Upper Chehalis River Basin Temperature Total Maximum Daily Load

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Washington State Department of Ecology
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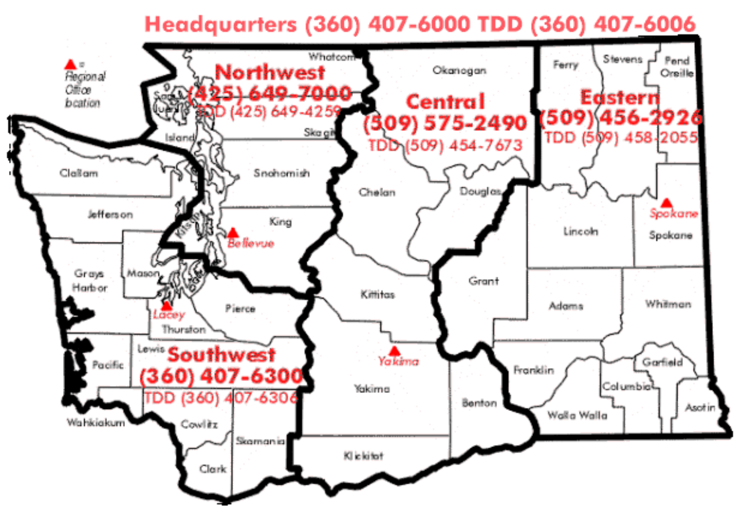

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Introduction

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

Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses, such as cold-water biota and drinking water supply, and criteria (both numeric and narrative), to achieve those uses. When a lake, river or stream fails to meet water quality standards after application of required technology-based controls, the Clean Water Act requires the state to place the water body on a list of "impaired" water bodies and prepare a TMDL.

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

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

The Upper Chehalis River Basin TMDL, developed by the Washington State Department of Ecology, is being established for surface water temperature standard exceedences that are caused almost entirely by solar radiation. Temperature is a measure of heat, which is considered a pollutant under Section 502(6) of the Clean Water Act. Heat generated by the amount of solar radiation from sunlight reaching the stream provides energy to raise water temperatures. Contributions of heat from municipal and industrial point sources in the Upper Chehalis River are small, but they have been addressed in this TMDL through wasteload allocations. This TMDL is designed to address impairments due to surface water temperature increases on nine water quality-limited streams (representing 19 segments) located in the watershed and provide goals for protection of all remaining streams. Streamside shade is used as a surrogate measure for water temperature. Use of surrogate measures is allowed by federal regulations (40 CFR 130.3) and the July 1998 Report to the Federal Advisory Committee on the TMDL Program (EPA-100-R-98-006). A decrease in shade increases incoming solar radiation and the resultant heat transfer to the stream. A more complete description of the factors influencing stream system temperatures appears in Appendix E.

The five elements of a TMDL as required by federal statute and regulation are summarized below:

Loading Capacity: The loading capacity for solar radiation is expressed as the shade levels needed in the riparian corridor (as percent stream shade) to reduce the radiation load sufficiently to meet state water quality standards for temperature. These determinations were conducted with the aid of computer models, which are described later in this document. Shade levels were determined by adjusting the vegetative shade values in the model such that the temperature standard was just met for each listed segment. The resulting loading capacities for streams in the Chehalis River Basin TMDL are presented in units of percent vegetative shade (Table 10).

For three streams (South Fork Chehalis River, Newaukum River, Black River), the amount of achievable shade alone is predicted to be insufficient to meet temperature standards. These stream sections are relatively wide and shallow with slow river flow velocity. These circumstances make them especially vulnerable to heating from direct sunlight. For these streams, targets for reduced width-to-depth ratio(s) that will mitigate these conditions are established in this TMDL in addition to the shade allocations to meet temperature standards. It is reasonable to assume that re-establishing riparian vegetation for shading will also restore functions such as stream bank stabilization, reduce sediment delivery, and improve groundwater recharge of the river. Although there is considerable documentation of the benefits to water quality associated with healthy riparian functions, there is insufficient information to predict how long it will take to achieve these targets. Therefore, monitoring will be necessary to determine if the width-to-depth targets of this TMDL are accomplished by managing the processes that affect stream channels.

Load Allocations: Load allocations of riparian shade are established for 13 stream reaches. In addition to the defined numeric load allocations for shade, there are several assumptions used in the modeling that must be met in the streams if temperature standards are to be achieved. These assumptions are a critical part of the load allocation, since changing them would affect the load allocation and likely result in temperature standards not being met. The most important of these assumptions is that: 1) flow will not be further reduced during critical periods by direct withdrawal or pumping from aquifers adjacent to the river; and 2) stream channel morphology will be improved by managing sediment delivery to the stream.

Wasteload Allocation: The wasteload allocations for point source discharges in the TMDL area have been set at zero. Accordingly, the strategy is to permit each point source discharge so that it meets the temperature criteria for the river and not allow a cumulative increase of more than 0.3°C above criteria at the downstream edge of authorized mixing zones for all point sources.

Margin of Safety: The analysis provides the required margin of safety by using several conservative assumptions in the modeling, including extreme summer conditions, setting topographic shade to zero for most reaches, using the lowest basin latitude for all reaches, and applying the ten-year, seven-day low flow.

Seasonal Variation: A review of monitoring data collected in the Upper Chehalis River Basin shows that most temperature measurements that exceed the criteria occur in June and July. Since it is not possible to change allocations of shade over a season, allocations were set based on this critical summer period.

Background

The Upper Chehalis River Basin covers 1,293 square miles, extending from the Black Hills south of Olympia to the Willapa Hills (Figure 1). This large watershed is identified in state rule as Water Resource Inventory Area 23. The basin area covers five counties: Lewis (60%), Thurston (24%), Grays Harbor (11%), Pacific (4%), and Cowlitz (1%). The Chehalis Tribal Reservation is on the northwestern area of the basin along the mainstem Chehalis River. The river passes through the two biggest cities in the basin, Centralia with a population of over 12,000 and Chehalis with a population of about 6,500.

Land use in the basin is predominated by forested areas (83%), followed by agricultural lands (14%), and urban areas (2%). Average annual precipitation is 57 inches, and ranges from 30 inches near the city of Chehalis to 120 inches near the headwaters of the Chehalis River in the Willapa Hills.

Major tributaries of the Upper Chehalis River are the South Fork Chehalis River, the Newaukum River, the Skookumchuck River, and the Black River. Numerous creeks feed the mainstem, of which the largest are Elk, Bunker, Stearns, Dillenbaugh, Salzer, Rock, and Cedar Creeks. The headwaters of the mainstem and South Fork Chehalis rivers lie in the eastern Willapa Hills: the headwaters of the Newaukum and Skookumchuck Rivers flow from the Bald Hills, a western spur of the Cascade mountain range; and the Black River and Cedar Creek draining from the Black Hills (Figure 1).

A temperature TMDL for the Upper Chehalis River Basin was submitted to EPA for approval in January 1996. EPA determined that the TMDL was incomplete because cumulative effects were not assessed. As part of the TMDL lawsuit settlement agreement, Ecology agreed to revise and resubmit the TMDL. To address cumulative effects, the TMDL was revised based on a stream network temperature model (SNTEMP), which assesses the cumulative effects of several factors, since the accumulated heat is routed through the major streams of the watershed (Theuer et al. 1984). Additional revisions to the TMDL more accurately characterize the heat inputs from the point sources. Because reasonable potential exists for heat impacts from the point sources, this TMDL requires that point sources not increase the temperature of the river.

As in previous versions, this submittal report also assigns shade targets to help lower temperatures in the non-point source areas of the watershed.

Heat generated by sunlight reaching the stream provides energy to raise water temperatures. Riparian vegetation reduces stream temperature by blocking the sunlight from reaching the stream. Human-caused activities that contribute to degraded riparian vegetation conditions in the Upper Chehalis River Basin area include agricultural activities, residential and urban development, and silvicultural activities. Two other factors that influence the distribution of heat are assessed: in-stream flows and channel morphology. Low flows may contribute to high temperatures by reducing the volume of water that can absorb incoming heat. Channel morphology may also influence heat distribution. With increased sediment loads, stream channels may become wider and shallower, allowing more thermal radiation to be absorbed by the water surface.

Applicable Criteria

Within the state of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt rules, regulations, and standards as are necessary to protect the environment is vested with the Department of Ecology. Under the federal Clean Water Act, the EPA Regional Administrator must approve the water quality standards adopted by the state (Section 303(c)(3)). Through adoption of these water quality standards, Washington has designated certain characteristic uses to be protected and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201A]. These standards were last adopted in November 1997.

Listed streams in the Upper Chehalis River Basin are designated as Class A with a temperature criterion of 18°C. Temperature in a Class A waterbody shall not exceed 18°C due to human influences.

This TMDL is designed to address impairments of characteristic uses for this Class A waterbody caused by high temperatures. The characteristic uses designated for protection in a Class A waterbody such as the Upper Chehalis River Basin streams are:

> *(i) Water supply (domestic, industrial, agricultural).*
> *(ii) Stock watering.*
> *(iii) Fish and shellfish:*
> *Salmonid migration, rearing, spawning, and harvesting.*
> *Other fish migration, rearing, spawning, and harvesting.*
> *Clam and mussel rearing, spawning, and harvesting.*
> *Crayfish rearing, spawning, and harvesting.*
> *(iv) Wildlife habitat.*
> *(v) Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).*
> *(vi) Commerce and navigation.* [WAC 173-201A-030(2)]

The water quality standards establish criteria for temperature to protect these characteristic uses. The intent behind the water quality standards is that human alterations of the watershed, or direct discharges to the waterbody, shall not cause the established criterion for any parameter to be exceeded. This study finds that the Upper Chehalis River Basin has been so altered by human activity (forest clearing for agriculture, timber harvest and development, clearing and degradation of riparian zones, withdrawal of water that has changes flow regimes, and changes in channel shape) that, combined with what may be natural conditions in the system, the current temperature criterion of 18°C for this Class A waterbody is not being met at many locations. Under these conditions the temperature criterion in the water quality standards requires that for Class A waters:

> *"Temperature shall not exceed 18.0°C (freshwater)…due to human activities. When natural conditions exceed 18° C (freshwater)…no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3° C."*

"Incremental temperature increases resulting from point source activities shall not, at any time, exceed t=28/(T+7) (freshwater)…Incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8°C.

For purposes hereof, "t" represents the maximum permissible temperature increase measured at a mixing zone boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge."

[WAC 173-201A-030(2)(c)(iv)]

Due to the uncertainty of the relationship between "natural conditions" and human-caused degradation during the critical period, the goal of this TMDL is to meet the temperature criterion in the river. Accordingly, during the critical period where the river is impaired, point sources will be held to the more restrictive temperature limits established for situations where natural conditions cause the exceedence. During non-critical periods, point sources will be permitted using the temperature formula.

Water Quality and Resource Impairments

As a result of measurements that show temperature criteria are exceeded, nine streams (representing 19 segments) are included on the Washington 1998 Section 303(d) list (Table 1).

Table 1. Upper Chehalis River Basin 1998 Section 303(d) Listed Segments

Stream Name	Segment Location (Township-Range Section)
Black River	15N-04W-05
Chehalis River (mainstem)	13N-05W-12, 14N-02W-07, 14N-02W-18, 14N-02W-24, 14N-03W-12, 14N-03W-24, 14N-03W-25, 15N-03W-22, 16N-05W-36, 17N-05W-28
Chehalis River, South Fork	13N-04W-24
Dillenbaugh Creek	13N-02W-05, 14N-02W-31
Lincoln Creek	15N-03W-29
Newaukum River	14N-02W-31
Salzer Creek	14N-02W-19
Scatter Creek	15N-03W-08
Skookumchuck River	14N-02W-07

Temperature data collected in the Upper Chehalis River Basin show a definite pattern of seasonal variation. Data collected by Ecology's Ambient Monitoring Program at ten stations between October 1991 and September 1998 were compiled and descriptive statistics generated (Table 2). Most of the year, temperature criteria are met. The critical period for temperature in the Upper Chehalis River Basin is during the months of June and July.

Table 2. Temperature Statistics of the Upper Chehalis River Basin

Month	Number of Samples	Mean Temperature (°C)	Median Temperature (°C)	Maximum Temperature (°C)	Samples over the Criteria (%)
January	29	5.1	4.9	9.1	0%
February	29	5.1	5.0	9.7	0%
March	29	8.3	8.2	11.3	0%
April	29	10.0	10.0	12.8	0%
May	29	14.1	14.5	18.1	<0.1%
June	29	16.3	16.2	24.5	17%
July	29	18.9	18.5	22.2	62%
August	29	16.9	17.0	19.8	24%
September	29	13.6	13.6	18.4	<0.1%
October	29	9.4	9.4	13.1	0%
November	29	7.2	7.4	10.1	0%
December	29	5.4	4.9	10.5	0%

The Upper Chehalis River Basin TMDL establishes targets for shade as a surrogate measure designed to meet water quality standards for temperature. Few data are readily available on the existing shade conditions in the basin. The most quantitative data on shade have been collected as part of watershed analyses (WAC 222-22) conducted on four sub basins: Upper and Lower Skookumchuck, Stillman Creek, and the Chehalis River headwaters. In addition, qualitative information on removal of riparian vegetation was collected as part of a basin-wide U.S. Fish and Wildlife Service study (Wampler, et al 1993). This study found over 30 percent of riparian vegetation has been lost or reduced (Table 3).

Table 3. Conditions of Riparian Vegetation Estimated for the Upper Chehalis River Basin

Watershed	Stream Miles Surveyed	Observed Riparian Degradation			
		Vegetation Loss		Reduced Tree Canopy	
		Miles	Percent	Miles	Percent
Upper Chehalis River (Mainstem)	28	10.4	37%	6.7	24%
Gibson Creek	38	2.5	7%	2.2	6%
Rock Creek	53	6.4	12%	12.2	23%
Black River	88	26.1	30%	24.6	28%
Lincoln Creek	63	5.2	8%	24.6	39%
Scatter Creek	31	18.7	60%	16.3	53%
Skookumchuck River	110	70.2	64%	39.6	36%
China Creek	37	34.2	93%	23.0	62%
Newaukum River	125	28.3	23%	50.4	40%
Stearns Creek	20	1.2	6.1%	18.0	90%
Scammon Creek	47	6.2	13%	29.2	62%
Chehalis River, South Fork	113	35.8	32%	47.9	42%
Elk Creek	43	11.6	27%	5.5	13%
Rock Creek	42	6.3	15%	13.6	32%
Overall Total	**838**	**263.1**	**31%**	**313.8**	**37%**

The Upper Chehalis River Basin temperature TMDL addresses some fisheries concerns resulting from water temperature increases. Excessive summer water temperatures have reduced the quality of spawning and rearing habitat for salmonid fish in several Upper Chehalis River Basin streams. High temperatures harm salmonid fish.

The streams of the basin support substantial runs of anadromous fish and support commercial, sport, and tribal fisheries. An assessment by the state and tribes in 1992 showed all species of salmonid stock (Chinook, Chum, Coho, and Steelhead) in the basin to be healthy (SASSI, 1993). However, since that assessment, the U.S. Fish and Wildlife Service has listed the Bull Trout as a "threatened" species, and the National Marine Fisheries Service has identified the Coho salmon as a candidate for listing under the federal Endangered Species Act (ESA). The original Chehalis River TMDL for dissolved oxygen was initiated in part due to a major fish kill that occurred on the Black River in 1989. (Pickett, 1997).

Modeling Approach

SNTEMP and SSSHADE are the models used to assess the effects of solar radiation, channel morphology, and in-stream flow on temperature in stream reaches of the Upper Chehalis River watershed. SNTEMP, a stream temperature network model written by Theurer et al. (1984), is currently supported by the U.S. Geological Survey. It is a mechanistic, one-dimensional, heat transport model that analyzes temperature conditions for a network of streams in steady state. The model was developed to help predict the consequences of manipulation of various factors influencing stream temperatures. SSSHADE is a stream-shading model that is used to provide input variables to the SNTEMP model. SSSHADE estimates stream shading from various riparian characteristics.

SNTEMP and SSSHADE require input data for 28 parameters and variables ranging from channel conditions to climate. Many of these were kept constant for all model runs. Several others were varied to assess the impact of various factors. The following is a list of the model input parameters used.

Stream Network Geometry: The stream network was divided into numerous reaches based on location of significant tributaries and hydraulic characteristics. Tributary streams that are on the 1998 Section 303(d) list for temperature were modeled as branches to the network. Other significant tributaries were treated as point source inflows. The mainstem Chehalis River was divided into four separate hydraulic reaches based on staff best professional judgment (Pickett, 1999). A schematic of the modeled stream network is shown in Figure 2.

Reach Lengths: Derived from the Washington Department of Fisheries River Mile Index (WDF, 1975).

Latitude: Used 0.81158 radians (46.5°) for all reaches representing the lowest latitude of the study area. The most extreme value was selected as one element of the inherent margin of safety.

Elevation: Determined for each network stream node from the 7.5-minute GIS coverage derived from USGS and Forest Service digital elevation models.

Manning's n: Initially estimated for each reach in the range of 0.035 to 0.060 using channel and flow characteristics. Using knowledge of the stream characteristics, this parameter was adjusted within accepted ranges during model calibration, to approximate measured temperatures in the modeled reaches.

Width Coefficient and Exponent: These figures were derived from width and in-stream flow data collected by Pickett (1994a&b). For each hydraulic reach of the mainstem Chehalis River, measured wetted width and flow data from a representative reach not impacted by bridge crossings were regressed into a power function. Likewise, data from the tributaries (excluding the Black River) were pooled to derive these parameters. The Black River parameters were figured separately from the other modeled tributaries to the mainstem Chehalis River.

Stream Shading: Information was determined from the output results of the SSSHADE model. For each modeled stream reach, the type of vegetation was determined by intersection of the stream hydrology GIS coverage with the Washington Department of Natural Resources GIS coverage depicting canopy in 1991 derived from Landsat/TM satellite imagery. This intersection of GIS coverages resulted in a linear coverage estimating the adjacent canopy type for each stream reach. The percentage of each canopy type was determined for each reach. The SSSHADE model was run with applicable parameters for each reach and canopy type. The overall shade for the overall reach was determined by proportion of canopy type and the modeled shade results for each. The parameters and assumptions used in SSSHADE are described further below, and the results are shown in the Appendix (Table A1).

Ground Temperature: 9.9°C was used. That was the mean annual air temperature from 1948 to 1998 measured at Olympia Airport, just north of the watershed.

Streambed Thermal Gradient: 1.65 joules/m^2/sec/C was used. The model documentation recommended using that as the default value, in lieu of a measured value.

Time Period: For model calibration and validation, the conditions for the month of August were modeled. The SNTEMP model was run steady state for a 30-day averaging period (Julian days 213 to 243) to bound the watershed time of travel of 20 days determined by Pickett (1994a). The SSSHADE model was run for August 15, representing the sun angle during the middle of the month.

Dust Coefficient: The value of 0.06 was used as the summer mean measured in a similar geographic region (TVA, 1972).

Ground Reflectivity: The value of 0.29 was measured from late summer vegetation with leaves low in water content (TVA, 1972).

Meteorology Station Latitude: 0.81978 radians represents the location of Olympia Airport.

Meteorology Station Elevation: 58 meters represents the location of Olympia Airport.

Mean Annual Air Temperature: 9.9°C was based on the average of daily maximum and minimum air temperatures collected from Olympia Airport between 1948 and 1993.

Mean Air Temperature for Calibration & Validation: 18.5°C and 18.2°C were derived from measured values at Olympia Airport from August 1991 and 1992, respectively.

Mean Wind Speed for Calibration & Validation: 2.6 meters/second and 2.7 metes/second were derived from measured values at Olympia Airport from August 1991 and 1992, respectively.

Mean Relative Humidity for Calibration & Validation: 72 percent and 67percent were derived from measured values at Olympia Airport from August 1991 and 1992, respectively.

Percent Sunshine for Calibration & Validation: 100% assumed a cloudless day. The most extreme value was selected as one element of the inherent margin of safety.

Lateral Inflow Temperature: For many of the reaches, the mean annual air temperature measured at Olympia Airport between 1948 and 1993 (explained above) was used. This value is commonly used to approximate the temperature of the groundwater (Theuer et al. 1984).

However, many of the modeled reaches may have a considerable percentage of surface water entering as lateral inflow through small ditches and streams. These lateral surface water inflows probably have a higher temperature than ground water. In contrast, groundwater in the headwater streams at higher elevations is likely to be cooler than the temperature measured at Olympia Airport. This parameter was adjusted in the calibration of the model to approximate measured temperatures in the modeled reaches.

In-stream Flow for Calibration & Validation: For most reaches, modeled flows from Tables C3 and G1 in Pickett (1994a) were used. However, data from the USGS on August 27 was used for the headwaters at Skookumchuck River Mile 6.5 since this location was not modeled by Pickett (1994a). Also, data from Pickett (1994b) was used for the Black River.

In-stream Temperature for Calibration & Validation: For most river reaches, measured temperatures from Tables D1 and F1 in Pickett (1994a) were used. Also, data from Pickett (1994b) was used for the Black River. Since temperatures of the three wastewater treatment plant discharges were not measured, the maximum river temperature measured at the surface near the point of each discharge was used as the effluent temperature. Temperature values for the mainstem Chehalis River model nodes were compared to the first downstream station measured. Since the model is only one-dimensional, only surface temperatures were used where profile data were collected as one element of the inherent margin of safety. Due to a larger set of data available, the highest temperature measured in August was used for comparison to the 30-day steady state model runs. Values used for comparison to calibration and validation model runs are shown in the Appendix (Table A2).

Azimuth: For each modeled stream reach, the degrees representing the general bearing between the headwaters and the mouth (or beginning and end of the reach) were used.

Stream Width: For each modeled reach, the median stream wetted width was taken from measurements collected by Pickett (1994a&b). These measured values were used for the modeled mainstem Chehalis River reaches. However, the widths of the tributaries were generally measured at the widest location on the stream, since they were collected near the mouth. These streams typically range from the widest part measured near the mouth to decreasingly smaller widths progressing upstream to near zero at the headwaters. To account for the range in width on modeled headwater reaches, a value of one-half the width at the mouth was used in the SSSHADE model to approximate the width of the entire reach.

Topography: The topographic contribution to stream shade was assumed to be zero for most reaches. Only the two uppermost stream reaches of the mainstem Chehalis River in the Willapa Hills were assumed to have 40 percent topographic shade. Using the most extreme value of zero, topographic shade for the remaining streams serve as another element of the inherent margin of safety.

Vegetation Height: This was estimated from the Washington Department of Natural Resources GIS tree canopy coverage along each stream reach. Even though there are a number of tree species in the basin (e.g. Douglas Fir and Bigleaf Maple), the conifer species modeled were assumed to be Western Hemlock, since climax stands in this region would be dominated by this species (Cassidy, 1997). Early seral stage was assumed to be 50 years and mid-seral stage at 100 years. Hardwoods were assumed to be early seral stage Red Alder at 10 years, since this is the primary species for succession that starts after disturbance in mesic areas such as stream riparian corridors (Cassidy, 1997). Tree heights were derived from regional growth curves assuming a site index of 100 (Henderson, et al. 1989). Non-forested areas were assumed to be an even mix of early seral stage hardwoods, with treeless stream banks mostly supporting understory species, shrub fields, or meadows.

Vegetation Crown: This measurement was derived for a particular tree species from the ratio of the measured crown to the measured height of mature trees (B.C. Conservation Data Centre, 1999)

Vegetation Offset: Assuming typical streams will have a channel migration zone greater than the wetted perimeter, a 10-foot offset was used for all riparian vegetation when modeling shade levels.

Vegetation Density: An 85 percent density was assumed to represent a fir stand with good quality of shade from existing riparian vegetation.

Model Calibration and Validation

The model was calibrated to allow it to represent more closely the particular sensitivities of the stream network. Manning's n and lateral inflow temperature were adjusted within reasonable levels so that predicted temperature more closely matched measured temperature. The period representing August 1991 was used for calibration. The model performance was validated using an independent data set of variables with the same values. Data from a different period are commonly used to assess calibration. The period representing August 1992 was used for validation. The framework schematic, main parameters, and variables used in the model geometry are shown in Figure 2 on page 52 and Table 4 below.

Table 4. Upper Chehalis River Network Stream Temperature Model Geometry Parameters

Stream Reach Name	Elevation (m)	Azimuth (Degrees bearing)	Manning n	Width (m)	Width Coefficient	Width Exponent
Chehalis RM 123.0	483	5	0.040	26.8	27.01	0.14
Chehalis RM 100.2	85	80	0.040	22.6	22.06	0.14
Chehalis RM 88.3	59	80	0.040	22.6	22.06	0.14
Chehalis RM 75.4	49	0	0.060	23.6	19.75	0.18
Chehalis RM 74.7	48	0	0.060	23.6	19.75	0.18
Chehalis RM 69.4	47	0	0.060	23.6	19.75	0.18
Chehalis RM 67.0	46	-50	0.060	39.6	23.78	0.20
Chehalis RM 61.9	36	-50	0.060	39.6	23.78	0.20
Chehalis RM 88.8	34	-50	0.060	39.6	23.78	0.20
Chehalis RM 75.6	18	-50	0.060	39.6	23.78	0.20
South Fork Chehalis	291	0	0.040	6.3	10.67	0.21
Newaukum River	908	-70	0.060	4.4	10.67	0.21
Dillenbaugh Creek	162	-70	0.060	1.4	10.67	0.21
Salzer Creek	166	-90	0.080	1.7	10.67	0.21
Skookumchuck River	65	70	0.020	6.5	10.67	0.21
Lincoln Creek	180	90	0.080	3.1	10.67	0.21
Scatter Creek	101	85	0.025	3.5	10.67	0.21
Black River	27	55	0.060	13.1	10.67	0.21

Four statistical tests were applied to the results of the model calibration and validation. The root mean square error, median absolute deviation, scaled residuals, and relative error are the best statistical measures commonly used to test model performance (Reckhow, et al. 1986). The root mean square error presents an estimate of the variation in the same units as the measurement (e.g. °C). The relative error presents this variation as a percentage of the measurement mean. The median absolute deviation describes the central tendency of model performance. The median scaled residual provides a relative estimate, whether the model is over- or under-predicting measured conditions. These statistics were compiled for the combined data set of ten mainstem Chehalis River stations and eight tributary stations near the mouths of the streams (Table 5).

Table 5. Performance of the Upper Chehalis River Network Stream Temperature Model in Predicting Maximum Daily Temperature

Location	Calibration – August 1991			Validation - August 1992		
	Measured (°C)	Predicted (°C)	Delta (°C)	Measured (°C)	Predicted (°C)	Delta (°C)
Chehalis River Mile 106.3	15.3	16.0	0.7	18.1	15.6	-2.5
Chehalis River Mile 88.3	18.1	20.1	2.0	18.1	19.7	1.6
Chehalis River Mile 75.4	23.4	22.7	-0.7	23.4	22.2	-1.2
Chehalis River Mile 74.7	23.0	22.1	-0.9	21.7	21.8	0.1
Chehalis River Mile 69.4	19.2	22.1	2.9	20.1	21.3	1.2
Chehalis River Mile 67.0	21.7	21.7	0.0	22.6	20.9	-1.7
Chehalis River Mile 61.9	22.6	22.8	0.2	22.9	22.5	-0.4
Chehalis River Mile 55.2	21.3	20.9	-0.4	20.8	21.6	0.8
Chehalis River Mile 47.0	22.1	21.9	-0.2	19.5	21.9	2.4
Chehalis River Mile 33.8	19.8	21.7	1.9	21.2	21.6	0.4
South Fork Chehalis Mouth	21.2	21.1	-0.1	20.0	20.1	0.1
Newaukum River Mouth	17.7	20.9	3.2	20.5	20.5	0.0
Dillenbaugh Creek Mouth	18.8	21.0	2.2	18.6	20.4	1.8
Salzer Creek Mouth	19.2	19.3	0.1	18.2	20.1	1.9
Skookumchuck River Mouth	20.4	18.7	-1.7	18.7	18.9	0.2
Lincoln Creek Mouth	19.0	21.8	2.8	16.2	21.4	5.2
Scatter Creek Mouth	20.9	20.7	-0.2	21.1	20.2	-0.9
Black River Mouth	21.0	20.1	-0.9	18.7	20.5	1.8
Statistics						
Median Absolute Deviation	1.4°C			1.5°C		
Median Scaled Residual	0.5%			1.6%		
Root Mean Square Error	3.2°C			3.2°C		
Relative Error	16%			16%		

The results of these statistical tests show little difference in model performance between the model calibration and validation runs. The median absolute deviations for both time periods are similar at 1.4°C and 1.5°C. The median scaled residuals show a low percentage, with the calibration run slightly under-predicting and the validation run slightly over-predicting measured stream temperatures overall. Also, the model root mean square error for predicting daily maximum stream temperature for both time periods is 3.2°C, which provides a relative error of 16 percent These error measures are reasonable, based on the difficulty of predicting maximum daily temperatures (Bartholow, 1989).

Reviewing model performance at specific sites provides some insight on important factors. Near the headwaters of the mainstem, the maximum temperature is over-predicted. This is likely due to the model not representing the effects of water moving from the surface into the ground water in this reach as it moves from bedrock into alluvium. The model also under-predicted maximum temperature in the pooled reach of the mainstem Chehalis River between the confluence of the Newaukum and Skookumchuck Rivers. This is likely due to modeling only surface temperatures in a thermally stratified water. Overall, the model performance is adequate to test the effect of different management strategies on the temperature of the stream network as a whole.

Model Application

Using the water quality model to determine the loading capacity and evaluate alternative management strategies requires defining the critical conditions when pollutant loading has the greatest impact on attaining water quality standards. For this analysis, three factors were used to define critical conditions: flow, climatic, and solar apex. For flow, critical conditions are defined in the state's water quality standards as the statistical seven-day low flow event that occurs every ten years (7Q10). For climate variables, the 90th percentile maximum air temperature measured at Olympia Airport in the summer (June-August) over the past 50 years was used (31.1°C). The other concurrent climatic variables (wind speed and relative humidity) were used from the latest date that this maximum temperature was measured (July 21, 1998). For solar apex, the day with the maximum daylight was used (June 21). All of these critical conditions occur during the same period that standards are not being met in the watershed (Table 2)

Two factors that influence stream temperatures were assessed with the SNTEMP model: in-stream flow and wetted width-to-depth ratios of tributary stream channels. Changes to in-stream flow can affect the heat-carrying capacity of the stream and influence the degree at which ground water affects temperature. Changes in width-to-depth ratio affect the amount of solar load that reaches the streambed. Excessive sediment loading can cause stream channels that are shallow and wide, increasing both solar radiation loading and stream temperature.

Another factor that can have a very significant influence on stream temperature is cooling caused by the interaction or exchange between surface and ground water. There is insufficient information to estimate with certainty this effect in the various reaches of the Chehalis watershed. It is assumed that changes to the hydraulic regime caused by logging, agriculture, and development have diminished the influence of this factor. As mentioned later in the TMDL, this analysis attributes some improvement to the influence of groundwater cooling of surface water as the result of restoring riparian functions and limiting additional surface and ground water withdrawals.

The Upper Chehalis River system has had base flows established at 14 locations, by state rule (Chapter 173-522 WAC) for the protection of in-stream uses (e.g. salmonid habitat). Recent assessments show that the Chehalis River is not meeting these flows between 33 to 77 days per year, depending on the location (Wildrick, et al. 1995). During the summer months water rights and claims exceed the natural stream flow in many instances.

The calibrated network model was used to determine the effect on stream temperatures if the in-stream flows set by rule were met. Critical conditions were used except for the added base flow established by rule. The in-stream flow rule for base flow on July 1 was used to correspond to the critical period with the highest stream temperatures (Table 2). Streams with no base flow rule were left at 7Q10 flows for the model simulation.

Modeling results predict that only one listed segment would meet the temperature criterion of 18°C, if the base flows from the rule were attained (Table 6). This result raises the question of whether the current water quality standard for temperature can be met during the critical conditions used in the model even *if* the watershed still existed in natural conditions. The current temperature criterion of 18°C is established as a not to exceed standard. However, it has been documented (Hatten, 1995) that the temperature standard is occasionally exceeded during severe conditions even in some Olympic watersheds that are essentially undisturbed by man. It is also known that the existing temperature criteria may not be adequately protective of all aquatic species during all of their life stages. Accordingly, Ecology is currently undertaking development of revised temperature standards that are both protective of aquatic life and takes into consideration time and duration of exposure to occasional water temperature increases.

A more thorough evaluation of 'natural conditions' requires consideration of all the geomorphic and biological functions existing in an undisturbed watershed that help mitigate effects of solar heat on stream temperature and aquatic life. Such an evaluation is not included in this TMDL. These functions include riparian cooling of ambient air temperature, reduced sediment loading and stream width-to-depth ratio, additional cooling from increased groundwater, and improved in-stream refugia for aquatic life. Restoring these functions mitigates the uncertainty of model predictions in achieving the current temperature standard during certain critical conditions.

The approach of this TMDL is to prescribe allocations that, if implemented, should restore temperatures close to those that existed prior to human influences on receiving waters. Thereafter, monitoring to assess both implementation and effectiveness of the allocations is critical for providing information that can be used to more accurately access natural conditions and modify the TMDL if necessary.

Table 6. Comparison of Temperature Criterion with Predicted Maximum Daily Temperature under In-stream Flow Rule Compliance.

Section 303(d) Listed Segment Name	Listed River Mile	Segment Township-Range-Section	Predicted Maximum Daily Temperature (°C)	Amount Above Criterion (°C)
Chehalis River	101.7	13N-05W-12	16.9	0
Chehalis River	74.6	14N-03W-24	21.1	3.1
Chehalis River	73.6	14N-03W-25	21.2	3.2
Chehalis River	70.7	14N-02W-24	21.6	3.6
Chehalis River	69.1	14N-02W-18	22.0	4.0
Chehalis River	67.5	14N-02W-07	22.3	4.3
Chehalis River	66.3	14N-03W-12	22.4	4.4
Chehalis River	59.9	15N-03W-22	22.2	4.2
Chehalis River	44.0	16N-05W-36	21.2	3.2
Chehalis River	33.8	17N-05W-28	19.5	1.5
South Fork Chehalis	0.5	13N-04W-24	19.3	1.3
Newaukum River	0.1	14N-02W-31	20.9	2.9
Dillenbaugh Creek	0.1	14N-02W-31	20.9	2.9
Dillenbaugh Creek	1.7	13N-02W-05	21.0	3.0
Salzer Creek	0.2	14N-02W-19	21.7	3.7
Skookumchuck River	0.1	14N-02W-07	19.6	1.6
Lincoln Creek	4.2	15N-03W-29	23.0	5.0
Scatter Creek	1.3	15N-03W-08	21.8	3.8
Black River	1.2	15N-04W-05	19.6	1.6

The calibrated network model was also used to determine the effect of channel morphology on stream temperatures. A width-to-depth ratio of ten or less is commonly used as describing good anadromous fish habitat (USDA, 1995). The Chézy-Manning formula (Lindsley, et al. 1982) was used with modeled parameters to determine the change in the headwater streams' wetted width and model width coefficient term that would be required to meet the target width-to-depth ratio of ten. The channel morphology of the other modeled reaches of the mainstem Chehalis River was not altered, since it is unlikely that management of sediment loads would affect the channel due to the existing hydro modification, such as extensive levies. Critical conditions were used for all other model parameters. Results show that only one of the listed segments would meet the temperature criterion of 18°C, if the width-to-depth ratio were ten in the modeled headwaters (Table 7).

Table 7. Comparison of Temperature Criterion with Predicted Maximum Daily Temperature with Width-to-Depth Ratios of 10 in Headwater Streams.

Section 303(d) Listed Segment Name	Listed River Mile	Segment Township-Range-Section	Predicted Maximum Daily Temperature (°C)	Amount Above Criterion (°C)
Chehalis River	101.7	13N-05W-12	17.2	0
Chehalis River	74.6	14N-03W-24	22.9	4.9
Chehalis River	73.6	14N-03W-25	23.1	5.1
Chehalis River	70.7	14N-02W-24	23.4	5.4
Chehalis River	69.1	14N-02W-18	23.9	5.9
Chehalis River	67.5	14N-02W-07	24.1	6.1
Chehalis River	66.3	14N-03W-12	23.8	5.8
Chehalis River	59.9	15N-03W-22	23.5	5.5
Chehalis River	44.0	16N-05W-36	23.6	5.6
Chehalis River	33.8	17N-05W-28	23.4	5.4
South Fork Chehalis	0.5	13N-04W-24	22.6	4.6
Newaukum River	0.1	14N-02W-31	23.1	5.1
Dillenbaugh Creek	0.1	14N-02W-31	20.9	2.9
Dillenbaugh Creek	1.7	13N-02W-05	21.0	3.0
Salzer Creek	0.2	14N-02W-19	21.7	3.7
Skookumchuck River	0.1	14N-02W-07	19.8	1.8
Lincoln Creek	4.2	15N-03W-29	23.0	5.0
Scatter Creek	1.3	15N-03W-08	21.8	3.8
Black River	1.2	15N-04W-05	22.4	4.4

The SNTEMP model is constructed by linking output results from the reach sub model SSTEMP. This model was undergone a rigorous sensitivity analysis to evaluate the parameters having the greatest effect on model results (Sullivan et al. 1990). Various input parameters were varied up to 100 percent of the standard value to assess the change of predicting maximum daily temperatures. Results of the analysis for medium-sized streams show that the climatic factors of air temperature and humidity had the greatest influence on relative model sensitivity (Table 8).

Table 8. Ranked Sensitivity of Model Parameters in Predicting Maximum Daily Temperature (from Sullivan et al. 1990)

Parameter	Change in Prediction of Maximum Daily Temperature (0°C)
Air Temperature	15.2
Humidity	7.6
Solar Radiation	5.2
Shade	-1.6
Wind Speed	-0.7
Stream Depth	0.7
Travel Time	-0.6
Groundwater	-0.3
Inflow Water Temperature	0.02

Loading Capacity Analysis

Identification of the loading capacity is an important step in developing TMDLs. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water into compliance with water quality standards. By definition, a TMDL is the sum of the allocations. An allocation is defined as the portion of a receiving water's loading capacity that is assigned to a particular source. EPA defines the loading capacity as "the greatest amount of loading that a water can receive without violating water quality standards."

In order to determine loading capacity, the stream network model was used to estimate the maximum temperature under critical flow and climate conditions, using the current estimated riparian shade levels and channel morphology. These estimates of these current conditions were then compared to the water quality criteria. This difference represents the temperature reduction necessary to achieve water quality standards. Only the listed segment in the Chehalis River headwater reach showed standards currently being met. All other listed segments are predicted to exceed water quality standards during critical conditions (Table 9).

Table 9. Comparison of Predicted Maximum Daily Temperature with Existing Shade under Critical Conditions to Water Quality

Section 303(d) Listed Segment Name	Listed River Mile	Segment Township-Range-Section	Predicted Maximum Daily Temperature (°C)	Water Quality Criteria (°C)	Necessary Temperature Reduction (°C)
Chehalis River	101.7	13N-05W-12	17.2	18.0	0
Chehalis River	74.6	14N-03W-24	22.9	18.0	4.9
Chehalis River	73.6	14N-03W-25	23.1	18.0	5.1
Chehalis River	70.7	14N-02W-24	23.4	18.0	5.4
Chehalis River	69.1	14N-02W-18	23.9	18.0	5.9
Chehalis River	67.5	14N-02W-07	24.1	18.0	6.1
Chehalis River	66.3	14N-03W-12	23.8	18.0	5.8
Chehalis River	59.9	15N-03W-22	23.5	18.0	5.5
Chehalis River	44.0	16N-05W-36	23.6	18.0	5.6
Chehalis River	33.8	17N-05W-28	23.4	18.0	5.4
South Fork Chehalis	0.5	13N-04W-24	22.6	18.0	4.6
Newaukum River	0.1	14N-02W-31	23.1	18.0	5.1
Dillenbaugh Creek	0.1	14N-02W-31	20.9	18.0	2.9
Dillenbaugh Creek	1.7	13N-02W-05	21.0	18.0	3.0
Salzer Creek	0.2	14N-02W-19	21.7	18.0	3.7
Skookumchuck River	0.1	14N-02W-07	19.8	18.0	1.8
Lincoln Creek	4.2	15N-03W-29	23.0	18.0	5.0
Scatter Creek	1.3	15N-03W-08	21.8	18.0	3.8
Black River	1.2	15N-04W-05	22.4	18.0	4.4

The Upper Chehalis River Basin TMDL utilizes a measure other than *"daily loads"* to fulfill requirements of Section 303(d). Although heat loads can be derived and allocated (e.g. joules per square meters per day), they are of limited value in guiding management activities needed to solve identified water quality problems. Instead, the Upper Chehalis River Basin TMDL is expressed in terms of vegetative shade as a surrogate for thermal load, as allowed under EPA regulations [defined as *"other appropriate measures"* in 40 CFR §130.2(i)]. A decrease in shade, as the result of a lack of adequate riparian vegetation, causes a subsequent increase in solar radiation and thermal load.

Since the loading capacity will be presented in units of shade, the next step is to determine the amount of shade required to meet the water quality criteria. The loading capacity determined is dependant on the parameters assumed in the model. Besides shade, stream morphology is another significant factor that is manageable to some degree. Therefore, the loading capacity depends on the type of stream morphology modeled.

The loading capacity for each of the modeled reaches was determined by adjusting the vegetative shade values in the model such that the temperature standard was just met at each listed segment. The SNTEMP model does not provide results on the actual solar radiation load, which would be of limited use for management anyway. The resulting loading capacities for streams in the Chehalis River Basin TMDL are presented in units of percent vegetative shade (Table 10).

Two separate loading capacities are derived for each of the modeled reaches: (1) required shade with the existing tributary channel form, and (2) required shade with stable tributary channel forms. Stable channel forms are defined as the mean width-to-depth ratio measured by Rosgen (1996) for each specific channel type. These loading capacities are compared to the estimated amount of vegetative shade that is achievable by allowing the existing riparian corridor to mature to a late seral stage (Table 10). The mature riparian shade is estimated using SSSHADE by modeling existing species at late seral stage without species replacement. Late seral stage for existing conifers was derived at an average site index of 100, in a Western Hemlock-dominated forest of 200 years, with a height of 125 feet. Late seral stage for existing hardwoods was derived at an average site index of 100, in a Red Alder-dominated forest of 60 years, with a height of 100 feet.

Table 10. Loading Capacities for Upper Chehalis River Basin Stream Reaches

Stream Reach	Percent Vegetative Shade		
	Existing Channel Morphology	Stable Channel Morphology	Achievable Late Seral Stage Shade
Chehalis River - Headwaters to Elk Creek	49%	20%	75%
Chehalis River - Elk Creek to Newaukum River	48%	48%	53%
Chehalis River - Newaukum River to Skookumchuck R.	64%	64%	64%
Chehalis River - Skookumchuck R. to Scatter Creek	43%	43%	47%
Chehalis River - Scatter Creek to the Town of Porter	44%	44%	47%
South Fork Chehalis	85%	74%	82%
Newaukum River	84%	78%	78%
Dillenbaugh Creek	85%	77%	85%
Salzer Creek	81%	80%	85%
Skookumchuck R.	79%	70%	81%
Lincoln Creek	78%	78%	84%
Scatter Creek	81%	80%	85%
Black River	79%	68%	75%

Comparison of the two estimated loading capacities indicates that achieving maximum shade from a late seral stage riparian corridor will not alone be quite sufficient to meet the temperature standard for three of the tributaries. The South Fork Chehalis River, the Newaukum River, and the Black River will likely also need to reduce the width-to-depth ratio to meet temperature standards. Therefore, the loading capacity for these streams assumes that managing the processes that affect them will form stable channels. It is acknowledged that reestablishing naturally functioning channel in these streams by addressing sediment delivery, river flow and riparian vegetation will take a long period of time. However, these loading capacities represent the most practical, time efficient approach to stream channel restoration.

The calibrated stream network model was also used to estimate maximum temperatures that might exist under the influence of natural conditions (i.e. critical conditions in a watershed not altered by human activities). Three factors were considered in the modeling approach to represent natural conditions: forest canopy cover, stream flow and channel shape.

- It was assumed that all the stream riparian corridors would have a late seral stage Western Hemlock forest stand of 200 years old (Cassidy, 1997).

- It was assumed that the critical low flows we see today are due to the amount of water taken out of the system for human use, and could be adjusted to reflect natural conditions. Linear regression of the annual stream flow values for the Chehalis River indicate a decrease of about 10 percent since 1930 (Wildrick et al. 1995). To estimate natural conditions for the model, critical low flow values of streams were increased by 10 percent, and point source flows were eliminated.

- The width-to-depth ratios of the headwater streams were adjusted in the model to conform to values that would be expected for that particular channel type in an undisturbed system. Streams were classified according to stream types defined by Rosgen (1996) and the mean width-to-depth ratio reported was used in the model.

Results of this analyses (Table 11) indicate that predicted temperatures may exceed the current water quality criteria in three tributaries and on several sections of the mainstem of the Upper Chehalis River..

Table 11. Model Predicted Maximum Daily Temperatures under Critical Climatic Conditions with Mature Riparian Forest and Increases in Stream Flow

Section 303(d) Listed Segment Name	Listed River Mile	Segment Township-Range-Section	Predicted Maximum Daily Temperature (°C)
Chehalis River	101.7	13N-05W-12	12.9
Chehalis River	74.6	14N-03W-24	17.8
Chehalis River	73.6	14N-03W-25	18.1
Chehalis River	70.7	14N-02W-24	18.6
Chehalis River	69.1	14N-02W-18	19.2
Chehalis River	67.5	14N-02W-07	20.0
Chehalis River	66.3	14N-03W-12	20.1
Chehalis River	59.9	15N-03W-22	20.4
Chehalis River	44.0	16N-05W-36	20.6
Chehalis River	33.8	17N-05W-28	20.7
South Fork Chehalis	0.5	13N-04W-24	17.3
Newaukum River	0.1	14N-02W-31	17.5
Dillenbaugh Creek	0.1	14N-02W-31	17.2
Dillenbaugh Creek	1.7	13N-02W-05	17.2
Salzer Creek	0.2	14N-02W-19	19.6
Skookumchuck River	0.1	14N-02W-07	17.5
Lincoln Creek	4.2	15N-03W-29	20.0
Scatter	1.3	15N-03W-08	19.8
Black River	1.2	15N-04W-05	17.5

Load Allocations

The load allocations established by this TMDL are identical to the loading capacity with existing channel morphology (see Table 10) except for three reaches. For the South Fork Chehalis River, the Newaukum River, and the Black River, the load allocation is based on achieving a stable channel with decreased width-to-depth ratios. The load allocations were compared to the estimated existing shade derived for the model calibration and validation (Table A1). Only the Chehalis River headwater reach currently meets the load allocation. The other streams all need additional shade, ranging from 12% to 42% (Table 12).

Table 12. Load Allocations for Upper Chehalis River Basin Stream Reaches

Stream Reach	Percent Vegetative Shade		
	Load Allocation	Estimated Existing Shade	Additional Shade Needed
Chehalis River - Headwaters to Elk Creek	49%	53%	0%
Chehalis River - Elk Creek to Newaukum River	48%	18%	30%
Chehalis River - Newaukum River to Skookumchuck R.	64%	22%	42%
Chehalis River - Skookumchuck R. to Scatter Creek	43%	16%	27%
Chehalis River - Scatter Creek to the Town of Porter	44%	16%	28%
South Fork Chehalis	74%	52%	22%
Newaukum River	78%	43%	35%
Dillenbaugh Creek	85%	64%	21%
Salzer Creek	81%	68%	13%
Skookumchuck R.	79%	59%	20%
Lincoln Creek	78%	59%	19%
Scatter Creek	81%	69%	12%
Black River	68%	37%	31%

Per EPA guidance, a quantitative link to an identified pollutant should be shown in order to use a surrogate measure such as channel morphology as a factor in a load allocation. In this case, the widening of the streams may have occurred because of a greater than normal input of sediment to the stream system through erosion processes. The historic use of splash dams to transport logs down streams is known to have been a very significant source of sediment loading to many locations in the Chehalis watershed. Two approaches were investigated to correlate-stream width-to-depth ratios as measures of erosion.

First, a relationship was investigated between width-to-depth data collected as part of the Regional Environmental Monitoring and Assessment Program (Merritt, 1997) and the percent of bank erosion observed by the US Fish and Wildlife Service (Wampler et al. 1993) in the watershed upstream of these sample locations. There was essentially no predictive relationship between these data sets, with a non-significant explained variance of only six percent. Data transformation did not improve this regression.

Second, a relationship was investigated between the width-to-depth data collected as part of the Dry Season TMDL study (Pickett, 1994a) and historical sediment loading data collected by the U.S. Geological Survey (Glancy, 1966). Data collected since this time is not adequate to derive more reasonable, current loading estimates. Again, there was essentially no predictive relationship between these data sets with a non-significant explained variance of only 25 percent. Data transformation did not improve this regression.

These analyses show that *with existing information*, the stream morphology cannot be quantitatively linked to a manageable pollutant, as suggested by EPA guidance for TMDLs. Therefore, specific numeric load allocations for sediment load cannot be established. However, the assumed channel width-to-depth ratio required to meet the load allocation described by shade can be used as a target. Only the three tributaries (South Fork Chehalis River, the Newaukum River, Black River) need to reduce mean width-to-depth ratios to achieve the load allocations. All other reaches must at least maintain existing channel morphology to meet the load allocation. (Table 13).

Table 13. Mean Tributary Width-to-depth Ratios (W:D) Needed to Meet Load Allocations

Stream Reach	Existing Mean W:D	Required Mean W:D	Percent Reduction
South Fork Chehalis	82	17	80%
Newaukum River	60	17	72%
Dillenbaugh Creek	83	83	0
Salzer Creek	135	135	0
Skookumchuck R.	67	67	0
Lincoln Creek	135	135	0
Scatter Creek	147	147	0
Black River	71	27	62%

The load allocations are based on two assumptions: 1) riparian vegetation will be protected and re-established as the result of management actions, and 2) water quality will be degraded no further by other influences. Although the bulk of this analysis focused on riparian shade, the calibration of the model resulted in estimates of ground water inflow, stream and tributary flow, and channel morphology of the stream. Since the model was calibrated to predict current conditions, the implication of these assumptions is that existing influences on temperature other than shade must remain constant in order for the shade allocations to effectively control in-channel water temperatures. Since alterations of them would affect the assimilative capacity of the stream, existing groundwater inflow, stream flow, tributary flow, and channel morphology are considered part of the load allocation. Further degradation of these factors could affect the loading capacity of heat and may result in temperature standards not being met.

In-stream flow levels at critical low flows must remain the same. Any additional water withdrawals must not be allowed during critical low flow periods. This includes any groundwater withdrawals with continuity to streams. Control measures need to be implemented to prevent further flow depletion. Restoration of flow levels more like pre-European settlement would probably further improve the rivers' temperatures.

Processes that affect channel morphology must at least be held constant for most streams. For the South Fork Chehalis River, the Newaukum River, and the Black River, the process affecting channel morphology must be improved to achieve stable channels with decreased width-to-depth ratios. The more significant factors affecting stream morphology that must be at least held constant are sediment delivery and watershed hydrology. Restoration activities that would reconnect or reestablish side channels, backwaters, and riverine wetlands would probably further improve channel water temperatures.

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

Watershed hydrology must not be further altered. Activities that shift hydrographs from base flow to more surface storm flow will affect temperatures. Excessive storm flows can result in further stream bank erosion and will likely raise stream temperatures. Lower base flow in the summer caused by the hydrograph shift will also likely raise stream temperatures. Expansion of dikes and levies that could further alter stream hydrology should be curtailed.

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

Wasteload Allocations

Several point source discharges enter the river in areas that are documented to routinely exceed the temperature criteria of 18°C during the summer critical (low-flow) period. Since the entire heat load in this TMDL has been allotted to nonpoint sources as load allocations, the temperature wasteload allocations for these point source discharges have been set at zero. Accordingly, the strategy is to permit each existing discharge so that they meet the temperature criteria for the river and not allow a cumulative increase of more than 0.3°C at the downstream edge of authorized mixing zones for all point sources.

Due to the uncertainty of the relationship between "natural conditions" and human-caused degradation during the critical period, the goal of this TMDL is to meet the temperature criterion in the river. Accordingly, during the critical period where the river is impaired, point sources will be held to the more restrictive temperature limits established for situations where natural conditions cause the exceedence. During non-critical periods, point sources will be permitted using the temperature formula.

Any new point source discharges will be required to meet the temperature criteria of the river at the end of the discharge pipe.

A separate TMDL for dissolved oxygen has been established by Ecology for the Upper Chehalis River. EPA approved the dissolved oxygen TMDL on October 21, 1996. The dissolved oxygen TMDL provides no wasteload allocation of BOD within the Centralia Reach during specified low-flow conditions (the critical period). The calendar-based wasteload allocations established in the dissolved oxygen TMDL approved by EPA on October 21, 1996 have been formally modified and are now based on seasonal flow conditions, which vary from year to year. Typically the critical low-flow period for the dissolved oxygen TMDL occurs between June and September. This coincides with the period when the river exceeds the water quality standard for temperature. Since the critical period for the dissolved oxygen TMDL and the critical period for this temperature TMDL overlap, restricting temperature discharges from point sources under this temperature TMDL to the same period when discharge is allowed under the TMDL for dissolved oxygen will also be protective of river temperature.

Critical Period for Temperature Defined

The critical period applies to all point source discharges that enter the river in areas that are documented to routinely exceed the temperature criteria.

For all existing point source dischargers, except for WestFarm Foods (formerly Darigold): the critical period for temperature starts on the next day after the seven-day moving average flow in the Centralia Reach falls below 1000 cfs. The critical period ends on the next day after the seven-day moving average flow in the Centralia Reach is greater than 1,000 cfs and the daily flow of the Centralia Reach has been greater than 2,500 cfs during at least one day of the preceding seven days.

WestFarm Foods: between May 1 and September 15 the critical period for temperature under this TMDL starts on the next day after the flow in the Centralia Reach falls below 500 cfs. The critical period for temperature between May 1 and September 15 shall cease to exist any time the flow in the Centralia Reach goes above 1000 cfs for three consecutive days until the flows again drop to 500 cfs. From September 16 through October 31, the critical period shall cease to exist after three consecutive days during which the flow of the Centralia Reach is greater than 500 cfs. Counting of consecutive days shall begin on September 13. From November 1 through April 30, the critical period for temperature does not exist regardless of the flow in the River.

Flow of the Chehalis River in the Centralia Reach shall be determined by the USGS Grand Mound gage using the following conversion equation:

$$y = 0.7396x - 28.28$$

Where: y is the flow, in cfs, in the Centralia Reach.
x is the flow of the Chehalis River, in cfs, as measured at the USGS Grand Mound gage.
cfs means cubic feet per second.

During the non–critical period, waste load allocations for point source discharges are based on the background water temperature upstream of the mixing zone. Table 14 summarizes the wasteload allocation for the existing point source discharges to the portion of the Chehalis River addressed in this TMDL.

The allocation strategy described in this section is required by EPA (1991) when there are no reasonable assurances provided that nonpoint source reductions will be achieved. Without these assurances, wasteload allocations must be established based on the assumption that the nonpoint sources will not be reduced.

Table 14. Basis for Temperature Wasteload Allocations for Point Source Discharges

River Conditions	Background Water Temperature (T) Upstream of the Mixing Zone	Allowable Temperature Increase (t)
CRITICAL PERIOD	T ≥ Water Quality Criterion	For Existing Sources: t = 0.3°C at the mixing zone boundary For New Sources: t = 0.0°C at the end of the discharge pipe
NON-CRITICAL PERIOD	IF (Water Quality Criterion – T) > 28/(T+7)	THEN For all Sources: t = 28/(T+7)
	IF (Water Quality Criterion – T) ≤ 28/(T+7) AND i. (Water Quality Criteria –T) ≤ 0.3°C ii. (Water Quality Criteria –T) > 0.3°C	THEN i. For all Sources: t = 0.3°C ii. For all Sources: t = (WQ Criterion –T)

NOTES:

1) "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge, and "t" represents the maximum permissible temperature increase. Unless specified otherwise "t" applies at the mixing zone boundary.

2) The temperature criterion can change over time depending on how State Water Quality Standards are modified.

Margin of Safety

The statute requires that a margin of safety be identified to account for uncertainty when establishing a TMDL. The margin of safety can be explicit in the form of an allocation, or implicit in the use of conservative assumptions in the analysis. Several assumptions and critical conditions used in the modeling analysis of the Chehalis River TMDL provide an inherent margin of safety over uncertainty as required by the statute. These conservative assumptions and critical conditions are listed below:

1. The highest water temperatures recorded in August were used to calibrate and validate the model. Lower water temperatures were recorded at various times and locations. As such, the model represents the worst-case condition measured in the system.
2. The topographic shade was set to zero for all of the streams modeled, except for the headwater reaches of the mainstem Chehalis River. Several of the stream reaches benefit from shade caused by the steeper topography of the surrounding hills block additional solar radiation. This benefit was disregarded in the modeling.
3. The lowest latitude of the study area was used for all modeled reaches. Some of the reaches are at a slightly higher latitude and could have a smaller solar radiation load at certain times.
4. Used 100 percent sunshine in all model runs. Clouds that could block solar radiation were not accounted for in the model.
5. Ten-year, seven-day low flows derived by Pickett (1994a) were used for loading capacity analysis and management strategies.
6. Climate conditions recorded on the 90th percentile maximum daily measured temperature were used.
7. The date of June 21 was used for the maximum annual solar radiation.

The modeling results and the loading capacity show that existing shade levels and some channel forms are not sufficient to meet stream temperature standards in the Upper Chehalis River Basin. The implementation strategy of passive restoration of the riparian corridor will meet the load allocations established. First, the existing riparian vegetation must be maintained on all riparian areas. Passive restoration entails allowing the existing riparian vegetation to grow into a mature forest (e.g. late seral stage). This implementation strategy will meet the load allocations by increasing shade to adequate levels. Second, passive riparian restoration will also reduce the sediment loads so that channel morphology can stabilize in the South Fork Chehalis River, the Newaukum River, and the Black River. Recent research has shown that streamside buffers are effective at preventing sediment delivery and direct physical disturbances to streams (Rashin et al. 1999). A mature riparian corridor will also improve temperatures by supplying adequate large wood for proper channel forming processes.

Comparing model predicted temperatures to the water quality standard (Table 15), demonstrates that temperature will be improved by increasing riparian shading. However, it also indicates that the standard may not be met during these critical conditions for some stream reaches. Since restoring stream shade and improving stream morphology are the only practical solutions to temperature problems in this watershed, the approach of this TMDL is one of *adaptive management*. If monitoring documents that restoring riparian shade to near natural occurring levels, maintaining or enhancing stream flow during critical low flow conditions, and improving other associated functions of a healthy stream environment do not result in compliance with water quality standards, then either the allocations or the standard itself will need to be reevaluated and the TMDL amended. The time necessary to reestablish riparian vegetation will provide ample opportunity to gather information on the effectiveness of this TMDL.

Table 15. Comparison of Temperature Standards with Predicted Maximum Daily Temperatures under Critical Conditions using a Riparian Shade Restoration Strategy

Section 303(d) Listed Segment Name	Listed River Mile	Segment Township-Range-Section	Predicted Maximum Daily Temperature (°C)	Water Quality Standard (°C)
Chehalis River	101.7	13N-05W-12	16.1	18.0
Chehalis River	74.6	14N-03W-24	17.5	18.0
Chehalis River	73.6	14N-03W-25	18.0	18.0
Chehalis River	70.7	14N-02W-24	18.6	18.0
Chehalis River	69.1	14N-02W-18	19.1	18.0
Chehalis River	67.5	14N-02W-07	19.5	18.0
Chehalis River	66.3	14N-03W-12	19.4	18.0
Chehalis River	59.9	15N-03W-22	20.0	18.0
Chehalis River	44.0	16N-05W-36	20.5	18.0
Chehalis River	33.8	17N-05W-28	20.6	18.0
South Fork Chehalis	0.5	13N-04W-24	16.9	18.0
Newaukum River	0.1	14N-02W-31	17.9	18.0
Dillenbaugh Creek	0.1	14N-02W-31	17.8	18.0
Dillenbaugh Creek	1.7	13N-02W-05	17.9	18.0
Salzer Creek	0.2	14N-02W-19	19.3	18.0
Skookumchuck River	0.1	14N-02W-07	17.8	18.0
Lincoln Creek	4.2	15N-03W-29	19.4	18.0
Scatter	1.3	15N-03W-08	19.4	18.0
Black River	1.2	15N-04W-05	17.3	18.0

Each modeled reach currently contains riparian vegetation that covers several different seral stages (Table A1). Using the assumptions made on the average age of each of the seral stages defined in the modeling approach section, one can estimate how long it would take for all vegetation in any particular reach to grow to late seral stage (Table 16). Reaches that are dominated with hardwoods or non-forested areas that will be replaced by hardwoods will grow to late seral stage soonest. Reaches with conifers will take considerably longer.

Table 16. Estimated Maximum Time for Each Reach to Attain Full Late Seral Stage with Existing Vegetation

Stream Reach	Years to Late Seral Stage
Chehalis River -Headwaters to Elk Creek	150
Chehalis River -Elk Creek to Newaukum River	100
Chehalis River - Newaukum River to Skookumchuck R.	60
Chehalis River -Skookumchuck R. to Scatter Creek	150
Chehalis River -Scatter Creek to the Town of Porter	150
South Fork Chehalis	150
Newaukum River	60
Dillenbaugh Creek	100
Salzer Creek	150
Skookumchuck River	150
Lincoln Creek	150
Scatter Creek	150
Black River	150

Summary Implementation Strategy

Implementation Plan Development

The Detailed Implementation Plan (DIP) for the Chehalis Temperature TMDL required under the Memorandum of Understanding between Ecology and U.S. EPA will be developed in conjunction with local watershed planning currently underway in the Chehalis Basin.

Implementation of the Chehalis Temperature TMDL is closely related to these watershed planning and salmon recovery activities. This local planning was initiated to meet the requirements of recent state legislation (ESHB 2514 – Local Watershed Planning, and ESHB 2496 – Salmon Recovery), which recognized the importance of local planning and implementation to salmon recovery, water quality, and water supply. Although these are separate pieces of legislation with different emphases, they both address critical components of fish habitat. Coordination between the two is a state and local priority.

The Chehalis Basin Partnership has been recognized by the state as the Local Planning Unit for Watershed Planning under ESHB 2514, and as the Lead Entity for Salmon Recovery activities under ESHB2496.

The statutory deadline for completing water management planning under the Watershed Planning Act (90.82 RCW) is four years after an assessment of existing data and information for the basin is initiated. In the Chehalis Basin, this initial assessment started during September 1999 so the deadline for completing the watershed water management plan that will also serve as the DIP is September 2003.

It is anticipated that the river will meet the temperature criteria in the Water Quality Standards by the year 2065 when the actions described in this Summary Implementation Strategy and the Detailed Implementation Plan have been achieved. Since this is a very long time, interim milestones will be incorporated into the Detailed Implementation Plan.

Washington State Forest Practice Regulations

In 1999, various state and federal agencies, counties, some tribes, and the timber industry entered into the Fish and Forest Agreement (F&F) to address impacts caused by forest harvesting activities on water quality and habitat for fish and six riparian-dependent amphibians. This agreement was contingent on the state adopting improved forest practice regulations as well as funding and implementing a monitoring and adaptive management program to demonstrate the effectiveness of the new rules in protecting water quality and fisheries habitat. Landowners also agreed to share water quality information with the other parties to the agreement.

Emergency forest practice regulations were adopted by the Washington Forest Practices Board and became effective March 20, 2000. These rules are representative of the F&F agreement. Permanent rules have been adopted and are being implemented.

Negotiated "assurances" were provided to the timber industry under the agreement for supporting improved forest practice regulations. These assurances include 1) development of

TMDLs for 303(d) listed waterbodies impacted primarily or solely by forest practices are a lower priority and will be conducted beginning in the year 2009, 2) EPA and Ecology would not ask the Forest Practices Board to adopt any more stringent rules except through the adaptive management program set out in F&F, and 3) the F&F adaptive management process will be used for adjusting forest practices if necessary, to meet load allocations of TMDLs produced for streams in mixed use watersheds.

Initial development of this TMDL predates F&F by several years and the allocations are necessary to address all the sources/causes of temperature problems in the upper Chehalis River system. Therefore, Ecology has proceeded with TMDL completion. Load allocations are included in this TMDL for forest-lands in the Upper Chehalis Watershed in accordance with the section of F&F entitled "TMDLs produced prior to 2009 in mixed use watersheds". Also consistent with the F&F agreement, implementation of the load allocations established in this TMDL for private and state forestlands will be accomplished via implementation of the revised forest practice regulations. The effectiveness of the Forest and Fish rules will be measured through the adaptive management process and monitoring of streams in the watershed. If shade is not moving on a path toward the TMDL load allocation by 2009, Ecology will suggest changes to the Forest Practices Board.

Again, the F&F assurances are provided for forest harvesting activities conducted under regulations adopted pursuant to F&F, the 20 Acre Exempt Rule is not covered. The Chehalis TMDL analysis concludes that all stream segments downstream of river mile 101.7 in the upper Chehalis watershed are shade deficient, existing shade should not be further reduced in the riparian buffers. Accordingly, forest practices conducted under the 20 acre exempt rule are expected to comply with the allocations for stream shade established in this TMDL. Therefore, DNR is encouraged to condition forest practices to prohibit any further reduction of stream shade and not to waive or modify any shade requirements for timber harvesting activities on these state and private lands. Ecology is committed in assisting DNR in identifying those site specific situations where reduction of shade has the potential for or could cause material damage to public resources.

Water Withdrawal

The Washington Department of Ecology is responsible for issuing permits for surface and ground water withdrawal. Reduction in river flow and ground water flow into the river would increase temperature problems in the river during critical low flow conditions. Ecology will consider this TMDL analyses when evaluating new applications for surface and groundwater use that might reduce river flow during summer low flow conditions.

RCW 90.82 – Local Watershed Planning

RCW 90-82 authorizes local planning units and establishes a process that will lead to effective water management within designated watersheds. Each planning unit is made up of local citizens who join together in an effort to assess the factors affecting in-stream flows, and if they choose, water quality and fish habitat. The assessment is used to develop management strategies that provide adequate flows of high quality water for fish, as well as finding ways to meet the needs of people who rely on out-of-stream uses of water.

The resulting watershed plans may be used to develop in-stream flow levels where they do not already exist, or to recommend changes to existing established minimum flows where appropriate. The local planning unit for the Chehalis Basin chose to include water quality as a component of its plan, so the plan must include recommendations for implementing TMDLs to achieve water quality standards. A primary purpose of the watershed management planning under RCW 90.82 is to address water and habitat issues affecting listed and soon-to-be listed salmon stocks under the federal Endangered Species Act.

RCW 77.85 – Salmon Recovery

RCW 77.85 addresses many aspects of salmon recovery. Of particular interest to this TMDL project is the section directing the Washington State Conservation Commission to form watershed based technical advisory groups (TAC) to complete an analysis of salmon habitat factors that limit the ability of habitat to fully sustain natural spawning populations of salmon. Each TAC is comprised if individuals representing private, federal, state, tribal and local government entities.

The limiting factors analysis for the Chehalis Basin has been completed. The basin has been broken down into 15 sub-basins that have been prioritized for completion of limiting factor analysis. Within each sub-basin, the limiting factor analysis attempted to identify all types of habitat impediments that negatively affect natural spawning salmon populations. These impediments include fish passage, riparian corridors, wetlands, water quality, water quantity, and stream channel health.

The limiting factor analysis provides a foundation for future conservation work. It will be used to identify specific riparian areas that will be a high priority for the riparian shade protection and restoration required under this temperature TMDL.

Coordination of Local Watershed Planning and Salmon Recovery Activities with Development of a Detailed Implementation Plan

Under RCW 90.82, the local planning unit must submit a proposed watershed plan within four years of receiving funding for beginning the assessment. In the Chehalis, this means that the TMDL DIP would be completed in 2003 when the proposed watershed plan is due. This schedule does not meet the 12-month timeframe described in the TMDL MOA. However, there are three overriding reasons that it would not be a wise use of limited resources to prepare the DIP independent of the local watershed plan.

First, since the watershed plan developed under RCW 90.82 must include recommendations for implementing existing TMDLs, and because of the local commitment to meeting the requirements of both the Watershed Planning Act and the Salmon Recovery Act, there would be little local interest in agreeing to separate TMDL implementation activities until the local watershed plan is complete. It also makes good sense to build TMDL implementation into the locally developed recommendations in the watershed plan.

The second reason for delaying the DIP so that it is integrated with the local watershed plan developed under RCW 90.82 is that there are significant riparian zone protection and restoration efforts already underway. These efforts are consistent with any implementation activities that could be recommended in the DIP. A summary of some of the current riparian zone restoration and protection activities is provided in Table 17.

Finally, Bull Trout was listed as threatened in November 1999. Sea-Run Cutthroat Trout and coastal Coho are being considered for listing on the federal Endangered Species Act within the next two or three years. The potential for a "take" under ESA will create real incentives for restoring and protecting riparian zones, which is the key to promoting tree growth that results in increased shade and lower water temperatures.

Local Watershed Planning Goals

The Chehalis Basin Partnership was forming as a local coordinating body before the watershed planning and salmon recovery legislation described above was passed. The Intergovernmental Agreement forming the Partnership states the following goal:

"The parties shall work cooperatively to establish a planning unit to be called the Chehalis River Basin Partnership and to seek participation from interested and affected parties. The Chehalis River Basin Partnership serving in an advisory and informational capacity, shall coordinate efforts focusing on:

- Improvement of water quality
- Management of water resources to provide ample supplies for farms, fish, industry and people (including restoration of healthy runs of salmon and steelhead)
- Reduction of the effects of flooding
- Increase in recreational opportunities
- Increase in watershed awareness through education

Local Watershed Planning Participants

The Chehalis Basin Partnership currently consists of representatives from the following groups: (Membership may change over time.)

- Each county with lands contributing significant flows to the Chehalis Watershed (4).
- Each interested city and town in the watershed (9 have signed on).
- The Confederated Tribes of the Chehalis Reservation and the Quinault Indian Nation.
- One representative of the water supply utilities.
- One representative of the Port Districts.
- One representative from each: the state Departments of Agriculture, Ecology, Fish & Wildlife, and Natural Resources. Ecology represents all other state agencies not specifically named.
- One private citizen from each of the counties (four).

Other major interests represented currently include the Chehalis Basin Fisheries Task Force, the Washington Cattlemen's Association, and Weyerhaeuser. A business representative position is currently vacant.

In addition to the formal members, the US Fish and Wildlife Service, US EPA, and the US Army Corps of Engineers participate in the partnership. Other federal agencies are welcome.

Adaptive Management

For those streams that currently exceed temperature standards, lack sufficient shade, or have channels that do not meet expected width to depth ratios, exact projections of when water quality standards will be attained are not possible. Where stream temperatures are largely a function of shade, and past timber harvest or land clearing has already occurred in the riparian shade zone, re-growth of trees of suitable size to meet shade functions will take many years.

At the end of every five-year period, beginning in the year 2005, implementation of the actions required under this TMDL will be reviewed and evaluated. Based on these regular evaluations, implementation efforts will be adjusted until acceptable levels of positive change are reached. This evaluation will include any new monitoring data to determine if the temperature problem is changing. It is likely that there will be an increase in the number of tributaries or mainstem river segments that show up as temperature impaired as data becomes available from sites that have not previously been monitored. This should be anticipated and should not be used as a measure of the effectiveness of this long-term effort to restore riparian shade, stream flow, and channel morphology that reflect more natural conditions.

Summary of Public Involvement

Public review and comment on the proposed temperature TMDL for the Upper Chehalis River was solicited through:

- Announcements in the state register
- Advertisements in the legal sections of The Centralia Chronicle and The Olympian
- An article requesting comments on the proposed TMDL in "Drops of Water," a monthly newspaper insert distributed to newspaper subscribers in the basin by the Chehalis River Council.
- An announcement on the web site for the Chehalis River Council.
- Individual letters to parties who commented on the original version in 1999.

At the request of several interested parties who were not individually notified of the review/comment period, Ecology extended the comment period one additional week for those who requested it.

Copies of the newspaper advertisements, state register notice and newsletter article are provided as Appendix C.

The response to public comments is provided in Appendix D.

Monitoring Effectiveness

There are EPA (1991) guidance calls for a monitoring plan for TMDLs where implementation will be phased in over time. The monitoring is conducted to provide assurance that the control measures achieve the expected load reductions. Monitoring can be conducted in three ways. First, the actual water temperature can be measured to test for downward trends. Second, the level of factors influencing temperature (e.g. shade) can be measured. Third, implementation can be monitored to assess the progress on implementation. There are a number of monitoring activities planned that touch on all three types of monitoring:

- Both Ecology and the Chehalis Tribe conduct routine monitoring of surface water temperatures throughout the basin.
- The Conservation Reserve Enhancement Program will monitor the amount of land taken out of agriculture for riparian restoration.
- The Conservation Districts will monitor the amount of riparian corridor restored by their cooperators.
- The effectiveness monitoring of best management practices and fisheries habitat restoration efforts is being conducted for several more years under a continuing grant from the Chehalis Fisheries Basin Restoration Program.

These monitoring activities individually provide valuable information. To effectively evaluate the short- and long-term effectiveness of riparian restoration, these programs will have to be coordinated and augmented. This will be addressed in the Detailed Implementation Plan.

Existing Programs Implementing TMDL Recommendations

Reasonable assurance that point source wasteload allocations will be achieved:

Wasteload allocations for point source dischargers will be implemented by the Department of Ecology thorough its NPDES permitting authority. NPDES permits for all point source dischargers will be revised so that facilities will comply with the waste load allocations in this TMDL.

Reasonable assurance that nonpoint source load allocations will be achieved:

Load allocations for nonpoint sources will be achieved through the involvement of state and federal agencies, local government, tribes, and private organizations. In addition to new rules protecting aquatic habitat and water quality, state and federal governments are appropriating the requests for implementation dollars, which improves the likelihood that agencies and tribes will be able to effectively implement the forest and fish requirements (forest practices rules – FFR). For the 1999-01 biennium, a total of $21, 436, 000 has been appropriated to assist in implementing the various program components of the FFR and permanent rules consistent with FFR. Some highlights include: four million federal dollars were allocated to help fund FFR rule implementation, particularly adaptive management, through the Salmon Recovery Funding Board. The state agencies (DNR, DOE, and WDFW) will or have received approximately $2.1 million this year and three million dollars (including the supplemental budget) for 2001 to fund compliance monitoring, review technical forest practices, and implement the small landowner office. These monies are in addition to $1.5 million that has been appropriated during the current biennium to assist with Board rule adoption and improvements in the DNR/Forest Practices GIS and electronic data systems. Washington State Tribes received an appropriation of $3.026 million last year and anticipate equal funding for the next fiscal year.

Examples of programs that will help reduce river water temperature are described below. As watershed planning continues under Ch. 90.82 RCW and a Detailed Implementation Plan designed to achieve the necessary temperature reductions identified in this TMDL is prepared, additional implementation activities, with interim milestones will develop.

There are many parties actively restoring riparian shade in the Upper Chehalis Basin today. Below is a description of the various programs underway to maintain or restore the riparian corridor at the time this TMDL was prepared.

Conservation Reserve Enhancement Program

The Washington Conservation Reserve Enhancement Program is a joint effort between the state of Washington and the U.S. Department of Agriculture to restore fisheries habitat on private agricultural lands adjacent to depressed or critical-condition salmon streams. The streams in the Upper Chehalis River basin have been approved for inclusion in this program. Landowners will contract with the federal Farm Services Agency to take land adjacent to these streams out of agricultural production and plant it with native trees. The trees must remain undisturbed for up to 15 years. In return, the landowner will receive an annual rental check. In addition to the payment, grant funds that cover nearly 90 percent of the cost of converting the agricultural land back to trees will be available to participating landowners.

The program began in January 1999 and is being coordinated by the Washington State Conservation Commission. Local Conservation Districts market the program to landowners; assist with the lease agreements and help design the riparian restoration and protection practices. The program requires establishing a buffer that is a minimum of three-quarters of the site potential tree height. The site potential tree height is based on soil conditions, climatic conditions, and native plant communities, so it will be somewhat different for each locale. In addition to developing recommendations for re-vegetation, other practices such as livestock fencing and vegetation watering in dry periods may also be included in the site plan.

Chehalis River Council "Shade to Chehalis" Program

The Chehalis River Council was established in 1994 by a group of citizens concerned about the environmental conditions and water quality in the Chehalis River Basin. In 1995, Ecology awarded the Council a grant to develop a tree-planting program for the river basin. "Shade the Chehalis" (the name the council has given this program) contacts shoreline residents and concerned citizens to encourage native tree planting projects along stream banks. The council has published a tree-planting guide to help these people design and implement riparian vegetation restoration projects.

Other Forest Practice Activities

Watershed analyses have been conducted in the Chehalis River headwaters, Stillman Creek, and the Skookumchuck River watersheds. These watershed analyses (conducted under WAC 222-

22) focus on site-specific characteristics, and establish reach-specific prescriptions for future forest management activities. Factors influencing temperature that are addressed through the watershed analysis process include riparian function, stream channel morphology, water quality, mass wasting, surface erosion, hydrology, and fish habitat.

In addition, there is new legislation derived from a proposal by several significant forest landowners to improve riparian management beyond the requirements of current forest practice rules. The strategies described in the proposal are designed to result in a mature riparian forest. These strategies meet the goals set forth in this TMDL. Part of the proposal is an agreement between EPA and Ecology to not establish TMDLs for waters managed under these riparian strategies. Since the goals of the proposal are the same goals as the TMDL, the effect of the agreement is only administrative. The result of either action will bring the waters into compliance with water quality standards for temperature.

Conservation Districts

Conservation districts are continually developing conservation plans on agricultural property throughout the Chehalis River Basin. For a farm plan to be approved by the Conservation District Board of Supervisors, it must identify all resource concerns, specify which alternative solutions the landowner has selected to address those concerns, project a schedule for implementation, and document the landowner's commitment to address all the identified concerns.

When streams or other waterbodies are part of the landowner's holdings, livestock exclusion or limited access to the riparian corridor is always a component of the plan. When the fence is built for the livestock exclusion, the riparian corridor is sometimes replanted with native trees and shrubs. The work of Lewis County Conservation District in the Deep Creek watershed is a fine example. Nearly 14,000 feet of riparian corridor has been fenced and replanted with trees since 1995.

One concern is the survival rates of the plantings. Past projects have documented a large range (10%-70%) of trees surviving after planting. The main problem contributing to low survival rates is the invasion of grasses and weeds that compete for soil nutrients and available water, and shade out the young seedlings. Other problems affecting the survival of planted trees include wildlife damage (mice, deer and beaver) and drying of soils during hot summer periods. These problems are being addressed by the use of foil or plastic to protect the ground around young trees and having landowners water and weed around the trees until they are established.

Confederated Tribes of the Chehalis Reservation

The Confederated Tribes of the Chehalis Reservation has an ongoing program to restore and protect riparian corridors. Under this program, the Tribe provides technical and financial assistance to landowners that are interested in protecting riparian zones on their property. The Tribe has often been successful working with landowners who are otherwise reluctant to work with "governmental agencies." In some cases, these landowners have become active proponents of riparian zone protection. Over a five-year period (1994-1998) the Chehalis Tribe has assisted with the installation of 20.6 miles of riparian fencing, resulting in the protection of 123 acres of riparian area. In addition, they have helped install approximately six off-channel wetland/rearing habitats that provide another 40 to 50 acres of protected riparian areas.

Chehalis Basin Fisheries Restoration Program

The Chehalis Basin Fisheries Restoration Program was initiated by congressional legislation (Public Law 101-452) and is coordinated by the U.S. Fish and Wildlife Service. The goal of the program is to optimize natural salmon and steelhead production while allowing the highest compatible level of hatchery production. The program provides funding and guidance to improve aquatic habitats throughout the Chehalis River Basin.

Under this program, Ecology has implemented a six-year project to evaluate the effectiveness of best management practices and fisheries habitat restoration efforts. Numerous stream sites are being monitored and evaluated under this grant. A number of interim project reports have been published which document the effectiveness of BMPs (Sargent, 1996a&b; Sargent 1997; Sargent, 1998a&b).

In addition to monitoring the effectiveness of these activities, the program has provided grant funds to various cooperators for specific restoration activities (Table 17).

Table 17. Riparian Restoration Projects funded by the Chehalis Basin Fisheries Restoration Program.

Fiscal Year	Cooperator	Location	Project Description
1993	GHCD	Confluence of Cedar Creek and Chehalis River	7300 ft of livestock exclusion fencing.
1993	GHCD	Confluence of Cedar Creek and Chehalis River	2500 ft of fencing and riparian re-vegetation; 228 ft of bank stabilization w/ LWD
1993	LCD	Dillenbaugh Creek near town of Chehalis	11,000feet livestock exclusion fencing; off-channel refuge alcoves; bank stabilization; and re-vegetation. Five landowners.
1994	GHCD	Black River	10,000 ft. livestock exclusion fencing
1994	CBFTF	Stearns Creek (Upper Chehalis near Adna)	3850 feet of livestock exclusion fencing; re-vegetation; and spawning pads.
1994	CBFTF	Mill Creek (Upper Chehalis near Adna)	500 feet of livestock exclusion fencing and re-vegetation.
1994	CBFTF	Allen Creek (Black River basin)	8911 feet of livestock exclusion fencing; 10 in-stream LWD structures; 1 spawning pad; and re-vegetation.
1994	CBFTF	Allen Creek (Black River basin)	7011 feet of livestock exclusion fencing and re-vegetation.
1994	CBFTF	Upper Dillenbaugh Creek	2400 feet of livestock exclusion fencing; off-channel refuge alcove; LWD placement; and bank stabilization.
1994	CBFTF & Chehalis Tribe	N. and S. Forks Lincoln Creek.	960 feet livestock exclusion fencing; 8 LWD structures; and re-vegetation.
1994	Chehalis Tribe	Garrard Creek	1000 ft. fencing; bank stabilization; LWD; re-vegetation
1994	Tilton River Company, & LCD	Lucas Creek (North Fork Newaukum basin)	318ft. bank stabilization using re-vegetation, log deflectors and root wads. Most structures swept away the week after completion. Bank not eroding as of 1997, additional willow planting 1997.

Table 17 Continued… Riparian Restoration Projects funded by the Chehalis Basin Fisheries Restoration Program.

Fiscal Year	Cooperator	Location	Project Description
1995	Chehalis Tribe	Garrard Creek	5,000 feet fencing, LWD placement, re-vegetation.
1995	TCD	Skookumchuck River/Scatter Creek	Riparian planting at 16 sites.
1995	LCD	Deep Creek	12,400 ft of fencing, re-vegetation, three pasture pumps, and three crossings. Five landowners on creek involved.
1995	LCD	Bunker Creek	4000 ft fencing; bank stabilization using LWD, vegetation and bank sloping; and 3,000 linear ft re-vegetation.
1996	TCD	Allen Creek/Black River	1,300 feet of livestock fencing, 10,000 square feet of planting, and a Conservation Plan.
1996	TCD	Dempsey Creek/Black River	11,500 feet of livestock fencing, native plantings, four pasture pumps, two livestock crossings and a Conservation Plan.
1996	TCD	Waddell Creek/Black River	700 feet of livestock fencing, re-vegetation, bank stabilization and in-stream habitat structures
1996	GHCD	Mainstem Black River	700 feet of livestock fencing, re-vegetation, bank stabilization and in-stream habitat structures
1996	LCD	Salzer Creek/China basin	4,600 feet of livestock, bioengineering and large woody debris placement for 70 feet of bank protection, and re-vegetation of the riparian corridor.
1997	LCD	Salzer Creek/China basin	The lower 2100 feet of Salzer Creek will be re-vegetated with native riparian trees and shrubs.

Table 17 Continued... Riparian Restoration Projects funded by the Chehalis Basin Fisheries Restoration Program.

Fiscal Year	Cooperator	Location	Project Description
1997	LCD	Coal Creek/China basin	2000 feet of Coal Creek re-vegetated with native riparian trees and shrubs. Reed canary grass will be controlled by scalping, installing ground cover matting, and active maintenance until plants become established.
1997	TCD &GREEN	Various CFRP project sites	Monitoring of riparian re-vegetation and help with maintaining existing re-vegetation projects. High school students, funded by the Private Industry Council, provided the data collection and labor. We provided funds for the crew leader's salary and training, and equipment. The project also included classroom activities and training for the students.
1997	WDNR	OLC1000 Road tributary to Scatter Creek	500 feet of livestock fencing, 0.6 acres of riparian planting and 10 large whole tree habitat structures
1998	GHCD	Various CFRP project sites in GH County	Monitoring, maintenance and replanting at six GHCD/CFRP riparian re-vegetation sites
1998	TCD	O'Connor Creek/ Skookumchuck basin	2,600 feet of re-vegetation on O'Conner Creek, which has been fenced by other cooperators to exclude livestock.
1998	LCD	Kearney Creek/ S. Fork Newaukum basin	1320 feet of livestock exclusion fencing and a rocked crossing.
1998	CBFTF	Stearns Creek (Upper Chehalis Basin)	700 feet of livestock fencing and re-vegetation.

Cooperator Acronyms
CBFTF - Chehalis Basin Fisheries Task Force.
LCD - Lewis Conservation District
TCD - Thurston Conservation District
GHCD - Grays Harbor Conservation District
GREEN - Global Rivers Environmental Education Network
WDNR - Washington State Department of Natural Resources

References Cited

Barthowlow, J.M. 1989. Stream Temperature Investigations: Filed and Analytical Methods. In-stream Flow Information Paper No. 13. U.S. Fish and Wildlife Service Biol. Report 89(17). U.S. Fish and Wildlife Service. Fort Collins, CO.

B.C. Conservation Data Centre. 1999. Great Trees of British Columbia, British Columbia Ministry of the Environment. Data at www.env.gov.bc.ca: 8000/wld/cdc/trees.htm.

Cassidy, K.M. 1997. Land Cover of Washington State: Description and Management. Volume 1 in Washington State Gap Analysis Project Final Report. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, WA.

Glancy, P.A. 1966. Sediment Transport by Streams in the Chehalis River Basin, Washington, October 1961 to September 1965. Supply Paper 1798-H, U.S. Geological Survey, Washington D.C.

Hatten, J.R., Conrad, R.H. 1995. A Comparison of Summer Stream Temperatures in Unmanaged and Managed Sub-Basins of Washington's Western Olympic Peninsula. Northwest Fishery Resource Bulletin - Project Report Series No. 4. Northwest Indian Fisheries Commission, Olympia, WA.

Henderson, J.A., Peter, D.H., Lesher, R.D. and D.C. Shaw. 1989. Forested Plan Associations of the Olympic National Forest. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, R6 ECOL Technical Paper 001-88. Portland OR.

Lindsley, R.K. Jr., Kohler, M.A. and J.L.H. Paulhus. Hydrology for Engineers. McGraw-Hill Book Company. New York.

Merritt, G.D. 1997. Biological Assessment of Wadable Streams in the Upper Chehalis River Basin - Quality Assurance Project Plan. Washington Department of Ecology, Olympia, WA.

National Advisory Council for Environmental Policy and Technology. 1998. Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program. U.S. Environmental Protection Agency. EPA –100-R-98-006. Washington, D.C.

Pickett, P.J. 1994a. Upper Chehalis River Dry Season Total Maximum Daily Load Study. Publication No. 94-126. Washington Department of Ecology, Olympia, WA.

Pickett, P.J. 1994b. Black River Dry Season Total Maximum Daily Load Study. Publication No. 94-106. Washington Department of Ecology, Olympia, WA.

Pickett, P.J. 1997. Pollutant Loading Capacity for the Black River, Chehalis River System, Washington. J. American Water Resources Association 33(2): 465-480.

Pickett, P.J. 1999. Personal Communication, Water Quality Engineer, Environmental Assessment Program, Washington Department of Ecology, Olympia, WA.

Rashin, E., Clishe, C., Loch, A. and J. Bell. Effectiveness of Forest Road and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. Publication No. 99-317. Washington Department of Ecology, Olympia, WA.

Reckow, K.H., Clements, J.T. and R. Dodd. 1986. Statistical Goodness-of-fit measures for wasteload allocation models. Work Assignment Number 33. U.S. EPA Contract Number 868-01-6904.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Sargeant, D. 1996a. Beaver/Allen Creek Water Quality Data Report: 1994-1995. Report No. 96-310, Washington Department of Ecology, Olympia, WA.

Sargeant, D. 1996b. Chehalis Best Management Practices Evaluation Project -- 1995 Temperature Monitoring Data. Report No. 96-340, Washington Department of Ecology, Olympia, WA.

Sargeant, D. 1997. Chehalis Best Management Practices Evaluation Project -- 1995-96 Water Quality Data Report for Bunker/Deep Creek Project Area. Report No. 97-306, Washington Department of Ecology, Olympia, WA.

Sargeant, D. 1998a. Chehalis Best Management Practices Evaluation Project --1996-97 Beaver/Allen Creek Water Quality Data Report. Report No. 98-309, Washington Department of Ecology, Olympia, WA.

Sargeant, D. 1998b. Chehalis Best Management Practices Evaluation Project --1996-97 Water Quality Data Report for Bunker Creek and Deep Creek Project Area. Report No. 98-333, Washington Department of Ecology, Olympia, WA.

SASSI, 1993. 1992 Washington State Salmon and Steelhead Stock Inventory. Washington Department of Fisheries, Washington Department of Wildlife and Western Washington Treaty Indian Tribes. Olympia, WA.

Sullivan, K., Tooley, J., Doughty, K., Caldwell, J.E., and P. Knudsen. 1990. Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington. Timber/Fish/Wildlife Report No. TFW-WQ3-90-006. Washington Department of Natural Resources, Olympia, WA.

Theuer, F.D., Voos, K.A., and W.J. Miller. 1984. In-stream Water Temperature Model. In-stream Flow Inf. Paper 16. FWS/OBS-84/15. In-stream Flow and Aquatic System Group, U.S. Fish and Wildlife Service. Fort Collins, CO.

Tennessee Valley Authority. 1972. Heat and Mass Transfer between a Water Surface and the Atmosphere. Water Resources Res. Lab Report 14, Tennessee Valley Authority, Norris, TN.

U.S. Department of Agriculture. 1995. Inland Native Fish Strategy (INFISH).

U.S. Environmental Protection Agency. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001. Washington, DC.

Wampler, P., Knudsen, E., Hudson, M. and T. Young. 1993. Chehalis River Basin Fishery Resources: Salmon and Steelhead Stream Habitat Degradation. U.S. Fish and Wildlife Service, Olympia, WA.

Washington Department of Fisheries. 1975. A Catalog of Washington Streams and Salmon Utilization. Washington Department of Fisheries, Olympia, WA.

Wildrick, L., Davidson, D., Sinclair, K. and B. Barker. Initial Assessment of Water Resource Inventory Are 23 - Upper Chehalis River. Open-File Report 95-03. Washington State Department of Ecology, Olympia, WA.

Figures

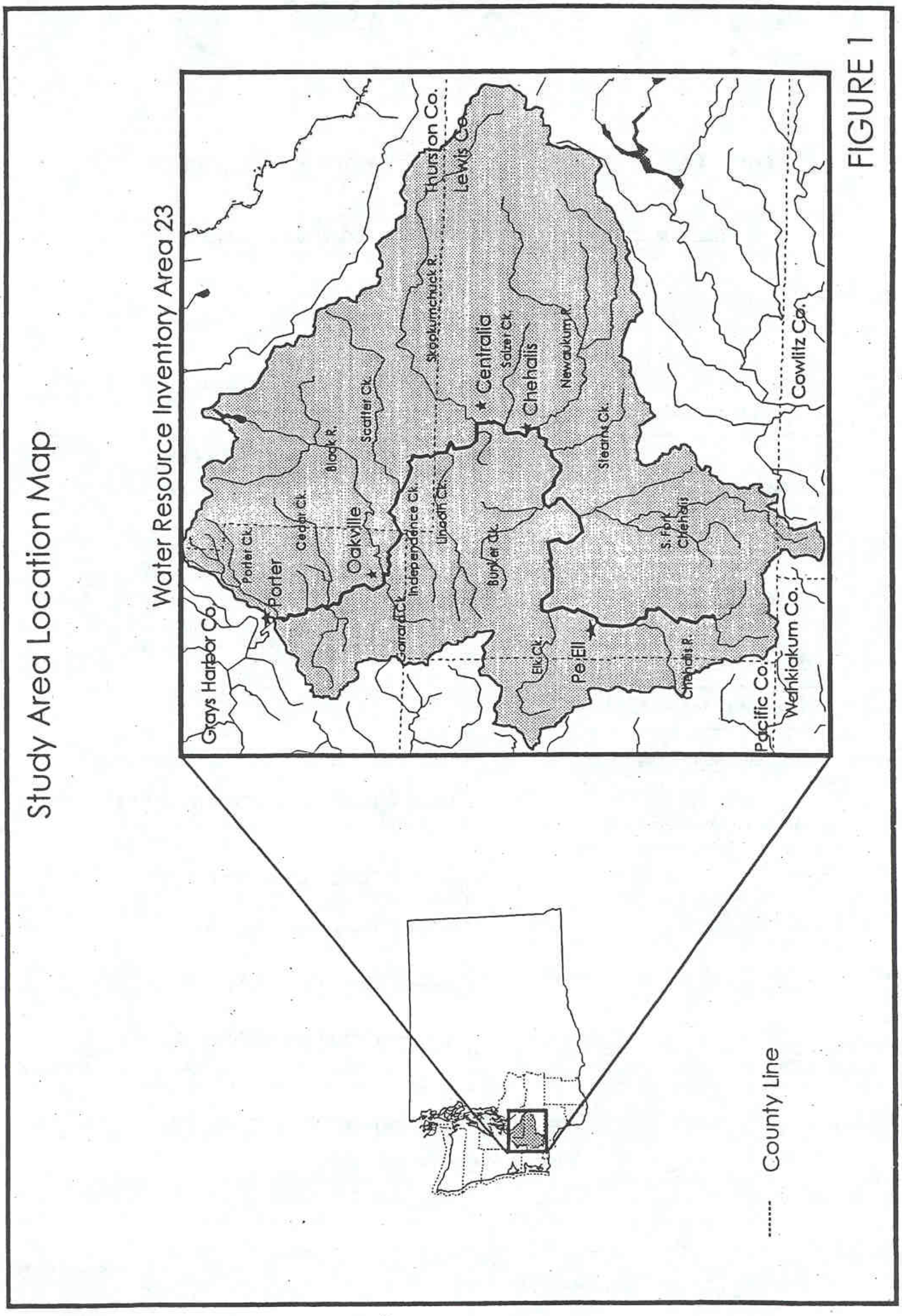
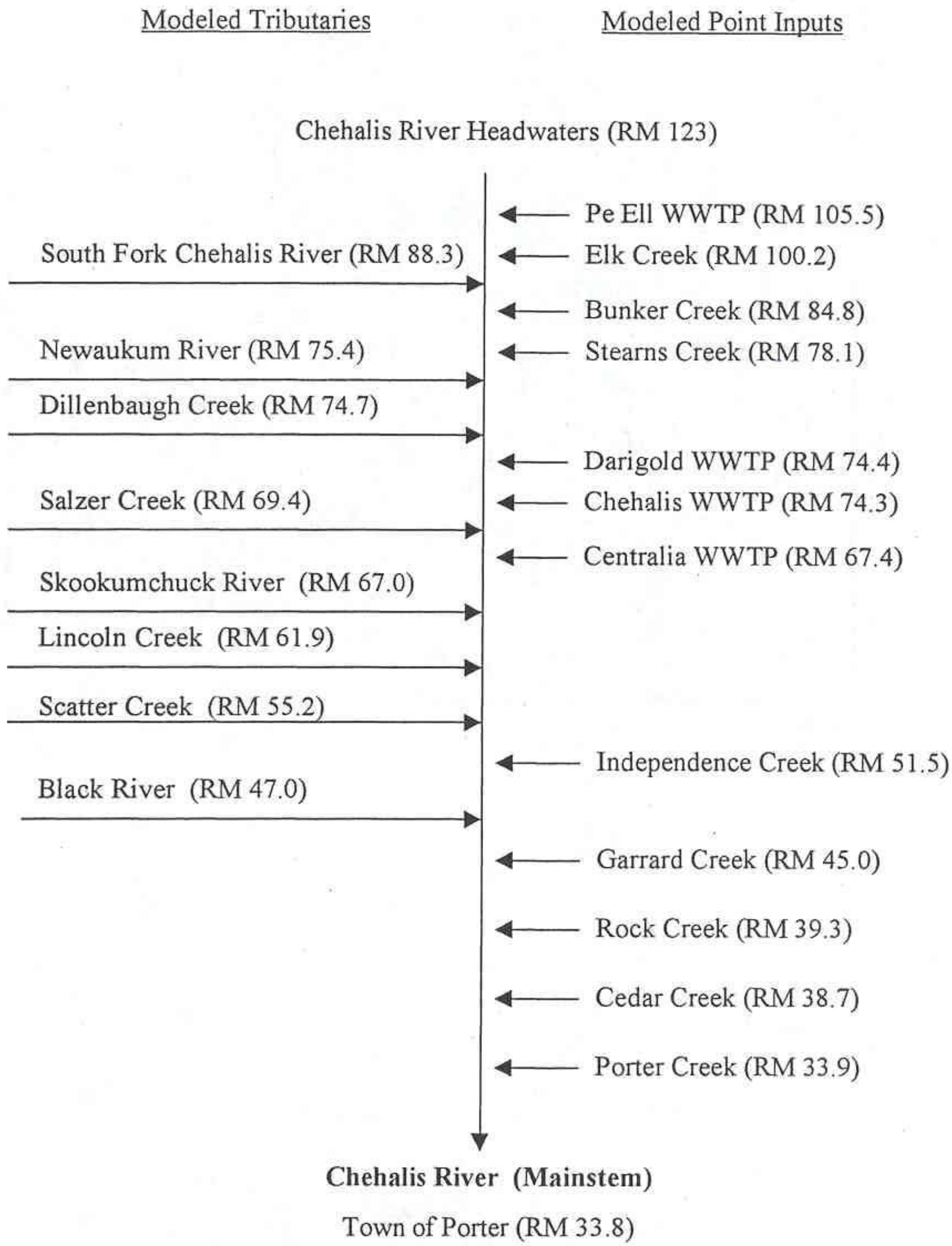

Study Area Location Map
Water Resource Inventory Area 23
Grays Harbor Co.
Thurston Co.
Lewis Co.
Pacific Co.
Wahkiakum Co.
Cowlitz Co.
Porter
Oakville
Centralia
Chehalis
Pe Ell
Porter Ck.
Cedar Ck.
Black R.
Scatter Ck.
Garrard Ck.
Independence Ck.
Lincoln Ck.
Bunker Ck.
Skookumchuck R.
Salzer Ck.
Newaukum R.
Stearns Ck.
S. Fork Chehalis
Elk Ck.
Chehalis R.
County Line
FIGURE 1

Figure 2. Schematic of the Stream Network Model Geometry



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Appendix A

Modeling Analysis Data

Table A1. Riparian Shade Data used for Model Calibration and Validation

Stream Segment Name	Median Width (ft)	Azimuth to due South (degrees)	Canopy Type	Riparian Canopy Type on Segment (%)	Modeled Shade for Canopy Type (%)	Overall Proportional Segment Shade (%)
Chehalis River - Headwaters to Elk Creek	44	5°	Mid- Seral Conifer	31%	68%	53%
			Early Seral Conifer	11%	57%	
			Hardwoods	42%	50%	
			Non-Forested Land	16%	30%	
Chehalis River - Elk Creek to Newaukum River	74	80°	Mid- Seral Conifer	6%	54%	18%
			Hardwoods	25%	23%	
			Non-Forested Land	69%	13%	
Chehalis River - Newaukum River to Skookumchuck River	77	0°	Non-Forested Land	100%	22%	22%
Chehalis River - Skookumchuck River to Town of Porter	130	-50°	Mid- Seral Conifer	1%	43%	16%
			Early Seral Conifer	1%	28%	
			Hardwoods	44%	20%	
			Non-Forested Land	54%	12%	

Table A1. Riparian Shade Data used for Model Calibration and Validation

Stream Segment Name	Median Width (ft)	Azimuth to due South (degrees)	Canopy Type	Riparian Canopy Type on Segment (%)	Modeled Shade for Canopy Type (%)	Overall Proportional Segment Shade (%)
Black River -	43	55°	Mid- Seral Conifer	4%	69%	37%
			Early Seral Conifer	7%	56%	
			Hardwoods	27%	47%	
			Non-Forested Land	62%	28%	
Dillenbaugh Creek	5	-70°	Mid- Seral Conifer	3%	83%	64%
			Hardwoods	47%	80%	
			Non-Forested Land	50%	47%	
Lincoln Creek	10	90°	Mid- Seral Conifer	11%	83%	59%
			Early Seral Conifer	2%	80%	
			Hardwoods	22%	80%	
			Non-Forested Land	65%	47%	
Newaukum River	15	-70°	Non-Forested Land	100%	43%	43%
Salzer Creek	6	-90°	Mid- Seral Conifer	3%	84%	68%
			Early Seral Conifer	1%	81%	
			Hardwoods	56%	82%	
			Non-Forested Land	40%	48%	
Scatter Creek	12	85°	Mid- Seral Conifer	5%	82%	69%
			Early Seral Conifer	6%	78%	
			Hardwoods	59%	78%	
			Non-Forested Land	30%	46%	

Table A1. Continued Riparian Shade Data used for Model Calibration and Validation

Stream Segment Name	Median Width (ft)	Azimuth to due South (degrees)	Canopy Type	Riparian Canopy Type on Segment (%)	Modeled Shade for Canopy Type (%)	Overall Proportional Segment Shade (%)
South Fork Chehalis River -	21	0°	Mid- Seral Conifer	9%	75%	52%
			Early Seral Conifer	3%	68%	
			Hardwoods	36%	65%	
			Non-Forested Land	52%	38%	
Skookumchuck River	22	70°	Mid- Seral Conifer	6%	78%	59%
			Early Seral Conifer	5%	71%	
			Hardwoods	57%	67%	
			Non-Forested Land	31%	39%	

Table A2. Instream Flow and Temperature Data used for Model Calibration and Validation

Description of Location	Model Node Type	River Mile	Calibration (August 1991		Validation (August 1992)	
			Modeled Flow (cfs) ①	Measured Temperature (°C) ③	Modeled Flow (cfs) ①	Measured Temperature (°C) ③
Pe Ell Wastewater Treatment Plan	Point	105.5	0.2	16.0 ⑧	0.1	15.6 ⑧
Elk Creek near Mouth	Point	100.2	29.0	14.7	29.9	17.2
South Fork Chehalis River near Mouth	Tributary	0	11.1	21.2	14.8	20.1
Chehalis River confluence with South Fork	Junction	88.3	66.3	20.1	66.1	19.7
Bunker Creek near Mouth	Point	84.8	1.3	15.2	0.3	17.5
Stearns Creek near Mouth	Point	78.1	3.1	15.2	3.6	18.0
Newaukum River near Mouth	Tributary	0	48.4	20.9	46.4	20.4
Chehalis River confluence with Newaukum	Junction	75.4	109.0	22.7	106.2	22.2
Dillenbaugh Creek near Mouth	Tributary	0	1.4	18.8	1.3	18.6
Chehalis River confluence with Dillenbaugh	Junction	74.7	110.2	22.1	110.0	21.8
Darigold Wastewater Treatment Plant	Point	74.4	0.4	25.5 ⑧	0.6	23.2 ⑧
Chehalis Wastewater Treatment Plant	Point	74.3	1.9	25.5 ⑧	0.7	23.2 ⑧
Salzer Creek near Mouth	Tributary	0	2.8	19.2	0.5	18.2
Chehalis River confluence with Salzer	Junction	69.4	125.8	20.2	111.0	24.4
Centralia Wastewater Treatment Plant	Point	67.4	2.3	24.2 ⑧	1.8	23.9 ⑧
Skookumchuck River modeled Headwater	Headwater	6.5	88.0 ⑤	14.9	54.0 ⑥	14.9 ④
Skookumchuck River near Mouth	Tributary	0	74.1	20.4	60.3	18.7
Chehalis River confl. With Skookumchuck	Junction	67.0	220.1	22.7	176.7	22.5

Table A2. Continued. Instream Flow and Temperature Data used for Model Calibration and Validation

Description of Location	Model Node Type	River Mile	Calibration (August 1991		Validation (August 1992)	
			Modeled Flow (cfs) ①	Measured Temperature (°C) ③	Modeled Flow (cfs) ②	Measured Temperature (°C) ③
Lincoln Creek near Mouth	Tributary	0	1.2	19.0	0.5	16.2
Chehalis River confluence with Lincoln	Junction	61.9	223.7	23.2	190.8	22.9
Scatter Creek near Mouth	Tributary	0	4.0	20.9	0.6	21.1
Chehalis River confluence with Scatter	Junction	55.2	297.7	21.3	203.9	20.8
Independence Creek near Mouth	Point	51.5	0.6	17.4	2.1	17.4
Balck River modeled Headwater O	Headwater	15.3	18.5	16.0	22.9	16.2
Black River near Mouth	Tributary	0	66.4	21.0	51.0	18.7
Chehalis River confluence with Black	Junction	47.0	372.8	22.5	286.4	19.5
Garrard Creek near Mouth	Point	45.0	3.9	18.3	5.0	15.9
Rock Creek near Mouth	Point	39.3	2.6	14.7	3.2	14.7
Cedar Creek near Mouth	Point	38.7	13.9	14:9	2.9	15.0
Porter Creek near Mouth	Point	33.9	12.8	14.5	11.4	14.5
Chehalis River at Town of Porter	End	33.8	412.6	19.8	312.8	21.2

① From Table C3 in Pickett (1994a)
② From Table G1 in Pickett (1994a)
③ From Tables D1 and F1 in Pickett (1994a). Mainstem temperature values used were the first downstream station measured from location of modeled node. Only surface temperatures were used where depth profile data were collected. The highest temperatures measured in the month were used if multiple dates were sampled.
④ Data from 1991 were used since no data were collected in 1992.
⑤ USGS measured flow was used from the same date (Aug. 27/91) as the temperature was measured.
⑥ USGS measured flow was used from the same day (Aug 27th) as the temperature measured the pervious year.
⑦ From Pickett (1994b)
⑧ Used the temperature of the river since wastewater discharge temperatures were not measured.

Table A3. Riparian Shade Estimates of Passive Restoration Strategy

Stream Segment Name	Median Width (ft)	Azimuth to due South (degrees)	Canopy Type	Riparian Canopy Type on Segment (%)	Modeled Shade for Canopy Type (%)	Overall Proportional Segment Shade (%)
Chehalis River - Headwaters to Elk Creek	44	5°	Late Seral Conifer	42%	72%	75%
			Late Seral Hardwoods	58%	77%	
Chehalis River - Elk Creek to Newaukum River	74	80°	Late Seral Conifer	6%	47%	53%
			Late Seral Hardwoods	94%	53%	
Chehalis River - Newaukum River to Skookumchuck River	77	0°	Late Seral Hardwoods	100%	64%	64%
Chehalis River - Skookumchuck River to Town of Porter	130	-50°	Late Seral Conifer	2%	46%	47%
			Late Seral Hardwoods	98%	47%	

__Table A3 Continued.__ Riparian Shade Estimates of Passive Restoration Strategy

Stream Segment Name	Median Width (ft)	Azimuth to due South (degrees)	Canopy Type	Riparian Canopy Type on Segment (%)	Modeled Shade for Canopy Type (%)	Overall Proportional Segment Shade (%)
Black River	43	55°	Late Seral Conifer	11%	71%	75%
			Late Seral Hardwoods	89%	76%	
Dillenbaugh Creek	5	-70°	Late Seral Conifer	3%	81%	85%
			Late Seral Hardwoods	97%	85%	
Lincoln Creek	10	-90°	Late Seral Conifer	13%	80%	84%
			Late Seral Hardwoods	87%	85%	
Newaukum River	15	70°	Late Seral Hardwoods	100%	78%	78%
Salzer Creek	6	-90°	Late Seral Conifer	4%	83%	85%
			Late Seral Hardwoods	96%	85%	
Scatter Creek	12	85°	Late Seral Conifer	11%	82%	85%
			Late Seral Hardwoods	89%	85%	
South Fork Chehalis River	21	0°	Late Seral Conifer	12%	78%	82%
			Late Seral Hardwoods	88%	83%	
Skookumchuck River	22	70°	Late Seral Conifer	11%	76%	81%
			Late Seral Hardwoods	89%	82%	

Appendix B

Previous TMDL Submittal

"Upper Chehalis River Basin Temperature Total Maximum Daily Load"
September 1999. Water Quality Publication Number 99-52
Available at www.ecy.wa.gov/biblio/9952wq.html
or
Paper copy available upon request

Appendix C

Public Notice Materials

Published in the Chehalis River Council's "Drops of Water" March 2001

Public Comment Invited

The public is invited to comment on a newly revised Department of Ecology water cleanup plan for the Upper Chehalis watershed called the Upper Chehalis River Basin Temperature Total Maximum Daily Load.

The plan addresses both point (specific points of discharge such as the end of a pipe) and nonpoint (numerous and diffuse) sources of temperature pollution. It proposes that the primary nonpoint cause of the temperature problem is a decrease in shade due to inadequate streamside (riparian) vegetation. Agricultural activities, residential and urban development, and forest practices are also contributing to degraded riparian conditions. In addition, point sources from municipal and industrial wastewater treatment systems are contributing heat to the river system.

A water cleanup plan describes ways that the impaired water will attain water quality in order to protect beneficial uses of the water. It includes a technical study that assesses the water quality problems and the pollutant sources that cause the problem. It also determines the amount of a given pollutant a water body can assimilate and still support beneficial uses (called the iloadi), and allocates the load among the various sources.

The Upper Chehalis River Basin Temperature TMDL was originally presented for public comment and submitted to EPA in 1999. Technical issues raised during review have resulted in changes to the original study and recommendations. The changes are substantial enough that we are asking for additional public comment. The primary revisions in the current version are:

Adjustments to the waste load allocations for point source discharges, resulting in more stringent requirements for municipalities and industries who discharge into the river, and Changes in the Summary Implementation Strategy section to incorporate the new Washington State Forest Practice Regulations (referred to as the Fish and Forest agreement, or F&F).

These regulations, adopted by the Forest Practices Board in 2000, are designed to address impacts caused by forest harvesting activities on water quality and fish and wildlife habitat. F&F allows for the delay of some forest practices-based TMDLs. However, initial development of this TMDL predates F&F by several years and the allocations are necessary to address all the sources/causes of temperature problems in the Upper Chehalis River system. Consistent with the F&F agreement,

implementation of the load allocations established in this TMDL for private and state forestlands will be accomplished via implementation of the revised forest practice regulations as they apply to strewn buffers and harvest in the riparian area.

Upper Chehalis River Basis Temperature TMDL

Water temperatures in some areas of the Upper Chehalis River Watershed have become so warm during June and July that all the expected life-cycle stages of salmon, steelhead, and trout cannot be sustained. In some cases, temperatures are so warm that they can be lethal for these species.

Temperature problems have been documented in the Black River, the mainstem Chehalis, the south fork of the Chehalis, Dillenbaugh Creek, Lincoln Creek, Newaukum, River, Salzer Creek, Scatter Creek and the Skookumchuck River.

Temperature data show a definite pattern of seasonal variation. Most of the year temperature water quality standards are met. The critical period for temperature in the Upper Chehalis River Basin is in the months of June and July, when flows are lowest.

Several point source discharges enter the river in areas routinely documented as too warm, especially during the critical summer low-flow period. Since we can't count on human actions to reduce the nonpoint effects on the river quickly enough, the cleanup plan proposes that these municipal and industrial discharges be reduced to zero during the critical low-flow period.

For nonpoint sources the study recommends that, first, the existing riparian vegetation must be maintained and allowed to reach old growth stage without replacement. In addition, some sort of restoration will be needed to achieve the required shade levels. Reaches that are now devoid of trees should be planted to help achieve the higher density for these lands. The predicted result of this passive restoration approach would be that all impaired areas of the streams meet temperature standards by the time existing vegetation reached old growth stage.

The Upper Chehalis River Basin T`MDL addresses some fisheries concerns resulting from water temperature increases. The streams of the basin support bulltrout as well as substantial runs of anadromous fish and support commercial, sport, and tribal fisheries. The U.S. Fish and Wildlife Service has identified bull- trout as a threatened species under the federal Endangered Species Act (ESA). Excessive summer water temperatures in several Upper Chehalis River Basin streams may in part be causing impairment of the beneficial uses of the bulltrout and other salmonids by reducing spawning and rearing habitat.

Public Comment Invited

You are invited to comment on the Upper Chehalis River Basin Temperature Total Maximum Daily Load through March 16, 2001. Please submit comments to Dave Rountry, Department of Ecology, PO Box 47775, Olympia WA 98504-7775. Or e-mail drou461 @ecy.wa.gov

You can review the Upper Chehalis River Basin Temperature TMDL on the Internet at http://www.ecy.wa.gov/programs/wq/tmdl/tmdls-review.html There are also hard copies available for review at the Centralia Timberland Library, 110 S. Silver Street, and at the Olympia Timberland Library, 313 8th Avenue SE.

For more information call Dave Rountry at (360) 407-6276.

Chehalis Basin Partnership

Meeting Summary-February 23, 2001

A. GENERAL PARTNERSHIP BUSINESS

Temperature Total Maximum Daily Load (TMDL)

Portions of the upper Chehalis River (WRIA 23) and many of its tributaries don't meet the state's Water Quality Standards for temperature during the summer months. Under the federal Clean Water Act, when violations of the water quality standards occur the State Department of Ecology is required to study the problem and submit a plan to EPA that will correct the violations of the water quality standards. The federal Clean Water Act calls this package (the study and corrective action plan) a Total Maximum Daily Load or TMDL.

Computer modeling of flow, channel shape, and shade has determined that the amount of solar radiation reaching the water is the primary factor responsible for increasing water temperatures above natural conditions. The modeling shows that the only really effective way to reduce water temperatures is to increase the amount of riparian shade. The draft TMDL identifies segments of the upper Chehalis Basin where water temperatures violate the water quality standards, shows how much water temperatures must be reduced in each of those segments to meet the standards, and sets targets for how much shade must be established to bring about those temperature reductions.

The draft TMDL recommends that a combination of passive restoration - letting trees grow to maturity where they exist - and active restoration - tree planting - be used to achieve the levels of riparian shade necessary to reduce water temperature. The draft TMDL recognizes the effects of river flow on temperature, and recommends that if flows can't be increased from current levels, they at least be protected from further reduction. The draft TMDL also recognizes that restoring shade in the riparian zone won't happen immediately. It establishes a goal of reaching the recommended shade levels by 2065, with an evaluation of progress every five years until then. A detailed implementation plan establishing exactly what must be done, who will be involved, and the schedule for completing the work is required. The draft TMDL recommends that the detailed implementation plan be done in conjunction with the Watershed Planning the Partnership has agreed to do.

A public review and comment period for this TMDL is open through March 16, 2001. The Department of Ecology encourages anyone affected by, or concerned about, the issues raised in this TMDL to express their thoughts and concerns. Each comment received during the public review and comment period will be responded to in the final TMDL that is submitted to the U.S. EPA for approval.

Published in State Register

JANUARY 30, 2001

PUBLIC COMMENT PERIOD ON THE TOTAL MAXIMUM DAILY LOAD (TMDL) STRATEGY FOR REDUCING WATER TEMPERATURE IN THE UPPER CHEHALIS RIVER

Water temperatures in many areas of the Upper Chehalis River Watershed (upstream from Porter) have become too warm during the dry summer months to sustain all the expected life-cycle stages of cold water fish. including salmon, steelhead, and trout.

This is a violation of state water quality standards. When this occurs, the Federal Clean Water Act requires that the State develop strategies called Total Maximum Daily Loads (TMDLs) to reverse these conditions and restore water temperatures to levels that will sustain the cold water fish that still survive in the Upper Chehalis River system.

In 1999 the Department of Ecology developed a TMDL for reducing water temperature in the Upper Chehalis River. The TMDL was presented for public comment, and submitted to EPA. Technical issues raised during review resulted in changes to the original TMDL and its recommendations. The changes are substantial enough that Ecology is asking for additional public review and comment before submitting the TMDL to EPA for final approval.

The primary changes in the current draft are:

- Adjustments to the waste load allocations for point source discharges, resulting in lower temperature limits for some municipalities and industries that discharge into the river, and;

- Changes in the section of the TMDL 'Summary Implementation Strategy' that discusses requirements of the Washington State Forest Practices Regulations.

You are invited to comment on this draft TMDL and its recommendations through March 16, 200 1. Please submit comments to Dave Rountry, Department of Ecology, PO Box 47775, Olympia WA 98504-7775. Or email drou461@ecy.wa.gov

You can review the draft Upper Chehalis River Basin Temperature TMDL on the Internet at http://www.ecy.wa.gov/programs/wq/tmdl/tmdls-review.html There are also hard copies available for review at the Centralia Timberland Library, 110 S. Silver Street. and at the Olympia Timberland Library, 313 8th Avenue SE.

For more information call Dave Rountry at (360) 407-6276.

February 7, 2001

Dr. C.S. Sodhi, Ph.D.
Director, Department of Natural Resources
Confederated Tribes of the Chehalis Reservation
P.O. Box 536
Oakville, WA 98568

Dear Dr. Sodhi:

In 1999 the Department of Ecology developed a Total Maximum Daily Load (TMDL) for reducing water temperature in the Upper Chehalis River. The TMDL was presented for public comment, and submitted to EPA.

Technical issues raised during Ecology's review of the TMDL with EPA resulted in changes to the original TMDL and its recommendations. The changes are substantial enough that Ecology is asking for additional public review and comment before submitting the TMDL to EPA for final approval.

The primary changes in the current draft are:

- Adjustments to the waste load allocations for point source discharges, resulting in lower temperature limits for some municipalities and industries that discharge into the river, and:
- Changes in the section of the TMDL 'Summary Implementation Strategy' that discusses requirements of the Washington State Forest Practices Regulations.

Enclosed is a copy of the revised draft Temperature TMDL. You are invited to comment on this draft TMDL and its recommendations through March 16, 2001. Please submit comments to Dave Rountry, Department of Ecology, PO Box 47775, Olympia WA 98504-7775. Or email drou461@ecy.wa.gov

You can review the draft Upper Chehalis River Basin Temperature TMDL on the Internet at http://www.ecy.wa.gov/programs/wq/tmdl/tmdls-review.htm Hard copies of the TMDL are also available for review at the Centralia Timberland Library, 110 S. Silver Street, and at the Olympia Timberland Library, 313 8th Avenue SE.

For more information you can contact me at (360) 407-6276.

Sincerely,

Dave Rountry

Dave Rountry
Water Quality Program

DR:jr
Enclosure

The above letter was also sent to the following:

Kevin Godbout, Weyerhaeuser Company

Joe Muller, West Farm Food

Dave Palmer, Chehalis River Council

Dick Southworth, City of Centralia

Molly Hemmen, Preston Gates & Ellis LLP

James Nichols, City of Chehalis

Christine Psyk, US EPA Region 10

March 2, 2001

Mr. Joseph L. Muller
Director of Regulatory Compliance
WestFarm Foods
P.O. Box 79007
Seattle, WA 98119-7907

Dear Mr. Muller:

The enclosed letter announcing the public comment period for the draft Upper Chehalis River Temperature TMDL was mailed to you on February 8th. Unfortunately, it was mailed to a non-existent address. I only became aware of the situation this week.

This TMDL will affect temperature limits in the NPDES permit for WestFarm Foods. However, the land application discharge alternative that WestFarm Foods agreed to in the consent decree negotiated with Ecology for the Dissolved Oxygen TMDL will also meet the requirements of this Temperature TMDL.

Dave Rountry is the Water Quality Program's lead on this TMDL, however since Dave was not involved in the preparation of the TMDL or the negotiations for the consent decree on the Dissolved Oxygen TMDL, I have agreed to serve as the contact for technical questions.

Because of the delay in getting the information on this draft TMDL to you, I have enclosed two copies of the document to expedite your review and comment. If you have any questions on the document I can be reached at (3 60) 407-6310.

Sincerely,

Kahle Jennings
Shorelands and Environmental Assistance

KJ:bl

Legal # 3552

Affidavit of Publication

Legal #3552
Department of Ecology Requests Public Comment On Water Temperature Strategy for the Upper Chehalis River
Water temperature in many areas of the Upper Chehalis River Watershed (upstream from Porter) have become too warm during the dry summer months to sustain all the expected life-cycle stages of cold water fish, including salmon, steelhead, and trout.
This is a violation of state water quality standards. The Federal Clean Water Act requires the state to develop strategies to reverse these conditions and restore temperatures to levels that will sustain the cold water fish that still survive in the Upper Chehalis River system.
The Department of Ecology has developed a **draft** Total Maximum Daily Load (TMDL, or water cleanup plan) for water temperature in the Upper Chehalis River. This study evaluates water temperatures and makes recommendations about what must be done to reduce those temperatures to levels that will sustain all life-cycle stages of cold water fish.
This study was originally presented for public comment and submitted to EPA during 1999. Technical issues raised during review and subsequent changes to closely related regulations have resulted in changes to the original study and recommendations. The changes are substantial enough that we are asking for additional public comment.
The primary changes in the current draft are:
* Adjustments to the waste load allocations, resulting in more stringent requirements for municipalities and industries who discharge into the river, and
* Changes in the Summary Implementation Strategy section to incorporate the new Forest and Fish regulations.
You are invited to comment on this draft study and recommendations through March 16, 2001. Please submit comments to Dave Rountry, Department of Ecology, PO Box 47775, Olympia, WA 98504-7775. Or email drou461@ecy.wa.gov
You can review the Upper Chehalis River Basin Temperature TMDL on the Internet at http://www.ecy.wa.gov/programs/wq/tmdl/tmdls-review.html There are also hard copies available for review at the Centralia Timberland Library, 110 S. Silver Street, and at the Olympia Timberland Library, 313 8th Avenue SE.
For more information call Dave Rountry at (360) 407-6376.

Publish: January 30, 2001

NGTON
County
ss.

The undersigned being first duly sworn on oath deposed and says: That she is the Principal Clerk of The Olympian which is a legal newspaper printed and published in the City of Olympia, Thurston County, Washington: of general circulation in said City, County and State;
that the Request for public comment
in the case of water temperature
Strategy for upper Chehalis River
of which the attached is a printed copy, was published in said newspaper:

On the 30th day of January 2001
the ______ day of ______ 2001
the ______ day of ______ 2001
the ______ day of ______ 2001
the ______ day of ______ 2001
the ______ day of ______ 2001
the ______ day of ______ 2001

that the said newspaper was generally circulated during all of said time, and has been published for more than six months prior to the dates of the publication of this legal document, and that said notice was published in the newspaper proper and not in supplement form.

The amount of fee charged for this publication $155.53

Faith Richard
Principal Clerk

Subscribed and sworn to me this 30th day of January 2001.

Martha L. Hogan
Notary Public in and for the State of Washington residing at Olympia, Thurston County, Washington

MARTHA L. HOGAN
COMMISSION EXPIRES
NOTARY
PUBLIC
MARCH 18, 2001
STATE OF WASHINGTON

...inted as a legal ...perior Court of ...urston County, ...inty in which ... accordance ...63.16.040.

Note - The above affidavit and fee is in compliance with RCW 63.16.030 and Sec. 3, Chapter 34, Laws of 1977.

AFFIDAVIT OF PUBLICATION

STATE OF WASHINGTON
COUNTY OF LEWIS } SS

Jeanne Rudeen, says that she is the legal clerk of

The Chronicle

a daily newspaper, which has been established, published in the English language, and circulated continuously as a daily newspaper in the City of Centralia, and in said County and State, and of general circulation in said county for more than six (6) months prior to the date of the first publication of the Notice hereto attached, and that the said Chronicle was on the 7th day of July 1941, approved as a legal newspaper by the Superior Court of said Lewis County.

And that the attached is a true copy and was published in regular issues (and not in supplement form) of said newspaper as Legal # 0158,

once each day for a period of 1

~~consecutive~~ day,

commencing on the

30th day of January, 2001

and ending on the

30th day of January, 2001, and both dates inclusive, and that such newspaper was regularly distributed to its subscribers during all of said period. That the full amount of the fee charged for the foregoing publication is the sum of

$ 78.65 .

Jeanne Rudeen

Subscribed and sworn to before me this

2 day of Feb, 2001.

Linda R. Stewart

Notary Public in and for the State of Washington, residing at

Centralia

Department of Ecology requests public comment on Water Temperature Strategy for the Upper Chehalis River

Water temperatures in many areas of the Upper Chehalis River Watershed (upstream from Porter) have become too warm during the dry summer months to sustain all the expected life-cycle stages of cold water fish, including salmon, steelhead, and trout.

This is a violation of state water quality standards. The Federal Clean Water Act requires the state to develop strategies to reverse these conditions and restore temperatures to levels that will sustain the cold water fish that still survive in the Upper Chehalis River system.

The Department of Ecology has developed a draft Total Maximum Daily Load (TMDL, or water cleanup plan) for water temperature in the Upper Chehalis River. This study evaluates water temperatures and makes recommendations about what must be done to reduce those temperatures to levels that will sustain all life-cycle stages of cold water fish.

This study was originally presented for public comment and submitted to EPA during 1999. Technical issues raised during review and subsequent changes to closely related regulations have resulted in changes to the original study and recommendations. The changes are substantial enough that we are asking for additional public comment.

The primary changes in the current draft are:

- Adjustments to the waste load allocations, resulting in more stringent requirements for municipalities and industries who discharge into the river, and
- Changes in the Summary Implementation Strategy section to incorporate the new Forest and Fish regulations.

You are invited to comment on this draft study and recommendations through March 16, 2001. Please submit comments to Dave Rountry, Department of Ecology, PO Box 47775, Olympia WA 98504-7775. Or email drou461@ecy.wa.gov.

You an review the Upper Chehalis River Basin Temperature TMDL on the Internet at http://www.ecy.wa.gov/programs/wq/tmdl/tmdls-review.html. There are also hard copies available for review at the Centralia Timberland Library, 110 S. Silver Street, and at the Olympia Timberland Library, 313 8th Avenue SE.

For more information call Dave Rountry at (360) 407-6376.

L#0158 January 30, 2001

Appendix D

Response to General Comments and Correspondence

Responsiveness Summary for the Proposed "Upper Chehalis River Basin Temperature Total Maximum Daily Load"

The public comment period for this proposed TMDL opened on January 30th, 2001. Legal advertisements were published in the *Centralia Chronicle* and the *Olympian* on 1/30/01. An article about the proposed changes was published in the March 2001 issue of *Drops Of Water* (a newspaper insert published by the Chehalis River Council that is delivered to approximately 40,000 newspaper recipients in the Chehalis Basin). Additional invitation for public comment was provided via:

- Public notice in the State Register (therefore also sent to the associated list serve).
- An article describing the TMDL including some of the key changes, and notifying people of the comment period in *Drops of Water*. This is a newspaper insert periodical, produced by the Chehalis River Council - a sort of newsletter of water related issues in the Chehalis basin. It is inserted into several newspapers that serve the basin, and has a circulation of approximately 40,000.
- Notice of the TMDL comment period mailed to the Chehalis Basin Partnership mailing list (approximately 170). This is a local coordinating council for water-related issues.
- A presentation on the TMDL to the Chehalis Basin Partnership.
- Mailings on February 8th, 2001 to eight selected primary interests

The comment period closed on March 16, 2001

The following people provided comments:

Marcy Golde, Board Member
Washington Environmental Council

James Nichols, P.E., Director
City of Chehalis Public Works

Dick Southworth, Utilities Director
City of Centralia Utilities

Ann Goos, Director of Environmental Affairs
Washington Forest Protection Association

Kevin Godbout, Director of External and Regulatory Affairs
Weyerhaeuser

Joseph Muller, Director of Regulatory Compliance
WestFarm Foods

John Sims, Manager, Department of Natural Resources
Quinalt Indian Nation

Several comment themes emerged, and where it was practical to do so, responses have been prepared to align with those themes.. However, several of the comments and questions received do not fit well into the themes of categorical comments. Appendix D includes all the correspondence received during the public comment period, and responses to unique comments raised.

1) Should the existing Forest and Fish Agreement process be expected or relied upon to achieve temperature remedies?

Timber harvesting conducted on state and private forest lands are regulated under the Forest Practices Act. The Act and associated rules have been updated pursuant to the Forest and Fish Report (FFR). . Development of this TMDL utilized the best information available at the time. The "adaptive management" approach of FFR being developed for forest harvesting activities is expected to verify over time if the TMDL allocations are being met by FFR prescriptions. Federal forest lands are expected to meet or exceed TMDL allocations using strategies recommended by the Federal Ecosystem Management Assessment Team and incorporated within the Northwest Federal Forest Plan.

The Summary Implementation Strategy (SIS) identifies many activities that are underway or planned for restoring riparian shade and habitat. Other than forest harvesting activities most of these are voluntary. Ecology acknowledges that establishing necessary shade on agricultural and other private lands will be a considerable effort and take a long period of time and there is always uncertainty associated with totally voluntary implementation by landowners.

2) Does the TMDL provide Reasonable Assurance of Success?

The important point with this TMDL is that temperature will be reduced by increasing riparian shading. Ecology agrees that the standard may not be met for some stream reaches during some critical conditions, (bottom of page 29 of TMDL report). Accordingly, wasteload allocations for the point-source dischargers into stream segments having no assimilative capacity were established as zero during critical warm water conditions (page 25 of TMDL submittal report). This allocation strategy is consistent with guidance from EPA (The TMDL Process, 1991 guidance).

The strategy is to permit the facilities so that they meet the temperature criteria for the river, and collectively do not allow a cumulative increase of more than 0.3 degrees C.

The approach of this TMDL is one of adaptive management. If monitoring documents that riparian shade or stream channel and flow improvements do not help achieve standards then allocations or the standard itself will be reevaluated. The time needed to achieve a healthy riparian cover will allow ample opportunity to evaluate effectiveness and make adjustments if necessary.

Ecology agrees that it may take more than 65 years for landscape changes to allow the river to achieve temperature standards. This is partly because the ambient temperature of the water during the critical period is generally warmer than the criteria of 18 degrees. Increases in shade in the non-point areas will occur through voluntary action, and in forested areas via compliance with the forest practices rules.

3) The TMDL should account for an analysis of flows, water withdrawals, and propose other controls besides shade.

Best available information about river flows, water usage/withdrawal was applied to an analysis of flow rates (Wildrick et.al 1995, bottom paragraph page 21 of the TMDL report). Additional calculations of critical low-flows, based on width/depth ratios, are described on pages 15 and 16 of the TMDL report.

Water withdrawal was factored into calculation of the river sensitivity to temperature, and setting of the load allocations. Pages 24 and 25 of the TMDL report discuss water withdrawals, sediment delivery and other factors affecting temperature. Pages 24 and 25 conclude that any additional water withdrawals must not be allowed during critical low-flow periods, and that activities that increase the temperature, reduce the flow, or impact the stream channel forming processes must be prevented… More explanation is provided below about the coordination of water flow and quality analyses.

Active monitoring is required as an element of the NPDES permits, and the F/F Agreement. A Memorandum of Agreement (MOA) was established between the US EPA and the Department of Ecology regarding the implementation of Section 303(d) of the Federal Clean Water Act. The MOA calls for completion of a detailed implementation plan (DIP)one year after the (current) summary implementation strategy is approved. Ecology has recommended that the DIPs for each of the TMDLs in the Chehalis watershed be completed in an integrated fashion in collaboration with the Chehalis Basin Partnership. The Partnership is funded and equipped to conduct systemmatic planning for water quality, water quantity/usage, and fish habitat concerns. A more integrated approach to detailed planning by the Partnership will assure a more complete and integrated detailed plan, on a 'wholistic' scale with higher likelihood for success.

4) Shouldn't this temperature TMDL reference or integrate with other TMDLs already issued for the Chehalis watershed?

Financial planning for TMDL projects and TMDL workload statewide best fit a schedule for concluding the TMDLs on a more systematic basis. In the case of temperature TMDLs, the causes and hence prescriptions do not correlate closely with those of other impairments (like toxics, bacteria, or pH for instance).

As mentioned in the response to comment 3 above, there is an expectation that the Chehalis Basin Partnership will help provide systemmatic planning for water quality, water quantity/usage, and fish habitat concerns. This approach will help provide integration of the various TMDLs in the Chehalis basin.

5) Does the TMDL reflect an appropriate level of Margin-of-Safety, i.e, are considerations used in the modeling too conservative? Could a more refined and detailed modeling effort be used to more accurately characterize the actual watershed conditions-and therefore reduce the margin-of-safety needed?

The technical analysis to determine load allocations used a series of conservative assumptions for several reasons. The margin-of-safety(MOS) chosen must correlate to the level of uncertainty in accounting for the actual (i.e., natural ecological conditions and processes) *conditions in the watershed. In a river system of the size and complexity of the Chehalis where there is significant variability in the natural conditions (flow, depth, groundwater recharge, vegetation canopy classification, effective tree shade, etc.,) there is less certainty in predicting the outcomes of proposed temperature controls. The TMDL statute provides that more conservative assumptions are necessary in this case to compensate for the uncertainty of the predictive modeling. The MOS approach taken is also consistent with other TMDLs completed by Ecology.*

A more refined and costly approach to modeling might have been done for his TMDL. However, given the significance of the temperature impairment in the upper Chehalis, The added work would not have been reasonable because it wouldn't have changed the prescription. In order to achieve the state water quality standard the river system needs as much shade as can be possibly provided.

6) Ecology has failed to follow the letter of the carefully drafted MOA with the Environmental Protection Agency.

Ecology has made a best-faith effort to complete this TMDL effort according to the intent of the MOA.

a.)TIMELINE FOR TMDLS Remedies are already being implemented for reducing non-point heat loading. This is being accomplished initially via the emergency forest practices rules and now through the newly adopted permanent rules resulting from the forest and fish report. Adaptive management strategies and forest practices rules provide reasonable assurance that the protective strategies will be monitored, and if not effective, adjusted to become effective. For point source controls, several years are typically needed for the municipalities to obtain funding, develop facility plans, and construct facility improvements. Ecology's permit review and approval process is conducted on a 5-year frequency cycle to balance workload and human resource planning on a statewide level..

b.) PUBLIC INVOLVEMENT: The Water Quality program is working to improve the way we do public involvement. We typically maintain, and actively update mailing lists for each separate TMDL project. Based on comments received on this TMDL from outside the geographic scope of the project area, we have added several new names to the project mailing list. We did the following outreach for the public comment period for the Chehalis Temperature TMDL:

- *Legal advertisement in the Olympian and the Centralia Chronicle.*
- *Public notice in the State Register (therefore also sent to the associated list serve).*
- *An article describing the TMDL including some of the key changes, and notifying people of the comment period in 'Drops of Water'. This is a newspaper insert periodical, produced by the Chehalis River Council - a sort of newsletter of water related issues in the Chehalis basin. It is inserted into several newspapers that serve the basin, and has a circulation of approximately 45,000.*
- *Notice of the TMDL comment period mailed to the Chehalis Basin Partnership mailing list (approximately 170). This is a local coordinating council for water-related issues.*
- *A presentation on the TMDL to the Chehalis Basin Partnership.*
- *The review document was accessible on Ecology's internet pages, and copies were placed at all Timberland Regional Public Library locations throughout the watershed.*
-

All information about the TMDL is available to anyone who wishes it. Hard copy files are *always accessible and available to the public. Often times the appendices and data details are voluminous, cumbersome for the typical audience to read and so are not always part of what is initially sent for public review. As we continue to expand use of electronic media for information transmittal, we try to anticipate and provide the appropriate level of detail for our primary audience.*

7) Could Reference Watershed Conditions have been identified, to better determine natural background conditions?

No such reference watershed could be found which might be absent of human influence and have only natural background conditions. The approach of this TMDL is to prescribe allocations that should restore temperatures close to those that existed before human influences on receiving waters. Thereafter, monitoring and appropriate refinement of corrective actions will help maintain needed temperature controls.

8) The relative error shown on the last row of Table 5 on page 14, is 13%. Is this relative error plus/minus 13% or plus/minus 6.5%?

The value reported is a total relative error of 16% (plus or minus 8%).
The 13% figure originally published in Table 5 did not agree with the text. That error has been corrected to 16%.

9) Additional comments provided in Appendix D

Several of the comments and questions received do not fit well into the themes of categorical comments addressed above. Appendix D includes all correspondence received during the public comment period. Ecology responses to the additional unique comments are incorporated within the correspondence in Appendix D.

This letter was scanned so responses could be incorporated under each comment

City of Centralia Utilities

March 16, 2001

Mr. Kahle Jennings
Washington State Department of Ecology
Water Quality Program
P.O. Box 47600
Olympia, WA 980505-7600

Subject: Review Comments on Upper Chehalis River Basin Temperature Total Daily Maximum Load Revised November 2000

Dear Kahle:

We appreciate this opportunity to comment on the November 2000 Upper Chehalis River Basin Total Daily Maximum Load report. The City of Centralia is committed to improving water quality in the Chehalis River as demonstrated by our efforts to implement a new wastewater treatment plant, but we find the temperature effluent requirements for point source discharges troubling. Our comments and requested changes are summarized below:

1. We are unclear of the authority used by Ecology to develop the discharge limits for the point source discharges. We request that Ecology clarify this.

   ***Response*: Temperature is defined as a pollutant for which state water quality standards exist, (Chapter 173-201 A WAC). The Department of Ecology is authorized to administer the NPDES permit program, to include permit limits for temperature as well as other pollutants in order to assure that water quality standards are attained, (Chapter 173-220 WAC).**

2. We believe Ecology has erred basing the point source discharger on the 18.0 C Class A water quality standard. We request Ecology use existing Chehalis River temperatures and the WAC 173-201A temperature criteria for Class A waters.

***Response*: The temperature criterion for Class "A" waters in the Washington State Water Quality Standards (Ch. 173-201A WAC) states "Temperature shall not exceed 18.0C (freshwater) ... due to human activities. When natural conditions exceed 18°C (freshwater) …, no temperature increases will be allowed which will raise the receiving water temperature by greater than 0.3°C."**

Computer modeling always contains a degree of uncertainty, which is accounted for by incorporating a margin of safety. Modeling of Chehalis River temperatures shows that the most important factor affecting water temperature is riparian shade. However, other conditions such as river flow, channel shape and point source discharges do have an affect. Allowing for the uncertainty in the results of computer modeling. Ecology believes that the

allocations for nonpoint and point sources contained in this TMDL, if implemented, should restore temperatures close to those that existed prior to human influences on receiving waters. Because of this Ecology has concluded that the "natural conditions" provisions in the water quality standards criterion for temperature does not apply and point source dischargers will be limited to a temperature that would not cause the 18°C criterion to be exceeded. Taking this conservative approach helps build in some margin of safety.

3. We believe that Ecology has erred requiring point source dischargers to study and meet the NPDES permit in the next permit cycle. We request Ecology implement point source discharge limits after the nonpoint shade controls have improved water temperatures and then base the limits on actual Chehalis River temperatures.

Response: ***The critical period for point sources in the November 2000 version of the Upper Chehalis River Basin Temperature TMDL was modified from the previous version to be consistent with the critical period agreed to in the consent decree settling the lawsuit over the Upper Chehalis River Dissolved Oxygen TMDL. This could be done because the critical period for the two TMDLs overlaps. EPA "Guidance For Water Quality-Based Decisions: the TMDL Process" (EPA, 1991), requires that when the state cannot provide reasonable assurance that the required level of nonpoint source pollution reduction can be achieved, wasteload allocations for point sources must be established at a level that provides the maximum amount of resource protection. Computer modeling predicts that achieving the recommended levels of riparian shade should restore water temperatures close to the 18°C temperature criterion. However, the state does not by itself have sufficient resources to ensure that all land owners along the river will take the necessary actions to meet the shade requirements . Under these conditions, the state cannot provide EPA with reasonable assurance that the nonpoint source controls necessary to restore water temperatures will be achieved. Therefore, consistent with EPA's policy cited above, this temperature TMDL establishes a temperature wasteload allocation for point sources of zero. A temperature wasteload allocation of zero means that point sources will not be allowed to discharge any heat to the system above 18°C.***

To provide some flexibility to existing point source dischargers, Ecology has chosen to apply the standard permitting practice of applying the wasteload allocation at the edge of an authorized mixing zone for existing point source discharges. Any new point source discharges will have to meet the 18°C temperature criterion at the end of pipe.

4. We are unclear of the discharge limits on page 26. We request that Ecology clarify this.

Response: The City of Centralia's current outfall location and the proposed location of its new treatment facility below the Skookumchuck River are both in areas of the Chehalis River where temperatures have been documented to exceed the 18°C criterion. The temperature wasteload allocation for Centralia at both these locations is zero. Under this TMDL the City of Centralia cannot discharge effluent from either outfall at a temperature that would cause river temperature to increase more than 0.3°C above river temperature as measured upstream of the outfall. The point of compliance for this discharge limit is the edge of an authorized mixing zone.

This discharge limit was developed in recognition of the fact that river temperatures currently exceed the 18°C criterion and that the major contributing environmental condition is a lack of

riparian shade. As nonpoint source controls take effect riparian shade will increase and river temperatures are expected to decline. Centralia's discharge limit was developed to ensure that the temperature of Centralia's effluent will decline over time in proportion to declines in river temperatures as nonpoint source controls (increased shade) take effect.

We'd like to begin by summarizing our understanding of your report. First, your report appears to conclude that the Chehalis River "natural temperatures are in excess of the 18 degrees C water quality standard (page 15). Second, the report states that the entire heat load has been allotted to nonpoint sources (page 25). As a result, the wasteload allocation to Centralia is zero and Ecology has developed a new discharge criteria that we aren't sure how to interpret (page 28). Finally, in review of our new NPDES permit, it is our understanding that we, as part of the new wastewater treatment plant certification process, will have to perform studies and comply with the temperature TMDL in its next permit, even though the nonpoint shade controls will require 60 to 150 years to reach maturity (page 31) and then does not appear to meet the 18' C temperature water quality standard (page 30).

The report does not provide the authority by which Ecology has developed these new temperature criteria for point source discharges. We have reviewed the report and WAC 173-201A and are unclear how Ecology arrived at the regulatory position it did for the point source discharges. Under WAC 173-201A-070(2) "Whenever the natural conditions of said waters are of lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria." We are troubled that Ecology has applied a water quality criteria of 18 degrees C to point sources when this may be less than "natural conditions" and this standard is being applied immediately to point source discharges when existing river temperatures are at times above effluent temperatures and well above water quality standards. We believe that a phased implementation of the TMDL would implement controls on point source discharges after results from the major problem sources are controlled (shade) and the results are demonstrated.

Our calculations of the impact of effluent on Chehalis River temperature show that the effluent has a minimal effect even if the Chehalis River achieved water quality standard temperature of 18degrees C. Centralia wastewater treatment plant discharge has to be two times the year 2025 design flow and over 41degrees C greater than the Chehalis River to violate the WAC 173-201A temperature increase for Class A waters. We believe that since we have such a minimal effect on river temperature, the City of Centralia wastewater discharge should be one of the last implementation measures rather than being one of the first.

We again thank you for this opportunity to comment and welcome your call if you have any questions about our comments.

Sincerely,

Dick Southworth
Utilities Director

SEA\Document2

This letter was scanned so responses could be incorporated under each comment

Quinault Indian Nation

POST OFFICE BOX 189 TAHOLAH, WASHINGTON 98587 TELEPHONE (360)276-8211

DEPARTMENT OF NATURAL RESOURCES
Environmental Protection Division
(360) 276-8125 FAX: (360)276-4682 E-Mail:jsims@quinault.org

April 4, 2001

Dave Rountry
Department of Ecology
Southwest Regional Office
PO Box 47775
Olympia, WA 98504-7775

Dear Dave:

Thank you for the opportunity to comment on the proposed Chehalis River Basin temperature TMDL. Specifically, that you are accepting these comments after your announced deadline. A death in our immediate family, coupled with a short illness, combined to make the original date impossible. Hopefully, our comments below will be helpful.

Overview

At your request we have reviewed the Upper Chehalis Temperature TMDL. Generally, the study recommends increased shading throughout much of the Basin. The implementation strategy largely relies on existing efforts (watershed planning, salmon recovery, conservation district work, etc.) to achieve shading goals over the next 65 years. Although sub-basin specific recommendations are made (e.g. decreasing the width/depth ratio in three sub-basins), these recommendations do not appear to be detailed as part of the implementation strategy.

We support these general conclusions and direction of the implementation strategy. Clearly, the Upper Chehalis would benefit from increased shading and a more complex riparian zone. It is also beneficial that the implementation strategy supports existing efforts rather than set additional specific requirements. This should allow the existing basin planning efforts to move forward with setting priorities based on the whole gamut of basin issues, rather than having efforts be driven by specific TMDL needs. We also think the TMDL effort was valuable for assessing natural worst case conditions in the mainstem. Through this effort it was recognized that existing temperature criteria were not attainable in much of the mainstem, and more realistic criteria are now being used.

That said, we have concerns with the general approach used in this study. Applying TMDL techniques to a temperature problem is a difficult task. EPA requirements to assess cumulative loads may also be what caused the authors to utilize a basin model.

Nonetheless, our concerns are with the appropriateness of using a basin model and regional input variables (rather than basin or reach specific) to assign subbasin specific allocations. A reach-based model would have allowed better use of subbasin specific knowledge and improved confidence in results. The high margin of safety and series of conservative assumptions used, also affect the reasonableness of the modeling effort for assessing solutions. While it is important to be conservative in predictions, if assumptions are overly conservative, a model's usefulness is impaired. These concerns are described in more detail below.

MODEL SELECTION AND USE

An explanation should be provided in the Modeling Approach section about why this particular basin model was selected and the advantages and disadvantages of its use. And also, why a basin model was used rather than a site or reach model. A quite thorough analysis of site and basin temperature models was done through research funded by TFW. Basin model results were found to be poor; "It can be said that basin models were imprecise, and only gross differences in temperature would be detectable using them" (Sullivan et al., 1990).

***Response*: The basin model that was used in this TMDL was originally written by USFWS and is supported by the USGS. Earlier work on this TMDL (Pickett, 1996) utilized a "reach model". The approach was not endorsed by EPA however, but requested the basin modeling be used in order to show better cumulative effects of heat loading.**

The explanation for model selection should also provide more detail on how SNTEMP is linked with SSTEMP and SSShade. It is possible that some of the concerns described below are in some way mitigated by use of the SSShade submodel. If this is so, this should be described as part of the modeling rationale section of the report.

***Response:* Citations appearing in the References section of this submittal report provide a thorough explanation of the model. See Theur et al., 1984, and Bartholow, 1989.**

Model Sensitivity and Performance

It is necessary to understand the relative importance or sensitivity of an input variable to a model. A sensitivity analysis was performed by TFW researchers (Sullivan et al., 1990), for SSTEMP, the reach model that is linked to SNTEMP. Although the TMDL document provides a table summarizing TFW sensitivity analysis results, the significance is not discussed.

***Response*: Ecology agrees with the comment. We could have discussed the sensitivity analysis by Sullivan in the context of the Chehalis study. While greater understanding of the relative significance of variables like humidity and air temperature could have been provided, the added explanation would not have resulted in a change of emphasis on using shade as the most important management variable.**

SSTEMP was found to be most sensitive to input values for air temperature, humidity, and solar radiation. The model was only moderately sensitive to shade for small and medium sized streams, and had almost no sensitivity to shade for large streams. In general, model sensitivity was higher for small and medium sized streams than rivers. If the model is not sensitive to changes in shade, then it follows that it would not be very valuable for predicting shade needs. That is, large changes in shade levels would be needed before any difference in temperature would be predicted by the model. Likewise, the model was not found to be sensitive to stream flow and water depth (a surrogate for the width to depth ratio in this model). Therefore, it is also not surprising that when the TMDL authors ran the model to determine whether flow or W/D could be modified to affect changes in temperature, only one of the sub-basins were shown to be affected.

***Response*: Same as previous reply.**

In contrast, the model was most sensitive to air temperature and second most sensitive to humidity. Yet, in the TMDL study, air temperature and humidity measured at the Olympia airport was used in model runs for all sites. Given the importance of these variables more effort should have been made to estimate their value for different locations within the basin, especially if subbasin specific allocations were to be made.

***Response*: Same as previous reply.**

Another TFW research finding was that the SSTEMP model was "strongly affected" by the length of the reach. "Unreasonable results" were obtained for maximum temperatures when short reaches were specified. Reaches were accordingly set at a length equal to the 24 hour travel time. It is difficult to know whether the reach lengths used in the TMDL meet this criteria. Due to its importance to model performance a discussion should be included in the Modeling Approach section as to how reach lengths were assigned and whether they meet this 24 hour criteria.

***Response*: The average reach travel time is 65 hours which we agree does not met the 24 hour criteria described in the TFW report mentioned. The longer time period was used so that there was enough data to calibrate and validate the model.**

Priority setting

Although we are pleased that the TMDL did not set priorities for basin planners, it may be possible to use the model to provide information that might be helpful for others to use in setting priorities. A few example questions that would help in priority setting include:

- Are there certain sub-basins that might be prioritized for riparian plantings because existing conditions of temperature, flow, or stream morphology would affect larger relative benefits?
- In terms of the length of time to recovery, can the model be used to identify which sub-basins might be prioritized for restoration or to compare between restoration strategies (e.g. shading Scatter Creek as compared to deepening the South Fork)?
- Can the authors provide some discussion as to the relative benefits of recommendations? For example, how does the value of shading the mainstem of the river compare to shading the tributaries? Also, given that a large portion of the South Fork Chehalis is on bedrock, can narrowing the alluvial portion of the subbasin still affect a temperature change?

Specific Edits

- Page 3. The Background Information should provide an overview for the reader of the history of the TMDL effort and the differences between each edition (i.e. 1996, 1999, and 2000, and 2001).

***Response*: The Background section of the submittal report has been amended to better describe the evolution of the project and reports.**

- Page 5 and 6. The new criteria set for the Chehalis should be described, as well as the current efforts to change temperature criteria by EPA and the State. This should be discussed in terms of the possible effects, if any, on the TMDL recommendations or implementation.

<u>Response</u>*: Current shade targets are still appropriate as a baseline. Future changes in standards will be addressed during adaptive management stages. As other control strategies are identified, so may new standards be taken into account.

- Page 8, Last Paragraph. Please provide an explanation as to why the Black River was handled differently.

<u>Response</u>*: The Black River was treated separately because it is a significant source of flow to the system compared to other tributaries, and more data were available for the Black River from the detailed study by Pickett, 1994b.

- Page 9. Was the period of record used to estimate ground temperature and air temperature different? Was it 1948-1998 or 1948-1993?

<u>Response</u>*: The period of record is 1948 -1993.

- Page 13. The summary statistics shown in Table 5 do not match those discussed in the text. If the table values are correct, then it appears as though the model were consistently over-predicting temperatures and some correction factor might be justified.

<u>Response</u>*: The data in the tables are correct, and the report text has been corrected to align with the tables.

- Page 19. Table 9. Page 30. Table 15. New water quality standards for the Centralia Reach should be shown. These new criteria should also be used to estimate the "Amount above Criterion" column for Tables 6,7,9 and etc.

<u>Response</u>*: Current shade targets are still appropriate as a baseline. Future changes in standards will be addressed during adaptive management stages. As other control strategies are identified, so may new standards be taken into account.

Reference used in this reply:

Sullivan, K., J. Tooley, K. Doughty,J.E. Caldwell, P. Knudson. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Rep. No. TFW-WQ3-90-006. Washington Dept. Nat. Resources, Olympia, Washington. 224pp.

I hope these comments will assist you and your staff in the development of meaningful values and models for the final TMDL. If you have any questions, please call.

Sincerely,

John Sims
Manager

cc: Lee Hansmann, Grays Harbor County; Fran Wilshusen, NWIFC; Chad Stussy, WDFW; Raman Iyer, Chehalis Tribe; John Kendigg, NRCS

This letter was scanned so responses could be incorporated under each comment

March. 16, 2001 Via fax, and regular mail

David Rountry
Water- Quality Program-SWRO
WA Department of Ecology
P.O. Box 47775
Olympia, WA 98504-7775

Re: Upper Chehalis River Basin Temperature TMDL

Dear Mr. Rountry,

Please accept the enclosed comments on the Upper Chehalis River Basin temperature TMDL on behalf of the Washington Environmental Council (WEC).

***Response**: The following comments are addressed within the "General Response to Comments"*

WEC is concerned that:
(1) There is no reasonable assurance that the water quality standards for temperature will ever be met in the upper Chehalis basin with the implementation measures recommended in this TMDL.
(2) No effort has been made to reference or integrate, the many TMDLS already issued for this troubled watershed
(3) Ecology has failed to follow the letter of the carefully drafted MOA with the Environmental Protection Agency.
(4) Ecology has failed to quantify the water withdrawals from the watershed or to consider any changes to help. solve. this element of the temperature problems in the basin. It has also failed to consider. other causes of the temperature problems.

One aspect of the draft TMDL that we support and believe must be retained in the final TMDL is the requirement for full and immediate implementation of shade protections, for those forest activities under the 1998 forest practices rules.

WEC requests that you consider our recommendations for improving the potential effectiveness of this TMDL. We expect that either our recommendations will be adopted or their rejection will be explained in the responsiveness summary.

Thank you for the opportunity to comment.

Sincerely

Marcy Golde
WEC Board Member

cc: Laurie Mann, EPA
Chehalis River Council

Washington Environmental Council Comments
November 2000 Draft Upper. Chehalis River Basin Temperature TMDL

Failures to meet MOA *(Memorandum of Agreement Between the United States Environmental Protection Agency and the Washington State Department* of Ecology *regarding the Implementation . of Section 303(d) of the Federal Clean. Water Act, October 29, .1997)* `

1) Timeline for TMDLs
"Year 4 WQMA PLAN OF ACTIQN: ...Issue draft TMDLs for public comment and subsequent submittal to EPA. Summarize strategies and management activities needed to implement TMDLs, to issue or reissue waste discharge permits; to form partnerships, and to address funding issues. Submit final *TMDLs and summary implementation strategies* to *EPA" (MOA, p. 5)* .

- WEC is concerned with the long delays in implementation proposed for this TML3L. At best it recommends that implementation will not start until 2004 for non-point problems and 2005 for point source changes.

***Response*: Remedies are already being implemented for reducing non-point heat loading. This is being accomplished via the forest practices rules resulting from Forest/Fish agreement. For point source controls, several years are typically needed for the municipalities to obtain funding, develop facility plans, and construct facility improvements. Ecology's permit review and approval process is conducted on a 5-year frequency cycle to balance workload and human resource planning on a statewide level.**

3) Public Involvement

***Response*: The "response to general comments" section contains a complete reply to the following concerns about public involvement.**

The Department of Ecology (Ecology) appears to have neglected *a* number of requirements of the MOA regarding public involvement: These include:

"C. TMDL Development".... will ...meet federal requirements for public involvement (40 CFR 25; ' part 25.4). " . . , .

- *"(1) Information and Assistance: Ecology will make all information -used in the development of a TMDL process available to the-public: In addition, lists of interested ,and affected parties will be compiled and maintained" (MOA, p. 9). .,*
  - It is not clear whether the information used in the development of this TMDL . *was* made available. The draft TMDL made available to the public on the DOE website does not include the information in the Figures or the Appendices.
  - If Ecology compiled lists of interested and affected parties, they did not use them to make information available to the public, or to inform the public who might reasonably be *on* such lists of this TMDL at and stage: ,

- "(3) Public Consultation: Ecology will consult with interested and affected parties prior *to making final major decisions," (MOA; p. 9); ,*
  - Such consultation must take *place* before the TMDL is finalized and notice must be *given* to an adequate list of interested and affected parties:

"D: Ecology will also ensure that TMDL submittals include a responsiveness summary to public comments, as described in federal regulations (40 CFR, part 25.8)...set forth specific responses by modification of *the proposed alternative or an explanation for the rejection* of *any proposals made by the public"* (MOA, p 9-10).

- WEC is including specific recommendations for improving this TMDL and expects responsiveness comments. This must take place before EPA reviews the final TMDL.

3) Requirements of All TMDLs

"B: TMDLs submitted by Ecology shall include:..:

(3) a *description of alternative allocation strategies explored*

(4) an allocation scheme and a description, of how the allocations were developed, including loading capacity estimation, load allocations, waste load allocations and margin of safety; : ,

(5) for those TMDLs in which wasteload allocations to point sources are based on the assumption that loads from nonpoint sources will be *reduced,: reasonable assurance that the nonpoint source load allocations will be achieved.(e.g., control actions and implementation schedules); and... " (MOA, p.11). .*

- The TMDL lacks description of alternative strategies (including reducing the impact from point sources) or how they were developed. The wasteload for point sources could have been evaluated without any mixing zone, for example. It should also have been evaluated in units of heat at the end of the pipe, not in units of shade that does not come *out* of *a* pipe.
- *"Since the entire heat load in this TMDL has been allotted to nonpoint sources as load allocations, the temperature wasteload allocations for these point source discharges have been set at zero* (draft TMDL, p. 25)."
  - Is that statement really intended to mean that no point source in the basin contributes any heat to the stream system? Unless that is really the case, making that assumption grandfathers *in all* such contributions and denies the ability to gain any load reduction from any point source.
- Waste loads must have control actions and implementation schedules. These must be part of the summary implementation strategy described in the MOA on p. l 1-12. They must be completed. *in* Year 5, and we see no reason, to delay this until 2005 (draft TMDL, p. 6).
- Reasonable Assurances as required on p. 11 are discussed below; they do not, however provide any specifies on *control* actions or any *im*plementation schedules.

<u>Response</u>: The TMDL does provide description of alternative strategies for the point sources, and the adaptive management approach of the forest practices rules provides various alternatives for reducing heat loading. The waste load allocations for the point sources are set at zero, (i.e., based on an anti-degradation objective), consistent with state criteria for water quality protection. Ecology cannot set a wasteload allocation of less than zero. The waste load allocations do not imply that the point sources are not contributing heat to the river. The point sources often discharge water at temperatures cooler than the ambient river temperature. Waste loads for the point sources are controlled by NPDES permits.

4) Summary Implementation Strategies .

"A. Ecology will develop summary implementation strategies for each TMDL, which will be submitted with the TMDL in Year 4: Summary implementation strategies will identify:

(1) "the timeframe for meeting water quality standards;

(2) the approaches to be used to meet load tend wasteload allocations,. Which consider flow rates and seasonal variations;

(3) interim targets, if appropriate, with linkages to the pollution sources;

(4) a monitoring strategy to measure implementation activities and achievement of interim targets and water quality standards.

(5) schedule for monitoring and evaluation of TMDL and implementation effectiveness, including source control feedback loops. "

- Interim targets are most appropriately developed at, this stage. They should not be delayed. .

***Response:* Interim targets for achieving water quality standards are inherent in the NPDES permits for point sources. The load allocations for non-point sources represent target milestones with provisions for monitoring of corrective strategies, and strategy adjustments to assure progress towards the target shade improvements over time.**

- The analysis of the impacts *of flow* rates; water withdrawals and options to increase flow seems almost entirely missing. It needs to be added to both the analysis and the implementation strategy.

Response: See general comments regarding integration of strategies for managing water flow and quality.

- The comprehensive and integrated monitoring strategy needs to be developed now.

Response: The Detailed Implementation Plan will include a comprehensive monitoring strategy. As discussed in the general response to comments, it is our intent to coordinate development of an integrated detailed cleanup plan with the Chehalis Basin Partnership. Those efforts will ideally integrate the cleanup and monitoring strategies for all TMDL parameters in the watershed.

"Year 5 IMPLEMENTATION:- (Point source implementation components: draft and final NPDES permits and state waste discharge permits identified in Year 4 report; :.., ." (MOA;: p 6). . "'B. Ecology will develop detailed implementation plans for nonpoint, source and mixed source, TMDLs; these plans Will be submitted an Year 5" (MOA p. 12).

- This detailed, plan is being postponed for almost three years in violation of the MOA. The reason seems valid, but some effort should have been made to secure the consent of the EPA and demonstrate it to the public in the accompanying documents. However, there is no reason to delay the wasteload implementation. It should be completed by Year 5 as required in the MOA on p. 6. It should certainly not be delayed until June 30, 2005.
- Because of the uncertainties and significant delays associated with producing the Detailed Implementation Plan there needs to be firm deadlines for this plan and alternative protective measures implemented immediately by Ecology, if the plan is late.

Response: There are milestones, monitoring, and adaptive management provisions in the forest and fish requirements (F/F), which serve as controls in this TMDL. Prescriptions for

other non-point sources not covered within the F/F where Ecology lacks regulatory authority, will be implemented voluntarily. Targets and implementation schedules exist within permit provisions for the point sources.

5) Nonpoint and **Mixed Source TMDLs**
Requirements include:

- *"... ,progress must be checked against specific, measurable interim targets: :. "*
- Ecology *will specify in the implementation plan other more restrictive measures which will be applied should. initial measures not be implemented or, successful" (1VIOA, P. 13). ,*
- *"(4) The alternative allocation strategies contained within the draft TMDL will be referenced in the Plan of Action. for the WQMA prepared by Ecology in Year 4 or early in Year 5.*
-

For mixed source *TMDLs, the technical report will include recommendations for waste load allocations and effluent limits for contributing point sources, and load allocations for nonpoint sources with associated interim targets" (MOA, p. 14).*

- The recommendations are there, but *no* interim targets have been given. *Ecology* must -also be *sure* to add the other more restrictive measures to be. applied if the original plan fails *to* be implemented or successful.
- Exceeds timelines in MOA both for, Implementation Plan and for revising NPDES, ' permits (MOA, p. 5-6).
- Lack of "summary implementation strategies... Which will be submitted with the TMDL in Year 4.;" Five pieces to be included in this.
- There are no alternative allocation plans in this document.
- No interim targets for point and nonpoint allocations are included.

<u>Response</u>: See "Response to General Comments", and additional explanation above

Analysis - Supporting Comments And Concerns

Forestry Controlled by1998 Rules

- It is totally appropriate and indeed necessary to place immediate additional shade requirements on those forest practices permits not *following* the Emergency Forest Practices *Rules.* While *we* do not consider those emergency rules adequate, Ecology, EPA and WEC *all* agree that the 1998 rules do not meet the 'Clean Water Act and do not protect all the. shade: for, a ,stream. In *fact,* they only protect the. shade within the Riparian Management *Zone:* of ,generally 25 feet.

Shade Control Alone Is Inadequate

- Shade as the surrogate measure for temperature is incomplete. The analysis of causes mentions this; but does not make any effort to control the other factors affecting temperature. These factors include: water withdrawal, large wood; sediment and landslides, road effects. Other causes also need to be considered and actions to address them are needed [Attachment 1; Review of the December 2001 Draft Sufficiency

Analysis: Stream Temperature (Oregon Departments: of Forestry and Environmental Quality) by the Environmental Protection Agency, National Marine Fisheries Service and U.S. Fish. and Wildlife Service; February 200l, p. 3-9]. Only by considering and reducing the impacts from all the factors will appropriate temperatures even be approached

Response: ***Analyses of causes besides shade were conducted, and are described in the last paragraph of page 24, and at the top of page 25. Recommendations include controls of water withdrawals, channel morphology changes, and sediment delivery.***

The report says, "Activities that increase the temperature, reduce the flow, or impact the stream channel forming processes must be prevented in all tributaries of the watershed." Some causal factors besides shade will be managed according to the F&F agreement, or adaptive management. Additional control strategies like those mentioned above will be addressed more completely in the forthcoming Detailed Implementation Plan.

Use Reference Conditions to Establish Natural Conditions

- The difficulty in establishing natural conditions should have begin addressed by use of reference watersheds. The definition of Natural Conditions or Natural Background Levels states: *"When estimating natural conditions in the headwaters* of *a disturbed watershed it may be necessary to use the less disturbed conditions* of *a neighboring or similar watershed* as *a reference condition (WAC* 173-201A-024)." We believe that had this been done; it would have been clear that many streams in their headwaters originally had water as cold as or colder than the current standards and very different width to depth ratios, in-stream flows, large wood loading, surface and mass wasting erosion rates than those currently observed, that could be linked to temperature. It is especially troubling that no effort was made to quantify the water withdrawals from the whole basin and from the main stem and the tributaries separately. Water rights, in-stream flows and all water resource issues are administered by Ecology, so the agency has a special responsibility to identify, quantify, and implement solutions to this source of heat pollution.

Response*:* ***The "response to general comments" provides a reply to the foregoing comments.***

Concerns with Reasonable Assurances

There is no reasonable assurance that the water quality standards for temperature will ever be met in the upper Chehalis basin with the implementation measures recommended in this TMDL:

- *The Weyerhaeuser Company, did not complete an LLP.* The LLP program was a pilot that is now complete. The Weyerhaeuser Company, elected not to complete pilot planning nor submit their plan for LLP approval.

- CREP *has a poor implementation record.* Few farmers have elected to enter the program. It is also important to note that the plan only lasts for 12 years and may not contribute significantly to shade in that period or thereafter.

- *"Shade Program" is* too *small to have significant impact on overall temperatures*:

This excellent program is dependent on uncertain funding and probably can make only a small overall contribution on a basin-wide scale..

- *Watershed Analysis (WSA) Prescriptions superseded by Forests and Fish.* Under the Forests and Fish agreement, the completed prescriptions for riparian and roads (surface erosion) are replaced by the Forests and Fish regulations. The whole WSA program appears to have been superseded by the Forests and Fish effort; no Watershed Analyses have been started anywhere in the' state since 1998.

- The fencing efforts shown on pages 43-45 of the TMDL should increase streambank stability, reduce bank erosion and may add some shade, if they remain in place for some time. However, it is not likely that they will lead to the significant mature forest shade conditions recommended in this TMDL. It can help, but will not do the job.

***Response**: The "response to general comments" provides a reply to the foregoing comments.*

All Six TMDLs in the Chehalis Must Be Integrated
Some of the human impacts and the remediation for those impacts are common in the various TMDLs. They must be integrated and common solutions and implementation found.

***Response**: See the" Response to General Comments".*

Water Withdrawals Must Be Evaluated and Flows Increased

It is probably impossible to fully address the temperature problems in the Chehalis watershed without addressing the water withdrawals and temperature preventing new withdrawals. This TMDL has omitted any analysis of the impacts of water withdrawal on temperature. It does not indicate the amounts of withdrawal at a11, either for the whole river or for any of the tributaries.

***Response**: Page 15 of the report provides an estimate of the effect of water withdrawals. This was estimated in part based on a statistical calculation of the seven-day low flow event that occurs every 10 years (7Q-10), and using base flow data for 14 locations in the river system. During the summer months water rights and claims exceed the natural stream flow in many instances.*

Although returning water to the system is difficult, it must be done if temperatures are ever to return near natural levels. Additional in-stream -flows must be found through methods such as conservation, enforcement against waste and illegal use, and purchase of water rights.

***Response**: As mentioned in the general comments, the RCW 90.82 watershed planning process used by the Chehalis Basin Partnership will provide integration of water quality and water quantity solutions in the Chehalis watershed.*

Integrated Monitoring Plan Must Be Established Now

"To effectively evaluate the short- and long-term effectiveness of riparian restoration, these programs will have to be coordinated and augmented. This will be addressed in the Detailed Implementation Plan."

- The scattered monitoring efforts will not show the achievements or failures of this TMDL. An integrated, comprehensive monitoring program must be established immediately, so that current conditions throughout the basin can form a baseline of information. There are five other TMDLs on the Chehalis River; the monitoring must be integrated for all of them:

***Response*: An integrated monitoring approach is expected to occur given the involvement of many agencies and volunteer monitoring efforts underway for the several TMDL's throughout the basin. In the meantime, monitoring of forest practices by Wash. State Department of Natural Resources and others will evaluate implementation of riparian buffers. Ongoing ambient monitoring in the basin by Ecology will also serve to track TMDL progress towards the temperature targets.**

WEC Alternative

- Roads:- speed up the milestones for the F.P. Road Maintenance and Abandonment Plans. Two and a half years should, be sufficient to produce all the plans for the Chehalis basin and ten years should be sufficient to complete. the work in this basin. The strict priorities in the draft Permanent. Rules must be closely followed.
- Reduce road density. The abandonment of unnecessary and duplicative roads and reduction of new roads is vital to reduction of surface erosion and mass wasting. , Removal of two miles of old road for everyone mile of new road as a minimum would lead to a steady improvement, without imposing a huge up-front cost.
- Allow only hardwood conversions that can be documented as' having no negative short-term impacts to any of the conditions being corrected in any of the TMDLs, and that provide long-term benefits to temperature ,& shade.
- Wetlands - Identify forested wetlands with hydrologic, links to the. channel network and retain all shade over shallow groundwater.
- Allow no activities where a very high potential for mass wasting exists. There is no geologically-sound evidence that mitigation on such sites is effective.
- Flow reduction has impacted the temperature regime in the Chehalis basin and must be addressed. Methods of adding to flows must be found and implemented.
- Summary Implementation Plan
    - o Milestones for completion of Detailed Implementation Plan: the plan will be completed .and sent to EPA for review and acceptance by December, 2003; the current implementation date for he NPDES permits is 2005.

- Alternative protective actions if the Detailed Implementation Plan is not completed on time and implementation begun immediately: put into action all the parts of the WEC recommendations.

- Integrate this TMDL with all other TMDLs on Chehalis River: Currently they are:

Water Body Name	WBID	Parameter	# TMDLs	Approval Date
ChehaIis River -	WA-23-1010	Ammonia-N. B(JD (5-day) -	17	26-Oct-96
Chehalis River. (re-submit) .	WA-23-1019 WA-23-1024 WA-23-2060	Dissolved Oxygen	3	OS-May-00
Black River	WA-23-1015	Ammonia-N BOD (5-day)	4	26-Oct-96
		Total Phosphorus	3	26-0ct96
		Fecal Coliform	5	26-Oct-96

***Response*: The Dept. of Ecology appreciates the specific recommendations provided above. As part of the public record, the recommendations are available to the DNR and other land managers, and may be utilized at their discretion. The recommendations may also be considered during development of the Detailed Implementation Plan..**

Comments on the administrative scheduling aspects of the TMDL implementation are addressed in the "Response to General Comments".

This letter was scanned so responses could be incorporated under each comment

Westfarm Foods

March 12, 2001

HAND DELIVERED

Mr. Kahle Jennings
Watershed Specialist
Water Quality Program, Dept. of Ecology
Southwest Regional Office
P.O. Box 47775
Olympia, WA 98504-7775

Re: Draft Upper Chehalis River Basin Temperature Total Maximum Daily Load

Dear Mr. Jennings:

This letter is being submitted as WestFarm Foods formal comments to the draft Upper Chehalis River Basin Temperature Total Maximum Daily Load (TMDL). We appreciate Ecology's efforts to write the Temperature TISML WasteLoad Allocations for WFF to coincide with the Dissolved Oxygen TMDL Consent Decree negotiated between WFF and Ecology. ,

As I mentioned to you on the phone last week, we were unable to find a compliance date in the Temperature TMDL. Therefore, we request that the compliance date in the Dissolved Oxygen TMDL Consent Decree also be incorporated into this TMDL. You commented during that phone conversation that Ecology overlooked the compliance date and you expect that the same date will be added to the Temperature TMDL.

***Response*: Ecology determined that it is impractical to assign a single compliance date for all NPDES permittees in the text of the TMDL, because the 5-year renewal schedule may not the same for each one. However, for West Farm Foods, the compliance date will be January 2008, which is consistent with the dissolved oxygen TMDL consent decree. The permits for your facility will be developed to be consistent with the load allocations in this TMDL, and the dissolved oxygen TMDL.**

Thank you for the opportunity to review and comment on this TMDL before it is submitted to EPA.

Sincerely,

Joseph L. Muller
Director of Regulatory Compliance

Cc: Ron Taylor Jerry Blaser
Chetmptmdl3.doc

This letter was scanned so responses could be incorporated under each comment.

March 14, 2001

Mr. Dave Rountry
Department of Ecology
PO Box 47775
Olympia, WA 98504-7775

RE: **Upper Chehalis River Basin Temperature Total Maximum Daily Load as** Revised November 2000

Dear Mr. Rountry:

The purpose of this letter is to submit Weyerhaeuser Company comments on the revised draft TMDL. By our membership association, we support the comments submitted by the Washington Forest Protection Association. We would initially like to acknowledge the responsiveness of agency staff to our recent inquiries regarding this TMDL. For the record, our comments will focus on the draft proposal and where appropriate provide recommendations for your consideration.

Obviously a great deal of work went into the draft TMDL, but key parts seem based on questionable assumptions about the effects of current and historical human activities, overemphasis on negative effects of human activities but disregard of positive effects, and excessively pessimistic assumptions. More importantly, proposed changes that discuss requirements of the Washington State Forest Practices Regulations are entirely inconsistent with Clean Water Act Section 303 assurances contained in the Forest and Fish Agreement (F&F) dated April 29, 1999, and codified by the Washington State legislature as ESHB 2091-1999 1st special Session.

Our specific comments follow:

Forest Practices

Forest practices rules are controlling. The draft TMDL erroneously suggests that DNR can and should condition forest practice approvals to require compliance with the TMDL where it requires more shade than the forest practices rules [p. 34]. Both the state water quality laws and the forest practices act specifically provide that the forest practices rules will be used to satisfy all requirements of the federal water pollution control act and state water quality laws. RCW 90.48.425; 76.09.010(2)(g). If compliance with the forest practices rules proves insufficient to meet water quality standards, DOE. must amend the water quality standards, recommend amendments to the forest practice rules, or both.

RCW 90.48.420(2). Under current statutes and rules, DOE cannot compel DNR to impose special conditions on forest practices to implement a TMDL.

ESHB 2091 codified the Forest and Fish Agreement; it's the law. The Washington State Legislature in 1999 found that the changes in laws and rules contemplated by F&F provide substantial and sufficient contribution to salmon recovery and water quality enhancement in areas impacted by forest practices and are intended to <u>fully satisfy</u> the requirements of the endangered species act with respect to incidental take of salmon and other aquatic resources and the clean water act with respect to nonpoint source pollution attributable to forest practices. ESHB 2091 Section 101(2). The legislature also modified RCW 90.48.420 such that no permit system pertaining to non-point source of pollution arising from forest practices shall be authorized . . . if the forest practice is conducted in full compliance with the applicable provisions of RCW 76.09.010 through 76.09.280 forest practices rules. ESHB 2091 Section 1101. By this Act, the legislature reaffirmed its intent, and further strengthened prior existing state law to rely solely on forest practices regulations for clean water act attainment and compliance for forestry activities.

The Forest and Fish Agreement (April 29,1999) determined that TMDLs heed hot be prepared prior to July 1, 2009, on private and state lands subject to Forest Practices Board regulations. The draft TMDL contains a puzzling statement that F&F assurances are not provided for forest harvest activities not being conducted under regulations adopted pursuant to F&F [p. 34]. EPA and Ecology agreed to not require more stringent forest practices in mixed-use watershed-based TMDLs before July 1, 2009, <u>except through adaptive management</u> and subject to reopeners. (See F&F Schedule M-2 Pp.167-173.) Those assurances obviously are not being met in this proposal and we would ask that the TMDL be revised to reflect the F&F assurances.

Adaptive management. The draft TMDL appropriately relies on adaptive management and correctly notes that the temperature standard itself may have to be reconsidered if the TMDL does not succeed in achieving it: ". . . the approach of this TMDL is one of *adaptive management.* If monitoring documents that restoring riparian shade to near critical low flow conditions and improving other associated functions of a healthy stream environment do not result in compliance with water quality standards, then either the allocations or the standard itself will to [sic] be reevaluated and the TMDL amended." [Pp. 29-30 (emphasis in original)]. Once permanent Forest and Fish rules are adopted, any changes in them will need to be based on adaptive management. RCW 76.09.370(6). DOE is required to monitor water quality where it is affected by forest practices and, if it fords compliance with forest practices rules is not achieving water quality standards, DOE must "either promulgate appropriate revisions to such water quality standards or propose appropriate revisions to such forest practices regulations or both." RCW 90.48.420(2).

Existing approved forest practices are vested. Once this TMDL is approved by EPA, there may be a few forest practices yet to be completed under pre-F&F rules (since approved applications are "good" for two years), but it makes no differences whether "Forest & Fish assurances" apply to them or not - the landowners have vested rights to complete those operations under the rules in effect at the time they filed their applications, subject only to DNR's right to impose additional conditions through a Notice to Comply or Stop Work Order if necessary to prevent material damage to a public resource. RCW 76.09.080, -090. Mere inconsistency with a subsequently adopted TMDL is not, by itself, sufficient evidence of material damage to public resources to justify a Notice to Comply or Stop Work Order.

Riparian Buffer widths as defined in the WAC 222 are sufficient for meeting the temperature standard and load allocation. The proposed riparian stream buffer widths of approximately 150 feet on all stream segments regardless of presence or absence of fish is entirely inconsistent with the riparian prescriptions in WAC 222-30-040 and the Forest and Fish Agreement. Because TMDLs need not be prepared for forest land owners in single use and mixed use waterbodies, forest land owners need only comply with the riparian buffer requirements contained in WAC 222, at the time of FPA approval.

Water typing under Forest & Fish rules. The draft TMDL notes that current forest practices emergency rules do not include the new stream typing system contemplated by the Forest & Fish Report [p. 33]. However, this probably is not contributing to high water temperatures in the Upper Chehalis. It is well understood by all the resource agencies -including Ecology - that the emergency rules over-classify many stream segments, based on physical parameters, so they are treated as fish bearing when in fact they do not contain fish. Further, some non-fish bearing streams are classified as Type III streams because of water intakes or other factors, and thus receive protection under the current emergency rules comparable to what they would receive if the new FFR stream typing system was fully implemented. There is no basis to conclude that fully implementing the F&F stream typing system will provide significantly more shade or other temperature benefits for the Upper Chehalis compared to the current emergency rules and or watershed analysis prescriptions.

Weyerhaeuser's Chehalis - Willapa landscape plan. Weyerhaeuser is no longer pursuing state approval of its proposed Chehalis Willapa landscape plan. Portions of the plan may be voluntarily implemented, but the reference to it on p. 38 and the discussion of it on p. 40 of the draft TMDL should be deleted.

Response: Reference to the landscape plan has been deleted from the document.

Attainability of the Temperature Standard

Human versus natural influences. The standard for Class A waters is that temperature should not exceed 18º C due to human activities [p. 5]. A sensitivity analysis shows that "air temperature and humidity had the greatest influence on relative model sensitivity" [p. 17]. Table 8, p. 18, shows the ranked sensitivity of model parameters in predicting maximum daily temperature: air temperature is #1 (15.2), humidity #2 (7.6), solar radiation is #3 (5.2), and shade is –1.6. Nevertheless, the draft TMDL relies on one of the least sensitive factor "vegetative shade as a surrogate for thermal load" as the surrogate measure for water temperature[p. 19]. It seems to assume that air temperature and humidity are "natural" and not subject to human change. By choosing vegetative shade, Ecology is clearly failing to recognize that high stream temperatures on unusually hot- and low-humidity days could be attributable largely, if not completely, to factors other than human activities and that the surrogate used for thermal load, vegetative shade, is not the largest or most easily controlled causal factor for high water temperatures.

The draft TMDL assumes temperature exceedences are caused by human activities: "… the Upper Chehalis River Basin has been so altered by human activity (forest clearing for agriculture, timber harvest and development, clearing and degradation of riparian zones, withdrawal of water that has changes (sic) flow regimes, and changes in channel shape) that, combined with what may be natural conditions in the system, the current temperature criterion of 18º C for this Class A waterbody is not being met at many locations" [p. 5]. "It is assumed that changes in the hydraulic regime caused by logging, agriculture and development have diminished the influence of" groundwater cooling [p. 15].

Each of those points is subject to question. Has there been net clearing of forests for agriculture since pre-settlement times? Reports and journals of early explorers describe extensive open prairies in this basin, probably resulting partly from burning by Indians to improve berries, forage, etc. In much of this basin Douglas fir forests have been encroaching into former prairies and oak savannas for over 100 years. (See WDFW status report on the western gray squirrel.) Trees, often hardwoods, grow along the streams on many agricultural lands in the basin; it is not clear that most stream reaches crossing through farmlands have less shade now than in pre-settlement times. Timber harvest obviously has removed shade in some areas, but the heavily timbered headwaters are the only listed segment expected to meet the temperature standards in the near term [p. 19]. Relatively little urban development has occurred in riparian areas in this basin, compared to many other areas in western Washington; rather, most urban development is concentrated along the I-5 corridor and in small towns that did not depend on water transportation and therefore are not river-focused. Some withdrawn water probably returns to the river (through point source discharges, irrigation return flows, or infiltration back into shallow aquifers) and — during times when stream temperatures are highest — may return as ground water with an estimated temperature of only 9.9ºC [p. 10]. Changes in channel shape can have positive as well as negative effects on water temperature; generally channelization straightens the river alignment and deepens the channel, shortening the distance and time when slow-moving shallow water may be exposed to solar radiation, sometimes increasing topographic shading, stabilizing banks so that riparian vegetation can mature, etc.
The draft TMDL seems to reflect a bias that human activity always, or at least usually, harm water temperature. A more objective analysis might show that human activities have had both positive and negative effects at different points in time and space, and that human activities since pre-settlement times may have caused either net increase or decrease in maximum water temperatures — or perhaps have not had a significant net effect in either direction.

***Response*: Ecology agrees that the criteria of 18 degrees C may not be attainable, but the standard (of 0.3 degrees C above natural conditions) can be met. The goal must be continuous improvement/reduction of stream temperatures over time. Over time as temperature controls are implemented and monitored, it will be more feasible to estimate natural conditions. At that point it will be more feasible to determine what additional controls may be needed to achieve the standard of 'natural conditions plus 0.3 degrees C'. The point may be mute though, since the goal is to achieve as much shade as is humanly possible. One reason shade was chosen as the primary mechanism is because it can be influenced by human management, whereas air temperature, humidity, and other parameters are much more difficult for people to influence.**

A use attainability analysis should be considered. The draft TMDL focuses on the 18°C standard, which by its terms applies only where exceedences are caused by human activity. It recognizes that there is a ". . . question of whether the current water quality standard for temperature can be met during the critical conditions used in the model even if the watershed still existed in natural conditions .. . [T]he temperature standard is occasionally exceeded during severe conditions even in some Olympic watersheds that are essentially undisturbed by man." [pp. 15-16 (emphasis in original)]. "Results of this analysis (shown in Table 11) indicate that even under natural conditions the predicted temperatures may exceed the current water quality criteria in three tributaries and on several sections of the mainstem of the Upper Chehalis River..." [pp. 22]. As discussed above, the draft TMDL seems to overestimate negative impacts and disregard potential positive impacts of human activities. It is not clear that the Chehalis and its tributaries would stay under 18°C even if there was no human activity or that, in aggregate, human activities have caused or significantly contributed to temperatures above that level.

***Response**: Ecology believes that the historical uses of the watershed (including healthy habitat for fish and other aquatic life) should be maintained, and that the temperature standards and protective strategies provided in the cleanup plan are appropriate for attaining the beneficial uses. A use attainability analysis would not change the need to protect aquatic health.*

General Technical Comments

Effects on groundwater of "re-establishing" riparian vegetation. The draft TMDL says "It is reasonable to assume that re-establishing riparian vegetation for shading will also .. . improve groundwater recharge of the river" [p. 2]. One of the most important assumptions, critical to achieving the temperature standards, is that "flow will not be further reduced during critical periods" [p. 2]. The amount of riparian vegetation on many reaches may already be at or above historic and pre-settlement levels. In fact, increased riparian vegetation may be a cause - rather than a cure - for low summer flows. Riparian vegetation transpires significant amounts of water from soils into the atmosphere, particularly in summer when vegetative growth and air temperatures are high and relative humidity is low. Rather than assume more riparian vegetation is good for streamflows, the TMDL could acknowledge that there may be trade-offs between relying on riparian trees for shade and maximizing groundwater inflows during summer low flow periods, and that the optimum balance can be sought through adaptive management. It is questionable that re-establishing streamside vegetation will improve groundwater recharge to river. This assumption is counter to most work that shows regrowth of riparian vegetation reduces flow.

***Response**: Ecology recognizes the differences of scientific opinion about the relationship of riparian vegetation to groundwater flows. We believe that the prevailing view agrees that groundwater flow is increased in the long-term by the presence of riparian vegetation. No other scientific information or reference was presented to affirm the other view.*

Loading capacity subheading. The draft TMDL states that reducing width-to-depth ratios will mitigate for low shading. This does not acknowledge that there are streams within the Chehalis system that are too wide to be fully shaded.

The study (as shown in Table 4) does acknowledge wide areas of the river, and wide widths were included in application of the model, although adjustments of width-depth ratios were only applied to the tributaries and not the mainstem Chehalis river.

Water withdrawal as source of streamflow reduction. The draft TMDL indicates that streamflows in the Chehalis have decreased about 10% since 1930, and assumes this is attributable to "water taken out of the system for human use" [p. 21]. However, it does not document that increased water withdrawals caused these streamflow reductions. Parts of the basin have lost population, industry and agriculture since 1930, and some Chehalis basin consumptive uses rely on groundwater sources that do not have direct continuity with low streamflows during the summer months. Reduced low flows in summer months may be attributable to increased biomass as much or more than withdrawals of water for human consumption.

<u>Response</u>*: Ecology believes that it is reasonable to say that human withdrawals of water have resulted in a 10% reduction of streamflows since 1930. This is supported by the study. Initial Watershed Assessment Water Resource Inventory Area 23 Upper Chehalis River, February 1995, Wildrick et.al, 1995 that says: "Annual mean streamflow in three streams (the Chehalis, Newaukum, and Skookumchuck Rivers) of WRIA 23 varies by approximately the same pattern from year to year. Linear regression of the annual streamflow values for the Chehalis River near Grand Mound indicates a decrease since 1930 of about 200-300cfs or about 10%. Linear regression of the annual precipitation values for the same period indicates only a small change of about 1%. For the shorter record of streamflow at the mouth of WRIA 23 (Chehalis River near Porter), annual streamflow decreased (as revealed by best-fit regression) by about 800 cfs, or 19%, since 1953 when gauging began. During the same period, the annual precipitation decreased by only about three inches, or about 6%. Interestingly, the amount of groundwater and surface rights increased by about 800 cfs during the same period, with much of the growth occurring between 1966 and 1981. Thus, the records of annual flow for both streamflow gages suggest a cause-and-effect relationship between consumptive water use and reduced streamflow."

Water withdrawals and opportunities to reduce them. **"Restoration of flow levels to** more like pre-European settlement would probably further improve the rivers' temperatures [p. 24]. "During summer months water rights and claims exceed the natural stream flow in many cases." [p. 15]. "It was assumed that the critical low flows we see today are due to the amount of water taken out of the system for human use . . ." [p. 21]. However, the TMDL does not contain data on how much water is in fact being withdrawn; i.e., to what extent water rights and claims are actually being exercised during summer months. Many of the water rights and claims may have been issued for old mills that no longer exist, irrigation that is no longer occurring, etc. To the extent water actually is being withdrawn, there may be opportunities to reduce withdrawals through water conservation, storage, recycling, etc. The TMDL could suggest further study of actual water withdrawals and opportunities to reduce them. This could be done through the regional WRIA planning process or by DOE itself.

***<u>Response</u>*: Ecology agrees that regional planning processes are an appropriate venue for integrating water flow/withdrawal and water quality management.**

Biological health of the basin. "The streams of the basin support substantial runs of anadromous fish and support commercial, sport and tribal fisheries. An assessment by the state and tribes in 1992 showed all species of salmonid stock (Chinook, Chum, Coho, and Steelhead) in the basin to be healthy (SASSI, 1993)." [p. 8]. These statements clearly contradict other undocumented assertions found on [p. 8], "Excessive summer water temperatures have reduced the quality of spawning and rearing habitat for salmonid fish in several Upper Chehalis river basin streams. High temperatures harm salmonid fish." As previously stated, the F&F agreement addresses ESA requirements. As part of the federal ESA assurances, the Services will promulgate one or more 4(d) rules that would exempt forest practices from "take" and would not require the performance of any additional acts or the commitment of any additional resources-other than those derived from adaptive management. Additionally, the services are committed to develop a habitat conservation plan that will form the basis of an incidental take permit under Section 10 of the ESA.

Given the federal ESA assurances and all of the changes to the forest practices rules starting with the 1992 amendments, followed by implementation of watershed analysis prescriptions and then emergency salmonid rules in 1999 and 2000- it is hard to connect the SASSI findings with the TMDL inference that fish are harmed in this basin and that forest practices continue to contribute to this problem. Habitat conditions in the Upper Chehalis are improving already and can be expected to continue improving independent of any TMDL requirements.

***Response:* The water quality standards for temperature are used as a surrogate measurement for protection of aquatic health in general, and for fish in particular. Temperature reductions as proposed in this SIS are needed for aquatic health protection.**

Splash dams. The draft TMDL says "The historic use of splash dams to transport logs down streams is known to have been a very significant source of sediment loading to many locations in the Chehalis watershed." [p. 23]. No references are given for this statement, which may not be accurate or relevant to the Upper Chehalis. Splash dams have not been used anywhere in the Chehalis for decades and never were used in many tributaries and headwater areas. There probably was little or no use of them in the Upper Chehalis area covered by this TMDL.

***Response*: A reference which documents the use of splash dams throughout the upper and lower Chehalis basin is "Logging Dams on Coastal Washington Streams", Henry O. Wendler and Gene Deschamps, printed in Fisheries Research Papers, Volume 1, Number 3, 1955, Washington State Dept. of Fisheries.**

Water Quality Resource Impairments are incorrect and qualitative at best. Table 2 indicates that June and July have the highest percent of temperature criterion exceedences. However, the TMDL analysis is only completed for the month of August. Table 3 focused on "Observed Riparian Degradation." The method to arrive at this is not defined. In the preceding paragraph it is mentioned that this is a qualitative method.

***Response*: August temperature data were applied to the model calibration because the best data were available for that time period.**

Model Approach

Margin of safety. The analysis uses "several conservative assumptions in the modeling, including: extreme summer conditions, setting topographic shade to zero for most reaches, using the lowest basin latitude for all reaches, and applying the ten-year, seven-day low flow." [p. 2]. The models use worst case or nearly worst case assumptions on each of seven factors [p. 29]. The cumulative effect of using a series of conservative assumptions simultaneously may be to create a much larger margin of error (safety) than would result from using less conservative assumptions for all but one or two parameters at a time or using estimated probabilities of each of the conservative factors actually occurring at any particular time. For example, the models apparently assume each day is clear and cloudless, with maximum solar radiation (June 21), high air temperatures, 10-year 7-day low flows, etc. In many years it is not clear and cloudless on June 21; no other days have as much solar radiation potential as June 21, and nearly all of the basin is farther north than the lowest basin latitude; further, the highest air temperatures and lowest streamflows typically occur later in the summer. It is physically impossible for all the conservative assumptions to occur simultaneously throughout the basin. It is statistically unlikely that the worst case combinations will ever occur. Except at extremely rare intervals, at any one time only a few of the seven parameters are likely to be as unfavorable as assumed in the models.

***Response*: The "response to general comments" provides a relevant reply to this comment.**

Stream shading. Stream shading was estimated using the intersection of the hydrology layer and the WDNR Landsat/TM satellite imagery for canopy. While Landsat can have an accuracy up to 80% or more for larger areas, on a single pixel (30m x 30m) the accuracy is far less (25% maybe). Using Landsat to classify the narrow band of vegetation along a stream may not accurately reflect the actual vegetation. Generally, a cover type has to be at least 65% of the pixel to have the pixel classified as that type. In addition, it appears there was no ground-truthing for determining accuracy of Landsat data in predicting riparian composition.

Apparently the models were run based on "GIS coverage depicting canopy in 1991 derived from Landsat/TM satellite imagery." [p. 9]. Did the modeling first simulate timber growth from 1991 to 2001? Even if it did, Landsat imagery does not accurately describe the conditions of young timber plantations and often shows lands as deforested for a number of years after reforestation has been successfully completed

"Even though there are a number of tree species in the basin (e.g., Douglas fir and Bigleaf Maple), the conifer species modeled were assumed to be Western Hemlock, since climax stands in this region would be dominated by this species .... Early seral stage was assumed to be 50 years and mid-seral stage at 100 years. Hardwoods were assumed to be early seral stage Red Alder at 10 years .. .. Tree heights were derived from regional growth curves assuming a site index of 10 .... Non-forested areas were assumed to be an even mix of early seral stage hardwoods, with treeless stream banks mostly supporting understory species, shrub fields, or meadows." [pp. 11-12]. "Late seral stage for existing conifers was derived at an average site index of 100, in a Western Hemlock-dominated forest of 200 years, with a height of 125 feet. Late seral stage for existing hardwoods was derived at an average site index of 100, in a Red Alder-dominated forest of 60 years, with a height of 100 feet." [p. 20] These are very pessimistic and unrealistic assumptions. See the next comment for some realistic assumptions.

***Response*: Additional modeling was not conducted because the data about tree species composition and heights was believed reasonable (page 11). Even if more refined tree cover data and modeling had been applied to the analysis, the outcome would not have changed the prescriptions. In any case, the system needs as much shade as can be humanly provided.**

Poor data and assumptions on riparian vegetative shade. The draft TMDL assumes much riparian shade has been "removed" or "degraded" but this does not seem to be based on good recent data or to reflect improvements made since the early 1990s. At least since 1975, most commercial timber harvests in the basin have been followed by hand planting, usually with Douglas fir, often with improved stock that grows significantly faster than natural stands. Riparian areas often are among the highest site lands in the landscape, with a index well above 100. The NW Forest Plan assumed an average site potential tree height of 150 feet for federal lands, which generally are of much higher elevation and lower site than typical lands in this basin. In relatively low elevation, high site riparian areas, Douglas fir can be expected to reach 125 feet in much less than 200 years - sometimes less than 50 years. Some riparian areas have cottonwood, which grows faster than alder. It is not accurate to assume that riparian areas in farmlands, residential areas and other non-forestlands have treeless stream banks or at most early seral hardwoods; many of those riparian areas have older hardwoods or conifers that provide significant amounts of shade.

***Response*: Reasonable data about riparian shade (page 11) were applied to the analysis. Some simplifying assumptions were made about the characteristics of riparian vegetation because of the complexity and size of the watershed riparian conditions. Conditions included in the analysis are believed to be representative of riparian vegetation in the basin.**

Time period. August was the month chosen for their modeling effort even though Table 2 indicates that June and July have the highest percent of temperature criterion exceedences. What was the reasoning behind this decision?

Response: *August temperature data were utilized only to calibrate and verify the model. The model was applied using critical condition parameters from June and July.*

Vegetation height. The TMDL states: *"Even though there are a number of tree species in the basin, the conifer species modeled were assumed to be western hemlock, since climax stands in this region would be dominated by this species."*

This statement is not substantiated by knowledge of historic vegetation or what current soil or geomorphic conditions can support, especially in the lowlands where there are extensive wetlands. For example, in the analysis of the Newaukum River (Weyerhaeuser 1997) it states:

- *Wetlands are most common in lowland areas of the watershed, with most in the lower North Fork Newaukum sub-basin.* This indicates that the lower portion of the river was not dominated by climax western hemlock.

- *Most of the riverine impounded wetlands are influenced to some degree by beaver activity, either past or present. Also, many of the riverine flow-through wetlands were likely formed and maintained by past beaver activity, as evidenced by old dams. The present lack of impounded wetlands indicates formation and maintenance of wetlands from beaver dams was likely more extensive in the past.*

Our data indicates that prior to European settlement there were more open water areas and hence more potential warming of stream water. Furthermore, research in the Cascade Range of Oregon indicates: ***"Alluvial laudforms support vegetation different from that of adjacent uplands."*** Hawk and Zobel, 1974. In the western Cascades Hawk and Zobel (1974) found a prevalence of hardwoods on alluvial terraces of the upper McKenzie River. Likewise, Means et al. (1996) found that riparian areas along a tributary of the South Fork McKenzie River with frequent disturbances and a high moisture content often are dominated **by early** seral species or broad-leaved vegetation. Likewise, Andrus and Froehlich (1987) found that Oregon Coast Range stream-adjacent terraces were dominated by hardwoods while conifers tended to dominate hillslopes.

In a recent modeling effort in the Oregon Coast Range, Wimberly et al. (2000) estimated the historical variability in the amount of old growth and late-successional forest in over the past 3,000 years. The model simulated temporal and spatial patterns of forest fires along with the resulting fluctuations in the distribution of forest age classes across the landscape. The results indicated that the historical age-class distribution was highly variable and that variability increased with decreasing landscape acreage. Simulated old growth percentages were generally between 25% and 75% at the large scale (8,000 mi2) and never fell below 5%.

The TMDL focuses on a 1993 study, (Wampler et al.) "found over 30 percent of riparian vegetation has been lost or reduced." [p. 7]. However, that study, like others, may have assumed unrealistically high amounts of riparian areas were in old growth timber conditions during pre-settlement times. A BLM study of pre-settlement timber stand conditions in the coast range of Oregon (which has similar topography, climate, timber types, etc.) showed that only a relatively small part of the landscape was in "old growth" or mature timber stands in the 1800s. Further, the Wampler study reflected timber harvest under earlier versions of the forest practice rules, which were amended to require substantially larger riparian buffers in 1992 and again in 2000. Most riparian areas logged under the pre-1992 rules now have timber stands more than 9 years old and 40 feet high

Thus, assuming that riparian areas in the entire upper Chehalis River basin were dominated by late seral hemlock is not scientifically supportable.

***Response*: Some simplifying assumptions were made about the characteristics of riparian vegetation because of the complexity and size of the watershed riparian conditions. Conditions included in the analysis are believed to be representative of riparian vegetation in the basin.**

Topographic shade. "The topographic contribution to stream shade was assumed to be zero for most reaches. Only the two uppermost stream reaches on the mainstem Chehalis River in the Willapa Hills were assumed to have 40 percent topographic shade." [p. I 1]. Much of the mainstem Chehalis has relatively high and steep banks which do provide substantial amounts of shade during critical low flow conditions, even at solar noon on June 21 (when the sun is at its azimuth). Other reaches receive shade from more distant topographic features.

Heat dissipation and dilution. *"To* address cumulative effects, the TMDL has been revised based on a stream network temperature model (SNTEMP) ... since the accumulated heat is routed through the major streams of the watershed." [p. 3]. While heat absorbed in water does move downstream, the water does not necessarily continue to increase in temperature as additional solar radiation is absorbed. Stream temperatures move toward air temperatures, and when air temperatures are cooler than water temperatures the streams will cool even though they continue to receive solar radiation. Also, streams can be cooled by incoming groundwater. The models do predict lower temperatures at Chehalis River mile 33.8 than some points upstream. [See Tables 7 and 7, pp. 13, 17]. Nevertheless, the SNTEMP model may not adequately reflect cooling influences but instead may err toward overestimating heat gain and underestimating heat loss.

***Response*: The model utilized is not capable of accounting for differing air temperatures moving throughout the basin. In this case a network model was utilized to address the temperature distribution throughout the basin. The only way to add cooling to the model would be to factor in groundwater cooling. However, the more sophisticated modeling would not change the prescriptions, because the outcome would still require as much shade as can be humanly provided.**

Model Application

Inconsistent data utilization. The model used climatic parameters from the latest date that the maximum temperature was measured, which was July 21, 1998. However, the solar apex date (June 21, a full month earlier) was used for other input parameters. We do not understand how the Agency technically justifies mixing climatic parameters that are temporally dependent.

***Response**: The analysis combined the most critical conditions as a Margin of Safety.*

Sediment loading. The TMDL states that excessive sediment loading can cause stream channels to become shallow and wide thereby increasing stream temperatures. However, there are several instances where sediment (depending on particle size distribution) can cause streams to go subsurface and thereby decrease temperature. This factor needs to be measured and also assessed.

***Response**: The consequences and effects of sedimentation (like stream widening, increased temperatures, etc.) are more numerous and negative than the possible advantages of sedimentation causing subsurface flow. Determining the effect of sedimentation on subsurface flows would not contribute to a solution better than reducing temperature via the sedimentation mechanism.*

Loading Capacity Analysis

The use of Rosgen's (1994) channel classification scheme to define what width-to-depth ratios a "stable channel" should have, as compared to current condition, is questionable. To attempt to force a channel into an ideal of stability ignores the larger context of the processes acting on the channel. In addition, even if Ecology could correctly model basin-wide changes including changes in sediment supply, routing, hydrologic and vegetative cover, a pre-European stable channel was still dynamic, especially in the glacially dominated, volcanically active Pacific Northwest. The Rosgen system does not necessarily provide a mechanism for predicting new stable channel forms in disturbed systems (Gillilan 1996).

***Response**: Ecology agrees that the classification scheme used is not ideal for this purpose, but it was determined to be reasonable. Rosgen's method is accepted and commonly used for similar purposes. A better method was not identified for assessing width/depth for "stable" channels.*

Load Allocations

Pre-settlement climatic patterns. The TMDL seems to focus on restoration to flow levels more like pre-European settlement. With the expectation that this would probably further improve the river's temperatures. However, the pre-European time frame is not mentioned. If a pre-settlement condition is desired, than there needs to be a reconstruction of the climatic patterns of that time. In general, this section of the TMDL makes several generalized and unsupported claims about the role of both surface and groundwater hydrology

***Response**: Many other factors might have been evaluated to determine natural conditions. However, the number and inter-relationships of those factors made it too daunting and impractical to determine natural conditions in the basin.*

Riparian Buffer widths as defined in the WA C 222 are sufficient for meeting the temperature standard and load allocation. The proposed riparian stream buffer widths of approximately 150 feet on all stream segments regardless of presence or absence of fish is entirely inconsistent with WAC 222. As required by RCW 90.48.425; 76.09.010(2)(g) and ESH13 2091, the load allocation for forest landowners are those riparian prescriptions contained in WAC 222 at the time of FPA approval.

Response: The "response to general comments" provides a relevant reply to this comment.

* * * * *

By your response to this comment letter, we hope to reaffirm Ecology and EPA commitment to implementing the Forest and Fish Agreement. When implemented it will provide the quickest and most efficient means of achieving environmental goals and State of Washington water quality standards.

We trust that you will accept these comments in the cooperative manner in which they are intended. And in closing, we would like to acknowledge the responsiveness of the Agency to our recent questions on this proposal. Should you have any questions, please feel free to contact me at (253) 924-3878.

Sincerely,

Kevin Godbout
Director of External and Regulatory Affairs

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cc: Steven Bernath, Ecology
Ann Goos, WFPA
Mariann Reitier, Weyerhaeuser
Jan Pauw, Weyerhaeuser
Cassie Phillips, Weyerhaeuser

References

Andus, C. W. and H. A. Froehlich. 1987. Riparian forest development after logging or fire in the Oregon Coast Range: wildlife habitat and timber value. Presented at the Symposium on Streamside Management: Riparian Wildlife and Forestry Interactions. University of Washington, Seattle, WA. February 11-13, 1987.

Gillilan, S. 1996. Use and misuse of channel classification systems. From: Stream notes. Published by USDA Forest Service Stream Systems Technology Center. Fort Collins, CO.

Hawk, G. M. and D. B. Zobel. 1974. Forest succession on alluvial landforms of the McKenzie River Valley, Oregon. Northwest Sci. 48(4): 245-265.

Means, J. E., R. R. Harris, T. E. Sabin and C. N. McCain. 1996. Spatial variation in productivity of Douglas fir stands on a valley floor in the western Cascades Range, Oregon. Northwest

Sci. 70(3): 201-212.

Rosgen, D. L. 1994. A classification of natural rivers. Catena Vol. 22: 169-199. Weyerhaeuser Company. 1997. Upper north fork and upper south fork Newaukum River WAU watershed analysis. Weyerhaeuser Company Report.

Wimberly, M. C., T. A. Spies, C. J. Long, and C. Whitlock. 2000. Simulating Historical Variability in the Amount of Old Forests in the Oregon Coast Range. Conservation Biology 14(1): 167-180.

This letter was scanned so responses could be incorporated under each comment.

Washington Forest Protection Association (WFPA)

Mr. Dave Rountry
Department of Ecology
PO Box 47775
Olympia, Washington 98504-7775

RE: Upper Chehalis River Basin Temperature Total Maximum Daily Load (November 2000 Revision)

Dear Mr. Rountry:

The Washington Forest Protection Association (WFPA) appreciates the opportunity to provide comments on the revised draft Upper Chehalis temperature TMDL. WFPA members are large and small private landowners who grow and harvest trees on 4.5 million acres in Washington State, including the upper Chehalis. WFPA will focus its comments on two issues of concern: (1) the description of the Washington State Forest Practices Regulations and (2) the conservative assumptions described in the Margin of Safety section of the draft TMDL.

***Response*: The "Response to General Comments" provides a relevant reply to the points made about the 'Forest Practices Regulations' and the 'Margin of Safety'.**

The Washington State Forest Practices Regulations

The revised TMDL should re-examine the descriptions of the Forest Practices Act (RCW 76.09), the Forests & Fish Report and ESHB 2091, and the Water Pollution Control Act (RCW 90.48). The revised TMDL does not adequately or correctly describe the Forests & Fish Report (FFR). WFPA recommends that DOE should directly note its role in developing FFR and implementing rules. DOE should also acknowledge the role of the Environmental Protection Agency (EPA) in actively developing the recommendations for new forest practices rules. Through the support and expertise of both DOE and EPA, the FFR contains a full suite of recommendations for changes in forest practices statutes, regulations, and management systems to meet among other goals, the requirements of the Clean Water Act for water quality on non-federal forestlands.[1]

1 The participants in developing the FFR included, in addition to DOE and EPA, the National Marine Fisheries Service, the US Fish and Wildlife Service, technical assistance from the US Forest Service, the state Department of Natural Resources, the Department of Fish and Wildlife, the Governor's Office, the tribes, counties, small and large timber managers and owners, and until September 1998, the environmental community.

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Further, the DOE should acknowledge that the state Legislature and Governor endorsed the FFR as witnessed by their actions. On June 7, 1999, Governor Gary Locke signed House Bill (ESHB 2091) into law. This act directed the Forest Practices Board (Board) to adopt emergency forest practices rules consistent with the FFR and strongly encouraged the Board to follow the FFR recommendations in adopting permanent rules that are consistent with FFR.[2] In March 2000, the

Board passed emergency rules consistent with the FFR as required under ESHB 2091 and is currently adopting permanent rules consistent with FFR. These new rules include standards and guidelines to manage riparian vegetation and sediment input to maintain or enhance stream habitats and water quality.[3] The law contemplated that new laws and rules are intended to fully satisfy the requirements of the Clean Water Act with respect to non-point source pollution attributable to forest practices. This fact should be acknowledged in the TMDL.

The revised TMDL expresses concerns about the FFR in relation to stream-typing criteria. DOE should re-examine this concern in relation to emergency actions taken by the Forest Practices Board and still in effect. Some background may help. Starting in 1994, tribes along with state and federal agencies were reviewing water types throughout the state of Washington. The findings were that streams previously thought to be non-fish bearing are in fact either supporting fish or capable of supporting fish habitat based on defined physical characteristics.

Based on this information, the Forest Practices Board (Board) enacted emergency rules in 1996 to modify the definition of type 2 and 3 waters.[4] Fish use determination protocols were included in the Board manual to efficiently and correctly implement the water typing system. The emergency rules and protocols were deemed necessary to protect public resources by ensuring that riparian rules are being applied to fish bearing streams and that the water quality upstream of fish hatchery intakes is protected. This emergency rule, with some modifications since the adoption of the new FFR emergency rules, is still in effect pending permanent rule adoption of a new stream-typing system based on a multi-parameter model for determining fish habitat streams. The revised TMDL should correct its description of stream-typing to reflect actions taken by the Board in 1996, and still in effect, to address public resource protections

The revised TMDL would also benefit from describing the assurances provided by FFR in balanced and equitable language. For instance, though the FFR stakeholders, including DOE and EPA, did provide the assurances as described in Appendix M and Schedule M2 of the FFR, the state and federal agencies, tribes, and citizens of the state also received

[2] The Department of Natural Resources anticipates sending a letter to the Legislature acknowledging that the proposed final rule package will comply with the ESHB 2091.
[3] See: *Forests and Fish Report* (April 29, 2000), Schedule H-1 for complete list of native fish, salmonid, and marine fish species covered by the Report and emergency rules
[4] See WAC 222-16-030 5
[5] Data presented during the FFR discussions demonstrates that the 2-foot channel break specified in the emergency stream-typing rule over-predicts the actual upper limit of fish distribution in 94% of the sites (data for this assessment was collected during the "end of fish" field surveys in 1997 to characterize channel width and gradient at the upper end of fish distribution. Surveys were conducted in more than 30 basins, representing a broad range of environmental conditions). Most fish distributions ended where channels were 4-10 ft. wide. The current emergency stream-typing rule is a conservative default that more than adequately protects fish and non-fish habitat streams in almost all cases.

benefits from the FFR. In addition to new rules protecting aquatic habitat and water quality, state and federal governments are appropriating the requests for implementation dollars, which provide "assurances" to the agencies and tribes that they will be able to effectively implement the FFR.

For the 1999-01 biennium, a total of $21,436,000 has been appropriated to assist in implementing the various program components of the FFR and permanent rules consistent with FFR. Some highlights include: four million federal dollars were allocated to help fund FFR rule implementation, particularly adaptive management, through the Salmon Recovery Funding Board. The state agencies (DNR, DOE and WDFW) will or have received approximately $2.1 million this year and three million dollars (including the supplemental budget) in `O1 to fund compliance monitoring, technical forest practices review, and implement the small landowner office. These monies are in addition to $1.5 million that has been appropriated during the current biennium to assist with Board rule adoption and improvements in the DNR/Forest practices GIS and electronic data systems. Washington State Tribes received an appropriation of $3.026 million last year and anticipate equal funding for the next fiscal year.

***Response*: Additional language provided above has been added to the "reasonable assurances" section of the Summary Implementation Strategy.**

With these suggested improvements in the description of the FFR, the revised TMDL needs to re-examine how the proposal actually comports with the Forest Practices Act rules, ESHB 2091, and the assurances provided in the FFR. The language seems to be directly counter to what DOE, EPA, and other stakeholders, the Legislature, and the Governor supported, agreed to and signed into law. For instance, the FFR determined that TMDLs need not be prepared prior to July 1, 2009 on private and state land subject to Forest Practices Board regulations. This was due in part, to the adequacy of riparian buffer widths as defined in the WAC 222, particularly in relation to temperature.

To address heat inputs from forest practices, the FFR contains a set of specific rules for managing shade across the landscape and the revised TMDL is less than accurate in describing the rule. The forest practices measures are focused to protect resources at locations where water temperature is a concern for water quality and fish and other aquatic resources. The shade management measures include a shade rule with requirements to maintain water temperature in fish-habitat streams. RMZs on both sides of fish-habitat streams are managed to provide adequate shade to maintain compliance with temperature standards.

The practical application of the Shade Rule requires that if a tree within 75 feet of a fish-habitat stream, or Channel Migration Zone (CMZ), is providing shade needed to meet water quality standards, the tree may not be removed (see temperature prediction method of the Forest Practices Board Manual, attached). The revised TMDL should acknowledge that under some circumstances, harvest of trees beyond 75' may be restricted if they are shown by the methodology to be required to meet the Shade Rule. Tree retention beyond what is required to meet the shade rule will be dependent on pre-harvest stand condition and the selected management option. Sparse, hardwood or brush-dominated, or patchy, riparian stands probably would not contain sufficient growing stock to qualify for any harvest in the inner zone.[6] In this case, no entry buffers on average growing sites could be fixed at 93' for streams less than 10' wide, or 105' feet for streams greater than 10' wide. If harvest options are available, the conifer density in the near-stream riparian zone would control the intensity of harvest. Where conifer density is low and, by implication the shading is low, harvest in the inner zone will be more restricted. Where there is an abundance of conifers in the near-stream riparian areas, harvest options would be more liberal. To this extent, the westside riparian rules per the FFR are self-adjusting for shade retention beyond 75 feet. Furthermore, shade requirements must be satisfied whether or not a stream-adjacent parallel road is present. Shade requirements in the Forest Practices Manual will be adjusted if the Department of Ecology changes water temperature standards.

The revised TMDL's recommendations for buffer widths to address temperature are overly conservative and not supported by the science. The effectiveness of the forest practices shade rule based on FFR is supported by several studies, which represent that most of the potential shade, comes from the riparian area within 75' (23 m) of the channel (Castelle and Johnson 2000):

- Brazier and Brown (1973) found that a 79-foot buffer would provide maximum shade to the stream;
- Corbett and Lynch (1985) concluded that a 39-foot buffer should adequately protect streams from large temperature changes following logging;
- Broderson (1973) reported that a 49-foot-wide buffer provides 85% of the maximum shade for small streams;
- Lynch et al. (1985) found that a 98-foot-wide buffer provides the same level of shading as that of an old growth stand;
- Steinblum et al. (1984) concluded that a 56-foot buffer provides 90% of the maximum ACD.

Furthermore, the preliminary Final EIS on Alternatives for Forest Practices Rules for Aquatic and Riparian Resources concluded that the effects of the FFR, the proposed action, has "low *risk of adverse effects on fish due to temperature increases in fish bearing streams".*[7] The preliminary Final EIS (FEIS) states: *"Under Alternative 2 [the FFRJ, the nominal RMZ widths for Type S and F streams exceed the criteria to provide complete shade, using both a 100 year and 250 year site potential tree height".* The FEIS concludes that overall, the RMZ effectiveness to provide shade to fish bearing streams is high. The FEIS also noted that the non-fish perennial buffer strategy should maintain stream temperatures in these streams. The FEIS states that there *"may be a low to moderate risk of temperature increases at the mouth of non-fish perennial streams containing reaches with no buffers. However, any potential increases in stream temperature is expected to be attenuated downstream within 500 ; when water flows through shaded, no harvest RMZ".*[8]

[6] Please consult the attached FFR or the attached emergency rules for a detailed description of the inner zone management options and widths.

[7] The Forest Practices Board adopted the preliminary Final EIS as the Final EIS on February 21, 2001.

With this fuller and more accurate explanation in mind, WFPA is in complete disagreement with the proposed riparian buffer widths described in the revised TMDL. Not only is the requirement of a 150' buffer on all stream segments regardless of presence or absence of fish inconsistent with the recommendations and findings in the (1) FFR, (2) preliminary Final EIS, and (3) scientific literature on the subject, it is not in compliance with the law. We also disagree with the notion that DOE can compel DNR to impose special conditions on any forest practice to implement a TMDL. Further, ESHB 2091 requires that DOE and DNR must implement Clean Water Act requirements and forest practices permit conditioning in conformance with FFR. Any changes in the FFR rules will be based on adaptive management as specified in RCW 76.09.370(6), and not by actions such as the revised TMDL. Given the scientific support for the shade rule and related riparian habitat rules, the legal and policy direction as specified in ESHB 2091 and FFR are justified and must not be compromised by the revised TMDL.

We are attaching copies of the FFR, ESHB 2091, the Forest Practices Act, and a Review of the Scientific Foundations of the Forests & Fish Plan. We encourage the DOE to also acknowledge the findings of the preliminary Final EIS. We recommend that the language and scientific underpinnings of the revised TMDL accurately reflect what the agency has agreed to, what the law says, and what the science supports.

Margin of Safety

WFPA is very concerned with the approach DOE is taking to implementing a "margin of safety" to account for uncertainty when establishing a TMDL. It is one thing to account for uncertainty by making reasonable conservative assumptions; it is quite another to take the worst-case scenarios in every situation and apply the most pessimistic and unlikely conditions to form assumptions. These assumptions are questionable and not statistically valid within the context of the upper Chehalis, or any other riverine system.

It is highly unlikely that the seven conservative assumptions and critical conditions will all occur at the same time or for any interval of time that is based in reality. Stream temperature patterns vary in response to stream size, drainage area, elevation, geographical location, prevailing climatic conditions, aspect, potential riparian vegetation, etc. (Lewis et al. 2000). To model the entire area by using the highest temperature recorded, the lowest latitude of the study area, the maximum sunshine available, and lowest flows, in addition to other extreme inputs, is not an accurate portrayal of what is occurring within the stream system and is not an acceptable way to ensure a margin of safety. We strongly encourage better modeling approaches that use balanced data and documentation while also recognizing water temperature is influenced

[8] See Preliminary Final EIS on Alternatives for Forest Practices Rule for Aquatic and Riparian Resources: page 2-41 (Summary and Comparison of the Environmental Effects of the Alternatives); pages 3-106 107, and more detailed descriptions in Section 3.4 Riparian Habitats.

by a multitude of factors besides just solar input. Though providing shade is one management practices that can influence water temperature, it is clearly not the only factor.[9]

Thank you for your consideration of our comments and suggested changes in the revised TMDL. Suffice it to say that WFPA is extremely concerned with the document and we look forward to working directly with DOE to address issues and concerns we have raised. Please feel free to contact me at 360 705-9289.

Sincerely,

Ann Goos, Director of Environmental Affairs

cc. Stephen Bernath, DOE
Dick Wallace, DOE

Attachments

[9] On March 12, 2001, DOE hosted a Pacific Northwest Water Quality Temperature Criteria Guidance Workshop. In the presentation on the Technical Workgroup Synthesis paper, it was noted that climate, elevation, orientation to the sun (i.e., north facing slope), shade, depth and width of the stream, groundwater influences, morphology (physical characteristics of stream) and flow all determine water temperature. In the case of the revised TMDL, instead of trying to model the reality of these factors in determining shade, it ignored the reality within the actual landscape and simply assumed the worst case in every factor.

References Cited:

Brazier, J.R. and G.W. Brown. 1973. Buffer strips for stream temperature control. Research Paper 15. School of Forestry, Oregon State University, Corvallis, OR.

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

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

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

Lewis, T.E., D.W. Lamphear, D.R. McCanne, A.S. Webb, J.P. Krieter, and W.D. Conroy. 2000. Regional assessment of stream temperatures across northern California and their relationship to various landscape-level and site-specific attributes. Forest Science Project, Humboldt State University Foundation, Arcata, CA. Technical Report.

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

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

This letter was scanned so responses could be incorporated under each comment

City of Chehalis Public Works

March 16, 2001

Mr. David Rountry
Water Quality Program-SWRO
WA Department of Ecology
PO Box 47775
Olympia, WA 98504-7775

Re: Chehalis Temperature Total Maximum Daily Load Study (November 2000 draft) Comment Letter

Dear Dave,

This letter is written to provide comments on the Chehalis Temperature Total Maximum Daily Load (TMDL) Study (November 2000 draft) as part of the public review period. As you may know, we submitted a comment letter on June 26, 2000 regarding the June 2000 draft. Based on our review of the current draft, it does not appear that Ecology has addressed or included those comments in the November 2000 TMDL draft. We originally provided the June 26th comment letter to help Ecology develop this TMDL. Because we spent a great deal of time and resources to generate those comments and because we feel the issues raised are still valid, we respectfully request they be given appropriate attention during this review period. We are attaching the June 26, 2000 comment letter for your convenience. Although the page number and paragraph references in the old comment letter no longer correlate with the latest revision of the TMDL study, we feel the comments are still pertinent.

We would like to provide some additional general comments regarding the Temperature TMDL as it relates to the new proposed use-based Water Quality Standards. First, it should be pointed out that the computer model developed by Ecology shows Class A temperature criterion of 18°C cannot be met even under natural conditions with old-growth trees providing shade all along the river. Ecology correctly points out that this is not unusual and cites a study (Hatten, 1995) that provides Olympic watersheds as an example. Nevertheless, Ecology establishes 18°C as the temperature standard and disregards the temperature obtained from the modeled natural conditions. If the temperature criterion were set based on natural conditions, the standard would be 28/(T+7) °C for the edge of the chronic mixing zone and a rise of not more than 0.3°C over the natural river temperature under complete-mix conditions. Based on this information, we should now look at what the temperature standard would be under the new proposed use-based standards.

***Response*: The Chehalis watershed and timing of this TMDL are quite different from what Hatton described. Prevailing in this case are the current regulatory standards and requirements for a TMDL for Chehalis River conditions. The Chehalis is a mixed-use watershed, meaning that there are both point and non-point sources influencing the water quality impairment. According to the TMDL regulations, both point and non-point sources**

have TMDL responsibilities in this case. Use-based standards are being proposed by Ecology, but current standards are relevant to the TMDL at this time.

According to the latest draft of the proposed new standards, the temperature criteria for the upper Chehalis River Basin would have to meet the most restrictive of water-use standards identified for the water body segment. This use would be to provide protection for the spawning of Salmon, Steelhead, and Cutthroat Trout (proposed WAC173-201A-030 (a)(ii), December 2000). This use then places the weekly average temperature standard at 12°C and the daily maximum standard at 14.5°C. The proposed 7-day average standard would be 6°C lower than the existing Class A standard. Furthermore, Ecology is establishing a wasteload allocation for a period of time when the fish species identified are not in the river. Based on this, it appears that this model has little to do with protecting the river and the aquatic life in the river, but has much to do with deciding that more shade is desirable for the watershed. Perhaps a new approach needs to be developed to provide a strategy on how the TMDL analysis will be used to develop wasteload allocations that would assist the river to revert to its natural temperature conditions.

Response: The water quality standards for temperature are used as a measurement for protection of aquatic health in general, and for fish in particular. Temperature reductions identified are needed to protect the aquatic system, and shade targets are applied as a surrogate condition necessary to achieve temperature standards. Shade was chosen as a mechanism for non-point controls also because compared to other factors like air temperature and channel characteristics, shade can be more practically managed and improved.

Such a strategy should also include an economic study to determine the cost of implementation as compared to the estimated improvement of water quality and most importantly how these improvements will improve the water quality for the designated water uses for the river. As you may know, the City's sewer rates are already among the highest city rates charged in Washington State per capita. These rates are the direct result of implementing the Upper Chehalis River Basin Dissolved Oxygen TMDL that requires us to remove our discharge from the river during low flow conditions. Ecology acknowledges that once the work identified in our recently completed General Sewer Plan is implemented, there will be no measurable DO improvement in the river. Therefore, to spend substantially more funds to address the temperature issue with again no improvement to the river will be very difficult to justify to our constituents.

Response: While Ecology recognizes that implementation of this TMDL will have economic impacts, we also believe that over time the TMDL will have numerous benefits to affected communities and natural resources.

In February 2001, Ecology revised their Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (DOE Pub. No. 01-03-003). This requires that a Quality Assurance Project Plan (QAPP) be prepared for any environmental study undertaken by Ecology. Was a QAPP prepared to address quality assurance and quality control concerns during data collection and modeling for this Temperature TMDL Study? If such a document was prepared, we feel it would have been fair to the public reviewers if a copy of this document were made available. We believe that Ecology strives to provide management decisions based on the best available information. However, much of the data used by Ecology has never had the benefit of being gathered or analyzed under the scrutiny of a QAPP. For example, can you explain why the highest temperature ever recorded for the Chehalis River (24.5°C) occurred in June 1992 and why the river cooled as it moved downstream? This TMDL and TMDLs in general, result in extremely important water quality management decisions being made (i.e. allocation of wasteloads). However, those decisions are being made without the benefit of quality data or analysis. It is known that information can be subject to bias and error and if there are no Data Quality Objectives identified, this misinterpretation of information can lead to wrong management decisions resulting in unnecessarily high costs to taxpayers. A public review of the QAPP would assure the affected parties that this is not the case.

<u>Response</u>: A Quality Assurance Project Plan is required when Ecology undertakes field sampling. Ecology did not collect new field data for this TMDL. Instead, we utilized data previously collected and reported in other studies. However, a description of project methods and Quality Assurance/Quality Control procedures are described in appendices "B" and "C" of the original "Upper Chehalis River Dry Season Total Maximum Daily Load Study" report, publication # 94-126, July 1994. We relied upon quality assurance controls that others applied to their data and analyses that we utilized in the current TMDL study. Ecology applied reasonable scientific rigor to selection and use of data, and followed accepted scientific protocols in the modeling and technical analysis.

The following comments are more specific to the November 2000 Temperature TMDL Study document:

1. Page 5, fourth paragraph - It should be added that this study also finds that even in pre-European settlement conditions, with old-growth trees providing 100% shade canopy all along the river, temperature criteria are still exceeded. It seems inappropriate to blame the fact that temperature criteria cannot be met due to human development. This inappropriateness is further compounded by the fact that point source dischargers who actually tend to cool the river during the warmest days of the year are forced to undertake costly actions in an attempt to mediate a temperature problem in the river that is largely caused by other factors.

   <u>Response</u>: There are really two issues that are being raised in this comment. The first issue is whether high water temperatures are really due to human causes or are the result of natural conditions. This temperature study does not say that human activities alone are the cause of high water temperatures. The study finds that state temperature criterion are not being met at many locations, recognizes that both natural conditions and human activities may be a significant contributing factor, and makes recommendations directed towards the only thing that can be controlled – human impact on water temperatures. This position is explained in the paragraph cited in the comment starting with the fourth sentence. It is also explained in the last paragraph on page 15 through the third paragraph on page 16.

   The second issue raised in this comment questions the appropriateness of requiring point source discharges to undertake costly action to address a problem that is largely caused by other factors.

   Computer modeling always contains a degree of uncertainty that is accounted for by incorporating a margin of safety. Modeling of Chehalis River temperatures shows that the most important factor affecting water temperature is riparian shade. However, other conditions such as river flow channel shape and point source discharges do have an affect. Allowing for the uncertainty in the results of computer modeling, Ecology believes that the

allocations for nonpoint and point sources contained in this TMDL, if implemented, should restore temperatures close to those that existed prior to human influences on receiving waters. Because of this Ecology has concluded that the "natural conditions" provisions in the water quality standards criterion for temperature does not apply and point source dischargers will be limited to a temperature that would not cause the 18°C criterion to be exceeded. Taking this conservative approach helps build in some margin of safety.

EPA "Guidance For Water Quality Based Decisions: the TMDL Process"(April 1991), requires that when the state cannot provide reasonable assurance that the required level of nonpoint source pollution reduction can be achieved, wasteload allocations for point sources must be established at a level that provides the maximum amount of resource protection. Computer modeling predicts that achieving the recommended levels of riparian shade should restore water temperatures close to the 18°C temperature criterion. However, the state does not by itself have sufficient resources to ensure that all landowners along the river will take the necessary actions to meet the shade requirements. Under these conditions, the state cannot provide EPA with reasonable assurance that the nonpoint source controls necessary to restore water temperatures will be achieved. Therefore, consistent with EPA's policy cited above, this temperature TMDL establishes a temperature wasteload allocation for point sources of zero. A temperature wasteload allocation of zero means that point sources will not be allowed to discharge any heat to the system above 18°C.

To provide some flexibility to existing point source dischargers, Ecology has chosen to apply the standard permitting practice of applying the wasteload allocation at the edge of an authorized mixing zone for existing point source discharges. Any new point source discharges will have to meet the 18°C temperature criterion at the end of pipe.

2. Page 6; last sentence - The critical period for temperature should be based on flow during dry weather conditions rather than by month. Data already available supports this fact. The City would gladly share several years worth of river temperature data that was collected on the City's own initiative.

   Response: The statement referenced in this comment is a general statement about the time of year when environmental conditions combine to cause high water temperatures. The critical period for this temperature TMDL is created by a number of environmental conditions. As you have pointed out, low summer flows due to the seasonal precipitation patterns in the northwest are certainly one of the contributing factors. Other contributing factors include the angle and duration of solar radiation and air temperature. The critical period for this TMDL recognizes these contributing factors and establishes a critical period for temperature based on the period of the year when the combination of these environmental conditions have been documented to, or are likely to, cause high water temperatures. The regulatory trigger for defining critical conditions has been based on river flow.

3. Page 7, Table 2 - What were the Data Quality Objectives of this data collected? Were there any QA/QC samples? Did the data take into account any information on stratification? In the June 26th letter, we also commented on the quality of this temperature data. How can it be that the highest temperature recorded was on June 23, 1992 for the Chehalis River at Dryad

(STA #23A160) that is in the upper portion of the Chehalis River? A scan of temperature data from other Chehalis River stations taken at the approximately same time (within a day or two) suggests that the temperature of the river actually cools as it moves downstream from Dryad. This seems counter-intuitive since the river water would be exposed to additional solar radiation as it travels downstream. We feel the data needs to be subjected to the rigorous requirements of a properly prepared QAPP to properly identify and address such trends and relationships.

***Response*: The discussion above about a Quality Assurance Project Plan provides a response to this question as well.**

4. Page 9, Modeling Approach - We believe that it is inappropriate to model the entire basin using inputs that represent the basin as a whole. We understand that a temperature network model was used, but the inputs listed use the most conservative of each parameter for the whole basin. Might it not be more appropriate to break up this large basin into many smaller sub-basins for more accurate model output?

   ***Response*: The basin model that was used in this TMDL was originally written by U.S. Fish and Wildlife Service and is supported by the U.S. Geological Survey. Earlier work on this TMDL (Pickett, 1996) utilized a "reach model". That approach was not endorsed by EPA however, who requested that a basin modeling approach be used in order to show better cumulative effects of heat loading.**

5. Page 11, In-Stream Temperature for Calibration and Validation - Why was the temperature data from the wastewater treatment plants not used? Ecology should have this data available to them in the form of monthly Discharge Monitoring Reports. This section further states that the highest temperature used was in August that doesn't correspond to page 15 where the temperature used for the model input was July; this also doesn't correspond with page 7 where the maximum temperature identified occurred in June. This highest daily temperature was used to model a 30-day steady state modeling run. Shouldn't a 30-day steady state modeling run use daily temperature values instead of assuming that the highest daily temperature occurred for all 30 days? Again, why was stratification not taken into account? Temperature should be taken in accordance to depth and a weighted average developed since fish would not be found in the warmer surface waters.

   ***Response*: This comment raises several issues. Chehalis DMRs do contain effluent temperature data, however to our knowledge this is not "end of pipe" data. If Chehalis can demonstrate that the DMR temperature data is closer to actual effluent temperature at the end of its discharge pipe than the temperatures used for the TMDL model calibration, applies those temperatures to the model, and demonstrates that it will change the conclusion of this TMDL the resulting information can be incorporated into future changes to the TMDL once it has been verified by Ecology.**

   The different temperature values were simply used for different purposes. The August water temperatures (page 11) were used to calibrate and validate the model. The July air temperature (page 15) representing a 50-year period was used to represent the critical condition for model application. The June water temperature (page 7) presents descriptive statistics for temperature data combined from all Ecology stations in the Upper Chehalis Basin over an 8-year period. The June water temperature statistics were not used in the

modeling.

The highest temperatures measured in August were used to calibrate and validate the model performance to critical conditions because a larger data set exists for that month. The use of maximum temperatures representing a 30-day steady state is a conservative assumption serving as part of the margin of safety required by EPA.

Stratification was not taken into account because the model in one-dimensional. Surface temperatures were used as one element of the required margin of safety.

6. Page 13, Model Calibration and Validation - As mentioned towards the beginning of this letter, we feel that this section does not provide much insight as to the usefulness of the model since a QAPP was not identified as being prepared prior to data collection or modeling. This section merely states what was done without identifying or meeting any Data Quality Objectives.

Response: The discussion about QAPP just before comment #1 applies to this comment as well.

7. Page 14, Table 5 - As -stated in the June 26th letter, the statistics portion of this table does not correspond with the text in the paragraph immediately following.

Response: The table has been changed to be consistent with the text.

8. Page 15, Model Application, first paragraph - The 90th percentile maximum air temperature determined from data at Olympia Airport was 31.1°C. Why is temperature from Olympia Airport used? Olympia Airport is a long distance from the Chehalis River. The longest day of the year (June 21st) does not correspond to the date in which the 90th percentile temperature March 16, 2001 occurred (July 21,1998). The maximum temperature used should correspond to the 7-day period when the 7Q10 low flow occurs. We understand that you used several extreme conditions that will not occur together as an attempt to design a safety factor into your model. However, you should specifically quantify what that safety factor is.

Response: Olympia weather data was the best (i.e., most reliable) recorded data available. This comment is addressed more fully in the "General Response to Comments" (i.e., Margin-of Response: The general response to comments, (i.e., Margin-of-Safety) applies to this comment. Also, the most sensitive variable influencing temperature is shade. Other conditions mentioned above are more difficult to control; air temperature is primarily a natural phenomenon. The reference to monitoring and re-allocation of waste loads is based on the need for long-term evaluation of the effectiveness of corrective strategies. Major improvements in shade are predicted to occur incrementally over several decades. It may take a long time before non-point source strategies demonstrate durable improvements such that recalculation of point-source waste-load allocations may be justified.

Safety).

9. Page 16, second and third paragraphs - If the model used (which the TMDL allocations are based) does not include riparian cooling of ambient **air (which is paramount to any**

temperature model), reduced sediment loading, and stream width-to-depth ratio, then how can any water quality management decisions be confidently made? The third paragraph further says that additional monitoring and re-allocating wasteloads can be done in the future to modify the TMDL, if necessary. It has been our experience with the dissolved oxygen TMDL that Ecology does not have adequate resources to make these modifications and in fact is reluctant to modify a TMDL after it is approved by EPA, even if the original TMDL is based on data and models which are acknowledged to be insufficient.

10. Page 18, Table 8 - Please explain the results of this sensitivity analysis. The numbers have no units associated with them.

***Response**: The units for the right hand column are degrees Celsius. This table shows the effect on individual modeling parameters of doubling the value for that parameter while the other parameters remain constant. For example, if you double the humidity the result in the model is a 7.6°C increase in the predicted temperature. The analysis shows that an inaccuracy in the value for air temperature has the greatest effect on the model results. Inaccuracy of other parameter values still affect the model results, some of them to a significant degree.*

11. Page 22, last sentence - Please explain what this means. Again it would help to quantify the likelihood of these critical conditions occurring simultaneously.

***Response**: The general response to comments (Margin of Safety) provides a reply to this comment.*

12. Page 24, fourth paragraph, first sentence - The assumption that riparian vegetation will be re-established seems to be a century or two in the future. Does this imply that regular maintenance of this Temperature TMDL will be conducted over the next two centuries?

***Response**: It will take decades for non-point strategies to produce all the necessary temperature improvements. TMDL follow-up monitoring and "maintenance" is an on-going responsibility for the state.*

13. Page 25, last sentence - This suggests that end of pipe limits will be required for new point source discharges. If Chehalis replaces its existing outfalls then would Chehalis' new WWTP need end of pipe discharge limitations? Please clarify how end of pipe discharge limits can be applicable while at the same time permitting temperature increases allowable in the chronic mixing zone (using the temperature equation) and the complete-mixing zone (using a 0.3°C maximum increase).

***Response**: This comment raises two issues. This first issue is the definition of what constitutes a "new discharge." The City of Chehalis has an existing municipal wastewater point source discharge with a long history of discharging to the Chehalis River. Replacing an existing out fall with a new out fall at the same general location would not result in the City of Chehalis being considered a "new" point source discharge under this temperature TMDL. Chehalis would not have to meet the state's class "A" temperature criterion at the end of its discharge pipe under this temperature TMDL. However, if the outfall is replaced, the "new" dilution factor should be at a minimum the same as that of the existing out fall. Thus, the temperature limitation would not change for the Chehalis WWTP even if the existing facility is upgraded and a new diffuser constructed.*

The second issue asks for clarification on the relationship between end of pipe discharge limits and mixing zones. There is no relationship. End of pipe discharge limits do not provide for a mixing zone. A new point source discharge would not be provided either a chronic mixing zone or an acute mixing zone under this temperature TMDL. A new point source discharge would have to meet the state's temperature criterion at the end of the pipe where its effluent enters the Chehalis River or one of its temperature-limited tributaries.

14. Page 26, first paragraph, last sentence - It is not appropriate to refer to the dissolved oxygen TMDL and assume that all point source dischargers would be out of the river during low flow conditions. It does not seem to be logical for Chehalis to be out of the river during winter low flow conditions when the river temperature may be 5-10°C. Although this may be the resultant outcome of the DO TMDL, there are still several issues that need to be resolved to implement the wasteload allocation. The existing sentence implies that Ecology is not willing to work together with the dischargers to obtain a cost-effective alternative to meet the wasteload allocations stated in the DO TMDL. Hopefully, this statement is not the intention of Ecology as the City is still willing to work with Ecology to address these TMDL issues. Each TMDL should be kept separate until the wasteload allocations are implemented.

<u>Response</u>: The purpose of the sentence was to recognize the fact that the critical period for both dissolved oxygen (June – September) as well as for temperature (May – September) were essentially the same. It is not intended to imply that all point source discharges would be "out of the river" during low flows. "Restricting temperature discharges," means only that the wasteland allocation provided in this TMDL must be met. The wasteload allocation does not require any discharges to remove its effluent from the river, it only requires that the temperature of the discharge be limited.

As written, the critical period temperature limits apply whenever the low-flow conditions specified on page 26 are met, regardless of ambient water temperatures. The critical period could occur during the middle of winter because it is only based on river flow. If Chehalis believe that this is overly restrictive and that some flexibility needs to be built into the definition of critical period to recognize the fact that low-flows can occur during the winter when water temperature is not an issue they should contact the person at Ecology who manages the permit. Ecology and Chehalis can evaluate and develop a cold season threshold during the normal permit development process

15. Page 28 - Again, please clarify, how the temperature limitations would be implemented. During the critical period, how can there be 0.3°C cumulative increases in temperature when the discharge is limited to the temperature criterion while the river is already above the temperature criterion? Furthermore, it states that the 0.3°C cumulative increases is at the edge of an authorized mixing zone. The 0.3°C rise has in the past been applied to complete-mixed conditions not the chronic mixing zone. The second half of Table 14 appears to be redundant and a bit confusing with the top half of the table.

<u>Response</u>: A complete mix condition is generally never achieved within the regulatory mixing zone. Table 14 has been revised to better explain the wasteload allocations during critical and non-critical conditions.

16. Page 30, first sentence - Again, the time necessary to re-establish riparian vegetation will

provide ample opportunity to gather information on the effectiveness of this TMDL. This also implies that regular maintenance of this TMDL would occur over the next two centuries.

***Response**: See response to comment # 12.*

The city appreciates the opportunity to comment on the current draft of the Temperature TMDL. We hope these comments will be of use to Ecology as you work to develop a technically sound document. Because Ecology was unable to utilize the original comments we submitted, we would like to request a meeting at some point in the future to discuss how all of our comments are being dealt with. We realize Ecology will need some time to sift through all of the comments submitted on the temperature TMDL. However, since we are a stakeholder in the outcome of this study, it is important to us that we see a definitive response to each of the issues we raised. A meeting would seem to be an ideal format to discuss our comments.

If you have any questions and/or comments please feel free to give me a call at (360) 748-0238. Thank you very much for your time and consideration.

Sincerely,

CITY OF CHEHALIS

James R. Nichols, P.E.

Public Works Director/City Engineer

cc: Dave Campbell, City of Chehalis
Patrick Wiltzius, City of Chehalis
Dick Riley, Gibbs & Olson

This letter was scanned so responses could be incorporated under each comment.

City of Chehalis Public Works

June 26, 2000

Mr. Darrel Anderson
Department of Ecology
P.O. Box 47775
Olympia, WA 98504-7775

Re: Temperature TMDL Comments Dear Mr. Anderson,

I am writing as a follow up to our recent meeting at the Department of Ecology (DOE) offices concerning the revised Temperature TMDL for the Chehalis River. During that meeting, the revisions proposed by the Environmental Protection Agency were reviewed with representatives from Westfarm Foods, the City of Centralia, and the City of Chehalis. Several issues and questions were noted during the discussion. As a result, the affected interests were asked to provide written comments on the Temperature TMDL by June 26, for consideration by DOE. The following is a summary of the areas of concern noted by the City of Chehalis:

1. Page 2, paragraph 3, "1) flow will not be further reduced during critical periods by direct withdrawal or pumping from aquifers." The term "critical periods" is used throughout the document in reference to the months of June and July (see page 5, the end of paragraph 2), as well as the low flow periods. How is it actually defined for the purposes of this report?

   <u>Response</u>: The term "critical period" for this temperature TMDL overlaps the critical period for the Upper Chehalis Dissolved Oxygen TMDL. It has been refined so that it is 1) based on river flow, and 2) consistent with the critical period negotiated under the consent decree for the Upper Chehalis Dissolved Oxygen TMDL.

2. Page 2, paragraph 4, "discharge temperatures for four point source inputs are established at the level that would not cause or contribute to increasing the stream temperature above standards." DOE's sensitivity analysis indicated that the Chehalis WWTP effluent would <u>NOT</u> create an increase in river temperature at any time of year. However, 18.0°C is being established as a "not to exceed" value when the river is over 18.0°C under critical conditions versus the no impact to existing temperatures, noted for wasteload allocations. Why is the wasteload allocation definition being ignored in the TMDL? In addition, the sensitivity analysis showed that inflow water temperature was ranked at the bottom (9") of the sensitivity table. Why has that analysis been removed from the TMDL report and the focus of the study shifted from non-point sources to point sources?

   <u>Response:</u> Portions of this question have been answered in the response to question #1 in the city of Chehalis' comment letter dated March 16, 2001. The sensitivity analysis was removed from this TMDL because EPA disagreed with it.

3. Page 3, paragraph 4, "the TMDL has been revised based on a stream network temperature model (SNTEMP) which assesses the cumulative effects of several factors." DOE indicated

that EPA chose to disregard their sensitivity model that showed that WWTP effluent would have no impact on river temperature. Therefore, can it truly be stated that the TMDL was based on the SNTEMP model or was selective data utilized and/or ignored in the development of the document?

<u>Response:</u> EPA disagreed with the size of the mixing zone Ecology used to show that WWTP effluent at existing temperature would not have an impact on river temperature and did not accept the results of the modeling using the mixing zone. The SNTEMP model is still the basis for the model and data was neither selected for nor purposefully ignored.

4. Page 4, paragraph 4, "temperature shall not exceed 18.0°C ... due to human activities. When natural conditions exceed 18.0°C ..., no temperature will be allowed which will raise the receiving water temperature by greater than 0.3°C." The water quality standards noted in this paragraph appear to be contradicted by the TMDL. This draft convolutes the WAC such that the WQ Standard is applied in reverse, (i.e., if the temperature of the river is above 18.0°C then the WQ Standard is 18.0°C and if the temperature of the river is below 18.0°C then a 0.3°C rise is allowed). The Temperature TMDL must follow the WAC or, if the WAC is wrong, it should be changed appropriately.

    <u>Response:</u> Ecology is not able to determine that temperature violations are the result of "natural" conditions, so the provisions in the state Water Quality Standards that take effect when water quality violations are the result of natural conditions do not apply. See Ecology's response to question #1 in the City of Chehalis' comment letter dated March 16, 2001.

5. Page 5, paragraph 3, "few data are readily available on the existing shade conditions in the basin." How can the TMDL and associated modeling be developed if there is no reliable data upon which to base them?

    <u>Response</u>: Ideally, TMDLs would be developed based on copious amounts of very current data. It is not unusual, however, for TMDLs to be developed using limited amounts of data, and the TMDL regulations allow for reasonable assumptions to be used when data is not available. The use of computers is also an accepted method (using reasonable assumptions) for modeling conditions that have not been actually observed. Follow-up monitoring to track changes that result from the implementation of TMDLs is used to validate or adjust the implementation strategy of the TMDL.

6. Page 9, paragraph 3, "since temperatures of the three wastewater treatment plant discharges were not measured, the maximum river temperature measured at the surface near the point of each discharge was used as the effluent temperature." The City of Chehalis does have a record of effluent and river temperature measurements. There are many occasions during the summer months when the effluent temperature is lower than that of the river. Therefore, the assumption incorporated into the calibration is erroneous.

    <u>Response</u>: Chehalis DMRs do contain effluent temperature data, however to our knowledge this is not "end of pipe" data. If Chehalis can demonstrate that the DMR data is closer to actual effluent temperature at the end of its discharge pipe than the temperatures used for the TMDL model calibration, applies those temperatures to the model, and demonstrates that it will change the conclusion of this TMDL the resulting

information can be incorporated into future changes to the TMDL once it has been verified by Ecology.

7. Page 11, paragraph 2, "the median absolute deviations for both time periods are similar at 1.4'C and 1.5°C." This statement does not agree with the results summarized at the bottom of Table 5.

   ***Response:** This issue has been resolved. See Ecology's response to question #7 in the City of Chehalis' comment letter dated March 16, 2001.*

8. Page 11, paragraph 2, "also, the model root mean square error for predicting daily maximum stream temperature for both time periods is 3.2°C." This statement does not agree with the results summarized at the bottom of Table 5.

   ***Response:** This issue has been resolved. See Ecology's response to question #7 in the City of Chehalis' comment letter dated March 16, 2001.*

9. Page 13, paragraph 3, "this result raises the question of whether the current water quality standard for temperature can be met during the critical conditions used in the model even if the watershed still existed in natural conditions." If the water quality standards are potentially unattainable under any circumstances, what is the purpose of regulating effluent discharge temperatures? In addition, it is my understanding that when natural conditions exceed the Water Quality Standards, then those conditions become the new standards.

   ***Response**: This question has been answered in the response to question #1 in the city of Chehalis' comment letter dated March 16, 2001.*

10. Page 13, paragraph 5, "the approach of this TMDL is to prescribe allocations that, if implemented, should restore temperatures close to those that existed prior to human influences on receiving waters." DOE has noted that their analysis shows that current effluent discharge temperatures will not impact current river temperatures. Therefore, regulation of WWTP discharges will NOT restore temperatures as noted in the TMDL.

    ***Response**: See response to question #3 above and the response to question #1 in the city of Chehalis' comment letter dated March 16, 2001.*

11. Page 22, paragraph 3, "activities that increase the temperature, reduce the flow, or impact the stream channel forming processes must be prevented in all tributaries of the watershed." Since the sensitivity analysis indicated that WWTP effluent would not increase temperature, that activity should not be prevented, in accordance with this position by EPA. In addition, removing effluent discharges from the river will reduce flows and thus be in direct conflict with the stated TMDL objectives. It appears that the TMDL requires all dischargers to remove their discharge from the river regardless of their point of discharge. Is this a correct interpretation?

    ***Response**: No. See Ecology's response to questions #1 and # 14 in the City of Chehalis' comment letter dated March 16, 2001.*

12. Page 22, paragraph 4, "the wasteload allocation for these facilities is to limit discharge of

effluent(s) that cause or contribute to exceedence of the water quality standards." Since the DOE analysis indicated that the WWTP effluent discharges would not lead to exceedence of or impact existing river temperatures, why is the effluent temperature being maintained as a regulated issue?

***Response*: This question has been answered in the response to question #1 in the city of Chehalis' comment letter dated March 16, 2001.**

13. Page 31, paragraph 1 (first bullet), "both Ecology and the Chehalis Tribe conduct routine monitoring of surface water temperatures throughout the basin." The City of Chehalis collects stream and WVVTP effluent temperature data on a regular basis. The TMDL should use all readily available data including the temperature data for each WWTP discharge. Such data show Chehalis' discharge is often cooler, during critical conditions, than the river. Can this data be incorporated into the modeling efforts that support the TMDL?

    ***Response*: See response to question # 6.**

14. Table 2 shows the maximum annual temperature in the river occurs in June and that June has the greatest number of samples that exceed the WQ Standard for temperature. If the statistics in Table 2 are correct, then it seems DOE should have modeled the river in June not August. However, if June were modeled then the 7Q10 flow would not be used because that flow does not occur in June. Also, when is the critical period for fish passage and rearing? Do they occur during June and if not, why is June deemed a critical period?

    ***Response:* Review of data in Table 2 showed an error. The figure in the right hand column for April should have been 0% and all other amounts shifted down one row. The greater number of samples over the 18° criteria occur in July. Calibration of the model was done using data for August. However once it was demonstrated that the model was performing well, it was used to determine the amount of shade that would be necessary for temperature criterion to be met during each of the months during the critical period. Base flows for July 1 were used where they have been established by rule. Only in cases where base flows have not been established was the 7Q10 flow used for model simulation. TMDLs are developed with the intent of ensuring that state water quality standards are met so that all beneficial uses dependent on the applicable standard are protected during the period of time the standard applies.**

15. DOE's web page shows the 24.5°C reading in June (the maximum recorded in the river) occurred at Station 23A160 at Dryad and that the river cooled as it moved downstream. Furthermore, in 1992 the river was cooler in July than June was and cooler in August than July. This appears to be a unique condition (if it actually happened and was not a result of operator and/or equipment error) but yet it is the period DOE chose to validate their model.

    ***Response*: Model validation is based on the ability of the model to respond to changing environmental conditions correctly. A model that correctly predicts changes in temperature that occur during widely differing conditions is performing well and should perform equally well during "normal" conditions.**

16. DOE must start working with stakeholders when preparing TMDLs. They need to more clearly demonstrate to the citizens within the river basin that the TMDL will in fact protect

the river. For Chehalis (and the other dischargers) they need to provide a cost/benefit analysis that shows how much cooler the river will be if the discharges are removed from the river and what the costs of removing those discharges will be.

***Response*: Ecology's TMDL program continues to evolve and your comments regarding working with stakeholders are being incorporated. As Ecology's own recent legal history shows cost/benefit analysis are not factors in either state or local compliance with federal laws/regulations. TMDLs are based on the best available science. Results are tracked through follow-up monitoring and adjustments will undoubtedly have to be made over time.**

17. Except for the uppermost stream reaches, DOE assumed topographic contribution to stream shade was zero. During critical conditions much of the Centralia reach, as well as other sections of the river, have steep and high riverbanks. Such banks obviously provide considerable shade to the river. Therefore, the zero shade assumption is erroneous.

***Response*: The variability of bank condition along the wider portions of the Chehalis River, along with the depth of the cut banks results in very little shade reaching as far as the center of the channel along most of the river. Ecology believes that zero shade is a reasonable assumption and the fact that it may be conservative is part of the margin of safety. This assumption can be re-evaluated if new information becomes available.**

18. For many decades, climatological data has been recorded in Centralia. It seems that data would more accurately reflect conditions in the basin rather than the Olympia Airport data, used in developing the TMDL

***Response*: This question has been answered in the response to question #8 in the city of Chehalis' comment letter dated March 16, 2001.**

19. DOE makes seven conservative assumptions that contribute to the margin of safety for the model. Although we understand the need to provide a margin of safety, DOE needs to provide a numeric value for the margin of safety so all the stakeholders can understand the degree to which the river is protected. A quantitative safety factor will make it easier for the parties involved to support such conservative assumptions utilized in the development of the TMDL. However, if a numeric factor of safety were shown to be excessive from a practical standpoint, stakeholders would expect some refinement of the assumptions to provide a more appropriate level of safety.

***Response*: The margin of safety for most, if not all, TMDLs prepared by Ecology have been based on conservative assumptions. Often conservative assumption are used because there is a lack of data that, if available, might allow for development of a "degree" of protection for each environmental factor considered and the eventual selection of a numeric value for the margin of safety for each environmental factor. The conservative assumptions listed in the report are considered to be reasonable by Ecology.**

20. DOE should identify the range of values that can be used for the other twenty-one parameters and variables that go into the model. Such information will help the reader understand whether or not conservative assumptions are also being made for those values.

***<u>Response</u>*: Every TMDL is a trade-off between what could be done with unlimited time and resources and what can be done given the available time/resources. Since time, data and resources are limited, reasonable assumptions are made, and they are conservative to build in a margin of safety.**

21. To allow the city to monitor for compliance with the TMDL, the City of Chehalis, and most likely all dischargers, will need an end-of-pipe wasteload allocation (WLA) for temperature. This WLA can be based on historical data and modeled to protect the river, provided parameters are used in the model that have a reasonable potential to occur simultaneously and within the period being modeled.

    ***<u>Response</u>*: The wasteload allocation for this temperature TMDL has been applied at the edge of an approved mixing zone. The permit manager at Ecology responsible for the city of Chehalis' NPDES permit can assist in calculating a temperature limit for the end of the city's outfall that will result in meeting the wasteload allocation at the edge of the mixing zone.**

22. Without a specific WLA, the WQ Standard that must be met becomes a moving target. River and WWTP flows and temperatures will have to be monitored and calculations performed before the WQ Standard can be determined and an evaluation completed to see if the standard is met.

    ***<u>Response</u>*: If the city wants to assure complete certainty it should plan to meet both the current and anticipated future temperature criteria at the end of its discharge pipe. The approach taken in this TMDL is intended to provide point source dischargers some flexibility in scheduling compliance with the temperature TMDL. As non-point source implementation takes effect and riparian shade increases, river temperature will began to decline. As river temperatures decline, the temperature of point source discharges will also have to decline.**

I hope that this letter provides the level of input you requested as part of our previous meeting. It is my understanding that DOE will be initiating a formal comment period on the Temperature TMDL in the near future. The City of Chehalis wishes to remain involved in the process as it develops. The noted comments are not meant to supercede our potential future involvement in the TMDL review process, but instead serve as preliminary information for DOE to consider as they begin to evaluate the latest version of the TMDL.

As we discussed at our last meeting, I anticipate a written response from DOE that represents the agency's formal position on the Temperature TMDL. The affected interests all expressed a desire to know how the Department of Ecology stands in regards to the current version of the TMDL as well as DOE's intentions from this point forward. This information will be greatly appreciated.

Should you have any questions on the information included in this letter, feel free to contact me at (360) 748-0238. Thank you for the opportunity to provide input on the Temperature TMDL.

Sincerely,

CITY OF CHEHALIS

James R. Nichols, P.E.
Public Works Director/City Engineer

cc: Keli McKay, DOE
Kahle Jennings, DOE
Dick Southworth, City of Centralia
Joe Muller, Westfarm Foods
Dick Riley, Gibbs and Olson
Dave Campbell
Patrick Wiltzius

Appendix E

Processes Influencing Stream Systems

PATHWAYS OF HUMAN INFLUENCE ON WATER TEMPERATURE IN STREAM CHANNELS.

(Prepublication Draft: June 1999)[‡]

GEOFFREY C. POOLE

U. S. Environmental Protection Agency, Region 10, Office of *Environmental Assessment, OEA-095, 1200 6th Ave, Seattle, WA 98101.* poole.geoffrey@epa.gov

ABSTRACT

In-channel water temperature, the most common water quality metric used to measure the amount of heat in a stream, is a function of the amount of heat energy delivered to the stream channel and the amount of water flowing in the channel. Over the last 20 years, advances in the field of river ecology have lead to an understanding of streams as integrated systems comprised of at least three components: channel, riparian zone/floodplain, and alluvial aquifer. External factors ("drivers") determine the net amount of heat energy and water delivered to the integrated stream system, but the internal structure of the stream components determines how heat and water are distributed and exchanged amongst or lost from the system components. Therefore, channel water temperature is ultimately determined by the interaction between external drivers of stream temperature and the internal structure of the integrated stream system. This paper provides a synoptic discussion of the external drivers of stream temperature, the internal hydrologic processes that insulate and buffer channel water-temperatures, and the mechanisms of human influence on drivers and stream structure, which ultimate alter the temperature regime of stream networks. Key conclusions include: 1) management of in-channel water flow is a critical element for re-establishing desirable thermal regimes in streams; 2) in addition to modified riparian vegetation structure; human alteration of groundwater dynamics and channel morphology are critical pathways of human influence on channel-water temperature; and 3) watershed assessment, including analyses of land-use history and analysis of historic vs. contemporary structure of the stream channel, riparian zone, and alluvial aquifer, is an important tool in developing effective management prescriptions for meeting water quality targets for in-channel temperature. Although the discussion and examples in this paper have a Pacific Norwest focus, the ecological principles and processes discussed are applicable to lotic systems in general.

INTRODUCTION

Current understanding of stream ecology indicates that streams are comprised of at least three integrated and interdependent components: the channel, riparian zone, and alluvial aquifer (Findlay 1995; Gibert et al. 1994; Stanford and Ward 1988, 1993; Ward 1989, 1998a, 1998b; Ward and Stanford 1995). From this perspective, the "edge" of a river is not defined by its channel margin, but rather by the edge of the riparian zone (Gregory et al. 1991). Similarly, the "bottom" of a river is not the streambed, but the bottom of the alluvial aquifer (Ward et al. 1998). These components are set within the context of the phreatic surface and groundwater flow network in the catchment. (Figure 1).

[‡] Preferred citation: Poole, G.C. In preparation. Pathways of human influence on water temperature in stream channels. U.S. Environmental Agency, Region 10. Seattle, WA.

The **stream channel** is the area where water flows across the land surface. The channel boundary is approximately the typical annual high water level on each stream bank. Some streams have multiple channels (Kellerhalls et al. 1976; Leopold and Wohman 1957; Mosley 1987). This underscores the fact that a steam channel may be discontinuous in cross section, comprised of the main channel, side channels, and perhaps channels that are active only during the period of annual high flow. Where floodplains are present, the locations of channels change over time (Leopold et al. 1964; Naiman et al. 1992). Sometimes these changes occur gradually over decades as streams erode the outer banks along stream meanders and deposit sediment along the inner banks. In other instances, streams in flood stage rapidly cut new channels or recapture previously abandoned channels (Nanson and Knighton 1996). Channel migration processes are important for the creation and maintenance of floodplain complexity. This complexity, in turn, drives important in-stream dynamics (e.g., nutrient and carbon cycles, natural floodwater storage, and buffering water temperature) and enhances the variety of available aquatic and terrestrial habitats thereby supporting biological diversity (Abbe and Montgomery 1996; Creuzė des Chatelliers et al. 1994; Harvey and Bencala 1993; Sedell and Froggatt 1984).

The **riparian zone** is the area of land influenced by moisture derived directly from the stream. For small streams, this area may only extend a short distance (10° to 10^1 m) laterally from the channel margin. However, for larger streams, the riparian zone extends much further (10^1 to 10^3 m), at least to the edge of the active floodplain (Gregory et al. 1991). For the great rivers of the world such as the Mississippi and Amazon, the riparian zone sometimes extends even further (10^3 to 10^5 m) (Salo et al. 1986). Riparian zones form the transition zone (or *ecotone)* between terrestrial and aquatic systems. Periodic flooding of the riparian zone encourages the exchange of water, nutrients, sediments, and energy between the river channel and the riparian zone. This exchanges creates unique habitats, enhances natural productivity, and drives biological process that contribute to the ecological complexity and integrity of stream systems (Ward 1998b).

The sediments that have been deposited and sorted as the result of hydraulic processes (alluvium) along with the groundwater contained therein form the **alluvial aquifer** (Creuzė des Chatelliers et al. 1994). Generally speaking, the alluvial aquifer includes the sediments that underlie the riparian zone (including the floodplain) and the sediments that comprise the streambed. In streams that flow across bedrock, alluvial deposits (and therefore the alluvial aquifer) may be no more extensive than pockets of sediment trapped in depressions in the bedrock. However, in most large rivers, the entire floodplain is built from alluvial deposits often many meters thick. Stream channels actively exchange water back and forth with their alluvial aquifer (Gibert et al. 1994). *Hyporheic groundwater* is water that infiltrates into the alluvial aquifer from the stream, travels along localized subsurface flow pathways for relatively short periods of time (perhaps from 10^{-2} to 10^4 days), and re-emerges into the stream channel downstream without leaving the alluvial aquifer. The portion of the alluvial aquifer that contains at least some hyporheic groundwater (White 1993) is referred to as the *hyporheic zone* (Brunke and Gonser 1997; Stanford and Ward 1988). Therefore, there are two types of groundwater that influence streams, hyporheic groundwater and *phreatic groundwater* (water derived from the catchment aquifer). Phreatic groundwater often enters the hyporheic zone and mixes with hyporheic groundwater; therefore, the groundwater ultimately released into the stream channel at a given point may be predominantly phreatic, predominantly hyporheic, or a mixture of both. The hyporheic zone can exert an extremely strong influence on the biological, chemical, and physical processes that occur in a river (Brunke and Gonser 1997; Findlay 1995; Stanford and Ward 1993).

WATER TEMPERATURE IN STREAM CHANNELS

Water temperature is not a simple measure of the amount of heat energy in a stream reach.. Temperature is proportional to heat energy divided by, the volume of water.

Water Temperature oc Heat Energy / Water Volume

Therefore, conceptually, water temperature can be thought of as a measure of the concentration" of heat energy in a stream. All water contains heat energy; warmer water simply contains a higher "concentration" of heat energy than does cooler water.

The *heat load* is a measure of the net amount of heat addled to a stream channel; any increase or reduction in heat load will affect stream temperature by altering the amount of heat energy in the system. The *flow rate* is a measure of the volume of water flowing in a stream channel. Substituting "heat load" and "flow rate" into the above equation results in.

Water Temperature oc Heat Load / Flow Rate

Therefore, stream temperature is dependent on both heat load and stream flow; any processes that influences heat load to the channel *or* stream flow in the channel will influence the temperature of water in the stream channel and can be considered a *driver* of stream temperature. Since all water contains heat energy; heat energy is added to a stream channel any time water is added to the channel and lost any time water is removed. When cool water is added to a warm stream, the temperature falls not because heat energy was lost, but because the "concentration" of heat energy in the stream was diluted. In spite of the fact that heat energy is lost from a stream when water is removed from a stream, the, temperature remains unchanged became the "concentration" of heat energy in the stream remains the same.[1]

Heat energy is also gained or lost by a stream without adding or removing water. Heat energy flows between the stream and atmosphere in a variety of ways that does not require the exchange of water (Naiman et al. 1992). Heat energy is transferred directly from the sun to the stream surface via the process of radiation. Heat in the atmosphere is transported to the strewn surface via convection, conduction, and advection and is then transferred into the stream via conduction. When heat is added to or removed from a stream channel without altering flow, only the heat load is altered. Increasing .the heat load while holding flow constant will increase stream temperature while decreasing the heat load will decrease stream temperature. By extension, then, it follows that the same heat load applied to a lesser flow will result in higher water temperatures in the stream channel. This illustrates that the flow rate in a stream channel is an important determinant of the stream's ability to resist temperature changes in response to a given heat load.

DRIVERS OF STREAM TEMPERATURE

Drivers of stream temperature generally operate beyond the boundaries of the stream and help to form the physical setting or context within which the stream flows. Drivers control the rate at which heat and, water are delivered to the stream system and therefore have ability to actually cool or warm the water in the stream. Examples of stream drivers are listed in Table 1.

Atmospheric drivers interact with the geographic drivers (e.g., topography, lithology, and upland vegetation) in the basin to determine the rate and means by which water enters the stream.

[1] Evaporation is an exception to this rule. The cooling effect of evaporation results from the fact that the water adsorbs additional heat energy as it changes state from a liquid to a vapor. This additional energy that is removed from the stream alters the ratio of heat energy to water volume in the stream.

Ultimately, all stream flow derives from precipitation, but precipitation enters the stream via a number of pathways directly, via surface flow, or via groundwater discharge after infiltrating the catchment aquifer.

Although some streams in arid climates flow only as the result of surface runoff, most streams derive at least some of their flow from groundwater. Therefore the temperature of the surrounding upland aquifer is generally the "baseline" temperature from which stream temperature deviates. Channel water temperature trends away from groundwater temperature and toward atmospheric temperatures in a downstream direction.

As soon as groundwater enters the stream channel and is exposed to the atmosphere, heat exchange begins and the water begins to equilibrate with atmospheric temperature. In the absence of insulating, and buffering influences, streams will rapidly trend away from groundwater temperature and toward atmospheric temperature. Even in the presence of insulating and buffering influences, streams often naturally reflect a very gradual downstream trend in temperature. Groundwater from the catchment aquifer influences channel water temperature when it enters the stream channel; if the water in the channel has warmed or cooled while flowing downstream, lateral groundwater inputs moderate channel water temperature toward groundwater temperature.

Temperature of lateral surface water inputs to the stream network reflect the seasonal climate and is much less consistent over the year than that of groundwater inputs. Like groundwater inputs, however, lateral inputs from tributaries and surface run-off affect water temperature by pulling the channel temperature toward the temperature of the tributary/run-off.

PHYSICAL STRUCTURE OF STREAMS

Unlike drivers of stream temperature which operate outside the boundaries of the stream, the physical structure of a stream (as represented by channel and floodplain morphology, riparian vegetation structure, and the stratigraphy of the alluvial aquifer) exerts internal control of stream temperature. Rather than warm or cool a stream as the drivers do, the physical structures of a stream determines how well a stream resists warming or cooling. Stream structure is strongly influenced by the physical dynamics occurring within the stream (Beschta and Platts 1986; D'Angelo et al. 1997; Hawkins et al. 1997; Vannote et al. 1980). Unlike drivers, which deliver heat and water to the stream, the physical structure of a stream determines how well the water in a stream channel *resists* warming or cooling by determining the means and rates of heat and water entry into flow through, storage within, and release from the stream system and its components.

A wide variety of stream characteristics affect the way water temperature in stream channels responds to natural drivers of stream temperature (Table 2). Some stream characteristics enhance processes that *insulate* streams by reducing the rate of heat or water flux into or out of the channel. Other physical characteristics of stream influence processes that *buffer* stream channel temperature by removing heat/water from the channel when temperatures/flows, are high and releasing heat/water to the channel when temperatures/flows are low.

Insulating processes

Stream characteristics that influence the rate of heat exchange with the atmosphere can be said to insulate the stream. These characteristics include the height, density, and proximity to the channel of riparian vegetation and the width of the stream channel. Riparian vegetation shades the stream, blocking solar radiation from reaching the channel and reducing the heat load to the stream (Davies and Nelson 1994; Hostetler 1991; Li et al. 1994; Naiman et al. 1992). Vegetation also reduces wind speed across the stream channel. This action trapps air against the water surface thereby reducing conductive heat exchange with the atmospheric by decreasing the amount of heat energy delivered to the water surface via convection and advection (Naiman et al. 1992). Width influences channel surface area across which heat is exchanged; a greater surface area allows for more rapid conductive heat transfer. Under the same climatic conditions, narrower, deeper channels will not exchange heat with the atmosphere as rapidly as shallow, wide channels. Similarly, riparian vegetation of a given height will shade a larger percentage of a narrow channel than a wide channel.

Buffering processes

Buffering processes may either heat or cool the stream channel at any given point in time, but buffers differ from drivers in several important ways. First, buffers operate by storing heat that is already in the stream system rather than by adding or removing heat from the stream. For instance, buffers may transfer water and heat between the components of the stream (i.e., from the alluvial aquifer to the stream channel), but water and heat are not added to nor withdrawn from the system. Secondly, buffers operate by integrating variation in flow and temperature over time. If water and heat flux into the stream were constant, buffers would have no effect on channel water temperature.

The two-way exchange of water between the alluvial aquifer and stream channel (*hyporheic flow*) is an important stream temperature buffer. The magnitude of hyporheic flow in a stream in determined by the stream channel pattern, the structure of the alluvial aquifer, and the variability in the stream hydrograph (Creuzė des Chatelliers et al. 1994; Evans et al. 1995; Evans and Petts 1997; Hendricks and White 1995, Henry, 1994 #435; Morrice et al. 1997; White et al. 1987; Wondzell and Swanson 1996)

Hyporheic flow occurs at three different spatial and temporal scales. At the finest scale (*streambed scale*), hyporheic flow is driven by alternative pool/riffle sequences in the stream channel (Vaux 1968; White et al. 1987). Water enters the stream bed (i.e., the top of the alluvial aquifer) at the downstream end of pools, flows through the streambed sediments, and re-emerges into the channel in a riffle downstream (Figure 2). Channels with complex streambed topography have higher rates of streambed hyporheic flow (Harvey and Bencala 1993). Streams with relative little streambed complexity may lack the pool/riffle sequences that drive streambed hyporheic flow. Streambed scale hyporheic flow pathways apt to influence channel temperature might be anywhere from 10^{-2} to 10^{1} days in duration. At an intermediate spatial scale (*meander-bend scale*) hyporheic flow is driven by the development of mid-channel bars and meander bends in streams (Wroblicky et al. 1994) and by the presence of side channels, backwaters, and abandoned channels (Stanford et al. 1994). Water enters the upstream end of a gravel or sand bar, flows through the underlying alluvium, and re-emerges into the stream at the downstream end. Similarly, hyporheic water follows preferential flow pathways underneath abandoned channels or flood charnels and re-emerges in backwaters and side channels or as springbrooks on the floodplain which eventually rejoin the river (Stanford and Ward 1992). Stream sinuosity and the presence of geomorphic features such as side channels, flood channels, and backwaters are critical influences on the magnitude of hyporheic flow at the meander-bend scale. Hyporheic flowpath duration at the meander-bend scale might be anywhere from 10° to 10^{3} days in duration. At the coarsest scale (*floodplain scale*) water tends to enter the alluvial aquifer at the upstream end of floodplains, flow laterally through the alluvial aquifer, and re-emerge at the lower end of the floodplain (Stanford and Ward 1993). The simple model of a trough placed on a slight incline and filled with marbles provides an analogy. Water poured into the upper end of the trough will trickle down through the marbles, flow laterally along the trough through the marbles, and reemerge at the surface of the marbles before spilling over the lower end of the trough. Hyporheic flow duration at the floodplain scale may perhaps be on the order of 10^2 to 10^5 days.

Hyporheic flow at the streambed and meander-bend scales buffer channel water temperature because hyporheic flow pathways are short in duration and are often somewhat separate from the phreatic groundwater flow network. Because of the short residence time and discrete flow pathways, hyporheic water may not equilibrate with mean groundwater temperature before re-emerging into the stream. For instance, if a hyporheic flow pathways is four months in duration, the temperature of emerging hyporheic water may be very close to the channel temperature from four months ago (C. Frissell, University of Montana, unpublished data). Since river temperature fluctuates in diel cycles, the most significant buffering affect of streambed scale hyporheic flow occurs when water from the alluvial aquifer re-enters the channel at a time of day opposite that of its entry into the aquifer. Similarly, meander-bend scale hyporheic flow will be most effective as a temperature buffer if water infiltrates and re-emerges at opposite times of the year. Thus, hyporheic exchange results in a horizontal and vertical mosaic of groundwater temperature across the alluvial aquifer, the pattern of which is, determined by the structure of the alluvial aquifer, the morphology of stream channel, and variations in channel flow and temperature (Evans et al. 1995; Evans and Petts 1997; Stanford et al. 1994; White et al. 1987). Because of infra- and inter-day variations in stream temperature, streambed and meander-bend flow pathways of virtually any duration have the potential to buffer stream temperature.

The flow path duration of floodplain scale hyporheic flow is likely long enough to allow temperature to equilibrate with the mean subsurface temperature. Therefore, floodplain scale hyporheic flow likely buffers stream water temperature by extracting water of varying temperature from the channel and returning that water to the channel at a relatively constant temperature approximating mean annual air temperature.

The hydrograph of the stream also plays, an, important role in driving hyporheic exchange of water. Although hyporheic exchange (both recharge and discharge of the alluvial aquifer) occurs year-round, the *net* recharge to the alluvial aquifer varies seasonally depending on the flow regime in the channel (Creuzė des Chatelliers et al. 1994; Hendricks and White 1995; Morrice et al. 1997; Wroblicky et al. 1998). Positive net recharge generally occurs during high-flow periods; negative net recharge occurs during periods of low flow. In streams where flood spates occur during winter and spring months, the highest aquifer recharge period occurs while the stream channel is coldest. In these systems, hyporheic exchange and floodplain storage of floodwaters may be an especially effective buffer against stream channel warming because the aquifer is recharged predominantly with cold water and this cold water is discharged predominantly during baseflow periods when the highest stream temperatures are apt to occur.

VARIATION IN STREAM STRUCTURE

Over time, humans have substantively altered the structure of stream systems and the physical context through which streams flow. It is sometimes difficult to imagine the historic structure of streams based on an examination of their current state. A conceptual understanding of the processes and structures that influence stream temperature in unaltered systems can provide a framework from which to understand the breadth of human activities that may substantively influence stream temperature. The following discussion attempts to provide a brief synopsis of stream and catchment dynamics that influence stream temperature and a discussion of how those dynamics are influenced by the natural diversity in stream system structure.

The physical structure of stream channels, riparian zones, and alluvial aquifer changes along the continuum from headwaters to river mouth (Creuzė des Chatelliers et al. 1994; Vannote et al. 1980). For a summary of the ecological implications for these structural changes from low-order (headwater streams) to mid-order to high-order (mainstem rivers) streams, see Naiman et al. (1992). As the structure of streams changes from headwaters to mouth, the processes that drive and mediate stream temperature vary in their relative importance. Generally speaking, as streams become larger, insulating processes become less effective and buffering processes, which are driven by stream morphology, become more important.

Low-order Streams

While notable exceptions exist (e.g. alpine meadow streams), headwater streams, as a rule, have smaller, steeper, narrower channels and narrower riparian areas. These small channels generally carry small amounts of water and therefore, in the absence of processes that cool, insulate, or buffer the stream, experience wide temperature swings as they exchange even relatively small amounts of heat with the atmosphere. Substrate particle sizes in the alluvial aquifer of low-order streams are generally coarse suggesting that there is little resistance to the flux of water between the stream bed and stream channel, subsurface flow rates are high (D'Angelo et al. 1993) and subsurface residence times are short. However, the alluvial aquifer may be poorly developed. Limited aquifer size combined with the low porosity of coarse alluvium results in limited potential for water storage in the alluvial aquifer.

Small channels, on the other hand, are easily shaded by topography and riparian vegetation, which provides substantial resistance to the exchange of heat with the atmosphere. Except during snowmelt periods and heavy precipitation events, small streams derive a large percentage of their water from lateral groundwater inputs, which can provide substantial thermal stability during periods of low flow.

Since most headwater streams generally lack significant alluvial aquifers, hyporheic flow occurs predominantly at the streambed scale. In forested streams, individual pieces of large woody debris (LWD) lodge in the channel and trap sediments that would otherwise be washed downstream (Beschta and Platts 1986; Montgomery and Buffington 1993; Nakamura and Swanson 1993). LWD also creates turbulent flow that contributes substantially to variation in streambed topography – a critical driver of streambed-scale hyporheic flow. Therefore, large wood may play an important, albeit indirect role in buffering small streams against temperature changes by trapping sediments and increasing the storage capacity of the alluvial aquifer and by contributing to streambed complexity that drives streambed-scale hyporheic flow.

Mid-order Streams

Moderate gradients and somewhat wider channels characterize mid order streams. Morphology often alternates between reaches closely confined in their valleys and unconfined reaches that occupy montane flood plains. Substrate particle size is medium to coarse, allowing for substantive hyporheic exchange within and across the streambed, though streambed resistance may be higher than in low-order streams (D'Angelo et al. 1993). Alluvial aquifers can be somewhat to very well developed in floodplain reaches. The high porosity of sand/gravel alluvium allows for substantive water storage and transport in these alluvial aquifers, but, relative to headwater streams, finer grained sediments suggest slower (though still rapid) subsurface flow rates and short to moderate residence times.

Because mid-order channels carry more water, their capacity to absorb heat without substantive changes in temperature is higher than low-order streams, but the somewhat wider channels are less easily shaded by riparian vegetation and have more surface area to exchange heat with the atmosphere. In floodplain reaches, riparian vegetation likely becomes a less effective insulator as the channel widens, the littoral zone widens pushing vegetation away from the low-flow water surface, and topographic shading is reduced as the sides of the valley retreat from the stream. Still, in confined reaches where channels are narrower, riparian vegetation and topographic shade may be important insulators against heat exchange with the atmosphere while hyporheic buffering capacity is likely reduced. Flow from small tributaries is often the predominant source of lateral water inflow; therefore, the riparian condition of tributaries may play a major role in determine channel temperature in mid-order streams.

Channel pattern and morphology begins to play a key role in buffering channel water temperature on montane floodplains. Sinuosity and the presence or absence of gravel-bars, backwaters, and multiple channels determines the potential for hyporheic flow at the meander-bend scale (Stanford and Ward 1993). Multiple channels also allow for more effective riparian shade (Sedell and Froggatt 1984) since the width of each channel is less than the width of a single channel would be.

Large wood continues to play an important role in determining stream morphology. Aggregates of large wood act as roughness elements that redirect flow, causing evulsions and creating pools, bars, and side channels (Abbe and Montgomery 1996; Nanson and Knighton 1996). Single pieces of large wood are often mobile and therefore might not store sediments from year to year. However, hydraulic forces in the proximity of large wood continue to contribute to streambed complexity and streambed-scale hyporheic flow.

High-order Streams

Low gradients and wide channels are typical of high-order streams. Although most are single channels today, many high order, streams once had complex assemblages of active and seasonally active channels, meander-bends, and oxbow lakes (Sedell and Eroggatt 1984). Substrate particle size is typically fine to very fine, reducing the rate of flux into, the streambed and alluvial aquifer. Alluvial aquifers are large and well to extremely well developed; combined with the moderate porosity of the sediments, this results in a large potential for water storage in the alluvial aquifer. High-order channels move large amount of water and therefore can absorb and release relatively large amounts `of heat energy without substantive temperature swings observed in smaller channels. Riparian vegetation and topography generally provide little to no insulation for a wide, single channel with a well-developed littoral zone. The sheer volume of water delivered from upstream may overwhelm temperature effects of lateral inflow from phreatic groundwater sources and tributaries.

The catchment aquifer may influence channel water temperature as much by removing water from the alluvial aquifer as by supplying water to it. Where alluvial aquifers of high-order streams lose water to the catchment aquifer, hyporheic exchange is reduced since water entering the alluvial aquifer from the stream channel is apt to be drawn out of the bottom of the alluvial aquifer rather than returning to the stream channel. This has the effect of both reducing the amount of water in the stream channel as well as damping an important temperature buffer within the stream system.

Meander-bend and floodplain scale hyporheic flow likely provides buffering against temperature changes in the stream and result from stream's channel pattern and morphology. Meander-bends, side channels and other features such as oxbow lakes enhance floodplain scale hyporheic flow. Variable hydrographs likely play an important roll in alluvial aquifer discharge and recharge. The fine-grained substrate has higher resistance to groundwater flow, thereby increasing the duration of hyporheic flow paths resulting in discharges from the hyporheic zone being a more constant temperature over the course of the year. Substantial networks of side-channels and mid-chapel bar formation allow for the inter-fingering of channels with riparian vegetation, providing a much greater, opportunity for channel interactions with the riparian zone (Sedell and Froggatt 1984) including channel shading. In short, the complexity of channel patterns across the floodplain creates a diversity of surface and subsurface flow pathways within which water to moves downstream. These differential flow rates, when combined with seasonal variation in temperature and river stage, allow for stratification, storage, insulation, and remixing of waters with different temperature within and across the floodplain. The resulting mosaic of water temperatures across the floodplain surface and within the floodplain sediments ultimately buffer the main channel against temperature change so long as the natural connections between the floodplain and the stream channel are operational (Ward and Stanford 1995).

PATHWAYS of HUMAN INFLUENCE ON RIVER TEMPERATURE

Based on an ecological understanding of the role of drivers, physical characteristics of stream systems, and resulting insulating and buffering processes in influencing channel temperature, several key conclusions can be drawn.

1) Human activities that alter the ecological drivers of stream temperature can affect water temperature in stream channels by changing: a) the amount of heat energy delivered to the channel (heat load); or b) the regime of water flow in the channel.

2) In stream systems with different structural characteristics (e.g., low-, mid-, and high-order streams), the dominant mechanism that controls water temperature will be different. Therefore, streams with different structural characteristics will differ in their sensitivity to specific human activities that alter ecological drivers and/or stream system structure.

3) The physical structure of streams influences how the water temperature in a stream channel will respond to a given heat load and flow regime. Changing the physical structure of a stream system has the potential to influence both the heat load to the channel and the streams ability to withstand a given heat load without substantive increase in channel water temperature (i.e., the stream's "assimilative capacity" for heat).

Dams, water withdrawals, channel engineering, and the alteration of vegetation (upland or riparian) alter the drivers of stream temperature, the structure of stream systems, or both. Therefore, they are all potential mechanisms by which human activities can influence stream temperature. Table 3 summarizes these impacts by operative mechanism; Figure 3 diagrams the pathways of influence that would tend to increase temperature during low flow periods.

Dams – Dams directly effect downstream temperature based on the mechanism of water release (top- or bottom-release). When considering stream temperature alone, dams can be operated to provide "desirable" stream temperature regimes directly downstream (e.g. through selective withdrawal of water from varying depths in the reservoir) (Stanford and Hauer 1992). However, from a broader perspective, other ecologically deleterious impacts from flow regulation (Ward and Stanford 1995) including effects on temperature insulating and buffering processes are not so easily addressed.

Commonly, dams store spring and summer flows for use in irrigation, recreation, and in order to generate hydropower during cold winter months. In basins where water rights are over-allocated, there is a tendency for dams to be operated such that summertime flows below dams are severely restricted. This massive reduction in flow (sometimes to the point of river stagnation) affects water temperature by reducing or virtually eliminating the assimilative capacity of the stream for heat.

Flow regulation also reduces the magnitude of hyporheic flow. As a temperature buffer (vs. an insulator or driver), hyporheic flow relies on the differential storage of heat and water over time as a means of moderating stream temperature. Differential heat and water storage is driven by *variation* in stream temperature and flow. Since flow regulation dampens variation in both flow and temperature, the potential for hyporheic exchange to act as a temperature buffer is reduced by flow ,regulation (Ward and Stanford 1995). Dams also affect hyporheic flow by altering the downstream morphology of the channel and geomorphology of the alluvial aquifer. The downstream flux of sediment along the river continuum is disrupted which can resulting in downcutting, bed armoring, and, when combined with reduced peak flows, channel stabilization. (Church 1995; Simons 1979). The lack of channel migration and evulsion disrupt fluvial processes critical to creating and maintaining heterogeneous channel patterns (Stanford et al. 1996; Ward and Stanford 1995) and alluvial aquifer structure (Creuzė des Chatelliers et al. 1994) that drive hyporheic flow at the streambed and meander-bend scales.

Dams are often built at constrictions in rivers just below large alluvial floodplains in order to, maximize the storage capacity of the dam while minimizing the size of the structure. Therefore, dams tend to inundate free-flowing alluvial river segments where hyporheic buffering and groundwater inputs are most prevalent thereby reducing the assimilative capacity for heat in the stream. For example, dams have inundated all free-flowing alluvial segment on the mainstem Columbia River with the exception of the Hanford Reach (National Research Council 1996).

Water Withdrawals

Withdrawals from streams have the effect of reducing flow and therefore the assimilative capacity of the streams for heat (Dauble 1994). Although some of this water is eventually returned to the stream, this fraction is typically low; Solley et al. (1993) estimated that only approximately one-third of the water withdrawn in the Pacific Northwest was returned to lakes and streams (as cited in National Research Council 1996). Also, in many cases, water returned to the river after withdrawal is at a markedly different temperature than it was when withdrawn, thereby affecting the heat load to the stream. The water, withdrawals are typically used for industry, municipal water supplies, or agricultural. Regulations may require that the temperature of industrial and municipal returns be restored before they are discharging to the stream, but the fate of water withdrawn for agriculture is less certain. Water from agricultural withdrawals that is not transpired or evaporated will eventually return to the stream. In some cases, this water percolates into the phreatic flow network after application and returns to the stream as groundwater. Although there is the theoretical potential to moderate, stream temperature by using irrigation to increase phreatic groundwater inputs to the stream, the impact on the stream of the initial reduction in stream flow is not likely to be overcome by returning a small fraction of that water through phreatic flow pathways. Further, recharging aquifers by allowing water to percolate through agricultural fields carries the risk of groundwater contamination by pesticides and fertilizers.

Drain tiles are commonly installed in agricultural fields to remove excess water from the soil after irrigation. Water flowing out of these drain tiles usually enters a network of artificial ditches, which deliver the water back to the stream. The temperature of these returns can be more extreme than the stream temperature, further exacerbating the temperature affects of agricultural withdrawals (Dauble 1994; National Research Council 1996).

Major withdrawals from wells penetrating the phreatic groundwater network that feeds a stream can reduce flows in a stream channel (Bouwer and Maddock 1997; Glennon 1995; Wilber et al. 1996). However, when considering the hyporheic zone as a source of stream temperature buffering, a substantial influence on water temperature may *precede* marked reductions in in-channel flows. Less noticeable than reductions in channel flow are subtle changes in the net exchange of water between the hyporheic zone and larger phreatic groundwater system and in groundwater flow within the alluvial aquifer (Long and Nestler 1996). Withdrawals via wells can result in the loss of hyporheic water to the larger phreatic groundwater system (Hibbs and Sharp 1992). In such a case, the buffering capacity of the hyporheic flow network could be substantially reduced because hyporheic water would not be returned to the stream channel to moderate channel-water temperature.

Channel engineering

Straightening, diking, dredging, snagging (removal of LWD), and rip-rapping of channels are all undertaken in an effort to prevent lateral movement of stream channels and to allow stream channels to move water more efficiently. These activities focus the erosive energy of streams toward the middle of the channel, encouraging downcutting (National Research Council 1996), and ultimately decreasing the interaction of stream channels with their floodplain in all but extreme flood events. This loss of ecological connectivity between the channel and floodplain can occur through one or all of the following mechanism. First, because engineered channels carry water more efficiently, both the amount of time floodwaters spend on the floodplain and the surface area inundated is reduced during average annual high-flow events. This reduces the opportunity for floodwaters to penetrate the alluvial aquifer (Steiger et al. 1998) and therefore reduce baseflow in the river by reducing groundwater discharge during the low-flow season. Second, engineered channels typically lack heterogeneity in channel pattern and streambed topography (Jurajda 1995), thereby reducing hyporheic flow. Third, removal of LWD from the channel eliminates major structural elements responsible for creating channel pattern heterogeneity (Abbe and Montgomery 1996; Piegay and Gurnell 1997; Sedell and Froggatt 1984). Fourth, when downcutting occurs, the stream bed is lowered; stream water no longer reaches the floodplain surface and existing subsurface preferential flow pathways can be disconnected from the stream channel (Wyzga 1993). In a manner similar to flow regulation below dams, channel modification severs linkages between channel and floodplain and reduces groundwater buffering of stream flow and temperature (.Ward 1998a) and eliminating interactions between the channel and riparian zone that would insulate the stream from exchange of heat with the atmosphere.

Upland vegetation

Whether the catchment of a stream is urban, forested, rangeland, or agriculture, disturbance of upland vegetation associated with human activities has the tendency to increase sediment delivery, warm lateral water inputs, alter the relative amount of surface runoff (and therefore, peak flows), and alter upland water infiltration and groundwater recharge. (Naiman 1992; National Research Council 1996). Increasing sediment load can also clog coarse streambed gravels with fine sediments (Megahan et al. 1992) decreasing streambed conductivity and reducing the exchange of groundwater and surface water across the streambed (Schalchli 1992). Where shallow groundwater systems are important sources of stream water, removal of vegetation in the catchment can alter upland groundwater temperatures, increasing the temperature of water delivered to the stream (Hewlett and Fortson 1982). Depending on basin characteristics and the nature of the land use, upland land-use can also augment (Harr et al. 1982; Ziemer and Keppeler 1990) or reduce (Burt and Swank 1992; Harr 1980) baseflows thereby altering the assimilative capacity of the stream. When considering stream channel temperature, the most pervasive and best studied effect of upland land use is arguably the change in channel morphology (usually widening and shallowing of channels) in response to increased sediment load (Dose and Roper 1994; Knapp and Matthews 1996; Richards et al. 1996; Sidle and Sharma 1996). Wider channels have more surface area and are not as easily shaded, thereby facilitating the exchange of heat with the atmosphere.

Riparian Vegetation

Removal or alteration of riparian vegetation can have important implications for stream temperature (Beschta and Taylor 1988; Hostetler 1991; Naiman 1992; National Research Council 1996). The primary mechanism of thermal control of riparian vegetation is through shading the stream and trapping air next to the stream surface. However, removal of riparian vegetation can also destabilize streambanks, facilitating erosion and increasing sediment loads. Increased sediment and unstable banks can cause changes; in streambed and channel morphology (Li et al. 1994) that alter the rate of heat exchange with the atmosphere and restrict hyporheic flow by reducing streambed permeability. Riparian vegetation is also a primary source of LWD to the channel. Clearly denudation of riparian vegetation pan have major consequences for in channel processes. However, since the size of LWD (Hauer et al. In press; Ralph et al. 1994) and rate of delivery can be critical to determining its influence on the channel, even the selective removal of standing riparian vegetation may have important ramifications for channel morphology (and therefore channel temperature) over time.

MANAGEMENT OF CHANNEL WATER TEMPERATURE

A holistic understanding of the pathways of human influence on water temperature in stream channels underscores the need for an integrated approach to managing and restoring channel water temperature. To be effective, management programs designed to prevent degradation of water temperature or restore previously degraded systems should consider the breadth of practices occurring in the basin in order to determine which are apt to be the most influential on water temperature. Restoration of historic channel structures, channel-forming processes, sediment delivery, and flow regimes (Puff et al. 1997; Stanford et al. 1996) may be critical to the re-establishment of historic temperature regimes in large rivers.

Clearly not all of the pathways illustrated in Figure 3 are operational in any one catchment. Determining which human activities have been or may be most influential on water temperature is important for designing an effective management strategy. Watershed analysis is a powerful tool for determining the current and potential pathways of human influence on aquatic systems (Montgomery et al. 1995). The analysis should include an assessment of historic stream structures and processes, thereby providing a referent for assessing the present-day influences on stream temperature (Kondolf and Larson 1995). This analysis should attempt to document, in a spatially explicit manner, the historic channel morphology, riparian structure, and extent of the alluvial aquifer along the stream network. An assessment of management history and ongoing activities within the basin (Wissmar et al. 1994) is useful for interpreting identified changes in stream structure and for making strong inference regarding causal linkages between management activities and degradation of water temperature. Additionally, an analysis of the present day channel morphology, riparian structure, and extent of the alluvial aquifer along the stream network is helpful in prioritizing stream segments for restoration and in the design of effective management prescriptions. The phrase "effective prescriptions" means prescriptions that are specifically designed to protect or restore appropriate hydrologic processes based on an analysis of the historic stream structure throughout the stream network.

SUMMARY

Since stream temperature is a measure of the amount of heat energy per unit volume of water, changing either the amount of heat energy entering the stream or the amount of water flowing in the channel has the potential to alter stream temperature. Further, since a diversity of physical processes in the stream channel, riparian zone, and alluvial aquifer influence the temperature of water in stream systems, degradation of stream temperature can result from modification of external drivers as well as modification of the structure of the integrated stream system. Although the discussions, examples, and literature cited in this paper were drawn primarily from the Pacific Northwest of the U.S.A, the principles, processes, and integrative approach outlined in this paper are applicable to and appropriate for lotic systems in general.

Depending on the structure of a stream system, different processes are primary determinants of in-channel water temperatures. In order to be effective, management prescriptions designed to restore of protect water temperature dynamics in stream systems must be matched to the dominant processes that influence (or historically influenced) channel-water temperatures in a given stream. For instance, restoration of riparian vegetation will likely not be sufficient to meet temperature standards in streams if channel morphology played an important historic role in mediating water temperature, but has been severely degraded. Recovery and protection of stream temperature dynamics might be best accomplished by identifying the dominant historic external drivers and internal structural modifiers of water temperature in a spatially explicit manner across a basin and designing spatially explicit management prescriptions to address relevant human influences.

LITERATURE CITED

Abbe, T. B., and D. R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. *Regulated Rivers: Research and Management* 12: 201-221.

Beschta, R. L., and W. S. Platts. 1986. Morphological features of small streams: significance and function. *Water Resources Bulletin* 22: 369-377.

Beschta, R. L., and R. L. Taylor. 1988. Stream temperature increases and land use in a forested Oregon watershed. *Water Resources Bulletin* 24: 19-25.

Bouwer, H., and T. Maddock, III. 1997. Making sense of the interactions between groundwater and streamflow: Lessons for water masters and adjudicators. *Rivers* 6: 19-31.

Brunke, M., and T. Gonser.,1997. The ecological significance of exchange processes between rivers and groundwater. *Freshwater biology (Oxford)* 37: 1-33.

Burt, T. P., and W. T. Swank. 1992. Flow Frequency Responses to Hardwood-To-Grass Conversion and .Subsequent Succession. *Hydrological Processes* 6: 179-188.

Church, M. 1995. Geomorphic response to river flow regulation: case studies and time-scales. *Regulated Rivers: Research and Management* 11: 3-22.

Creuzė des Chatelliers, M., D. Poinsart, and J.P. Bravard. 1994. Geomorphology of alluvial groundwater ecosystems. Pages 157-185 in J. Gibert, D. L. Danielopol, and J. A. Stanford, eds. *Groundwater Ecology.* Academic Press, San Diego.

D'Angelo, D. J., S. V. Gregory, L. R. Ashkenas, and J. I. Meyer. 1997. Physical and biological linkages within a stream geomorphic hierarchy: A modeling approach. *Journal of the*

North American Benthological Society 16: 480-502.

D'Angelo, D. J., J. R. Webster, S. V. Gregory, and J. L. Meyer. 1993. Transient storage in Appalachian and Cascade mountain streams as related to hydraulic characteristics. *Journal of the North American Benthological Society* 12: 223-235.

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

Davies, P. E., and M. Nelson. 1994. Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. *Aust. J. Mar. Freshwat.* Res. 45: 1289-1305.

Dose, J.J., and B. B. Roper. 1994. Long-term changes in low-flow channel widths within the South Umpqua Watershed, Oregon. *Water Resources Bulletin* 30: 993-1000.

Evans, E.C., M. T. Greenwood, and G. E. Pets. 1995. Thermal profiles within river beds. *Hydrological Processes* 9: 19-25.

Evans, E. C., and G. E. Pelts. 1997. Hyporheic temperature patterns within riffles. *Hydrological Sciences Journal* 42: 199-213.

Findlay, S. 1995. Importance of surface-subsurface exchange in stream ecosystems: The hyporheic zone. *Limnology and Oceanography* 44: 159-164.

Gibert, J., J. A. Stanford, M.J. Dole-Oliver, and J. V. Ward. 1994. Basic attributes of groundwater ecosystems and prospects for research. Pages 7-36 in J. Gibert, D. L. Danielopol; and J. A. Stanford, eds. *Groundwater Ecology*. Academic Press, San Diego, California.

Glennon, R.J. 1995. The threat to river flows from groundwater pumping. *Rivers* 5: 133-139.

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

Harr, R. D. 1980. Streamflow after patch logging in small drainages within the bull run municipal watershed, Oregon. USFS Pacific Northwest Forest and Range Experiment Station Research Paper #PNW 268.

Harr, R.D., A. Levno, and R. Mersereau. 1982. Streamflow Changes after Logging 130-Year-Old Douglas Fir in Two Small Watersheds. *Water Resources Research* 18: 637-644.

Harvey, J. W., and K. E. Bencala. 1993. The effect of streambed topography on surface-subsurface water exchange in mountain catchments. *Water Resources Research* 29: 89-98.

Hauer, F. R., G. C. Poole, J. T. Gangemi, and C. V. Baxter. In press. Large woody debris in bull trout spawning streams of logged and wilderness watersheds in northwest Montana. *Canadian Journal of Fisheries and Aquatic Science*.

Hawkins, C. P., J. N. Hogue, L. M. Decker, and J. V. Feminella. 1997. Channel morphology, . water temperature, and assemblage structure of stream insects*. Journal of the North American Benthological Society* 16: 728-749.

Hendricks, S. P., and D. S. White. 1995. Seasonal biogeochemical patterns in surface water, subsurface hyporheic, and riparian ground water in a temperate strewn ecosystem. *Archiv fur Hydrobiologie. Stuttgart* 134: 459-490.

Hewlett, J. D., and J. C. Fortson. 1.982. Stream temperature under an inadequate buffer strip in the southeast Piedmont. *Water Resources Bulletin* 18: 983-988.

Hibbs, B., and J. Sharp. 1992. Impact of high capacity wells on flows of the lower Colorado River. *New Waves* 5: 3-4.

Hostetler, S. W. 1991. Analysis and modeling of long-term stream temperatures on the Steamboat Creek Basin, Oregon: Implications for land use and fish habitat. *Water Resources Bulletin* 27: 637-648.

Jurajda, P. 1993. Effect of channelization and regulation on fish recruitment in a flood plain river. *Regulated Rivers: Research & Management* 10: 207-215.

Kellerhalls, R., M. Church, and D. I. Bray. 1976. Classification and analysis of river processes. *Journal of the Hydraulics Division, America Society of Civil Engineers* 102: 813-829.

Knapp, R. A., and K. R. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: Impacts and management implications. *North American Journal of Fisheries Management* 16: 805-820.

Kondolf, G. M., and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5: 109-126.

Leopold, L. B., and M. G. Wolman. 1957. River channel patterns: braided, meandering, and straight. U.S. Geological Survey Profession Paper #282-B.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. *Fluvial processes in geomorphology.* W.H. Freeman and Co., San Francisco, Calif6riia.

Li, H. W., G. A. Lamberti, T. N. Pearsons, C. K. Tait, J. L. Li, and J. C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. *Transactions of the American Fisheries Society* 123: 627-640.

Long, K. S., and J. M. Nestler. 199.6. Hydroperiod changes as clues to impacts on cache river riparian wetlands. *Wetlands* 16: 379-396.

Megahan, W. F., J. P. Ptoyondy, and K. A. Seyedbagheri. 1992. Best management practices and cumulative effects from sedimentation in the South Fork Salmon River: an Idaho case study. Pages 401-414 in R. J. Naiman, ed. Watershed Management: Balancing Sustainability and Environmental Change. Springer-Verlag, New York, New York.

Montgomery, D. R., and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington State Timber/Fish/Wildlife Agreement, Department of Natural Resources #TFW-SH10-93-002.

Montgomery, D.R., G. E. Grant, and K. Sullivan. 1995. Watershed analysis as a framework for implementing ecosystem management. *Water Resources Bulletin* 31: 369-386.

Morrice, J. A., H. M. Valett, C. N. Dahm, and M. E. Camparia. 1997. Alluvial characteristics, groundwater-surface water exchange and hydrological retention in headwater streams. Hydrological Processes 11: 253-267.

Mosley, M. P. 1987. The classification and characterization of rivers. Pages 225-320 in K. Richards, ed. *River Channels: Environment and Process.* Basil Blackwell, Oxford, England.

Naiman, R. J., ed. 1992. *Watershed Management: Balancing Sustainability and Environmental Change.* Springer Verlag, New York.

Naiman, R. J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bisson, L. H. MacDonald, M. D. O'Connor, P. L. Olsen, and E. A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. Pages 127-188 in R. J. Naiman, ed. *Watershed Management: Balancing Sustainability and Environmental Change.* Springer-Verlag, New York, New York.

Nakamura, F. and F. J. Swanson. 1993. Effects of coarse woody debris on morphology and sediment storage on a mountain stream in system in western Oregon. *Earth Surface*

Processes and Landforms 18: 43-61.

Nanson, G. C., and A. D. Knighton. 1996. Anabranching rivers, their cause, character, and classification. *Earth Surface Processes and Landforms* 21: 217-239.

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

Piegay, H., and A. M. Gurnell. 1997. Large woody debris and river geomorphological pattern: Examples from S.E. France and S. England. *Geomorphology* 19: 99-116.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime. A paradigm for river conservation and restoration. *Bioscience* 47: 769-784.

Ralph, S. R., G. C. Poole, L.L. Conquest, and R. J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of western Washington. *Canadian Journal of Fisheries and Aquatic Science* 51: 37-51.

Richards, C., L. B. Johnson, and G. E. Host. 1996. Landscape-scale influences on stream habitats land biota. *Canadian Journal of Fisheries and Aquatic Sciences* 53: 295-311.

Salo, J., R. Kalliola, I. Hakkinen, Y. Makinen, P. Niemela, M. Puhakka, and P. D. Coley. 1986. River dynamics and the diversity of Amazon lowland forest. *Nature* 322: 254-258.

Schächli, U. 1992. The clogging of coarse gravel river beds by fine sediment. *Hydrobiologia* 235/236: 189-197.

Sedell, J. R., and J. L. Froggatt. 1984. Importance of streamside forests to large rivers: the isolation of the Willamette River, Oregon, U.S.A., from its floodplain by snagging and streamside forest removal. Internationale Vereinigung für theoretische und angewandte Limnologie, Yerhandlungen, 22: 1828-1834.

Sidle, R. C., and A. Sharma. 1996. Stream channel changes associated with mining and grazing in the Great Basin: *Journal of Environmental Quality* 25: 1111-1121.

Simons, D. B. 1979. Effects of stream regulation on morphology. Pages 95-111 in J. V. Ward and J. A. Stanford, eds. *The Ecology of Regulated Streams*. Plenum, New York.

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

Stanford, J. A., and F. R. Hauer. 1992. Mitigating the impacts of stream and lake regulation in the Flathead River catchment, Montana, USA: An ecosystem perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems* 2: 35-63.

Stanford, J. A., and J. V. Ward. 1988. The hyporheic habitat of river ecosystems. *Nature* 335: 64-66.

Stanford, J. A., and J. V. Ward. 1992. Management of aquatic resources in large catchments: recognizing interactions between ecosystem connectivity and environmental disturbance. Pages 91-124 in R. J. Naiman, ed. *Watershed Management. Balancing Sustainability and Environmental Change.* Springer-Verlalg, New York, New York.

Stanford, J. A., and J. V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. *Journal of the North American Benthological Society* 12: 48-60.

Stanford, J. A., J. V. Ward, and B. K. Ellis. 1994. Ecology of the alluvial aquifers of the Flathead River, Montana. Pages 367-390 in J. Gibert, D. L. Danielopol, and J. A. Stanford, eds. *Groundwater Ecology.* Academic Press, San Diego, California.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich, and C.

C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers: Research and Management* 12: 391-413.

Steiger, J., M. James, and F. Gazelle. 1998. Channelization and consequences on floodplain system functioning on the Garonne River, SW France. *Regulated Rivers: Research & Management* 14: 13-23.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Science* 37: 130-137.

Vaux, W. G. 1968. Intragravel flow and interchange of water in a streambed. *Fishery Bulletin* 66: 479-489.

Ward, J. V. 1989. The four-dimensional nature of lotic ecosystems. *Journal of the North American Benthological Society* 8: 2-8.

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

Ward, J. V. 1998b. A running water perspective of ecotones, boundaries and connectivity. *Internationale Vereinigung für theoretische und angewandte Limnologie, Verhandlungen* 26: 1165-1168.

Ward, J. V., G. Bretschko, M. Brunke, D. Damelopol, J. Gibert, T. Gonser, and A. G. Hildrew. 1998. The boundaries of river systems: the metazoan perspective. *Freshwater Biology* 40: 531-569.

Ward, J. V., and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation., *Regulated Rivers: Research and Management* 11: 105-119.

White, D. S. 1993. Perspectives on defining and delineating hyporheic zones. *Journal of the North American Benthological Society* 12: 61-69.

White, D. S., C. H. Elzinga, and S. P. Hendricks. 1987. Temperature patterns within the hyporheic zone of a northern Michigan river. *Journal of the North American Benthological Society* 6: 85-91.

Wilber, D. H., R. E. Tighe, and L. J. O'Neil. 1996. Associations between changes in agriculture and hydrology in the Cache River basin, Arkansas, USA. *Wetlands* 16: 366-378.

Wissmar, R. C., J. E. Smith, B. A. McIntosh, H. W. Li, G. H. Reeves, and J. R. Sedell. 1994. A history of resource use and disturbance in riverine basins of eastern Oregon and Washington (early 1800s-1990s). *Northwest Science* 68: 1-35.

Wondzell, S. M., and F. J. Swanson. 1996. Seasonal and storm dynamics of the hyporheic zone of a 4th-order mountain stream. I: Hydrologic processes. *Journal of the North American Benthological Society* 15: 3-19.

Wroblicky, G. J., M. E. Campana, C. N. Dahm, H. M. Valett, J. A. Morrice, K. S. Henry, and M. A. Baker. 1994. Simulation of stream-groundwater exchange and near-stream flow paths of two first-order mountain streams using MODFLOW. Pages 187-198 in J. A. Stanford and H. M. Valett, eds. *The Second International Conference on Ground Water Ecology*. American Water Resources Association, Atlanta, GA.

Wroblicky, G. J., M. E. Campana, H. M. Valett, and C. N. Dahm. 1998. Seasonal variation in surface-subsurface water exchange and lateral hyporheic area of two stream-aquifer systems. *Water Resources Research* 34: 317-328.

Wyzga, B. 1993. River response to channel regulation: Case study of the Raba River, Carpathians, Poland. *Earth Surface Processes and Landforms* 18: 541-556.

Ziemer, R. R., and E. T. Keppeler, 1990. Logging Effects on Streamflow: Water Yield and Summer Low Flows at Caspar Creek in Northwestern California. *Water Resources Research* 26: 1669-1679.

Table 1: Examples of natural drivers of channel water temperature

Topographic Shade	Solar angle
Upland Vegetation	Cloud cover
Precipitation	Relative humidity
Air temperature	Phreatic groundwater temperature & discharge
Wind speed	Tributary temperature & flow

Table 2: Stream structures that influence insulating and buffering characteristics.

Component Characteristic	*Ecological function:*	*Determined by:*
Channel		
Channel slope	– Influences flow rate.	catchment topography
Channel substrate	– Particle size determines resistance to groundwater flux – Influences channel roughness and therefore flow rate	flow regime, sediment sources, stream power
Channel width	– Determines surface area for convective heat exchange	flow regime, sediment sources, stream power, bank stability
Streambed topography	– Determines gradients that drive hyporheic flux	flow regime, sediment sources, stream power, bank stability, large roughness elements (e.g., large woody debris)
Channel pattern	– Determines gradients that drive hyporheic flux – Determines potential shade from riparian vegetation	flow regime, sediment sources, stream power, bank stability, large roughness elements, valley shape
Riparian Zone		
Riparian Vegetation	– Provides shade to reduce solar radiation – Reduces wind-speed to reduce advective heat transfer – Traps air against the stream to reduce conductive heat transfer – Provides bank stability	Vegetation height, density, growth form, rooting pattern
Riparian zone width	– Influences potential for hyporheic flux	(same as channel pattern)
Alluvial Aquifer		
Sediment particle size	– Influences potential for hyporheic flux	(same as channel pattern)
Sediment particle sorting	– Influences diversity of subsurface temperature patterns by determining stratigraphy – Influences extent of hyporheic flux	(same as channel pattern)
Aquifer depth	Influences extent of hyporheic flux –	(same as channel pattern)

Table 3: Mechanism and influence of pathways of human influence on channel water temperature.

Process / Implication	Influence and Mechanism
Reduced phreatic groundwater discharge results in reduced assimilative capacity	Removal of *upland vegetation* decreases infiltration of groundwater on hill slopes and reduces baseflow in streams. Pumping *wells* for irrigation or municipal water sources can reduce baseflow in nearby streams and rivers.
Reduced stream and tributary flow during low-flow periods reduces assimilative capacity	*Water withdrawals* reduce baseflow in streams and tributaries and draw down the water table in the alluvial aquifer. *Dams* alther the flow regime of a river. Removal of *upland vegetation* result in flashier stream flow. *Dikes and levies* confine flows that would otherwise interact with the floodplain and recharge the alluvial aquifer.
Simplified alluvial system structure reduces assimilative capacity by reducing hyporheic flow.	*Dams* reduce peak flows that rejuvenate the alluvial aquifer structure. Removal of *upland vegetation* increases fine sediment load, which clogs gravels and reduces hyporheic exchange. *Dikes and levies* confine flood-flows that would otherwise interact with the floodplain and rejuvenate alluvial aquifer structure; channelization severs natural subsurface preferential flow pathways. *Riparian management* may remove large woody debris (and its sources) that contributes to streambed complexity.
Simplified channel morphology reduces hyporheic flow reducing assimilative capacity; wider, consolidated channels are less easily shaded and have greater surface area increasing heat load	Removal of *upland vegetation* increases peak stream power and/or increases sediment volumes altering the interaction between water and sediment regimes and changing channel morphology. *Dams* remove peak flows that maintain channel morphology. *Dikes and levies* confine flood flows that maintain channel morphology and decrease subsurface floodwater storage and, therefore, reduce groundwater discharge during baseflow periods. *Riparian management* may remove large woody debris (and its sources) that contributed to streambed complexity.
Reduced riparian vegetation reduces shade and increases heat load.	*Riparian management* may reduce shade to the channel and reduce the amount of air trapped by the vegetation, increasing convective and advective heat transfer from the atmosphere to the riparian zone and stream surface.

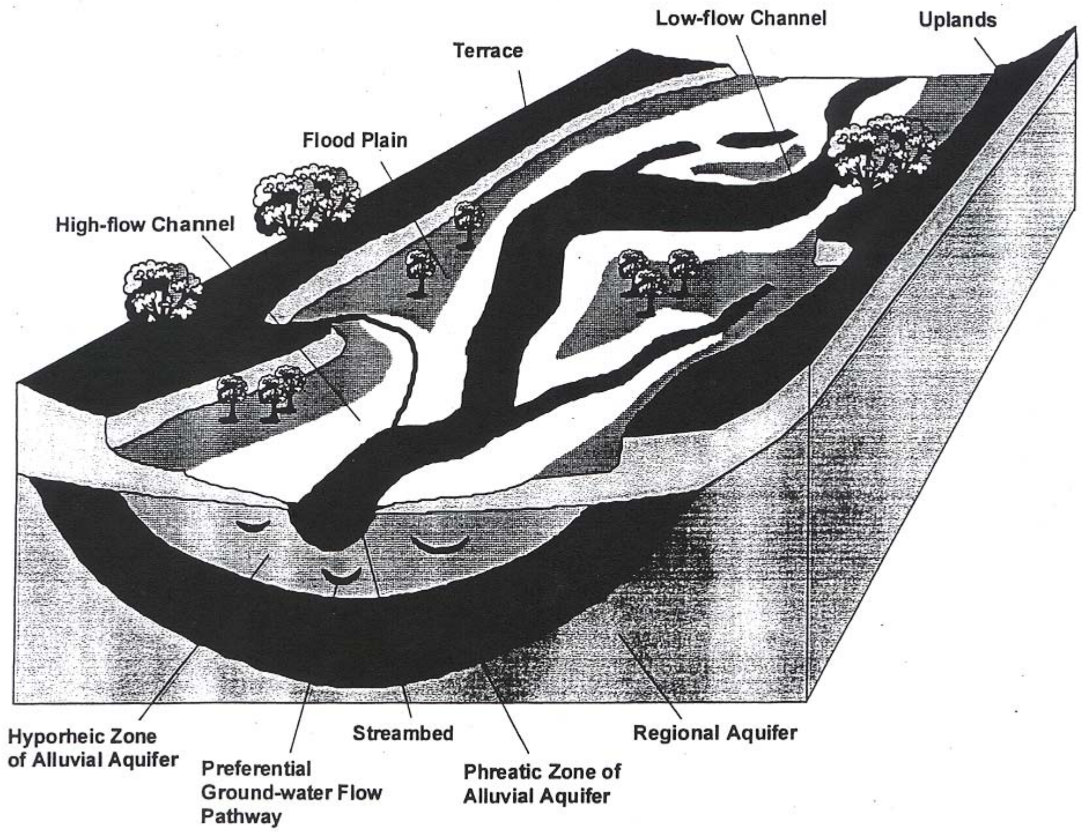


Figure 1. Elements of a stream system.

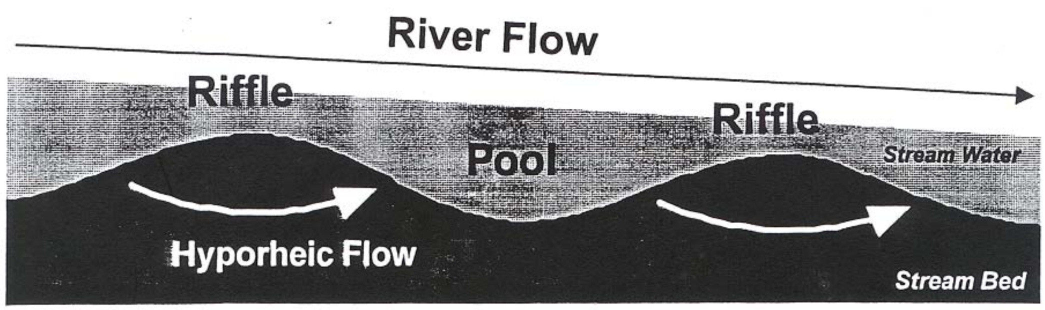
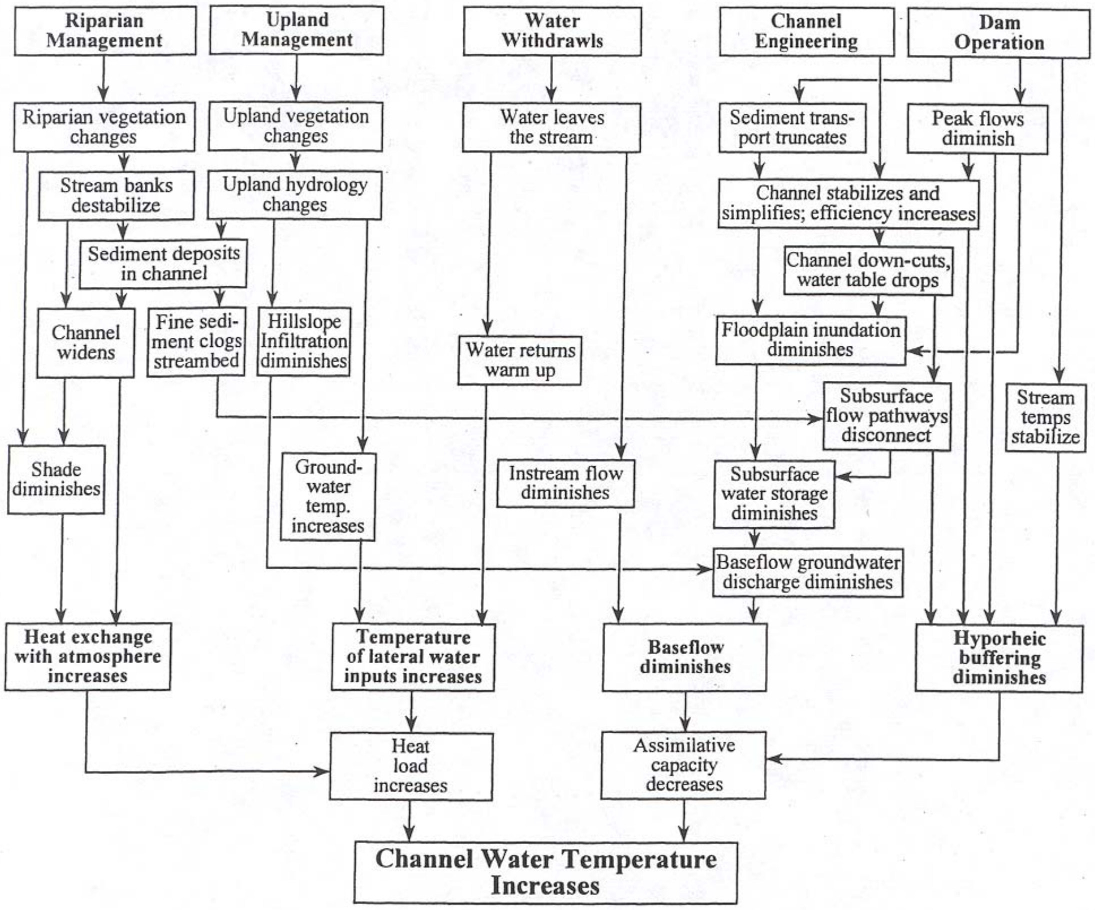


Figure 2. Downstream vertical profile of a stream showing streambed hyporheic flow in the streambed.



F igure 3. Pathways of human-caused warming of water stream channels.