TMDL Development for Squaw Creek and Stillwell Creek, Wisconsin

FINAL REPORT

September 27, 2006

Prepared for:

Fort McCoy
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Wisconsin Department of Natural Resources

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1.0 INTRODUCTION

Squaw Creek and Stillwell Creek are tributary streams of the Upper La Crosse River Basin, located in Monroe County in west-central Wisconsin, as shown in 1. The streams are within the boundaries of Fort McCoy, a federal military facility. Both Squaw Creek and Stillwell Creek are classified as "water quality-limited" and have been placed on Wisconsin's list of water bodies in need of restoration, a list prepared in accordance with Section 303(d) of the Clean Water Act and known as the "303(d) list." The Wisconsin Department of Natural Resources (WDNR) listed Squaw Creek due to temperature impairments. WDNR listed Stillwell Creek due to temperature and sediment impairments. Stillwell Creek was added to the 303(d) list in 2003, but there was an error in listing the precise segment of the creek. The State of Wisconsin has since provided information to USEPA to correct this information.[1]

Additionally, Squaw Creek is within the boundaries of Fort McCoy, a federal military facility. Stillwell Creek is located within the Fort McCoy Military Reservation and Habelman's Cranberry Marsh, a privately owned cranberry operation.

The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require that states develop Total Maximum Daily Loads (TMDLs) for waters on the Section 303(d) lists. The TMDL and water quality restoration planning process involves several steps. The first step consists of characterizing the environment in which the water bodies exist (this step is referred to as "watershed characterization").

The next step is to develop a thorough understanding of water quality problems and establish water quality goals ("targets"). Once the water quality problems have been defined, the next step is to identify all significant sources of pollutants ("source assessment"). Then, the maximum load of a pollutant (for example, sediment or nutrients) that a water body is able to assimilate and still fully support its designated uses is determined (the TMDL). Next, the pollutant load is allocated among all sources within the watershed, and voluntary (for nonpoint sources) and regulatory control (for point sources) measures are identified for attaining the source allocations (i.e., "restoration strategy"). Last, a monitoring plan and associated corrective feedback loop are established to ensure that the control measures are effective at restoring water quality and all designated water uses.

The overall goals and objectives in developing the Squaw Creek and Stillwell Creek TMDLs were to:

- Assess the water quality of both creeks and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine water quality conditions that will result in both creeks fully supporting all of their designated uses.
- Prepare a final TMDL report that meets the requirements of the Clean Water Act, 40 CFR Section 130.7 including Section 130.7 (c) (2), and provides information to the key stakeholders that can be used to facilitate implementation activities to improve water quality.

EPA Region 5 developed this TMDL (rather than WDNR) at the request of WDNR. To remain in compliance with federal specifications for extra mural organizations found at 40 CFR Parts 30, 31, and 35

[1] See March 10, 2006 memo from Nicole L.Richmond, Wisconsin DNR, to David Werbach on the topic of "Ft. McCoy 303(d) Listed Waters." Stillwell Creek was added to the 303(d) list in 2003, but the segment of stream identified was incorrect and has been since corrected and described as follows: Stream miles .6-2.8 (total miles 2.2)

and EPA Requirements for Quality Management Plans (EPA, QA/R-2, EPA, 2001), this TMDL has a Quality Assurance Project Plan (QAPP) that was developed in conjunction with EPA's contractor.

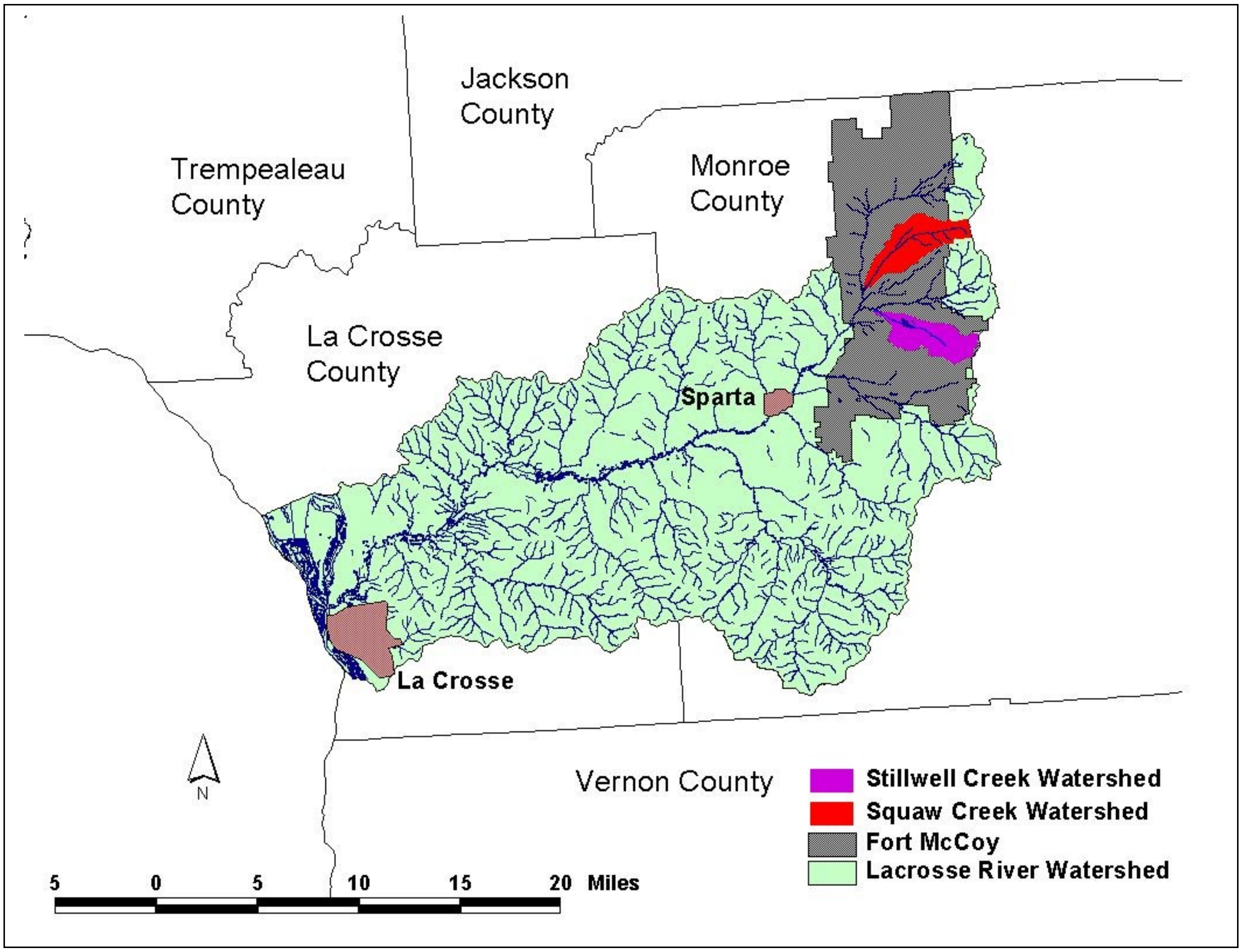

Figure 1-1.Location of the Stillwell Creek and Squaw Creek watersheds.

2.0 DESCRIPTION OF WATERBODIES AND WATERSHED CHARACTERISTICS

The purpose of this section of the report is to provide a brief background of Stillwell Creek and Squaw Creek and their corresponding watersheds. The Section 303(d) list status of the two waterbodies is summarized in Table 2-1.

Table 2-1 2004 Section 303(d) listing information for Squaw Creek and Stillwell Creek.

Waterbody	Stream Miles	Total Miles	Existing Use	Potential Use	Codified (Designated) Use	Pollutant	Impairment	Priority
Squaw Creek	0-0.2	0.2	Cold III	Cold II	Cold II	Temperature	Temperature	High
Stillwell Creek	.6-2.8	2.2	Cold III	Cold II	Cold II	Sediment[2]	Degraded Habitat Temperature	High

2.1 Stillwell Creek

Stillwell Creek is a 4.7-mile trout stream with a gradient of 28 feet per mile that drains an area of approximately five square miles. A 2.2-mile segment downstream from the cranberry operation supports a class III trout fishery whereas the segment upstream of the cranberry operation is classified as a class II trout fishery. The segment of the creek downstream of the cranberry operation is considered impaired because the fish community is rated poor as measured using the Index of Biotic Integrity (IBI). The low IBI scores are believed to be due to high temperatures, and degraded habitat which is reflected in an elevated fine sediment count.

Water temperature increases cause cold water communities to suffer a variety of ill effects, which can range from decreased spawning to death. Dissolved oxygen sags can also be influenced by an increase in the water temperature because less oxygen is soluble as temperature increases. Water temperature increases can be caused as a result of stream bank erosion, widening the river channels, which exposes more of the river water to direct sunlight.

Sedimentation reduces the suitable habitat for fish and macroinvertebrate communities. Filling-in of pools with sediment reduces the amount of available cover for juvenile and adult fish. Sedimentation of riffle areas reduces the reproductive success of fish by reducing the exposed gravel substrate necessary for appropriate spawning conditions. Sedimentation also affects macroinvertebrate biomass (fish food source) which tends to be lower in areas with predominantly sand substrate than in a stream substrate with a mix of gravel, rubble and sand.

Sedimentation (particularly in the case of fine sediments which remain in suspension longer) also causes elevated turbidity, which reduces the penetration of light necessary for photosynthesis in aquatic plants, reduces feeding efficiency of visual predators and filter feeders, and lowers the respiratory capacity of aquatic invertebrate by clogging their gill surfaces.

In addition, other contaminants such as nutrients (phosphorus) attached to sediment particles can be transported to lakes and streams during runoff events. Nutrient enrichment can contribute to dissolved oxygen sags by stimulating aquatic plant growth and their oxygen consumption demands.

[2] See March 10, 2006 memo from Nicole L.Richmond, Wisconsin DNR, to David Werbach on the topic of "Ft. McCoy 303(d) Listed Waters." Stillwell Creek was added to the 303(d) list in 2003, but inadvertently did not list temperature as a pollutant.

As seen in Figure 2-1, grassland cover dominates the watershed, although the very upper portion of the watershed along the drainage divide contains significant areas of mixed forest. Additionally, forested land cover is found in the lower most portion of the basin. Vegetative cover in the riparian corridor along Stillwell Creek is varied; grassland comprises the greatest percentage (28%) of vegetative cover in the riparian corridor, while forested wetland and aspen comprise nearly 15% and 13% of the riparian cover, respectively. A detailed characterization of the riparian vegetation along Stillwell Creek is presented in Section 4.2. Furthermore, Stillwell Lake, an artificially created lake, is located in the middle portion of the watershed with a surface area of six acres, a maximum depth of 10 feet, and mean depth of 5.9 feet.

A privately owned cranberry operation is located along Stillwell Creek in the lower portion of the watershed. The operation includes 49 acres of cultivated cranberry bogs and six small storage ponds used for irrigation during various periods of the year, and provide a mechanism through which the intake of water for storage and its release, can be controlled. The impoundments have a total surface area of 15 acres; the largest impoundment has a surface area of four acres and a maximum depth of 15 feet. The other five impoundments have an average surface area of approximately two acres and a maximum depth of seven feet. The cranberry bogs and storage ponds are shown in Figure 2-2.

2.2 Squaw Creek

Squaw Creek is a 5.8-mile trout stream with a gradient of 25 feet per mile that drains an area of approximately six square miles. Squaw Lake, is a 15-acre artificially created lake, near the mouth of Squaw Creek. The lake has a surface area of 15 acres, maximum depth of 16 feet, and a mean depth of 9 feet. Squaw Creek is a class I trout stream upstream of the impoundment, and a class III trout stream downstream of the impoundment. The 0.2-mile segment downstream of Squaw Lake is considered impaired because the fish community is rated poor as measured using the IBI. The low IBI scores are believed to be due to high temperatures associated with the release of warm water from Squaw Lake.

Water temperature increases causes the cold water communities to suffer a variety of ill effects, which can range from decreased spawning to death. Dissolved oxygen sags can also be influenced by an increase in the water temperature because less oxygen is soluble as temperature increases.

Land cover (see Figure 2-1) in the upper portion of the watershed is predominantly forested, while the lower portion of the basin is dominated by grassland, barren, and urban land covers. (The area classified as “barren” is the Fort McCoy artillery/bombing range.)

A development plan consisting of 42 cabins and two recreational beaches has been proposed for the Squaw Creek watershed which may have the potential to impact Squaw Creek and Squaw Lake. This TMDL is presented for current conditions and does not reflect the proposed development. The proposed development plan should be closely evaluated for potential water quality impacts in general and temperature impacts in particular. This should be done through other appropriate regulatory mechanisms.

It is strongly recommended that the Unified Facilities Criteria system prescribed by MIL-STD 3007, specifically UFC 3-210-10 (October 25, 2004), be should be consulted in the planning to ensure low impact development practices are applied where ever appropriate, and to identify opportunities to minimize impacts to Squaw Lake and Squaw Creek.

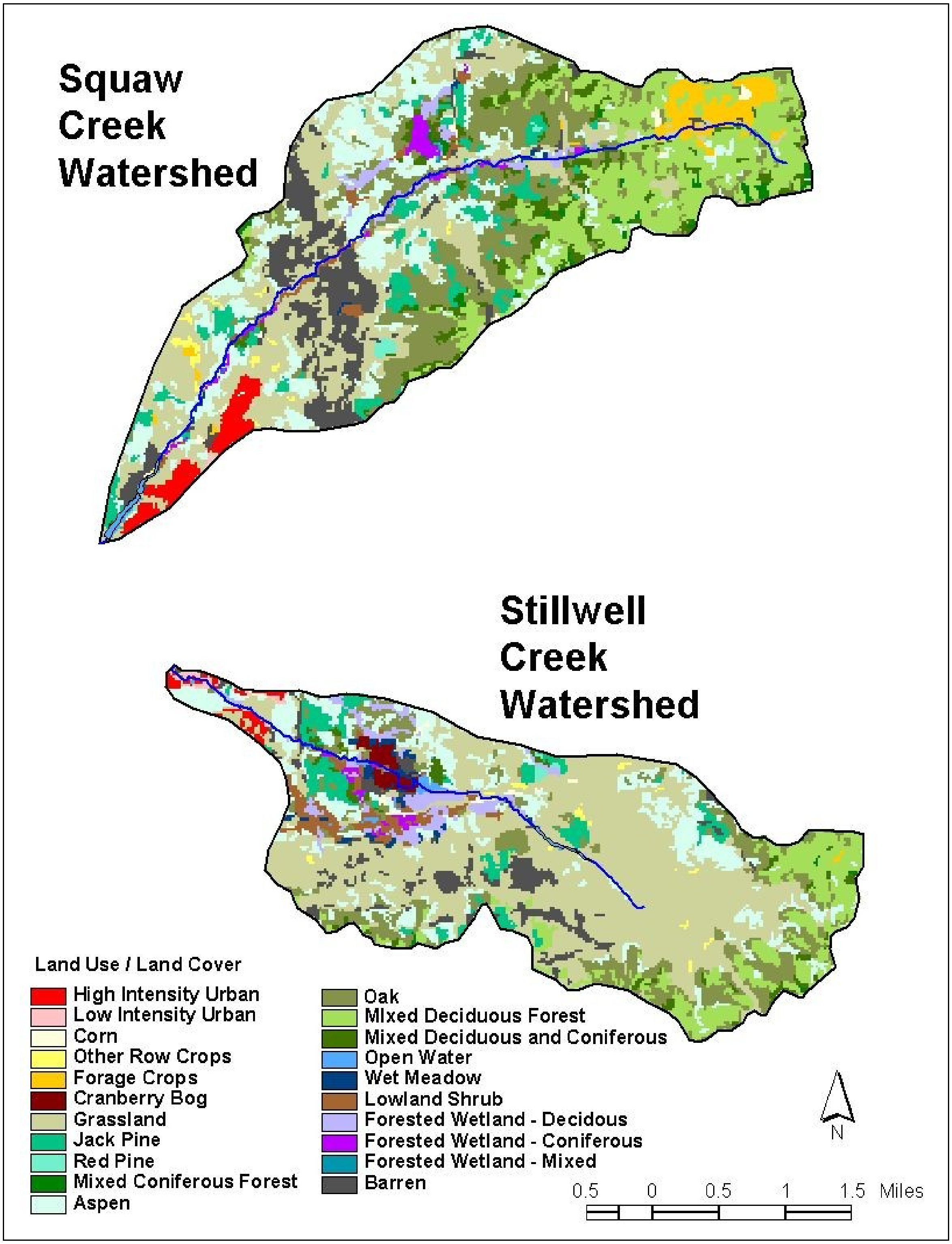

Figure 2-1.Land Use and Land Cover in the Stillwell Creek and Squaw Creek watersheds.

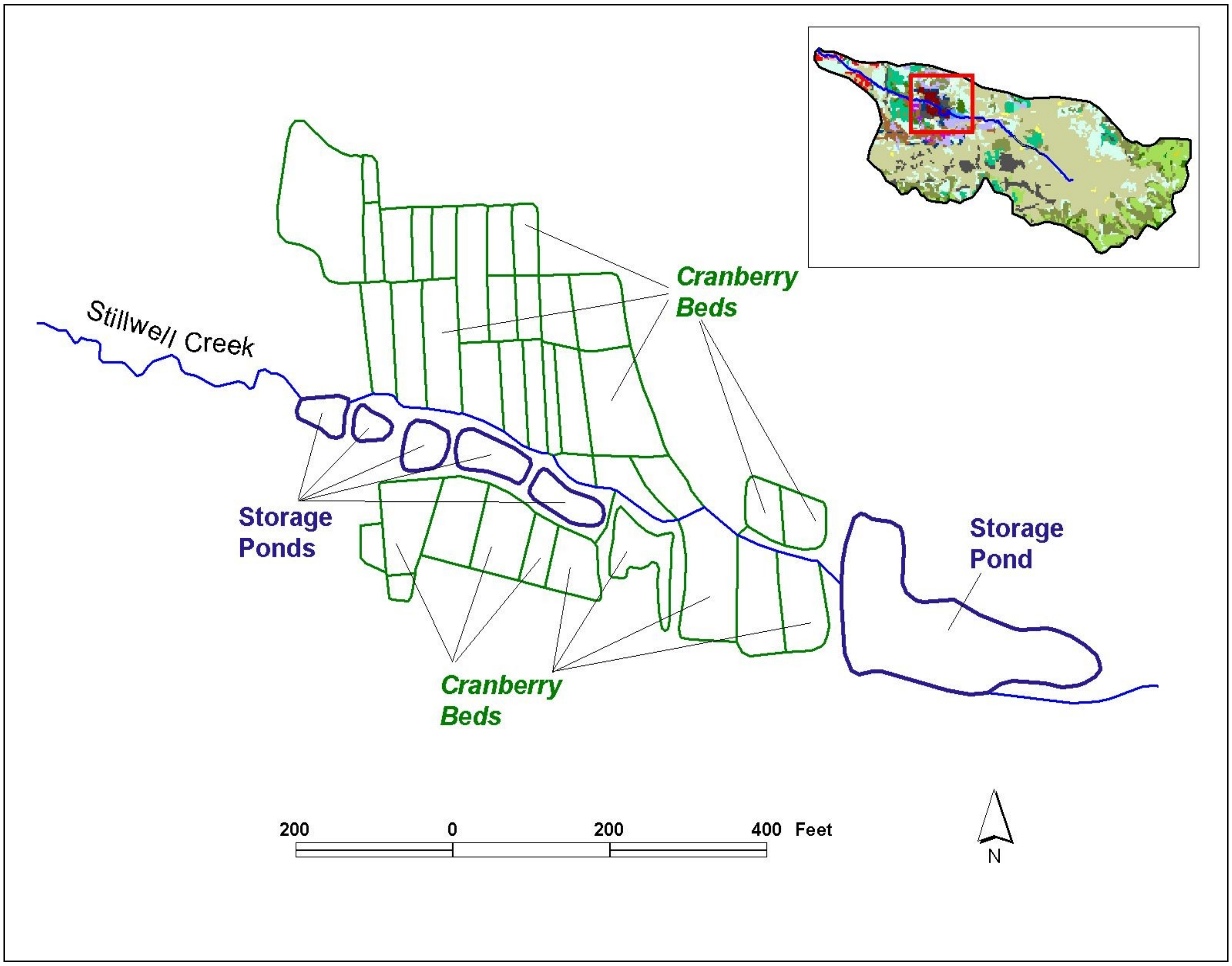

Figure 2-2. Location of storage ponds and cranberry bogs in the Stillwell Creek watershed.

3.0 WATER QUALITY STANDARDS AND ASSESSMENT OF WATER QUALITY DATA

This section presents the applicable water quality standards and a summary of the historic water quality data for Stillwell Creek, Squaw Creek, and Squaw Lake.

3.1 Applicable Water Quality Standards

Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three different components:

- **Designated uses** reflect how the water can potentially be used by humans and how well it supports a biological community. Examples of designated uses include aquatic life support, drinking water supply, and recreation. Every water has a designated use or uses; however, not all uses apply to all waters.
- Criteria express the condition of the water that is necessary to support the designated uses. **Numeric criteria** represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. **Narrative criteria** are the general water quality criteria that apply to all surface waters. These criteria state, for example, that substances shall not be "present in amounts which are acutely harmful to animal, plant or aquatic life."
- The **antidegradation policy** establishes situations under which the state may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need.

The objective of this TMDL project is to produce conditions in Squaw Creek and Stillwell Creek that meet narrative water quality standards described in Tables 3.1 and 3.2 below, and support at least a Class II trout fishery (see Table 2-1). A Class III trout fishery is not a self-sustaining community.

Chapter NR 1.02(7)(b), Wis. Adm. Code, describes the different classes of trout fishery as follows:

"A class III trout stream is a stream or portion thereof that:

a. Requires the annual stocking of trout to provide a significant harvest, and
b. Does not provide habitat suitable for the survival of trout throughout the year, or for natural reproduction of trout."

"A class II trout stream is a stream or portion thereof that:

a. Contains a population of trout made up of one or more age groups, above the age [of] one year, in sufficient numbers to indicate substantial survival from one year to the next, and
b. May or may not have natural reproduction of trout occurring; however, stocking is necessary to fully utilize the available trout habitat or to sustain the fishery."

"A class I trout stream is a stream or portion thereof with a self-sustaining population of trout.

> Such a stream contains trout spawning habitat and naturally produced fry, fingerling, and yearling in sufficient numbers to utilize the trout habitat, or
>
> Contains trout with 2 or more age groups, above the age of one year, and natural reproduction and survival of wild fish in sufficient numbers to utilize the available trout habitat and to sustain the fishery without stocking."

The following section describes the water quality standards that apply to Stillwell Creek and Squaw Creek for the pollutants of concern, based upon their designated (codified) uses.

3.1.1 Temperature

Table 3-1 presents Wisconsin's water quality standards for temperature. The provisions of the standards that apply to mixing zones do not apply because there are no point sources (facilities with National Pollutant Discharge Elimination System (NPDES) permits) in either watershed. The maximum limit of 89° F also does not apply because both Stillwell Creek and Squaw Lake are designated as cold water fisheries rather than warm water fisheries. Therefore, as they apply to this TMDL, the temperature standards are narrative and essentially prohibit changes from natural temperatures "to such an extent that trout populations are adversely affected". The narrative standards have been violated in both Stillwell Creek and Squaw Creek because the current artificially increased temperatures are believed to be causing adversely affected trout populations (see Section 3.2.1 and 3.2.2 for more information). A significant goal of this TMDL is therefore to estimate natural temperatures in each waterbody and the extent to which current temperatures deviate from natural temperatures.

Table 3-1.Wisconsin Water Quality Standards for Temperature.

Regulation	Text
Chapter NR 102.04(4)(b)	Temperature: (1) There shall be no temperature changes that may adversely affect aquatic life. (2) Natural daily and seasonal temperature fluctuations shall be maintained. (3) The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5º F for streams and 3º F for lakes. (4) The temperature shall not exceed 89º F for warm water fish.
Chapter NR 102.04(4)(e)	Temperature and dissolved oxygen for cold waters. Streams classified as trout waters by the department of natural resources (Wisconsin Trout Streams, publication 6–3600 (80)) or as great lakes or cold water communities may not be altered from natural background temperature and dissolved oxygen levels to such an extent that trout populations are adversely affected. (1) There shall be no significant artificial increases in temperature where natural trout reproduction is to be protected. (2) Dissolved oxygen in classified trout streams shall not be artificially lowered to less than 6.0 mg/L at any time, nor shall the dissolved oxygen be lowered to less 7.0 mg/L during the spawning season. (3) The dissolved oxygen in great lakes tributaries used by stocked salmonids for spawning runs shall not be lowered below natural background during the period of habitation.

3.1.2 Sediment

Similar to most states, the State of Wisconsin does not have numeric criteria for sediment or suspended solids. Sediment criteria are narrative, as presented in Table 3-2. The approach for identifying sediment targets for the Stillwell Creek TMDL is similar to that used for temperature (i.e., attempt to determine "natural" sediment conditions). The narrative standards have been violated in Stillwell Creek because excessive fine sediments are believed to be causing adversely affected trout populations (see Section 3.2.1 and 3.2.3 for more information). Excess sediment in a stream bottom can reduce dissolved oxygen concentrations in stream bottom substrates, and it can reduce the quality and quantity of habitats for aquatic organisms.

Table 3-2.Wisconsin Water Quality Standards for Sediment.

Regulation	Text
Chapter NR 102.04(1)(a)	Substances that will cause objectionable deposits[A] on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state.
Chapter NR 102.04(1)(b)	Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in the waters of the state.
Chapter NR 102.04(1)(c)	Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.
Chapter NR 102.04(1)(d)	Substances in concentrations of combinations which are toxic or harmful to humans shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant or aquatic life.

[A]WNDR considers excessive sedimentation to be an objectionable deposit.

3.2 Water Quality and Hydrologic Data Assessment

Data provided by Fort McCoy were compiled and reviewed to characterize water quality conditions at various locations in Stillwell Creek, Squaw Creek, and Squaw Lake. The locations of the stream and lake monitoring sites are shown in Figure 3-1. Observed stream and lake temperature data includes both grab samples (i.e., collected on one day and time) available from 1998 to 2004 and continuous (i.e., collected every hour) temperature recordings available at multiple sites from 1998 to 2004. Sediment data were also collected at each of the sampling sites and consist of grab samples collected and analyzed for turbidity and total suspended solids (TSS). In addition, stream discharge was calculated from stream velocity, width and depth measurements during various sampling events and is available from 2001 to 2004 for several sites in Stillwell and Squaw Creeks.

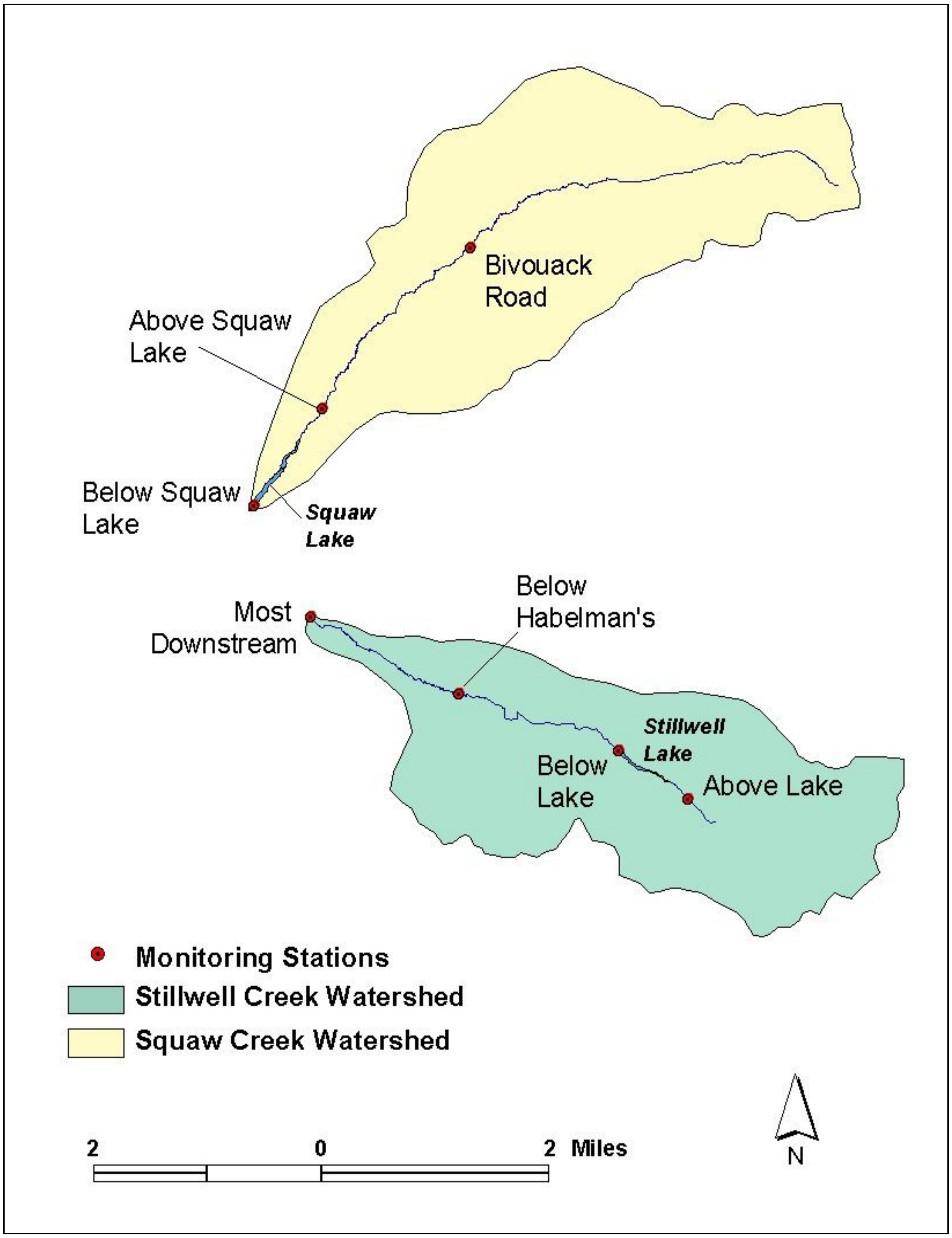

Figure 3-1. Location of monitoring stations in the Stillwell Creek and Squaw Creek watersheds. Habelman's refers to the cranberry operation located on Stillwell Creek.

3.2.1 Biological Data

Various biological assessments have been made for Squaw and Stillwell Creeks and provide information on the aquatic community characteristics of each stream. The Index of Biotic Integrity (IBI) is a fish index based on species richness, trophic composition, diversity, presence of pollution-tolerant individuals or species, abundance of biomass, and the presence of diseased or abnormal organisms. Higher IBI scores indicate healthier and more desirable fish populations.

The results of annual IBI scores for Stillwell Creek are shown in Figure 3-2 and illustrate that conditions at the Below Habelman's site are considerably poorer than at other locations in the watershed. The healthiest fish populations are typically found at the Above Lake site.

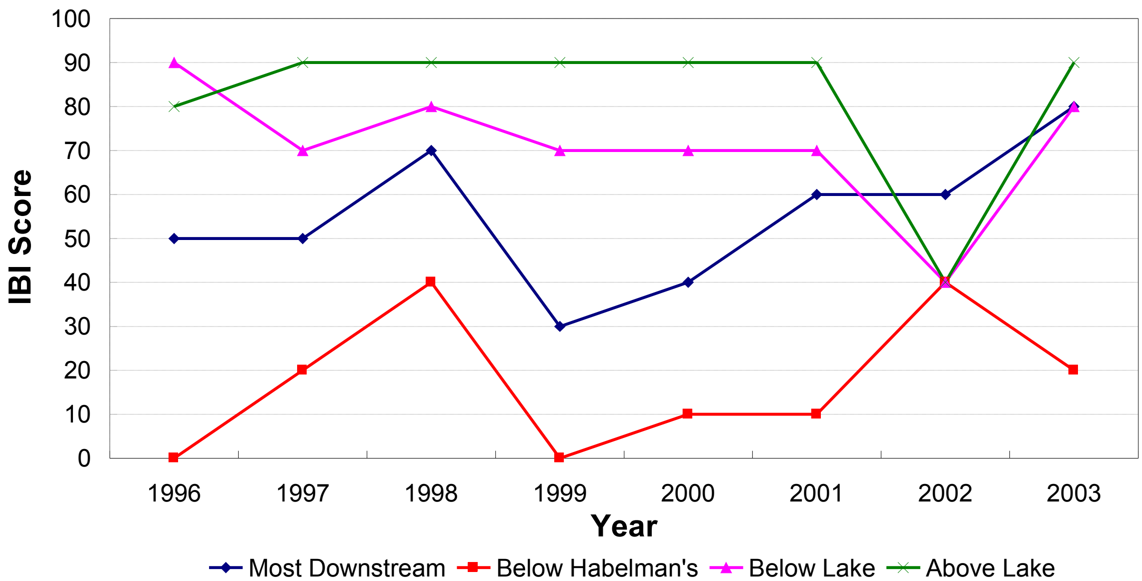

Figure 3-2. Results of IBI scores for Stillwell Creek. The Most Downstream and Below Habelman's sites are the two considered impaired. Temperatures and fine sediment are highest at the Below Habelman's site.

The results of annual IBI scores for Squaw Creek are shown in Figure 3-3 and illustrate that conditions at the Below Squaw Lake site are considerably poorer than at other locations in the watershed. The healthiest fish populations are typically found at the most upstream site.

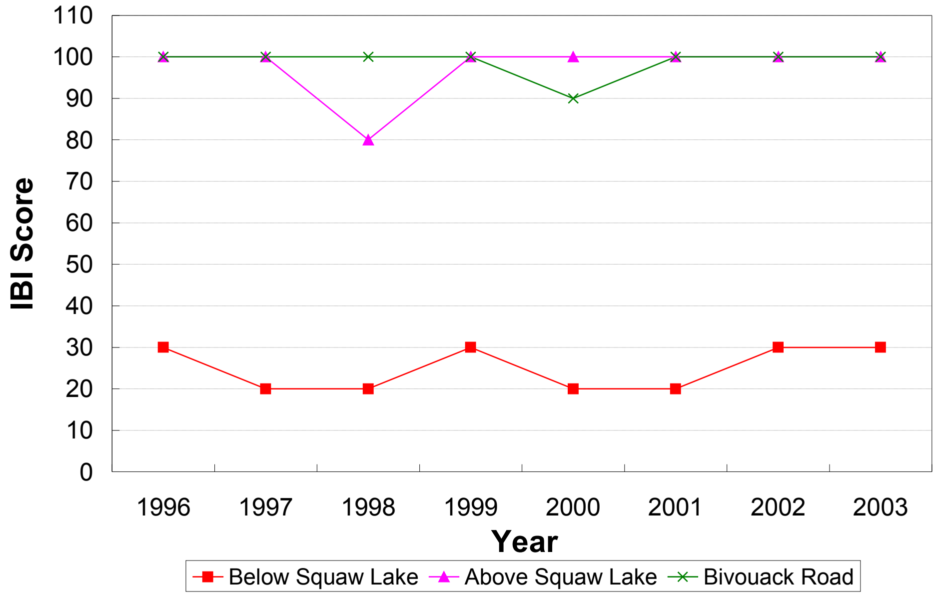

Figure 3-3. Results of IBI scores for Squaw Creek. The Below Squaw Lake site is considered impaired.

3.2.2 Stillwell Creek Temperature Data

Four temperature-monitoring sites are located in Stillwell Creek, as shown in Figure 3-1. One station is located in the uppermost portion of the basin above Stillwell Lake. A second station is located below Stillwell Lake. A third station is located below the Habelman cranberry farm. The fourth station is located at the most downstream segment of Stillwell Creek, just above the confluence with the La Crosse River. Although the period of record and the beginning and ending of dates of these sites vary, a significant amount of hourly stream temperatures have been collected during the warm season months of March through October. The observed hourly stream temperatures have been aggregated to a daily mean temperature, and are summarized in Table 3-3 and graphically displayed in Figure 3-3. A statistical summary of the data is presented in Figure 3-4.

Stream flow in Stillwell Creek above Stillwell Lake is dominated by groundwater baseflow, which has a relatively low and fairly constant temperature. Furthermore, a bottom draw device installed near the base of Stillwell Lake provides for the release of cool water into Stillwell Creek. Consequently, stream temperatures observed in this reach are cooler and exhibit a much smaller variance than do temperatures at the other sites. The maximum temperature observed in Stillwell Creek is 24.7 degrees Celsius (76.4°F) that was recorded below the Habelman's cranberry operation. The data suggest that increased stream temperatures below the cranberry operation are related to warm flows released from the cranberry operation.

Table 3-3. Summary of Available Surface Water Temperature Data (°C) for Stillwell Creek.

Station ID	Count	Mean	Min	Max	Period of Record
Above Stillwell Lake	807	10.8 (51)	3.7 (39)	14.1 (57)	3-09-99 to 9-30-04
Below Stillwell Lake	914	13.7 (57)	3.3 (38)	20.8 (69)	3-15-00 to 10-05-04
Below Habelman's	698	13.6 (56)	1.0 (34)	24.7 (76)	3-30-01 to 10-05-04
Most Downstream	797	11.4 (53)	0.0 (32)	21.7 (71)	10-02-99 to 10-23-03

values in parenthesis indicate °F

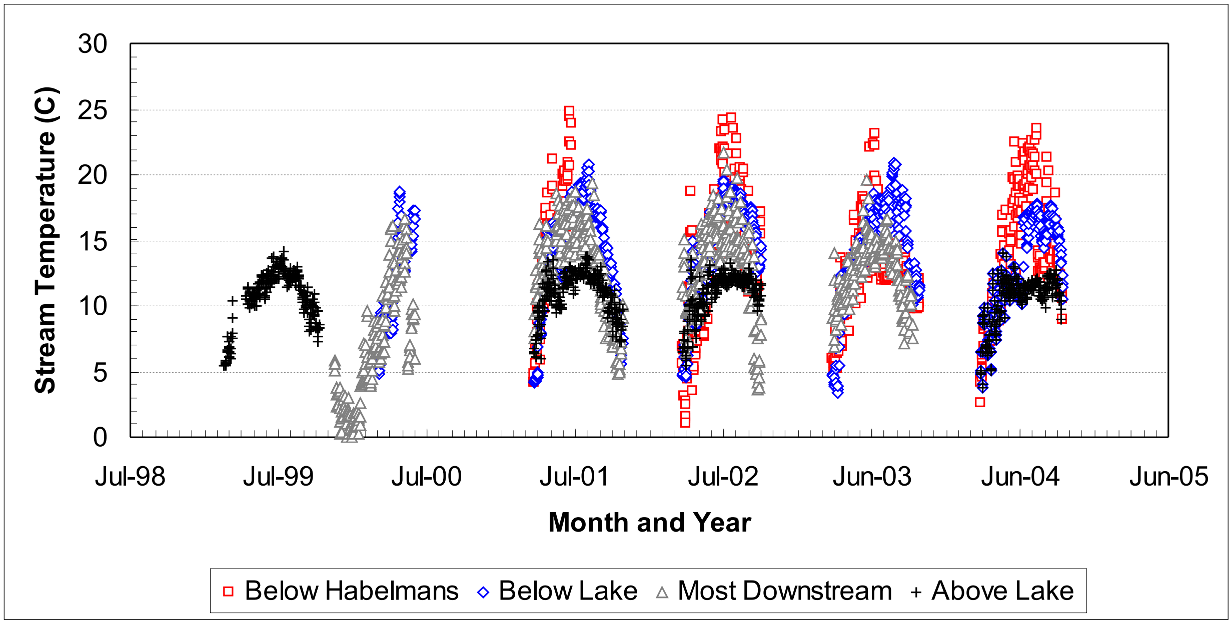

Figure 3-4. Stream temperatures observed at the four monitoring stations in Stillwell Creek.

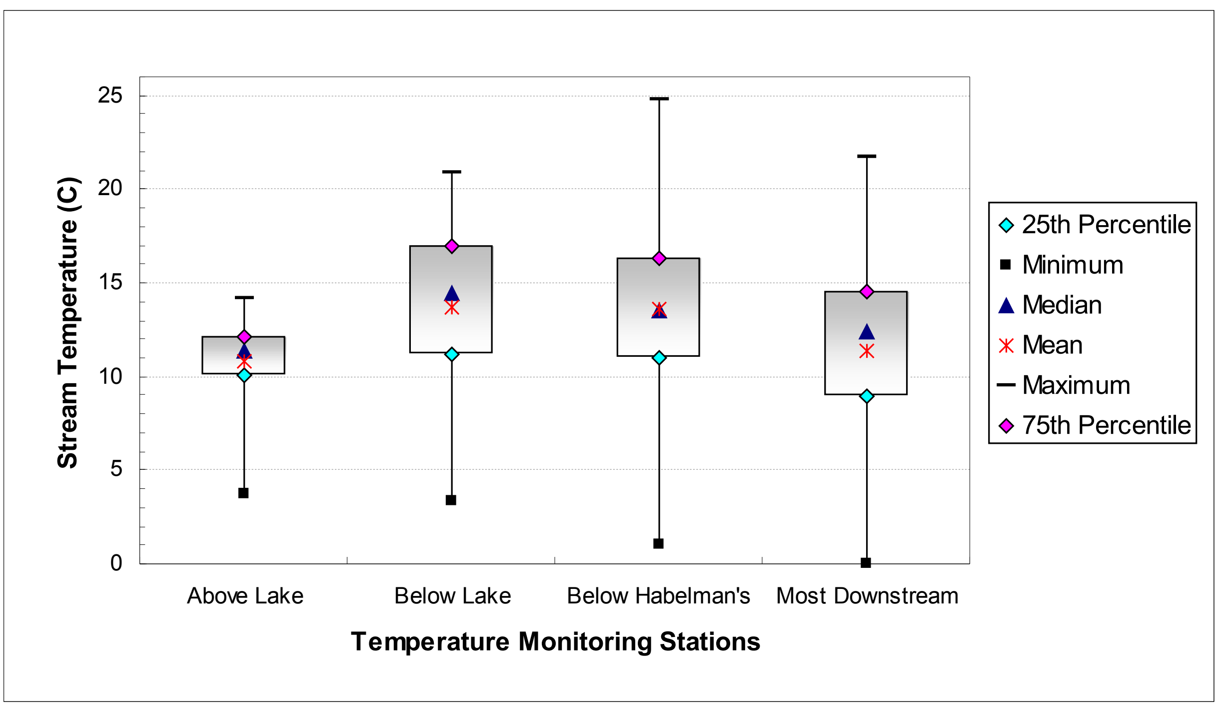

Figure 3-5. A statistical summary of stream temperatures observed in Stillwell Creek, 1999-2004.

3.2.3 Stillwell Creek Sediment Data

Total suspended sediment (TSS) data collected for Stillwell Creek are summarized in Table 3-4. Table 3-4 indicates that observed mean TSS concentrations are approximately 30 percent greater at the Habelman's site relative to the Below Lake site. Pebble counts conducted at these two sites also indicate that the percentage of fine materials is considerably more at the Below Habelman's site (92 percent) compared to the Below Lake site (68 percent). Percent fines are a good measurement of stream habitat quality because fish and macroinvertebrates require a clean substrate for spawning and feeding.

Table 3-4. Summary of Sediment Data (TSS) Observed in Stillwell Creek.

Station ID	Count	Mean (mg/l)	Min (mg/l)	Max (mg/l)	Period of Record
Below Lake	16	4.47	0.5	47.0	4-17-01 to 7-21-04
Below Habelman's	25	5.96	0.5	45.0	4-17-01 to 7-21-04

3.2.4 Stillwell Creek Stream Flow Data

Continuous stream flow data are not available for Stillwell Creek. However, estimated stream flow was calculated from stream velocity, width and depth measurements taken during the collection of stream temperature and other parameters, and is available from 2001 to 2004.

Stream flow data for Stillwell Creek is summarized in Table 3-5 and indicates that observed mean and maximum stream flow is significantly greater at the Below Habelman's site relative to the Below Lake site. The variability in flows at the Below Habelman's site is also much greater than at the Below Lake site.

Table 3-5. Summary of Available Stream Flow Data for Stillwell Creek (cfs).

Station ID	Count	Mean	Min	Max	Period of Record
Below Lake	16	0.9	0.4	1.6	4-17-01 to 7-21-04
Below Habelman's	28	2.6	0.2	14.1	4-17-01 to 7-21-04

3.2.5 Squaw Creek Temperature Data

Two temperature-monitoring sites with long-term data are located in Squaw Creek (see Figure 3-1). One is located above Squaw Lake, and the second is located below the lake. Hourly stream temperatures have been collected during the warm season months of March through October, and were aggregated to a daily mean temperature. Observed daily mean stream temperatures are summarized in Table 3-6 and Figure 3-6. A statistical summary of the data is graphically presented in Figure 3-7. Table 3-6 and Figures 3-6 and
3-7 show that mean and maximum stream temperatures are significantly warmer (30 percent) downstream of Squaw Lake compared to the site above the lake.

Table 3-6. Summary of Available Surface Water Temperature Data for Squaw Creek (°C).

Station ID	Count	Mean	Min	Max	Period of Record
Above Squaw Lake	1181	9.9 (50)	0.1 (32)	19.0 (66)	2-1-1998 to 10-23-2003
Below Squaw Lake	1362	13.2 (56)	0.7 (33)	25.4 (78)	2-1-1998 to 10-05-2004

values in parenthesis indicate °F

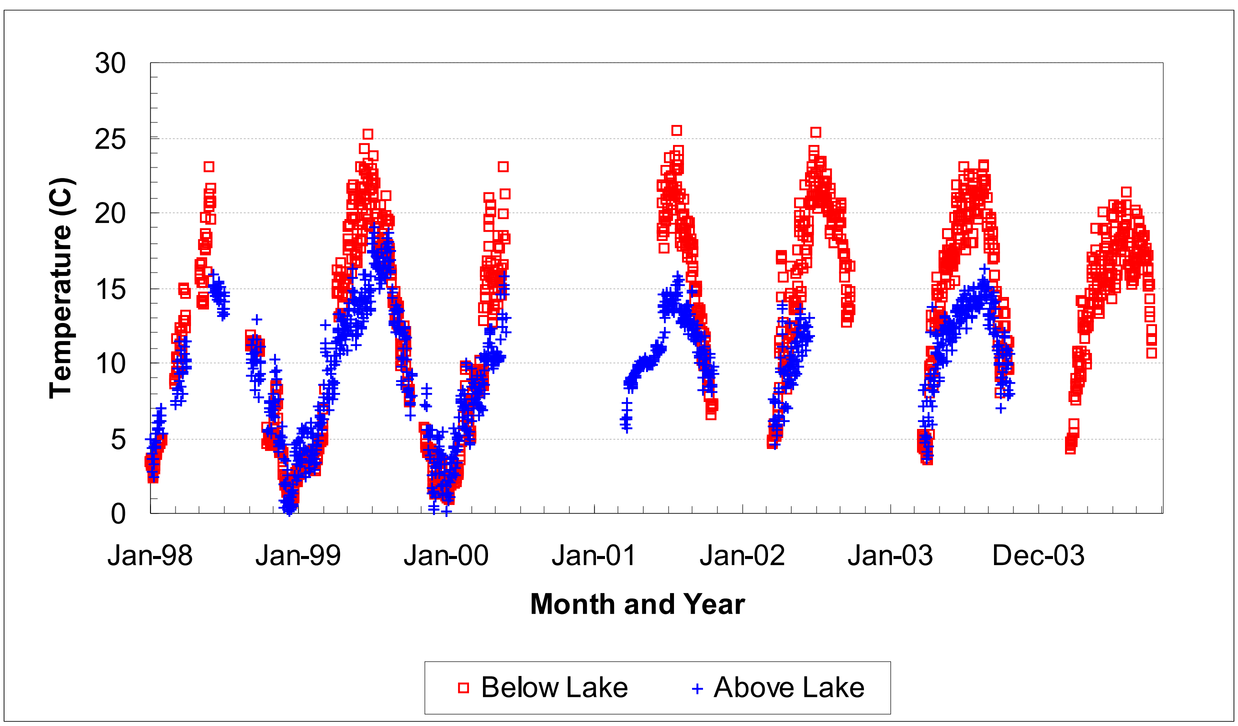

Figure 3-6. Stream temperatures observed at the two monitoring stations in Squaw Creek.

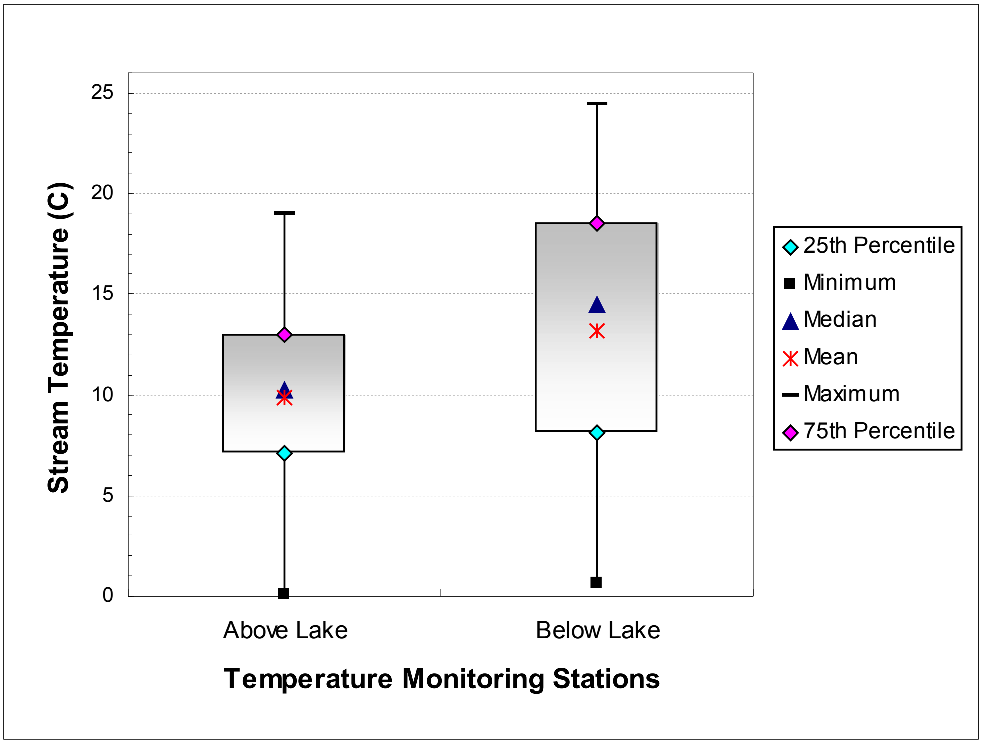

Figure 3-7. A statistical summary of stream temperatures observed in Squaw Creek, 1999-2004.

3.2.6 Squaw Creek Stream Flow Data

Continuous stream flow data are not available for Squaw Creek. However, estimated stream flow was calculated from stream velocity, width and depth measurements taken during the collection of stream temperature and other parameters, and is available from 2001 to 2004. Observed stream flow data for Squaw Creek is summarized in Table 3-7 and indicate that observed mean and maximum stream flow is significantly greater at the Above Lake site relative to the Bivouack Road site. Temporal trends in flows appear to be generally similar at the two sites.

Table 3-7. Summary of Available Stream Flow Data for Squaw Creek (cfs).

Station ID	Count	Mean	Min	Max	Period of Record
Above Lake	28	7.2	3.5	19.4	4-5-01 to 10-6-04
Bivouack Rd.	15	0.9	0.1	2.7	4-17-01 to 1-13-04

3.2.7 Squaw Lake Temperature Data

Temperature data in Squaw Lake were collected at various depths in 2002 and 2004 and the resulting temperature profiles are graphically presented in Figure 3-8. Lake surface temperatures were colder than deeper depths during January and February sampling. However, during summer months the data illustrate weak to mild thermal stratification, with temperatures at the surface of the lake as much as 10 to 15° C warmer than the lake bottom.

Figure 3-9 displays the dissolved oxygen data for Squaw Lake. Most observed dissolved oxygen concentrations are well above 5 mg/L, even at the bottom of the lake.

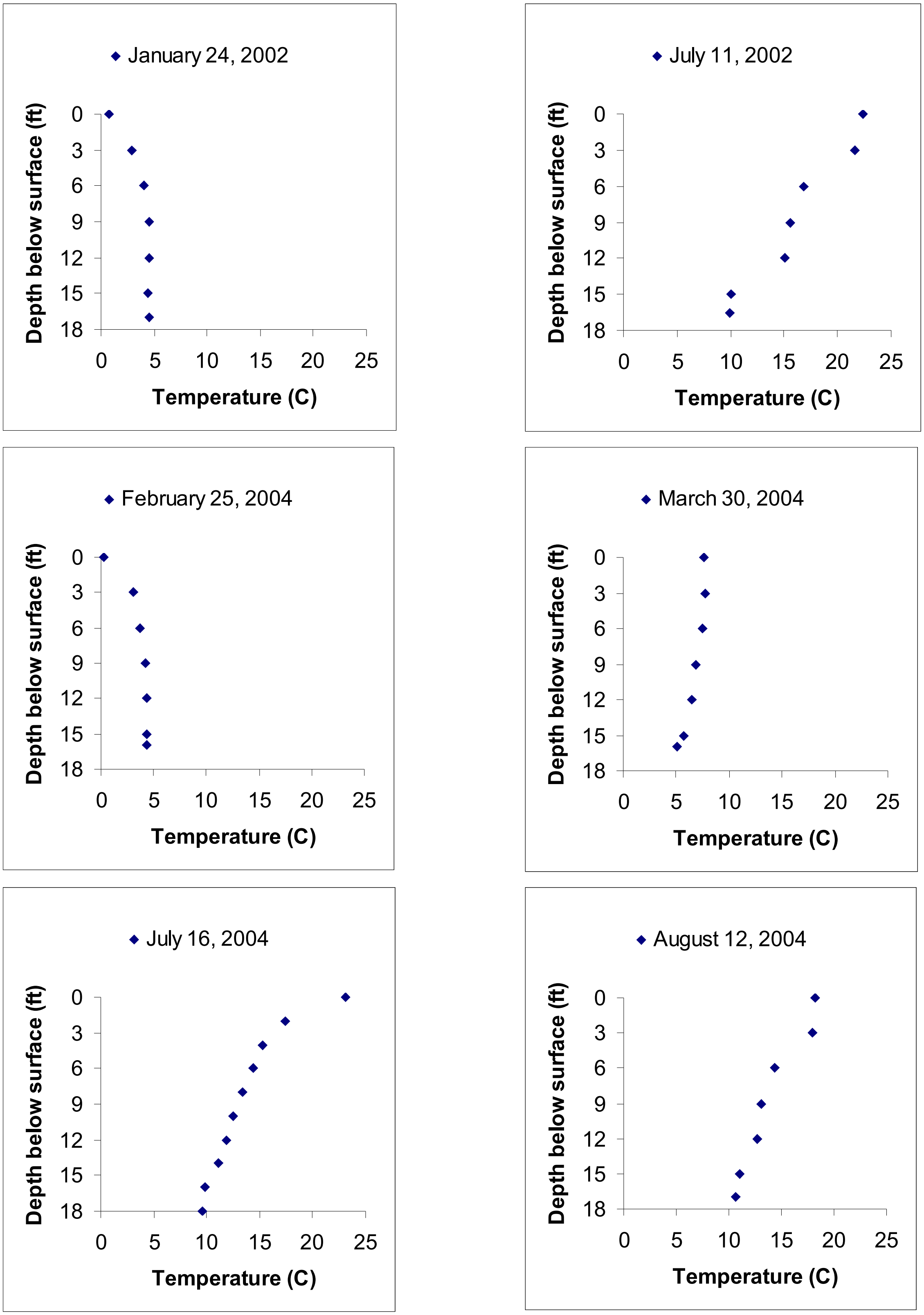

Figure 3-8. Temperature profiles for Squaw Lake, 2002 and 2004.

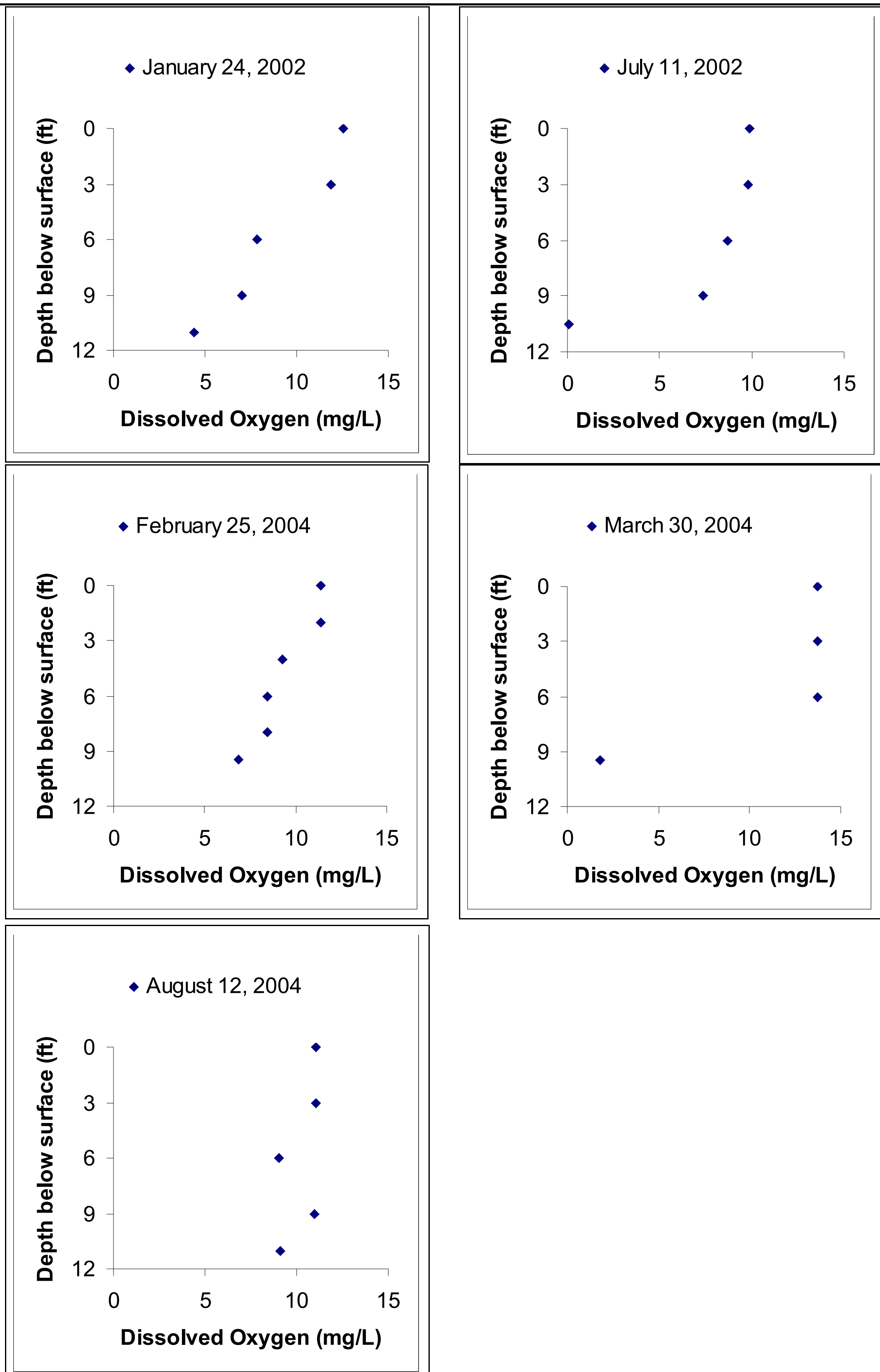

Figure 3-9. Dissolved oxygen profiles for Squaw Lake, 2002 and 2004.

4.0 SOURCE ASSESSMENT

This section of the report briefly identifies potential sources of temperature alteration in Stillwell and Squaw Creek, and sedimentation in Stillwell Creek.

4.1 Point Sources

There are no point source discharges to either Stillwell Creek or Squaw Creek.

4.2 Nonpoint Sources

Aside from the cranberry operation, very little agricultural activity occurs within Stillwell Creek watershed (see Figure 2-1) and the activity that does occur is buffered by grass. Grasses will filter sediment leaving the row crop area preventing transport of significant loads to Stillwell Creek. Although there is an area of row crop activity adjacent to Stillwell Lake, sediment entering the lake from overland flow will most likely be trapped by the lake and will not be transported in flows to the middle reaches of Stillwell Creek. Given these characteristics of agricultural activity within the watershed, significant overland sediment transport is not considered an important component of the sediment issues in Stillwell Creek.

The reasons that temperatures are so much warmer below the cranberry operation are not straightforward. Figure 3-2 illustrates that summer temperatures below Stillwell Lake have already warmed considerably compared to the most upstream site. Summer temperatures immediately downstream of the cranberry operation are typically even warmer than below Stillwell Lake. This could be due to warm water from the storage ponds being used to irrigate the cranberries and then infiltrating back into the creek. However, it could also be due to warming that results from a lack of shade along Stillwell Creek.

To evaluate the potential significance of shading on Stillwell Creek water temperatures, a 98-foot (30-meter) buffer zone around Stillwell Creek was created within the geographic information system (GIS) and overlain on the land cover spatial data layer. The land cover types occurring within the buffer zone were extracted and are summarized in Table 4-1. The table shows that grassland is the largest vegetative cover type within the riparian zone comprising 28 percent of the vegetative cover within the buffer. However, a summation of all forested cover reveals that 39 percent of the riparian corridor is forested. The riparian land cover analysis also indicates that grassland is the dominant vegetative cover type in the upper portion of the Stillwell Creek watershed, and virtually no shade is provided along the margins of Stillwell Lake. Between Stillwell Lake and the cranberry bog the riparian cover consists of patches of deciduous forested wetland interrupted by grassland and row crop. Below the Habelman's cranberry bog, the forest cover is comprised of a various mix of forest cover types, such as deciduous and coniferous wetland forests, mixed deciduous, aspen, oak, and jack pine. A lack of shade therefore appears to be a relatively greater source of high temperatures in the most upstream section of Stillwell Creek, a moderate source between Stillwell Lake and the cranberry bog, and less of a source in the most downstream section of the creek.

Stream temperatures cool considerably by the time stream flow reaches the outlet of Stillwell Creek (presumably due to cool groundwater inflows and the effects of shading) but are still warmer than the most upstream site.

Temperatures in lower Squaw Creek appear to be warmer than natural primarily because of the presence of the lake, which restricts downstream flows. Releases from the warm surface layer of Squaw Lake also contribute to increased temperatures during the critical summer months. Section 5 of the report describes these sources and their impact on water quality in more detail.

Table 4-1.Land Use and Land Cover Characteristics within the Stillwell Creek Riparian Zone.

Land Use / Land Cover Classification within Riparian Zone	Percent of Land Cover within Riparian Zone
Grassland	28.2
Forested Wetland - Deciduous	15.1
Aspen	12.8
Cranberry Bog	7.2
Low-intensity Urban	6.2
Oak	5.2
Open Water	4.3
Lowland Shrub	4.3
Wet Meadow	4.1
High-intensity Urban	3.1
Forested Wetland - Coniferous	2.7
Barren	1.9
Mixed Deciduous and Coniferous Forest	1.6
Corn	1.4
Jack Pine	1.2
Forested Wetland - Mixed	0.6
Total Forested Riparian	**39.2**

5.0 TECHNICAL ANALYSIS

Establishing the link between watershed characteristics and resulting water quality is one of the most important steps in developing a TMDL. This link can be established through a variety of techniques ranging from simple mass balance analyses to sophisticated computer modeling. The objective of this section of the report is to describe the approach that was used to evaluate stream temperatures and sediment loading in Stillwell Creek, and stream temperatures in Squaw Creek below Squaw Lake.

The primary questions to be answered by the analyses were:

1. What are natural temperatures in the impaired segments of Squaw Creek and Stillwell Creek? This question is addressed in 5.1.1.
2. What are the natural sediment concentrations under naturally occurring flow conditions in the impaired segment of Squaw Creek?
3. To what degree have human activities altered the natural temperatures and sediment concentrations?
4. What will be the impacts of various management options to restore the segments to their more natural condition?

Natural temperatures are important because the water quality standard for temperature states that temperature may not be altered from natural background temperature to such an extent that the trout populations are adversely affected, and that there shall be no significant artificial increases in temperature where natural trout reproduction is to be protected. The first question is perhaps the most challenging because of a lack of historical data to represent conditions prior to human disturbance. It is believed that temperatures in lower Stillwell Creek are warmer because of the presence of the cranberry operation. Similarly, it is believed that temperatures in lower Squaw Creek are warmer than natural because of the presence of the lake and restricted downstream flows. Releases from the warm surface layer of Squaw Lake also contribute to increased temperatures in the summer.

5.1 Stillwell Creek

This section describes the methods used to estimate stream temperature, stream flow and sediment loading in Stillwell Creek.

5.1.1 Comparison of Estimated Natural Stream and Human-Impacted Stream Temperatures

The following explains why natural stream temperatures for Stillwell Creek can be approximated by conditions at the Above Lake monitoring site. This site is located in the upper portion of the Stillwell Creek watershed and drains a relatively undisturbed area.

To understand how stream temperatures below the Habelman's cranberry operation compare to the Above Lake and other monitoring sites on Stillwell Creek, the relationship between air and stream temperatures was evaluated. Since air temperatures are essentially the same at all the sites, the relationship between air temperatures and stream temperatures can provide insight into how sites differ.

To quantify the relationship between of stream temperatures and air temperatures, observed mean daily stream temperatures were regressed against mean daily air temperature recorded at the National Weather Service (NWS) Sparta cooperating observer station 477977. As expected, the regression results showed a significant correlation between air temperatures and stream temperature at all four stations. The regression plots are presented in Appendix A.

The best-fit mean lines for the Above Lake and the Below Habelman's temperature monitoring stations are shown in Figure 5-1. Figure 5-1 shows that both monitoring stations respond in a similar manner to air temperatures (i.e., as expected stream temperatures generally increase with increasing air temperatures). However, Figure 5-1 suggests that the Above Lake site is more "resistant" to warm air temperatures than is the site Below Habelman's site. In other words, when mean air temperatures are greater than approximately 4°C, stream temperatures below the cranberry operation are much more likely to be warmer than at the Above Lake site.

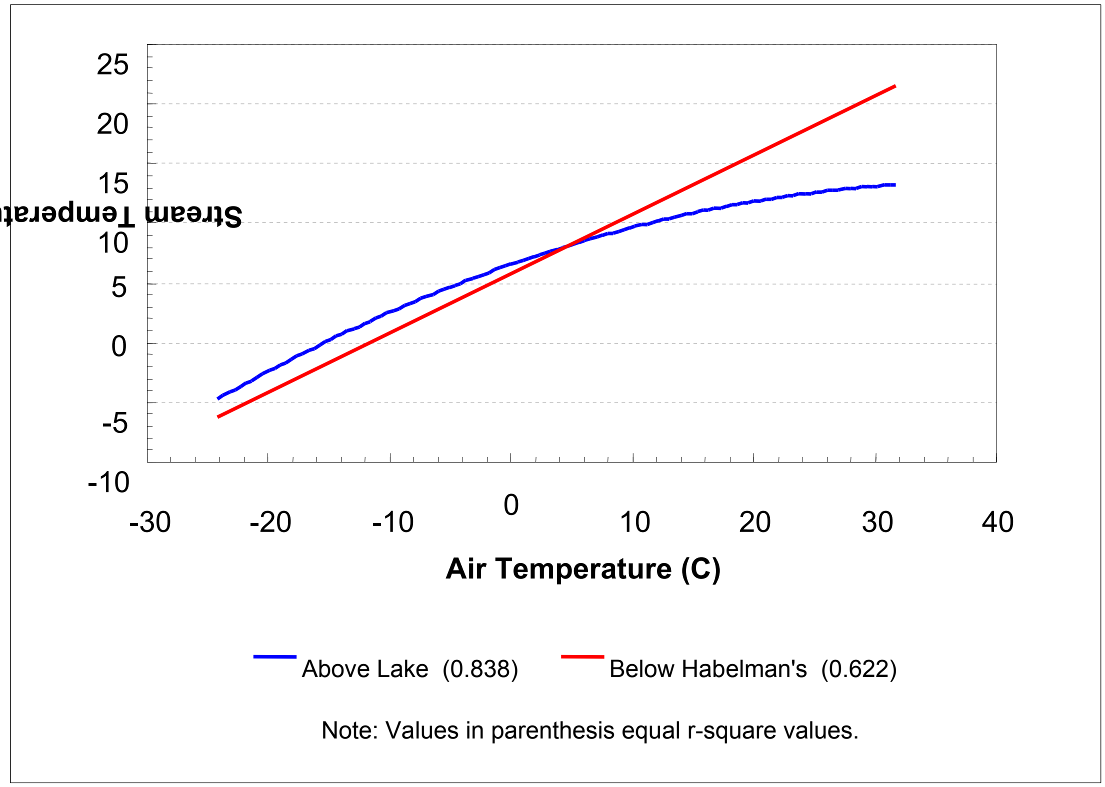

Figure 5-1. Best-fit lines from regression analysis of stream temperature and air temperature data for Above Lake and Below Habelman's sites in Stillwell Creek.

One interpretation of the difference in stream temperature between the Below Habelman's site and the Above Lake site is that it reflects the stream temperature reduction that is required to meet the natural condition. This topic is discussed in more detail in Section 6.1.

5.1.2 Estimates of Naturally Occurring Stream Flow

Since continuous stream flow data are not available for Stillwell Creek, they were extrapolated from stream flow data for the La Crosse River at Sparta (U. S. Geological Survey (USGS) station 05382325). Naturally occurring stream flows were calculated as proportional based upon the ratio of drainage area of the various points of interest along Stillwell Creek compared to the area drained by the La Crosse River USGS gage. For example, the ratio of the drainage area at the Below Habelman's monitoring site compared to the drainage area at Sparta is 4.7 square miles divided by 167 square miles or 0.028. Thus, the Sparta daily stream flows were multiplied by 0.028 to estimate naturally occurring daily stream flow for the Habelman's monitoring site.

This initial estimate of natural stream flow proved to be too large, possibly due to the large difference in drainage areas or anthropogenic flow alterations at the La Crosse River gage (see Appendix A). To more accurately estimate naturally occurring stream flows, a ratio of observed to estimated flow was calculated first for corresponding dates. Next, the median of the ratios was calculated and found to equal 0.31. Finally, the initial estimated flows were multiplied by the median ratio (0.31) to reduce the estimates of natural stream flow in Stillwell Creek.

It is recognized that there is a great deal of uncertainty with this approach but the resulting estimates are believed to adequately characterize the important naturally occurring seasonal variations in flow within the Stillwell Creek watershed and provide a rough estimate of the magnitude of the natural flows.

5.1.3 Comparison of Existing and Natural Stream Flows

To examine the impacts of water releases from a storage pond located within the Habelman's cranberry operation to Stillwell Creek, a simple spreadsheet model was developed. Daily stream flow in Stillwell Creek is estimated by summing existing upstream flows plus water discharged to the creek from the cranberry operation. The model uses estimated stream flow into the cranberry bog, daily mean air temperature, and important assumptions related to the operational procedures of the cranberry farm. The owners of the cranberry operation provided the following assumptions employed in the model:

- A large four-acre pond located on Stillwell Creek immediately upstream and adjacent to the cranberry bog operation is the source of water used for irrigation purposes during the course of a year. The volume of the storage pond is normally at storage capacity except during periods of summer drought. During periods of summer drought, groundwater is pumped into the storage pond to allow sufficient water availability for irrigation purposes.

- A small 0.6-acre detainment pond is located on Stillwell Creek just downstream of the cranberry bog operation. This pond stores excess water applied to the bog during irrigation periods. The excess water is then pumped through a piped network back to the main upstream storage pond. The pond's overflow control structure allows water flow to Stillwell Creek. The actual volume of flow released by this pond to Stillwell Creek has not been observed nor recorded.

- During the months of April and May, if daily mean air temperatures are forecasted to be below 0°C (32°F), a user-specified volume of water is applied from the storage pond to the entire cranberry bog, thereby serving as frost protection. The model assumes 0.3 acre-feet of water is applied to the entire 49-acre cranberry bog from the main storage pond, and that excess water collected in the detainment pond is pumped back to the main storage pond (hence, there is no direct discharge from the cranberry bog to Stillwell Creek). Local experts estimate that approximately five to ten percent of the infiltrated water may contribute to stream flow through shallow subsurface flow. The model therefore assumes that 7.5 percent of the applied frost protection water contributes to the flow of Stillwell Creek through subsurface flow.

- During the months of June through August, if forecasted daily mean air temperatures approach 27°C (80°F), water is applied from storage ponds to the entire cranberry bog, thereby keeping the cranberry plant root zone moist. This function of the model applies water every other day from June through August. Presently, the model applies 0.0625 acre-feet (0.75 inch) when the temperature threshold of 26°C (79°F) is met. All water applied to the cranberry bog is either evapotranspired or infiltrated; thus, no flood volumes are discharged to Stillwell Creek.

- During the months of September and October, if forecasted daily mean air temperature is less than 0°C (32°F), 0.3 acre-feet of water is applied from the main storage pond to the entire cranberry bog, thereby serving as frost protection. There is no direct discharge to Stillwell Creek, although 7.5 percent of the applied frost protection water is assumed to contribute to the flow of Stillwell Creek through subsurface flow.

- On a user-specified date corresponding to the annual harvest, water is applied from the storage pond for harvest and de-thrashing operations. In the present model, this flood volume equals nine inches (0.75 ft) applied to a 3.5-acre parcel or cell (an equivalent of 2.6 acre-feet of water) in a management-defined manner. That is, water is applied to a specific 3.5-acre cell that has been deemed ready for harvest. Selected cells may or may not be adjacent; hence the water application pattern may appear random. Additionally, water applied to an upslope cell moves laterally in the subsurface to an adjacent downslope cell. It is estimated that only half of the 2.6 acre-feet irrigation water is required to irrigate the downslope parcel, which in turn will deliver an undetermined percentage of infiltrated water to its most downslope-neighboring cell. Determining the location of cells to be harvested and subsequent subsurface water movement during a given harvest season is not possible in the spreadsheet model. However, it is understood that some of the infiltrated water may contribute to stream flow through shallow subsurface flow. Although this quantity is unknown, 10 percent of the water applied to the most downstream cell (e.g. 10 percent of 2.6 ac-ft) is assumed to contribute to the flow of Stillwell Creek.

Within the model, the net groundwater flow into and out the bog is assumed to be zero, since hydraulic data are not available. In addition, the net impacts of evapotranspiration and precipitation are assumed to be zero. User-defined input is permitted for the following variables:

- Total volume of storage ponds (acre-feet): currently set at 90 acre-feet
- Total area devoted to cranberry farming (acres): currently set at 49 acres
- Spring, Summer, Fall, and Harvest flood volumes (acre-feet)
- Minimum temperature for Spring, Summer, and Fall flood
- Maximum number of days the cranberry bog remains flooded
- Harvest flood date (Julian days): currently set to Julian day 293 (October 20)

The spreadsheet model was run from January 1998 through September 2004 to correspond to the available data, and the results are presented graphically in Figure 5-2. The estimated natural flows (see Section 5.1.2), estimated existing flows, and observed flows are plotted. Figure 5-2 illustrates the effect of flow contribution to Stillwell Creek from the cranberry bog. These flow contributions occur mainly in October due to water application for frost protection and the fall harvest operation. Also present in Figure 5-2, although less frequently, are flow contributions from the bog to the creek during the month of April. These flow contributions are the result of water application for spring frost protection. In general the model indicates that existing streamflows are not significantly different than natural streamflows.

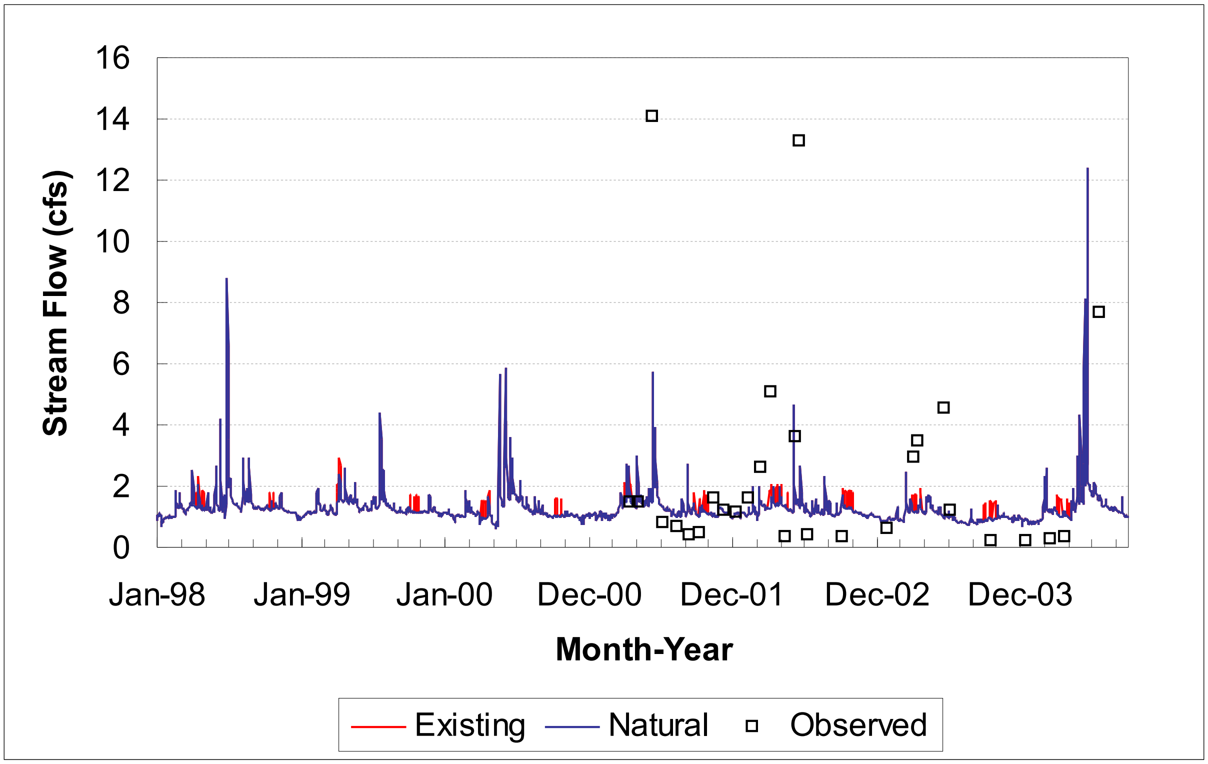

Figure 5-2.Comparison of estimated and observed stream flow for Stillwell Creek.

5.1.4 Sediment Estimates

The observed relationship between stream flow and in-stream sediment concentrations was used to estimate the difference between existing and natural total suspended solids (TSS) concentrations in Stillwell Creek downstream of the cranberry operation. Although TSS data have been collected at the Below Lake and the Below Habelman's monitoring stations along Stillwell Creek, both of these sites are below impoundments and are therefore not representative of sediment concentrations in naturally occurring flow conditions.

TSS and instantaneous stream flow collected for a reference watershed (Tarr Creek) were therefore used to establish a natural relationship between stream flow and TSS. The regression results showed a moderate positive relationship between flow and TSS as shown in Figure 5-3. It should be noted that an initial regression analysis indicated a stronger relationship between flow and TSS (r-squared of 0.92) but was considered questionable because of one extreme data point. This data point was excluded from the final analysis, but provides added evidence that flow is an adequate predictor of TSS. Furthermore, factors potentially affecting TSS concentration that are unrelated to flow (e.g., in-stream disturbance by wildlife or vehicles, excessive algal growth, point source discharges, sand and gravel mining) are not considered significant sources in Stillwell Creek. The complete regression analysis is presented in Appendix A.

The regression yielded a power function equation, shown in Figure 5-3, which was used to estimate daily concentrations of TSS as a function of daily stream flow for Stillwell Creek (Figure 5-4). Both the existing (with the cranberry bog) and natural (no bog) estimates of flows were used to estimate TSS concentrations. These daily estimates of flows and concentrations were multiplied (along with a conversion factor) to generate the loads presented in Table 6.1.

Figure 5-4 shows many periods where the existing TSS concentrations slightly exceed the natural TSS concentrations. These exceedances occur during the months of March and October, and coincide with spring and fall frost protection activities and with the fall harvest activities.

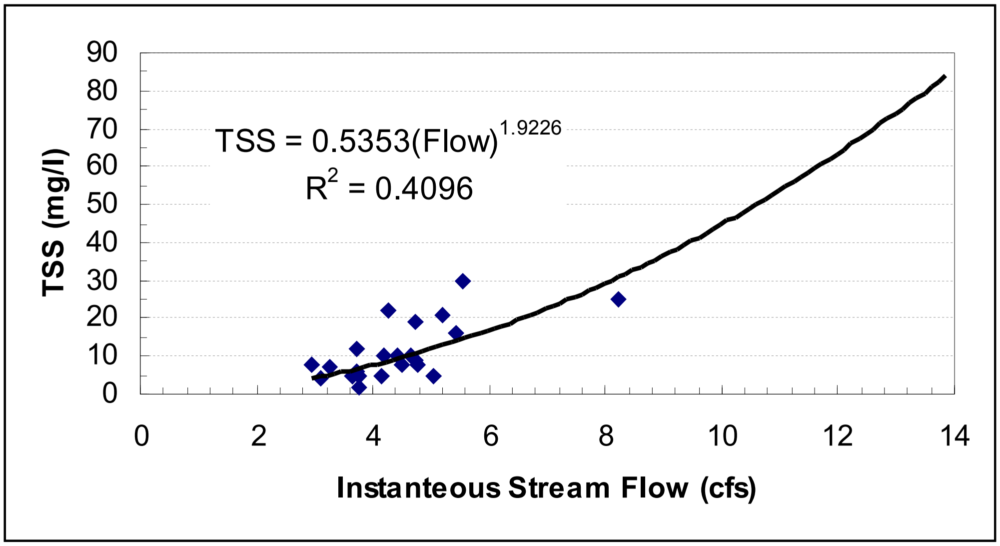

Figure 5-3. Best-fit line from regression analysis of total suspended sediment (TSS) and instantaneous stream flow for Tarr Creek.

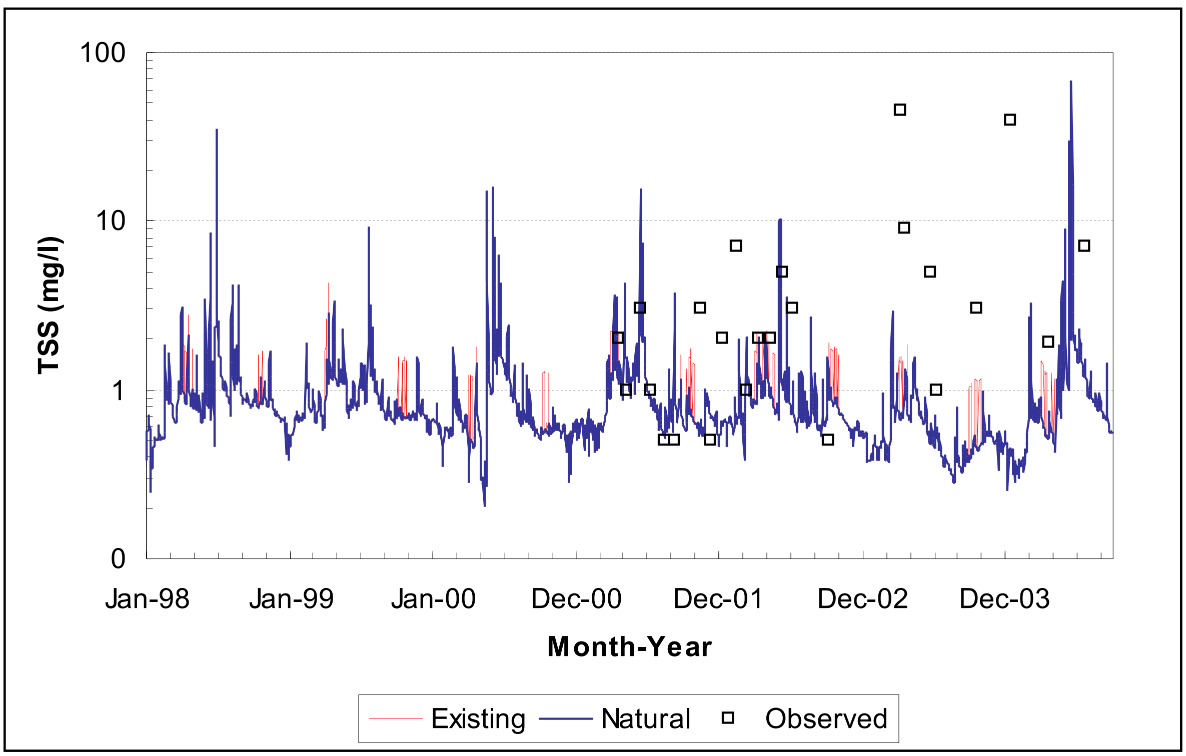

Figure 5-4. Comparison of estimated daily existing average TSS (existing and natural) and observed instantaneous TSS for Stillwell Creek. The timing of the large observed TSS concentrations that occurred from 2002 to 2003 is related to large storm events that are not reflected in the record of the USGS stream flow gage at Sparta.

5.2 Squaw Creek

Natural and existing stream temperatures in Squaw Creek were estimated in a manner similar to that used for Stillwell Creek, as explained in the following sections.

5.2.1 Natural Stream Temperature Estimates

Natural stream flow and natural stream temperature for Squaw Creek can be estimated based on the Above Lake monitoring site located in the upper portion of the Squaw Creek watershed. To understand how the temperatures below Squaw Lake compare to those above Squaw Lake, observed mean daily stream temperatures were regressed against mean daily air temperature recorded at the NWS Sparta cooperating observer station (477977). As expected, the regression results were significant for both sites. The regression plots are presented in Appendix A.

A best-fit mean line for both of the temperature monitoring stations is shown in Figure 5-5. This figure shows the average stream temperature as a function of daily air temperature for the Above Lake and Below Lake temperature monitoring stations. Figure 5-5 suggests that when mean air temperatures are greater than 0°C, stream temperatures below Squaw Lake are considerably warmer than at the Above Lake site.

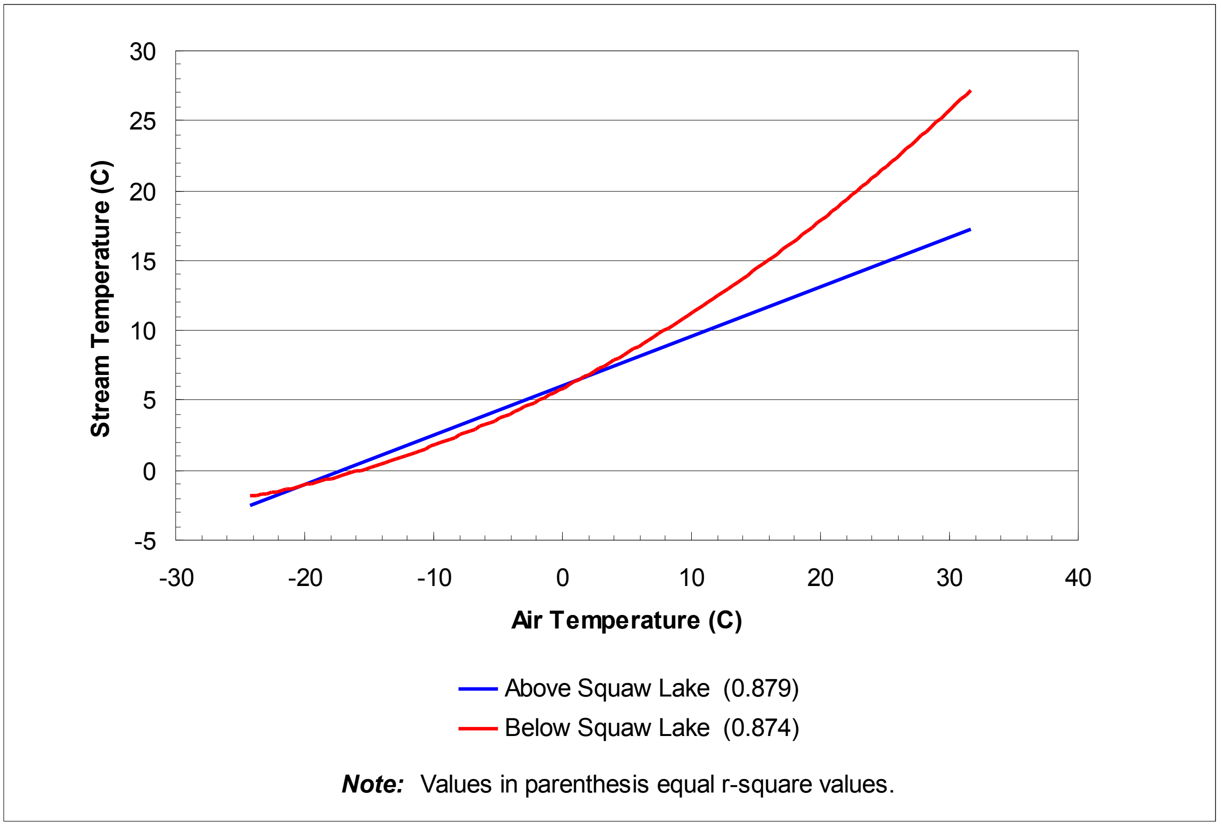

Figure 5-5. Best-fit lines from regression analysis of stream temperature and air temperature data for Squaw Creek.

TMDL

A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure [40 CFR 130.2(i)]. This section of the report presents the various components of the Stillwell Creek and Squaw Creek TMDLs, as required by the Clean Water Act.

6.1 Stillwell Creek TMDLs

The water quality problems in Stillwell Creek are believed to be a result of temperature, flow and habitat alterations caused by Stillwell Lake, an artificial lake, and the cranberry operation. Flow alterations, habitat alterations, and other types of "pollution[3]" can be addressed through the TMDL process by focusing on discrete pollutants, such as sediment, that produce measureable loads, and that have a relationship or linkage to identified water quality impairments. The Stillwell Creek TMDL focuses on temperature and sediments, but also describes the relationships between general pollution problems (such as flow alterations) and those caused by specific pollutants (such as sediment). Although no TMDLs will be established to specifically address the "pollution" problems, the impairments will be addressed within the context of TMDLs developed for the related "pollutants" of concern.

As described in 5.1.2, continuous stream flow data are not available for Stillwell Creek, and were extrapolated from stream flow data for the La Crosse River at Sparta (U. S. Geological Survey (USGS) station 05382325). Stream flows based upon the ratio of drainage area of the various points of interest along Stillwell Creek compared to the area drained by the La Crosse River USGS gage. The revised stream flows are shown in Figure A-6, and overall correspond well to the observed instantaneous stream flows.

6.1.1 Stillwell Creek Sediment TMDL

To determine the loads, the regression analysis described in 5.1.4, yielded a power function equation, shown in Figure 5-3, which was used to estimate daily concentrations of TSS as a function of daily stream flow for Stillwell Creek (Figure 5-4). Both the existing (with the cranberry bog) and natural (no bog) estimates of flows were used to estimate existing and natural TSS concentrations. These daily estimates of flows and concentrations were multiplied (along with a conversion factor) to generate the (daily) loads.

Daily estimates of current and natural sediment loads were then summed monthly. The estimate of natural loads is considered the loading capacity and therefore the sediment TMDL is based on reducing current loads to natural loads (Table 6-1). A 10 percent explicit margin of safety (MOS) is included as part of the TMDL as required by the Clean Water Act (see Section 6.1.3 for additional details). Sediment reductions are needed for April, May, and October and are related to slightly elevated stream flows associated with water used for frost protection and harvesting during these months.

[3] For definitions of pollution and pollutants see "Cleaner Waters Across America: Identification of Polluted Waters," U.S. EPA Office of Water, EPA841-F-99-003B, August 1999

Table 6-1 Streambank Sediment TMDL for Stillwell Creek Segment Below Cranberry Operation.

Month	Current Sediment Load kg/day (kg/month)	Loading Capacity=Natural Sediment Load kg/day (kg/month)	10% of Loading Capacity for MOS kg/day (kg/month)	Natural Sediment Load - MOS = TMDL kg/day	Necessary Reduction (Including 10% MOS) kg/day	Necessary Reduction (%)
January	1.32 (41)	1.32 (41)	N/A	None Required	None Required	None Required
February	1.82 (51)	1.82 (51)	N/A	None Required	None Required	None Required
March	2.58 (80)	2.58 (80)	N/A	None Required	None Required	None Required
April	4.93 (148)	3.4 (102)	.34 (10)	3.06	1.87	38%
May	4.23 (131)	4.10 (127)	.41 (13)	3.69	.54	13%
June	13.77 (413)	13.77 (413)	N/A	None Required	None Required	None Required
July	3.77 (117)	3.77 (117)	N/A	None Required	None Required	None Required
August	2.68 (83)	2.68 (83)	N/A	None Required	None Required	None Required
September	1.93 (58)	1.93 (58)	N/A	None Required	None Required	None Required
October	3.10 (96)	1.97 (61)	.20(6)	1.77	1.33	43%
November	1.90 (57)	1.90 (57)	N/A	None Required	None Required	None Required
December	1.52 (47)	1.52 (47)	N/A	None Required	None Required	None Required

N/A = Not Applicable, Values in parenthesis represent kg/month values

Since structures are already in place to control the release of water from the cranberry operation, best management practices (BMPs) might best focus on protecting downstream streambank conditions. An example of such a BMP is streambank rip rap covered with soil and planted with grasses. Other BMPs should be identified and finalized with local experts.

The effectiveness of these BMPs will vary based on their placement and extent, but is believed to be sufficient to obtain the additional sediment load reduction that is needed (i.e., in the range of 40 percent during critical conditions).

6.1.2. The Stillwell Creek Temperature TMDL

The Stillwell Creek temperature TMDL is expressed as a recommended reduction in mean daily stream temperature for each month from current conditions to natural conditions. The TMDL utilizes the part of EPA's regulations that allow TMDLs to be expressed using "other appropriate measures" because of the complexity associated with presenting allowable "loads" of temperature. The results are summarized in Table 6-2 and indicate that the summer months of May through August require the largest percent reductions. The mechanisms that result in stream temperatures downstream of the cranberry bog being much warmer during these months are not fully understood. It is likely related to the water that is used for irrigation being warmed either in the storage pond or in the bog and then infiltrating back into the stream. Best management practices to address this problem might include increased shading upstream and around the storage pond and or increased use of groundwater for summer irrigation of the bogs.

Table 6-1.Temperature TMDL for Stillwell Creek Segment Below Cranberry Operation.

Month	Mean dailyTemperature under Current Conditions °C (°F)	Daily Average Temp. from -Estimated Mean Monthly Temp. Under Natural Conditions (represents Load Capacity) °C (°F)	10% of Natural Temperature for MOS °C (°F)	Total Maximum Daily Load expressed as Temperature (Including 10% MOS) °C (°F)	Necessary Temperature Reduction (Including 10% MOS) °C (°F)	Necessary Average Daily Temperature Reduction (%)
January	2.6 (37)	3.9 (39)	N/A	N/A	None Required	None Required
February	6.0 (43)	6.5 (44)	N/A	N/A	None Required	None Required
March	9.2 (49)	8.6 (47)	-0.9 (-4.7)	7.7 (42.3)	-1.5 (-6.7)	-16%
April	12.7 (55)	10.6 (51)	-1.1 (-5.1)	9.5 (45.9)	-3.2 (-9.1)	-25%
May	15.4 (60)	11.7 (53)	-1.2 (-5.3)	10.5 (47.7)	-4.9 (-12.3)	-32%
June	16.9 (62)	12.2 (54)	-1.2 (-5.4)	11 (48.6)	-5.9 (-13.4)	-35%
July	16.3 (61)	12.0 (54)	-1.2 (-5.4)	10.8 (48.6)	-5.5 (-12.4)	-34%
August	14.0 (57)	11.1 (52)	-1.1 (-5.2)	10 (46.8)	-4.0 (-10.2)	-29%
September	10.3 (51)	9.3 (49)	-0.9 (-4.9)	8.4 (44.1)	-1.9 (-6.9)	-19%
October	7.4 (45)	7.6 (46)	N/A	N/A	None Required	None Required
November	3.2 (38)	4.3 (40)	N/A	N/A	None Required	None Required
December	2.1 (36)	3.5 (38)	N/A	N/A	None Required	None Required

values in parenthesis indicate °F; N/A = Not Applicable

6.1.3 Allocations

Sediment TMDL Allocations

The Total Maximum Daily Load can be defined as the sum of all allocations to point sources (waste load allocation) plus the sum of all the allocations to nonpoint sources (load allocation) plus a margin of Safety. In Table 6-1, the loading capacity is equal to the estimated natural daily sediment load. The wasteload allocation for the Stillwell Creek sediment TMDL is zero because there are no point sources in the watershed. Because the wasteload allocation is zero, the load allocation is therefore equal to the estimated natural daily sediment load (i.e., loading capacity), minus the margin of safety (in this case ten percent of the natural daily sediment load).

Temperature TMDL Allocations

In Table 6-2, the loading capacity is equal to the estimated natural temperatures. The wasteload allocation for the Stillwell Creek temperature TMDL is zero because there are no point sources in the watershed. Because the wasteload allocation is zero, the load allocation is therefore equal to the estimated natural temperature minus the margin of safety (in this case ten percent of the natural temperature).

6.1.4 Seasonality

Section 303(d) (1) (C) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7(c) (1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. Seasonal variation has been addressed in the Stillwell Creek TMDLs by estimated temperatures and sediment loads on a daily basis (thus accounting for seasonal variations in stream flows and weather) and presenting the required reductions on an average daily basis for each month.

6.1.5 Margin of Safety

Section 303(d) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991). A 10 percent explicit margin of safety has been incorporated into Stillwell Creek TMDLs by reserving a portion of the loading capacity. A moderate margin of safety was chosen because there are a number of uncertainties associated with the analysis. These include:

- The need to estimate current and natural flows based on an extrapolated flow record.
- Incomplete information with which to characterize the operation and impact of the cranberry operation.
- Indirect link between TSS (which measures suspended sediment in the stream column) and streambed siltation (which is what causes problems for macroinvertebrates and fish).

6.1.6 Critical Conditions

The greatest sediment loading is expected to occur in April, May, and October due to the natural hydrology of the watershed and the impacts of the cranberry operations. The warmest temperatures occur in June and July due to air temperatures and impacts associated with the cranberry operation. The TMDL has taken these critical conditions into account by making daily estimates of sediment loading and temperatures and presenting the TMDL in terms of average daily reductions for each month.

6.2 Squaw Creek TMDL

A temperature TMDL was developed for Squaw Creek. As stated in Section 2.2, the Squaw Creek TMDL is presented for current conditions and does not reflect the proposed recreational development for areas in the watershed that drains to Squaw Creek. The Squaw Creek TMDL is expressed as a recommended reduction in average daily stream temperature for each month, from current conditions to natural conditions (i.e., loading capacity). The results are summarized in Table 6-4 and indicate that most months require fairly significant percent reductions (20 to 35 percent).

Since the warm temperatures downstream of Squaw Creek are primarily related to the surface release of water from Squaw Lake, one implementation measure would be to set up a new control structure that would release water from deeper in the lake (where the water is colder). To evaluate the potential impacts of this implementation measure, the available Squaw Lake temperature data at depth were regressed against mean monthly air temperatures (Figure 6-1). It appears that the relationship between air temperature and water temperature at a depth of approximately 8 to 10 feet most closely approximates the relationship at the reference site. A potential implementation measure would therefore be to install a new control structure at a depth of 8 to 10 feet below the surface of Squaw Lake. The water released from the lake would therefore be cooler (especially during the summer) and would result in cooler temperatures in Squaw Creek below the lake.

Table 6-2.Temperature TMDL for Squaw Creek Segment Below Squaw Lake.

Month	Mean Daily Temperature under Current Conditions °C (°F)	Daily Average Temp. from Estimated Mean Monthly Temp. Under Natural Conditions (represents Load Capacity) °C (°F)	10% of Natural Temperature for MOS °C (°F)	Total Maximum Daily Load expressed as Temperature (Including 10% MOS) °C (°F)	Necessary Reduction in Temperature (Including 10% MOS) °C (°F)	Necessary Average Daily Daily Temperature Reduction (%)
January	2.6 (37)	3.0 (37)	N/A	N/A	None Required	None Required
February	4.8 (41)	5.0 (41)	N/A	N/A	None Required	None Required
March	6.7 (44)	6.5 (44)	-0.6 (-4.4)	5.9 (39.6)	-0.8 (-4.4)	-12%
April	9.5 (49)	8.4 (47)	-0.8 (-4.7)	7.6 (42.3)	-1.9 (-6.7)	-21%
May	15.1 (59)	11.7 (53)	-1.2 (-5.3)	10.5 (47.7)	-4.6 (-11.3)	-31%
June	17.4 (63)	12.8 (55)	-1.3 (-5.5)	11.5 (49.5)	-5.9 (-13.5)	-34%
July	19.8 (68)	14.0 (57)	-1.4 (-5.7)	12.6 (51.3)	-7.2 (-16.7)	-36%
August	19.0 (66)	13.6 (57)	-1.4 (-5.7)	12.2 (51.3)	-6.7 (-14.7)	-35%
September	15.3 (60)	11.7 (53)	-1.2 (-5.3)	10.5 (47.7)	-4.7 (-12.3)	-31%
October	11.2 (52)	9.4 (49)	-0.9 (-4.9)	8.5 (44.1)	-2.7 (-7.9)	-24%
November	7.6 (46)	7.1 (45)	-0.7 (-4.5)	6.4 (40.5)	-1.2 (-5.5)	-16%
December	3.5 (38)	3.7 (39)	N/A	N/A	None Required	None Required

values in parenthesis indicate °F; N/A = Not Applicable

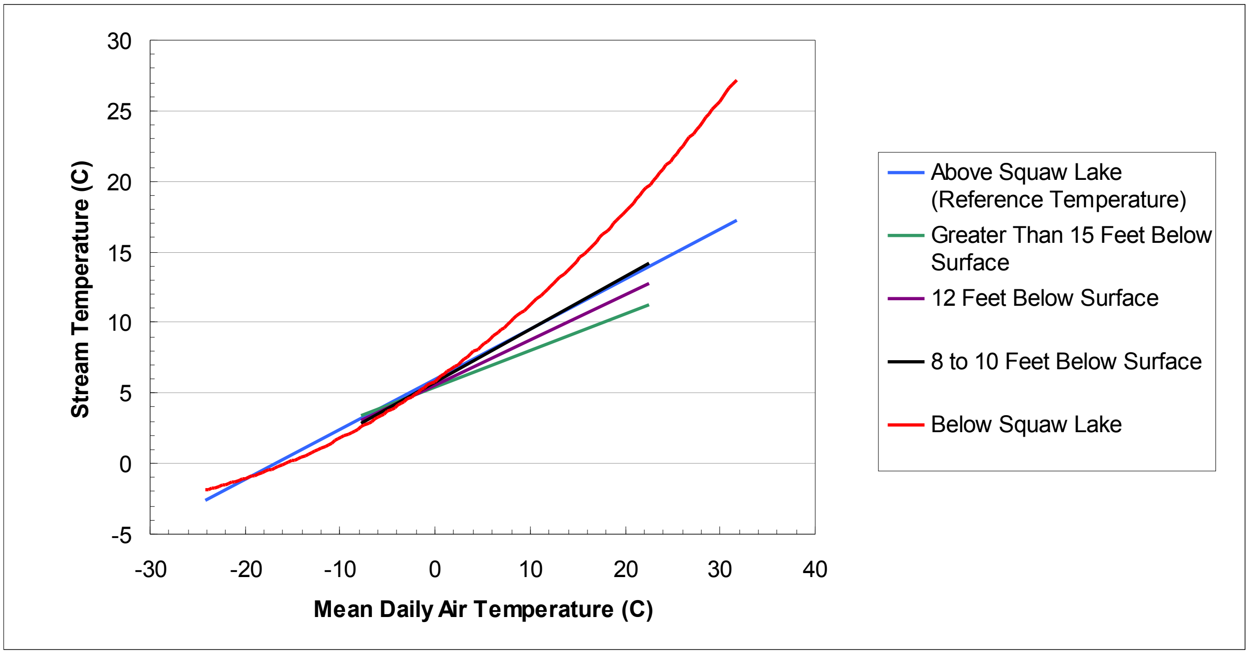

Figure 6-1. Relationship between mean daily air temperature and in-lake or in-stream water temperatures below Squaw Lake.

6.2.1 Allocations

The Total Maximum Daily Load can be defined as the sum of all allocations to point sources (waste load allocation) plus the sum of all the allocations to nonpoint sources (load allocation) plus a margin of Safety. In Table 6-4, the loading capacity is equal to the estimated natural temperatures. The wasteload allocation for the Squaw Creek temperature TMDL is zero because there are no point sources in the watershed. Because the wasteload allocation is zero, the load allocation is therefore equal to the estimated natural temperature (i.e., loading capacity) minus the margin of safety (in this case ten percent of the natural temperature).

6.2.2 Seasonality

Section 303(d) (1) (C) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7(c) (1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. Seasonal variation has been addressed in the Squaw Creek TMDLs by estimating temperatures as a function of the full range of air temperatures, thus taking into account seasonal variations.

6.2.3 Margin of Safety

Section 303(d) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991). A 10 percent explicit margin of safety has been incorporated into the Squaw Creek TMDL by reserving a portion of the loading capacity. A moderate margin of safety was chosen because there are a number of uncertainties associated with the analysis. These include:

- Incomplete information with which to fully characterize temperature conditions within Squaw Lake.

6.2.4 Critical Conditions

The warmest temperatures in the segment downstream of Squaw Lake are in June, July, and August (see Table 6-4). The TMDL has taken these critical conditions into account by presenting the TMDL in terms of specific daily reductions for each month.

6.0 IMPLEMENTATION

As discussed in Section 6, the recommended implementation option for the Squaw Creek temperature TMDL is to investigate the possibility of setting up a new control structure that would release water from deeper in the lake (where the water is colder).

A possible option for the Stillwell Creek sediment TMDL is to try and protect the streambank downstream of the cranberry operation by installing streambank rip rap covered with soil and planted with grasses. A possible option for the Stillwell Creek temperature TMDL might be to improve the shading upstream of the cranberry operation so that incoming temperatures are lower. This hypothesis was examined using the USGS stream temperature model SSTEMP to estimate mean daily stream temperatures at the point where Stillwell Creek enters the cranberry bog.

6.1.1 SSTEMP Application for Stillwell Creek

SSTEMP (Bartholow, 2002) is typically used to analyze the effects of changing riparian shade or the physical features of a stream, evaluate alternative reservoir release proposals, and examine the effects of different stream withdrawals and returns on instream temperature. The model requires inputs describing the stream geometry, as well as hydrology and meteorology, and stream shading. SSTEMP estimates the combined effect of topographic and vegetative shade as well as solar radiation penetrating the water. The model then predicts the minimum, mean, and maximum daily water temperature at a specified distance downstream. The model application to Stillwell Creek is described below.

6.1.1.1 Model Setup and Calibration

The first step was to calibrate the SSTEMP model to Stillwell Creek. Model calibration was performed by using observed stream temperature and stream flow at the Below Habelman's and Most Downstream sites. These observed data, along with other required model parameters, were input into SSTEMP. An important assumption was the percent of vegetative shading over Stillwell Creek from the Below Habelman's site to the Most Downstream site. A 30-meter stream buffer analysis for this segment, performed in GIS, found that 83 percent of the buffer consisted of forest cover, which in turn is dominated by deciduous forest land cover. Given this vegetative cover type and density, the Total Shade value was set to 50 percent, and Ground Reflectivity was set to 20 percent in the SSTEMP model. SSTEMP was then run for 17 dates, to correspond to the available sampling data collected from 4-17-01 to 1-13-04.

The model's predictions of mean daily instream water temperature at the Most Downstream site were then compared to observed instream temperatures at the site. Model results are presented in Figure 6-1 and indicate that SSTEMP performs well (r-square = 0.812) in estimating instream temperatures at the Most Downstream site.

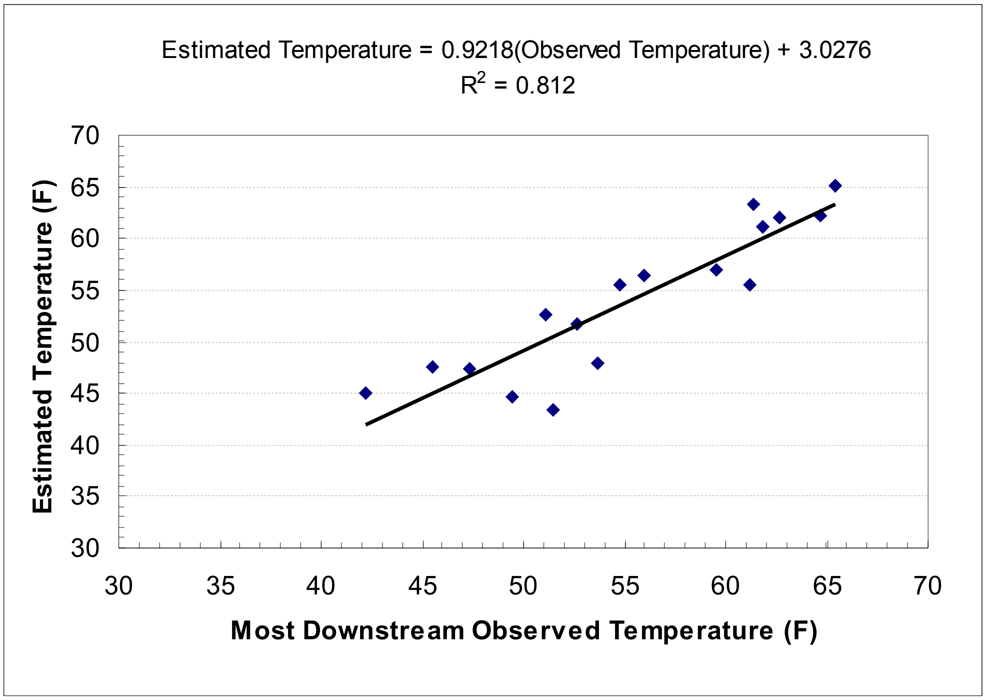

Figure 7-1. Results of SSTEMP estimates of daily mean instream temperature at the Most Downstream monitoring site.

6.1.1.2 Temperature Estimates at Inlet to Cranberry Bog

The calibrated SSTEMP model was then used to simulate in-stream temperatures along a stream segment beginning at the Below Lake site (below Stillwell Lake) to the inlet of the Habelman cranberry bog. The Total Shade parameter was set to 20 percent and the Ground Reflectivity parameter was set at 10 percent to reflect the dominant grassland cover in this section of the creek. The model was then run for 15 dates, ranging from 4-17-01 to 7-21-04. These dates were selected because in stream temperature and flow data were available for the Below Lake site. Stream flow observations at the inlet to the cranberry bog have not been collected. Consequently, required stream flow at the end of the stream segment was set to the upstream flow value. Model results, along with observed stream temperatures at the Below Habelman's site, are presented graphically in Figure 6-2. The figure shows water temperatures are projected to cool by the time they reach the inlet to the cranberry bog. This cooling is due to the exchange of colder shallow groundwater to Stillwell Creek.

Figure 6-2 also includes the observed stream temperatures at the Below Habelman's site and therefore illustrates the net effect of the cranberry operation on stream temperatures.

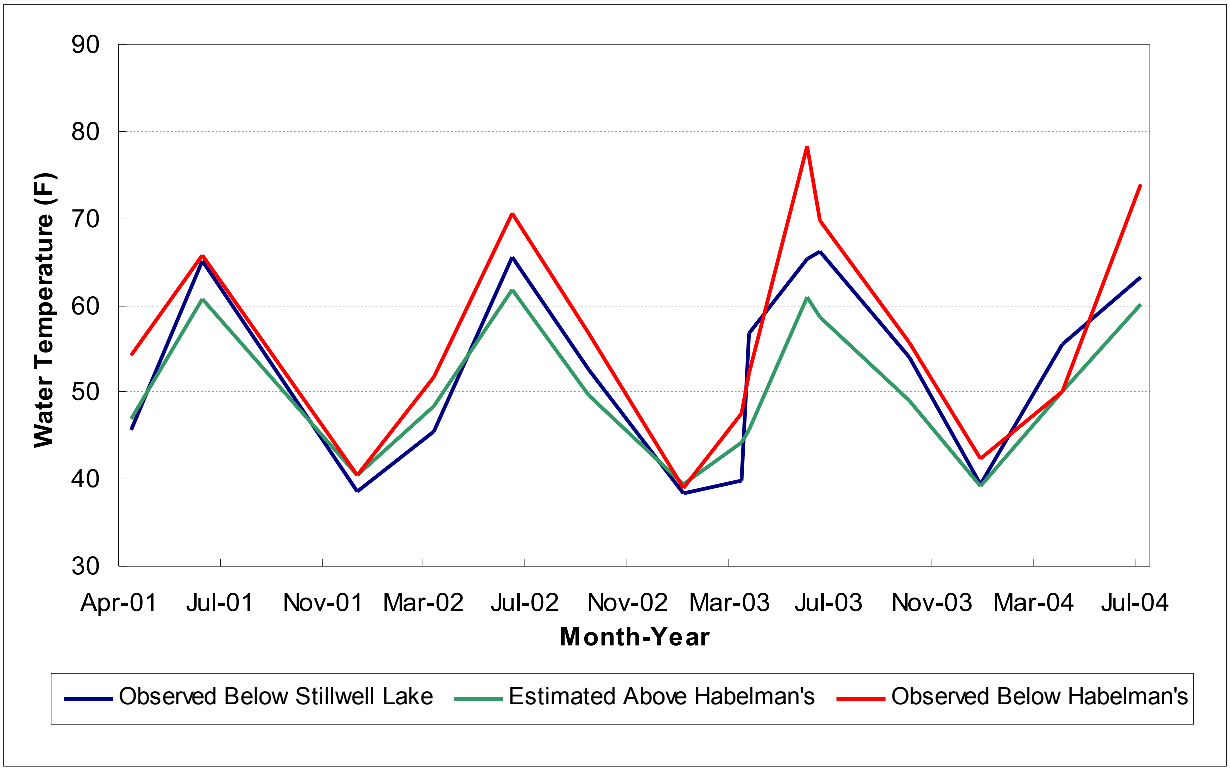

Figure 7-2. SSTEMP stream temperature estimates at the inlet to Habelman's cranberry bog, and stream temperature comparisons for observed data for the Below Stillwell Lake and Below Habelman's sites.

6.1.1.3 Estimating Shading Effects on Stream Temperature

SSTEMP was used to estimate potential instream temperature reduction from vegetative shading along the stream segment beginning at the Below Lake site (below Stillwell Lake) to the inlet of the Habelman cranberry bog. Model shading parameter values along the riparian corridor were increased from 20 percent to values of 50 percent and 70 percent. Ground reflectance values were increased from 10 percent to 20 percent. The fifty percent shading value and twenty percent ground reflectance value reflects the vegetative cover characteristics of the lower portion of Stillwell Creek; the stream reach from below the cranberry bog to the basin outlet.

SSTEMP model results are presented in Table 6-2 and in Figure 6-3. Table 6-2 and Figure 6-3 show that vegetative shading can potentially be an effective method of reducing instream temperatures, particularly in the warmer months of May through August. A review of Table 6-2 suggests that 50 percent shading of the stream reduces instream temperature by an average of 2.8 °F in the months of June and July. A 70 percent shading factor reduces instream temperatures by an average of 4.0 degrees in June and July. Vegetative shading along the riparian corridor between the Below Lake site and the inlet into the Habelman cranberry bog would result in cooler water temperatures flowing into the bog, which might possibly result in slightly cooler water temperatures below the cranberry operation.

Table 7-1.Estimated Instream Temperature Changes due to Vegetative Shading from the Below Lake Site to the Inlet into the Cranberry Bog.

Date	Air Temp (°F)	Current Stream Temp (°F)	SSTEMP Estimate, 50% Shading (°F)	SSTEMP Estimate, 70% Shading (°F)	Difference Between Current and 50% Shading (°F)	Difference Between Current and 70% Shading (°F)
04/17/01	45.7	46.9	45.6	44.5	1.3	2.4
07/10/01	70.2	60.8	57.9	56.7	2.9	4.0
01/08/02	39.6	40.4	40.6	40.5	-0.2	-0.2
04/09/02	51.4	48.4	47.4	46.4	1.0	2.0
07/09/02	72.5	61.7	58.5	57.2	3.3	4.5
10/08/02	54.5	49.8	48.3	47.8	1.5	1.9
01/28/03	34.5	39.4	39.3	39.1	0.1	0.3
04/08/03	39.6	44.3	43.1	42.1	1.2	2.2
04/16/03	37.8	45.7	43.1	42.0	2.6	3.7
06/24/03	73.9	61.0	58.6	57.2	2.4	3.8
07/08/03	67.5	58.6	55.7	54.4	2.9	4.3
10/21/03	56.7	49.1	48.1	47.7	1.0	1.4
01/13/04	34.5	39.1	39.0	38.9	0.1	0.2
04/20/04	52.9	50.0	48.4	47.2	1.6	2.8
07/21/04	70.5	60.1	57.6	56.5	2.5	3.6

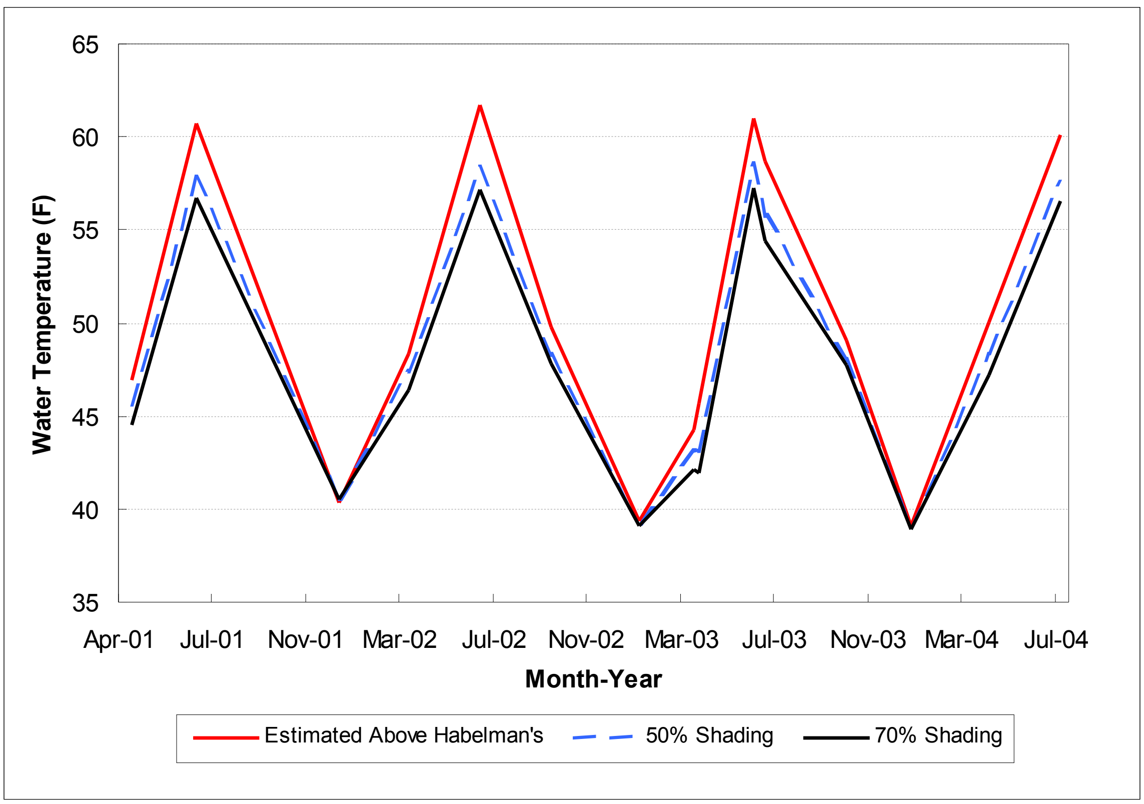

Figure 7-3. SSTEMP estimated instream temperature effects of two vegetative shading scenarios at inlet into cranberry bog along Stillwell Creek.

REFERENCES

Bartholow, J.M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). US Geological Survey computer model and documentation. Available on the Internet at http://www.fort.usgs.gov/

APPENDIX A

A-1. REGRESSION ANALYSES FOR STILLWELL CREEK TEMPERATURE DATA

Regression analysis between observed stream temperature and mean daily air temperature was performed for each stream temperature monitoring site on Stillwell Creek. Graphical summaries of the analyses are presented in Figures A-1 through A-4. Each of the figures shows a significant relationship between observed stream temperature and mean daily air temperature. Furthermore, each figure suggests that as air temperatures increase, stream temperatures correspondingly increase at each monitoring site.

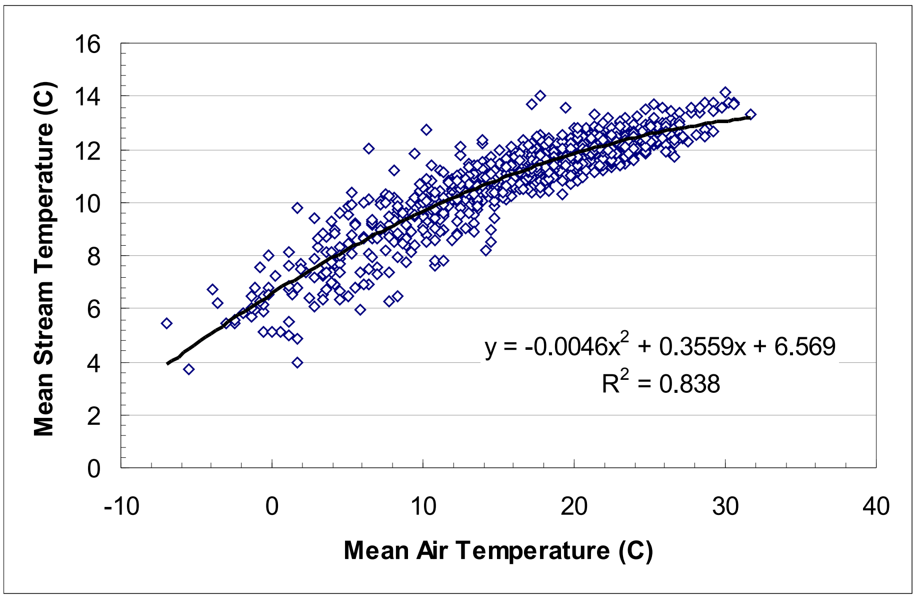

Figure A-1. Above Stillwell Lake

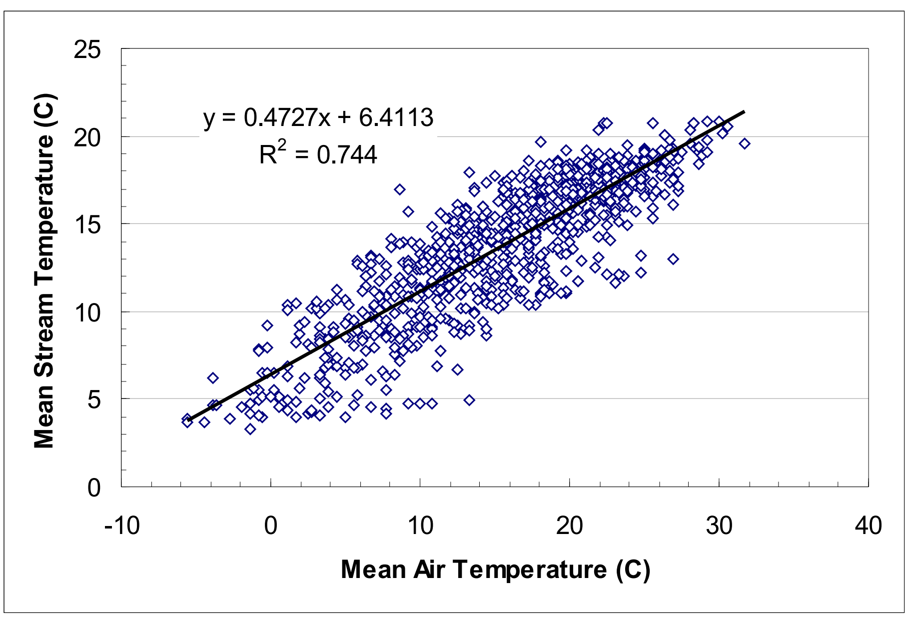

Figure A-2. Below Stillwell Lake

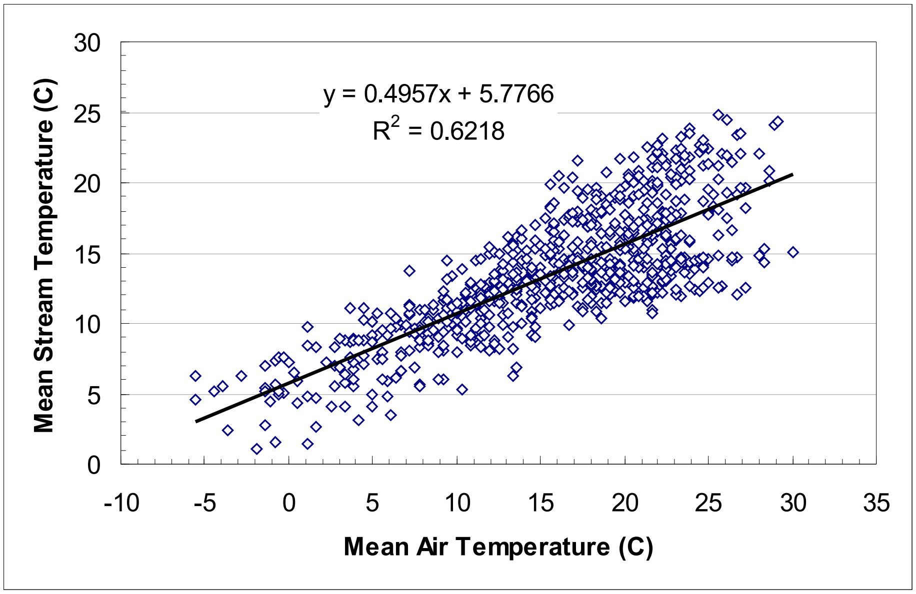

Figure A-3. Below Habelman's

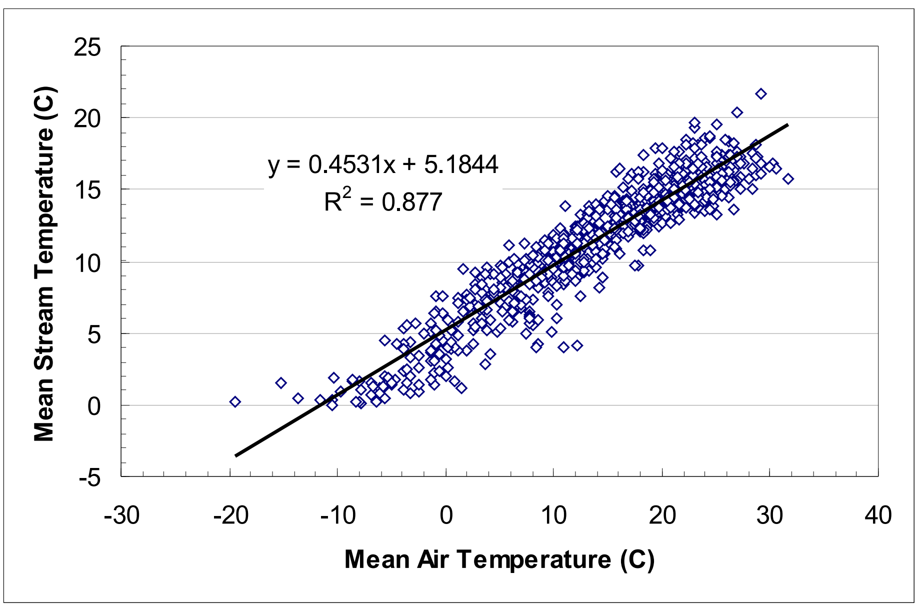

Figure A-4. Most Downstream

A-2. STREAM FLOW ANALYSES FOR STILLWELL CREEK

Since continuous stream flow data are not available for Stillwell Creek, they were extrapolated from stream flow data for the La Crosse River at Sparta (U. S. Geological Survey (USGS) station 05382325). Stream flows were calculated as proportional based upon the ratio of drainage area of the various points of interest along Stillwell Creek compared to the area drained by the La Crosse River USGS gage. For example, the ratio of the drainage area at the Below Habelman's monitoring site compared to the drainage area at Sparta is 4.7 square miles divided by 167 square miles or 0.028. Thus, the Sparta daily stream flows were multiplied by 0.028 to estimate the natural daily stream flow for the Below Habelman's monitoring site. The initial flow estimates are presented in Figure A-5. Figure A-5 shows that the initial procedure overestimates stream flows observed at the Below Habelman's monitoring site.

To more accurately estimate naturally occurring stream flows, a ratio of observed to estimated flow was calculated first for corresponding dates. Next, the median of the ratios was calculated and found to equal 0.31. Finally, the initial estimated flows were multiplied by the median ratio (0.31) to reduce the estimates of natural stream flow in Stillwell Creek. The revised stream flows are shown in Figure A-6. The figure shows that with the exception of two summer storm events, the overall reduced stream flows correspond well to the observed instantaneous stream flows.

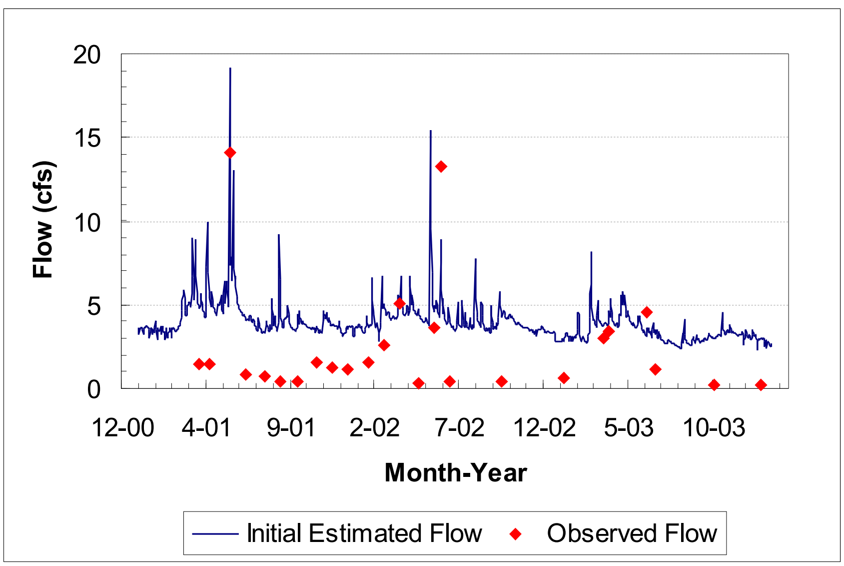

Figure A-5. Initial stream flow estimates for the natural condition in Stillwell Creek.

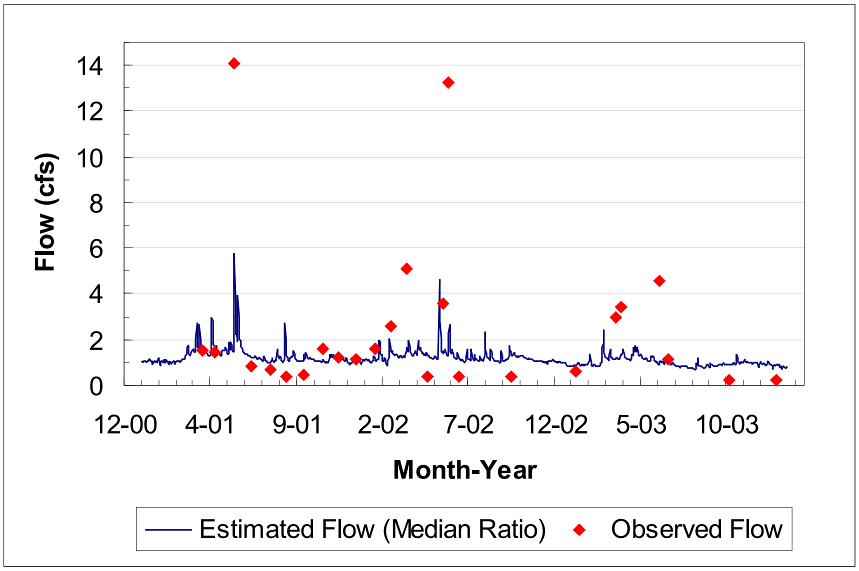

Figure A-6. Revised stream flow estimates for the natural condition in Stillwell Creek.

Figure 1-2.A-2. REGRESSION ANALYSES FOR TARR CREEK SEDIMENT DATA

Regression analysis between observed total suspended sediment (TSS) and instantaneous stream flow was performed for data collected on Tarr Creek, East Bounding site. Results of the initial analysis are presented graphically in Figure A-7 and show a strong relationship between flow and TSS concentrations. However, much of the relationship is caused by one data point that is potentially an outlier. This data point was therefore removed from the analysis and the revised regression is shown in Figure A-8. Figure A-8 suggests that the relationship between observed TSS and instantaneous stream flow is moderate, and has an associated r-square of 0.4096. That is, approximately 41 percent of the variability in the data is described by the regression equation.

The equation in Figure A-7 was used to estimate TSS concentrations for the Below Habelman's site in Stillwell Creek. Estimated stream flows for the Below Habelman's site were used for the "Flow" variable in the equation to calculate TSS concentrations for the site. The results are shown in Figure A-9. Figure A-9 shows a high degree of agreement between observed and estimated TSS levels for the Below Habelman's site.

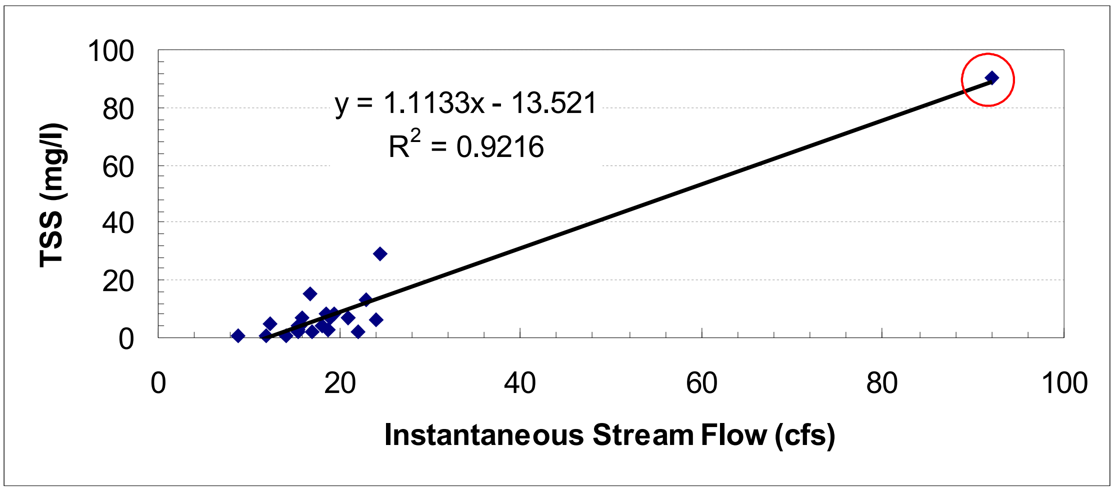

Figure A-7. Initial TSS and stream flow regression plot for Tarr Creek, East Bounding site with all data points.

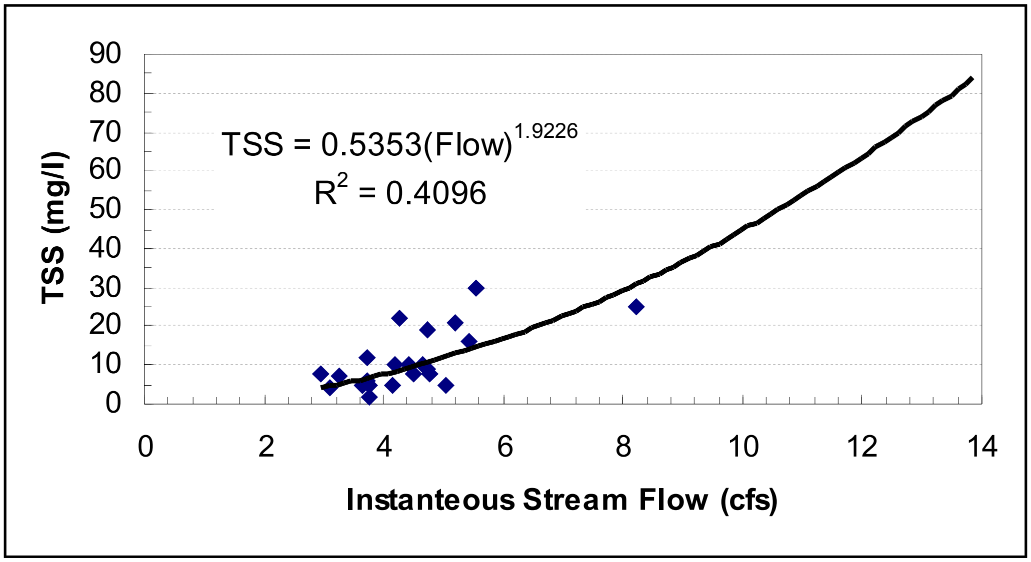

Figure A-8. TSS and stream flow regression plot for Tarr Creek, East Bounding site.

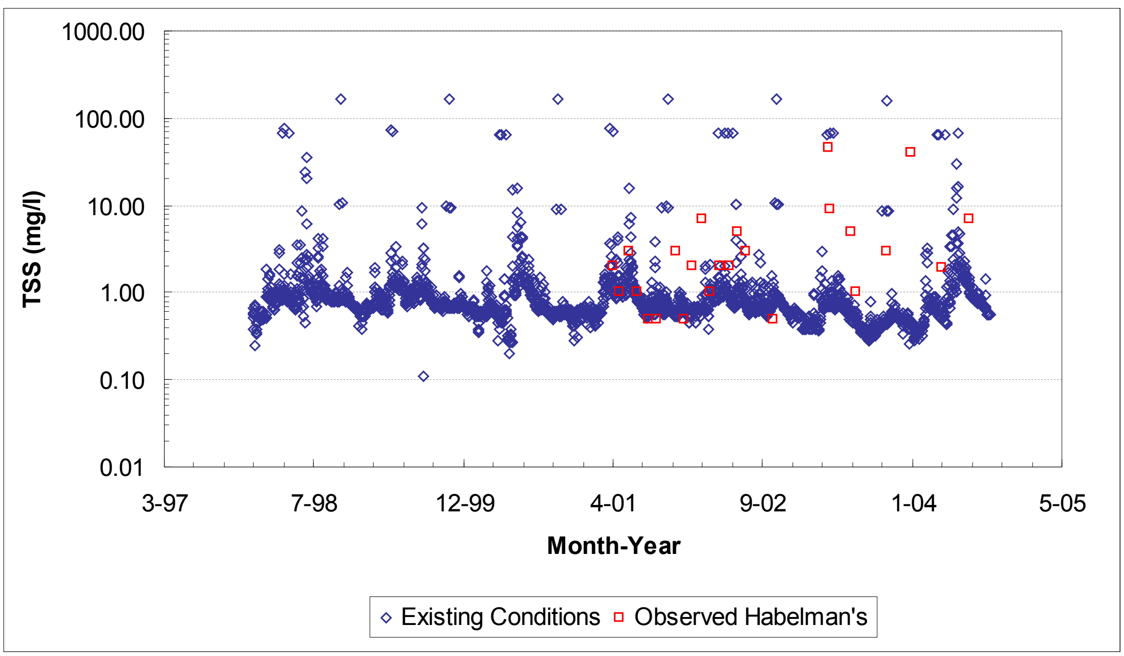

Figure A-9. Comparison of estimated and observed TSS concentrations at the Below Habelman's site in Stillwell Creek.

A-3. REGRESSION ANALYSES FOR SQUAW CREEK TEMPERATURE DATA

Regression analysis between observed stream temperature and mean daily air temperature was performed for two stream temperature monitoring sites on Stillwell Creek. Graphical summaries of the analyses are presented in Figures A-10 and A-11. Both figures show a significant relationship between observed stream temperature and mean daily air temperature. Furthermore, each figure suggests that as air temperatures increase, stream temperatures correspondingly increase at each monitoring site.

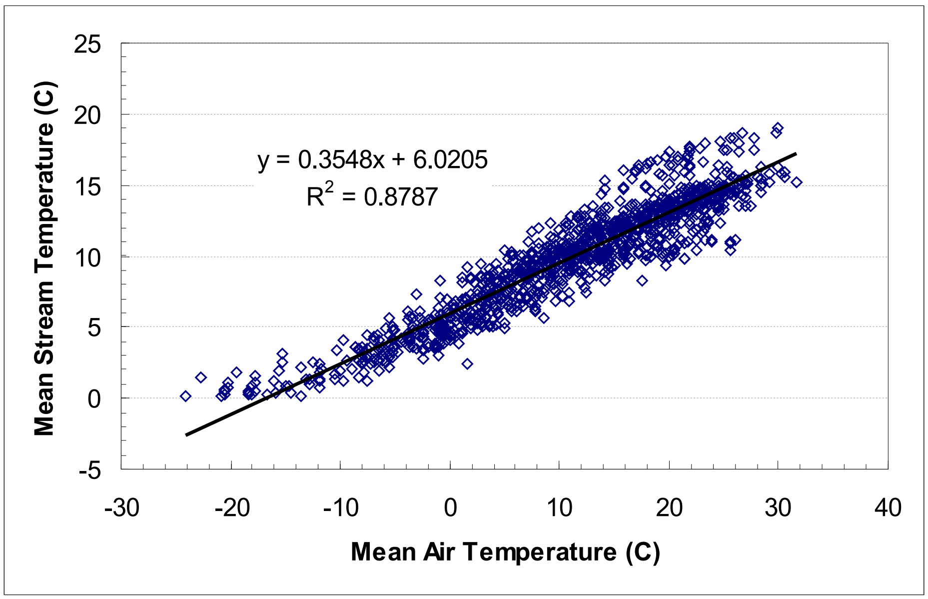

Figure A-10. Above Squaw Lake

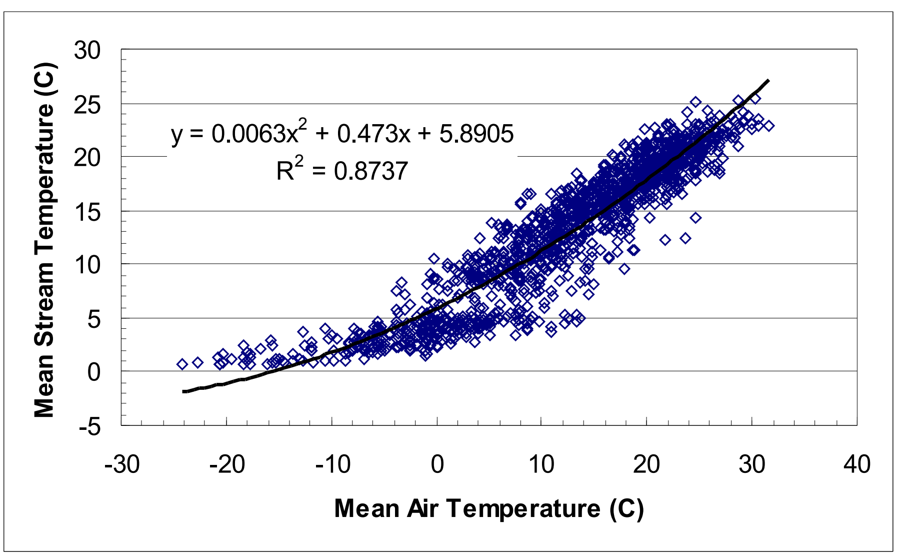

Figure A-11. Below Squaw Lake