Willapa River Temperature Total Maximum Daily Load

Quality Assurance Project Plan

by
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1998 303(d) listings addressed in this study

Waterbody	T	R	S	New ID	Old WBID	Parameter
Fork Creek	12N	07W	06	MO06ZS	WA-24-2037	Temperature
Willapa River	14N	08W	43	YN05JR	WA-24-2020	Temperature

Approvals

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Table of Contents

Introduction

The Willapa River drains into Willapa Bay, located in Pacific County in southwestern Washington State. Ecology's assessment of the Willapa River watershed identified the system as a high priority for development of a temperature Total Maximum Daily Load (TMDL).

The purpose of this Willapa River temperature TMDL is to characterize the water temperature in the basin and to establish load and wasteload allocations for the heat sources to meet water quality standards for surface water temperature. Studies to evaluate 303(d) listings for dissolved oxygen and fecal coliform were initiated in the Willapa River watershed in 1998. Water temperature is the only remaining 303(d) listed water quality parameter in the study area and will be addressed during this study.

The study area has two segments that are listed for not meeting water quality criteria for temperature. Temperature problems in the basin are likely not limited to the two segments reported on the 303(d) list; therefore, this study concentrates not only on the temperature concerns of the listed segments but those in the entire study area as well. Pickett (2000) and Weyerhaeuser (1994) documented temperatures in excess of 18°C in additional segments throughout the basin (Figure 1).

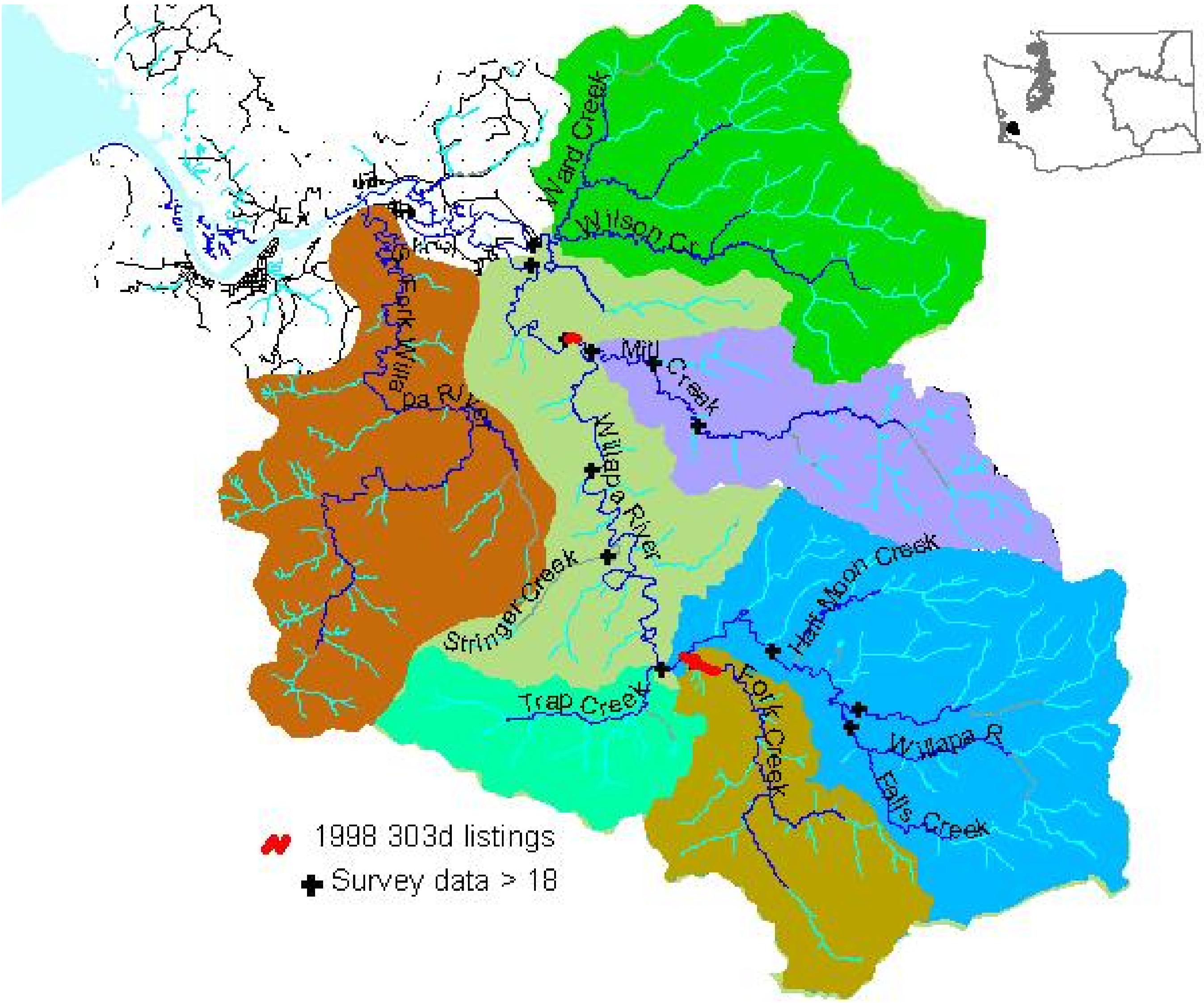

Figure 1. Study area sub-watersheds and 1998 303(d) listings.

Project Description

Study Area

The study area includes all major tributaries to the Willapa River upstream of the area of tidal influence. This 220 square mile area consists of the South Fork of the Willapa River, the Wilson Creek and Ward Creek drainages, and the mainstem and tributaries of the Willapa River above the USGS gage near Camp One Road (river mile 14.5).

The watershed includes a mix of public and private land. The lower elevation land is owned primarily by small landowners and is in agriculture or rural use. Upper elevation land is dominated by private timber or Washington State Department of Natural Resources ownership (Figure 2). Load allocations are expected to be developed for all areas of the basin that are not covered under the Forests and Fish agreement (DNR, 1999).

The climate of the basin is heavily influenced by its proximity to the ocean with cool, wet winters and mild summers. Annual precipitation ranges from 80 in the lowlands to 120 in the higher elevations; heaviest precipitation occurs between October and June.

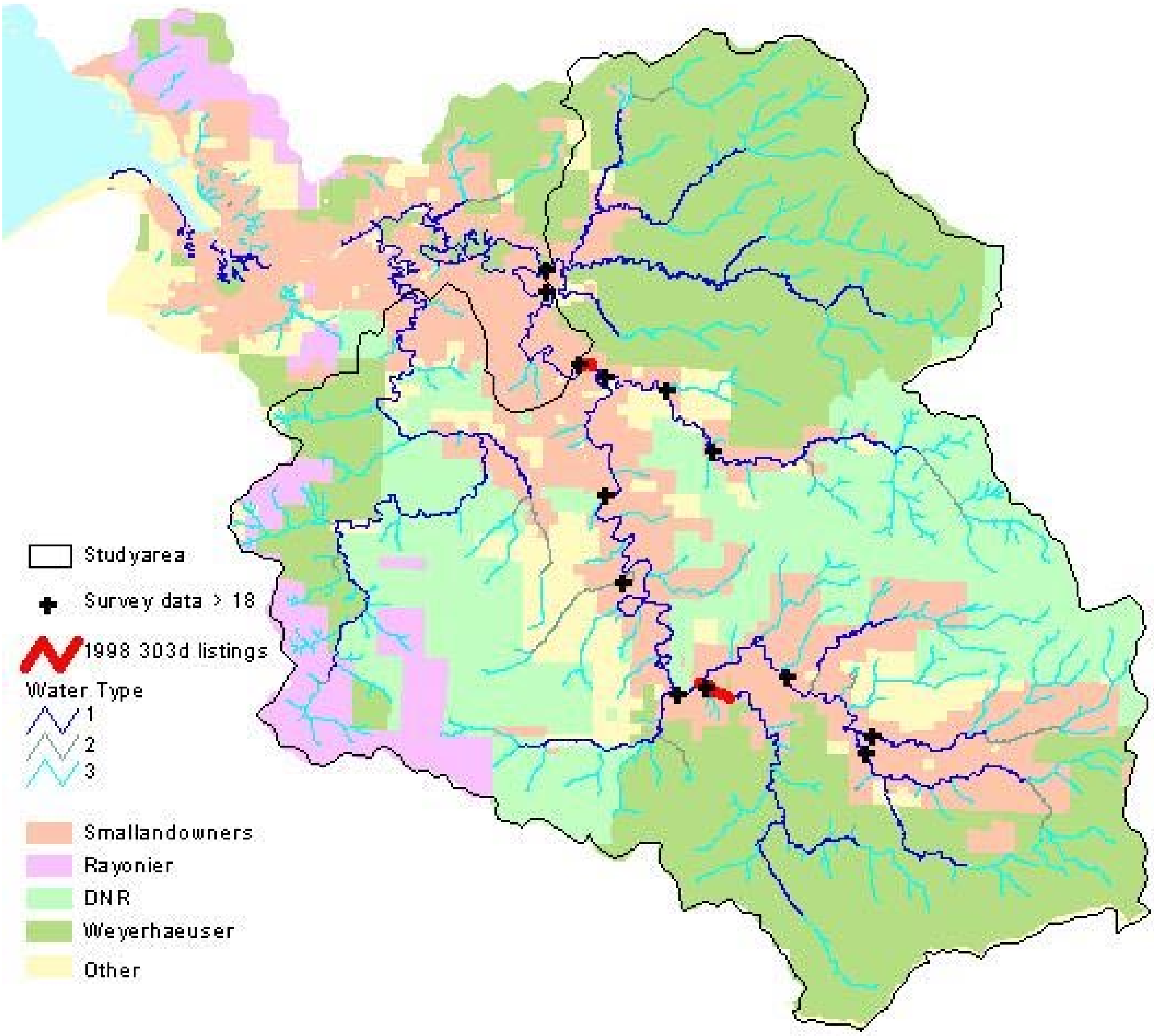

Figure 2. Study area land ownership

Project Objectives

1. Characterize summer (June – October) water temperature in the Willapa River watershed.
   - Compile existing data, including:
     - ◊ Data collected at Ecology's long-term ambient monitoring stations and during the 1998 fecal coliform and dissolved oxygen surveys.
     - ◊ Data collected during the Willapa Headwaters Watershed Analysis prepared for the Weyerhaeuser Corporation.
     - ◊ Data collected by Washington State Department of Fish and Wildlife, Pacific County, Pacific County Conservation District, and other potential data sources that are discovered during the study.
   - Collect additional data at selected sites throughout the basin.

2. Develop a predictive computer temperature model of the Willapa River mainstem and Fork Creek stream networks.
   - Model the basin temperature regime at critical conditions.
   - Evaluate the ability of various watershed best management practices (BMPs) to reduce water temperatures to meet water quality standards.

3. Establish a TMDL for temperature in the Willapa River watershed.
   - Develop a TMDL for thermal load to the stream (expressed as incoming solar radiation in units of joules/meter^2/second).
   - For ease of implementation, load allocations will be reported in terms of a surrogate for solar radiation such as shade, size of tree necessary in the riparian zone to produce adequate shade, channel width, channel width-to-depth ratio, or miles of active eroding stream banks.

Sources of Thermal Pollution

Many environmental variables affect water temperature, including (Brown, 1969):

- Solar radiation
- Air temperature
- Stream width, depth, and velocity
- Stream flow
- Tributary and groundwater influence

Sources of nonpoint thermal pollution are:

- Riparian vegetation disturbance and loss of shade due to:
  - ◊ Removal of trees and shrubs for pasture, crops, or timber harvest.
  - ◊ Heavy grazing by livestock.
  - ◊ Conversion of forest to pasture land.

- Channel morphology impacts resulting from:
  - ◊ Removal of large woody debris by commercial harvest and agriculture.
  - ◊ Increased sediment loading from agriculture, timber harvest, and roads.
  - ◊ Channel constraint/diking for agriculture and flood control.
  - ◊ Bank instability/erosion and sedimentation from removal of root structure and increased land-use practices in the watershed.
- Hydrologic changes from:
  - ◊ Extraction of water for irrigation or other purposes.
  - ◊ Altered stream flow patterns from urbanized and timber harvest areas resulting in increased spring runoff and decreased summer baseflows.

These activities potentially raise the water temperature of rivers due to increased solar input resulting from lack of shade along streams, reduction of river water volume from withdrawals, and increased water surface area from sedimentation, making the channel wider and shallower.

Beneficial Uses

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

- *Recreation:* Fishing and swimming.
- *Fish and Shellfish:* Fall chinook salmon (Oncorhynchus tshawytscha) and coho salmon (O. kisutch) and winter steelhead trout (O. mykiss) are the predominate anadromous fish species in the Willapa Basin. The mainstem Willapa River, Trap Creek and Forks Creek are heavily used by all species, with coho found throughout the watershed. Some use by chum salmon (O. keta) occurs primarily in the lower portions of the watershed.
- *Water Supply and Stock Watering:* Agriculture extracts water for irrigation and stock watering.
- *Wildlife Habitat:* Riparian areas are used by a variety of wildlife species, which are dependent on the habitat.

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

Temperature is a water quality concern because most aquatic organisms, including salmonids, are cold-blooded and are strongly influenced by water temperature (Schuett-Hames et al., 1999). Temperature is a major concern in the Willapa River and its tributaries because of the use of its waters by salmonids. Elevated temperature and altered channel morphology resulting from various land-use activities, such as timber harvest and agriculture in the area, limit available spawning and rearing habitat for salmonids.

Historic Data Review

Weyerhaeuser (1994) initiated the Willapa Headwaters Watershed Analysis which includes a biological and physical assessment of the drainages flowing into the mainstem Willapa River above river mile 24 near the town of Menlo and the river's confluence with Highland Creek. Data are organized into the following modules: mass wasting, surface erosion, hydrology, riparian function, stream channels, fish distribution and habitat, water supply and public works, and water quality. The mass wasting, surface erosion, hydrologic condition, and riparian condition modules address hillslope hazards. The vulnerability of resources are addressed by the fish habitat, stream channel, water quality, and public works/water supply modules.

Water temperature data gathered for this analysis showed measurements exceeding 18°C in Half Moon Creek, Trap Creek, upper Forks Creek, lower Forks Creek, Fern Creek, Patton Creek, lower Willapa River, and the mid-Willapa River. The analysis identified areas of temperature concern due to loss of riparian shade, a majority of which is along the mainstem Willapa River.

Pickett (2000) took thermometer readings during field surveys in 1998. The readings were taken during collection of water quality samples, sometime between 8:00am and 5:00pm, and were not intended to capture the daily maximum temperature. During the course of these surveys, temperatures in excess of 18°C were recorded at nine locations in the current study area.

Washington State Department of Fish and Wildlife personnel do numerous stream surveys to evaluate fish health and population each year. Data provided by Fish and Wildlife was the basis for the 303(d) listing at Forks Creek. Pacific County and the Pacific County Conservation District also do water quality monitoring and survey work in the basin.

Ecology has a long-term ambient monitoring station near Camp One Road. Data from the monthly ambient surveys was the basis for the 303(d) listing on the mainstem Willapa River (Ecology, 2000). A second long-term station near Lebam was discontinued in 1992. The ambient monitoring program began installing continuous water temperature recorders at most of their monitoring sites in 2000.

Water temperatures in excess of the marine standard of 16°C have been recorded in the saltwater or tidally influenced areas of Willapa Bay. Ecology (2000) reported that these exceedances, measured at Ecology ambient monitoring stations WPA001, WPA003, WPA004, WPA006, and WPA007, are a natural condition with no direct human caused influence due to solar heating.

The U.S. Geological Survey (USGS) maintains a continuous flow gaging station (Willapa River at Willapa, Station No. 12013500) at Camp One Road. The Willapa River experiences a wide range of flows, from minimum flows below 20 cfs to maximum flows above 10,000 cfs. Average summer flows are usually under 100 cfs.

Pitz (1998) found that the response of the watershed to rainfall and summer drought is consistent with the geology of the basin. The alluvium in the valley bottoms is shallow and bedrock is near the surface throughout the basin. This results in little retention of stormwater and little storage of groundwater to maintain summer baseflow.

Study Design

Approach

The Willapa Temperature TMDL will be developed for heat, which is considered a pollutant under Section 502(6) of the Clean Water Act. Heat energy processes that control energy transfer to and from a given volume of water include:

- Shortwave solar radiation.
- Longwave radiation exchange between the stream and both the adjacent vegetation and the sky.
- Evaporative exchange between the stream and the air.
- Convective exchange between the stream and the air.
- Conduction transfer between the stream and the streambed.
- Groundwater exchange with the stream (Adams and Sullivan, 1989).

If the heat energy entering the water from these sources is greater than the heat energy leaving the water, then stream water temperature will rise. Water temperature change, which is an expression of heat energy exchange per unit volume (Equation 1), is most strongly influenced by solar radiation input (Adams and Sullivan, 1989; Matthews, 1992).

Equation 1. Relationship between Temperature and Heat Energy for Surface Waters.

$$\Delta Temperature = \frac{\Delta Heat\ Energy}{Volume}$$

Increased solar radiation levels at the stream surface due to anthropogenic causes result from the following conditions:

- Channel widening (increased width-to-depth ratios) that increases the stream surface area exposed to energy processes.
- Riparian vegetation disturbance that reduces stream surface shading through reductions in riparian vegetation height and density. (Shade is commonly measured as percent effective shade.)
- Reduced summer baseflows resulting from instream withdrawals, wells in hydraulic continuity with the stream, or altered stream flow patterns due to land-use practices that increase runoff instead of storage.

The sources of increased stream temperatures will be examined in this Willapa River Temperature TMDL to produce a loading capacity and load and wasteload allocations for the heat load sources. Loading capacity and allocations will be established via field surveys and development of a predictive computer temperature model. Field data collection and assessment will be governed by the data set requirements of the computer temperature model.

Model Data Requirements

Six water quality/temperature models gathered from the U.S. Environmental Protection Agency, the Washington State Department of Natural Resources, and the Oregon Department of Environmental Quality were evaluated to determine the most practical application to model the temperature regime in the basin (USEPA, 1997; Sullivan et al., 1990; Oregon DEQ, 2000). Criteria for model selection were ease of use, reliability of predictions, data requirements, region for which it was developed, success in application to previous TMDL studies, applicability to the Willapa River region, public availability and model sensitivity to selected parameters.

At this point the preferred model is the HeatSource model. HeatSource was developed at the Oregon State University Department of Bioresource Engineering and Civil Engineering and is currently maintained by the Oregon Department of Environmental Quality. HeatSource is the primary model used by Oregon in its temperature TMDL work and is being applied in Washington in the Wind River and Little Klickitat temperature TMDLs. Data requirements and proposed sources of these data are shown in (Table 1)

Table 1. Model data requirements and collection source.

<table>
<tr><th colspan="2"></th><th>MODEL</th><th colspan="3">COLLECTED BY</th></tr>
<tr><th></th><th>Parameter</th><th>HeatSource Required Data</th><th>Ecology Field Sampling</th><th>GIS or Orthophoto Coverages</th><th>Other</th></tr>
<tr><td rowspan="6">Flow</td><td>discharge - tributary</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>discharge (upstream & downstream)</td><td>x</td><td>x</td><td></td><td>USGS gage</td></tr>
<tr><td>flow regression constants</td><td>x</td><td></td><td></td><td>calculated from field data</td></tr>
<tr><td>flow velocity</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>Bed friction factor</td><td>x</td><td></td><td></td><td>calculated from flow data</td></tr>
<tr><td>groundwater inflow rate/discharge</td><td>x</td><td>x</td><td></td><td>Ecology hydrogeology study</td></tr>
<tr><td rowspan="4">General</td><td>calendar day/date</td><td>x</td><td></td><td></td><td>calendar</td></tr>
<tr><td>elevation/altitude</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>latitude</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>longitude</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td rowspan="8">Physical</td><td>channel azimuth/stream aspect</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>percent bedrock</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>reach length</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>stream bank slope/incision</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>topographic shade angle</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>stream gradient</td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>Width - average channel</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td>width - wetted</td><td>x</td><td>x</td><td>x</td><td></td></tr>
<tr><td rowspan="4">Temperature</td><td>temperature - groundwater</td><td>x</td><td>x</td><td></td><td>mean annual air or T of ground</td></tr>
<tr><td>temperature - water downstream</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>temperatures - water upstream</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>temperature - air</td><td>x</td><td>x</td><td></td><td>airport as check</td></tr>
<tr><td rowspan="6">Vegetation</td><td>vegetation overhang</td><td>x</td><td>x</td><td></td><td rowspan="5">Vegetation information will be gathered at representative sites throughout the basin. Orthophotos will be used to determine vegetation characteristics for remaining stream reaches.</td></tr>
<tr><td>canopy density</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>distance to shading vegetation</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>vegetation height</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>vegetation width</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>vegetation shade angle</td><td>x</td><td></td><td>x</td><td>calc using GIS from veg ht @ width</td></tr>
<tr><td rowspan="4">Weather</td><td>% possible sun/cloud cover</td><td>x</td><td></td><td></td><td>weather station</td></tr>
<tr><td>solar radiation</td><td>x</td><td></td><td></td><td>calc from day, latitude, and cloud</td></tr>
<tr><td>wind speed/velocity</td><td>x</td><td>x</td><td></td><td>weather station and field checks</td></tr>
<tr><td>relative humidity</td><td>x</td><td>x</td><td></td><td>weather station and field checks</td></tr>
</table>

Data Collection and Ecology Field Surveys

Data collection, compilation, and assessment will be governed by the data set requirements of the computer temperature model. The data will be assembled from local third party studies and Ecology field surveys. Local third party studies include investigations by Pacific County, the Pacific County Conservation District, the USGS, the Washington state Department of Fish and Wildlife, the Willapa Headwaters Watershed Analysis initiated by Weyerhaeuser, and other potential data sources that are discovered during the study.

Ecology Field Surveys

Four types of Ecology field surveys will be conducted: 1) continuous flow monitoring at selected gaging stations, 2) temperature monitoring, 3) riparian surveys of the streams and rivers in the study area, and 4) remote sensing of surface temperatures using FLIR.

1. Stream Flow Monitoring

Four on-site continuous flow-monitoring stations will be established by Ecology's Environmental Assessment Program's Stream Hydrology Unit in the study area during the duration of the sampling season, June through October. An additional station maintained by the USGS provides continuous flow monitoring near Camp One Road (Table 2). Periodic and synoptic flow measurements taken at the five continuous flow-monitoring stations, and at 29 additional locations in the watershed, will be used to estimate groundwater inflow by difference. The standard protocols for the on-site continuous data loggers will follow those currently established by the Stream Hydrology Unit (Ecology, 2000).

Table 2. Continuous stream flow-monitoring stations

	Name
1	South Fork Willapa River near municipal drinking water facility
2	Willapa River at Oxbow Road
3	Willapa River at Lebam
4	Forks Creek at State Hatchery
5	USGS site at Camp One Road below Mill Creek

2. Temperature Sites

Water temperature sites will be established at 34 locations (Figure 3) throughout the study area. Air temperature will be monitored at 20 of these sites, and relative humidity will be monitored at four of these sites. Water and air temperature will be measured with Onset StowAway Tidbits. Relative humidity will be measured with an Onset H8 Pro RH/temperature data logger. The temperature data loggers will be installed in a location in the stream or riparian forest which is shaded from direct sunlight. They will be placed in an area representative of the surrounding

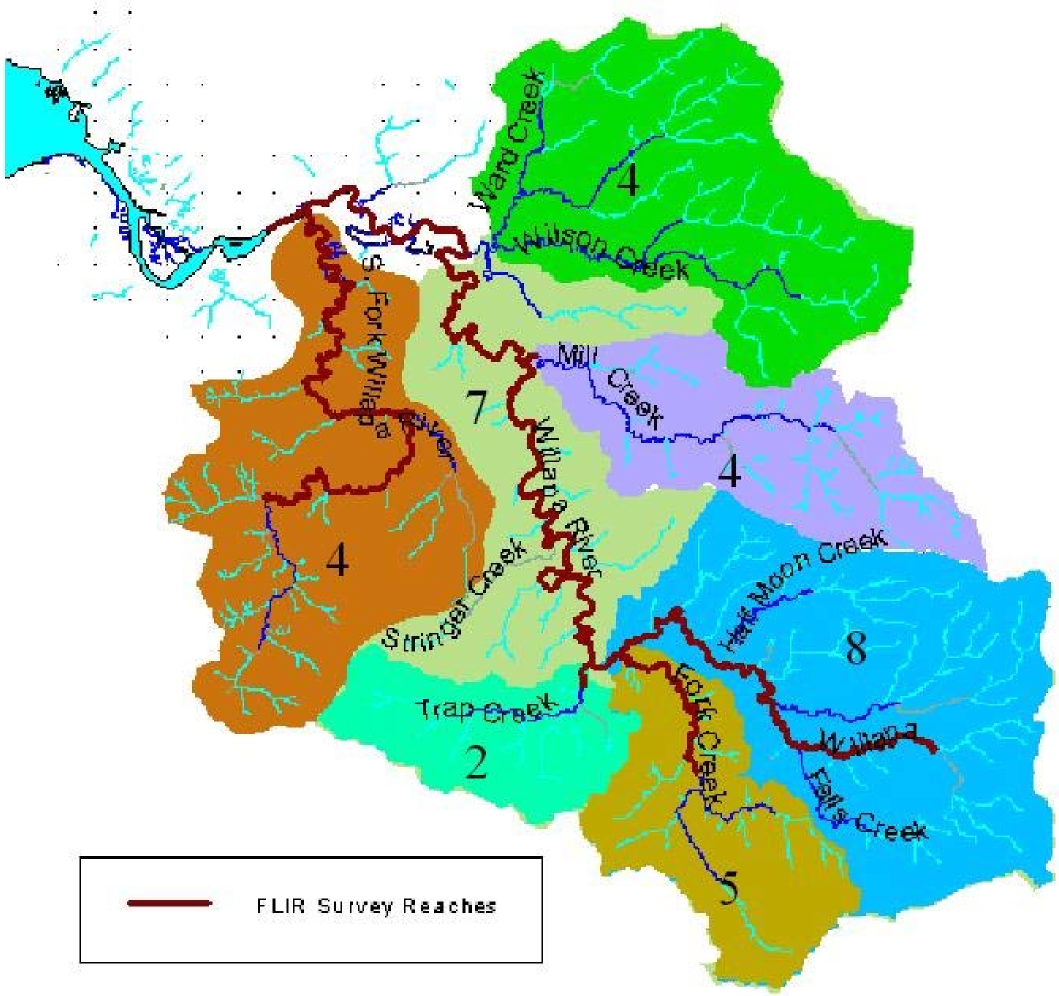

Figure 3. FLIR survey reaches and proposed number of temperature data loggers located in each subbasin

environment. The water temperature logger will be installed at approximately one-half of the water depth and as close to the center of the thalweg as possible. The installation site will be located where there is obvious water mixing and at a depth that will not become exposed if the water level drops but will not be affected by groundwater inflow or stratification. The air temperature data loggers will be installed adjacent to the water temperature probe about one to three meters into the riparian zone from the edge of the bankfull channel and about one meter off the ground.

3. Riparian Stream and Habitat Surveys

Timber-Fish-Wildlife Stream Temperature Survey methods will be followed for the collection of data during thermal reach surveys (Schuett-Hames et al., 1999). The surveys will be conducted mid-July to August 2001 at the temperature sites established by Ecology (Table 3). Field measurements taken every 30 meters over a 300-meter thermal reach will consist of bankfull width and depth, wetted width and depth, canopy closure, stream gradient, and channel type. Riparian Management Zone (RMZ) characteristics, such as active channel width, cover, size, density, bank erosion, and windthrow, will also be recorded during the surveys. Instream flow will be measured at the upstream and downstream boundaries of the thermal reaches. Hemispherical photography will be used to measure effective shade and canopy density at all water temperature stations, and at approximately 20 additional selected locations, to ground-truth the range of vegetation classes digitized from inspection of digital orthophotos.

Table 3. Summary of field measurements, target accuracy or reporting values, and methods.

Parameter	Accuracy or Reporting Values	Method[1]
Temperature	Air ± 0.4°C Water ± 0.2°C	Thermograph
Velocity	± 0.5 feet/second	Marsh-McBirney model 201 current meter

[1]Method references: TFW Stream Survey, 1999; WAS, 1993

4. Forward Looking Infrared Radiometer (FLIR) Thermal Imagery

Approximately 65 miles of streams and rivers in the study area (Figure 3) will be flown to provide simultaneous thermal (FLIR) and visible video coverage that are geographically linked through a Global Positioning System (GPS) and geo-referenced through a Geographic Information System (ArcView GIS). Each thermal image will cover a ground area of approximately 100 x 150 meters and have a spatial resolution of less than 0.5 meters per pixel. The thermal imagery will be calibrated to measured water temperatures and will have an accuracy of approximately +/- 0.4 degrees C. The FLIR survey will occur sometime between July 15 and August 31. Data collection will be timed to capture the maximum daily stream temperatures, which typically occur between 14:00 and 17:00 hours. The contractor for the FLIR survey will be Watershed Sciences, LLC.

Data Collection Timeline

The field schedule during 2001 shows approximate dates of datalogger installation, data download, and stream surveys:

May 15 - 30	Continuous flow monitoring devices installed and launched
May 15 - June 15	Temperature data logger (tidbit) installed
June 1 - Oct 30	Instantaneous flow measurements for rating curves
June 18 -30	Download temperature data from loggers and take instantaneous flow measurements
July 15 - Aug 31	FLIR survey (schedule depends on FLIR contractor and weather)
July 15 - Aug 31	Stream and habitat surveys
July 30 - Aug 1	Synoptic flow measurements taken on tributaries and mainstem. Download temperature data from loggers
Aug 13 - 17	Download temperature data from loggers and take instantaneous flow measurements
Sept 17 - 21	Download temperature data from loggers and take instantaneous flow measurements
Oct 22 - 31	Download final temperature data, remove tidbits

Project Organization

The roles and responsibilities of Ecology staff involved in this project are provided below:

Anita Stohr: Project manager, Watershed Ecology Section, Environmental Assessment Program. Responsible for overall project management. Defines project objectives, scope, and study design. Responsible for review of the project quality assurance project plan (QAPP) and final technical report. Responsible for primary contact with the client and stakeholders.

Trevor Swanson: Field lead, Watershed Ecology Section, Environmental Assessment Program. Coordinates and conducts field sampling and data collection. Assists in defining project objectives, scope, and study design. Assists with data analysis and modeling tasks. Responsible for writing portions of the final report relating to data collection, field methods, and data quality review and analysis.

Dave Rountry: TMDL lead, Water Quality Program, Southwest Regional Office (SWRO). Reviews and comments on QAPP and reports. Coordinates local outreach and information exchange about the technical study and local development of implementation and monitoring plans between Ecology and local planning groups. Supports data collection as part of the TMDL implementation monitoring.

Brad Hopkins, Chuck Springer, and Chris Evans: Stream Hydrology Unit, Environmental Monitoring and Trends Section, Environmental Assessment Program. Responsible for the deployment and maintenance of continuous flow loggers and staff gages on mainstem tributaries. Responsible for producing records of hourly flow data at select sites for the study period.

Darrel Anderson: Unit supervisor, Water Quality Program, SWRO. Reviews and comments on QAPP and reports. Responsible for approval of TMDL submittal to EPA.

Kelly Susewind: Section supervisor, Water Quality Program, SWRO. Reviews and comments on QAPP and reports. Responsible for approval of TMDL submittal to EPA.

Will Kendra: Section supervisor, Watershed Ecology Section, Environmental Assessment Program. Responsible for approval of the project QAPP and final technical report.

Karol Erickson: Unit supervisor, Watershed Studies Unit, Environmental Assessment Program. Responsible for the technical study budget, review of the project QAPP, and review of the final technical report.

Cliff Kirchmer: Ecology Quality Assurance Officer, Environmental Assessment Program,. Responsible for review of QAPP. Available for technical assistance on quality assurance issues and problems.

Data Quality Objectives

Accuracy objectives for field measurements are presented in Table 3. Experience at Ecology has shown that duplicate field thermometer readings consistently show a high level of precision, rarely varying by more than 0.2°C. Therefore, replicate field thermometer readings were not deemed to be necessary and will not be taken. Accuracy of the thermograph data loggers will be maintained by a two-point comparison between the thermograph, a field thermometer, and a certified reference thermometer. The certified reference thermometer, manufactured by HB Instrument Co. (part No. 61099-035, serial No. 2L2087), is certified to meet ISO9000 standards and calibrated against National Institute of Standards and Technology traceable equipment. The field thermometer is a Brooklyn Alcohol Thermometer (model No. 67857).

First, the field thermometer's accuracy will be evaluated by comparison to a certified reference thermometer. If there is a temperature difference of greater than 0.2°C, the field thermometer's temperature readings will be adjusted by the mean difference. Secondly, the accuracy of the thermal data loggers will be evaluated by comparison to the field thermometer. Manufacturer specifications report an accuracy of ±0.2°C for the Onset StowAway Tidbit (-5°C to +37°C) and ±0.4°C for the Onset StowAway Tidbit (-20°C to +50°C). If the mean difference between the field thermometer and the thermal data loggers differs by more than the manufacturer's reported specifications, the thermal data logger will not be used during field work.

Ecology will install two water temperature thermographs at three of the five sites where continuous flow is monitored. Accuracy of the data loggers will be evaluated by comparing data downloaded from the loggers to reference temperature readings taken with a calibrated field thermometer during site visits throughout the sampling season. The mean difference between the downloaded data and the reference thermometer readings will be calculated. Data are only acceptable if they do not exceed a maximum mean difference of 0.2C. The comparability of the data loggers will be determined by comparing the mean difference between each groups downloaded temperature data. The data are deemed acceptable if the mean difference does not exceed 0.2C.

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, and seasonal variation of instream flow and temperatures in the basin. Extra calibrated field thermometers and thermograph data loggers will be taken in the field during site visits and surveys to minimize data loss due to damaged or lost equipment

Measurement and Sampling Procedures

Field sampling and measurement protocols will follow those described in the Timber-Fish-Wildlife (TFW) Stream Temperature Survey Manual (Schuett-Hames et al, 1999) and the Watershed Assessment Section (WAS) protocol manual (WAS, 1993). Temperature thermographs will be installed in the water and air in areas which are representative of the surrounding environment and are shaded from direct sunlight. To safeguard against data loss, data from the loggers will be downloaded midway through the sampling season. The stream surveys will collect data according to TFW protocols for bankfull width and depth, wetted width and depth, canopy closure, stream gradient, and channel type. Riparian management zone (RMZ) characteristics, such as width, cover, size, density, and windthrow, will also be recorded during the surveys. Instream flow will be measured at the upstream and downstream boundaries of the thermal reach (Schuett-Hames et al., 1999).

Quality Control Procedures

Variation for field sampling will be addressed with a field check of the instruments with a hand held thermometer at all thermograph sites upon deployment, retrieval, and also once during the sampling season (mid-August). Field sampling and measurements will follow quality control protocols described in the WAS protocol manual (WAS, 1993) and the TFW stream temperature manual (Schuett-Hames et al., 1999). The Optic Stowaway Tidbits will be pre- and post-calibrated in accordance with TFW stream temperature survey protocol to document instrument bias and performance at representative temperatures. A certified reference thermometer will be used for the calibration. At the completion of the monitoring, the raw data will be adjusted for instrument bias, based on the pre- and post-calibration results, if the bias is greater than ±0.2°C (Schuett-Hames et al, 1999).

Data Analysis and Modeling Procedures

From the raw data collected at each monitoring location, the maximum, minimum, and daily average will be determined. The data will be used to characterize the water temperature regime of the basin and to determine periods when the water temperatures are above state numeric water quality standards (18°C). Estimates of groundwater inflow will be calculated by constructing a water mass balance from continuous and instantaneous streamflow data.

A model will be developed for observed and critical conditions. Critical conditions for temperature are characterized by a period of low flow and high water temperatures. The model will be used to develop load and wasteload allocations for heat energy to the stream. Sensitivity analysis will be run to assess the reliability of the model results.

Reporting Schedule

The reporting schedule for this project is as follows:

September 2002	Draft report due to Watershed Studies Unit Supervisor
November 2002	Draft report due to clients
December 2002	Draft report out for external review
February 2003	Final report to printer

References

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