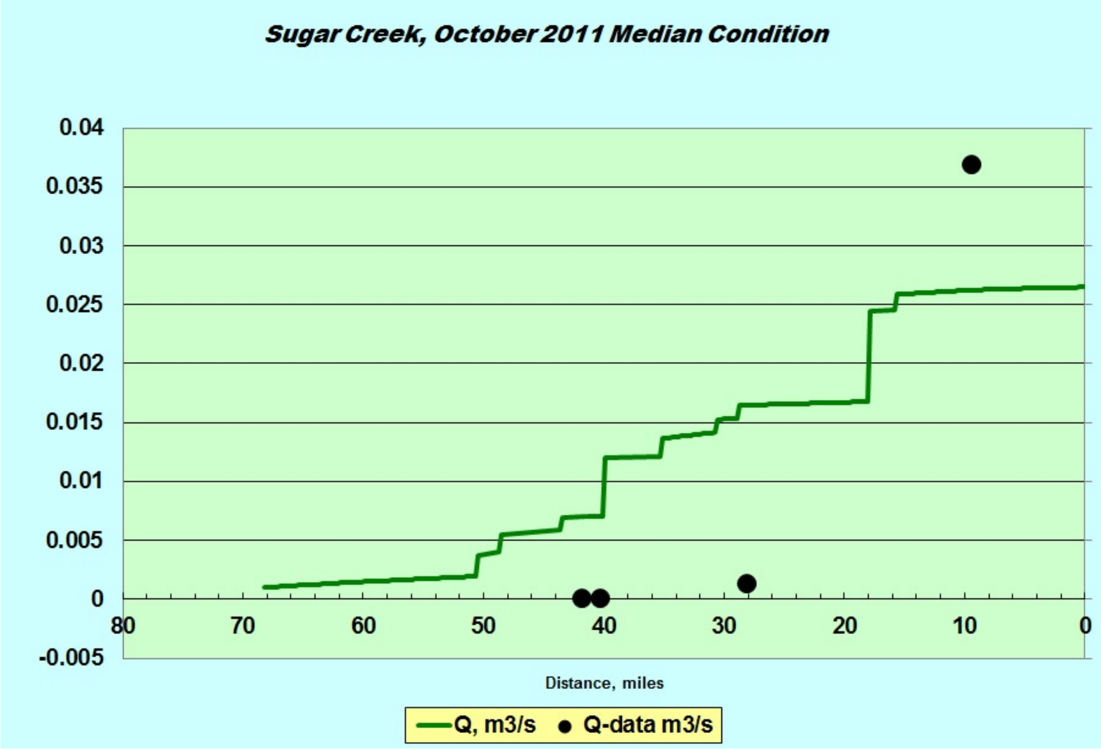


Sugar Creek, June 2011 Median Condition
14
12
10
8
6
4
2
0
-2
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s


Sugar Creek, July 2011 Median Condition
2.3
1.8
1.3
0.8
0.3
-0.2
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s


Sugar Creek, August 2011 Median Condition
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s


Sugar Creek, September 2011 Median Condition
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s


Sugar Creek, October 2011 Median Condition
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
80
70
60
50
40
30
20
10
0
Distance, miles
Q, m3/s
Q-data m3/s

Appendix H: Sugar Creek Mainstem Fecal Coliform Monthly Loads

May

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	4.18	490,950
Geometric Mean	1.00	201,939
Minimum/Low	0.003	287

June

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	11.74	41,687,657
Geometric Mean	2.72	8,619,685
Minimum/Low	0.006	21,393

July

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	1.83	2,664,640
Geometric Mean	0.36	607,339
Minimum/Low	0.001	903

August

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	0.07	385,484
Geometric Mean	0.01	2,012
Minimum/Low	0.001	2,012

September

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	0.03	62,443
Geometric Mean	0.01	7,628
Minimum/Low	0.001	237

October

Flow	Q (m3/s)	Actual Load (mil. col/day)
Maximum/High	0.03	21,974
Geometric Mean	0.01	1,355
Minimum/Low	0.001	7

Appendix I: Acronyms

MODELING and GENERAL

BASINS	Better Assessment Science Integrating point & Non-point Sources
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operations
CSO	Combined Sewer Overflow
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DOM	Dissolved Organic Matter
DOM-N	Dissolved Organic Matter - Nitrogen
DOM-P	Dissolved Organic Matter - Phosphorus
DP	Dissolved Phosphorus
GWLF	Generalized Watershed Loading Function
HUC	Hydrologic Unit Code
LA	Load Allocation
LC	Loading Capacity
LiDAR	Light Detection and Ranging
MCL	Maximum Contaminant Level
MOS	Margin of Safety
OM	Organic Matter
OM-N	Organic Matter - Nitrogen
OM-P	Organic Matter - Phosphorus
POM	Particulate Organic Matter
POM-N	Particulate Organic Matter - Nitrogen
POM-P	Particulate Organic Matter - Phosphorus
RC	Reserve Capacity
S-O	Simulated minus Observed
STP	Sewage Treatment Plant
TDS	Total Dissolved Solid
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USLE	Universal Soil Loss Equation
VSS	Volatile Suspended Solid
WLA	Waste Load Allocation
WQS	Water Quality Standard
WTP	Water Treatment Plant

STATISTICS

NSE	Nash-Sutcliffe efficiency
PBIAS	Percent bias
R^2	Pearson's coefficient of determination
RMSE	Root mean square error
RSR	RMSE-Observations standard deviation ratio

DATA SOURCE

CREP	Conservation Reserve Enhancement Program
IL-GAP	Illinois Gap Analysis Project
NEXRAD	Next Generation Weather Radar
NHD	National Hydrography Dataset
QCLCD	Quality Controlled Local Climatological Data
SSURGO	Soil Survey Geographic Database
ULDC	Unedited Local Climatological Data

STATE AND FEDERAL AGENCY

IEPA	Illinois Environmental Protection Agency
ISWS	Illinois State Water Survey
MRCC	Midwest Regional Climate Center
NCDC	National Climatic Data Center
NRCS	National Resource Conservation Service
USDA	United States Department of Agriculture
USGS	United States Geological Survey

UNITS

MG	Mega Gallon
MGD	Mega Gallon per Day

Appendix J: Public Notice

Illinois Environmental Protection Agency (IEPA)
Bureau of Water

NOTICE
of
Draft Total Maximum Daily Load for Vermont City Reservoir/Sugar Creek Watershed

(McDonough, Fulton, and Schuyler Counties)

and

Public Comment Period

Public Notice Beginning Date:	**February 7, 2019**
Public Notice Ending Date:	**March 8, 2019**

The purpose of this public notice is to provide an opportunity for the public to provide comments on the draft Phase II Total Maximum Daily Load (TMDL) study concerning impairments to Vermont City Reservoir/Sugar Creek Watershed.

The potential causes of impairment for Vermont City Reservoir (IL_RDM) are Atrazine, and Phosphorus Total (TP). Potential cause of impairments for Sugar Creek (IL_DH-01) is Fecal Coliform.

The draft report includes watershed characterization, data analysis, and pollutant loading capacity analysis that have been used to determine the reductions necessary to meet designated uses and water quality standards. Also included is an implementation plan designed to meet the reductions needed.

IEPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act. A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

The public is encouraged to provide input on the draft TMDL report including potential Best Management Practice (BMP) projects that could be included as part of the implementation plan in the final draft Phase II report.

The draft Phase II TMDL report for Vermont City Reservoir/Sugar Creek Watershed is available on-line at: https://www2.illinois.gov/epa/public-notices/Pages/general-notices.aspx. A hard copy of the draft report is available for viewing at the Vermont Public Library, Astoria Town Hall, and Table Grove Village Hall during business hours. Questions and comments about the draft TMDL report should be directed to Abel Haile (see contact information below).

The public notice comment period will close on March 6, 2019.
E-mail comments must be received no later than 11:59 p.m. on March 6, 2019. Written comments need not be notarized but must be postmarked no later than March 6, 2019 and mailed to:

Abel Haile
Manager, Planning (TMDL) Unit, Mail Code#15
Watershed Management Section, Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
P. O. Box 19276
Springfield, IL 62794-
9276 Phone 217-782-
3362
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TDD (Hearing impaired) 866-273-5488
Fax: 217-785-8346

Appendix K: Responsiveness Summary

Responsiveness Summary

Sugar Creek and Vermont City Reservoir Watershed

Total Maximum Daily Load

The responsiveness summary responds to questions and comments received during the public comment period from February 7, 2019, through March 8, 2019.

What is a TMDL?

A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant. **The Sugar Creek and Vermont City Reservoir Watershed** TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies 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 regulations thereunder.

Background

The watershed targeted for TMDL development is the **Sugar Creek and Vermont City Reservoir Watershed** located in McDonough, Fulton, and Schuyler counties in western Illinois. The headwaters of Sugar Creek are in southeast McDonough County. Sugar Creek flows in a northeasterly direction as it enters Fulton County, but gradually swings to the southwest over the next 5 miles and passes through McDonough County and into Schuyler County until its confluence with the West Branch of Sugar Creek. After the West Branch joins the mainstem, Sugar Creek continues in a general southeasterly direction until its confluence with the Illinois River. Total drainage area for the Sugar Creek watershed is approximately 161 square miles.

Vermont City Reservoir, also known as Vermont New Lake, is located on an unnamed tributary to Sugar Creek in southeast McDonough County. The reservoir spillway is located approximately 0.3 river miles above the mouth of the unnamed tributary. The Vermont City Reservoir watershed has a total drainage area of approximately 2.3 square miles.

The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA has developed TMDLs for pollutants that have numeric water quality standards in Sugar Creek and Vermont Reservoir watershed. Therefore, Total Phosphorus (TP), and Atrazine TMDLs were developed for Vermont City Reservoir (IL_RDM), and Fecal Coliform TMDL was developed for Sugar Creek (IL_DH-01). These waterbodies are listed as impaired in the 2012-2018 *Draft Illinois Integrated Water Quality Reports and Section 303(d) List.*

Illinois EPA contracted with Illinois State Water Survey (ISWS) to prepare the TMDL report for t Sugar Creek and Vermont City Reservoir Watershed.

Public Notice

The Illinois Environmental Protection Agency (IEPA) issued a public notice and the draft Phase II report was posted on the Agency's website: https://www2.illinois.gov/epa/public-notices/Pages/general-notices.aspx on February 9, 2019, with the public comment period running through March 8, 2019.

IEPA also issued a public notice by placing a display-ad, in The Astoria South Fulton Argus (the local newspaper in Albion, Illinois) on February 13, 2019. In addition, a direct mailing of the public notice was sent to non-governmental organizations, NPDES Permittees and stakeholders in the watershed. The public notice also provided references on how to obtain additional information about the draft TMDL report, the TMDL program, and other related information. A hard copy of the draft TMDL report was available for viewing at Vermont Public Library, Astoria Town Hall, and Table Grove Village during business hours.

Questions & Comments

No comments received.