TILLAMOOK BASIN TEMPERATURE

TOTAL MAXIMUM DAILY LOAD

(TMDL)

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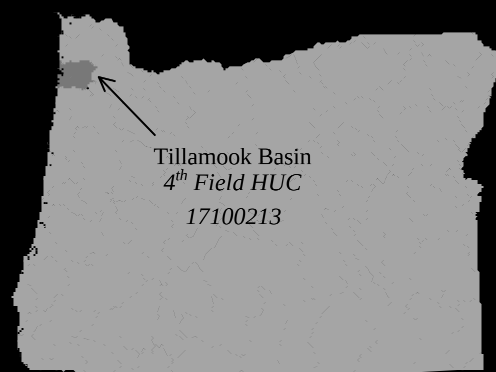
TMDL at a Glance



Basin: **Tillamook**

Key Resources: **Chinook Salmon**
Coho Salmon
Chum Salmon
Steelhead Trout
Cutthroat Trout

Uses Affected: **Salmonid Spawning & Rearing**

Impairment: **Water Temperature Increase**

Pollutant: **Heat Energy (Solar Radiation)**

Sources Considered: **PS – Fish Hatcheries, Waste Water Treatment Facilities, Dairy Effluent**
NPS – Forest Practices, Roads, Agriculture, Rural Residential

DOCUMENT ORGANIZATION

Preparation of the Tillamook Basin TMDL considers a number of issues regarding surface water temperature and the relationship to requirements of the Federal Clean Water Act's section 303(d). These issues have been divided into topic areas which include target identification (quantified end-points that will lead to attainment of water quality standards), source identification (a description of hazards areas that contribute to the problem), allocations designed to reduce pollutant inputs to those waters exceeding State water quality standards, and a margin of safety. In order to provide a framework for discussing these issues, this TMDL development document is organized into the following sections:

- ✓ **Introduction,**
- ✓ **Overview,**
- ✓ **Source Assessment,**
- ✓ **Targets,**
- ✓ **TMDL – Loading Capacities and Surrogate Measures (Allocations),**
- ✓ **Margin of Safety, and**
- ✓ **Seasonal Variation.**

*Highlights of each TMDL development document section are summarized **in Table 1**.*

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Table 1. Tillamook Basin TMDL Components

State/Tribe: Oregon
Waterbody Name(s): All perennial streams within the 4th field HUC (hydrologic unit code) 17100213 excluding those that drain to the Nestucca River.
Point Source TMDL: X Nonpoint Source TMDL: X (check one or both)
Date: April 1999

Component	***Comments***
Pollutant Identification	Stream temperature is an expression of *Heat Energy per Unit Volume* and is expressed in English Units as Btu per cubic feet. *Pollutant:* Heat Energy *Anthropogenic Contribution:* Excessive Solar Energy Input
Target Identification *CWA 303(d)(1)* *40 CFR 130.2(f)*	*Applicable Water Quality Standards* **Temperature: OAR 340-41-205(2)(b)(A)** The seven day moving average of the daily maximum shall not exceed the following values unless specifically allowed under a Department-approved basin surface water management plan: **64°F (17.8°C)** -or- **55°F (12.8°C).** Where **55°F (12.8°C)** applies during times and in waters that support salmonid spawning, egg incubation and fry emergence from the egg and from the gravel. *Loading Capacities* 1. For stream reaches with known active channel widths, daily solar radiation loading capacities have been calculated and are listed in **Table 11**, 2. Stream reaches without quantified active channel widths are assigned a solar radiation loading capacity of **422 Btu/ft^2 per day** (justification provided in **Figure 30**), or 3. Upon future quantification of stream reach active channel widths, solar radiation loading capacities can be derived from **Section 3.5 – Effective Shade Curves**
Existing Sources *CWA 303(d)(1)*	*Anthropogenic sources of thermal gain:* Forest management, Agriculture Related Riparian Disturbance, Rural Residential Related Riparian Disturbance and Roads
Seasonal Variation *CWA 303(d)(1)*	*Condition*: Based on ODEQ data (1997 to 1998) *Flow*: Low flow associated with maximum stream temperatures *Critical Conditions*: Increase desirable riparian vegetation to site potential (climax) conditions. *Inputs*: Solar ration increased by more exposed stream surface area as a result of decreased effective shade and increased channel width.
TMDL/Allocations *40 CFR 130.2(g)* *40 CFR 130.2(h)*	*Waste Load Allocations*: **APPENDIX E** *Allocations (Surrogate Measures):* 1. For stream reaches with known active channel widths, site potential effective shade levels have been allocated and are listed in **Table 12** and displayed in **Image 22**, 2. Stream reaches without quantified active channel widths are allocated **81% effective shade** (justification provided in **Figure 35**), 3. Upon future quantification of stream reach active channel widths, effective shade allocations can be derived from **Section 3.5 – Effective Shade Curves**
Margins of Safety *CWA 303(d)(1)*	Margins of Safety demonstrated in critical condition assumptions regarding solar loading, groundwater inflow, wind speed and air temperature.
WQS Attainment Analysis *CWA 303(d)(1)*	• Statistical demonstration of temperature related to current shade conditions. • Analytical assessment of simulated stream temperature related to allocated solar loading.
Public Participation *40 CFR 25*	To be conducted by Oregon Department of Environmental Quality

1. INTRODUCTION

The Tillamook Basin is home to productive forested and agriculture lands and has the distinction of containing streams with historically abundant salmonid populations. Valuable contributions from agriculture, forestry and fisheries in the Tillamook Basin have prompted extensive data collection and study of the interaction between land use and water quality. The knowledge derived from these data collection efforts and academic study, some of which is presented in this document, will be used to design protective and enhancement strategies that address water quality issues.

Recently several agencies have been mandated to take proactive roles in developing management strategies in the Tillamook Basin. In the near future water quality management plans will be developed for forested, agricultural and urban lands that address both nonpoint and point sources of pollution. It is imperative that these plans consider the relatively robust data that describe water quality, instream physical parameters and landscape features. The impending management efforts (*see* section **1.2 Existing Water Quality Programs**) demand that stakeholders, land managers, public servants and the general public become knowledgeable with water quality issues in the Tillamook Basin.

A Total Maximum Daily Load (TMDL) has been developed to address fisheries concerns for all streams in the Tillamook Basin (excluding those that drain to the Nestucca River). The TMDL builds upon the current land management programs in the Tillamook Basin:

- ✓ Tillamook National Estuary Program (NEP)
- ✓ Northwest Forest Plan and Forest Ecosystem Management Assessment Team (FEMAT) protection/restoration measures (federal forest lands),
- ✓ Oregon’s Forest Practices Act (state and private forest lands),
- ✓ Senate Bill 1010 (agricultural lands),
- ✓ Oregon Plan (all lands), and

The data review contained in this document summarizes the varied, yet extensive, data collection and study that has recently occurred in the Tillamook Basin. It is hoped that water quality programs will utilize this TMDL to develop and/or alter water quality management efforts. In addition, this TMDL should be used to track water quality, instream physical parameters and landscape conditions that currently exist. In the future it will be important to determine the adequacy of planned water quality improvement efforts. Looking back at this TMDL, written in April 1999, it will be possible to track the changes that have occurred in water quality, instream and landscape parameters that affect fish, as well as people, in the Tillamook Basin.

Excessive summer water temperatures in several tributaries and mainstem reaches throughout the Tillamook Basin may be reducing the quality of rearing habitat for chinook, coho and chum salmon, as well as steelhead trout and cutthroat trout. Primary watershed disturbance activities which contribute to surface water temperature increase include past forest management within riparian areas, current timber harvest in sensitive areas within and outside the riparian zone, agricultural riparian disturbances, road construction and maintenance, and rural residential development near streams and rivers. As a result of water quality standards (WQS) exceedances for temperature, waters in the Tillamook Basin are on Oregon's 1998 303(d) list. Specific management prescriptions designed to reduce input of pollutants into streams within the lands covered by this TMDL are riparian conservation reserves that promote targeted shade levels

Surrogate Measures (*"other appropriate measures"*) are used in conjunction with heat **Load Capacity** targets to address water temperature increases. Namely, *percent effective shade* is an accurate measure of anthropogenic heat contributions and a descriptor of riparian condition. In essence, the **Surrogate Measure** (*percent effective shade*) is **Allocated** as a translation of the developed solar radiation **Loading Capacities**.

1.1 Scope

The following excerpt from the *Tillamook Bay Environmental Characterization* (Tillamook Bay National Estuary Project, 1997) accurately describes the Tillamook Basin.

> *Five rivers enter the Tillamook Bay from the south, east, and north. Salmon fishermen still recognize the Bay and its five rivers – the Tillamook, Trask, Wilson, Kilchis, and Miami – as some of the most productive fishing spots on the West Coast. Yet their bounty of chinook, chum, coho, and steelhead pales compared with earlier harvests. Today coho salmon is listed as a threatened species and chum and steelhead fish populations have been declining. Scientists point to the dramatic loss of spawning and rearing habitat as one of the principal reasons for the decline of Tillamook Bay salmonids. Today's salmon rivers drain 550 mi^2 (1,424 km^2) watershed that includes some of North America's richest timber and dairy lands. Although essential to the economy and character of Tillamook County, forestry, agriculture, and fishing activities have taken a high toll on salmon and other living resources dependent on the aquatic environment.*
>
> *Like most Pacific Northwest estuaries, Tillamook Bay is part of a coastal, temperate rainforest ecosystem. The Bay is surrounded by rich forests that blanket the rainy Coast Range. With mean annual precipitation around 100 inches per year in the lower basin and close to 140 inches per year in the uplands, the Watershed's coniferous forests – trees such as Douglas fir, true fir, spruce, cedar, and hemlock – cover about 89% of the total land area. Hardwood species such as alder and maple also grow throughout the region, especially as second growth riparian areas. Most of the older trees have been lost to fire and timber harvest. Today, Douglas fir is the dominant species. Foresters describe this environment as a highly productive ecosystem – from both biological and commodity perspectives.*

> *In the lower Watershed, the forest gives way to rich alluvial plains used primarily for dairy agriculture. Early settlers recognized the rich agricultural potential of the lowlands and drained the area with numerous dikes, levees, and ditches. Once characterized by meandering rivers and networks of small channels that provided fish habitat, woody debris, and organic matter; today's 40 mi^2 (104 km^2) lowland supports about 30,000 dairy cattle and produces half of Oregon's cheese. It is also the source of hundreds of thousands of tons of manure annually and much of the bacteria that washes into the estuary.*

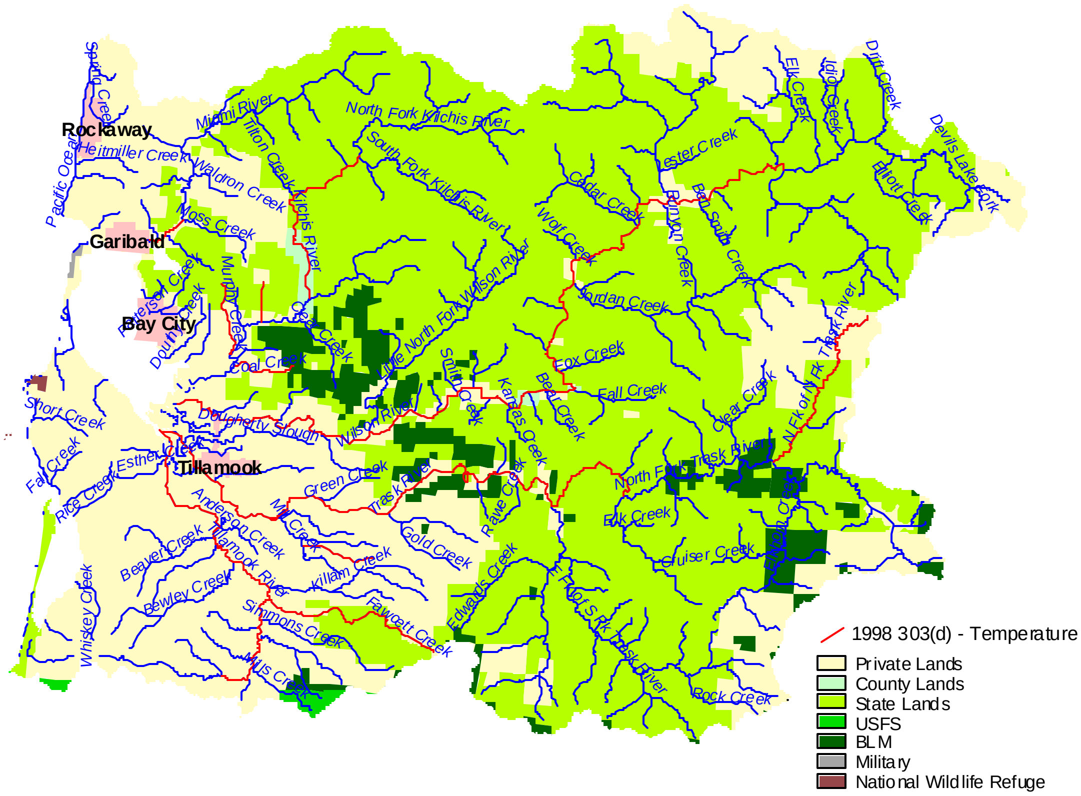
The area covered by the Tillamook Basin Temperature TMDL includes land managed primarily by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM), private and state forests, agricultural lands, rural residences, military lands and urban areas. Land ownership is displayed in **Image 1**.

As a result of water quality standards (WQS) exceedances for temperature, two waters are included on Oregon's 1998 303(d) list. **Table 2** displays 1998 303(d) listed stream segments for temperature violations (also shown in **Image 1**). In addition, this TMDL addresses potential water quality impairments for streams within the Tillamook Basin that are not currently on Oregon's 1998 303(d) list.

Table 2. 1998 303(d) Listed Segments and Applicable Water Quality Standards
OAR 340-41-205(2)(b)(A)

Stream	***Segment***
Kilchis River	Mouth to headwaters
Miami River	Mouth to Moss Creek
Tillamook River	Mouth to Yellow Fir
Trask River	Mouth to S.F. Trask River
Wilson River	Mouth to headwaters
Coal Creek	Mouth to headwaters
Fawcett Creek	Mouth to headwaters
Mill Creek	Mouth to headwaters
Murphy Creek	Mouth to Headwaters
Myrtle Creek	Mouth to headwaters
Trask River, North Fork	Mouth to Bark Shanty Creek
Trask River, North Fork of North Fork	Mouth to Headwaters

Image 1. Tillamook Basin Land Ownership and 1998 303(d) Listings for Temperature



1.2 Existing Water Quality Programs

1.2.1 Tillamook National Estuary Program

The Comprehensive Conservation and Management Plan (CCMP) of the Tillamook Bay National Estuary Project (NEP) has been developed over the last 4 years, with DEQ and EPA participation. EPA funds the NEP. One of the five major sections of the CCMP is water quality. Temperature is addressed in the CCMP and CCMP is to be implemented by the Tillamook County Performance Partnership, an organization specially created to implement actions related to Oregon Forest Practices, SB1010, and the Oregon Plan. The basic premise of the CCMP is that it incorporates the recommendations of all these plans into one overall plan for Tillamook County.

1.2.2 Oregon's Total Maximum Daily Load Program

The quality of Oregon's streams, lakes, estuaries and groundwater is monitored by the Department of Environmental Quality (DEQ). This information is used to determine whether water quality standards are being violated and, consequently, whether the *beneficial uses* of the waters are being threatened. *Beneficial uses* include fisheries, aquatic life, drinking water, recreation and irrigation. Specific State and Federal plans and regulations are used to determine if violations have occurred: these regulations include the *Federal Clean Water Act* of *1972* and its amendments 40 *Codified Federal*

Regulations 131, and *Oregon's Administrative Rules* (**OAR Chapter 340**) and *Oregon's Revised Statutes* (**ORS Chapter 468**).

The term *water quality limited* is applied to streams and lakes where required treatment processes are being used, but violations of State water quality standards occur. With a few exceptions, such as in cases where violations are due to natural causes, the State must establish *a Total Maximum Daily Load* or *TMDL* for any waterbody designated as *water quality limited*. A *TMDL* is the total amount of a pollutant (from all sources) that can enter a specific waterbody without violating the water quality standards.

The total permissible pollutant load is allocated to point, nonpoint, background, and future sources of pollution. *Wasteload Allocations* are portions of the total load that are allotted to point sources of pollution, such as sewage treatment plants or industries. The *Wasteload Allocations* are used to establish effluent limits in discharge permits. *Load Allocations* are portions of the *Total Maximum Daily Load* that are attributed to either natural background sources, such as soils, or from nonpoint sources, such as agriculture or forestry activities. *Allocations* can also be set aside in reserve for future uses. Simply stated, *allocations* are quantified measures that assure water quality standard compliance. The *TMDL* is the integration of all developed *allocations*.

1.2.3 Northwest Forest Plan

In response to environmental concerns and litigation related to timber harvest and other operations on Federal Lands, the United States Forest Service (USFS) and the Bureau of Land Management (BLM) commissioned the Forest Ecosystem Management Assessment Team (FEMAT) to formulate and assess the consequences of management options. The assessment emphasizes producing management alternatives that comply with existing laws and maintaining the highest contribution of economic and social well being. The "backbone" of ecosystem management is recognized as constructing a network of late-successional forests and an interim and long-term scheme that protects aquatic and associated riparian habitats adequate to provide for *threatened species* and *at risk species*. Biological objectives of the Northwest Forest Plan include assuring adequate habitat on Federal lands to aid the "recovery" of late-successional forest habitat-associated species listed as threatened under the Endangered Species Act and preventing species from being listed under the Endangered Species Act.

1.2.4 Oregon's Forest Practices Act

The Oregon Forest Practices Act (FPA, 1994) contains regulatory provisions that include the following objectives: classify and protect water resources, reduce the impacts of clearcut harvesting, maintain soil and site productivity, ensure successful reforestation, reduce forest management impacts to anadromous fish, conserve and protect water quality and maintain fish and wildlife habitat, develop cooperative monitoring agreements, foster public participation, identify stream restoration projects, recognize the value of biodiversity and monitor/regulate the application of chemicals. Oregon's Department of Forestry (ODF) has adopted Forest Practice Administrative Rules (1997) that clearly define allowable actions on State, County and private forest lands. Forest

Practice Administrative Rules allow revisions and adjustments to the regulatory parameters it contains. Several revisions have been made in previous years and it is expected that the ODF, in conjunction with DEQ, will continue to monitor the success of the Forest Practice Administrative Rules and make appropriate revisions that address water quality concerns.

1.2.5 Senate Bill 1010

Senate Bill 1010 allows the Oregon Department of Agriculture (ODA) to develop Water Quality Management Plans for agricultural lands where such actions are required by State or Federal Law, such as TMDL requirements. The Water Quality Management Plan should be crafted in such a way that landowners in the local area can prevent and control water pollution resulting from agricultural activities. Local stakeholders will be asked to take corrective action against identified problems such as soil erosion, nutrient transport to waterways and degraded riparian areas. It is the ODA's intent to establish Water Quality Management Plans on a voluntary basis. However, Senate Bill 1010 allows the ODA to use civil penalties when necessary to enforce against agriculture activity that is found to transgress parameters of an approved Water Quality Management Plan. The ODA has expressed a desire to work with the local stakeholders and other State and Federal agencies to formulate and enforce approved Water Quality Management Plans.

1.2.6 Oregon Plan

The State of Oregon has formed a partnership between Federal and State agencies, local groups and grassroots organizations, that recognizes the attributes of aquatic health and their connection to the health of salmon populations. The Oregon Plan considers the condition of salmon as a critical indicator of ecosystems (CSRI, 1997). The decline of salmon populations has been linked to impoverished ecosystem form and function. Clearly stated, the Oregon Plan has committed the State of Oregon to the following obligations: an ecosystem approach that requires consideration of the full range of attributes of aquatic health, focuses on reversing factors for decline by meeting objectives that address these factors, develops adaptive management and a comprehensive monitoring strategy, and relies on citizens and constituent groups in all parts of the restoration process.

The intent of the Oregon Plan is to conserve and restore functional elements of the ecosystem that supports fish, wildlife and people. In essence, the Oregon Plan is distinctly different from the traditional agency approach, and instead, depends on sustaining a local-state-federal partnership. Specifically, the Oregon Plan is designed to build on existing State and Federal water quality programs, namely: Coastal Zone Nonpoint Pollution Control Programs, the Northwest Forest Plan, Oregon's Forest Practices Act, Oregon's Senate Bill 1010 and Oregon's Total Maximum Daily Load Program.

1.3 Beneficial Uses

Oregon Administration Rules (**OAR Chapter 1, Division 41, Table 1**) lists the designated beneficial uses for which water is to be protected in the Tillamook Basin. The beneficial uses occurring are presented in **Table 3**.

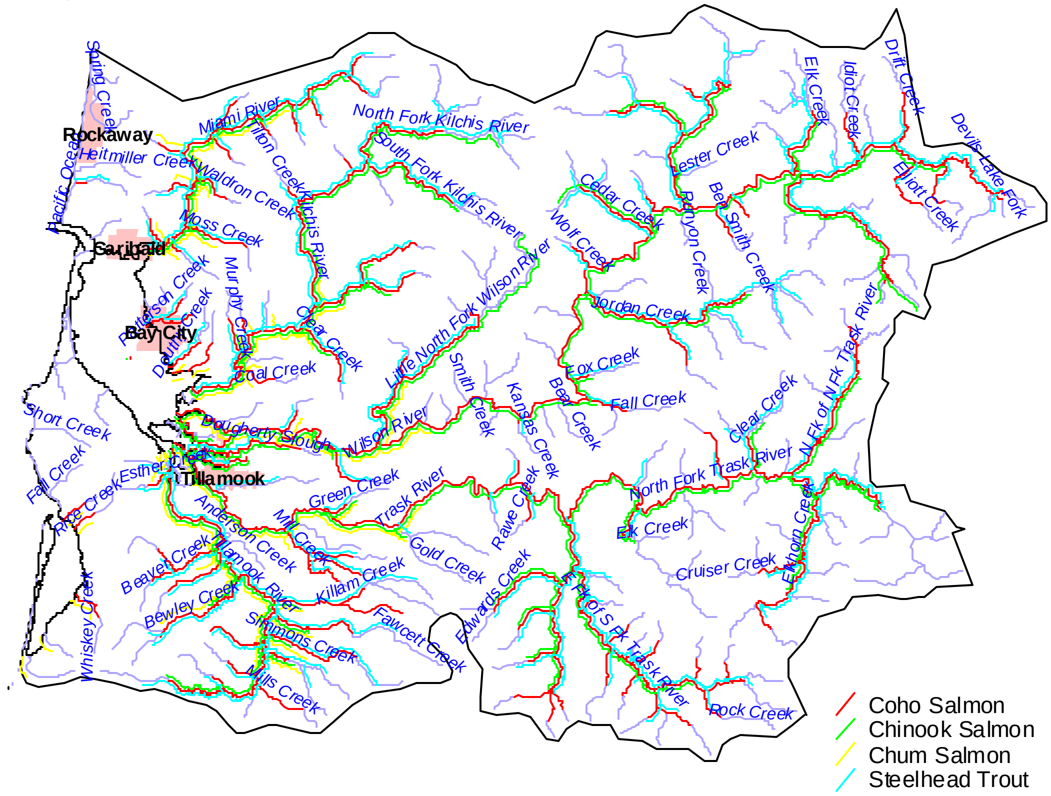
Table 3. Beneficial Uses Occurring in the Tillamook Basin
(OAR 340-41-202)

Temperature sensitive beneficial uses are marked in grey

Beneficial Use	*Occurring*	*Beneficial Use*	*Occurring*
Public Domestic Water Supply	✓	Anadromous Fish Passage	✓
Private Domestic Water Supply	✓	Salmonid Fish Spawning	✓
Industrial Water Supply	✓	Salmonid Fish Rearing	✓
Irrigation	✓	Resident Fish and Aquatic Life	✓
Livestock Watering	✓	Wildlife and Hunting	✓
Boating	✓	Fishing	✓
Aesthetic Quality	✓	Water Contact Recreation	✓
Commercial Navigation & Trans.		Hydro Power	

Numeric and narrative water quality standards are designed to protect the most sensitive *beneficial uses.* In the Tillamook Basin, resident fish and aquatic life and salmonid spawning, rearing and migration are designated the most sensitive *beneficial uses* (**Image 2**).

Image 2. Sensitive Beneficial Uses – Salmonid Migration, Spawning and Rearing



1.4 Temperature Related to Aquatic Life

Aquatic life is sensitive to warm water temperatures. Salmonid fishes, often referred to as cold water fish, and some amphibians appear to be highly sensitive to temperature. In particular, chinook salmon (*Oncorhynchus tshawytscha*) and bull trout (*Salvelinus confluentus*) are among the most temperature sensitive of the cold water fish species. Oregon's water temperature standard employs logic that relies on using these *indicator species*, which are the most sensitive. If temperatures are protective of *these indicator species*, other species will share in this level of protection.

One *indicator species*, the coho salmon, that is referenced in Oregon's water temperature standard has, coincidentally, been allotted protection (listed) under the Endangered Species Act (ESA, 1972) in the Tillamook Basin. Coho salmon are designated under ESA (1972) as *threatened* in the Tillamook Basin.

If stream temperatures become too hot, fish die almost instantaneously due to denaturing of critical enzyme systems in their bodies (Posser, 1967; Hogan, 1970). The ultimate *instantaneous lethal limit* occurs in high temperature ranges (upper-90^{o}F).

More common and widespread, however, is the occurrence of temperatures in the mid- to high- 70^{o}F range (mid- to high-20^{o}C range). These temperatures cause death of cold-water fish species during exposure times lasting a few hours to a 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 and on particular development life-stages. This cause of mortality, termed the *incipient lethal limit*, results from breakdown of physiological regulation of vital processes such as respiration and circulation (Houston, 1971; Roberts, 1973; Heath and Hughes, 1973). Brett (1952) reported an incipient lethal limit of 77°F (25°C) for spring chinook salmon. Similarly, Bell (1984) reported an incipient lethal limit for chinook salmon of 77°F (25°C). The Environmental Protection Agency (EPA) and National Marine Fisheries Service (NMFS) reported 50% mortality to adult salmon and steelhead trout with a constant water temperature of 70°F (21°C).

The most common and widespread cause of thermally induced fish mortality is attributed to interactive effects of decreased or lack of metabolic energy for feeding, growth or reproductive behavior, increased exposure to pathogens (viruses, bacteria and fungus), decreased food supply (impaired macroinvertebrate populations) and increased competition from warm water tolerant species. This mode of thermally induced mortality, termed indirect or *sub-lethal*, is more delayed, and occurs weeks to months after the onset of elevated temperatures (mid-60°F to low-70°F). **Table 4** summarizes the modes of cold water fish mortality.

Table 4. Modes of Thermally Induced Cold Water Fish Mortality

Modes of Thermally Induced Fish Mortality	Temperature Range	Time to Death
Instantaneous Lethal Limit – Denaturing of bodily enzyme systems	< 90°F < 32°C	Instantaneous
Incipient Lethal Limit – Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	74°F to 80°F 21°C to 27°C	Hours to Days
Sub-Lethal Limit – Conditions that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supply and increased competition from warm water tolerant species	64°F to 74°F 18°F to 21°F	Weeks to Months

1.5 Water Quality Impairments

Monitoring has shown that water quality in the Tillamook Basin often does not meet State water quality standards. The numeric standards for *temperature* are not achieved in the several mainstem and tributary reaches of the Tillamook Basin (**Table 5**). Section 303(d) of the Federal Clean Water Act (1972) requires that water bodies that violate water quality standards, thereby failing to fully protect *beneficial uses*, be identified and placed on a 303(d) list. Following further assessment, *Total Maximum Daily Load* (TMDL), will be implemented to restore water quality. In addition to watershed condition assessment and problem statements, a water quality management plan (TMDL) requires identification of water quality goals and objectives, designation of responsible parties, implementation of the management plan (TMDL), some measure of assurance that the plan (TMDL) will actually be implemented, and a monitoring of feedback loop (DEQ WQMP guidance 1997).

Table 5. 1998 303(d) Temperature Limited Waterbodies	
Location:	• Kilchis River (Mouth to headwaters) • Miami River (Mouth to Moss Creek) • Tillamook River (Mouth to Yellow Fir) • Trask River (Mouth to S.F. Trask River) • Wilson River (Mouth to headwaters) • Coal Creek (Mouth to headwaters) • Fawcett Creek (Mouth to headwaters) • Mill Creek (Mouth to headwaters) • Murphy Creek (Mouth to headwaters) • Myrtle Creek (Mouth to headwaters) • Trask River, North Fork (Mouth to Bark Shanty Creek) • Trask River, North Fork of North Fork (Mouth to headwaters)
Time Period:	• Rearing: June 1 through September 30 • Spawning Through Fry Emergence: October 1 through May 31 or waterbody specified as identified by ODFW biologist.
Supporting Data:	• ODEQ (1997 – 1998) • NRCS (1992 – 1994)

1.6 Pollutants

Water temperature is an expression of heat energy per unit volume:

$$Temperature \propto \frac{Heat \quad Energy}{Volume} = \frac{Btu}{ft^3}$$

Anthropogenic increase in heat energy is derived from solar radiation as increased levels of sunlight reach the stream surface and raises water temperature. The pollutant (solar heat energy) is a source of stream temperature increase that is within management measures and is targeted in this TMDL.

1.7 Surrogate Measures - Defined

The Tillamook Basin TMDL incorporates measures other than "*daily loads*" to fulfill requirements of 303(d). Although a loading capacity for heat energy is derived [e.g. British Thermal Units (Btu) per square foot per day], it is of limited value in guiding management activities needed to solve identified water quality problems. In addition to heat energy loads, the Tillamook Basin TMDL allocates "*other appropriate measures*" (or surrogates measures) as provided under EPA regulations [40 CFR 130.2(i)]. The specific surrogate measure used is *percent effective shade* (note: effective shade is defined in section **3.2 Mechanics of Shade**).

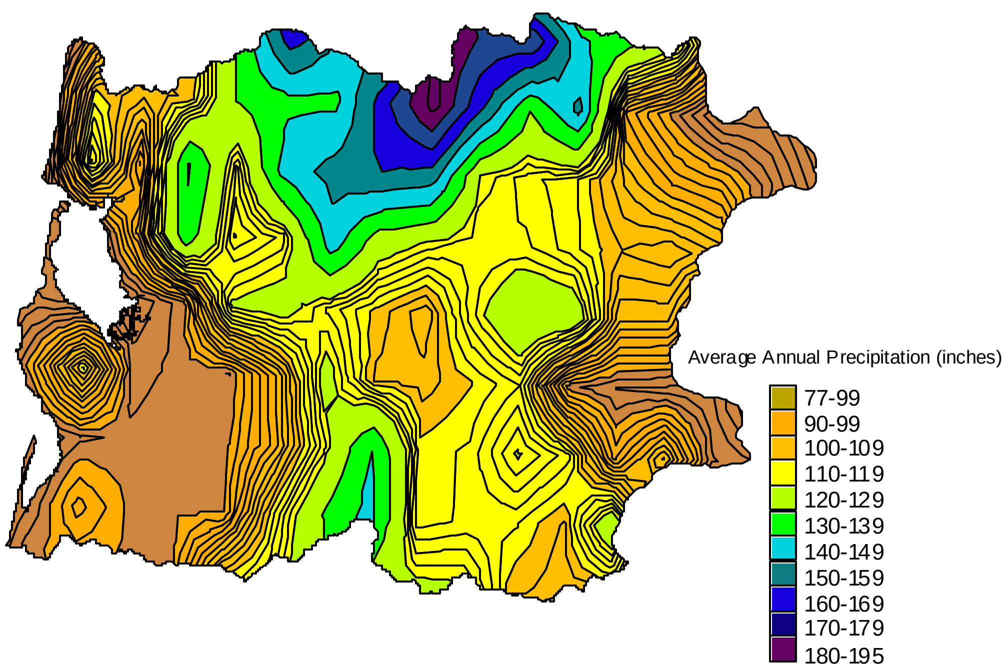
2. OVERVIEW

2.1 Hydrology

2.1.1 Climate

Tillamook Basin climate is influenced by proximity to the Pacific Ocean and elevation. Climatic conditions can vary considerably within the Tillamook Basin, a function of *orographic* influence and ocean effects. The Coastal Mountains that surround the city of Tillamook often receive between 125 and 200 inches of annual precipitation, most as rainfall. Lower portions of the basin, closer to the City of Tillamook, receive average annual precipitation totals between 80 and 125 inches (**Table 6**). **Image 3** graphically displays the Tillamook Basin's average annual precipitation.

Image 3. Average Annual Precipitation in the Tillamook Basin



Another excerpt from the Tillamook Bay Environmental Characterization (Tillamook National Estuary Project, 1997) describes the rains, winds, and temperatures experienced in the Tillamook Basin.

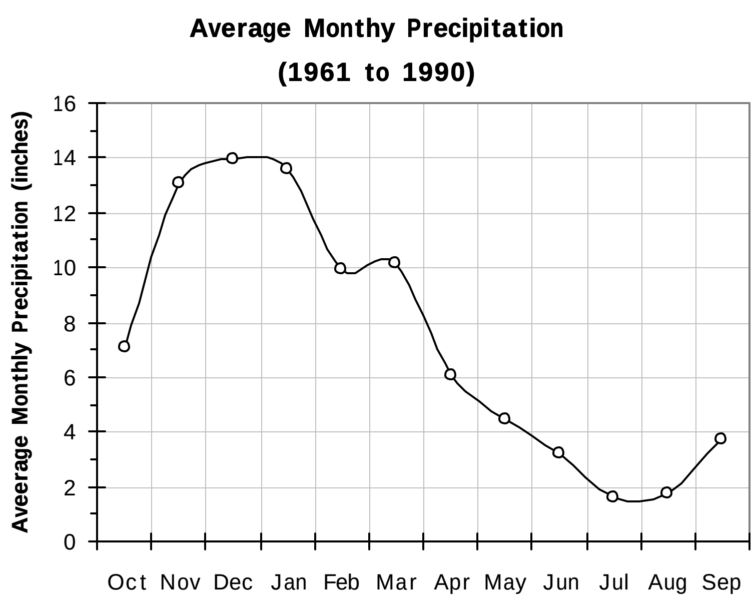
> *The seasonal, episodic nature of precipitation defines the natural system. Fall chinook migrate upstream with the first heavy rains in late autumn. Big storms cause major landslides in the steeply sloped upland regions. Although heavy*

storms have characterized the natural system for thousands of years, human activities have exacerbated the impacts and consequences of high rainfall (Coultan, et al. 1996). Westerly winds predominate and carry the temperature-moderating effects of the ocean over all of western Oregon. Summers are cool and dry; winters wet and moderate (USDA 1964). Winds blow nearly continuously throughout the year and often reach gale force in the winter. Prevailing winds come from the south and southwest during the summer.

Temperatures in Tillamook County are moderate. The mean annual temperature is 10.2°C (50.4°F), with yearly mean and maximum temperatures documented at 15.1°C (59.3°F) and 5.4°C (41.6°F), respectively. Those 30 years averaged less than one day per year with a temperature over 32°C (90°F). September had the greatest number of extreme temperatures while July and August recorded the highest temperature of 38.89°C (102°F).

Precipitation totals are greatest in winter and spring months (November through April), while much less precipitation is received in summer and early fall months (May through October). **Figure 1** displays monthly precipitation values averaged over 29 years (1961 to 1990) recorded at the City of Tillamook. As previously stated, precipitation totals vary throughout the basin, but it can be assumed that the timing of precipitation is similar to that presented in **Figure 1**.

Figure 1. Average Monthly Precipitation in Tillamook, Oregon (1961 to 1990)



Air temperatures in the Tillamook Basin are mild throughout the year. The Pacific Ocean has a moderating effect on air temperature, much more so at close proximity to the ocean. Summertime air temperatures may be much greater in areas only a few miles inland, relative to areas near the ocean. Climate data collected in the City of Tillamook is presented in **Table 6**.

Table 6. Average Monthly Climate Data for Tillamook, Oregon (1961 to 1990)

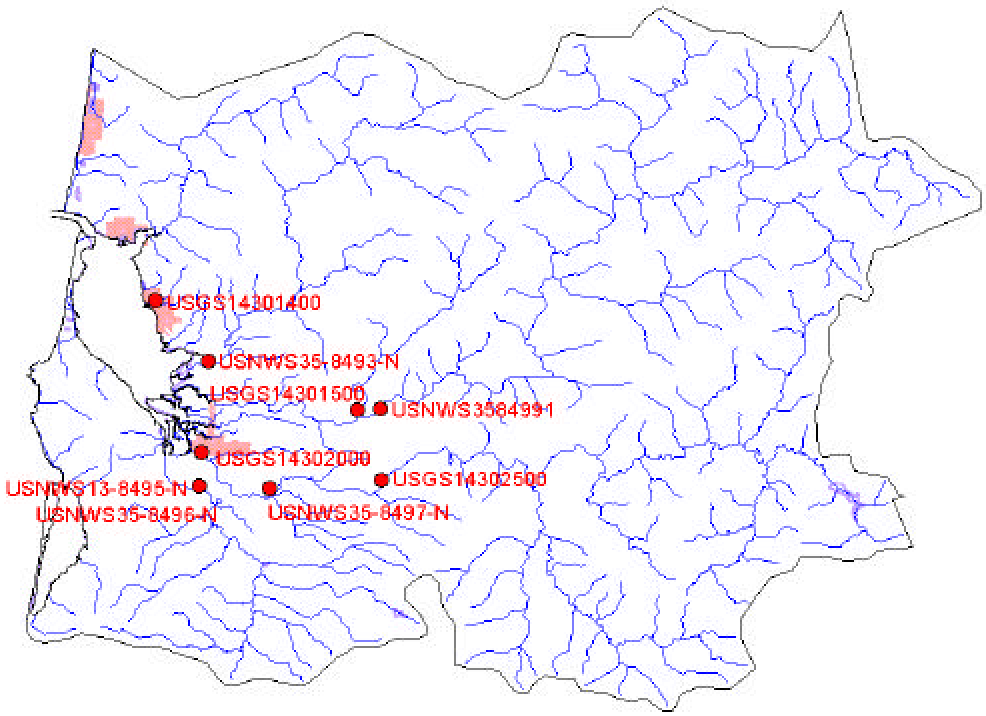
Parameter	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Year**
Air Temperature (^{o}F)													
Mean	53	47	43	43	45	46	48	52	56	58	59	58	50
Maximum	92	80	66	69	73	73	84	86	92	102	102	97	102
Minimum	22	14	4	11	8	21	23	27	31	35	34	27	4
Precipitation (inches)													
Mean	7	13	14	14	10	10	6	4	3	2	2	4	89
Extreme 24 hour	4	4	5	5	3	4	3	2	3	2	2	3	5
Precipitation (days)													
.01 inches or more	15	21	23	21	19	21	18	15	10	7	7	11	187
.10 inches or more	11	18	19	18	16	17	13	10	7	4	4	7	143
.50 inches or more	6	10	10	10	8	9	4	3	2	1	1	3	65
1.00 inches or more	2	4	4	4	3	3	1	1	1	0	0	1	24

2.1.2 Flow

Flow data has been collected in the Tillamook Basin by 4 U.S. Geological Survey (USGS) gages (**Image 4**). Two of these gages have been collecting daily stream flow measurements since 1930 (USGS #14301500 and USGS #14302500). These flow data files were processed by DEQ staff to quantify *return periods* for both high and low flow conditions. Duration periods for which flows were averaged were 1 day, 7 days and 14 days. Return periods estimations were performed using the Log Pearson Type III distribution for the following *return periods*: 1 year, 2 years, 5 years, 10 years, 25 years, 50 years and 100 years. Average monthly flows were also calculated for many of the gages, depending on the length of the period of recorded flow values. Return flows are presented as *XQY*, where *"X"* represents the flow duration (days) and *"Y"* represents the return period (years). For example, a *7Q10* would represent the 7-day average flow that occurs on average once every 10 years. Therefore, the probability that seven-day duration 10-year *return period* flow (7Q10) conditions will occur during any year is 10%.

Flow data collection has not been high priority in the Tillamook Basin. Statistical descriptions of temporal and spatial flow regimes/patterns require many years of daily collected flow data. This level of data resolution does not exist in the Miami River, Kilchis River and Tillamook River.

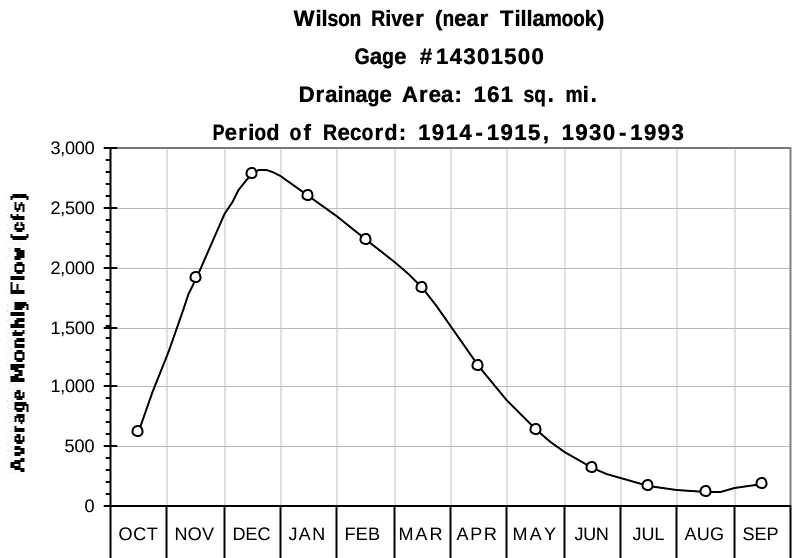
Image 4. Gage Identification and Location



Long-term flow data has been collected and statistically analyzed for the lower Trask and Wilson Rivers. Average monthly flow values reflect seasonal precipitation patterns (**Figure 2** and **Figure 3**). These systems are associated with rain events, and as a result, exhibit flashy flow regimes during periods of high rainfall intensities.

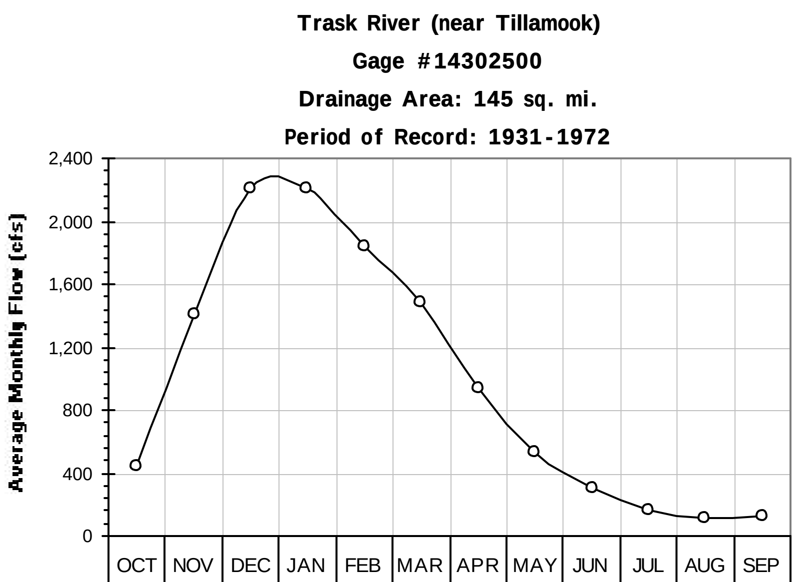
Perennial streams are those with flow throughout the year. *Intermittent* streams experience a period of time during the year without flow, completely de-watered. It is an extreme event when a stream becomes intermittent in terms of aquatic life and water quality. Intermittent streams are determined as such when the 7Q10 values were calculated to be *zero*. Therefore, any flow gage data that offered a 7Q10 value of greater than *zero* was determined to be *perennial*. The mainstem Trask and Wilson Rivers are *confirmed perennial* streams (**Figure 4** and **Figure 5**).

Figure 2. Wilson River Monthly Flow Averages



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Flow (cfs)	625	1,918	2,784	2,601	2,228	1,830	1,174	635	322	165	110	176

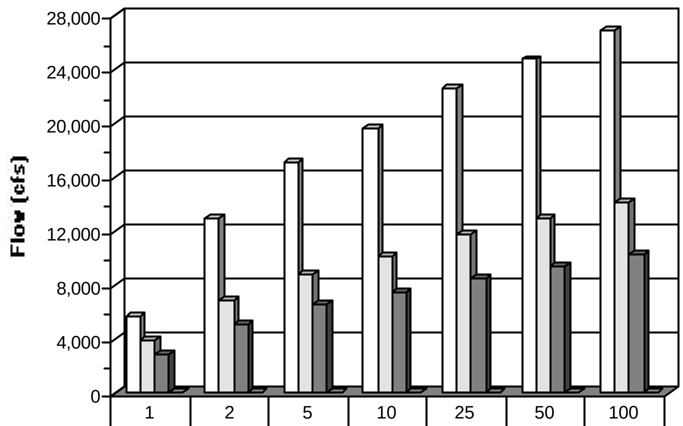
Figure 3. Trask River Monthly Flow Averages



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Flow (cfs)	445	1,406	2,205	2,212	1,846	1,488	943	530	302	165	108	127

Figure 4. Wilson River Log Pearson Type III High Flow and Low Flow Analysis

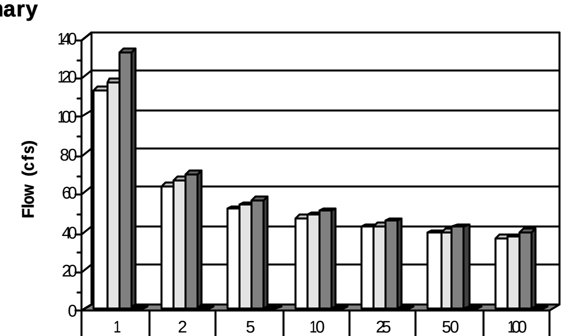
High Flow Summary



	1	2	5	10	25	50	100
1 Day Flow (cfs)	5,702	12,954	17,070	19,601	22,622	24,777	26,871
7 Day Flow (cfs)	3,835	6,878	8,807	10,088	11,722	12,953	14,203
14 Day Flow (cfs)	2,820	5,129	6,523	7,426	8,554	9,390	10,228
Yearly Probability (%)	100%	50%	20%	10%	4%	2%	1%

Return Period (years)

Low Flow Summary

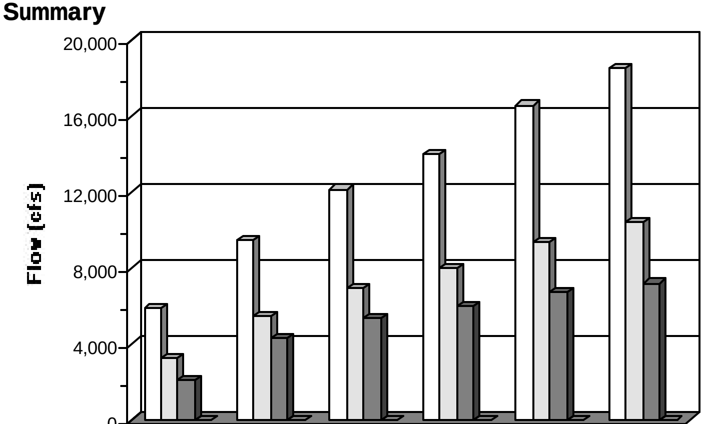


	1	2	5	10	25	50	100
1 Day Flow (cfs)	113	63	52	47	42	39	37
7 Day Flow (cfs)	117	66	54	48	43	40	37
14 Day Flow (cfs)	133	69	56	51	45	42	40
Yearly Probability (%)	100%	50%	20%	10%	4%	2%	1%

Return Period (years)

Figure 5. Trask River Log Pearson Type III High Flow and Low Flow Analysis

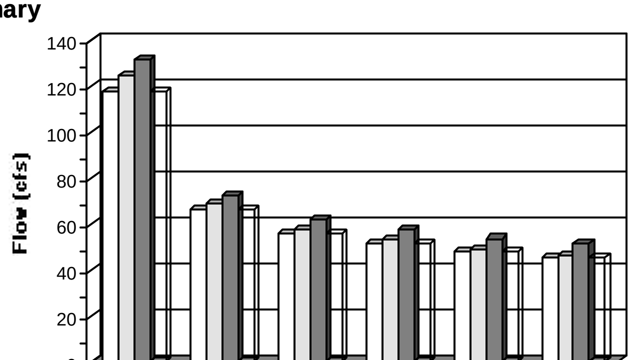
High Flow Summary



	1	2	5	10	25	50
1 Day Flow (cfs)	5,881	9,513	12,156	14,039	16,588	18,569
7 Day Flow (cfs)	3,236	5,427	6,940	7,992	9,386	10,459
14 Day Flow (cfs)	2,076	4,284	5,377	6,004	6,715	7,201
Yearly Probability (%)	100%	50%	20%	10%	4%	2%

Return Period (years)

Low Flow Summary



	1	2	5	10	25	50
1 Day Flow (cfs)	118	67	56	52	48	46
7 Day Flow (cfs)	125	69	58	54	49	47
14 Day Flow (cfs)	132	72	62	58	54	52
Yearly Probability (%)	118	67	56	52	48	46

Return Period (years)

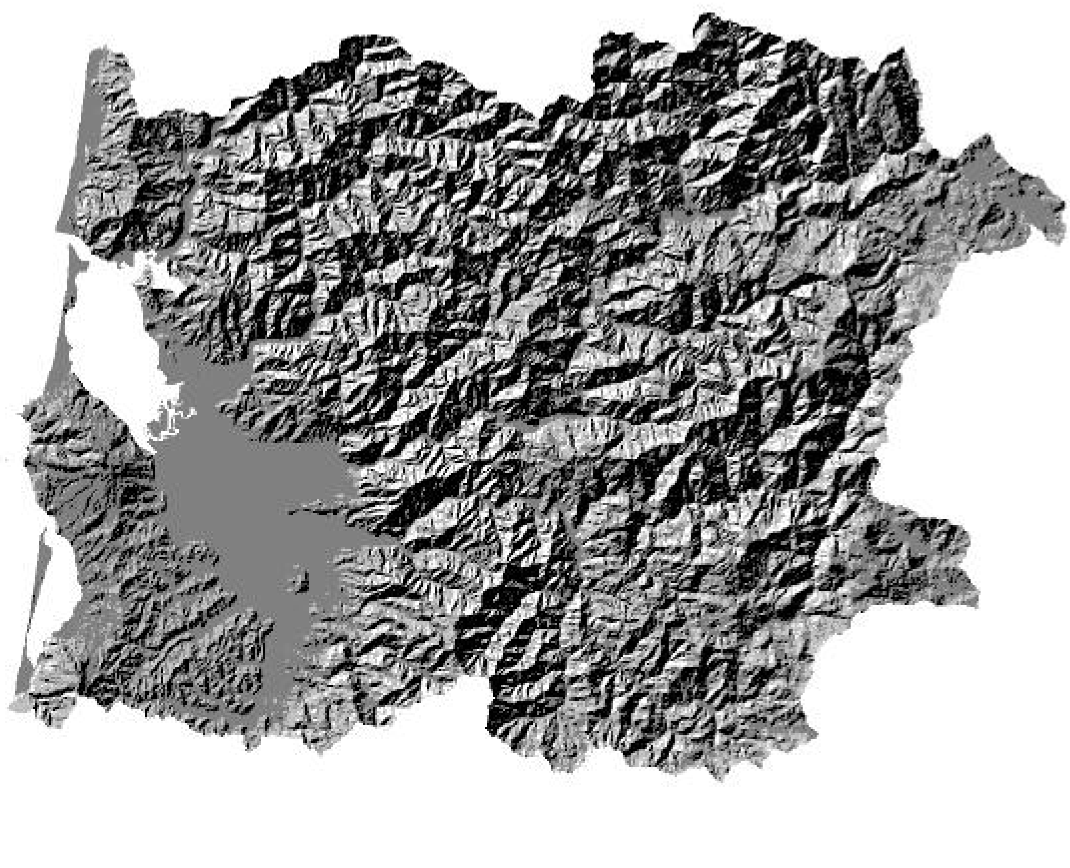
2.2 Landscape Parameters

2.2.1 Topography and Geology

Below is a shaded topographic map of the Tillamook Basin (**Image 5**). The Tillamook Bay Environmental Characterization (Tillamook Bay National Estuary Project, 1997) gives the following description of the Tillamook Basin's geology.

> *Tillamook Bay and its watershed are situated in typical Pacific Northwest coastal terrain. A relatively straight coastline consists of miles of sandy beaches punctuated with cliffs of igneous rock and small inlets such as the Bay. East of the Pacific Coast, the high, steep ridges of the coast range climb up to 3,500 feet. These upland areas consist mostly of volcanic basalt base material overlying soils formed from basalt, shale, and sandstone material. Primarily an Astoria-Hembre Association, moderately deep upland soils cover the gently sloping to very steep terrain of the forested uplands.*

Image 5. Shaded Topographic Map of the Tillamook Basin



2.2.2 Riparian Vegetation Characterization

The following are some excerpts from *Tillamook Bay Environmental Characterization* (Tillamook Bay National Estuary Project, 1997), which describes the vegetation present in the Tillamook Basin.

> *The spruce zone covers the lower regions of the Watershed and normally occurs at elevations below 450 feet (150 meters).*
>
> *Dense, tall stands of Sitka spruce, western hemlock, western red cedar (Thuja plicata), Douglas fir (Psuedotsuga menziesii), and grand fir (Abies grandis) dominate the spruce zone…hardwood species occurring in the zone include red alder (Alnus rubra), bigleaf maple (Acer macrophyllum), and occasional California bay (Umbrellularia californica) with red alder dominating recently disturbed sites and some riparian areas.*
>
> *Successional patterns in the spruce zone following fire or logging are often dominated by a dense shrub community composed of salmonberry (Rubus spectabilis), sword fern, elderberry, and huckleberry, with relative dominance varying with the site conditions. The shrub community can persist for quite some time doe to the excellent growing conditions, but at some point it yields to one of two types of seral forest stands. The conifer type is a mixture of spruce, hemlock, and Douglas fir and the hardwood type is a monotypic, dense stand of red alder.*
>
> *The hemlock zone normally extends in elevation between 450 feet (150 meters) and the subalpine zone of the Coast Range.*
>
> *In the hemlock zone the dominant vegetation is dense conifer forest. Forest stands are dominated by Douglas fir, western hemlock and western red cedar, with other conifers mixed in, such as grand fir, Sitka spruce, and Pacific yew (Taxus brevifolia). Hardwood species occurring in the hemlock zone include red alder, bigleaf maple, black cottonwood (Populus trichocarpa) and Oregon ash (Fraxinus latifolia).*
>
> *Successional patterns in the hemlock zone following fire or clearcut logging bring the first year residual species and invading herbaceous species from the genera Senecio and Epilobium. This community is replaced during years two to five by one dominated by fireweed (Epilobium angustifolium), thistle (Cirsium vulgare) and bracken fern (Pteridium aquilinum). The next community is dominated by shrubs such as vine maple, Oregon grape, rhododendron, salal and blackberry species (Rubus spp.). Eventually the shrubs are overtopped by conifers such as Douglas fir.*

2.3 Instream Physical Parameters

The analysis of instream physical parameter utilizes data collected since 1991 during stream surveys. Specifically, instream physical parameter data relies on two separate stream survey data compilations:

Survey 1: U.S. Forest Service (USFS) stream survey database for Oregon and Washington, 1997

Survey 2: Oregon Department of Fish and Wildlife (ODFW) stream reach information for Miami, Kilchis, Wilson, Trask and Tillamook Rivers, 1997

All presentations of instream physical parameter data refer to the data source (i.e., *Survey 1* or *Survey 2*) in an effort to maintain a distinction between each stream survey data analysis effort. In some instances, stream survey data manipulations were necessary to create similar data types that could be compared and analyzed.

The following list contains descriptions of the survey reaches for each Tillamook sub-basin.

1. *Miami River and Tributaries*: The mainstem Miami River has been surveyed from the mouth to Stuart Creek. Peterson and Moss Creeks have also been surveyed.
2. *Kilchis River and Tributaries*: The mainstem has been surveyed from the mouth to the confluence with the Little South Fork, as well as the entire length of Clear Creek.
3. *Wilson River and Tributaries*: Stream reaches that have been surveyed include: Bear Creek, Buck Creek, Deyoe Creek, Devils Fork Wilson River, Drift Creek, Elliot Creek, Fall Creek, Idiot Creek, Kansas Creek, Little North Fork Wilson River, Rogers Creek, South Fork Jordan Creek, South Fork Wilson River, West Fork of the North Fork Wilson River and White Creek. It is important to note that there have been few surveys of the mainstem Wilson River and little is known about corresponding instream physical parameters.
4. *Trask River and Tributaries*: The Trask River stream network has been extensively surveyed upstream of the North and South Forks. In addition, the Little North Fork, Gold Creek, Smith Creek, Beaver Creek, Fall Creek, White Creek and Buck Creek were survey from mouth to headwaters.
5. *Tillamook River and Tributaries*: The Tillamook River was surveyed from Killam Creek to headwaters. Bewley, Killam and Simmons Creeks were also surveyed.

2.3.1 Stream Width and Depth

The width to depth ratio is a fundamental measure of channel morphology. High width to depth ratios (greater than 15.0) imply a wide shallow channel, while low width to depth ratios (less than 15.0) suggest that the channel is narrow and deep. It is generally favorable for stream channels to be narrow and deep (low width to depth ratios) in terms of reducing stream surface exposure to radiant energy source (lower stream temperature), creating pools for aquatic habitat and reducing the surface area for aquatic algae growth (lowering pH).

Riparian vegetation contributes to rooting strength and flood plain/stream bank roughness that dissipates erosive energies associated with flowing water. The condition of riparian vegetation will ultimately affect the width and depth that the stream channel will gravitate towards. Established/Mature woody riparian vegetation adds the highest rooting strengths and flood plain/stream bank roughness. Annual (grassy) riparian vegetation communities offer less rooting strength and flood plain/stream bank roughness. It is expected that width to depth ratios would be lower (narrower and deeper channels) when established/mature woody vegetation is present. Annual (grassy) riparian communities may allow channels to widen and become shallower.

Unfortunately, the relationship between channel form and riparian condition is complicated by a difference between the time in which riparian vegetation communities are established and the time it takes for channels to react to the riparian condition. In essence, there is a difference between riparian vegetation growth time periods and stream geomorphology time periods of change. In effect, there is a lag-time between riparian vegetation alterations and channel modifications. This lag-time is referred to as a *legacy condition*. Land use and natural events have shaped the current composition of riparian vegetation: major forest fires, insect and disease damage to forested riparian stands, timber harvesting, road building/maintenance, agricultural encroachment into riparian areas, urbanization, grazing and trampling of riparian areas by cattle. Some of these land use patterns continue today to varying degrees, while other occurred years (decades) in the past. However, the channel effects from each of these distinct human and natural riparian disturbance events are still apparent in many of the stream reaches surveyed.

Further, channel morphology, namely width and depth, are not solely dependent on riparian conditions. Sedimentation can deposit material in the channel and agrade the stream bed, reducing channel depth and increasing channel width. Flow events play a major role in shaping the stream channel. Channel modification usually occurs during high flow events. Naturally, land uses that affect the magnitude and timing of high flow events may negatively impact channel width and depth.

However, riparian vegetation conditions will affect the resilience of the stream banks/flood plain during periods of sediment introduction and high flow. Linking width to depth ratios to riparian vegetation is fundamental, in that a disturbance process may have drastically differing results depending on the ability of riparian vegetation to shape channels. Desirable low width to depth ratios (less than 15.0) are thus related to riparian vegetation community composition and condition by:

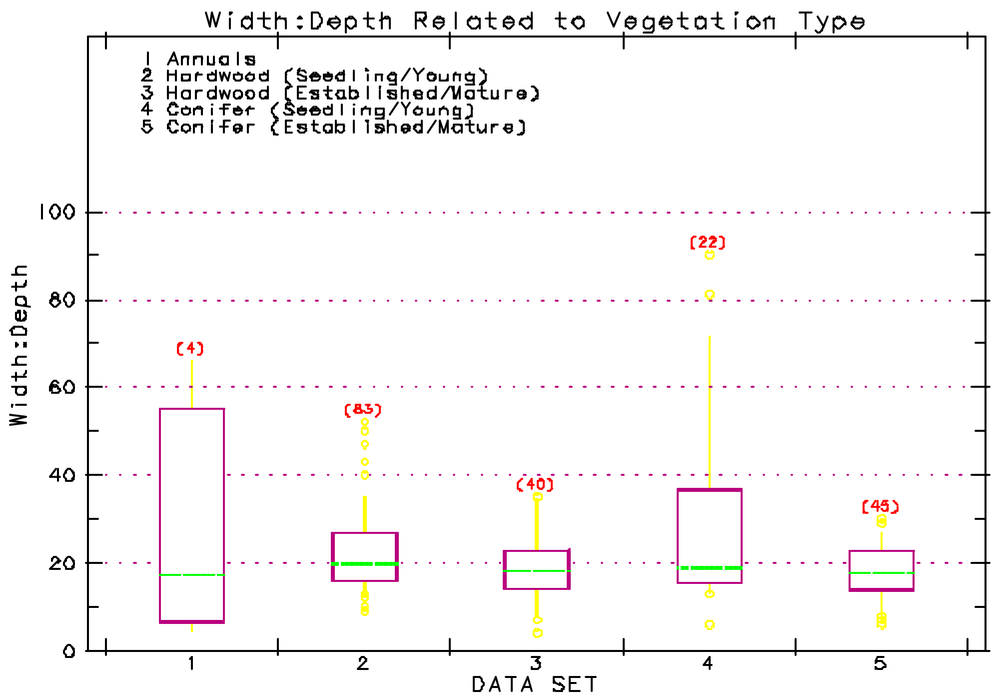
1. *Building stream banks*: trapping/reducing incoming sources of sediment.

2. *Maintaining stabile stream banks*: High rooting strength and high stream bank/flood plain roughness prevent stream bank erosion.

3. *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.

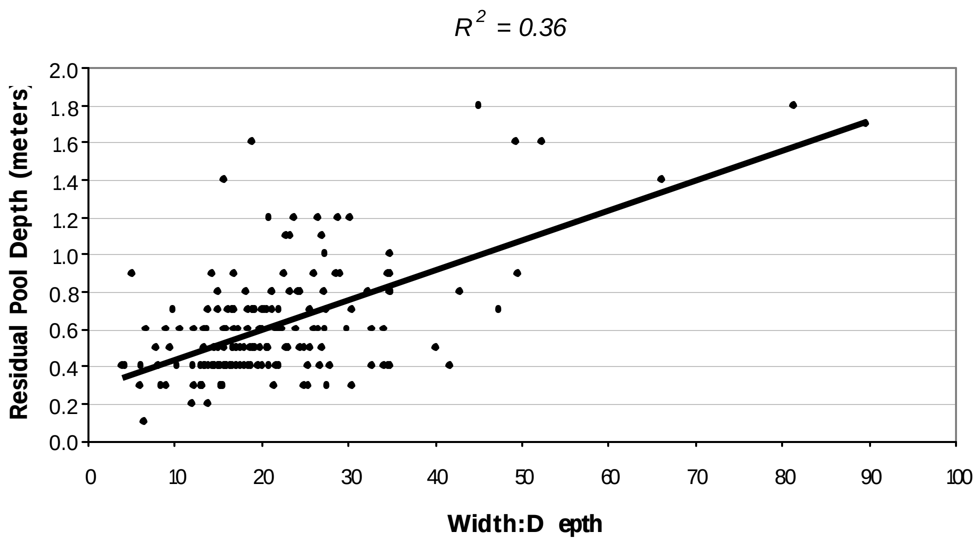
Figure 6 displays various width:depth ratios related to various riparian vegetation types. Annual, hardwood and conifer width to depth ratio comparisons have similar median values (18.0 to 20.0). However, the variability represented in the data sets is markedly different. Annual (grassy) riparian vegetation communities have high width to depth ratio variability (7.0 to 57.0), indicating annual riparian vegetation types provide insufficient rooting strengths and/or flood plain roughness to prevent channel widening. Woody vegetation correlates to less width:depth variability. Seedling/Young hardwoods and conifers have similar width to depth ration median values (≈20.0), and vary between 25^{th} and 57^{th} percentiles of 18.0 and 38.0, respectively. Established/Mature hardwood and conifer riparian communities have the lowest variability (25^{th} percentile of 17.0 and 75^{th} percentile of 22.0) and exhibit a high degree of similarity in median value (19.0).

Figure 6. Width:Depth Ratios Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and width:depth ratio data)



Residual pool depth and width to depth calculations are relatively similar measurements that express the channel depth, with the exception being that residual pool depth is limited to pool measurements. Pools, if present, represent a portion of the survey reach. Pools will have varied depths, which would be expressed in both residual pool depth measurement and width to depth ratio (**Figure 7**). It is expected that residual pool depths would increase (deeper pools) as width to depth ratios decrease (narrower channels).

Figure 7. Residual Pool Depth Related to Width to Depth Ratios (both *Survey 1* and *Survey 2* data presented)

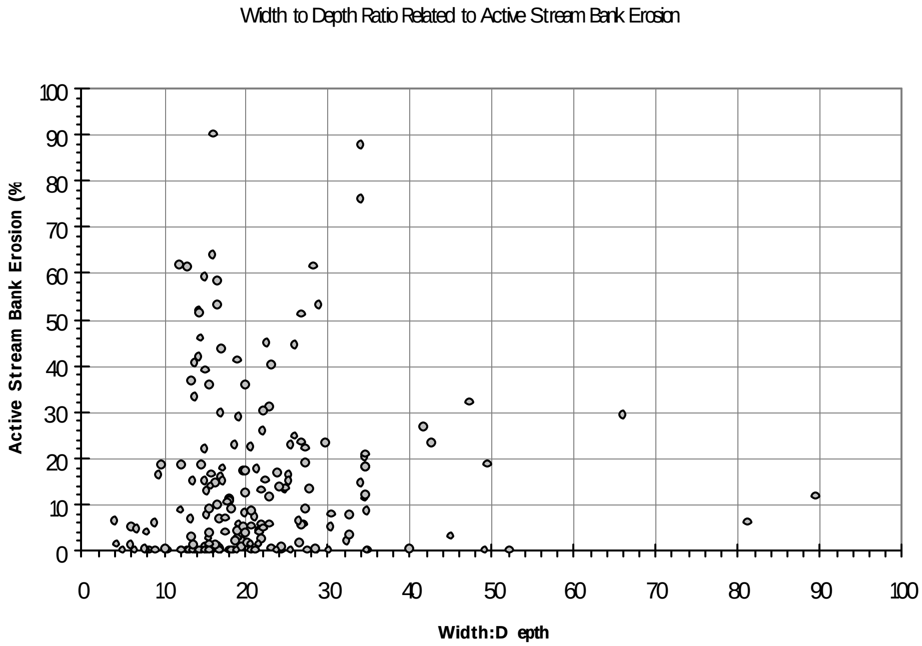


2.3.2 Active Stream Bank Erosion

Stream bank stability reflects the condition of riparian vegetation, which contributes to rooting strength in stream bank soils and flood plain roughness. Riparian vegetation rooting stream serves to strengthen the stream bank and resists the erosive energy exerted on the stream bank during high flow conditions. Flood plain roughness reflects the ability of the flood plain that dissipate erosive flow energy during high flow events that over-top stream banks and inundate the flood plain (see **Section 2.3.1 Stream Width and Depth**). There is often a compounding effect of increased stream bank to erosive energy and decreased bank stability and flood plain roughness from decreased rooting strength in stream bank soils that accompanies decreased riparian vegetation health and altered plant communities.

A high correlation between width to depth ratios and active stream bank erosion indicate that stream banks are unstable and the stream channel is likely widening. A weak correlation between the width to depth ratio and active eroding stream banks may indicate that erosion has occurred in the recent past, but stream banks have not experienced a rebuilding process that restores the channel to historically lower width to depth conditions.

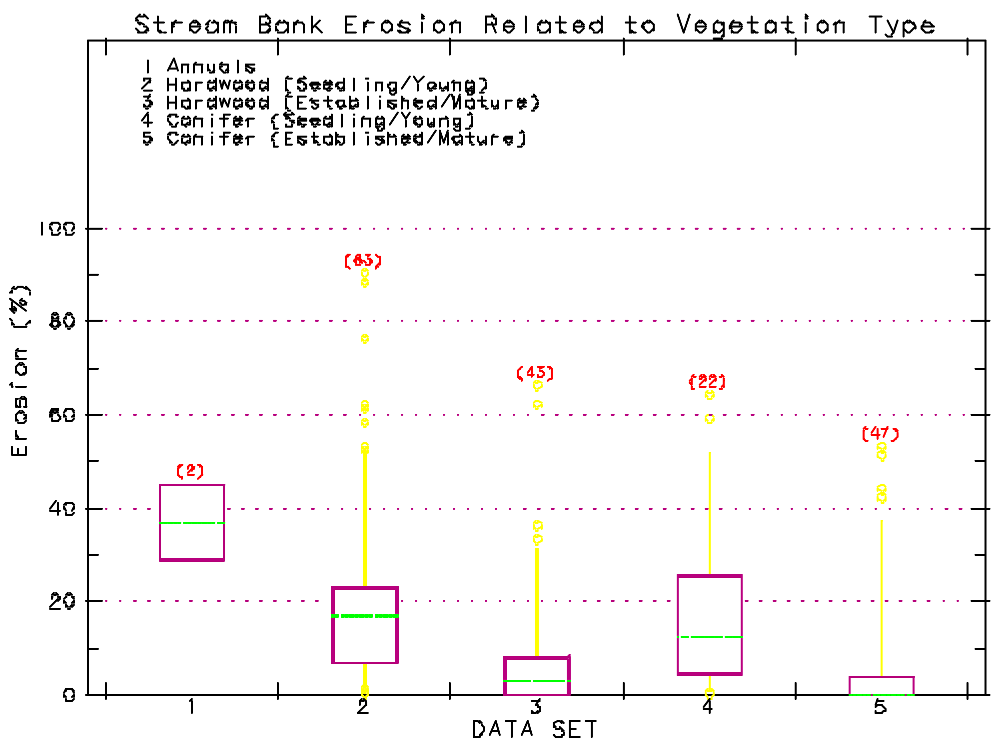
Figure 8. Sub-Basin Correlation of Active Stream Bank Erosion and Width to Depth Ratios



Low active stream bank erosion values that correlate to high width to depth ratios indicate a *legacy* condition. Note that low width to depth ratios (less than 7.5) correspond to low stream bank erosion activity (less than 7.5%) (**Figure 8**).

High rates of active stream bank erosion (greater than 22.5% of stream banks actively eroding) correlate with annual (grass dominated) riparian vegetation types. Annual vegetation types have a *median* active stream bank erosion rate of 37%. Moderate active stream bank erosion rates (7.5% to 22.5% of stream banks actively eroding) correlate with seedling and young hardwood and conifer riparian vegetation communities, 18% and 16% respectively. Low rates of active stream bank erosion (less than 7.5% of stream banks actively eroding) almost exclusively occur in areas where riparian vegetation communities comprised of established mature hardwoods or conifers. It should be noted that the lowest active stream bank erosion rates occurred in mature conifer riparian vegetation communities, where the median active stream bank erosion rate is zero (i.e. no active stream bank erosion is observed). **Figure 9** displays the range of active erosion rates that correspond to riparian vegetation types: annuals, hardwood (seedling/young), hardwood (established/mature), conifer (seedling/young) and conifer (established/mature).

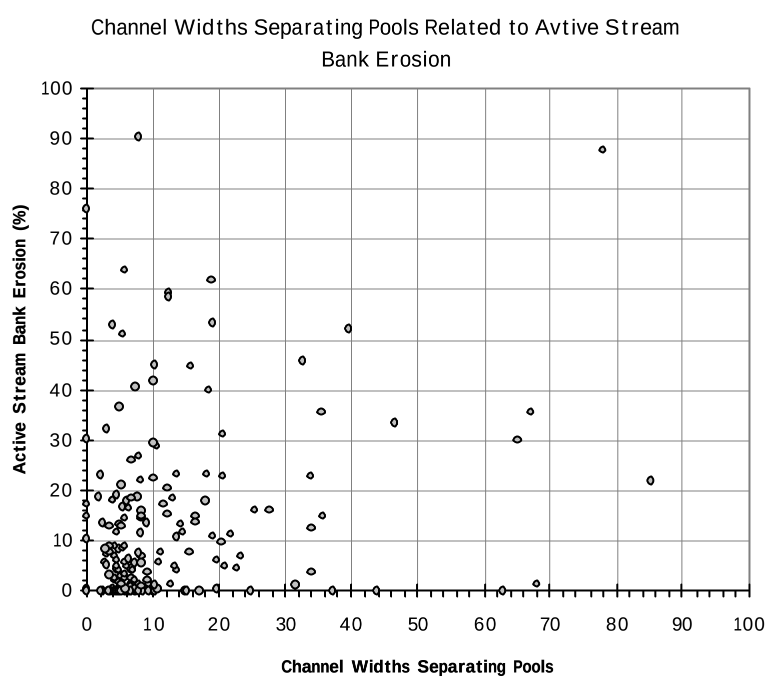
Figure 9. Active Stream Bank Erosion Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and stream bank erosion data)



2.3.3 Residual Pool Frequency

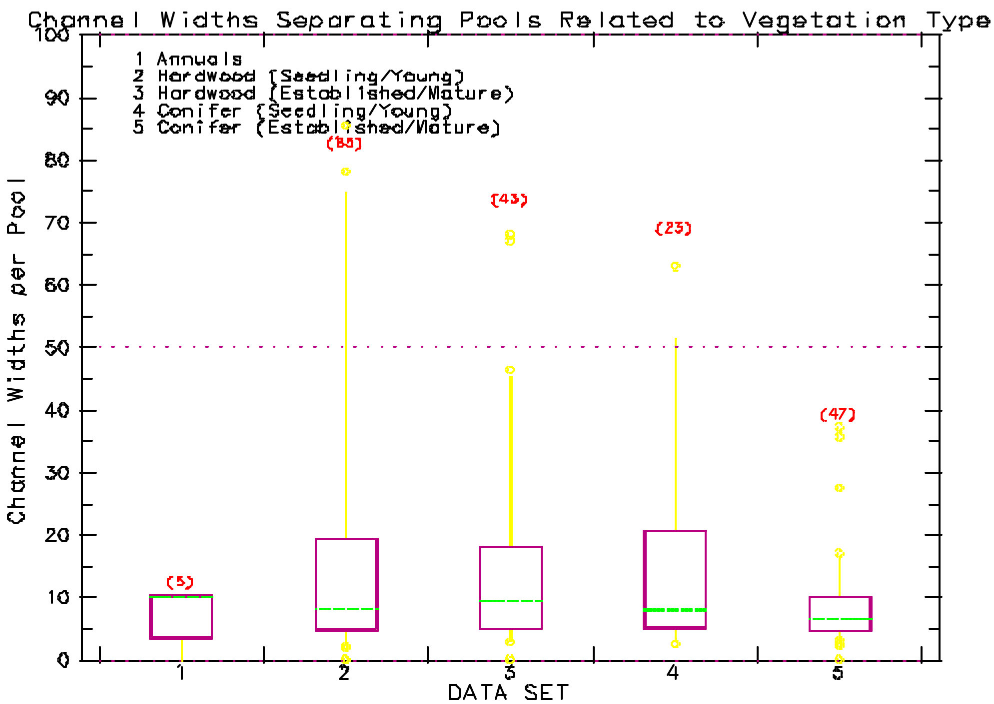
High pool frequencies imply channel complexity, while low pool frequencies imply channel simplification. A simplified stream may be wider and shallower on average, and offer fewer pools per channel width (i.e. a lower pool frequency). Active stream bank erosion is the primary process in which streams widen. It would therefore be expected that a correlation between active stream bank erosion and pool frequency would exist. **Figure 10** shows that there is a strong correlation between low rates of stream bank erosion and higher pool frequencies (expressed as fewer channel widths separating pools). Two deviations exist, however. First, there is a large portion of the data that has high rates of stream bank erosion, but pool frequencies are not low. These systems may be in the process of loosing channel complexity and suffering from loss of pools. Second, there are reaches that have a low rate of stream bank erosion, yet pool frequencies are quite low. A possible explanation is a legacy condition of historic widened channels via active erosion. Erosion rates may have decreased or stopped completely, but the channel response may be at varying stages of pool building, or unable to recover because current conditions do not encourage bank building processes that lead to increased pool frequencies.

Figure 10. Sub-Basin Correlation of Active Stream Bank Erosion and Channel Widths Separating Pools. *Note that low stream bank erosion activity tends to correspond to fewer channel widths separating pools (i.e. a higher pool frequency).*



It can be seen in **Figure 11** that a correlation to does not exist between riparian vegetation type and pool frequency (expressed as channel widths separating pools, where fewer channel widths separating pools implies a higher pool frequency). **Figure 11** does indicate that pool frequencies are less variable and slightly higher where mature conifer riparian vegetation types occur. Data to investigate the effects of sedimentation are currently unavailable, however. **Image 9** and **Image 10** display the pool frequencies recorded in *Survey 1* and *Survey 2*.

Figure 11. Pool Frequency (Channel Widths Separating Pools) Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and pool frequency data)



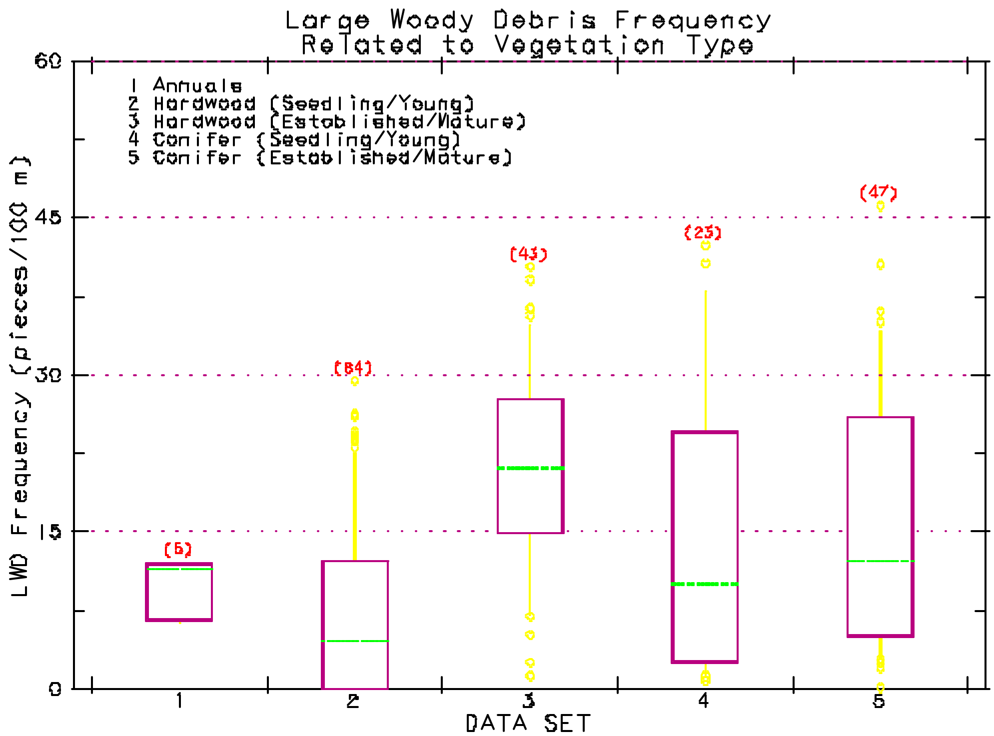
2.3.4 Large Woody Debris Frequency

Large woody debris in the active channel increases *channel complexity* and *instream roughness*. Large woody debris is an important source of habitat for aquatic insects and fish species. In addition to increasing habitat and food sources for salmonid species, large woody debris tends to slow stream velocities and reduce the erosive kinetic energy of flowing water. Instream roughness helps dissipate stream flow erosive energy and prevent/reduce stream bank erosion. Woody debris deficiencies in the active channel may indicate that upstream sources of large wood in the riparian zone have been compromised.

Figure 12 captures some of the complex relationships between riparian vegetation and large woody debris frequency. Annual and young woody riparian vegetation communities correspond to lower large woody debris frequencies in the active channel. Established/Mature hardwood riparian vegetation types correspond to the highest instream large woody debris frequencies, with a median value of 14 pieces per 100 meters of primary channel length. Perhaps the relationship between mature riparian hardwood vegetation and increased wood frequency is a reflection of the life cycle of hardwood vegetation. While coniferous vegetation is extremely long-lived, hardwood species tend to be shorter lived and may have a higher probability of being introduced into the active channel. Further, established hardwoods may be less stabile (lower rooting strengths) then established conifers. In periods of high flow and riparian disturbance, hardwoods are more likely to be damaged or toppled and introduced into the active channel.

Some of the variability in the data reflects the transient nature of wood in the active channel. Over time, woody debris is transported from upstream sources. Therefore, woody debris may not have originated from the reach in which the survey data was collected and would not be correlating to the riparian community in the survey reach.

Figure 12. Large Woody Debris Frequency Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and LWD data)



2.3.5 Substrate – Fines and Gravel Distributions

Streambed material classification defines fines as sand, silt and organic material that have a grain size of 6.4 mm or less. Studies have shown that fry emergence is seriously compromised as fine sediments are introduced into spawning gravel (Tappel and Bjornn 1993) (**Figure 13**). When fine grain sized substrate cover spawning gravel (*redd*) anadromous *sac-fry* (larval fish) may emerge prematurely. Studies have shown that *sac-fry* are often forced out of gravel before they have absorbed their yolk sacs as a fine sediments fill the interstitial pore spaces of the redd, resulting in a lack of oxygen (Tappel and Bjornn 1993). Low survival rates accompany *sac-fry* that have been forced to prematurely emerge from the *redd*. **Figure 14** presents the fine sediment values surveyed in the total reach length to the fine sediment values surveyed in the riffle areas. Riffles are likely spawning areas.

Figure 13. Percentage Emergence of Fry from Newly Fertilized Eggs in Gravel-Sand Mixtures. *Fine sediment was granitic sand with particles less than 6.4 mm (Bjornn 1969).*

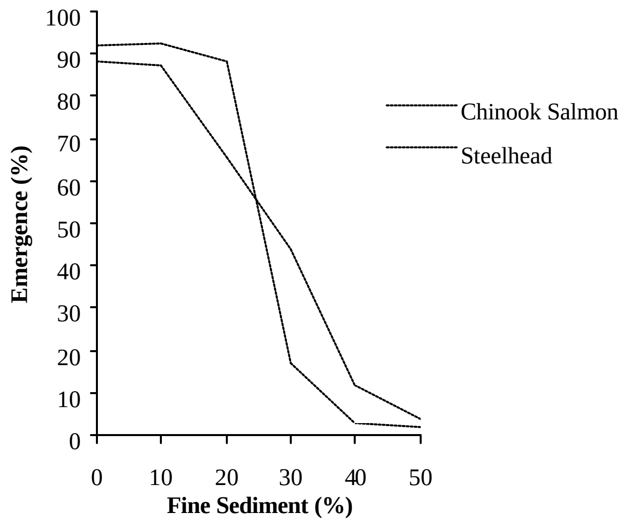
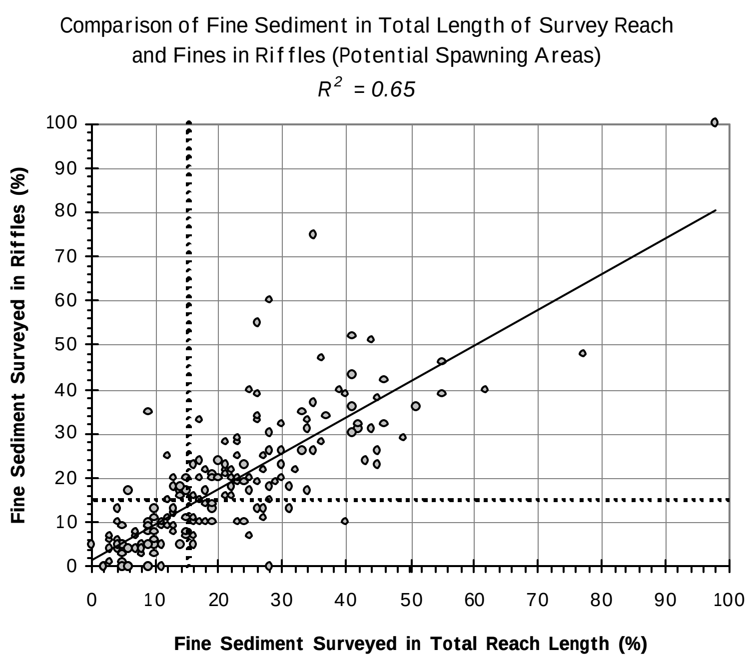


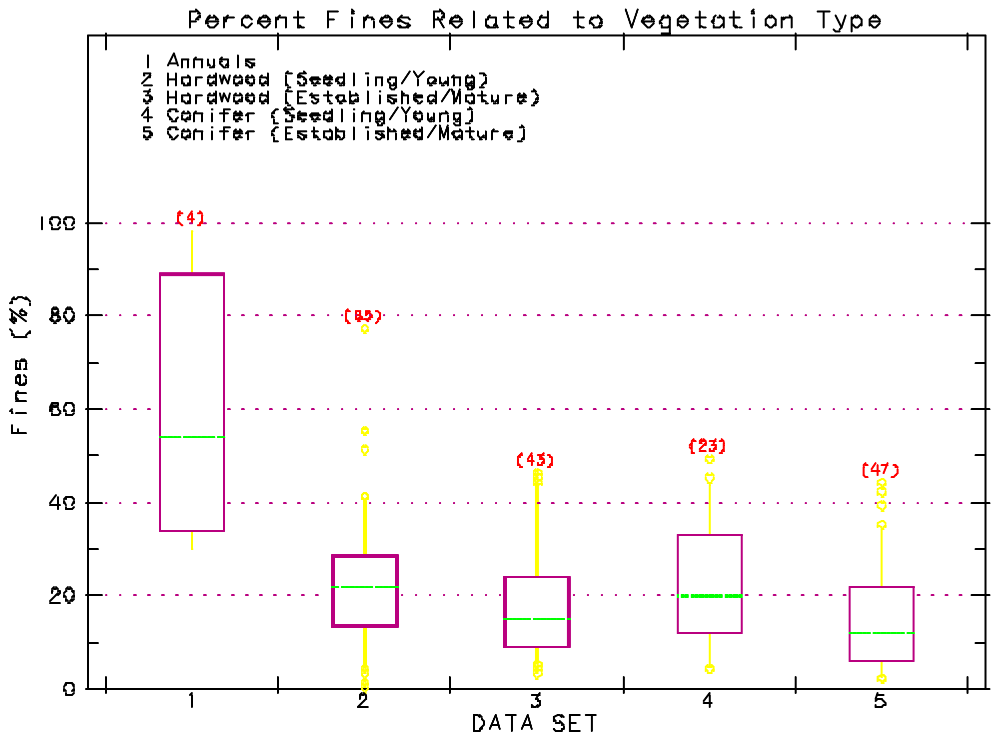
Figure 14. Fine Sediment Surveyed in the Total Reach Length Compared to the Fine Sediment Surveyed in Riffles in the Reach. *Riffles are likely spawning areas. A threshold has been placed on the plot at 15% fine sediment, at which sac-fry emergence becomes severely compromised.*



High fine sediment distributions in the Tillamook Basin correlates strongly with non-woody vegetation (annuals, grass) (**Figure 15**). Non-woody riparian vegetation has median percent fine sediment at twice that measured in the highest woody riparian vegetation classification (seedling or young hardwood). Within the woody riparian vegetation classification, it appears that age/maturity and hardwood/conifer distinctions are also controlling factors in the distribution of fine sediment.

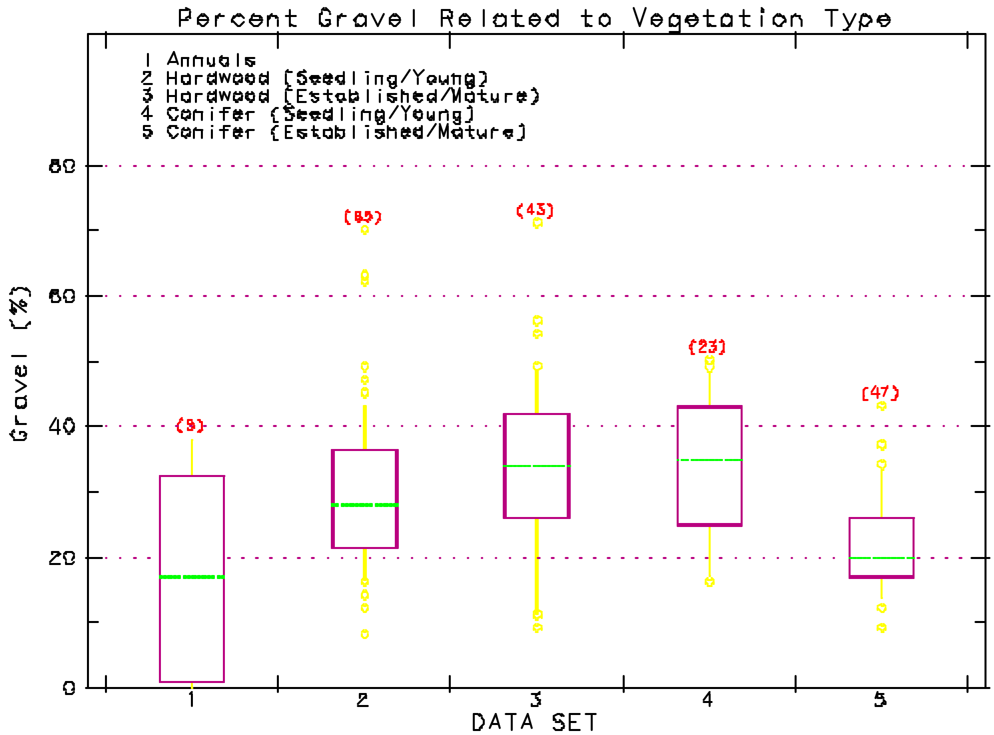
Established/Mature coniferous riparian vegetation correlate to the lowest median percent fine value (11% of the stream bed substrate). Referring to **Figure 13**, 11% of fine sediment distributed over *redds* is the upper limit before serious degradation occurs to *sac-fry*. Mature/Established hardwood riparian vegetation communities have a median value of 12% fines in the bed substrate. This value also constitutes worrisome impacts to *sac-fry* emergence. Serious detriment to sac-fry is occurring in the reaches with seedling/young hardwood and conifer riparian vegetation communities, where perhaps mortality rates are 40% to 60% of the expected *sac-fry* are emergence from *redds*. Non-woody (annual) riparian vegetation communities have a median percent fines in stream bed substrates of 52%, a value that would prevent nearly <u>all</u> *sac-fry* emergence. Simply stated, these survey reaches are degraded to a level that reduces salmonid reproductive fitness to near zero levels.

Figure 15. Streambed Percent Fines Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and percent fines data)



Streambed substrate gravel occurrence is lowest where riparian vegetation communities are annual plant species (18%) (**Figure 16**). Further, gravel distributions in areas with annual riparian vegetation types is highly variable. Woody riparian vegetation corresponds to higher gravel comprised in the stream bed substrate. The data show that established/mature conifers correlate with higher median gravel substrate values (20%) and have the lowest associated variability. Young conifers correlate to high median gravel distributions (27%), but have high data variability (25^{th} confidence interval – 23%, 25^{th} confidence interval – 42%). Hardwoods of both age classifications correlate to higher gravel distribution (Seedling/Young – 24%, Mature/Established – 27%). However, more variability in the data was observed for hardwood riparian vegetation types.

Figure 16. Streambed Percent Gravel Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and percent gravel data)

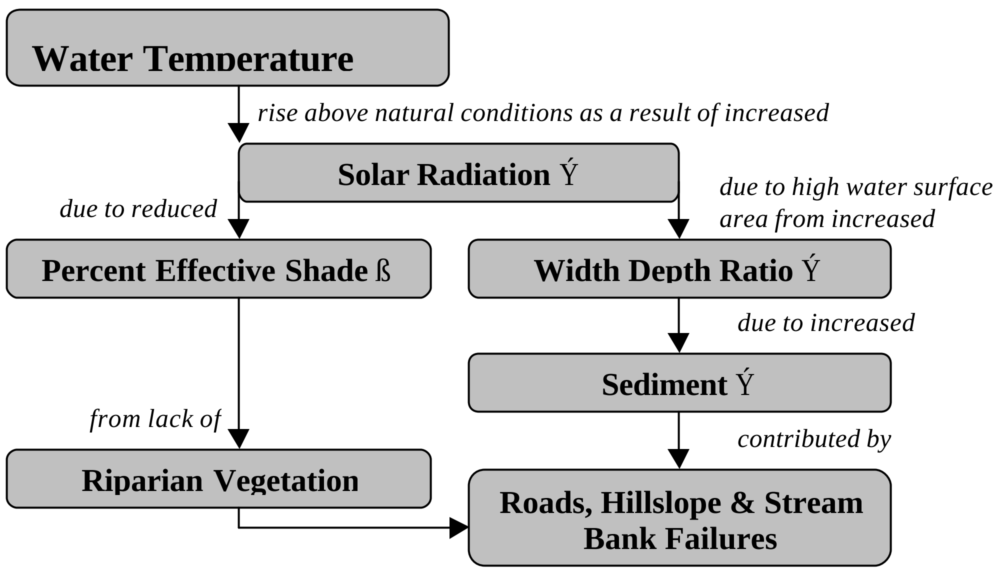


3. SOURCE ASSESSMENT

3.1 Stream Heating Processes

Decreased effective shade levels result from lack of adequate riparian vegetation available to reduce sunlight (e.g. heat from incoming solar radiation). Human activities that contribute to degraded water quality conditions in the Tillamook Basin include improper timber harvest, roads, and agriculture and rural residential related riparian disturbance. Wider channels also increase the stream surface area exposed to heat transfer from solar radiation. The relationship between the percent effective shade (surrogate measure) and factors that impact stream temperature are described in **Figure 17**.

Figure 17. Factors that Impact Water Temperature



Note: Boxes depict measured or calculated key indicators

These forestry, agriculture and rural residential related nonpoint sources of pollution primarily affect the water quality parameter (temperature) through increased solar loading by: (1) increasing stream surface solar radiation loading and (2) increasing stream surface area exposed to solar radiation loading. Although these nonpoint sources continue in the Tillamook Basin, altered management practices that comply with surrogate measures (allocations) presented in this document are intended to ameliorate pollutant delivery.

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, the condition of the riparian area, channel morphology and hydrology can be affected by human land use activities. Specifically, the elevated summertime stream temperatures attributed to anthropogenic causes in the Tillamook Basin result from the following listed conditions:

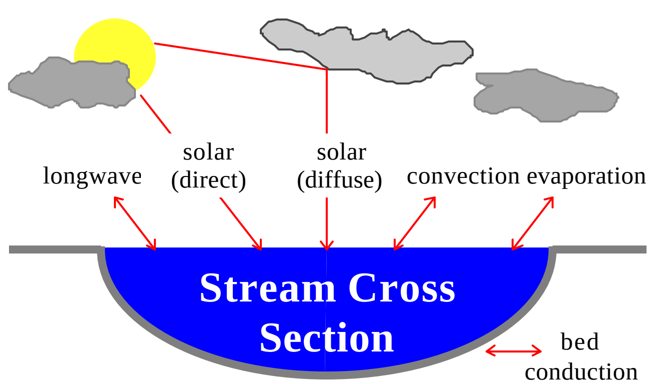
1. *Channel widening (increased width to depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation,*
2. *Riparian vegetation disturbance that compromises stream surface shading, riparian vegetation height and density (shade is commonly measured as percent effective shade),*
3. *Possible reduced summertime base flows (that result from instream withdrawals per instream water rights) and decreased extent of saturated riparian soils that capture and slowly release stored water to the channel over summertime low flow months.*

Analysis presented in this TMDL will demonstrate that developed loading capacities will strive toward attainment of State water quality standards. Specifically, the link between shade surrogate measures (allocations) for solar radiation loading capacities and water quality attainment will occur via two processes:

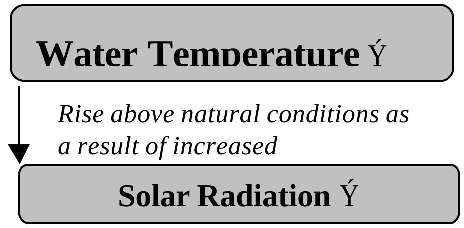
1. *Remove human (anthropogenic) solar radiation contributions from temperature dynamics in the Tillamook Basin, and*
2. *Restore riparian reserves that function to protect stream morphology and encourage bank-building processes in severe hydrologic events.*

Stream temperature is an expression of heat energy per unit volume, which in turn is an indication of the rate of heat exchange between a stream and its environment. The heat transfer processes that control stream temperature include solar radiation, longwave radiation, convection, evaporation and bed conduction (Wunderlich, 1972; Jobson and Keefer, 1979; Beschta and Weatherred, 1984; Sinokrot and Stefan, 1993; Boyd, 1996). With the exception of solar radiation, which only delivers heat energy, these processes are capable of both introducing and removing heat from a stream. **Figure 18** displays heat energy processes that solely control heat energy transfer to/from a stream.

Figure 18. Thermodynamic (Heat Transfer) Processes that Heat or Cool Water



When a stream surface is exposed to midday solar radiation, large quantities of heat will be delivered to the stream system (Brown 1969, Beschta et al. 1987). Some of the incoming solar radiation will reflect off the stream surface, depending on the elevation of the sun. All solar radiation outside the visible spectrum (0.36µ to 0.76µ) is absorbed in the first meter below the stream surface and only visible light penetrates to greater depths (Wunderlich, 1972). Sellers (1965) reported that 50% of solar energy passing through the stream surface is absorbed in the first 10 cm of the water column. Removal of riparian vegetation, and the shade it provides, contributes to elevated stream temperatures (Rishel et al., 1982; Brown, 1983; Beschta et al., 1987). The principal source of heat energy delivered to the water column is solar energy striking the stream surface directly (Brown 1970). While exposed to summertime midday solar radiation, large quantities of heat energy will be imparted to the stream. Exposure to direct solar radiation will often cause a dramatic increase in stream temperatures. When shaded throughout the entire duration of the daily solar cycle, far less heat energy will be transferred to the stream. The ability of riparian vegetation to shade the stream throughout the day depends on vegetation height, density and position relative to the stream.



Both the atmosphere and vegetation along stream banks emit longwave radiation that when received by the stream surface has a warming influence. Water is nearly opaque to longwave radiation and complete absorption of all wavelengths greater than 1.2µ occurs in the first 5 cm below the surface (Wunderlich, 1972). Longwave radiation has a cooling influence when emitted from the stream surface. The net transfer of heat via longwave radiation usually balances so that the amount of heat entering is similar to the rate of heat leaving the stream (Beschta and Weatherred, 1984; Boyd, 1996).

Evaporation occurs in response to internal energy of the stream (molecular motion) that randomly expels water molecules into the overlying air mass. Evaporation is the most effective method of dissipating heat from water (Parker and Krenkel, 1969). As stream temperatures increase, so does the rate of evaporation. Air movement (wind) and low vapor pressures increase the rate of evaporation and accelerate stream cooling (Harbeck and Meyers, 1970).

Convection transfers heat between the stream and the air via molecular and turbulent conduction (Beschta and Weatherred, 1984). Heat is transferred in the direction of warmer to cooler. Air can have a warming influence on the stream when the stream is cooler. The opposite is also true. The amount of convective heat transfer between the stream and air is low (Parker and Krenkel, 1969; Brown, 1983).

Depending on streambed composition, shallow streams (less than 20 cm) may allow solar radiation to warm the streambed (Brown, 1969). Large cobble (> 25 cm diameter) dominated streambeds in shallow streams may store and conduct heat as long as the bed is warmer than the stream. Bed conduction may cause maximum stream temperatures to occur later in the day, possibly into the evening hours. The instantaneous heat transfer rate experienced by the stream is the summation of the individual processes:

$$\Phi_{Total} = \Phi_{Solar} + \Phi_{Longwave} + \Phi_{Evaporation} + \Phi_{Convection} + \Phi_{Conduction}$$

Solar Radiation (Φ_{Solar}) is a function of the solar angle, solar azimuth, atmosphere, topography, location and riparian vegetation. Simulation is based on methodologies developed by Ibqal (1983) and Beschta and Weatherred (1984). *Longwave Radiation*

($\Phi_{Longwave}$) is derived by the Stefan-Boltzmann Law and is a function of the emissivity of the body, the Stefan-Boltzmann constant and the temperature of the body (Wunderlich, 1972). *Evaporation* ($\Phi_{Evaporation}$) relies on a Dalton-type equation that utilizes an exchange coefficient, the latent heat of vaporization, wind speed, saturation vapor pressure and vapor pressure (Wunderlich, 1972). *Convection* ($\Phi_{Convection}$) is a function of Bowen's Ratio (1926) and terms include atmospheric pressure, and water and air temperatures. *Bed Conduction* ($\Phi_{Conduction}$) simulates the theoretical relationship ($\Phi_{Conduction} = K \cdot dT_b / dz$), where calculations are a function of thermal conductivity of the bed (K) and the temperature gradient of the bed (dT_b/dz) (Sinokrot and Stefan, 1993). Bed conduction is solved with empirical equations developed by Beschta and Weatherred (1984).

3.2 Mechanics of Shade

Stream surface shade is a function of several landscape and stream geometric relationships. Some of the factors that influence shade are listed in **Table 7**. Geometric relationships important for understanding the mechanics of shade are displayed in **Figure 19**. In the Northern Hemisphere, the earth tilts on its axis toward the sun during summertime 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). Geographic position (i.e. latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation. Riparian height, width and density describe the physical barriers between the stream and sun that can attenuate incoming solar radiation (i.e. produce shade). The solar position has a vertical component (i.e. altitude) and a horizontal component (i.e. azimuth) that are both functions of time/date (i.e. solar declination) and the earth's rotation (i.e. hour angle). While the interaction of these shade variables may seem complex, the math that describes them is relatively straightforward geometry, much of which was developed decades ago by the solar energy industry.

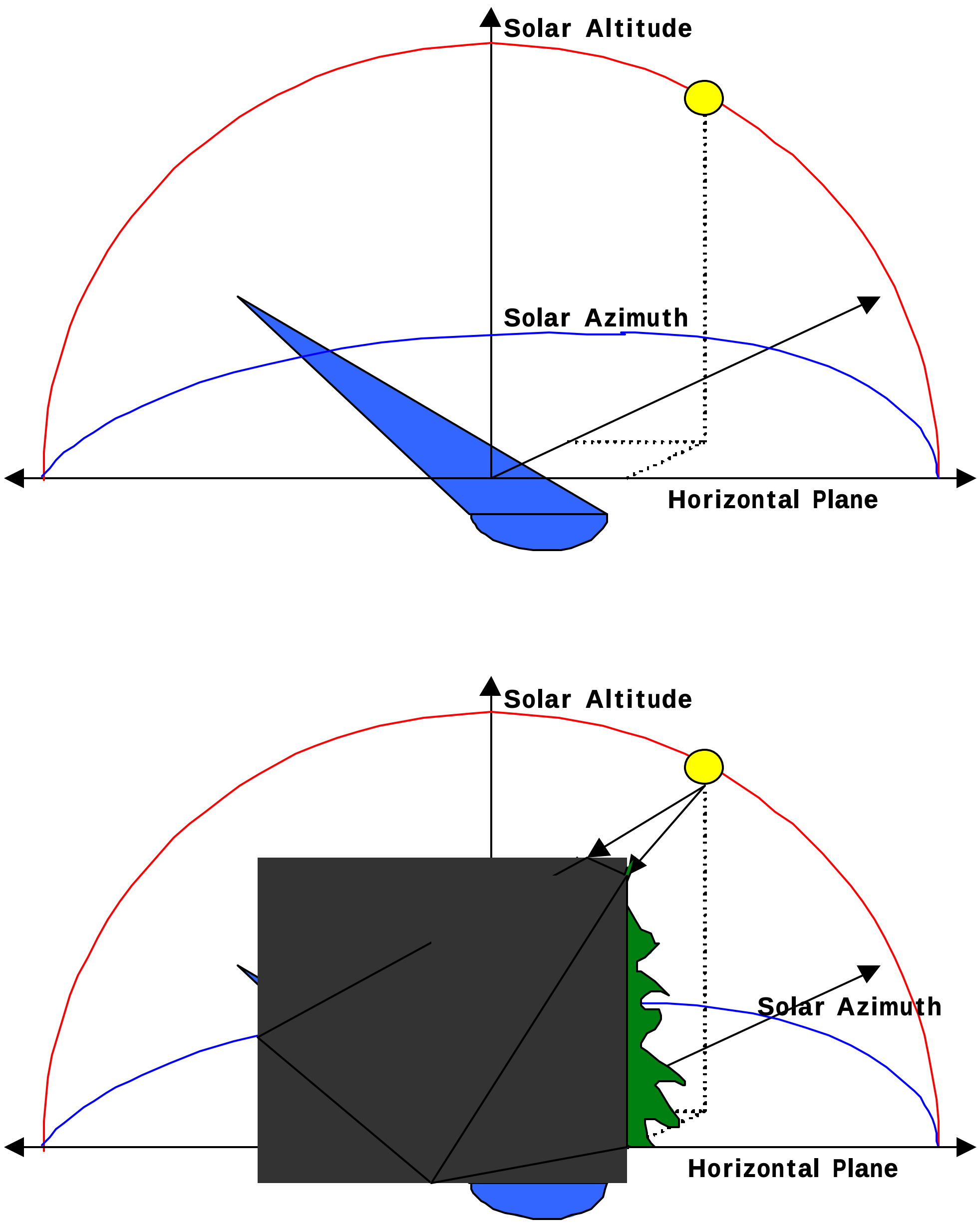
Table 7. Factors that Influence Stream Surface Shade

Description	Measure
Season	Date
Stream Characteristics	Aspect, Bankfull Width
Geographic Position	Latitude, Longitude
Vegetative Characteristics	Buffer Height, Buffer Width, Buffer Density
Solar Position	Solar Altitude, Solar Azimuth

Figure 19. Geometric Relationships that Affect Stream Surface Shade

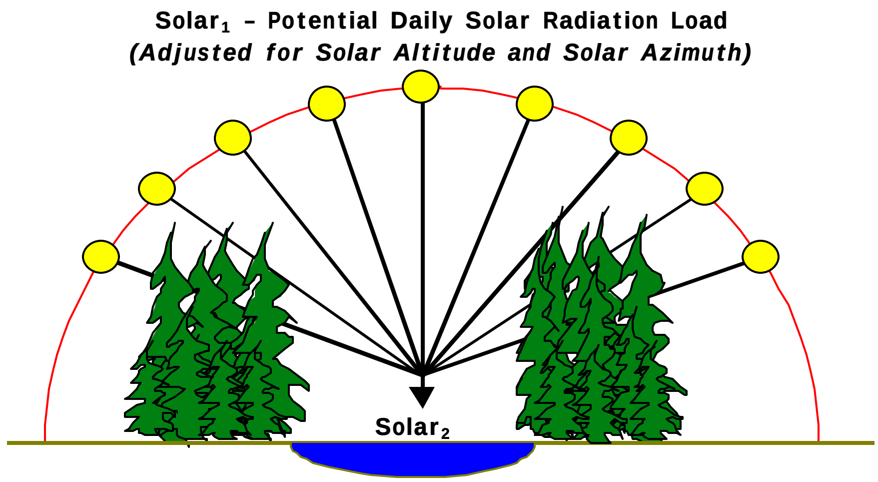
Solar Altitude and **Solar Azimuth** are two basic measurements of the sun's position. When a stream's orientation, geographic position, riparian condition and solar position are known, shadeing characteristic can be simulated.

Solar Altitude measures the vertical component of the sun's position
Solar Azimuth measures the horizontal component of the sun's position



The percent effective shade is perhaps one of the most straightforward stream parameters to monitor/calculate and is most helpful in directing water quality management and recovery efforts. **Figure 20** demonstrates how effective shade is monitored/calculated. Using solar tables or mathematical simulations, the *potential daily solar load* can be quantified. The *measured solar load at the stream surface* can easily be measured with a Solar Pathfinder© or estimated using mathematical shade simulation computer programs (Boyd, 1996 and Park, 1993).

Figure 20. Effective Shade Defined



Effective Shade Defined:

$$\text{Effective Shade} = \frac{(Solar_1 - Solar_2)}{Solar_1}$$

Where,

$Solar_1$: Potential Daily Solar Radiation Load

$Solar_2$: Measured Daily Solar Radiation Load at Stream Surface

3.3 Observed Relationships

Riparian vegetation, stream morphology and hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, the condition of the riparian area, channel morphology and hydrology can be degraded by human land use activities. Specifically, the elevated summertime stream temperatures measured throughout the Tillamook Basin result from:

1. Channel widening (increased width to depth ratios) that increases the stream surface area exposed to energy processes, namely solar radiation,

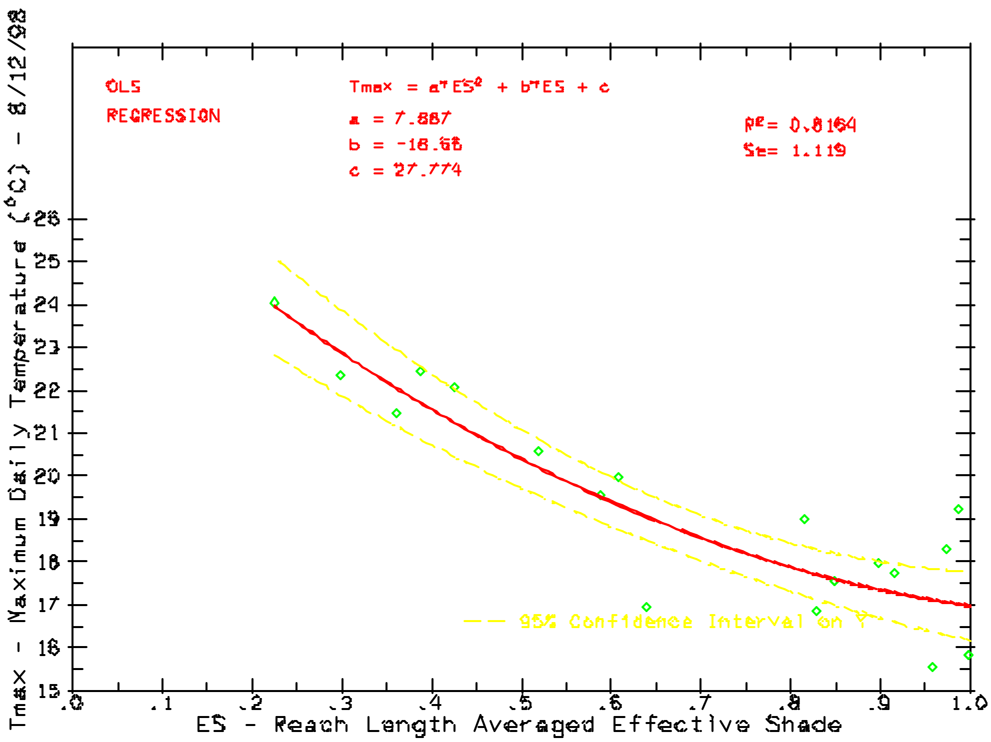
2. Riparian vegetation disturbance that compromises stream surface shading (decreased percent shade and increased open sky percentage),
3. Reduced summertime base flows that may result from loss of saturated riparian and upslope soils that capture and slowly release stored water.
4. Reduced summertime base flows that may result from instream withdrawals.

3.3.1 Effective Shade and Stream Temperature

Longitudinal heating is a natural process. However, rates of heating can be dramatically reduced when high levels of shade exist and solar radiation loading is minimal. The overriding justification for the solar radiation loading reduction (loading capacity) is to minimize longitudinal heating. A limiting factor in reducing longitudinal stream heating is the site potential effective shade level.

Effective shade measurements were reach length averaged for each tributary and mainstem. These values were then plotted against the maximum temperature (for August 12, 1998) recorded at the lowest end of the reach (**Figure 21**). High effective shade levels correspond to cooler daily maximum stream temperature values. Stream temperature may also exhibit a threshold condition in which slight reductions in shade allow considerable stream heating. Dramatic stream temperature increase is possible when the stream surface moves from a highly shaded condition to partial shade (Boyd, 1996). According to the regression equation, the reach length averaged effective shade value that corresponds to a maximum temperature of 17.8^{o}C (64^{o}F) is *81%* (see **Section 5.2.2 Effective Shade Surrogate Measures (Allocations)** for further discussion).

Figure 21. Reach Length Averaged Effective Shade and Maximum Daily Stream Temperature *(ODEQ, August 12, 1998)*



An F-test was performed on the regression in **Figure 21** to determine the significance of the third order polynomial regression (**Table 8**). Note that the calculated P-value indicates a highly significant correlation between daily maximum temperature and reach length averaged effective shade.

Table 8. ANOVA F-Test Results

Null Hypothesis (H_o)	Maximum temperatures are not related to reach averaged effective shade
Alternative Hypothesis (H_a)	Maximum temperatures are related to reach averaged effective shade
Degrees of Freedom	19
F Value	68.31
F Critical	3.603
One Tailed P-Value P(F)	0.00000015
Result	Highly Significant – P(F) < 1%
Null Hypothesis (H_o)	Reject Null Hypothesis (H_o)
Alternative Hypothesis (H_a)	Accept Alternative Hypothesis (H_a)

3.3.2 Instream Physical Parameters and Stream Temperature

It should be noted that less than half of the 47 temperature monitoring sites were located within surveyed reaches. This relatively small sample size prohibits conclusive correlation. In short, instream physical parameter relationships between stream temperature may or may not exist, despite the implied relationships, or lack there of. As is often the case, the number of sampling sites are limited and often fail to occur in areas where other data has been collected.

The number of data points in extremely important. As the number of sample points increases, the confidence in calculated R^2 values also increases. This data set is comprised of 22 temperature data sets. If this number were to increase, confidence in the implied relations would be bolstered. There is also a possibility that relationships currently not apparent may emerge.

A large portion of the total stream miles in the Tillamook has been surveyed and data is formatted for geographic information systems (GIS). Using instream channel morphology data, the relationships between temperature data and instream physical parameters were evaluated for *width to depth ratios* and *open sky* (%).

Changes in channel morphology can impact stream temperatures, especially channel widening (**Figure 22**). As a stream widens, the surface area exposed to radiant sources and ambient air temperature increases, resulting in increased energy exchange between the stream and its environment. Channel widening often is related to increased bank erosion and sedimentation of the stream bed which correlate strongly with riparian vegetation type, age and condition (see sub-sections of **Section 2.3 Instream Physical Parameters**).

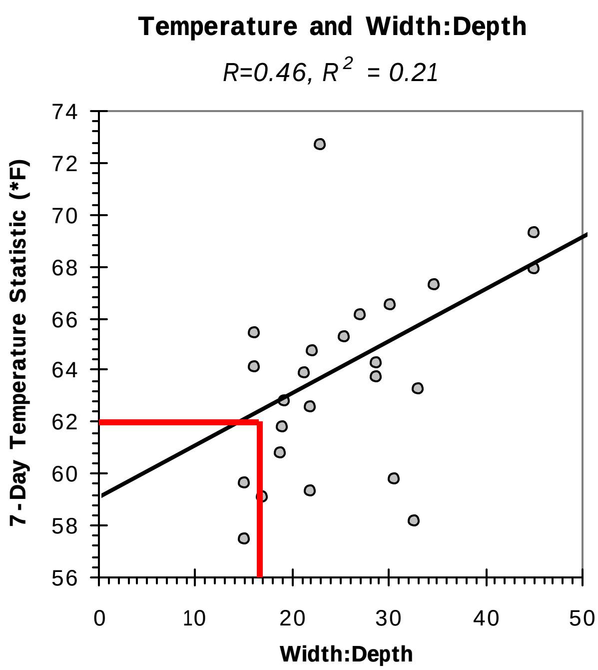


Figure 22. Width to Depth Ratios Corresponding to Measured Stream Temperatures (*Maximum 7-day Moving Average Daily Maximum*). *A linear regression line has been fitted to the data. Using this regression line, it can be seen that width:depth values of 15.0 or less correspond to a 7-day statistic of 62°F.*

Removal of riparian vegetation, and the shade it provides, contributes to elevated stream temperatures (Rishel et al. 1982, Brown 1983, Beschta et al. 1987). The principal source of heat energy for streams is solar energy striking the stream surface directly (Brown 1970). While exposed to summertime midday solar radiation, large quantities of heat energy will be imparted to the stream. Exposure to direct solar radiation will often cause a dramatic increase in stream temperatures (**Figure 23**). When shaded throughout the entire duration of the daily solar cycle, far less heat energy will be transferred to the stream. The ability of riparian vegetation to shade the stream throughout the day depends on vegetation height and the vegetation position relative to the stream. The condition of the riparian vegetation varies considerably in the Little River basin. The majority of the riparian vegetation is composed of narrow bands of hardwood and conifer species, where larger trees have been selectively removed. Lower mainstem and tributary reaches have riparian vegetation types primarily composed of annuals (grassy vegetation).

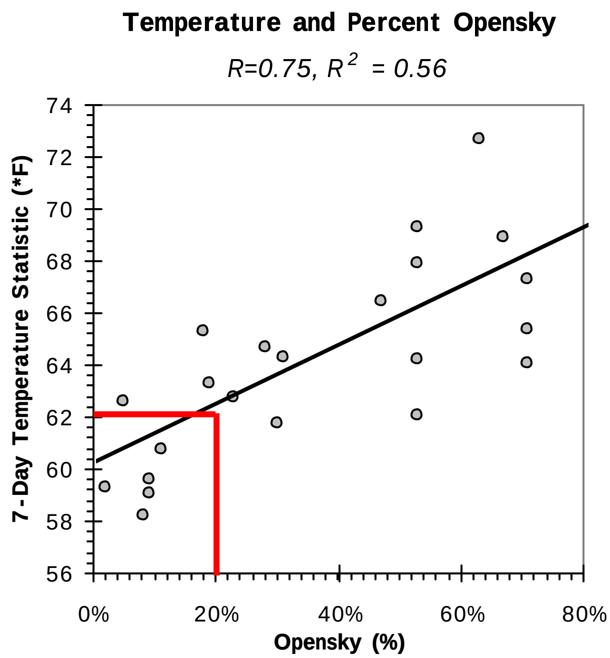


Figure 23. Open Sky Percentages Corresponding to Measured Stream Temperatures (*Maximum 7-day Moving Average Daily Maximum*). *A linear regression line has been fitted to the data. Using this regression line, it can be seen that an open sky percentage of 20% or less correspond to a 7-day statistic of 62°F.*

Results from a simple correlation testing between stream temperature and instream physical parameters are shown in **Figure 22** and **Figure 23**. The R^2 value may be controversial when considering whether a specific R^2 value implies correlation between the data and regression (see section **9.2 Statistical Terminology**). The significance of the linear regressions are left to reader's discretion.

3.3.3 Hydrology and Stream Temperature

Altered watershed hydrology can impair stream temperature if instream flows are reduced. Stream temperature is generally inversely related to flow volume; as flows decrease, stream temperature tends to increase. Many land use activities that disturb riparian vegetation or the stream channel affect the connectivity of a stream to groundwater sources. Groundwater inflow tends to cool summertime stream temperatures and augment summertime flows. Reductions or elimination in groundwater inflow will have a warming effect on a stream or river.

3.3.4 Natural Sources and Stream Temperature

Natural sources that may elevate stream temperature include drought, fires, insect damage to riparian vegetation, diseased riparian vegetation and windthrow and blowdown in riparian areas. The processes in which natural sources affect stream temperatures include increased stream surface exposure to solar radiation and decreased summertime flows. Legacy conditions (increased width to depth ratios and decreased levels of stream surface shading) that currently exist are, in part, a result of the extensive Tillamook burn, and fires that occurred prior to the burn.

3.3.5 Percent Open Sky and Riparian Vegetation Type

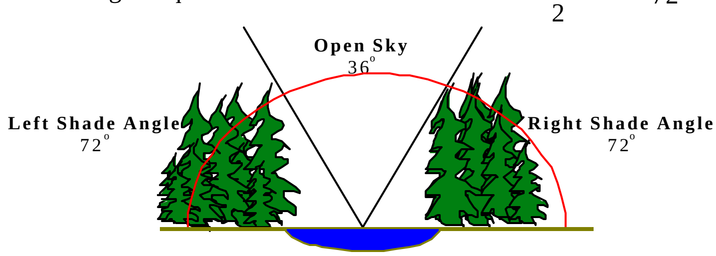
The percentage of open sky is a fraction of the horizon above the stream that is void of canopy and/or topographic barriers (stream bank slope, hills and ridges). In essence, the percentage of open sky is the opposite of percentage shade. **Figure 24** clarifies the measures (percentage open sky and percentage shade) using 80% shade and 20% open sky as an example.

Figure 24. Relationship Between the Percentage Open Sky and Percent Shade

What 80% Shade Implies:

Of the 180^o (half-circle) above the stream 144^o should be occupied by topographic barriers or riparian vegetation, preferably a 72^o shade angle along each stream bank, while the remaining 36^o may be open to the sky (canopy opening).

Shade angle required to achieve 80% shade: $\frac{(180^o \cdot 80\%)}{2} = 72^o$.



What 72^o Vegetation Shade Angle Implies:

The vegetation shade angle is a function of vegetation height and the position of the vegetation relative to the stream. Assuming that the vegetation is vertical along the stream banks, the estimated required vegetation height needed to produce a 72^o vegetation shade angle is:

$$\text{Height}_{\text{vegetation}} = \tan(72^o) \cdot \frac{1}{2} \text{Width}_{\text{stream}}$$

where,

$\text{Height}_{\text{vegetation}}$: Vegetation height
$\text{Width}_{\text{stream}}$: Width of the active channel

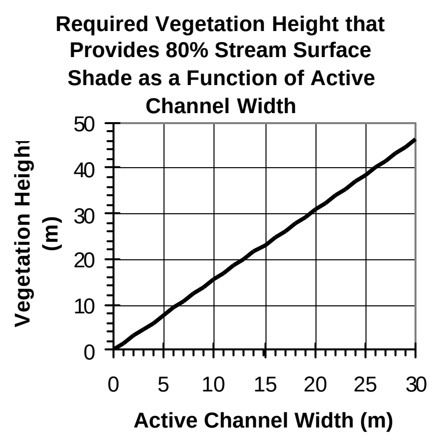
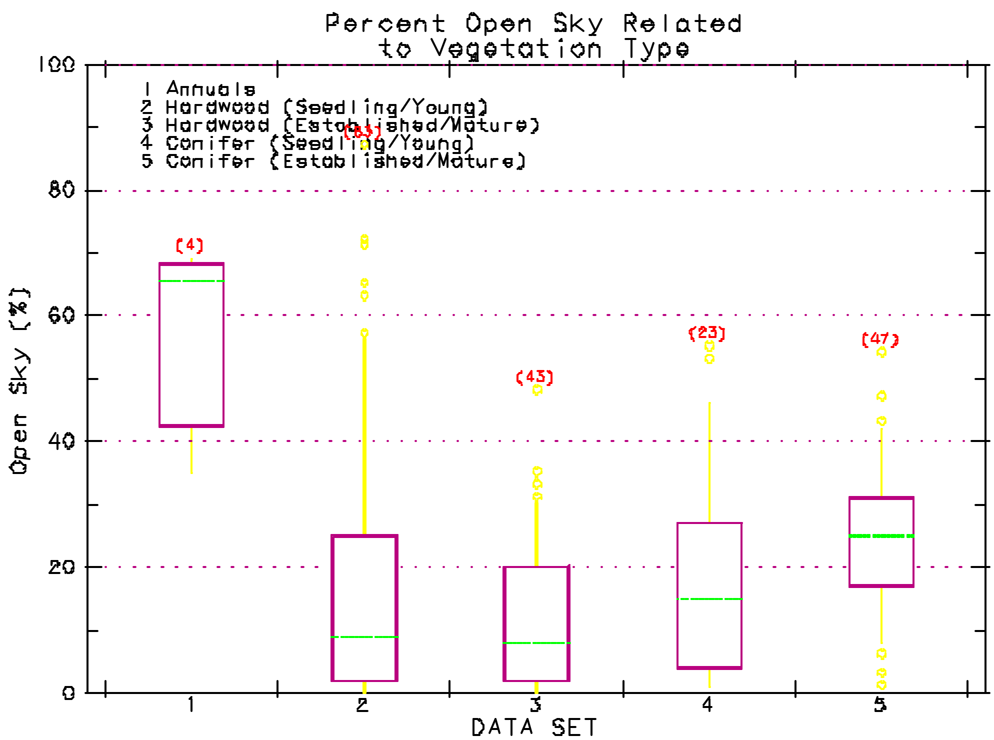


Figure 25 displays the percent open sky related to various riparian vegetation types. Annual riparian vegetation types correlate with low shade percentages (i.e., high open sky percentages). The median open sky value for annual riparian vegetation is 63%, which would suggest a median value of 37% shade. Woody riparian vegetation types have much less exposure incoming radiant sources due to lower open sky measurements. Hardwoods have lower median open sky percentages (Seedling/Young – 7%, Established/Mature – 6%). Conifers have a slightly higher open sky percentage (Seedling/Young – 12%, Established/Mature – 22%). The older woody riparian vegetation classification for both hardwoods and conifers has a lower amount of variability associate with the measured values.

Figure 25. Percent Open Sky Related to Various Riparian Vegetation Types (using only *Survey 2* riparian vegetation observations and open sky data)



3.4 Riparian Vegetation Geometry

The Oregon GAP Analysis Program has mapped the dominant vegetation and land covers in the Tillamook Basin (Oregon GAP Analysis Program, 1992). The minimal mapping unit was 133 hectares (320 acres), making this data layer coarse. However, the vegetation and land cover data layer does demonstrate that the Tillamook Basin is largely dominated by large growing conifers (i.e. evergreen trees). **Image 6** summarizes dominant vegetation types, and makes no reference to seral stage (i.e. vegetation life stages) or fragmentation. This data layer provides the basis for determinations of site potential tree geometry. Potential tree heights of species indigenous to the Tillamook Basin are presented in **Figure 26**, while **Table 9** defines various buffer stages, culminating with site potential riparian vegetation.

Image 6. Dominant Vegetation and Land Cover in the Tillamook Basin
(Oregon GAP Analysis Program, 1992)

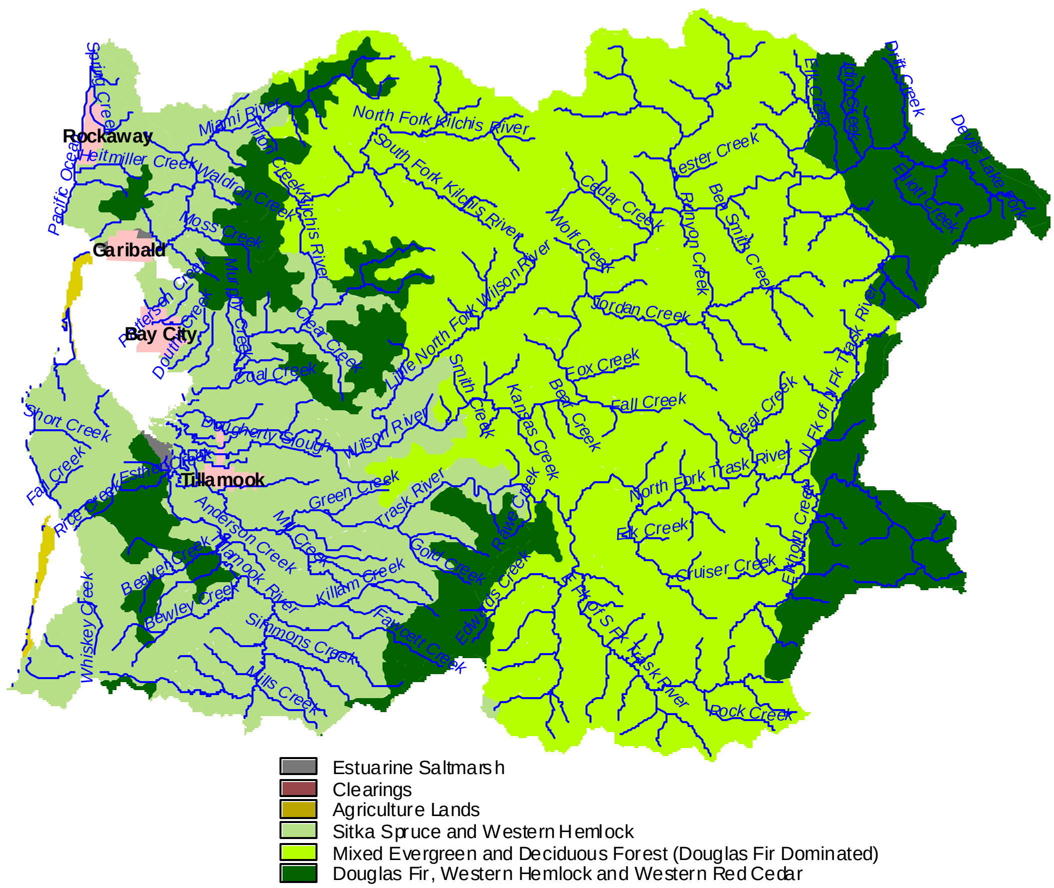
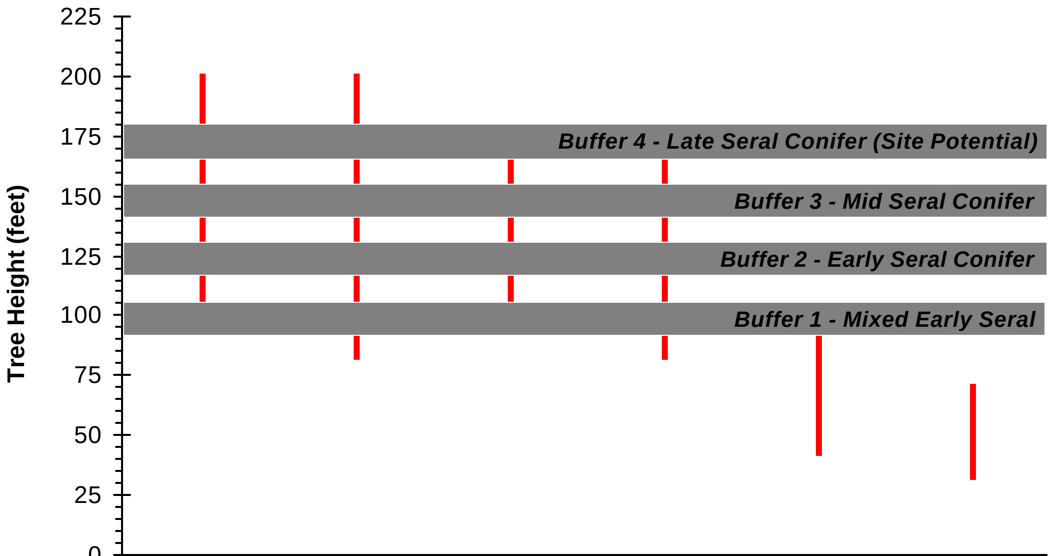


Figure 26. Tree Heights for Dominant Tree Species in the Tillamook Basin *(Whitney, 1997)*



	Western Red Cedar	Douglas Fir	Sitka Spruce	Western Hemlock	Red Alder	Giant Maple
Min	100	80	100	80	40	30
Max	200	200	175	175	100	70

Table 9. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition*					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

* This definition of ***Site Potential Riparian Condition*** is referenced heavily throughout this document.

3.5 Effective Shade Curves

Site potential effective shade and solar radiation loading were simulated for various active channel widths (bankfull widths). Site potential vegetation is assumed to be late seral conifer. In the Tillamook Basin, undisturbed riparian areas generally progress towards late seral woody vegetation communities (conifer dominated). Few, if any, riparian areas in the Tillamook Basin are unable to support either late seral woody vegetation or tall growing herbaceous vegetation. Further, the climate and topography are well suited for growth and maintenance of large woody vegetative species in the riparian areas that approach, and may exceed, the site potential buffer geometry described in **Table 9** (Buffer 4).

Active (bankfull) channel width, aspect, and riparian dimensions can be utilized to predict the effective shade that results for any given latitude and longitude. **Table 10** lists the active channel and aspect data that exist for streams within the Tillamook Basin. Buffer descriptions are listed in **Table 9**. Using these data, one can reference the *effective shade curves* (**Figures 27, 28, 29** and **30**) to estimate the effective shade and daily solar radiation loading that results for all mainstem and tributary reaches on the Tillamook Basin. For streams not listed in **Table 10**, further data collection may be needed to determine potential effective shade levels.

Table 10. Stream Reach Data – Active Channel Width and Aspect

Stream Reach	Lower Extent	Upper Extent	Active Channel Width (meters)	Aspect (Degrees from North)
Clear Cr.	Mouth	Headwaters	9.7	315
N.F. Kilchis R.	Mouth	Headwaters	20.3	270
Sam Downs Cr.	Mouth	Headwaters	9.6	270
S.F. Kilchis R	Mouth	Headwaters	17.4	270
Little S.F. Kilchis R	Mouth	Headwaters	16.0	245
Kilchis R.	Mouth	Little S.F.	36.0	250
Kilchis R.	Little S.F.	S.F./N.F.	33.7	180
Miami R.	Mouth	Headwaters	14.6	225
Moss Creek (OFIC)	Mouth	Headwaters	8.4	315
Peterson Creek (OFIC)	Mouth	Headwaters	4.4	135
Margary Cr. (OFIC)	Mouth	Headwaters	4.0	160
Little N.F.	Mouth	Headwaters	15.5	225
Devils Lake Fork	Mouth	Idiot Creek	11.3	270
Devils Lake Fork	Idiot Creek	Headwaters	7.1	270
Idiot Cr.	Mouth	Headwaters	7.4	160
Elliot Cr.	Mouth	Headwaters	5.4	45
Deyoe Cr.	Mouth	Headwaters	7.3	0
S.F. Wilson R	DLF	Headwaters	7.4	315
Drift Cr.	Mouth	Headwaters	7.2	180
Fall Cr.	Mouth	Headwaters	7.8	280
Kansas Cr.	Mouth	Headwaters	4.3	340

Table 10 (continued). Stream Reach Data – Active Channel Width and Aspect

Stream Reach	Lower Extent	Upper Extent	Active Channel Width (meters)	Aspect (Degrees from North)
SF Jordan Cr.	Mouth	Headwaters	8.9	315
Berry Cr.	Mouth	Headwaters	8.5	180
Wilson R.	Mouth	Little N.F.	42.7	90
Wilson R.	Little N.F.	Fall Cr.	38.1	45
Wilson R.	Fall Cr.	Cedar Cr.	45.7	180
Wilson R.	Cedar Cr.	N.F.	61.0	90
Wilson R.	N.F.	S.F./D.L.F.	21.3	45
N.F. Wilson R.	Mouth	W.F. of N.F.	27.4	90
N.F. Wilson R.	W.F. of N.F.	Headwaters	21.3	45
W.F. N.F. Wilson R.	Mouth	Headwaters	10.4	90
White Cr.	Mouth	Headwaters	6.9	180
Trask R.	Mouth	Gold Cr.	42.7	90
Trask R.	Gold Cr.	Gage	38.1	45
Trask R.	Gage	S.F./N.F.	36.6	90
M.F. of N.F. Trask	Mouth	Barney Res.	8.6	290
N.F. of N.F. Trask	Mouth	Headwaters	10.5	200
N.F. Trask	Mouth	Bark Shanty	24.1	270
N.F. Trask	Bark Shanty	NF of NF	22.9	250
Edwards Cr.	Mouth	Headwaters	9.3	90
E.F. of S.F. Trask	Mouth	HQ	12.6	315
E.F. of S.F. Trask	HQ	Headwaters	6.2	290
S.F. Trask	EF of SF	Headwaters	12.8	0
Rock Cr.	Mouth	Headwaters	5.5	315
N.F. Gold Cr.	Mouth	Headwaters	4.4	300
Gold Cr.	Mouth	Headwaters	5.7	300
Cruiser Cr.	Mouth	Headwaters	8.5	70
Elkhorn Cr.	Mouth	Headwaters	14.6	45
Stretch Cr.	Mouth	Headwaters	4.4	20
Steampot Cr.	Mouth	Headwaters	6.0	225
Scotch Cr.	Mouth	Headwaters	4.5	270
Pigeon Cr.	Mouth	Headwaters	4.6	225
Miller Cr.	Mouth	Headwaters	4.2	20
Joyce Cr.	Mouth	Headwaters	8.5	45
HQ Camp Cr.	Mouth	Headwaters	4.5	315
Clear Cr.	Mouth	Headwaters	12.1	180
Boundary Cr.	Mouth	Headwaters	4.7	45
Blue Bus Cr.	Mouth	Headwaters	4.9	280
Bill Cr.	Mouth	Headwaters	8.2	60
Bark Shanty Cr.	Mouth	Headwaters	12.7	315
Bales Cr.	Mouth	Headwaters	7.4	0
Killam Cr.	Mouth	Headwaters	6.6	270
Simmons Cr.	Mouth	Headwaters	9.0	300
Bewely Cr.	Mouth	Headwaters	7.8	45
Fawcett Cr.	Mouth	Headwaters	10.6	270
Tillamook R.	Simons Cr.	Mills Cr.	14.6	0
Tillamook R.	Mills Cr.	Headwaters	6.5	90
Tillamook R.	Mouth	Bewley Cr.	22.8	135
Tillamook R.	Bewley Cr.	Simons Cr.	20.7	180

Figure 27. Buffer 1 Effective Shade and Solar Radiation Loading Based on Bankfull Channel Width and Stream Orientation (Aspect) for Late July and Early August

Site Potential Riparian Vegetation

Buffer Height: 100 feet (30.48 meters)
Buffer Width: 100 feet (30.48 meters)
Buffer Density: 65%
Overhanging Vegetation: 15%

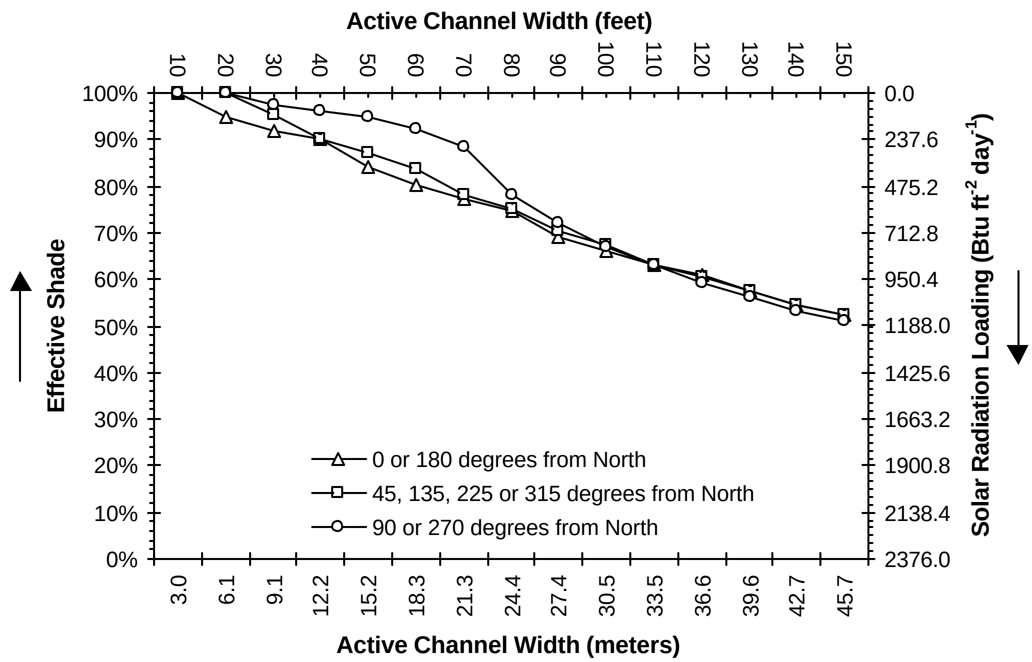


Figure 28. Buffer 2 Effective Shade and Solar Radiation Loading Based on Bankfull Channel Width and Stream Orientation (Aspect) for Late July and Early August

Site Potential Riparian Vegetation

Buffer Height: 125 feet (38.10 meters)
Buffer Width: 100 feet (30.48 meters)
Buffer Density: 70%
Overhanging Vegetation: 15%

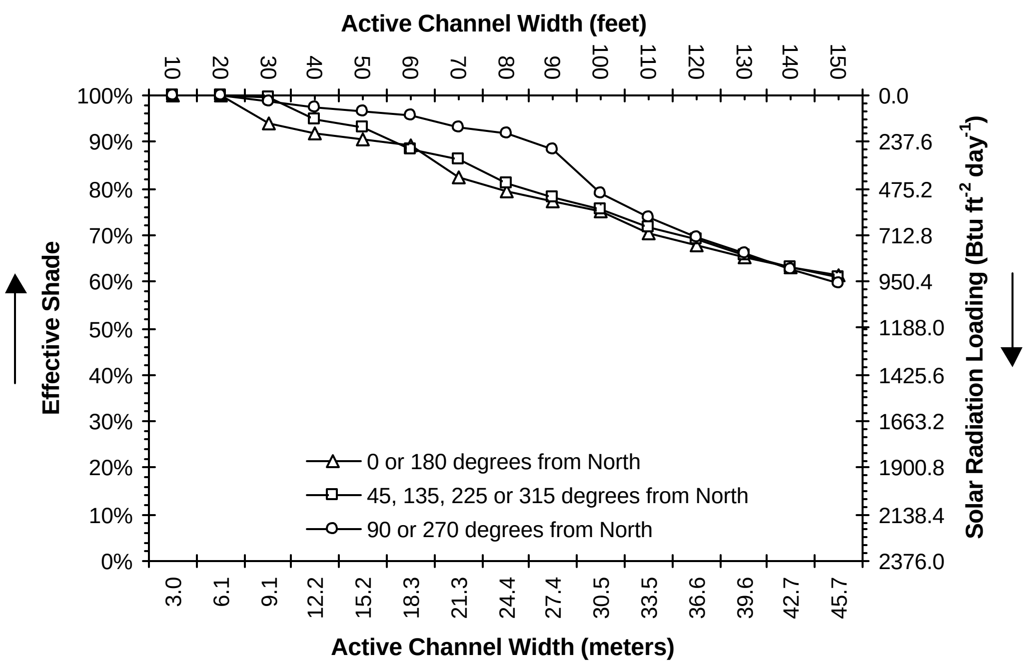


Figure 29. Buffer 3 Effective Shade and Solar Radiation Loading Based on Bankfull Channel Width and Stream Orientation (Aspect) for Late July and Early August

Site Potential Riparian Vegetation

Buffer Height: 150 feet (45.72 meters)
Buffer Width: 100 feet (30.48 meters)
Buffer Density: 75%
Overhanging Vegetation: 15%

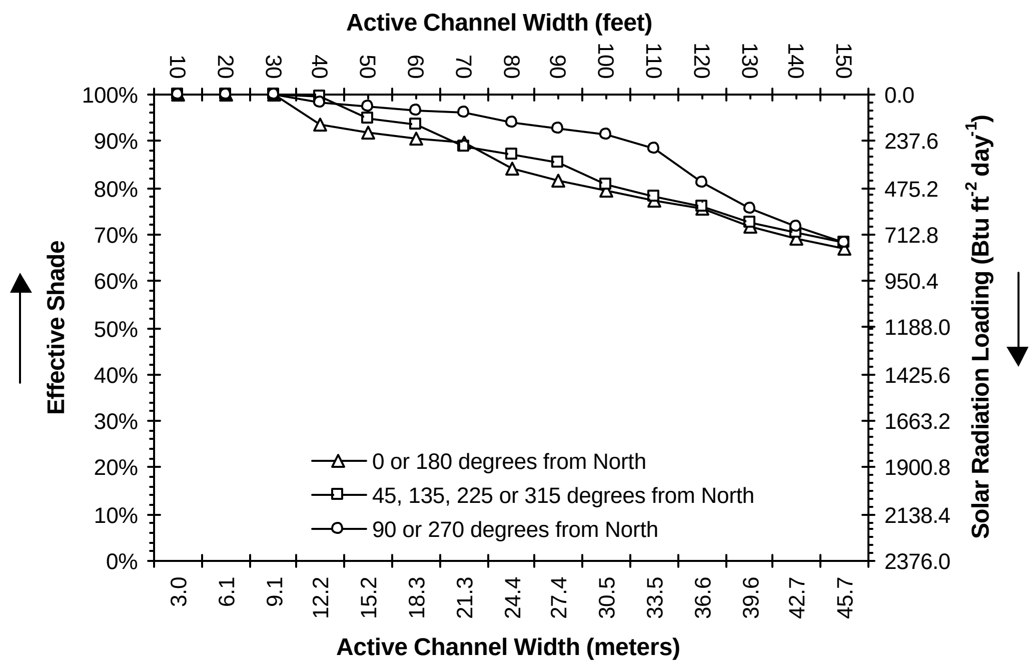
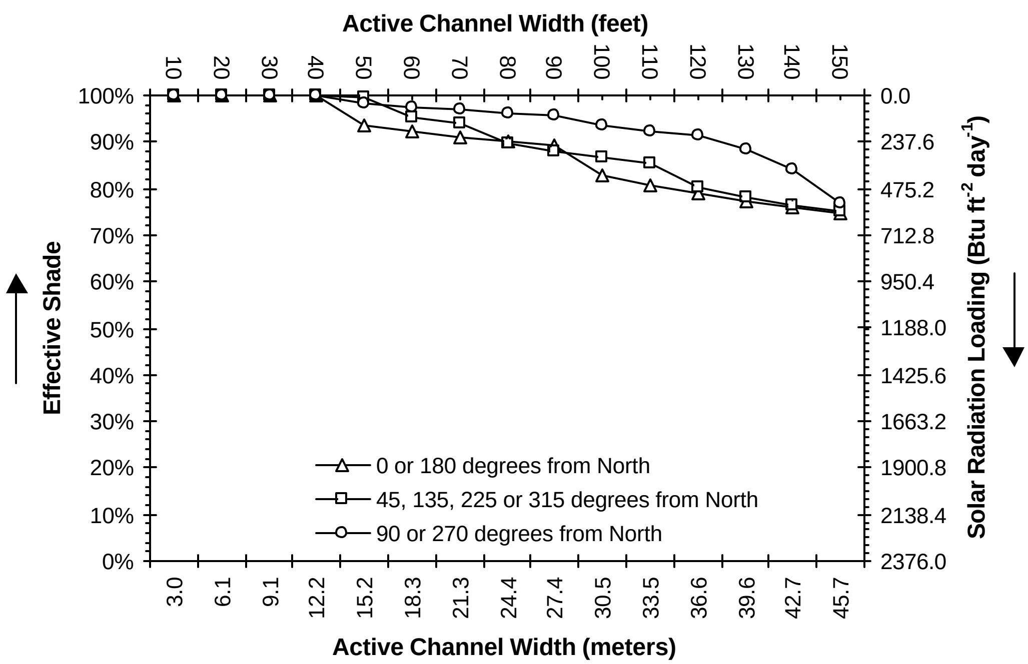


Figure 30. Buffer 4 (Site Potential) Effective Shade and Solar Radiation Loading Based on Bankfull Channel Width and Stream Orientation (Aspect) for Late July and Early August

Site Potential Riparian Vegetation

Buffer Height: 175 feet (53.34 meters)
Buffer Width: 100 feet (30.48 meters)
Buffer Density: 80%
Overhanging Vegetation: 15%



4. TARGETS

4.1 Target Identification - Applicable Water Quality Standards

The Oregon Environmental Quality Commission has adopted numeric and narrative water quality standards to protect designated *beneficial uses.* In practice, water quality standards have been set at a level to protect the most sensitive uses and seasonal standards may be applied for uses that do not occur year round. Cold-water aquatic life such as salmon and trout are often the most sensitive *beneficial uses* in the Tillamook Basin. In this largely forested basin, concerns related to the effects of excessive water temperatures on rearing of salmonid fish have been well documented. The 303(d) temperature limited waters in the Tillamook Basin are displayed in **Image 7**.

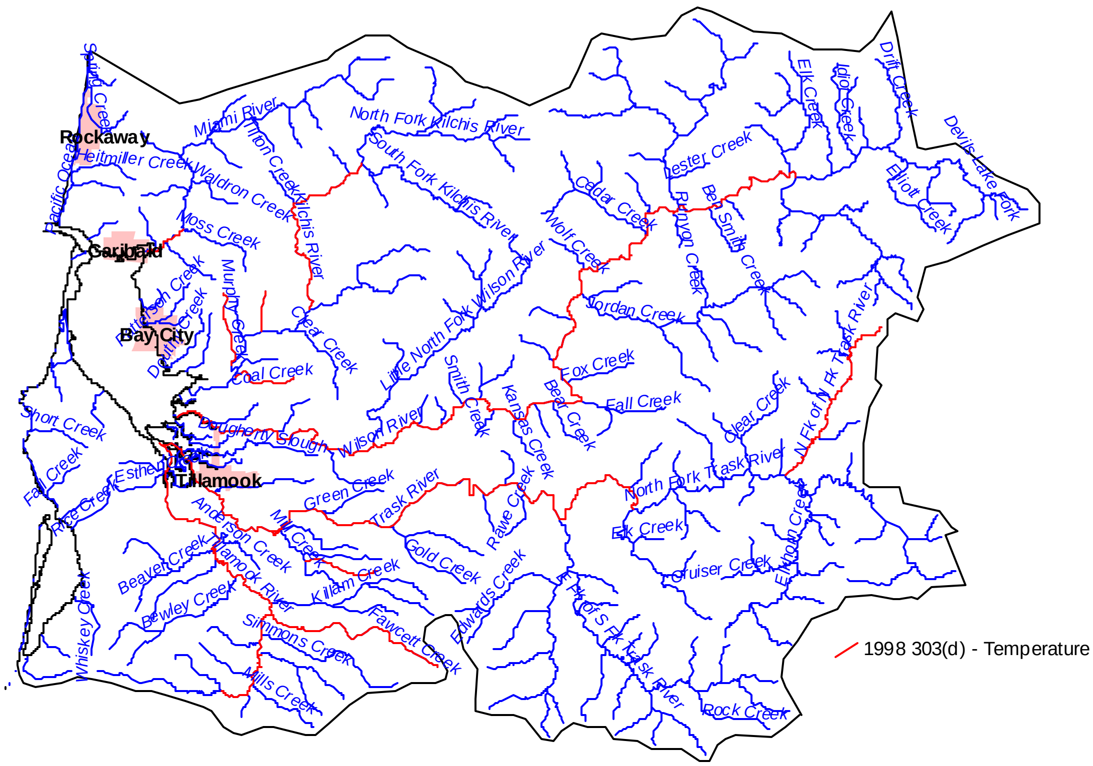
Applicable Water Quality Standards:

Temperature: *OAR 340-41-205(2)(b)(A)*
The seven day moving average of the daily maximum shall not exceed the following values unless specifically allowed under a Department-approved basin surface water management plan:

64°F (17.8°C)
-or-
55°F (12.8°C).

*Where **55°F (12.8°C)** applies during times and in waters that support salmonid spawning, egg incubation and fry emergence from the egg and from the gravel.*

Image 7. 303(d) Temperature Limited Waters in the Tillamook Basin



4.2 Deviation From Targets – Existing Conditions

4.2.1 Spatial Temperature Distributions

A summary of the temperature data collected in the Tillamook Basin during the 1997 and 1998 summertime seasons is shown in **Image 8**. Generally, stream temperatures follow a longitudinal (downstream) heating pattern, where smaller tributaries are cooler than the mainstem reaches. **Figure 31** displays stream heating as a function of measured perennial stream distance from headwaters. Headwater temperatures are near groundwater temperatures, 10.6°C to 11.7°C (51°F to 53°F), and warm roughly 11.1°C to 13.9°C to tidewater influences. A more detailed discussion of stream heating profiles is presented in **APPENDICES A, B, C** and **D**.

Image 8. Tillamook Basin 7-Day Statistic Stream Temperatures
(ODEQ, 1997 to 1998)

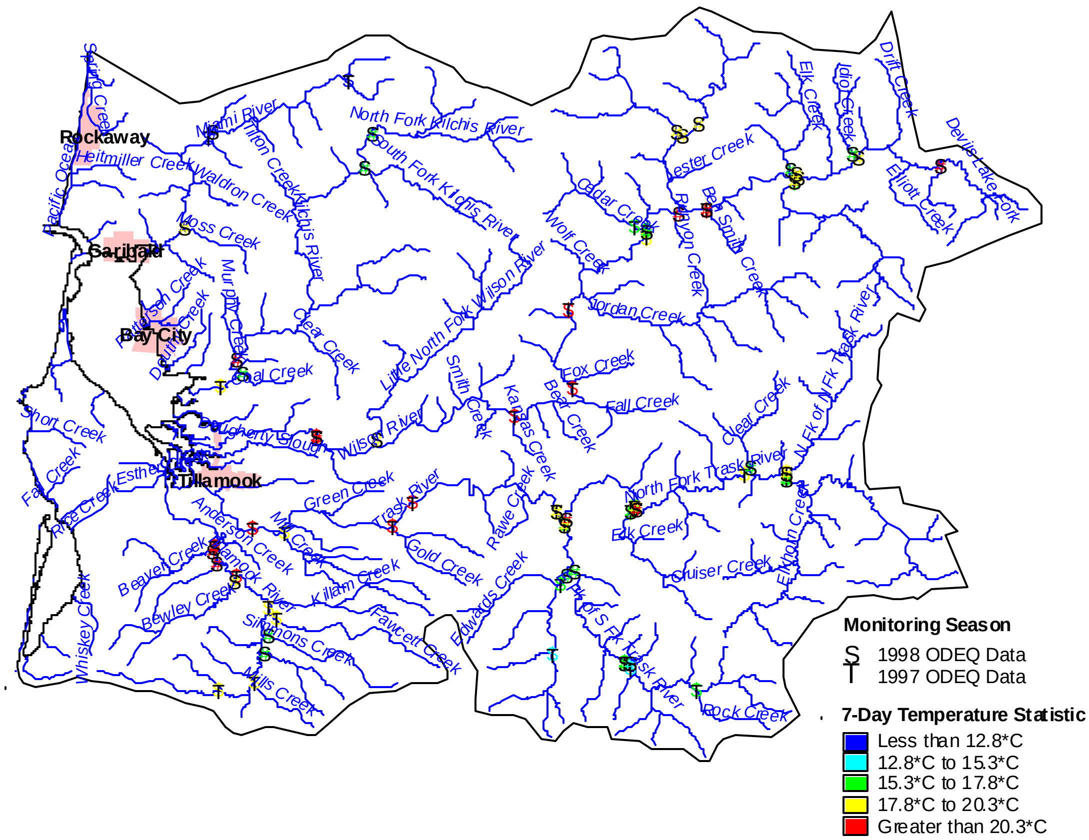
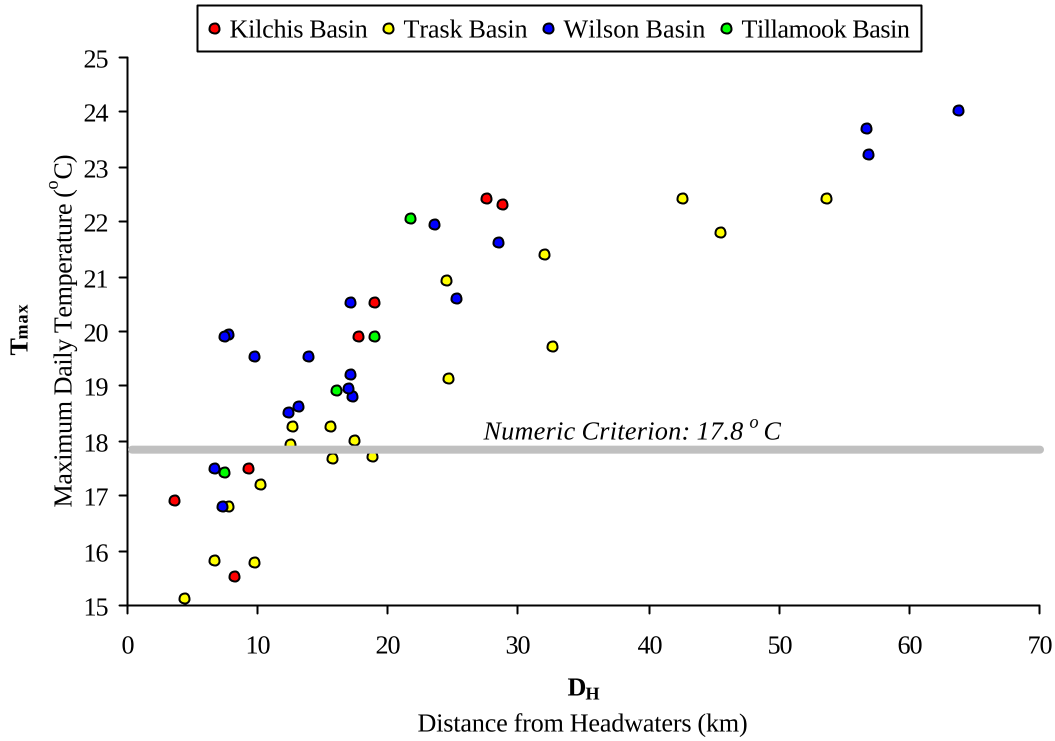


Figure 31. Maximum Daily Temperature Values Related to Distance from Headwaters *(ODEQ, August 12, 1998)*



5. TMDL – LOADING CAPACITIES AND SURROGATE MEASURES (ALLOCATIONS)

5.1 Loading Capacity

5.1.1 Regulatory Framework

Under the current regulatory framework for development of TMDLs, identification of the loading capacity is an important first step. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with standards. By definition, TMDLs are the sum of the allocations [40 CFR 130.2(i)]. Allocations are defined as the portion of a receiving water loading capacity that is allocated to point or nonpoint sources and natural background. EPA's current regulation defines loading capacity as "*the greatest amount of loading that a water can receive without violating water quality standards*."

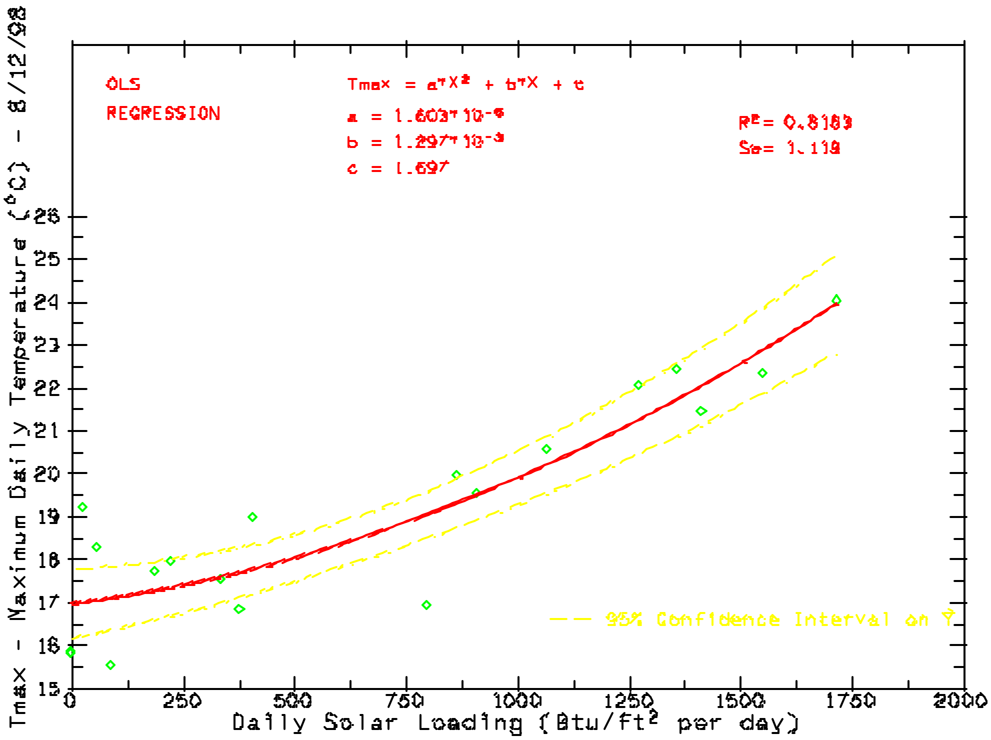
5.1.2 Solar Radiation Loading Capacities

- For stream reaches with known bankfull channel widths, daily solar radiation loading capacities have been calculated and are listed in **Table 11**,
- Stream reaches without quantified bankfull widths are assigned a solar radiation loading capacity of **422 Btu/ft^2 per day** (justification provided in **Section 5.1.3**), or
- Upon future quantification of stream reach bankfull widths, solar radiation loading capacities can be derived from **Section 3.5 – Effective Shade Curves**.

Loading capacities in the Tillamook Basin are heat energy from incoming solar radiation expressed as Btu/ft^2 per day. Analysis/Simulation of heat transfer processes indicate that water temperatures increase above natural daily fluctuations when the heat load from solar radiation is above those allowed by site potential riparian vegetation conditions (see **APPENDICES A, B, C** and **D**).

Site potential solar radiation loading is based on bankfull channel width and stream orientation for late July and early August. Recognition of riparian site potential is utilized to capture optimal and realistic heat energy reductions. Streams in which solar loading has been determined to correspond to climax riparian vegetation are allocated site potential solar loading capacities. **Table 11** lists the site potential loading capacities for stream reaches in the Tillamook Basin. Streams that are not listed in **Table 11** do not have data that allow site potential analysis, and therefore, are assigned *422 Btu/ft^2 per day* as a solar radiation loading capacity. **Figure 32** justifies the loading capacity determination by correlating reach length averaged solar radiation loading to maximum daily stream temperature magnitude.

Figure 32. Maximum Daily Stream Temperature Related to Solar Radiation Loading
(ODEQ Data – August 12, 1998)



In terms of water temperature increases, the principle source of heat energy is solar radiation directly striking the stream surface. **Figure 33** illustrates the total energy budget for Tillamook Basin streams in the *reach averaged* current condition (Current Solar Loading = 890 $Btu{\cdot}ft^{-2}{\cdot}day^{-1}$) and the targeted loading capacity condition (Solar Loading Capacity = 422 $Btu{\cdot}ft^{-2}{\cdot}day^{-1}$). Note that the targeted solar loading capacity condition results in significant diurnal heat energy reductions. **Figure 33** clearly shows solar radiation is the predominant heat energy process in the current condition simulation. The simulated loading capacity (targeted condition) is also displayed in **Figure 33**, where a significant reduction in the diurnal (daily) solar radiation load is apparent.

Figure 33. Simulated Daily Heat Energy Balance Based on Reach Average Current Conditions and Reach Average Loading Capacity
(ODEQ Simulation)

Current Condition
Total Reach Averaged Solar Loading
(Current Solar Loading = 890 $Btu \cdot ft^{-2} \cdot day^{-1}$)

Load Capacity – Targeted Condition
Reach Averaged Solar Loading
(Targeted Solar Loading = 422 $Btu \cdot ft^{-2} \cdot day^{-1}$)

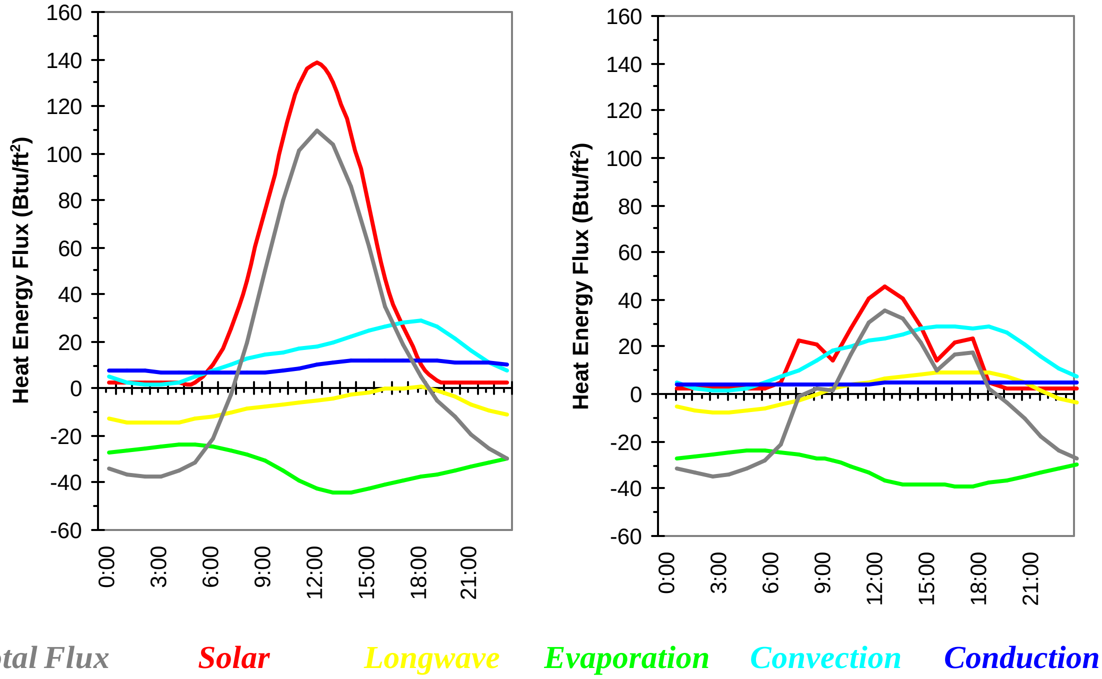


Table 11. Loading Capacity - (Daily Solar Radiation Loading)

Stream Reach			Daily Solar Radiation Loading (Btu·ft^{-2}·day^{-1})			
Stream	**Lower Extent**	**Upper Extent**	**Buffer 1**	**Buffer 2**	**Buffer 2**	***Loading Capacity*** **Buffer 4**
Kilchis and Miami Sub-Basin						
Clear Cr.	Mouth	Headwaters	29	11	0	0
N.F. Kilchis R.	Mouth	Headwaters	182	140	107	80
Sam Downs Cr.	Mouth	Headwaters	69	9	0	0
S.F. Kilchis R	Mouth	Headwaters	149	111	82	20
Little S.F. Kilchis R	Mouth	Headwaters	247	138	109	82
Kilchis R.	Mouth	Little S.F.	881	607	416	260
Kilchis R.	Little S.F.	S.F./N.F.	818	658	507	427
Miami R.	Mouth	Headwaters	271	142	105	7
Moss Creek (OFIC)	Mouth	Headwaters	91	2	0	0
Peterson Creek (OFIC)	Mouth	Headwaters	0	0	0	0
Margary Creek (OFIC)	Mouth	Headwaters	0	0	0	0
Wilson Sub-Basin						
Wilson R.	Mouth	Little N.F.	1110	885	674	378
Wilson R.	Little N.F.	Fall Cr.	919	716	556	460
Wilson R.	Fall Cr.	Cedar Cr.	1061	858	732	485
Wilson R.	Cedar Cr.	N.F.	1390	1212	1043	881
Wilson R.	N.F.	S.F./D.L.F.	483	309	245	136
N.F. Wilson R.	Mouth	W.F. N.F.	683	618	414	240
N.F. Wilson R.	W.F. N.F.	Headwaters	483	309	245	136
W.F. of N.F. Wilson R.	Mouth	Headwaters	71	44	0	0
Little N.F.	Mouth	Headwaters	289	151	113	11
S.F. Wilson R	Mouth	Headwaters	11	0	0	0
Devils Lake Fork	Mouth	Idiot Creek	78	53	31	0
Devils Lake Fork	Idiot Creek	Headwaters	38	0	0	0
Idiot Cr.	Mouth	Headwaters	11	0	0	0
Elliot Cr.	Mouth	Headwaters	0	0	0	0
Deyoe Cr.	Mouth	Headwaters	145	0	0	0
Drift Cr.	Mouth	Headwaters	145	0	0	0
Fall Cr.	Mouth	Headwaters	91	0	0	0
Kansas Cr.	Mouth	Headwaters	0	0	0	0
SF Jordan Cr.	Mouth	Headwaters	100	4	0	0
Berry Cr.	Mouth	Headwaters	167	122	0	0
White Cr.	Mouth	Headwaters	138	0	0	0
Trask Sub-Basin						
Trask R.	Mouth	Gold Cr.	834	449	229	142
Trask R.	Gold Cr.	Gage	723	538	396	231
Trask R.	Gage	S.F./N.F.	454	182	131	67
N.F. Trask	Mouth	Bark Shanty	500	191	111	87
N.F. Trask	Bark Shanty	NF of NF	409	242	142	113
M.F. of N.F. Trask	Mouth	Barney Res.	69	4	0	0

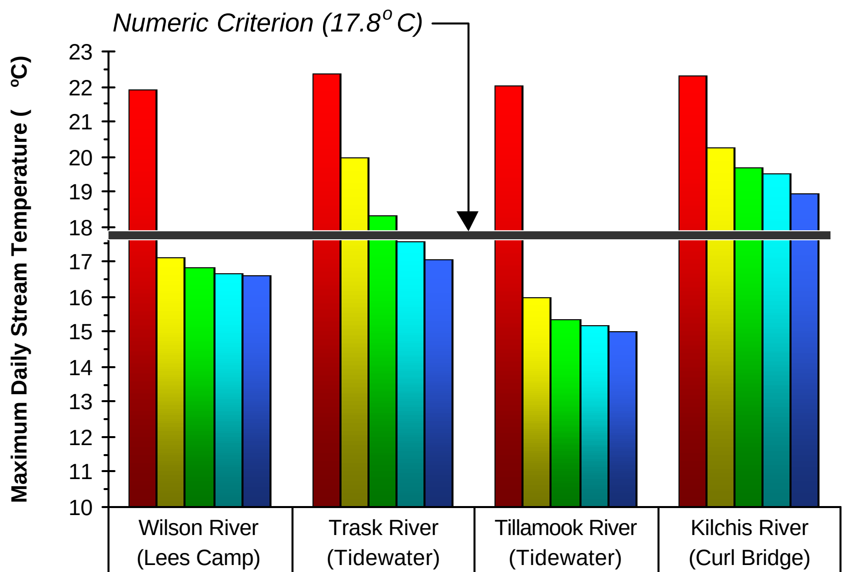
Table 11 (continued). Loading Capacity - (Daily Solar Radiation Loading)

Stream Reach			Daily Solar Radiation Loading ($Btu \cdot ft^{-2} \cdot day^{-1}$)			
Stream	**Lower Extent**	**Upper Extent**	**Buffer 1**	**Buffer 2**	**Buffer 2**	***Loading Capacity*** **Buffer 4**
Trask Sub-Basin (continued)						
N.F. of N.F. Trask	Mouth	Headwaters	140	16	2	0
S.F. Trask	Mouth	E.F. S.F.	256	127	16	4
S.F. Trask	E.F. S.F.	Headwaters	229	187	151	0
E.F. of S.F. Trask	Mouth	HQ	222	113	11	0
E.F. of S.F. Trask	HQ	Headwaters	2	0	0	0
Edwards Cr.	Mouth	Headwaters	60	36	0	0
Rock Cr.	Mouth	Headwaters	0	0	0	0
Gold Cr.	Mouth	Headwaters	0	0	0	0
N.F. Gold Cr.	Mouth	Headwaters	0	0	0	0
Cruiser Cr.	Mouth	Headwaters	67	2	0	0
Elkhorn Cr.	Mouth	Headwaters	271	142	105	9
Stretch Cr.	Mouth	Headwaters	0	0	0	0
Steampot Cr.	Mouth	Headwaters	0	0	0	0
Scotch Cr.	Mouth	Headwaters	0	0	0	0
Pigeon Cr.	Mouth	Headwaters	0	0	0	0
Miller Cr.	Mouth	Headwaters	0	0	0	0
Joyce Cr.	Mouth	Headwaters	98	2	0	0
Headquarters Camp Cr.	Mouth	Headwaters	0	0	0	0
Clear Cr.	Mouth	Headwaters	220	180	140	0
Boundary Cr.	Mouth	Headwaters	0	0	0	0
Blue Bus Cr.	Mouth	Headwaters	0	0	0	0
Bill Cr.	Mouth	Headwaters	18	0	0	0
Bark Shanty Cr.	Mouth	Headwaters	229	116	13	0
Bales Cr.	Mouth	Headwaters	149	0	0	0
Tillamook Sub-Basin						
Tillamook R.	Mouth	Bewley Cr.	507	394	231	198
Tillamook R.	Bewley Cr.	Simons Cr.	463	298	234	129
Tillamook R.	Simons Cr.	Mills Cr.	249	207	171	136
Tillamook R.	Mills Cr.	Headwaters	4	0	0	0
Killam Cr.	Mouth	Headwaters	31	0	0	0
Simmons Cr.	Mouth	Headwaters	22	7	0	0
Bewely Cr.	Mouth	Headwaters	13	0	0	0
Fawcett Cr.	Mouth	Headwaters	71	47	2	0
All other River Reaches see ***Section 3.5 – Effective Shade Curves***						--

5.1.3 Water Quality Attainment - Temperature Related to Solar Loading Capacities

Using mathematical modeling, stream temperatures were simulated for portions of the Tillamook River, Trask River, Wilson River and Kilchis River. With the exception of the Kilchis River, all of the simulations demonstrate that the *loading capacity* as defined (i.e. the solar loading that accompanies site potential riparian vegetation) induces stream temperatures below state of Oregon WQS numeric criterion (i.e., less than 17.8^{o}C). Stream heating is significantly reduced for all stream reaches when solar loading capacities persist. **Figure 34** displays simulation results.

Figure 34. Effect of <u>Solar Radiation Loads</u> on Water Temperature



	Wilson River (Lees Camp)	Trask River (Tidewater)	Tillamook River (Tidewater)	Kilchis River (Curl Bridge)
Current Condition	21.9	22.4	22.0	22.3
Buffer 1	17.1	20.0	16.0	20.3
Buffer 2	16.8	18.3	15.4	19.7
Buffer 3	16.7	17.6	15.2	19.5
Buffer 4 (Site Potential)	16.6	17.0	15.0	19.0

It is likely that the simulation results, presented in **Figure 34**, underestimate potential cooling induced by the loading capacities. The simulation reaches do not extend to headwaters, and in some cases fail to capture large portions of the mainstem and major tributaries. In effect, these modeling results do not represent the true stream networks as they exist, and instead, are selected stream reaches simulated in a series.

5.2 Surrogate Measures (Allocations)

5.2.1 Regulatory Framework

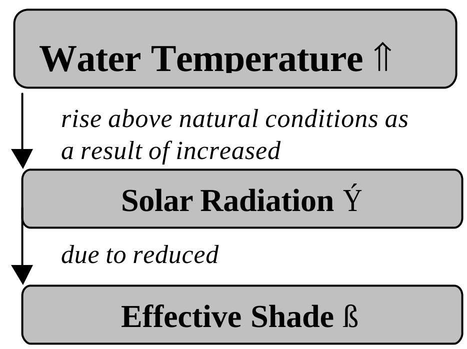
The Tillamook Basin TMDL uses measures other than *"daily loads"* to fulfill requirements of 303(d). Although a loading capacity for heat energy is derived, it is of limited value in guiding management activities needed to solve identified water quality problems. In addition to heat energy loads, the Tillamook Basin TMDL uses *"other appropriate measures"* (or surrogates) as provided under EPA regulations [40 CFR 130.2(i)].

The *Report of Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program"* (FACA Report, July 1998) offers a discussion on the use of surrogate measures for TMDL development. The FACA Report indicates:

> *"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. The criterion must be designed to meet water quality standards, including the waterbody's designated uses. The use of BPJ does not imply lack of rigor; it should make use of the "best" scientific information available, and should be conducted by "professionals." When BPJ is used, care should be taken to document all assumptions, and BPJ-based decisions should be clearly explained to the public at the earliest possible stage.*
>
> *If they are used, surrogate environmental indicators should be clearly related to the water quality standard that the TMDL is designed to achieve. Use of a surrogate environmental parameter should require additional post-implementation verification that attainment of the surrogate parameter results in elimination of the impairment. If not, a procedure should be in place to modify the surrogate parameter or to select a different or additional surrogate parameter and to impose additional remedial measures to eliminate the impairment."*

As discussed, water temperature warms as a result of increased solar radiation loads. A loading capacity for heat energy (i.e. incoming solar radiation) can be used to define a reduction target that forms the basis for identifying a surrogate. The specific surrogate used is percent effective shade (expressed as the percent reduction in potential solar radiation load delivered to the water surface and is defined in **Figure 20**). Decreased effective shade levels result from the lack of adequate riparian vegetation available to reduce sunlight (i.e., incoming solar radiation). The definition of effective shade allows direct measurement of the solar loading capacity.

Because factors that affect water temperature are interrelated, the surrogate measure (percent effective shade) relies on restoring/protecting riparian vegetation to increase stream surface shade levels, reduce stream bank erosion and stabilize channels. Likewise, narrower channels still require riparian vegetation to provide channel stability and shade, thus reducing heat loads (unless confined by canyon walls or shaded by topography). Effective shade screens the water's surface from direct rays of the sun. Highly shaded streams often experience cooler stream temperatures due to reduced input of solar energy (Brown 1969, Beschta et al 1987, Holaday 1992, Li et al 1994). Stream surface shade is dependent on topography as well as riparian vegetation type, condition, and shade quality. Over the years, the term shade has been used in several contexts, including its components such as shade angle or shade density. For purposes of this TMDL, shade is defined as the percent reduction of potential solar radiation load delivered to the water surface. Thus, the role of effective shade in this TMDL is to prevent or reduce heating by solar radiation and serve as a linear translator to the solar loading capacities.

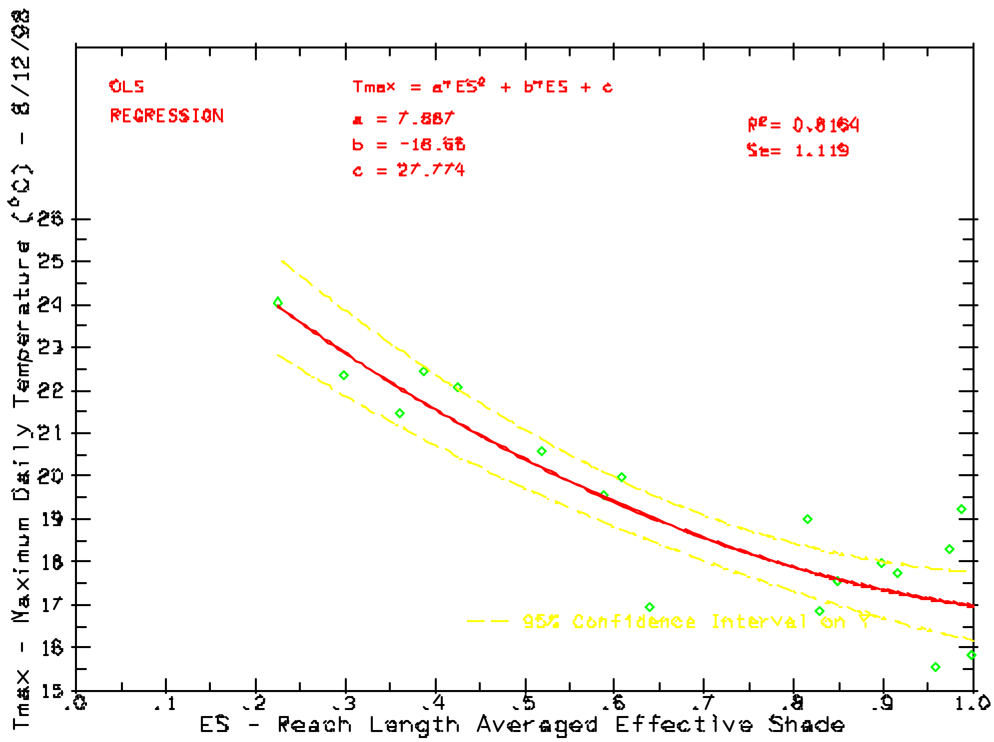


5.2.2 Effective Shade Surrogate Measures (Allocations)

- For stream reaches with known bankfull channel widths, site potential effective shade levels have been allocated and are listed in **Table 12** and displayed in **Image 12**,
- Stream reaches without quantified bankfull channel widths are allocated **81% effective shade** (justification provided in **Figure 35**), or
- Upon future quantification of stream reach bankfull channel widths, effective shade allocations can be derived from **Section 3.5 – Effective Shade Curves**.

Allocations in the Tillamook Basin Temperature TMDL are derived using heat loads. Percent effective shade (surrogate measure) can be linked to specific areas and, thus, to management actions needed to solve problems that cause water temperature increases. Site potential effective shade is based on bankfull channel width and stream orientation for late July and early August. Recognition of riparian site potential is utilized to capture optimal and realistic effective shade allocations. **Table 12** lists the site potential effective shade allocations (i.e. surrogate measure) for stream reaches in the Tillamook Basin. Streams that are not listed in **Table 12** do not have data that allow site potential analysis, and therefore, are assigned *81% effective shade* as an allocation (i.e. surrogate measure). **Figure 35** justifies the *81% effective shade* determination by correlating reach length averaged effective shade to maximum daily stream temperature magnitude.

Figure 35. August 12, 1998 Maximum Daily Temperature Correlated with Reach Length Averaged Effective Shade (*ODEQ data, 1998*)



Quadratic Equation:

$$T_{\max} = a \cdot ES^2 + b \cdot ES + c$$

$$T_{\max} = 7.887 \cdot ES^2 - 18.66 \cdot ES + 27.774$$

Solving for Reach Average Effective Shade (ES) when $T_{max} = 17.8^{o}C$:

$$Es = \frac{-b \pm \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$$

when a = 7.877, b = -18.66, and c = 9.974 (i.e., 27.774 – 17.8 (T_{max}))

Then

$$ES = \frac{-(-18.66) \pm \sqrt{(-18.66)^2 - 4 \cdot (7.877) \cdot (9.974)}}{2 \cdot (7.887)} = [81\%, 155\%]$$

Only the 81% result is applicable for purposes of this TMDL (155% is not a valid effective shade value).

Reach length averaged effective shade levels were calculated for all stream reaches that have measured bankfull channel width data. The effective shade calculations are based on the buffer definitions presented in **Table 9**. It is logical to assume the rate of tree growth is the limiting factor in attaining site potential effective shade levels. **Images 9, 10** and **11** represent an estimate of effective shade at various stages of tree maturation. **Image 12** displays the effective shade allocations for the Tillamook Basin where bankfull channel widths are known. **Table 12** contains the shade calculations for all four buffers for each reach.

Recall Table 9. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

Image 9. Buffer 1 Potential and Measured Effective Shade *(ODEQ Data, 1998)*

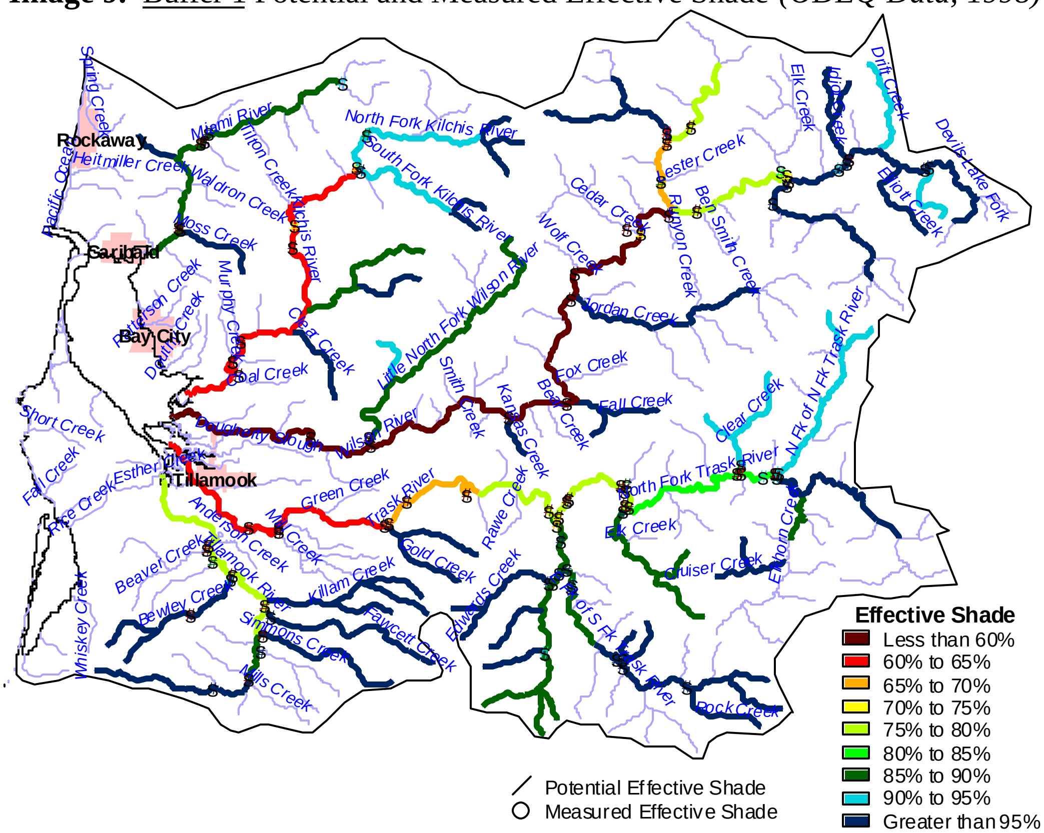


Image 10. Buffer 2 Potential and Measured Effective Shade *(ODEQ Data, 1998)*

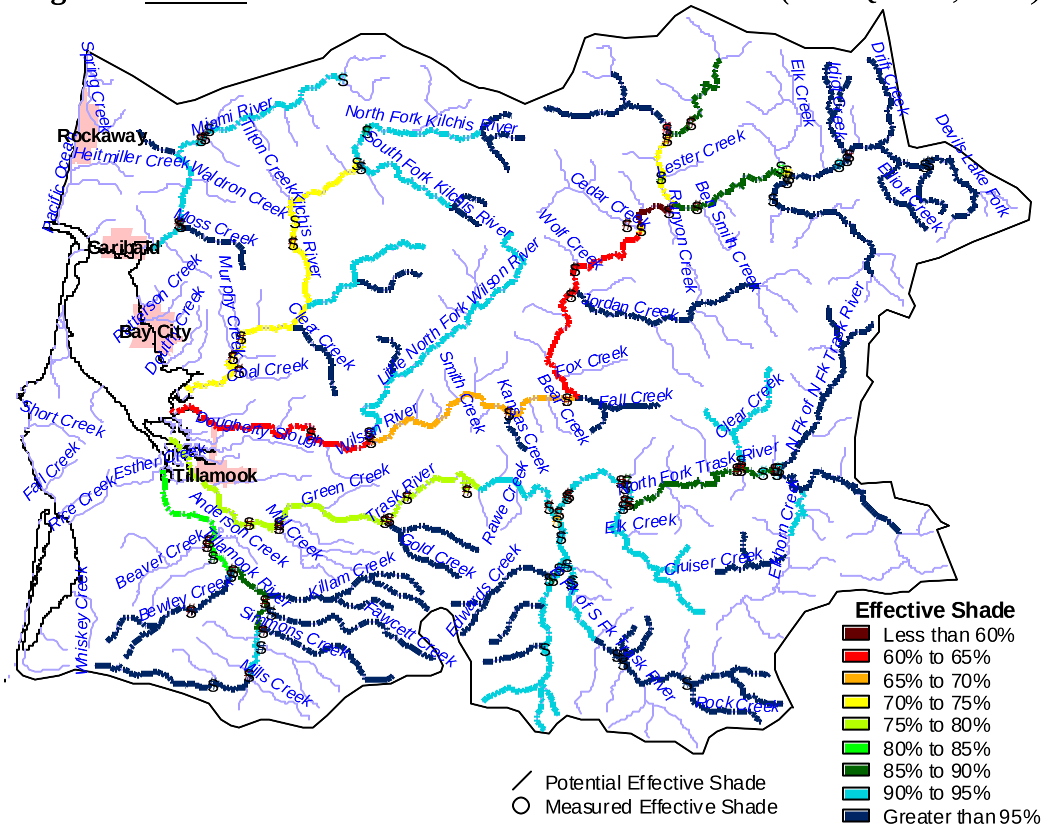


Image 11. Buffer 3 Potential and Measured Effective Shade *(ODEQ Data, 1998)*

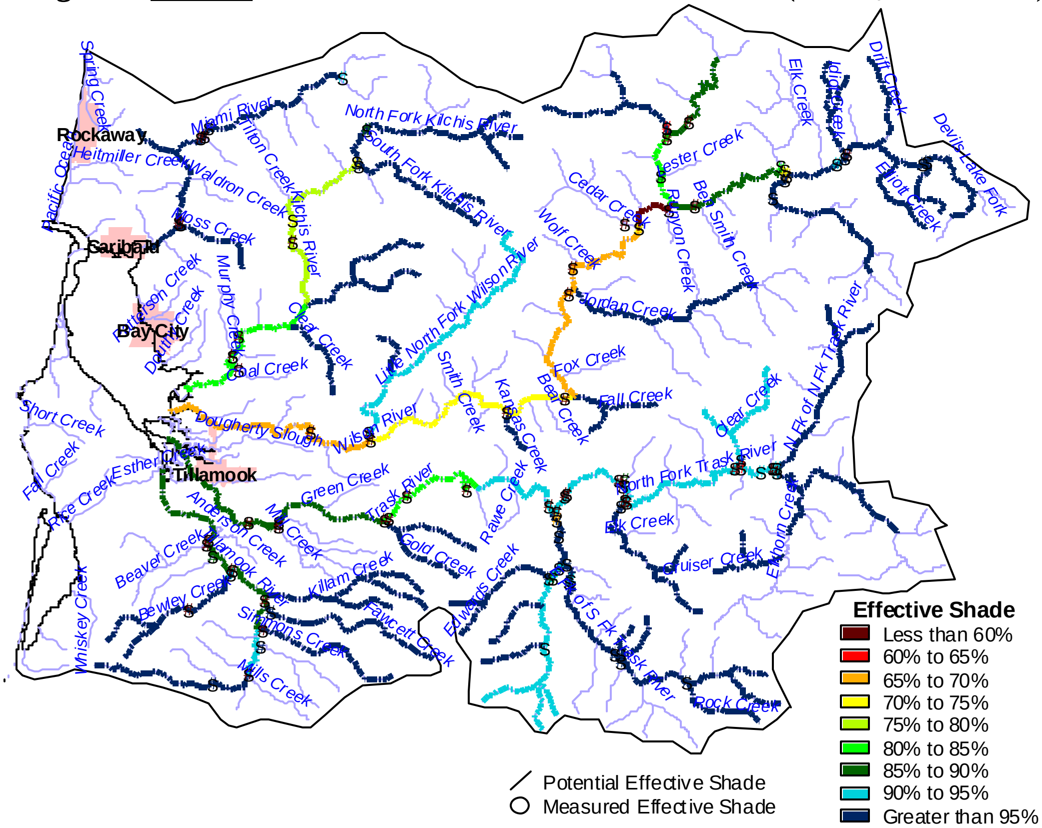


Image 12. <u>Buffer 4 (Site Potential)</u> and Measured Effective Shade *(ODEQ Data, 1998)*

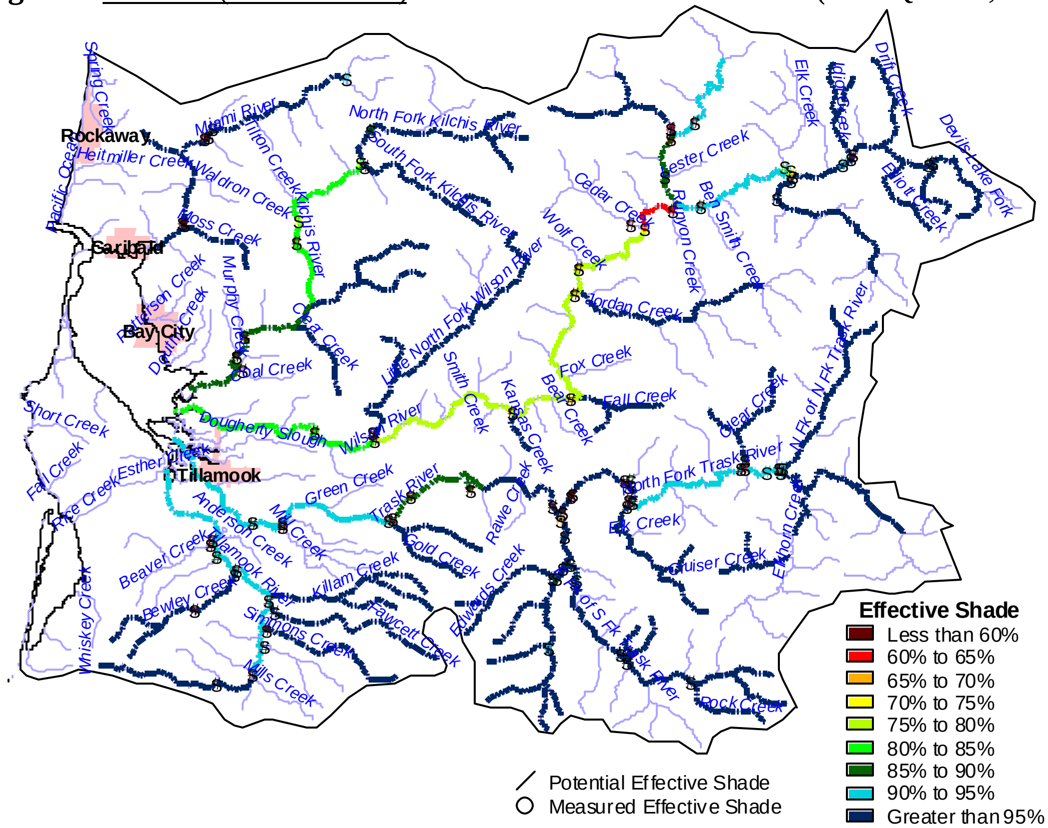


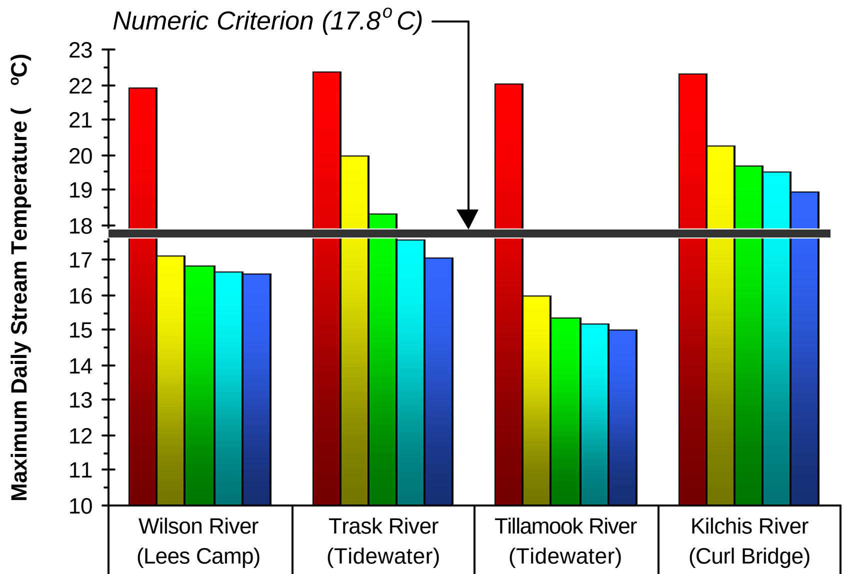
Table 12. Surrogate Measures – Allocations (Effective Shade)						
Stream Reach			**Effective Shade**			
Stream	**Lower Extent**	**Upper Extent**	**Buffer 1**	**Buffer 2**	**Buffer 2**	***Surrogate Measure*** **Buffer 4**
Kilchis Sub-Basin						
Clear Cr.	Mouth	Headwaters	98.7%	99.5%	100.0%	100.0%
N.F. Kilchis R.	Mouth	Headwaters	91.8%	93.7%	95.2%	96.4%
Sam Downs Cr.	Mouth	Headwaters	96.9%	99.6%	100.0%	100.0%
S.F. Kilchis R	Mouth	Headwaters	93.3%	95.0%	96.3%	99.1%
Little S.F. Kilchis R	Mouth	Headwaters	88.9%	93.8%	95.1%	96.3%
Kilchis R.	Mouth	Little S.F.	60.4%	72.7%	81.3%	88.3%
Kilchis R.	Little S.F.	S.F./N.F.	63.2%	70.4%	77.2%	80.8%
Miami R.	Mouth	Headwaters	87.8%	93.6%	95.3%	99.7%
Moss Creek (OFIC)	Mouth	Headwaters	95.9%	99.9%	100.0%	100.0%
Peterson Creek (OFIC)	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Margary Creek (OFIC)	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Wilson Sub-Basin						
Wilson R.	Mouth	Little N.F.	50.1%	60.2%	69.7%	83.0%
Wilson R.	Little N.F.	Fall Cr.	58.7%	67.8%	75.0%	79.3%
Wilson R.	Fall Cr.	Cedar Cr.	52.3%	61.4%	67.1%	78.2%
Wilson R.	Cedar Cr.	N.F.	37.5%	45.5%	53.1%	60.4%
Wilson R.	N.F.	S.F./D.L.F.	78.3%	86.1%	89.0%	93.9%
N.F. Wilson R.	Mouth	W.F. N.F.	69.3%	72.2%	81.4%	89.2%
N.F. Wilson R.	W.F. N.F.	Headwaters	78.3%	86.1%	89.0%	93.9%
W.F. of N.F. Wilson R.	Mouth	Headwaters	96.8%	98.0%	100.0%	100.0%
Little N.F.	Mouth	Headwaters	87.0%	93.2%	94.9%	99.5%
S.F. Wilson R	Mouth	Headwaters	99.5%	100.0%	100.0%	100.0%
Devils Lake Fork	Mouth	Idiot Creek	96.5%	97.6%	98.6%	100.0%
Devils Lake Fork	Idiot Creek	Headwaters	98.3%	100.0%	100.0%	100.0%
Idiot Cr.	Mouth	Headwaters	99.5%	100.0%	100.0%	100.0%
Elliot Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Deyoe Cr.	Mouth	Headwaters	93.5%	100.0%	100.0%	100.0%
Drift Cr.	Mouth	Headwaters	93.5%	100.0%	100.0%	100.0%
Fall Cr.	Mouth	Headwaters	95.9%	100.0%	100.0%	100.0%
Kansas Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
SF Jordan Cr.	Mouth	Headwaters	95.5%	99.8%	100.0%	100.0%
Berry Cr.	Mouth	Headwaters	92.5%	94.5%	100.0%	100.0%
White Cr.	Mouth	Headwaters	93.8%	100.0%	100.0%	100.0%
Trask Sub-Basin						
Trask R.	Mouth	Gold Cr.	62.5%	79.8%	89.7%	93.6%
Trask R.	Gold Cr.	Gage	67.5%	75.8%	82.2%	89.6%
Trask R.	Gage	S.F./N.F.	79.6%	91.8%	94.1%	97.0%
N.F. Trask	Mouth	Bark Shanty	77.5%	91.4%	95.0%	96.1%
N.F. Trask	Bark Shanty	NF of NF	81.6%	89.1%	93.6%	94.9%
M.F. of N.F. Trask	Mouth	Barney Res.	96.9%	99.8%	100.0%	100.0%
N.F. of N.F. Trask	Mouth	Headwaters	93.7%	99.3%	99.9%	100.0%
S.F. Trask	Mouth	E.F. S.F.	88.5%	94.3%	99.3%	99.8%
S.F. Trask	E.F. S.F.	Headwaters	89.7%	91.6%	93.2%	100.0%
E.F. of S.F. Trask	Mouth	HQ	90.0%	94.9%	99.5%	100.0%

Table 12 (continued). Surrogate Measures – Allocations (Effective Shade)						
Stream Reach			**Effective Shade**			
Stream	**Lower Extent**	**Upper Extent**	**Buffer 1**	**Buffer 2**	**Buffer 2**	***Surrogate Measure*** **Buffer 4**
Trask Sub-Basin (continued)						
E.F. of S.F. Trask	HQ	Headwaters	99.9%	100.0%	100.0%	100.0%
Edwards Cr.	Mouth	Headwaters	97.3%	98.4%	100.0%	100.0%
Rock Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Gold Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
N.F. Gold Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Cruiser Cr.	Mouth	Headwaters	97.0%	99.9%	100.0%	100.0%
Elkhorn Cr.	Mouth	Headwaters	87.8%	93.6%	95.3%	99.6%
Stretch Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Steampot Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Scotch Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Pigeon Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Miller Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Joyce Cr.	Mouth	Headwaters	95.6%	99.9%	100.0%	100.0%
Headquarters Camp Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Clear Cr.	Mouth	Headwaters	90.1%	91.9%	93.7%	100.0%
Boundary Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Blue Bus Cr.	Mouth	Headwaters	100.0%	100.0%	100.0%	100.0%
Bill Cr.	Mouth	Headwaters	99.2%	100.0%	100.0%	100.0%
Bark Shanty Cr.	Mouth	Headwaters	89.7%	94.8%	99.4%	100.0%
Bales Cr.	Mouth	Headwaters	93.3%	100.0%	100.0%	100.0%
Tillamook Sub-Basin						
Tillamook R.	Mouth	Bewley Cr.	77.2%	82.3%	89.6%	91.1%
Tillamook R.	Bewley Cr.	Simons Cr.	79.2%	86.6%	89.5%	94.2%
Tillamook R.	Simons Cr.	Mills Cr.	88.8%	90.7%	92.3%	93.9%
Tillamook R.	Mills Cr.	Headwaters	99.8%	100.0%	100.0%	100.0%
Killam Cr.	Mouth	Headwaters	98.6%	100.0%	100.0%	100.0%
Simmons Cr.	Mouth	Headwaters	99.0%	99.7%	100.0%	100.0%
Bewely Cr.	Mouth	Headwaters	99.4%	100.0%	100.0%	100.0%
Fawcett Cr.	Mouth	Headwaters	96.8%	97.9%	99.9%	100.0%
All other River Reaches see ***Section 3.5 – Effective Shade Curves***						--

5.2.3 Water Quality Attainment - Temperature Related to Shade Surrogate Measures (Allocations)

Stream temperature simulation results, presented in **Figure 34**, clearly demonstrate that site potential effective shade levels can have a drastic stream cooling effect. Language that is more precise would describe the effect of decreased solar loads as preventing stream temperature increases. Simulation results suggest that stream thermal conditions in the Tillamook Basin can have vastly different temperature regimes if adequate riparian protection measures are implemented to promote site potential riparian conditions. This conclusion is consistent with *all* temperature modeling efforts for other waterbodies in the Pacific Northwest (Brown, 1969; Beschta and Weatherred, 1984; Sullivan and Adams, 1990; Boyd, 1996;).

Recall Figure 34. Effect of Solar Radiation Loads on Water Temperature



	Wilson River (Lees Camp)	Trask River (Tidewater)	Tillamook River (Tidewater)	Kilchis River (Curl Bridge)
Current Condition	21.9	22.4	22.0	22.3
Buffer 1	17.1	20.0	16.0	20.3
Buffer 2	16.8	18.3	15.4	19.7
Buffer 3	16.7	17.6	15.2	19.5
Buffer 4 (Site Potential)	16.6	17.0	15.0	19.0

It should be noted that this modeling exercise solely focused on solar radiation as a function of riparian vegetation and the shade it provides the stream. Additional parameters related to riparian vegetation that affect stream temperature are (see **Section 6 - Margin of Safety**):

1. Possible summertime flow augmentation by increasing the volume of water stored in riparian areas and slowly released, and
2. Cool microclimates associated with late seral staged conifer riparian zones.

In essence, excluding flow changes and cool microclimates as they relate to riparian vegetation condition almost certainly underestimates the cooling attributed to allocated riparian restoration scenarios.

6. MARGIN OF SAFETY

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a margin of safety is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving water quality. A margin of safety is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The margin of safety may be implicit, as in conservative assumptions used in calculating the loading capacity (LC), WLAs, and LAs. The margin of safety may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources. **Table 13** presents six approaches for incorporating a margin of safety into TMDLs.

Table 13. Approaches for Incorporating a Margin of Safety into a TMDL

Type of Margin of Safety	Available Approaches
Explicit	1. Set numeric targets at more conservative levels than analytical results indicate 2. Add a safety factor to pollutant loading estimates 3. Do not allocate a portion of available loading capacity; reserve for MOS
Implicit	4. Conservative assumptions in derivation of numeric targets 5. Conservative assumptions when developing numeric model applications 6. Conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

The following factors may be considered in evaluating and deriving an appropriate margin of safety:

- ✓ The limitations in available data in characterizing the waterbody and the pollutant and addressing the components of the TMDL development process.
- ✓ The analysis and techniques used in evaluating the components of the TMDL process and deriving an allocation scheme.
- ✓ Characterization and estimates of source loading (e.g., confidence regarding data limitation, analysis limitation or assumptions)
- ✓ Analysis of relationships between the source loading and instream impact.
- ✓ Prediction of response of receiving waters under various allocation scenarios. (e.g., the predictive capability of the analysis, simplifications in the selected techniques)
- ✓ Expression of analysis results in terms of confidence intervals or ranges. Confidence may be addressed as a cumulative effect on the load allocation or for each of the individual components of the analysis.
- ✓ The implications of the MOS on the overall load reductions identified in terms of reduction feasibility and implementation time frames.

6.1 Adaptive Management

Establishing TMDLs employs a variety of analytical techniques. Some analytical techniques are widely used and applied in evaluation of source loading and determination of the impacts on waterbodies. For certain pollutants, such as heat, the methods used are newer or in development. The selection of analysis techniques is based on scientific rationale coupled with interpretation of observed data. Concerns regarding the appropriateness and scientific integrity of the analysis have been defined and the approach for verifying the analysis through monitoring and implementation addressed. Without the benefit of long term experience and testing of the methods used to derive TMDLs, the potential for the estimate to require refinement is high.

A TMDL and margin of safety, which is reasonable and results in an overall allocation, represents the best estimate of how standards can be achieved. The selection of the MOS should clarify the implications for monitoring and implementation planning in refining the estimate if necessary (adaptive management). The TMDL process accommodates the ability to track and ultimately refine assumptions within the TMDL implementation-planning component.

The Tillamook Basin Temperature TMDL is intended to be adaptive in management implementation. This plan allows for future changes in loading capacities and surrogate measures (allocations) in the event that scientifically valid reasons demand alterations. It is important to recognize the continual study and progression of understanding of water quality parameter addressed in this TMDL/WQMP (stream temperature). The Tillamook

Basin Temperature TMDL addresses future monitoring plans. In the event that data show that changes are warranted in the Tillamook Basin Temperature TMDL or WQMP, these changes will be made by Oregon DEQ.

6.2 Implicit Margin of Safety

Description of the margin of safety for the Tillamook Basin Temperature TMDL begins with a statement of assumptions. A margin of safety has been incorporated into the temperature assessment methodology. Conservative estimates for groundwater inflow and wind speed were used in the stream temperature simulations. Specifically, unless measured, groundwater inflow was assumed to be zero. Wind speed was also assumed to be zero (mph). Recall that groundwater directly cools stream temperatures via mass transfer/mixing. Wind speed is a controlling factor for evaporation, a cooling heat energy process. Further, cooler microclimates associated with late seral conifer riparian zones were not accounted for in the simulation methodology.

Calculating a numeric margin of safety is not easily performed with the methodology presented in this document. In fact, the basis for the loading capacities and allocations is the definition of site potential conditions. It is illogical to presume that anything more than site potential riparian conditions are possible, feasible or reasonable.

7. SEASONAL VARIATION

Section 303(d)(1) requires this TMDL to be "established at a level necessary to implement the applicable water quality standard with seasonal variations." Both stream temperature and flow vary seasonally from year to year. Water temperatures are coolest in winter and early spring months. Stream temperatures exceed State water quality standards in summer and early fall months (June, July, August and September). Warmest stream temperatures correspond to prolonged solar radiation exposure, warm air temperature, low flow conditions and decreased groundwater contribution. These conditions occur during late summer and early fall and promote the warmest seasonal instream temperatures. The analysis presented in this TMDL is performed during summertime periods in which controlling factors for stream temperature are most critical. Annual and seasonal variability is fully described in:

- ✓ **APPENDIX A – TRASK RIVER TEMPERATURE ASSESSMENT**
- ✓ **APPENDIX B – TILLAMOOK RIVER TEMPERATURE ASSESSMENT**
- ✓ **APPENDIX C – WILSON RIVER TEMPERATURE ASSESSMENT**
- ✓ **APPENDIX D – KILCHIS RIVER AND MIAMI RIVER TEMPERATURE ASSESSMENT**

8. PUBLIC PARTICIPATION

>>To be completed<<

9. GLOSSARY OF TERMS

9.1 General Terminology

Active Bank Erosion: Estimates from observation of the active stream bank erosion as a percentage (%) of the total reach length.

Adaptive Management: An iterative process where policy decisions that are implemented based on scientific experiments that tests the predictions and assumptions specified in a management plan. The results of the experiment are then used to guide policy changes for future management plans.

Allocations (Surrogate Measures): A term reference in the Clean Water Act that refers to "other appropriate measures" that can be specifically linked to an established and accepted pollutant loading capacity.

Anadromous Fish: Species of fish that spawn in fresh water, migrate to the ocean as juveniles, where they live most of their adult lives until returning to spawn in fresh water.

Anthropogenic Sources of Pollution: Pollutant deliver to a water body that is directly related to humans.

Base Flow: Groundwater fed summertime flows that occur in the long-term absence of precipitation.

Bank Building Event: A hydrologic event (usually high flow condition) that deposits sediments and organic debris in the flood plain and along stream banks.

Beneficial Use: Legislation that requires the reasonable use of water for the best interest of people, wildlife and aquatic species.

Channel Complexity: Implied high pool frequency of pools and large woody debris (instream roughness).

Channel Simplification: The loss (absence) of pools and large woody debris that is important for creating and maintaining channel features such as: substrate, stream banks and pool:riffle ratios.

Clearcut Harvest: Timber harvests that remove all trees are removed in a single entry from a designated area.

Debris Flow: A rapidly moving congregate of soil, rock fragments, water and trees, where over half of the material in transport has a particle size greater than that of sand.

Decommission: The removal of a road to improve hillslope drainage and stabilize slope hazards.

Endangered Species: A species that is declared by the Endangered Species Act (ESA) to be in danger of extinction throughout a significant portion of its range.

Fine Sediment: Sand, silt and organic material that have a grain size of 6.4 mm or less.

Fire Regime: The frequency, extent, intensity and severity of naturally occurring seasonal fires in an ecosystem.

FLIR Thermal Imagery: Forward looking infrared radiometer thermal imagery is a direct measure of the longer wavelengths emitted by all bodies. The process by which bodies emit longwave radiation is described by the Stefan-Boltzman 4^{th} Order Radiation Law. FLIR monitoring produces spatially continuous stream and stream bank temperature information. Accuracy is limited to 0.5°C. FLIR thermal imagery often displays heating processes as they are occurring and is particularly good at displaying the thermal impacts of shade, channel morphology and groundwater mixing.

Flood Plain: Strips of land (of varying widths) bordering streams that become inundated with floodwaters. Land outside of the stream channel that is inside a perimeter of the maximum probable flood. A flood plain is built of sediment carried by the stream and deposited in the slower (slack waters) currents beyond the influence of the swiftest currents. Flood plains are termed "living" if it experiences inundation in times of high water. A "fossil" flood plain is one that is beyond the reach of the highest floodwaters.

Flood Plain Roughness: Reflects the ability of the flood plain to dissipate erosive flow energy during high flow events that over-top streams banks and inundate the flood plain.

Fluvial: Of, found in or produced by a river.

Gradient: Reach gradient estimated by valley gradient reported in percent (%) from 1:24,000 topography.

Groundwater: Subsurface water that completely fills the porous openings is soil and rocks.

Incipient Lethal Limit: Temperature levels that cause breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation.

Indicator Species: Used for development of Oregon's water temperature standard as sensitive species that if water temperatures are reduced to protective levels will protect all other aquatic species.

Instantaneous Lethal Limit: Temperature levels where denaturing of bodily enzymes occurs.

Instream Roughness: Refers to the substrate (both organic and inorganic) that is found in the active channel. Large woody debris provides instream roughness and is sensitive to human land use.

Intermittent Flow: Stream flow that ceases seasonally, at least once a year.

Large Woody Debris[2]: Pieces of woody debris located in the active channel at least <u>36</u> inches in diameter and 50 feet in length.

LWD per 100 m: A measure in instream roughness and large woody debris frequency. The number of pieces of woody debris with a minimum diameter of 24 inches and at least 50 in length divided by the primary channel length and multiplied by 100 meters.

Legacy Condition: Past land management and historical disturbance affect the conditions that are currently observed in a stream channel. Present conditions may reflect chronic or episodic events that no longer occur.

Loading Capacity: A term reference in the Clean Water Act that refers to established and accepted rate of pollutant introduction to a waterbody that relates directly to water quality standard compliance.

Mass Movement: The movement of soil due to gravity, such as: landslides, debris avalanches, rack falls and creep.

Measured Daily Solar Radiation Load: Using a Solar Pathfinder©, the rate of heat energy transfer originating from the sun can be accurately determined.

Natural Sources of Pollution: Pollutant deliver to a water body that is directly related to processes that are inherent to normal process unaffected by humans.

pH: A measure of the hydrogen ion concentration is aqueous solutions. Acidic solutions have a pH less than 7, neutral solutions have a pH of 7, and basic solutions have a pH that is greater than 7.

Peak Flow: The largest flow volume occurring in one year due to one storm event.

Perennial Flow: Stream flow that persists throughout all seasons, yearlong.

Pools: Number of pools reported in the survey reach.

Pools per 100 m: The frequency of pools observed in the survey reach per 100 meters of stream length. Calculated as the number of observed pools in the reach multiplied by 100 meters and divided by the primary channel length.

Potential Daily Solar Radiation Load: Based on the Julian calendar, for any particular location on earth, there exists a potential rate of heat energy transfer originating from the sun.

Primary Channel Length: Length of the primary channel located in the survey reach. Units are meters.

Primary Channel Width: Active channel width reported in meters.

Rate: A measurable occurrence over a specified time interval.

Reach: Survey reaches in the same stream were numbered for organization.

Redd: An anadromous fish nest made in the gravel substrate of a stream where a fish will dig a depression, lay eggs in the depression and cover it forming a mound of gravel.

Residual Pool Depth: Average pool depth reported in meters.

Riparian Area: A geographic area that contains the aquatic ecosystem and the upland areas that directly affect it. Also defined as 360 feet from a fish bearing stream and 180 feet from a non-fish bearing stream.

Sac Fry: Larval salmonid that has hatched, but has not fully absorbed the yolk sac and has not emerged from the redd.

Sediment: Fragmented material that originates from the weathering of rocks and is transported by, suspended in, or deposited by water or air.

Seral Stage: Refers to the age and type of vegetation that develops from the stage of bare ground to the climax stage.

Seral Stage - Early: The period from bare ground to initial crown closure (grass, shrubs, forbs, brush).

Seral Stage - Mid: The period of a forest stand from crown closure to marketability (young stand of trees from 25 to 100 years of age, includes hardwood stands).

Seral Stage - Late: The period of a forest stand from marketability to the culmination of the mean annual increment (mature stands of conifers and old-growth).

Shear Stress: The erosive energy associated with flowing water.

Smolt: Juvenile salmonid one or two years old that has undergone physiological changes adapted for a marine environment. Generally, the seaward migrant stage of an anadromous fish species.

Soil Compaction: Activities/processes, vibration, loading, pressure, that decrease the porosity of soils by increasing the soil bulk density $\left(\frac{\text{Weight}}{\text{Unit Volume}}\right)$.

Stream Bank Erosion: Detachment, entrainment, and transport of stream bank soil particles via fluvial processes (i.e. local water velocity and shear stress).

Stream Bank Failure: Indicates a gravity related collapse of the stream bank by mass movement.

Stream Bank Retreat: The net loss of stream bank material and a corresponding widening of the stream channel that accompanies stream bank erosion and/or stream bank failure.

Stream Bank Stability: Detachment, entrainment, and transport of stream bank soil particles by local water velocity and shear stress.

Sub-Lethal Limit: Temperature levels that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supplies, and increased competition from warm water tolerant species.

Surface Erosion: Detachment, entrainment, and transport of flood plain or upslope soil particles by wind and water.

Surrogate Measures (Allocations): A term reference in the Clean Water Act that refers to "other appropriate measures" that can be allocated to meet an established and accepted pollutant loading capacity.

Temperature Limited Waterbody: Refers to a stream or river that has been placed on the 303(d) list for violating numeric criteria based on measured data.

Threatened Species: Species that are likely to become endangered through their normal range within the foreseeable future.

Wasteload Allocations: A term reference in the Clean Water Act that refers to point source rates of pollutant delivery that can be specifically linked to an established and accepted pollutant loading capacity.

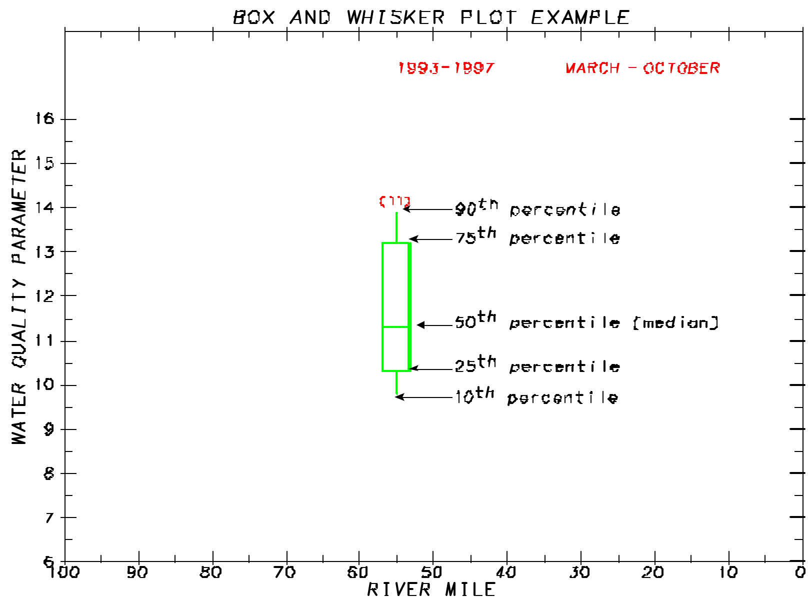
Watershed: A drainage basin that contributes water, organic material, dissolved nutrients, and sediment to streams, rivers, and lakes.

Width:Depth Ratio: The width of active channel divided by the average depth in the survey reach.

Woody Debris[1]: Pieces of woody debris located in the active channel at least $\geq$24 inches in diameter and 50 feet in length.

9.2 Statistical Terminology

Box and Whisker Plots: Water quality parameters and instream physical parameters are reviewed below using box and whisker plots for illustration. Below is an example of a box and whisker plot:



Example of box and whisker plot.

The box plots have river mile on the X-axis with the water quality parameter on the Y-axis. The box represents the data at the sampling sites, from upstream to downstream. Each box represents a summary of the data:

The upper corner of each box is the 75^{th} percentile (75 percent of the data are below that concentration), and the lower corner is the 25^{th} percentile (25 percent of the data are below that concentration). The upper and lower tails are the 90^{th} and 10^{th} percentiles, respectively. Points above and below the tails represent data higher and lower than the 90^{th} and 10^{th} percentiles. The dashed line in the box is the median concentration for that site (half of the data fall above and below that concentration).

Correlation Coefficient (R): Used to determine the relationship between two data sets. R-values vary between –1 and 1, where "–1" represents a perfectly inverse correlation relationship and "1" represents a perfect correlation relationship. A "0" R-value indicates that no correlation exists.

$$R = \frac{1}{n} \cdot \sum_{i=1}^{n} (x_i - \mu_x) \cdot (y_i - \mu_y)$$

Determinate Coefficient (R^2): The R^2 value represents "goodness of fit" for a linear regression. An R^2 value of "1" would indicate that all of the data variability is accounted for by the regression line. Natural systems exhibit a high degree of variability; R^2 values approaching "1" are uncommon. A value of "0" would indicate that none of the data variability is explained by the regression.

Mean (m): Refers to the arithmetic mean.

$$\mu = \frac{1}{n} \cdot \sum x_i$$

Median: Refers to a value in the data in which half the values are above and half are below.

Reach Averaged: Refers to an average that is based on the occurrence of a property weighted by the occurrence frequency over perennial stream length.

Standard Deviation (?): The measure of how widely values are dispersed from the mean (μ).

$$\sigma = \sqrt{\frac{n \cdot \sum x^2 - \left(\sum x\right)^2}{n \cdot (n-1)}}$$

Tempertaure Statistic: The maximum seasonal seven (7) day moving average of the daily maximum stream tempertaures.

WSTAT: A stistitical measure of model accuracy: $WSTAT = \frac{\sum(\text{Predicted} - \text{Observed})}{n}$

10. REFERENCES

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APPENDIX A

TRASK RIVER TEMPERATURE ASSESSMENT

Current Condition Assessment

Temperature

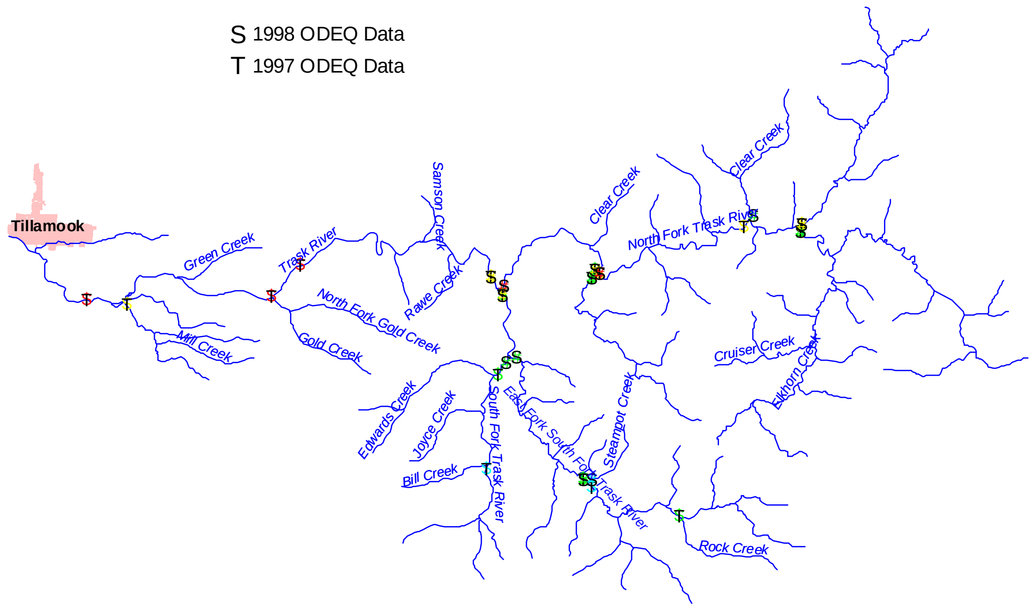
The Oregon Department of Environmental Quality (ODEQ) measured stream temperatures for summer months in both 1997 and 1998. A total of twenty-two sites were continuously monitored for stream temperature. Twelve additional sites were sampled for instantaneous temperature. Major tributaries, as well as the Trask River mainstem have been sampled for temperature in either the 1997 or 1998 summertime monitoring season. All continuous monitoring data has passed ODEQ quality control protocols. Monitoring sites displayed in **Image A-1** have been statistically processed to yield the 7-day average of the daily maximum temperatures (commonly referred to the *7-day statistic*). These 7-day statistics are used to specify if the sampled stream violates State water quality standards.

Spatial Temperature Patterns

A visual summary of the continuous temperature data is shown in **Image A-1**. Generally, smaller tributaries feeding the Trask mainstem and North Fork are cooler than the receiving waters. In some cases, these tributaries are significantly cooler (Clear Creek #1, Clear Creek #3, Bark Shanty Creek). Lower in the sub-basin, the one major tributary, Mill Creek, is not a source of mainstem cooling. The South Fork Trask River is generally cool, including all tributaries. Edwards Creek, Bills Creek, Steampot Creek and Rock Creek have cold temperatures that serve to cool an already cold South Fork Trask River receiving water.

Temperature patterns throughout the Trask River sub-basin follow continual heating in the downstream (longitudinal) direction (**Figure A-1**). Significant stream heating was measured in the North Fork Trask River while the South Fork Trask River maintains cooler temperatures. The mainstem Trask River downstream of the North/South Forks confluence continues to heat longitudinally to tidewater influences (at approximately the lower Boat Launch). Daily temperature profiles for August 12, 1998 display the relative temperatures of the North Fork, South Fork and Trask River mainstem (**Figure A-2**).

Image A-1. Maximum 7-Day Moving Average of Daily Maximum Temperature



Less than 12.8°C	12.8°C to 15.3°C	15.3°C to 17.8°C	17.8°C to 20.3°C	Greater than 20.3°F

Figure A-1. Stream Temperature Heating Curve
(August 12, 1998)

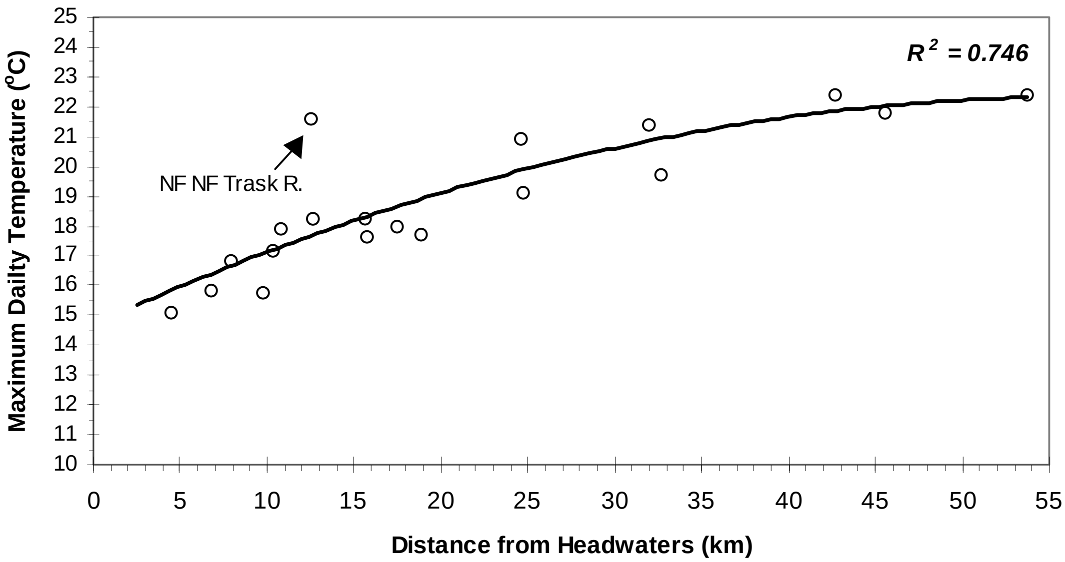
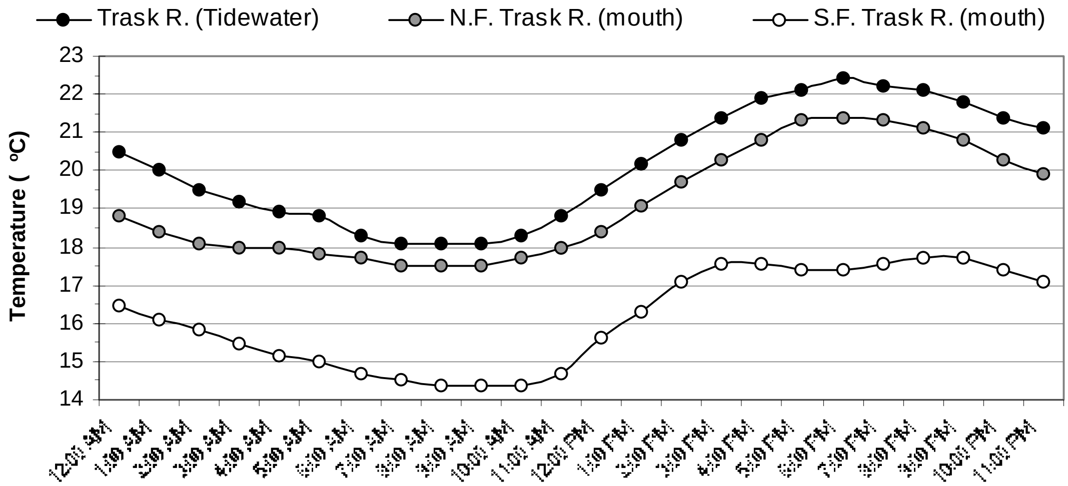


Figure A-2. North Fork, South Fork and Mainstem Stream Temperature Profiles
(ODEQ - August 12, 1998)

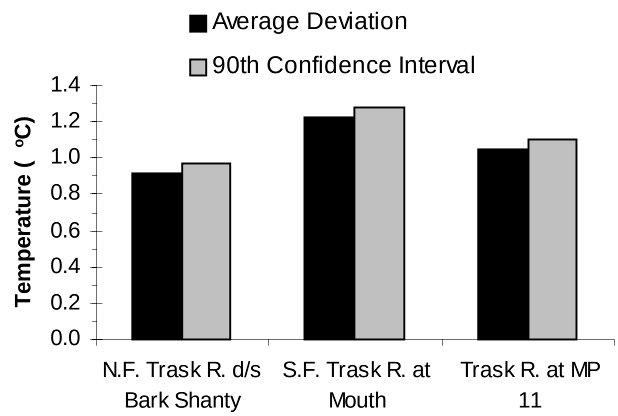


Temporal Temperature Patterns

<u>Yearly Variations</u>

Temperature data sampled at the same location over both the 1997 and 1998 monitoring seasons were graphically and statistically compared. Three sites were selected: North Fork Trask River downstream Bark Shanty Creek, South Fork Trask River at mouth and Trask River and Mile Post 11 (MP 11). These three sites are distributed throughout varying parts of the sub-basin and are representative of annual temperature variability. **Figure A-4** displays the maximum daily temperatures for the 1997 and 1998 monitoring period at all three monitoring sites. All statistics (i.e. average deviation and 90th confidence interval) were generated using only the overlapping portion of the 1997 and 1998 data for each site. Comparing years, the 90th percentile deviation in *maximum daily* stream temperatures during the sampling intervals was between 1.0^{o}C and 1.1^{o}C. The average temperature deviation between years was between 0.9^{o}C and 1.1^{o}C. **Figure A-3** displays the 90th percentile and average deviations for the three sites.

Figure A-3. Annual Variability Between 1997 and 1998 Temperature Data
(ODEQ - 1997 and 1998 Data)



Seasonal Variability

Seasonal maximum stream temperatures in the Trask River and tributary streams generally correspond to a combination of high levels of solar exposure, warm air temperatures and low flow conditions. Maximum stream temperatures occur in late July. Stream temperatures gradually decline through August and September due to decreasing solar radiation loading. Stream temperatures in August and September often reach relatively warm daily maximums. Significant stream cooling occurs with lower fall solar loading levels coupled with fall precipitation events that increase stream flow and reduce ambient air temperatures. Moving seven-day averages of daily maximum stream temperatures for selected sites in the Trask River sub-basin are displayed in **Figure A-5**. Maximum monthly seven-day moving averages of daily maximum stream temperatures are displayed in **Figure A-6**.

Figure A-4. Daily Maximum Stream Temperatures for 1997 and 1998

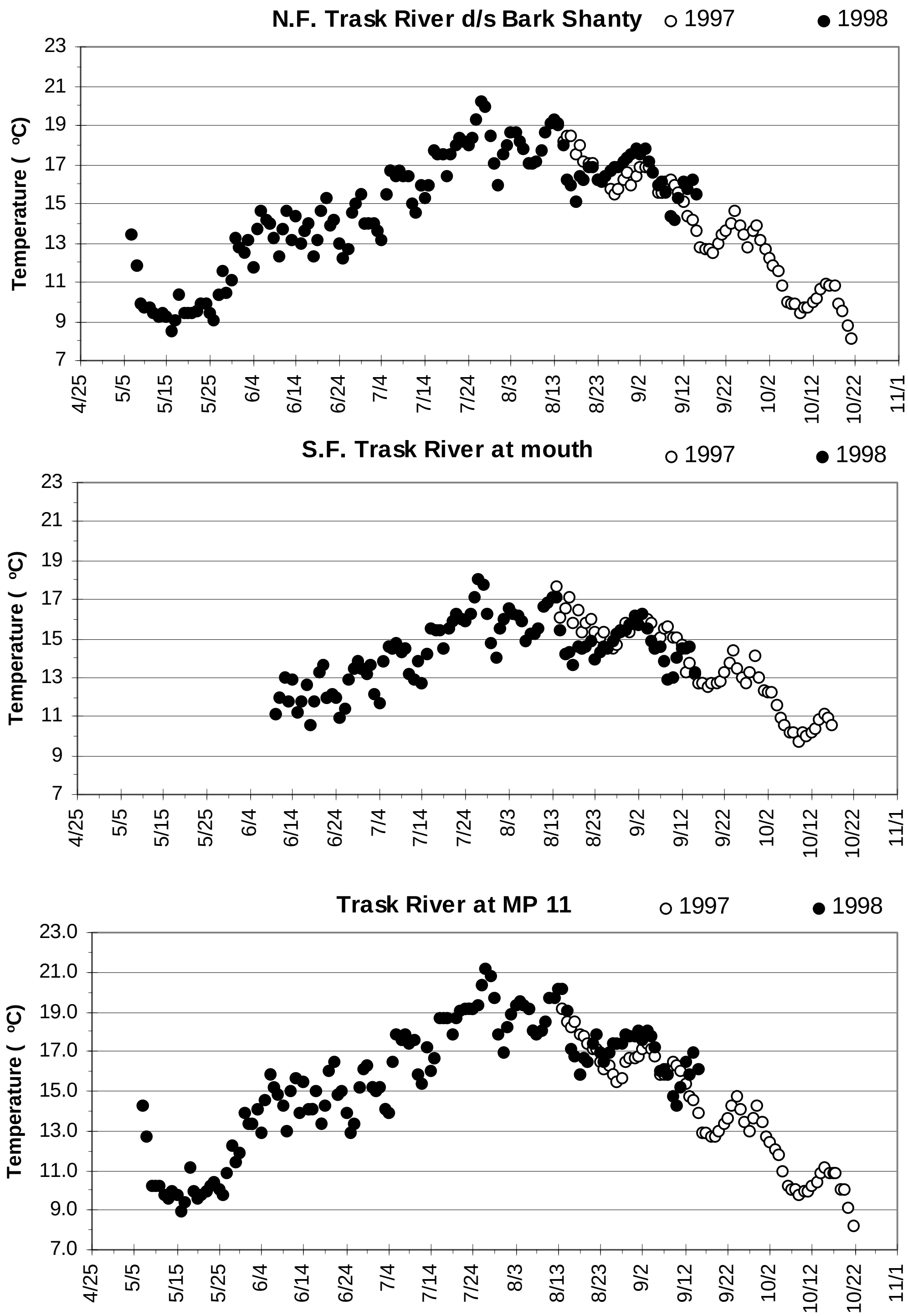


Figure A-5. Moving Seven-Day Averages of Daily Maximum Stream Temperatures for Selected Sites in the Trask River Sub-Basin (1998)

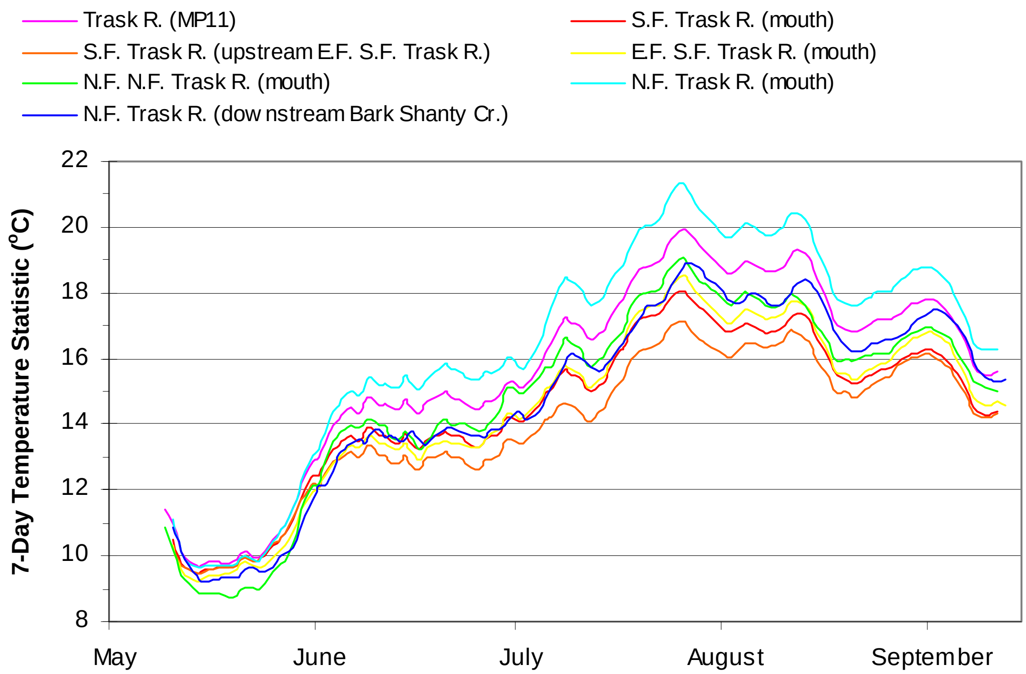
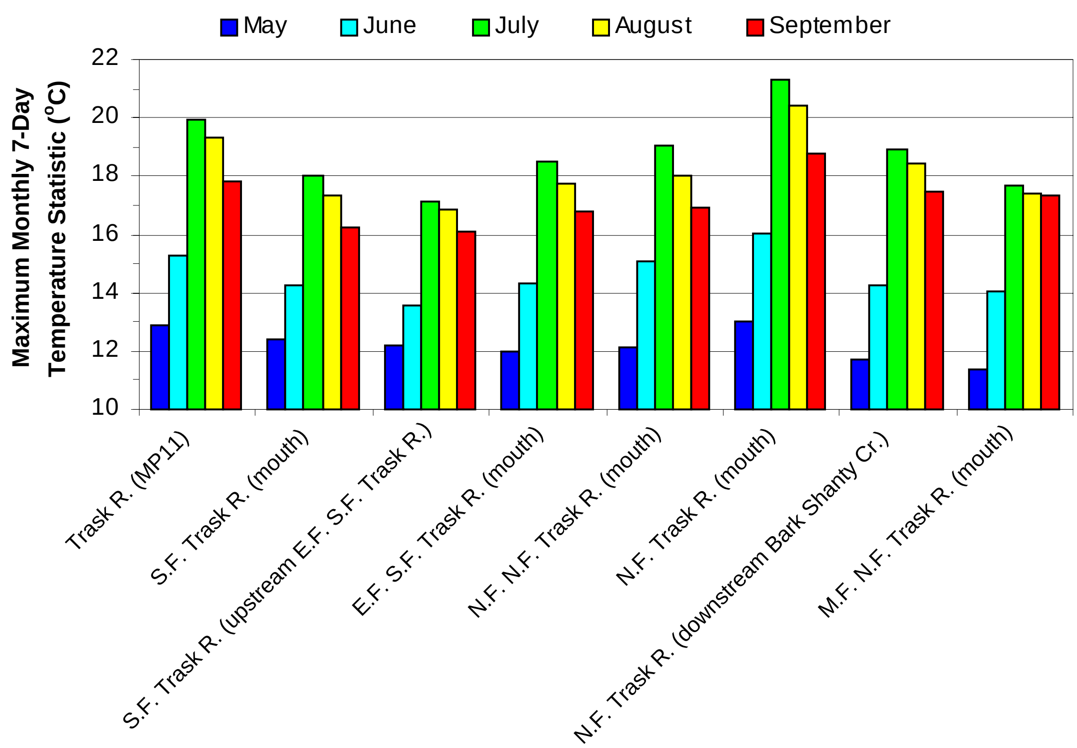


Figure A-6. Maximum Monthly Seven-Day Moving Averages of Daily Maximum Stream Temperatures (1998)



Shade

ODEQ measured stream surface shade during the summer months in 1998. A total of thirty-eight sites were monitored. Stream surface shade and canopy cover can be highly variable in disturbed riparian areas. Continued shade data monitoring efforts are ongoing and additional data are expected to increase accuracy in shade representations.

Effective shade was quantified by averaging the Solar Pathfinder data for the months of May through September. Hours of solar exposure and local sunrise/sunset were also collected. Solar attenuation was derived from the Solar Pathfinder data by measuring the portion of the day that receives shade relative to total day length. Canopy cover was measured with a densiometer. Narrative descriptions of riparian vegetation (vegetative species composition/condition, height, width and distribution) were also recorded at the shade monitoring sites.

The South Fork Trask River and tributaries all are highly shaded. The lowest effective shade measurement for the South Fork stream network was 67% (lower S.F. boat launch), while many on the South Fork Trask River monitoring sites have 100% effective shade. The alder dominated riparian vegetation dominant in the South Fork Trask system provides near daylong stream surface shade. The median effective shade value for the South Fork Trask River is 100% (n = 13).

The North Fork Trask stream network has highly shaded tributaries (Bark Shanty Creek, Clear Creek #1 and Clear Creek #3). Late seral (old growth) conifer riparian conditions exist along the upper North Fork Trask River (Middle Fork to Clear Creek #3). This stream reach has high levels of effective shade (94%) and should be considered a reference reach for the entire Trask River stream network. Downstream Clear Creek #3, the North Fork Trask River widens and riparian species composition becomes alder dominant, however, remnant late seral conifers are apparent throughout the entire North Fork Trask River and tributaries. The middle and lower North Fork Trask River has poor effective shading (22% to 63%). The median effective shade value for the North Fork Trask River is 59% (n = 17).

The Trask River mainstem is poorly shaded throughout its entire length (27% to 47%). Much of the stream surface is exposed to solar radiation throughout much of the day in the lower Trask River reaches. Wide active channel widths and largely alder dominated riparian corridors combine to produce low stream surface shade conditions (2% to 48%. Rural residential and agricultural disturbance have reduced the species composition and riparian conditions in the lower Trask River reach (Fish Hatchery to Lower Boat Launch) significantly lowering shade levels (2% to 27%).

A visual summary of the effective shade data collected with a Solar Pathfinder is shown in **Image A-2**. **Figure A-7** displays the median effective shade, solar attenuation and canopy cover measured for the South Fork and North Fork Trask systems, and the Trask River mainstem. **Figure A-8** shows a effective shade statistical summary (Box Plot) compared with the National Estuary Program (NEP) shade target of 75%.

Figure A-7. Median Shade Values (1998)

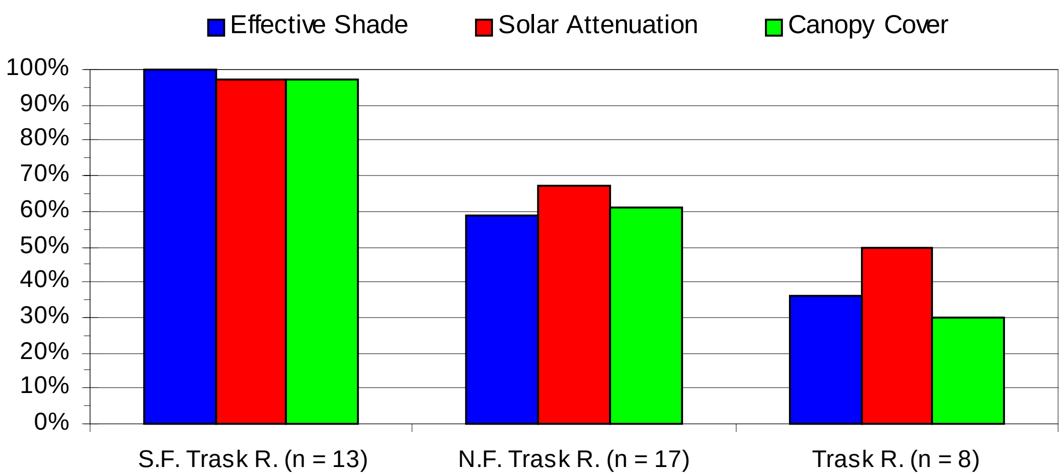


Figure A-8. Median Effective Shade Measurements Compared to NEP Shade Target (1998)

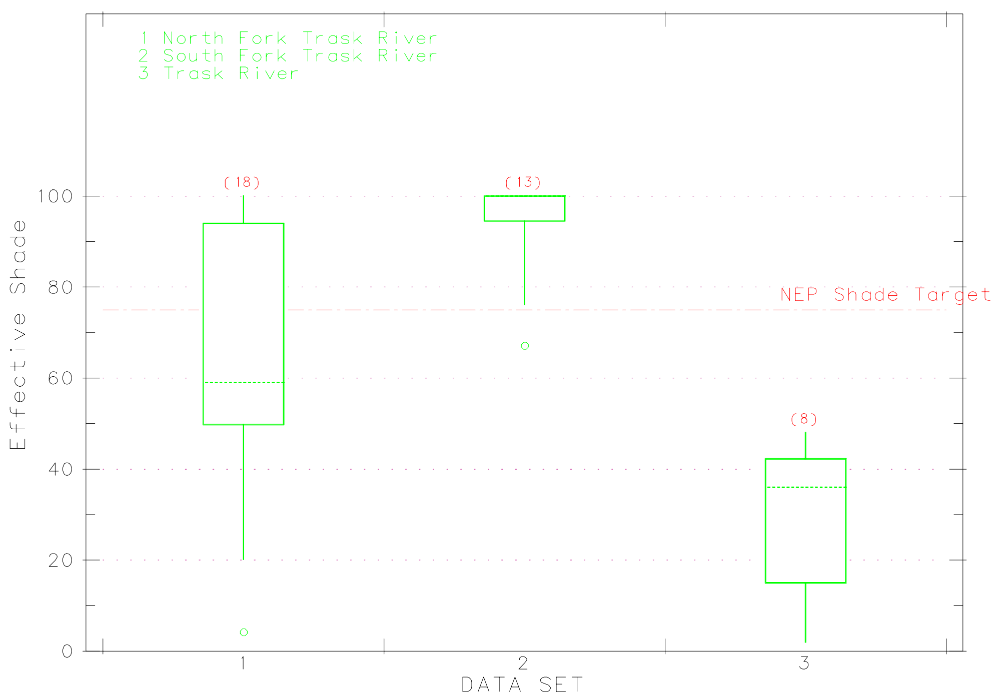
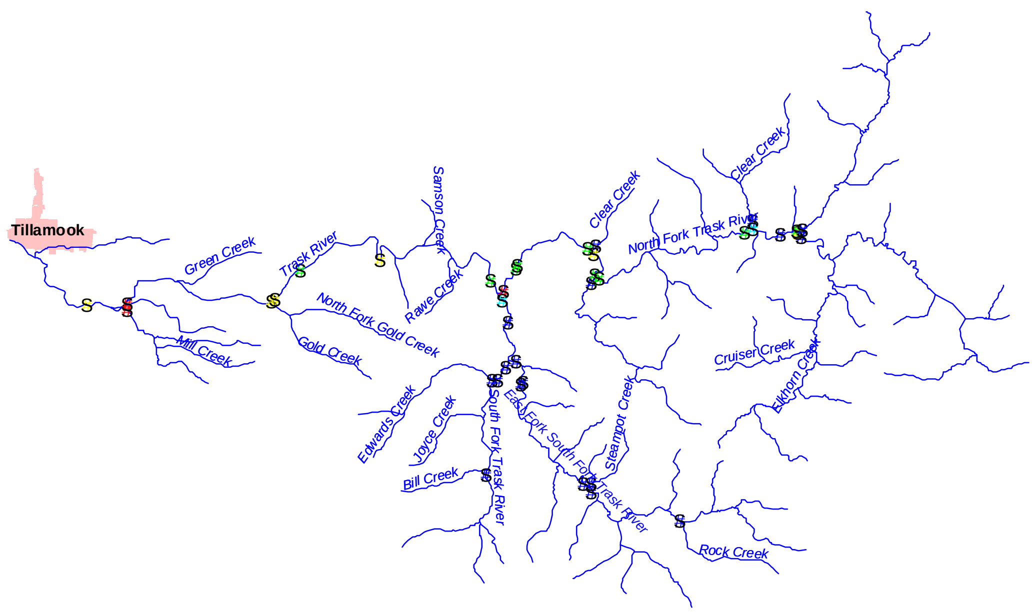
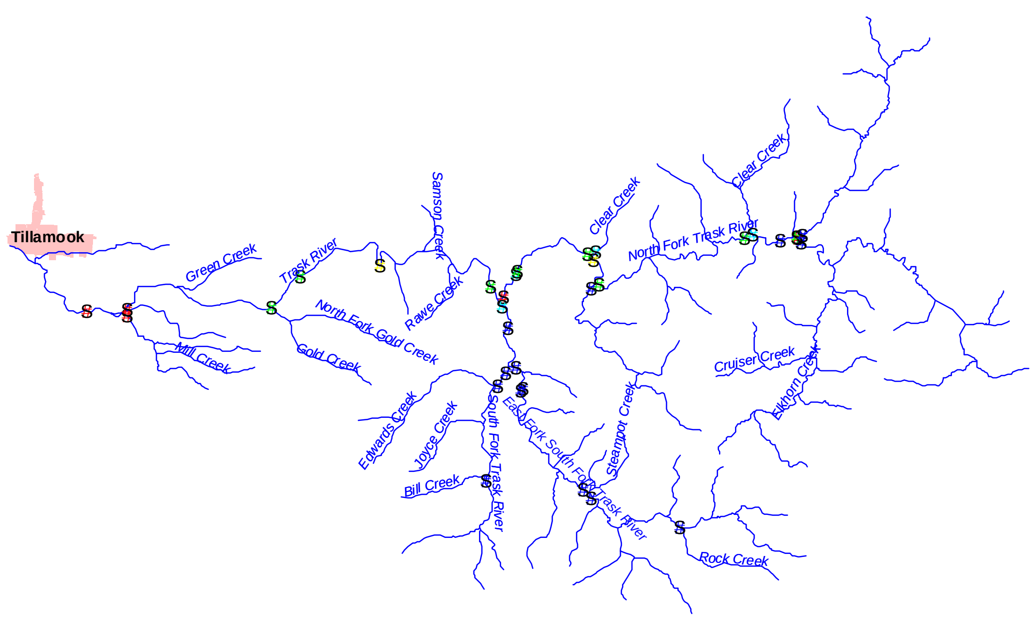


Image A-2. Effective Shade - Measured with Solar Pathfinder (1998)



Less than 20% 20% to 40% 40% to 60% 60% to 80% Greater than 80%

Image A-3. Daily Summertime Solar Exposure - Measured with Solar Pathfinder (1998)

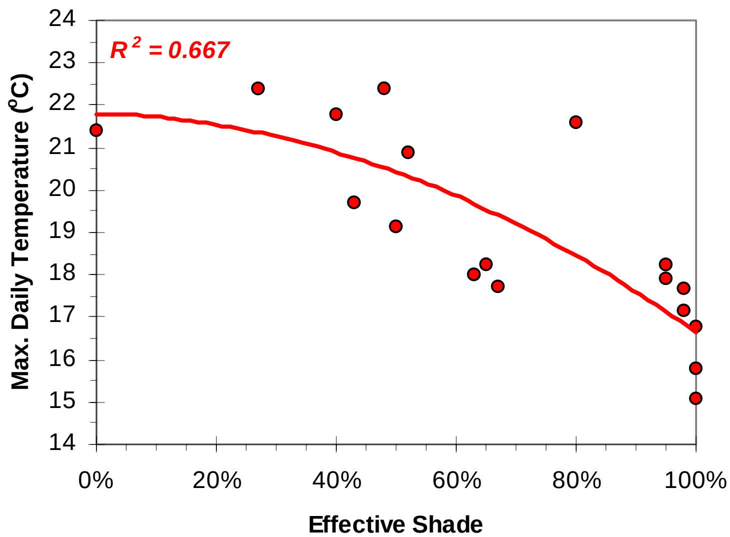


Less than 2 hours 2 to 4 hours 4 to 6 hours 6 to 8 Hours Greater than 8 hours

Shade Related to Stream Temperature

Cooler stream temperatures are strongly related to stream surface shade (Rishel et al. 1982, Brown 1983, Beschta et al. 1987, Sinokrot and Stefan 1993, Chen 1996, Boyd 1996). When graphically compared, the inverse relationship between shade and temperature becomes apparent. Simply stated, stream surface exposure to solar radiation is reduced or eliminated in a highly shaded condition (**Figure A-9**). A threshold shade level often occurs at 75% to 80% effective shade where temperature change (dT/dx and dT/dt) can increase dramatically (Boyd 1996). This threshold shade condition is most apparent on smaller streams less than 0.14 cms (5 cfs) (Boyd 1996).

Figure A-9. Maximum Daily Temperature and Effective Shade
(August 12, 1998)



Stream Temperature Simulation

The purpose of this stream temperature simulation effort is to quantify stream temperatures and the corresponding energy process conditions that result when estimated site potential riparian vegetation exists. The model is validated using hydrologic, thermal and landscape data describing the current condition. Only 1998 data were used. Once the modeled reach output has been validated, stream temperatures and energy conditions are predicted for a site potential riparian condition. All other model inputs are assumed to remain unchanged. In this series of predictions, the site potential riparian condition assumed a late seral (old growth) Douglas Fir conifer riparian buffer.

Model results should be used with caution. Associated prediction errors and goodness of fit estimates are provided with all model output. The author is aware of possible sources of error in the predictions. However, the methodology is sound and based on the most recent understanding of stream thermodynamics and hydraulics. As is generally the case in simulating non-linear water quality simulation, model results are best suited for relative comparisons, rather than determinations of water quality parameter magnitude. Ultimate stream temperature magnitude is estimated in the report and is presented with upper and lower error boundaries. Discussions of the model results should include considerations for these boundaries of error.

Methodology

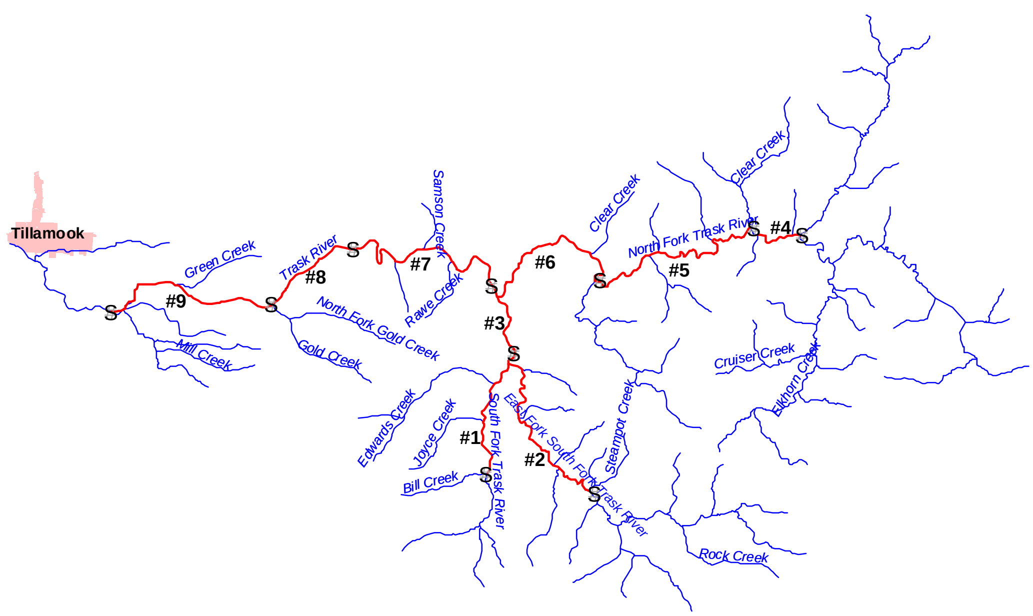
Using a stream temperature prediction model (Heat Source v. 5.5), a large extent of the North Fork, South Fork and mainstem Trask were simulated for temperature. The basic steps involved in stream temperature are as follows:

1. *Selection of Temperature Simulation Reaches*

Table A-1. Trask River Simulation Reaches

#	Simulation Reach	Upper Extent	Lower Extent
1	Upper S.F. Trask R.	Bills Creek	E.F. of S.F. Trask R.
2	E.F. of S.F. Trask R.	Steampot Creek	S.F. Trask R.
3	Lower S.F. Trask R.	E.F. of S.F. Trask R.	Mouth
4	Upper N.F. Trask R.	M.F./N.F. of N.F. Trask	Clear Creek #3
5	Middle N.F. Trask R.	Clear Creek #3	Bark Shanty Creek
6	Lower N.F. Trask R.	Bark Shanty Creek	Mouth
7	Upper Trask R.	S.F./N.F. Trask R.	Trask R. Gage
8	Middle Trask R.	Trask R. Gage	Fish Hatchery
9	Lower Trask R.	Fish Hatchery	Lower Boat Launch

Image A-4. Stream Temperature Simulation Extent – **Red** Indicates Simulation Reaches



2. *Model Input: Site Specific Data*

Table A-2. Heat Source v. 5.5 Model Input Parameters	
• Date	• Buffer Height
• Stream Aspect	• Buffer Width
• Latitude	• Buffer Density
• Longitude	• Topographic Shade Angle (West)
• Reach Length	• Topographic Shade Angle (East)
• Channel Width	• Min. Air Temperature
• Flow Volume	• Max. Air Temperature
• Flow Velocity	• Relative Humidity
• Percent Bedrock	• Buffer Distance to Stream
• Groundwater Inflow	• Elevation
• Groundwater Temperature	• Wind Speed
• Dispersion Coefficient	• Upstream Hourly Temperature Data

3. *Prediction of Current Condition (Downstream Temperature Profile)*

4. *Model Validation: Statistical Analysis of Model Output*

- Pearson's Product Moment (R^2)
- Standard Error (S.E.)

5. *Prediction of <u>Stream Reach Buffer Conditions</u>*

Table A-3. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

- Buffer dimensions were constant over all stream sections for each of the four site potential simulations.
- Assume that current condition standard error (S.E.) applies to site potential simulations.

6. *Prediction of Stream Reach Based on Cumulative Upstream Site Potential Conditions (Downstream Temperature Profile)*

- Utilize upstream reach for different buffer conditions stream temperature for upstream model input in downstream reach simulation (i.e. downstream site potential temperature profile or Reach#4 becomes input temperature profile for Reach #5).
- Account for tributary temperature mixing.
- Assume tributary temperature are at or near site potential
- Assume that current condition standard error (S.E.) applies to different buffer condition simulations.
- Standard error (S.E.) of upstream predictions accumulates in the downstream direction

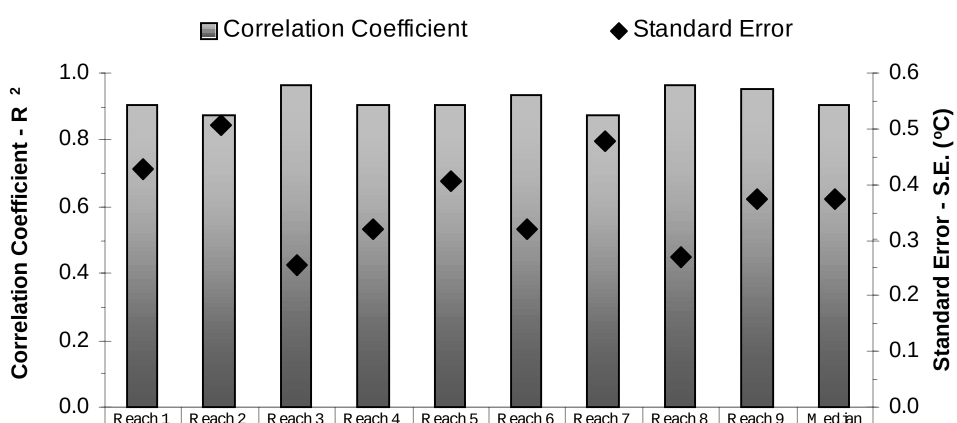
Model Validation

Temperature Validation

Two statistical measurements were used to assess the accuracy of stream temperature predictions. Comparisons between simulated and actual (measured) stream temperature profiles were used to generate the square of the Pearson product moment correlation coefficient (R^2) and the standard error (S.E.) for each simulation reach (**Figure A-10**). Median values for all simulation reaches were:

$$R^2 = 0.91$$
$$S.E. = 0.38^oC.$$

Figure A-10. Temperature Profile Prediction Accuracy

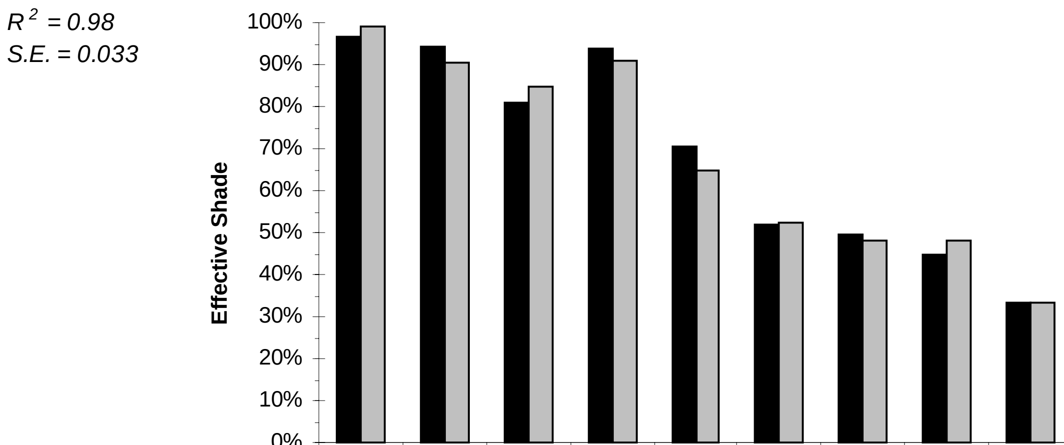


	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Median
Correlation Coefficient	0.91	0.87	0.97	0.90	0.90	0.93	0.87	0.97	0.95	0.91
◆ Standard Error	0.43	0.51	0.26	0.32	0.41	0.32	0.48	0.27	0.38	0.38

Solar Radiation Validation

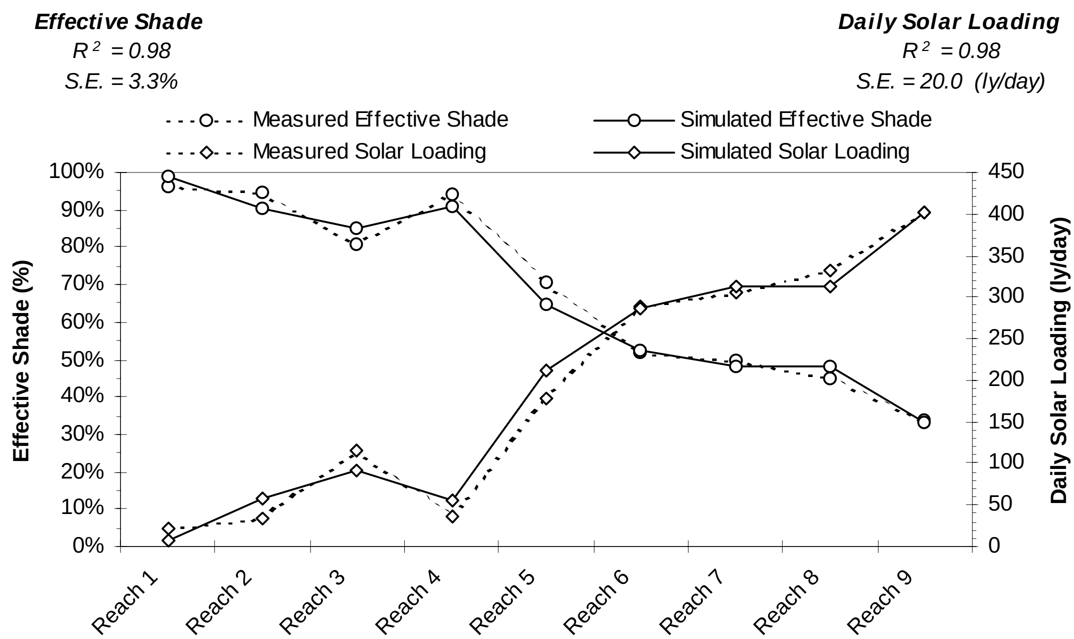
Solar energy is an important component of the model methodology. In a poorly shaded stream reach simulation, solar energy becomes the most dominant factor in stream temperature prediction. Median measured effective shade values are compared to median simulated effective shade in **Figure A-11**. Effective shade levels and daily solar loading values have a low standard error (S.E.) and high correlation coefficient (R^2) when compared to measured values (**Figure A-12**).

Figure A-11. Median Measured and Simulated Effective Shade Values
(ODEQ - August 12, 1998)



	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
Measured Effective Shade	97%	95%	81%	94%	71%	52%	50%	45%	34%
Simulated Effective Shade	99%	91%	85%	91%	65%	53%	48%	48%	33%

Figure A-12. Measured and Simulated Effective Shade and Daily Solar Loading
(ODEQ - August 12, 1998)



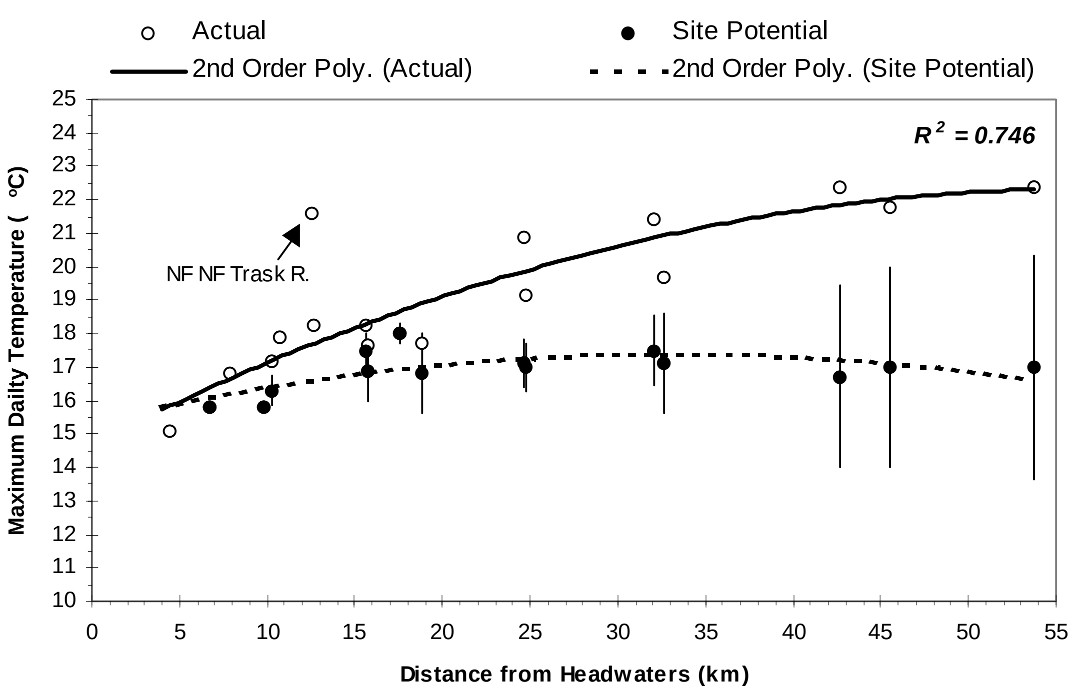
Model Output Summary

Temperature Output

Predicted maximum daily stream temperatures are cooler when site potential riparian conditions persist (buffer height = 38 meters, buffer width = 31 meters and buffer density = 80%). Longitudinal stream heating (displayed in **Figure A-1**) is drastically reduced in the simulated site potential riparian condition. **Figure A-13** shows the measured (actual) longitudinal stream heating pattern compared to those induced by simulated site potential riparian vegetation geometry. Site potential simulations demonstrate that stream temperature change occurs more gradually and temperature change becomes more dependent on tributary influences (mass transfer) than heat energy processes (heat transfer).

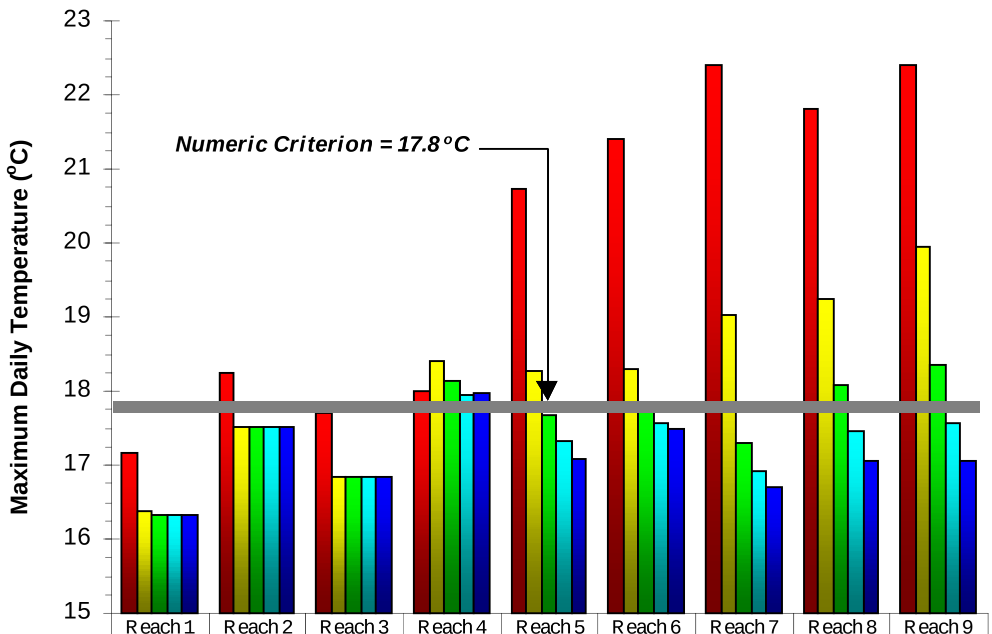
Vertical bars indicate the standard error associated with each simulation. Recall that all simulation errors of upstream prediction reaches were assumed to accumulate in the downstream direction. The result is an increasing margin of error for simulations in the downstream direction. Perhaps this method for accounting prediction error overstates the margin of error. However, it is important to recognize the limitations inherent to this methodology.

Figure A-13. Actual Stream Heating Curve and Predicted Site Potential Daily Maximum Temperatures with Associated Standard Error Bars
(ODEQ - August 12, 1998)



<u>Recall</u> Table A-3. Simulated Buffer Conditions					
Name	**Description**	**Buffer Height**	**Buffer Width**	**Buffer Density**	**Percent Overhanging**
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

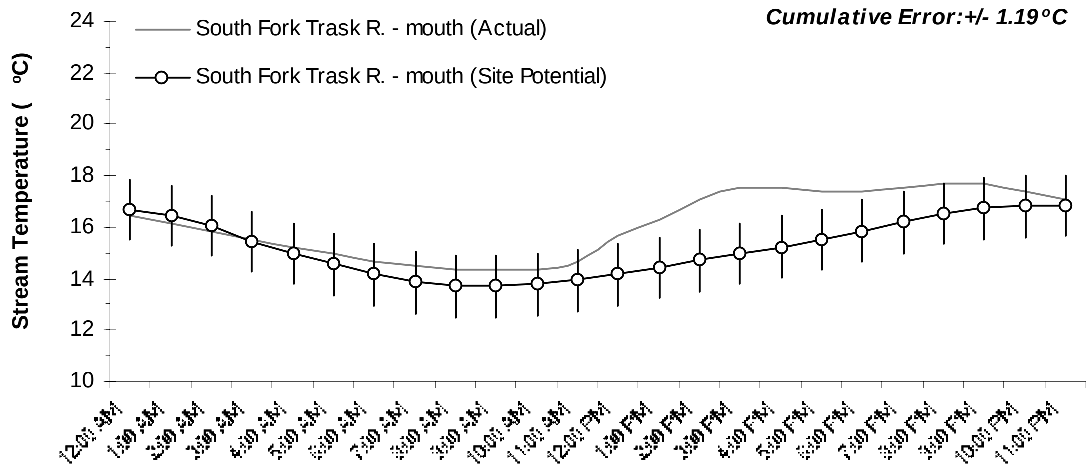
Figure A-14. Maximum Daily Stream Temperatures for Current Conditions and Varying Buffer Dimensions
(ODEQ - August 12, 1998)



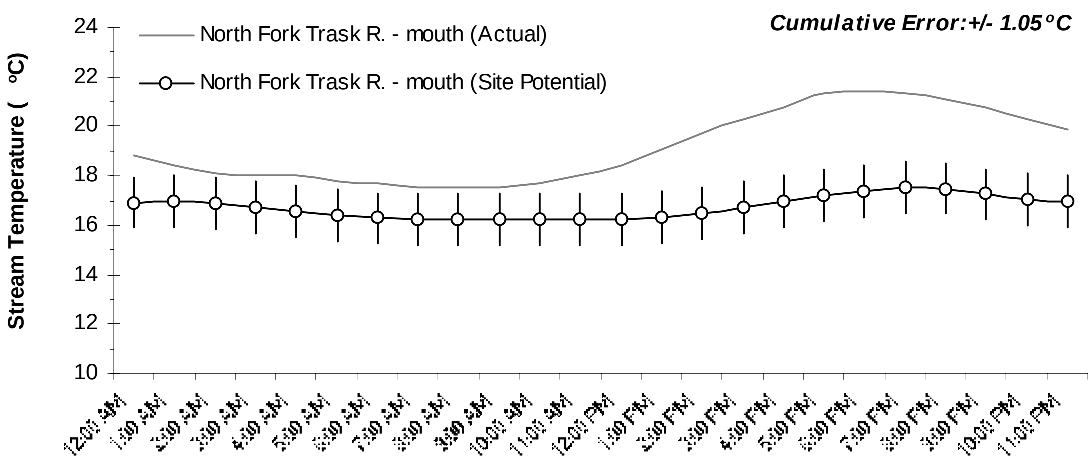
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
Current Conditions	17.2	18.3	17.7	18.0	20.7	21.4	22.4	21.8	22.4
Buffer1	16.4	17.5	16.8	18.4	18.3	18.3	19.0	19.2	20.0
Buffer2	16.3	17.5	16.9	18.1	17.7	17.7	17.3	18.1	18.3
Buffer3	16.3	17.5	16.9	18.0	17.3	17.6	16.9	17.5	17.6
Buffer4	16.3	17.5	16.9	18.0	17.1	17.5	16.7	17.0	17.0

Figure A-15. Current Condition and Site Potential Temperature Profiles
(ODEQ - August 12, 1998)

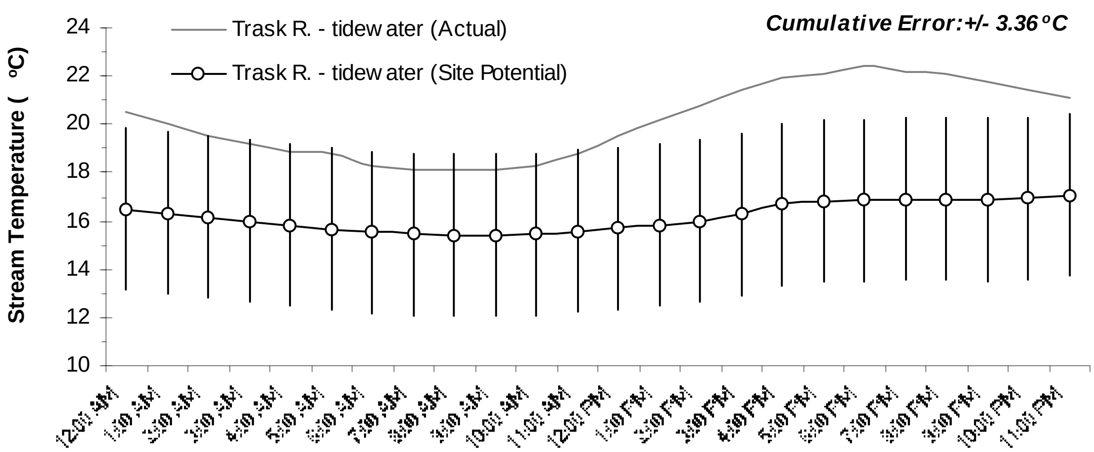
South Fork Trask R. (mouth)



North Fork Trask R. (mouth)



Lower Trask R. (tidewater)



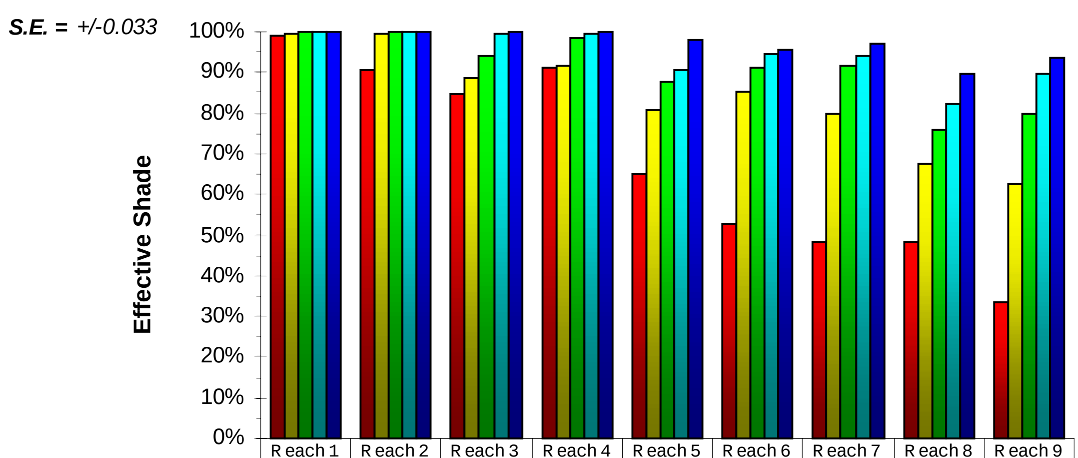
Solar Radiation Output

Generally, the South Fork Trask River and tributary streams are well shaded by a closed deciduous (alder) canopy. Simulation demonstrated that solar energy could be reduced to even lower levels when riparian height and stand density reflects that of riparian site potential (conifer late seral vegetation). The lower South Fork Trask River has the highest levels of solar exposure as channel width increases beyond the shading capacity of present vegetation. Throughout the entire South Fork Trask system, site potential conditions (Buffer 4) provided high levels of effective shade and low solar exposure.

The upper North Fork Trask River (Middle Fork of North Fork confluence to Clear Creek #3) experiences little solar exposure. Late seral conifer riparian vegetation predominates throughout this simulation reach. The upper North Fork Trask River (Reach #4, see **Image A-4**) is a reference reach where desired near site potential vegetation conditions exist. This area provides an example of low levels of solar loading and little stream temperature change. Middle and lower reaches of the North Fork Trask River experience higher levels of solar loading. Deciduous trees (alder) largely dominate riparian vegetation, however legacy conifers are common. Site potential conditions provide high levels of effective shade and low solar exposure.

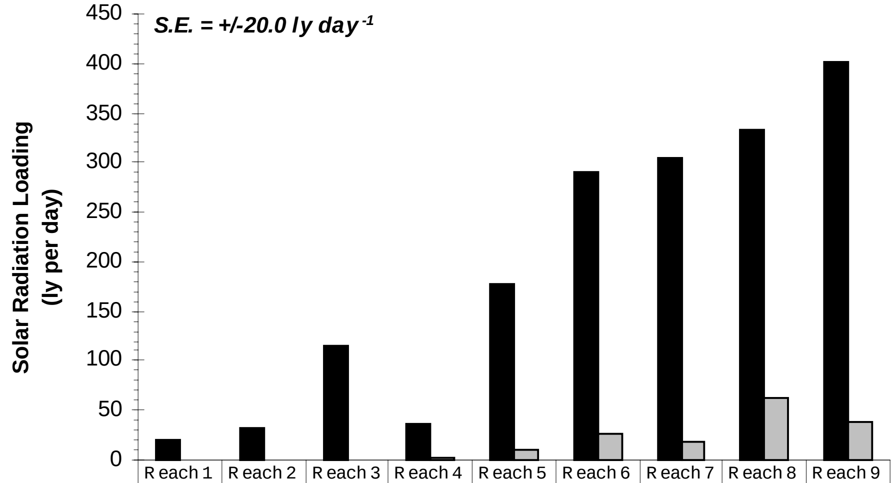
The Trask mainstem is poorly shaded throughout the entire stream length. Deciduous riparian vegetation offers the channel low shade potential, and high solar loading occurs. Rural residential and agricultural uses of the riparian zone have further diminished riparian species composition and condition. Site potential conditions provided high levels of effective shade and low solar exposure.

Figure A-16.Effective Shade Measurements (Current Condition) Compared to Simulated Buffer Conditions (1 to 4, where 4 is considered ***site potential***)



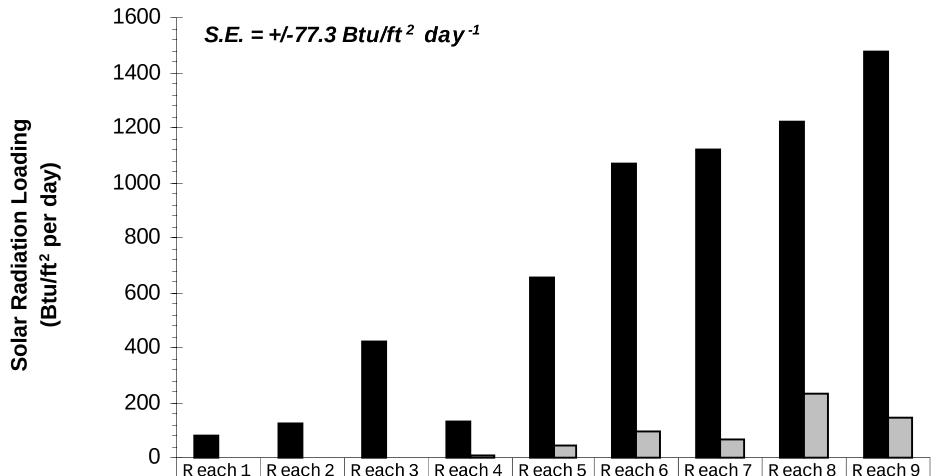
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
Current Conditions	98.9%	90.6%	84.8%	90.9%	64.9%	52.5%	48.1%	48.3%	33.3%
Buffer 1	99.7%	99.5%	88.5%	91.5%	80.8%	85.3%	79.6%	67.5%	62.5%
Buffer 2	100.0%	100.0%	94.3%	98.7%	87.5%	91.1%	91.8%	75.8%	79.8%
Buffer 3	100.0%	100.0%	99.3%	99.4%	90.8%	94.6%	94.1%	82.2%	89.7%
Buffer 4	100.0%	100.0%	99.9%	99.8%	98.2%	95.7%	97.0%	89.6%	93.6%

Figure A-17. Daily Solar Flux (ly day^{-1}) Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation
(ODEQ - August 12, 1998)



	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
■ Measured Effective Shade	21	33	115	36	178	290	305	332	402
□ Site Potential (Buffer 4 Conditions)	0	0	1	1	11	26	18	63	39

Figure A-18. Daily Solar Flux (Btu ft^{-2} day^{-1}) Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation
(ODEQ - August 12, 1998)



	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9
■ Measured Effective Shade	78	122	423	133	656	1068	1123	1223	1479
□ Site Potential (Buffer 4 Conditions)	0	0	2	4	40	96	67	231	142

Simulation Reach #1 – Upper South Fork Trask R.

S.F. Trask R. downstream of Bills Creek (looking upstream)

Input Parameters

Run Name	Trask 1 - Upper SF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.41	*(deg N)*
Longitude	-123.6	*(deg W)*
Stream Aspect	20	*(deg)*
Percent Bedrock	100%	
Reach Length	5295	*(meters)*
Channel Width	8.23	*(meters)*
Flow Volume	0.463	*(cms)*
Flow Velocity	0.335	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.17	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	0.50	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	87.0	*(deg)*
View to Sky	3%	
Effective Shade	99%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-19. Upper South Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

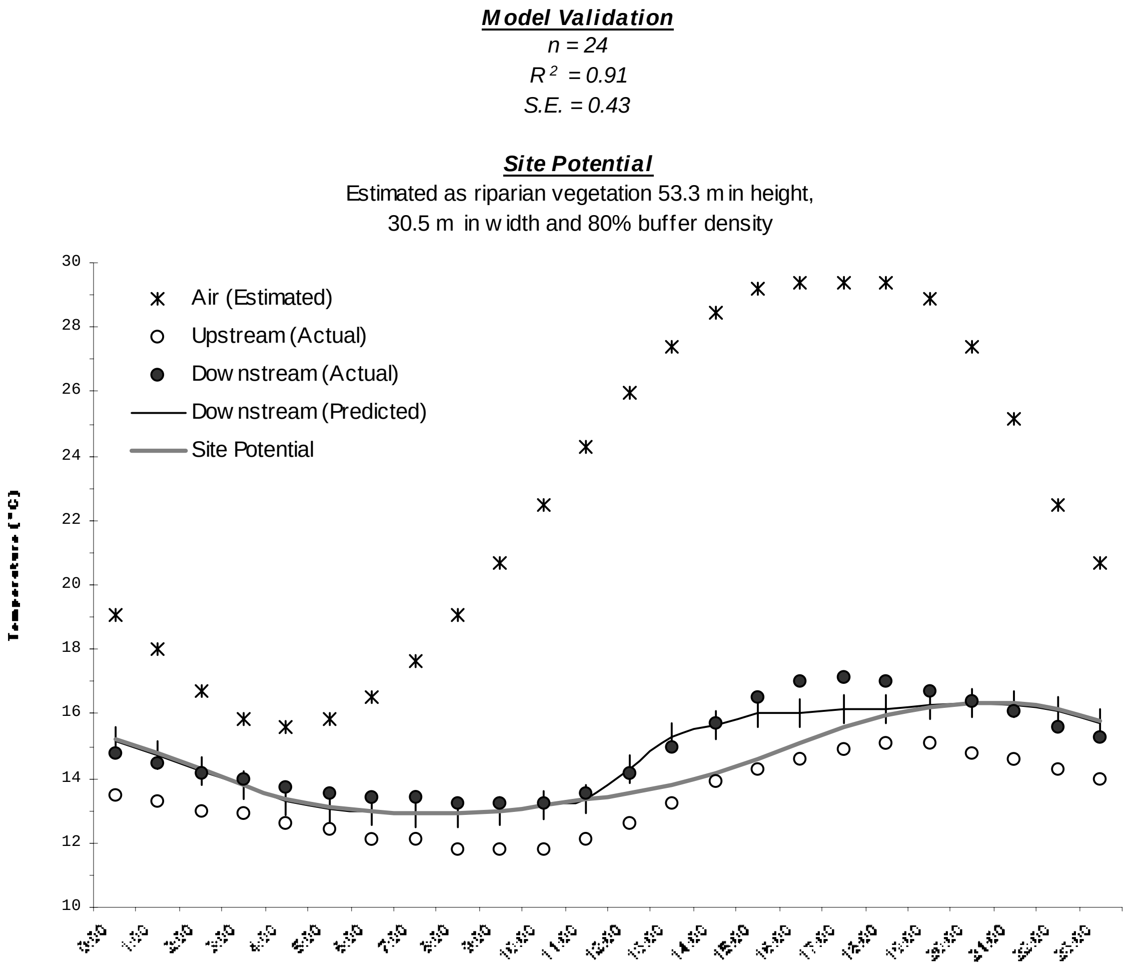
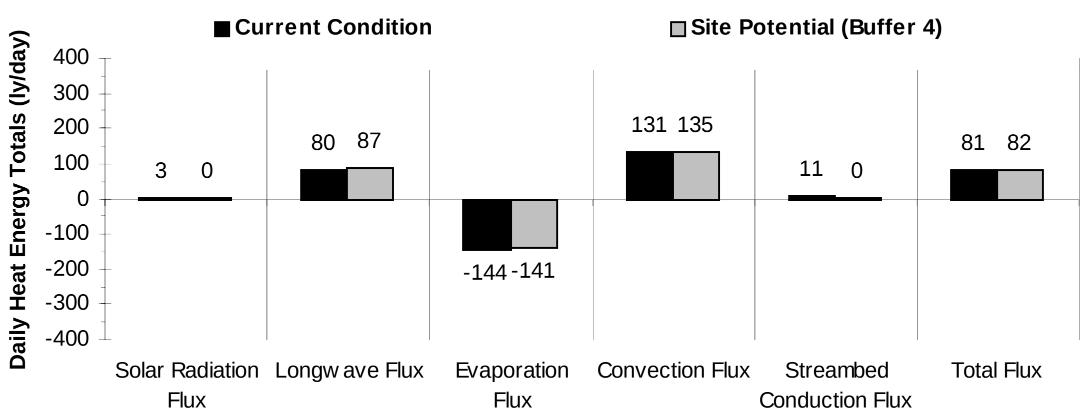


Figure A-20. Upper South Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #2 – East Fork of South Fork Trask R.

E.F. of S.F. Trask R. upstream of S.F. Trask R. confluence (looking upstream)

Input Parameters

Run Name	Trask 2 - Upper EF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.42	*(deg N)*
Longitude	-123.6	*(deg W)*
Stream Aspect	355	*(deg)*
Percent Bedrock	100%	
Reach Length	7563	*(meters)*
Channel Width	6.4	*(meters)*
Flow Volume	0.385	*(cms)*
Flow Velocity	0.366	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.16	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	25%	
Distance to Stream	0.50	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	1.91	*(meters)*
Shade Angle	83.3	*(deg)*
View to Sky	7%	
Effective Shade	91%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-21. East Fork of South Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

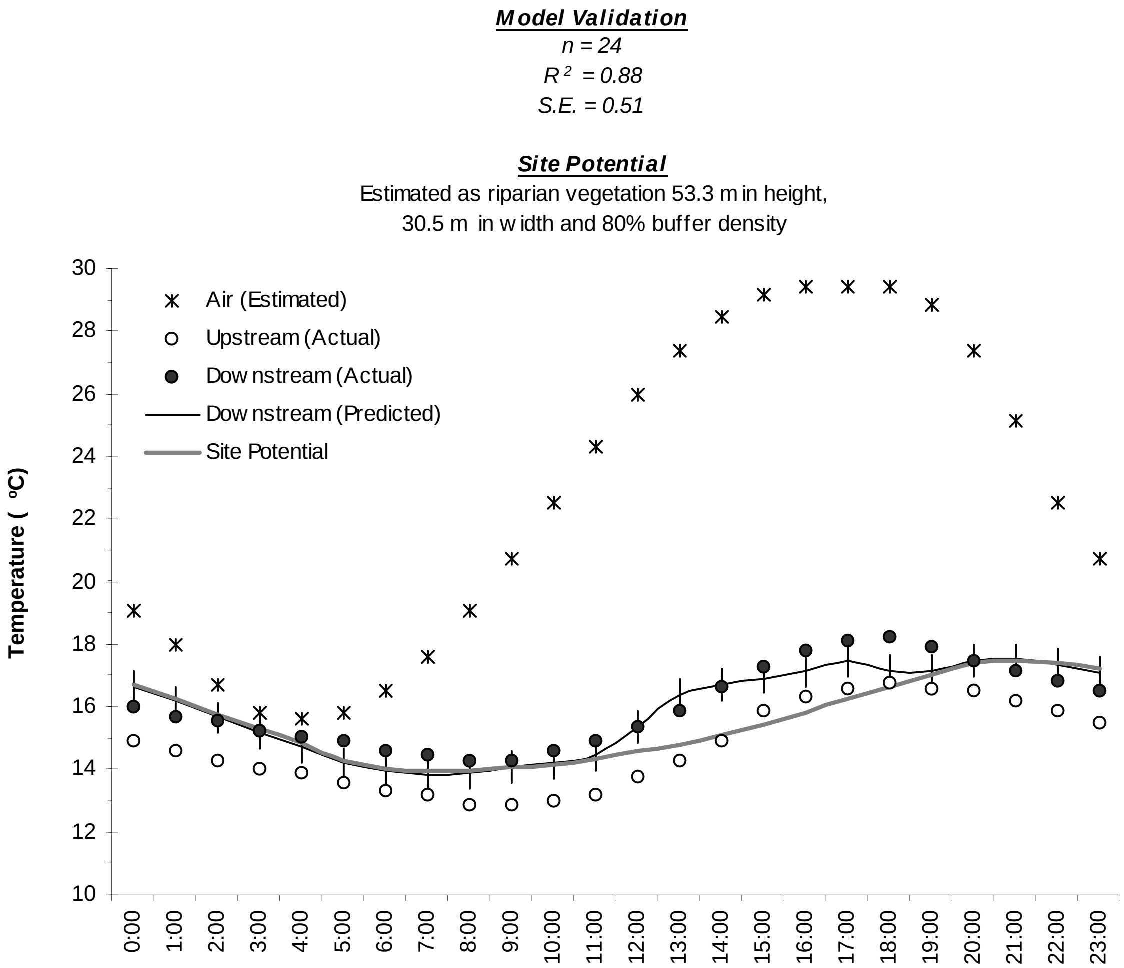
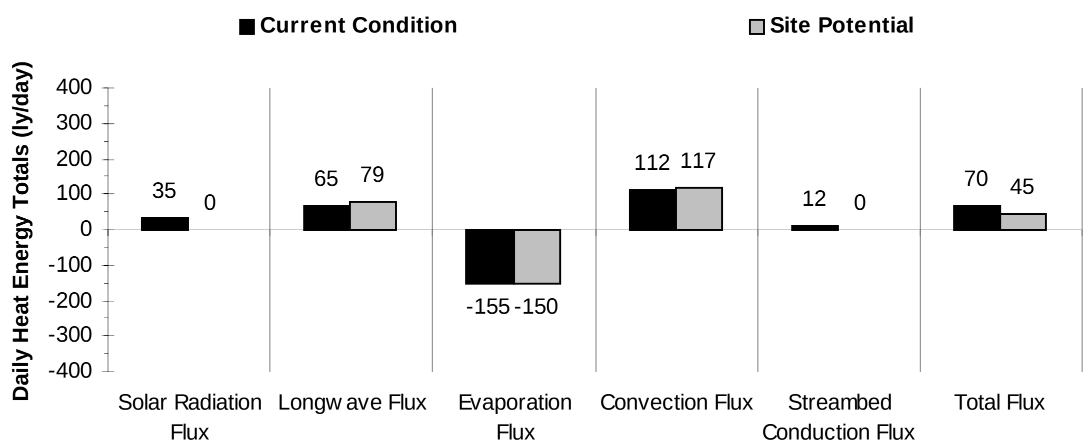


Figure A-22. East Fork of South Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #3 – Lower South Fork Trask R.

S.F. Trask R. upstream of Trask R. confluence (looking upstream)

Input Parameters

Run Name	Trask 3 - Lower SF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.44	*(deg N)*
Longitude	-123.61	*(deg W)*
Stream Aspect	350	*(deg)*
Percent Bedrock	100%	
Reach Length	3060	*(meters)*
Channel Width	12.5	*(meters)*
Flow Volume	0.848	*(cms)*
Flow Velocity	0.229	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.30	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	0.50	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	79.1	*(deg)*
View to Sky	12%	
Effective Shade	85%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-23. Lower South Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

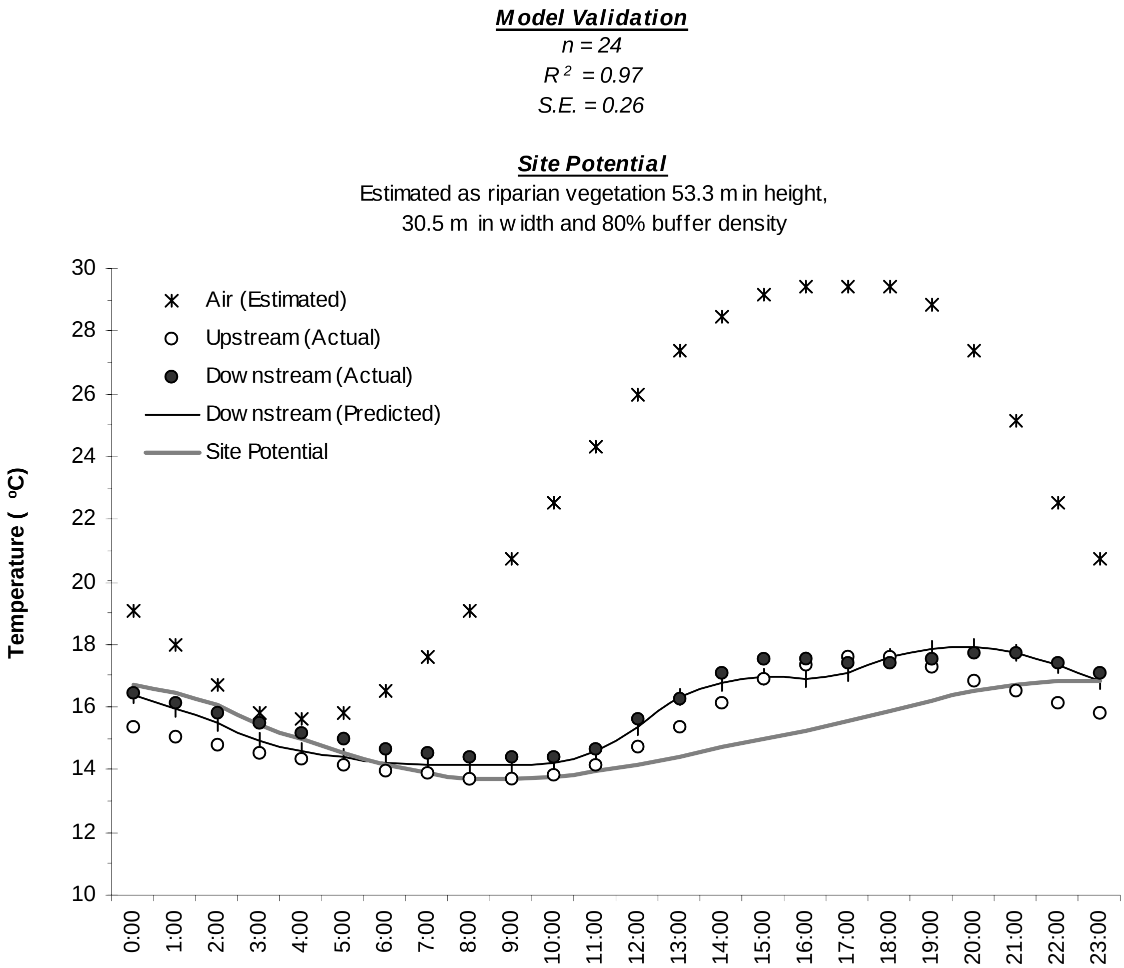
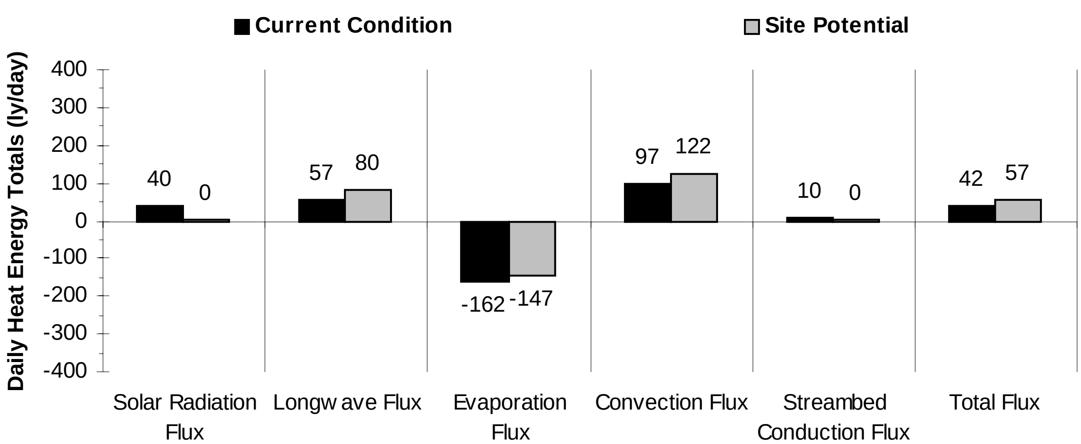


Figure A-24. Lower South Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #4 – Upper North Fork Trask R.

Upper N.F. Trask R. downstream of M.F. of N.F. Trask R. confluence (looking upstream)

Input Parameters

Run Name	Trask 4 - Upper NF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.47	*(deg N)*
Longitude	-123.48	*(deg W)*
Stream Aspect	240	*(deg)*
Percent Bedrock	75%	
Reach Length	6920	*(meters)*
Channel Width	11.89	*(meters)*
Flow Volume	1.032	*(cms)*
Flow Velocity	0.29	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^oC)*
Ave. Stream Depth	0.30	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	22.87	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	0.50	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	30%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.43	*(meters)*
Shade Angle	82.5	*(deg)*
View to Sky	8%	
Effective Shade	90%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-25. Upper North Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

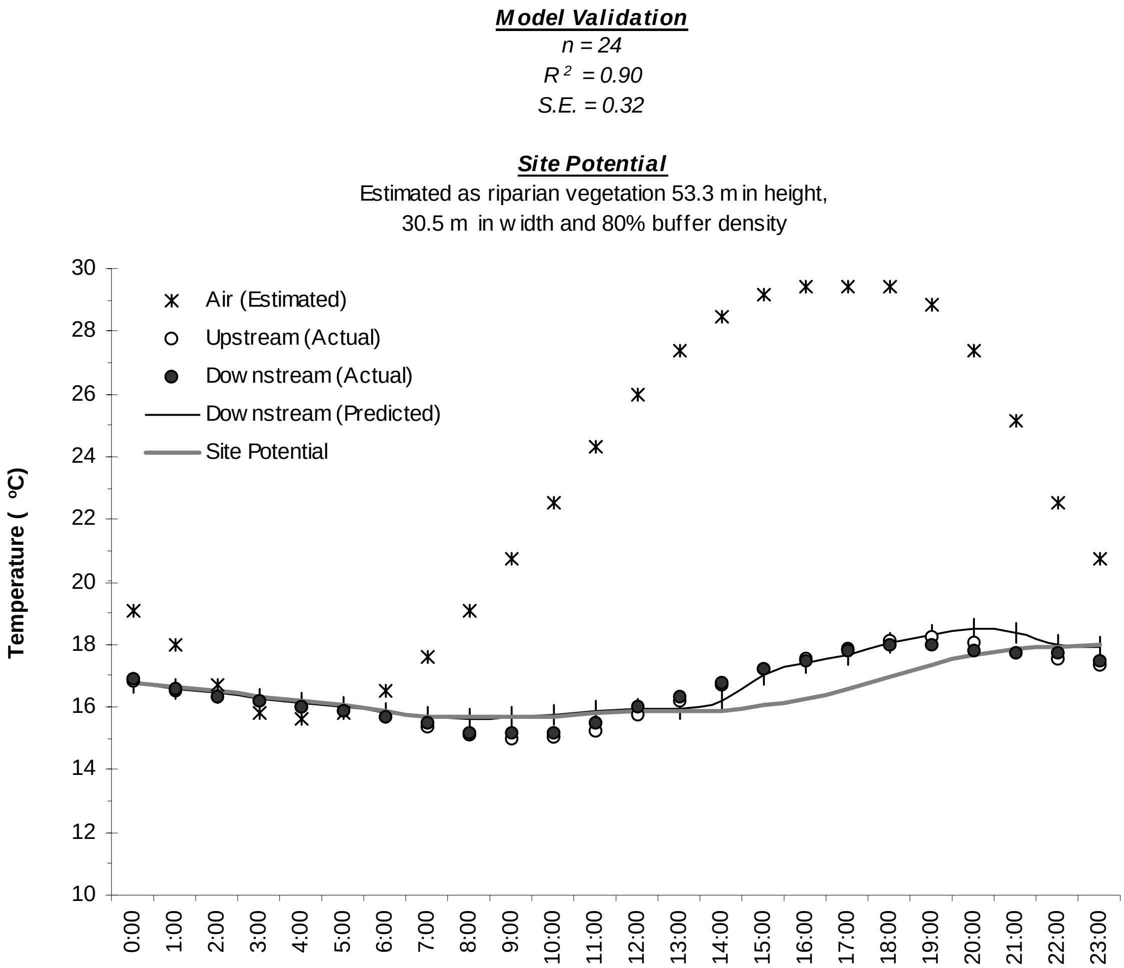
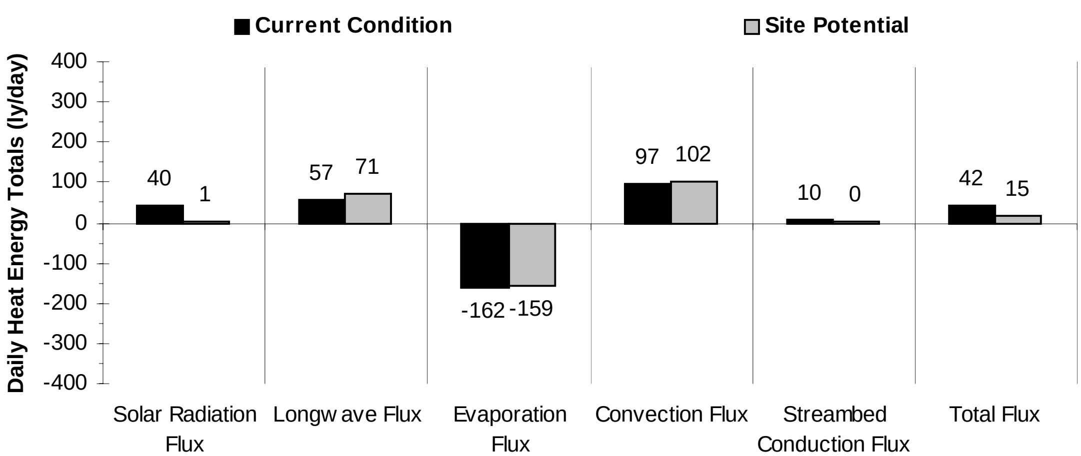


Figure A-26. Upper North Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #5 – Middle North Fork Trask R.

Middle N.F. Trask R. upstream of Clear Creek #3 confluence (looking upstream)

Input Parameters

Run Name	Trask 5 - Middle NF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.45	*(deg N)*
Longitude	-123.56	*(deg W)*
Stream Aspect	240	*(deg)*
Percent Bedrock	100%	
Reach Length	8369	*(meters)*
Channel Width	14.02	*(meters)*
Flow Volume	1.257	*(cms)*
Flow Velocity	0.198	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.45	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	64.7	*(deg)*
View to Sky	28%	
Effective Shade	65%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-27. Middle North Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

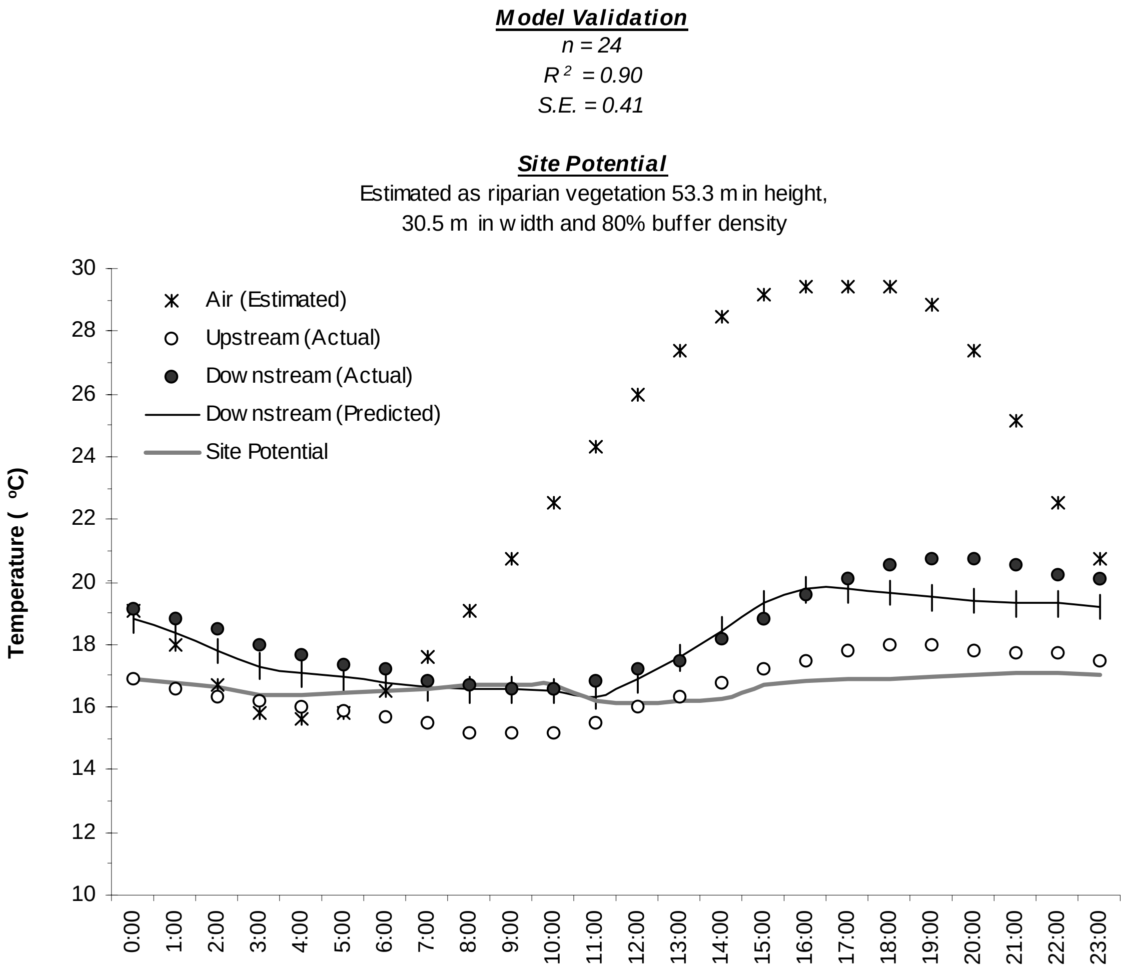
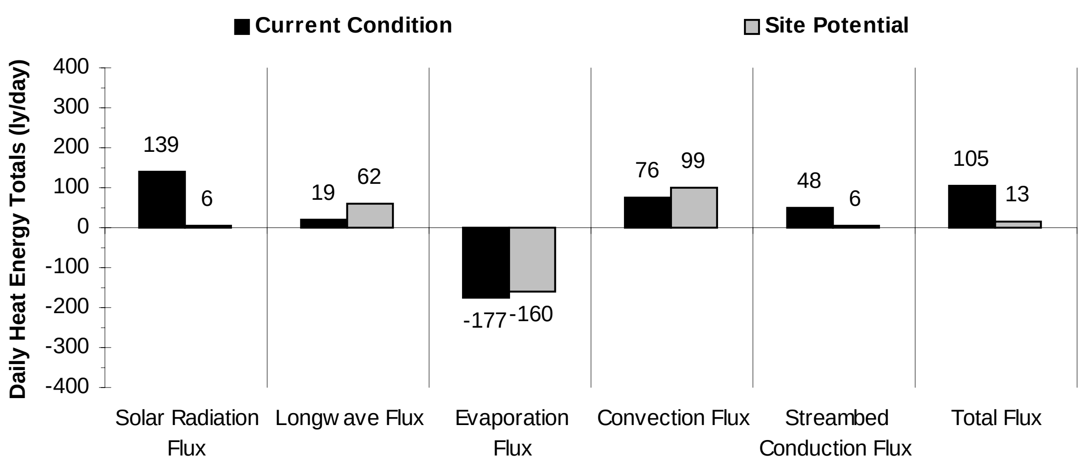


Figure A-28. Middle North Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #6 – Lower North Fork Trask R.

Lower N.F. Trask R. upstream of S.F./N.F. Trask R. confluence (looking upstream)

Input Parameters

Run Name	Trask 6 - Lower NF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.44	*(deg N)*
Longitude	-123.61	*(deg W)*
Stream Aspect	270	*(deg)*
Percent Bedrock	75%	
Reach Length	7244	*(meters)*
Channel Width	16.77	*(meters)*
Flow Volume	1.36	*(cms)*
Flow Velocity	0.183	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.44	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	60.6	*(deg)*
View to Sky	33%	
Effective Shade	52%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-29. Lower North Fork Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

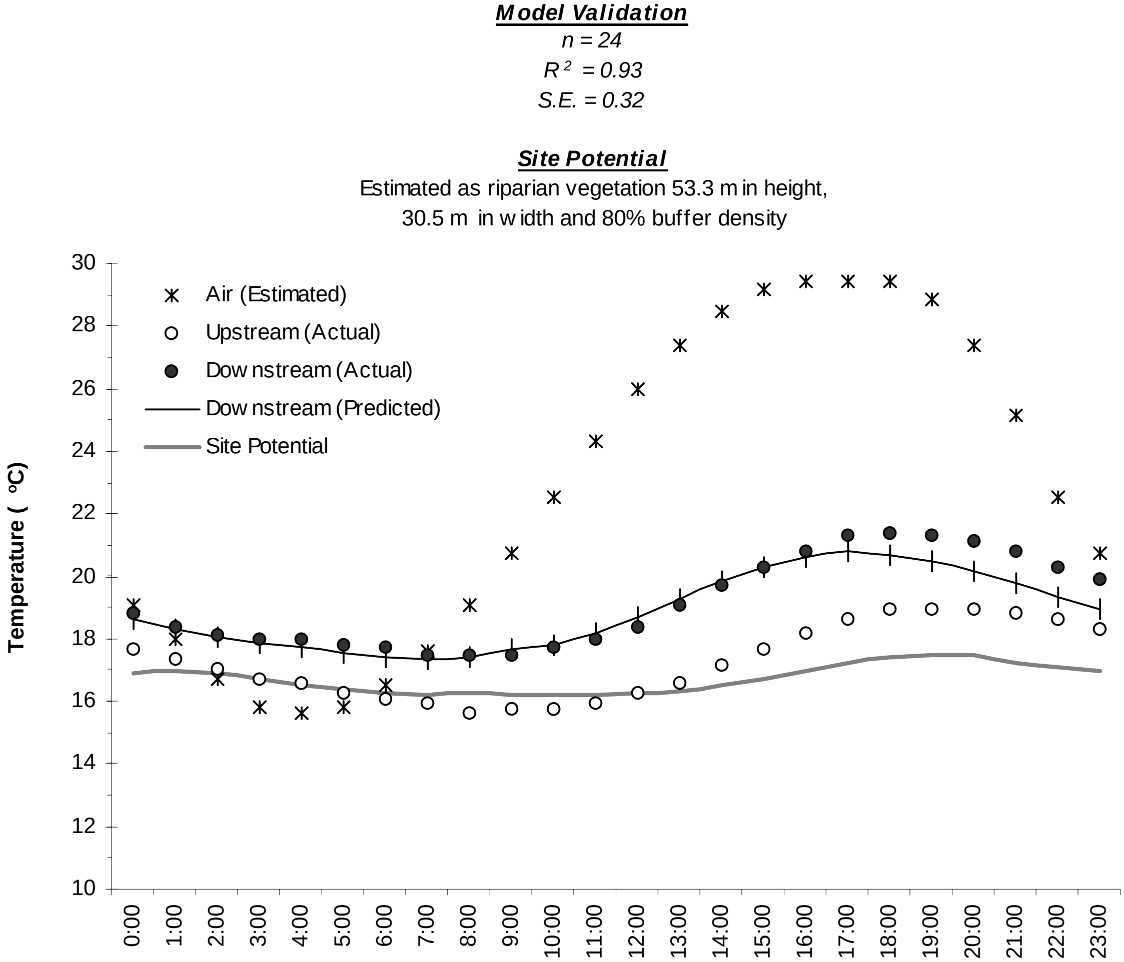
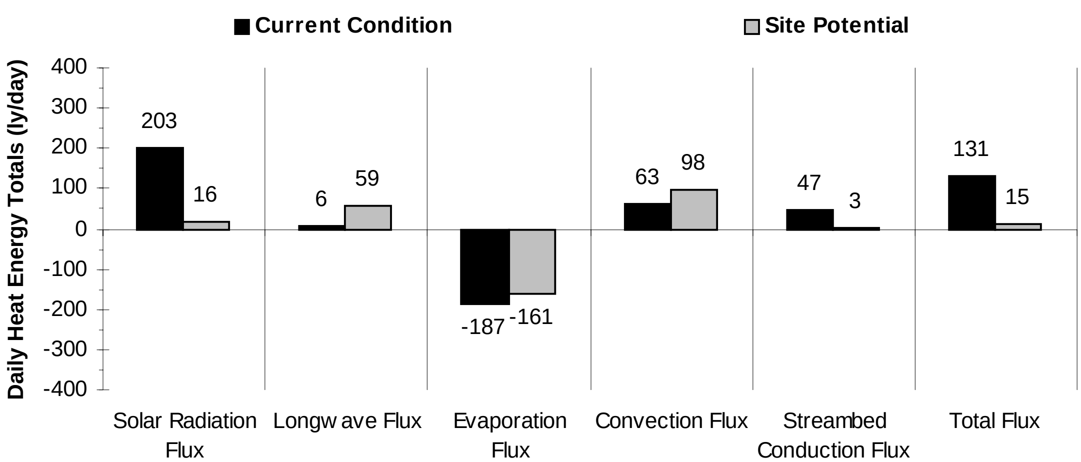


Figure A-30. Lower North Fork Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #7 – Upper Trask R.

Lower Trask R. downstream of S.F./N.F. Trask R. confluence – MP 11 (looking downstream)

Input Parameters

Run Name	Trask 7 - Upper Trask	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.46	*(deg N)*
Longitude	-123.64	*(deg W)*
Stream Aspect	260	*(deg)*
Percent Bedrock	100%	
Reach Length	10300	*(meters)*
Channel Width	19.82	*(meters)*
Flow Volume	2.556	*(cms)*
Flow Velocity	0.274	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.47	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	50%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	56.5	*(deg)*
View to Sky	37%	
Effective Shade	48%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-31. Upper Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

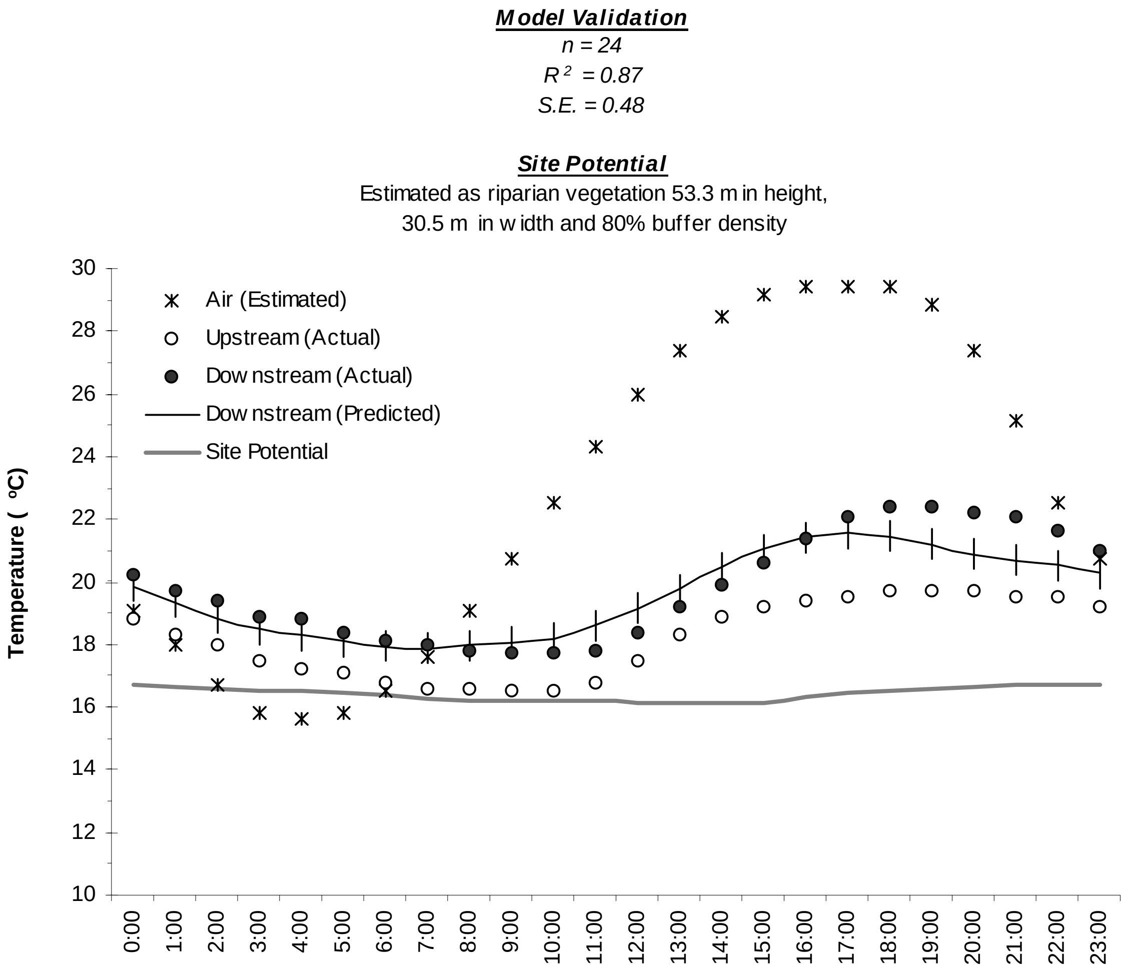
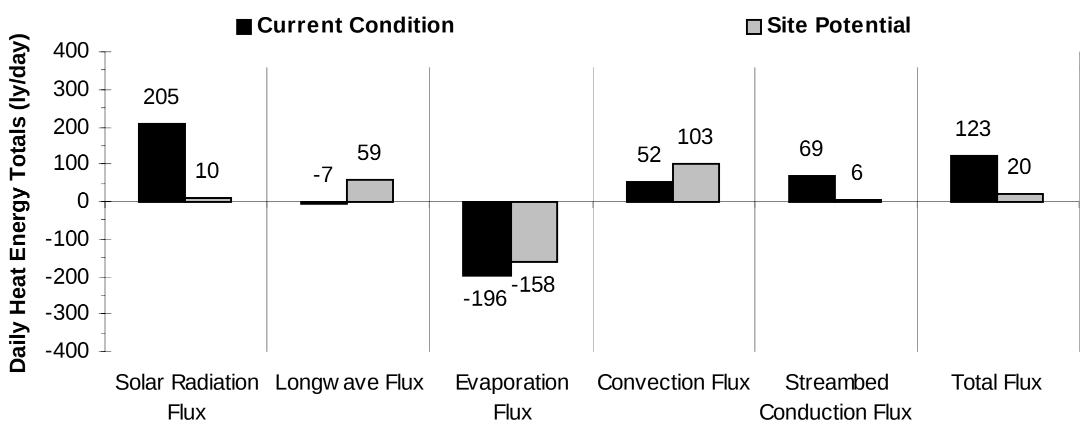


Figure A-32. Upper Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #8 – Middle Trask R.

Lower Trask R. upstream of Gold Creek – Fish Hatchery (looking upstream)

Input Parameters

Run Name	Trask 8 - Middle Trask	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.43	*(deg N)*
Longitude	-123.74	*(deg W)*
Stream Aspect	230	*(deg)*
Percent Bedrock	85%	
Reach Length	2989	*(meters)*
Channel Width	21.65	*(meters)*
Flow Volume	3.032	*(cms)*
Flow Velocity	0.244	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.57	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	15.24	*(meters)*
Buffer Density	50%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	3.81	*(meters)*
Shade Angle	54.2	*(deg)*
View to Sky	40%	
Effective Shade	48%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-33. Middle Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

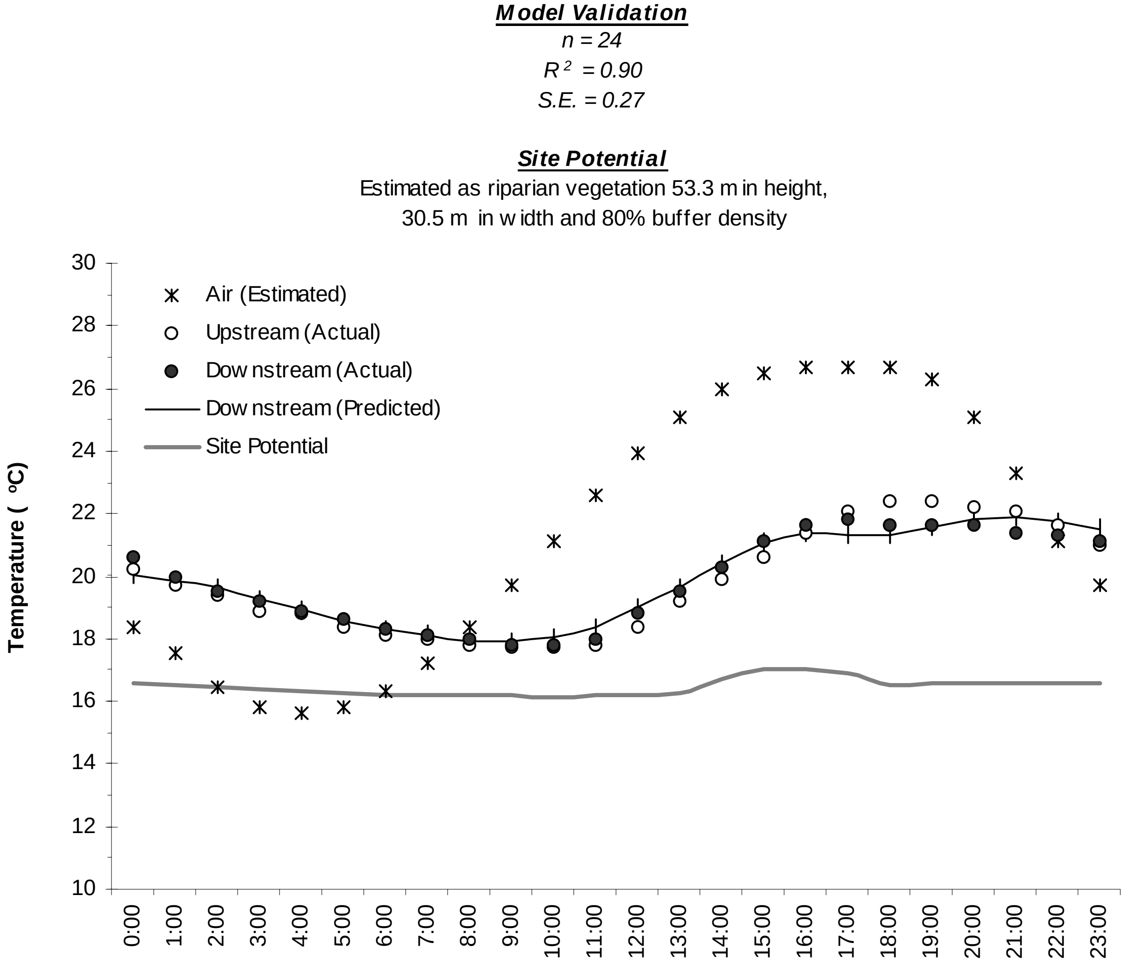
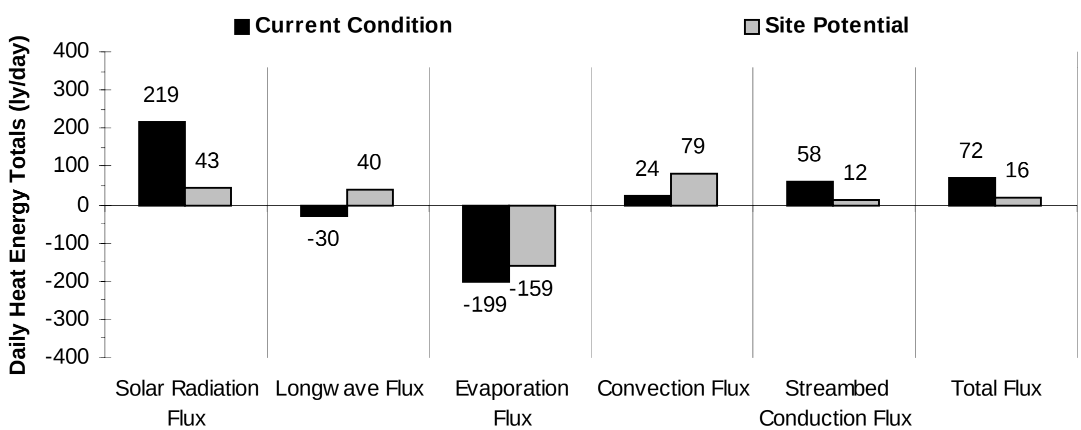


Figure A-34. Middle Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



Simulation Reach #9 – Lower Trask R.

Lower Trask R. downstream of Gold Creek – Fish Hatchery (looking downstream)

Input Parameters

Run Name	Trask 9 - Lower Trask	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.43	*(deg N)*
Longitude	-123.8	*(deg W)*
Stream Aspect	260	*(deg)*
Percent Bedrock	5%	
Reach Length	8210	*(meters)*
Channel Width	26.52	*(meters)*
Flow Volume	3.032	*(cms)*
Flow Velocity	0.244	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.47	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	7.62	*(meters)*
Buffer Density	30%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.29	*(meters)*
Shade Angle	45.5	*(deg)*
View to Sky	49%	
Effective Shade	33%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure A-35. Lower Trask R. Temperature Profiles
(ODEQ - August 12, 1998)

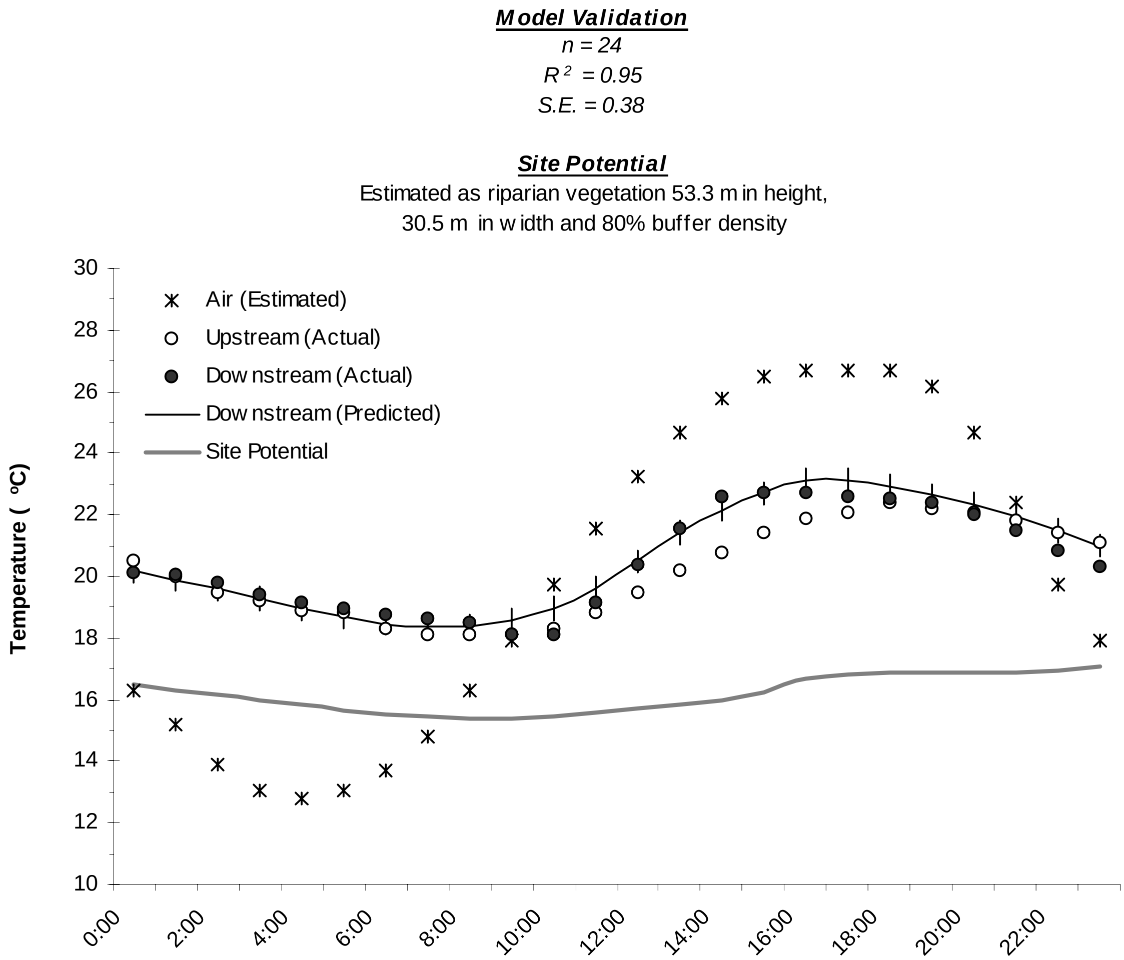
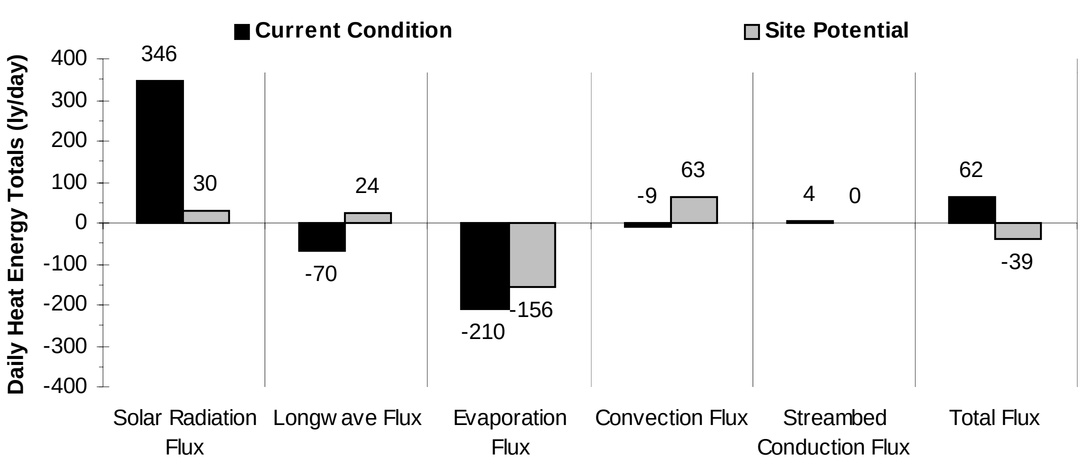


Figure A-36. Lower Trask R. Daily Heat Energy Totals
(ODEQ - August 12, 1998)



APPENDIX B

TILLAMOOK RIVER TEMPERATURE ASSESSMENT

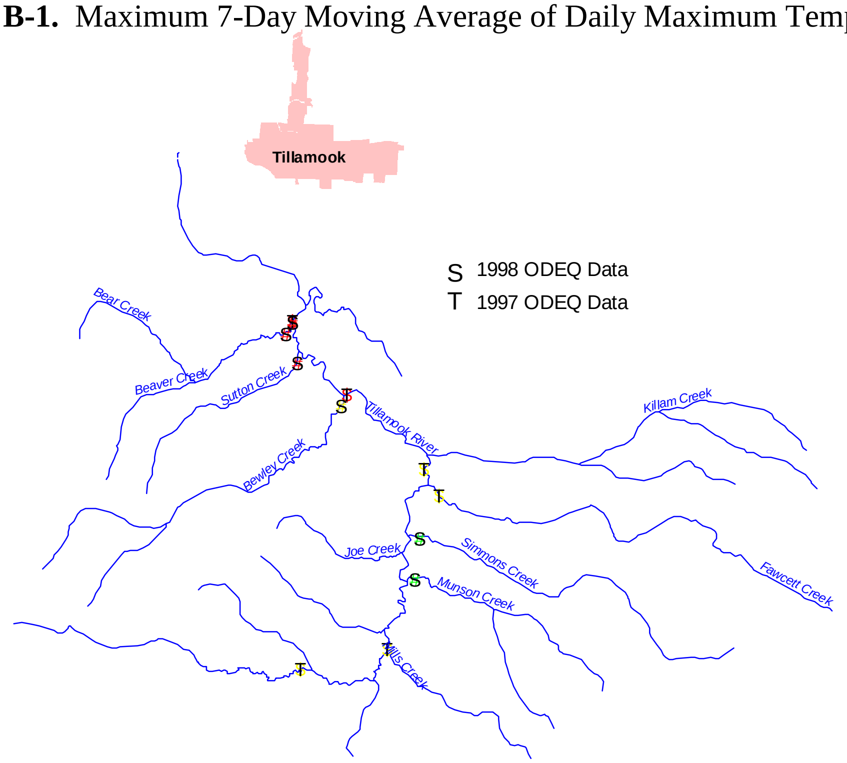
Current Condition Assessment

Temperature

The Oregon Department of Environmental Quality (ODEQ) measured stream temperatures for summer months in both 1997 and 1998. A total of eleven sites were continuously monitored. Major tributaries, as well as the Tillamook River mainstem have been sampled for temperature in either the 1997 or 1998 summertime monitoring season. All continuous monitoring data has passed ODEQ quality control protocols. **Image B-1** displays monitoring sites have been statistically processed to yield the 7-day average of the daily maximum temperatures (commonly referred to the *7-day statistic*). These 7-day statistics are used to specify if the sampled stream temperatures violate State water quality standards.

Spatial Temperature Patterns

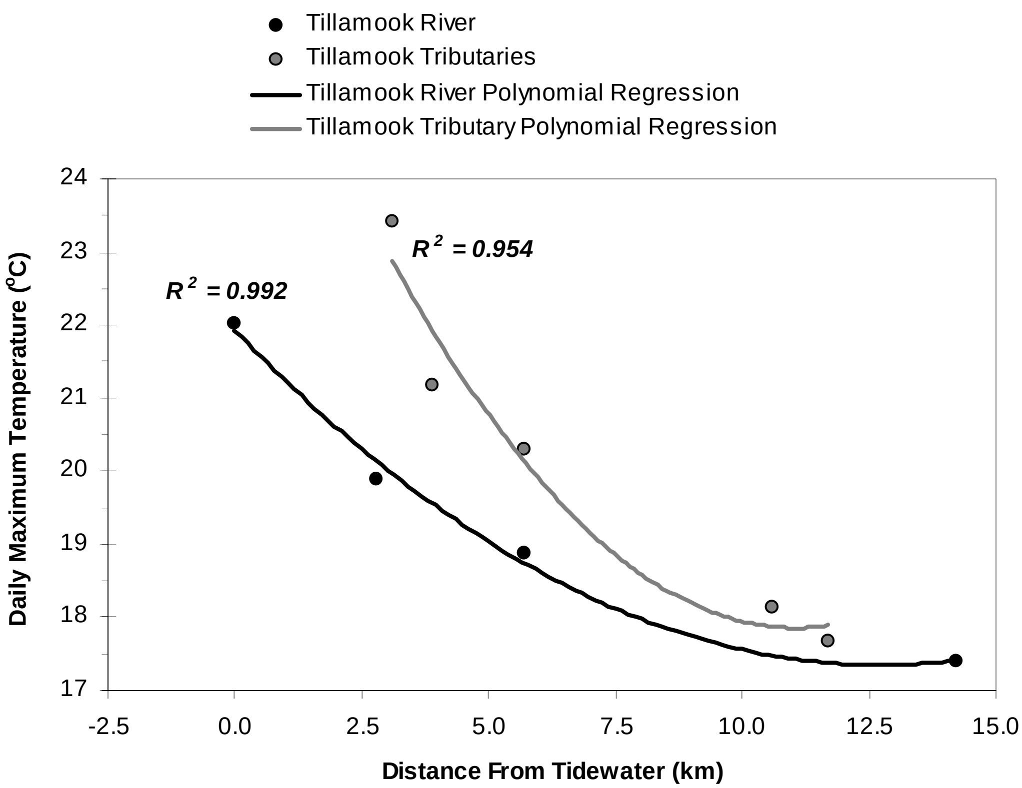
Image B-1. Maximum 7-Day Moving Average of Daily Maximum Temperature



Less than 12.8°C	**12.8°C to 15.3°C**	**15.3°C to 17.8°C**	**17.8°C to 20.3°C**	**Greater than 20.3°F**

Generally, tributaries feeding the Tillamook mainstem have warmer daily temperatures. Stream heating curves were developed for maximum daily temperatures sampled on August 12, 1998, for tributaries (Munson Creek, Simmons Creek, Beaver Creek, Bewley Creek and Sutton Creek) and the Tillamook mainstem (Yellow Fir, Rest Area, upstream Bewley Creek, and downstream Beaver Creek) (**Figure B-1**). Temperature patterns throughout the Tillamook River sub-basin follow continual heating in the downstream (longitudinal) direction. Significant stream heating was measured in the Tillamook River throughout its entire length (i.e. the slopes of both the tributary and mainstem regression lines in **Figure B-1** are steep).

Figure B-1. Stream Temperature Heating Curve
(August 12, 1998)



Daily temperature profiles for August 12, 1998 display the relative temperatures of the Tillamook River at the upper (Yellow Fir), middle (Rest Area), lower (upstream Bewley Creek), and tidewater (downstream Beaver Creek) sample sites (**Figure B-2**). Again, considerable longitudinal heating is apparent in the temperature data. **Figure B-3** displays diurnal temperature profiles for Tillamook tributaries. Many of the tributaries have temperatures warmer than the mainstem throughout the diurnal temperature cycle. Beaver Creek, Sutton Creek and Bewley Creek have significant heating influences on the mainstem receiving water. Median hourly temperature differences between tributaries and the mainstem are plotted in **Figure B-4**. A positive median temperature differential indicates mainstem heating by a tributary, while a negative median temperature differential indicates a tributary cooling influence on the mainstem.

Figure B-2. Tillamook Mainstem Stream Temperature Profiles
(August 12, 1998)

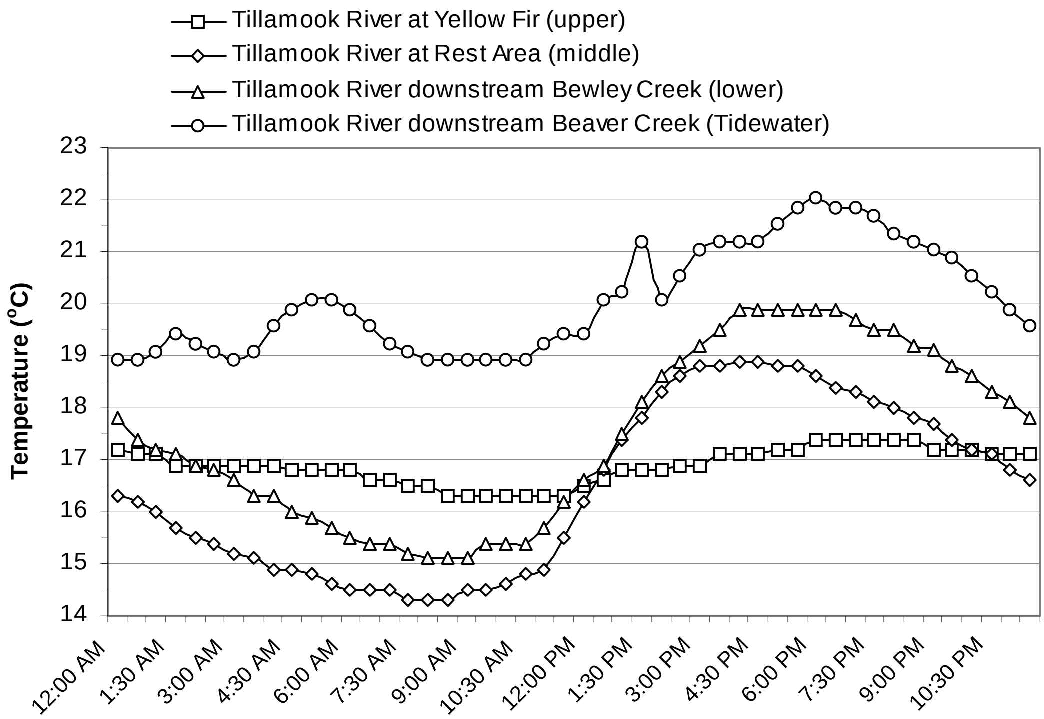


Figure B-3. Tillamook Tributary Stream Temperature Profiles
(August 12, 1998)

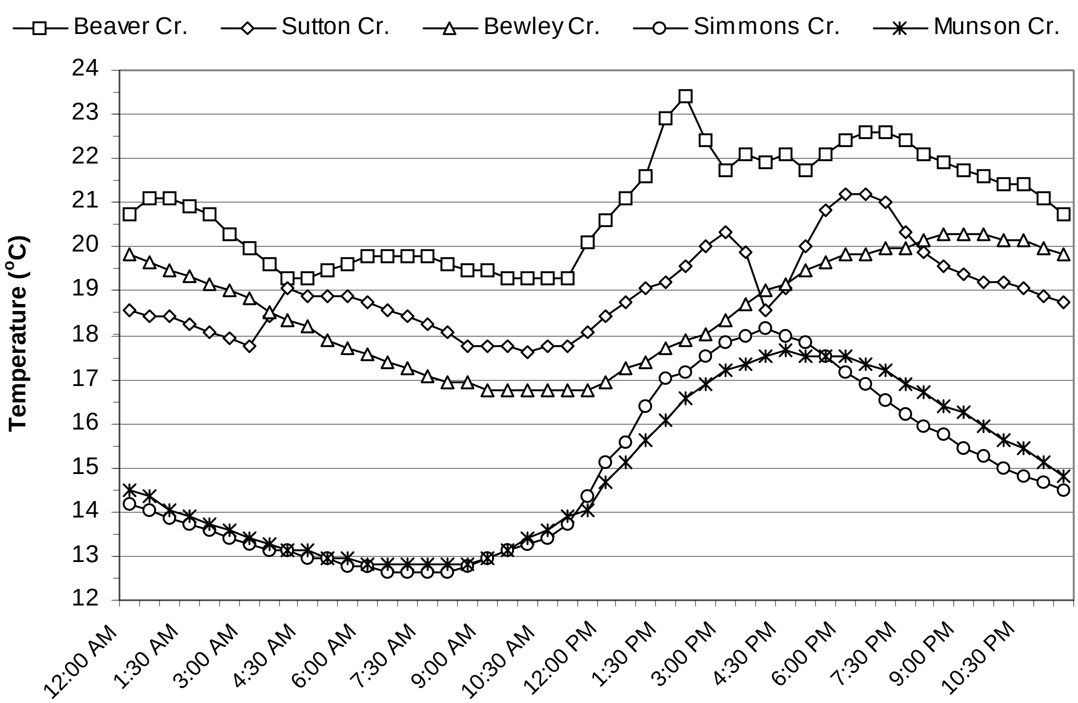
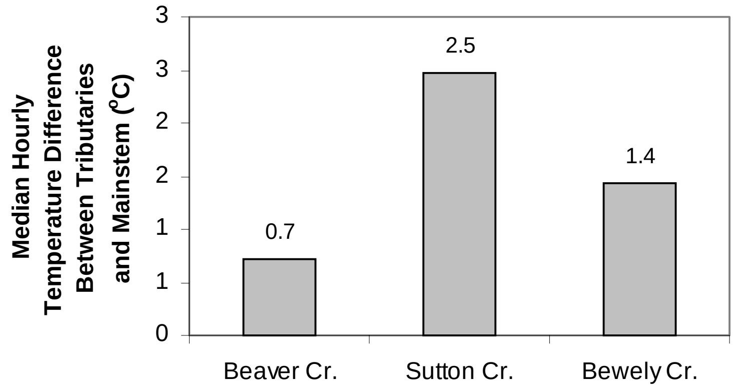


Figure B-4. Median Hourly Temperature Difference Between Tributaries and Mainstem *(August 12, 1998)*

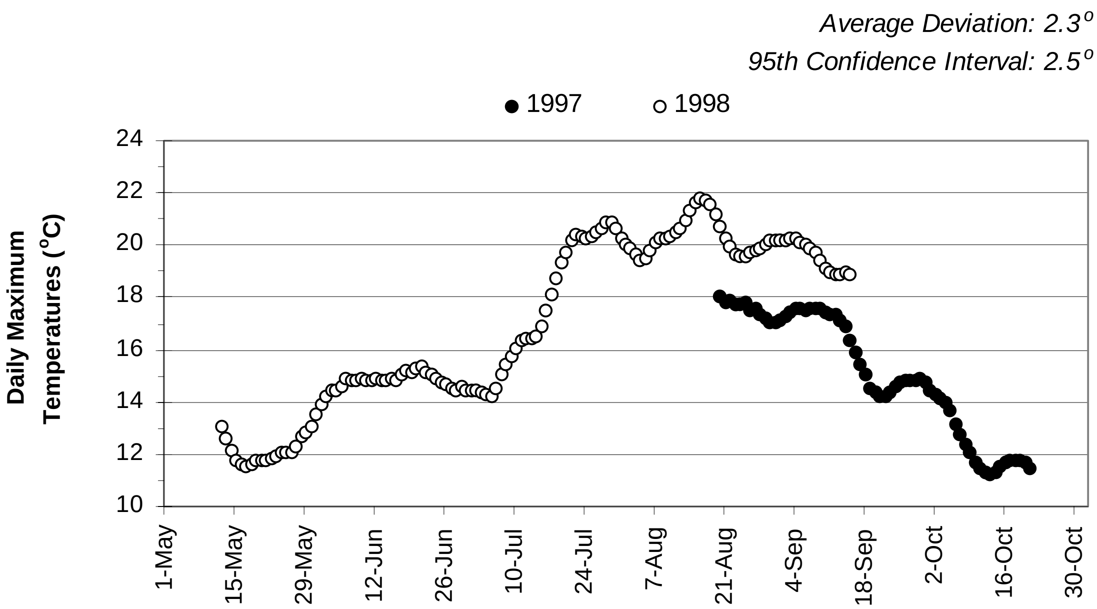


Temporal Temperature Patterns

<u>Yearly Variations</u>

Temperature data were sampled at the Tillamook River downstream Beaver Creek over both the 1997 and 1998 summertime seasons and data were graphically and statistically compared. **Figure B-5** displays the maximum daily temperatures for the 1997 and 1998 monitoring period at all three monitoring sites. All statistics (i.e. average deviation and 95^{th} confidence interval) were generated using only the overlapping portion of the 1997 and 1998 data. Comparing years, the 95^{th} percentile deviation in *maximum daily* stream temperatures during the sampling intervals was $2.5^{o}C$ and the average temperature deviation between years was $2.3^{o}C$.

Figure B-5. Seasonal Variability Between 1997 and 1998 Temperature Data
(Tillamook River downstream Beaver Creek)



<u>Seasonal Variations</u>

Seasonal maximum stream temperatures in the Tillamook River and tributary streams generally correspond to a combination of high levels of solar exposure, warm air temperatures and low flow conditions. Maximum stream temperatures occur in mid July and early August. Stream temperatures gradually decline through late August and September due to decreasing solar radiation loading. Stream temperatures in August and September often reach relatively warm daily maximums. Significant stream cooling occurs with decreased solar loading levels coupled with late Fall precipitation events that increase stream flow and reduce ambient air temperatures. Moving seven-day averages of daily maximum stream temperatures for selected sites in the Tillamook River sub-basin are displayed in **Figure B-6**. Maximum monthly seven-day moving averages of daily maximum stream temperatures are displayed in **Figure B-7**.

Figure B-6. Moving Seven-Day Averages of Daily Maximum Stream Temperatures for 1998 Monitoring Sites in the Tillamook River Sub-Basin

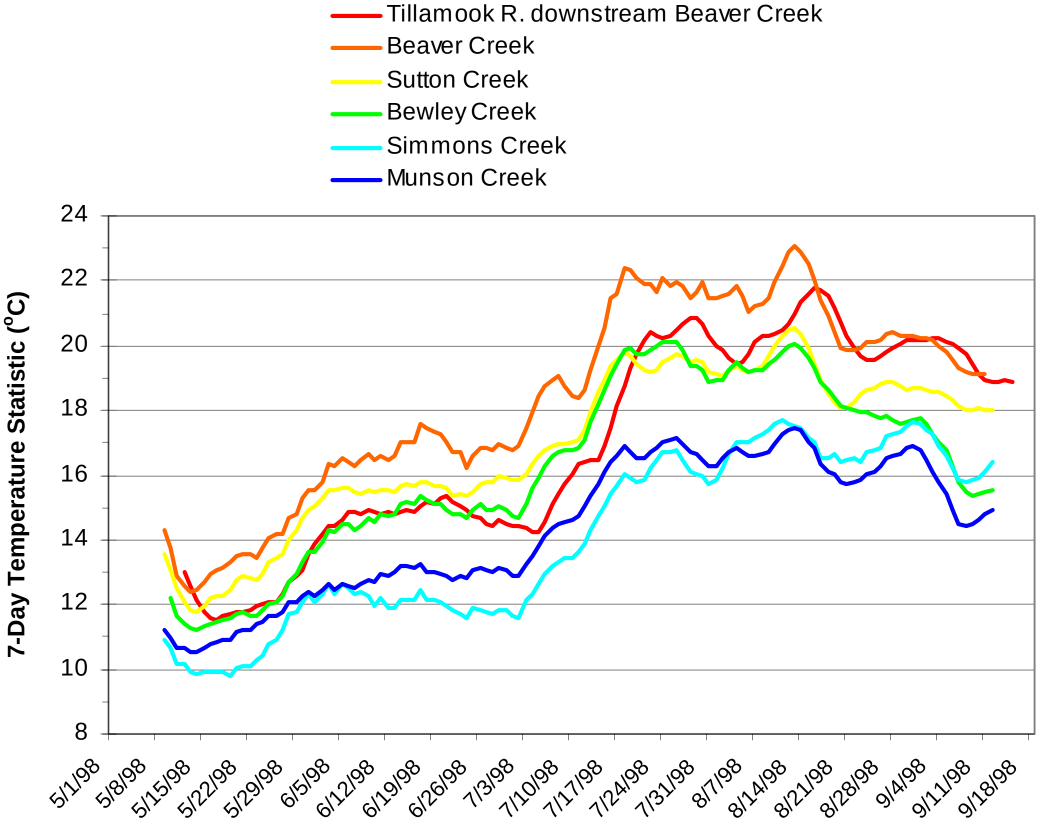
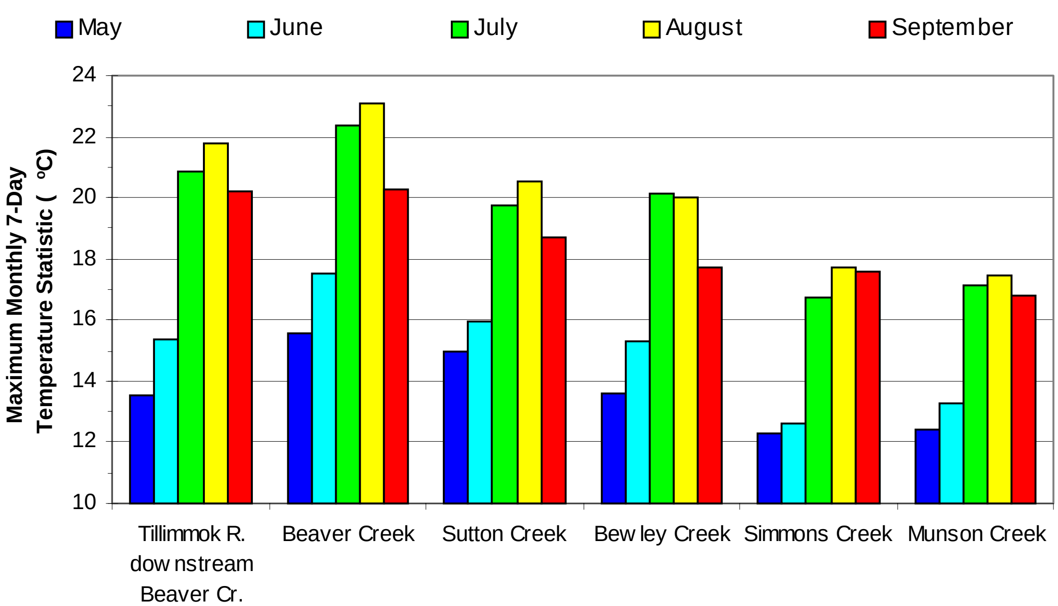


Figure B-7. Maximum Monthly Seven-Day Moving Averages of Daily Maximum Stream Temperatures (1998)



Shade

ODEQ measured stream surface shade during the summer months in 1998. A total of twelve sites were monitored. Stream surface shade and canopy cover can be highly variable in disturbed riparian areas. Continued shade data monitoring efforts are ongoing and additional data are expected to increase accuracy in shade representations.

Effective shade was quantified by averaging the Solar Pathfinder data for the months of May through September. Hours of solar exposure and local sunrise/sunset were also collected. Solar attenuation was derived from the Solar Pathfinder data by measuring the portion of the day that receives shade relative to total day length. Canopy cover was measured with a densiometer. Narrative descriptions of riparian vegetation (vegetative species composition/condition, height, width and distribution) were also recorded at the shade monitoring sites.

The Tillamook River is poorly shaded. The lowest effective shade measurement for the Tillamook River was 0% (at Beaver Creek and Bewley Creek confluences). Poor shading persists in middle reaches of the Tillamook River (Lab Acres and Rest Area). The upper most monitoring site (Yellow Fir) has 100% effective shade. The mixed alder, maple and pasture riparian vegetation throughout the Tillamook mainstem allows near daylong stream surface solar exposure. The median effective shade value for the Tillamook River is 10% (n = 5).

Tillamook tributaries have varied shade regimes that are highly dependent on surrounding land uses. Munson Creek, Simmons Creek, Fawcett Creek and Sutton Creek have fair to high shade levels. Bewley Creek and Beaver Creek have near zero shade levels due to intense grazing in the middle to lower reaches of both streams. The median effective shade value for Tillamook tributaries is 87% (n = 7).

Effective shade is extremely variable for the Tillamook stream network (0% to 100%). Much of the middle and lower tributary and mainstem reaches are poorly shaded. A median effective shade level throughout the entire stream length is 39%. Rural residential and agricultural/forestry disturbance have reduced the species composition and impaired riparian conditions in the middle and lower Tillamook mainstem and tributary reaches and shade levels are significantly compromised.

A visual summary of the effective shade data collected with a Solar Pathfinder is shown in **Image B-2**. **Figure B-8** displays the median effective shade, solar attenuation and canopy cover measured for the Tillamook mainstem and tributaries. **Figure B-9** shows an effective shade statistical summary (Box Plot) compared with the National Estuary Program (NEP) shade target of 75%.

Figure B-8. Tillamook Sub-Basin Measured Shade Data (1998)

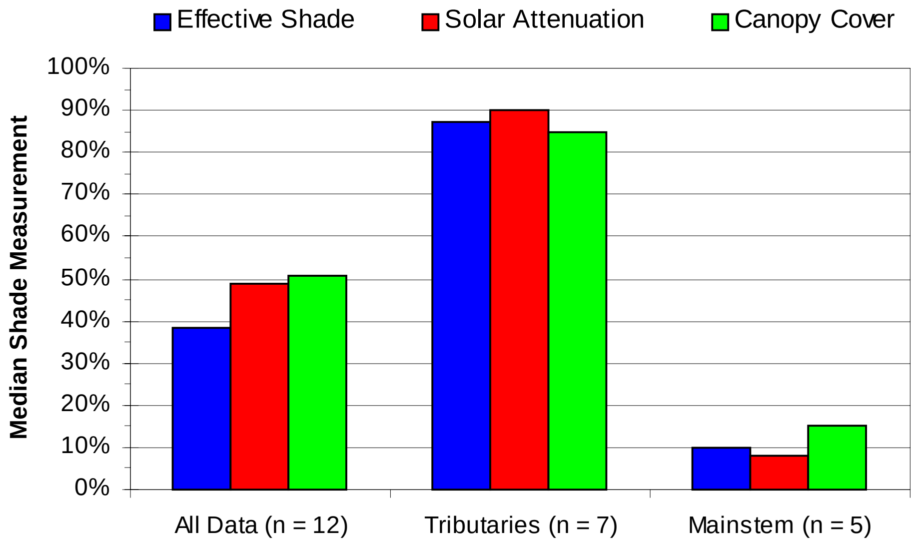


Figure B-9. Median Effective Shade Measurements Compared to NEP Shade Target *(1998)*

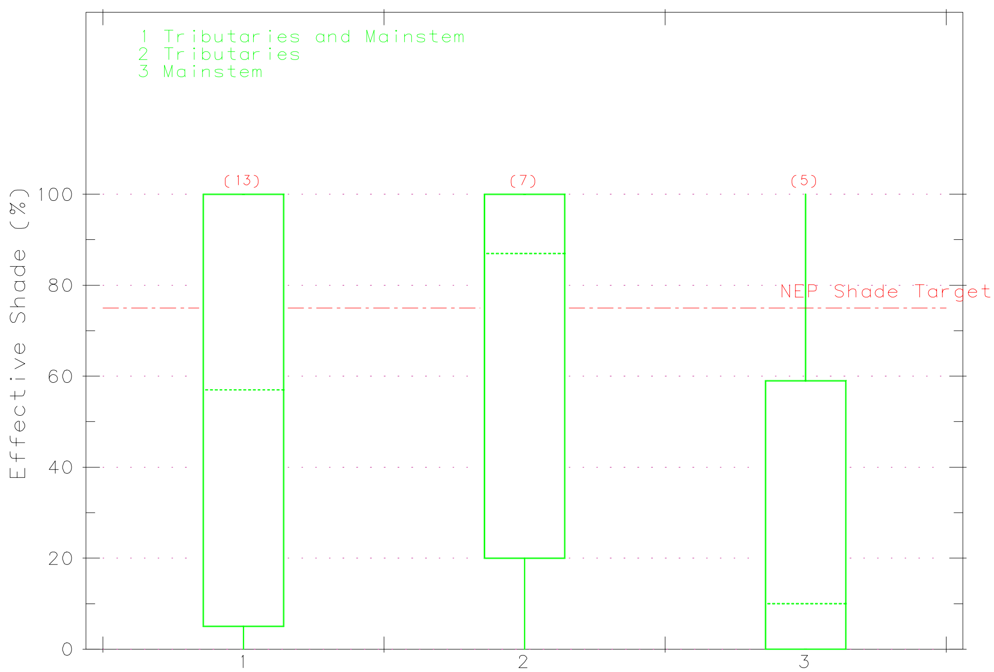
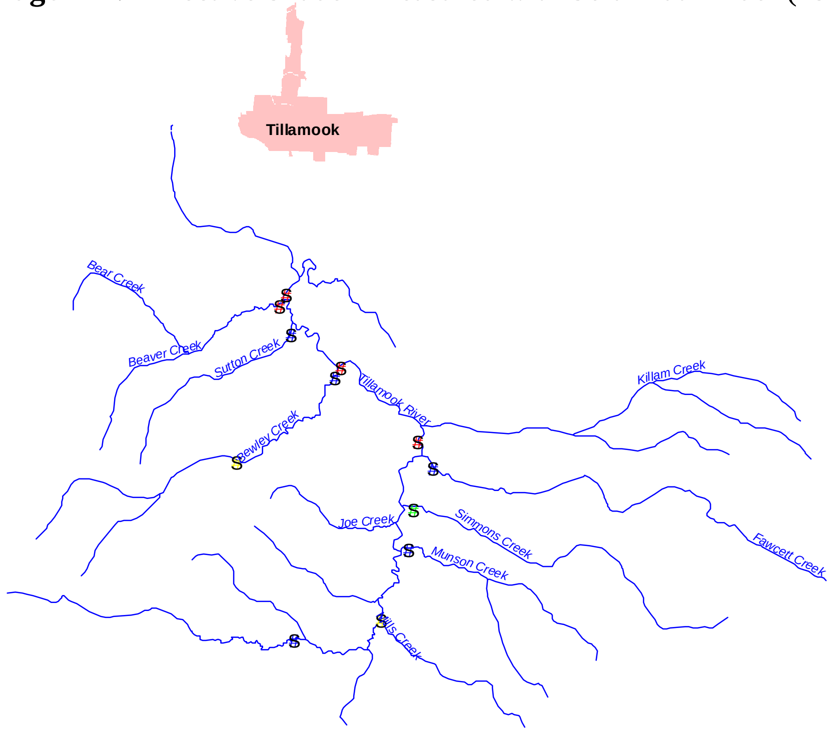
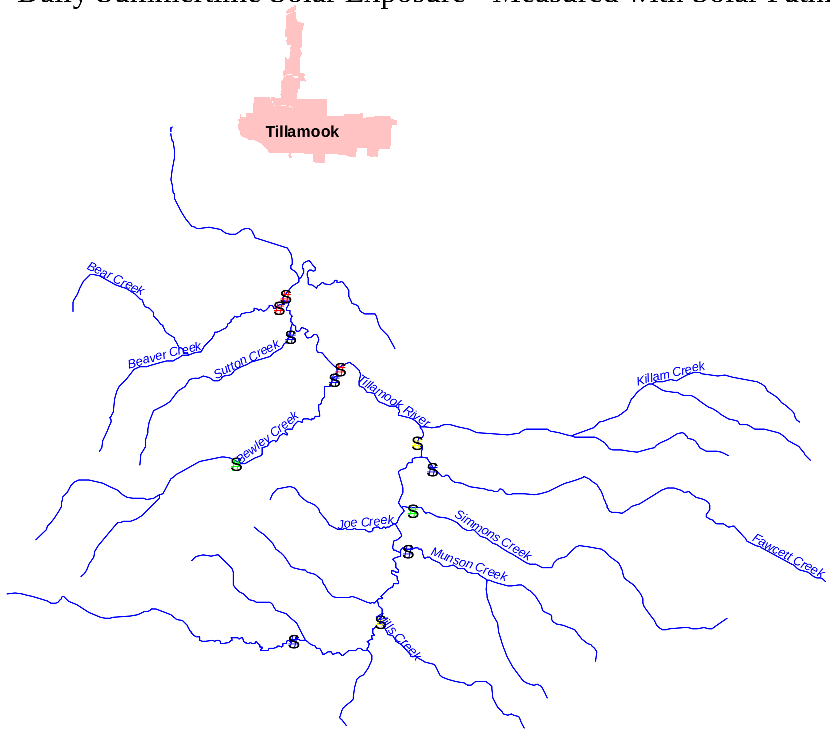


Image B-2. Effective Shade - Measured with Solar Pathfinder (1998)



Less than 20% **20% to 40%** **40% to 60%** **60% to 80%** **Greater than 80%**

Image B-3. Daily Summertime Solar Exposure - Measured with Solar Pathfinder (1998)

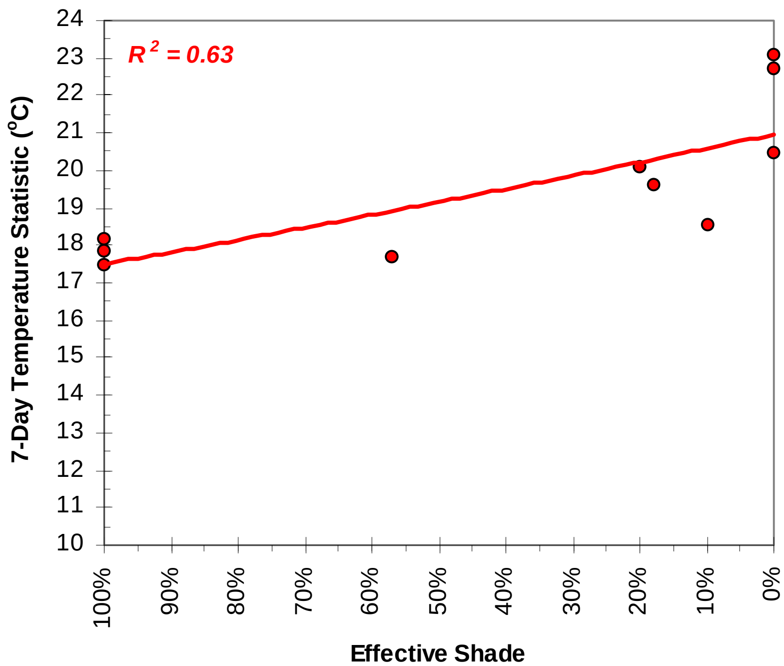


Less than 2 hours **2 to 4 hours** **4 to 6 hours** **6 to 8 Hours** **Greater than 8 hours**

Shade Related to Stream Temperature

Cooler stream temperatures are strongly related to stream surface shade (Rishel et al. 1982, Brown 1983, Beschta et al. 1987, Sinokrot and Stefan 1993, Chen 1996, Boyd 1996). When graphically compared, the inverse relationship between shade and temperature becomes apparent. Simply stated, stream surface exposure to solar radiation is reduced or eliminated in a highly shaded condition (**Figure B-10**). A threshold shade level often occurs at 75% to 80% effective shade where temperature change (dT/dx and dT/dt) can increase dramatically (Boyd 1996). This threshold shade condition is most apparent on smaller streams less than 0.14 cms (5 cfs) (Boyd 1996).

Figure B-10. Maximum Daily Temperature and Effective Shade
(August 12, 1998)



Stream Temperature Simulation

The purpose of this stream temperature simulation effort is to quantify stream temperatures and the corresponding energy process conditions that result when estimated site potential riparian vegetation exists. The model is validated using hydrologic, thermal and landscape data describing the current condition. Only 1998 data were used. Once the modeled reach output has been validated, stream temperatures and energy conditions are predicted for a site potential riparian condition. All other model inputs are assumed to remain unchanged. In this series of predictions, the site potential riparian condition assumed a late seral (old growth) conifer.

Model results should be used with caution. Associated prediction errors and goodness of fit estimates are provided with all model output. The author is aware of possible sources of error in the predictions. However, the methodology is sound and based on the most recent understanding of stream thermodynamics and hydraulics. As is generally the case in simulating non-linear water quality, model results are best suited for relative comparisons, rather than determinations of water quality parameter magnitude. Ultimate stream temperature magnitude is estimated in the report and is presented with upper and lower error boundaries. Discussions of the model results should include considerations for these boundaries of error.

Using a stream temperature prediction model (Heat Source v.5.5), a large extent of the Tillamook mainstem was simulated for temperature. The basic steps involved in stream temperature are as follows:

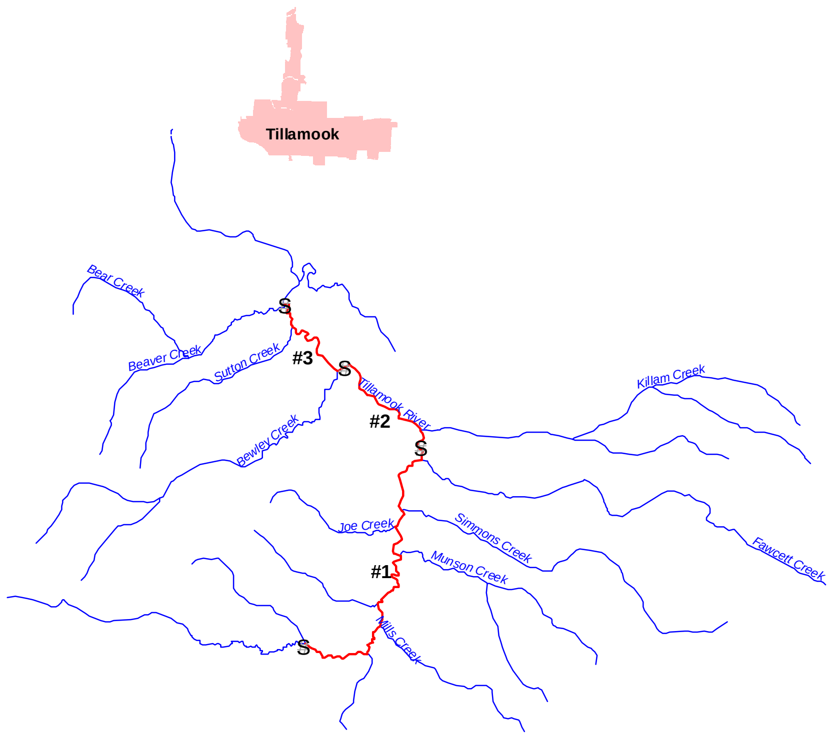
Methodology

1. *Selection of Temperature Simulation Reaches*

Table B-1. Trask River Simulation Reaches

#	Simulation Reach	Upper Extent	Lower Extent
1	Upper Tillamook R.	Yellow Fir	Rest Area
2	Middle Tillamook R.	Rest Area	Bewley Creek
3	Upper Tillamook R.	Bewley Creek	Beaver Creek

Image B-4. Stream Temperature Simulation Extent – **Red** Indicates Simulation Reaches



2. *Model Input: Site Specific Data*

Table B-2. Heat Source v. 5.3 Model Input Parameters	
• Date	• Buffer Height
• Stream Aspect	• Buffer Width
• Latitude	• Buffer Density
• Longitude	• Topographic Shade Angle (West)
• Reach Length	• Topographic Shade Angle (East)
• Channel Width	• Min. Air Temperature
• Flow Volume	• Max. Air Temperature
• Flow Velocity	• Relative Humidity
• Percent Bedrock	• Buffer Distance to Stream
• Groundwater Inflow	• Elevation
• Groundwater Temperature	• Wind Speed
• Dispersion Coefficient	• Upstream Hourly Temperature Data

3. *Prediction of Current Condition (Downstream Temperature Profile)*

4. *Model Validation: Statistical Analysis of Model Output*

Table C-3. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

- Pearson’s Product Moment (R^2)
- Standard Error (S.E.)

5. *Prediction of <u>Stream Reach Site Potential Conditions</u>*

- Site potential buffer dimensions were constant over all stream sections for each of the four site potential simulations.
- Assume that current condition standard error (S.E.) applies to site potential simulations.

6. *Prediction of Stream Reach Based on Cumulative Upstream Site Potential Conditions (Downstream Temperature Profile)*

- Utilize upstream reach site potential stream temperature for upstream model input in downstream reach simulation (i.e. downstream site potential temperature profile or Reach#1 becomes input temperature profile for Reach #2).
- Account for tributary temperature mixing.
- Assume tributary temperature are at or near site potential
- Assume that current condition standard error (S.E.) applies to site potential simulations.
- Standard error (S.E.) of upstream predictions accumulates in the downstream direction

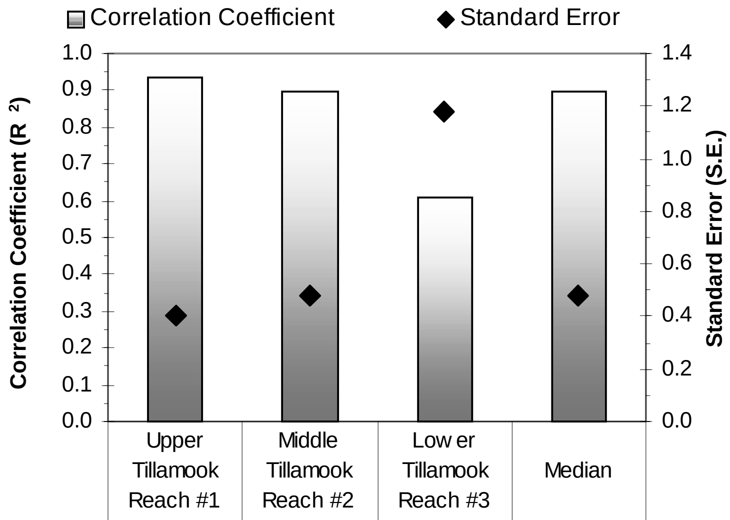
Model Validation

Temperature Validation

Two statistical measurements were used to assess the accuracy of stream temperature predictions. Comparisons between simulated and actual (measured) stream temperature profiles were used to generate the square of the Pearson product moment correlation coefficient (R^2) and the standard error (S.E.) for each simulation reach (**Figure B-11**). Median values for all simulation reaches were:

- Correlation Coefficient (R^2): 0.90
- Standard Error (S.E.): 0.48^{o}C

Figure B-11. Temperature Profile Simulation Accuracy
Heat Source v. 5.5 Model Validation (R^2 and S.E.)



	Upper Tillamook Reach #1	Middle Tillamook Reach #2	Lower Tillamook Reach #3	Median
Correlation Coefficient	0.93	0.90	0.61	0.90
Standard Error	0.40	0.48	1.18	0.48

Summary of Model Results

Temperature Output

Predicted maximum daily stream temperatures are cooler when site potential riparian conditions persist (buffer height = 38 meters, buffer width = 31 meters and buffer density = 80%). Longitudinal stream heating (displayed in **Figure B-1**) is drastically reduced in the simulated site potential riparian condition. **Figure B-12** shows the measured (actual) longitudinal stream heating pattern compared to those induced by simulated site potential riparian vegetation geometry. Site potential simulations demonstrate that stream temperature change occurs more gradually and temperature change becomes more dependent on tributary influences (mass transfer) than heat energy processes (heat transfer).

Vertical bars indicate the standard error associated with each simulation. Recall that all simulation errors of upstream prediction reaches were assumed to accumulate in the downstream direction. The result is an increasing margin of error for simulations in the downstream direction. Perhaps this method for accounting prediction error overstates the margin of error. However, it is important to recognize the limitations inherent to this methodology.

Figure B-12. Actual Stream Heating Curve and Predicted Site Potential Daily Maximum Temperatures with Associated Error Bars
(August 12, 1998)

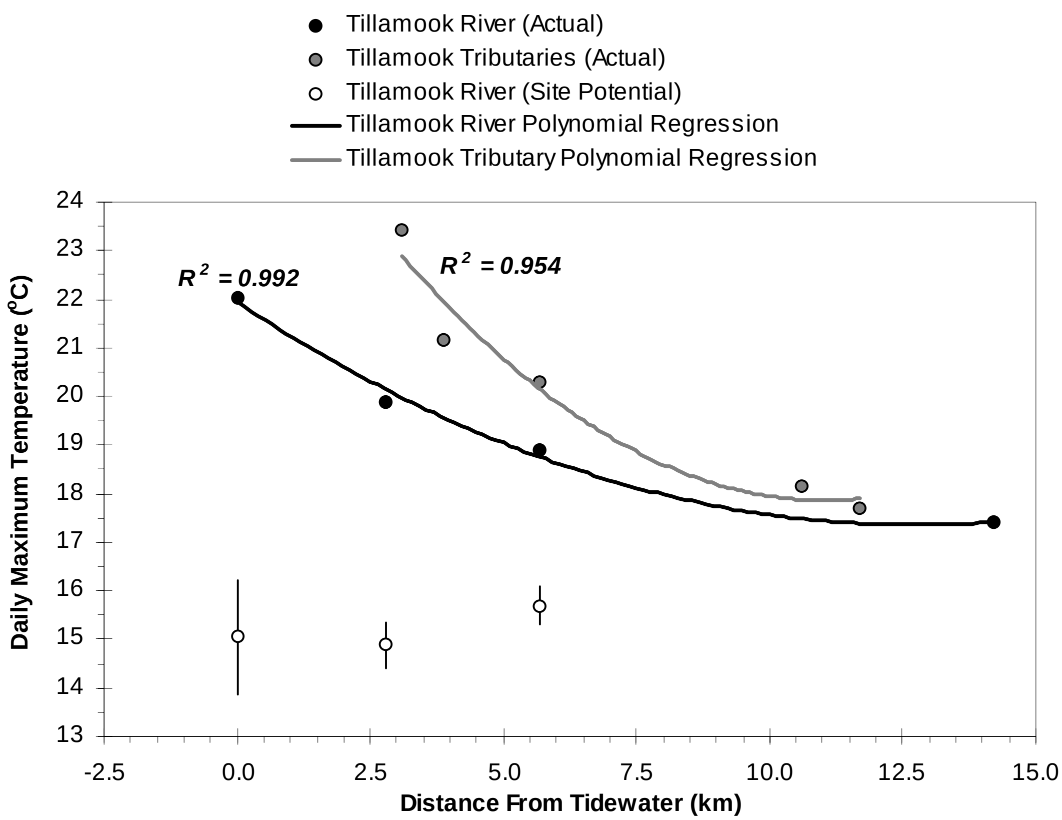
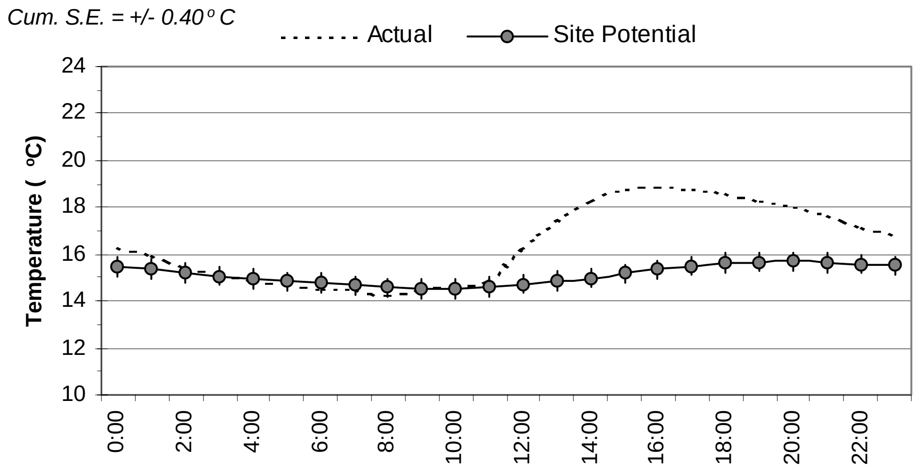
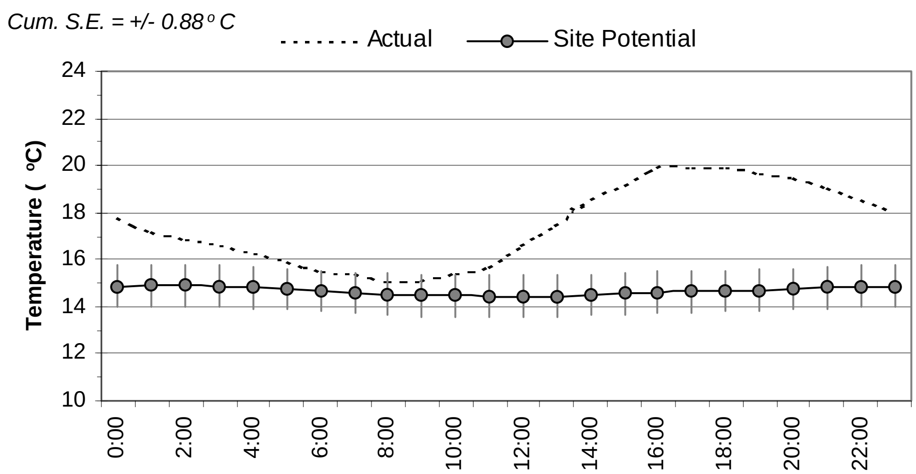


Figure B-13. Predicted and Actual Temperature Profiles - August 12, 1998

Upper Tillamook (Reach #1)



Middle Tillamook (Reach #2)



Lower Tillamook (Reach #3)

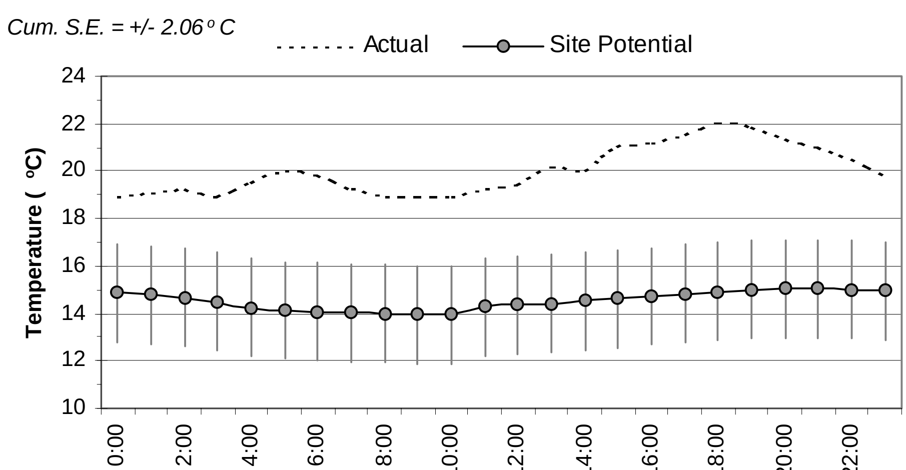
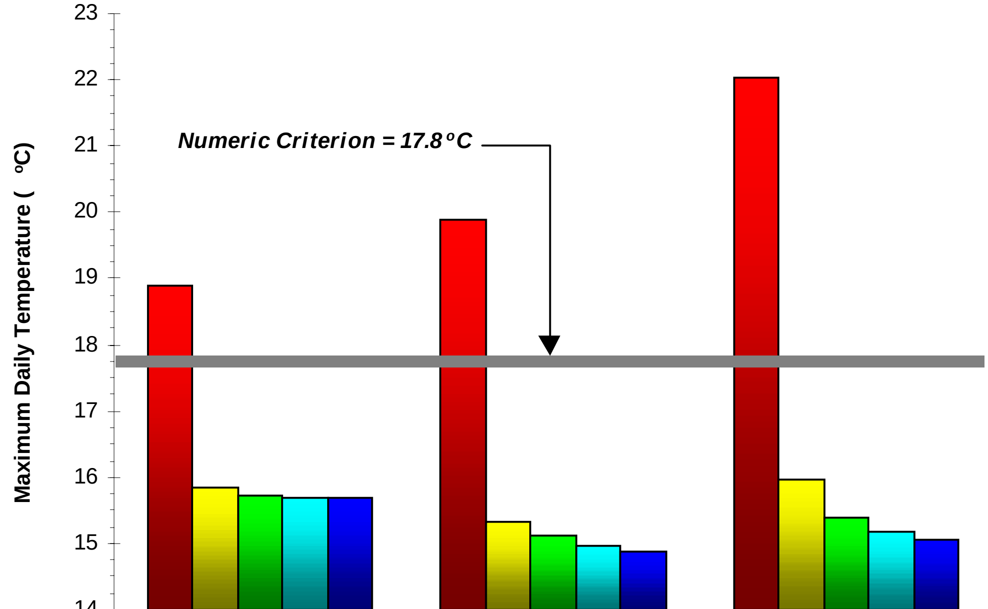


Figure B-14. Daily Stream Temperatures for Varying Buffer Dimensions
(August 12, 1998)



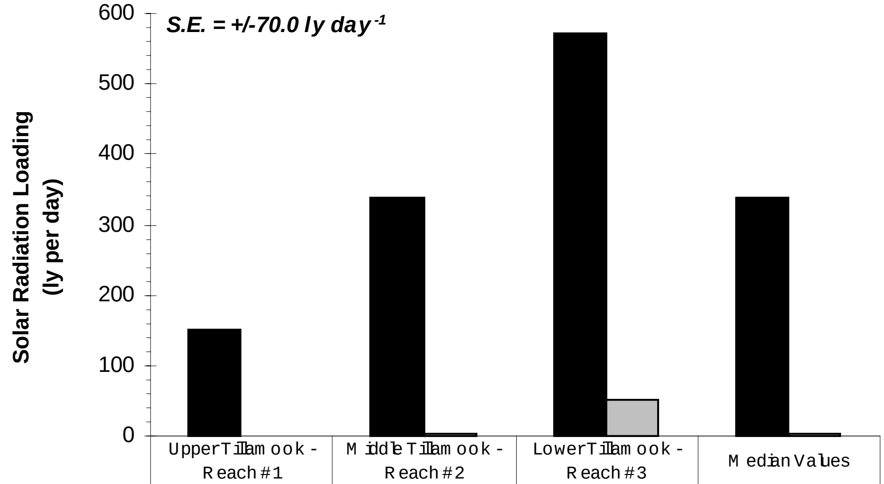
	Reach 1 - Upper Tillamook	Reach 2 - Middle Tillamook	Reach 3 - Lower Tillamook
Current Conditions	18.9	19.9	22.0
Buffer 1	15.8	15.3	16.0
Buffer 2	15.7	15.1	15.4
Buffer 3	15.7	15.0	15.2
Buffer 4	15.7	14.9	15.0

Recall Table C-3. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

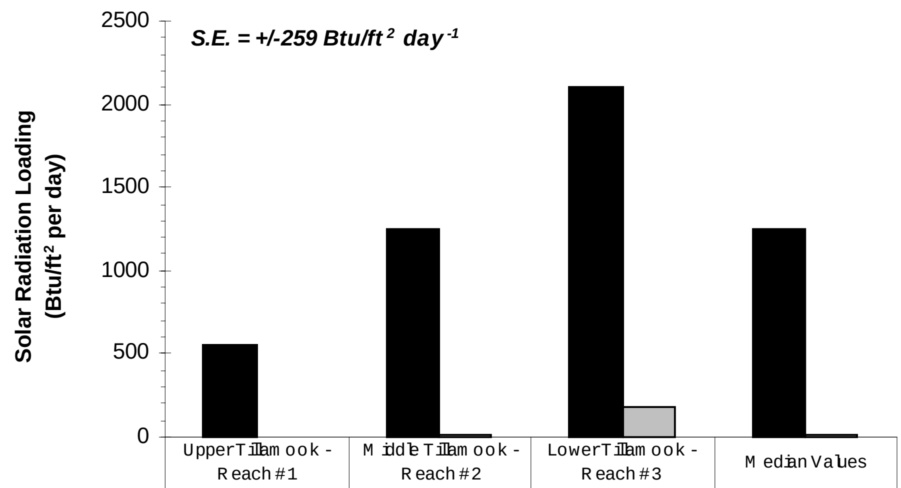
Solar Radiation Output

Figure B-15. Daily Solar Flux (ly day^{-1}) - Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation
(August 12, 1998)



	Upper Tillamook - Reach #1	Middle Tillamook - Reach #2	Lower Tillamook - Reach #3	Median Values
■ Measured Solar Loading	151	338	571	338
□ Site Potential (Buffer 4) Solar Loading	0	3	50	3

Figure B-16. Daily Solar Flux (Btu ft^{-2} day^{-1}) - Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation
(August 12, 1998)



	Upper Tillamook - Reach #1	Middle Tillamook - Reach #2	Lower Tillamook - Reach #3	Median Values
■ Measured Solar Loading	556	1245	2102	1245
□ Site Potential (Buffer 4) Solar Loading	0	11	185	11

Simulation Reach #1 – Upper Tillamook R.

Note: This reach is long (8.5 miles). Also, Munson and Simmons Creeks are not accounted for in this simulation.

Tillamook River at Rest Area (looking upstream)

Input Parameters

Run Name	Tillamook 1 - Upper	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.43	*(deg N)*
Longitude	-23.8	*(deg W)*
Stream Aspect	350	*(deg)*
Percent Bedrock	0%	
Reach Length	7732	*(meters)*
Channel Width	8.537	*(meters)*
Flow Volume	0.363	*(cms)*
Flow Velocity	0.168	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.25	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	12.20	*(meters)*
Buffer Width	15.24	*(meters)*
Buffer Density	35%	
Distance to Stream	1.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.13	*(meters)*
Shade Angle	75.6	*(deg)*
View to Sky	16%	
Effective Shade	81%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure B-17. Upper Tillamook R. Temperature Profiles *(August 12, 1998)*

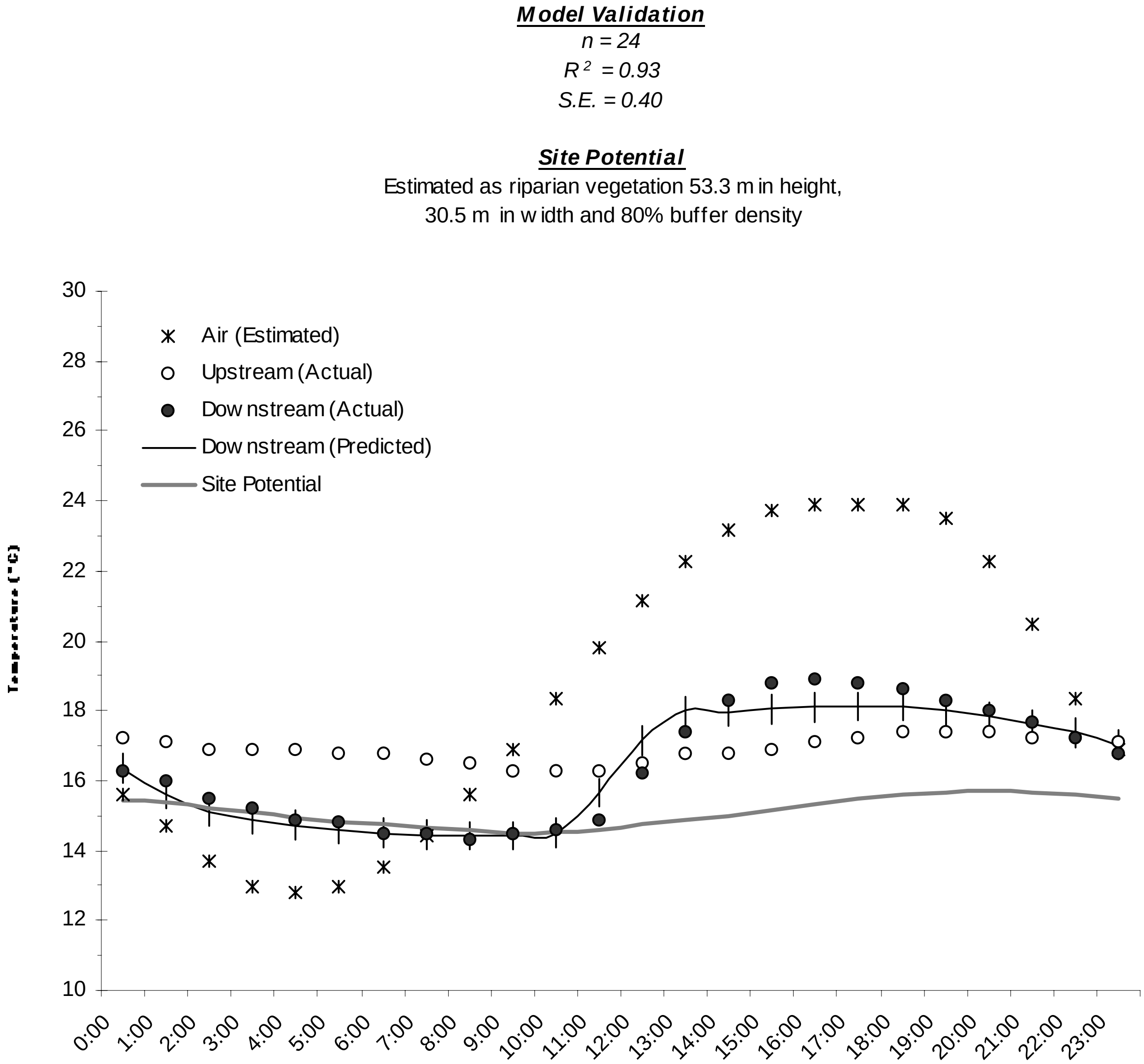
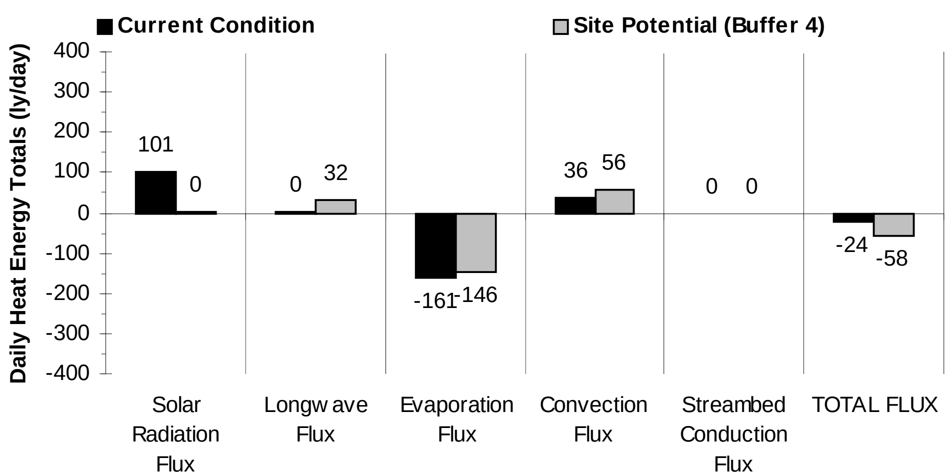


Figure B-18. Upper Tillamook R. Daily Heat Energy Totals *(August 12, 1998)*



Simulation Reach #2 – Middle Tillamook R.

Note: Killam Creek is not accounted for in this simulation.

Tillamook River at Bewley Creek Road (looking upstream)

Input Parameters

Run Name	Tillamook 2 - Middle	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.43	*(deg N)*
Longitude	-23.8	*(deg W)*
Stream Aspect	335	*(deg)*
Percent Bedrock	0%	
Reach Length	4667	*(meters)*
Channel Width	9.57	*(meters)*
Flow Volume	0.572	*(cms)*
Flow Velocity	0.122	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^oC)*
Ave. Stream Depth	0.49	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	9.15	*(meters)*
Buffer Width	7.62	*(meters)*
Buffer Density	10%	
Distance to Stream	3.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	0.46	*(meters)*
Shade Angle	51.3	*(deg)*
View to Sky	43%	
Effective Shade	30%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure B-19. Middle Tillamook R. Temperature Profiles *(August 12, 1998)*

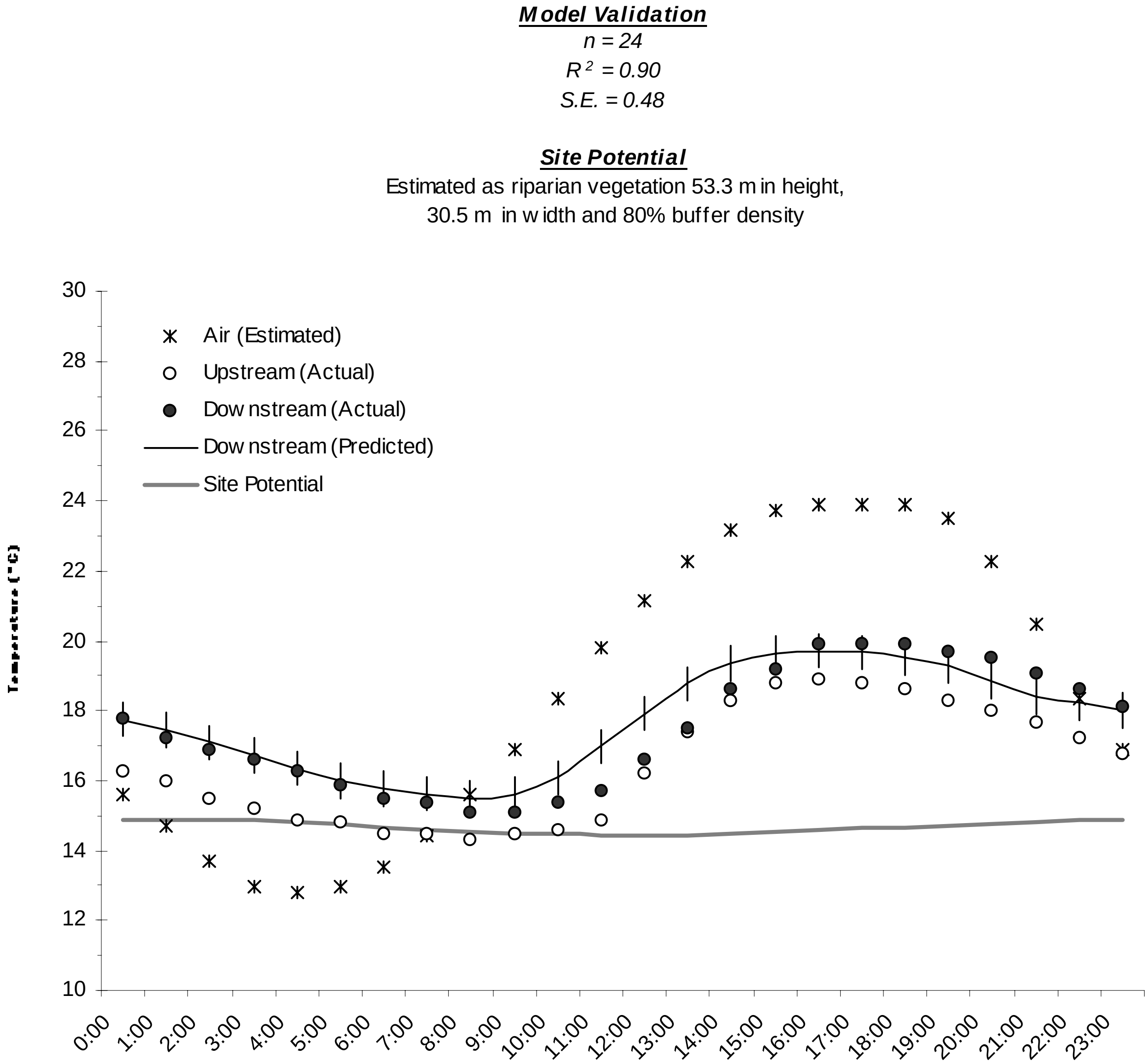
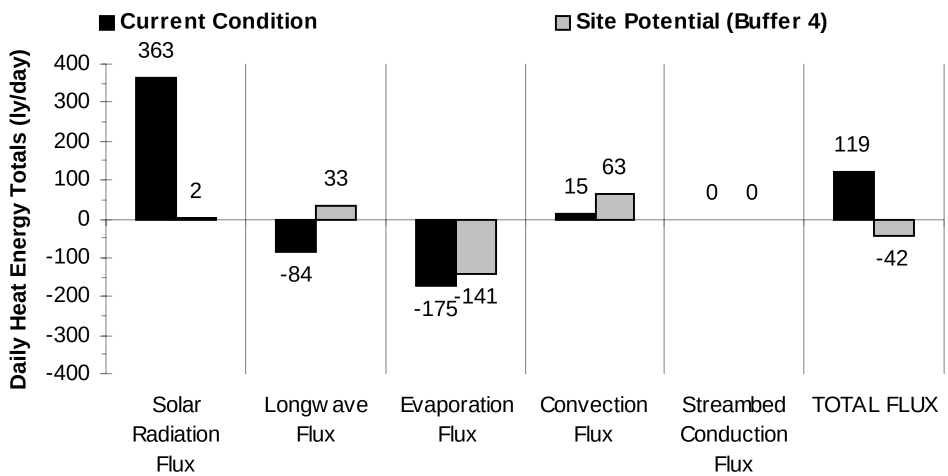


Figure B-20. Middle Tillamook R. Daily Heat Energy Totals *(August 12, 1998)*



Simulation Reach #3 – Lower Tillamook R.

Note: Sutton Creek and Beaver Creek are not accounted for in this simulation. Also, downstream end of simulation reach is influenced by tidewater.

Tillamook River at Beaver Creek Road (looking upstream)

Input Parameters

Run Name	Tillamook 3 - Lower	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.43	*(deg N)*
Longitude	-23.8	*(deg W)*
Stream Aspect	335	*(deg)*
Percent Bedrock	0%	
Reach Length	4506	*(meters)*
Channel Width	13.72	*(meters)*
Flow Volume	0.572	*(cms)*
Flow Velocity	0.076	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.55	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	3.05	*(meters)*
Buffer Width	7.62	*(meters)*
Buffer Density	5%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.00	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	0.08	*(meters)*
Shade Angle	15.8	*(deg)*
View to Sky	82%	
Effective Shade	4%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure B-21. Lower Tillamook R. Temperature Profiles *(August 12, 1998)*

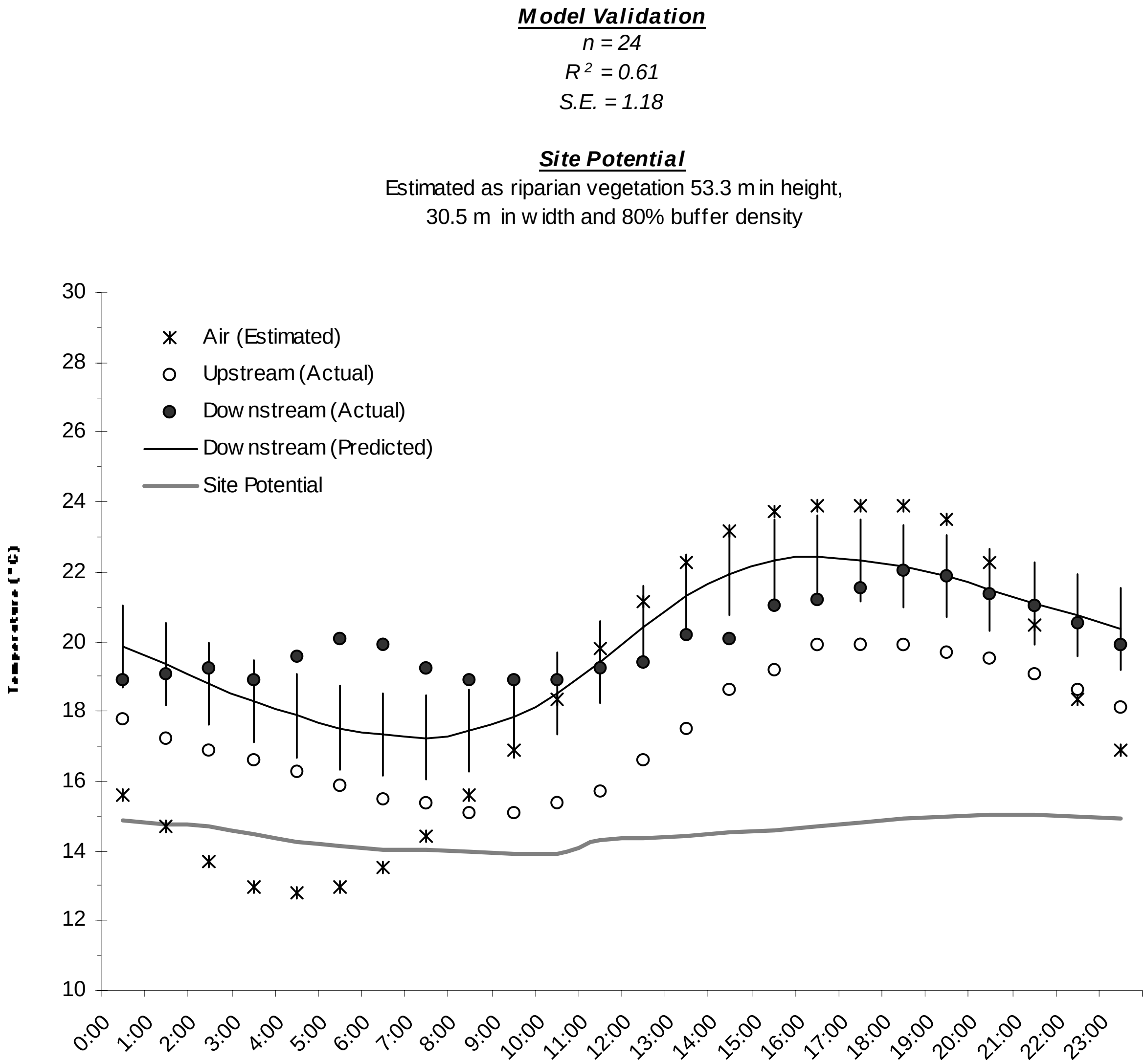
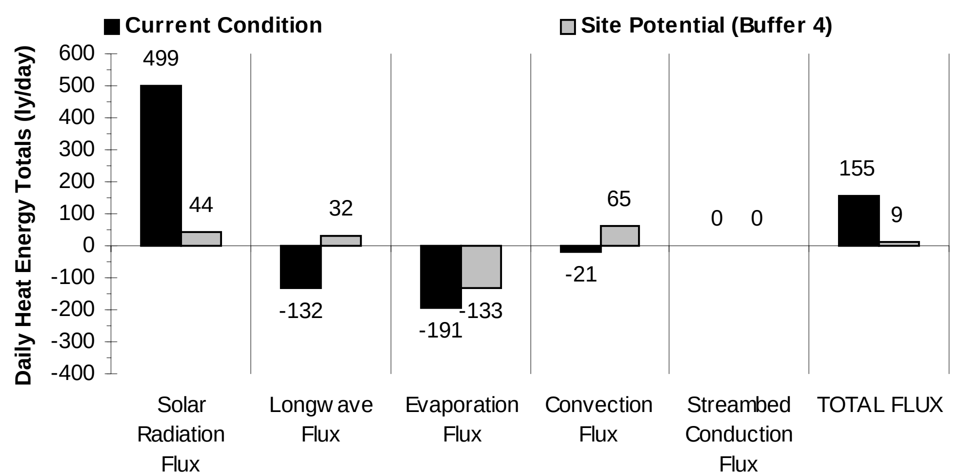


Figure B-22. Lower Tillamook R. Daily Heat Energy Totals *(August 12, 1998)*



APPENDIX C

WILSON RIVER TEMPERATURE ASSESSMENT

Current Condition Assessment

Temperature

The Oregon Department of Environmental Quality (ODEQ) measured a total of twenty continuous monitoring sites for stream temperatures during summer months in both 1997 and 1998. All major tributaries, as well as the Wilson River mainstem have been sampled for temperature in either the 1997 or 1998 summertime monitoring season and continuous monitoring data have passed ODEQ quality control protocols. **Image C-1** displays all continuous temperature monitoring sites where data have been statistically processed to yield the 7-day average of the daily maximum temperatures (commonly referred to the *7-day statistic*). These 7-day statistics are used to specify if the sampled stream temperatures violate State water quality standards.

Spatial Temperature Patterns

Wilson River and tributary temperatures are generally warm. Of the twenty sites monitored for continuous temperature data, only Elk Creek, Idiot Creek and Cedar Creek have a 7-day statistic below 17.8^{o}C (64.0^{o}F). All other mainstem and tributary sites exceed the numeric criteria (17.8^{o}C). The data suggest that heating occurs in upper watershed near the divide (headwaters). The mainstem Wilson continues stream warming to tidewater (Sollie Smith Bridge).

Upper watershed tributaries (North Fork Wilson River, South Fork Wilson River, and Devils Lake Fork Wilson River) allow rapid heating, relative to the short travel distances. Data collected indicate that much of the upper Wilson tributaries are temperature limited and pose an increased risk to salmonid fish populations.

The Wilson River mainstem is temperature limited throughout its entire stream length. In summer months the Wilson mainstem reaches stream temperatures greater than 20.3^{o}C (68.5^{o}F) and sometime exceed 24.0^{o}C (75.2^{o}F) in the lower reaches. Lower watershed tributaries have little effect on mainstem temperatures. Cedar Creek is cooler than the mainstem, but offers little mainstem cooling via mass mixing due to flow volume differentials. Temperature dynamics in Jordan Creek are unknown due to lost monitoring equipment. Little North Fork Wilson River temperatures are warm when considering its relative short perennial stream length. The Wilson River system in unique in that temperatures are warm throughout virtually all portions of the watershed. **Image C-1** displays all 7-day stream temperature statistics measured in the Wilson River watershed. A longitudinal stream heating curve has been developed for the Wilson River and tributaries. Wilson River and tributary temperatures continually heat in the downstream (longitudinal) direction (**Figure C-1**). Significant stream heating was measured in the Wilson River throughout its entire length.

Image C-1. Maximum 7-Day Moving Average of Daily Maximum Temperature

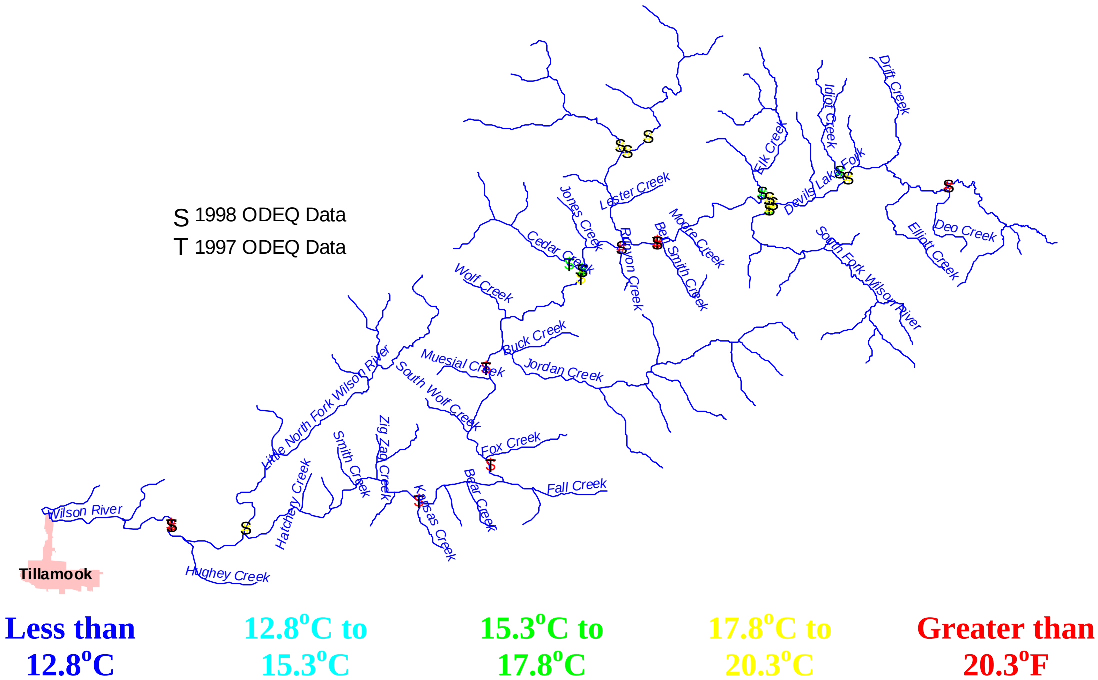
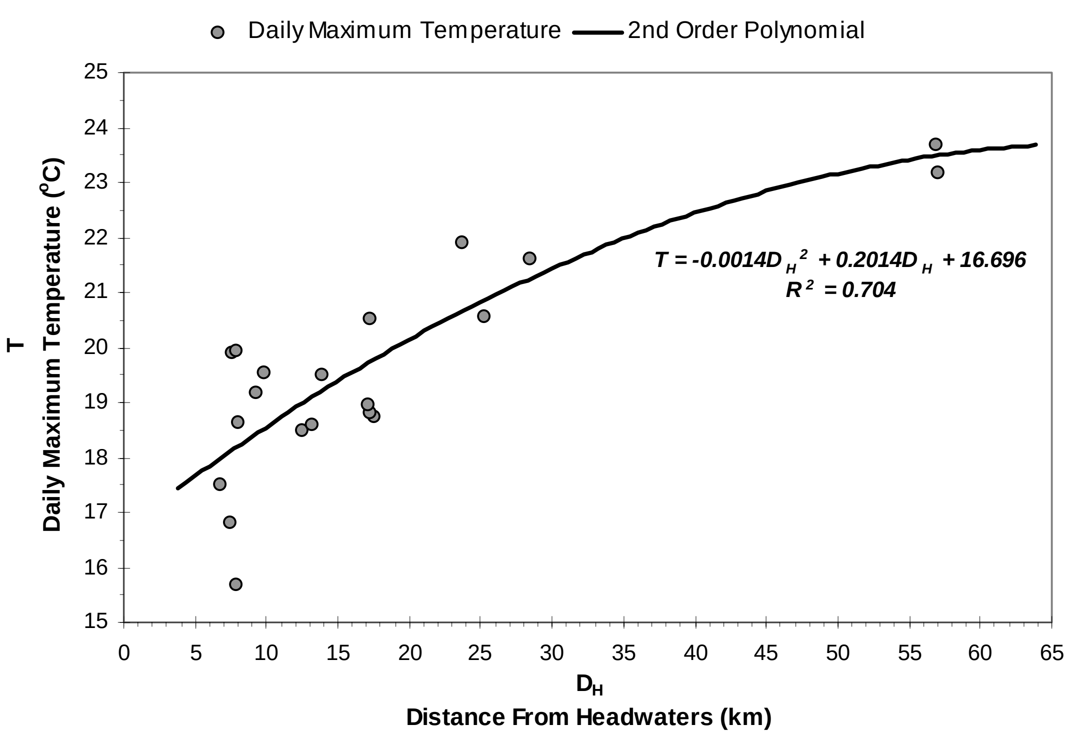


Figure 1. Stream Temperature Heating Curve
(August 12, 1998)



Daily temperature profiles for August 12, 1998 display the relative temperatures of the Wilson River at the upper (downstream Devils Lake Fork), middle (Lees Camp), lower (upstream Little North Fork), and tidewater (Sollie Smith Bridge) sample sites. (**Figure C-2**). Again, longitudinal heating is apparent in the temperature data. **Figure C-3** displays diurnal temperature profiles for several tributaries.

Figure C-2. Wilson Mainstem Stream Temperature Profiles
(August 12, 1998)

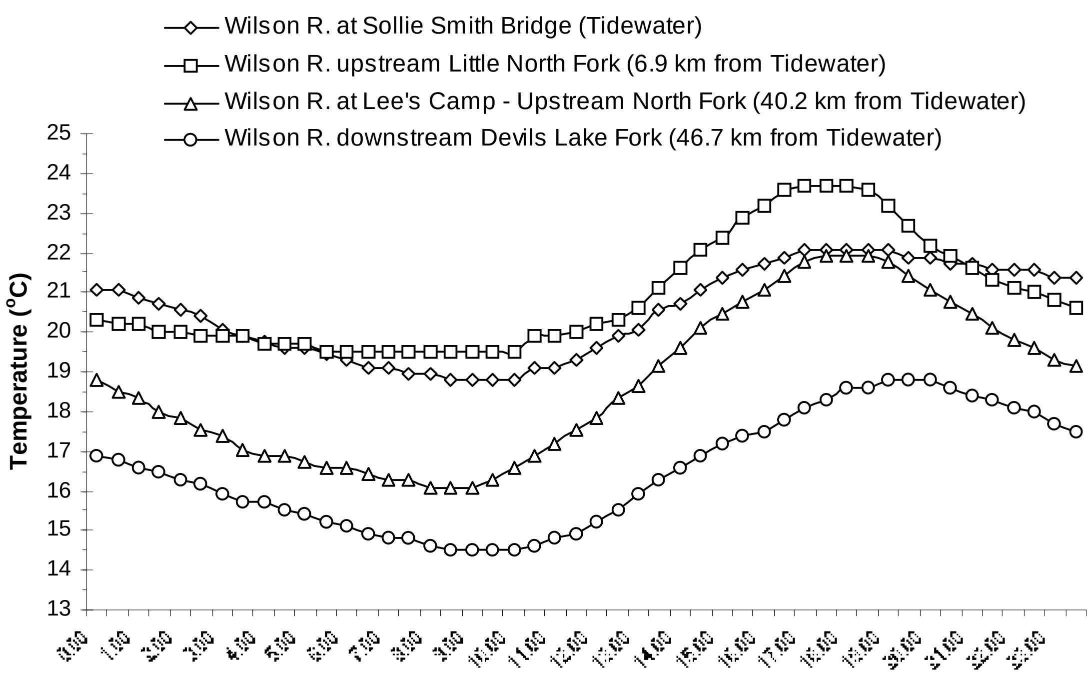


Figure C-3. Wilson Tributary Stream Temperature Profiles
(August 12, 1998)

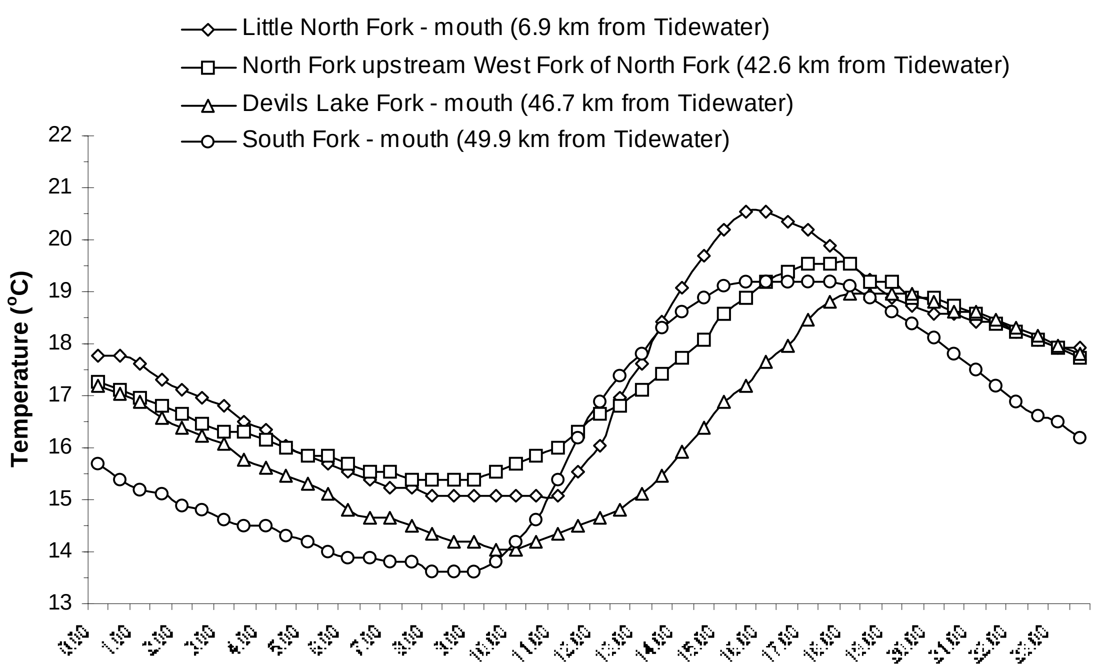
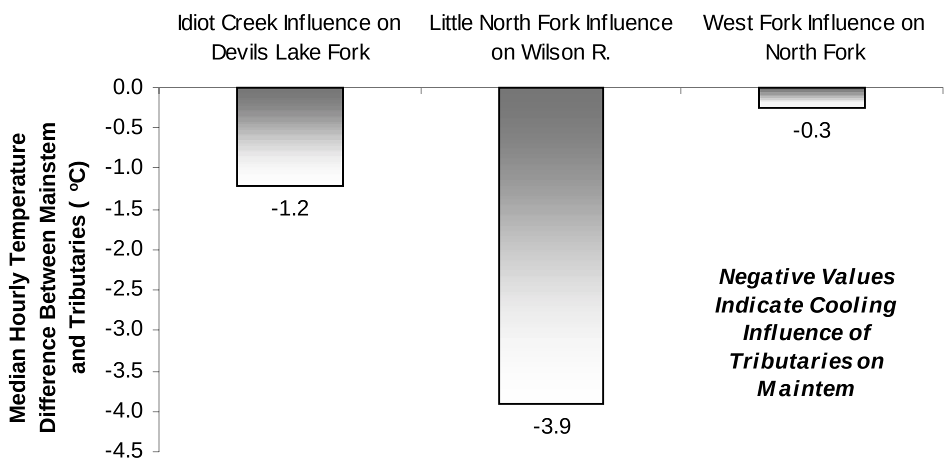


Figure C-3 displays daily temperature profiles for Wilson River tributaries. Many of the tributaries have temperatures cooler than the mainstem throughout the diurnal temperature cycle. Idiot Creek and Little North Fork have significant cooling influences on the mainstem receiving water. Median hourly temperature differences between tributaries and the mainstem are plotted in **Figure C-4**. Negative median hourly temperature differences between mainstem and tributary indicates mainstem cooling due to mass mixing. The magnitude of cooling is a function of the relative flow differential between the mainstem and a tributary.

Figure C-4. Median Hourly Temperature Difference Between Tributaries and Mainstem *(August 12, 1998)*



Temporal Temperature Patterns

<u>Yearly Variations</u>

Wilson River temperature data were sampled at Lees Camp and downstream North Fork confluence during both the 1997 and 1998 monitoring seasons. These data were processes to yield maximum daily temperatures, which were than graphically and statistically compared (**Figure C-5** and **Figure C-6**). All statistics (i.e. average deviation and 90th confidence interval) were generated using only the overlapping portion of the 1997 and 1998 data. Comparing years, the average deviation and 90th confidence interval of the *maximum daily* stream temperatures are presented in **Table C-1**.

Table C-1. Yearly Temperature Statistical Comparisons (1997 and 1998)

Site	*Average Deviation*	*90th Confidence Interval*
Wilson River at Lees Camp	1.4^{o}C	1.9^{o}C
Wilson River downstream North Fork confluence	1.2^{o}C	1.6^{o}C

Figure C-5. Seasonal Variability Between 1997 and 1998 Temperature Data
(Wilson River at Lees Camp)

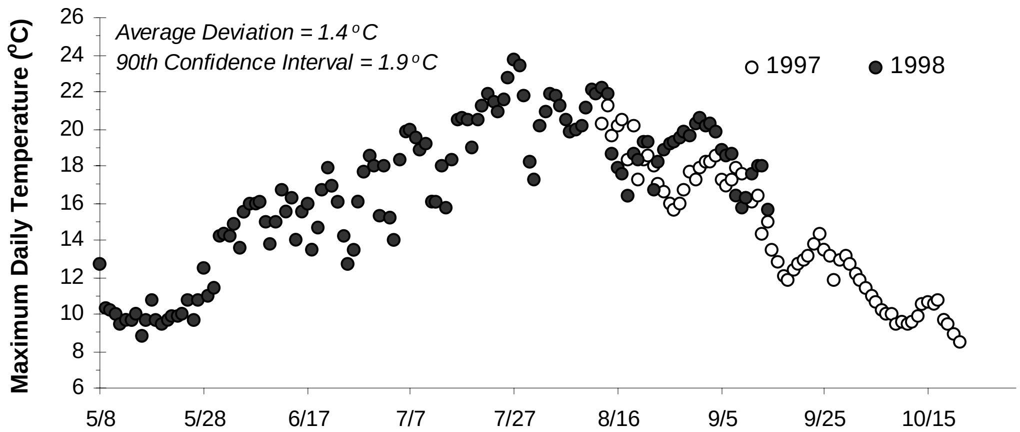
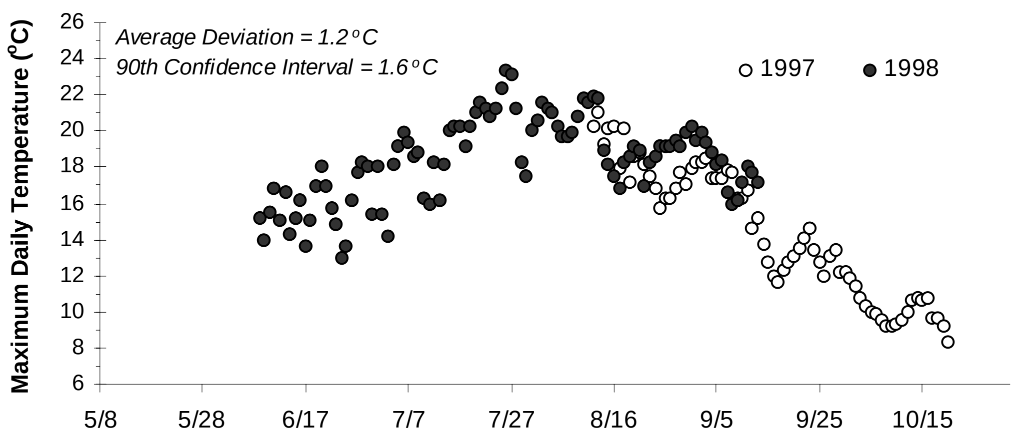


Figure C-6. Seasonal Variability Between 1997 and 1998 Temperature Data
(Wilson River downstream North Fork Confluence)



Seasonal Variations

Seasonal maximum stream temperatures in the Wilson River and tributary streams generally correspond to a combination of high levels of solar exposure, warm air temperatures and low flow conditions. Maximum stream temperatures occur in mid July and early August. Stream temperatures gradually decline through late August and September due to decreasing solar radiation loading. However, stream temperatures in August and September often reach relatively warm daily maximums. Significant stream cooling occurs in late Fall as lower solar loading levels couple with late Fall precipitation events and increased stream flow. Moving seven-day averages of daily maximum stream temperatures for selected sites in the Wilson River watershed are displayed in **Figure C-7**. Maximum monthly seven-day moving averages sorted by month are displayed in **Figure C-8**.

Figure C-7. Moving Seven-Day Averages of Daily Maximum Stream Temperatures for 1998 Monitoring Sites in the Wilson River Watershed

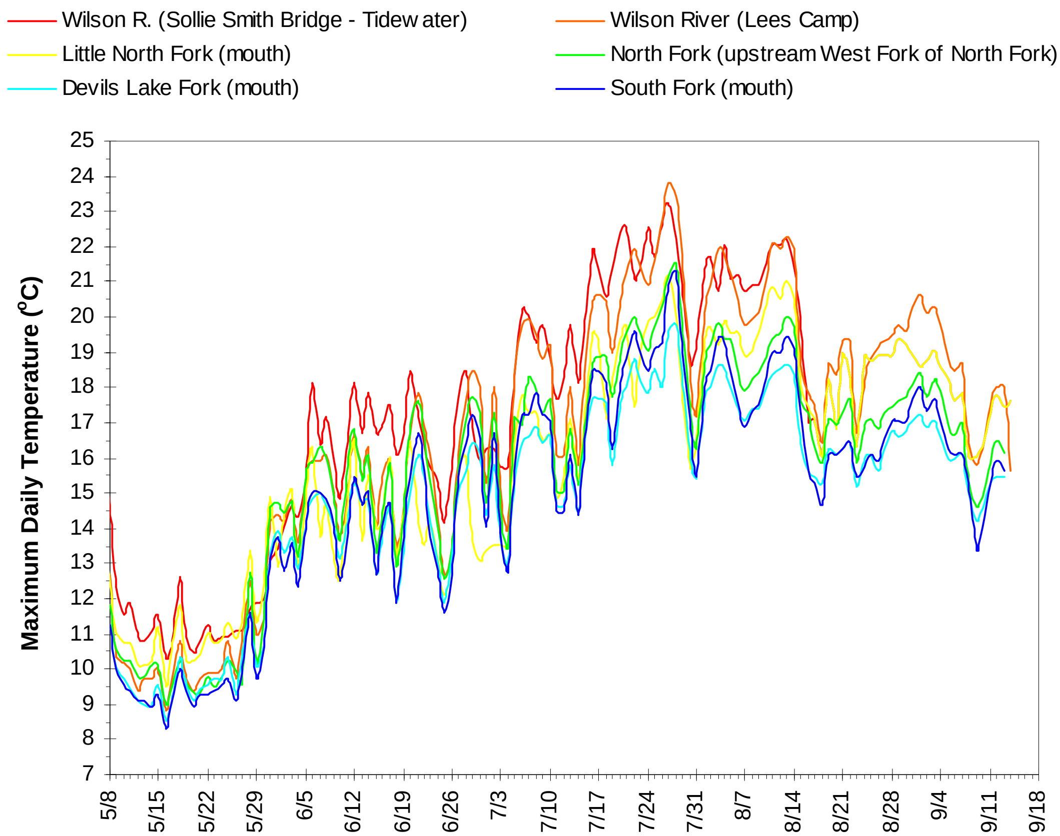
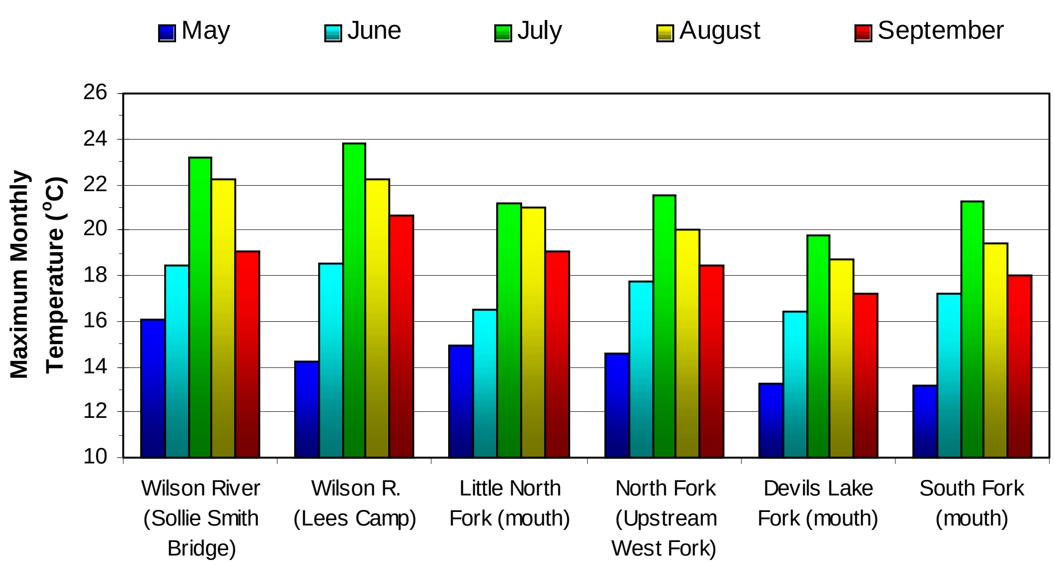


Figure C-8. Maximum <u>Monthly</u> Seven-Day Moving Averages of Daily Maximum Stream Temperatures (1998)



Shade

ODEQ measured stream surface shade during the summer months in 1998. A total of twenty-five sites were monitored. Stream surface shade and canopy cover can be highly variable in disturbed riparian areas. Certainly, the shade data collection sites should be expanded to capture variability throughout the watershed. Continued shade data monitoring efforts are ongoing and additional data are expected to increase accuracy in shade representations.

Effective shade was quantified by averaging the Solar Pathfinder data for the months of May through September. Hours of solar exposure and local sunrise/sunset were also collected. Solar attenuation was derived from the Solar Pathfinder data by measuring the portion of the day that receives shade relative to total day length. Canopy cover was measured with a densiometer. Narrative descriptions of riparian vegetation (vegetative species composition/condition, height, width and distribution) were also recorded at the shade monitoring sites.

The Wilson River is poorly shaded. The lowest effective shade measurement for the Wilson River was 0% (at Sollie Smith Bridge - tidewater). Low effective shade persists throughout the lower and middle Wilson River reaches (Sollie Smith Bridge to Lees camp). The upper Wilson River (Lees Camp to Devils Lake Fork confluence) has moderate effective shade (40% to 71%). The mixed alder, maple, conifer and pasture that compose riparian area vegetation throughout the Wilson River mainstem allows near daylong stream surface solar exposure. The median effective shade value for the Wilson River mainstem is 22% (n = 10).

Wilson River tributaries have varied shade regimes that are highly dependent on surrounding land uses. Cedar Creek, Devils Lake Fork, Elk Creek and South Fork have fair to high shade levels (50% to 100%). The North Fork and Little North Fork have low effective shade levels (45% to 52%). The median effective shade value for Wilson River tributaries is 85% (n = 15).

Effective shade is extremely variable for the Wilson River stream network (0% to 100%). Much of the middle and lower tributary and mainstem reaches are poorly shaded. A median effective shade level throughout the entire stream length is 61% (n = 25). Rural residential, roads and agricultural/forestry disturbance have reduced the species composition and impaired riparian conditions in the Wilson River mainstem and tributary reaches and shade levels are significantly compromised. Lower Wilson River reaches have near zero shade levels due to intense grazing.

Figure C-9 displays the median effective shade, solar attenuation and canopy cover measured for the Wilson mainstem and tributaries. **Figure c-10** shows an effective shade statistical summary (Box Plot) compared with the National Estuary Program (NEP) effective shade target of 75%. A visual summary of the effective shade data collected with a Solar Pathfinder is shown in **Image C-2**, while **Image C-3** displays the stream surface solar exposure (measured in hours).

Figure C-9. Wilson River Median Measured Shade Data (1998)

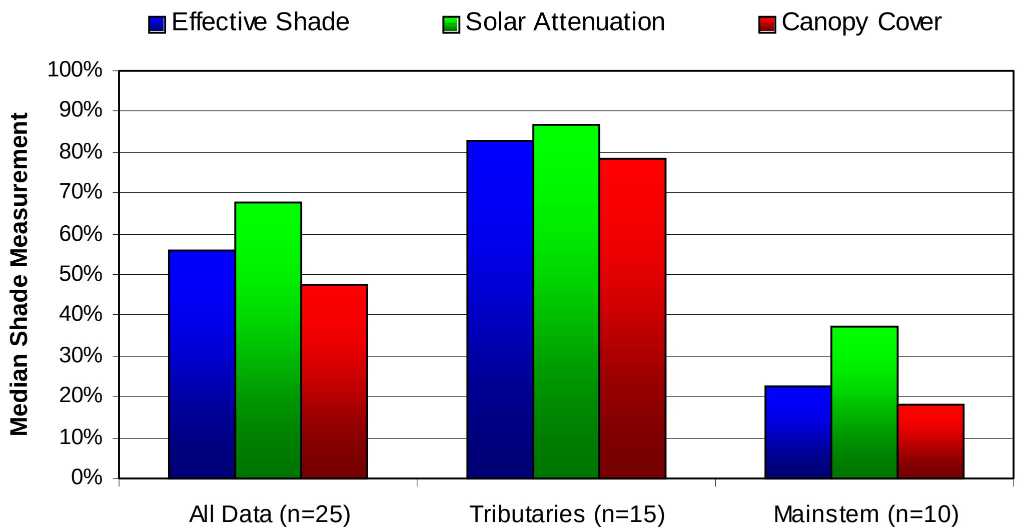


Figure C-10. Median Effective Shade Measurements Compared to NEP Shade Target *(1998)*

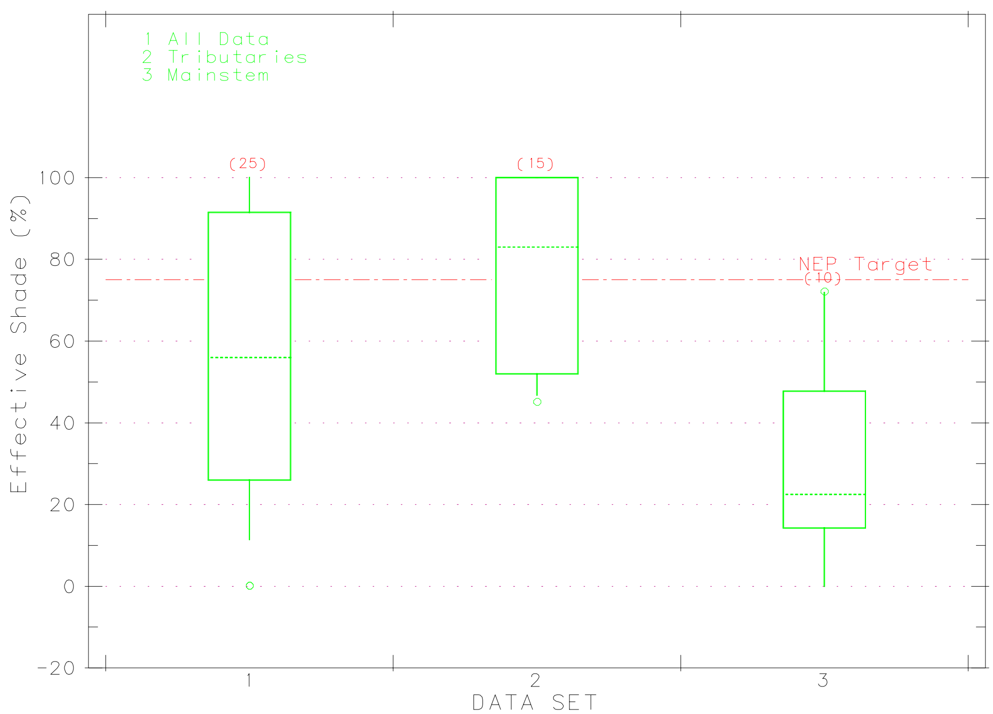
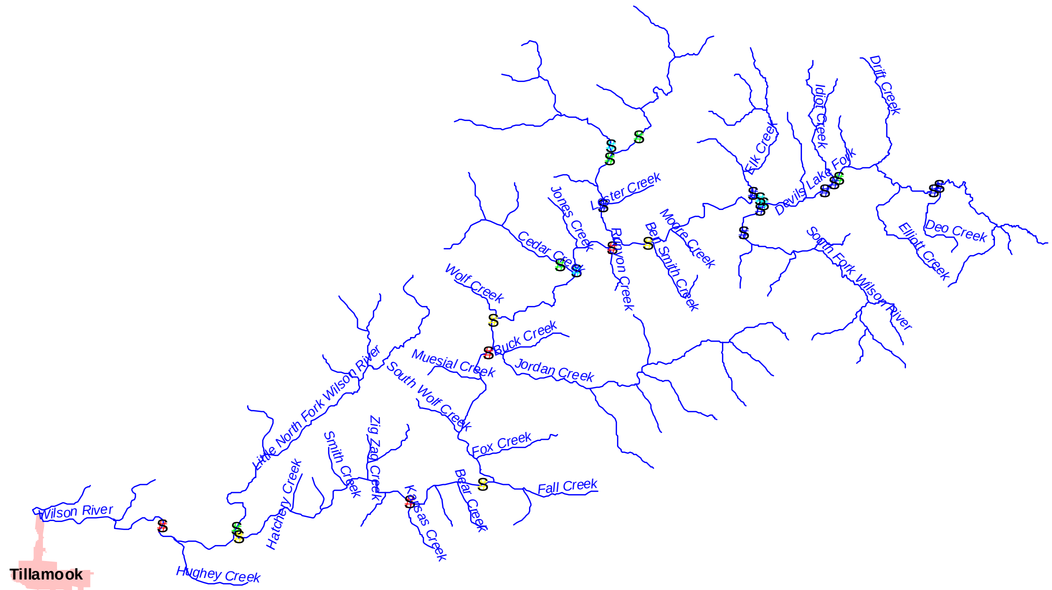
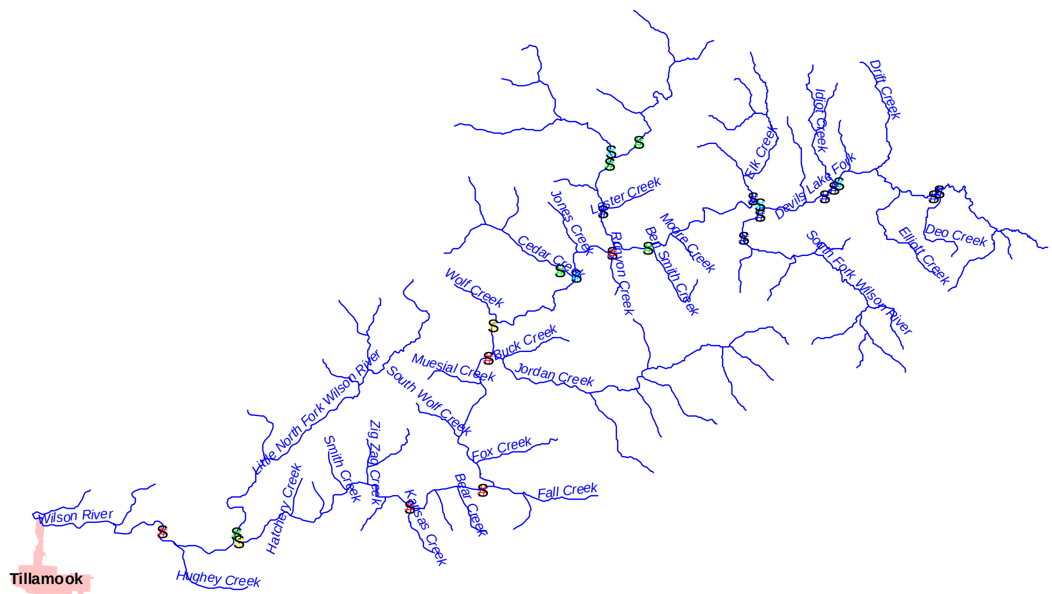


Image C-2. Effective Shade - Measured with Solar Pathfinder (1998)



Less than 20% 20% to 40% 40% to 60% 60% to 80% Greater than 80%

Image C-3. Daily Summertime Solar Exposure - Measured with Solar Pathfinder (1998)

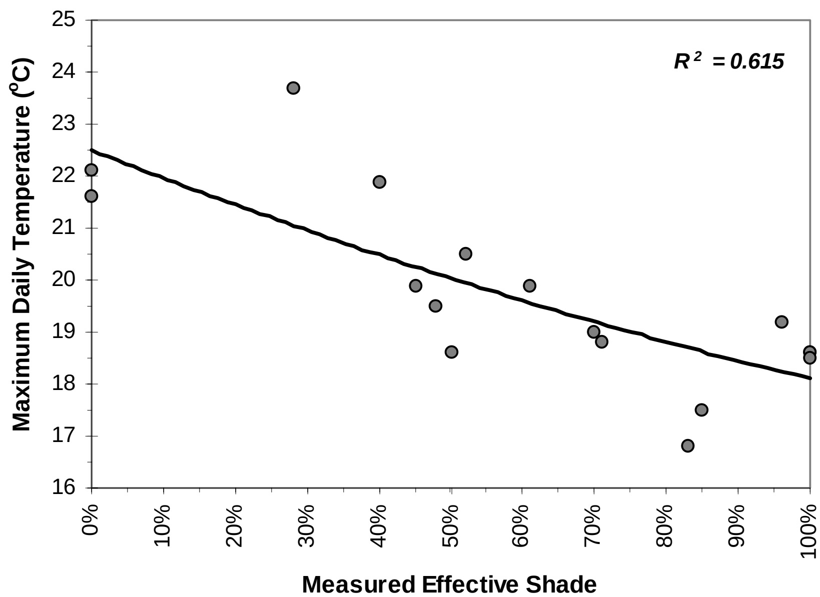


Less than 2 hours 2 to 4 hours 4 to 6 hours 6 to 8 Hours Greater than 8 hours

Shade Related to Stream Temperature

Cooler stream temperatures are strongly related to stream surface shade (Rishel et al. 1982, Brown 1983, Beschta et al. 1987, Sinokrot and Stefan 1993, Chen 1996, Boyd 1996). When graphically compared, the inverse relationship between effective shade and temperature becomes apparent. Simply stated, stream surface exposure to solar radiation is reduced or eliminated in a highly shaded condition (**Figure C-11**). A threshold shade level often occurs at 75% to 80% effective shade where temperature change (dT/dx and dT/dt) can increase dramatically (Boyd 1996). This threshold shade condition is most apparent on smaller streams less than 0.14 cms (5 cfs) (Boyd 1996).

Figure C-11. Maximum Daily Temperature and Effective Shade
(August 12, 1998)



Stream Temperature Simulation

The purpose of this stream temperature simulation effort is to quantify stream temperatures (and the corresponding energy processes) that result when estimated site potential riparian vegetation exists. The model is validated using hydrologic, thermal and landscape data describing the current condition. Only 1998 data were used. Once the modeled reach output has been validated, stream temperatures and energy conditions are predicted for a site potential riparian condition. All other model inputs are assumed to remain unchanged. In this series of predictions, the site potential riparian condition assumed a late seral (old growth) conifer (see **Table C-3**).

Model results should be used with caution. Associated prediction errors and goodness of fit estimates are provided with all model output. The author is aware of possible sources of error in the predictions. However, the methodology is sound and based on the most recent understanding of stream thermodynamics and hydraulics. As is generally the case in simulating non-linear water quality, model results are best suited for relative comparisons, rather than determinations of water quality parameter magnitude. Ultimate stream temperature magnitude is estimated in the report and is presented with upper and lower error boundaries. Discussions of the model results should include considerations for these boundaries of error.

Using a stream temperature prediction model (Heat Source v.5.5), a large extent of the Wilson mainstem was simulated for temperature. The basic steps involved in stream temperature are presented in the following section (see ***Methodology***).

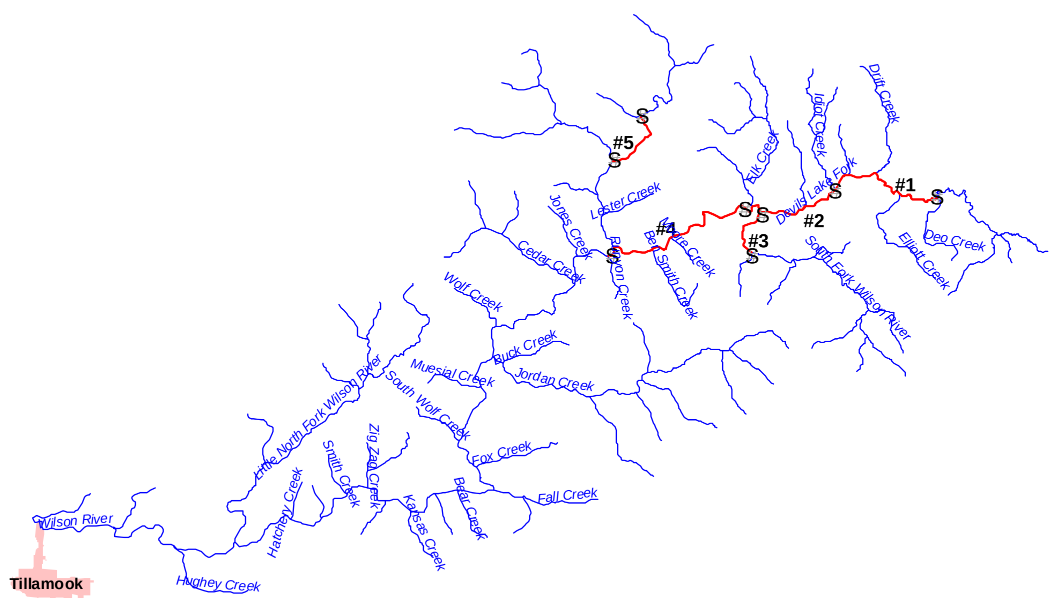
Methodology

1. *Selection of Temperature Simulation Reaches*

Table C-2. Trask River Simulation Reaches

#	Simulation Reach	Upper Extent	Lower Extent
1	Upper Devils Lake Fork	Deo Creek	Idiot Creek
2	Lower Devils Lake Fork	Idiot Creek	mouth
3	South Fork	1st Bridge	mouth
4	Upper Wilson	Devils Lake Fork Confluence	Lees Camp
5	Upper North Fork	Slide Area	West Fork Confluence

Image C-4. Stream Temperature Simulation Extent – **Red** Indicates Simulation Reaches



2. *Model Input: Site Specific Data*

Table C-3. Heat Source v. 5.3 Model Input Parameters	
• Date	• Buffer Height
• Stream Aspect	• Buffer Width
• Latitude	• Buffer Density
• Longitude	• Topographic Shade Angle (West)
• Reach Length	• Topographic Shade Angle (East)
• Channel Width	• Min. Air Temperature
• Flow Volume	• Max. Air Temperature
• Flow Velocity	• Relative Humidity
• Percent Bedrock	• Buffer Distance to Stream
• Groundwater Inflow	• Elevation
• Groundwater Temperature	• Wind Speed
• Dispersion Coefficient	• Upstream Hourly Temperature Data

3. *Prediction of Current Condition (Downstream Temperature Profile)*

4. *Model Validation: Statistical Analysis of Model Output*

Table C-4. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

- Pearson's Product Moment (R^2)
- Standard Error (S.E.)

5. *Prediction of <u>Stream Reach Site Potential Conditions</u>*

- Site potential buffer dimensions were constant over all stream sections for each of the four site potential simulations.
- Assume that current condition standard error (S.E.) applies to site potential simulations.

6. *Prediction of Stream Reach Based on Cumulative Upstream Site Potential Conditions (Downstream Temperature Profile)*

- Utilize upstream reach site potential stream temperature for upstream model input in downstream reach simulation (i.e. downstream site potential temperature profile or Reach#1 becomes input temperature profile for Reach #2).
- Account for tributary temperature mixing.
- Assume tributary temperature are at or near site potential
- Assume that current condition standard error (S.E.) applies to site potential simulations.
- Standard error (S.E.) of upstream predictions accumulates in the downstream direction

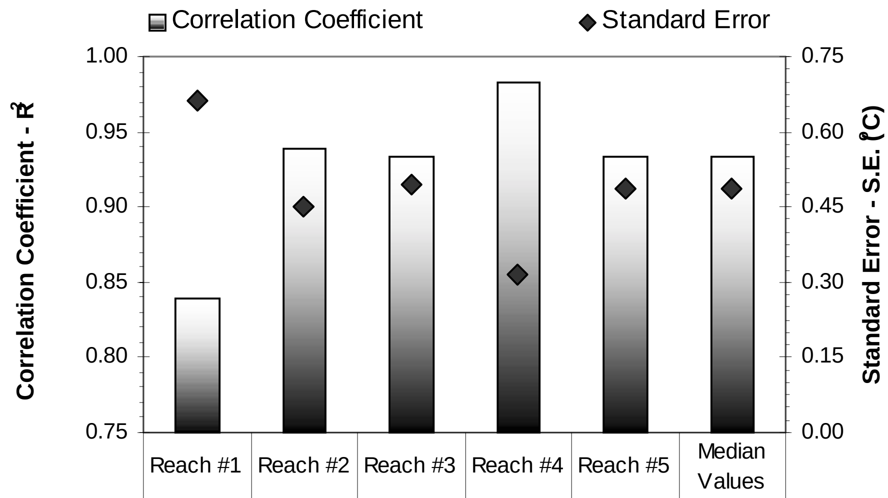
Model Validation

Temperature Validation

Two statistical measurements were used to assess the accuracy of stream temperature simulations. Comparisons between simulated and actual (measured) stream temperature profiles were used to generate the square of the Pearson product moment correlation coefficient (R^2) and the standard error (S.E.) for each simulation reach (**Figure C-12**). Median values for all simulation reaches were:

- Correlation Coefficient (R^2): 0.93
- Standard Error (S.E.): 0.49^{o}C

Figure C-12. Temperature Profile Simulation Accuracy
Heat Source v. 5.5 Model Validation (R^2 and S.E.)



	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5	Median Values
Correlation Coefficient	0.839	0.939	0.933	0.982	0.934	0.934
Standard Error	0.664	0.452	0.495	0.316	0.485	0.485

Summary of Model Results

Temperature Output

Predicted maximum daily stream temperatures are cooler when site potential riparian conditions persist (Buffer 4: Buffer Height = 53 meters, Buffer Width = 31 meters and Buffer Density = 80%). Longitudinal stream heating (displayed in **Figure C-1**) is drastically reduced in the simulated site potential riparian condition. **Figure C-13** shows the measured (actual) longitudinal stream heating pattern compared to those induced by simulated site potential riparian vegetation geometry (Buffer 4). Site potential simulations demonstrate that stream temperature change occurs more gradually and temperature change becomes more dependent on tributary influences (mass transfer) than heat energy processes (heat transfer).

Vertical bars indicate the standard error associated with each simulation. Recall that all simulation errors of upstream prediction reaches were assumed to accumulate in the downstream direction. The result is an increasing margin of error for simulations in the downstream direction. Perhaps this method for accounting prediction error overstates the margin of error. However, it is important to recognize the limitations inherent to this methodology.

Diurnal temperatures (current condition and site potential) are plotted for Devils Lake Fork (mouth), South Fork (mouth) and Wilson River (Lees Camp) in **Figure C-14**. Daily maximum stream temperatures for current conditions and all of the buffer scenarios (1 to 4) are displayed in **Figure C-15**.

Figure C-13. Actual Stream Heating Curve and Predicted Site Potential Daily Maximum Temperatures with Associated Error Bars
(August 12, 1998)

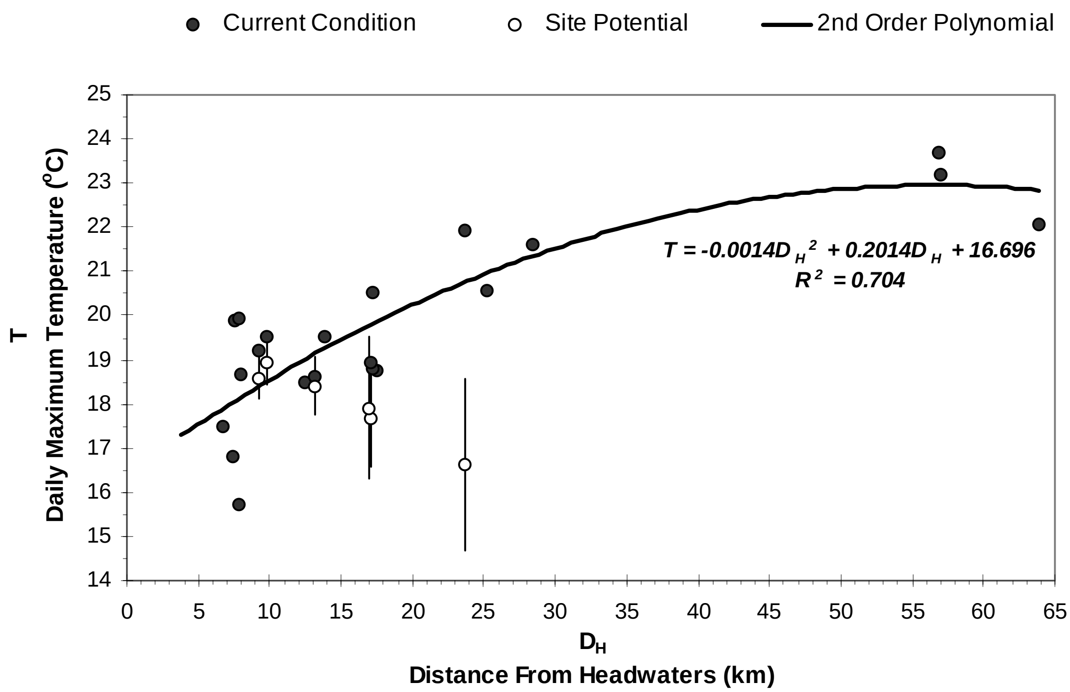
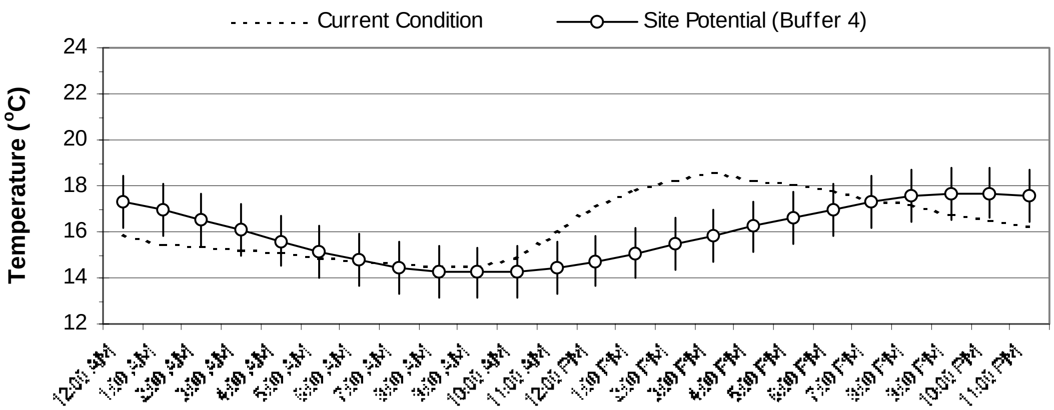


Figure C-14. Current Condition and Site Potential Diurnal Temperature Profiles
(August 12, 1998)

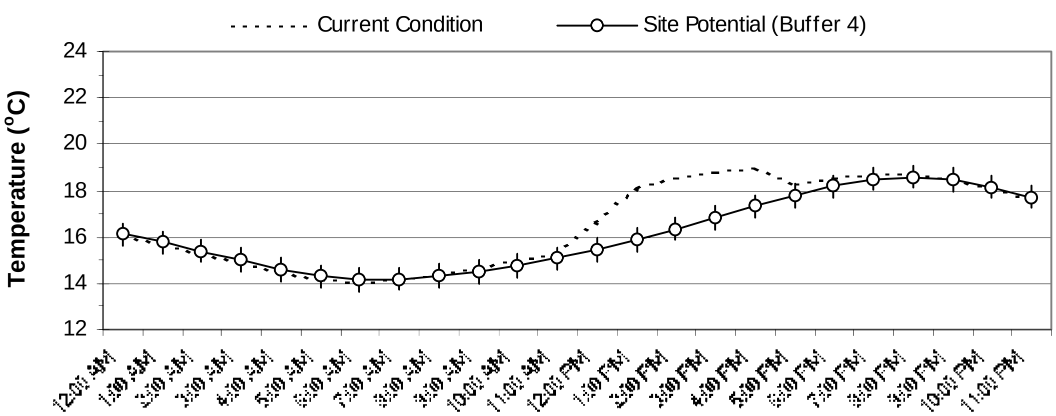
Devils Lake Fork - mouth (Reach #2)

Cum. S.E. = +/- 1.116 °C



South Fork – mouth (Reach #3)

Cum. S.E. = +/- 0.495 °C



Wilson River – Lees Camp (Reach #4)

Cum. S.E. = +/- 1.927 °C

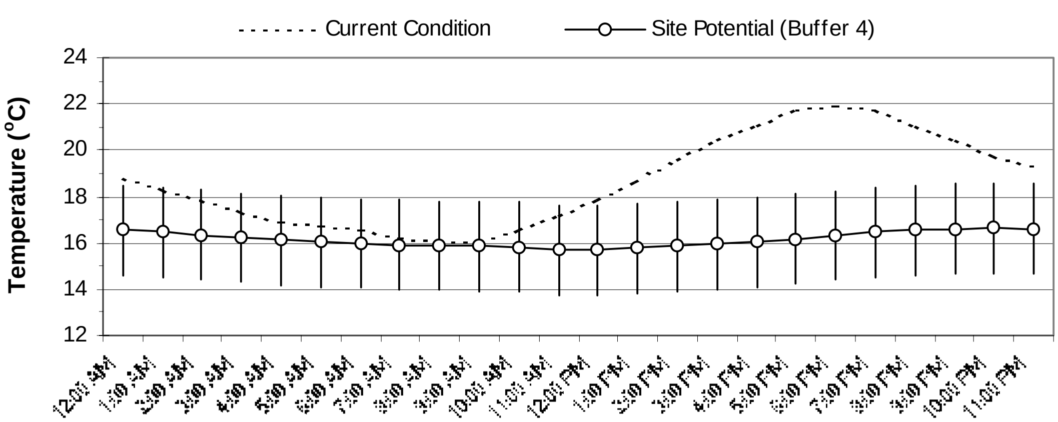
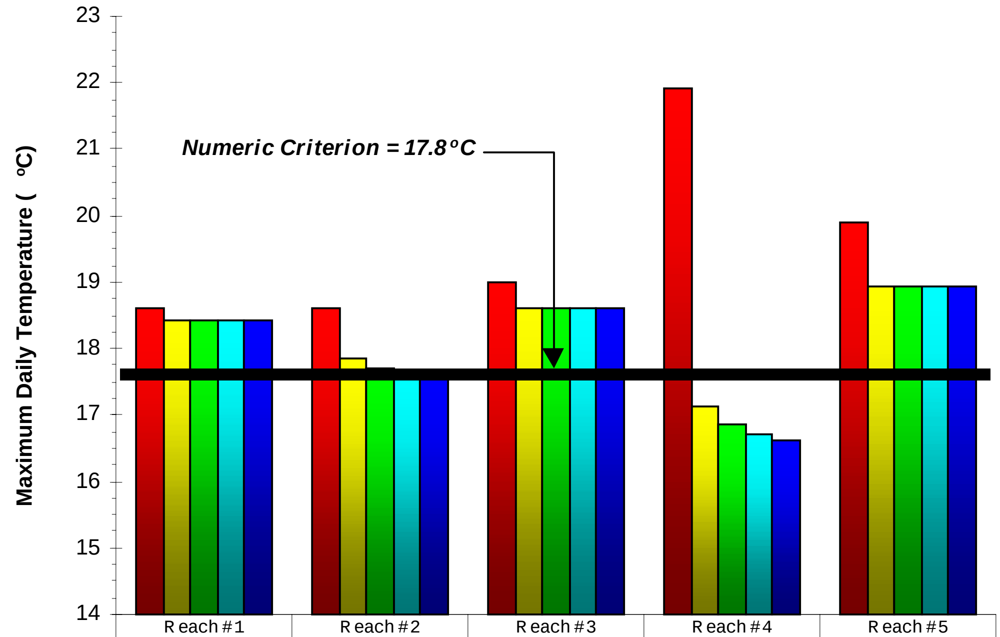


Figure C-15. Maximum Daily Stream Temperatures for Varying Buffer Dimensions *(August 12, 1998)*



	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5
Current Conditions	18.6	18.6	19.0	21.9	19.9
Buffer 1	18.4	17.8	18.6	17.1	18.9
Buffer 2	18.4	17.7	18.6	16.8	18.9
Buffer 3	18.4	17.7	18.6	16.7	18.9
Buffer 4	18.4	17.7	18.6	16.6	18.9

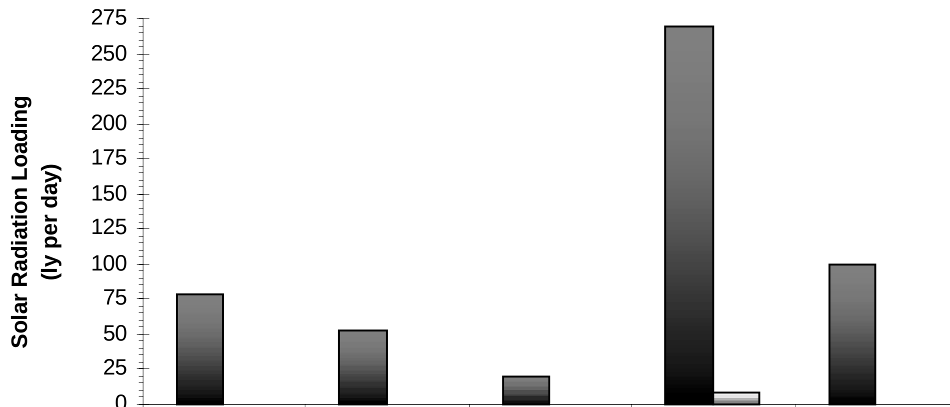
Recall Table C-4. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

Solar Radiation Output

Figure C-16. Daily Solar Flux (ly day^{-1}) - Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation

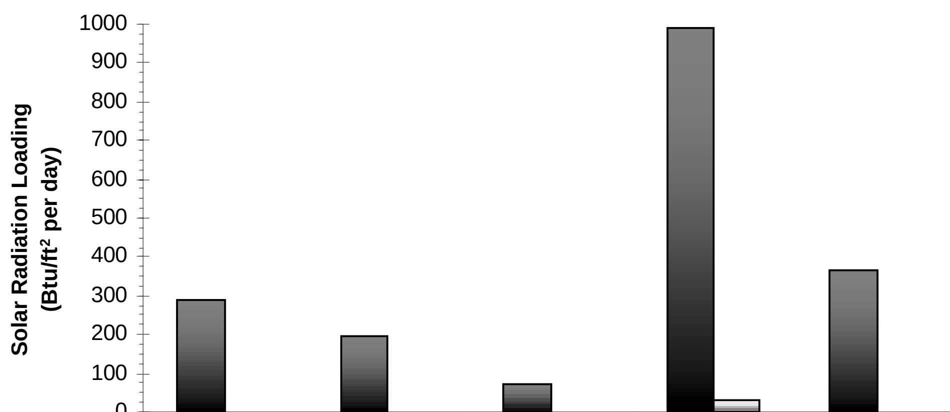
(August 12, 1998)



	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5
Current Conditions	77.9	53.2	19.9	269.4	99.7
Site Potential (Buffer 4)	0.0	0.6	0.0	8.5	0.0

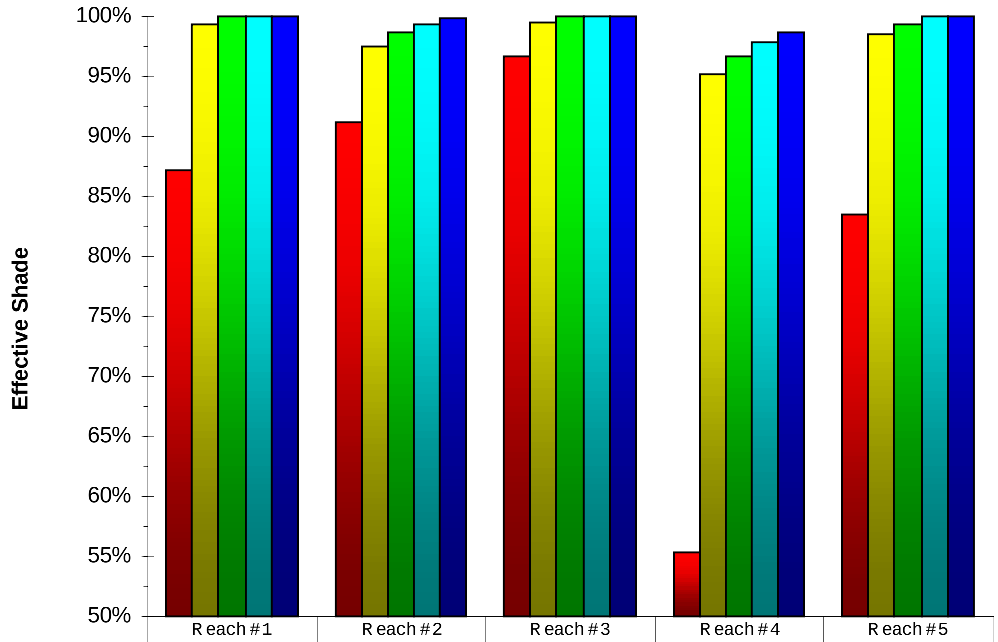
Figure C-17. Daily Solar Flux (Btu ft^{-2} day^{-1}) - Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation

(August 12, 1998)



	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5
Current Conditions	286.9	195.7	73.4	991.9	367.0
Site Potential (Buffer 4)	0.0	2.2	0.0	31.1	0.0

Figure C-18. Effective Shade - Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation



	Reach #1	Reach #2	Reach #3	Reach #4	Reach #5
Current Conditions	87.1%	91.2%	96.7%	55.4%	83.5%
Buffer 1	99.3%	97.5%	99.5%	95.1%	98.5%
Buffer 2	100.0%	98.6%	100.0%	96.6%	99.3%
Buffer 3	100.0%	99.4%	100.0%	97.8%	100.0%
Site Potential (Buffer 4)	100.0%	99.9%	100.0%	98.6%	100.0%

Simulation Reach #1 – Upper Devils Lake Fork Wilson R.

Devils Lake Fork upstream Idiot Creek (looking upstream)

Input Parameters

Run Name	Wilson 1 - DLF u/s Idiot	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.60	*(deg N)*
Longitude	-123.34	*(deg W)*
Stream Aspect	310	*(deg)*
Percent Bedrock	50%	
Reach Length	3900	*(meters)*
Channel Width	2.134	*(meters)*
Flow Volume	0.03	*(cms)*
Flow Velocity	0.305	*(m/s)*
Groundwater Inflow	0.07	*(cms)*
Groundwater Temp.	10.00	*(^oC)*
Ave. Stream Depth	0.05	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	30%	
Distance to Stream	3.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.29	*(meters)*
Shade Angle	83.3	*(deg)*
View to Sky	7%	
Effective Shade	87%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure C-19. Upper Devils Lake Fork Wilson R. Temperature Profiles *(August 12, 1998)*

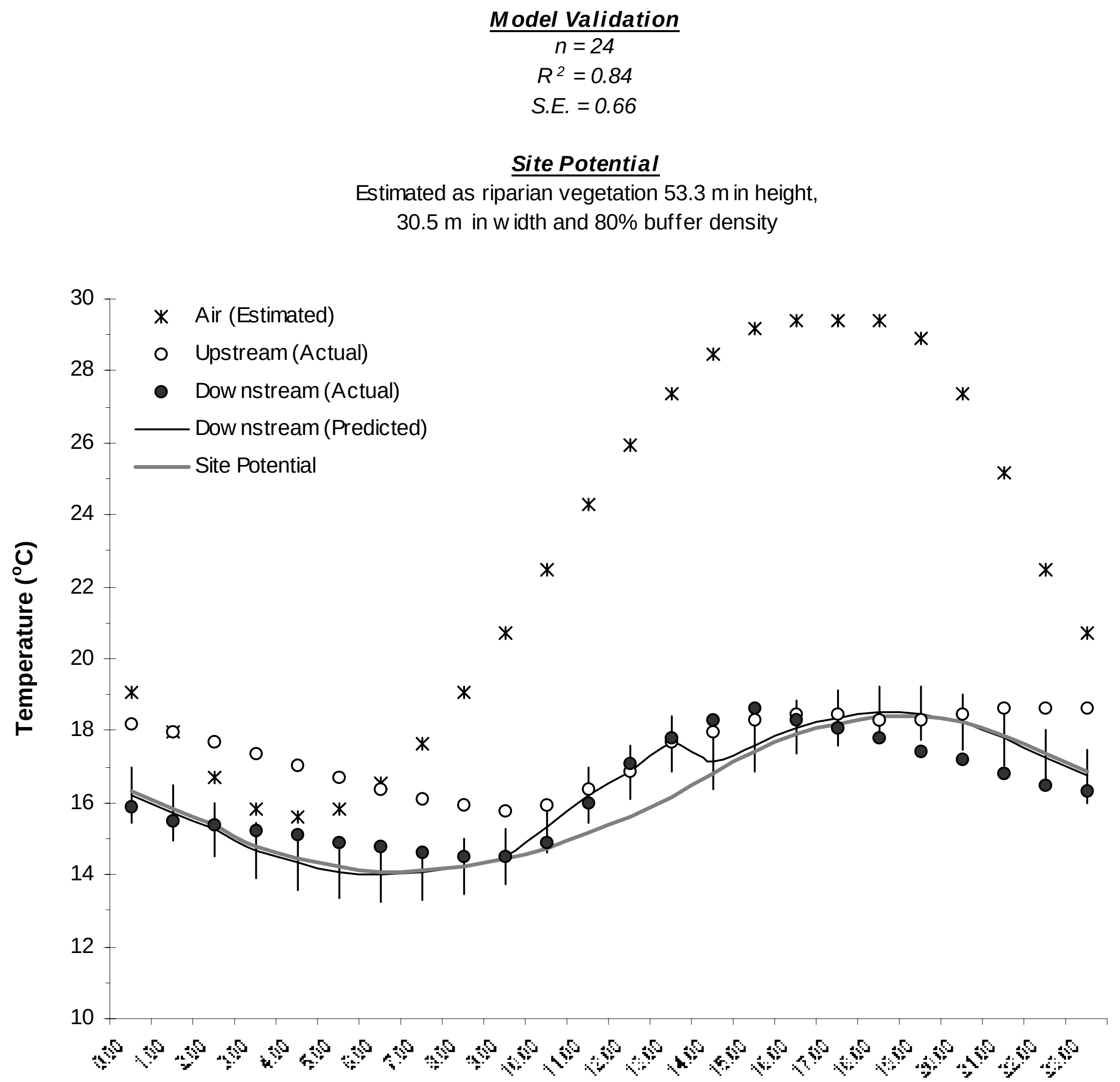
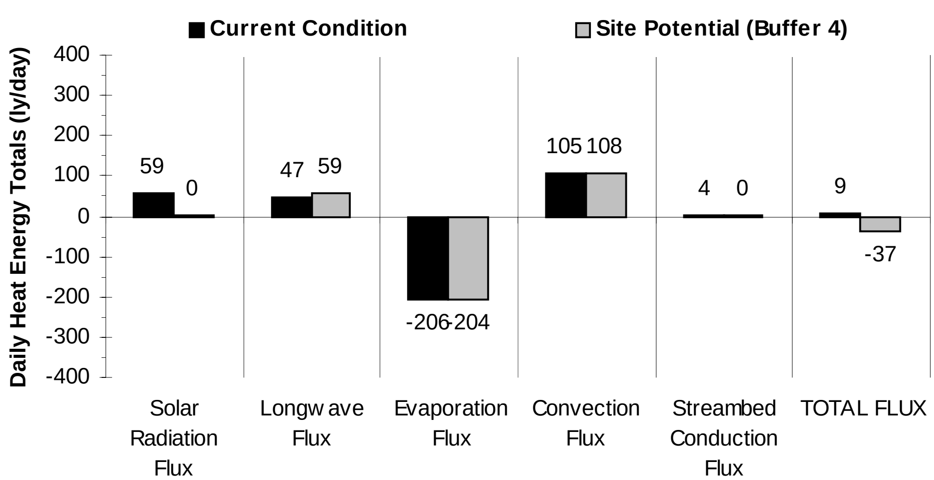


Figure C-20. Upper Devils Lake Fork Wilson R. Daily Heat Energy Totals *(August 12, 1998)*



Simulation Reach #2 – Lower Devils Lake Fork Wilson R.

Devils Lake Fork Wilson R. (looking upstream-not really)

Input Parameters

Run Name	Wilson 2 - DLF d/s Idiot	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.61	*(deg N)*
Longitude	-123.42	*(deg W)*
Stream Aspect	260	*(deg)*
Percent Bedrock	100%	
Reach Length	5150	*(meters)*
Channel Width	6.098	*(meters)*
Flow Volume	0.212	*(cms)*
Flow Velocity	0.183	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.19	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	30.49	*(meters)*
Buffer Density	30%	
Distance to Stream	3.50	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.29	*(meters)*
Shade Angle	74.4	*(deg)*
View to Sky	17%	
Effective Shade	91%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure C-21. Lower Devils Lake Fork Wilson R. Temperature Profiles *(August 12, 1998)*

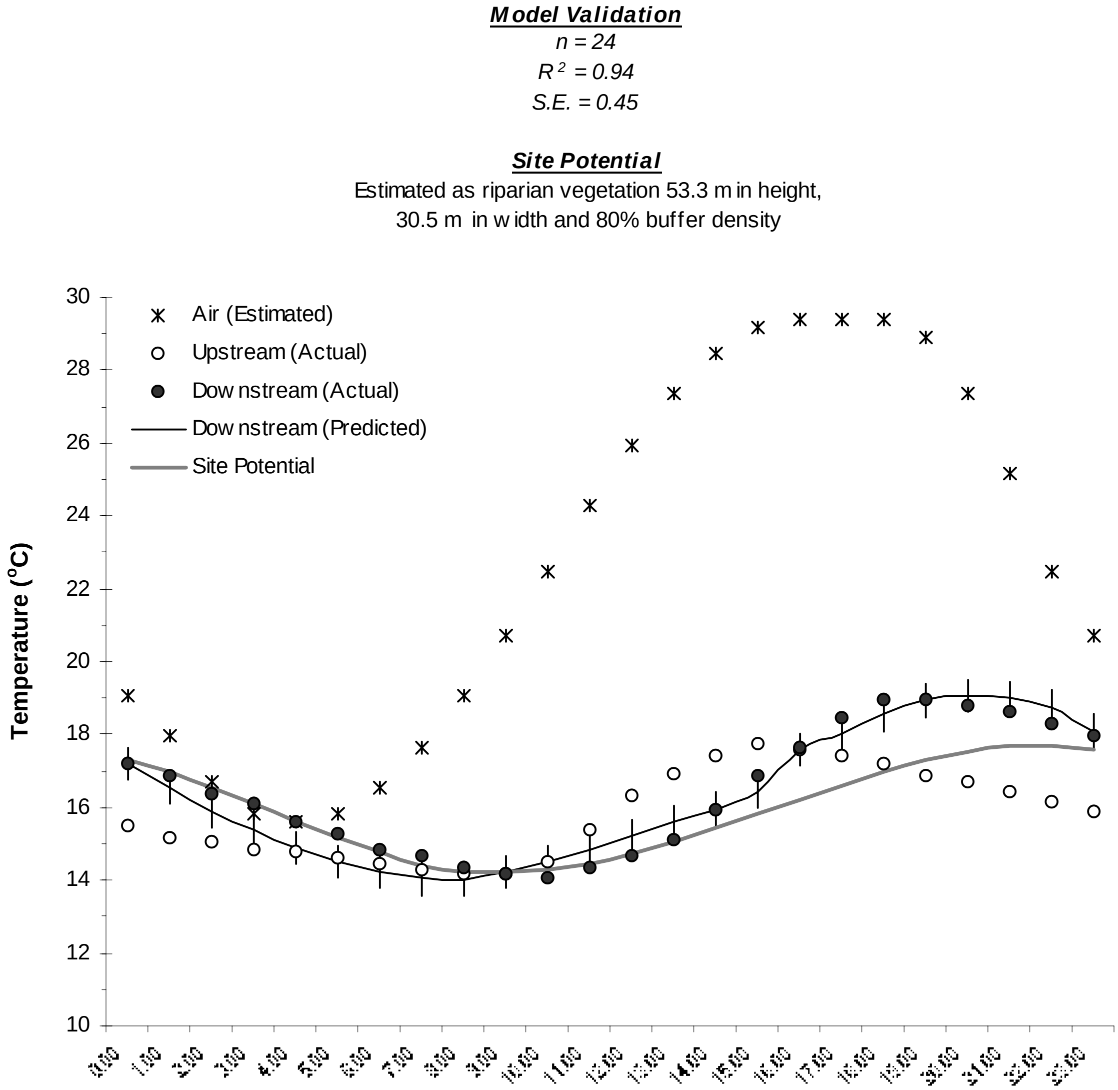
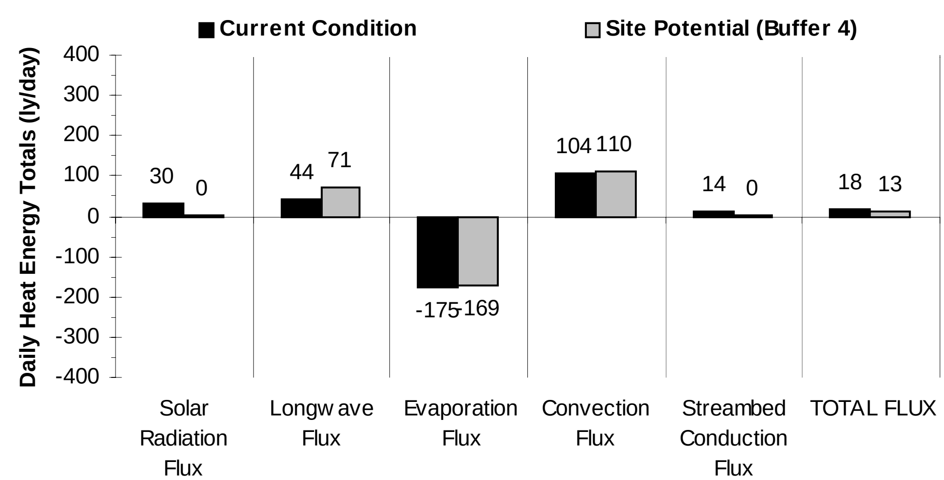


Figure C-22. Lower Devils Lake Fork Wilson R. Daily Heat Energy Totals *(August 12, 1998)*



Simulation Reach #3 – South Fork Wilson R.

South Fork Wilson R. (looking upstream-not really)

Input Parameters

Run Name	Wilson 3 - SF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.59	*(deg N)*
Longitude	-123.46	*(deg W)*
Stream Aspect	5	*(deg)*
Percent Bedrock	100%	
Reach Length	3380	*(meters)*
Channel Width	3.049	*(meters)*
Flow Volume	0.077	*(cms)*
Flow Velocity	0.213	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(°C)*
Ave. Stream Depth	0.12	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	15.24	*(meters)*
Buffer Density	30%	
Distance to Stream	2.25	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.29	*(meters)*
Shade Angle	84.4	*(deg)*
View to Sky	6%	
Effective Shade	97%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure C-23. South Fork Wilson R. Temperature Profiles *(August 12, 1998)*

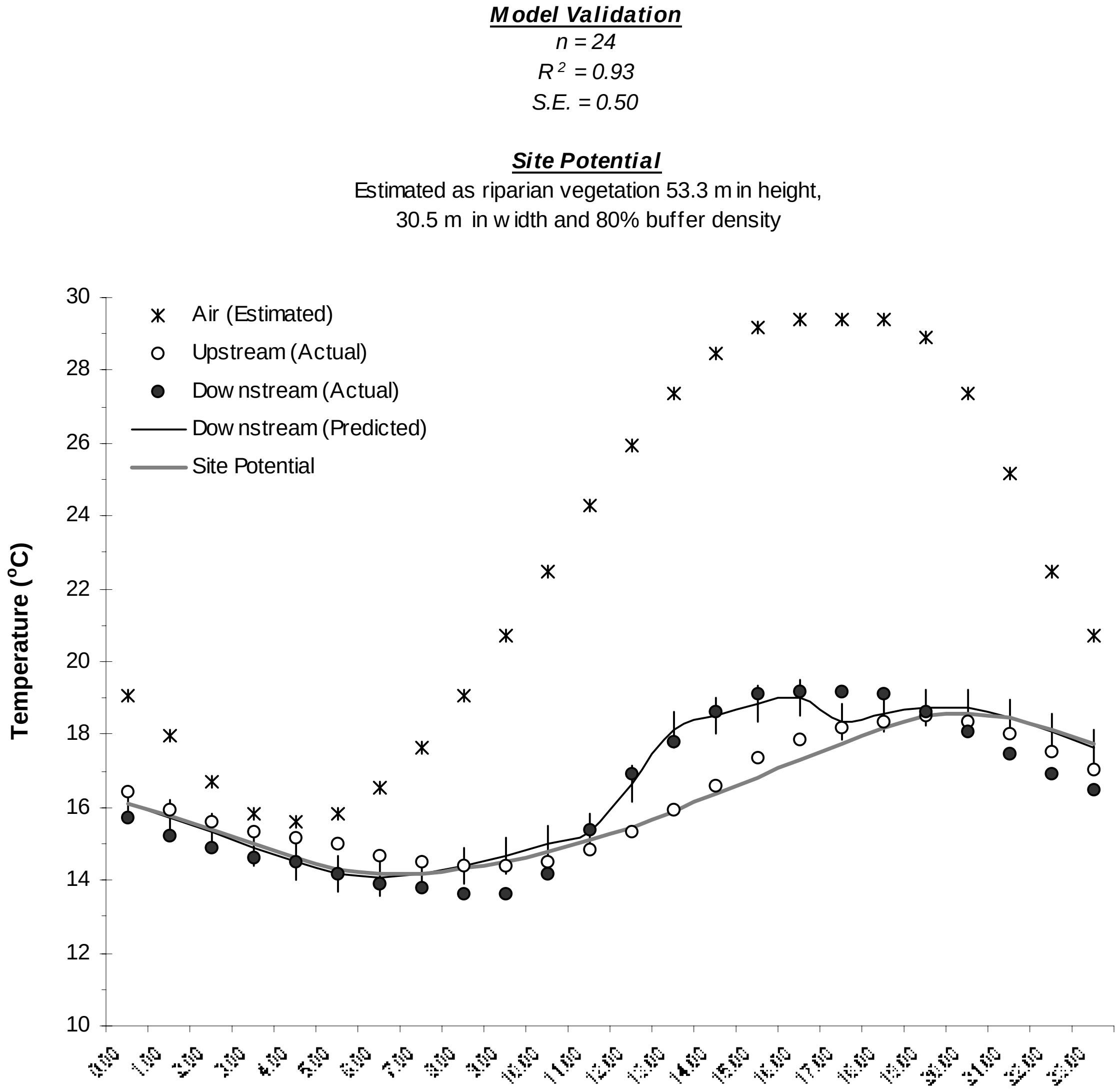
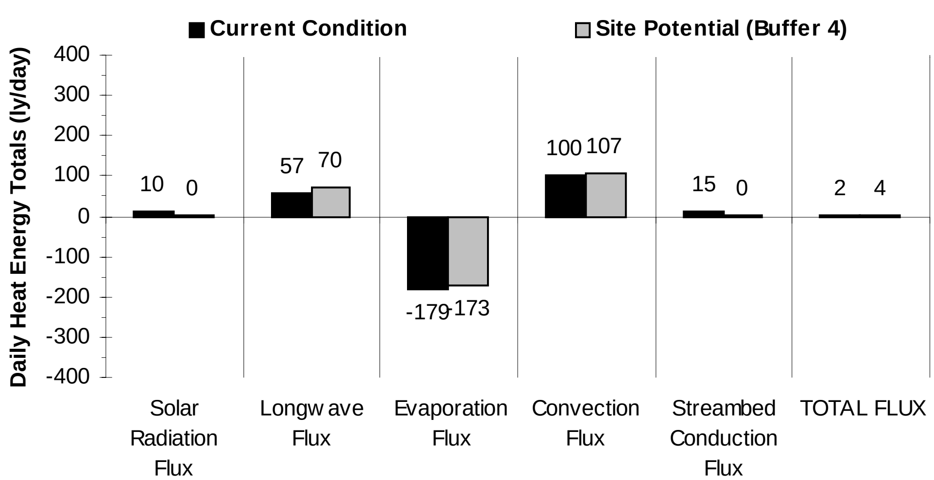


Figure C-24. South Fork Wilson R. Daily Heat Energy Totals
(August 12, 1998)



Simulation Reach #4 – Wilson R. to Lees Camp

Wilson R. at Lees Camp (looking upstream)

Input Parameters

Run Name	Wilson 4 - Lees	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.61	*(deg N)*
Longitude	-123.47	*(deg W)*
Stream Aspect	260	*(deg)*
Percent Bedrock	100%	
Reach Length	6437	*(meters)*
Channel Width	7.012	*(meters)*
Flow Volume	0.296	*(cms)*
Flow Velocity	0.152	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.28	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	15.24	*(meters)*
Buffer Density	20%	
Distance to Stream	6.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	1.52	*(meters)*
Shade Angle	62.4	*(deg)*
View to Sky	31%	
Effective Shade	62%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure C-25. Wilson R. to Lees Camp Temperature Profiles *(August 12, 1998)*

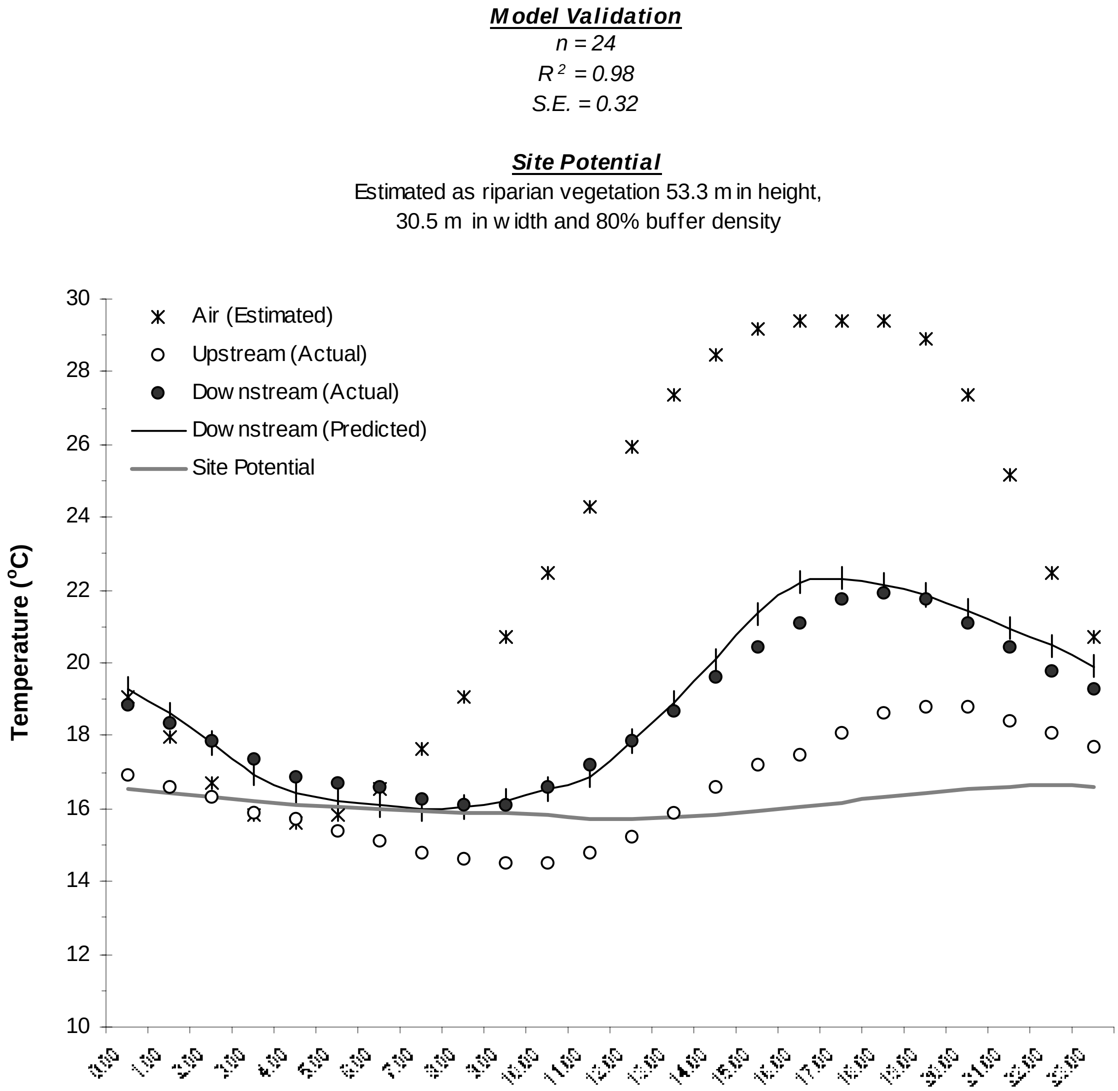
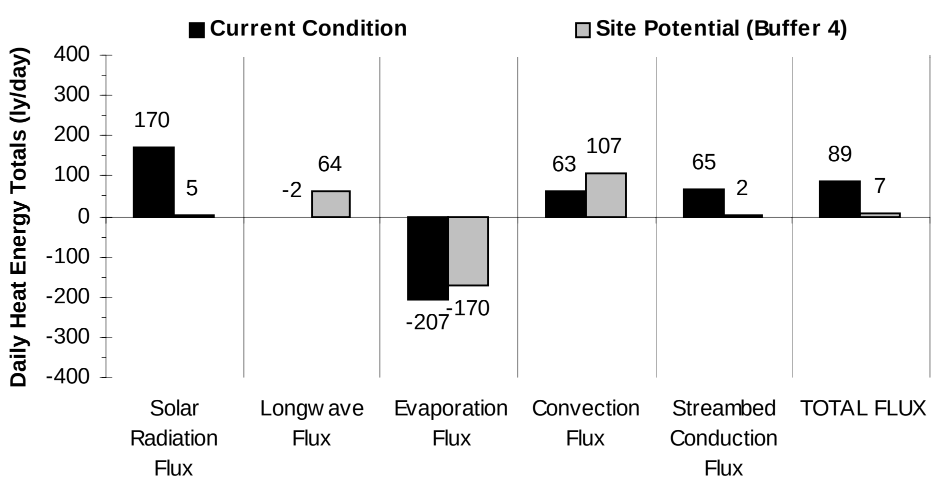


Figure C-26. Wilson R. to Lees Camp Daily Heat Energy Totals *(August 12, 1998)*



Simulation Reach #5 – North Fork Wilson R. to West Fork Wilson R.

North Fork Wilson R. upstream West Fork Wilson R. (looking upstream)

Input Parameters

Run Name	Wilson 5 - NF	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.64	*(deg N)*
Longitude	-123.53	*(deg W)*
Stream Aspect	190	*(deg)*
Percent Bedrock	100%	
Reach Length	2253	*(meters)*
Channel Width	2.439	*(meters)*
Flow Volume	0.088	*(cms)*
Flow Velocity	0.152	*(m/s)*
Groundwater Inflow	0.02	*(cms)*
Groundwater Temp.	10.00	*(^{o}C)*
Ave. Stream Depth	0.24	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	15.24	*(meters)*
Buffer Width	15.24	*(meters)*
Buffer Density	30%	
Distance to Stream	4.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	50%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	2.29	*(meters)*
Shade Angle	79.1	*(deg)*
View to Sky	12%	
Effective Shade	83%	
Elevation	457	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure C-27. North Fork Wilson R. to West Fork Wilson R. Temperature Profiles
(August 12, 1998)

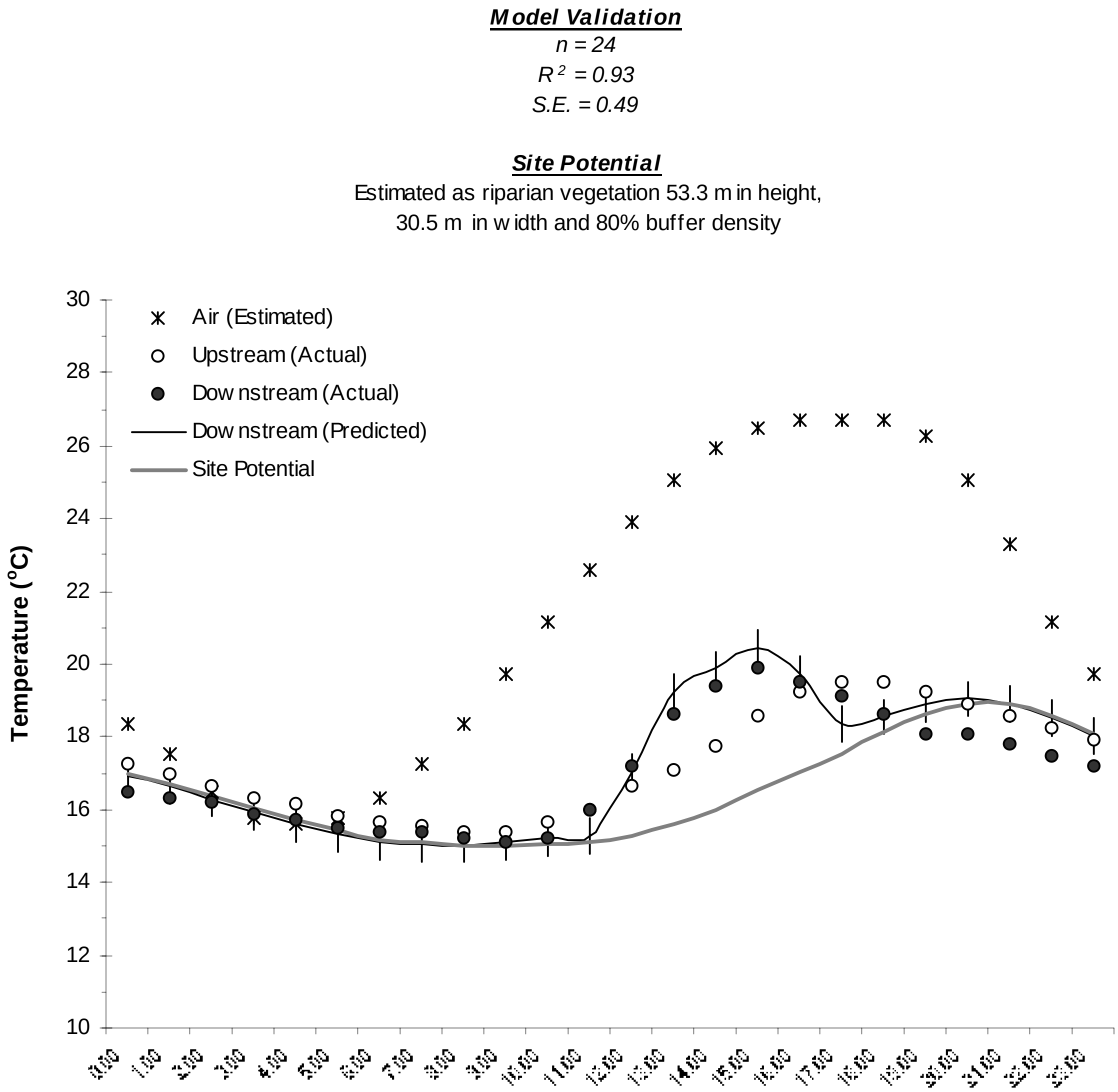
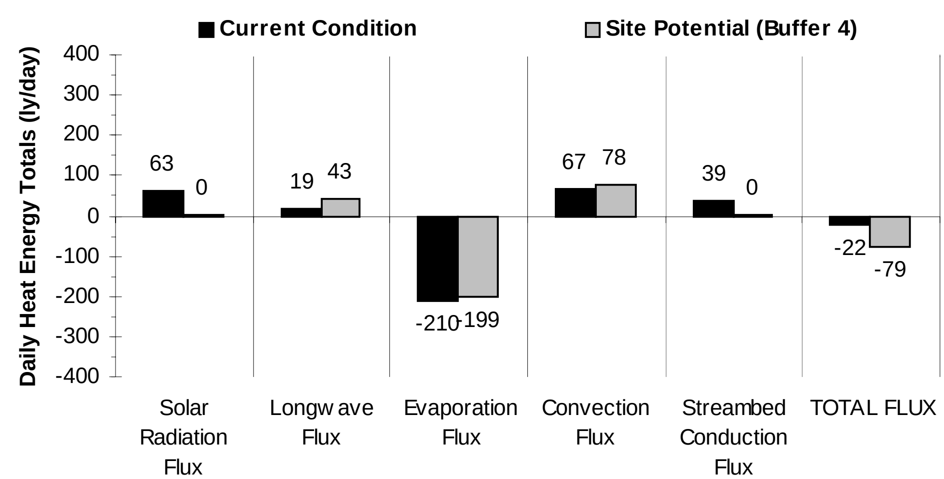


Figure C-28. North Fork Wilson R. to West Fork Wilson R. Daily Heat Energy Totals
(August 12, 1998)



APPENDIX D

KILCHIS AND MIAMI RIVERS TEMPERATURE ASSESSMENT

Current Condition Assessment

Temperature

The Oregon Department of Environmental Quality (ODEQ) measured stream temperatures for the summer months of 1998 and 1997. All of the displayed monitoring sites have been statistically analyzed to obtain the 7-day average of daily maximum temperatures (also known as the 7-day statistic). These 7-day statistics are used to determine if the stream violates the State water quality standard.

Spatial Temperature Patterns

A visual depiction of the continuous temperature monitoring data is shown in **Image D-1**. Since the Miami River lacks sufficient data collection sites and is similar to the Kilchis River, it will be analyzed in conjunction with the Kilchis River. Note that the forks and the tributaries to the Kilchis generally have cooler temperatures than the mainstem.

Temperature trends throughout the Kilchis and Miami sub-basins follow continual heating in the downstream (longitudinal) direction (**Figure D-1**). Daily temperature profiles for selected sites sampled on August 12, 1998 are represented in **Figure D-2**. Longitudinal heating is apparent. The Kilchis River mainstem is clearly warmer than the North Fork Kilchis River, South Fork Kilchis River, and Coal Creek.

Figure 1. Stream Temperature Heating Curve
(August 12, 1998)

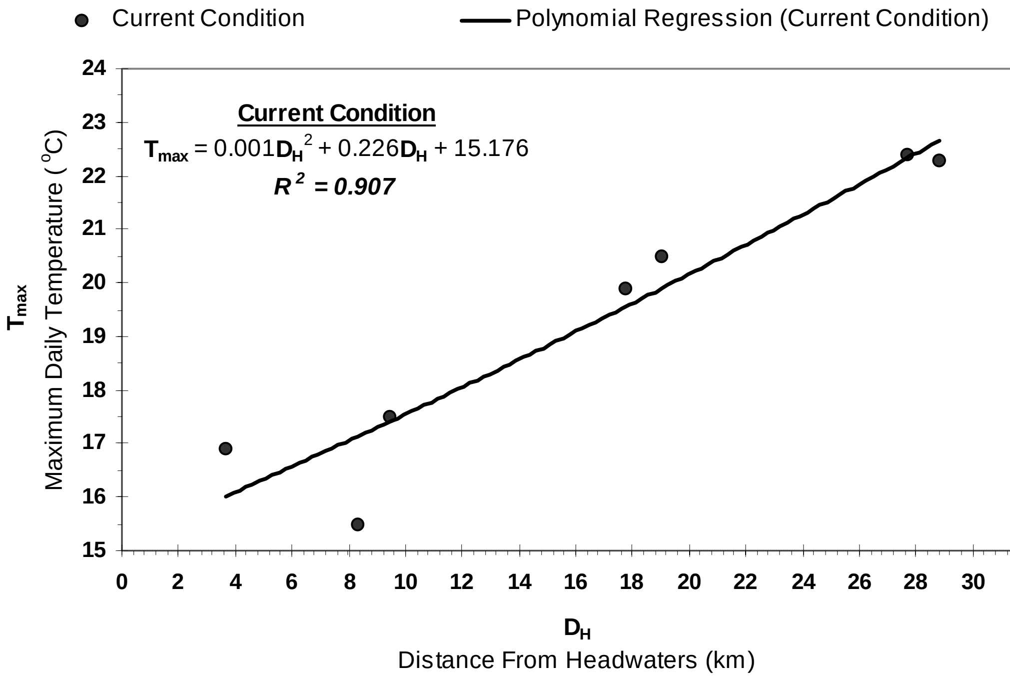


Figure D-2. Stream Temperature Profiles
(*August 12, 1998*)

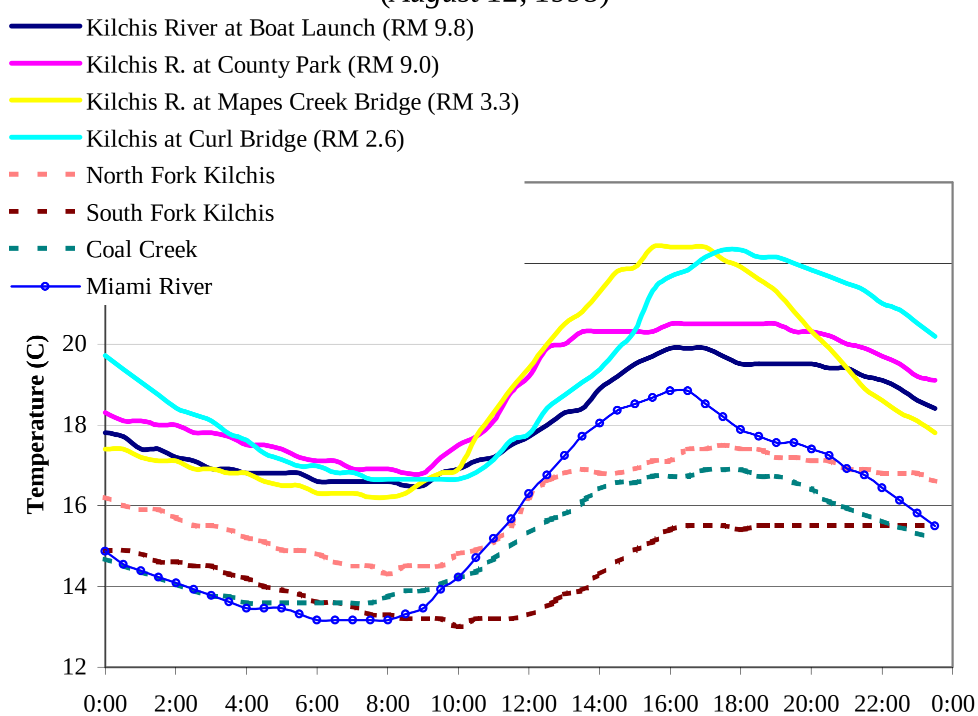
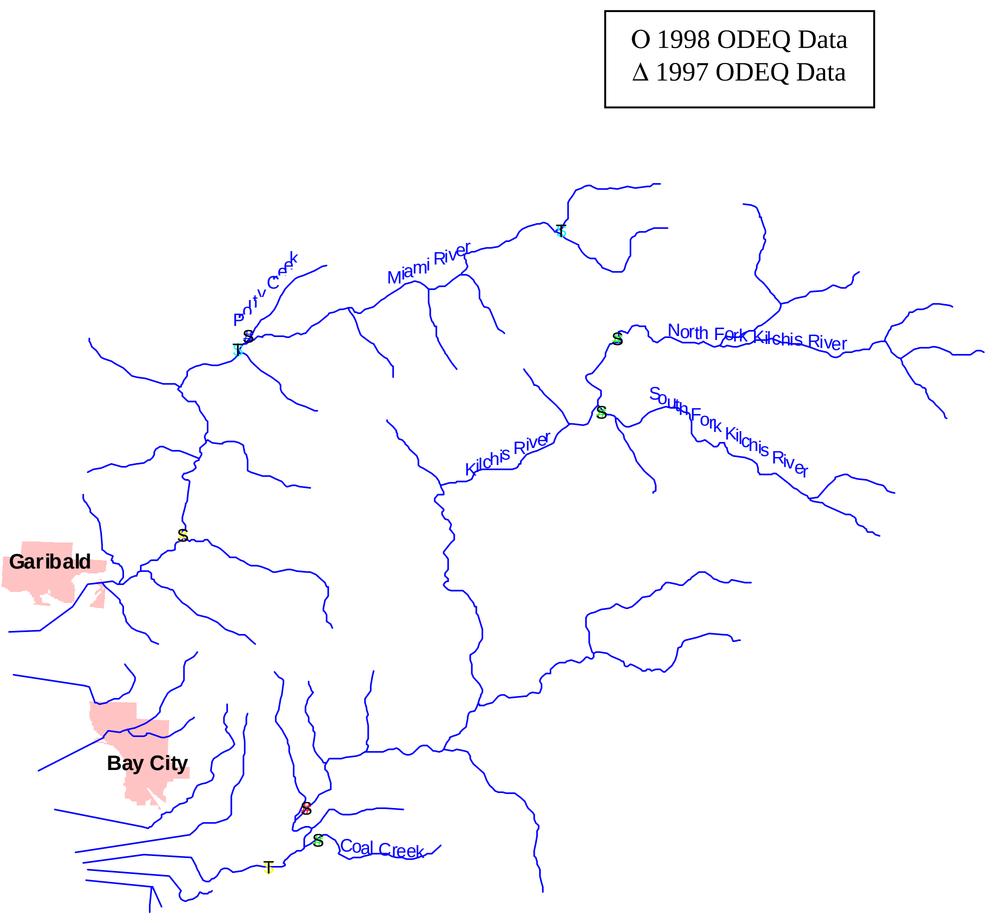


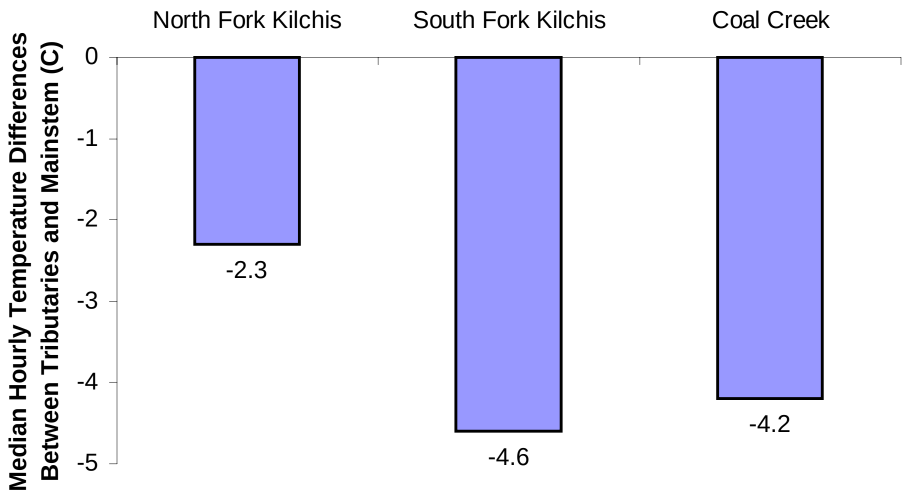
Image D-1. Maximum 7-Day Moving Average of Daily Maximum Temperatures



Less than 12.8°C	**12.8°C to 15.3°C**	**15.3°C to 17.8°C**	**17.8°C to 20.3°C**	**Greater than 20.3°C**

Figure D-3 shows the median hourly temperature differences between the Kilchis River mainstem and its tributaries. Negative median hourly temperature differentials between the tributaries and mainstem indicate that tributaries are cooling the mainstem. The North Fork is warmer than the South Fork, however, it is still cooler than the mainstem. Coal Creek is significantly cooler than the Kilchis River mainstem, but has a limited ability to exert a cooling influence due to the disparity between flows in Coal Creek (low) and the Kilchis River mainstem (relatively high).

Figure D-3. Median Hourly Temperature Differences Between Tributaries and Mainstem
(August 12,1998)



Temporal Temperature Patterns

Continuous temperature data were collected in the Kilchis River (at Curl Bridge) during the summer of 1998; however, no 1997 data was available for comparison. Seasonal maximum stream temperatures are typically due to a combination of high solar exposure levels, warm air temperatures, and low flow conditions. Maximum stream temperatures peak in late July and early August. Temperatures begin to decline in late August, due to decreased solar loading and increased flow rates from rain events. **Figure D-4** shows the relative 7-day maximum temperatures for selected sites on the Kilchis and Miami Rivers. Note that the Kilchis River mainstem has the highest 7-day maximum temperatures. **Figure D-5** displays the maximum monthly 7-day temperatures for the selected sites. Temperatures tend to peak in July and begin to decline in late August.

Figure D-4. Moving Seven-Day Averages of Daily Maximum Stream Temperatures for Selected Sites on the Kilchis and Miami Rivers (1998)

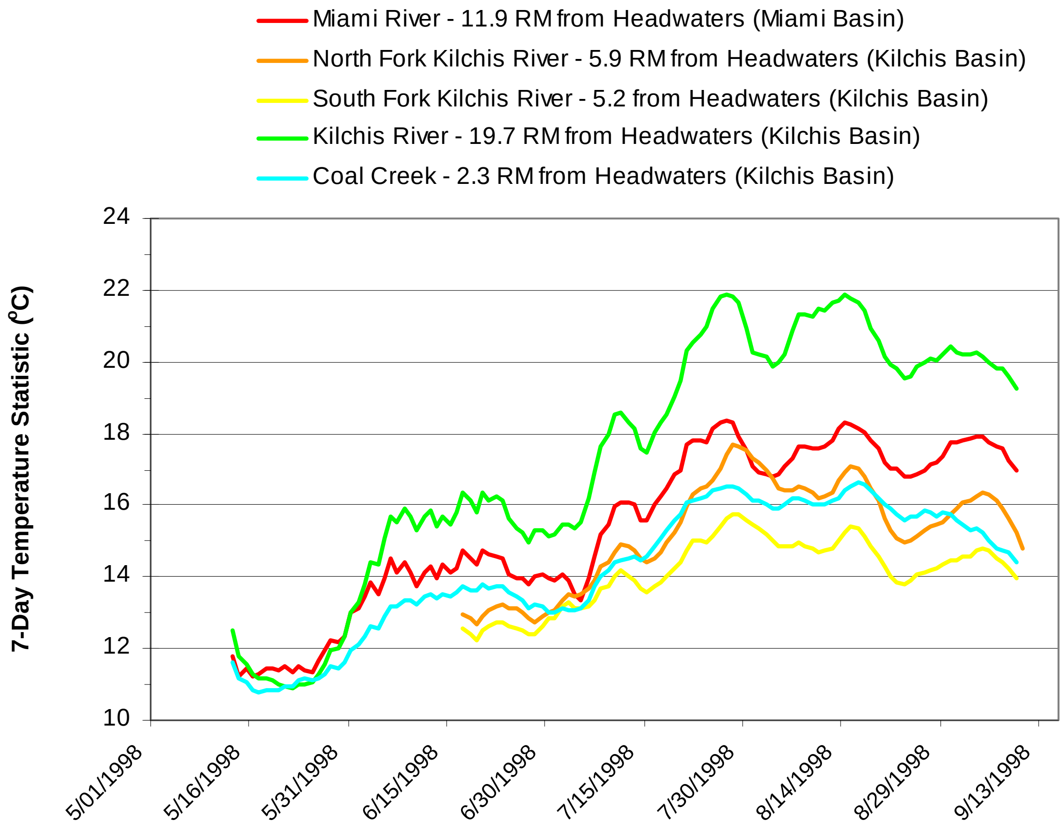
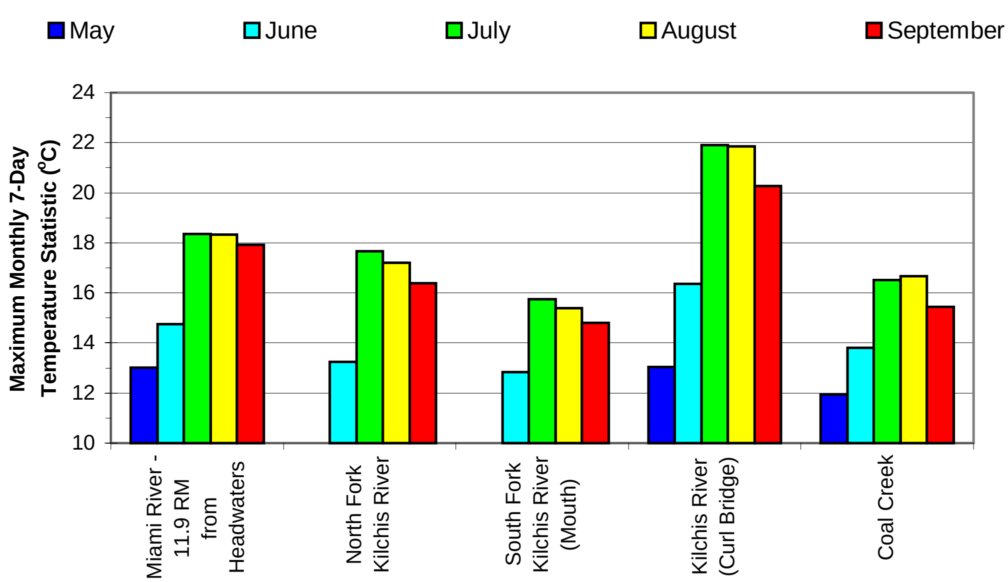


Figure 5. Maximum Monthly Seven-Day Moving Averages of Daily Maximum Stream Temperatures (1998)



Shade

ODEQ measured stream surface shade at selected sites along the Kilchis and Miami Rivers during the summer of 1998. Solar Pathfinder data was used to quantify average effective shade for May through September. The hours of solar exposure from sunrise to sunset were also collected using the Solar Pathfinder. A densiometer was used to determine canopy cover. Narrative descriptions of vegetation were also recorded at the selected sites.

Effective shade is extremely variable for the Kilchis and Miami rivers. The effective shade ranges from 0% in the lower reaches of the Kilchis and Miami mainstems to 100% in the North and South Forks of the Kilchis River.

Figure D-6 displays the median effective shade for the Kilchis and Miami River sub-basins. Canopy cover was not recorded at all sites that effective shade was measured. The Tillamook Bay National Estuary Project (NEP) has designated an effective shade target of 75% for streams within the Tillamook basin. **Figure D-7** compares the measured effective shade values with the NEP target. Note that neither the Kilchis River nor the Miami River fully meet the NEP target.

Figure D-6. Measured Shade Data (1998)

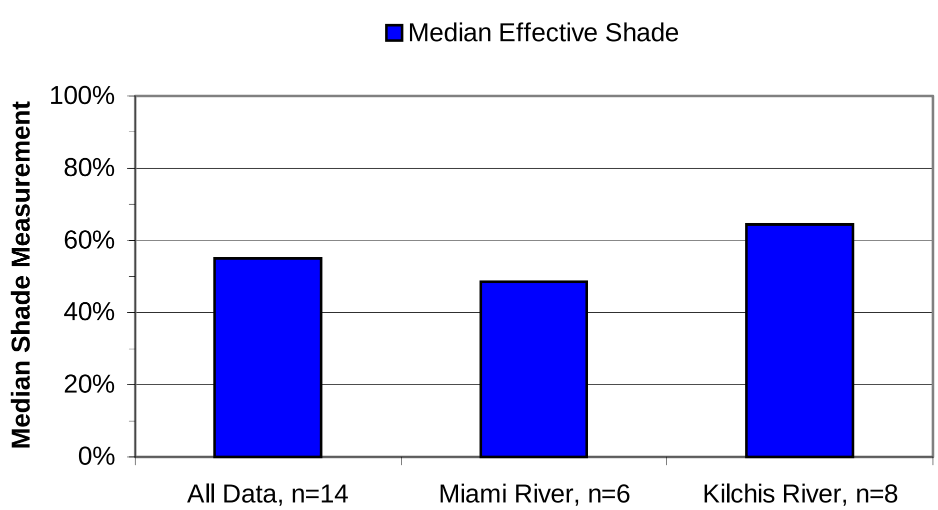


Figure D-7. Median Effective Shade Measurements Compared to NEP Shade Target

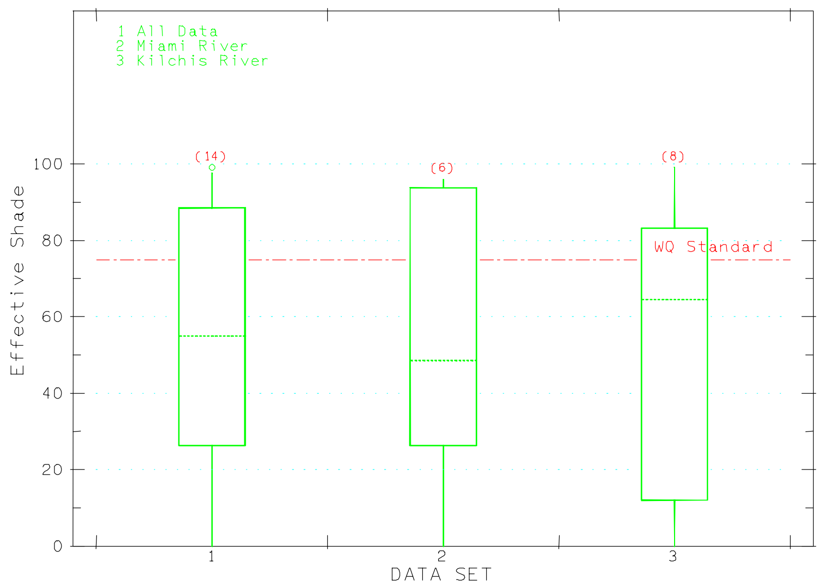


Image D-2 graphically displays the effective shade measurements recorded for the Miami and Kilchis Rivers in 1998. The upper reaches have higher effective shade values than the lower reaches. Shade appears to decrease in the downstream direction (longitudinally), similar to the temperature trends discussed previously. **Image D-3** graphically shows the daily summertime solar exposure measurements recorded in 1998. Parallel to effective shade measurements, daily solar exposure is lowest in the upper reaches, while it is higher in the lower reaches.

Image D-2. Effective Shade – Measured with Solar Pathfinder (1998)

Less than 20% 20% to 40% 40% to 60% 60% to 80% Greater than 80%

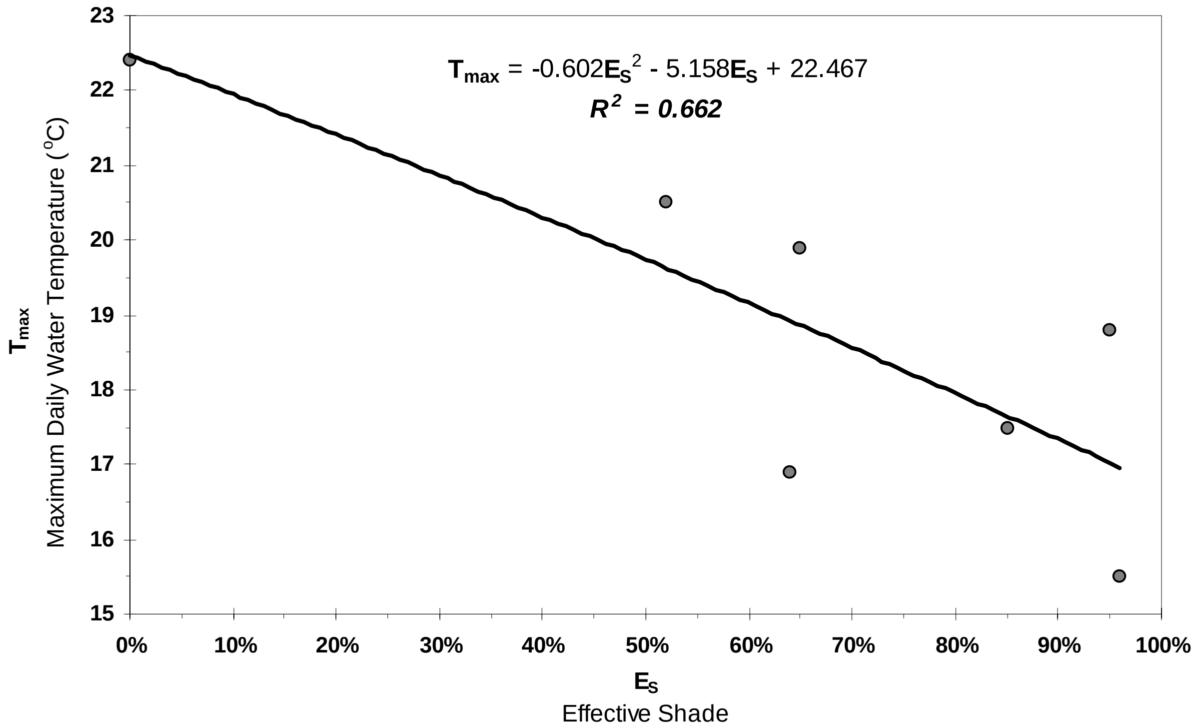
Image D-3. Daily Summertime Solar Exposure – Measured with Solar Pathfinder (1998)

Less than 2 hours 2 to 4 hours 4 to 6 hours 6 to 8 hours Greater than 8 hours

Shade Related to Stream Temperature

Solar exposure is commonly responsible for stream heating, especially in streams with low flow volumes or high surface to volume ratios. **Figure D-8** shows the relationship between effective shade and maximum daily temperatures for the Kilchis and Miami Rivers. The correlation between warmer stream temperatures and less effective shade is supported here.

Figure D-8. Stream Heating Profile - Maximum Daily Temperature and Effective Shade *(August 12, 1998)*



Stream Temperature Simulation

This stream temperature simulation is intended to quantify stream temperatures and the corresponding energy process conditions when site potential riparian vegetation exists. The model is validated using hydrologic, thermal, and landscape descriptions of the current condition, including only 1998 data. Following validation of the model, stream temperatures and energy conditions are predicted for site potential riparian conditions. All other model inputs remain unchanged. The site potential riparian condition assumed that in this series of predictions is of late seral (old growth) conifer buffer.

Model results should be cautiously considered. Standard errors and goodness of fit estimates are provided with all model output. As is generally the case in non-linear water quality modeling, model results are best suited for relative comparisons, rather than determinations of water quality parameter magnitude. Ultimate stream temperature is estimated in the report and is presented with upper and lower error boundaries. Discussions of the model results should include consideration for these error boundaries.

A large extent of the Kilchis River mainstem was modeled using Heat Source v. 5.5. The steps involved are presented in the next section (***Methodology***).

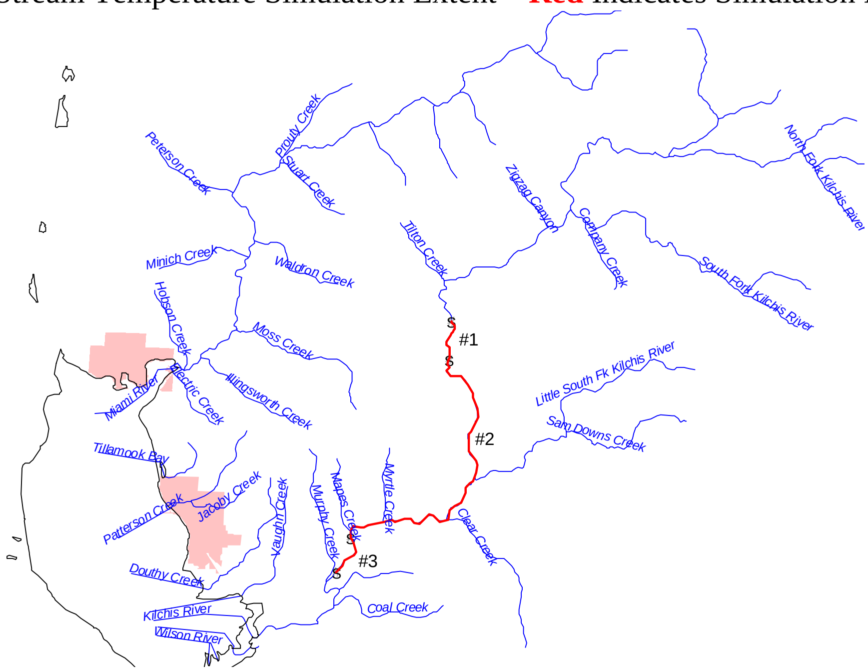
Methodology

1. *Selection of Temperature Simulation Reaches*

Table 1. Kilchis River Simulation Reaches

#	Simulation Reach	Upper Extent	Lower Extent
1	Upper Kilchis River	Boat Launch	County Park
2	Middle Kilchis River	County Park	Mapes
3	Lower Kilchis River	Mapes	Curl Bridge

Image D-4. Stream Temperature Simulation Extent – **Red** Indicates Simulation Reaches



2. *Model Input: Site Specific Data*

Table D-2. Heat Source v. 5.5 Model Input Parameters		
• Date	• Latitude	• Longitude
• Stream Aspect	• Reach Length	• Channel Width
• Flow Volume	• Flow Velocity	• Percent Bedrock
• Groundwater Inflow	• Groundwater Temp.	• Dispersion
• Buffer Height	• Buffer Width	• Buffer Density
• Min. Air Temp.	• Max. Air Temp.	• Relative Humidity
• Distance to Stream	• Elevation	• Wind Speed
• Upstream Hourly Temperature Data		

3. *Prediction of Current Condition (Downstream Temperature Profile)*

4. *Model Validation: Statistical Analysis of Model Output*

Table D-3. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

- Pearson's Product Moment (R^2)
- Standard Error (S.E.)

5. *Prediction of <u>Stream Reach Site Potential Condition</u>*

- Site potential buffer conditions were constant over all stream sections for each of the four site potential simulations.
- Assume that the current condition standard error (S.E.) applies to site potential simulations.

6. *Prediction of <u>Stream Reach Based on Cumulative Upstream Site Potential Conditions</u> (Downstream Temperature Profile)*

- Utilize upstream reach site potential stream temperature for upstream model input in downstream reach simulation (i.e. downstream site potential temperature profile or Reach#2 becomes input temperature profile for Reach #3).
- Account for tributary temperature mixing.
- Assume tributary temperatures are at or near site potential.
- Assume that current condition standard error (S.E.) continues to apply.
- Standard error (S.E.) of upstream predictions accumulates in the. downstream direction.

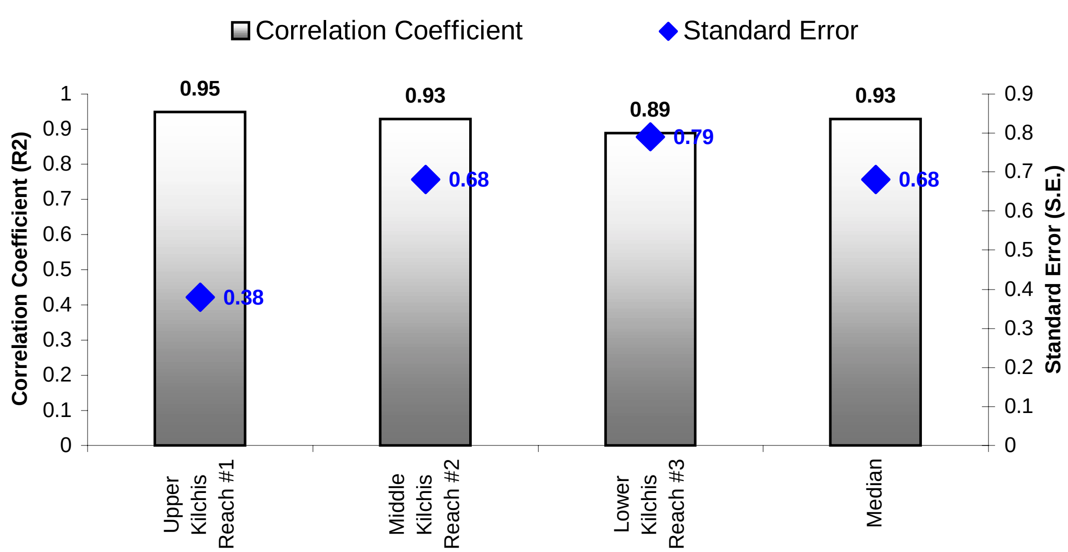
Model Validation

Temperature Validation

Actual (measured) and simulated temperatures were statistically compared to generate the square of the Pearson product moment correlation coefficient (R^2) and the standard error (S.E.) for each simulation reach (**Figure D-9**). Median values for all simulation reaches were:

- Correlation Coefficient (R^2): 0.93
- Standard Error (S.E.): 0.68°C

Figure D-9. Temperature Profile Simulation Accuracy
Heat Source v. 5.5 Model Validation (R^2 and S.E.)



Summary of Model Results

Temperature Output

Simulated maximum daily stream temperatures were generally cooler under site potential riparian conditions (buffer height = 38 meters, buffer width = 31 meters, and buffer density =80%). Longitudinal heating is reduced in the simulated site potential condition. **Figure D-10** shows that stream temperature changes more gradually under the site potential riparian condition. Standard errors associated with each simulation are indicated by vertical bars. As noted before, the simulation errors were assumed to accumulate in the downstream direction, resulting in an increased margin of error. It is possible that this method for accounting prediction error overestimates the margin of error; however, it is important to realize the limitations of stream temperature modeling.

Figure D-10. Actual Stream Heating Curve and Predicted Site Potential Daily Maximum Temperatures with Associated Error Bars (*August 12, 1998*)

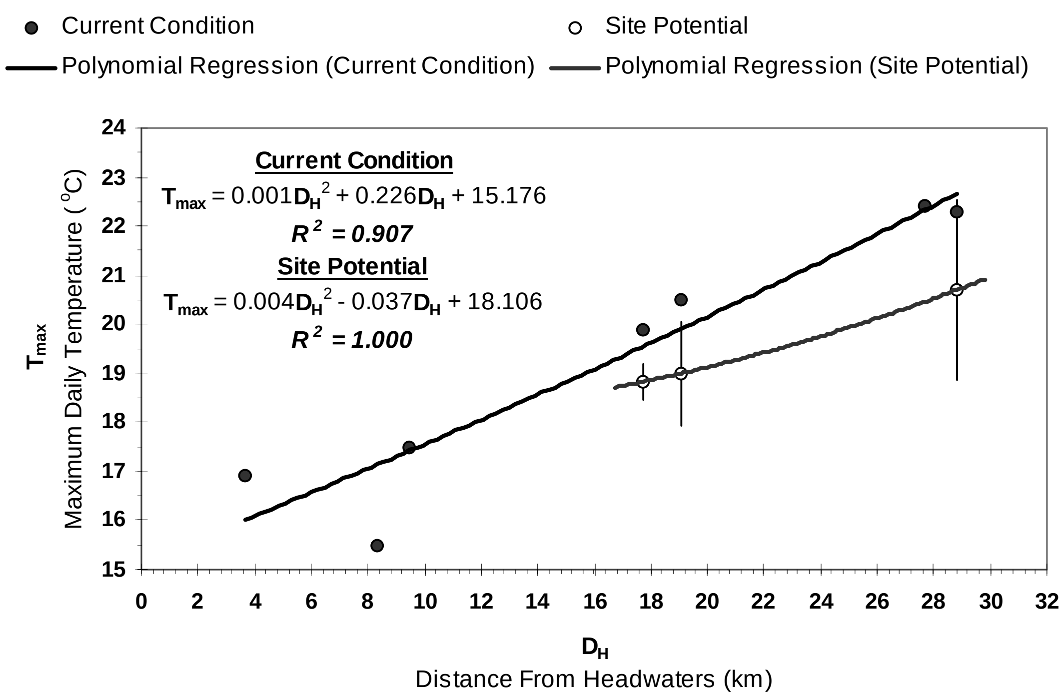
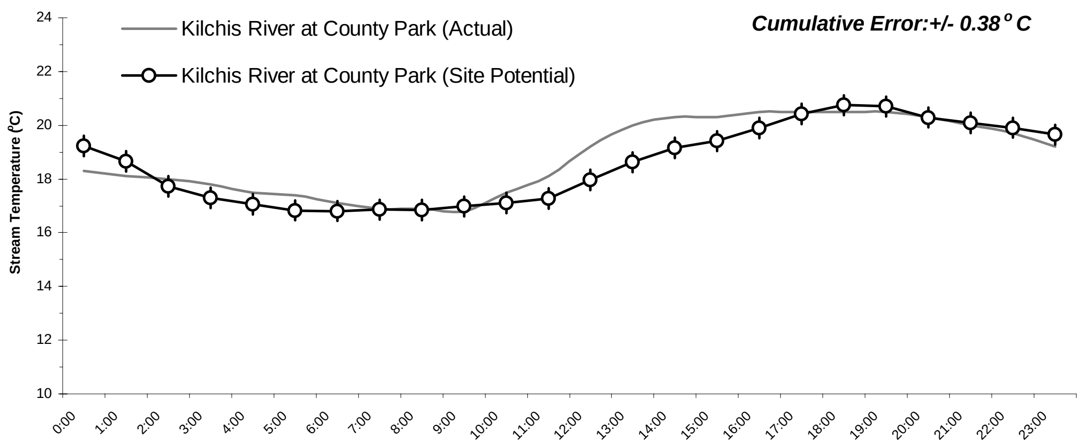
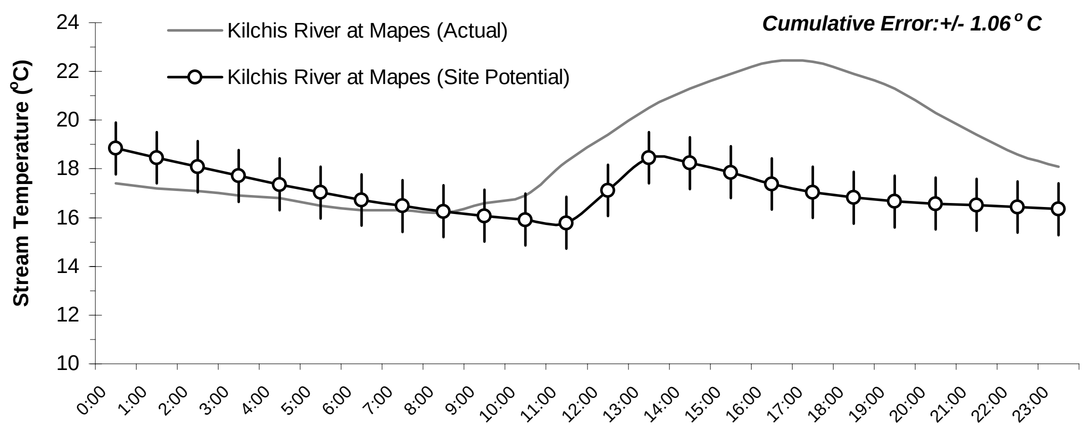


Figure D-11. Predicted and Actual Temperature Profiles (*August 12, 1998*)

Upper Kilchis River (Reach #1)



Middle Kilchis River (Reach #2)



Lower Kilchis River (Reach #3)

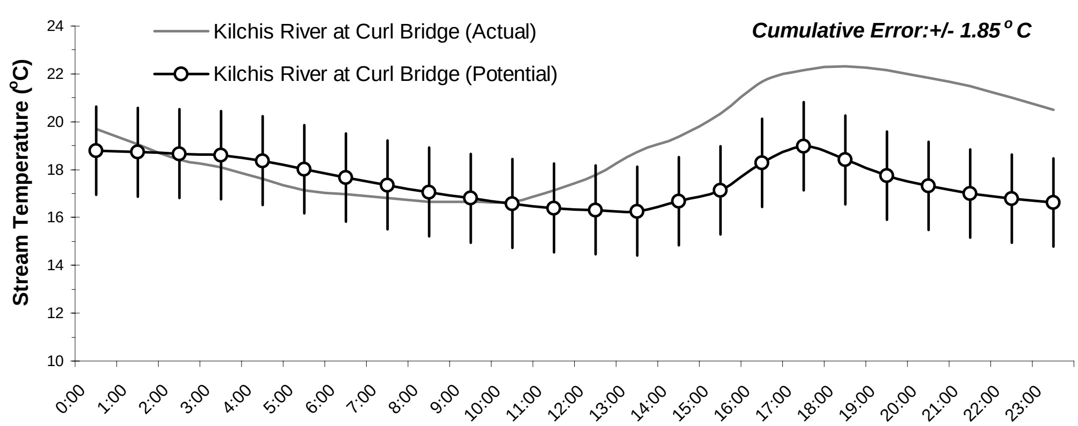
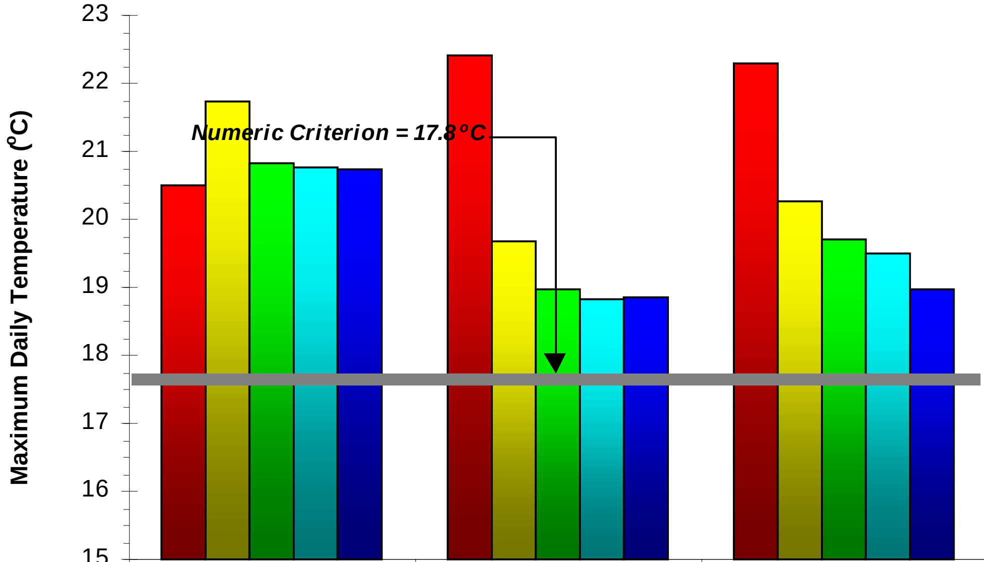


Figure D-12. Daily Stream Temperatures for Varying Buffer Dimensions (*August 12, 1998*)



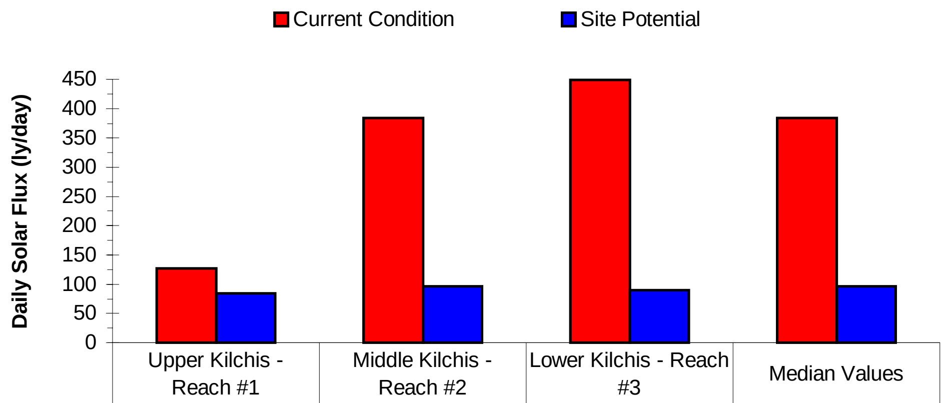
	Reach 1	Reach 2	Reach 3
Current Conditions	20.5	22.4	22.3
Buffer 1	21.7	19.7	20.3
Buffer 2	20.8	19.0	19.7
Buffer 3	20.8	18.8	19.5
Buffer 4	20.7	18.8	19.0

Recall Table D-3. Simulated Buffer Conditions

Name	Description	Buffer Height	Buffer Width	Buffer Density	Percent Overhanging
Buffer 1	Mixed Early Seral Buffer	30.5 meters (100 feet)	30.5 meters (100 feet)	65%	15%
Buffer 2	Conifer Early Seral Buffer	38.1 meters (125 feet)	30.5 meters (100 feet)	70%	15%
Buffer 3	Conifer Mid Seral Buffer	45.7 meters (150 feet)	30.5 meters (100 feet)	75%	15%
Site Potential Riparian Condition					
Buffer 4	Conifer Late Seral Buffer	53.3 meters (175 feet)	30.5 meters (100 feet)	80%	15%

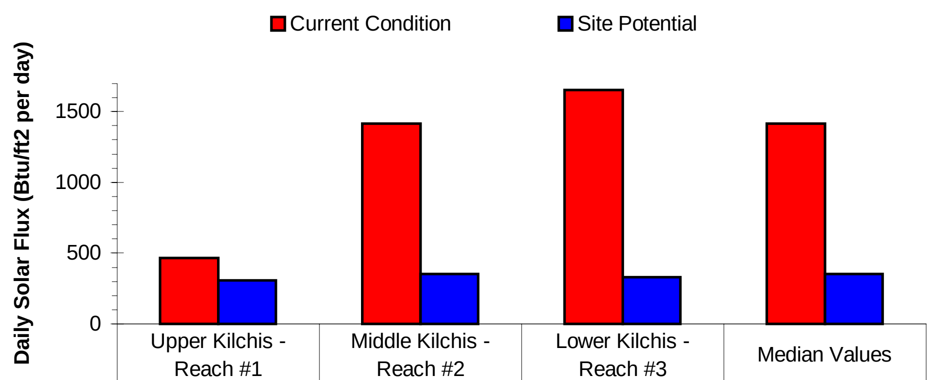
Solar Radiation Output

Figure D-13. Daily Solar Flux (ly day^{-1}) – Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation (*August 12, 1998*)



	Upper Kilchis - Reach #1	Middle Kilchis - Reach #2	Lower Kilchis - Reach #3	Median Values
Current Condition	127	384	449	384
Site Potential	84	96	90	96

Figure D-14. Daily Solar Flux (Btu ft^{-2} day^{-1}) – Calculations for Current Conditions and Site Potential (Buffer 4) Riparian Vegetation (*August 12, 1998*)



	Upper Kilchis - Reach #1	Middle Kilchis - Reach #2	Lower Kilchis - Reach #3	Median Values
Current Condition	468	1414	1653	1414
Site Potential	309	353	331	353

Simulation Reach #1 – Upper Kilchis River

Kilchis River at River Mile 9 (looking upstream)

Input Parameters

Run Name	Kilchis 1 - Upper	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.58	*(deg N)*
Longitude	-123.79	*(deg W)*
Stream Aspect	168	*(deg)*
Percent Bedrock	60%	
Reach Length	1287	*(meters)*
Channel Width	12	*(meters)*
Flow Volume	0.557	*(cms)*
Flow Velocity	0.13	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(*C)*
Ave. Stream Depth	0.36	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	32.00	*(meters)*
Buffer Width	22.87	*(meters)*
Buffer Density	70%	
Distance to Stream	11.00	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	25%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	5.60	*(meters)*
Shade Angle	70.4	*(deg)*
View to Sky	22%	
Effective Shade	72%	
Elevation	427	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure D-15. Upper Kilchis River Temperature Profiles (*August 12, 1998*)

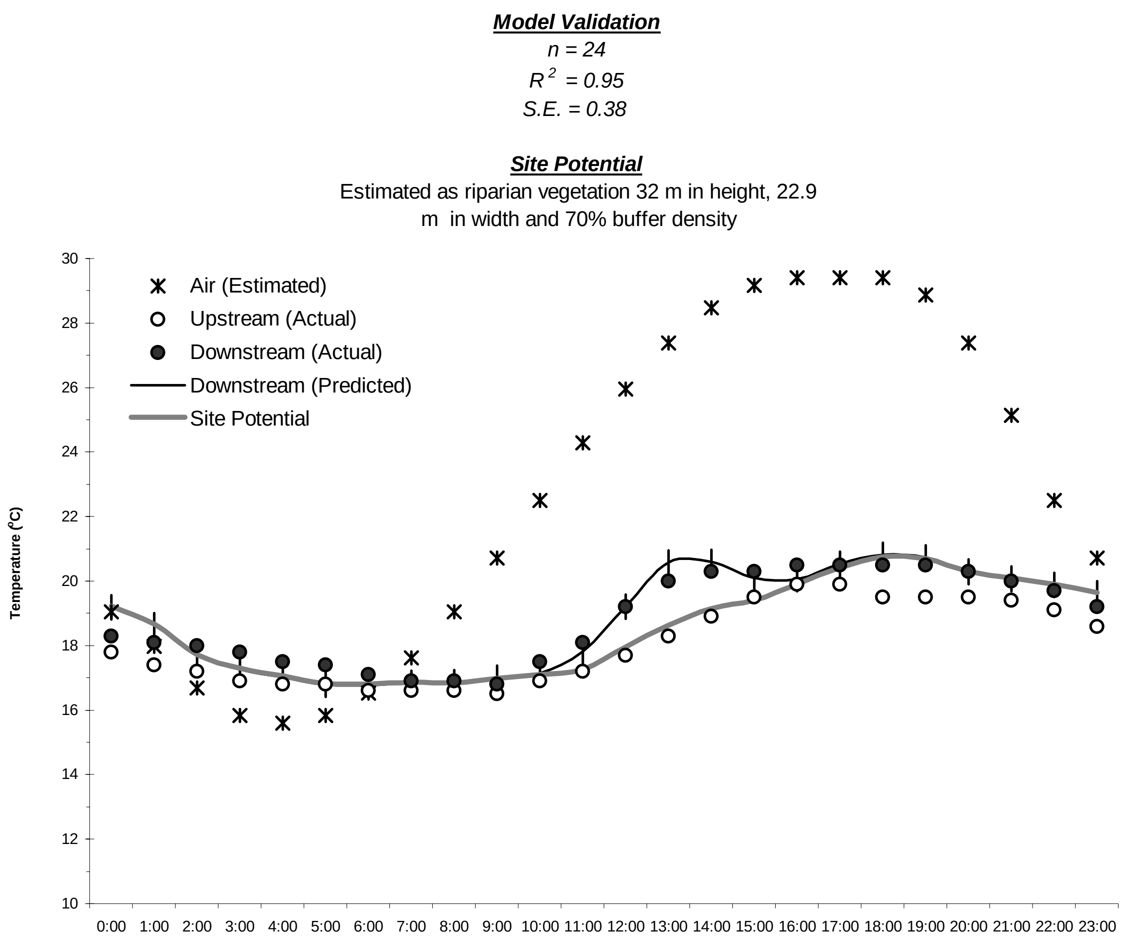
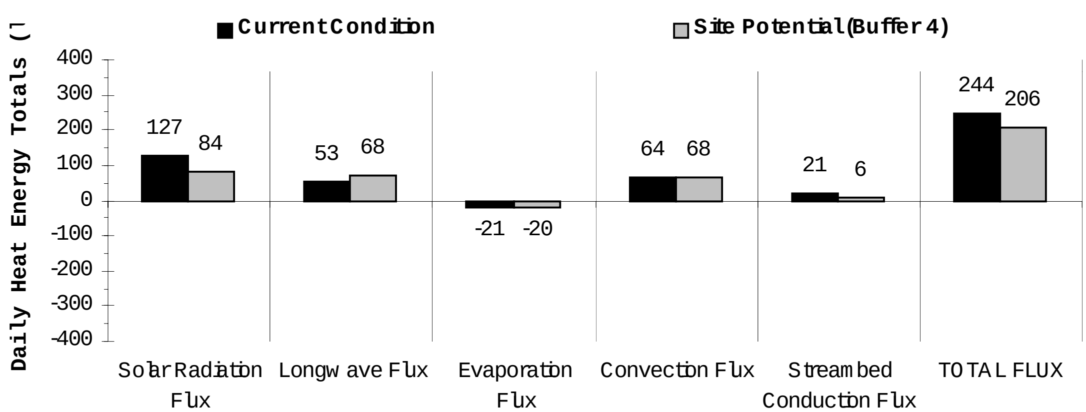


Figure D-16. Upper Kilchis River Daily Heat Energy Totals (*August 12, 1998*)



Simulation Reach #2 – Middle Kilchis River

Note: This is a long reach (5.7 miles). Also, the Little South Fork Kilchis River is not accounted for.

Kilchis River at Mapes Creek (looking downstream)

Input Parameters

Run Name	Kilchis 2 - Middle	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.58	*(deg N)*
Longitude	-123.79	*(deg W)*
Stream Aspect	188	*(deg)*
Percent Bedrock	50%	
Reach Length	9173	*(meters)*
Channel Width	13.415	*(meters)*
Flow Volume	0.85	*(cms)*
Flow Velocity	0.168	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(*C)*
Ave. Stream Depth	0.38	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	9.15	*(meters)*
Buffer Width	7.62	*(meters)*
Buffer Density	50%	
Distance to Stream	11.28	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	20%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	0.91	*(meters)*
Shade Angle	28.2	*(deg)*
View to Sky	69%	
Effective Shade	16%	
Elevation	250	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure D-17. Middle Kilchis River Temperature Profiles (*August 12, 1998*)

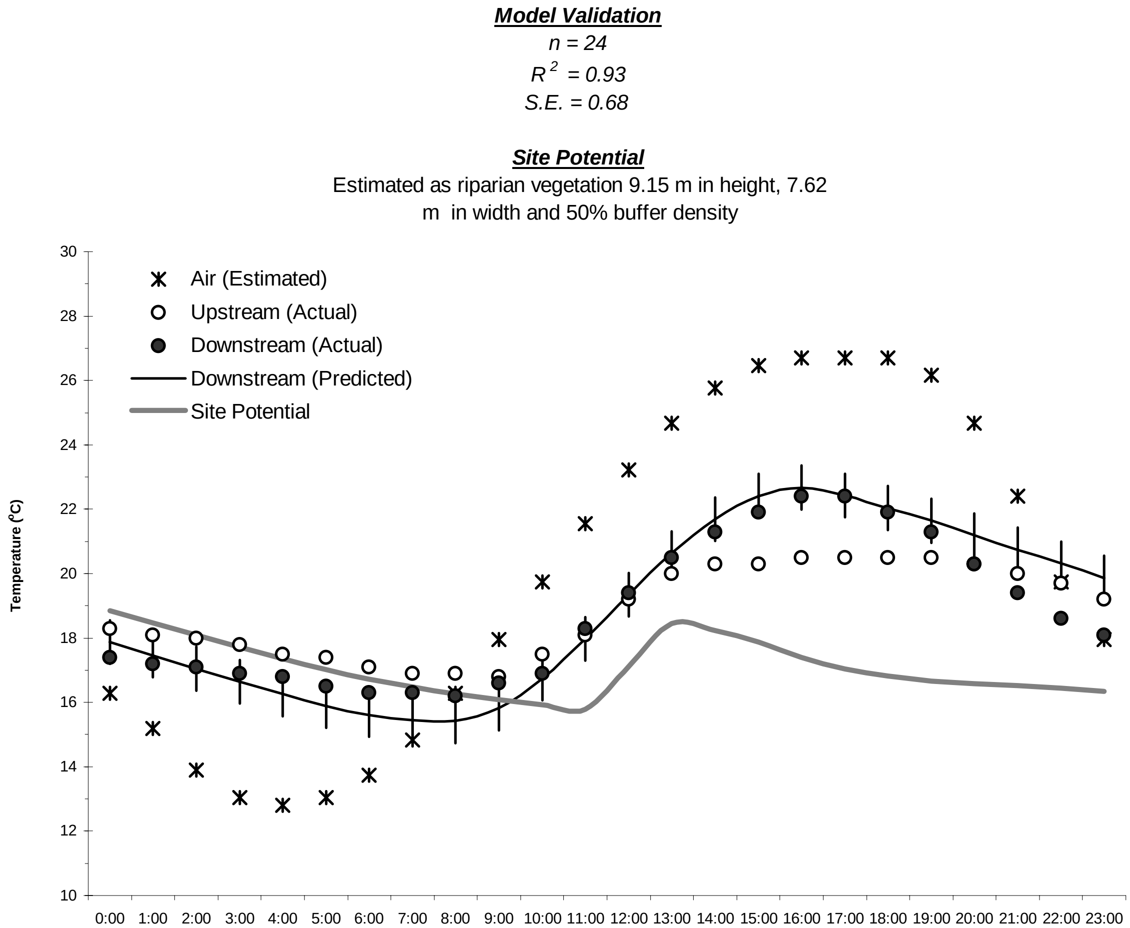
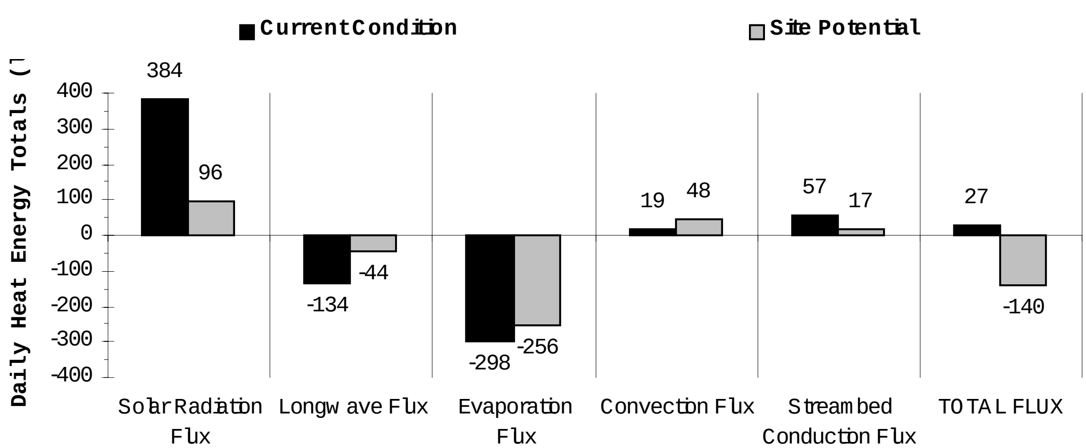


Figure D-18. Middle Kilchis River Daily Heat Energy Totals (*August 12, 1998*)



Simulation Reach #3 – Lower Kilchis River

Kilchis River at Curl Bridge (looking upstream)

Input Parameters

Run Name	Kilchis 3 - Lower	
Date	August 12, 1998	
Julian Day	223	
Latitude	45.58	*(deg N)*
Longitude	-123.79	*(deg W)*
Stream Aspect	210	*(deg)*
Percent Bedrock	100%	
Reach Length	1127	*(meters)*
Channel Width	12.7	*(meters)*
Flow Volume	0.864	*(cms)*
Flow Velocity	0.06	*(m/s)*
Groundwater Inflow	0.00	*(cms)*
Groundwater Temp.	10.00	*(*C)*
Ave. Stream Depth	1.13	*(meters)*
Dispersion	0.00	*(m2/s)*
Buffer Height	7.62	*(meters)*
Buffer Width	4.57	*(meters)*
Buffer Density	25%	
Distance to Stream	10.67	*(meters)*
Bank Slope	0.10	*(rise/run)*
% Tree Overhang	25%	
Topographic (West)	0.0	*(deg)*
Topographic (East)	0.0	*(deg)*
Overhanging Distance	0.48	*(meters)*
Shade Angle	24.7	*(deg)*
View to Sky	73%	
Effective Shade	12%	
Elevation	200	*(meters)*
Wind Speed	0.00	*(m/s)*

Figure D-19. Lower Kilchis River Temperature Profiles (*August 12, 1998*)

Model Validation

n = 24

R^2 = 0.89

S.E. = 0.79

Site Potential

Estimated as riparian vegetation 7.62 m in height, 4.57 m in width and 25% buffer density

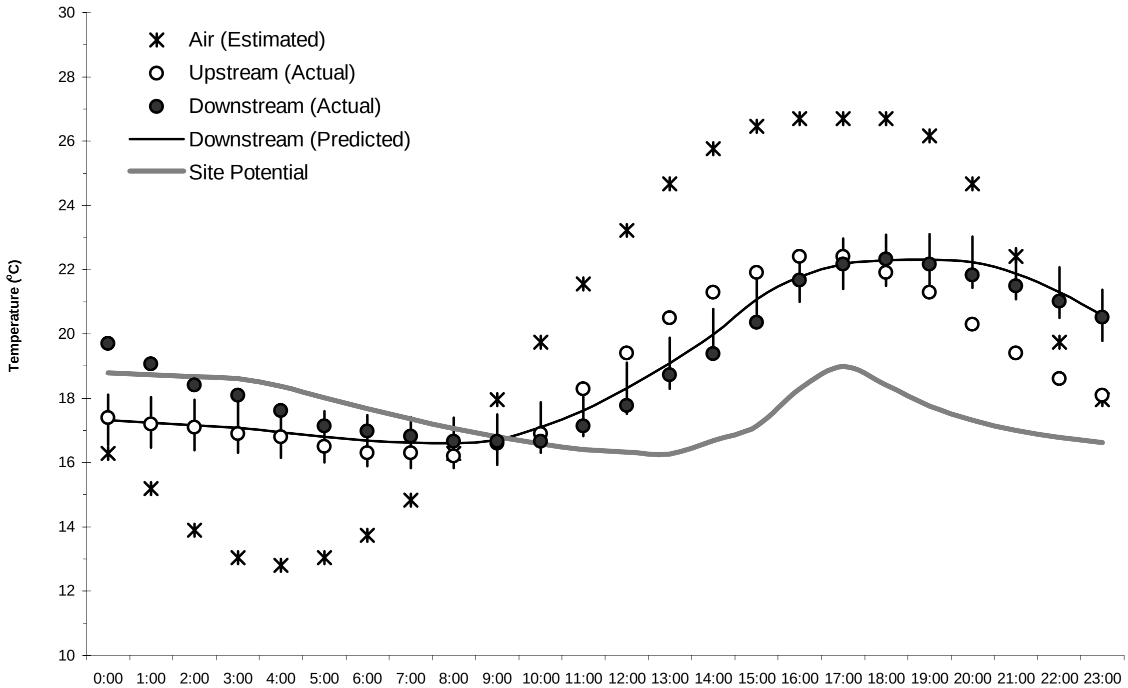
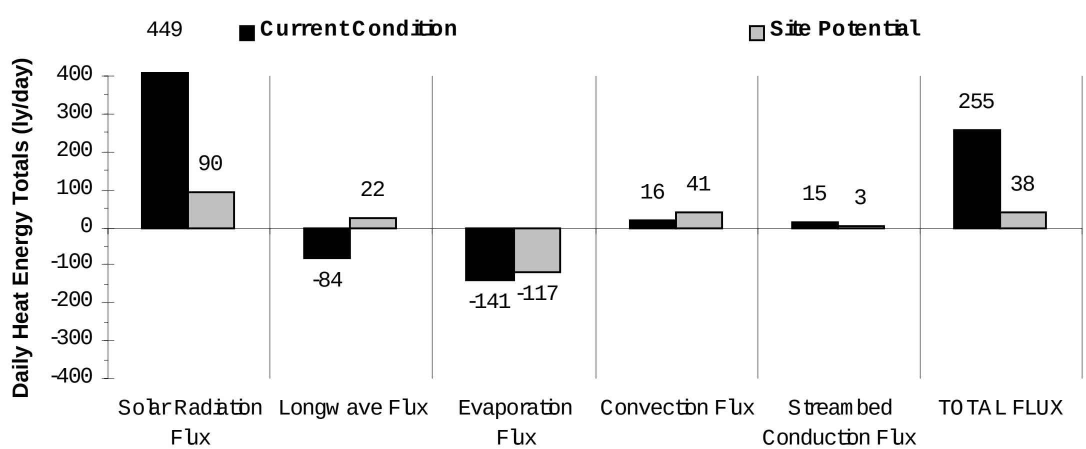


Figure D-20. Lower Kilchis River Daily Heat Energy Totals (*August 12, 1998)*



APPENDIX E

TEMPERATURE WASTELOAD ALLOCATIONS

>>To be completed by Northwest Region<<

APPENDIX F

PROPOSED MONITORING PLAN

>>To be completed by Northwest Region<<

APPENDIX G

WATER QUALITY MANAGEMENT PLAN

>>To be completed by Northwest Region<<