Lower Skagit River Tributaries Temperature Total Maximum Daily Load

Water Quality Improvement Report

July 2008

Publication No. 08-10-020

DEPARTMENT OF
ECOLOGY
State of Washington

Publication Information

This Water Quality Improvement report is published in two parts:

Volume 1 – Study Findings

Volume 2 – Improvement Report

On the web

Volume 1 - www.ecy.wa.gov/biblio/0403001.html

Volume 2 – www.ecy.wa.gov/biblio/0810020.html

In printed form

For a printed copy, contact the Department of Ecology Northwest Regional Office, Water Quality Program

Address: 3190 160th Avenue SE, Bellevue, WA 98008

Phone: (425) 649-7105

Volume 1 – Publication No. 04-03-001

Volume 2 – Publication No. 08-10-020

Title page photograph: Fisher Slough

Lower Skagit River Tributaries Temperature Total Maximum Daily Load

Water Quality Improvement Report

Sally Lawrence
Water Quality Program
Washington State Department of Ecology
Northwest Regional Office
Bellevue, Washington 98008-5452

July 2008

Publication No. 08-10-020

leave this blank page here –

Table of Contents

List of Figures and Tables

Page

Figures

Tables

Acknowledgements

I am grateful to the members of the Advisory Committee who met several times during 2007 and 2008. They reviewed draft sections of this report and provided their perspective on this project. Inclusion of their names here does not imply that they support or agree with the recommendations in this Department of Ecology report. Nevertheless, their participation and comments have helped to improve this Water Quality Improvement Report.

Dave Boon, resident of Carpenter Creek basin
Doug Couvelier, Upper Skagit Tribe
Rick Haley, Skagit County Monitoring Program
Carolyn Kelly, Skagit Conservation District
June Kite, resident of Fisher Creek basin
Cara McKinnon, Washington Department of Agriculture
Jon-Paul Shanahan, Upper Skagit Tribe
Betsy Stevenson, Skagit County Planning and Permitting Center
Bob Warinner, Washington Department of Fish and Wildlife
Larry Wasserman, Swinomish Tribe
Perry Welch, Skagit Fisheries Enhancement Group
Andrea Xaver, resident of Nookachamps Creek basin
Jane Zillig, Skagit Land Trust

Ecology staff that played critical roles during the development of this TMDL:

Dave Garland, for endless encouragement
Kevin Fitzpatrick, for finding funding for the Vegetation Change Analysis
Joanne Polayes, for keeping me informed of grant progress
DouGlas Palenshus, for guidance on outreach, meetings and facilitation
Stephanie Brock, for assistance with the Temperature TMDL technical report
Callie Meredith, GIS analyst and author, *Lower Skagit River Tributaries Riparian Vegetation Change Analysis Results* (with project oversight by Teizeen Mohammedali and Karol Erickson)
Diane Dent for editorial guidance
Helen Bresler and Todd Bolster for laying out Ecology's regulatory authority under the Clean Water Act and the Water Pollution Control Act
Anita Stohr, for help with comments on temperature science and modeling

And finally, many thanks to Brian Zalewsky and Dustin Bilhimer of Ecology's Environmental Assessment Program for their high quality technical report, *Lower Skagit River Tributaries Temperature Total Maximum Daily Load* (Appendix A).

Executive Summary

Under the federal Clean Water Act, Washington State Department of Ecology (Ecology) has the authority and responsibility to develop Water Quality Improvement Reports, also called Total Maximum Daily Loads, for water bodies of the state that do not meet water quality standards. This Water Quality Improvement Report represents Ecology's strategy for reducing late summer maximum temperatures in nine creeks that are tributaries to the Lower Skagit River in Skagit County.

In summer 2001, Ecology determined that Fisher, Carpenter, Hansen, Red, Nookachamps, Otter Pond, Lake, East Fork Nookachamps, and Turner Creeks do not meet state water quality standards for temperature. Ecology conducted a modeling study that determined that full, mature native riparian shade along these creeks would reduce the heat load sufficiently to meet the water quality standard of 18^{o} C. The modeling results indicate that, except for the reaches that receive warm lake discharges (Lake Creek below Lake McMurray and Nookachamps Creek below Big Lake), these creeks would also meet the revised water quality standard of 16^{o} C. The standard was revised in 2006 to reflect the spawning and juvenile rearing needs of salmon that are known to use these creeks.

To encourage private landowners to increase the amount of riparian shading along these creeks, Ecology recommends an approach with three main elements:

- **Incentive programs** in the form of:
  - The Conservation Reserve and Enhancement Program (CREP), administered by Skagit Conservation District, which compensates farmers that put land into buffers.
  - A proposed Skagit County program of financial incentives for landowners that independently install and maintain riparian buffers adequate to shade the stream.
- **An outreach and technical assistance program** using Basin Stewards hired to work one-on-one to educate and support landowners to improve the health of riparian land and creeks.
- **A communications program** in which landowners that do not protect creeks would be sent a letter by Ecology explaining the need for creek protection and outlining the options available for protecting the creek. Ecology is requesting the assistance of Skagit County GIS services in identifying parcels needing shade protection.

When working with landowners, Ecology initially uses outreach and education to seek compliance. Landowners whose management practices are determined to be deficient in protecting creek water quality would be required to develop and implement a farm plan through consultation with the local Conservation District, Natural Resource Conservation Service, or private consultant.

With these elements in place, Ecology expects these creeks will meet water quality standards for temperature by 2080.

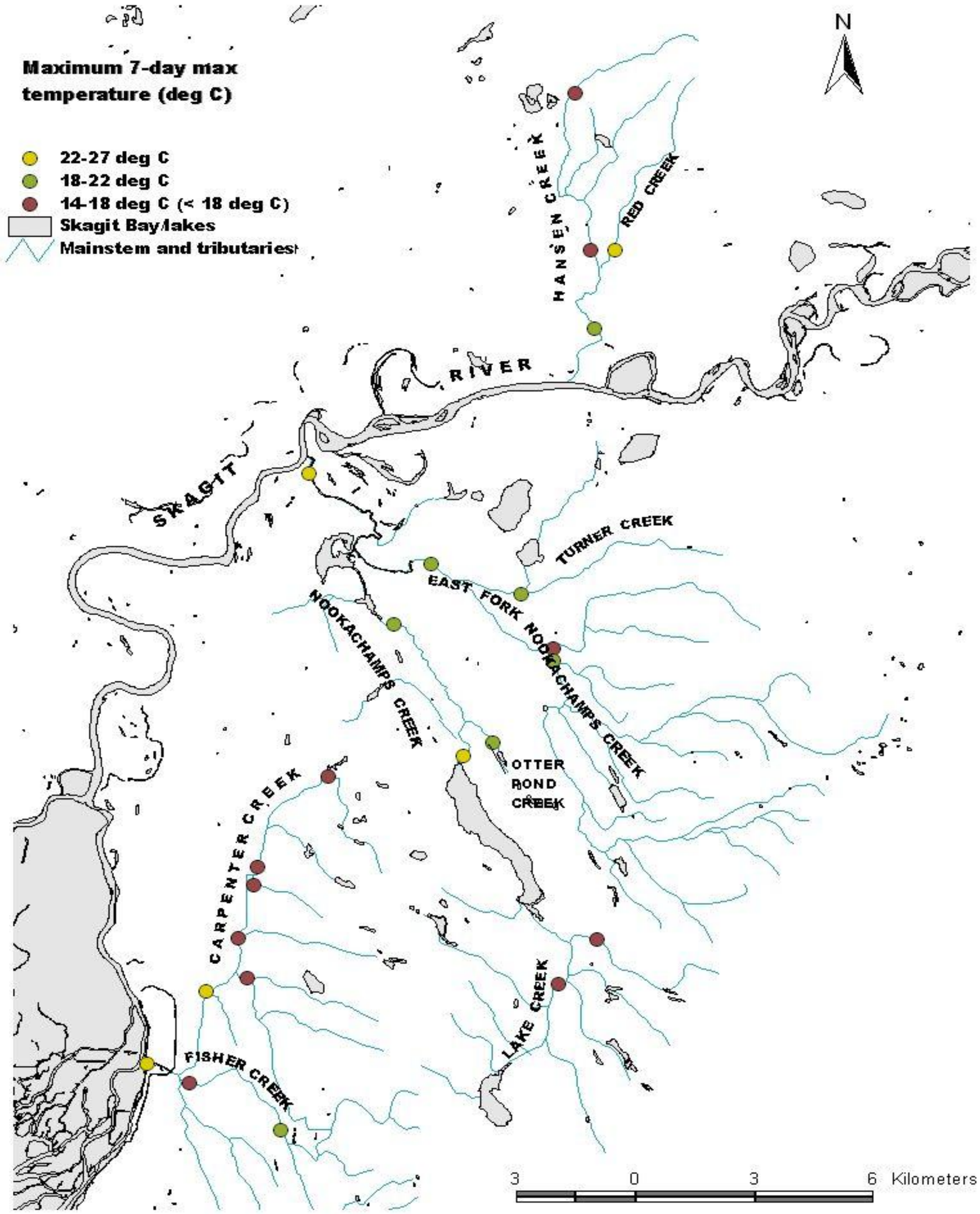


Figure 1. Critical temperatures in the TMDL creeks in summer 2001

Overview

The Washington State Department of Ecology (Ecology) found high water temperatures during the late summer, low-flow season in nine creeks that discharge to the Lower Skagit River. Temperature was measured in Carpenter, Fisher, Hansen, Red, East Fork Nookachamps, Turner, Nookachamps, Otter Pond, and Lake Creeks in August 2001 (Figure 1, opposite). The measurements exceed the state water quality standards for temperature (Chapter 173-201A Washington Administrative Code) and put at risk cold-water fish and invertebrates that normally live in these creeks.

Stream temperatures too high for cold water species

Important habitat for cold-water species is reduced in these streams because of the high water temperatures in late summer. The most important environmental variables affecting water temperature in forested streams are: stream depth, air temperature, solar radiation, riparian vegetation, and ground water (Adams and Sullivan, 1989). These streams are affected by land management practices that result in increased exposure to sun, altered drainage patterns, and reduced connection to ground water. Channelization and manmade drainage systems have altered flow and connections to cool ground water in some of the creeks. Removal of native trees and other shade-providing vegetation has increased exposure to sunlight. In some creeks, upstream logging or development has increased sediment load and sediment deposits, creating shallower, wider streams with more exposure to sunlight.

Ecology prepared this report[1], the *Lower Skagit Tributaries Temperature Total Maximum Daily Load Water Quality Improvement Report* (referred to hereafter as the *Water Quality Improvement Report*, or *this Report*) to identify actions that will help reduce temperatures in the creeks. It reviews potential solutions to the problem of stream heating, and provides a set of recommended actions to solve the problem. It identifies the organizations that can undertake many of these recommended actions.

The success of this effort depends on landowners, living along these creeks, adopting land-management practices to protect the water. They need to establish shade-producing buffers that can lead to lower late-summer stream temperatures. This Report outlines an approach that would be led by local organizations in order to increase participation by landowners in riparian restoration and protection and bring water temperatures into compliance with state standards.

The Federal Clean Water Act requires TMDLs if standards not met

Section 303(d) of the Federal Clean Water Act requires a scientific study and plan for cleanup when waters do not meet water quality standards. The study is called a Total

[1] *Some of the content of this report is technical in nature. Much of what follows is required to meet federal or state requirements for Total Maximum Daily Loads (TMDLs). Highlights are provided in an Ecology Focus Sheet, available at: http://www.ecy.wa.gov/biblio/0810017.html. The Focus Sheet directs you to staff who can assist you with questions about this project.*

Maximum Daily Load (TMDL). In Washington State, Ecology prepares a Water Quality Improvement Report that includes results and recommendations of the scientific study (the Total Maximum Daily Load) and a strategy for improving water quality. Ecology sends the Report to the U.S. Environmental Protection Agency (EPA) for review and approval. The federal TMDL program is described at *http://www.epa.gov/owow/tmdl/intro.html*.

The Lower Skagit Tributaries Temperature Total Maximum Daily Load Study (the Temperature Study, published in 2004, available at *www.ecy.wa.gov/biblio/0403001.html* and included as Appendix A) was initiated to address water quality impairments for temperature in creeks on the 1998 303(d) list (the state list of impaired waterbodies) (Table 1). The study was designed to (1) collect data to confirm that eight creeks in the watershed do not meet standards in the late-summer low-flow period; (2) use the data to understand creek temperature variations and support modeling; and (3) use a water quality model to determine whether shading by mature riparian buffers would permit the creeks to meet water quality standards. An additional creek, Lake Creek, was studied with the others but was not on the 303(d) list. Ecology's Water Quality Assessment, also known as the "303(d) list"(referring to the Section of the Clean Water Act), is explained at: www.ecy.wa.gov/programs/wq/303d/index.html.

Table 1. 1998 and 2004 303(d) listings for temperature in the Lower Skagit River basin

Waterbody ID	Creek	1998	2004 Listing Number
WA-03-1011	Carpenter	x	6421, 6422
WA-03-1012	Fisher	x	6425
WA-03-1019	Hansen	x	6426
WA-03-1017	Nookachamps	x	6427, 6428, 6429
WA-03-4200	East Fork Nookachamps	x	6423, 6424
WA-03-1019	Red	x	6430
WA-03-1017	Turner	x	6431
WA-03-4200	Otter Pond	x	6432

Monitoring in 2001 confirmed temperature exceedances

Detailed temperature and flow measurements (Figure 2) made in the eight listed creeks during summer 2001 confirmed that they do not meet state water quality standards for temperature during the late-summer, low-flow critical period (results shown earlier in Figure 1). Lake Creek met the more stringent 16^{o}C water quality standard during the study, except for the upstream end where Lake McMurray discharges.

Modeling indicates full shade will protect creeks adequately from solar heat

This Report addresses the results and recommendations of the Temperature Study, which included stream temperature modeling to determine whether mature native riparian shade would be effective in protecting the creeks from the heating effects of sunlight. The model predicted that the creeks would be able to meet the revised temperature standard of 16^{o} C, except for reaches immediately downstream of lakes.

This Report lists actions to be taken by local organizations, landowners

This Report provides a framework for improving water quality. It describes the roles and authorities of cleanup partners (those organizations with jurisdiction, authority, or direct responsibility for cleanup) and the means through which they will address these water quality issues. It was developed with participation and comment from an advisory committee composed of citizen-landowners, local government agencies, tribes, and watershed organizations. While committee members provided their perspective on the strategy, not all fully agree with it.

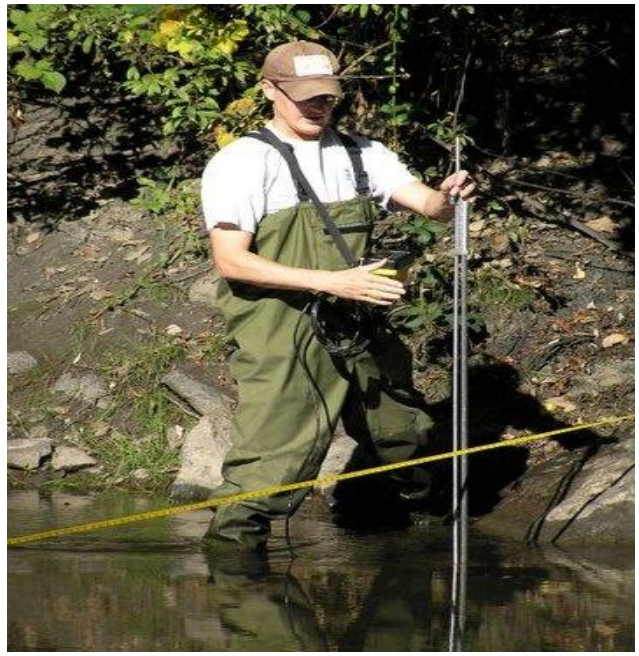


Figure 2. Measuring stream cross-sectional area and flow to calculate discharge

Private forestlands in this basin are not covered by this Water Quality Improvement Report. Instead, consistent with the Forests and Fish agreement (DNR, 1999), implementation of the load allocations for private and state forestlands will be accomplished via implementation of the revised forest practices regulations. The effectiveness of the Forests and Fish rules will be measured by monitoring streams and riparian condition in the watershed. If shade is not moving on a path toward the TMDL load allocation by 2009, Ecology will suggest changes to the Forest Practices Board.

Nonpoint TMDLs reveal noncompliance and provide direction for meeting standards

A TMDL must determine what must be done in order to bring a water body back into compliance with water quality standards. A TMDL sets limits for the allowable amounts of pollution based upon the numeric and narrative criteria and the antidegradation provisions of the water quality standards. The TMDL uses science-based evidence to demonstrate what pollution sources and activities are causing the water not to comply with the water quality standards. As such, TMDLs serve as a vital "link in the implementation chain…all to the end of attaining compliance with the water quality goals for the nation's waters." *Pronsolino v. Nastri*, 291 F.3d 1123, 7914 (9th Cir. 2002).

However, a TMDL is not the legal instrument that brings nonpoint sources of pollution into compliance with the water quality standards. Nonpoint sources and activities causing pollution may be subject to individual enforcement actions based upon the evidence put forth in the

TMDL and site-specific determinations made in accordance with the state's Water Pollution Control Act. While Ecology typically relies on individuals and local jurisdictions to voluntarily comply with the water quality standards, Ecology has statutory authority to require that nonpoint sources of pollution comply with TMDL requirements as discussed below.

To address nonpoint sources of pollution, the Clean Water Act requires TMDLs

The Clean Water Act (CWA) requires Washington State to develop TMDLs for water bodies listed on the 303(d) list of impaired waters for those pollutants EPA has identified under section 304(a)(2) of the CWA. The CWA explicitly states that "such loads shall be established at a level necessary to *implement the applicable water quality standards*..." 33 U.S.C. § 1313 (d)(1)(c) emphasis added.

TMDLs must set load allocations for waters solely impaired by nonpoint sources of pollution, a matter decided by the United States Ninth Circuit Court in *Pronsolino*, 291 F.3d 1123, 1130.

The CWA relegates authority to control nonpoint sources of pollution largely to the states. See 33 USC § 1251(b); see also *Pronsolino*, 291 F.3d 1123. Nonetheless, it is still an explicit goal of the CWA to ensure that "…the control of nonpoint sources of pollution be developed *and implemented* in an expeditious manner so as to..." "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 USC § 1251(a)(7) and 33 USC § 1251(a).

The Washington State Pollution Control Hearing Board also acknowledged that the purpose of a TMDL "is to bring a waterbody into compliance with the water quality standards." *Chandler v. Ecology*, PCHB No. 96 – 35 (1997**).** This statement recognizes the statutory requirement that TMDLs identify and limit the amount of pollution that can be discharged into a waterbody in order to meet water quality standards. The water quality standards codify this position:

> to fully achieve and maintain the foregoing water quality in the state of Washington, it is the intent of the Department to apply the *various implementation and enforcement authorities at its disposal, including participation in the programs of the Clean Water Act* [such as TMDLs]," WAC 173-201A-500 emphasis added.

TMDLs implement the Water Quality Standards by revealing noncompliance with Washington State Water Laws

The water quality standards regulations state that activities which "adversely affect" water quality, such as those identified in a TMDL, must "be in compliance with the waste treatment and discharge provisions of state or federal law" WAC 173-201A-500. The Water Pollution Control Act (WPCA) makes it unlawful to cause or tend to cause pollution from either point or nonpoint sources. RCW 90.48.080.

Essentially, a TMDL identifies point and nonpoint activities that cause or tend to cause pollution in a specific water body. A TMDL accomplishes this by using scientific based evidence to demonstrate how certain actions cause water to be of a lesser quality than allowed by the legal limits set by the numeric and narrative criteria of the water quality standards. Accordingly, TMDLs demonstrate that particular activities are causing pollution that violates water quality standards.

Figure 3. Fisher Creek at Starbird Road

The antidegradation policy of the water quality standards applies legal protections to all surface waters of the state. Tier I protections prohibit any impact to water quality that "would interfere with, or become injurious to, existing or designated uses." WAC 173-201A-310. TMDLs provide evidence that activities cause water quality to be lower than that of the water quality standards criteria, and in doing so, demonstrate that those sources are interfering with the designated uses. Because Tier I protections apply broadly "to all human activities that are likely to impact the water quality of surface water," as well as "to all waters and all sources," they therefore apply to nonpoint sources of pollution. WAC 173-201A-300. Therefore, TMDLs must ensure that nonpoint sources of pollution do not further interfere with a surface water's designated uses.

The Water Resources Act clearly states:

> Notwithstanding that standards of quality established for the waters of the state would not be violated, wastes and other materials and substances shall not be allowed to enter such waters which will reduce the existing quality thereof, except in those situations where it is clear that overriding considerations of the public interest will be served.
> RCW 90.54.020

Through load allocations, TMDLs provide direction on how to bring waters back into compliance with the water quality standards. Load allocations must be established within nonpoint pollution loading capacity so as to prevent injury or interference with the designated use of the standards. Load allocations are often implemented through the use of Ecology-approved best management practices to reduce the pollutant load. Implementation of best management practices can result in compliance with the standards by adjusting or eliminating practices that cause pollution. The supporting implementation provisions of the standards codify this approach to nonpoint sources:

> The primary means to be used for requiring compliance with the standards shall be through best management practices required in waste discharge permits, rules, orders, and directives issued by the department for activities which generate nonpoint source pollution.
> WAC 173-201A-510(3)(a).

TMDLs use scientific evidence to identify those sources that are likely contributing nonpoint pollution in excess of the legal limits set by the water quality standards. Sources within the geographic scope of the TMDL that are lacking best management practices may be contributors of the pollutant and may interfere with designated uses. The implementation provisions of the water quality standards codify this presumptive approach:

> Activities which contribute to nonpoint source pollution shall be conducted utilizing best management practices to prevent violation of water quality criteria. *When applicable best management practices are not being implemented, the department may conclude individual activities are causing pollution in violation of RCW 90.48.080*. In these situations, the department may pursue orders, directives, permits, or civil or criminal sanctions to gain compliance with the standards.
> WAC 173-201A-510(3)(c)

Ultimately, in accordance with the Clean Water Act, TMDLs identify the pollution reductions necessary to bring a waterbody into compliance with the water quality standards. The TMDL, as a link in the chain of implementation, uses scientific evidence to identify noncompliance with the standards, and also provides a means to attain compliance. When owners or operators ignore applicable requirements of a TMDL, they may be in violation of the Water Pollution Control Act, Water Resources Act, and the Antidegradation and Implementation regulations of Washington State's water quality standards, and may be subject to enforcement actions for these violations.

The Water Quality Improvement Process

Washington State's process for developing water quality improvement reports and implementation plans is designed to address the requirements for Total Maximum Daily Loads as required under the Clean Water Act. For the Lower Skagit tributaries' temperature impairments, Ecology is following a three-step process (Figure 4). This stepwise approach provides the maximum opportunity for local review and involvement.

Step 1: Using our best science, Ecology monitors water quality, then develops a model to determine how much pollution needs to be reduced in order for the water body to meet standards. The study (published in 2004 and included as Appendix A) shows how badly affected the water is and how much needs to be done to restore it.

Step 2: Ecology prepares a *Water Quality Improvement Report* (this Report) that addresses the results and recommendations of the water quality study. Ecology begins a public process, working with an advisory committee to develop a strategy to implement the TMDL. The combined study and implementation strategy are sent to U.S. EPA for approval.

Step 3: Ecology collaborates with local government, organizations, tribes, and citizens to identify the actions needed to reduce temperatures in the Lower Skagit Tributaries. These actions will be detailed in a future document, the water quality implementation plan.

A water quality improvement report contains a total maximum daily load or "TMDL." The TMDL is the maximum amount of a pollutant (the load) from several sources that a water body can accept before the risk of injury to human or aquatic life becomes too high. A **load allocation** is the allowable amount of a pollutant from one source that, when added to loads from other sources, is sufficiently low that the total allows the water body to meet state standards. Some TMDLs establish both **load allocations** (from nonpoint sources such as poorly managed rural lots, farms or forests) and **wasteload allocations** (from point sources such as industries or wastewater treatment plants). The lower Skagit tributaries Temperature Study did not include any point sources. Therefore, it assigned load allocations for land management practices along the creeks to improve stream temperatures. Under EPA guidelines, a TMDL must also include a **margin of safety**. As explained

Figure 4. Ecology's TMDL Process

in the Temperature Study, this Water Quality Improvement Report's margin of safety is implicit in its modeling assumptions. The modeling used a conservative set of assumptions, including critical seasonal conditions of temperature and flow, for modeling the effects of shade.

Ecology's temperature TMDLs are designed to determine the heat load that a water body can accept so that its temperatures still meet water quality standards**.** Because mature vegetation along streams blocks the sun, and therefore lessens the heat load to streams, our temperature TMDLs establish load allocations for "Effective Shade." Effective shade is defined as the fraction of incoming solar radiation that is blocked by vegetation and topography before it reaches the water surface. Effective shade is a "surrogate," or *substitute measure* for how much protection is needed to keep the water cool. Ecology's temperature models test whether a certain amount of shade will be effective in keeping waterbodies cool enough to meet water quality standards. The Temperature Study for the lower Skagit tributaries concluded that restoring stream shade and improving stream morphology are the most effective and practical solutions to temperature problems in the watershed.

The Lower Skagit Watershed

The Skagit River basin includes some area within British Columbia, Canada and covers most of Skagit County as well as the eastern parts of Whatcom and Snohomish Counties. The basin encompasses about 2,370 square miles. The Skagit River originates in British Columbia, flows through Ross Lake, which extends a short distance across the international boundary, and continues southwestward to discharge into Skagit Bay below Mount Vernon. The river contributes approximately 20 percent of the total freshwater discharge to Puget Sound.
The major sub-basins in the Skagit River are: the Upper Skagit, Baker, Cascade, Sauk, and Lower Skagit. Carpenter, Fisher, Hansen, Red, Nookachamps, Otter Pond, Lake, East Fork Nookachamps, and Turner creeks are all temperature-impaired tributaries to the Skagit River in the Lower Skagit basin and are addressed in this Report (Figure 5).

The Lower Skagit River, its tributaries, sloughs, and estuaries serve as important migration corridors, spawning areas, and rearing areas for five major species of salmon (chinook, coho, pink, chum, and sockeye), as well as steelhead and cutthroat trout, and two char species—Dolly Varden and bull trout. The Skagit River watershed contains the second largest wild run of coho salmon and the largest run of chinook salmon in the Puget Sound watershed. The salmonid species' Puget Sound populations that are listed by federal and state agencies as threatened under the Endangered Species Act are (with listing dates):

- Puget Sound Chinook salmon (March 24, 1999)
- Puget Sound bull trout (November 1, 1999)
- Puget Sound steelhead (May 7, 2007).

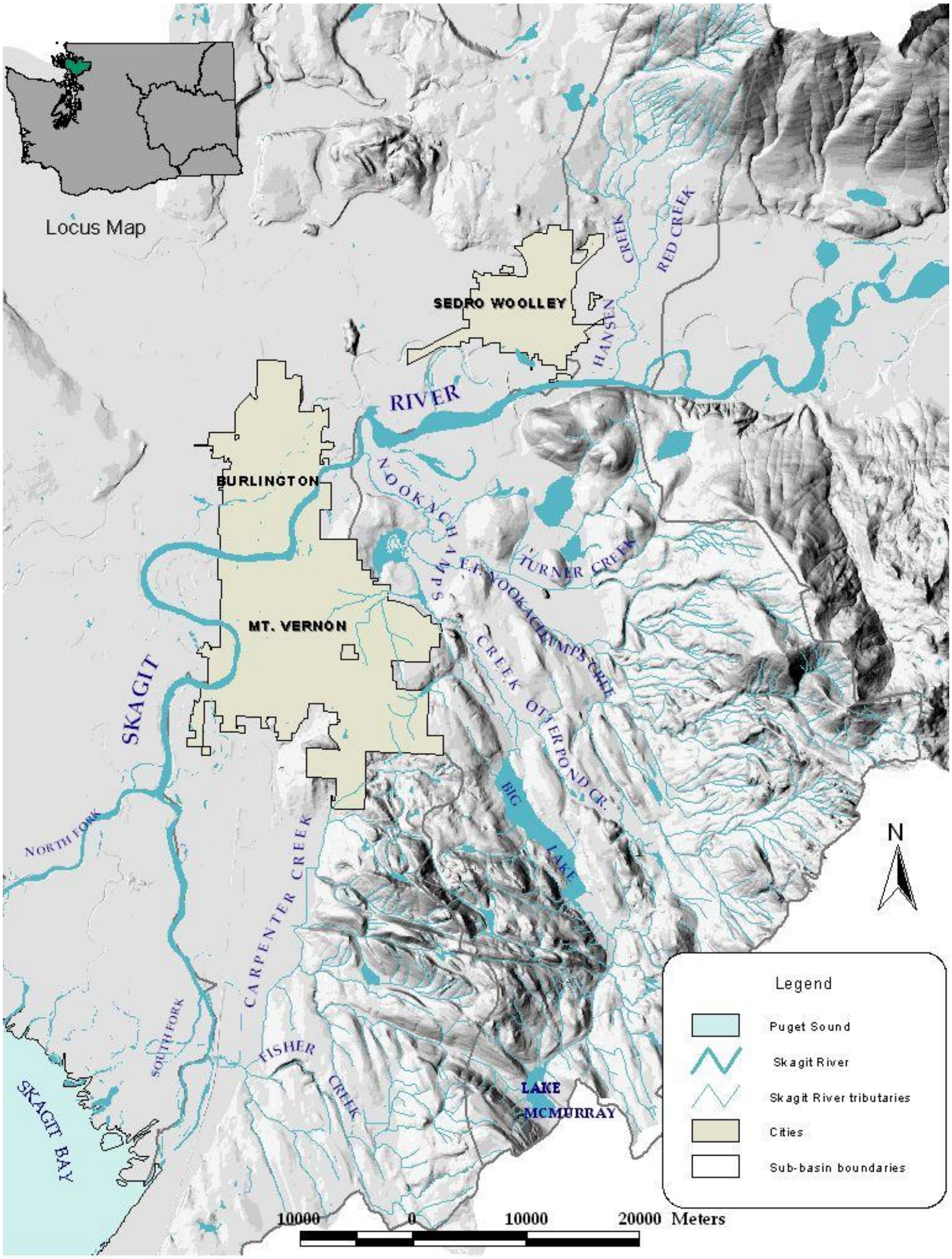


Figure 5. Study area – Lower Skagit River watershed

The *Skagit Chinook Recovery Plan* (Skagit River Systems Cooperative and WDFW, 2005) was prepared in 2005 and later adopted as part of the U.S. Fish and Wildlife Service and National Marine Fisheries Service recovery plan for Puget Sound Chinook salmon. The Skagit Plan provides information about the habitat use by different populations of Chinook salmon within the upper and lower Skagit watersheds for migration, spawning and rearing. Carpenter, Nookachamps, and Hansen creeks are among several Lower Skagit streams cited for degraded riparian habitat that could affect Lower Skagit Fall chinook salmon.

The climate in the lower Skagit basin is mild with cool dry summers and mild wet winters. Mean annual precipitation ranges from 27 to 42 inches per year, increasing from west to east (NOAA 1973). Most precipitation occurs between October and March.

Small farms and rural residential development dominate the lowland portion of the basin. Agricultural land use (largely cropland and pasture) dominates the western portion of the basin. The eastern uplands are predominantly forest with some scattered residential development. An extensive drainage network exists in the agricultural portions of the study area. Many of the water bodies addressed in this study have been diked, dredged, or otherwise channelized. This has resulted in extensive stream reaches with little or no riparian vegetation.

Lower elevation forests (< 2300 feet) are within the western hemlock zone. Dominant conifer species in these forests are western hemlock, Douglas-fir, western red cedar, and Sitka spruce. Deciduous trees include red alder, black cottonwood, and bigleaf maple. Middle elevation forests (2300 to 4300 ft) are in the silver fir zone.

Water Quality Standards and Beneficial Uses

This Water Quality Improvement Report addresses Carpenter, Fisher, Hansen, Red, East Fork Nookachamps, Turner, Nookachamps, Lake and Otter Pond creeks. These creeks provide core summer salmonid habitat. Core habitat is a geographic area with environmental conditions supporting one or more stages of the life history of salmonid fishes**.**

Temperature affects the physiology and behavior of fish and other aquatic life. It may be the most influential factor limiting the distribution and health of aquatic life and can be greatly influenced by human activities. Stream temperatures fluctuate over the day and night and in different seasons in response to changes in incoming sunlight, air temperature, soil and groundwater temperatures, flow, and other factors. Since the health of aquatic species is tied predominantly to patterns of maximum temperatures, the water quality criteria are expressed as the highest seven-day average of the daily maximum temperatures (7-DADM) occurring in a water body.

Revised temperature criteria for fresh waters of Washington state

The Lower Skagit Temperature Study (published in 2004 and included as Appendix A) addressed the water quality standards in effect when the study was conducted in 2001-2003. The temperature goal for all creeks in the Lower Skagit basin was the summertime maximum temperature standard for Class A freshwaters, 18^{o} C.

In July 2003, Ecology made significant revisions to the state's surface water quality standards (Chapter 173-201A WAC). These changes included eliminating the state's classification system used for decades to designate uses for protection by water quality criteria (e.g., temperature, dissolved oxygen, turbidity, bacteria). Ecology also revised the numeric temperature criteria assigned to waters to protect specific types of aquatic life uses (e.g., native char, trout and salmon spawning and rearing, warm water fish habitat). However, EPA disapproved some of Ecology's temperature criteria for some water bodies, based on findings that certain salmonid uses of those water bodies were not protected. In response, in 2006 Ecology adopted stricter standards for those water bodies (Ecology, 2006). The revised standards and list of water bodies affected are on the Ecology website at www.ecy.wa.gov/biblio/0610091.html.

Revised temperature criteria for these creeks

EPA developed maps of the Lower Skagit Watershed (Water Resource Inventory Area 3, or WRIA 3) to show river and stream reaches where the revised temperature criteria apply. For the streams and reaches in this Water Quality Improvement Report:

- Fisher, Carpenter (including Hill Ditch), Lake, Otter Pond, Turner, Hansen, Red, Nookachamps, and Lake creeks are assigned a 7-DADM temperature of 16^{o} C.
- Most of East Fork Nookachamps Creek is also assigned a 7-DADM temperature of 16^{o} C. However, certain upper reaches and smaller creeks tributary to East Fork are assigned Char Use, which has a 7-DADM of 12^{o}C.

In addition, certain reaches of three creeks are assigned a supplemental 13^{o} C criterion for the period February 15-June 15, for salmon and trout spawning and incubation. These are:

- Upper Lake Creek
- A middle reach of East Fork Nookachamps Creek below Walker Creek
- Lower Hansen Creek.

To determine whether the creeks could achieve compliance with the 2006 standards, this Report uses the modeling results of the Temperature Study (Appendix A). Results demonstrate that the basic requirement for full, mature native riparian shade and improved channel structure are sufficient to meet the stricter 2006 standards:

- In Figures 30, 31 and 32 of the Temperature Study (Appendix A), the model predicts that full riparian shade would enable Carpenter, Fisher, and Hansen creeks, respectively, to meet the stricter 16^{o} C standard.
- In Figure 33, the model predicts Lake Creek, which cools due to existing shade between source (Lake McMurray) and discharges to Big Lake, could meet the stricter standard at its downstream end. However, due to the "lake effect," the upstream end would not meet standards under any modeled shade condition.
- In Figures 34 and 35, modeling predicts that with full riparian vegetation and expected deepening and narrowing of channels that occurs with well established buffers, both East Fork Nookachamps and Nookachamps creeks would meet the 16^{o} C standard.

Global Climate Change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Summer streamflows depend on the snowpack stored during the wet season. Studies of the region's hydrology indicate a declining tendency in snow water storage coupled with earlier spring snowmelt and earlier peak spring streamflows (Hamlet et al., 2005). Factors affecting these changes include climate influences at both annual and decadal scales, and air temperature increases. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

The University of Washington Climate Impacts Group used ten climate change models to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average warming rate is expected to be in the range of 0.1-0.6°C (0.2-1.0°F) per decade, with a best estimate of 0.3°C (0.5°F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer streamflows are also predicted to decrease as a consequence of global climate change (Hamlet and Lettenmaier, 1999).

The expected changes coming to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool. As global climate change progresses, the thermal regimes of streams will change due to reduced summer streamflows and increased air temperatures.

Stream temperature improvements obtained by growing mature riparian vegetation corridors along stream banks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global climate change – helping keep conditions from getting worse. It will take considerable time, however, to reverse those human actions that contribute to excess stream warming. The sooner such restoration actions begin and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources. These efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they are expected to help maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species.

The state is writing this Report to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature associated with global climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry is to begin now to protect as much of the thermal health of our streams as possible.

What Needs to Be Done?

This Water Quality Improvement Report provides a phased implementation strategy for reaching water quality standards in 2080. To achieve the goals of this TMDL, four implementation strategies are proposed:

- Promote known, physical methods to improve stream temperatures on a parcel by parcel scale.
- Support and further focus current regulatory programs and policies that support the goals of this Report, through funding and agency commitment.
- Promote existing incentive programs, and develop new ones, to reward landowners who improve land management and protect creeks through addition of riparian buffers.
- Expand educational and technical assistance efforts through a Basin Steward program and other approaches.

Effective Physical Methods to Improve Stream Temperature

Both the Temperature Study modeling and widely accepted scientific research on stream temperature and hydrology tell us that, with a substantial increase in shading over Lower Skagit tributaries cooler water temperature regimes can be achieved. The scientific literature also confirms that a number of factors, including air temperature, shading, elevation, surface hydrology, channel shape and complexity, and connectivity to ground water, combine to influence stream temperature (Poole and Berman, 2000).

Washington's water quality improvement reports for temperature generally focus on improved stream shading to achieve temperature reductions. However, other approaches to temperature improvement are possible and in some cases are easier to implement. The *Teanaway Temperature Total Maximum Daily Load: Detailed Implementation Plan*, for example, included the increases in river flow that were expected once farmers switched to more efficient irrigation methods (Ecology, 2003).

The physical methods prescribed in the Lower Skagit Temperature Study to improve the temperature regime of the nine creeks include, but are not limited to:

- **Manage riparian zones to allow maturation of vegetation, preferably including native woody plants that offer shade protection**. Planting native vegetation where buffers are lacking (Figure 6) is a priority. Such managed zones provide not only shading with direct temperature benefit to streams, but also indirect benefits related to air cooling, source of woody debris, and eventual narrowing and deepening of the stream channel.
- **Address erosion and sedimentation**. Streams that are wide and shallow because of erosion and sedimentation are susceptible to warming and should be investigated to determine the causes of erosion and sources of sediment. Eroding streambanks and

poorly managed upland areas should be addressed through appropriate riparian restoration and improved land management.

- **Encourage residents next to streams to reduce water use during late-summer, low-flow conditions.** Even though instream flows and water withdrawals are managed under a state regulatory program that is different from the federal regulations requiring TMDLs, this common-sense advice is appropriate in our public outreach and education.
- **Promote restoration activities that increase groundwater discharge to streams**. Groundwater inflow to streams could increase if recharge is increased as a result of renewed channel-floodplain connectivity. Years ago, some creeks were channelized to reduce flooding. However, this reduced the amount of time floodwaters spend on the floodplain and also reduced infiltration of floodwaters to the surface aquifer and reduced summer baseflow.

Figure 6. Site of riparian planting project on Nookachamps Creek (photo: Skagit Fisheries Enhancement Group)

Regulatory Programs and Policies

Skagit County Critical Areas Ordinance for Ongoing Agriculture requires meeting state water quality standards

The Washington State Legislature enacted the Growth Management Act (GMA) in 1990 (Ch. 36.70A RCW) in response to growth and development pressures in the state. The act requires local governments to adopt development regulations, such as subdivision and zoning ordinances, to carry out comprehensive plans. The GMA also requires counties to adopt effective regulatory programs for critical areas, including wetlands, geologically hazardous areas, fish and wildlife habitat conservation areas, critical aquifer recharge areas, and frequently flooded areas.

In 2004, after adopting other Critical Areas Ordinances, Skagit County adopted a **Critical Areas Ordinance for Ongoing Agriculture (Skagit County Code 14.24.120).** Under the ordinance, activities in areas zoned as "ongoing agriculture" are required to do no harm to water quality and fish and wildlife habitat. The ordinance does not require specific riparian buffers. Farm plans and agricultural best management practices are implemented as necessary to prevent harm. This approach relies, to a significant degree, on existing federal and state programs that already regulate certain farm practices. For example, it invokes Washington State standards for water quality and requires the county to assist Ecology in implementing TMDLs.

Under the GMA, the county is required to update its Critical Areas Ordinance (CAO) on a periodic basis. The county should consider the Lower Skagit Tributaries Temperature TMDL and its findings as Best Available Science in developing the updated ordinance.

Court decision and legislative action could affect future Ag CAO update

The Washington State Supreme Court ruled in September 2007 (*Swinomish Indian Tribal Community v. Western Washington Growth Management Hearings Board*) on an appeal of the county's ordinance that the county does not need to mandate buffers in order to ensure that agricultural activities cause no harm. However, the court also ruled that the county's CAO was deficient in developing a monitoring and adaptive management program that would ensure compliance with state water quality standards and protect fish habitat.

A separate Washington State action also impacts Skagit County's ability to implement an adaptive management program in relation to its Growth Management Act responsibilities. In spring 2007, the Washington State Legislature passed legislation (SSB 5248, codified as Chapter 36.70A.560 and 36.70A.5601 RCW) "Agricultural Lands – Viability" prohibiting counties and cities from changing already-adopted Critical Areas Ordinances as they specifically apply to agricultural activities. The law establishes a "time out" on such changes until July 1, 2010. The Ruckelshaus Center at University of Washington will report to the legislature by September 2009 on their fact-finding efforts, stakeholder discussions, and proposed solutions.

With the Supreme Court ruling that an adaptive management program must be developed to ensure compliance with the Growth Management Act, but with the prohibition of immediate action enacted by the legislature, at the time this report is written (June 2008) the county has contracted for a report that will review alternatives and make recommendations for improvements to its monitoring and adaptive management programs. Even if the county decides on a preferred approach, the "time out" law enacted in 2007 prevents the county from making any change to its existing Critical Areas Ordinance for Ongoing Agriculture until after the Ruckelshaus Center makes its recommendations.

Skagit River instream flow rule

Streamflow is a significant factor in the heat budget of rivers and streams. Reduced creek flow due to human uses and influences can have a significant impact on stream temperatures, most likely by increasing the influence of ground and air temperatures.

Under state laws, Ecology oversees both the appropriation of water for out-of-stream uses (for irrigation, municipal use, and commercial and industrial uses) and the protection of instream uses (for example, for fish habitat and recreational use). Ecology does this by adopting and enforcing water allocation and instream flow regulations, as well as by providing assistance to citizens with both public and private water management issues.

In 2006, Ecology amended the Skagit River water management rule (Chapter 173-503 WAC). The amendments created reservations to provide reliable water supplies for future development in the Skagit River basin, while still protecting flows needed for fish and other in-stream values. The reservations are for year-round, uninterruptible sources of water for out-of stream uses. They are finite amounts of water from various sub-basins set aside for future uses, and will eventually be depleted. The three types of water uses eligible for the reservations are: (1) domestic, municipal, commercial/industrial; (2) agricultural irrigation; and (3) stock watering.

All the creek basins in this Report have reservations set aside under the amended Skagit Rule: the Fisher-Carpenter sub-basin; the Nookachamps-East Fork sub-basin; the Nookachamps-Upper sub-basin; and the Hansen sub-basin. When the concept of reservations was under public discussion, Ecology conducted an additional run of the temperature model using two percent less flow (the reservation amount) for the Nookachamps, the largest creek with a reservation and the most likely to show temperature impacts. The analysis (Appendix F) shows that this reduction would lead to a maximum temperature increase of 0.06^{o} C (or a 0.26% relative increase) for current vegetation and a 0.04^{o} C (or 0.19% relative increase) for site potential vegetation. (Site potential vegetation is the mature assemblage of native conifers and deciduous trees that are compatible with the soil types found at the location.) The results indicate that any temperature impacts of the reservation are not sufficiently large to make the reservation untenable.

The responsibility for administering the reservation under the Skagit water management rule is shared by Ecology and Skagit County. The county informs Ecology about local water availability decisions, which must be consistent with the rule. Ecology keeps track of water allocations from each reservation until they are depleted.

More information about the Skagit rule and reservations is on Ecology website at: www.ecy.wa.gov/programs/wr/instream-flows/skagitbasin.html.

Incentive Programs for Landowners to Better Protect Creeks

In Washington State, more than 70 governmental and foundation programs offer some form of incentive to private landowners to promote conservation activities on their land. These include:

- Direct financial incentives, including grants, subsidized loans, shares, and leases [such as the Conservation Reserve Enhancement Program (CREP)].
- Indirect financial assistance such as property or sales tax relief.
- Technical assistance, including referral services, education and design assistance.
- Recognition and certification for products or operations (such as *Salmon Safe*, see References).

Some of these approaches will be described in this section. Additional information is on a Washington state website: http://www.biodiversity.wa.gov/stewardship/index.html.

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program (CREP) was established to provide a flexible and cost-effective means to address agriculture-related environmental issues. It provides federal and state funds for restoration projects in geographic regions of particular environmental sensitivity. In April 1999 the state of Washington submitted a CREP contract proposal to the Farm Service Agency (FSA) to enhance riparian habitat conditions on agricultural lands along streams which provide important habitat for listed salmonid species.

The program, cooperatively administered by the FSA and the Washington State Conservation Commission, relies on voluntary participation by landowners. Farmers and ranchers who participate in the program sign 10- to 15-year contracts with the FSA, agreeing to remove portions of their land from agricultural production and planting woody or shrub vegetation. The landowners are eligible for rental payments and other financial incentives in return for the loss of production.

The Washington State CREP program is designed to address water quality degradation that is a direct or indirect result of agricultural activities on private lands along freshwater streams. On a statewide basis, approximately 37 percent of the freshwater salmon streams on private lands in Washington pass through agricultural land use areas. Farming and ranching activities on these lands have contributed to removal or elimination of native riparian vegetation with resultant increases in water temperature and sedimentation rates, and changes in channel morphology.

The six objectives of the Washington CREP are directly related to improvement of riparian and aquatic ecosystems that provide key habitats for salmonids. These six objectives are:

- Restore 100 percent of the area enrolled for the riparian forest practice to a properly functioning condition for distribution and growth of woody plant species.
- Reduce sediment and nutrient pollution from agricultural lands next to the riparian buffers by more than 50 percent.

- Establish adequate vegetation on enrolled riparian areas to stabilize 90 percent of stream banks under normal (non-flood) water conditions.
- Reduce the rate of stream water heating to ambient levels by planting adequate vegetation on all riparian buffer lands.
- Help farmers and ranchers meet water quality requirements established under federal law and Washington's water quality laws.
- Provide adequate riparian buffers on 2,700 stream miles to permit natural restoration of stream hydrologic and geomorphic characteristics that meet the habitat requirements of salmon and trout.

Washington CREP includes a set of best management practices (BMPs) designed to reduce adverse environmental impacts including stream heating. These BMPs are to be followed on all CREP activities and will be provided to all farmers and ranchers who enroll in the program. The FSA regards these BMPs as integral components of the Washington CREP and considers them a contractual part of each CREP project. The primary long-term benefits the buffers will provide for salmonids is shade and the corresponding reduction in water temperature, which is a limiting factor for salmonid reproduction in most of the waterways targeted by CREP.

In Skagit County, 67 CREP projects with substantial buffer widths were installed in the period 2000 through 2003. This was a period of considerable public controversy regarding whether the county ordinance for protecting fish and wildlife habitat on Ongoing Agriculture should require buffers. After the ordinance (that did not require buffers) was adopted in 2003 (Skagit County Code 14.24.120), only four CREP projects were installed in 2004 and 2005 (Table 2).

Table 2. CREP projects in Skagit County, 2000 to 2005. (personal communication, Washington Conservation Commission, 2007)

Year	Number of Projects	Stream Feet Planted	Acres	Buffer Widths
2000	6	12225	39.2	150-180
2001	21	37445	130.6	120-180
2002	35	72070	231.8	101-180
2003	5	11165	39.7	108-180
2004	2	7900	25.5	180
2005	2	4585	18.7	155-180

Conservation Easements

A conservation easement is a binding agreement and transfer of certain property rights between the landowner and another party, the holder of the easement. This is a way to protect lands with high biodiversity value and may be used when outright donation or sale of property is not preferred. Conservation easements restrict the type and amount of development that can take place on the land and often extinguish development rights completely. Easements are recorded on the deed and therefore "run with the land," applying to both present and all future owners.

In central Skagit County, the Skagit Land Trust used Salmon Recovery Funding Board (SRF Board) funds to purchase a perpetual conservation easement on 60 acres of private agricultural land just east of Sedro-Woolley. Located in the Skagit River floodplain, the parcels contain over 30 acres of mature woodland which will be protected and will protect riparian areas and side-channel habitat on two sloughs and the mainstem of the Skagit River (more than 6,000 feet of shoreline). Some restoration of riparian areas is currently underway by the Land Trust and Skagit Fisheries Enhancement Group.

Strategy for Increasing Landowner Involvement

In the Lower Skagit watershed, with its critical agricultural lands and rapidly increasing population, the idea of setting aside land next to streams for water quality and salmon has been controversial (Breslow, 2001). This Water Quality Improvement Report acknowledges this controversy and takes the perspective that all sides of the issues need to be understood, even though ultimately Ecology's approach may not be able to address them all. Ecology's experience in other parts of the state suggests that landowners may need to be won over, one by one, to an understanding that stream health and land health and productivity are related and that restoration practices that are good for a creek may also reduce some of the maintenance costs on the land.

Advocate broadly for improved land and stream health

This Report recommends that public outreach should educate broadly about the interrelationships between land practices and stream health, for example:

- Trees, shrubs, and hedgerows can filter out nutrients as well as shade a creek.
- Wildlife habitat along streams can provide a haven for beneficial insects.
- Adding large wood and protecting groundwater inputs can help ensure locally cool areas within creeks.

This Report also recommends a strategy that incorporates education and outreach at a parcel-by-parcel and landowner-by-landowner scale. Other watersheds across Washington State have seen success in programs involving direct landowner outreach with occasional cost-share incentives and a small amount of enforcement. For example:

- Kitsap County's Pollution Identification and Correction program focuses on one small creek basin at a time, with education, technical assistance and potential enforcement for septic system owners and commercial property owners. *(More information at* http://www.kitsapcountyhealth.com/environmenta_health/water_quality/pic.htm*).*
- Ecology's Eastern Washington office employs a Nonpoint Specialist to work directly with farmers to fence livestock away from streams and plant riparian vegetation. *(An example of this work is described at:* http://www.ecy.wa.gov/programs/wq/wq_stories/projects-county/garfield.html*).*

- Whatcom Conservation District hired a local farmer as “Basin Steward” to conduct water quality outreach and education and help initiate restoration projects in the Tenmile Creek watershed (page 30).

Outreach and incentive programs for private landowners

Because nearly all the stream riparian areas are on private property, this Water Quality Improvement strategy encourages participation by landowners through a program of educational outreach and financial incentives. In addition to the incentives described below, Ecology will work with Skagit County to mail information to individual landowners if their property is identified as lacking stream protection and contributing to poor water quality.

This strategy provides three alternative pathways for landowners to help get these streams to meet standards:

1. Landowners can choose to enroll land in the Conservation Reserve and Enhancement Program administered by Skagit Conservation District.

2. Ecology recommends that Skagit County develop a financial incentives alternative with features different from CREP, such as a program to purchase conservation easements on private property with well-maintained buffers of adequate width. Such financial incentives could be designed to be available on a “first-come, first-served” basis to encourage timely responses by participants, providing that projects have adequately addressed shade and stream condition criteria.

3. For landowners that do not elect either alternative (1) or (2), Ecology proposes a local Basin Steward program to be funded through a Centennial Clean Water Program Grant (Centennial Grant) or other funds. The Basin Steward hired under the grant would work one-on-one with landowners and assist them with riparian management plans with goals focusing on improved health of both land and water. No financial incentives would be offered under the Basin Steward program.

   Basin steward technical assistance could include strategies for improved riparian condition including riparian area planting; bank stabilization; improved ditch management to reduce the need for dredging and other maintenance; control of reed canary grass and other invasive plants; reducing erosion; and other assistance of value to landowners.

   The Basin Steward concept is modeled on a successful program on Tenmile Creek in Whatcom County (next page). Through this program, managed by Whatcom Conservation District and funded by a Centennial Clean Water Grant, 35 of 37 parcel owners on Fourmile Creek (a tributary to Tenmile Creek) were persuaded to improve their land management practices and install riparian buffers to protect and enhance creek health.

Local agencies or organizations capable of managing a Basin Steward program include Skagit County Public Works; Skagit Conservation District; Skagit Fisheries Enhancement Group, the Upper Skagit Tribe, and others. These organizations are already working actively on restoration projects and stewardship advocacy in one or more of the creek basins.

Tenmile Creek Project – A Model for Local Stewardship

A good example of progress in restoring small watersheds is happening in Whatcom County (Figure 7). Initiated by the Whatcom Conservation District, which contracted with a motivated farmer to work as a Basin Steward, the Tenmile Creek project has succeeded in convincing many property owners to install and maintain plantings to improve shade and watershed health. Started in 2001 with a Centennial Grant, thousands of trees and shrubs were installed over 11 miles along Tenmile, Fourmile, and Deer creeks. Water quality monitoring at four sites in the watershed demonstrated significant reductions in bacteria concentrations at two of the four sites. However, temperature monitoring has not been conducted long enough to demonstrate improvement.

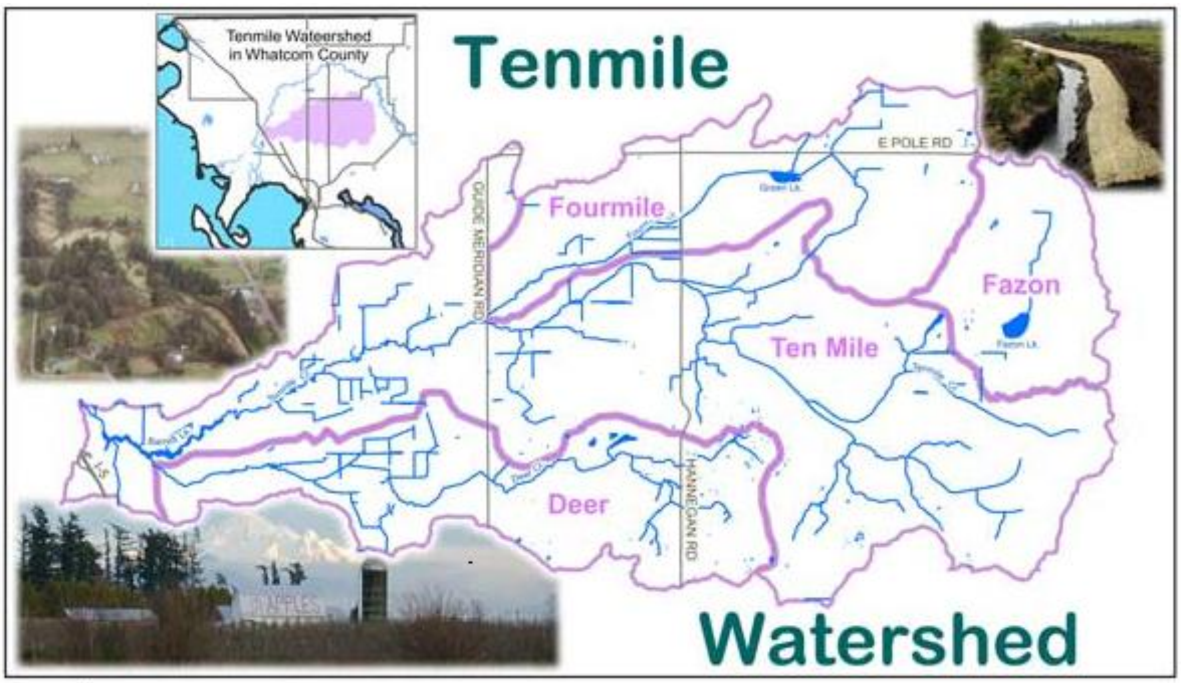


Figure 7. Tenmile Creek project location in Whatcom County

The Tenmile project works by teaming the land use and land management needs of streamside property owners with the community's desire and need to improve water quality for present and future generations. With the encouragement of Basin Steward Dorie Belisle, who owns and manages an apple orchard in the watershed, landowners along the creeks are able to work toward the goal of improving stream health, including wildlife habitat, while maintaining their ability to use and farm the land.

More than 200 families have participated, walking their creeks and looking at ways to improve stream health while improving their land (Figure 8). Some landowners learned that reed canary grass can be controlled by installing trees that shade and crowd out the grass, reducing the need to dredge. In addition to miles of plantings, nine sites have added large wood; fish passages have been improved; and temperature is being monitored at eight sites.

One of the Tenmile projects is “Farmers Growing Trees for Salmon,” designed to appeal to and involve local farmers. Farmers donated their land, time and growing expertise for one to two years to take care of tree starts (“plugs”) purchased by the program. The plugs were then given away to landowners in the county to transplant along their creeks, rivers, lakes and ponds.

Basin Steward Dorie Belisle made a significant commitment of time for communication and outreach. The project began with a survey mailed to 480 households of the Tenmile Creek watershed and yielded over 25 percent responses. The survey was repeated four years later to assess changes in landowner perspective about the importance of water quality and wildlife habitat. Through a quarterly newsletter and website (www.whatcomcd.org), the community is informed of local restoration progress, availability of plants, ways to prevent the spread of invasive plants, results of stream temperature monitoring, volunteer opportunities, and personal histories of the watershed.

Figure 8. Residents of Tenmile Creek watershed assess streamside condition

George Boggs, manager of Whatcom Conservation District, lists several factors that made the Tenmile watershed community receptive to this program:

- The Dairy Nutrient Management program communicated to producers higher expectations about reducing water quality impacts.
- The USDA EQIP farm program ranked farmers higher who would make additional effort to improve water quality—providing a strong incentive for greater commitment.
- The county adopted a critical area ordinance for agricultural lands which set an expectation to protect streams and creeks.
- The Nooksack Salmon Enhancement Alliance worked throughout the basin, educating and installing riparian projects.
- Workshops were held for middle school students about water quality and fish habitat.
- The Fourmile Drainage Improvement District needed to clean the stream but could not, without addressing the issue of mitigation.
- One of the Drainage District commissioners provided needed leadership.

These factors, plus this Basin Steward's commitment and effectiveness as a water quality advocate, gave the Tenmile project an advantage. It has become a good model for others.

"Outside the Box" - Addressing Landowner Concerns that Fall outside Ecology's Regulatory Authority

Some of the factors that affect the willingness of Skagit landowners to establish riparian vegetation next to streams are outside of Ecology's authority and outside the scope of this Water Quality Improvement Report (TMDL). This report makes one recommendation related to concerns frequently raised when Ecology meets with landowners and asks them to establish riparian buffers to protect water quality. Ecology will look for opportunities to work informally with relevant agencies and encourage them to consider this recommendation.

The intent of the TMDL is to restore the temperature regime of these streams and protect use by salmonids and other cold-water aquatic life. Ecology's role with respect to salmon recovery is to implement the water quality standards for temperature and protect the beneficial uses of surface waters for aquatic life and human uses. This regulatory role provides direct support for restoring freshwater habitat for salmon populations. The fact that stream temperature is only one of several factors that limit salmon populations is not relevant to our goal of ensuring these creeks meet water quality standards for temperature.

However, a landowner who is asked to devote some acreage to riparian buffers may want to know about other limiting factors that may affect the success of salmon recovery efforts, and whether these factors are being addressed effectively. It is difficult to hear a message about the need for creeks to be cool to protect salmon uses and not connect this goal with messages from other organizations about the need for actions to help restore salmon in watersheds. These other organizations are asking for the same action of adding riparian buffers to protect salmon that Ecology is asking to protect stream temperature. The landowner may logically ask, "If I do my part and set aside this land to improve creek temperature and help restore salmon, how can I be assured that other organizations whose actions affect salmon recovery are similarly doing their part to make sure the salmon can recover and take advantage of this stream habitat?"

A letter sent to Ecology by a Skagit-area farmer who served on Ecology's advisory committee for this TMDL demonstrates this thought process that links the buffer requirements of the TMDL and questions about salmon harvest management (Appendix G).

Since Skagit landowners are aware that some level of harvest is occurring for some salmon species that used to populate these streams, it follows that harvest could be an important factor in affecting salmon returns. Neither the Washington State Department of Fish and Wildlife (WDFW) website nor the WRIA 3 Chinook Recovery Plan provides a description that is easily understandable to a lay reader regarding how harvest level decisions are made. Some fisheries scientists and conservation organizations contend that current harvest levels may not be sufficiently protective (e.g., see Montgomery 2003, p. 241; note also, in 2006, Wild Fish Conservancy filed suit in federal court alleging the harvest levels for Puget Sound Chinook were endangering recovery [Wild Fish Conservancy, 2006]).

Explaining how these decisions are made could help provide assurance that the harvest levels are protective and conservative. This in turn may provide some assurance to landowners that they are not alone in helping meet the challenges of salmon restoration.

Recommendation: Provide clear description of the process used to establish harvest levels for salmon, in order to assure landowners that this limiting factor is being appropriately addressed commensurate with other limiting factors (Washington Department of Fish & Wildlife, working with tribes with harvest rights).

Who Needs to Participate?

Local organizations, government agencies, and tribes are expected to undertake or facilitate the implementing actions identified in this Report. This Report's recommendations will be developed in more detail in the Water Quality Implementation Plan to follow in 2009. The roles and regulatory authority, if applicable, of organizations and agencies involved in implementation are described in this section. Also identified in this section is an important plan (the WRIA 3 Chinook Salmon Recovery Plan) and two programs (the Governor's Puget Sound Partnership and the Conservation Reserve Enhancement Program) that could lead to or support actions, programs or projects that would assist in reaching the goals of this TMDL.

Skagit County

Skagit County should implement the following activities to help improve the temperature regimes in the creeks addressed by this TMDL Water Quality Improvement Report:

- **This TMDL should inform updates to the Critical Areas Ordinance (CAO) to ensure that Skagit County properly complies with RCW 36.70A.040, .060, and .172 of the Growth Management Act.** When reviewing development regulations and the CAO pertaining to aquatic habitat, the county must consider this TMDL, and subsequently the pronounced impacts of lack of shade on water temperature, and the water quality standards, as "best available science." This TMDL meets and exceeds the criteria for best available science for water temperature impairments of Lower Skagit tributaries provided under WAC 365-195-905. Skagit County will conduct its review and consideration of best available science during its CAO update process. This TMDL will be included in that evaluation.

- **Develop an incentive program for landowners to plant riparian shade along the nine creeks in this TMDL.** The program should provide compensatory funds for farmers with approved and well-maintained riparian buffers. Skagit County's Salmon Heritage Program, developed in early 2007 but not funded, would enable the purchase of conservation easements on riparian lands to protect streams and streamside wildlife habitat. Any incentive programs should be designed to complement the USDA Conservation Reserve Enhancement Program (CREP). Skagit County also received funding to create a "Natural Resource Stewardship Program." This program will provide funding to small riparian fencing and fish habitat restoration projects on streams that are impaired. The Natural Resource Stewardship Program will not only provide small grant funding to willing landowners, but will also provide educational material. The first grant round is scheduled to be available in 2009.

- **Work with Skagit Fisheries Enhancement Group, Skagit Conservation District, Upper Skagit Tribe, and other interested organizations to coordinate grant applications for Basin Stewards**. See Potential Funding Sources.

- **Water quality monitoring.** With partial funding from a Centennial Grant, the Skagit County Public Works Department has conducted surface water monitoring since 2003 in streams flowing through agricultural lands. Results are available on the county website at: www.skagitcounty.net. The Centennial Grant will end in fall 2008. This Report recommends the county develop a funding source so that, at a minimum, temperature, dissolved oxygen, fecal coliform bacteria, pH, and turbidity monitoring of the TMDL creeks can continue.

- **Continue to enforce critical area protections.** The county enforces its ordinances that protect fish and wildlife habitat conservation areas, including establishment of setbacks from streams, as parcels are developed. Similar protections are in place for wetlands, geologically hazardous areas, frequently flooded areas, and critical aquifer recharge areas. Shorelines are more fully protected under the Shoreline Management Program.

- **Adaptive management/follow up water quality data.** The county currently does not have staff assigned to work with landowners and make referrals to the Skagit Conservation District or Skagit Health Department where monitoring data provide evidence of a water quality problem. Skagit County should develop resources for a compliance and inspection/technical assistance program by fall of 2009. Such a program would be consistent with the existing agriculture ordinance which references state water quality standards and commits the county to supporting TMDLs.

- **GIS assessment of riparian vegetation status and parcel protection status.** Ecology assessed current riparian conditions and amount of change since 1990 (or 1998) along six of the nine TMDL creeks in *Lower Skagit River Tributaries Riparian Vegetation Change Analysis Results* (Ecology, 2008). Skagit County should consider conducting such an assessment of the nine creek basins on a periodic basis to assess progress toward improved riparian conditions. The assessment should include locations of parcels that have riparian zones under permanent protection status, such as those with a conservation easement. Ecology will request these data from Skagit County in order to send letters informing landowners of options for improving riparian condition.

- **Hansen Creek Management Plan.** The county should give high priority to implementing this plan (Skagit County, 2002) and should coordinate with the Upper Skagit Tribe, the Sub-Flood Control District, and local property owners.

- **Review potential for future stormwater impacts**. The county should coordinate with city of Mount Vernon to review the potential for future development-related stormwater impacts (from Urban Growth Areas) to affect flow and temperature of creeks in Nookachamps and Fisher-Carpenter basins. The county should coordinate with the city of Mount Vernon Planning Department to encourage Low Impact Development (LID) in these basins.

Skagit Watershed Council

The Skagit Watershed Council (SWC) is a non-profit agency of 36 member organizations including tribes, county, state, and federal government entities, conservation organizations, and business and industry groups. SWC is a state lead entity under the Salmon Recovery Act.

The mission of the SWC is to provide technical assistance, public outreach and education, and a collaborative approach within the Skagit watershed to understand, protect, and restore the production and productivity of healthy ecosystems in order to support sustainable fisheries. The SWC has been instrumental in the coordination, prioritization, funding, and implementation of habitat protection and restoration projects for salmon and other fish species, including native char in the Skagit River basin.

As the lead entity for salmon recovery in the Skagit, the SWC administers the local solicitation and review process for applications for Salmon Recovery Funding Board (SRFB) funds for habitat restoration projects. Under this process, SRFB funds have been allocated for several restoration projects on the creeks in this Report: two Nookachamps Creeks projects (Skagit Conservation District, 2000 and 2002); Verdoes Reach on East Fork Nookachamps (Skagit Fisheries Enhancement Group, 2002), and Fisher Slough (Nature Conservancy, 2006).

Ecology encourages SWC to continue its good work supporting salmon recovery and continue to provide a venue for discussion and information exchange among natural resource users in the Skagit watershed.

Skagit Fisheries Enhancement Group

The Skagit Fisheries Enhancement Group (SFEG) is a nonprofit organization dedicated to the enhancement of salmon resources through education, restoration, and public involvement. Established in 1990 as one of 14 Regional Fisheries Enhancement Groups in Washington State, SFEG is part of a coordinated effort to educate and involve the public in salmon enhancement activities across the state at the community level. SFEG works cooperatively with local landowners to identify restoration opportunities on their property and find the funding to implement them.

SFEG conducts restoration projects that include riparian restoration, improvement of fish passage, nutrient enhancement, and instream enhancement projects such as channel enhancement and streambank stabilization. The SFEG monitoring program is designed to evaluate the effect of restoration work to improve natural watershed conditions and salmon resources. Results of monitoring programs help guide designs for future restoration projects and document successes to funding entities.

SFEG has a current Centennial Grant project to work in the Nookachamps Creek basin to identify restoration opportunities and work with landowners to increase participation in planting and restoration projects.

Skagit Fisheries Enhancement Group action item: Coordinate with Skagit County, Skagit Conservation District, Upper Skagit Tribe and other interested organizations to coordinate grant applications for Basin Stewards. (See Potential Funding Sources.)

Skagit Conservation District

The Skagit Conservation District (SCD) is a legal subdivision of Washington State government organized under "Conservation District Law" RCW Title 89, Chapter 89.08 and composed of farmers, landowners, and concerned citizens. The district priorities and goals include:

- Protection and improvement of the quality of surface and ground water.
- Watershed planning and implementation.
- Riparian reforestation and enhancement.
- Forest stewardship.
- Wildlife habitat enhancement.
- Conservation education.
- Protection and preservation of prime farmlands.
- County government assistance.
- Increase district capacity.

The SCD encourages and promotes the preservation and optimum beneficial use of agricultural, range and forested lands by helping landowners plan and implement best management practices (BMPs) that reduce soil erosion, improve water quality and water conservation, as well as protect the natural resource base of SCD. The SCD also provides:

- Education and technical assistance to non-industrial forest landowners.
- Soils information, conservation maps and knowledge of BMPs to landowners and land managers.
- Implementation programs aimed at protecting the water resources of Skagit County.
- Surveys, research studies, comprehensive plans, and demonstration and implementation projects on public and private lands within the district.
- Responsible and accountable management and financial assistance.
- Conservation leadership to federal, state and local governmental agencies.
- Monitoring of enhancement projects and BMP implementations that document success and/or the need for adaptive management measures.

SCD administers the Conservation Reserve and Enhancement Program (CREP) in Skagit County, and since 2000 has overseen the installation of eight projects, with one pending, along some of the creeks in this TMDL. SCD has managed several Centennial Grant projects in the Nookachamps and Fisher-Carpenter basins that were aimed at educating landowners on best management practices to avoid water quality degradation, including riparian improvement projects. For the Fisher-Carpenter basins, SCD developed both a watershed characterization (SCD 2007) and a feasibility study (SCD 2006) that details potential stream channel restoration and water quality improvement projects on many properties in these basins.

Skagit Conservation District action items:

- Coordinate with Skagit Fisheries Enhancement Group, Skagit County, Upper Skagit Tribe, and other interested organizations to coordinate grant applications for Basin Stewards. See Potential Funding Sources.
- Promote CREP projects through farm tours and other innovative outreach methods. Develop an effective communications approach to explain CREP revisions and new leasing rates.
- Add recommendations for water conservation practices to farm plans and to guidance for small non-commercial farm owners.
- Develop hedgerow planting program for agricultural ditches.

Skagit River System Cooperative

The Skagit River System Cooperative (SRSC) is a natural resource consortium of the Swinomish and Sauk-Suiattle tribes with fishing rights in some of the waters in WRIA 3. The Swinomish Tribe has a reservation on Skagit Island just west of LaConner. The Sauk-Suiattle Tribe has offices near the Sauk River in Darrington in Snohomish County. The SRSC's policy is to protect, preserve, and enhance Skagit-area fish habitat and other natural resources and environment that affect the quality of that habitat. In addition, the SRSC and tribal policies are designed to achieve a net gain in the productive capacity of Skagit-area fish habitat.

SRSC has conducted valuable research on the life history strategies and habitat needs of Skagit River salmonids.

SRSC action item: Coordinate with other conservation organizations on opportunities to restore and enhance salmon habitat.

Washington Department of Fish and Wildlife

Washington Department of Fish and Wildlife (WDFW) has responsibilities to protect and manage fisheries resources of the state. WDFW biologists are an important source of information on the status of salmonid populations in the Lower Skagit tributaries in this TMDL. An additional recommendation that is outside Ecology's regulatory authority is made on page 32.

WDFW action items (as staff resources allow):

- Provide expertise on salmonid resources and design of smolt traps to any Basin Stewards hired to work in the creek basins targeted in this Report.

- Coordinate with Ecology in participating in the development of local Comprehensive Flood Hazard Management Plans to encourage the incorporation of language relating to retention or development of healthy riparian buffers.

Drainage and Irrigation District 3

Drainage and Irrigation District 3 includes Hill Ditch (the channelized lower reach of Carpenter Creek).

Ecology recommends that the District: Participate in development of the implementation plan for this TMDL, and look for opportunities to manage drainage in ways that will improve water quality in Hill Ditch. Consider mowing and maintenance practices that allow riparian vegetation development along ditches with headwaters, particularly along Hill Ditch.

Upper Skagit Tribe

The Upper Skagit Tribe has offices and reservation lands in Sedro-Woolley, near Red Creek. The Tribe's Usual and Accustomed Fishing Areas include the creeks addressed by this Report. The Tribe participated in the advisory committee meetings for this Report and is managing a Centennial Grant to improve water quality in Red Creek.

Ecology recommends that the Upper Skagit Tribe:

- Coordinate with Skagit Fisheries Enhancement Group, Skagit Conservation District, and other interested organizations to coordinate grant applications for Basin Stewards.
- Coordinate with Skagit County Public Works as resources allow, to supplement their water quality monitoring resources.

City of Mount Vernon

Mount Vernon has Urban Growth Areas both to the east and south of current city boundaries. Development to the south could impact the Carpenter Creek watershed, and development to the east has some particularly steep terrain. Future development here, if not planned with rigorous criteria to prevent erosion, could impact the Nookachamps Creek watershed.

Ecology recommends that the city of Mount Vernon:

- Review available development guidance for reducing impacts of erosion and stormwater, and work closely with Skagit County to ensure development proceeds with as little impact as possible to these creeks.
- Review development codes to make sure that Low Impact Development approaches can be incorporated into development designs.

Washington Department of Ecology

Ecology is responsible for developing the detailed Lower Skagit Tributaries Temperature TMDL implementation plan with local organizations in 2009 - 2010. Working with these organizations will provide opportunity for additional ideas for implementation and further refinement of the strategy outlined in this Report. Once the plan is published, Ecology will be responsible for leading periodic assessment of progress made in meeting water quality standards.

Ecology's Water Resources Program is responsible for administering state water rights law regulating use of ground and surface water. Unauthorized water withdrawals can negatively impact stream temperatures by reducing stream flows and groundwater contribution to stream flows. Ecology currently has limited compliance staff to ensure water use in the basin complies with existing water rights and water law. Ecology anticipates increasing compliance staff in 2008 to investigate water use and work with water users to ensure compliance with water law.

Action items:

- After parcels are identified as lacking in riparian shade and not protected through CREP, Conservation Easement, or other protection, Ecology will work with Skagit County to send letters explaining the need for water quality protection and outlining options for obtaining technical assistance for riparian improvements. This action requires the support and cooperation from Skagit County in identifying such parcels.
- Ecology will request resources to increase the current compliance staff to investigate water use and develop appropriate compliance actions.
- Ecology will work with diking and drainage districts to review mowing and other maintenance practices that could be modified to allow maturation of riparian vegetation along ditches with headwaters.
- Ecology will coordinate with WDFW in participating in the development of local Comprehensive Flood Hazard Management Plans to encourage the incorporation of language relating to retention or development of healthy riparian buffers.

Reasonable Assurances

The goal of the Lower Skagit Tributaries Temperature Water Quality Improvement Report is for the nine temperature-impaired creeks to meet the state's water quality standards. The prospect of mandatory buffers along streams has aroused opposition for years in the Lower Skagit watershed. This more flexible approach recognizes that a variety of solutions may be appropriate and includes landowner incentives. We expect this approach to be more widely accepted than a less-flexible approach would be.

A number of organizations and agencies are already engaged in riparian and in-stream restoration actions that will help reduce stream temperatures. Riparian restoration projects currently under way include:

- Hansen Creek (Skagit County and Upper Skagit Tribe).
- Nookachamps Creek and East Fork Nookachamps Creek projects by Skagit Fisheries Enhancement Group and Skagit Conservation District.
- Fisher Slough (Nature Conservancy and Skagit County).

Also, the *Feasibility Study of Proposed Water Quality, Stream Flow and Habitat Improvement Activities in the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington* (Skagit Conservation District, 2006) provided a good start in identifying projects to improve temperature in Fisher and Carpenter Creeks.

The monitoring and adaptive management process described in a later section of this report is designed to provide information in a positive feedback loop to encourage more landowner participation in restoration projects. Should the monitoring results indicate that the approaches being used are not working, then the organizations involved in monitoring and implementation will re-convene to determine whether different approaches should be used.

Education, outreach, technical and financial assistance, and enforcement all will be used to ensure that the goals of this Water Quality Improvement Report are met. Ecology will seek funding resources to increase the number of current compliance staff to investigate water use and develop appropriate compliance actions.

It is the goal of all participants in the Lower Skagit Tributaries Temperature TMDL process to achieve improved water quality through voluntary control actions. If voluntary programs are not successful, Ecology will consider enforcement action and issue notices of noncompliance in accordance with Chapter 90.48 RCW and with its authority under the federal Clean Water Act in situations where the cause or contribution of cause of noncompliance with load allocations are known or can be established.

What is the Schedule for Achieving Water Quality Standards?

Ecology estimates that it will take two years to obtain necessary funds and three more years (2013) for Basin Stewards and Ecology to contact and educate all landowners about the needed water quality improvements.

Our goal is for 100 percent of all stream miles of these creeks to be protected by riparian shade or enrolled as part of larger creek restoration and improvement projects by 2020. If we are successful in meeting that goal, then we expect these creeks would meet water quality standards by 2080. This is shorter than the 100 years needed for full maturation of native conifers and deciduous trees because of existing riparian shade and projects initiated over the past 10 years.

Table 3 provides a timeline and list of objectives for the phases of the TMDL implementation strategy.

Table 3. Phased Implementation Elements and Timeline

Time Period	Program Element or Objective	Responsible Party	Cooperating Entity	Measurement Objective
2008-2010	Develop funding source for creek Basin Stewards	Applicant for Centennial or EPA Targeted Watershed Funds	Ecology and EPA	Funds secured by 6/2010
2008 - 2010	Develop landowner incentive program GIS report – identify parcels already protected and those in need of protection	Skagit County	Funding Sources	Program in place by 2011
2011 - 2013	Basin Stewards conduct one-on-one outreach and technical assistance to landowners; Ecology letter to landowners needing to add riparian vegetation	Recipient of Grant Funds, Ecology	Ecology, Skagit County, EPA	100% of owners of parcels next to streams contacted within 3 years
2015	Streamside landowners enrolled in creek protection program	Recipient of Grant Funds	Ecology, EPA	80% of owners enrolled
2011 - 2020	Riparian planting, restoration, protection for 80% of stream length in each creek basin	Landowners enrolled in creek protection program		80% of length of each creek planted, protected, or evaluated by basin steward
2008 – 2020 (ongoing)	Water quality monitoring: temperature (year round); Dissolved Oxygen, bacteria. Include nutrients as resources allow.	Skagit County; Upper Skagit Tribe	Ecology	Monthly monitoring and annual report
2008 – 2020 (ongoing)	Develop enforcement resources: Shade and filter strip requirement for parcels with impairments (fecal coliform, dissolved oxygen) in addition to temperature	Skagit County and Ecology	Ecology, WSDA	Compliance with water quality standards for fecal coliform bacteria and dissolved oxygen
2080	Project tracking – riparian and creek condition. Volunteer monitoring: Macroinvertebrate monitoring Smolt traps on 3 – 6 small creeks	Ecology and Basin Stewards	Skagit County; Upper Skagit Tribe	Compliance with temperature standard

Measuring Progress toward Goals

Assessing progress in meeting the goals of this Water Quality Improvement Report requires water quality monitoring at key locations in these creek basins. Ecology recommends that Skagit County make it a priority to find resources to continue water quality monitoring of the creeks in this Report. Reviewing temperature data on a periodic basis will provide the necessary feedback for determining the effectiveness of the recommendations in this TMDL implementation strategy. Other watershed organizations may be able to supplement the work of Skagit County's monitoring program. The current sites on Fisher, Carpenter-Hill Ditch, Nookachamps, East Fork Nookachamps, Lake, and Hansen creeks should be monitored for temperature, dissolved oxygen, pH, conductivity, turbidity and fecal coliform bacteria.

Ecology conducts effectiveness monitoring to assess how well TMDL actions are doing to help waterbodies meet water quality standards. However, because of the lead time involved in getting riparian planting projects underway and achieving some height of the vegetation for effective shading, Ecology does not expect to schedule this in the near future. Implementation review will include periodic assessment of temperature data and of riparian vegetation along the creeks. The Ecology report, *Lower Skagit River Tributaries Riparian Vegetation Change Analysis Results (2008)* provides a model for such assessment, which should be conducted on a five-year frequency by Skagit County.

Monitoring and assessment are considered critical to generating understanding and support for improving creek health among landowners living in each creek basin. It will be the responsibility of each Basin Steward (if a Basin Steward approach is adopted by a local organization) to develop a monitoring plan to take advantage of local priorities, interests, and volunteer hours that may be available. The plan may consider a variety of monitoring approaches and assessment methods, because some provide better feedback and will generate more interest among the public. Creek health can be defined in a variety of ways, and could include measurements of:

- Water quality parameters such as temperature, dissolved oxygen and turbidity.
- Aquatic life – macroinvertebrates, freshwater mussels.
- Amphibians such as frogs, which are sensitive to chemicals.
- The presence/quantity of invasive plants – hopefully this will be a declining measure.
- The frequency that a channel needs to be dredged or gravel removed.
- The presence, number and size of large wood along a particular reach.

It would be beneficial if monitoring of salmon smolt traps could be included as one component of monitoring. This could be planned and initiated at a location below an area where substantial creek improvements are expected. The smolt trap monitoring could be conducted for three years prior to the improvements, during the restoration/planting project years, and then for three to five years afterward. Smolt traps generally work best on very small creeks, are labor-intensive (many volunteer hours would be required), and should be located only after professional consultation with Washington Department of Fish and Wildlife or other fisheries biologist.

This page intentionally blank

Adaptive Management

The temperature reductions that are the goal of this Water Quality Improvement Report should be achieved by 2080. Working with local government and organizations on the next phase of the TMDL, the water quality implementation plan, Ecology will identify action items (implementation measures), organizations responsible for them, and interim targets. If initial implementation measures fail, then Ecology will assess the implementation approach and progressively more aggressive efforts will be employed to meet water quality goals. This allows locally-driven programs a chance to be successful before more restrictive measures are applied. Ecology will specify, in the implementation plan, other more restrictive measures which will be applied should initial measures not be put into action or successful. The process relies heavily on the development of interim and final targets to identify the desired future condition of a water body. These final targets must meet water quality standards at the end of the planned period.

Partners identified in this Water Quality Improvement Report will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the water quality improvement strategy as needed.

Ultimately it is Ecology's responsibility to assure that temperature improvements are being actively pursued and that water quality standards are achieved. Ecology will monitor the progress of stakeholders and parties to this TMDL who, like Ecology, need to adaptively manage implementation roles and responsibilities to help ensure TMDL goals are met.

Temperature monitoring results will provide an important feedback mechanism to help guide adaptive management of this TMDL. (See Measuring Progress toward Goals.)

This page is purposely left blank

Public Involvement

Washington Department of Ecology has made a number of presentations in Skagit County to educate the public and local organizations about the Lower Skagit Tributaries Temperature TMDL and to provide an opportunity for public comment.

> May 2003: Presentation to the Skagit County Planning Commission on the findings of the Lower Skagit Tributaries Temperature TMDL Study.
>
> June 2003: Public Meeting, Skagit College: Presentations on the Temperature TMDL Study and the Implementation Plan.
>
> January 2007 to January 2008: Advisory Committee meetings for the Draft Temperature TMDL – Water Quality Improvement Report.
>
> February 25, 2008: Public Meeting on the Draft Lower Skagit Tributaries Temperature Water Quality Improvement Report (submittal report to EPA), City Library, Burlington, Washington.

Ecology also organized an advisory committee made up of citizens, local government agency staff, Tribal natural resources agency staff, and local organizations, which met five times in 2007 and 2008.

In addition, two local organizations were awarded Centennial Grants with education and outreach tasks. Over the past four years, their combined outreach efforts are estimated to have reached more than 100 residents of the nine creek basins with messages about watershed protection, enhancing riparian habitat for fish and wildlife, water quality improvement, riparian buffer functions, and wetland values.

- Skagit Fisheries Enhancement Group – Nookachamps Creek Restoration Project. Conducted a series of educational workshops in spring 2006.
- Skagit Conservation District:
  - Watershed Masters – educational workshop series.
  - Backyard Conservation – educational workshop series.
  - Small Farm Landowners – educational workshop series.
  - Stream Team – volunteers make a nine-month commitment to water quality monitoring at sites throughout the Lower Skagit Watershed.

This page is purposely left blank

Potential Funding Sources

Funding is available for projects to restore and enhance riparian condition along streams; to improve stream channel structure and complexity; and to plan and develop public educational strategies needed to increase landowner participation in such projects.

1. **EPA Targeted Watershed Grants 2008 Puget Sound Initiative.** U.S. EPA Region 10 uses this grant opportunity to support the protection and restoration of high-valued Puget Sound aquatic resources in areas threatened by growth pressure through holistic watershed protection and management approaches at the local level. The grant funds will assist local and tribal governments in managing land uses while protecting watershed functions and values. Successful projects will match proposed activities to the appropriate watershed scale to ensure environmental results. Although this was a January 2008 opportunity, EPA may repeat this Request for Proposals later in 2008 or early 2009. http://yosemite.epa.gov/r10/water.nsf/Office+of+Water/PS08RFP

2. **Ecology Centennial and Section 319 Nonpoint Funds.** Annual application period (in 2008, September 1 to October 31). Grant and loan projects for implementing actions to restore and improve water quality; projects to implement TMDL recommended actions are given higher priority. www.ecy.wa.gov/programs/wq/funding/funding.html

3. The state **Recreation and Conservation Funding Board (RCFB)** administers several grant programs for recreation and habitat conservation purposes. Depending on the program, eligible project applicants can include municipal subdivisions of the state (cities, towns, and counties, or port, utility, park and recreation, and school districts), tribes, state agencies, and in some cases, federal agencies and nonprofits.

   The **Aquatic Lands Enhancement Account (ALEA)** grant program provides grant-in-aid support for the purchase, improvement, or protection of aquatic lands for public purposes, and for providing and improving access to such lands. http://www.rco.wa.gov/rcfb/grants/alea.htm

   The **Land and Water Conservation Fund (LWCF)** provides funding to assist in preserving, developing, and assuring accessibility to outdoor recreation resources including but not limited to parks, trails, wildlife lands, and other lands and facilities desirable for individual active participation. http://www.rco.wa.gov/rcfb/grants/lwcf.htm

4. The state **Salmon Recovery Funding Board (SRFB)** administers two grant programs for protection and restoration of salmon habitat—the Salmon Recovery Funding Board grants, and the Family Forest Fish Passage Program grants. The board also supports feasibility assessments for future projects and other activities. Project applications must go through the lead entity review process, which in WRIA 3 is coordinated by the Skagit Watershed Council. http://www.rco.wa.gov/srfb/grants.asp

5. Washington Department of Fish and Wildlife administers the ALEA Volunteer Cooperative grant program, which provides monetary support for qualifying volunteer organizations and individuals who want to undertake projects that are beneficial to fish and wildlife. http://wdfw.wa.gov/volunter/vol-7.htm

6. Washington Department of Fish and Wildlife administers the Washington funding allocation under the federal **Fisheries Restoration and Irrigation Management Act (FRIMA). The Fisheries Restoration and Irrigation Mitigation Act of 2000 (FRIMA)** (PL 106-502) is a federal fish screening and passage partnership program in Idaho, Oregon, Washington and western Montana that is administered by the U.S. Fish and Wildlife Service (USFWS). The purpose of this program is to match federal funds with local, state, and tribal programs to increase fish survival, reduce entrainment in existing water distribution systems, and increase access to productive fish habitat. Total funds available for 2007 in Washington state were $235,000. http://www.wdfw.wa.gov/recovery/frima_application-07.htm

7. Funded by the state legislature in spring 2007, the **Puget Sound Partnership** (Partnership) is a partnership of business, government, tribes, and conservation organizations to address pollution and development-related environmental challenges of the Puget Sound basin. The partnership will focus on stormwater, pollution, habitat protection and restoration, freshwater quantity, and fish and wildlife. The Partnership's mission is to:

    - Recommend key actions.
    - Engage citizens, government, tribes, business and conservation communities.
    - Coordinate government agencies and private organizations working on Puget Sound issues.
    - Access funding resources and set spending priorities.
    - Work with scientists to recommend how broad-based scientific knowledge can be used to make policy decisions and set goals to protect Puget Sound.

    Ecology will have opportunities to work with the Partnership and its boards and committees, and will advocate for the funding needs of the Lower Skagit Tributaries Temperature TMDL for the work that coincides with the mission of the Partnership.

8. In spring 2008, Skagit County Public Works was awarded a Centennial Clean Water Fund grant for the Skagit County Natural Resource Stewardship Program, which will provide funds to community organizations for small riparian fencing and salmon habitat restoration projects.

Implementation Summary

The implementation actions assigned to responsible organizations in a previous section, "Who Needs to Participate" are summarized in Table 4.

Table 4. Summary of Implementation Actions

Organization	Action	Date
Skagit County	Include this TMDL's stream temperature analyses and recommendations as "Best Available Science" during update of Critical Areas Ordinance for Ongoing Ag (SCC 14.24.120).	2010
	Coordinate with other organizations to develop funding source for Basin Steward program.	2009
	Develop financial incentive program for landowners that install and maintain riparian buffers.	2011
	GIS assessment of riparian condition and of parcels with riparian protection (conservation easements, public property, other). Work with Ecology on mailing to landowners with parcels identified as contributing to temperature impairment.	Periodic
	Develop funds to continue water quality monitoring.	2009
	Develop staff resource to follow up water quality data where land practices not in compliance with Critical Areas Ordinance for Fish & Wildlife Habitat Areas in Ongoing Agriculture.	2009
	Implement Hansen Creek Management Plan.	2015
	Review potential for development-related stormwater impacts to affect flow and temperature of creeks in Nookachamps and Fisher-Carpenter basins/Coordinate with city of Mount Vernon Planning Dept on LID guidance for these basins.	2009
Skagit Watershed Council	Provide/assist with venue for presenting progress reports for Lower Skagit Tributaries Temperature TMDL.	Ongoing
Skagit Conservation District	Coordinate with other organizations to develop funding source for Basin Stewards.	2009
	Promote CREP projects through farm tours and other innovative outreach methods. Develop effective communications approach to explain CREP revisions and new leasing rates.	Ongoing
	Add recommendations for water conservation practices to farm plans and to guidance for small non-commercial farm owners.	Ongoing

Table 4. Summary of Implementation Actions

Organization	Action	Date
	Develop hedgerow planting program for agricultural ditches.	2010
Skagit Fisheries Enhancement Group	Coordinate with other organizations to develop funding source for Basin Stewards.	2009
	Secure funding for riparian restoration projects with willing landowners.	Ongoing
Drainage District 3	Participate in developing Implementation Plan for this Report. Consider mowing practices that allow riparian vegetation development along ditches with headwaters, particularly along Hill Ditch.	2009
Washington State Department of Ecology	Develop Implementation Plan with local organizations.	2009
	Facilitate annual Implementation Review meeting.	2009 - 2012
	Work with Skagit County on mailing to landowners explaining water quality improvement needs.	Following Skagit County GIS assessment
	To ensure water use compliance, look for resources to increase the current compliance staff to investigate water use and develop appropriate compliance actions.	2008-2009
	Coordinate with WDFW during the development of local Comprehensive Flood Hazard Management Plans to encourage the incorporation of language relating to retention or development of healthy riparian buffers.	As CFHMPs are updated
	Work with diking and drainage districts to ensure riparian plantings on ditches with headwaters.	Ongoing
Skagit River Systems Cooperative	Coordinate with other conservation organizations on opportunities to restore and enhance salmon habitat.	Ongoing
Upper Skagit Tribe	Coordinate with other organizations to develop funding source for Basin Stewards.	2010
	Coordinate with Skagit County Public Works, as resources allow, to supplement their water quality monitoring resources.	Ongoing
Washington Department of Fish and Wildlife	Coordinate with Ecology during the development of local Comprehensive Flood Hazard Management Plans to encourage the incorporation of language relating to retention or development of healthy riparian buffers.	As CFHMPs are updated
	Provide expertise on salmonid resources and design of smolt traps to the Basin Steward.	As needed

Table 4. Summary of Implementation Actions

Organization	Action	Date
City of Mount Vernon	Review potential for stormwater impacts to increase in Nookachamps and Fisher-Carpenter basins as development occurs in Urban Growth Areas on south, east sides of city. Review current planning requirements and make sure planning codes allow for LID approaches that infiltrate stormwater and reduce stormwater impacts. Coordinate with Skagit County Planning and Development Services on development recommendations for county UGA sections of these basins.	2009

Conclusions

1. Eight tributaries to the Lower Skagit River are too warm during late summer relative to state water quality standards for temperature.

2. Ecology's Temperature Study for the Lower Skagit tributaries, published in 2004 (Appendix A) concludes that mature native riparian vegetation would provide shade sufficient to protect these streams from the heating effects of sunlight. The model results indicate the state's revised water quality standards (2006) can also be met with the same recommendation for full riparian shade.

3. Achieving temperature reductions necessary for Lower Skagit tributaries to meet water quality standards will require parcel-by-parcel implementation of projects to increase riparian shade and improve creek health.

4. The strategy to help keep the Lower Skagit tributaries cool will be implemented by administration of Skagit County's Critical Areas Ordinance for Areas of Ongoing Agriculture; incentive programs administered by Skagit Conservation District and Skagit County; proposed Basin Steward outreach and technical assistance programs; and a proposed communications program involving Skagit County and Ecology.

5. If the recommendations and schedules in this Water Quality Improvement Report are followed, Ecology expects these creeks will meet water quality standards by 2080.

References

Adams, T.N. and K. Sullivan. 1989. The physics of forest stream heating: a simple model. Timber, Fish and Wildlife Report No. TFW-WQ3-90-007. Washington State Department of Natural Resources, Olympia, WA.

Andrews, A. and D. Stuart. 2003. *Economic Impacts of Agriculture in Skagit County, WA*. A baseline assessment prepared for and in cooperation with Skagitonians to Preserve Farmland, Washington State University Skagit County Cooperative Extension, and Economic Development Association of Skagit County. August 1, 2003

Breslow, Sara Jo. 2001. *Farmers' perceptions of salmon habitat restoration measures: loss and contestation*. Internship report for funding agencies - Society for Applied Anthropology and U.S. Environmental Protection Agency. Nov. 5, 2001. 52 pp.

Casola, J.H., J.E. Kay, A.K. Snover, R.A. Norheim, L.C. Whitely Binder, and the Climate Impacts Group. 2005. *Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture.* A report prepared for King County (Washington) by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle).

DNR. 1999. *Forests and Fish Report*. Forest Practices Board. April 29, 1999.Washington Dept. of Natural Resources, Olympia, Washington. www.dnr.wa.gov/forestpractices/rules/forestsandfish.pdf

Ecology. 2008. *Lower Skagit River Tributaries Riparian Vegetation Change Analysis Results.* Callie Meredith, Environmental Assessment Program, Washington State Department of Ecology, Olympia, Washington. Nov. 2007, revised April 2008. Pub. No. 07-03-050. www.ecy.wa.gov/biblio/0703050.html

Ecology. 2006. *Water Quality Standards for Surface Waters of the State of Washington*. Chapter 173-201A WAC. Amended Nov. 20, 2006. Washington State Department of Ecology. Pub. No. 06-10-091. www.ecy.wa.gov/pubs/0610091.pdf

Ecology. 2006. *Stillaguamish River Watershed Temperature Total Maximum Daily Load Submittal Report.* Washington State Department of Ecology, Olympia, Washington. Pub. No. 06-10-057. www.ecy.wa.gov/biblio/0610057.html

Ecology. 2004. *Lower Skagit River Tributaries Temperature Total Maximum Daily Load Study.* Brian Zalewsky and Dustin Bilhimer, Environmental Assessment Program, Washington State Department of Ecology, Olympia, Washington. Jan. 2004. Pub. No. 04-03-001. www.ecy.wa.gov/biblio/0403001.html

Ecology. 2003. Teanaway *Temperature Total Maximum Daily Load: Detailed Implementation Plan.* Washington State Department of Ecology, Olympia, Washington. Pub. No. 03-10-025.

www.ecy.wa.gov/biblio/0310025.html

Ecology. 2001. *Teanaway Temperature Total Maximum Daily Load Submittal Report*. Washington State Department of Ecology, Olympia, Washington. Pub. No. 01-10-019. www.ecy.wa.gov/biblio/0110019.html

Hamlet, A.F. and D.P. Lettenmaier. 1999. *Effects of climate change on hydrology and water resources in the Columbia River Basin.* Journal of the American Water Resources Association, 35(6):1597-1623.

Hamlet, A.F., P.W. Mote, M. Clark, and D.P. Lettenmaier. 2005. *Effects of temperature and precipitation variability on snowpack trends in the western U.S.* Journal of Climate, 18 (21): 4545-4561.

Independent Multidisciplinary Science Team, 2004. Oregon's Water Temperature Standard and its Application: Causes, Consequences, and Controversies associated with Stream Temperature. Technical Report 2004-1.

Montgomery, David R. 2003. *King of Fish. The Thousand-Year Run of Salmon*. Westview Press. 290 pp.

Mote, P.W., E. Salathé, and C. Peacock. 2005. Scenarios of future climate for the Pacific Northwest, Climate Impacts Group, University of Washington, Seattle, WA. 13 pp.

NOAA. 2003. The NOAA Integrated Surface Irradiance Study (ISIS) - A New Surface Radiation Monitoring Program", B.B. Hicks, J.J. DeLuisi, and D.R. Matt. Bull. Amer. Meteor. Soc. 77, 2857-2864. http://www.atdd.noaa.gov/isis/isis.htm

Pelletier, G. and D. Bilhimer. 2001. Stillaguamish River temperature total maximum daily load: quality assurance project plan. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-66. http://www.ecy.wa.gov/biblio/0103066.html.

Poole, G.C., and C.H. Berman. 2000. Pathways of human influence on water temperature in stream channels (in preparation). Submitted to *Environmental Management*. U.S. Environmental Protection Agency, Region 10, Seattle.

Salmon Safe Certification Program. Information at: www.salmonsafe.org/. Salmon-Safe Inc., 805 SE 32nd Avenue, Portland, OR 97214.

Skagit Conservation District. 2007. Characterization of the Fisher and Carpenter Creek Watershed of Skagit and Snohomish Counties, Washington. Prepared pursuant to Washington Department of Ecology Centennial Clean Water Fund Grant No. G0400195 "Fisher/Carpenter TMDL Implementation." 80 pp.

Skagit Conservation District. 2006. Feasibility Study for Fisher and Carpenter Creek Watershed, Skagit and Snohomish Counties, Washington. Prepared pursuant to Washington Department of

Ecology Centennial Clean Water Fund Grant No. G0400195 “Fisher/Carpenter TMDL Implementation.” 59 pp.

Skagit County. 2002. Hansen Creek Watershed Management Plan. Prepared by Miller Consulting and Watershed Professionals Network for Surface Water Management, Skagit County Public Works Department, Mount Vernon, Washington. September 2002. 98 pages.

SRSC and WDFW. 2005. *Skagit Chinook Recovery Plan*. Skagit River System Cooperative, 11426 Moorage Way, LaConner, Wash. and Washington Department of Fish and Wildlife. 296 pp. http://www.skagitwatershed.org/navbar_chinook.html

Steiger, J.M., James, and F. Gazelle. 1998. *Channelization and consequences on floodplain system functioning on the Garonne River, SW France.* Regulated Rivers: Research and Management 12: 391-413.

USDA. 1981. Soil Survey of Skagit County Area, Washington. U.S. Department of Agriculture. 372 pp.

Washington State Supreme Court. 2007. *Swinomish Indian Tribal Community v. Western Washington Growth Management Hearings Board,* __Wn.2d __, 2007 WL 2683150 (September 13, 2007.

Western Washington Agricultural Association. 2006. *Skagit Basin Comprehensive Irrigation District Management Plan, October 2006.* Prepared by HDR Engineering, Inc. Mount Vernon, WA.

Wild Fish Conservancy. 2006. http://www.wildfishconservancy.org/what-we-do/advocacy/wild-salmon-recovery-initiative/wsri-projects#puget-sound-salmon-harvest

Appendices

this page intentionally left blank)

Appendix A. Lower Skagit River Tributaries Temperature Total Maximum Daily Load Study

Lower Skagit River Tributaries Temperature Total Maximum Daily Load Study

January 2004

Publication No. 04-03-001

Printed on Recycled Paper

This report is available on the Department of Ecology home page on the
World Wide Web at http://www.ecy.wa.gov/biblio/0403001.html

For additional copies of this publication, please contact:

Department of Ecology Publications Distributions Office

Address: PO Box 47600, Olympia WA 98504-7600

E-mail: ecypub@ecy.wa.gov

Phone: (360) 407-7472

Refer to Publication Number 04-03-001

Lower Skagit River Tributaries Temperature Total Maximum Daily Load Study

by

Brian Zalewsky and Dustin Bilhimer

Washington State Department of Ecology
Environmental Assessment Program

January 2004

Waterbody Numbers: See Table 1

Publication No. 04-03-001

Printed on Recycled Paper

This page is purposely left blank

Table of Contents

Page

List of Attachments

A. Instream water temperature standard exceedances and station disposition.

B. Tables

B1. Riparian codes used in Shade model vegetation classification.

B2. Additional riparian codes used for 100-year-old riparian vegetation.

B3. 7Q2 and 7Q10 low-flow model inputs for discharge, width, depth, and velocity.

B4. Summary of flow measurements in the lower Skagit River study area.

B5. Methodology and calculations for estimating future riparian vegetation species, heights, and widths.

List of Figures

List of Tables

Abstract

The study area for this Total Maximum Daily Load (TMDL) includes the major tributaries to the lower Skagit River below Skiyou Island. The federal Clean Water Act Section 303(d) listings for impaired stream temperature in the lower Skagit River basin include these creeks: Carpenter, Fisher, Hansen, Lake, Nookachamps, East Fork Nookachamps, Red, Turner, and Otter Pond.

Significant reductions in water temperature are predicted for hypothetical conditions with 100-year-old riparian vegetation, improvements in riparian microclimate, and reductions in channel width. Maximum reductions in water temperature would likely result from a combination of mature riparian vegetation, historic channel complexities, and pre-settlement flow regimes.

Potential reduced temperatures are predicted to be less than the Washington State water quality standard of 18°C for Class A waters in most of the segments evaluated. Those segments not expected to be less than the 18°C are the outlets of Lake McMurray and Big Lake. Surface water temperatures in these two lakes frequently exceed 22°C during the summer.

Natural conditions may exceed the numeric temperature criteria mandated by the water quality standards. In these cases, the antidegradation provisions of those standards apply (Chapter 173-209A-030 WAC). These provisions state that "*whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.*"

This technical study uses effective shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d) for a temperature TMDL. Effective shade is defined as the fraction of incoming solar shortwave radiation, above the vegetation and topography that is blocked from reaching the stream surface.

In addition to load allocations for effective shade, other management activities are recommended for compliance with water quality standards for water temperature, including measures to promote efficient water use and increase groundwater inflows into the streams.

Acknowledgements

We would like to thank the following Washington State Department of Ecology staff for their contributions to this study:

- Sally Lawrence for reviewing the draft report, coordinating the public review process for the study, and drafting the section of the report on instream flow rules.
- Greg Pelletier, Mindy Roberts, and Anita Stohr for consultation on GIS and modeling.
- Darrel Anderson, Greg Pelletier, and Anita Stohr for reviewing the draft report and providing many valuable comments.
- Joan LeTourneau for formatting and editing the final report.

Introduction

The lower Skagit River basin includes portions of Skagit and Snohomish counties in northwest Washington State (Figure 1). Ecology's assessment of the lower Skagit River watershed identified the system as a high priority for the development of a Total Maximum Daily Load (TMDL) for temperature.

The purpose of the lower Skagit River temperature TMDL is to characterize water temperatures in the basin and to establish load and wasteload allocations for heat sources in order to meet water quality standards for surface water temperature. This study focuses on the 303(d) listings in Carpenter, Fisher, Hansen, Nookachamps, East Fork Nookachamps, Red, Turner, and Otter Pond creeks for exceeding the state's water quality standards for temperature (Table 1).

Table 1. 1998 303(d) listings for temperature in the lower Skagit River basin.

Waterbody Name	Township	Range	Section	Watercourse IIP 303(d) number	Waterbody ID number	1996 303(d) List	1998 303(d) List
CARPENTER CREEK	**33N**	**04E**	**17**	**YA61IC**	**WA-03-1011**		**X**
CARPENTER CREEK	**33N**	**04E**	**20**	**YA61IC**	**WA-03-1011**		**X**
CARPENTER CREEK	**33N**	**04E**	**9**	**YA61IC**	**WA-03-1011**		**X**
COAL CREEK	35N	05E	10	RE17FI	None11		X
CUMBERLAND CREEK	35N	06E	23	QX54OS	None7		X
DAY CREEK	35N	06E	28	QT99QB	None8		X
FISHER CREEK	**33N**	**04E**	**30**	**JK73SN**	**WA-03-1012**		**X**
HANSEN CREEK	**35N**	**05E**	**29**	**PU87PF**	**WA-03-1019**		**X**
HANSEN CREEK	**35N**	**05E**	**20**	**PU87PF**	**WA-03-1019**		**X**
HANSEN CREEK	**35N**	**05E**	**17**	**PU87PF**	**WA-03-1019**		**X**
INDIAN (BIG) SLOUGH				390KRD	WA-03-3100	X	X
INDIAN (BIG) SLOUGH				390KRD	WA-03-3100	X	X
INDIAN (BIG) SLOUGH				390KRD	WA-03-3100		X
JOE LEARY SLOUGH				390KRD	WA-03-3000		X
JOE LEARY SLOUGH				390KRD	WA-03-3000	X	X
JOE LEARY SLOUGH				390KRD	WA-03-3000	X	X
JONES CREEK	35N	06E	17	UT72SQ	None9		X
MUD LAKE CREEK	34N	04E	11	IL21OS	None10		X
NOOKACHAMPS CREEK	**34N**	**04E**	**25**	**LZ60MT**	**WA-03-1017**		**X**
NOOKACHAMPS CREEK	**34N**	**04E**	**25**	**LZ60MT**	**WA-03-1017**		**X**
NOOKACHAMPS CREEK	**33N**	**05E**	**8**	**ZZ50GP**	**WA-03-1017**		**X**
NOOKACHAMPS CREEK	**34N**	**04E**	**4**	**LZ60MT**	**WA-03-1017**		**X**
NOOKACHAMPS CREEK	**34N**	**04E**	**14**	**LZ60MT**	**WA-03-1017**		**X**
NOOKACHAMPS CREEK, E.F.	**34N**	**04E**	**11**	**DV97DN**	**WA-03-4200**		**X**
NOOKACHAMPS CREEK, E.F.	**34N**	**05E**	**19**	**FE06WU**	**WA-03-4200**		**X**
OTTER POND CREEK	**34N**	**04E**	**25**	**GK78TY**	**None5**		**X**
RED CREEK	**35N**	**05E**	**17**	**TL30EW**	**None6**		**X**
TURNER CREEK	**34N**	**05E**	**18**	**EI77IQ**	**None12**		**X**
WISEMAN CREEK	35N	05E	27	XZ26WG	None13		X

Water bodies in bold denote 303(d) listings included in the study area.

Separate TMDLs are planned in the future that will address temperature impairments in the sloughs and Mid-Skagit tributaries. These water bodies are not addressed in this TMDL.

Section 303(d) of the federal Clean Water Act mandates that the state establish TMDLs for surface waters that do not meet standards after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has promulgated regulations (40 CFR 130) and developed guidance (EPA 1991) for establishing TMDLs.

Under the Clean Water Act, each state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses. When a lake, river, or stream fails to meet water quality standards, the Clean Water Act requires the state to place the water body on a list of "impaired" water bodies and to prepare an analysis called a TMDL.

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the water body and still meet standards, meet the loading capacity, and allocate that load among the various sources.

If the pollutant comes from a discrete (point) source such as an industrial facility’s discharge pipe, that facility’s share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from a diffuse (nonpoint) source, that portion of the loading capacity is called a *load allocation*. No point sources of heat were found in the lower Skagit study area; therefore, no wasteload allocation was developed.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity. This TMDL addresses both the numeric and narrative condition provisions of the state’s temperature criteria.

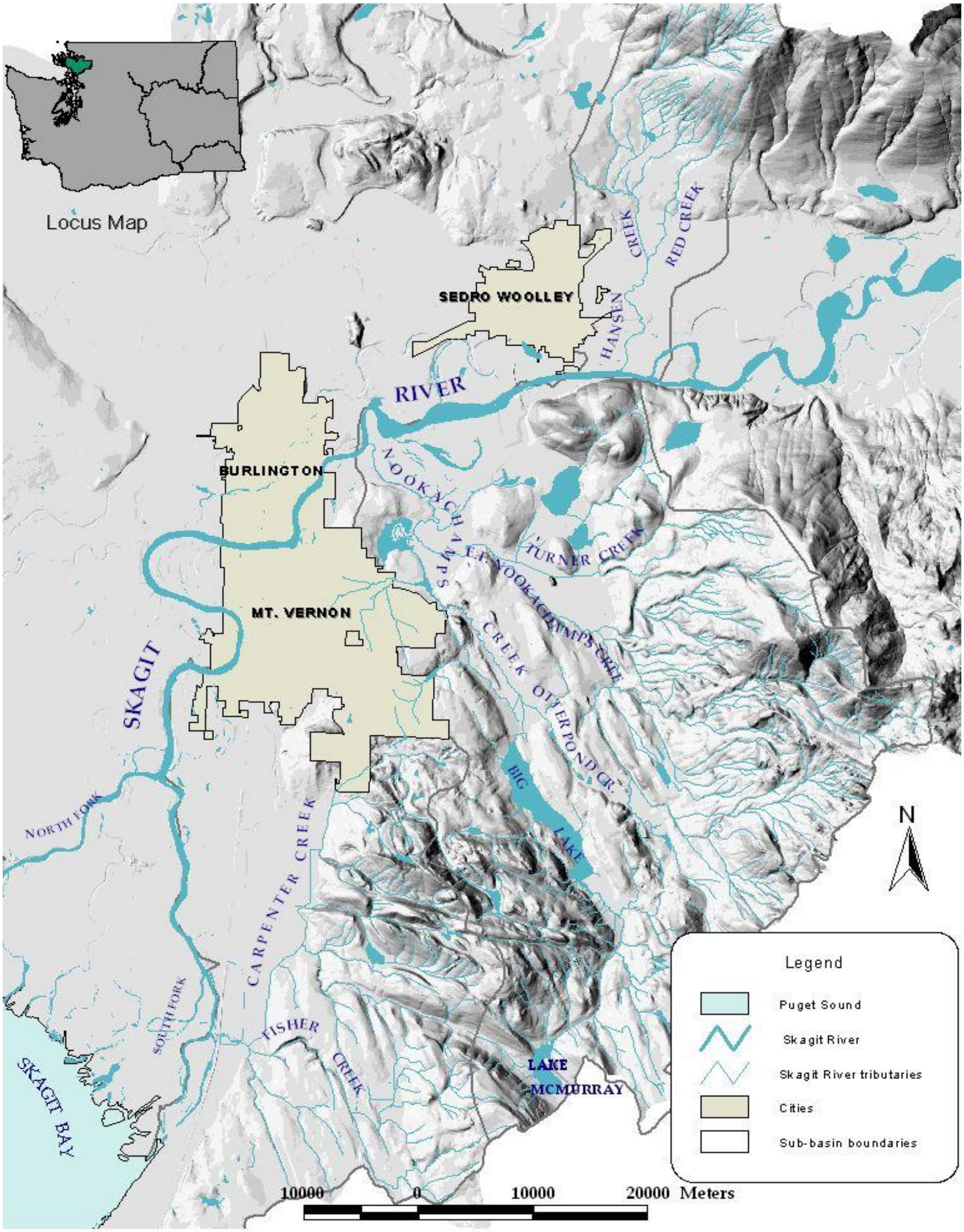


Figure 1. Lower Skagit River study area.

Overview of Stream Heating Processes

At any particular instant of time, a defined stream reach is capable of sustaining a particular water column temperature. A parcel of water traversing a stream/river reach enters that reach with a given temperature. If that temperature is greater than the energy balance is capable of supporting, the temperature will decrease. If that temperature is less than the energy balance is capable of supporting, the temperature will increase. Stream temperature change within a stream segment is induced by the energy balance in the parcel of water that is affected by the surrounding environment during transport of the parcel through the reach. The general relationships between stream parameters, thermodynamic processes (heat and mass transfer), and stream temperature change are outlined in Figure 2.

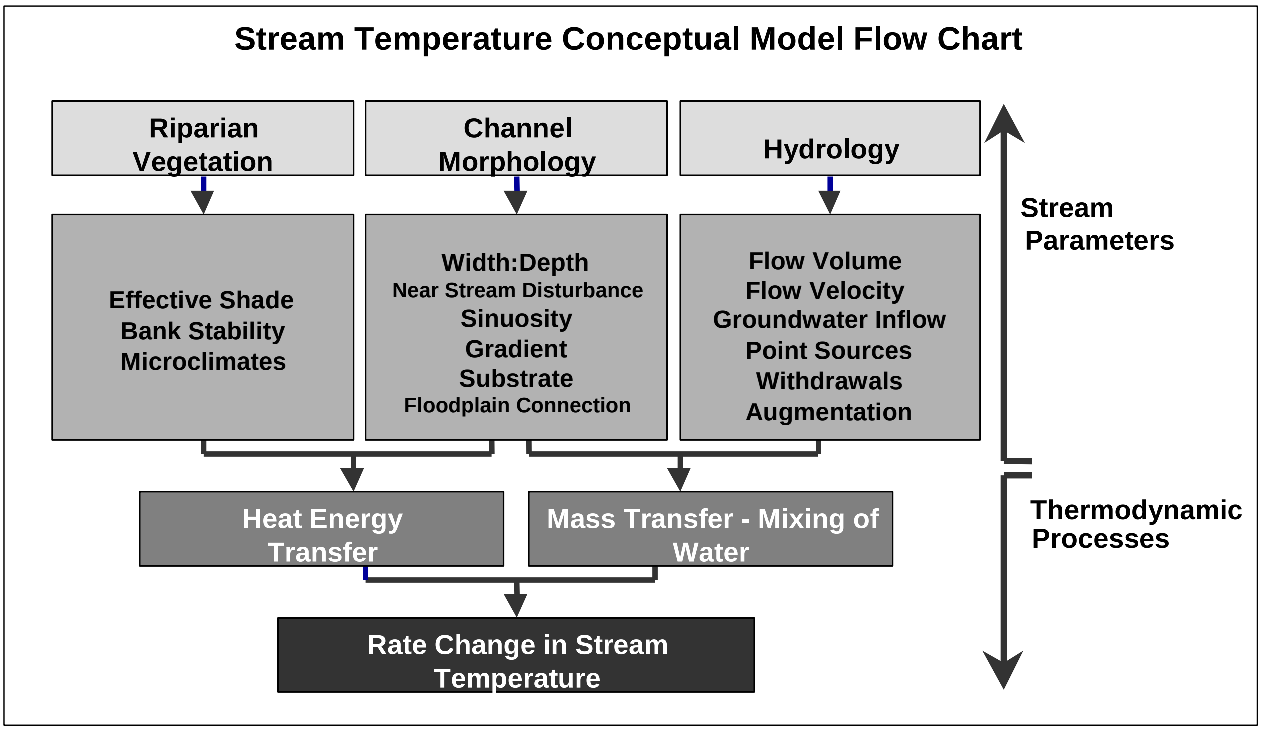


Figure 2. Conceptual model of factors that affect stream temperature.

Adams and Sullivan (1989) reported that the following environmental variables were the most important drivers of water temperature in forested streams:

- *Stream depth.* Stream depth is the most important variable of stream size for evaluating energy transfer. Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.

- *Air temperature.* Daily average stream temperatures are strongly influenced by daily average air temperatures. When the sun is not shining, the water temperature in a volume of water tends to approach the dew-point temperature (Edinger et al. 1974).
- *Solar radiation and riparian vegetation.* Riparian vegetation moderates the amount of solar radiation that reaches the stream channel, thereby dampening seasonal and diel fluctuations in stream temperature (Beschta et al. 1987). The effectiveness of riparian vegetation in providing shade to the stream channel depends on local topography, channel orientation and width, forest composition, and stand age and density (Beschta et al. 1987).
- *Groundwater.* Since groundwater is generally much cooler than the stream temperatures during summer, inflows can have an important depressing effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream, as well as the difference in temperatures between the groundwater and the stream.

Heat Budgets and Temperature Prediction

The transport and fate of heat in natural waters has been the subject of extensive study. Edinger et al. (1974) provide an excellent and comprehensive report of this research. Thomann and Mueller (1987) and Chapra (1997) have summarized the fundamental approach to mathematical modeling of temperature in natural waters that was used in this temperature TMDL analysis. Figure 3 shows the major heat energy processes or fluxes in a heat budget that control temperature changes in a given volume of water. Heat flux between the water and streambed occurs through conduction and hyporheic exchange.

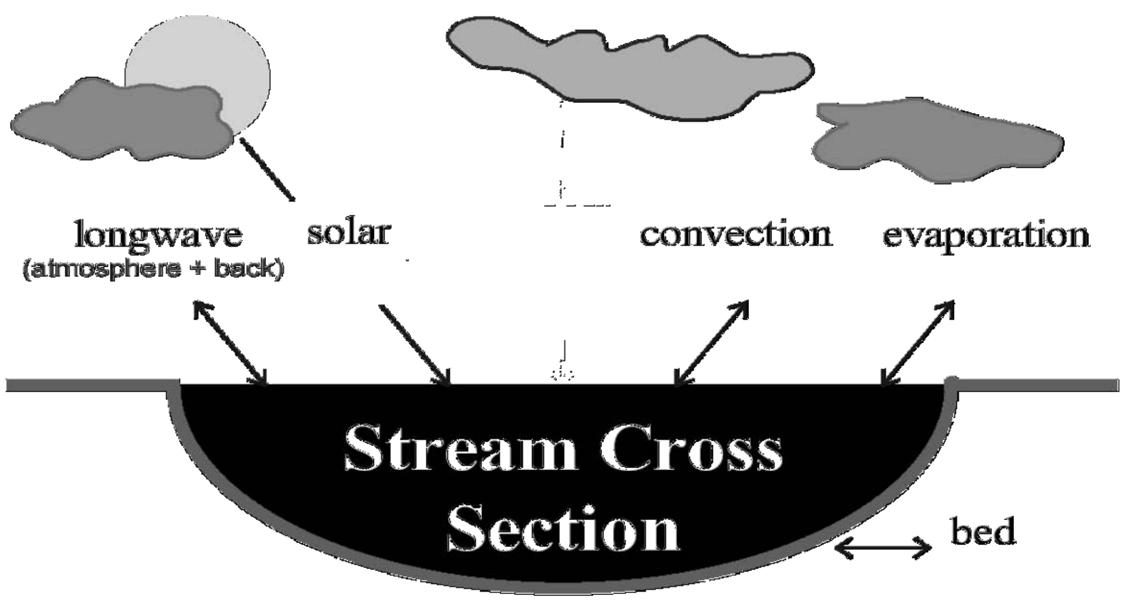


Figure 3. Heat transfer processes in the QUAL2Kw model that affect water temperature. (net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed)

The heat flux components with the greatest magnitude, and therefore the greatest influence on water temperature, are as follows (Edinger et al. 1974):

- *Shortwave solar radiation.* Shortwave solar radiation is the radiant energy which passes directly from the sun to the earth. Shortwave solar radiation is contained in a wavelength range between 0.14 µm and about 4 µm. At NOAA's ISIS station in Seattle, the daily average global shortwave solar radiation for July-August 2001 was 240 W/m^2 (NOAA 2003). The peak values during daylight hours are typically about 3 times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an un-shaded body of water during the day when the sky is clear.

- *Longwave atmospheric radiation.* The longwave radiation from the atmosphere ranges in wavelength range from about 4 µm to 120 µm. Longwave atmospheric radiation depends primarily on air temperature and humidity, and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al. 1974).

- *Longwave back radiation from the water to the atmosphere.* Water sends heat energy back to the atmosphere in the form of longwave radiation in the wavelength range from about 4 µm to 120 µm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from longwave back radiation typically ranges from about 300 to 500 W/m^2 (Edinger et al. 1974).

Figure 4 shows the relative importance of the fluxes in the heat budget at a station near the mouth of Hansen Creek with current riparian vegetation. This figure was derived using Ecology's QUAL2Kw (Ecology 2003b). The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar shortwave heat flux (Adams and Sullivan 1989). The net heat flux into a stream can be managed by increasing the shade from vegetation, which reduces the shortwave solar flux. Other processes, such as longwave radiation, convection, evaporation, bed conduction, or hyporheic exchange, also influence the net heat flux into or out of a stream.

Heat exchange between the stream and the streambed has an important influence on water temperature. The temperature of the streambed is typically warmer than the overlying water at night and cooler than the water during the daylight hours. Heat is typically transferred from the water into the streambed during the day then back into the stream during the night (Adams and Sullivan 1989). This has the effect of dampening the diurnal range of stream temperature variations without affecting the daily average stream temperature.

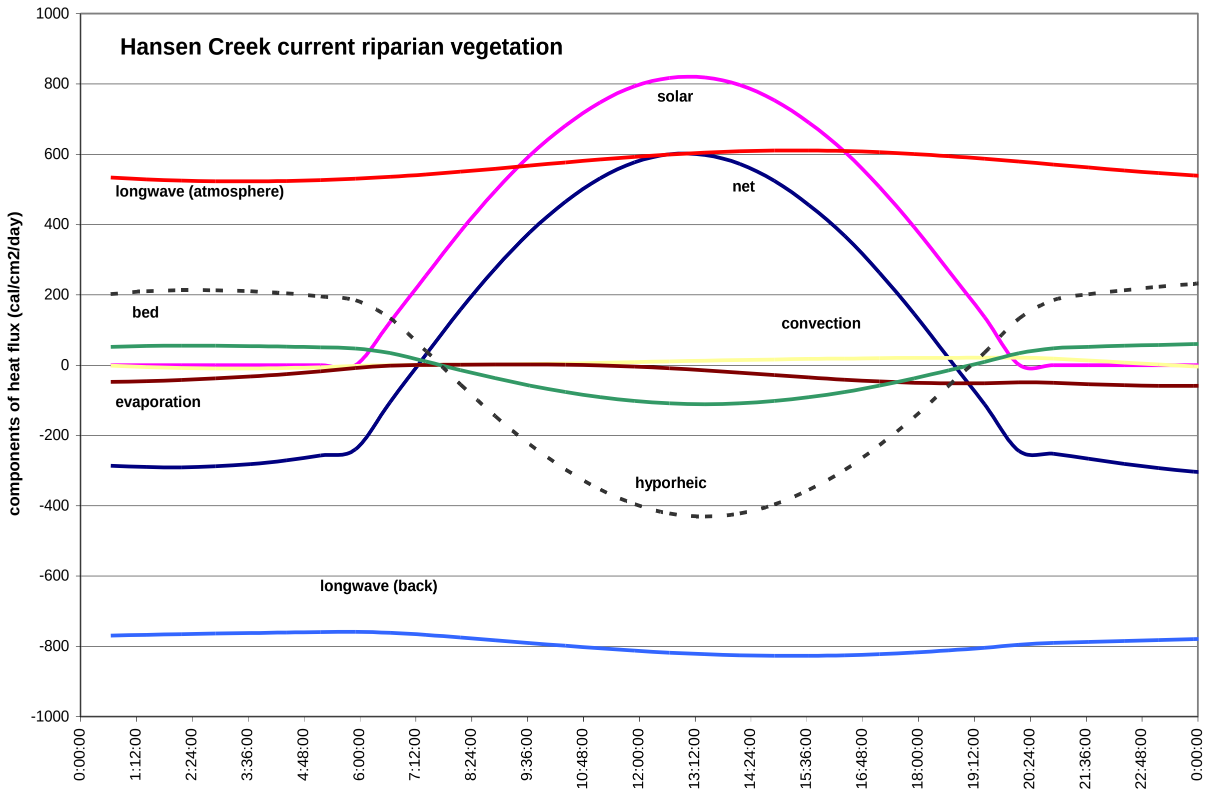


Figure 4. Heat fluxes in Hansen Creek near the mouth under current riparian vegetation conditions and during hottest 7-day air temperatures in 2001. (Net heat flux = solar + longwave atmosphere + longwave back + air convection + evaporation + sediment conduction + hyporheic.)

The bulk temperature of a vertically mixed volume of water in a stream segment under natural conditions tends to increase or decrease with time during the day according to whether the net heat flux is either positive or negative. When the sun is not shining, the water temperature tends toward the dew-point temperature (Edinger et al. 1974; Brady et al. 1969). The equilibrium temperature of a natural body of water is defined as the temperature at which the water is in equilibrium with its surrounding environment, and the net rate of surface heat exchange would be zero. The dominant contribution to the seasonal variations in the equilibrium temperature of water is from seasonal variations in the air temperature and dew-point temperature. The main source of hourly fluctuations in water temperature during the day is solar radiation. Solar radiation at the stream surface generally reaches a maximum during the day when the sun is highest in the sky unless cloud cover or shade from vegetation interferes.

The complete heat budget for a stream also accounts for the mass transfer processes which depend on the amount of flow and the temperature of water flowing into and out of a particular volume of water in a stream segment. Mass transfer processes in open channel systems can occur through advection, dispersion, and mixing with tributaries and groundwater inflows and outflows. Mass transfer relates to transport of flow volume downstream, instream mixing, and the introduction or removal of water from a stream. For instance, flow from a tributary will cause a temperature change if the temperature is different from the receiving water.

Thermal Role of Riparian Vegetation

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation is well documented (e.g., Holtby 1988, Lynch et al. 1984, Rishel et al. 1982, Patric 1980, Swift and Messer 1971, Brown et al. 1971, and Levno and Rothacher 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al. 1992, Beschta et al. 1987, Bolton and Monahan 2001, Castelle and Johnson 2000, CH2MHill 2000, Ice 2001, and Wenger 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. The list of important benefits that riparian vegetation has upon the stream temperature includes:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.

- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.

- Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land cover type and condition by affecting floodplain and instream roughness, contributing coarse woody debris, as well as influencing sedimentation, stream substrate compositions, and stream bank stability.

The warming of water temperatures as a stream flows downstream is a natural process. However, the rates of heating can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. There is a natural maximum level of shade that a given stream is capable of attaining. The importance of shade decreases as the width of a stream increases.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Effective Shade

Shade is an important parameter that controls the stream heating derived from solar radiation. Solar radiation has the potential to be one of the largest heat transfer mechanisms in a stream system. Human activities can degrade near-stream vegetation and/or channel morphology, and in turn, decrease shade. Reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Stream shade is an important factor in describing the heat budget for this TMDL analysis. Stream shade may be measured or calculated using a variety of methods including hemispherical photography, solar pathfinder, and angular canopy densiometer (Chen 1996, Chen et al. 1998a, Ice 2001, OWEB 1999, Teti 2001).

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography above a stream. Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

$$\text{effective shade} = (J_1 - J_2)/J_1$$

where J_1 is the potential solar heat flux above the influence of riparian vegetation and topography and J_2 is the solar heat flux at the stream surface.

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summer months, allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun) (Figure 5). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation (direction of streamflow). Near-stream vegetation height, width, and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e., produce shade) (Table 5). The solar position has a vertical component (i.e., solar altitude) and a horizontal component (i.e., solar azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation.

Table 2. Factors that influence stream shade.

Description	Parameter
Season/time	Date/time
Stream characteristics	**Aspect channel width**
Geographic position	Latitude, longitude
Vegetative characteristics	**Riparian vegetation height, width, and density**
Solar position	Solar altitude, solar zenith

Bold indicates factors influenced by human activities.

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry (Ice 2001, OWEB 1999, Teti 2001). Using solar

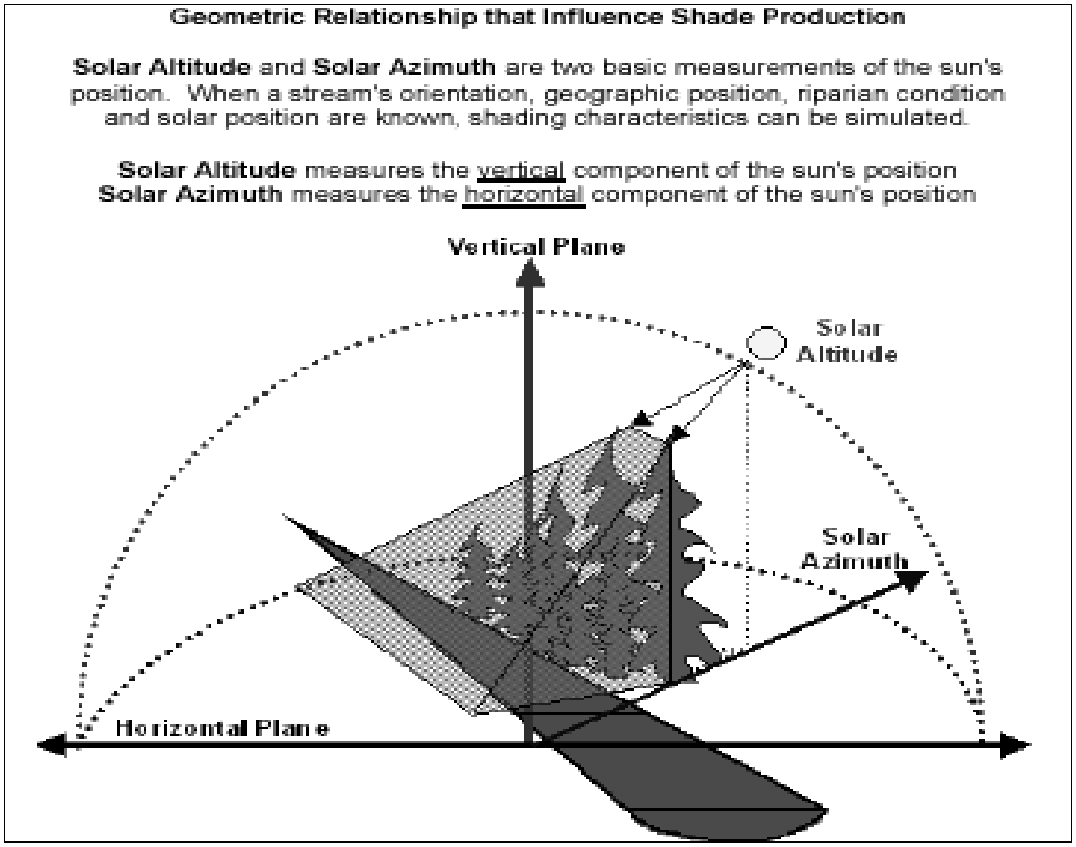


Figure 5. Parameters that affect shade and geometric relationships. Solar altitude is a measure of the vertical angle of the sun's position relative to the horizon. Solar azimuth is a measure of the horizontal angle of the sun's position relative to north.

tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including:

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers provide a good balance of cost and accuracy for measuring the importance of riparian vegetation in preventing increases in stream temperature (Teti 2001, Beschta et al. 1987.) Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the angular canopy density (ACD) is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 A.M. and 2 P.M. in mid to late summer) when the potential solar heat flux is most significant. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80 to 90%.

Computer programs for the mathematical simulation of shade may also be used to estimate shade (Ecology 2002, Chen 1996, Chen et al. 1998b, Boyd 1996, and Boyd and Park 1998).

Riparian Buffers and Effective Shade

Tree retention in riparian areas provides shade to streams and minimizes undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al. 1984). The shading effectiveness, as measured by the ACD of riparian vegetation, can be correlated to riparian area width (Figure 6). ACDs for a given riparian buffer width vary over space and time because of differences among site potential vegetation, forest development stages (e.g., height and density), and stream width. For example, a 50-foot-wide riparian area with fully developed trees could provide from 45 to 72% of the potential shade in the two studies shown in Figure 6.

The Brazier and Brown (1973) shade data show a stronger relationship between ACD and buffer strip width than the Steinblums et al. (1984) data; the r^2 correlation for ACD and buffer width was 0.87 and 0.61 in Brazier and Brown (1973) and Steinblums et al. (1984), respectively. This difference supports the use of the Brazier and Brown curve as a base for measuring shade effectiveness under various riparian buffer proposals. These results reflect the natural variation among old growth sites studied, and show a possible range of potential shade.

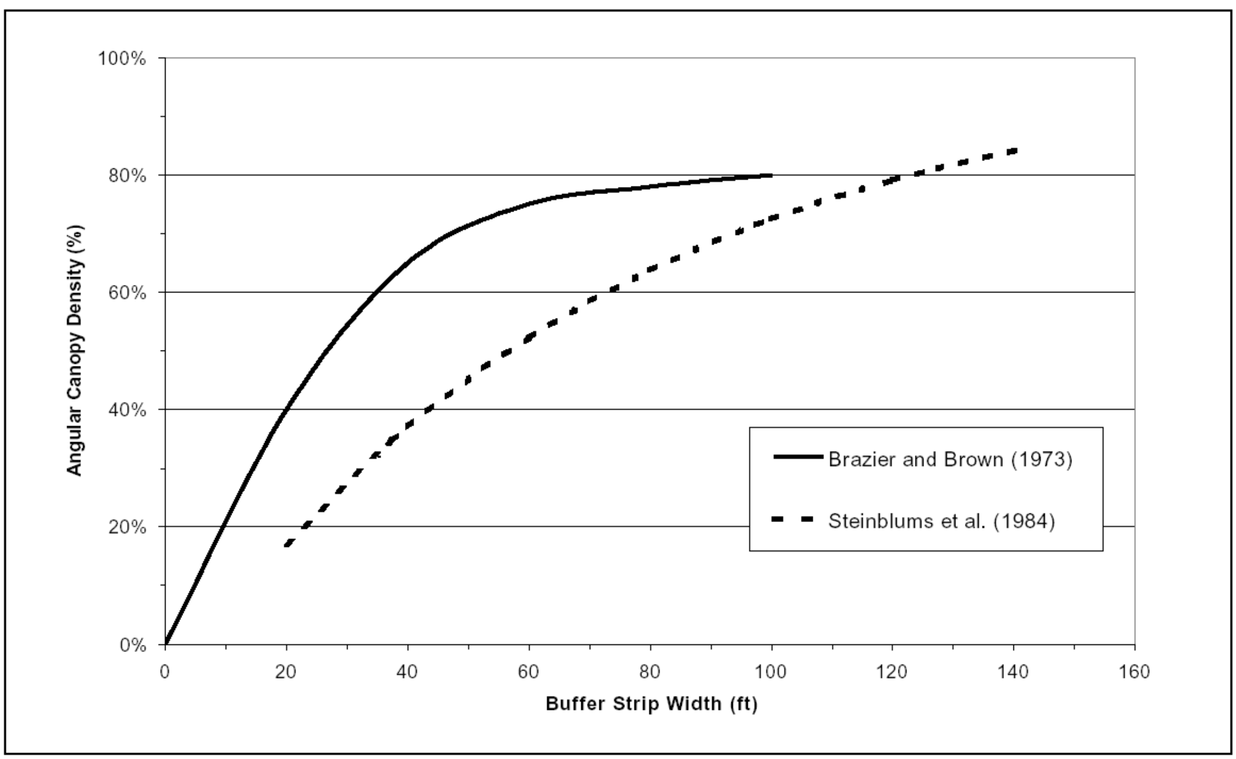


Figure 6. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands (Beschta et al. 1987, CH2MHill 2000).

Several studies report that most of the potential shade comes from the riparian area within about 75 feet (23 m) of the channel (CH2MHill 2000, Castelle and Johnson 2000):

- Beschta et al. (1987) report that a 98-foot-wide (30-m) buffer provides the same level of shading as that of an old-growth stand.
- Brazier and Brown (1973) found that a 79-foot (24-m) buffer would provide maximum shade to streams.
- Steinblums et al. (1984) concluded that a 56-foot (17-m) buffer provides 90% of the maximum ACD.
- Corbett and Lynch (1985) concluded that a 39-foot (12-m) buffer should adequately protect small streams from large temperature changes following logging.
- Broderson (1973) reported that a 49-foot-wide (15-m) buffer provides 85% of the maximum shade for small streams.
- Lynch et al. (1985) found that a 98-foot-wide (30-m) buffer maintains water temperatures within 2°F (1°C) of their former average temperature.

Steinblums et al. (1984) found that shade could be delivered to streams from beyond 75 feet and potentially out to 140 feet. In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively low because the potential solar radiation decreases significantly as solar elevation decreases.

Microclimate - Surrounding Thermal Environment

A secondary consequence of near-stream vegetation is its effect on the riparian microclimate. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity, and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures by decreasing daily maximum and increasing daily minimum air temperatures. Increases in relative humidity result from evapotranspiration that is occurring by riparian plant communities. Wind speed is reduced by the physical blockage produced by riparian vegetation.

Riparian buffers commonly occur on both side of the stream, compounding the edge influence on the microclimate. Brosofske et al. (1997) reported that a buffer width of at least 150 feet (45 m) on each side of the stream was required to maintain a natural riparian microclimate environment in western Washington forests with predominantly Douglas-fir and western hemlock. Ledwith (1996) recommended that a minimum buffer width of 30 m was required to avoid significantly altering the microclimate of a riparian zone.

Bartholow (2000) provided a thorough literature summary of documented changes to the environment of streams and watersheds associated with extensive forest clearing. Changes summarized by Bartholow (2000) are representative of hot summer days and indicate the mean daily effect unless otherwise indicated:

- *Air temperature.* Edgerton and McConnell (1976) showed that removing all or a portion of the tree canopy resulted in cooler terrestrial air temperatures at night and warmer temperatures during the day, enough to influence thermal cover sought by elk (Cervus canadensis) on their eastern Oregon summer range. Increases in maximum air temperature varied from 5 to 7ºC for the hottest days (estimate). However, the mean daily air temperature did not appear to have changed substantially since the maximum temperatures were offset by almost equal changes to the minima. Similar temperatures have been commonly reported (Childs and Flint 1987; Fowler et al. 1987), even with extensive clearcuts (Holtby 1988). In an evaluation of buffer strip width, Brosofske et al. (1997) found that air temperatures immediately adjacent to the ground increased 4.5ºC during the day and about 0.5ºC at night (estimate). Fowler and Anderson (1987) measured a 0.9ºC air temperature increase in clearcut areas, but temperatures were also 3ºC higher in the adjacent forest. Chen et al. (1993) found similar (2.1ºC) increases. All measurements reported here were made over land instead of water, but in aggregate support about a 2ºC increase in ambient mean daily air temperature resulting from extensive clearcutting.

- *Relative humidity.* Brosofske et al. (1997) examined changes in relative humidity within 17 to 72 m buffer strips. The focus of their study was to document changes along the gradient from forested to clearcut areas, so they did not explicitly report pre- to post-harvest changes at the stream. However, there appeared to be a reduction in relative humidity at the stream of 7% during the day and 6% at night (estimate). Relative humidity at stream sites increased exponentially with buffer width. Similarly, a study by Chen et al. (1993) showed a decrease of about 11% in mean daily relative humidity on clear days at the edges of clearcuts.

- *Wind speed.* Brosofske et al. (1997) reported almost no change in wind speed at stream locations within buffer strips adjacent to clearcuts. Speeds quickly approached upland conditions toward the edges of the buffers, with an indication that wind actually increased substantially at distances of about 15 m from the edge of the strip, and then declined farther upslope to pre-harvest conditions. Chen et al. (1993) documented increases in both peak and steady winds in clearcut areas; increments ranged from 0.7 to 1.2 m/s (estimated).

Chen (1991) reported that soil and air temperatures, relative wind speed, humidity, soil moisture, and solar radiation all changed with increasing distance from clear-cut edges in upslope forests of the western Cascades. Based on Chen's results, the Forest Ecosystem Management Assessment Team (FEMAT 1993) concluded that loss of upland forests likely influences conditions within the riparian zone. FEMAT also suggested that riparian buffers necessary for maintaining riparian microclimates need to be wider than those for protecting other riparian functions (Figure 7).

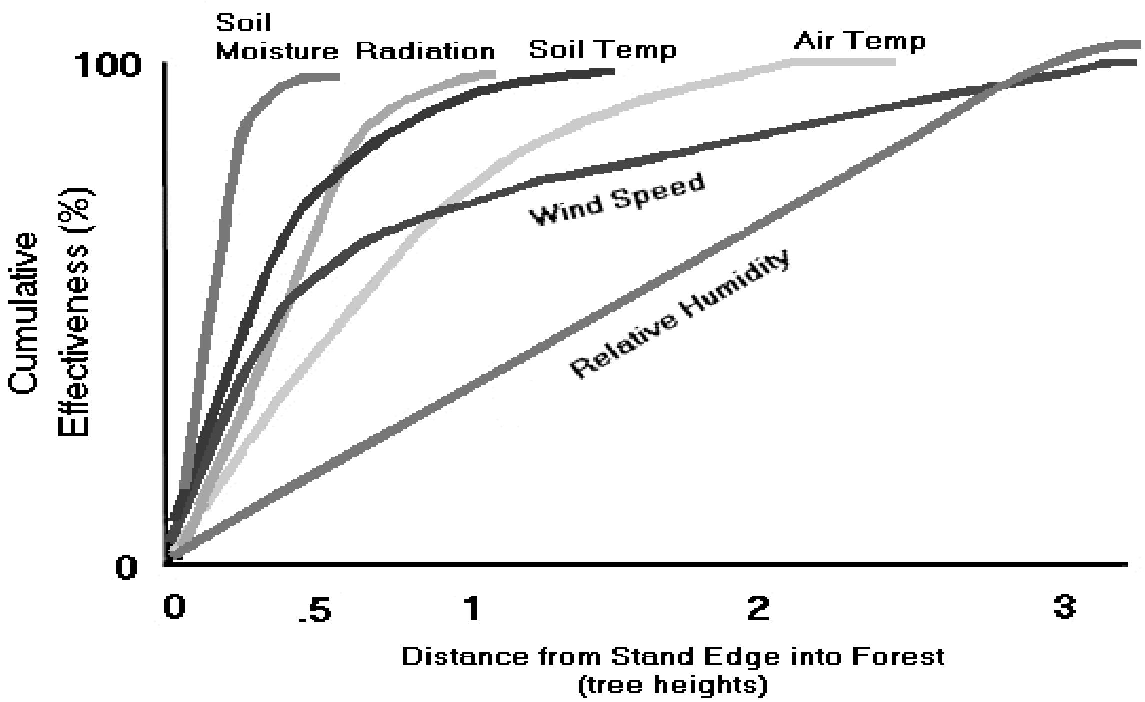


Figure 7. Riparian buffer effects on microclimate (FEMAT 1993).

Thermal Role of Channel Morphology

Channel widening (increased width-to-depth ratios) increases the stream surface area exposed to heat energy processes. In addition, wide channels are likely to have decreased levels of shade due to the increased distance created between vegetation and the wetted channel. Conversely, narrow channels are more likely to experience higher levels of shade. Riparian vegetation contributes to channel stability by increasing roughness and dissipating the erosive energies of higher flows.

Channel widening is often related to degraded riparian conditions that allow increased streambank erosion and sedimentation of the streambed, both of which correlate strongly with riparian vegetation type and condition (Rosgen 1996). Channel morphology is not solely dependent on riparian conditions. Sedimentation can deposit material in the channel, fill pools, and aggrade the streambed, reducing channel depth and increasing channel width.

Channel modification usually occurs during high-flow events. Land uses that affect the magnitude and timing of high-flow events may negatively impact channel width and depth. Riparian vegetation conditions will affect the resilience of the streambanks/floodplain during periods of sediment introduction and high flow. Disturbance processes may have differing results depending on the ability of riparian vegetation to shape and protect channels. Channel morphology is related to riparian vegetation composition and condition by:

- *Building streambanks:* Trapping suspended sediments, encouraging deposition of sediment in the floodplain, and reducing incoming sources of sediment.

- *Maintaining stable streambanks:* Preventing streambank erosion by high rooting strength and high streambank and floodplain roughness.

- *Reducing flow velocity (erosive kinetic energy):* Supplying large woody debris to the active channel, high pool:riffle ratios, and adding channel complexity that reduces shear stress exposure to stream bank soil particles.

Channel straightening, diking, and dredging are all undertaken to prevent the lateral movement of stream channels and increase channel efficiency. These activities focus the erosive energy of streams toward the middle of the channel, encouraging downcutting (National Research Council 1996), and ultimately decreasing the interaction of stream channels with their floodplain in all but extreme flood events. This loss of connectivity between the channel and floodplain can occur through one or all of the following mechanisms:

- Since engineered channels carry water more efficiently, both the amount of time floodwaters spend on the floodplain and the surface area inundated are reduced during average annual high-flow events. This action reduces the opportunity for floodwaters to penetrate the alluvial aquifer and, in turn, decreases baseflow by reducing groundwater discharge during the low-flow season (Steiger et al. 1998).
- Engineered channels reduce the heterogeneity in channel pattern and topography, thereby reducing hyporheic flow (Jurajda 1995).

In summary, channel modifications sever the linkages between the channel and the floodplain, thereby reducing groundwater buffering of streamflow and temperature (Ward 1998) as well as eliminating interactions between the channel and riparian zone that would insulate the stream from exchange of heat with the atmosphere.

Water Withdrawals and Stream Temperature

Water withdrawals reduce instream flow and therefore reduce the assimilative capacity of streams (Dauble 1994). Although some of this water is eventually returned to the stream, the fraction is typically low. Solley et al. (1993) estimated that only one-third of the water withdrawn in the Pacific Northwest was returned to lakes and streams. Additionally, water withdrawn from the river or stream is often at a markedly different temperature than it was when withdrawn, thereby affecting the heat load to the stream. Water withdrawals in the Skagit River study area are typically used for agriculture, with maximum withdrawals occurring during the hottest summer months.

Reductions in instream flows also can reduce the magnitude of hyporheic flow. For hyporheic flow to act as a temperature buffer, differential storage of heat and water over time must occur. Differential heat and water storage is driven by variations in stream temperature and flow. Since flow regulation dampens variation in both flow and temperature, the potential for hyporheic exchange to act as a temperature buffer is reduced by flow regulation (Poole et al. 2000).

Summary of the Pathways of Human Influence on Stream Temperature

Riparian vegetation, stream morphology, hydrology, climate, and geographic location all influence stream temperatures. While climate and geographic location are outside of human control, riparian condition, channel morphology, and hydrology are affected by human activities.

Human activities can affect water temperature in stream channels by changing the timing or magnitude of the amount of (1) heat delivered to the channel or (2) water delivered to the channel (flow regime). Figure 8 summarizes the web of pathways by which temperature may be increased in stream channels.

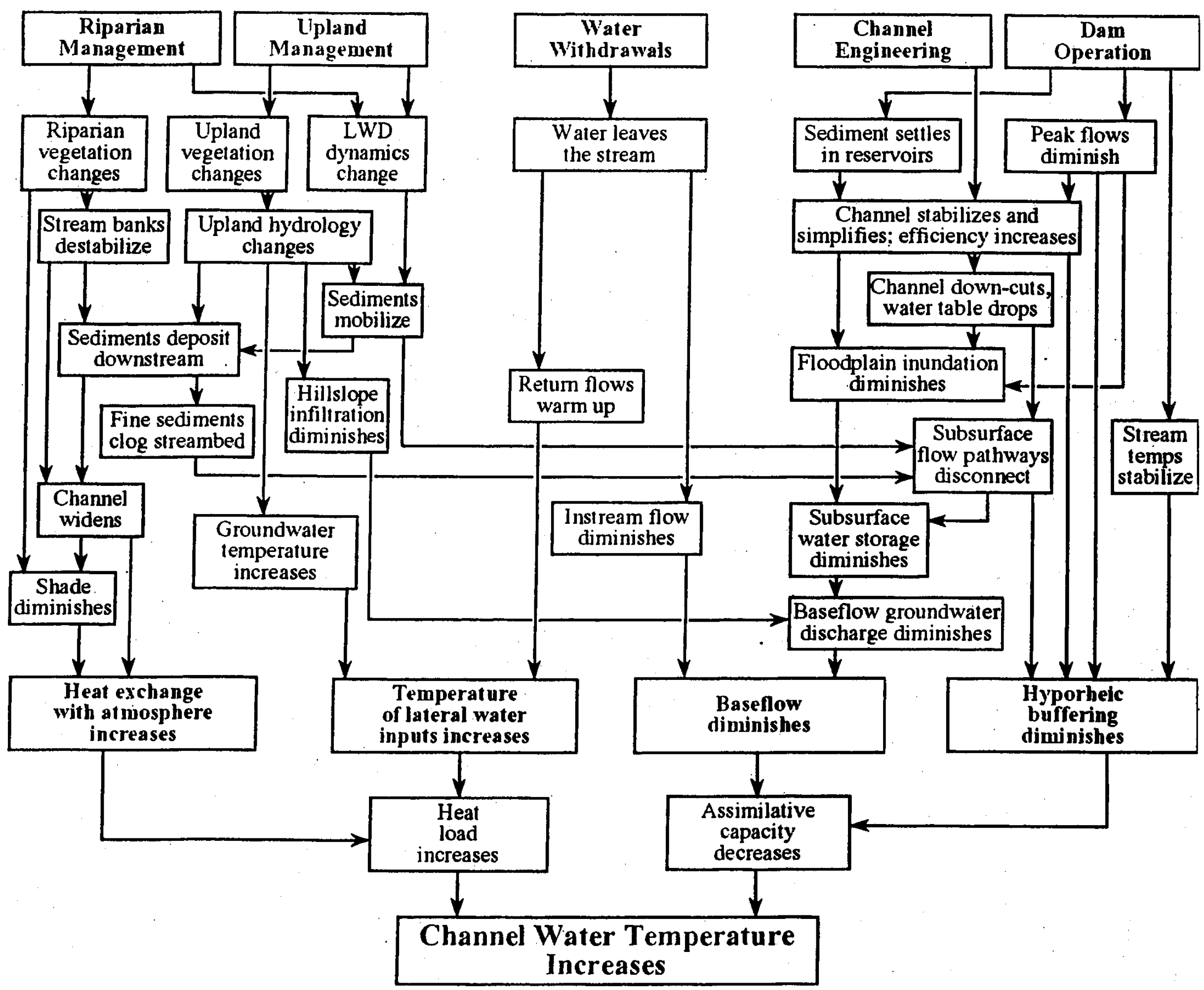


Figure 8. Pathways of human influence on water temperatures in stream channels (Poole et al. 2000).

Pollutants and Surrogate Measures

Heat loads to the stream are calculated in this TMDL study in units of calories per square centimeter per day or watts per square meter. However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems.

This TMDL incorporates measures other than "daily loads" to fulfill the requirements of Section 303(d). This TMDL allocates other appropriate measures or "surrogate measures" as provided under EPA regulations [40 CFR 130.2(i)]. The "Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program" (EPA 1998) includes the following guidance on the use of surrogate measures for TMDL development:

"When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not."

This technical assessment for the lower Skagit River tributaries temperature TMDL uses riparian shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Effective shade accounts for the interception of solar radiation by vegetation and topography.

A decrease in shade due to inadequate riparian vegetation causes an increase in solar radiation and thermal load upon the affected stream section. Other factors influencing the distribution of the solar heat load were also considered, including changes in the width-to-depth ratios.

Channel width is evaluated in this TMDL as a function of stream effective shade production. It is expected that the establishment and maintenance of site potential riparian vegetation will promote channel recovery by decreasing channel widths, increasing channel depths, and increasing channel complexity.

This page is purposely left blank

Background

The Skagit River basin covers most of Skagit County and the northeastern and eastern parts of Snohomish and Whatcom counties, respectively, and extends northward into Canada. The basin encompasses approximately 6,138 km^2 (2,370 mi^2). The Skagit River originates in British Columbia, flows through Ross Lake which extends a short distance across the international boundary, and continues in a southwestward path to empty into Skagit Bay below Mount Vernon. The river contributes approximately one-third of the total freshwater discharge to Puget Sound.

The major sub-basins in the Skagit River are the Upper Skagit, Baker, Cascade, Sauk, and Lower Skagit.

Carpenter, Turner, Otter Pond, Red, Fisher, Hansen, Lake, Nookachamps, and East Fork Nookachamps creeks are all temperature-impaired tributaries to the Skagit River in the 520 km^2 of the lower Skagit basin. These creeks are addressed in this TMDL study (Figure 1).

The lower Skagit River, its tributaries, sloughs, and estuaries serve as important migration corridors, spawning areas, and rearing areas for five major species of salmon (chinook, coho, pink, chum, and sockeye), as well as steelhead and cutthroat trout (Entranco 1993). The Skagit River watershed contains the second largest wild run of coho salmon and the largest run of chinook salmon in the Puget Sound watershed.

The climate in the lower Skagit basin is mild with cool, dry summers and mild, wet winters. Mean annual precipitation ranges from 71 to 107 cm per year, increasing from west to east (USDA 1981). The majority of annual precipitation occurs between October and March.

Small farms and rural residential development dominate the lowland portion of the basin. Agricultural land use dominates in the western portion of the basin, largely supporting cropland and pasture. The eastern uplands are predominantly forestland, with some scattered residential development. An extensive drainage network exists in the agricultural portions of the study area, and many of the water bodies addressed in this study have been diked, dredged, or otherwise channelized. This has resulted in extensive segments with little or no channel complexity and reduced riparian vegetation.

Lower elevation forests (< 700m) are within the western hemlock zone (Franklin and Dyrness 1973). Dominant conifer species in these forests are western hemlock, Douglas-fir, western red cedar, and Sitka spruce. Deciduous trees include red alder, black cottonwood, and big leaf maple. Middle elevation forests (700-1300m) are in the silver fir zone.

Skagit County's population is currently estimated at 103,478 and is projected to grow to about 137,478 by the year 2015 (Skagit County OFM 2003), an increase of 33%. Such rapid growth would be expected to put considerable pressure on the county's natural resources, including potential impacts to surface water quality and quantity.

The Study Area

Carpenter-Fisher Creek Sub-basin

The Carpenter Creek and Fisher Creek drainages are located in southern Skagit County, southeast of the city of Mount Vernon, with a small portion covering northern Snohomish County. The basin topography ranges from a flat-lying alluvial plain (Skagit plain) in the westernmost portion of the basin, low rolling hills to the south (lowland), and rugged upland foothills to the east and northeast (uplands). Basin surface elevations range from approximately 2 to 520 meters above mean sea level.

The Carpenter Creek mainstem occupies the northern half of the basin, draining towards the south. The portion of the Carpenter Creek mainstem that flows across the Skagit plain has been diked and channelized adjacent to the base of the uplands, and is known as Hill Ditch. Hill Ditch is maintained by Skagit County Dike District #3. Tributaries feeding both mainstem Carpenter Creek and Hill Ditch drain largely from the east. Elevated stream temperatures in Carpenter Creek are located primarily in Hill Ditch. Flow in Hill Ditch is fairly sluggish, and there is little riparian vegetation to shade the wide and shallow channel.

The Fisher Creek mainstem drains towards the northwest and is fed by several smaller tributaries that drain the lower elevation hills of the southern and southeastern lowlands. Fisher Creek flows through alternating sections of forest and agricultural lands.

The confluence of Fisher and Carpenter creeks is located approximately 0.8 km east of the South Fork of the Skagit River. The combined drainage area for the two creek systems is approximately 65 km^2. Those portions of the drainage area with an elevation less than the local mean high-water mark may be routinely influenced by the tide (Pitz et al. 2000).

Land use in the Carpenter-Fisher basin consists mostly of a mixture of rural and agricultural uses. Agricultural uses include dairy farming operations, small farm and other livestock operations, and some pastureland. Riparian vegetation is sparse in several areas of the watershed.

Hansen Creek Sub-basin

The Hansen Creek watershed lies in northwestern Skagit County, draining an area of approximately 35 km^2 and flowing from its headwaters in the Lyman Hill area south to its confluence with the Skagit River near Sedro Woolley. Red Creek is the major tributary to Hansen Creek, with several smaller tributaries entering just above the Northern State Recreation Area.

Land use in the Hansen Creek watershed consists mostly of a mixture of forestry, rural, and agricultural uses. Agricultural uses include dairy farming operations, small farm and other livestock operations, and some pastureland. Timber harvesting occurs in the upper reaches of the watershed and is most concentrated in the Lyman Hill area.

The headwater sections of Hansen Creek have been extensively logged, and large amounts of sediment from landslides have filled in the lower portions of the creek (Skagit County 2002). The watershed is forested from just below Lyman Hill to the Northern State Recreational Area; the remainder of Hansen Creek flows through extensive areas with little or no riparian vegetation. Long-term dredging has resulted in the creek's thalweg becoming raised above the level of the surrounding ground and contained within dredge spoils that act as small dikes, allowing little opportunity for surface water to drain back into the creek during flood events. The dredging has also contributed to the wide and shallow channel, which increases the surface area available to solar radiation (Skagit County 2002).

Historically, the Hansen Creek watershed was used by large numbers of several salmon species, including Puget Sound chinook, and bull trout, both currently listed as "threatened" under the Endangered Species Act (Skagit County 2002). The watershed still supports salmon runs; however, the runs are greatly reduced from historic numbers, in part from lack of woody debris and associated pools for refuge, lack of sufficient riparian cover to provide shade, increased sediment load from upstream sources, and decreased floodplain and wetland areas (Skagit County 2002).

Skagit County has several Sub Flood Control Zones (SFCZs), established pursuant to RCW 86.15. The purpose of these self-taxing districts is to provide for flood control in small to medium watersheds. Hansen Creek is included in one of these SFCZs. The county is responsible for conducting flood control activities prescribed by these zones on behalf of the residents of the zones. The county will apply reasonable best management practices for flood control activities in an effort to comply with TMDL recommendations. However, anytime this flood control responsibility conflicts with TMDL recommendations for SFCZs, reasonable accommodation for flood control activities must be allowed and take precedence.

Nookachamps Creek Sub-basin

The Nookachamps Creek watershed is located in south-central Skagit County and drains approximately 210 km^2, making it the largest sub-basin in the study area. High elevations and rugged terrain border the Nookachamps basin on both the east and west sides, while the northern boundary of the watershed is defined by almost 14 miles of the Skagit River. Devils Mountain to the west divides the Nookachamps watershed from the Carpenter-Fisher Creek drainage. Through the Nookachamps Valley, elevations range from 48 m at Lake McMurray to approximately 15 m at the Skagit River. Surface waters in the watershed include approximately 320 kilometers of creeks and streams, including Lake, East Fork Nookachamps, Turner, and Otter Pond creeks. The Nookachamps Creek watershed is the first important salmon-producing tributary in the Skagit River and provides key habitat for a successful wild Coho stock (Skagit County Dept. of Planning 1995).

Lake Creek flows from the outlet of Lake McMurray south to Big Lake. Water from Big Lake discharges into Nookachamps Creek, which flows approximately 11 km through mostly agricultural lands, before its confluence with the Skagit River midway between the cities of Mount Vernon and Sedro Woolley. Nookachamps Creek forks near Barney Lake just south of the mainstem Skagit River. This branch, referred to as the East Fork of Nookachamps Creek, is formed by tributary streams descending from Cultus Mountain. The main tributaries to East Fork Nookachamps Creek are Day Creek, Turner Creek, Mundt Creek, and Walker Creek.

Most of the Nookachamps Creek watershed supports forestry (14,500 hectares) and agriculture (3,640 hectares) (Skagit County Dept. of Planning 1995). Forest lands account for almost 70% of the total watershed area with approximately 4,860 hectares owned and managed by the Washington State Department of Natural Resources. The remaining forest land, approximately 9,800 hectares, is privately owned.

Agricultural uses are found mostly throughout the floor of the Nookachamps Valley from Lake McMurray to the Skagit River. The majority of the lower sections of both Nookachamps Creek and East Fork Nookachamps Creek have been extensively channelized and diked, which has resulted in wide shallow channels with little riparian vegetation. Lake McMurray, a shallow lake (< 2 m at outlet) comprises the headwaters of Lake Creek. Summer outflow temperatures frequently exceed the Class A standard for temperature. Big Lake, a shallow lake (< 2 m at outlet) comprises the headwaters of Nookachamps Creek. Summer outflow temperatures frequently exceed the Class A standard for temperature.

Land Use in the Study Area

Land use in the study area is a mixture of agriculture, urban, suburban, and forestland (Figure 9). Digital orthophotos (Figures 10-12) show the matrix of land uses in each sub-basin. These images provide a good perspective of stream temperature issues within the study area, as they relate to land use, specifically riparian shade. Stream segments lacking substantial riparian areas or those reaches that have been diked or channelized are clearly visible.

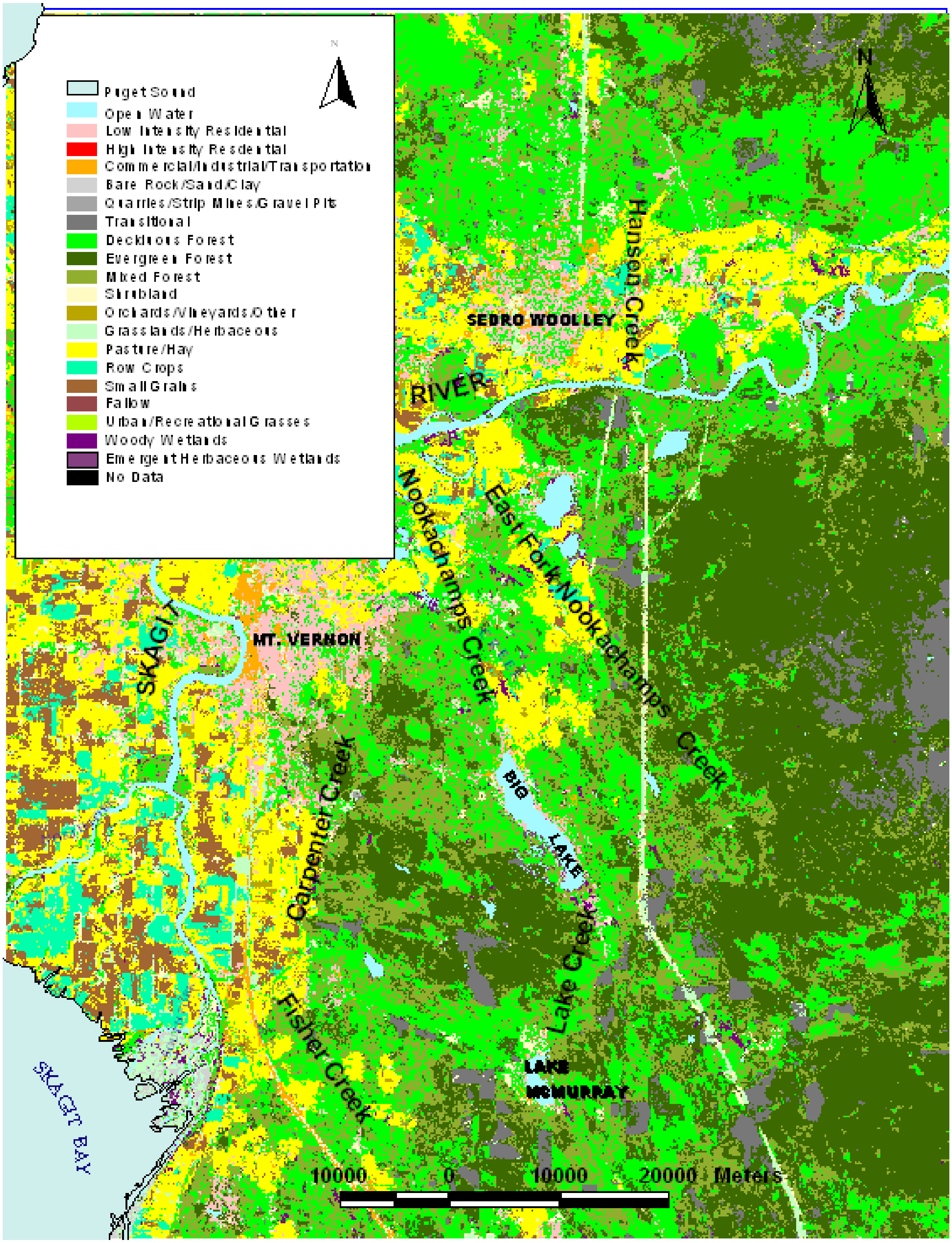


Figure 9. Generalized land use within the study area (1997).

Figure 10. Landsat image of Carpenter and Fisher Creek study area showing a matrix of land uses (1991).

Figure 11. Landsat image of Hansen Creek sub-basin showing a matrix of land uses (1991).

Figure 12. Landsat image of Nookachamps sub-basin showing a matrix of land uses (1991).

Fisheries Resources

Fisheries resources in the study area include both anadromous and resident fish. Table 3 shows the stream type classifications for streams in the study area. Stream type classifications are designated by the Washington State Department of Natural Resources established under WAC 222-16-031.

Table 3. Stream type classifications in lower Skagit River study area.

Creek Name	Stream Type *
Carpenter	**2**
Fisher	**2**
Hansen	**2**
Red	3
Lake	**1,2**
Otter Pond	3
Nookachamps	**1**
East Fork Nookachamps	**1**,2,3,4
Turner	3,4

* Stream type in bold indicates stream type of modeled segment.

Type 1- All waters inventoried as "Shorelines of the State"

Type 2- Segments of natural waters which are not classified as Type 1 water and have a high fish, wildlife, or human use and which are used for fish spawning, rearing, or migration, and used by fish for off-channel habitat.

Type 3- Segments of natural waters which are not classified as Type 1 or 2 and have a moderate to slight fish, wildlife, and human use and which are used by fish for spawning, rearing, or migration.

Type 4- Segments of natural waters within the bankfull width of defined channels that are perennial non-fish habitat streams.

The Nookachamps system, which includes the East Fork, Lake, Otter Pond, and Turner creeks produces several species of anadromous fish, including coho salmon, chum salmon, chinook salmon, pink salmon, steelhead trout, a small run of sockeye salmon, and sea-run cutthroat trout (Skagit County Dept. of Planning 1995). The most successful anadromous species in the watershed is coho salmon, which is able to use most of the stream systems within the study area. The Nookachamps Creek watershed is a good producer of steelhead and cutthroat trout (Skagit County Dept. of Planning 1995).

The remainder of the creeks within the study area also produce, to varying degrees, several species of anadromous fish, including coho, chum, chinook, and pink salmon, as well as steelhead and sea-run cutthroat trout.

In addition to anadromous resources, streams within the study area also support a variety of resident fish, including rainbow trout, cutthroat trout, bass, perch, crappie, brown trout, bullhead, sculpin, lamprey, and whitefish. Stream temperatures in the lower Skagit River tributaries are of particular concern because of their use by Puget Sound chinook, a species listed as threatened under the Endangered Species Act, as a migration corridor and as spawning and rearing habitat.

Salmonid Stream Temperature Requirements

Many Pacific salmon (*Oncorhynchus spp.*) stocks in the Pacific Northwest are currently listed under the Endangered Species Act because of dramatic population declines in the past few decades. The causes of decline are many and vary within different watersheds; however, virtually all declines are at least partly attributed to changes in freshwater habitat conditions (Spence et al. 1996). In many watersheds, habitat and fishery managers view increases in summer maximum stream temperature as a significant source of mortality for juveniles during their freshwater life history stages (Hicks et al. 1991).

Water temperature plays an important role in regulating biological and ecological processes in aquatic systems. Virtually all biological and ecological processes are affected by ambient water temperature. Below is a list of some of the more important physiological and ecological processes affected by temperature (Spence et al. 1996).

- Decomposition of organic materials
- Metabolism of aquatic organisms, including fishes
- Food requirements, appetite, and digestion rates of fishes
- Growth rates of fish
- Developmental rates of embryos and alevins
- Timing of life-history events including adult migrations, fry emergence, and smoltification
- Competitor and predator-prey interactions
- Disease-host and parasite-host relationships
- Development rate and life history of aquatic invertebrates

Salmonids use a variety of habitats during their life histories. Anadromous species in particular have complex life histories that involve periodic shifts in habitat (Spence et al. 1996). Depending on the species or stock, freshwater streams, lakes, or intertidal sloughs may be used for reproduction; streams, lakes, estuaries, or oceans may be used for juvenile rearing. For all anadromous species, habitats between spawning streams and the ocean are required for upstream and downstream migrations.

Differences in spatial and temporal use of specific habitats exist for each species, yet the diversity among species and by life stage indicates that most freshwater habitats are used year round (Spence et al. 1996). To persist, each species or stock must be able to survive within the entire range of habitats encountered during its life; degradation or alteration of habitat required at any life stage can limit production. Much of the available information on salmonid habitat requirements has been summarized in reviews by Bell (1986), Everest et al. (1985), and Bjornn and Reiser (1991).

A brief summary of the importance of water temperatures to salmonids during adult migration, spawning, and incubation, and juvenile and adult rearing is provided below. Table 4 provides a summary of tolerable and preferred temperature ranges for adult migration, spawning, and incubation of native salmonids. An extensive review of studies examining the temperature requirements of salmonid species during specific life histories is provided by Hicks (2001).

Adult Migration

Most adult salmonids typically migrate at temperatures less than 14°C; however, summer and fall chinook salmon migrate during periods when temperatures are substantially warmer (Spence et al. 1996). Excessively high or low temperatures may result in delays in migration (Hallock et al. 1970; Monan et al. 1975). Adult steelhead that move from the ocean into river systems in the summer and fall may overwinter in larger rivers, delaying entry into smaller spawning tributaries until they are free of ice in the spring. Similarly, spring-spawning resident salmonids, including cutthroat and rainbow trout, may hold at the mouths of spawning streams until temperatures warm up to the preferred temperature range (Bjornn and Reiser 1991). In addition to delaying migration, excessively high temperatures during migration may cause outbreaks of disease.

Table 4. Tolerable and preferred temperature ranges (°C) for adult migration, spawning, and incubation of embryos for native salmonids in the Pacific Northwest (Bjornn and Reiser 1991).

Species	Life Stage		
	Spawning Migration (min - max)	Spawning (preferred range)	Incubation (preferred range)
ANADROMOUS			
Pink salmon	7.2 - 15.6*	7.2 - 12.8*	4.4 - 13.3*
Chum salmon	8.3 - 15.6*	7.2 - 12.8*	4.4 - 13.3*
Coho salmon	7.2 - 15.6*	4.4 - 9.4*	4.4 - 13.3*
Sockeye salmon	7.2 - 15.6*	10.6 - 12.2*	4.4 - 13.3*
Spring chinook	3.3 - 13.3*	5.6 - 13.9*	5.0 - 14.4*
Summer chinook	13.9 - 20.0*	5.6 - 13.9*	5.0 - 14.4*
Fall chinook	10.6 - 19.4*	5.6 - 13.9*	5.0 - 14.4*
Steelhead trout		3.9 - 9.4*	
Cutthroat trout		6.1 - 17.2*	
RESIDENT			
Kokanee		5.0 - 12.8*	
Mountain		0.0 - 5.6†	
Cutthroat trout	5.0 - 10.0†	4.4 - 12.8† 5.5 - 15.5‡	
Rainbow trout		2.2 - 20.0* 4.4 - 12.8†	
Dolly Varden		7.8†	
Bull trout		< 9.0§ 4.5	2.0 - 6.0§

* Bell 1986.
† Everest et al. 1985.
‡ Varley and Gresswell 1988.
§ Pratt 1992.
¶ Ratliff 1992.

Spawning

Salmonids have been observed to spawn at temperatures ranging from 1-20°C (Bjornn and Reiser 1991), but most spawning occurs at temperatures between 4 and 14°C (Table 5). Resident trout, including rainbow and cutthroat trout, may spawn at temperatures up to 20.0°C and 17.2°C, respectively, while coho salmon, steelhead trout, Dolly Varden, bull trout, and mountain whitefish tend to prefer lower temperatures. The wide range of spawning temperatures used by most salmonid species strongly suggests that adaptation has allowed salmonids to persist in a variety of thermal environments and that attempting to identify species-specific preferenda may fail to account for ecological requirements of individual stocks (Spence et al. 1996).

Juvenile and Adult Rearing

Juvenile and resident salmonids are variable in their temperature requirements, though most species are at risk when temperatures exceed 23-25°C (Bjornn and Reiser 1991). Upper and lower lethal temperatures, as well as the "preferred" temperature ranges of several western salmonids, are shown in Table 5. These values provide a general range of tolerable temperatures; however, the ability of fish to tolerate temperature extremes depends on their recent thermal history (Spence et al. 1996).

Table 5. Lower lethal, upper lethal, and preferred temperatures for selected salmonids. Based on techniques to determine incipient lethal temperatures (ILT) and critical thermal maxima (CTM). From Bjornn and Reiser (1991).

Species	Lethal temperature (C) Lower lethal*	Lethal temperature (C) Upper lethal†	Preferred temperature (°C)	Technique	Source
Chinook salmon	0.8	26.2	12-14	ILT	Brett (1952)
Coho salmon	1.7	26.0 28.8‡	12-14	ILT CTM	Brett (1952) Becker and Genoway (1979)
Sockeye salmon	3.1	25.8	12-14	ILT	Brett (1952)
Chum salmon	0.5	25.4	12-14	ILT	Brett (1952)
Steelhead trout	0.0	23.9	10-13		Bell (1986)
Rainbow trout		29.4 25.0		CTM ILT	Lee (1980) Charlon et al. (1970)
Cutthroat trout	0.6	22.8			Bell (1986)

* Acclimation temperature was 10°C; no mortality occurred in 5,500 min.
† Acclimation temperature was 20°C unless noted otherwise; 50% mortality occurred in 1,000 min.
‡ Acclimation temperature was 15°C.

If stream temperatures become too hot, fish die almost instantaneously due to denaturing of critical enzymes in their bodies (Hokanson et al. 1977). The ultimate *instantaneous lethal limit* occurs in high temperature ranges (above 32°C). Such warm temperature extremes may never occur in the lower Skagit River tributaries. More common and widespread, however, is the occurrence of temperatures in the mid to high 20°C range. These temperatures can cause death of cold water fish species during exposure times lasting a few hours to one day. The exact temperature at which a cold water fish succumbs to such a thermal stress depends on the temperature that the fish is acclimated to, and on life-stage of development. Table 6 summarizes the modes of cold water fish mortality.

Table 6. Modes of thermally-induced cold water fish mortality (Brett 1952, Bell 1986, and Hokanson et al. 1977).

Modes of Thermally-Induced Fish Mortality	Temperature Range (°C)	Time to Death
Instantaneous Lethal Limit - Denaturing of bodily enzyme systems	> 32°C	Instantaneous
Incipient Lethal Limit - Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	21°C - 25°C	Hours to days
Sub-Lethal Limit - Conditions that (1) cause decreased or lack of metabolic energy for feeding, growth, or reproductive behavior, and (2) encourage increased exposure to pathogens, decreased food supply, and increased competition from warm water tolerant species	20°C - 23°C	Weeks to months

Protection and restoration of salmonid habitats requires that water temperatures in streams and lakes remain within the natural range for the particular site and season. Although “natural” temperature ranges may vary, the current water quality standards for temperature are intended to maintain the long-term health of fish and other aquatic life. Temperature standards exist to ensure the protection of entire communities of aquatic life and, to the extent consistent with this goal, avoid unnecessary impact on human economic activities.

Ecology (Hicks 2001) conducted a comprehensive review of the available technical literature on the temperature requirements of native fish and aquatic life. Based on this review, Hicks (2001) recommended expanding the existing state water quality standards for temperature to ensure the protection of the key life-stages of adult holding, spawning and incubation, juvenile rearing, smoltification, and adult migration. The proposed standards have also been set to avoid significant increases in the risks of warm water fish diseases and parasites, and include recommendations to avoid acute lethality from wastewater plumes.

Associated with the proposed criteria are directives on how to properly implement the criteria. The recommended criteria have been set at values representing the full protection for the species and their key life-stages. The proposed metrics express the criteria (typically both a 21-day average or the daily average temperatures, and a 7-day average of the daily maximum temperatures) were chosen to better match with laboratory and field research results that were used as the basis for the recommendations.

Instream Flows in the Lower Skagit River

Streamflow is a significant factor in the heat budget of lotic systems. Human-related reductions in flow volume can have a significant influence on stream temperature dynamics, most likely by increasing the diurnal variability in stream temperature. Lower streamflows also decrease hyporheic exchange between the alluvial aquifer and the channel. It follows then that water resource policy should ensure that instream flows be maintained such that biological communities are protected, while still allowing for consumptive uses.

Instream flows and water withdrawals are managed through regulatory avenues separate from TMDLs. However, stream temperature is related to the amount of instream flow, and increases in flow generally result in decreases in maximum temperatures. The complete heat budget for a stream segment accounts for the amount of flow and the temperature of water flowing into and out of the stream. The primary statutes relating to flow setting in the Washington State are as follows:

- Water Code, Chapter 90.03 RCW (1917), Section 247, describes Ecology's exclusive authority for setting flows and describes specific conditions on permits stating where flows must be met. It requires consultation with the state departments of Fish and Wildlife (WDFW); Community, Trade, and Economic Development; and Agriculture; as well as affected Indian tribes, on the establishment of "minimum flows".

- Construction Projects in State Waters, Chapter 77.55 RCW (formerly 75.20)(1949), Section 050, requires Ecology to consult with the Department of Fish and Wildlife prior to making a decision on any water right application that may affect flows for food and game fish. Fish and Wildlife may recommend denial or conditioning of a water right permit.

- Minimum Water Flows and Levels Act, Chapter 90.22 RCW (1967), set forth a process for protecting instream flows through adoption of rules. Among other provisions, it says Ecology must consult with the Department of Fish and Wildlife and conduct public hearings.

- Water Resources Act of 1971, Chapter 90.54 RCW, particularly Section 020, includes language that says "baseflows" are to be retained in streams except where there are "overriding considerations of the public interest". Further, waters of the state are to be protected and used for the greatest benefit to the people, and water allocation is to be generally based on the securing of "maximum net benefits" to the people of the state. This Act also authorizes Ecology to reserve waters for future beneficial uses.

- In 1998, the legislature passed Engrossed Substitute House Bill 2514, which was codified as "Watershed Planning," Chapter 90.82 RCW. This chapter provides an avenue for local citizens and various levels of governments to be involved in collaborative water management, including the option of establishing or amending instream flow rules. The Watershed Planning process specifies that local watershed planning groups can recommend instream flows to Ecology for rule-making, and directs Ecology to undertake rule-making to adopt flows upon receiving such a recommendation.

Under state laws, the Washington State Department of Ecology (Ecology) oversees both the appropriation of water for out-of-stream uses (e.g., irrigation, municipalities, commercial and industrial uses) and the protection of instream uses (e.g., water for fish habitat and recreational use). Ecology does this by adopting and enforcing regulations, as well as by providing assistance to citizens with both public and private water management issues.

Ecology is required by law to protect instream flows by adopting regulations and to manage water uses that affect streamflow. To develop an "instream flow rule" which sets for a particular stream the minimum flows needed during critical times of year, Ecology considers existing flow data, the hydrology of a stream and its natural seasonal flow variation, fish habitat needs, and other factors. Once adopted, an instream flow rule acquires a priority date similar to that associated with a water right. Water rights existing at the time an instream flow rule is adopted are unaffected by the rule, and those issued after rule adoption are subject to the requirements of the rule.

The Watershed Planning process is expected to address flows in the lower Skagit River tributaries including those tributaries addressed by this TMDL study. Upon recommendation by the Washington State Department of Fish and Wildlife, Carpenter Creek and Nookachamps Creek are closed to further appropriations. Skagit County has adopted these closures under Section 14.24.350 of the Critical Areas Ordinance, which the county developed under the directives of the Growth Management Act.

The rule-making process is expected to take several years. It will involve data collection, modeling and analysis, as well as consultation with other natural resource agencies and affected tribes, to obtain their recommendations. A draft instream flow regulation will be distributed for public and agency review and revision prior to any Ecology decision to adopt the rule.

Water Withdrawals

Withdrawal of water from a stream is an important consideration for the instream flow and heat budget. Actual water withdrawals at any given time from streams in the lower Skagit River study area are not known, but information from Ecology's Water Rights Application Tracking database system (WRAT) was used as an indicator of the amounts of water that may be withdrawn. The water quantity potentially withdrawn from surface waters for consumptive use is about 0.90 and 1.3 cubic meters per second (cm) from non-consumptive uses (Table 7). Irrigation represents the majority of the consumptive withdrawal from surface waters.

Table 7. Summary of consumptive water rights in selected lower Skagit River tributaries.

Creeks	Consumptive Surface Withdrawals (cms)	Non-consumptive Surface Withdrawals (cms)
Carpenter- Fisher	0.06	0.12
Hansen	0.01	unknown
Nookachamps	0.36	0.001
East Fork Nookachamps	0.47	1.15
Total	0.9	1.271

Stakeholders and Key Projects in the Study Area

Washington State Conservation Commission

The Washington State Conservation Commission was created in 1939 with the passage of Chapter 89.08 Revised Code of Washington, more commonly known as the Conservation Districts Law. The Conservation Commission exists to assist and guide conservation districts in protecting, conserving, and enhancing the natural resources of the state of Washington. The Commission provides leadership, partnerships, and resources to support locally governed conservation districts in promoting conservation stewardship by all. The Commission takes an active role in the development and implementation of state policies. The Commission manages multiple conservation programs, which are discussed below.

Agriculture, Fish and Water

The Governor's Statewide Salmon Recovery Strategy calls for the development of conservation practice standards for use by farmers to provide appropriate levels of resource protection. This is part of the state's effort to restore the habitat functions needed by salmon to meet recovery goals under the federal Endangered Species Act. The basis of these practice standards is the Field Office Technical Guides (FOTGs) developed by the U.S. Department of Agriculture, Natural Resource Conservation Service.

In 1998 Washington State entered into a Memorandum of Understanding with the Natural Resource Conservation Service, the National Marine Fisheries Service, EPA, and the U.S. Fish & Wildlife Service to update the FOTGs to comply with the Endangered Species Act. It is also hoped that the revised FOTGs will meet the federal Clean Water Act standards, giving farmers certainty on both issues.

This Memorandum of Understanding was the vehicle used to negotiate the Riparian Forest Buffer Standards currently used for the Conservation Reserve Enhancement Program. The process, however, did not include agriculture producers or representation from the environmental community. The Agriculture, Fish and Water process expands the negotiations to include these groups.

The state departments of Agriculture, Fish and Wildlife, and Ecology, as well as the Washington Conservation Commission and staff from the Governor's Office, have begun meeting with representatives from the agricultural community, federal agencies, local government, interested legislators, environmental groups, and tribes to discuss their possible involvement in a collaborative process, called Agriculture, Fish and Water. This is a negotiated process aimed at voluntary compliance.

The Agriculture, Fish and Water process involves (1) negotiating changes to the existing FOTG and (2) developing guidelines for irrigation districts. These guidelines will be used to enhance, restore, and protect habitat for endangered fish and wildlife species, as well as to address state water quality needs. This two-pronged approach has developed into two processes, one involving agricultural interests and the other involving irrigation districts across the state.

Habitat Limiting Factors Analysis

Section 10 of Engrossed Substitute House Bill 2496 (Salmon Recovery Act of 1998) directed the Washington State Conservation Commission, in consultation with local governments and treaty tribes, to invite private, federal, state, tribal, and local government personnel with appropriate expertise to convene as a Technical Advisory Group (TAG). The purpose of the TAG is to identify habitat limiting factors that affect the natural production of salmonids. One important task in identifying these habitat limiting factors is to map salmonid distribution. Maps of salmonid distribution within WRIA 3, and including the lower Skagit River tributaries, are available at the following url: http://salmon.scc.wa.gov/

The results of assessing habitat limiting factors are intended to be used by locally-based selection committees to prioritize projects for funding under the state salmon recovery program. The results are also intended to be used by local organizations and individuals interested in habitat restoration to identify projects by focusing resources on habitat work that will have the greatest benefit to fish. The TAGs also identify gaps in existing information so future data collection can be efficiently targeted.

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program (CREP) was established to provide a flexible and cost-effective means to address agriculture-related environmental issues by targeting federal and state funding for restoration projects in geographic regions of particular environmental sensitivity. In April 1999 the state of Washington submitted a CREP contract proposal to the Farm Service Agency (FSA) to enhance riparian habitat conditions on agricultural lands along streams which provide important habitat for listed salmonid species.

The program, cooperatively administered by the FSA and the Washington State Conservation Commission, relies on voluntary participation by landowners. The farmers and ranchers who participate in the program sign 10- to 15-year contracts with the federal government, agreeing to remove their land from agricultural production and planting it to woody or shrub vegetation. The landowners will be eligible to receive rental payments and other financial incentives in return for the loss of production from their lands.

The Washington State CREP program is designed to address water quality degradation that is a direct or indirect result of agricultural activities on private lands along freshwater streams. On a statewide basis, approximately 37% of the freshwater salmon streams on private lands in Washington pass through agricultural land use areas. Farming and ranching activities on these lands have led to removal or elimination of native riparian vegetation with resultant increases in water temperature, rates of sedimentation, and reductions in channel complexity.

The project area includes private agricultural lands along streams identified in the 1993 Salmon and Steelhead Status Inventory that provide habitat for salmonid stocks in depressed or critical condition and that are listed under the federal Endangered Species Act. Up to 100,000 acres of private cropland and grazing land, including 3-4,000 miles of riparian area, will be eligible for inclusion in this program. The riparian forest buffer is the primary conservation practice authorized in the Washington CREP. It is anticipated that restoring forested riparian buffers will have a significant positive impact on the targeted freshwater streams.

The six objectives of the Washington CREP are directly related to improving riparian and aquatic ecosystems that provide key habitats for salmonids. These six objectives are:

1. Restore 100% of the area enrolled for the riparian forest practice to a properly functioning condition for distribution and growth of woody plant species.
2. Reduce sediment and nutrient pollution from agricultural lands next to the riparian buffers by more than 50%.
3. Establish adequate vegetation on enrolled riparian areas to stabilize 90% of stream banks under normal (non-flood) water conditions.
4. Reduce the rate of stream water heating to ambient levels by planting adequate vegetation on all riparian buffer lands.
5. Help farmers and ranchers to meet the water quality requirements established under Federal law and Washington's agricultural water quality laws.
6. Provide adequate riparian buffers on 2,700 stream miles to permit natural restoration of stream hydraulic and geomorphic characteristics that meet the habitat requirements of salmon and trout.

Washington CREP includes a set of best management practices (BMPs) designed to reduce adverse environmental impacts. These BMPs will be followed on all CREP activities and will be provided to all farmers and ranchers who enroll in the program. The FSA regards these BMPs as integral components of the CREP and consider them to be part of the action.

The FSA believes that this programmatic consultation on the Washington CREP removes the requirement for most project-level consultation. Consequently, unless otherwise identified within the biological opinion, activities performed within the CREP that are consistent with the BMPs described in the biological assessment, reasonable and prudent measures, and terms and conditions described in the biological opinion will not require further consultation. However, the FSA has identified certain activities which have a greater likelihood of adverse impacts to salmonids and their habitat which will require site-specific consultation. These activities are identified within the biological opinion and include, but are not limited to, bank shaping that exceeds 30 linear feet and any activities that are not consistent with the CREP biological assessment (BMPs inclusive) and this biological opinion (reasonable and prudent measures and terms and conditions inclusive).

The National Marine Fisheries Service and the U.S. Fish & Wildlife Service believe that full achievement of the Washington CREP is likely to make a substantial contribution to the survival and recovery of those aquatic species covered by this opinion. Nonetheless, the FSA also believes that some of the site-specific actions associated with CREP may result in short-term adverse effects to listed fish and associated incidental take. Accordingly, the FSA provided a set of nondiscretionary "reasonable and prudent measures" in the accompanying incidental take statement which they believe are necessary to minimize the take of listed species associated with the CREP.

The primary long-term benefits the buffers will provide for salmonids is shade and the corresponding reduction in water temperature, which is a limiting factor for salmonid reproduction in most of the waterways targeted by the CREP.

Skagit County

Water Quality Monitoring

The Skagit County Public Works Department Surface Water Management Section conducts baseline water quality monitoring in streams flowing through agricultural lands. The goal of the monitoring is to establish a baseline that characterizes streams in Skagit County's agricultural areas and to provide a foundation to identify any trends in watershed health in the Samish and Skagit river basins. The Surface Water Management Section plans to expand its water quality monitoring program by adding additional stations in Hansen, Carpenter, Red, and Fisher creeks for continuous temperature monitoring. Current water quality parameters measured at each station include dissolved oxygen, nutrients, fecal coliform, temperature, pH, turbidity, and conductivity.

Growth Management Act and Critical Areas Ordinance

The Washington State Legislature enacted the Growth Management Act in 1990 in response to growth and development pressures in the state. The Act requires local governments to adopt development regulations, such as subdivision and zoning ordinances, to carry out comprehensive plans.

The Growth Management Act has been amended several times between 1991 and 1998 to further define requirements and to establish a framework for coordination among local governments. The plans include the following chapters: land use, housing, capital facilities, transportation, utilities, shorelines, economic development, and rural (for counties). Chapters on economic development and parks and recreation also are required, if state funding is provided.

Under the Growth Management Act, Skagit County has put into place effective regulatory programs for critical areas, including wetlands, geologically hazardous areas, fish and wildlife habitat conservation areas, critical aquifer recharge areas, and frequently flooded areas. Pioneering plans for flood hazard reduction, nonpoint pollution control, and stormwater management have been developed.

Skagit County adopted a new Critical Areas Ordinance in June 2003 that is intended to address the requirements of the Growth Management Act. Under the new Ordinance, which is scheduled to take effect January 1, 2004, agricultural activities are required to do no harm to water quality and fish and wildlife habitat. Farm plans and BMPs would be implemented as necessary to prevent harm. This approach relies to a significant degree on existing federal and state programs that already regulate certain farm practices. Agricultural practices would need to be conducted in a manner that protects and does not degrade the habitat functions and values of adjacent watercourses.

Skagit Watershed Council

The Skagit Watershed Council (SWC) is a non-profit agency of 36 member organizations including tribes, county, state, and federal government entities, conservation organizations, and business and industry groups. SWC is recognized as a state lead entity under the Salmon Recovery Act.

The mission of the SWC is to provide technical assistance, public outreach and education, and a collaborative approach within the Skagit watershed to understand, protect, and restore the production and productivity of healthy ecosystems in order to support sustainable fisheries. The SWC has been instrumental in the coordination, prioritization, funding, and implementation of habitat protection and restoration projects for salmon and other fish species including native char in the Skagit River basin.

Watershed planning for protecting and restoring fish resources in the Skagit basin follows the SWC's "Habitat and Restoration Strategy". This landscape-based strategy is based upon the best available science regarding natural processes, human disturbance, habitat conditions, fish population distribution and trends, and ecosystem health.

The SWC has completed a basin-wide evaluation of habitat conditions for salmon. This planning tool has been used to screen and prioritize fish habitat protection and restoration projects in the basin and to identify "priority" sub-basins in the Skagit River watershed for protection and restoration projects.

Skagit Fisheries Enhancement Group

The Skagit Fisheries Enhancement Group (SFEG) is a nonprofit organization dedicated to the enhancement of salmon resources through education, restoration, and public involvement. Established in 1990 as one of 14 Regional Fisheries Enhancement Groups in Washington State, SFEG is part of a coordinated effort to educate and involve the public in salmon enhancement activities across the state at the community level. SFEG works cooperatively with local landowners to identify restoration opportunities on their property and find the funding to implement them.

SFEG conducts restoration projects that include riparian restoration, improvement of fish passage, nutrient enhancement, and instream enhancement projects such as channel enhancement and streambank stabilization. The SFEG monitoring program is designed to evaluate the effect of restoration work to improve natural watershed conditions and salmon resources. Results of monitoring programs help guide designs for future restoration projects and document successes to funding entities.

Skagit Conservation District

The Skagit Conservation District (SCD) is a legal subdivision of Washington State government organized under "Conservation District Law" RCW Title 89, Chapter 89.08, and is composed of farmers, landowners, and concerned citizens. The district priorities and goals include:

- Protection and Improvement of the Quality of Surface and Ground Water
- Watershed Planning and Implementation
- Riparian Reforestation and Enhancement
- Forest Stewardship
- Wildlife Habitat Enhancement
- Conservation Education
- Protection and Preservation of Prime Farmlands
- County Government Assistance
- Increase District Capacity

The SCD encourages and promotes the preservation and optimum beneficial use of agricultural, range and forested lands by helping landowners plan and implement BMPs that reduce soil erosion, improve water quality and water conservation, as well as protect the natural resource base of the SCD. The SCD also provides:

- Education and technical assistance to non-industrial forest landowners.
- Soils information, conservation maps, and knowledge of BMPs to landowners and land managers.
- Implementation programs aimed at protecting the water resources of Skagit County.
- Surveys, research studies, comprehensive plans, and demonstration and implementation projects on public and private lands within the SCD.
- Responsible and accountable management and financial assistance.
- Conservation leadership to federal, state, and local governmental agencies.
- Monitoring of enhancement projects and BMP implementations that document success and/or the need for adaptive management measures.

Skagit System Cooperative

The Skagit System Cooperative (SSC) is a natural resource consortium of the Swinomish and Sauk-Suiattle tribes with fishing rights in Skagit County waters. The Swinomish Tribe has a reservation on Skagit Island just west of La Conner. The Sauk-Suiattle Tribe has tribal offices near the Sauk River in Darrington in Snohomish County. The SSC's policy is to protect, preserve, and enhance Skagit-area fish habitat and other natural resources and environment that affect the quality of that habitat. In addition, the SSC's and tribes' policy is to achieve a net gain in the productive capacity of Skagit-area fish habitat.

The Upper Skagit Tribe, which has tribal offices in Sedro-Woolley, was until recently a member of the SSC. As of January 1, 2004, the Tribe will manage its natural resources programs independently of the SSC.

Applicable Water Quality Criteria

Section 303(d) of the federal Clean Water Act mandates that Washington State establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet water quality standards after application of technology-based pollution controls.

The goal of a TMDL is to ensure the impaired water body will attain water quality standards. The TMDL determines the maximum amount of a given pollutant that can be discharged to the water body and still meet the state water quality standards (referred to as the loading capacity) and allocates that load among the various sources. If the pollutant comes from a discrete (point) source such as an industrial facility discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a diffuse (nonpoint) source such as a farm, that facility's share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the calculated loading capacity for the specific pollutant.

All tributaries within the lower Skagit River study area are classified as Class A, excellent, as defined by the Water Quality Standards for Surface Waters of the State of Washington (Hicks 2000; Chapter 173-201A-030 WAC). The standards establish beneficial uses of waters and incorporate specific numeric and narrative criteria for parameters such as water temperature. The criteria are intended to define the level of protection necessary to support the beneficial uses (Rashin and Graber 1992). The beneficial uses of the waters in the lower Skagit River watershed are:

- *Recreation:* Fishing and swimming.
- *Fish and Shellfish:* Spring chinook, cutthroat, and coho use the waters in the study area for migration, rearing, and spawning.
- *Water Supply and Stock Watering:* Agriculture extracts water for irrigation and stock watering.
- *Wildlife Habitat:* Riparian areas are used by a variety of wildlife species which are dependent on the habitat.

Numeric water quality criteria for Class A freshwater streams state that temperature shall not exceed 18.0°C due to human activities. When natural conditions exceed 18.0°C, no temperature increases will be allowed which will raise the receiving water temperature greater than 0.3°C. If natural conditions are below 18.0°, incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C or bring the stream temperature above 18.0°C at any time (Chapter 173-201A-030 WAC).

During critical periods, natural conditions may exceed the numeric temperature criteria mandated by the water quality standards. In these cases, the antidegradation provisions of those standards apply.

"Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria." (Chapter 173-201A-030 WAC).

Load allocations for Nookachamps Creek and Lake Creek use both the numeric criteria of 18°C and the narrative natural condition provision. The numeric criteria of 18°C are used within the load allocations for the remaining water bodies within the study area.

Water Quality and Resource Impairments

The 1998 303(d) listings for temperature in the lower Skagit River basin are presented in Table 8.

Table 8. 1998 303(d) listing rationale for temperature in the lower Skagit River basin.

Waterbody ID	Creek	Date placed on 303(d) List	Rationale: Excursions beyond the criterion in 1997*
WA-03-1011	Carpenter	1998	10
WA-03-1012	Fisher	1998	3
WA-03-1019	Hansen	1998	6
WA-03-1017	Nookachamps	1998	20
WA-03-4200	E.F. Nookachamps	1998	5
None5	Otter Pond	1998	9
None6	Red	1998	10
None12	Turner	1998	9

* Data from Skagit System Cooperative

The 303(d) listings for temperature are also confirmed by recent data collected in 2001 and 2002 by Ecology and the Skagit County Surface Water Management Division. Temperatures in excess of the water quality standards (18°C) have been observed throughout the lower Skagit River tributaries at numerous locations (Table 9). Detailed station location maps are given in Figures 15 and 19.

Both Ecology and Skagit County temperature data show that the warmest temperatures in the lower Skagit River tributaries occur in Carpenter, Red, and Nookachamps creeks. Temperatures in these three tributaries have frequently been measured near or above the lethal limit for steelhead of about 24ºC.

Table 9. Highest daily maximum temperatures in the lower Skagit River tributaries during 2001 Data in *italics* indicate values greater than the water quality standard.

Station ID	Station Name	Latitude decimal degrees NAD27	Longitude decimal degrees NAD27	Highest daily maximum temperatures during 2001 (degrees C)	Highest 7-day averages of daily maximum temperatures during 2001 (degrees C)	Water Quality Classification	Water Quality Standard (degrees C)
Ecology Stations, 2001							
03C01	Carpenter Cr. near mouth	48.323	-122.342	*24.18*	*22.89*	A	18
03C02	Carpenter Cr. at SR534	48.341	-122.323	*23.27*	*22.01*	A	18
03C03	Carpenter Cr. at Stackpole Rd	48.341	-122.307	*18.42*	17.93	A	18
03C04	Carpenter Cr. at Little Mountain	48.395	-122.284	16.16	15.54	A	18
03EF01	EF Nookachamps Cr. at SR9	48.446	-122.251	*19.68*	*19.06*	A	18
03EF02	EF Nookachamps at Beaver Lake Rd	48.424	-122.209	*19.7*	*19.25*	A	18
03F01	Fisher Cr. at Franklin Rd	48.319	-122.328	14.72	14.38	A	18
03F02	Fisher Cr. at Starbird Rd	48.309	-122.296	*19.06*	*18.15*	A	18
03H01	Hansen Cr. at Hoehn Rd	48.503	-122.197	*19.21*	*18.75*	A	18
03H02	Hansen Cr. at Highway 20	48.521	-122.198	17.99	17.19	A	18
03U04	Red Cr. near Highway 20	48.523	-122.191	*28.26*	*26.71*	A	18
03H03	Hansen Cr. at Hansen Cr. Rd	48.559	-122.208	*18.29*	17.93	A	18
03N01	Nookachamps Cr. nr mouth	48.467	-122.292	*25.25*	*24.3*	A	18
03N02	Nookachamps Cr. abv Barney Lake	48.431	-122.263	*22.17*	*21.58*	A	18
03T01	Turner Cr. at Beaver Lake Rd	48.439	-122.219	*18.77*	*18.35*	A	18
03N03	Nookachamps Cr. blw Big Lake	48.4	-122.237	*24.41*	*23.7*	A	18
03N04	Lake Cr. above Big Lake	48.345	-122.205	*20.11*	17.53	A	18
03U03	Otter Pond Cr. near mouth	48.403	-122.227	16.17	15.67	A	18
Skagit County Surface Water Stations, 2001 (Aug - Sept)							
12	Nookachamps Cr. at Swan Rd	48.453	-122.27	*23.44*	*22.56*	A	18
13	EF Nookachamps Cr. at Hwy 9	48.446	-122.251	*19.59*	*18.99*	A	18
15	Nookachamps Cr. at Knapp Rd	48.428	-122.257	*20*	*19.68*	A	18
16	EF Nookachamps Cr. at Beaver Lake Rd	48.424	-122.208	*19.86*	*19.47*	A	18
17	Nookachamps Cr. at Hwy 9-Big Lake outlet	48.4	-122.237	*23.52*	*23.08*	A	18
18	Lake Cr. at Hwy 9	48.356	-122.202	17.6	17.15	A	18
19	Hansen Cr. at Hoehn Rd	48.503	-122.197	*19.66*	*19.02*	A	18
20	Hansen Cr. at Northern State	48.53	-122.199	*19.22*	*18.69*	A	18
Skagit County Surface Water Stations, 2002 (June 1 - Sept 10)							
12	Nookachamps Cr. at Swan Rd	48.453	-122.27	na	na	A	18
13	EF Nookachamps Cr. at Hwy 9	48.446	-122.251	*20.67*	*19.41*	A	18
15	Nookachamps Cr. at Knapp Rd	48.428	-122.257	*22.82*	*21.77*	A	18
16	EF Nookachamps Cr. at Beaver Lake Rd	48.424	-122.208	*20.46*	*19.04*	A	18
17	Nookachamps Cr. at Hwy 9-Big Lake outlet	48.4	-122.237	*26.13*	*24.84*	A	18
18	Lake Cr. at Hwy 9	48.356	-122.202	*18.09*	17.22	A	18
19	Hansen Cr. at Hoehn Rd	48.503	-122.197	*20.03*	*18.75*	A	18
20	Hansen Cr. at Northern State	48.53	-122.199	*18.69*	17.55	A	18

Seasonal Variation and Critical Conditions

The federal Clean Water Act Section 303(d)(1) requires that TMDLs "be established at levels necessary to implement the applicable water quality standards with seasonal variations". The current regulation also states that determination of "TMDLs shall take into account critical conditions for streamflow, loading, and water quality parameters" [40 CFR 130.7(c)(1)]. Finally, Section 303(d)(1)(D) suggests consideration of normal conditions, flows, and dissipative capacity.

Existing conditions for stream temperatures in the lower Skagit River tributaries reflect both seasonal and diurnal variation. Average temperatures are hottest in the summer months, while cooler temperatures predominate in the winter months. Minimum temperatures occur in the evening, while maximum temperatures are observed in the daytime. Figures 13 and 14 summarize the highest daily maximum and the highest seven-day average maximum water temperatures of 2001 for water bodies in Carpenter-Fisher, Hansen, and Nookachamps creek watersheds. The highest temperatures typically occur from July through August. This time frame is used as the critical period for development of the TMDL.

Seasonal estimates for streamflow, solar flux, and climatic variables for the TMDL are taken into account to develop critical conditions for the TMDL model. The critical period for evaluation of solar flux and effective shade was assumed to be August 12, because it is the mid-point of the period when water temperatures are typically at their seasonal peak.

Critical streamflows for the TMDL were evaluated as the lowest 7-day average flows with a 2-year recurrence interval (7Q2) and 10-year recurrence interval (7Q10) for the months of July and August. The 7Q2 streamflow was combined with air temperatures during a typical climatic year, and the 7Q10 streamflow was combined with atmospheric conditions during a worst-case climatic year.

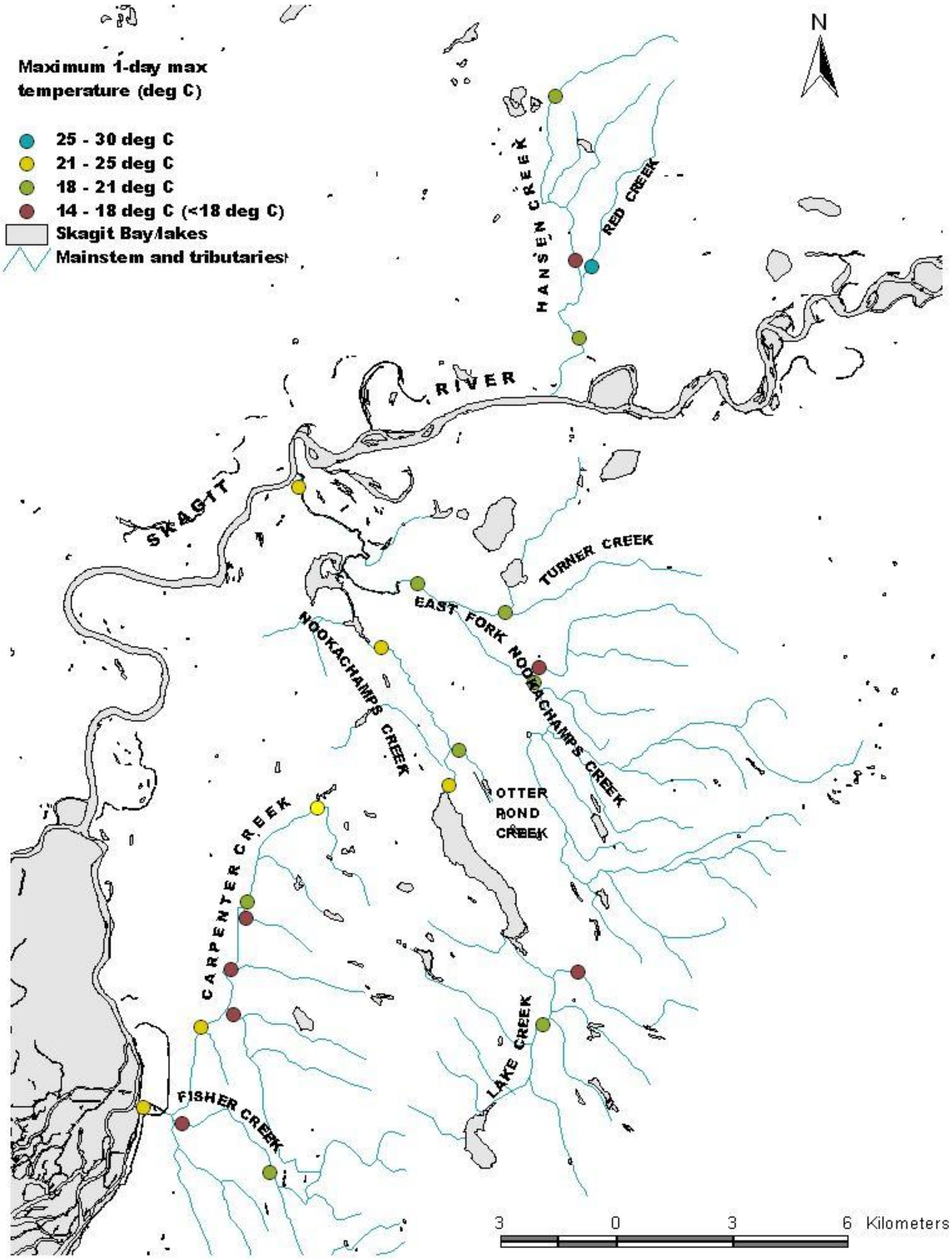


Figure 13. Highest daily maximum temperatures in the lower Skagit River tributaries in 2000 on the hottest day of the year for each station.

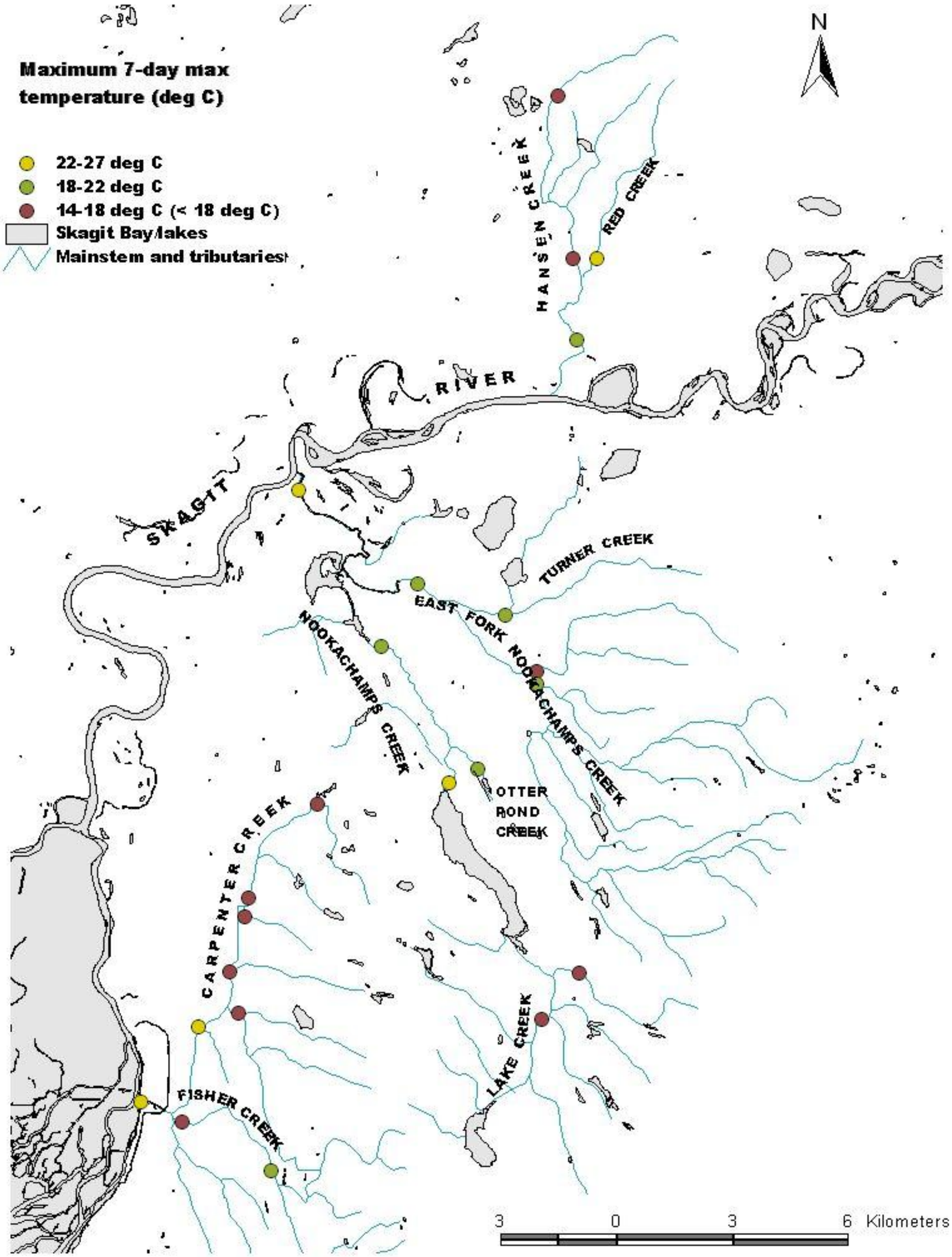


Figure 14. Maximum 7-day averages of daily maximum temperature in the lower Skagit River tributaries in 2000.

Technical Analysis

Stream Heating Processes

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology, hydrology, and ultimately temperature are affected by land use activities. Specifically, the elevated summertime stream temperatures attributed to anthropogenic sources in the lower Skagit River tributaries result from the following:

- Riparian vegetation disturbance reduces stream surface shading via decreased riparian vegetation height, width, and/or density, thus increasing the amount of solar radiation reaching the stream surface. Current riparian forests are extensively degraded compared with historic (circa 1873) conditions (Pess et al. 1999). Pess et al. reported that the most severely degraded riparian forests in the adjacent Stillaguamish River watershed are those with extensive agricultural activity, followed by rural residential development. Forest lands generally have the least degraded riparian forests, and riparian forests in federal lands are generally in much better condition than those on state and private land.
- Past land management activities in the lower Skagit River watershed were likely very similar to those which occurred in the adjacent Stillaguamish River watershed. Landslides triggered by forest practices and riparian logging, as well as agricultural and urban activities, have caused numerous tributaries to widen and aggrade at some point in the last half century. Widening of the channels throughout the lower Skagit River study area has likely decreased the effectiveness of potential shading from near-stream vegetation.
- Reduced summertime baseflows may result from instream withdrawals and hydraulically connected groundwater withdrawals. Reducing the amount of water in a stream can increase stream temperature (Brown 1972).

Current Conditions

Available Water Temperature Data

Ecology installed a network of continuous temperature dataloggers in the lower Skagit River watershed, as described by Pelletier and Bilhimer (2001) (Figure 15). Data from 2001 show that water temperatures in excess of the Class A standards of 18°C are common throughout the study area (Figures 13-14 and 16-18).

A network of continuous temperature dataloggers has also been developed and maintained in Skagit County by the Skagit County Surface Water Management Division. Water and air temperatures were continuously monitored in the spring, summer, and fall of 2001 and 2002 in Nookachamps, East Fork Nookachamps, Lake, and Hansen creeks (Table 9, Figure 19). Water temperatures in excess of 20°C have been observed in the lower Nookachamps Creek, as well as near the outlet of Big Lake and Lake McMurray (Table 9).

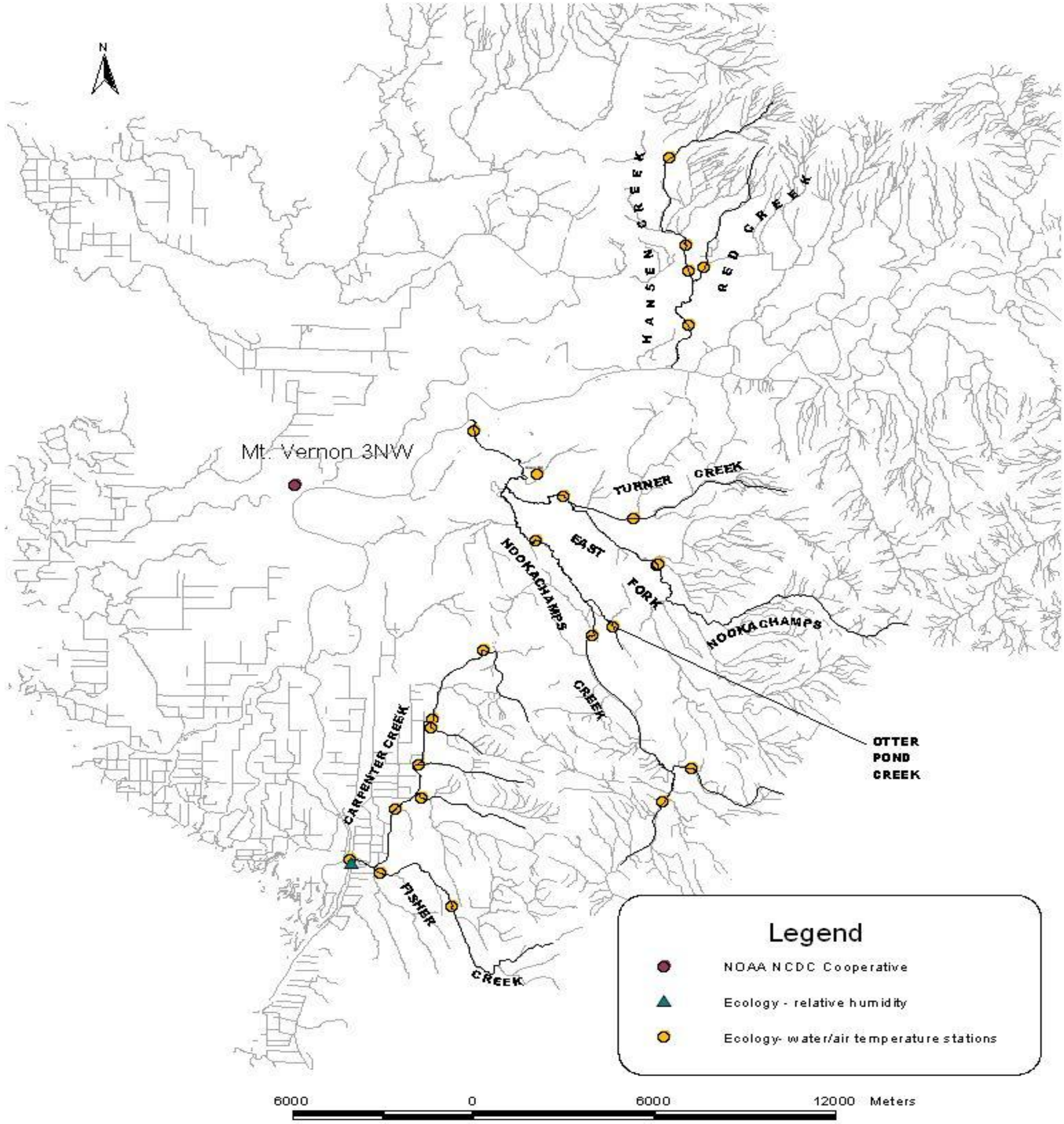
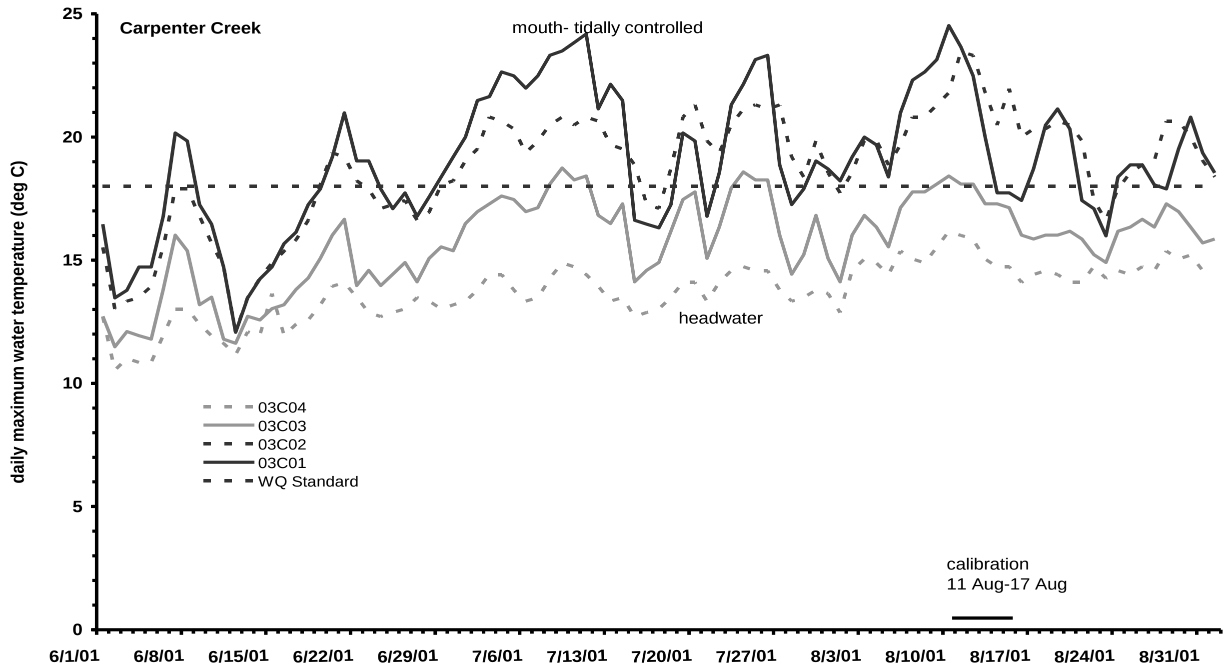


Figure 15. Location of Ecology air and water temperature recording devices, relative humidity station, and NOAA NCDC Cooperative weather station.



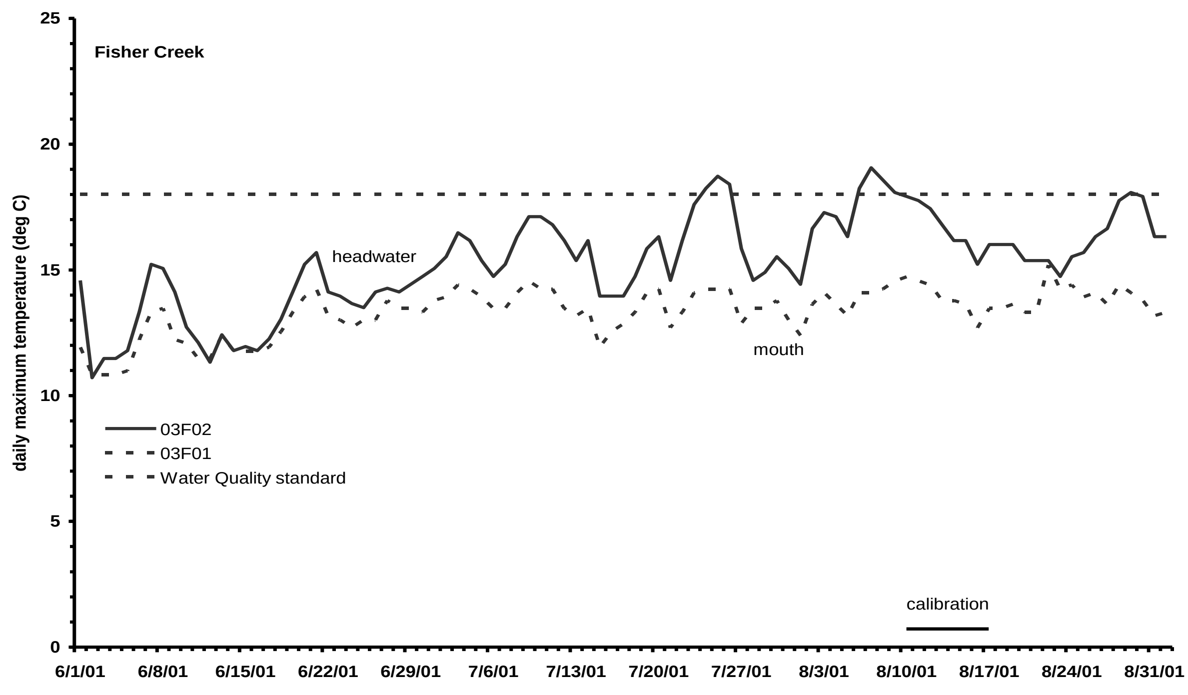
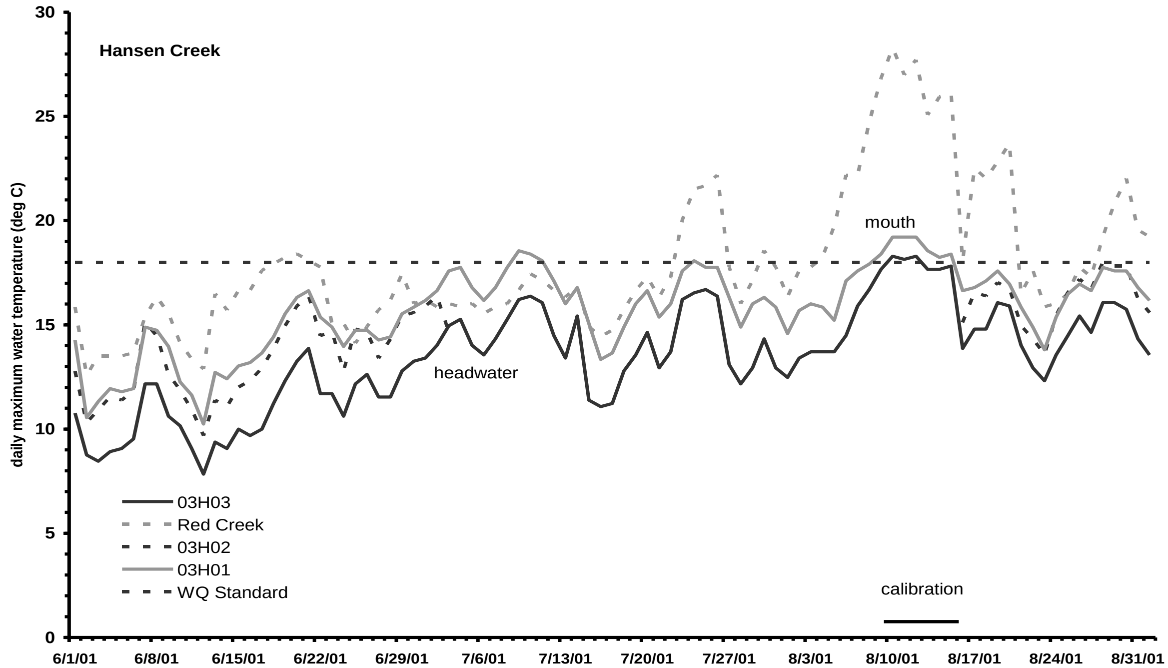


Figure 16. Daily maximum water temperatures in Carpenter and Fisher creeks from June to September 2001.



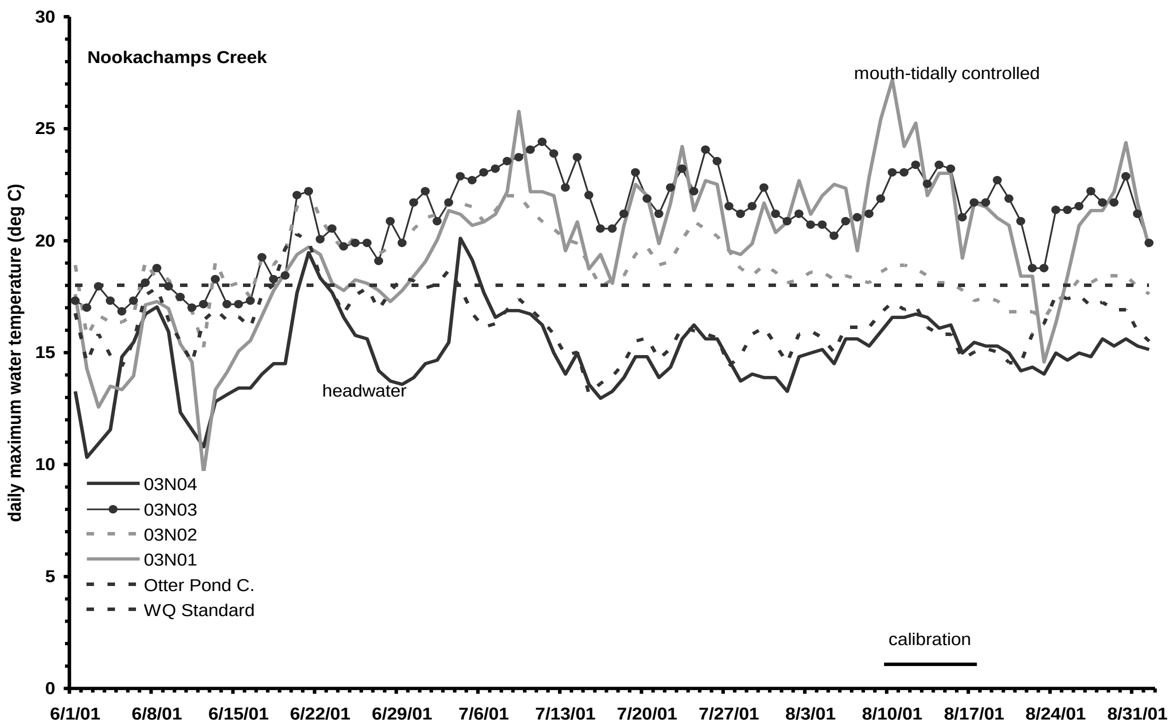


Figure 17. Daily maximum water temperatures in Hansen, Red, Lake (03N04), Nookachamps, and Otter Pond creeks from June to September 2001.

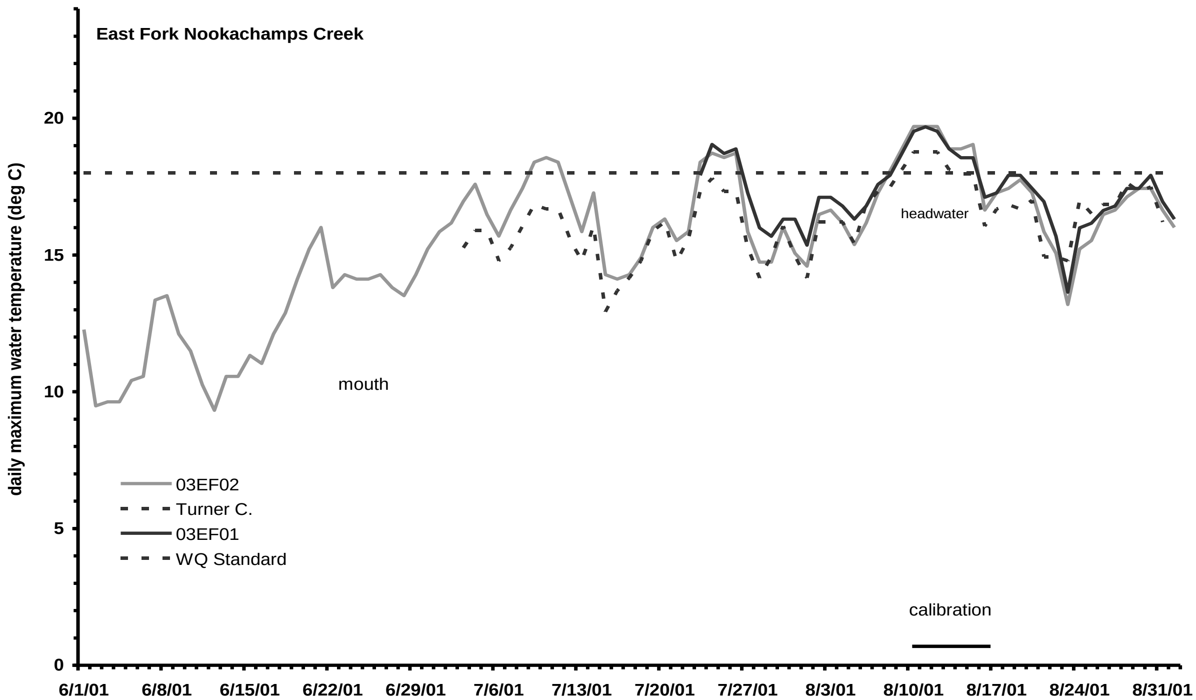


Figure 18. Daily maximum water temperatures in East Fork Nookachamps and Turner creeks from June to September 2001.

Stream Flow Data

Ecology installed a flow measurement station in East Fork Nookachamps Creek during 2001 and made numerous flow measurements at all other stations, including a synoptic flow survey in August 2000. The Skagit County Surface Water Management Division also measured instantaneous flows at a number of stations in Hansen, Nookachamps, and East Fork Nookachamps creeks in 2001. Measured streamflow summaries are given in Appendix B-4. The lowest 7-day-average flows during the July-August period with recurrence intervals of 2 years (7Q2) and 10 years (7Q10) were estimated based on low-flow statistics from the USGS gauging station in Pilchuck Creek (#12168500 Pilchuck Creek near Bryant, WA, elevation 119.8 ft, drainage area 52 mi^2). The 7Q2 and 7Q10 flows in the study area were then estimated by scaling the estimates at the USGS Pilchuck Creek gage (period of record 1929-1998) according to the sub-watershed areas weighted by annual average precipitation[2] (Table 10). Because of the close proximity of the Pilchuck watershed to the study area, similar annual precipitation values were used as part of the 7Q2 and 7Q10 flow estimations. Widths, depths, and velocities under 7Q2 and 7Q10 conditions for each station are given in Appendix B-3.

[2] Annual average precipitation values were obtained from NOAA NCDC weather stations at Mount Vernon, Arlington, and Sedro Woolley, WA.

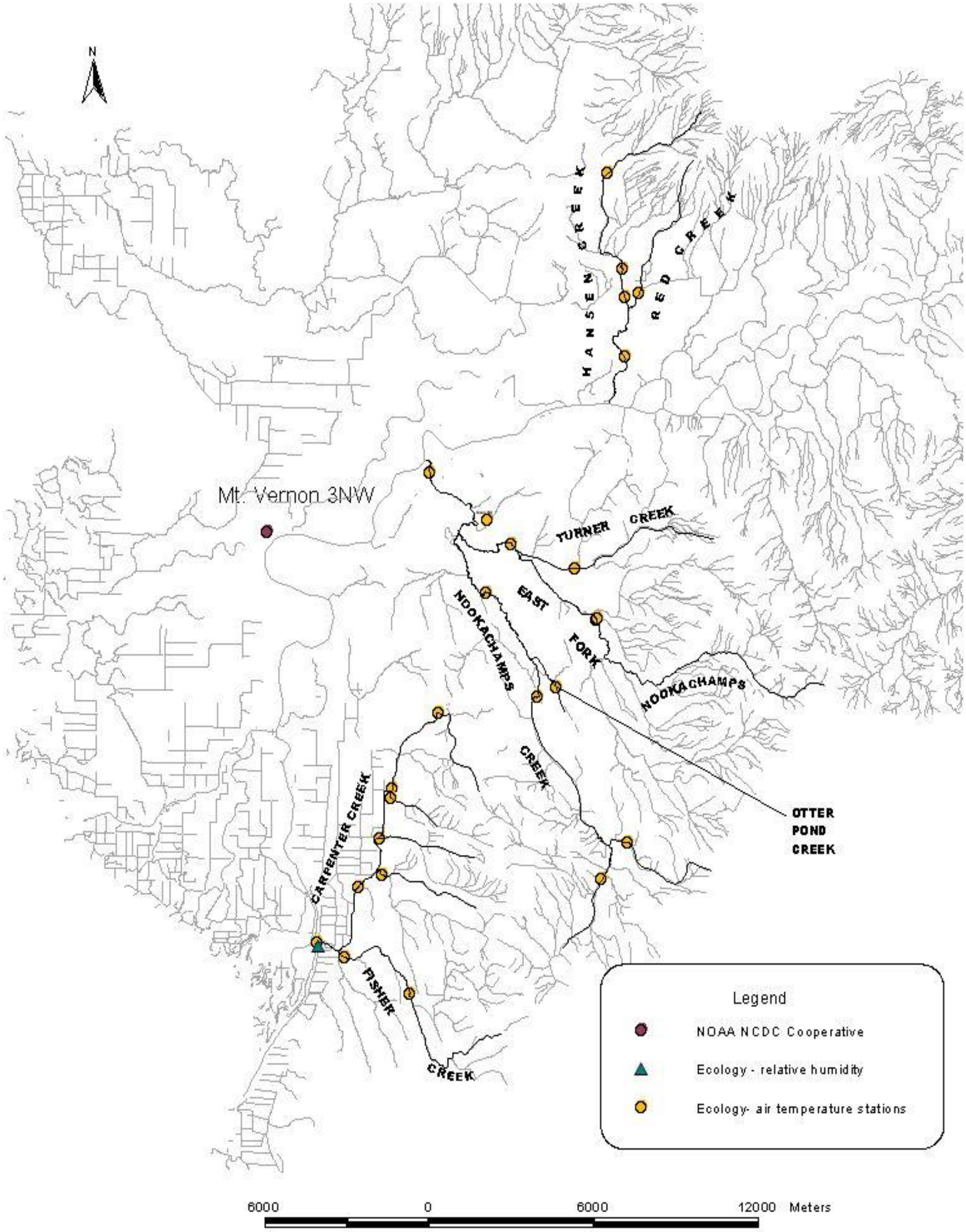


Figure 19. Location of Skagit County air and water temperature recording devices, Ecology relative humidity station, and NOAA NCDC Cooperative weather station.

Table 10. Estimated 7Q2 and 7Q10 flows for selected streams in the lower Skagit River study area.

Creek	Drainage area (km2)	Drainage area (mi2)	Estimated 7Q2 flow (cm)	Estimated 7Q2 flow (cfs)	Estimated 7Q10 flow (cm)	Estimated 7Q10 flow (cfs)
Pilchuck	134	52	0.15	5.40	0.05	1.80
Carpenter	95	37	0.11	3.82	0.04	1.27
Fisher	17	7	0.02	0.65	0.01	0.22
Hansen	33	13	0.04	1.34	0.01	0.46
Lake	40	15	0.02	0.85	0.01	0.28
Nookachamps	180	69	0.20	7.20	0.07	2.40
E.F. Nookachamps	91	35	0.10	3.64	0.03	1.20

Hydraulic Geometry

The channel width, depth, and velocity have an important influence on the sensitivity of water temperature to the flux of heat. The near-stream disturbance zones (NSDZ or bankfull width) were digitized from digital rectified orthophotos. In areas where NSDZ edges were not easily identified from the orthophotos (heavy vegetation, cutbanks, floodplain relief), the NSDZ was estimated from a log-log regression of measured bankfull width versus drainage area (Figure 20).

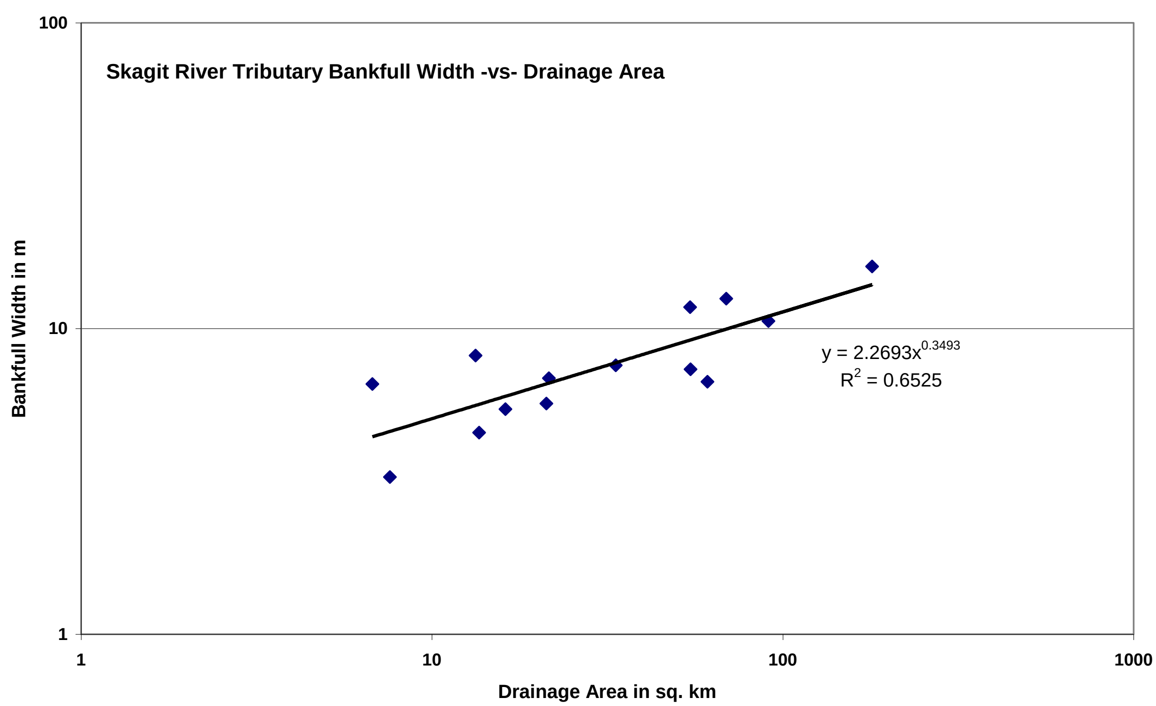


Figure 20. Relationship between bankfull width and drainage area in lower Skagit River tributaries.

Stream widths at low flow were estimated from field measurements as described in Pelletier and Bilhimer (2001). Wetted widths in many parts of the study area were not easily identified from the digital orthophotos. In these reaches the wetted widths were estimated by using the exponents for each basin as shown in Table 11, which shows the general relationships between wetted width, depth, velocity[3], and flow at all stations in the study area during the June to September low-flow period.

Table 11. Summary of hydraulic geometry relationships with flow in the lower Skagit River study area, May-October 2001.

Parameter / Power Function	Coefficient or Exponent	All Stations	Carpenter Creek head-waters	Carpenter Creek "Hill Ditch"	Fisher Creek main-stem	Hansen Creek head-waters	Hansen Creek lower	Lake Creek main-stem	Nooka-champs Creek head-waters	Nooka-champs Creek lower	EF Nooka-champs Creek lower
width	coefficient a	8.0258	3.4597	5.833	2.639	5.8239	7.3012	9.1013	7.4918	5.6837	8.1036
aQ^b	exponent b	0.2405	0.0177	0.14	0.0276	0.1488	0.2895	0.2937	0.3109	0.2206	0.2767
depth	coefficient c	0.3244	0.1509	0.2867	0.2018	0.4358	0.4131	0.2166	0.3417	0.3553	0.328
cQ^f	exponent f	0.4135	0.3011	0.4472	0.0106	0.3327	0.514	0.2395	0.4345	0.3405	0.4253
velocity	coefficient k	0.403	1.8615	0.6141	1.7181	0.3903	0.3027	0.4967	0.5218	0.4834	0.4385
kQ^m	exponent m	0.3596	0.6704	0.4248	0.9154	0.6403	0.1872	0.5142	0.1434	0.4034	0.2494

At different discharges, the observed mean velocity, mean depth, and width of flowing water reflect the hydraulic characteristics of the channel cross section. Graphs of these three parameters as functions of discharge at the cross section constitute a part of what Leopold and Maddock (1953) called the hydraulic geometry of stream channels. The principal hydraulic parameters are related to discharge as power functions. The relations to discharge at a given river cross section can be written as

$$w = aQ^b, \qquad d = cQ^f, \qquad u = kQ^m$$

where w is width, Q is discharge, d is mean depth, and u is mean velocity. The letters b, f, and m are exponents, and a, c, and k are coefficients.

The product of width and mean depth is the cross-sectional area of flowing water. Discharge is the product of mean velocity and cross-sectional area of flow. Thus

$$w \times d = A, \text{ and } w \times d \times v = Q.$$

[3] Flow is in cubic meters per second. Width and depth are in meters. Velocity is in meters per second.

It follows that aQ^b x cQ^f x kQ^m = Q, or $b + f + m$ =1, and a x c x k = 1.0 (Leopold et al. 1992).

Using these power functions, it is possible to determine the channel widths, depths, and velocities for each of the modeled segments. Once a specific discharge (7Q2 or 7Q10) is calculated, the exponents and coefficients are used to derive the width, depth, and velocities for a cross section, which can then be applied to an adjacent reach.

Manning's equation is commonly used to solve for depth (y) given flow (Q), Manning's roughness coefficient (n), wetted width (B_0), and channel slope (S). Manning's equation for a rectangular channel (side slope s=0) is as follows (Chapra 1997):

$$Q = \frac{1}{n}\frac{\left[(B_0 + sy)y\right]^{5/3}}{\left(B_0 + 2y\sqrt{s^2+1}\right)^{2/3}}S_e^{1/2}$$

equation 1

Manning's n typically varies with flow and depth (Gordon et al. 1992). As the depth decreases at low flow, the relative roughness increases. Typical published values of Manning's n, which range from about 0.02 for smooth channels to about 0.15 for rough natural channels, are representative of conditions when the flow is at the bankfull capacity (Rosgen 1996). Critical conditions of depth for evaluating the period of highest stream temperatures are generally much less than bankfull depth, and the relative roughness may be much higher.

Reach-averaged values of Manning's n may be higher than those estimated at any point where flow was measured because the locations of the cross sections for flow measurements were typically selected for laminar flow conditions that occur in channels that are deeper and narrower than average. Likewise, reach-averaged depth may be considerably less than the depth at the flow measurement stations. Therefore, reach-averaged relative roughness is likely to be greater than the measured roughness at the flow stations. Estimated Manning's roughness coefficients (n) are shown in Table 12.

Table 12. Estimated Manning's roughness coefficients (n)

Stream, Stream segment	Average Manning's n value
Carpenter Creek	0.1
Hill Ditch	0.04
Fisher Creek	0.11
Hansen Creek upper	0.0916
Hansen Creek lower	0.0377
Lake Creek	0.081
Nookachamps Creek nr Hwy 9 and 538	0.03
Nookachamps Creek	0.05
East Fork Nookachamps Creek	used hydraulic geometry coefficients

The relationships in Tables 11 and 12 were used to define the longitudinal channel characteristics used as input to the QUAL2Kw model.

Ecology used the Rosgen stream morphology classification system (Rosgen 1996) to describe the channel characteristics for streams in the lower Skagit River study area (Table 13). This information is helpful in determining what morphological parameters are contributing to elevated water temperatures in the watershed.

Table 13. Rosgen classification for the lower Skagit River study area.

Stream Name	Identifying Station(s)	Average Slope (%)	Bankfull Width/Depth Ratio	Sinuosity	Dominant Bed Material	Rosgen Channel Classification
Hill Ditch	03C01, 03C02, 03C03	1	28	very low	sand, silt, clay	diked-channelized
Carpenter Creek	03C04	5	12	low	gravel-cobble	C3
Fisher Creek	03F01	5	13	moderate	gravel-cobble	C3
	03F02	2	17	moderate	gravel-cobble	C3
Hansen Creek	03H03	2.3	20	moderate	cobble-gravel	B3
	03H02, 03H01	1	19	low	gravel	dredged channel
Nookachamps Creek	03N03	1	28	very low	gravel-cobble	channelized
	03N02	1	28	low	cobble-boulder	C2
	03N01	1	28	very low	sand	diked-channelized
Lake Creek	03N04	1	18	low	gravel-cobble	C4
East Fork Nookachamps Creek	03EF02	1	50	low	sand silt clay	channelized
	03EF01	1	24	low	gravel sand	diked channelized

Climate Data

A network of dataloggers was installed to continuously monitor air temperature throughout the study area according to Pelletier and Bilhimer (2001) (Figure 15). Relative humidity was continuously monitored at one station located near the mouth of Carpenter Creek. The NOAA National Climate Data Center (NCDC) station at Mt. Vernon 3WNW (1956-present) also provides a record of long-term trends in climate data. The Mt. Vernon 3WNW station was used to estimate the median year hottest week and 90th percentile year hottest week conditions for climate.

The highest daily maximum and highest 7-day-average of daily maximum air temperatures for each year of record at the Mt. Vernon 3WNW station were ranked to determine the median and 90th percentile conditions (Table 14).

Intact riparian corridors often produce a microclimate that surrounds the stream where cooler air and ground temperatures, higher relative humidity, and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures, reducing maximum air temperatures and increasing minimum air temperatures.

Table 14. Estimated daily maximum and minimum air temperatures at the NCDC station (Mt. Vernon 3WNW) on days and weeks with the highest daily maximum temperatures (ºC) for a median year and 90th percentile year, based on records for 1956 to 2001.

Average daily air temperature	Median year		90th percentile year	
	Hottest week 8/21-8/27 1986	Hottest day 8/17/1997	Hottest week 8/10-8/16 1967	Hottest day 8/17/1977
Maximum	27.2	30.6	29.7	33.9
Minimum	10.1	11.7	10.6	10

An accurate estimation of air temperatures in the riparian areas during the 7Q2 and 7Q10 model simulations should incorporate this ‘microclimate’ effect. In order to do this, it was necessary to first make comparisons between the air temperatures reported at the Mt. Vernon 3WNW station and those air temperatures measured by the thermistors at each Ecology station during the 2001 model calibration and verification period. Table 15 summarizes these comparisons.

The average difference between the air temperatures at the Mt. Vernon 3WNW station and Ecology stations during the calibration and verification period was either subtracted or added to the median and hottest week air temperature maximum and minimum values calculated from the Mt. Vernon 3WNW dataset. These modified maximum and minimum air temperatures were then used for the 7Q2 and 7Q10 model inputs.

The average wind speed in riparian areas of the streams in the study area during July and August was estimated to be approximately 1 m/sec based on regional grids of long-term monthly average surface winds (Quigley et al. 2001).

Table 15. Comparison between air temperatures at the NCDC station (Mt. Vernon 3WNW) and Ecology stations during 2001 calibration and verification periods (°C).

Ecology Stations	Maximum Temperature, 8-12-01			Minimum Temperature, 8-12-01		
	Ecology Data	Mt. Vernon 3WNW Station Data	Difference	Ecology Data	Mt. Vernon 3WNW Station Data	Difference
03C04	21.6	27.8	**6.2**	11.6	10.6	**-1.0**
03C03	22.2	27.8	**5.6**	12	10.6	**-1.4**
03C02	21.6	27.8	**6.2**	13.8	10.6	**-3.2**
03C01	21.9	27.8	**5.9**	12.1	10.6	**-1.5**
03F02	23.02	27.8	**4.8**	11.69	10.6	**-1.1**
03F01	17.38	27.8	**10.4**	12.7	10.6	**-2.1**
03EF02	21.6	27.8	**6.2**	11.6	10.6	**-1.0**
03EF01	28	27.8	**-0.2**	11	10.6	**-0.4**
03H03	21	27.8	**6.8**	13	10.6	**-2.4**
03H02	25.2	27.8	**2.6**	11.5	10.6	**-0.9**
03H01	21	27.8	**6.8**	11.8	10.6	**-1.2**
03N04	26.2	27.8	**1.6**	11.1	10.6	**-0.5**
03N03	22.7	27.8	**5.1**	10.4	10.6	**0.2**
Knapp Rd	28.2	27.8	**-0.4**	10.39	10.6	**0.2**
Swan Rd	28.11	27.8	**-0.3**	9.79	10.6	**0.8**
03N01	18.12	27.8	**9.7**	10.61	10.6	**0.0**
			avg difference +4.81			**avg difference -0.97**

Ecology Stations	Maximum Temperature, 8-18-01			Minimum Temperature, 8-18-01		
	Ecology Data	Mt. Vernon 3WNW Station Data	Difference	Ecology Data	Mt. Vernon 3WNW Station Data	Difference
03C04	17.2	21.6	**4.4**	13.3	12.8	**-0.5**
03C03	18.3	21.6	**3.3**	13.3	12.8	**-0.5**
03C02	18.8	21.6	**2.8**	13.8	12.8	**-1**
03C01	19.4	21.6	**2.2**	13	12.8	**-0.2**
03F02	18.12	21.6	**3.5**	12.31	12.8	**0.49**
03F01	16.2	21.6	**5.4**	12.99	12.8	**-0.19**
03EF02	17.4	21.6	**4.2**	12.7	12.8	**0.1**
03EF01	20.7	21.6	**0.9**	12.7	12.8	**0.1**
03H03	17.7	21.6	**3.9**	12.4	12.8	**0.4**
03H02	19.6	21.6	**2.0**	12	12.8	**0.8**
03H01	17.6	21.6	**4.0**	13	12.8	**-0.2**
03N04	18.8	21.6	**2.8**	13	12.8	**-0.2**
03N03	18.7	21.6	**2.9**	13	12.8	**-0.2**
Knapp Rd	21.49	21.6	**0.1**	12.88	12.8	**-0.08**
Swan Rd	21.19	21.6	**0.4**	12.43	12.8	**0.37**
03N01	17	21.6	**4.6**	13.08	12.8	**-0.28**
			avg difference +2.96			**avg difference -0.07**

Riparian Vegetation and Effective Shade

In a study focusing on the adjacent Stillaguamish River watershed, Pess et al. (1999) reported that historic floodplain forests along the larger channels were a mix of deciduous and coniferous species. Nearly one-third of the stems were red alder, one-third were other deciduous species (mainly big leaf maple and vine maple), and the remainder were coniferous species (mainly western hemlock, western red cedar, and Sitka spruce). The largest trees in the riparian areas were mainly Sitka spruce and the smallest were mostly red alder. Upland forests were predominantly coniferous species (mainly western hemlock, Douglas-fir, and western red cedar).

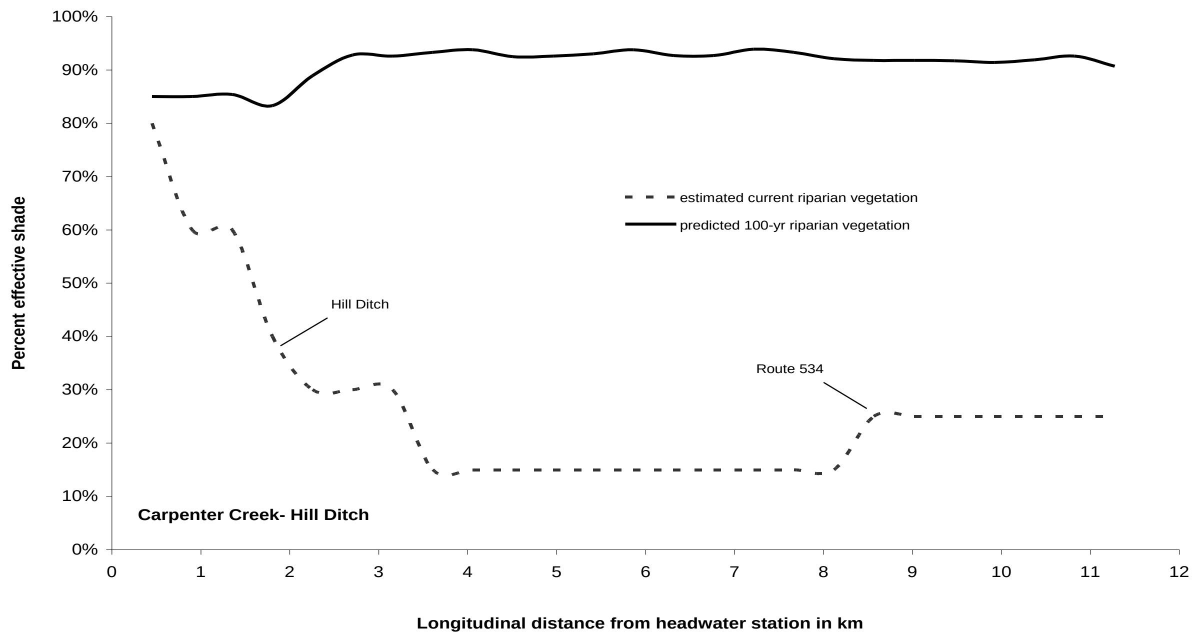
Because of similar climate, geology, and elevation, the lower Skagit River study area was assumed to have similar historic riparian vegetation characteristics as those reported by Pess et al. (1999) in the Stillaguamish River watershed. According to the soil survey for Skagit County (USDA 1981), the most common trees on the riparian soils within the lower Skagit River tributaries study area include Douglas-fir, western red cedar, red alder, big leaf maple, and some western hemlock.

Effective shade produced by current riparian vegetation was estimated using Ecology's Shade model (Ecology 2003a) (Figures 21-23). GIS coverages of riparian vegetation in the study area were created from information collected during the 2001 temperature study as described in Pelletier and Bilhimer (2001) and analysis of the most current digital orthophotos (1990-1993). Riparian forest coverages were created by qualifying four attributes: tree height, species and/or combinations of species, percent vegetation overhang, and the average canopy density of the riparian forest.

All four attributes of vegetation in the riparian zone on the right and left bank were sampled from GIS coverages of the riparian vegetation along the stream at 30-meter to 100-meter intervals using the Ttools extension for Arcview that was developed by ODEQ (ODEQ 2001). Other spatial data that were estimated at each transect location include stream aspect, elevation within the riparian area, and topographic shade angles to the west, south, and east.

For the TMDL load allocations, future riparian characteristics such as dominant species type and height were taken from soils information given in the Soil Survey of Skagit County (USDA 1981). The survey provides predominant species and height for the most common trees found on the riparian soils within the study area. Predominant species are similar to those reported by Pess et al. (1999) in his characterization of historic riparian vegetation characteristics in the adjacent Stillaguamish River watershed.

Table B-5 in Appendix B details the methodology for determining riparian tree species, heights, and widths, based on information given in the Soil Survey of Skagit County (USDA 1981), FEMAT (1993), and Oliver (1988).



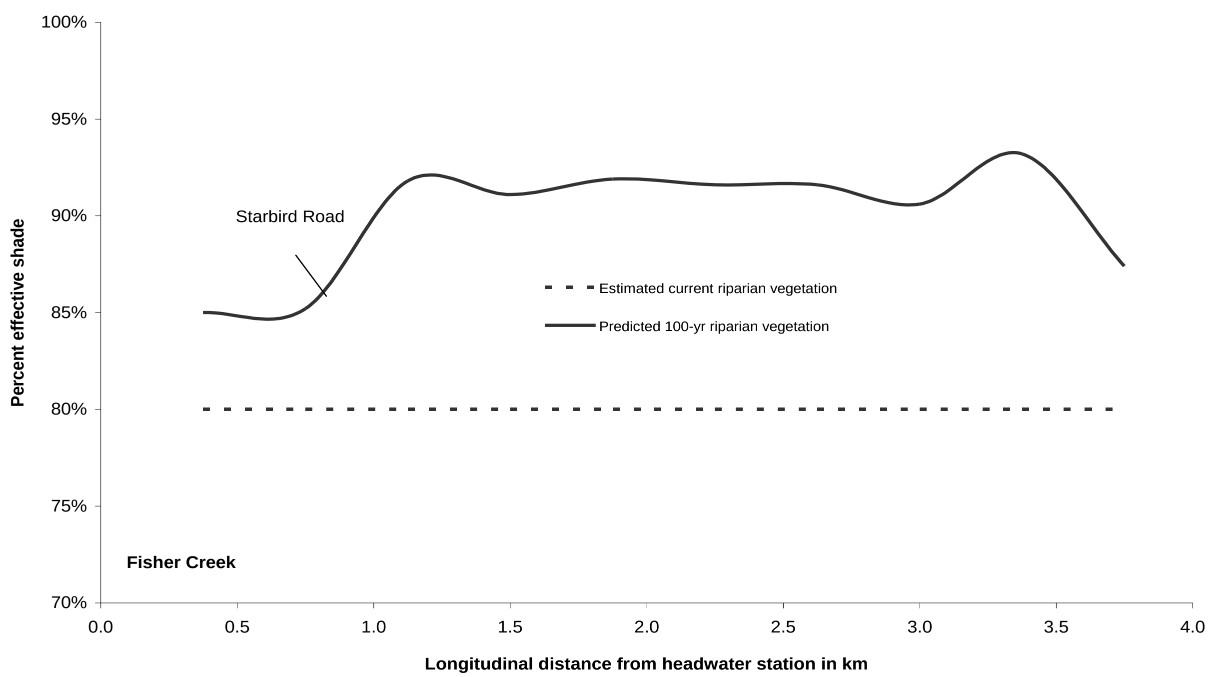
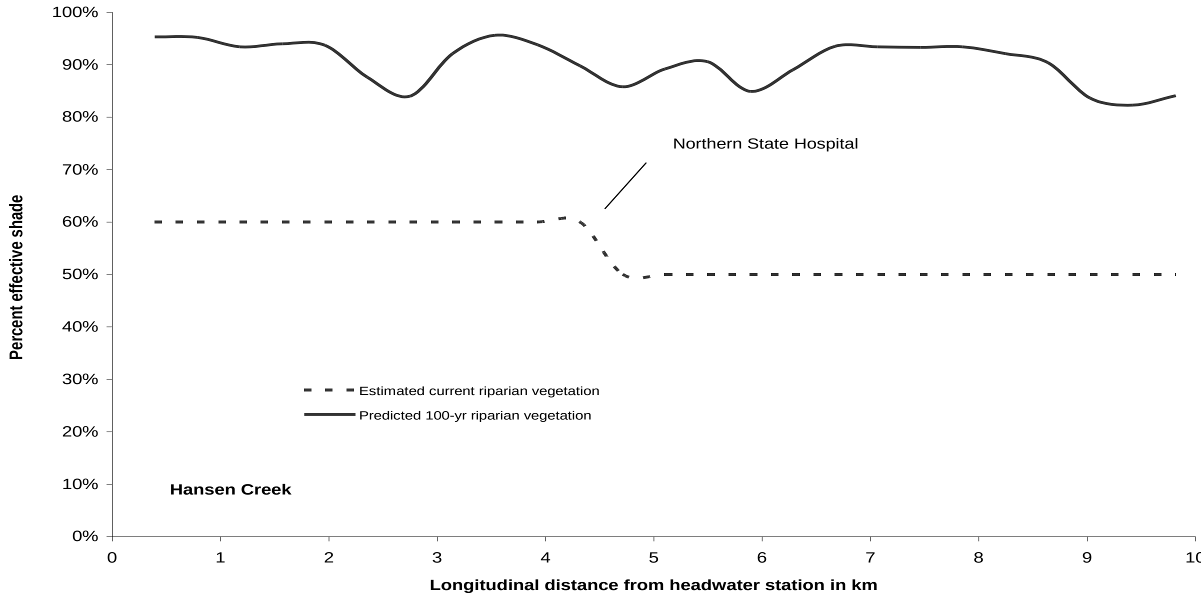


Figure 21. Effective shade from current and potential riparian vegetation in Carpenter Creek and Fisher Creek.



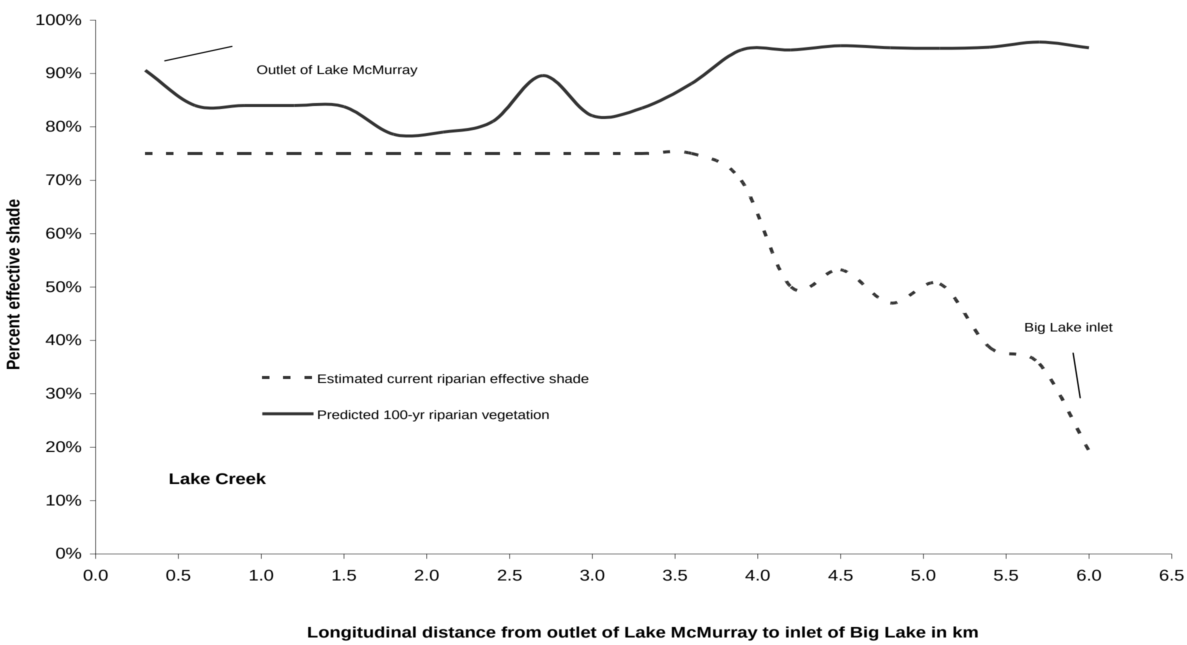
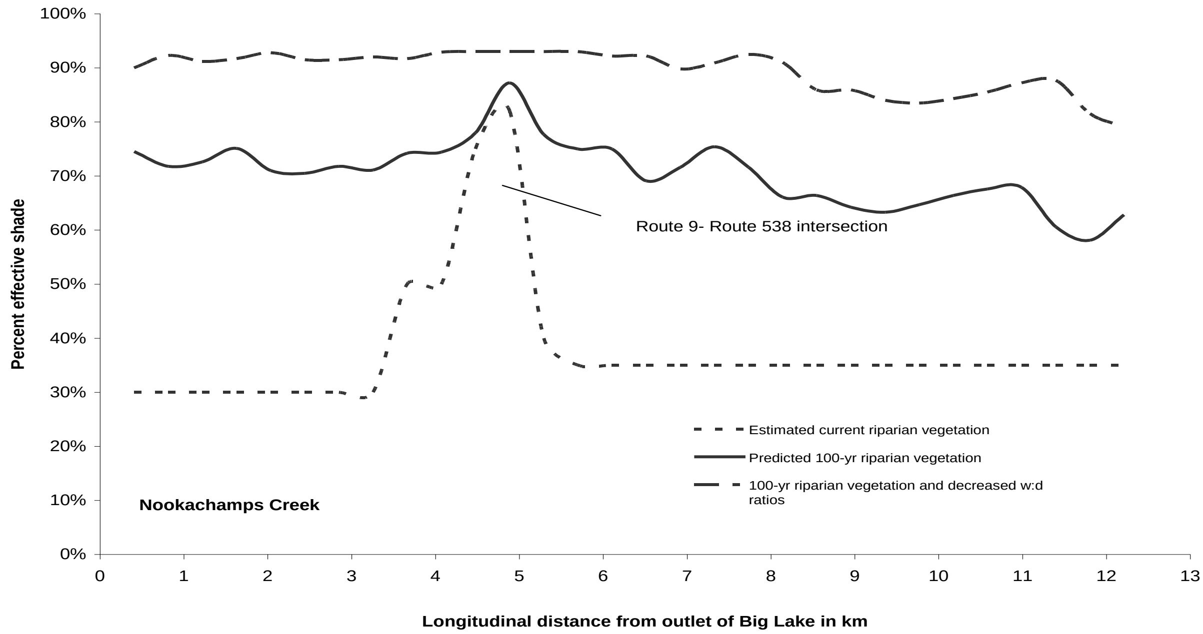


Figure 22. Effective shade from current and potential riparian vegetation in Hansen Creek and Lake Creek.



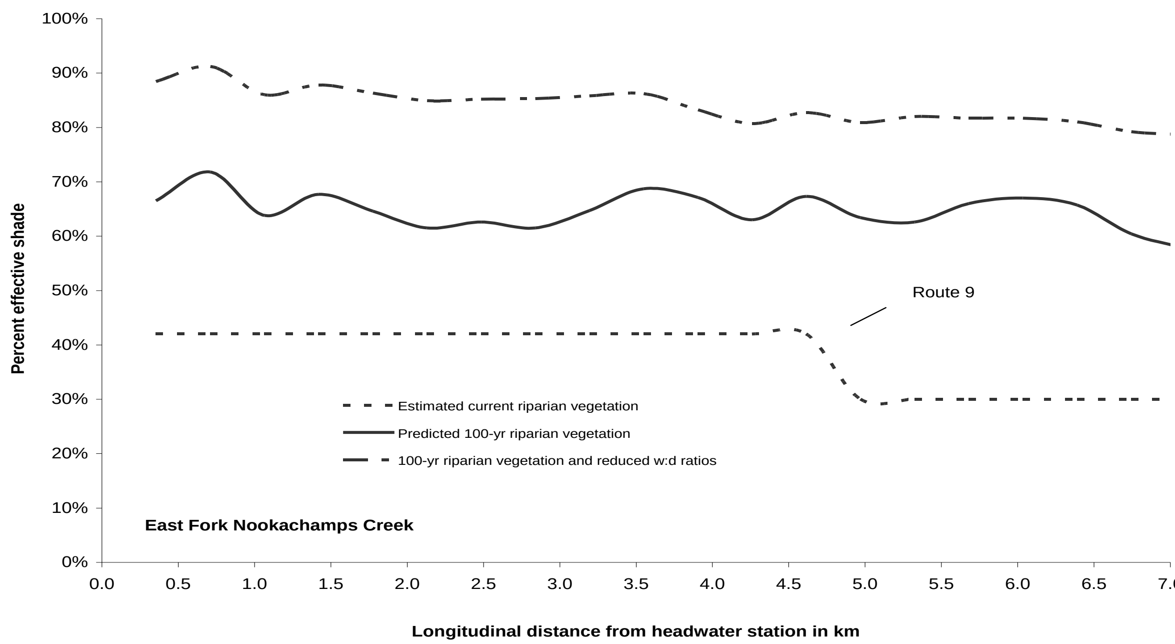


Figure 23. Effective shade from current and potential riparian vegetation in Nookachamps Creek and East Fork Nookachamps Creek.

Effective shade calculations were made for three scenarios of vegetation and channel geometry:

- *Current vegetation.* Estimates for current vegetation were based on spatial data for height and canopy density.
- *Effective shade from 100-year-old riparian vegetation.* The average height of trees for 100-year-old riparian vegetation was taken from site-specific information provided in the U.S. Department of Agriculture Soil Survey for Skagit County (USDA 1981). Riparian vegetation consisted of mixed deciduous and coniferous species in the floodplain, with average tree heights ranging from 28-40 meters and average canopy densities of 75%.
- *Effective shade from 100-year-old riparian vegetation and reduced channel width.* Effective shade from a combination of 100-year-old riparian vegetation and associated natural reductions in the current width-to-depth ratios that may occur in portions of Nookachamps and East Fork Nookachamps creeks, as elsewhere in the study area.

Analytical Framework

Data collected during this TMDL effort have allowed the development of a temperature simulation methodology that is both spatially continuous and which spans full-day lengths (quasi-dynamic steady-state diel simulations). The GIS and modeling analysis was conducted using three specialized software tools:

1. ODEQ's Ttools extension for Arcview (ODEQ 2001) was used to sample and process GIS data for input to the Shade and QUAL2Kw models. Appendices B-1 and B-2 list the codes and descriptions of current and site potential vegetation used in Ecology's Shade model (Ecology 2003a).

2. Ecology's Shade model (Ecology 2003a) was used to estimate effective shade along six of the lower Skagit River tributaries. Effective shade was calculated along the mainstems of Carpenter, Fisher, Hansen, Lake, Nookachamps, and East Fork Nookachamps creeks using the Shade model. Effective shade was calculated at intervals ranging from 30 to 100 meters along the streams and then averaged over 300- to 400-meter intervals for input to the QUAL2Kw model.

3. The QUAL2Kw model (Chapra 2001; Ecology 2003b) was used to calculate the components of the heat budget and to simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. QUAL2Kw was applied by assuming that flow remains constant for a given condition such as a 7-day or 1-day period, but key variables are allowed to vary with time over the course of a day. For temperature simulation, the solar radiation, air temperature, relative humidity, headwater temperature, and tributary water temperatures were specified or simulated as diurnally varying functions. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are shown in Figure 2 and described in Chapra (1997). Diurnally varying water temperatures at 300- to 500-meter intervals along the streams in the lower Skagit River study area were simulated using a finite difference numerical method. The water temperature model was calibrated to instream data along the mainstems of the streams.

All input data for the Shade and QUAL2Kw models are longitudinally referenced, allowing spatial and/or continuous inputs to apply to certain zones or specific river segments. Model input data were determined from available GIS coverages using the Ttools extension for Arcview, or from data collected by Ecology or other data sources. Detailed spatial data sets were developed for the following parameters for model calibration and verification:

- Rivers and tributaries were mapped at 1:3,000 scale (or less) from 1-meter-resolution Digital Orthophoto Quads from 1990-1993.

- Riparian vegetation species, size, and density were mapped and sampled from the GIS coverage at 100-meter intervals along the streams in the study area.

- Near-stream disturbance zone (NSDZ) widths were digitized at 1:3000 scale (or less).

- West, east, and south topographic shade angle calculations were made from the 10-meter DEM grid using ODEQ's Ttools extension for Arcview.

- Stream elevation and gradient were sampled from the 10-meter DEM grid with the Arcview Ttools extension. Gradient was calculated from the longitudinal profiles of elevation from the 10-meter DEM.

- Aspect (stream flow direction in decimal degrees from north) was calculated by the Ttools extension for Arcview.

- The daily minimum and maximum observed temperatures for the boundary conditions at the headwaters and tributaries were used as input to the QUAL2Kw model for the calibration and verification periods. The QUAL2Kw model was calibrated and verified using data collected during August 9-15, 2001 and August 17-20, 2001, respectively (Figures 23-28).

- Flow balances for the calibration and verification periods were estimated from field measurements and gage data of flows made by Ecology. The lowest 7-day-average flows during the July-August period with recurrence intervals of 2 years (7Q2) and 10 years (7Q10) were estimated based on low-flow statistics from the USGS gauging station in the adjacent Pilchuck Creek basin. The 7Q2 and 7Q10 flows in the study area were then estimated by scaling the estimates at the USGS gage according to the sub-watershed areas weighted by annual average precipitation. Flow balance spreadsheets of the stream networks for Carpenter, Fisher, Hansen, Lake, Nookachamps, and East Fork Nookachamps creeks were constructed to estimate surface water and groundwater inflows by interpolating between the stream gauging stations.

- Hydraulic geometry (wetted width, depth, and velocity as a function of flow) was estimated using the equations developed in Table 11. Manning's equation was used to estimate channel depth and velocity (Table 12).

- The temperature of groundwater is often assumed to be similar to the mean annual air temperature (Theurer et al. 1984). The mean annual air temperature along the streams in the lower Skagit River study area ranges from approximately 11.2°C at low elevation to about

6°C at the highest elevations. Because there are very limited data, and most of the modeled reaches lie in the lowest elevations, a mean groundwater temperature of 11.2°C was used in the QUAL2Kw model.

- Air temperature and relative humidity were estimated from meteorological data collected by Ecology. The observed minimum and maximum air temperatures and relative humidity at the stations occupied by Ecology during 2001 were used to represent the conditions for the calibration and verification periods. Cloud cover for the calibration and verification periods was estimated from data reported at the Arlington, WA airport weather station. A cloud cover of 40% was used for the calibration period, and 60% was used for the verification period. The average July-August wind speed of 1 m/sec was used for temperature modeling.

- Heat exchange between the water and the streambed is simulated in QUAL2Kw by two processes: (1) conduction according to Fick's law is estimated as a function of the temperature gradient between the water and surface sediment, thickness of the surface sediment layer, and the thermal conductivity which is a function of thermal diffusivity, sediment density, and sediment heat capacity, and (2) hyporheic exchange is estimated as a function of the temperature gradient between the water and surface sediment and the bulk diffusive flow exchange between the water and the streambed, the thickness of the surface sediment layer, the density and heat capacity of water.

  Calibration of the QUAL2Kw model involved specification of the thickness of the surface sediment layer in the range of 10 to 100 cm, and specification of the bulk diffuse flow exchange between the water and the streambed between 0 and 100% of the surface flow in a stream reach. Typical values for the thermal diffusivity at the sediment surface ranged from 0.0045 to 0.0150 cm^2/sec, which is similar to the literature values summarized by Sinokrot and Stefan (1993) for typical streambed materials.

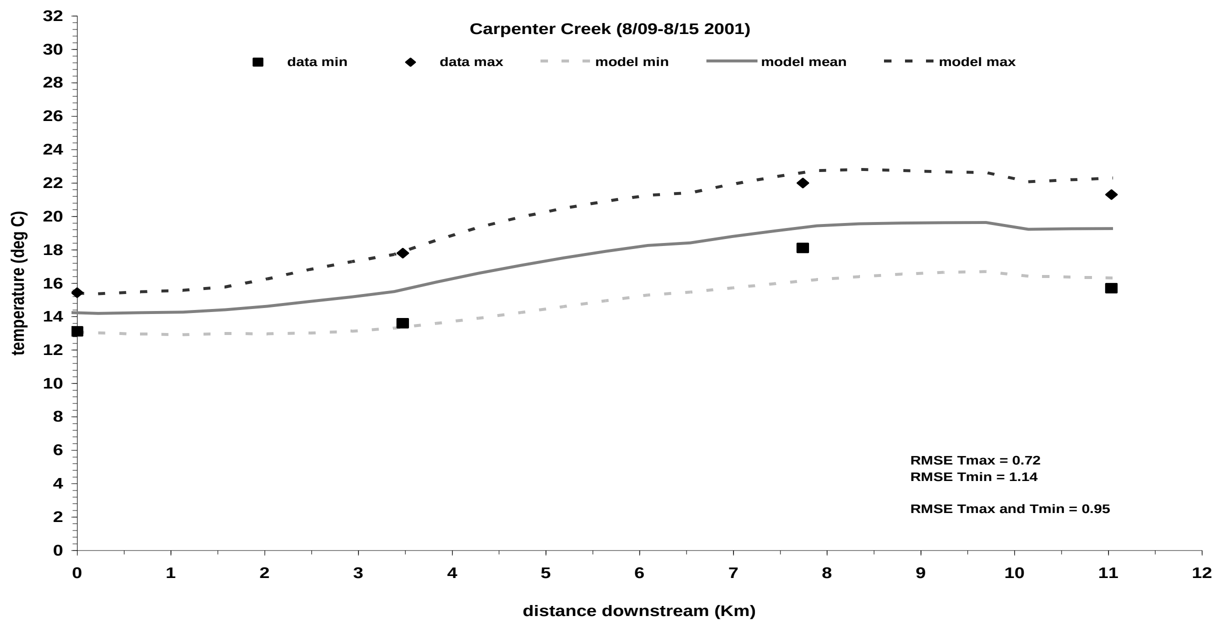
Calibration and Verification of the QUAL2Kw Model

The hottest 7-day period of 2001 occurred from August 9-15, 2001 and was used for calibration of the QUAL2Kw model (Figures 24-29). The August 17-20, 2001 period was used for verification of the QUAL2Kw model to test the calibration (Figures 24-29).

The uncertainty or goodness-of-fit of the predicted temperatures from the QUAL2Kw model was evaluated by calculating the root mean squared error (RMSE) of the predicted versus observed maximum and minimum temperatures (Table 16). The average maximum RMSE for the calibration period was 0.56°C. The average maximum RMSE for the verification period was 0.44°C. In general, the error of the models predictions is less than 1ºC, and slightly greater for Carpenter Creek.

Table 16. Summary of RMSE of differences between the predicted and observed daily maximum temperatures (ºC) in the lower Skagit River study area, 2001.

Modeled Creek	Calibration Period August 9 -15		Verification Period August 17 - 20	
	max	min	max	min
Carpenter	0.72	1.14	0.26	1.41
Fisher	0.66	0.25	0.55	0.42
Hansen	0.51	0.61	0.77	0.67
Lake	0.58	0.35	0.17	0.74
Nookachamps	0.73	0.59	0.71	0.85
E.F. Nookachamps	0.17	0.7	0.25	0.92



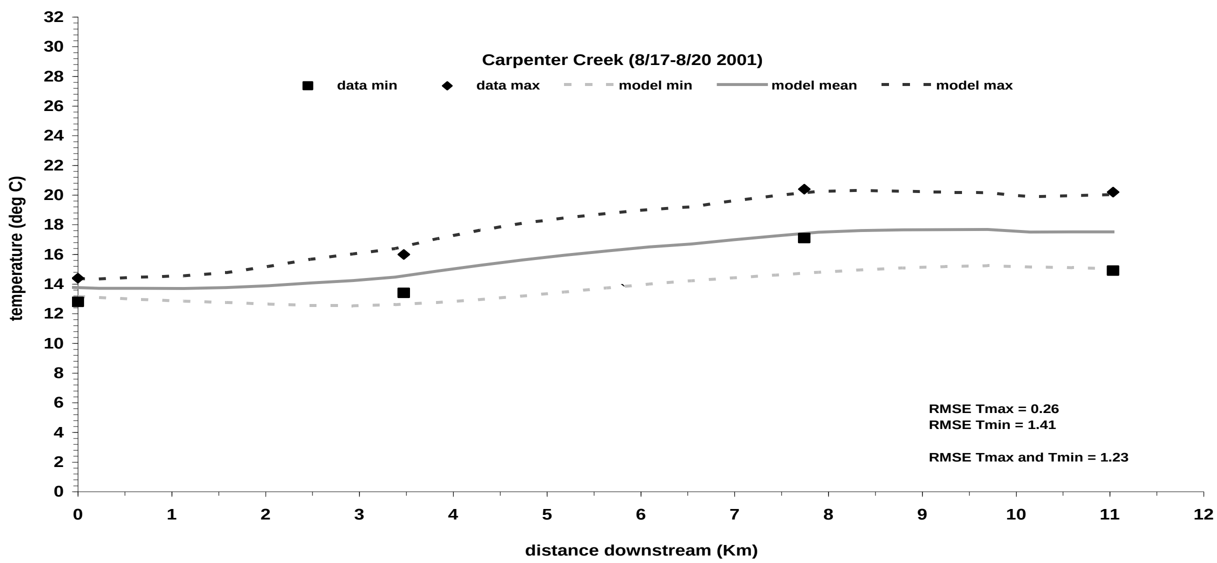
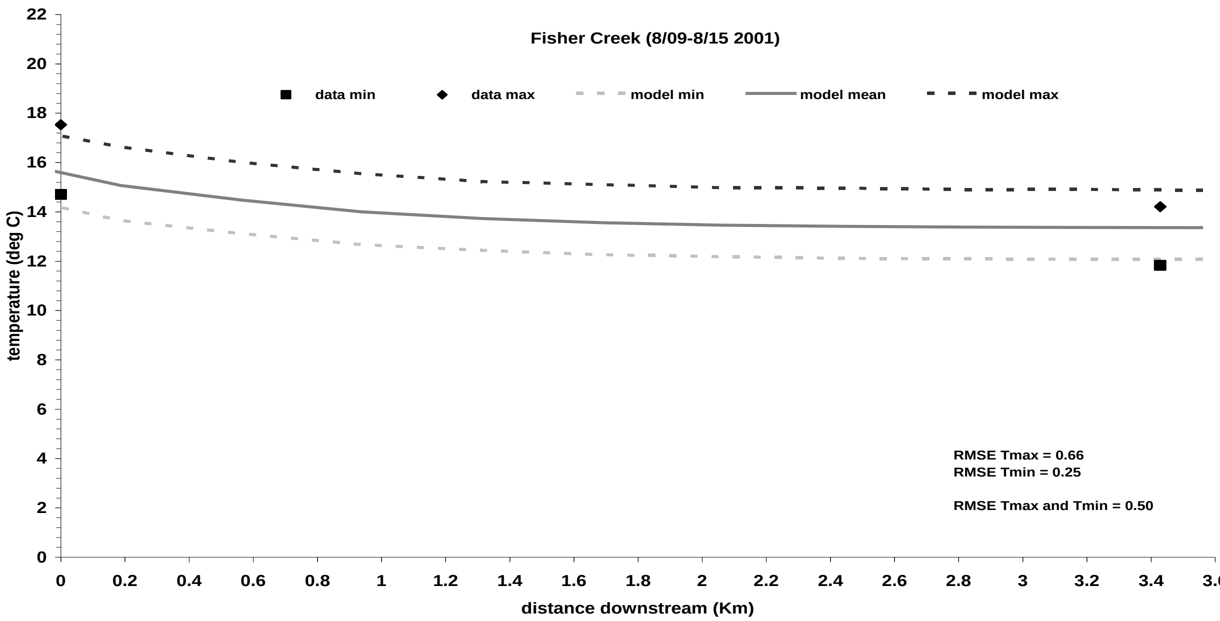


Figure 24. Predicted (top figure) and observed (bottom figure) water temperatures in Carpenter Creek during calibration and verification periods.



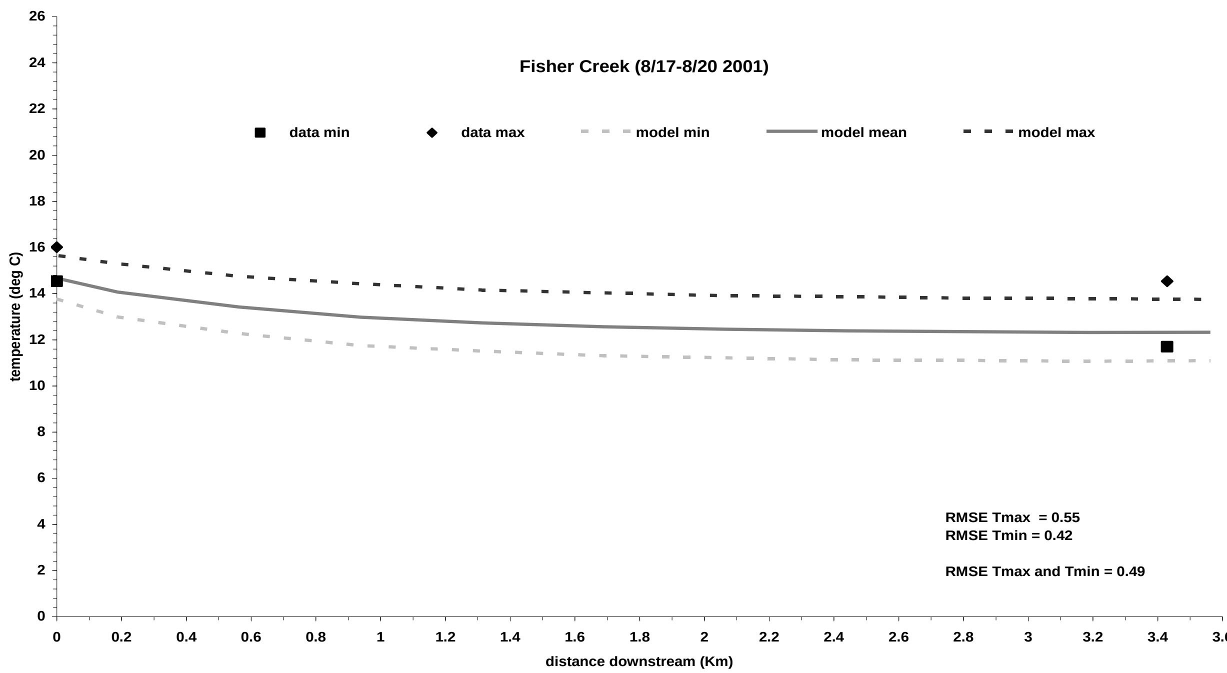
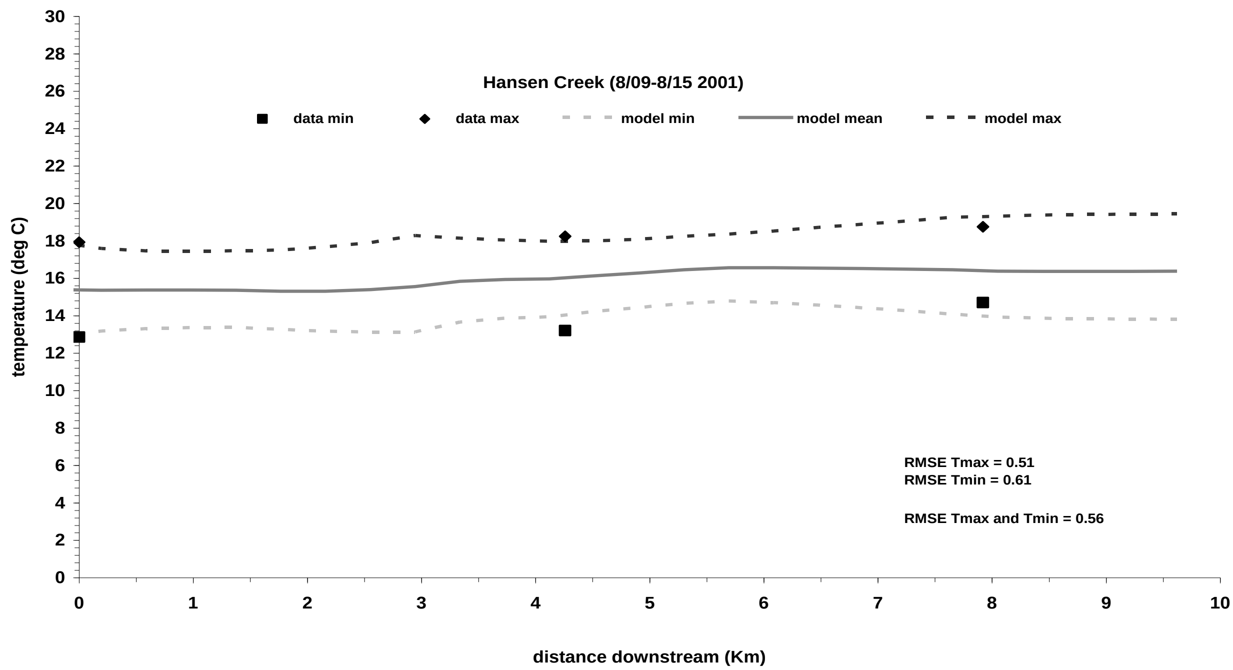


Figure 25. Predicted (top figure) and observed (bottom figure) water temperatures in Fisher Creek during calibration and verification periods.



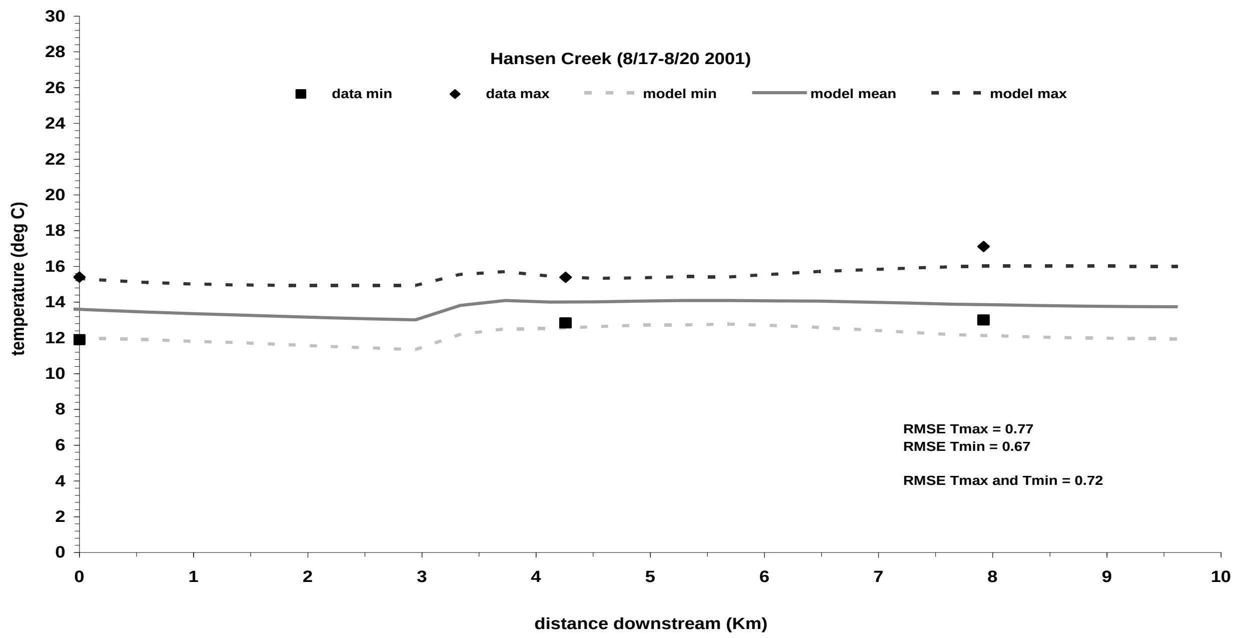
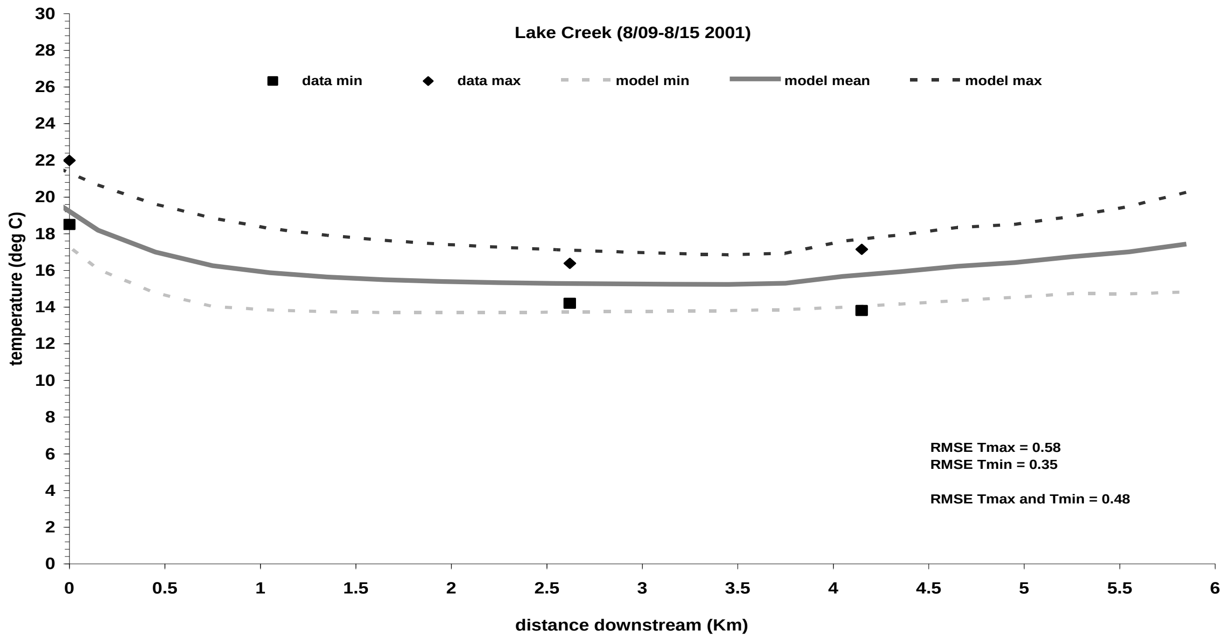


Figure 26. Predicted (top figure) and observed (bottom figure) water temperatures in Hansen Creek during calibration and verification periods.



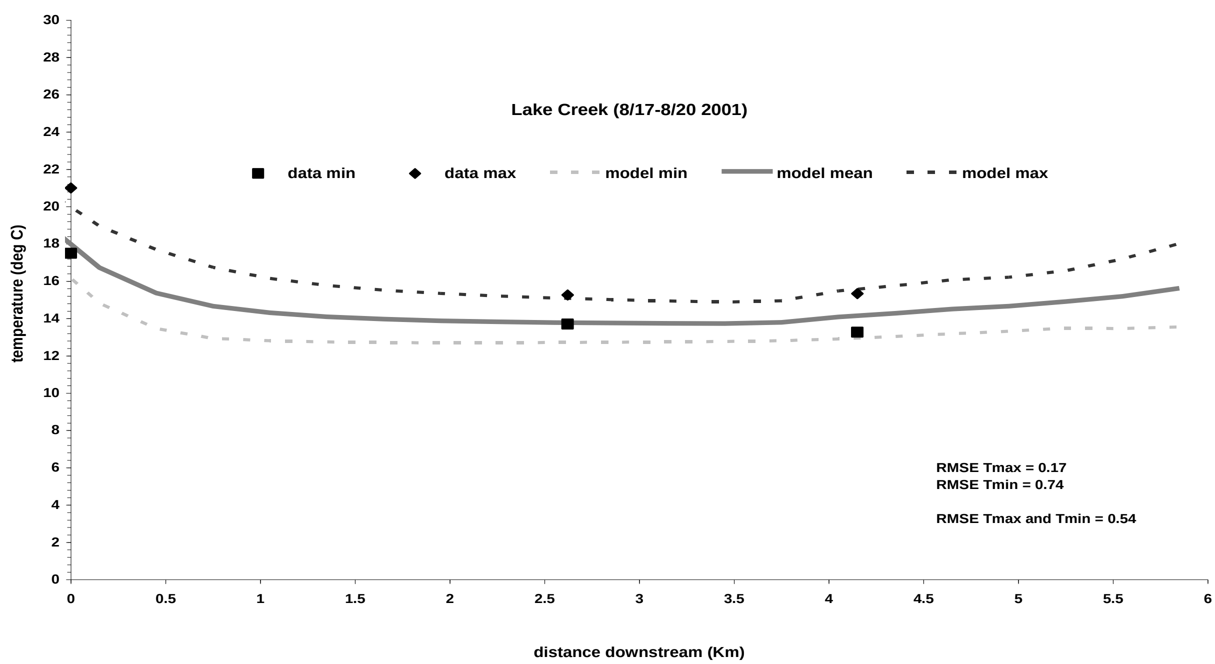
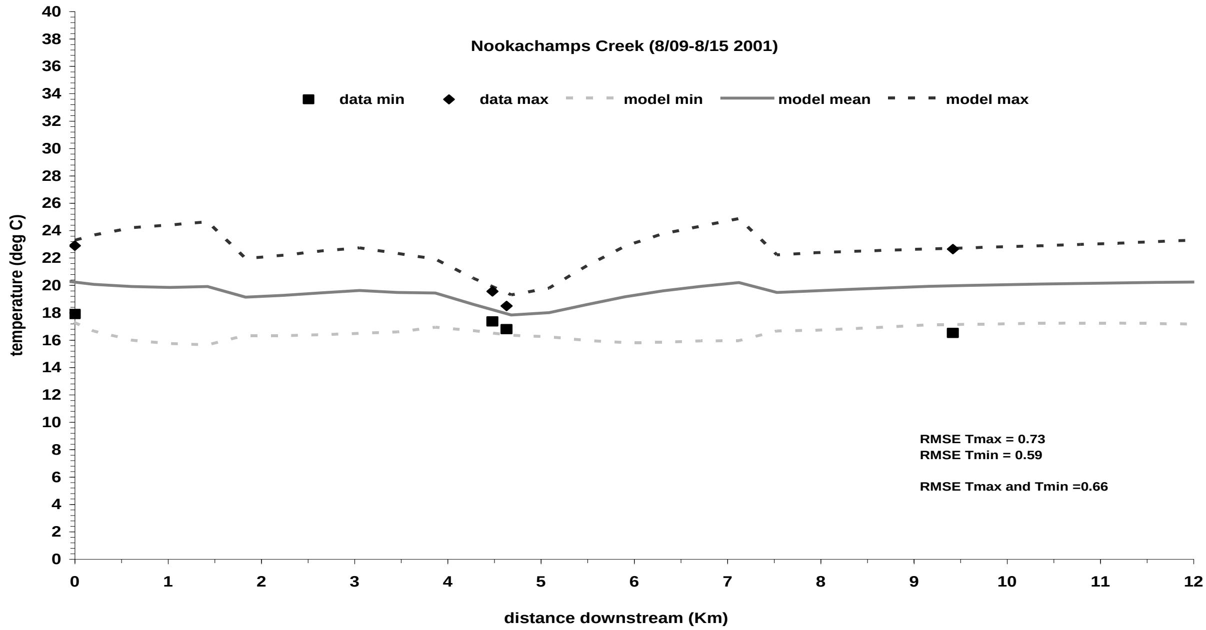


Figure 27. Predicted (top figure) and observed (bottom figure) temperatures in Lake Creek during calibration and verification periods.



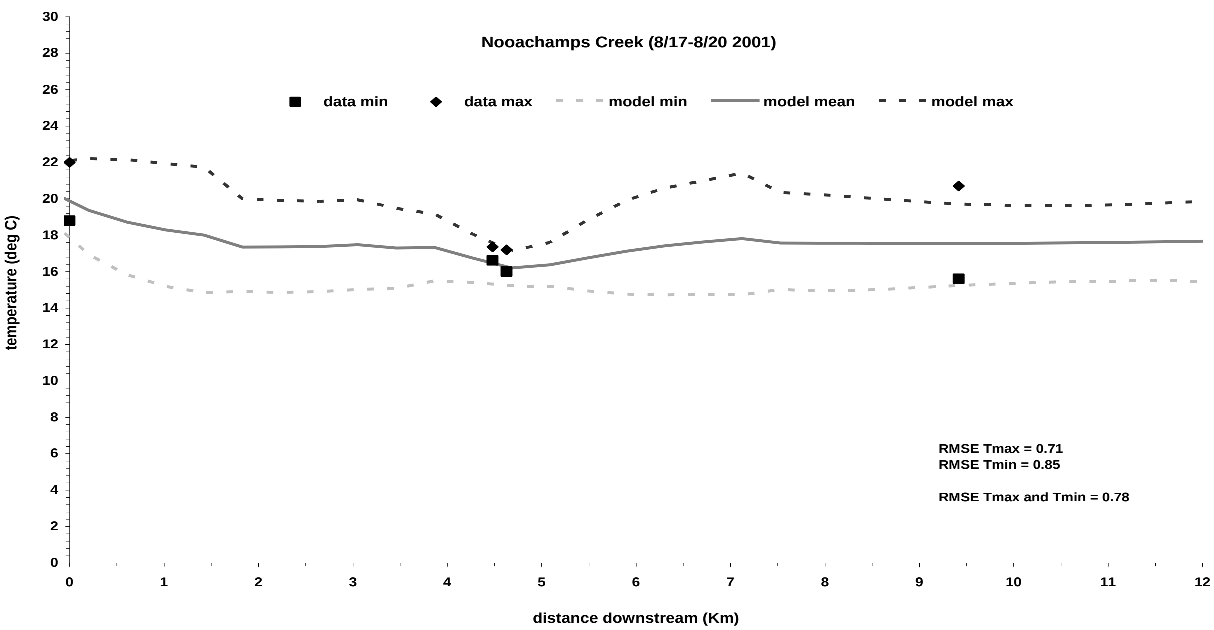
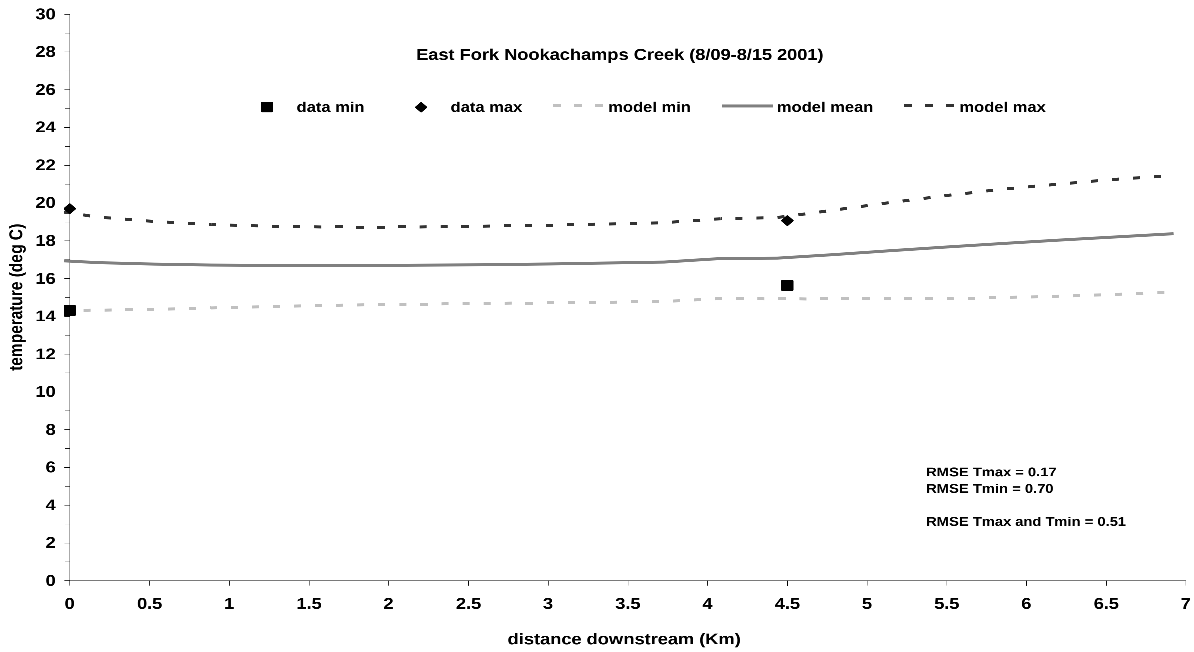


Figure 28. Predicted (top figure) and observed (bottom figure) water temperatures in Nookachamps Creek during calibration and verification periods.



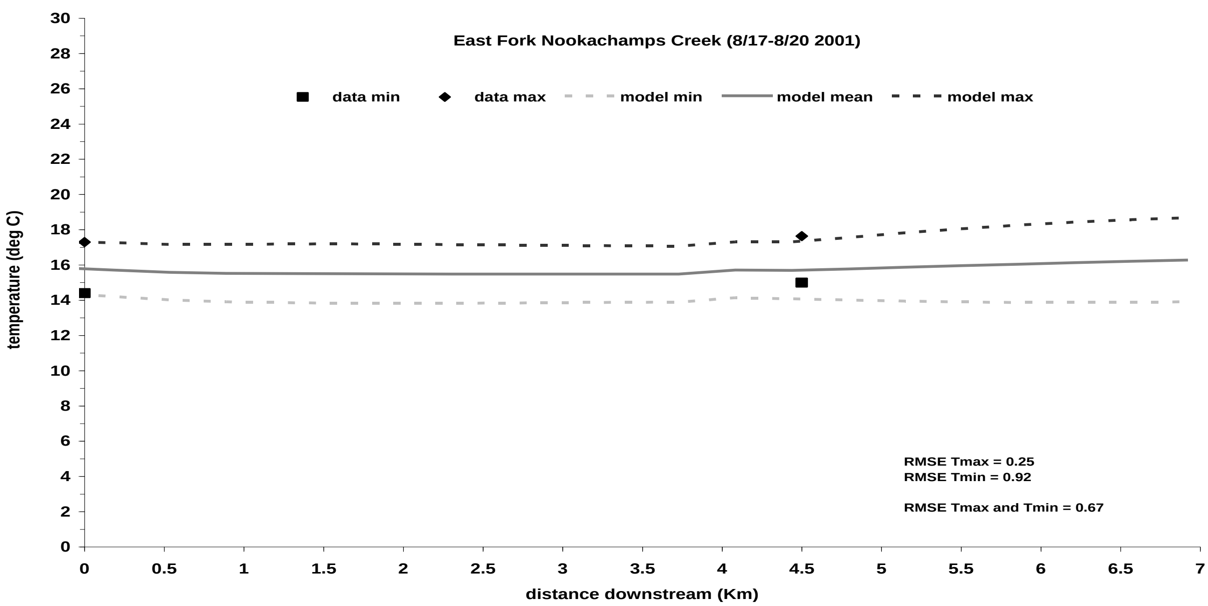


Figure 29. Predicted (top figure) and observed (bottom figure) water temperatures in East Fork Nookachamps Creek during calibration and verification periods.

Loading Capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water body into compliance with standards. EPA's current regulation defines loading capacity as *the greatest amount of loading that a water body can receive without violating water quality standards.*

The loading capacity for this TMDL is based on both portions of the temperature standards.

1. The numeric portion states that *temperature shall not exceed 18.0°C….due to human activities*. This standard applies to areas of the lower Skagit study area where pollution is attributed to increases in solar radiation as a result of human-caused decreases in effective shade. The lack of shading has resulted from the removal of trees throughout the study area, and a subsequent widening of stream channels.
2. The natural condition portion states that *whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.* In these areas, the natural condition provision of the water quality standard is the basis of the loading capacity.

The calibrated QUAL2Kw model was used to determine the loading capacity for effective shade for streams in the lower Skagit River basin. Loading capacity was determined based on prediction of water temperatures under typical and extreme flow and climate conditions combined with effective shade conditions resulting from 100-year-old riparian vegetation and resulting natural decreases in channel width-to-depth ratios.

The lowest 7-day average flow with a 2-year recurrence interval (7Q2) was selected to represent a typical climatic year, and the lowest 7-day average flow with a 10-year recurrence interval (7Q10) was selected to represent a reasonable worst-case condition for the July-August period. Air temperatures for the 7Q2 condition were assumed to be represented by the hottest week of 1986, which was the median condition from the historical record at Mt. Vernon station 3NW (Table 7). The air temperatures for the 7Q10 condition were taken from the hottest week of 1967, which was the 90th percentile condition from Mt. Vernon station 3NW.

The following scenarios for effective shade were evaluated for the 7Q2 and 7Q10 flow and climate conditions:

- *Effective shade resulting from the existing riparian vegetation and channel conditions.*
- *Effective shade from 100-year-old riparian vegetation that would naturally occur in riparian areas within the study area.* Riparian species were chosen based on soil site potential, as given in the Soil Survey for Skagit County, WA. (USDA 1981). The predominant tree species on all soils within the study area included red alder, western red cedar, and Douglas-fir.

A canopy density of 75% was used for all site potential vegetation (Brazier et al. 1973 and Steinblums et al. 1984). Tree heights (at 100-year site index) ranged from 37 to 53 meters. Riparian zone widths were estimated as 75% of average tree height (FEMAT 1993) and ranged from 28 to 40 meters (Appendix B, Table B-5).

- *Effective shade from 100-year-old riparian vegetation and a natural decrease in channel width for modeled segments of Nookachamps Creek and East Fork Nookachamps Creek.* It is likely that 100-year-old vegetation and associated riparian functions of moderate-aged riparian stands would result in concomitant decreases in width-to-depth ratios. Channel widths are expected to decrease as the maturing riparian vegetation along the stream stabilizes the streambanks and prevents lateral erosion.

  Changes in riparian microclimate, decreases in channel width, and reduction of headwater and tributary temperatures were incorporated into the predictions of water temperatures within the study area:

- *Microclimate.* Increases in vegetation height and density in the riparian zone are expected to result in decreases in air temperature, increases in relative humidity, and decreases in wind speed. In order to evaluate the effect of these potential changes in microclimate on water temperature, the air temperature, relative humidity, and wind speed in the riparian areas for scenarios with maximum potential shade from mature riparian were adjusted relative to the estimated current condition as follows:
  - Based on a study by Dong et al. (1998): average air temperatures within the modeled reaches were decreased by 1°C.
  - Maximum relative humidity remained constant at 100%. Minimum relative humidity ranged from 70-80%.
  - Wind speed was reduced to 0 or 1m/sec.

- *Channel width.* Channel widths are expected to decrease as the riparian vegetation along the stream matures due to reduced loading of sediment from unstable banks. The sensitivity of predicted stream temperatures to reduction of channel width was tested by predicting stream temperatures that would be associated with decreasing bankfull channel widths by one-third in Nookachamps Creek and East Fork Nookachamps Creek.

- *Reduced headwater and tributary temperatures.* Scenarios were evaluated with the assumption that the inflowing headwaters and tributaries did not exceed the 18°C (for Class A waters).

The results of the model runs for the critical 7Q2 and 7Q10 conditions are presented in Figures 30 through 35. The current conditions in the lower Skagit study area are expected to result in daily maximum water temperatures that are greater than 18°C in all or most of the evaluated reaches. Temperatures in portions of Carpenter, Lake, Nookachamps, and East Fork Nookachamps creeks could be greater than the approximate threshold for lethality of 23°C under current conditions.

Substantial reductions in water temperature are predicted for hypothetical conditions with 100-year-old riparian vegetation and concomitant changes in riparian microclimate and reduction of channel widths. Potential reduced temperatures are predicted to be less than 18°C in Class A reaches in most of the streams that were evaluated. Those segments not expected to be less than the 18°C standard comprise the outlets of Lake McMurray and Big Lake. Surface water temperatures in both Big Lake and Lake McMurray frequently exceed 22°C during the summer months.

Carpenter Creek

Figure 30 shows the predicted water temperatures in Carpenter Creek and Hill Ditch for the lowest 7-day average flow during July-August with a 2-year recurrence interval (7Q2) and a 10-year recurrence interval (7Q10). Figure 30 shows that increases in effective shade resulting from 100-year-old riparian vegetation and associated changes in microclimate have the potential to produce water temperatures that would meet the water quality standard in the mainstem of Carpenter Creek and Hill Ditch. Riparian vegetation in Carpenter Creek upstream of the modeled segments should be maintained and protected to ensure that the temperature standard of 18°C is met.

Fisher Creek

Figure 31 shows the predicted water temperatures in Fisher Creek for the 7Q2 and 7Q10 conditions. Increases in effective shade from 100-year-old riparian vegetation and associated changes in microclimate have the potential to produce water temperatures that would meet the water quality standard in the lower portions of Fisher Creek. Those portions of Fisher Creek upstream of the modeled segments have a loading capacity set to equal the effective shade produced by 100-year-old riparian vegetation within the riparian corridor. Stream temperatures are warmest in the upper reaches of Fisher Creek, above the modeled segments. Efforts to increase riparian vegetation should be focused in these upper reaches.

Hansen Creek

Figure 32 shows the predicted water temperatures in Hansen Creek for the 7Q2 and 7Q10 conditions. Effective shade from 100-year-old riparian potential riparian vegetation and associated changes in microclimate has the potential to produce water temperatures that would meet the water quality standard in the mainstem of Hansen Creek. Those portions of Hansen Creek upstream of the modeled segments have a loading capacity set to equal the effective shade produced by 100-year-old riparian vegetation within the riparian corridor.

Skagit County has drafted a Watershed Management Plan (Skagit County 2002) for Hansen Creek, which includes measures to restore historic channel morphology, reduce current width-to-depth ratios, and reestablish connectivity between the floodplain and stream channel. The Hansen Creek plan, currently a ‘concept plan’, presents alternative solutions that address sediment loading from upstream sources. In past years, downstream flooding has been addressed through the periodic dredging of the stream channel, which is no longer desirable due to effects on fish habitat. The plan identifies reaches of the creek system that could be re-engineered and restored to provide sediment storage and return downstream areas to a riparian condition more supportive of fish habitat. These proposed alternatives should be examined in detail to determine which would provide the overall greatest benefit with respect to stream temperature and fish habitat.

Red Creek, a tributary to Hansen Creek, has a loading capacity set equal to the effective shade produced by 100-year-old riparian vegetation.

Lake Creek

Figure 33 shows the predicted water temperatures in Lake Creek for the 7Q2 and 7Q10 conditions. Effective shade resulting from 100-year-old riparian vegetation and associated changes in microclimate have the potential to produce water temperatures that would meet the water quality standard in the majority of the mainstem of Lake Creek. Lake McMurray, a shallow lake (< 2 m at outlet) comprises the headwaters of Lake Creek. Summer outflow temperatures frequently exceed the Class A standard for temperature. Figure 33 shows resulting water temperatures in Lake Creek with the addition of 100-year-old riparian vegetation along the mainstem. Figure 33 shows that the highest water temperatures (exceeding 18°C) in Lake Creek are expected to remain at the outflow of Lake McMurray, even with increases in riparian vegetation.

For this section of Lake Creek (approximately 1 km below the discharge from Lake McMurray), the 'natural condition' provision applies. This provision states that "*During critical periods, natural conditions may exceed the numeric temperature criteria mandated by the water quality standards. Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria." (Chapter 173-201A-030 WAC).* The loading capacity in this reach is set to the natural condition temperature.

Nookachamps Creek

Figure 34 shows the predicted water temperatures in Nookachamps Creek for the 7Q2 and 7Q10 conditions. Effective shade resulting from 100-year-old riparian vegetation and associated changes in microclimate have the potential to produce water temperatures that would meet the water quality standard in the majority of the mainstem of Nookachamps Creek.

Big Lake, a shallow lake (< 2 m at outlet), comprises the headwaters of Nookachamps Creek. Summer outflow temperatures frequently exceed the Class A standard for temperature. Figure 34 shows resulting water temperatures in Nookachamps Creek with the addition of 100-year-old riparian vegetation along the mainstem. Figure 34 shows that the highest water temperatures (exceeding 18°C) in Nookachamps Creek are expected to remain at the outflow of Big Lake, even with increases in riparian vegetation.

For this section of Nookachamps Creek (approximately 1 km below the discharge from Big Lake), the natural condition provision of the temperature water quality standards apply. This provision states that "*During critical periods, natural conditions may exceed the numeric temperature criteria mandated by the water quality standards. Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria." (Chapter 173-201A-030 WAC).* The loading capacity in this reach is set to the natural condition temperature.

Much of the Nookachamps mainstem downstream of the Route 9 and Route 538 intersection has been channelized and diked and currently supports little or no riparian vegetation. Natural reductions of at least 30% of stream width-to-depth ratios are recommended for these sections of Nookachamps Creek to further reduce the water temperatures and produce water temperatures that meet the Class A temperature standard during 7Q10 critical conditions of flow and climate.

Otter Pond Creek, a tributary to Nookachamps Creek, has a loading capacity set equal to the effective shade produced by 100-year-old riparian vegetation.

East Fork Nookachamps Creek

Figure 35 shows the predicted water temperatures in East Fork Nookachamps Creek for the 7Q2 and 7Q10 conditions. Effective shade resulting from 100-year-old riparian vegetation and associated changes in microclimate have the potential to produce water temperatures that would meet the water quality standard in the majority of the mainstem of East Fork Nookachamps Creek. Those portions of the East Fork upstream of the modeled segments have a loading capacity set to equal the effective shade produced by 100-year-old riparian vegetation within the riparian corridor.

Nearly the entire modeled segment of the East Fork has been channelized and diked and currently supports little or no riparian vegetation. Natural reductions of at least 30% of stream width-to-depth ratios are recommended for these sections of East Fork Nookachamps Creek to further reduce the water temperatures and produce water temperatures that meet the Class A temperature standard during 7Q10 critical conditions of flow and climate.

Turner Creek, a tributary to East Fork Nookachamps Creek, has a loading capacity set equal to the effective shade produced by 100-year-old riparian vegetation along the riparian corridor.

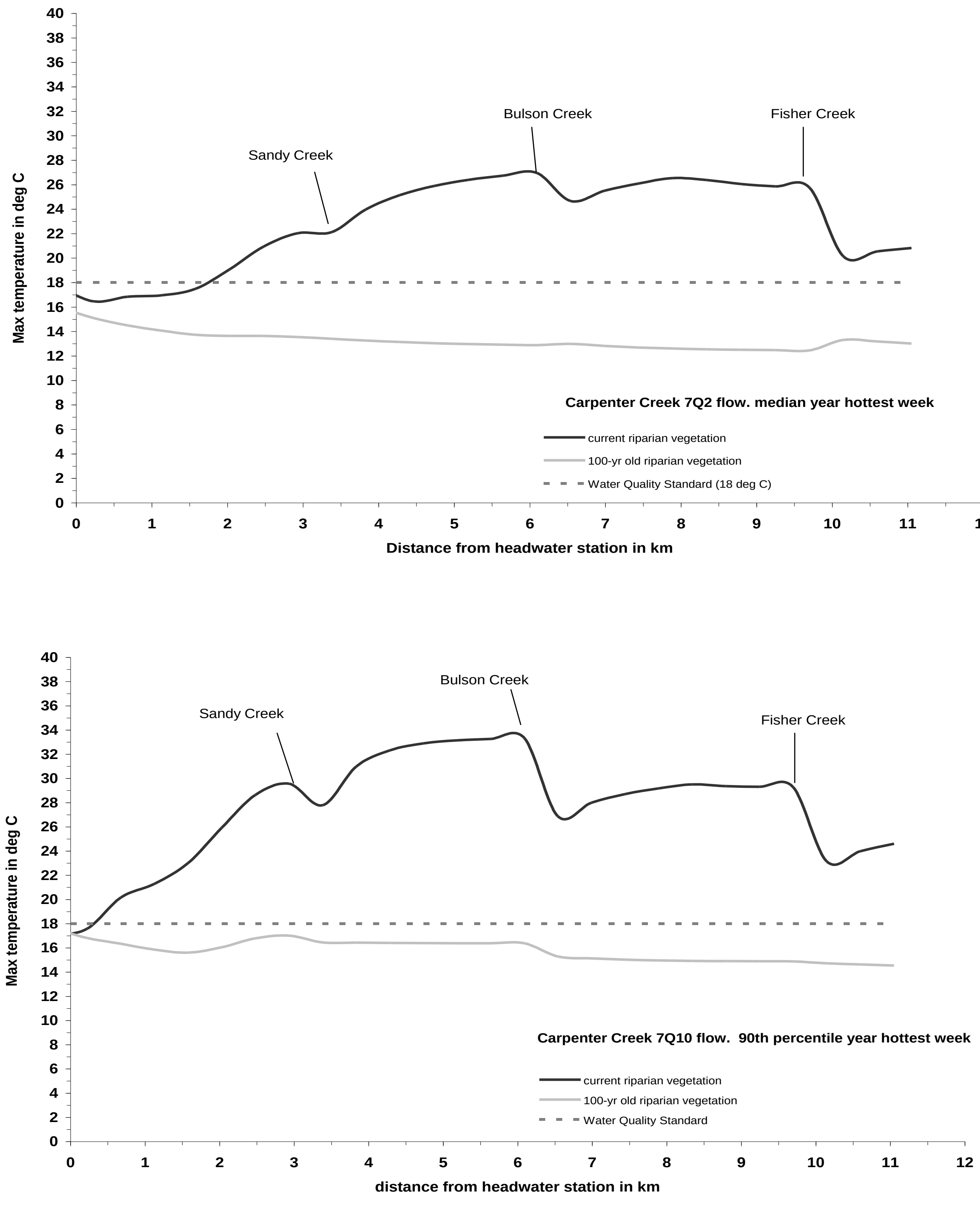


Figure 30. Predicted daily maximum temperature in Carpenter Creek under critical conditions for the TMDL.

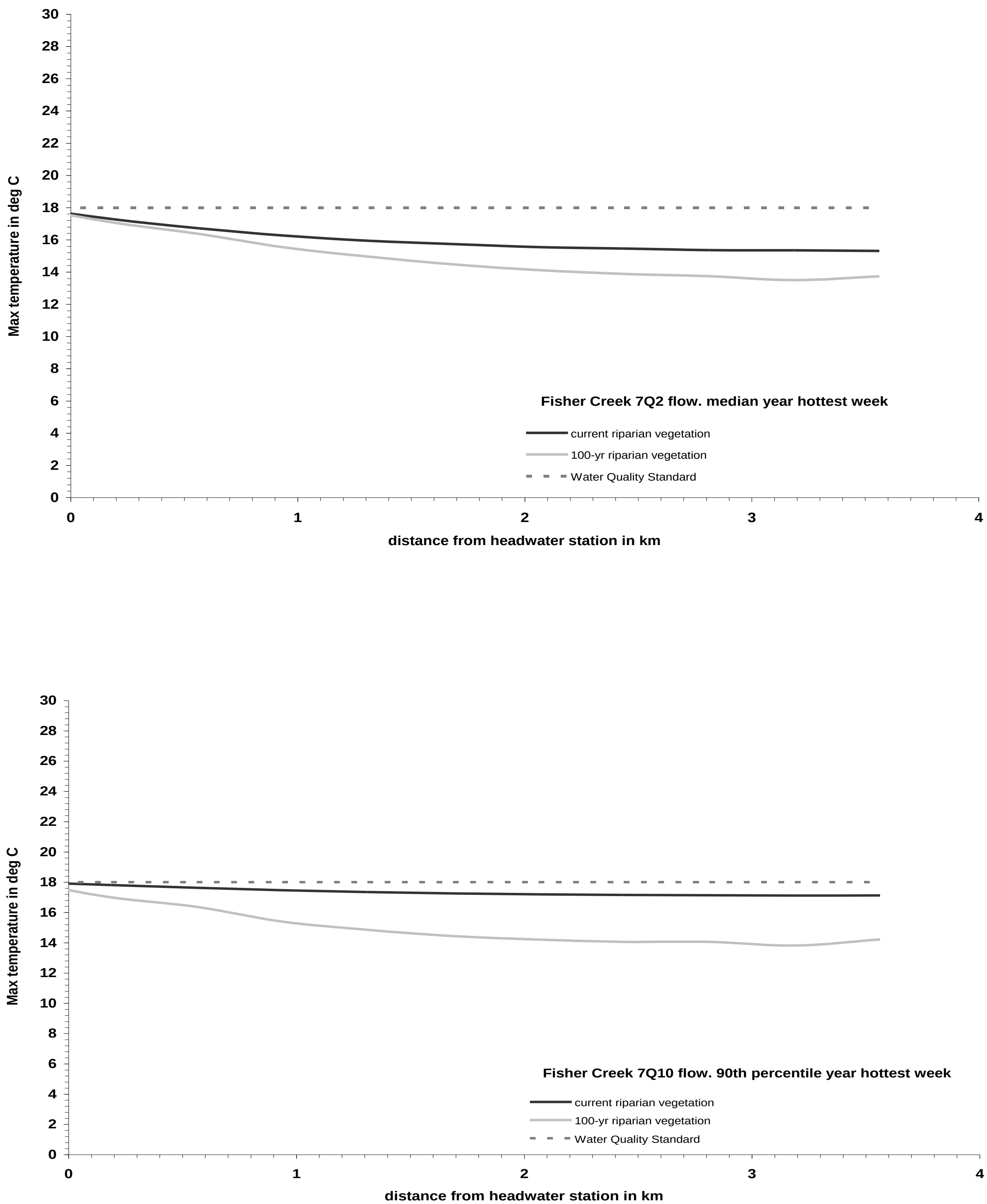
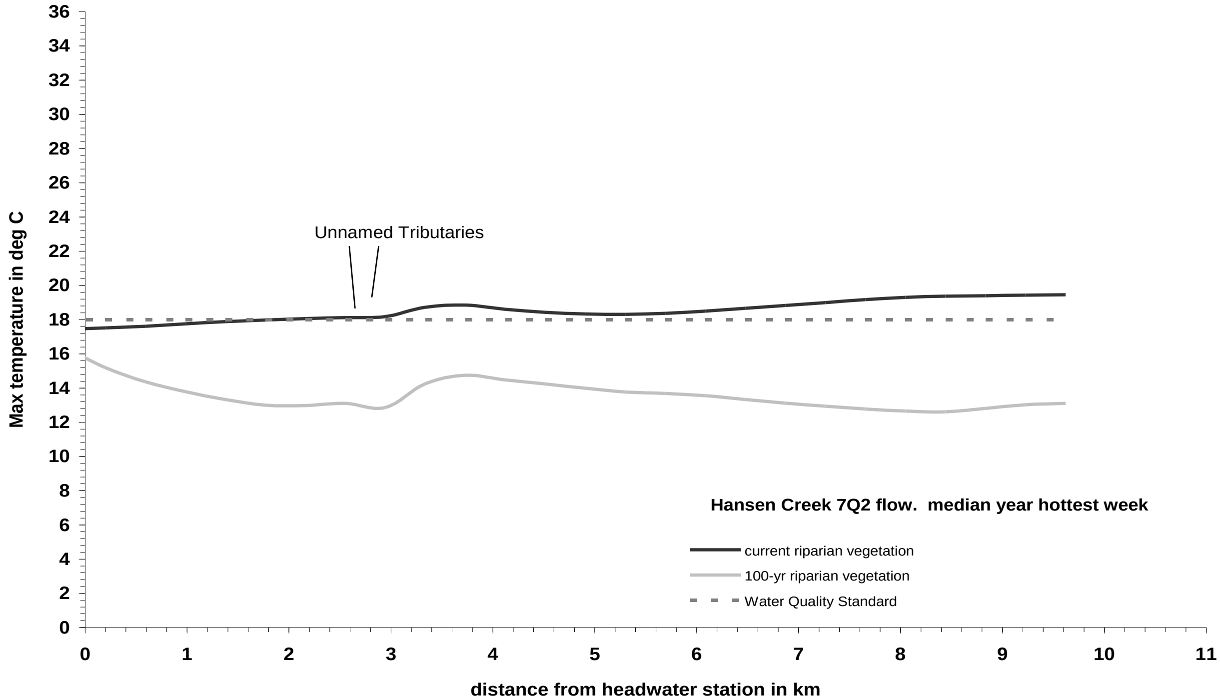


Figure 31. Predicted daily maximum temperature in Fisher Creek under critical conditions for the TMDL.



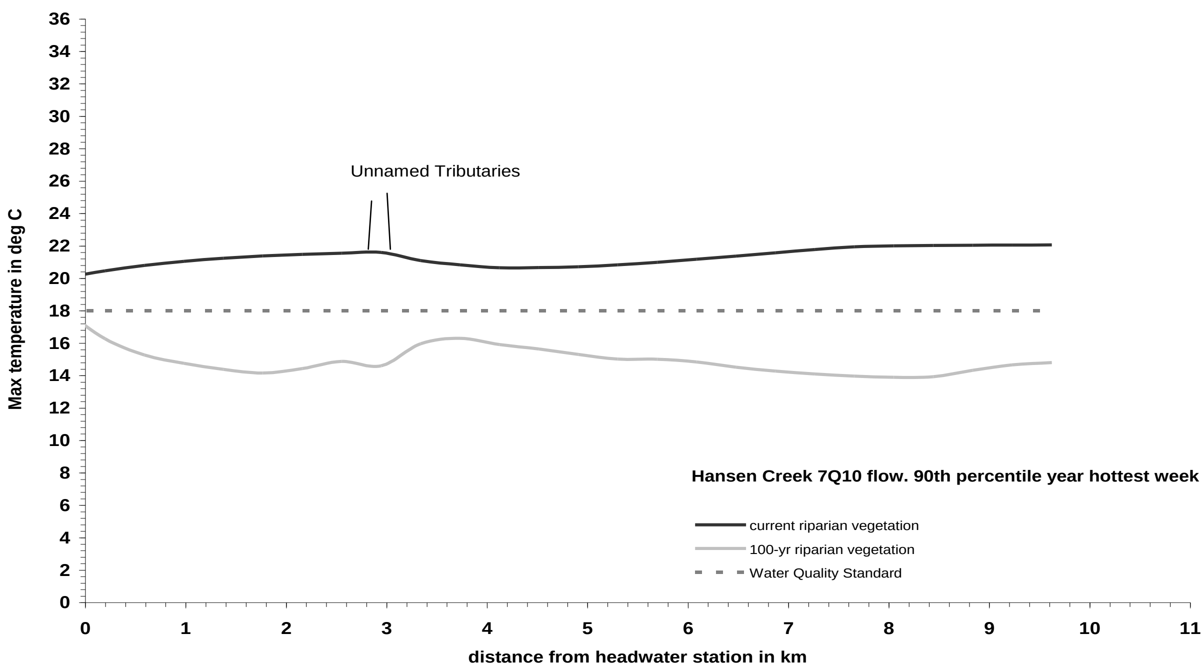


Figure 32. Predicted daily maximum temperature in Hansen Creek under critical conditions for the TMDL.

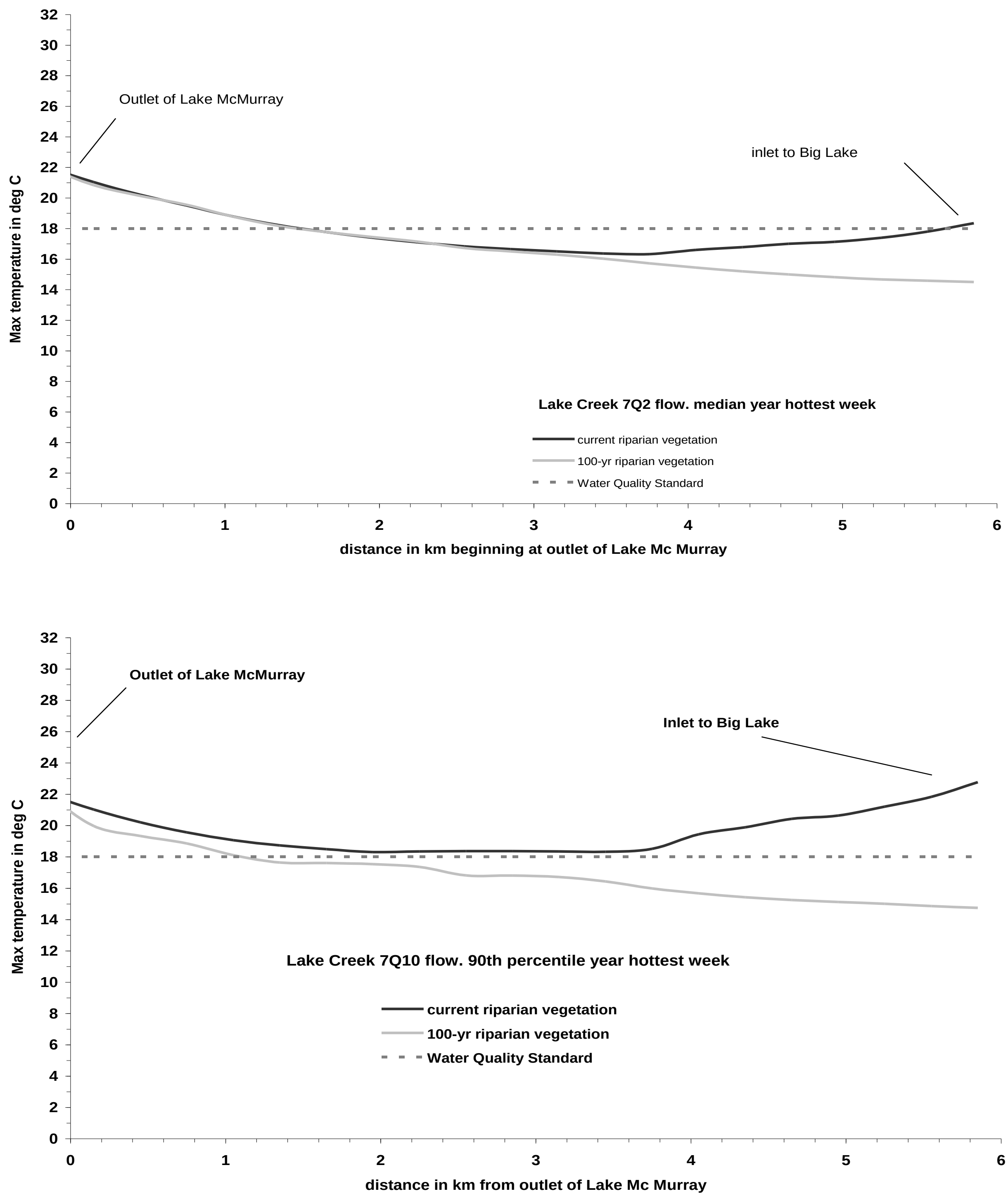
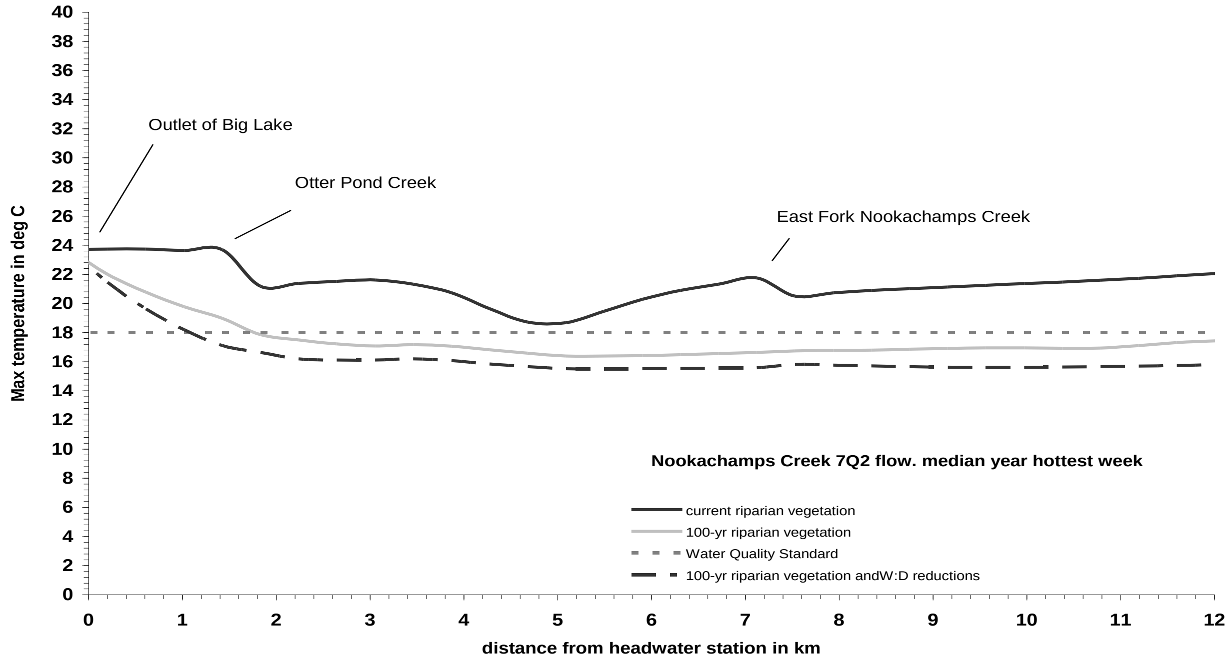


Figure 33. Predicted daily maximum temperature in Lake Creek under critical conditions for the TMDL.



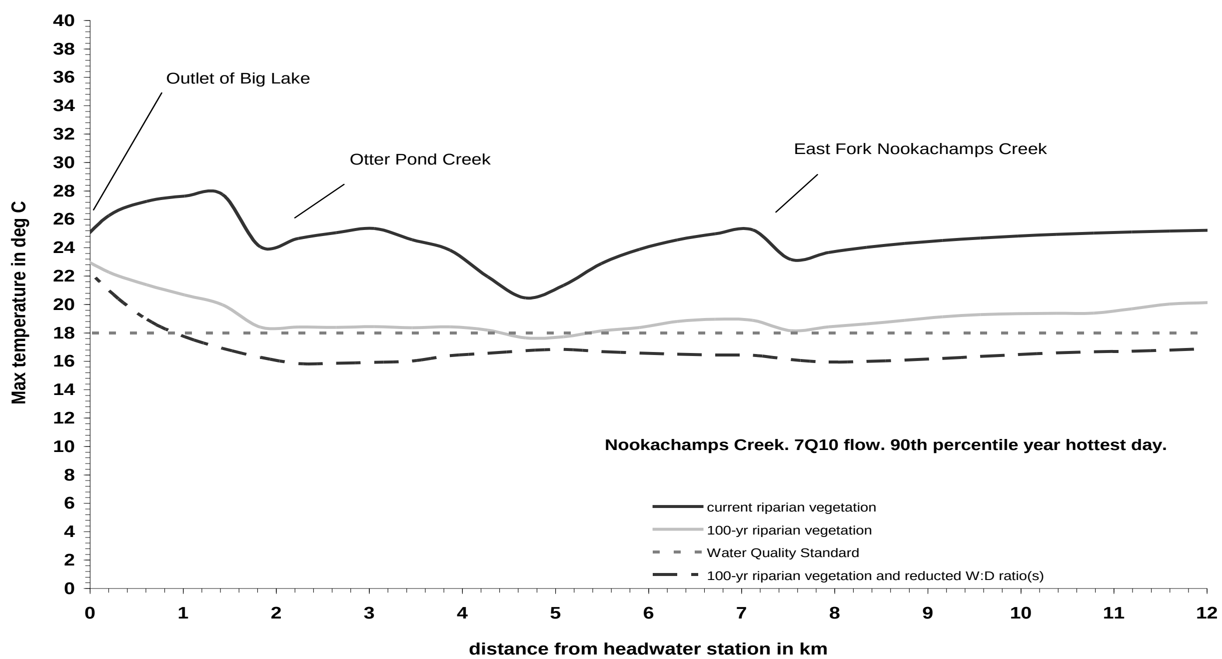
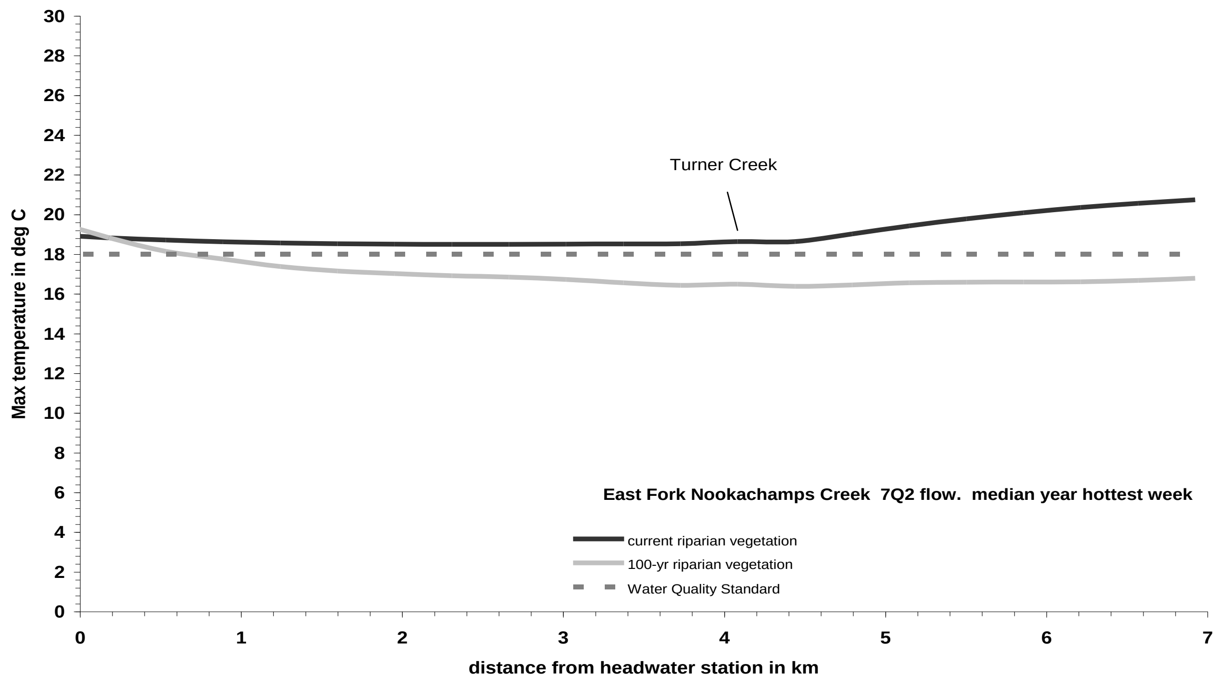


Figure 34. Predicted daily maximum temperature in Nookachamps Creek under critical conditions for the TMDL.



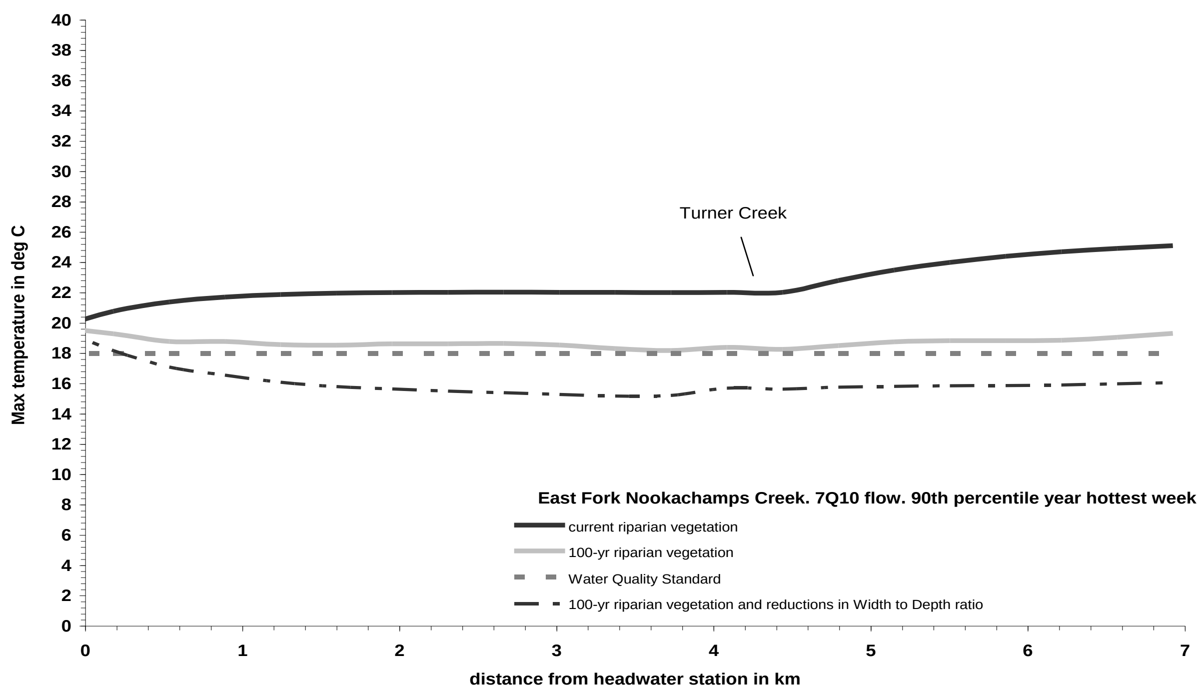


Figure 35. Predicted daily maximum temperature in East Fork Nookachamps Creek under critical conditions for the TMDL.

This page is purposely left blank

Load Allocations

Load allocations for effective shade in the lower Skagit River study area are as follows:

- For Carpenter, Fisher, Hansen, Lake, Turner, Red, and Otter Pond creeks, the load allocation is the effective shade that would result from 100-year-old riparian vegetation.
- For Nookachamps and East Fork Nookachamps creeks, the load allocation is the effective shade that would result from 100-year-old riparian vegetation and natural reductions in channel width-to-depth ratios.

The Load Allocations are Daily Load Allocations. Both the requirement for shade to block solar radiation (the Load Allocation) and the solution, the presence of mature riparian vegetation, occur on a daily basis throughout the critical period.

Daily Load Allocations for effective shade are quantified in Tables 17-22 for the following modeled creeks of the lower Skagit River study area: Carpenter, Fisher, Hansen, Lake, Nookachamps, and East Fork Nookachamps. The recommended load allocations for effective shade and reduced channel widths are predicted to result in significant reductions of the flux of solar radiation to streams within the lower Skagit River basin.

The potential future vegetation at 100 years was assumed to be represented by average tree heights ranging from 37 to 53 meters. Riparian zone widths were estimated as 75% of average tree heights (FEMAT 1993) and ranged from 28 to 40 meters. Canopy densities at these widths were estimated as 75%.

The load allocations established by this TMDL study are identical to the loading capacity with both existing channel morphology and reduced channel widths. For those reaches downstream of Big Lake and Lake McMurray, the loading capacity is equal to the natural condition caused by warm outflow temperatures. For Nookachamps and East Fork Nookachamps creeks, the load allocation is based on achieving a stable channel with decreased width-to-depth ratios. The load allocations were compared to the estimated current condition effective shade derived for the model calibration and verification (Tables 17-22).

The load allocations are based on two assumptions: (1) riparian vegetation will be protected and reestablished as the result of management actions, and (2) water quality will be degraded no further by other influences. Although the bulk of this analysis focused on riparian shade, the calibration of the model resulted in estimates of groundwater inflow, stream and tributary flow, and channel morphology of the stream. Since the model was calibrated to predict current conditions, the implication of these assumptions is that existing influences on temperature other than shade must remain constant in order for the shade allocations to effectively control in-channel water temperatures. Since alterations of these influences would affect the assimilative capacity of the stream, existing groundwater inflow, streamflow, tributary inflow, and channel morphology are considered part of the load allocations. The following factors would need to remain constant or unchanged for the above load allocations to be effective:

- *Instream flow levels at critical flows.* Any additional water withdrawals must not be allowed during critical low-flow periods. This includes any groundwater withdrawals with continuity to streams. Control measures need to be implemented to prevent further flow depletion.

- *Processes affecting channel morphology.* For the Nookachamps and East Fork Nookachamps creeks, the process affecting channel morphology must be improved to achieve stable channels with decreasing width-to-depth ratios. The more significant factors affecting stream morphology that must be at least held constant are sediment delivery and watershed hydrology. Restoration activities that would reconnect or reestablish side channels, backwaters, and riverine wetlands would probably further improve channel water temperatures.

- *Sediment delivery to streams.* Sediment delivery to streams must be held constant or reduced. Excessive sediment loading to streams can raise temperatures. Surface erosion and delivery from mass wasting must not increase.

- *Watershed hydrology.* Activities that shift hydrographs from baseflow to more surface storm flow will affect temperatures. Excessive storm flows can result in further stream bank erosion and will likely raise stream temperatures. Lower baseflow in the summer caused by the hydrograph shift will also likely raise stream temperatures. Expansion of dikes and levies that could further alter stream hydrology should be curtailed.

The load allocations described also apply to all tributary streams in the modeled reaches. The load allocations are based on the assumption that lateral temperatures and flows are held at current level. Lateral inflow represents all the smaller surface tributaries and groundwater inflow to the segments that are not specifically modeled. These temperature and flows must not get worse. Activities that increase temperature, reduce the flow, or impact the stream channel-forming processes must be prevented in all tributaries of the watershed.

Load allocations, primarily for the tributary streams in the modeled reaches, are established in this TMDL in accordance with Schedule M-2 of the *Forests and Fish Report*. Also consistent with the Forests and Fish agreement, implementation of the load allocations for private and state forestlands will be accomplished via implementation of the revised forest practice regulations. The effectiveness of the Forests and Fish rules will be measured through the adaptive management processes and monitoring of streams in the watershed. If shade is not moving on a path toward the TMDL load allocation by 2009, Ecology will suggest changes to the Forest Practices Board.

Table 17. Daily load allocations for effective shade in Carpenter Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0 (headwater)		
0.45	80.0	85.0
0.90	60.0	85.0
1.35	60.0	85.4
1.80	40.0	83.3
2.26	30.0	88.9
2.71	30.0	92.8
3.16	30.0	92.6
3.61	15.0	93.3
4.06	15.0	93.8
4.51	15.0	92.5
4.96	15.0	92.6
5.41	15.0	93.0
5.86	15.0	93.8
6.31	15.0	92.7
6.77	15.0	92.7
7.22	15.0	93.9
7.67	15.0	93.3
8.12	15.0	92.1
8.57	25.0	91.8
9.02	25.0	91.8
9.47	25.0	91.7
9.92	25.0	91.4
10.37	25.0	91.9
10.82	25.0	92.6
11.28	25.0	90.7

Table 18. Daily load allocations for effective shade in Fisher Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0 (headwater)		
0.38	80.0	85.0
0.75	80.0	85.2
1.13	80.0	91.8
1.50	80.0	91.1
1.88	80.0	91.9
2.25	80.0	91.6
2.63	80.0	91.6
3.00	80.0	90.6
3.38	80.0	93.2
3.75	80.0	87.4

Table 19. Daily load allocations for effective shade in Hansen Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0(headwater)		
0.39	60.0	95.3
0.79	60.0	95.2
1.18	60.0	93.4
1.57	60.0	94.0
1.96	60.0	93.7
2.36	60.0	87.6
2.75	60.0	84.0
3.14	60.0	92.1
3.53	60.0	95.6
3.93	60.0	93.8
4.32	60.0	89.8
4.71	50.0	85.8
5.10	50.0	89.2
5.50	50.0	90.6
5.89	50.0	84.9
6.28	50.0	89.0
6.67	50.0	93.5
7.07	50.0	93.4
7.46	50.0	93.3
7.85	50.0	93.4
8.24	50.0	92.1
8.64	50.0	90.4
9.03	50.0	83.6
9.42	50.0	82.3
9.82	50.0	84.1

Table 20. Daily load allocations for effective shade in Lake Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0 (headwater)		
0.30	75.0	90.6
0.60	75.0	84.0
0.90	75.0	84.0
1.20	75.0	84.0
1.50	75.0	83.8
1.80	75.0	78.6
2.10	75.0	79.0
2.40	75.0	81.0
2.70	75.0	89.6
3.00	75.0	82.1
3.30	75.0	83.5
3.60	75.0	88.1
3.90	70.0	94.4
4.20	50.0	94.4
4.50	53.2	95.2
4.80	47.0	94.8
5.10	50.6	94.7
5.40	38.7	94.9
5.70	35.6	95.9
6.00	19.3	94.8

Table 21. Daily load allocations for effective shade in Nookachamps Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0 (headwater)		
0.41	30.0	90.0
0.81	30.0	92.3
1.22	30.0	91.2
1.63	30.0	91.7
2.04	30.0	92.8
2.44	30.0	91.5
2.85	30.0	91.5
3.26	30.0	92.0
3.66	50.0	91.7
4.07	50.0	92.9
4.48	75.0	93.0
4.88	82.0	93.0
5.29	40.0	93.0
5.70	35.0	93.0
6.11	35.0	92.2
6.51	35.0	92.2
6.92	35.0	89.8
7.33	35.0	90.9
7.73	35.0	92.5
8.14	35.0	91.0
8.55	35.0	85.9
8.95	35.0	85.9
9.36	35.0	84.0
9.77	35.0	83.5
10.18	35.0	84.3
10.58	35.0	85.5
10.99	35.0	87.2
11.40	35.0	87.7
11.80	35.0	81.5
12.21	35.0	79.1

Table 22. Daily load allocations for effective shade in East Fork Nookachamps Creek.

Distance in km from headwater station	Current condition average effective shade (%)	Daily load allocation for effective shade on August 12 (%)
0 (headwater)		
0.36	42.00	88.40
0.71	42.00	91.20
1.07	42.00	86.00
1.42	42.00	87.80
1.78	42.00	86.30
2.13	42.00	84.90
2.49	42.00	85.20
2.84	42.00	85.30
3.20	42.00	85.80
3.55	42.00	86.20
3.91	42.00	83.20
4.26	42.00	80.70
4.62	42.00	82.70
4.97	30.00	80.90
5.33	30.00	82.00
5.68	30.00	81.70
6.04	30.00	81.70
6.39	30.00	81.00
6.75	30.00	79.20
7.10	30.00	78.60

Wasteload Allocations

No point sources of heat were found in the study area; therefore, the wasteload allocation is set to zero.

This page is purposely left blank

Margin of Safety

The margin of safety accounts for uncertainties regarding pollutant loading and water body response. In this TMDL, the margin of safety is addressed by using critical climatic conditions in the modeling analysis. The margin of safety in this TMDL is implicit because of the following:

- The 90th percentile of the highest 7-day averages of daily maximum air temperatures for each year of record was used to develop a reasonable worst-case condition for prediction of water temperatures in the lower Skagit River study area. Typical conditions were represented by the median of the highest 7-day averages of daily maximum air temperatures for each year of record.

- The lowest 7-day average flows during July-August with recurrence intervals of 10 years (7Q10) were used to evaluate reasonable worst-case conditions. Typical conditions were evaluated using the lowest 7-day average flows during July-August with recurrence intervals of 2 years (7Q2).

- Model uncertainty for prediction of water temperature was assessed by estimating the root mean squared error (RMSE) of model predictions compared with observed temperatures during model validation. The average RMSE for model calibration and verification was 0.56 and 0.44°C, respectively.

- 7Q10 low-flow conditions were used when calculating the effective shade and solar fluxes from site potential vegetation at a 100-year site index.

The modeling results and the loading capacity show that existing shade levels and some channel forms are not sufficient to meet stream temperature standards in the lower Skagit River tributaries. Comparing model predicted stream temperatures to the water quality standard (Figures 30-35) demonstrates that temperature will be improved by increasing riparian shading. However, it also indicates that the standard may not be met during these critical conditions for some stream reaches. Since restoring stream shade and improving stream morphology are the only practical solutions to temperature problems in the watershed, the approach of this TMDL is one of *adaptive management.*

If monitoring documents that restoring riparian shade to near natural-occurring levels, maintaining or enhancing streamflow during critical low-flow conditions, and improving other associated functions of a healthy stream environment do not result in compliance with water quality standards, then either the allocations or the standard itself will need to be re-evaluated and the TMDL amended. The time necessary to reestablish riparian vegetation will provide ample opportunity to gather information on the effectiveness of this TMDL.

Recommendations

For Management

Implementing the three management recommendations described below should result in long-term temperature reductions in streams within the lower Skagit River basin.

1. Riparian zones should be managed to allow full maturation of vegetation, preferably including native woody species that offer shade protection. Such managed zones would not only provide temperature benefits associated with direct shading of streams, but also would provide indirect benefits related to microclimate development, source of woody debris, and eventual narrowing and deepening of the stream.

   Streams identified as having large width-to-depth ratios as a result of erosion and sedimentation should be investigated to determine the causes of erosion and sources of sediment. Sources such as eroding streambanks and poorly managed upland areas should be addressed through riparian restoration projects and/or improved land management practices.

2. Instream flows and water withdrawals are managed through regulatory avenues separate from TMDLs. However, to protect the remaining instream flow, property owners next to streams should be encouraged to reduce water consumption during late-summer, low-flow conditions.

3. Stream restoration activities that increase groundwater inflows to streams should be encouraged.

   Groundwater inflows to streams could increase if recharge is increased as a result of renewed channel-floodplain connectivity. Engineered channels reduce the likelihood of flooding and the amount of time floodwaters spend on the floodplain. This action reduces the opportunity for floodwaters to penetrate the alluvial aquifer and, in turn, decreases baseflow by reducing groundwater discharge during the low-flow season (Steiger et al 1998).

For Monitoring

To determine the effects of management strategies within the lower Skagit River watershed, regular monitoring is recommended. Continuously-recording water temperature monitors should be deployed from July through August to capture the critical conditions. The following streams are suggested for inclusion as part of the Skagit County Surface Water Management sampling program or as a separate sampling program:

- Carpenter Creek
- Hansen Creek
- Lake Creek

- Nookachamps Creek
- East Fork Nookachamps Creek
- Red Creek
- Turner Creek
- Otter Pond Creek
- Coal Creek
- Wiseman Creek
- Mannser Creek
- Cumberland Creek
- Day Creek

Shade management practices involve the development of mature riparian vegetation, which requires many years to become established. Interim monitoring of water temperatures during summer is recommended, perhaps at five-year intervals. Interim monitoring of the composition and extent of riparian vegetation is also recommended (e.g., using photogrammetry or remote sensing methods).

Methods to measure effective shade at the stream center in various segments for comparison with load allocations could employ hemispherical photography, angular canopy densiometers, or solar pathfinder instruments.

References Cited

Adams, T.N. and K Sullivan. 1989. The physics of forest stream heating: a simple model. Timber, Fish, and Wildlife, Report No. TFW-WQ3-90-007. Washington State Department of Natural Resources, Olympia, WA.

Bartholow, J.M. 2000. Estimating cumulative effects of clearcutting on stream temperatures. Rivers 7(4), 284-297.

Becker, C.D. and R.G. Genoway. 1979. Evaluation of the critical thermal maximum for determining thermal tolerance of freshwater fish. Environmental Biology of Fishes 4:245-256.

Bell, M.C. 1986. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, Office of the Chief of Engineers, Fish Passage Development and Evaluation Program, Portland, OR.

Belt, G.H., J. O'Laughlin, and W.T. Merrill. 1992. Design of Forest Riparian Buffer Strips for the Protection of Water Quality: Analysis of Scientific Literature. Report No. 8. Idaho Forest, Wildlife, and Range Policy Analysis Group, University of Idaho, Moscow, ID.

Beschta, R.L. and J. Weathered. 1984. A computer model for predicting stream temperatures resulting from the management of streamside vegetation. USDA Forest Service. WSDGAD-00009.

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Streamside management: forestry and fishery interactions, E.O. Salo and T.W. Cundy, editors, p 192-232. Proceedings of a conference sponsored by the College of Forest Resources, University of Washington, Seattle, WA. Contribution No. 57 – 1987.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *in* W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. American Fisheries Society, Bethesda, MD.

Bolton, S. and C. Monohan. 2001. A review of the literature and assessment of research needs in agricultural streams in the Pacific Northwest as it pertains to freshwater habitat for salmonids. Prepared for: Snohomish County, King County, Skagit County, and Whatcom County. Prepared by: Center for Streamside Studies, University of Washington, Seattle, WA.

Boyd, M.S. 1996. Heat source: stream, river, and open channel temperature prediction. Oregon State University. M.S. Thesis. October 1996.

Boyd, M. and C. Park. 1998. Sucker-Grayback Total Daily Maximum Load. Oregon Department of Environmental Quality and U.S. Forest Service.

Brady, D.K., W.L. Graves, and J.C. Geyer. 1969. Surface heat exchange at power plant cooling lakes. Cooling water discharge project report No. 5. Edison Electric Institute. Publication No. 69-901, New York.

Brazier, J.R., and G.W. Brown. 1973. Buffer strips for stream temperature control. Res. Pap. 15. Forest Research Laboratory, Oregon State University. 9 p.

Brett, J.R. 1952. Temperature tolerance in young Pacific salmon, genus *Oncorhynchus*. Journal of the Fisheries Research Board of Canada 9:265-323.

Broderson, J.M. 1973. Sizing buffer strips to maintain water quality. M.S. Thesis, University of Washington, Seattle, WA.

Brosofske, K.D., J. Chen, R.J. Naiman, and J.F. Franklin. 1997. Harvesting effects on microclimate gradients from small streams to uplands in western Washington. Ecol. Appl. 7(4):1188-1200.

Brown, G.W. 1972. An improved temperature prediction model for small streams. Water Resources Research 6(4):1133-1139.

Brown, G.W., G.W. Swank, and J. Rothacher. 1971. Water temperature in the Steamboat drainage. USDA Forest Service Research Paper PNW-119, Portland, OR. 17 p.

Brown, G.W. and J.T. Krygier. 1970. Effects of clear-cutting on stream temperature. Water Resources Research 6(4):1133-1139.

Castelle, A.J. and A.W. Johnson. 2000. Riparian vegetation effectiveness. Technical Bulletin No. 799. National Council for Air and Stream Improvement, Research Triangle Park, NC. February 2000.

CH2MHill. 2000. Review of the scientific foundations of the forests and fish plan. Prepared for the Washington Forest Protection Association. http://www.wfpa.org/.

Chapra, S.C. 1997. Surface water quality modeling. McGraw-Hill Companies, Inc.

Chapra, S.C. 2001. Water-Quality Modeling Workshop for TMDLs, Washington State Department of Ecology, Olympia, WA. June 25-28, 2001.

Charlon, N., B. Barbier, and L. Bonnet. 1970. Resistance de la truite arc-en-ciel (Salmo gairdneri Richardson) a des variations brusques de temperature. Annals of Hydrobiology 1:I:73-79.

Chen, J., J.F. Franklin, and T.A. Spies. 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agricultural and Forest Meteorology 63, 219-237.

Chen, Y.D. 1996. Hydrologic and water quality modeling for aquatic ecosystem protection and restoration in forest watersheds: a case study of stream temperature in the Upper Grande Ronde River, Oregon. PhD dissertation. University of Georgia, Athens, GA.

Chen, Y.D., R.F. Carsel, S.C. McCutcheon, and W.L. Nutter. 1998a. Stream temperature simulation of forested riparian areas: I. watershed-scale model development. Journal of Environmental Engineering. April 1998. p 304-315.

Chen, Y.D., R.F. Carsel, S.C. McCutcheon, and W.L. Nutter. 1998b. Stream temperature simulation of forested riparian areas: II. model application. Journal of Environmental Engineering. April 1998. p 316-328.

Childs, S.W. and L.E. Flint. 1987. Effect of shadecards, shelterwoods, and clearcuts on temperature and moisture environments. Forest Ecology and Management 18, 205-217.

Corbett, E.S. and J.A. Lynch. 1985. Management of streamside zones on municipal watersheds. P. 187-190 In: R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Folliott, and R.H. Hamre (eds.). Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, April 16-18, 1985. Tucson, AZ.

Connolly, P.J. 2001. Stillaguamish River Watershed Restoration. 1999 Annual Report. Edited by P.J. Connolly, U.S. Geological Survey, Columbia River Research Laboratory, Cook, WA. Prepared for Bonneville Power Administration, Environment, Fish and Wildlife, Portland, OR, Project Number 1998-019-01.

Dauble, D. 1994. Influence of water use practices on fisheries resources in the Yakima River basin. Northwest Science 68.

Dong, J., J. Chen, K.D. Brosofske, and R.J. Naiman. 1998. Modeling air temperature gradients across managed small streams in western Washington. Journal of Environmental Management. 53, 309-321.

Ecology. 2001. Upper Humptulips River Temperature Total Maximum Daily Load -- Technical Report. Water Quality Program, Washington State Department of Ecology, Olympia, WA. Publication No. 01-10-056.

Ecology. 2003a. Shade.xls - a tool for estimating shade from riparian vegetation. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/programs/eap/models/.

Ecology. 2003b. QUAL2Kw.xls - a diurnal model of water quality for steady flow conditions. Washington State Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/programs/eap/models/.

Edgerton, P.J., and B.R. McConnell. 1976. Diurnal temperature regimes of logged and unlogged mixed conifer stands on elk summer range. Station Research Note PNW-277.

Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.

Edinger, J.E., D.K. Brady, and J.C. Geyer. 1974. Heat Exchange and Transport in the Environment, Report No. 14, Electric Power Res. Inst. Publication No. EA-74-049-00-3, Palo Alto, CA. November. 125 p.

Entranco. 1993. Lower Skagit River Basin Water Quality Study- Final Report. Bellevue, WA.

EPA. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. U.S. Environmental Protection Agency. EPA 440/4-91-001. http://www.epa.gov/owow/tmdl/

EPA. 1998. Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program. The National Advisory Council For Environmental Policy and Technology (NACEPT). U.S. Environmental Protection Agency, Office of The Administrator. EPA 100-R-98-006.

Everest, F.H., N.B. Armantrout, S.M. Keller, W.D. Parante, J.R. Sedell, T.E. Nickelson, J.M. Johnston, and G.N. Haugen. 1985. Salmonids. Pages 199-230 *in* E. R. Brown, editor. Management of wildlife and fish habitats in forests of western Oregon and Washington. Publication R6-F&WL-192-1985. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

Faux, R. 2002. Aerial surveys in the Stillaguamish and Skagit River basins, thermal infrared and color videography. March 16, 2002. Report to: Washington State Department of Ecology, Olympia, WA. Watershed Sciences LLC, Corvallis, OR.

FEMAT. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. U.S. Government Printing Office 1993-793-071. U.S. Government Printing Office for the U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Land Management, and National Park Service; U.S. Department of Commerce, National Oceanic and Atmospheric Administration and National Marine Fisheries Service; and the U.S. Environmental Protection Agency.

Fowler, W.B., and T.D. Anderson. 1987. Illustrating harvest effects on site microclimate in a high-elevation forest stand. Research Note PNW-RN-466. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 10 p.

Fowler, W.B., J.D. Helvey, and E. N. Felix. 1987. Hydrologic and climatic changes in three small watersheds after timber harvest. Research Paper PNW-RP-379. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Franklin, J.F. and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. Forest Service. General technical report PNW-8.

Gordon, N.D, T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology, An Introduction for Ecologists. Published by John Wiley and Sons, NY.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41: 540-551.

Hallock, R.J., R.J. Elwell, and D.H. Fry Jr. 1970. Migrations of adult king salmon *Oncorhynchus tshawytscha* in the San Joaquin Delta as demonstrated by the use of sonic tags. Fish Bulletin 151. California Department of Fish and Game, Sacramento, CA.

Hewlett, J.D. and J.C. Fortson. 1983. Stream temperature under an inadequate buffer strip in the southern piedmont. Water Resources Bulletin 18(6):983.

Hicks, M. 2001. Evaluating standards for protecting aquatic life in Washington's surface water quality standards. Temperature Criteria. Wash. State Department of Ecology, Olympia, WA.

Holtby, L.B. 1988. Effects of logging on stream temperatures in Carnation Creek, B.C., and associated impacts on the coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 45:502-515.

Hokanson, K.E.F., C.F. Kleiner, and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, Salmo gairdneri. J. Fish Res. Bd. Can. 34:639-648.

Ice, G. 2001. How direct solar radiation and shade influences temperatures in forest streams and relaxation of changes in stream temperature. In: Cooperative Monitoring, Evaluation, and Research (CMER) workshop: heat transfer processes in forested watershed and their effects on surface water temperature, Lacey, WA. February 2001.

Jezorek, I. and P.J. Connolly. 2001. Stillaguamish River Watershed Project 1999 Annual Report, Report H: Flow, Temperature, and Habitat Conditions in the Stillaguamish River Watershed. USGS Columbia River Research Laboratory, Cook, WA.

Johnson, A.W. and D. Ryba. 1992. A literature review of recommended buffer widths to maintain various functions of stream riparian areas. King County Surface Water Management Division, Seattle, WA.

Jones, J.J., J.P. Lortie, and U.D. Pierce, Jr. 1988. The identification and management of significant fish and wildlife resources in southern coastal Maine. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine.

Jurajda, P. 1995. Effect of channelization and regulation on fish recruitment in a floodplain river. Regulated Rivers: Research & Management 10: 207-215.

Knutson, K.L. and V.L. Naef. 1997. Management recommendations for Washington's priority riparian habitats. Washington Department of Fish and Wildlife, Olympia, WA.

Ledwith, T. 1996. The effects of buffer strip width on air temperature and relative humidity in a stream riparian zone. http://watershed.org/news/sum_96/buffer.html. Watershed Management Council, P.O. Box 1090, Mammoth Lakes, CA 93546

Lee, R.M. 1980. Critical thermal maxima of five trout species in the southwestern United States. Trans. Amer. Fish. Soc. 109:632-635.

Leopold, L.B., and T. Maddock. 1953. The hydraulic geometry of stream channels and some physiographic implications. U.S. Geol. Survey Prof. Paper 252.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1992. Fluvial Processes in Geomorphology. General Publishing Company, Ltd., Toronto, Ontario.

Levno, A. and J. Rothacher. 1967. Increases in maximum stream temperatures after logging in old growth Douglas-fir watersheds. USDA Forest Service PNW-65, Portland, OR. 12 p.

Lynch, J.A., E.S. Corbett, and K. Mussallem. 1985. Best management practices for controlling nonpoint-source pollution on forested watersheds. Journal of Soil and Water Conservation 40:164-167.

Lynch, J.A., G.B. Rishel, and E.S. Corbett. 1984. Thermal alterations of streams draining clearcut watersheds: quantification and biological implications. Hydrobiologia 111:161-169.

Mankowski, J. and S. Landino. 2001. Riparian Ecosystem Literature Citations.

Meisner, J.D. 1990. Effect of climatic warming on the southern margins of the native range of brook trout (*Salvelinus fontinalis)*. Canadian Journal of Fisheries and Aquatic Sciences 47: 1065-1070.

Monan, G.E., J.H. Johnson, and G.F. Esterberg. 1975. Electronic tags and related tracking techniques aid in study of migrating salmon and steelhead trout in the Columbia River basin. Marine Fisheries Review 37:9-15.

Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—Requirements for protection and restoration. Decision Analysis Series Number 1. U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Coastal Ocean Program, Juneau, Alaska.

Naiman, R.J., T.J. Beechie, L.E. Benda, D.R. Berg, P.A Bisson, L.H.MacDonald, M.D. O'Connor, P.L. Olson, and E.A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest Coastal Ecoregion. p. 127-188 *In* Watershed Management. RlJ. Naiman (ed.). Springer-Verlag, NY.

National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. National Academy Press, Washington, D.C. 452 p.

NOAA. 2003. The NOAA Integrated Surface Irradiance Study (ISIS) - A New Surface Radiation Monitoring Program", B.B. Hicks, J.J. DeLuisi, and D.R. Matt. Bull. Amer. Meteor. Soc. 77, 2857-2864. http://www.atdd.noaa.gov/isis/isis.htm

Nookachamps Watershed Nonpoint Action Plan. 1995. Skagit County Dept. of Planning and Community Development, Mount Vernon, WA.

ODEQ. 2000. Umatilla River Basin Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP). Oregon Department of Environmental Quality, Portland, OR. October 2000. http://www.deq.state.or.us/wq/TMDLs/Umatilla/UmatillaTMDLAppxA-4.pdf

ODEQ. 2001. Ttools 3.0 User Manual. Oregon Department of Environmental Quality, Portland OR. http://www.deq.state.or.us/wq/TMDLs/WQAnalTools.htm

Oliver, C. D. et al. 1988. Coastal stand silvicultural potential for western red cedar. *In* Smith N.J. ed. Western red cedar: Does it have a future? Conference Proceedings, University of British Columbia, Faculty of Forestry, Vancouver BC.

OWEB. 1999. Water quality monitoring technical guidebook: Chapter 14, stream shade and canopy cover monitoring methods. Oregon Watershed Enhancement Board. http://www.oweb.state.or.us/pdfs/monitoring_guide/monguide2001_ch14.pdf

Patric, J.H. 1980. Effects of wood products harvest on forest soil and water relations. Journal of Environmental Quality 9(1):73-79.

Pelletier, G. and D. Bilhimer. 2001. Stillaguamish River temperature total maximum daily load: quality assurance project plan. Washington State Department of Ecology, Olympia WA. Publication No. 01-03-066. http://www.ecy.wa.gov/biblio/0103066.html.

Pess, G.R., B. Collins, M. Pollock, T. J. Beechie, A. Haas, and S. Grigsby. 1999. Historic and current factors that limit coho salmon production in the Stillaguamish River basin, Washington State: Implications for salmonid habitat protection and restoration. Prepared for Snohomish County Department of Public Works and The Stillaguamish Tribe of Indians.

Pitz, C.F. and R.S. Garrigues. 2000. Summary of streamflow conditions, September 2000: Fisher Creek and Carpenter Creek basin. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-049. http://www.ecy.wa.gov/biblio/0003049.html.

Poole, G.C. and C.H. Berman. 2000. Pathways of human influence on water temperature dynamics in stream channels. Environmental Management.

Pratt, K. L. 1992. A Review of Bull Trout Life History. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, 1992. Philip Howell and David Buchanan, ed’s.

Quigley, T.M, R.A. Gravenmier, and R.T. Graham. 2001. The Interior Columbia Basin Ecosystem Management Project (ICBEMP): project data. Station Misc. Portland OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Ratliff, D. E. 1992. Bull Trout Investigations in the Metolius River_Lake Billy Chinook System. Proceedings of the Gearhart Mountain Bull Trout Workshop. Oregon Chapter of the American Fisheries Society, 1992. Philip Howell and David Buchanan, ed's.

Rishel, G.B., J.A. Lynch, and E.S. Corbett. 1982. Seasonal stream temperature changes following forest harvesting. Journal of Environmental Quality 11(1):112-116.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology publishers. Pagosa Springs, CO.

Sinokrot, B.A. and H.G. Stefan. 1993. Stream temperature dynamics: measurements and modeling. Water Resources Research Vol. 29, No. 7, p. 2299-2312.

Skagit County. 2002. Hansen Creek Watershed Management Plan. Prepared by Miller Consulting with Watershed Professionals Network. September 2002. Prepared for Skagit County Public Works Department and Surface Water Management. 98 p.

Skagit County Department of Planning and Community Development. 1995. Nookachamps Watershed Nonpoint Action Plan.

Skagit County OFM. 2003. Skagit County Office of Financial Management; data cited in Skagit County Comprehensive Plan, County Profile. http://www.skagitcounty.net/PlanningandPermit/Documents?CompPlan?Chap03-Profile.pdf

Solley, W.B., R.R. Pierce, and H.A. Perlman. 1993. Estimated use of water in the United States in 1990. Geological Survey Circular 1081, U.S. Department of Interior. 76 p.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, OR.

Steiger, J.M., James, and F. Gazelle. 1998. Channelization and consequences on floodplain system functioning on the Garonne River, SW France. Regulated Rivers: Research and Management 12: 391-413.

Steinblums, I., H. Froehlich, and J. Lyons. 1984. Designing stable buffer strips for stream protection. Journal of Forestry 821(1): 49-52.

Swanson, F.J. and G.W. Lienkaemper. 1978. Physical consequences of large organic debris in Pacific Northwest streams. USDA Forest Service, PNW GTR-69.

Swift, L.W. and J.B. Messer. 1971. Forest cuttings raise water temperatures of a small stream in the southern Appalachians. Journal of Soil and Water Conservation 26:11-15.

Teti, P. 2001. A new instrument for measuring shade provided by overhead vegetation. Cariboo Forest Region Research Section, British Columbia Ministry of Forests, Extension note No. 34, http://www.for.gov.bc.ca/cariboo/research/extnotes/extnot34.htm

Theurer, F.D. K.A. Voos, and W.J. Miller. 1984. Instream water temperature model, instream flow information paper 16. Western Energy and Land Use Team, Division of Biological Services, Research and Development, U.S. Fish & Wildlife Service. FWS/OBS-84/15.

Thomann, R.V. and J.A. Mueller. 1987. Principles of surface water quality modeling and control. Harper and Row Publishers, New York, NY. 644 p.

USDA. 1981. Soil Survey of Skagit County Area, Washington. U.S. Department of Agriculture. 372 p.

USFS. 1994. Standards and guidelines for management of habitat for late-successional and old-growth forest related species with the range of the Northern Spotted Owl. USDA Forest Service, Pacific Northwest Region, Portland, OR.

USGS. 1997. The ground-water system and ground-water quality in western Snohomish County, Washington. U.S. Geological Survey, Water Resources Investigations Report 96-4312, Tacoma, WA.

Varley, J.D. and R.E. Gresswell. 1988. Ecology, status, and management of the Yellowstone Cutthroat Trout. American Fisheries Society Symposium 4:13-24.

Ward, J.V. 1998. Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation. Biological Conservation 83: 269:278.

Wenger, S. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia, Athens, GA.

Wetzel, R.G. 1983. Limnology, 2nd edition. Saunders College Publishing, Philadelphia, PA.

Attachments

This page is purposely left blank

Attachment A. Instream water temperature standard exceedances and station disposition

This appendix totals the daily temperature standard exceedances of the maximum daily temperature for each instream tidbit[4] station in this study during 2001. Station descriptors and any data qualifiers are included in the paragraphs following the total exceedances for each station.

Station 03B01 Bulson Creek at Bulson Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	9
Maximum Daily Temperature Threshold of 18°C	0

The tidbit station on Bulson Creek was located on the east side of Bulson Creek Road. The June storm event washed out the instream tidbit, and the data were lost from May 25 through June 21 until the author installed the new tidbit. No other problems with this station were encountered for the remainder of the study period (2001). The temperature instruments were removed on October 16.

Station 03C01 Carpenter Creek near mouth

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	102 (104 not tidally corrected)
Maximum Daily Temperature Threshold of 18°C	50 (67 not tidally corrected)

This station was located beneath the Pioneer Highway bridge on Fisher Slough. The instream tidbit was definitely affected by tidal exchanges that were regulated by a tide gate about 20 feet directly downstream of the tidbit. There were several times the tidbit was checked and found dry because of a low tide (at which point it was repositioned closer to the bottom of the stream); however, it is highly likely that air temperature could have affected the instream tidbit during the periods of low tides. Unfortunately, the daytime low tides occurred during the hottest parts of the day (between 11am and 5pm) during the majority of the study period, and these data should be qualified. It is not clear that the total exceedances above were all instream temperatures. However, the exceedances from the upstream station 03C02, most of the exceedances at station 03C01 were real, although the instream temperatures may be positively skewed.

The relative humidity sensor was found vandalized on August 6, and no data were recovered for the period from June 21 to August 6. The replacement air tidbit recorded air temperature data from August 6 to October 17. The temperature instruments were removed on October 17.

[4] A tidbit is a small (0.8 oz), completely sealed, underwater temperature recording device made by the Onset Computer Corporation. The device is deployed within the water body and records continuous stream temperature, given a user-selected sampling interval. Optic communication is used for launch and readout of the data.
.

Station 03C02 Carpenter Creek at SR 534

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	97
Maximum Daily Temperature Threshold of 18°C	69

This station was located beneath the Highway 534 bridge over Carpenter Creek. This location was tidally influenced; however, the low water height was still above the instream tidbit so that it never went dry. There was also a soil temperature tidbit buried on the left bank at this location. The temperature instruments were removed on October 19.

Station 03C03 Carpenter Creek at Stackpole Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	52
Maximum Daily Temperature Threshold of 18°C	11

This station was located on Carpenter Creek adjacent to Stackpole Road about 200 feet north of Kanoko Lane. Streamflow throughout this reach was sluggish, and there were many aquatic plants in the stream that added to the reduced streamflow. The air tidbit was only about one foot from the water surface and may have been submerged during some of the major storm events during the study period, as evidenced by debris on and around the tidbit. The temperature instruments were removed on October 16.

Station 03C04 Carpenter Creek at Little Mountain Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	1
Maximum Daily Temperature Threshold of 18°C	0

This station was located (with permission) on private property near Little Mountain Road and was well shaded by riparian vegetation. The temperature data do not need qualifying. The temperature instruments were removed on October 19.

Station 03CL01 Unnamed tributary from Clear Lake

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	40
Maximum Daily Temperature Threshold of 18°C	25

This station was located on the south side of Swan Lake Road near the intersection of Babcock and Mud Lake roads on an unnamed stream. This seemed to be only an ephemeral stream, and it dried up during the summer. The dry period was discerned from the air and water temperature comparisons as occurring from July 12 until it was recovered in October (at which point the stream was still dry), and data for that time period were excluded.

Station 03EF01 East Fork Nookachamps Creek at SR 9

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	51
Maximum Daily Temperature Threshold of 18°C	25

This station was located immediately downstream of the Highway 9 bridge on the East Fork Nookachamps Creek. The original instream tidbit was anchored to a large piece of woody debris that, unexpectedly, was washed away during the large June storm event. After the instream tidbit was replaced on July 23, no further problems were encountered. The temperature instruments were removed on October 18.

Station 03EF02 East Fork Nookachamps Creek at Beaver Lake Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	48
Maximum Daily Temperature Threshold of 18°C	15

This station was initially located on the left bank about 20 feet from the Beaver Lake Road bridge on the East Fork Nookachamps Creek. There was a continuous flow gage operated by Ecology's Stream Hydrology Unit also located at the bridge. This station was placed above any influence from the mouth of the unnamed stream for station 03U01. The instream tidbit was then moved to the right bank on July 3 after the download check found the drop in water height had changed the thalweg from the left to right bank. The second location had more vegetative shade cover than the previous location. There does not appear to be any bad data before the probe was moved, and all data were retained. The temperature instruments were removed on October 18.

Station 03F01 Fisher Creek at Franklin Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	0
Maximum Daily Temperature Threshold of 18°C	0

This station was located about 30 feet downstream of the Franklin Road bridge on Fisher Creek. The instream tidbit was well shaded and had no problems with going dry. The air tidbit recorded temperatures much lower than the reference temperatures collected during the download checks. The location of the air tidbit was close to the ground, and the placement seems to have resulted in cooler air temperature measurements than what would more likely represent an "average" air temperature for that site. The temperature instruments were removed on October 19.

Station 03F02 Fisher Creek at Starbird Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	43
Maximum Daily Temperature Threshold of 18°C	8

This station was located, with permission, on private property about 500 feet downstream from the Starbird Road crossing of Fisher Creek. The instream tidbit was well shaded and always submerged; however, the creek was found to have stopped almost all surface flow on September 17 (there was only a small trickle between that was probably less than 1% of the normal flow) and the instream tidbit was just basically in a large pond. The author talked with one of the landowners who said the creek had been "pretty much" dried up for the last month. Most of the water data during late July through August are qualified. The temperature instruments were removed on October 17.

Station 03H01 Hansen Creek at Hoehn Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	54
Maximum Daily Temperature Threshold of 18°C	11

This station was located about 50 feet downstream of the Hoehn Road bridge on Hansen Creek. There was significant bed movement at this location; on July 3 the instream tidbit was found partially buried with sediment. This was the only time it was found in this condition, and it does not seem to have significantly affected instream temperature measurements during June. Ground temperature was also recorded at this location. The temperature instruments were removed on October 18.

Station 03H02 Hansen Creek at SR 20

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	19
Maximum Daily Temperature Threshold of 18°C	0

This station was located about 50 feet upstream of the Highway 20 bridge crossing Hansen Creek. The instream tidbit was missing the August 16 field check, and all data from July 3 through August 16 were lost. All other data for the study period were recovered. The temperature instruments were removed on October 18.

Station 03H03 Hansen Creek at Hansen Creek Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	18
Maximum Daily Temperature Threshold of 18°C	3

This station was located on Hansen Creek about 300 feet downstream from the crossing with Hansen Creek Road. Everything worked well with this station, and none of the data needs to be qualified. The temperature instruments were removed on October 18.

Station 03J01 Johnson Creek at Johnson Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	0
Maximum Daily Temperature Threshold of 18°C	0

This station was next to Johnson Creek Road only 10 feet upstream from the culvert crossing the road. This reach of streambed is a deep ditch, although the water was shallow. The tidbit was found partially buried with sediment on August 7; however, this does not appear to have negatively influenced the temperature readings. The instream tidbit appears to have been submerged for the entire study period, although the stream surface water flow was very low when the author checked it (est. <0.5cfs during download checks). The temperature instruments were removed on October 16.

Station 03N01 Nookachamps Creek near mouth

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	116 (118 not tidally corrected)
Maximum Daily Temperature Threshold of 18°C	88 (90 not tidally corrected)

This station was located at the Francis Road crossing of the Nookachamps Creek about 400 feet from its confluence with the Skagit River. This station was tidally influenced similar to station 03C01. The only time the instream tidbit was found dry was during the station's removal on October 18. The instream temperatures exceedances were probably real as exhibited by the next station upstream, 03N02, which was not tidally influenced and never went dry but still had exceedances; however, the maximum temperatures may not be accurate and should be qualified as such. The air tidbit was close to the ground and appears to have been influenced by cooler ground temperatures. The temperature instruments were removed on October 18.

Station 03N02 Nookachamps Creek above Barney Lake

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	111
Maximum Daily Temperature Threshold of 18°C	78

This station was located on the Nookachamps Creek approximately 150 feet downstream of the Highway 9 bridge near the Big Rock gas station. This reach was not tidally influenced and was at the bottom of a steep box-shaped canyon with lots of vegetative shading along with good topographic shading. There did not appear to be any problems with the instream tidbit, although the location was moved about 20 feet downstream to allow for lowering water stage. The author could not find the air tidbit that was originally installed on May 22, so a replacement tidbit was installed on August 30, but the previous air temperature data were lost. However, that air tidbit was mistakenly set to record at one-minute intervals, so only data from August 30 through September 22 were collected. The temperature instruments were removed on October 18.

Station 03N03 Nookachamps Creek below Big Lake

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	133
Maximum Daily Temperature Threshold of 18°C	111

This station was located at the crossing of Highway 9 and the Nookachamps Creek below Big Lake. The instream temperature of this reach is heavily influenced by Big Lake, as indicated in the thermograph comparison with the air temperature. The instream tidbit was found barely covered with water on August 15 and was moved to a location directly underneath the Highway 9 bridge. It is difficult to tell from the temperature data if the instream tidbit was dry at any time, because instream temperatures were higher than recorded air temperatures. From that comparison and the reference temperatures measured in situ, it seems the tidbit was wet for the period leading up to it being checked on August 15. The temperature instruments were removed on October 17.

Station 03N04 Nookachamps Creek above Big Lake

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	25
Maximum Daily Temperature Threshold of 18°C	6

This station was located on the Nookachamps Creek above Big Lake as it crosses Highway 9 near Devil's Creek Lane. The instream tidbit was attached to the side of an old piling under the existing bridge. The instream tidbit was submerged during the entire study period, and no data need to be qualified. The temperature instruments were removed on October 19.

Station 03S01 Sandy Creek at Kanoko Lane

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	0
Maximum Daily Temperature Threshold of 18°C	0

This station was located on Sandy Creek about 15 feet upstream from the culvert on Kanoko Lane. The instream tidbit was submerged during the entire study period. No data need to be qualified. The temperature instruments were removed on October 16.

Station 03T01 Turner Creek at Beaver Lake Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	40
Maximum Daily Temperature Threshold of 18°C	5

This station was located on Turner Creek about 20 feet downstream of the crossing with Beaver Lake Road. There is no riparian shading along this reach of the creek, and it is adjacent to the Beaver Lake Rock and Gravel quarry. The location of the instream tidbit was changed on July 3 when it was found dry, and the new location was about 10 feet upstream from the initial location. It was not possible to discern exactly when it went dry since it started recording data four days after it was installed, so the author did not include any water temperature data until after it was moved on July 3. The air tidbit data were corrupt when downloaded on August 20 and October 18, so no air temperature data were used after July 3. The temperature instruments were removed on October 18.

Station 03U01 Unnamed tributary near station 03EF02

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	24
Maximum Daily Temperature Threshold of 18°C	0

This station was located on an unnamed stream that enters the East Fork Nookachamps just above the bridge where station 03EF02 is located. The air temperature information from 03EF02 was compared with the instream temperatures, and the instream tidbit did not appear to go dry at any point during the study period. Streamflow measurements were not possible at this site because shrubs and blackberries grew over the stream, and the author had to crawl along the stream bottom to access the site. The author estimates the amount of water this small stream contributes to the East Fork at about 5% of the East Fork during low-flow conditions. The temperature instruments were removed on October 18.

Station 03U02 Unnamed tributary at Otter Pond Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	57
Maximum Daily Temperature Threshold of 18°C	12

This station was located on an unnamed stream on Otter Pond Road approximately 0.5 mile from Highway 9. The instream tidbit appears to have stayed submerged for the entire study period. Small freshwater lampreys, maybe western brook lamprey, were seen creating little mounds (spawning possibly) at this site during the tidbit installations. The temperature instruments were removed on October 17.

Station 03U03 Unnamed tributary at Lake Cavanaugh Road

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	3
Maximum Daily Temperature Threshold of 18°C	0

This station was located on an unnamed creek immediately downstream of the culvert crossing Lake Cavanaugh Road approximately one mile from Highway 9. The instream tidbit was downloaded once on August 15 but was not found when the station was being removed on October 17. Consequently all instream temperature data during this period of mid-August to mid-October were lost.

Station 03U04 Red Creek near Highway 20

	Total Daily Exceedances
Maximum Daily Temperature Threshold of 16°C	97
Maximum Daily Temperature Threshold of 18°C	50

This station was located on Red Creek (previously thought to be unnamed) as it crosses the pedestrian trail adjacent to Highway 20. The only point of access to this creek was in an area where the stream channel was undefined in a muddy grassy area. The instream tidbit was placed in the creek's area of greatest streamflow as close to the fence as possible. The grassy area just upstream has a slight impounding effect on the creek, but water was moving in the area of the instream tidbit. The temperature instruments were removed on October 18.

Attachment B. Riparian characteristics used in modeling

Table B-1. Riparian codes used in Shade model vegetation classification.

Code	Description	Height (m)	Density (%)	Overhang (m)
301	water	0.0	0%	0.0
302	pastures/cultivated field/lawn	0.5	75%	0.0
304	barren - rock	0.0	0%	0.0
305	barren - embankment	0.0	0%	0.0
308	barren - clearcut	0.0	0%	0.0
309	barren - soil	0.0	0%	0.0
400	barren - road	0.0	0%	0.0
401	barren - forest road	0.0	0%	0.0
500	l. mixed con/hard (50-100% cc)	24.4	75%	2.4
501	s. mixed con/hard (50-100% cc)	8.2	60%	1.0
502	mixed forest	45.7	90%	4.6
550	l. mixed con/hard (<50% cc)	24.4	25%	2.4
551	s. mixed con/hard (<50% cc)	12.2	25%	1.2
555	l. mixed con/hard (10% cc)	16.4	10%	2.1
600	large hardwood	30.0	75%	4.0
601	small hardwood	12.2	35%	1.2
650	large hardwood	15.0	30%	***2.0***
651	small hardwood	6.2	40%	0.9
652	small hardwood	15.0	35%	0.9
655	large hardwood	15.0	10%	***2.0***
700	large conifer	30.5	90%	3.1
701	small conifer	10.2	60%	1.0
750	large conifer	20.3	30%	2.0
751	small conifer	10.2	30%	1.0
800	upland shrubs	4.6	75%	0.5
800	shrubs on wet floodplain	0.8	25%	0.7
820	riparian shrubs (blackberries)	1.8	75%	0.3
850	upland shrubs	1.8	25%	0.3
851	shrubs on wet floodplain	1.8	25%	0.3
3011	active channel bottom	0.0	0%	0.0
3255	canal	0.0	0%	0.0
3256	dike	0.0	0%	0.0
5555	disturbance	0.0	0%	0.0
4000	upland shrubs	1.8	80%	0.3
4001	riparian shrubs	3.2	90%	0.5
5000	upland grasses	0.5	90%	0.3
4304	barren - rock	0.0	0%	0.0
4500	l. mixed con/hard (50-100% cc)	16.4	60%	2.1
4550	l. mixed con/hard (<50% cc)	16.4	30%	2.1
4600	large hardwood	12.5	60%	2.0
4650	large hardwood	12.5	30%	2.0
4700	large conifer	20.3	60%	2.0
4750	large conifer	20.3	30%	2.0

cc = canopy cover

Table B-2. Riparian codes used for 100-year-old riparian vegetation.

Code	Description	Height (m)	Density (%)	Overhang (m)
67	Douglas-fir, red alder	33.3	85%	3.0
98	red alder, western red cedar	27.4	75%	3.0
136	red alder, western red cedar	24.4	75%	3.0
123	western red cedar, Douglas-fir, red alder	25.9	75%	3.0
125	Douglas-fir, red alder	31.4	75%	3.0
124	Douglas-fir, red alder	31.4	75%	3.0
17	Douglas-fir, red alder	28.0	75%	3.0
114	red alder, western red cedar	25.9	72%	3.0
157	Douglas-fir, red alder	36.5	75%	3.0
92	Douglas-fir, red alder	35.6	75%	3.0
56	Douglas-fir, red alder	34.1	75%	3.0
34	Douglas-fir, red alder	35.2	75%	3.0
11	red alder	25.9	75%	3.0
101	red alder, western red cedar	24.4	75%	3.0
145	red alder, western red cedar	36.6	75%	3.0
101	Douglas-fir, red alder	36.6	75%	3.0
56	Douglas-fir, red alder	34.1	75%	3.0
101	red alder, western red cedar	36.6	75%	3.0
123	red alder, Douglas-fir, western red cedar	36.6	72%	3.0
118	Douglas-fir, red alder	37.1	75%	3.0
89	Douglas-fir, red alder	35.2	75%	3.0
34	Douglas-fir, red alder	35.2	75%	3.0
101	red alder	36.6	75%	3.0
136	red alder, western red cedar	36.6	75%	3.0
56	Douglas-fir, red alder	34.1	75%	3.0

The source for this table is the Site Index (SI), a designation of the quality of a forest site, typically based on soil type and the height of the dominant stand at an arbitrary age. In this case, the SI represents the average height of dominant trees at 100 years of age on that particular soil site.

Table B-3. 7Q2 and 7Q10 low-flow model inputs for discharge, width, depth, and velocity.

Carpenter Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03C04	0.0195	3.12	0.037	0.091
03C03	0.0195	3.17	0.043	0.122
03C02	0.0195	3.29	0.07	0.305
03C01	0.1082	3.35	0.079	0.427

Hansen Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03H03	0.029	2.22	0.027	0.152
03H02	0.064	2.91	0.052	0.182
03H01	0.038	3.23	0.067	0.182

Carpenter Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03C04	0.0065	3.05	0.028	0.031
03C03	0.0065	3.09	0.03	0.061
03C02	0.0065	3.2	0.049	0.152
03C01	0.0361	3.23	0.058	0.213

Hansen Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03H03	0.011	1.72	0.012	0.12
03H02	0.025	2.26	0.028	0.152
03H01	0.013	2.5	0.037	0.152

Fisher Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03F02	0.0184	1.71	0.091	0.091
03F01	0.0184	1.78	0.122	0.091

Lake Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03N04	0.034	3.53	0.085	0.085

Fisher Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03F02	0.0061	1.39	0.07	0.061
03F01	0.0061	1.43	0.073	0.061

Lake Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03N04	0.011	2.61	0.064	0.052

Nookachamps Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03N03	0.048	4.57	0.113	0.128
03N02	0.101	4.88	0.119	0.143
03N01	0.204	6.35	0.155	0.216

EF Nookachamps Creek- 7Q2				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03EF02	0.0433	4.37	0.116	0.128
03EF01	0.1033	5.00	0.137	0.158

Nookachamps Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03N03	0.016	3.39	0.082	0.08
03N02	0.034	3.61	0.088	0.088
03N01	0.068	4.7	0.116	0.134

EF Nookachamps Creek- 7Q10				
Station	Discharge (cms)	Width (m)	Depth (m)	Velocity (m/s)
03EF02	0.016	3.31	0.082	0.08
03EF01	0.034	3.77	0.098	0.1

Table B-4. Summary of flow measurements in the lower Skagit River study area, 2001.

Station	Date	Creek Name	Wetted Width (ft)	Average Depth (ft)	Average Velocity (fps)	Discharge (cfs)
03B01	8/7	Bulson @ Bulson Rd	6.60	0.24	0.29	0.46
03B01	8/15	Bulson @ Bulson Rd	7.10	0.24	0.24	0.40
03C01	5/23	Carpenter near mouth	14.60	0.36	1.24	6.57
03C02	7/3	Carpenter @ SR 534	13.80	0.34	1.00	4.69
03C02	8/6	Carpenter @ SR 534	11.30	0.23	0.50	1.30
03C02	8/15	Carpenter @ SR 534	9.60	0.08	0.21	0.17
03C02	9/19	Carpenter @ Hwy 534	10.70	0.18	0.35	0.68
03C02	10/19	Carpenter blw Bulson	17.50	0.60	0.78	8.22
03C04	5/23	Carpenter @ headwater	10.73	0.21	1.38	3.12
03C04	7/23	Carpenter @ headwater	10.50	0.07	0.33	0.24
03C04	8/15	Carpenter @ headwater	10.10	0.07	0.22	0.16
03C04	9/19	Carpenter @ headwater	10.10	0.11	0.07	0.07
03C04	10/19	Carpenter @ headwater	11.00	0.32	0.98	3.45
03EF01	5/22	E.F. Nookachamps @ Hwy 9	37.60	1.20	1.87	84.34
03EF01	7/23	E.F. Nookachamps @ Hwy 9	22.90	0.73	0.50	8.29
03EF01	8/15	E.F. Nookachamps @ Hwy 9	13.10	0.26	1.41	4.81
03EF01	8/21	E.F. Nookachamps @ Hwy 9	19.60	0.63	0.32	3.99
03EF01	9/5	E.F. Nookachamps @ Hwy 9	22.33	0.60	0.67	8.99
03EF01	10/18	E.F. Nookachamps @ Hwy 9	25.10	0.84	1.36	28.63
03EF02	8/20	E.F. Nookachamps @ mouth	38.40	0.34	0.17	2.18
03F01	5/23	Fisher near mouth	8.20	0.57	0.96	4.46
03F01	6/21	Fisher near mouth	7.90	0.76	0.59	3.57
03F01	8/6	Fisher @ Franklin Rd	7.80	0.56	0.15	0.65
03F01	8/15	Fisher @ Franklin Rd	13.00	0.12	0.28	0.42
03F01	9/17	Fisher @ Franklin Rd	10.07	0.20	0.27	0.53
03F01	10/19	Fisher near mouth	8.40	0.58	1.18	5.80
03F02	8/15	Fisher @ Starbird Rd	13.50	0.39	0.00	0.00
03H01	5/21	Hansen near mouth	22.60	1.04	1.14	26.71
03H01	8/15	Hansen @ Hoehn Rd	17.40	0.11	0.61	1.18
03H01	8/16	Hansen @ Hoehn Rd	7.40	0.30	0.60	1.31
03H01	9/20	Hansen near mouth	9.08	0.33	0.42	1.27
03H01	10/18	Hansen near mouth	12.55	0.93	0.57	6.67
03H02	8/15	Hansen @ SR 20	17.50	0.16	0.53	1.50
03H02	8/16	Hansen @ SR 20	12.80	0.30	0.59	3.55
03H03	8/16	Hansen @ headwater	6.48	0.22	0.69	0.98
03J01	8/7	Johnson @ Johnson Rd	4.00	0.02	0.06	0.01
03J01	8/15	Johnson @ Johnson Rd	4.50	0.02	0.01	0.00
03N01f	7/3	Nookachamps @ Swan Rd	56.35	1.53	0.38	32.51
03N01f	8/15	Nookachamps @ Swan Rd	28.65	0.52	1.26	18.81
03N01f	8/31	Nookachamps @ Swan Rd	32.80	0.81	0.41	10.96
03N01f	9/17	Nookachamps @ Swan Rd	28.35	0.54	0.39	6.03
03N01f	10/18	Nookachamps @ Swan Rd	49.09	0.98	1.09	52.67
03N02	8/30	Nookachamps @ Hwy 9	18.63	0.39	0.16	1.13
03N03	8/15	Nookachamps blw Big Lake	9.10	0.19	0.33	0.58
03N03	8/21	Nookachamps blw Big lake	9.15	0.18	0.51	0.86
03N04	5/22	Nookachamps abv Big Lake	20.60	0.29	1.34	8.11
03N04	7/23	Nookachamps abv Big Lake	17.50	0.40	0.16	1.14
03N04	8/15	Nookachamps abv Big Lake	4.32	0.12	0.75	0.39
03N04	8/21	Nookachamps abv Big Lake	17.80	0.41	0.10	0.70
03N04	9/5	Nookachamps abv Big Lake	17.40	0.39	0.11	0.76
03N04	10/19	Nookachamps abv Big Lake	18.50	0.71	0.89	12.01
03S01	8/7	Sandy @ Kanoko Ln	5.10	0.17	0.09	0.08
03S01	8/15	Sandy @ Kanoko Ln	4.70	0.14	0.11	0.07
03T01	8/15	Turner @ Beaver Lake Rd	2.50	0.14	0.60	0.20
03T01	8/20	Turner @ Beaver Lake Rd	2.40	0.15	0.54	0.19

Table B-5. Methodology and calculations for estimating future riparian vegetation species, heights, and widths.

Stream Name	TTools Segment ID upstrm to dwnstrm	Soil Type	Potential Productivity Common Trees	50-yr SI* Red Alder (ft)	100-yr SI Douglas Fir (ft)	Estimated SI for W. Red Cedar (ft)	Estimated 100-yr SI for Red Alder (ft)	Buffer Height Tallest Trees (ft)	Estimated Buffer Width (ft)	Estimated Buffer Density (%)	Buffer Height (m)	Buffer Width (m)	Other Trees of Limited Extent
Carpenter Creek	93-118	67	douglas-fir, red alder		156	109.2		156	117.00	75%	47.5	35.7	w. hemlock
	119-126	98	red alder, w. red cedar	90			120	120	90.00	75%	36.6	27.4	w. red cedar
	127-153	136	red alder, w. red cedar	80			120	120	90.00	75%	36.6	27.4	w. red cedar
	154- end of segment	123	w. red cedar, douglas-fir, red alder	85			120	120	90.00	75%	36.6	27.4	w. red cedar, big leaf maple
								avg	**96.75**			**29.5**	
Fisher Creek	199-203	125	douglas-fir, red alder	97	147	102.9		147	110.25	75%	44.8	33.6	w. red cedar, w. hemlock
	204-208	124	douglas-fir, red alder	97	147	102.9		147	110.25	75%	44.8	33.6	w. red cedar, w. hemlock
	209-211	17	douglas-fir, red alder		131	91.7		131	98.25	75%	39.9	29.9	red alder, w. red cedar
								avg	**106.25**			**32.4**	
Hansen Creek	120-142	114	red alder, w. red cedar	85			120	120	90.00	75%	36.6	27.4	w. red cedar, Sitka spruce
	143-152	157	douglas-fir, red alder		171	119.7		171	128.25	75%	52.1	39.1	red alder, w. red cedar
	153-162	136	red alder, w. red cedar	80			120	120	90.00	75%	36.6	27.4	w. red cedar
	163-166	92	douglas-fir, red alder		167	116.9		167	125.25	75%	50.9	38.2	red alder, w. red cedar
	167-205	56	douglas-fir, red alder		160	112		160	120.00	75%	48.8	36.6	w. red cedar
	206- end of segment	34	douglas-fir, red alder	95	165	115.5		165	123.75	75%	50.3	37.7	w. red cedar, w. hemlock
								avg	**112.88**			**34.4**	
Lake Creek	118-180	101	red alder, w. red cedar	80			120	120	90.00	75%	36.6	**27.4**	w. red cedar, w. hemlock
Nookachamps Creek	12-147	145	red alder, w. red cedar	70			120	120	90.00	75%	36.6	27.4	w. red cedar
	148-188	na	na	na	na	na		na	na	na			
	189-263	101	red alder, w. red cedar	80			120	120	90.00	75%	36.6	27.4	w. red cedar, w. hemlock
	264-280	56	douglas-fir, red alder		160	112		160	120.00	75%	48.8	36.6	w. red cedar
	281-307	101	red alder, w. red cedar	80			120	120	90.00	75%	36.6	27.4	w. red cedar, w. hemlock
	308-336	123	red alder, w. red cedar, douglas-fir	85			120	120	90.00	75%	36.6	27.4	w. red cedar, big leaf maple
	337- end of segment	118	douglas-fir, red alder		174	121.8		174	130.50	75%	53.0	39.8	w. red cedar, red alder
								avg	**104.10**			**31.7**	
East Fork Nookachamps Creek	118-127	89	douglas-fir, red alder		165	115.5		165	123.75	75%	50.3	37.7	w. red cedar, hemlock, red alder
	128-147	34	douglas-fir, red alder	95	165	115.5		165	123.75	75%	50.3	37.7	w. red cedar, w. hemlock
	148-161	101	red alder	80			120	120	90.00	75%	36.6	27.4	w. red cedar, w. hemlock
	162-174	136	douglas-fir, red alder	80			120	120	90.00	75%	36.6	27.4	w. red cedar
	175- end of segment	56	douglas-fir, red alder		160	112		160	120.00	75%	48.8	36.6	w. red cedar
								avg	**109.50**			**33.4**	

* SI (site index) is a designation of the quality of a forest site, typically based on soil type and the height of the dominant stand at an arbitrary age. In this table, the SI represents the total height of leading trees at 50 and 100 years of age.

Appendix B. Glossary and Acronyms

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

7-DADM: Seven-day average of daily maximum temperatures. This statistic replaces the single-day maximum temperature criterion in the 1997 state water quality standards. This criterion is preferable to the single-day peak temperature because a high average temperature over several days is more stressful to aquatic life than a single-day peak

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act (CWA): Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the CWA establishes the TMDL program.

Core salmon habitat: Portions of the natural environment considered critical to one or more stages of the life history of salmonid fishes**.**

Critical conditions: Under EPA guidelines for TMDLs, a conservative set of environmental conditions that is required in modeling that establishes loading capacity of a water body.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

EPA: U.S. Environmental Protection Agency

EQIP: Environmental Quality Incentives Program, administered by the Farm Services Administration

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Load allocation (LA): The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety (MOS): Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than five acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

RCW: Revised Code of Washington

SRSC: Skagit River Systems Cooperative. A resource and conservation partnership of the Sauk Suiattle Tribe and the Swinomish Tribe.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands, and all other surface waters and water courses within the jurisdiction of the state of Washington.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: 1) individual wasteload allocations (WLAs) for point sources, 2) the load allocations (LAs) for nonpoint sources, 3) the contribution of natural sources, and 4) a Margin of Safety to allow for uncertainty in the wasteload determination.

WAC: Washington Administrative Code

Wasteload allocation (WLA): The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. WLAs constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

WDFW: Washington Department of Fish and Wildlife

WQIR: Water Quality Improvement Report

WRIA: Water Resource Inventory Area. Numbered watershed areas of Washington state. WRIA 3 is the Lower Skagit watershed.

WWAA: Western Washington Agricultural Association

(this page intentionally left blank)

Appendix C. Record of Public Participation

List of public meetings

May 2003: Ecology presentation to Skagit County Planning Commission on the findings of the Lower Skagit Tributaries Temperature TMDL Study

June 2003: Ecology public meeting, Skagit College: Presentations on the Temperature TMDL Study and the Implementation Plan

January 2007 to January 2008: Advisory Committee meetings for the Draft Temperature TMDL – Water Quality Improvement Report

February 25, 2008: Ecology public meeting on the Draft Lower Skagit Tributaries Temperature Water Quality Improvement Report (submittal report to EPA), City Library, Burlington, Washington

Centennial Grant-funded local public education and outreach:

- Skagit Fisheries Enhancement Group – Nookachamps Creek Restoration Project. Conducted a series of educational workshops in spring 2006
- Skagit Conservation District
    - Watershed Masters – educational workshop series
    - Backyard Conservation – educational workshop series
    - Small Farm Landowners – educational workshop series
    - Stream Team – volunteers make a nine-month commitment to water quality monitoring at sites throughout the Lower Skagit Watershed.

Outreach and announcements

Ecology published this announcement in the Skagit Valley Herald on February 19, 2008 and February 24, 2008:

Dept. of Ecology Public Meeting & Comment Period

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Lowering Stream-Temperatures In Lower Skagit Tributaries

The State Department of Ecology would like your comments on the draft *Lower Skagit Tributaries Temperature Total Maximum Daily Load Water Quality Improvement Report*. It outlines actions that are both already underway, and those still needed to reduce temperature problems in several major tributary streams to the Lower Skagit River: the Nookachamps (& E Fork), Carpenter, Fisher, Hansen, Red, Turner, Lake, and Otter Pond Creeks. Temperatures that exceed Washington's Water Quality Standards do not protect fish or other aquatic animals that need cold water. And warm temperatures, which occur in the late-summer low-flow season, also create more favorable conditions for bacteria and other pathogenic organisms.

We welcome hearing your opinions about how well the proposed solutions address these problems. Share your thoughts with us and your neighbors at:

Two public meetings on Feb. 25 at the Burlington Public Library, 820 E Washington Ave. Open house discussion at 3 and 6:30 p.m. for 30 minutes, followed by presentations and public comments.

- To submit written comments (by March 26), or obtain a copy of the report, go to: http://www.ecy.wa.gov/programs/wq/tmdl/watershed/tmdl_info-nwro.html or contact The Department of Ecology, Northwest Regional Office, c/o Sally Lawrence, 3190 160th Ave SE, Bellevue WA 98008-5452; or by email to: slaw461@ecy.wa.gov
- Copies of the *Report*, will also be available after February 22 at the Mount Vernon, Burlington, and Skagit Valley College libraries.

If you have special accommodation needs or require this publication in an alternate format please contact: DouGlas Palenshus at (425) 649-7041 (Voice) or (425) 1-800-8336388 (TTY).

WA Dept of Ecol. SVH 2-19-08 TB3

Appendix D. Review of Creek Riparian Vegetation

In fall 2007, Ecology analyzed available aerial photography to assess whether substantive change in riparian cover on the principal TMDL creeks between an earlier year (either 1990 or 1998) and a recent year (2006). The GIS analysis quantified the amount of riparian area for vegetation belonging to 8 classes differentiated by height or density. The analysis assessed the riparian vegetation classes for two widths of riparian zones, 50 ft and 150 ft from the centerline of the stream. The six principal creeks are Nookachamps, Lake, East Fork Nookachamps, Hansen, Fisher and Carpenter. The results of the analysis are reported in *Lower Skagit River Tributaries Riparian Vegetation Change Analysis Results,* available at www.ecy.wa.gov/biblio/0703050.html. The report was revised in April 2008.

The objective of the study was to assess how much change has occurred over recent years. Incentive programs such as CREP were available from the late 1990s and state Salmon Recovery Funding has been available for salmon habitat restoration projects since about 2000.

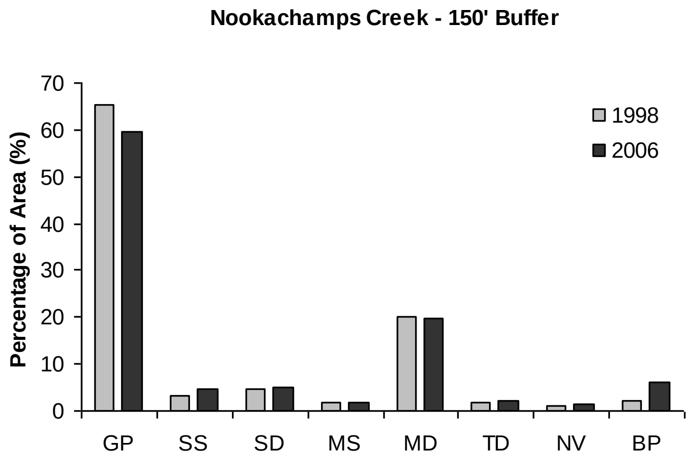
This section provides a description of the three main watersheds followed by side-by-side examples of the GIS-based riparian assessment of the aerial photographs of the six principal creeks. These side-by-side figures show only small segments of the creeks. Some were selected to show where change has occurred, while others were selected to show a long reach with little riparian vegetation and little change between the two photographs.

Nookachamps Sub-basin: Nookachamps Creek, Lake Creek, and East Fork Nookachamps Creek

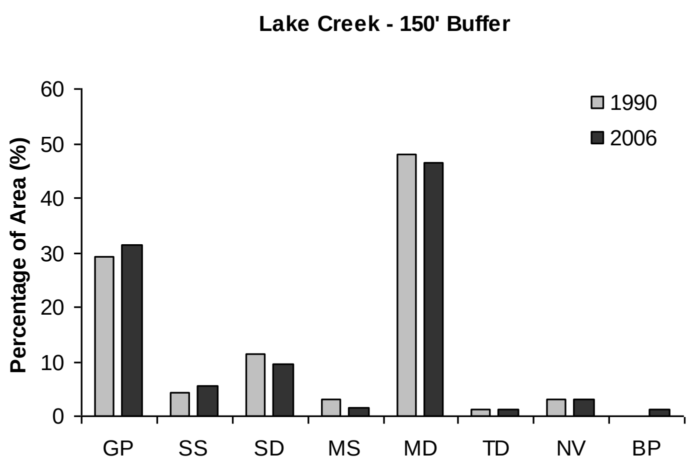
The Nookachamps Creek watershed in south-central Skagit County is the largest sub-basin in the study area (81 square miles). High elevations and rugged terrain border the Nookachamps basin on both east and west sides, while the northern boundary of the watershed is defined by almost 14 miles of the Skagit River. Elevations range from 150 feet at Lake McMurray to about 50 feet at the Skagit River.

Agricultural uses are concentrated in the floor of the Nookachamps Valley from Lake McMurray to the Skagit River. Much of the lower sections of both Nookachamps Creek and East Fork Nookachamps Creek have been extensively channelized and diked, which has resulted in wide shallow channels with little riparian vegetation. Lake McMurray, a shallow lake (about 6 feet deep at the outlet) comprises the headwaters of Lake Creek. Big Lake, a shallow lake with 6 feet depth at outlet, comprises the headwaters of Nookachamps Creek. Summer temperatures for both outflows frequently exceed the Class A standard for temperature.

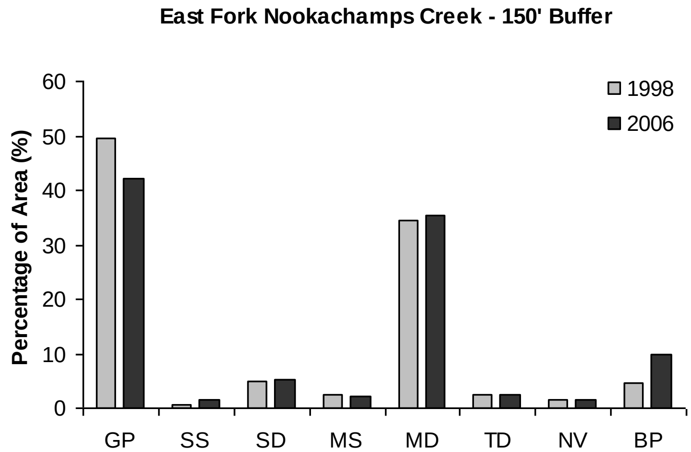
Nookachamps Creek. The vegetation analysis covered the entire length of Nookachamps Creek from its source at the discharge of Big Lake to its confluence with the Skagit River, a distance of about 12 km (7.4 miles). Between 1998 and 2006, tall dense trees increased within the riparian zone. There was also a decrease in non-shade-bearing grass and an increase in shade-producing shrubs. However, barren lands increased in area within both widths of riparian zone. Based on the analysis of the 2006 aerial photograph, about 22 percent of the 150-ft riparian corridor is in medium dense (MD) or tall (TD) trees.



Lake Creek. The vegetation analysis covered the entire length of Lake Creek from its source, the discharge from Lake McMurray to its discharge to Big Lake, about 6 km (3.7 miles). Based on the analysis of the 2006 aerial photograph, about 48 percent of the 150-ft riparian corridor is in medium dense (MD) or tall (TD) trees. Between 1990 and 2006, there was an increase in non-shade land types along the length of Lake Creek. Barren lands greatly increased, with most of the increase occurring in the broader 150-ft zone. Other land types that do not contribute shade increased as well, although not as dramatically. While little change occurred with dense, medium trees and dense, tall trees, dense shrubs and sparse medium trees decreased throughout the riparian zone.



East Fork Nookachamps Creek. In general, there was little change in vegetation types along East Fork Nookachamps Creek. There was some increase of shade-producing vegetation within the 150-ft riparian zone. Within the 50-foot zone, the increase in medium, dense trees was slight, and dense shrubs decreased. No change occurred in the total area of tall, dense trees in either zone. The amount of barren land increased in both buffer widths, while grasses decreased in area. There was a decrease in the amount of non-vegetated surfaces within the 50-ft zone and an increase in the same type within the 150-ft zone. In 2006, about 38 percent of the 150-ft width riparian zone was covered by medium height, dense trees and tall trees.

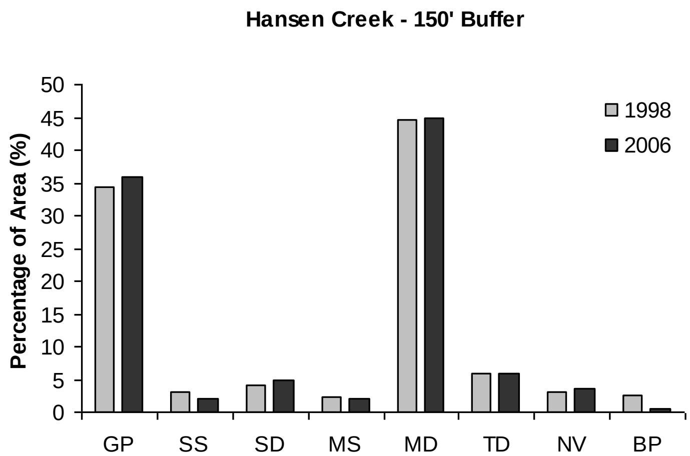


Hansen Creek Sub-basin

Hansen Creek. The Hansen Creek watershed lies in northwestern Skagit County, draining an area of about 13.5 square miles. Hansen Creek flows from headwaters in the Lyman Hill area south to its confluence with the Skagit River east of Sedro-Woolley. Red Creek is a major tributary to Hansen Creek, and several smaller tributaries enter just above the Northern State Recreation Area. Land use is a mixture of forestry in the headwaters and rural and agricultural uses along the lower half.

The vegetation analysis covered 9.8 km (6 miles) of Hansen Creek, from the "headwater" station located about 300 feet downstream from the Hansen Creek Road bridge, to its discharge to the Skagit River. Between 1998 and 2006, there was a growth in dense shrubs and a decline of sparse shrubs within the riparian zones. Little change occurred in the area of dense, medium trees and dense, tall trees, although dense, tall trees did increase slightly. Non-vegetated lands increased in both buffer zones (50-ft and 150-ft) but barren land decreased.

Based on the analysis of the 2006 aerial photograph, about 50 percent of the 150-ft riparian corridor is in medium dense (MD) or tall (TD) trees.

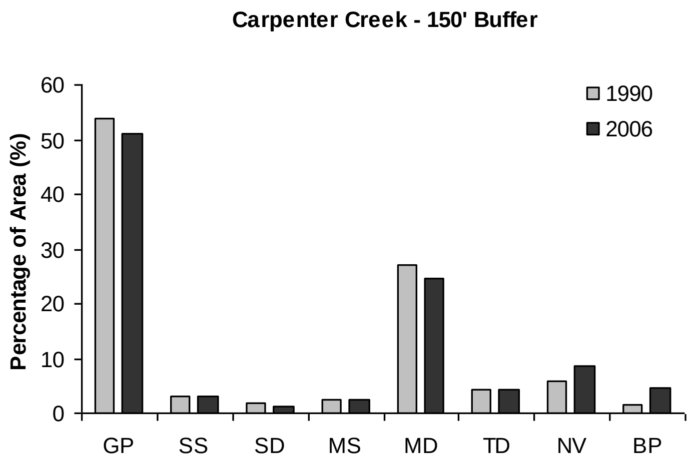


Carpenter-Fisher Creek Sub-basin.

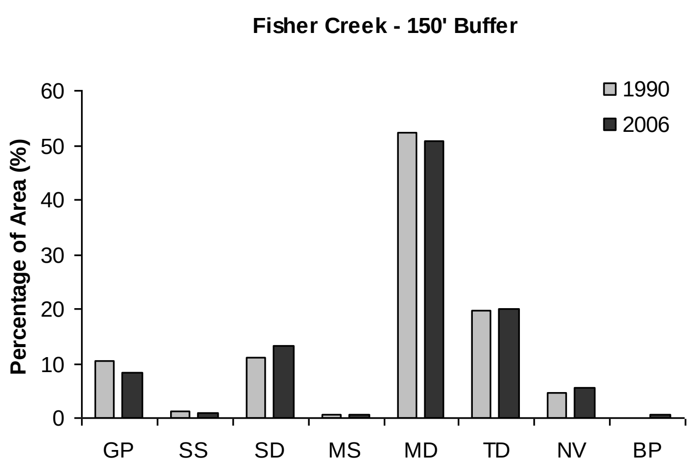
The Carpenter Creek and Fisher Creek drainages, about 25 square miles in area, are located in southern Skagit County, southeast of the city of Mount Vernon, with a small portion in northern Snohomish County. The topography ranges from flat-lying alluvial Skagit plain in the westernmost portion of the basin, low rolling hills to the south, and rugged upland foothills to the east and northeast. Elevations range from about 6 to 1720 feet above sea level.

The Carpenter Creek mainstem occupies the northern half of the basin, draining towards the south. Its lower reach, called Hill Ditch, has been diked and channelized adjacent to the base of the uplands. It is maintained by Skagit County Dike District #3. Tributaries feeding both mainstem Carpenter Creek and Hill Ditch drain largely from the east. Elevated stream temperatures in Carpenter Creek are located primarily in Hill Ditch, which has fairly sluggish flow and little riparian vegetation to shade the channel. Land uses are a mixture of rural and agricultural. Some of the headwaters of Carpenter Creek are in an Urban Growth Area of the city of Mount Vernon, so substantial change in land use is expected in the future.
The Fisher Creek mainstem drains toward the northwest and is fed by several smaller tributaries that drain the lower elevation hills of the southern and southeastern lowlands. Fisher Creek flows through alternating forest and agricultural lands.

Carpenter Creek. The vegetation analysis covered 11.7 km (7 miles) of Carpenter Creek, from the "headwater" station on the creek at Little Mountain Road to the discharge from Hill Ditch to a slough next to the South Fork Skagit River. Between 1990 and 2006, two categories of shade-producing vegetation along Carpenter Creek decreased in area, while non-vegetation and barren land surfaces increased. However, there was a slight increase in the total area of tall, dense trees. This pattern was true for both 50-ft and 150 ft riparian zones. A 3.9 acre area occupied by dense medium trees in 1990 appears to have turned into wetland in 2006. Wetlands in this analysis are classified as grass/pasture. Based on the analysis of the 2006 aerial photograph, about 30 percent of the riparian corridor is in medium dense (MD) or tall (TD) trees.



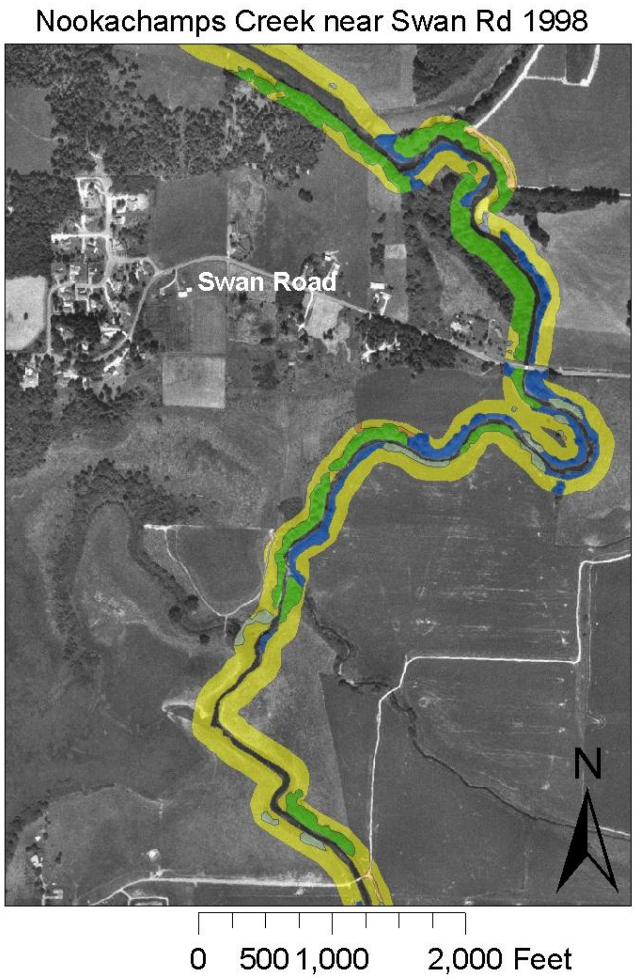
Fisher Creek. The vegetation analysis covered 3.7 km (2.3 miles) of Fisher Creek, from the "headwater" station about 500 feet downstream of Starbird Road to its discharge into Hill Ditch (Carpenter Creek). The shade-producing categories of shrubs and tall trees increased in area between 1990 and 2006 within both riparian zone widths, while the grass/pasture and sparse shrub polygons decreased in area. However, shade-producing medium, dense trees decreased in area. Within the 50-ft zone, non-vegetated surfaces decreased, but the same category increased in the 150-ft zone. Based on the analysis of the 2006 aerial photograph, about 64 percent of the 150-ft riparian corridor is in medium dense (MD) or tall (TD) trees.



Key to Vegetation Classifications for Figures D1 – D6 on next pages:

Vegetation was classified according to height, density, and type:

- Barren pasture (BP) – orange
- Grasses/pasture (GP) – yellow
- Medium height (10 to 80 ft) trees – sparse (MS-pale green) or dense (MD – medium green)
- No vegetation (NV) – gray
- Shrubs – sparse (SS-pale blue) or dense (SD-medium blue)
- Tall trees (TD) – dark olive green (trees greater than 80 ft height)



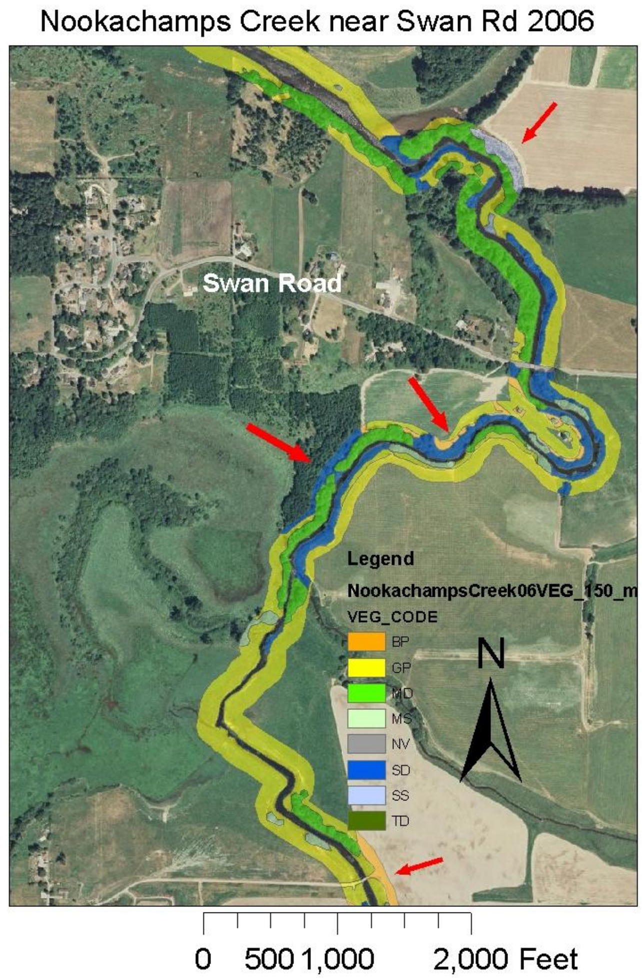


Figure D-1. Nookachamps Creek near Swan Road. Red arrows indicate locations where vegetation classification is different for the two years

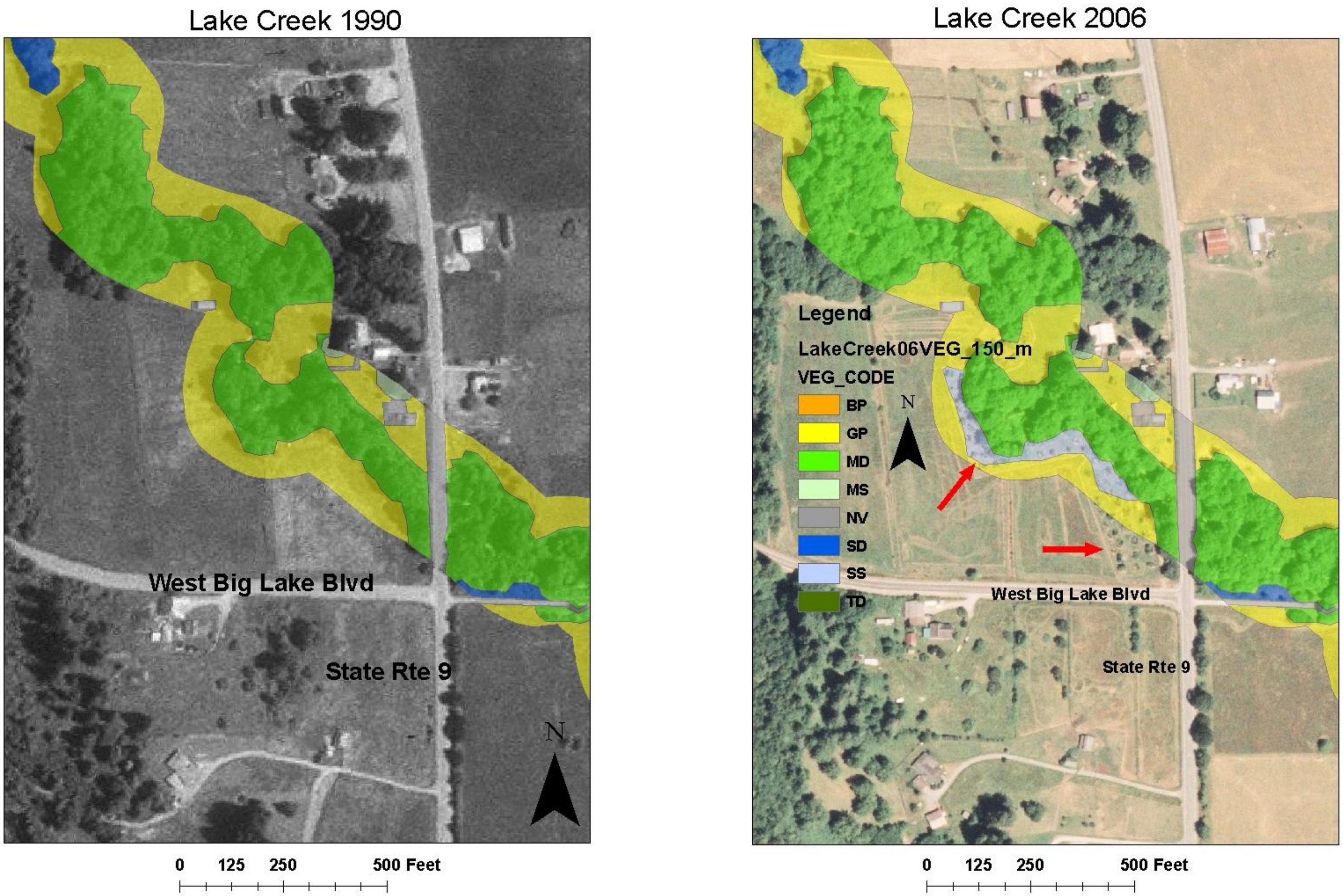
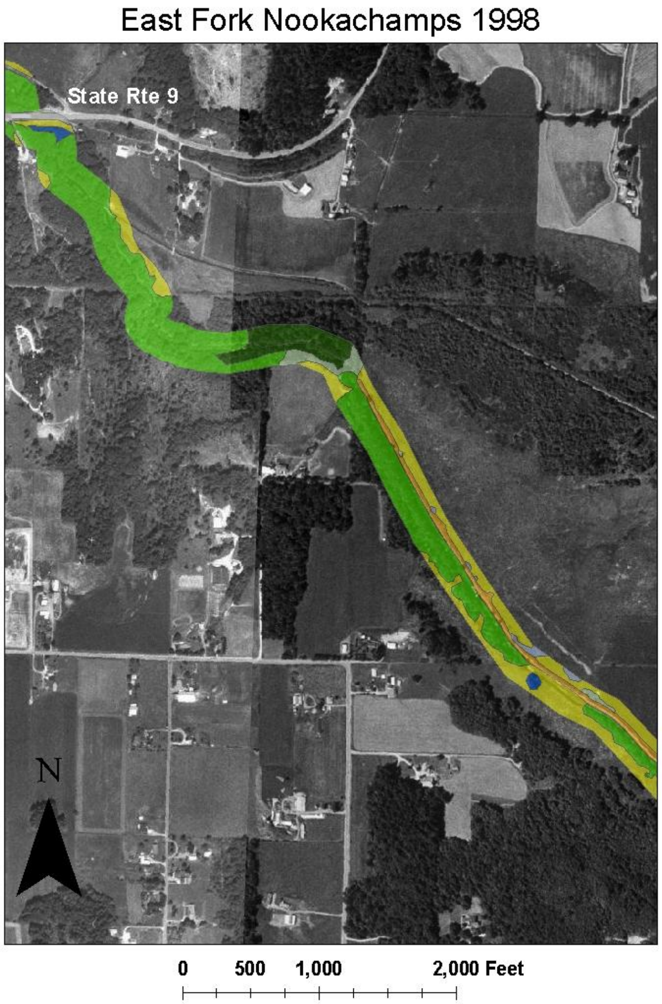


Figure D-2. In 2006, a "young" CREP project (red arrows) appears along the southwest bank of Lake Creek at the corner west of SR-9 and north of West Big Lake Boulevard



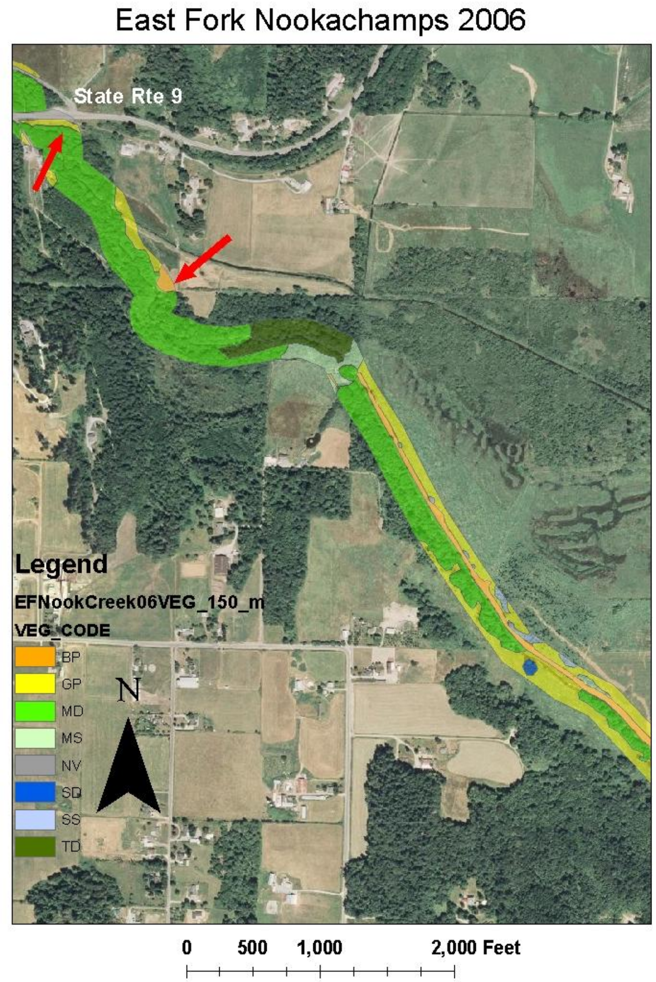


Figure D-3. 2006 photo indicates less medium shrubs (medium blue) in upper left corner but little change overall in riparian vegetation.

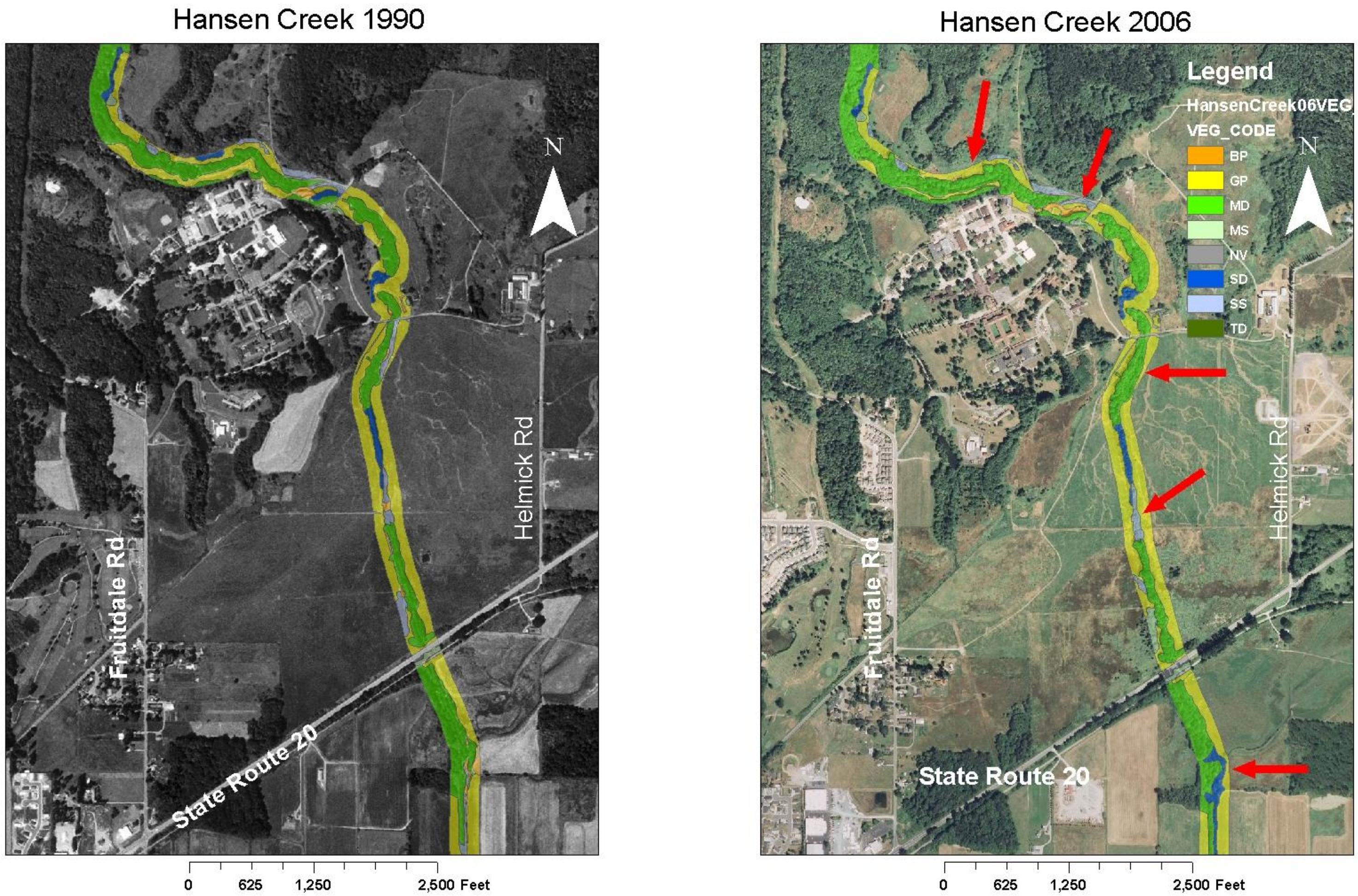
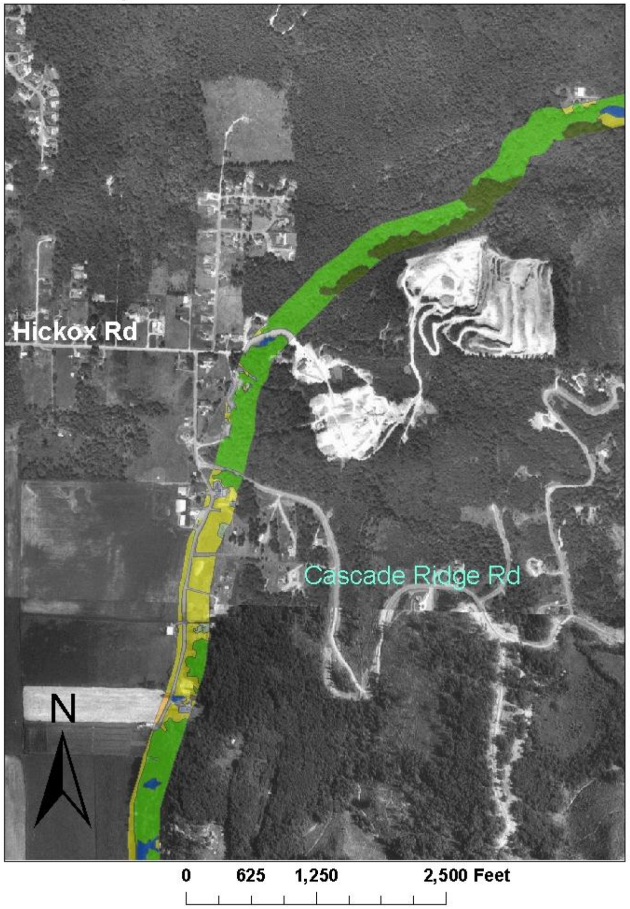


Figure D-4. Between 1990 and 2006, an area of dense shrubs (SD) at upper left was replaced by grasses and pasture (GP), and in the lower right an area of grasses and pasture (GP) grew to dense shrubs(SD).

Carpenter Creek middle section 1998



Carpenter Creek middle section 2006

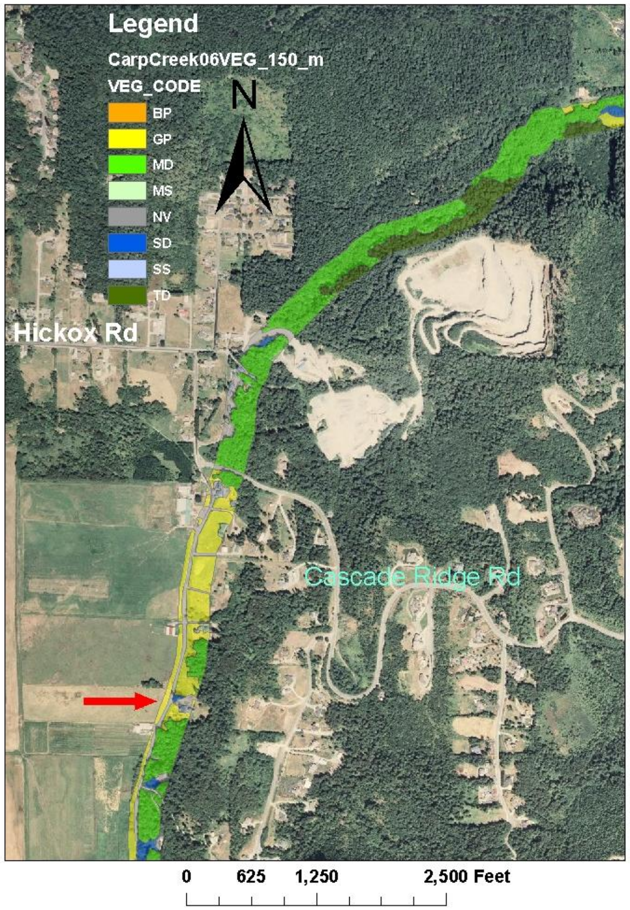


Figure D-5. Little change is evident in riparian vegetation along Carpenter Creek in these photos.

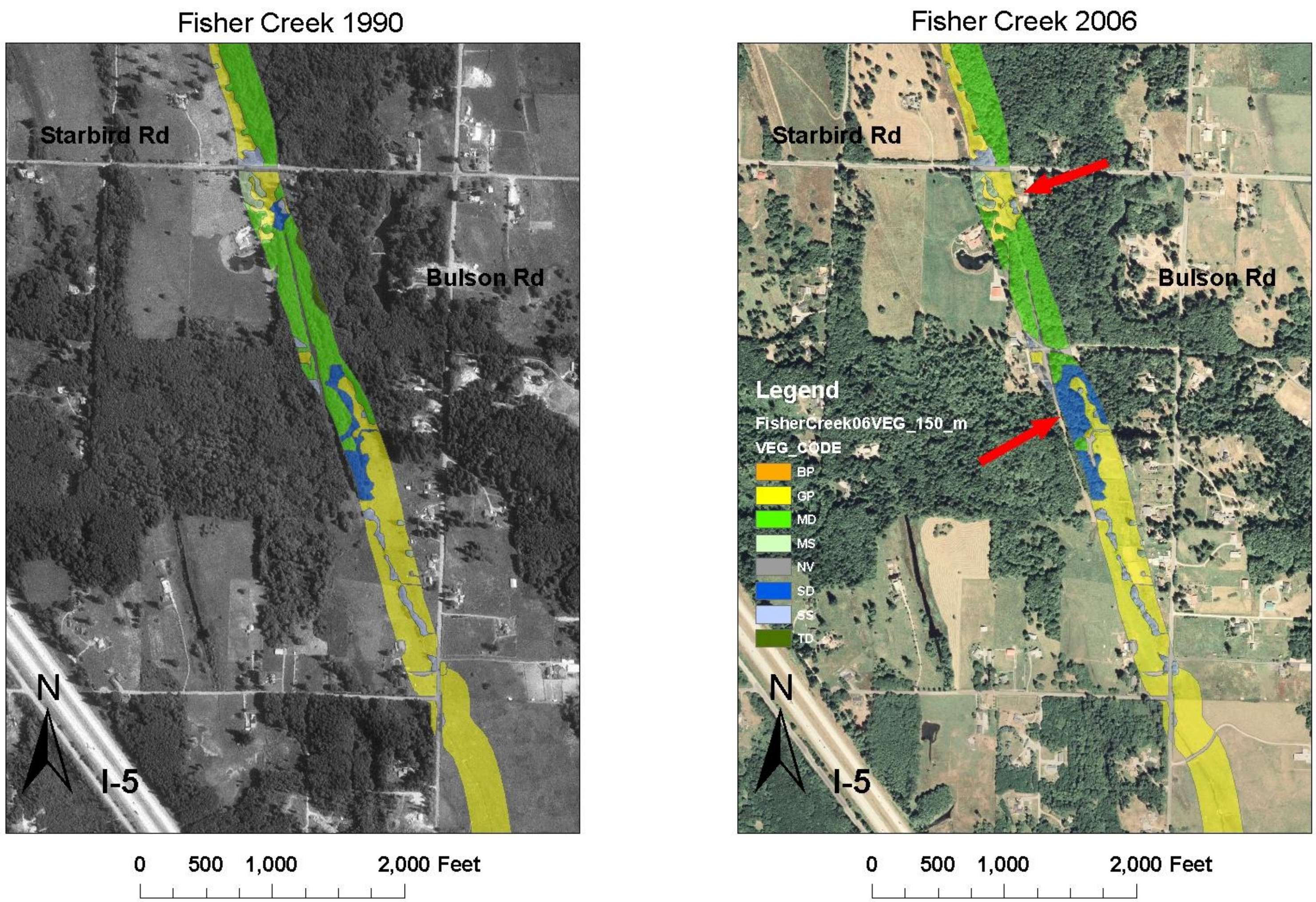


Figure D-6. Upper part of photo, just south of Starbird Rd: A small patch of medium blue (dense shrubs) visible in 1990 is replaced by grasses and pasture (yellow) in 2006. In the center, a patch of medium-height trees (medium green) is replaced in 2006 by greater area of dense shrubs (SD).

Appendix E. Revisions to the Water Quality Standards for Temperature

Ecology submitted the revised water quality standards regulation to the U.S. Environmental Protection Agency (EPA) for federal approval in July 2003. EPA was not satisfied that Ecology's 2003 standards met the requirements of the federal Clean Water Act (CWA) and the federal Endangered Species Act (ESA). Their main concerns were the designated uses for salmonids for some waters in the state. EPA did not believe they protect summer spawning. These designated use changes mean that the numeric criteria to protect these uses became more stringent for temperature and dissolved oxygen. As a consequence, EPA formally disapproved portions of the revised standards. In December 2006, Ecology responded by adopting standards with EPA's recommended changes. These standards were approved by EPA in February 2008.

Ecology developed an implementation plan that describes when to use the new 2006 state standards while the state awaits formal EPA approval of those standards. According to the implementation plan, because this TMDL's field work and technical study were complete prior to December 2006, it will be based on the 1997 version of the state standards. However, it must also include:

a) A scenario evaluating what would be required to meet the 2006 standards where the existing data allows.
b) An implementation plan designed to assess compliance with the 2006 standards.

The revisions to the existing standards are online at Ecology's water quality standards website: http://www.ecy.wa.gov/programs/wq/swqs. Table D-1 provides a general structure for understanding the changes:

Table E-1. 1997 and 2006 revised temperature criteria

1997 Standards Classification	Water Quality Parameter	1997 Criteria[1]	2006 Use Revision	2006 Criteria[1]
Class AA	Temperature	16°C 1-Dmax[3]	Char Spawning/Rearing	12°C 7-DADMax[2, 4]
			Core Summer Salmonid Habitat	16°C 7-DADMax[2, 4]
Class A	Temperature	18°C 1-Dmax[3]	Char Spawning/Rearing	12°C 7-DADMax[2, 4]
			Salmonid Spawning, Rearing, and Migration	17.5°C 7-DADMax[2, 4]

1. Criteria have been established in the existing water quality standards for specific water bodies that differ from the general criteria shown in the above table. These special conditions can be found in WAC 173-201A-130 of the 1997 version, and WAC 173-201A-602 of the 2003 version of the standards.
2. The 2006 corrected water quality standards rule contains supplemental spawning and incubation temperature criteria (13°C for salmon and trout, and 9°C for native char) that are to be applied to specific portions of many of these waters.
3. 1-DMax means the highest annual daily maximum temperature occurring in the water body.
4. 7-DADMax means the highest annual running 7-day average of daily maximum temperatures.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition].

(1) To protect the designated aquatic life uses of "Char Spawning and Rearing" the highest 7-DADMax temperature must not exceed 12°C (53.6°F) more than once every ten years on average.

(2) To protect the designated aquatic life uses of "Core Summer Salmonid Habitat" the highest 7-DADMax temperature must not exceed 16°C (60.8°F) more than once every ten years on average.

(3) To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only" the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

The state uses the criteria described above to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides an additional allowance for additional warming due to human activities. In this case, the combined effects of all human activities must also not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must also be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to: (A) incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge), and B) Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not at any time exceed 2.8°C (5.04°F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where the department determines the temperature criteria established for a water body would likely not result in protective spawning and incubation temperatures, the following criteria apply: A) Maximum 7-DADMax temperatures of 9°C (48.2°F) at the initiation of spawning and at fry emergence for char; and B) Maximum 7-DADMax temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

The state uses the criteria described to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides an additional allowance for additional warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, one must also assess compliance against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to: (A) incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge), and B) Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not at any time exceed 2.8°C (5.04°F).

While the criteria generally apply throughout a water body, they are not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason, the standards direct that one must take measurements from well-mixed portions of the water body. For similar reasons, samples should not be taken from anomalously cold areas.

Appendix F. Analysis of Effects of Instream Flow Reservations on Creek Temperatures

DEPARTMENT OF ECOLOGY

February 28, 2005

TO: Geoff Tallent, Northwest Regional Office
Sally Lawrence, Northwest Regional Office

FROM: Stephanie Brock, Environmental Assessment Program

SUBJECT: NOOKACHAMPS FLOW REDUCTION AND STREAM TEMPERATURE ANALYSIS

The purpose of this memorandum is to summarize the findings of the analysis to evaluate the impacts of a 2% reduction of 7Q10 flows on the maximum temperature of Nookachamps Creek. The analysis is provided to accompany the Instream Flow Rule Amendment for the Lower Skagit Tributaries, which include Nookachamps Creek, Carpenter Creek, Fisher Creek, Hansen Creek and East Fork Nookachamps Creek. The Instream Flow Rule Amendment proposes to set aside a reserve, which is an estimated annual average quantity equal to a 2% reduction of the 7Q10 flows of each of the tributaries in the basin, to accommodate future exempt wells in the basin.

Nookachamps Creek was selected to calculate the impacts of the flow reduction on stream temperatures because it is the largest of the tributaries in the basin and the 2% reduction will capture the most flow and have the largest impacts on stream temperatures during critical low-flow periods. A 2% reduction of 7Q10 flow on Nookachamps Creek resulted in a 0.05-cfs reduction or a flow of 2.35-cfs (Table 1).

Table 1. Estimated 7Q10 flows for tributaries in the lower Skagit River study area.

Creek	***Drainage area (km2)***	***Drainage area (mi2)***	***Estimated 7Q10 flow (cms)***	***Estimated 7Q10 flow (cfs)***	***2% reduction flow (cfs)***
Pilchuck	134	52	0.05	1.80	1.76
Carpenter	95	37	0.04	1.27	1.24
Fisher	17	7	0.01	0.22	0.22*
Hansen	33	13	0.01	0.46	0.45
Lake	40	15	0.01	0.28	0.27
Nookachamps	**180**	**69**	**0.07**	**2.40**	**2.35**
E.F. Nookachamps	91	35	0.03	1.20	1.18

*too small to measure

Two riparian management scenarios were analyzed under the reduced flow condition: current vegetation and site potential vegetation. Definitions and characterization of each of these management scenarios is detailed in the Lower Skagit River Tributaries Temperature Total Maximum Daily Load Study (Ecology, 2004). These scenarios were analyzed to determine the stream temperature impacts under current and future conditions.

Results of the analysis for both current and site potential vegetation are provided in Table 2.

Table 2. Summary table of impact of a 2% reduction of 7Q10 flows on maximum Nookachamps stream temperature for current vegetation and site potential vegetation scenarios

Downstream Distance (km)	Current Vegetation		Site Potential Vegetation	
	Temperature Increase (^oC)	Relative Percent Increase	Temperature Increase (^oC)	Relative Percent Increase
-0.20	0.00	0.00%	0.00	0.00%
0.20	0.04	0.16%	-0.01	-0.04%
0.61	0.05	0.18%	-0.01	-0.03%
1.02	0.05	0.18%	0.00	-0.01%
1.42	0.05	0.18%	0.00	0.00%
1.83	0.04	0.17%	0.01	0.04%
2.24	0.05	0.20%	0.01	0.08%
2.65	0.05	0.22%	0.02	0.11%
3.05	0.06	0.22%	0.02	0.13%
3.46	0.04	0.16%	0.02	0.13%
3.87	0.04	0.15%	0.03	0.17%
4.27	0.01	0.07%	0.03	0.14%
4.68	0.00	0.01%	0.01	0.08%
5.09	0.03	0.15%	0.02	0.08%
5.49	0.05	0.23%	0.02	0.10%
5.90	0.06	0.26%	0.02	0.10%
6.31	0.06	0.26%	0.02	0.12%
6.72	0.06	0.25%	0.02	0.12%
7.12	0.06	0.24%	0.02	0.10%
7.53	0.04	0.19%	0.01	0.08%
7.94	0.05	0.21%	0.02	0.11%
8.34	0.05	0.23%	0.03	0.14%
8.75	0.06	0.23%	0.03	0.16%
9.16	0.06	0.23%	0.03	0.18%
9.56	0.06	0.23%	0.04	0.19%
9.97	0.06	0.22%	0.04	0.18%
10.38	0.05	0.22%	0.03	0.18%
10.79	0.05	0.21%	0.03	0.17%
11.19	0.05	0.20%	0.04	0.18%
11.60	0.05	0.19%	0.04	0.19%
12.01	0.05	0.19%	0.04	0.18%
Average	**0.05**	**0.19%**	**0.02**	**0.11%**
Maximum	**0.06**	**0.26%**	**0.04**	**0.19%**

The analysis indicates that the impacts on stream temperature of the 2% reduction are negligible under current vegetation and site potential vegetation conditions. The analysis shows that this reduction will lead to a maximum temperature increase of 0.06 deg-C (or a 0.26% relative increase) for current vegetation and a 0.04 deg-C (or 0.19% relative increase) for site potential vegetation. Instream temperature gauges/technology available today are only accurate to 0.1

deg-C; therefore, these differences are not even measurable by modern technology. Additionally, because the temperature increases are negligible for Nookachamps, the largest of the streams, it is not necessary to perform the analysis for the other tributaries.

If you have questions, please contact me at steb461@ecy.wa.gov or (360) 407-6498.

SB:sb

Cc: Darrel Anderson, Unit Supervisor, Environmental Assessment Program
Will Kendra, Section Manager, Environmental Assessment Program

Appendix G. Letter from Member of TMDL Advisory Committee

July 14, 2007

Sally Lawrence
Water Cleanup Lead
Department of Ecology, NWRO
3190-160th Ave. SE
Bellevue, WA 98008-5452

Dear Ms Lawrence, re: TMDL Advisory Committee

How can any plan be implemented if no certain causes or solutions can be determined?

Upon review of the various plans for salmonid recovery or enhancement, I believe there is one group singled out in this whole plan, and that is the agricultural landowner. The United States, Canada, Japan, Russia, and the Native American tribes all fish in the waters of the northern Pacific Ocean. No one 'owns' the water where the fish swim. There has been little publicly discussed or shared information about how much overfishing has been allowed by all the parties mentioned above. It seems as though all of the above want their 'rights', but need someone else to point at so they need not look at themselves. Agricultural practices by their very nature are sustainable. If too much nutrition is removed from the soil by overcropping, then very little will grow back in subsequent seasons. If too many fish are removed from the ocean, very few will come back in subsequent seasons. There is a very simple pattern here. Tribes and Government agencies in particular are looking to take away the rights that are given to the people in this United States of America. I have heard it stated many times that oceanic conditions and overfishing have as much influence as anything regarding how many fish survive. That seems to always be minimized when brought up in discussions. I think the government agencies should shoulder some of the responsibility for keeping the fish runs healthy, and help the landowners keep their land productive. Planting trees and bushes are fine if citizens want to volunteer to do that, but that should be an individual choice. Voluntary surrendering of water rights shouldn't even be a part of any proposed change. They were put in place for a reason. I sometimes wonder if the water is too clean that the fish don't want to return to a particular stream.

When the treaties were written, the technology of the time was spears, then hooks, then nets.

It seems to me the Department of Fish and Wildlife could be doing more to manage the size of the salmon runs by stopping the overfishing. The political pressure probably would be high, but again, no one party owns the fish, including the tribes. The urban growth areas, or the cities, towns, and non-farm people haven't been included in this discussion either. It seems to be non-agricultural 'special interest' groups that may be well intended, but misguided or misinformed. Highway runoff eventually makes it into the streams and waterways. City sewer systems are all allowed to discharge into the rivers, but that's all right because they have a permit.

Solutions from my perspective would be as follows:

1. Clean (dredge) the streambeds so 'cool waters run deep' if temperature is discovered to be a problem.
2. If the salmon runs are continuing to decline, stop the fishing for a while until they recover. Agriculture and farming cannot continue if we mine our resource.
3. Have development and urban growth areas plant more trees.
4. Allow for voluntary participation so active farms, (those who make their living off the land), can continue without interruption. Farms and farmers are far more fish friendly than houses, condos, apartments, or highways and automobiles.

Because of the passage of SSB 5248 in the Washington Legislature this current session, there should be a moratorium on implementation of the TMDL project. In the meantime, fishing seasons can be halted to allow fish runs to reestablish themselves.

Through all of this, it gives more time to the State and the Tribes to determine the definite causes, and the definite solutions so everyone in our region can measure the results and fix the problem appropriately.

Thank you for the opportunity to comment.

Dave Boon
20616 Bulson Rd
Mount Vernon, WA 98274
(360)445-6612

Appendix H. Response to Comments

Note: Lengthy comments have been edited to keep the document size manageable. Editorial comments have been addressed by revising the main text.

1. ***Comment:*** **We believe that an exemplary job was done on the scientific portion of the TMDL process. However, we are disappointed in the implementation approach's reliance on voluntary compliance. We believe this approach has little chance of success and that this document is flawed on a factual basis.**

Response: Ecology believes that the Basin Steward and incentives approach outlined in the implementation strategy can be successful, if supported by these elements: (1) an increasing body of evidence from on-the-ground Skagit-area restoration projects with documented temperature benefits, such as Skagit Fisheries Enhancement Group's restoration work in Day Creek; (2) education and outreach about improving stream hydrology and temperature with local landowners taking active roles as educators; and (3) a cooperative project with WDFW to document fish habitat improvements on selected creeks by establishing and monitoring salmonid smolt traps. The Basin Steward concept has resulted in measurable progress in riparian planting and temperature control in a Whatcom County watershed, and this approach deserves a trial in Skagit County.

Although Ecology seeks to work primarily with willing landowners using education and incentives, Ecology retains its authority to enforce (Reasonable Assurances). The successful programs cited for other parts of the state are characterized not only by incentive programs but also education which includes informing landowners of their responsibility to comply with local ordinances, the Clean Water Act and the state Water Pollution Control Act.

Further explanation of the legal enforceability of nonpoint TMDLs has been added to the "Overview" section. In addition, this document explains that the County should consider the TMDL Study (Appendix A) (which documents the need for adequate riparian shade) as Best Available Science for any update of the County Critical Areas Ordinance for Ongoing Ag.

2. ***Comment*:** **Provide an analysis supporting the goal of "100 percent of all stream miles of these creeks to be protected by riparian shade or enrolled as part of creek restoration and improvement projects by 2020."**

Response: Ecology acknowledges it will take considerable hard work and widespread community support to achieve the goal of 100 percent enrollment of stream miles by 2020. The need to establish as much riparian shade as possible is documented in the Lower Skagit Tributaries Temperature Study (Appendix A). The implementation timeline laid out in Table 3 is a statement of the goals and objectives of this TMDL and is not based on the pace of current efforts in Skagit County.

The examples cited in the implementation strategy include the Tenmile Creek project in Whatcom County and Ecology's nonpoint specialist in eastern Washington. The basin steward effort in Whatcom County accomplished 12.5 miles of riparian planting over nine years (Dorie

Belisle, Tenmile Creek Steward, personal communication April 21, 2008). Ecology's nonpoint specialist in eastern Washington has helped initiate projects that have accomplished about 35 miles of plantings per year with multiple sources of funding. Because western Washington properties are typically smaller and many more landowners need to be involved, the Whatcom County effort is probably a better example of the rate of planting that can be accomplished in Skagit County. With some existing shade, particularly along Fisher Creek, the estimated total stream length needing full riparian planting along the principal six creeks is about 26 miles. With adequate funds in place and a one mile per year planting rate, this could be accomplished in about twenty-five years, leading to a more conservative estimate of 2035 to establish necessary riparian shade.

In the interest of providing an impetus to meet the standards as soon as possible, the goals and objectives laid out in Table 3 have not been changed.

3. ***Comment:*** **Ecology has established a new Instream Flow Rule for the Skagit Basin that will permit additional water to be withdrawn from the creeks addressed by the TMDL. We are puzzled why there is no mention of how the rule change will affect stream temperature.**

Response: Thank you for pointing out this omission in the public review draft. This was an oversight in the original draft, so the document was revised to include Appendix F, Ecology's analysis of the impact on creek temperatures due to the additional reservations set aside under the Instream Flow Rule. Basic information about how the reservations will be managed is found at www.ecy.wa.gov/biblio/0711042.html. Both the water quality standards for temperature and Instream Flow regulations are designed to protect beneficial uses of these streams for salmonids and other cold-water aquatic life.

The Instream Flow Rule for the Skagit River and its tributaries were adopted to protect flow needed for fish and other instream values. The original Rule did not set aside reservations for future development. When the concept of additional reservations for growth was under discussion, Ecology conducted an additional run of the temperature model using 2% less flow (the reservation amount) for the Nookachamps, the largest creek with a reservation and the most likely to show temperature impacts. The analysis shows that this reduction would lead to a maximum temperature increase of 0.06^{o} C (or a 0.26% relative increase) for current vegetation and a 0.04^{o} C (or 0.19% relative increase) for site potential vegetation. The results indicate that anticipated or expected temperature impacts of the reservation are not sufficiently large to make the reservation untenable, and do not change the conclusions and recommendations of the TMDL. (Please see Appendix F for the analysis.)

4. ***Comment:*** **Ecology has included as a necessary action item, one that is irrelevant with regard to action necessary to meet water quality standards: the recommendation that SRSC on behalf of the Swinomish and Sauk-Suiattle Tribes should "Work with Washington Department of Fish and Wildlife on a revised introductory section of the Skagit Chinook Recovery Plan with explanation of fisheries management decisions as they relate to the status of Chinook stocks." We believe this is unnecessary and unrelated to the actions necessary to meet water quality standards, and would require**

expenditure of valuable time revising the Chinook Recovery Plan so that a public outreach campaign could be waged.

Response: Ecology recognizes that this action item does not come under the regulatory authority of the TMDL and that it is outside the usual suite of actions discussed in a Temperature TMDL. Accordingly, we have removed it from Table 4 which lists Implementation Actions. However, this recommendation is maintained in another part of the document ("Outside the Box") because the success of this TMDL depends on resolution of the ongoing landowner concerns about buffers.

Government and resource managers need to fully answer landowner questions about the basis of regulations, the relative certainties of the science underlying fisheries management decisions, and in addition explain clearly the risks to our resources if we do not implement sound regulatory programs. When these questions are fully debated, the whole community benefits from the educational process and increased credibility and accountability of government and natural resource managers.

5. *Comment:* Many of the TMDL stream reaches identified in TMDLs and WQMPs do not meet the criteria described in the Clean Water Act (CWA) as appropriate stream segments required to have a TMDL. The proposed Lower Skagit River TMDL does not reflect that Washington Department of Ecology (DOE) has conducted the TMDL assessments according to the law.

Response: See response #6 below and new section main text pp. 12-15.

6. *Comment*: The misidentified segments in the current TMDL documents are ones that do not have any point source discharges or point source permits and they should not be included in the TMDL. Non point segments for inclusion could be segments adjacent to a point source TMDL if DOE could justify their inclusion, but they should not have a TMDL set as though they were a point source stream segment. The inclusion of the Lower Skagit River sub basin for the Temperature TMDL assessment should be reconsidered. There are no point source permits in that drainage that suggest it should have a TMDL written.

Response: In accordance with the CWA, a Nonpoint TMDL reveals noncompliance with the Water Quality Standards and directs how to attain compliance. See new section pp. 12-15.

7. *Comment*: TMDLs described in Clean Water Act are aimed at 303(d) listed streams that cannot attain the standards due to the additional stressor of a "point source", which when combined with non point source plus natural background sources causes the stream segment to exceed applicable water quality criteria. DOE is stretching the TMDL allocations to include non point source streams that do not have point source discharges.

Response: As the discussion on pages 12-15 notes, the CWA does not describe that either 303(d) listings or TMDLs should apply only to waters that cannot attain water quality standards "due to the additional stressor of a point source." As you note, EPA's regulations define TMDLs as the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background." 40 CFR § 130.2(i). In addition, as you note, wasteload allocations are "the portion of receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution," and a load allocation is the "portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources." § 130.2(h) & (g). The load allocation regulation also advises that, if possible, "natural and nonpoint sources should be distinguished." However, as the *Pronsolino* Court has observed, "no reason appears why, under this TMDL definition the amount of either point source loads or non point source loads *cannot be zero*." *Pronsolino*, 291 F.3d 1123, at 7919. Therefore, if a wasteload allocation is zero, the TMDL would only apply to nonpoint sources and natural background.

Ultimately, the United States Ninth Circuit Court of Appeals in *Pronsolino* summarizes these relevant portions of the CWA best:

> Nothing in the statutory structure — or purpose — suggests that Congress meant to distinguish, as to § 303(d)(1) lists and TMDLs, between waters with one insignificant point source and substantial nonpoint source pollution and waters with only nonpoint source pollution….*There is no statutory basis for concluding that Congress intended such an irrational regime*.

Pronsolino, 291 F.3d 1123, at 7934 emphasis added.

As discussed throughout the previous responses, the CWA does not treat point sources and nonpoint sources differently in regards to the setting of water quality standards, listing impaired waters not complying with those standards, or completing TMDLs. As the *Pronsolino* court notes, the basic purpose for which the § 303(d) list and TMDLs are compiled, is the eventual attainment of state-defined water quality standards. *Id* at 7929. State-defined "water quality standards reflect a state's designated uses for a water body and *do not depend in any way upon the source of pollution*." *Id*.

8. *Comment*: RCW 90.48 is the statute that tells Ecology that it can only do what the EPA is able to do under the federal Clean Water Act when it comes to TMDLs. Where EPA cannot create non point source only TMDLs and enforce them against non point sources under the CWA (Pronsolino Case), Ecology cannot do it under state law either because RCW 90.48 sets the jurisdiction over TMDLs to coincide exactly with federal EPA jurisdiction over TMDLs.

Response: This comment suggests a misunderstanding of the state's Water Pollution Control Act (WPCA), RCW 90.48, which accords the department Ecology, "the jurisdiction to control and prevent the pollution of streams, lakes, rivers, ponds, inland waters, salt waters, water courses, and other surface and underground waters of the state of Washington." RCW 90.48.030. Nothing in this jurisdictional statute or in the entire Chapter precludes the Department of Ecology from creating or enforcing nonpoint TMDLs, or limiting its authority to the jurisdictional reach of the CWA.

Washington State's over arching policy toward integration with the CWA is clearly enunciated in WPCA, RCW 90.48.010. That statute reads:

> The state of Washington in recognition of the federal government's interest in the quality of the navigable waters of the United States, of which certain portions thereof are within the jurisdictional limits of this state, proclaims a public policy of working cooperatively with the federal government in a joint effort to extinguish the sources of water quality degradation, *while at the same time preserving and vigorously exercising state powers to insure that present and future standards of water quality* within the state shall be determined by the citizenry, through and by the efforts of state government, of the state of Washington.

Washington State's broad "power to insure…standards of water quality" largely lies within the above mentioned jurisdictional statement, RCW 90.48.080, provisions of the Water Resources Act, RCW 90.54, and the implementing regulations of the water quality standards. The RCW 90.48.080 makes actions which cause or permit water pollution, unlawful, stating:

> It shall be unlawful for any person to throw, drain, run, or otherwise discharge into any of the waters of this state, or to cause, permit or suffer to be thrown, run, drained, allowed to seep or otherwise discharged into such waters any organic or inorganic matter that shall cause or tend to cause pollution of such waters according to the determination of the department, as provided for in this chapter. RCW 90.48.080.

Notably, nothing in the WPCA's statutory provisions distinguishes between point or nonpoint sources of pollution. Nor is there any indication that the jurisdiction and authority granted under 90.48.080 is limited by either the reach of the Federal CWA, or an exclusion of nonpoint sources. Conversely, the Washington state courts have broadly interpreted the WPCA as creating a non-delegable legal duty to refrain from acts which will pollute waters on another's land as well as their own. *Sea Farms, Inc v. Foster & Marhsall Realty, Inc*. 42 Wash. App. 308, 711 P.2d 1049. So essentially, RCW 90.48.080 makes it unlawful for any person "cause, permit or suffer" pollution of state waters, an interpretation expressly devoid of the point and nonpoint source dichotomy.

In addition to broad authority granted under RCW 90.48.030 and RCW 90.48.080, the WPCA explicitly grants Ecology the authority to implement the programs of the CWA under RCW 90.48.260. That statute provides that, *in addition* to other authorities granted under 90.48, the department of Ecology is granted the authority to implement the requirements of the CWA, including but not limited to:

> 2.) Program elements authorized herein may include, but are not limited to: … (b) applicable receiving water quality standards requirements… (i) enforcement of the program through penalties, emergency powers, and criminal sanctions

***

> 3) The power to develop and implement appropriate programs pertaining to continuing planning processes…
> RCW 90.48.260

Notably, the continuing planning process of the CWA found in § 303(e) includes the production of TMDLs and *implementation* of the state-defined water quality standards. 33 U.S.C § 1313(e)(3). Therefore, the Department of Ecology both expressly and implicitly has the authority to both develop and implement TMDLs, including instances where the pollution source is solely nonpoint in nature.

Furthermore, nothing in the CWA preempts Washington State's authority to implement TMDLs that address nonpoint source pollution problems. On this matter, the CWA clearly states:

" It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources…" 33 U.S.C. § 1251(b)

In the Ninth Circuit Court of Appeals Case, *Pronsolino v. Nastri*, which you cite, the Court held that there were no federalism concerns with the EPA's compilation of a nonpoint TMDL, because the TMDL in that case "expressly recognize[ed] that implementation and monitoring *are state responsibilities*." *Pronsolino*, 291 F.3d 1123, at 7933 emphasis added. Moreover, as discussed in response to questions 2 and 3, the CWA actually *requires* the compilation of nonpoint TMDLs, and certainly does not preclude them. Therefore, nothing under the WPCA, CWA or the common law, even remotely suggests Ecology cannot complete or implement a TMDL for waters impaired solely by nonpoint sources.

9. *Comment*: It is inappropriate to use a non point source water quality management plan to provide a reasonable assurance that a TMDL load allocation for agriculture will be met. Under current law a load allocation developed in the establishment of a Total Maximum Daily Load (TMDL) is "attributed" to non point sources and background. It is not assigned to them.

Response: Since the feasibility study by Skagit Conservation District (2006) identified projects to improve stream temperature on Fisher and Carpenter Creeks, it is appropriate to include it with reasonable assurances in this TMDL. Once the total amount of pollution in a water body is "attributed" to its various sources, load allocations are "assigned" which will not allow the loading capacity to be exceeded. In that sense, loading is "attributed" and load allocations are "assigned." If by attributing load allocations to nonpoint sources, the commenter means that Ecology should merely acknowledge nonpoint source loading and not try and control it, that would contravene Ecology's water quality mission and state law RCW 90.48.

The CWA explicitly states that load allocations "shall be established at a level necessary *to implement* the applicable water quality standards." 33 U.S.C. § 1313 (d)(1)(c) emphasis added. Load allocations are to be "attributed to either one of its *existing or future nonpoint sources of pollution*..." 40 CFR 130.2(g) emphasis added. Webster's II New Riverside Dictionary defines "attributed" as "to assign to a cause, or source." But when Ecology "assigns" a load allocation, the regulatory implication is that the nonpoint source loading will be reduced to the assigned amount. Therefore, a load allocation must be assigned to *sources*, in order to ultimately achieve compliance with the water quality standards.

In *Chandler v. Ecology*, the Pollution Control Hearings Board affirmed this position by stating that the purpose of a TMDL "is to bring a waterbody into compliance with the water quality standards." *Chandler v. Ecology*, PCHB No. 96 – 35 (1996**).** The regulations implementing the Water Quality Standards (WQS), codify this position, stating, "[it is] the intent of the Department to apply the various implementation and enforcement authorities at its disposal, including participation in the programs of the CWA [such as TMDLs]," to achieve compliance with the WQS. WAC 173-201A-500.

TMDLs harness the legal authority of the WPCA, WRA, and the antidegradation and implementation provisions of the water quality standards to ensure that both the goals of the CWA, and § 303(d) are implemented. *See* 33 USC § 1251(a)(7) and 33 USC § 1251(a) stating the goals of the CWA are "…the control of nonpoint sources of pollution be developed *and implemented* in an expeditious manner so as to..." "restore and maintain the chemical, physical, and biological integrity of the Nation's waters"; see also § 1313 (d)(1)(c). Ultimately, those state statutory and regulatory provisions grant Ecology broad authority to protect waters of the state.

When nonpoint sources are the primary causes of water quality impacts, sources must implement Ecology-approved best management practices. The water quality standards state that nonpoint sources must implement these practices to both attain and express compliance with the standards. The implementing regulations of the water quality standards codify this position and state:

> "the primary means to be used for requiring compliance with the standards shall be through best management practices required in waste discharge permits, rules, orders, and directives issued by the department for activities which generate nonpoint source pollution." WAC 173-201A-510(3)(a).

Therefore, Ecology, through the TMDL process, can both assign load allocations to nonpoint sources, as well as require the use of best management practices to attain and express compliance with the water quality standards.

10. *Comment*: The proposed Lower Skagit River TMDL does not define and apply scientific procedures, for example:

- **A definition of science is needed in this document. Also, reference material used as an appeal to authority needs to be strengthened by reading and using studies that make an application of the physical laws. Modeling is a useful tool in taking a quick first look, but lacks methodology and statistical analyses required in scientific endeavors.**

- **Fundamental science is generally (there are exceptions) not interested in how a specific system behaves. Rather, the goal of science is to discover the fundamental laws of Nature, which means we are interested in finding that few set of rules that apply to all objects and systems in the Universe. The Laws of Physics are the same everywhere and for everything**

- **Science is "the systematic enterprise of gathering knowledge about the universe and organizing and condensing that knowledge into testable laws and theories." This definition possesses two key words: systematic and testable. Systematic ensures an organized, well thought out procedure for conducting an investigation. Testable requires that the research and information must be valid and consistent when peer-reviewed.**

Response: It is certainly a basic use of science to determine the fundamental laws of nature, including physical laws. In addition to developing an understanding of natural laws, the scientific method can be applied to natural systems and everyday phenomena ranging from the very simple to the complex.

The power of the scientific method is found in developing hypotheses that can be tested; in designing experiments well, using controls to elucidate the conditions that have produced the results; and in documenting the conditions and methods employed so other investigators can repeat and confirm the results.

- An example of everyday science might be the set of systematic observations by the manager of an outdoor swimming pool whose job is to ensure the health of pool users by making sure that sufficient chlorine is in the pool every day to kill bacteria that occur with human use. The pool manager notes the air temperature, the water temperature, and the hours of daylight every day during the summer, and notes that, even though he adds the same amount of chlorine at the beginning of each day, with longer days and warmer temperatures the chlorine disappears more rapidly. He charts the daily residual chlorine against the day's temperature and daylength and begins to see a relationship.

  Eventually the pool manager has sufficient data to plot a curve. This curve represents a simple model that he can test at another swimming pool. If the second swimming pool is a different size, the curve representing the change in residual chlorine with temperature and daylength may be somewhat different. So through his systematic work, the scientist-pool manager has discovered another variable that must be considered in developing his predictive model for chlorine residual in the pool as a function of the variables temperature and daylength.

- Both Ecology's models and many peer-reviewed scientific studies document the important role that riparian vegetation plays in affecting stream temperature. Literature citations (Appendix A) include Belt et al. (1992), Beschta et al. 1987, Bolton and Monahan (2001), Castelle and Johnson (2000), CH2M Hill (2000), Ice (2001) and Wenger 1999.

- Ecology's temperature TMDLs use the scientific method in the following ways: Our temperature studies utilize both monitoring of on-the-ground conditions and modeling. Measurements are made of current riparian vegetation height, vegetation type, percent cover over the stream, stream flow, bankfull width, and air and water temperature at a number of locations along each stream, and other characteristics. The methods are described in pages **49 – 65** of the study (Appendix A). We measure this large number of characteristics of each stream in developing our temperature models ***precisely because*** every stream is unique and therefore has a temperature regime that is slightly different from others. By quantifying a number of distinctive, measurable attributes for each stream in our models, we improve the ability of the model to predict future temperatures for that stream.

- For example, we know that riparian shade works well in blocking sun for narrow streams but has less effect on the temperature of a very wide stream or one with much higher discharge. This is why, for Nookachamps Creek, Ecology's model (Figure 34, Appendix A) predicts that even with maximum shade along its full length, the temperature at its wider downstream end will be slightly higher than mid-way along the creek where it is narrower and may have less flow.

- We test the accuracy of model predictions for a different period of the monitoring year than was used to calibrate the model. In this procedure, called verification, the model's predictions of stream temperatures can be compared with measured temperatures for that period. As described in Appendix A, pages 65-74, the models for the six creeks performed very well: the difference between predicted and measured temperatures was less than a degree for five of the creeks and slightly more than a degree for Carpenter Creek.

- Ecology's temperature models focus on shade as a variable: they assess the current temperature regime of a creek and the current, varying amounts of riparian vegetation along each reach (see Figures 21-23, Appendix A). Then we use the model to predict the temperature regime for the same creek if this single variable, shade, were maximized (Figures 30-35, Appendix A). Shade is selected as a variable and "surrogate measure" for heat loading ***<u>not</u>*** because it is the only variable of importance in affecting stream temperature, but because it is one of the few management tools that can make a difference in the stream temperature.

- Factors affecting stream temperature were systematically reviewed in determining that shade is the important factor that can be used as a management tool. Compared with adding shade-producing vegetation, doubling the amount of flow in the stream or changing the width-to-depth ratio of the stream bed might also have a significant effect on the temperature of a specific stream, depending on its size. But we usually do not have extra flow to add to these creeks, and changing the width-to-depth ratio would only work in a few circumstances where creek flow, gradient, soil types and stability of the adjacent stream bank and sediment load and other factors were suited to a different channel shape.

- It is a testable hypothesis that measurably increasing the amount of shade along one of the creeks in this Temperature TMDL will reduce the amount of incoming solar radiation and lead to measurable reductions in the temperature regime of the creek. Ecology invites the Cattlemen's Association to work with us in recruiting willing landowners along a significant stretch of one of the creeks so that we can further document the validity of the models and measure the response of the creek.

11. *Comment*: Ecology has failed to properly apply the natural laws that govern water temperatures…Ecology bears the burden to not only show that the standard is violated, but that there are fish impacted when the 7-day average has been surpassed.

Response: Data in the Temperature Study (Appendix A) demonstrate that the standard has been exceeded in the creeks that were studied. While the standards are intended to protect aquatic life, Ecology is not required to demonstrate negative impacts to salmon populations. State temperature standards are numeric criteria based on studies of salmonid tolerances of temperature. Whether there are fish in a water body or not, compliance with standards is determined based on temperature measurements. The maximum summer temperature criterion is a "7-day average of daily temperature maxima" (7DADM) which allows for some individual hot days as long as the 7-day average does not exceed the criterion.

Additionally, because fish are mobile and able to seek refuge in other waters, their most probable response to increasing temperatures, once these temperatures reach a range causing stress to the fish, would be to leave the water body in search of preferable temperatures in nearby water bodies. If many of the creeks exceed temperature criteria, this can impact salmon populations on a large scale because there is a reduction in suitable habitat available for migration, spawning or rearing, depending on the salmon species.

12. *Comment:* The Clean Water Act discusses temperature concerns in order to prevent excessive heating or cooling of streams due to "discharges" from industrial contributions which are under a permit and are allowed discharges from the operation into the stream.

Response: The Clean Water Act applies to nonpoint impacts to water quality as well; see answer to #7 above. See also answer to #29 below.

13. *Comment:* If the industry's discharge were more than the stream could handle the permit would require the industry to cool the discharge and require a cooler substance into the stream so that when the mixing zone calculation was completed then the standard would not be violated.

Response. This comment does not relate to a TMDL with no point sources.

14. *Comment*: Ecology has created a perception that shade will be effective in cooling stream water, and this "theory" has been shown to contain serious flaws.

Response: The overall approach, data collection and modeling conducted for this TMDL Temperature Study are consistent with Ecology's other temperature TMDLs, which have been approved by EPA. The studies cited under #10 are peer-reviewed, published scientific studies of stream temperature and the variables that influence it. Ecology has not been provided any review by a recognized scientist of its temperature TMDLs indicating serious flaws with the approach Ecology uses. When we conduct our studies, we do measure water temperature in comparison with, or in conjunction with, many other environmental variables such as bankfull width, stream depth, discharge rate, air temperature, and others. We have characterized the multiple benefits of fully-vegetated riparian zones that block incoming solar radiation and thereby reduce stream heating.

A report by the Independent Multidisciplinary Science Team (IMST, 2004), concludes that, "The scientific literature reviewed by the IMST indicates that removal of vegetation along small to medium sized streams usually results in increased surface water temperature. In addition, most scientists agree that riparian vegetation provides many benefits to stream and terrestrial ecosystems, in addition to shading streams."

Forty-five of forty-eight empirical studies that specifically measured changes in summer stream temperatures as a result of decreased riparian vegetation and canopy removal due to either land use practices or experimental manipulation, resulted in increases in summer stream temperature. The magnitude of the measured changes ranged from 2F to 22.9F. (IMST, 2004).

15. *Comment:* We encourage Ecology to review some of the history of science and focus on the development of modern heat theory.

Response: Ecology has included an overview of stream heating processes on pages 5-18 of Appendix A. This discussion is based on peer-reviewed scientific literature and an understanding of the laws of physics as they relate to the development of a heat budget for a stream. Multiple factors, including air temperature, flow rate, elevation above sea level, stream cross section, the amount of groundwater influence, and other factors, are known to influence stream temperature. The discussion clearly explains that shade produced by riparian vegetation is one of the important factors affecting stream temperature.

16. *Comment*: Recommend Ecology consult a physics textbook (e.g., Feynman et al.. 1993; Halliday and Resnick, 1988; Wheeler and Kirkpatrick [no date]; von Baeyer 1999) for an understanding of the laws of thermodynamics…the Laws of Thermodynamics were written in the mid-1800s, have been tested time and time again, always to be confirmed.

Response: Ecology's Temperature Study, using a heat budget approach for modeling the stream temperature response to environmental factors, is consistent with the laws of thermodynamics. . The Qual2Kw model uses the laws of thermodynamics. It has been peer-reviewed and is endorsed and supported by the United States Environmental Protection Agency for use in evaluating stream temperature and other water quality parameters. We agree that the laws of thermodynamics have remained the same over time.

17. *Comment:* The "heat budget" technique used by Ecology in its models may result in inaccurate predictions for natural systems. Cluis (1972) modeled water temperatures from ambient air temperatures rather than use the "heat budget" technique, which examines the

water in a static environment and make inaccurate predictions for natural streams. Walker et al. (1976) described a method to determine water temperatures using the site topographic altitude and ambient air temperatures.

Response: Ecology has verified that its models produce accurate predictions by comparing to time periods that were not used in model calibration but for which detailed monitoring data were collected. How well the QUAL2Kw model predicted maximum and minimum temperatures was evaluated by calculating the root mean square error (RMSE). See page 67 of Appendix A. In general, the error of the model predictions was less than 1^{o} C and slightly more than that for Carpenter Creek.

The models cited – Cluis (1972) and Walker (1976) – which predict stream temperatures from site altitude and ambient air temperatures – are suitable for other purposes. Ecology's models were chosen with a specific application in mind, which was to test whether added riparian shade would have a sufficiently large effect on maximum stream temperature that the stream could be in compliance with state temperature criteria. The Cluis and Walker models were not developed to answer this question.

Ecology believes that the best way for Skagit landowners to develop confidence in the Temperature TMDL study results is to work with Ecology and local partners on a number of test plots for shade over a significant reach of one of the creeks. We invite the Cattlemens' Association to assist us in recruiting willing landowners to help in a large scale test of the addition of riparian shade along these creeks.

18. *Comment:* Many of the mythical and factual concepts about heating and cooling are well explained in Bohren (1998) through atmospheric science and the application of the Thermodynamic Laws. Atmospheric science must apply the same laws as other science disciplines to describe air and land thermal cycles as well as water heating and cooling.

Response: Ecology has not had the opportunity to review Bohren (1998). As noted in response to Comment #16, Ecology's model is consistent with thermodynamic laws.

19. *Comment:* Ecology assumes all streams are thermally polluted simply based on the life cycle of the fish. Water temperature is not governed by fish but by universal physical laws. Fish and other beneficial uses should be examined after the natural water temperatures are established. Where are the Ecology data that establish the natural thermal cycles for the Skagit River Basin?

Response: The state's water quality standards for temperature are established based on review of fish presence and absence data from Washington Department of Fish & Wildlife and other resource agencies and review of both field and laboratory data related to the thermal tolerances of the salmonid species recorded as occurring in the past in these streams. We do not have records of the maximum summer temperatures in the Skagit basin for the period before large scale changes to the landscape and hydrology took place in the late 1800s.

It is not accurate to say that “the Heat Source model assumes shade will cool water and then goes on to predict water temperatures from that point.” It would be more accurate to say that Ecology uses an EPA-approved water quality model with a variety of input conditions specific to a particular stream including width, depth, air temperature, discharge rate, and other variables, including current shade conditions, to predict maximum and minimum temperatures for the specific stream. If the model’s predictions are shown to be accurate for these current conditions, then the model is run with hypothetical future shade conditions, to test the effect of shade on maximum summer stream temperatures.

In the case of the six creeks modeled in this TMDL, it was determined that all six would meet the temperature criteria if full riparian shade were present, with the exception of the reaches below Big Lake and Lake McMurray. Ecology’s temperature models do not always show that maximum riparian shade will make enough of a difference to meet temperature standards. An example is the mainstem Stillaguamish River, where the river has become widened and shallow due to excessive sediment loads over the years. Ecology’s model showed that this reach will still be above temperature criteria even with maximum riparian shade (www.ecy.wa.gov/biblio/0610057.html).

Ecology has not seen other models for these creeks that show shade will not be effective, so we cannot comment on this assertion.

20. *Comment:* Ecology’s approach failed to identify the overnight low water temperatures needed to establish a lower starting point for the water temperature increases at dawn. The model essentially ignores the equilibrium temperatures? Was equilibrium considered in the modeling effort? What does the monitoring data show for other days and months other than the one used in the TMDL document? Statistical testing of data already in the Skagit County records show that using the mathematical laws of probability that EF Nookachamps, Nookachamps, and Lake Creek have thermal cycles that are primarily influenced by natural conditions.

Response: Ecology’s approach does consider overnight low water temperatures in that we used temperature data recorded by dataloggers at 15-minute intervals for the full 24-hour day-night cycle for the summer 2001 monitoring period (June 1 to August 31). The QUAL2Kw model is a stream model that is run with appropriate flow conditions and day-night changes in temperature, for the full one-week, critical period model run. EPA requirements for TMDLs are that they be conservative and protective. This means that we needed to run the model for a worst-case, low flow condition (we ran the model for both a typical flow condition (7Q2) and a 10-year low flow condition (7Q10), and during the critical summer period when air temperatures are usually highest. The model predicts the equilibrium temperatures attained by the stream under the flow and climate conditions specified. Ecology has not had the opportunity to review the referenced “statistical testing of data already in the Skagit County records” and cannot therefore come to any conclusion about this statement. This TMDL acknowledges the role of natural conditions in the two shallow lakes (Lake McMurray and Big Lake) that affect downstream temperatures.

21. ***Comment:* Ecology assumes the temperature standard is correctly figured and can be scientifically supported**.

Response: This statement does not accurately describe the process that was used to develop revised temperature criteria for individual water bodies in 2004-2006. EPA and Ecology reviewed salmonid species presence and absence data from Dept of Fish and Wildlife to determine appropriate temperature criteria designations for each stream. In addition, Ecology's revised temperature criteria were presented to the public who were given opportunity to provide additional data relating to fish presence and temperature and to comment on the temperature designations.

22. *Comment:* Hurlbert (1984) noted that a model is a hypothesized process and its predictions of the state variables are the test consequences. Modelers call the process of comparing predicted and observed test consequences "verification" or "validation" and a valid model is one whose predictions are within a designated tolerance. The model is an informed guess and the calibration process is a process of "fiddling" to force better agreement between predicted and observed consequences. The model is an informed guess, a mixture of knowledge and error about a process of nature…Modeling was never intended to function as a means of scientific knowledge.

Response: Ecology used an approach for modeling stream temperature that has been used for many streams and rivers throughout Washington state and approved by EPA. The results of modeling are not used in the same way monitoring data are used, to decide whether water quality criteria have been exceeded. The model predictions are used to guide management decisions and estimate the expected impacts of potential implementation actions. In the case of the Lower Skagit Tributaries Temperature TMDL, the model results give Ecology and its local partners confidence that full riparian buffers can be an effective tool in protecting creek temperature regimes as well as offering other benefits to aquatic life.

23**: *Comment:* It is inappropriate to use an agricultural water quality management area plan to provide a reasonable assurance that a TMDL load allocation for agriculture will be met. Under current law a load allocation developed in the establishment of a Total Maximum Daily Load (TMDL) is "attributed" to nonpoint sources and background. It is not assigned to them.**

Response: See response to #9.

24. *Comment:* Ultimately statements made in the TMDL suggest that Ecology will revamp and revise as new ideas are formed and new technologies are implemented. While this makes some sense regarding waste treatment plants, point source discharges from industry, and other permitted discharges, we do not know of any technology that will hasten the stream temperature issues. We are also unaware of how new technologies will affect nonpoint source contributions. We would like this clarified and would like discussion about this aspect of the TMDL efforts over time.

Response: Ecology does not use the term "new technologies" in this TMDL and we do not know what you are referencing. As with all our TMDLs, Ecology plans to use an adaptive management approach (page 47) as we assess compliance progress. Adaptive management involves adjusting implementation actions according to documented actions and water quality response.

25. *Comment:* We are very concerned about the unintended consequences of land management activities intended to prevent contributions of pollutants to the stream, based on the limited explanations of how the natural environment and watershed system works and how the activities implied by the nonpoint source contributions affect the system. Ecology should not go forward with this TMDL until more study has been conducted on the ground. It is quite likely that great harm will be inflicted on the system and the protection of the beneficial uses will not happen. Ecology should assess the appropriateness of each standard for the streams in the Skagit River Basin.

Response: The activities outlined in this TMDL will be carried out with the full support and knowledge of many willing landowners. This is the best approach where there is a conflict between agricultural use of the land and planting native trees to protect the stream. There are many excellent studies by a variety of researchers and conservation organizations that document that native riparian vegetation protects and benefits the aquatic life in creeks. Sound management of land near creeks and ditches can also prevent soil loss and reduce the need for mowing and weed control. In addition, many programs provide economic incentives for willing landowners. Ecology is ready and willing to work with landowners on "on the ground" projects that will begin to improve water quality in the creeks. Ecology has already assessed the appropriateness of the temperature criteria established for these streams.

26. *Comment:* The agency has not demonstrated the application of sound scientific theories, which direct management activities that have to take place to bring water temperatures into compliance with the standards. Ecology has little if any authority to make agricultural practices bend to assist in meeting the TMDL. As we see things, a non point source contribution cannot be enforced without evidence and the evidence that must be used must meet the burden of showing a probable cause of water pollution due to an agriculture activity. Ecology has authority to enforce a water quality rule for "waste discharge" and we do not agree that sunshine is a "waste discharge" (RCW 90.48).

As discussed above, Ecology has compiled the Lower Skagit Tributaries Temperature TMDL based on modeling that has been reviewed by water quality scientists and supported by EPA, and based on sound, extensive, peer reviewed scientific literature and research. Also as discussed in response to comment #7, Ecology has authority and jurisdiction to protect, and prevent degradation to waters of the state. *See e.g.*, 33 USC § 1251 et seq.; RCW 90.48.030; RCW 90.48.080; RCW 90.54.020; WAC 173-201A-300.

In implementing the water quality standards and making determinations of pollution under RCW 90.48.080, Ecology may use a TMDL as supporting evidence to demonstrate what types of activities may prevent attainment of the standards. When that information is coupled with monitoring from the stream (showing instream water is actually not meeting standards), and site specific documentation that shows that adjacent practices are in fact exhibiting the known impacts to water quality, then Ecology may issue a notice of correction or a notice of violation.

The legal remedy for that violation may be the implementation of best management practices in accordance with the implementing regulations of the water quality standards.

This approach is in accord with the PCHB's understanding of TMDLs as a vehicle to compliance with the water quality standards, as well as the state court's understanding of RCW 90.48.080, as creating a non-delegable legal duty for a landowner duty not to cause, permit or suffer pollution. *See Chandler v. Ecology,* PCHB No. 96 – 35 (1996**);** *Sea Farms, Inc v. Foster & Marhsall Realty, Inc*. 42 Wash. App. 308, 711 P.2d 1049.

Also as discussed in response to comment #7 above, Ecology's jurisdiction extends beyond that of a waste discharge or disposal permit. See 90.48.080 in comparison to RCW 90.48.160. To read RCW 90.48.080 as only applying to point sources would be to ignore the language and construction of that statute, as well as render it superfluous, in light of the numerous and specific point source permitting statutes found throughout RCW 90.48. RCW 90.48.080 reads in full:

> It shall be unlawful for any person to throw, drain, run, or otherwise discharge into any of the waters of this state, *or to cause,* permit or suffer to be thrown, run, drained, allowed to seep or otherwise discharged into such waters any organic or inorganic matter that shall cause or tend to *cause pollution* of such waters according to the determination of the department, as provided for in this chapter.

Essentially, RCW 90.48.080 makes those actions that "cause pollution," according to Ecology's determination, unlawful. "Pollution," as defined under the WPCA, as follows:

> Whenever the word "pollution" is used in this chapter, it shall be construed to mean such contamination, *or other alteration of the physical, chemical or biological properties, of any waters of the state,* ***including change in temperature****,* taste, color, turbidity… RCW 90.48.020.

Notably, the statutory definition of pollution is expanded beyond contamination or the mere addition of wastes to a stream, but includes the alteration of the physical properties of a stream, and explicitly incorporates "change in temperature." Therefore, under the WPCA, it is unlawful to cause a change in temperature within the stream channel to such an extent that the water quality standards are violated and the beneficial uses are impaired. A landowner need not "discharge" to incite such changes, or otherwise cause pollution. A landowner need only to manipulate the landscape in a manner that tends to cause a physical alteration of the water quality, such as an increase in temperature. And so, Ecology has the duty and authority to ensure that landowners do not eschew their non-delegable legal duty not to cause or permit changes in temperature.

Nevertheless, Ecology prefers to work collaboratively, and when possible, encourage voluntary participation in efforts that will restore beneficial uses and attain compliance with the water quality standards.

27. *Comment*: Real true field tested science does not support the statement that shade cools water. The surrounding air temperature, ground temperature and velocity play the role in determining water temperature of a creek or river.

Response: ee responses to #14 and 15.

28. *Comment:* It was stated that a model developed in Oregon was used in this report when in fact this model has been discontinued in Oregon because of its flawed data.

Response: As described in Appendix A, pages 65-67, Ecology's stream temperature model has several components. A program called Ttools extension for Arcview (ODEQ 2001), developed by Oregon Department of Environmental Quality, was used to sample and process GIS data (computer based geographic data) for input to two models). First, Ecology's Shade model was used to estimate effective shade along six of the lower Skagit River tributaries. The second model, QUAL2Kw, is an EPA-approved water quality model that simulates day-night variations in stream temperature for a steady flow condition.

Ecology consulted with Oregon State Department of Environmental Quality to determine whether the agency has made any changes in use of the models used for Temperature TMDLs. We received the following response May 7, 2008 from Ryan Michie, Water Quality Analyst, Oregon State DEQ:

> I'm not sure what model the commenter is referring to but I do know we have not discontinued any of our models because they were "flawed". For temperature and shade we pretty much exclusively use the Heat Source model. We sometimes use CE-QUAL-W2 as well. We have made updates to Heat Source but the math and theory behind the model is pretty much the same. The most recent updates were primarily to increase model speed.
>
> In 2004 an independent science team (called the IMST) did a review of Oregon's temperature standard. This review included a review of Heat Source to determine if the model was based on "sound scientific principals" and if it "can be used effectively in water quality actions under the clean water act". I've attached the full report for your review. The conclusion was that it was sound and that it can be used for clean water act purposes.
>
> There has also been updates to the TTools application which we use to gather data for Heat Source (Ecology was involved in that) but the updates were made to get the application into ArcGIS not because the math or process was flawed.

29. *Comment:* The report did not mention the fact that both Hansen Creek and Red Creek dry up in late summer, early fall. Maybe that's the reason there are high temperatures.

Response: It is possible that creek temperature would be very high prior to a creek running dry. In 2001, the year of the TMDL Study, dataloggers in Hansen Creek at Hoehn Road, SR20 and Hansen Creek Rd appeared to stay submerged throughout the study period, so it may be this varies from year to year. The station on Red Creek near Highway 20 also appeared to remain submerged in 2001. Based on information in the County's Hansen Creek Watershed Management Plan (Skagit County, 2002), hydrology of Hansen Creek has changed considerably through excessive sediment deposition over the years as a result of extensive logging operations in the headwaters forested areas. It is expected that fairly substantial sediment capture and riparian restoration projects will be required to begin to address these problems. Currently the

County is installing several logjams along one reach to provide deeper pools that will begin to benefit the temperature regime in this part of the creek. Ultimately if a number of corrections are made to this system, it may be that the drying up you have been experiencing in many years will occur less frequently.

30. ***Comment:*** **The Skagit County Cattlemen's has finished a two-year study combining Skagit County Public Works data and the Cattlemen's data using real true field-tested science. The study concluded that buffers already existing are adequately protecting critical areas in Skagit County. The Cattlemen's study and over 150 other studies all that meet all criteria in WAC 365-195-900 through 925 for BAS are in public record. The Washington State Supreme Court recently also concluded that existing buffers are adequately protecting critical areas in Skagit County. The Cattlemen's study using data analysis sets the natural background conditions for the Samish and Skagit River Basins. The TMDL Report has no credibility because it does not address natural background conditions. The TMDL Report's assumed suggestions will likely only cause harm to water quality, fish habitat, fish environment and the ability to farm adjoining agricultural fields.**

Response: Ecology has not received a copy of the Skagit County Cattlemen's two-year study, so we are unable to comment on these findings. We are also unclear on the "150 other studies" you refer to, that "meet all criteria in WAC 365-195-900 through 925 for BAS" and that are in the public record. The Lower Skagit Tributaries TMDL Temperature Study (Ecology 2004) represents best available science for Skagit tributaries temperature. The Study (Appendix A) determined that Carpenter Creek, East Fork Nookachamps, Fisher, Hansen, Red, Nookachamps, Turner, and Lake creeks had 7-day averages of daily maximum temperatures that exceeded 16^{o} C (the revised temperature standard for these creeks). The only creek that met the 16^{o} C standard was Otter Pond Creek.

Skagit County Public Works Annual Monitoring Report (April 2007) provides 7-day averages of daily maximum temperatures for the most recent four years (Water Years 2004, 2005, 2006, and 2007). Of the nine TMDL creeks, the County monitors six: Carpenter (Hill Ditch); Fisher; East Fork Nookachamps; Nookachamps; and Hansen. Of these six, only Fisher Creek met the revised water quality criterion of 16^{o}C. The remaining five did not meet the criteria, which is in agreement with the TMDL findings.

In the Washington State Supreme Court decision of September 2007, the majority opinion regarding buffers is stated differently than your wording here. It does not conclude "that existing buffers are adequately protecting critical areas in Skagit County." Rather, on page 14, the majority opinion states: '…the "no harm" standard [in the County Critical Areas Ordinance for Ongoing Agriculture], in short, protects critical areas by maintaining existing conditions.' What the Supreme Court is affirming is that the no harm standard in the County Critical Areas Ordinance for Ongoing Agriculture is sufficiently protective.

The county CAO's "no harm standard" is that all ongoing agricultural activities shall be conducted so as to cause no harm or degradation to the existing functional values of Fish and Wildlife Habitat Conservation Areas in and adjacent to watercourses. The SCC defines "existing functions and values" to include "the water quality standards identified in 173-201A WAC."

SCC 14.24.120(1)(a). Included in those water quality standards is the specific numeric temperature criterion to protect aquatic life, with which this TMDL seeks to bring the watercourse into compliance. Based on the 2001 study and the Skagit County Public Works Annual Monitoring Report findings for five of the six creeks, there is harm being done to these waters, because they are not meeting the temperature criterion.

We respectfully request your assistance and that of your neighbors in reviewing your land uses and practices near these streams and determining whether you could accommodate some increases in riparian vegetation that could filter out nutrients, support wildlife and shade the creek to help improve its late summer temperatures.

31. *Comment:* Ecology has recommended that Skagit County make it a priority to find resources to continue water quality monitoring of the creeks in this report. Ecology grant personnel have informed the County that comprehensive monitoring projects will likely not receive funding in the future, but could fund more limited monitoring as a part of restoration projects or as part of investigatory and regulatory water cleanup projects such as Kitsap County's Pollution Identification and Correction program.

Response: Ecology's Centennial Grants projects are intended to "jump start" monitoring programs in counties that have not had such programs in the past. Ecology recommends that Skagit County develop a monitoring program that can be supported through local resources; we also recommend that Skagit County review such programs operated by counties of similar size and economic base to determine what might be affordable. An effective program might be developed through strategic selection of an affordable subset of the county's current set of 40 monitoring stations, combined with a rotating set of project-specific monitoring stations supported by grants.

32. *Comment:* We hope that the overall picture [in the Lower Skagit Tributaries Temperature TMDL Water Quality Improvement Plan] is being reviewed in the process of salmon recovery, protection of the environment, and encouragement of working farms and forests. We appreciate that landowners can voluntarily improve streamside vegetation on their lands that adjoin adjacent creeks. We are curious why Ecology endorses many environmentally protective efforts, yet at the same time supports other projects that seem contrary to the same endeavors. When an agency endorses projects at seemingly sharp contrast philosophically and environmentally, it's hard to discern what is credible and scientific, and when to lend public support. Examples are a proposal to discharge treated effluent from the Big Lake Sewer District into Nookachamps Creek [treated effluent from this facility currently is piped to the Skagit River]; and Ecology's support of wetland mitigation banks.

Response: This Temperature TMDL does not include the projects cited because each will be evaluated on its own merits through environmental review processes outside of this TMDL. For the wetland mitigation bank proposals, Ecology is the agency assigned by the legislature to develop a permitting pathway which includes both environmental review and public review of banks proposed for certification.

33. ***Comment:*** **Diking and drainage district operations have a great impact on water temperature in the lower tributaries. The report does not address policies – or lack thereof – that affect the operations of the County's various dike and drainage districts. Ecology should work more closely with WDFW to ensure that planting and maintenance of tree buffers to achieve TMDL temperature goals are included in the districts' operations.**

Response: Ecology agrees with this comment and will look for additional opportunities to work with WDFW and the diking and drainage districts as staff time permits.

34: ***Comment:*** **Ecology should be more proactive in focusing its regulatory and policy development efforts to push local dike and drainage districts to take an active role in water quality protection just as they have begun to do in fish habitat protection.**

Response: Ecology agrees with this comment; however the agency has limited resources statewide for regulatory and policy development and this particular issue must compete with other priorities in order for resources to be directed to it.

35. ***Comment:*** **The second regulatory program and policy approach that must be strengthened is Skagit County's Growth Management Act critical area ordinance for fish and wildlife habitat on lands in ongoing agriculture (Skagit County Code 14.24.120).**

Response: Ecology notes that the county is required to consider "best available science" when updating Critical Areas Ordinances and when reviewing development regulations pertaining to aquatic habitat. This TMDL Water Quality Improvement Report documents the pronounced impacts of lack of shade on water temperature and is a study specific to Skagit tributaries that drain parts of the area covered by the county CAO for lands in ongoing agriculture. This TMDL meets and exceeds the criteria for best available science provided under WAC 365-195-905 and should inform updates to the CAO and development regulations to ensure that Skagit County complies with RCW 36.70A.040, .060, and .172 of the Growth Management Act.

36. ***Comment:*** **Ecology should consider including mandatory planting of riparian buffers as a condition of flood hazard mitigation funding or other technical assistance that it provides down-river parts of the county.**

Response: There are no measures in the FCAA Program (Washington state's Flood Control Assistance Account Program) that would enable Ecology to require mandatory planting of riparian buffers. The Program has guidelines that encourage such buffers (Publication #91-44), but nowhere does it state that they can be mandated, since the Comprehensive Flood Hazard Management Plan (CFHMP) is a plan that is developed locally.

However, as a plan is developed locally, a strong presence by citizens, resource agencies, and other stakeholders can and frequently does steer the plan to incorporate language relating to retention or development of healthy riparian buffers. Further, WDFW is a required member of all Advisory Committees for CFHMPs, and this agency has generally been an influential voice throughout the planning process. This is important, because WDFW has to sign off on all CFHMPs before Ecology can approve them.