Quality Assurance Project Plan

Naches River Temperature Total Maximum Daily Load

by
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1998 303(d) Listings Addressed in this Study:

Water Body	***Twn***	***Rng***	***Sec***	***New ID***	***Old ID***	***Parameter***
American River	17N	13E	12	QX86IU	WA-38-1060	Temperature
Bear Creek	19N	13E	32	JJ42VM	WA-38-1088	Temperature
Blowout Creek	19N	12E	35	OL73EW	WA-38-1091	Temperature
Bumping River	17N	13E	12	XR40PP	WA-38-1070	Temperature
Cowiche Creek	13N	17E	11	AR69RI	WA-38-1015	Temperature
Cowiche Creek	13N	15E	22	VD04IL	WA-38-1015	Temperature
Cowiche Creek, N.F.	14N	17E	18	TY98TL	WA-38-1016	Temperature
Cowiche Creek, N.F.	13N	17E	3	TY98TL	WA-38-1016	Temperature
Cowiche Creek, S.F.	13N	17E	3	VD04IL	WA-38-1017	Temperature
Cowiche Creek, S.F.	14N	16E	35	VD04IL	WA-38-1017	Temperature
Crow Creek	18N	14E	30	TL45HC	WA-38-1081	Temperature
Gold Creek	17N	14E	36	CR82VL	WA-38-1041	Temperature
Little Naches River	18N	14E	33	OC24XW	WA-38-1080	Temperature
Little Naches River	17N	14E	4	JR85ZB	WA-38-1080	Temperature
Little Naches River	19N	13E	31	JR85ZB	WA-38-1080	Temperature
Little Naches River	18N	14E	32	JR85ZB	WA-38-1080	Temperature
Little Rattlesnake Creek	15N	15E	1	FD68UD	WA-38-1036	Temperature
Mathew Creek	18N	13E	10	LW85BJ	WA-38-1086	Temperature
Naches River	13N	18E	12	NK19LR	WA-38-1010	Temperature
Naches River	13N	18E	12	NK19LR	WA-38-1010	Temperature
Nile Creek, N.F.	16N	15E	3	IN37QB	WA-38-2110	Temperature
Rattlesnake Creek	15N	14E	10	MB08QY	WA-38-1035	Temperature
Rattlesnake Creek	15N	15E	9	MB08QY	WA-38-1037	Temperature
Reynolds Creek	13N	15E	15	BI05EL	WA-38-1018	Temperature
Tieton River, S.F.	13N	13E	13	NV27KW	WA-38-3000	Temperature

User Study ID: STEB0001

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Approvals

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Abstract

Data collection--consisting of continuous temperature monitoring, Thermal Infrared Imagery (TIR), stream flow monitoring, riparian surveys, and an extensive groundwater study--is planned for the summer of 2004 in the Naches River Watershed. The Washington State Department of Ecology (Ecology) is working cooperatively with the Naches Technical Workgroup (TWG) to coordinate field work. Water temperature in the Naches Basin will be characterized and loading capacity and load and wasteload allocations established for heat sources in the watershed to meet water quality standards.

Introduction and Background

The Naches River has been selected for a temperature Total Maximum Daily Load (TMDL) study as required by the federal Clean Water Act. Temperature data collected by Ecology, the National Forest Service, and the Yakama Nation was the basis for placing 25 stream segments on the 1998 303(d) list of impaired waterbodies. Temperature is a water quality concern because high temperatures can affect aquatic organisms' ability to survive or reproduce and may compromise use by Steelhead and Bull Trout, which are listed in the Naches basin as threatened under the Endangered Species Act.

The purpose of the Naches River Temperature TMDL is to characterize water temperatures in the basin and establish load capacities and load and wasteload allocations for heat sources to meet water quality standards for surface water temperature. The high interest in water temperature issues in this basin is demonstrated by the level of data collection and by the initiation of streamflow and riparian vegetation improvement projects.

Data collection, consisting of continuous temperature monitoring, TIR, stream flow monitoring, riparian surveys, and an extensive groundwater study, are planned for the summer of 2004. Data collection methods will be discussed in more detail in the study design section of this report. Ecology is working cooperatively with the TWG--a group composed of local, county, state, and federal technical stakeholders from the Naches Basin--to coordinate field work. Data collected during the summer 2004 field season will be utilized to characterize the water temperature in the Naches Basin and develop loading capacities and load and wasteload allocations for heat sources to meet water quality standards.

In total, Naches Basin has twenty-five segments (Table 1) on the 303(d) list as impaired for temperature. The majority of the listings occur on lands managed by the USFS. A TMDL analysis has already been conducted for the USFS lands within this watershed and the results of the USFS TMDL analysis will be considered as part of this TMDL. Temperature problems in the basin are likely not limited to the remaining non-USFS segments reported on the 303(d) list; therefore, this study concentrates not only on the temperature concerns of the listed segments but those on all non-USFS lands within the entire Naches Watershed as well.

Table 1: 1998 303(d) Temperature Listings for the Naches River (WRIA 38).

Water Body	*Twn*	*Rng*	*Sec*	*New ID*	*Old ID*
American River	17N	13E	12	QX86IU	WA-38-1060
Bear Creek	19N	13E	32	JJ42VM	WA-38-1088
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Mathew Creek	18N	13E	10	LW85BJ	WA-38-1086
Naches River	13N	18E	12	NK19LR	WA-38-1010
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Reynolds Creek	13N	15E	15	BI05EL	WA-38-1018
Tieton River, S.F.	13N	13E	13	NV27KW	WA-38-3000

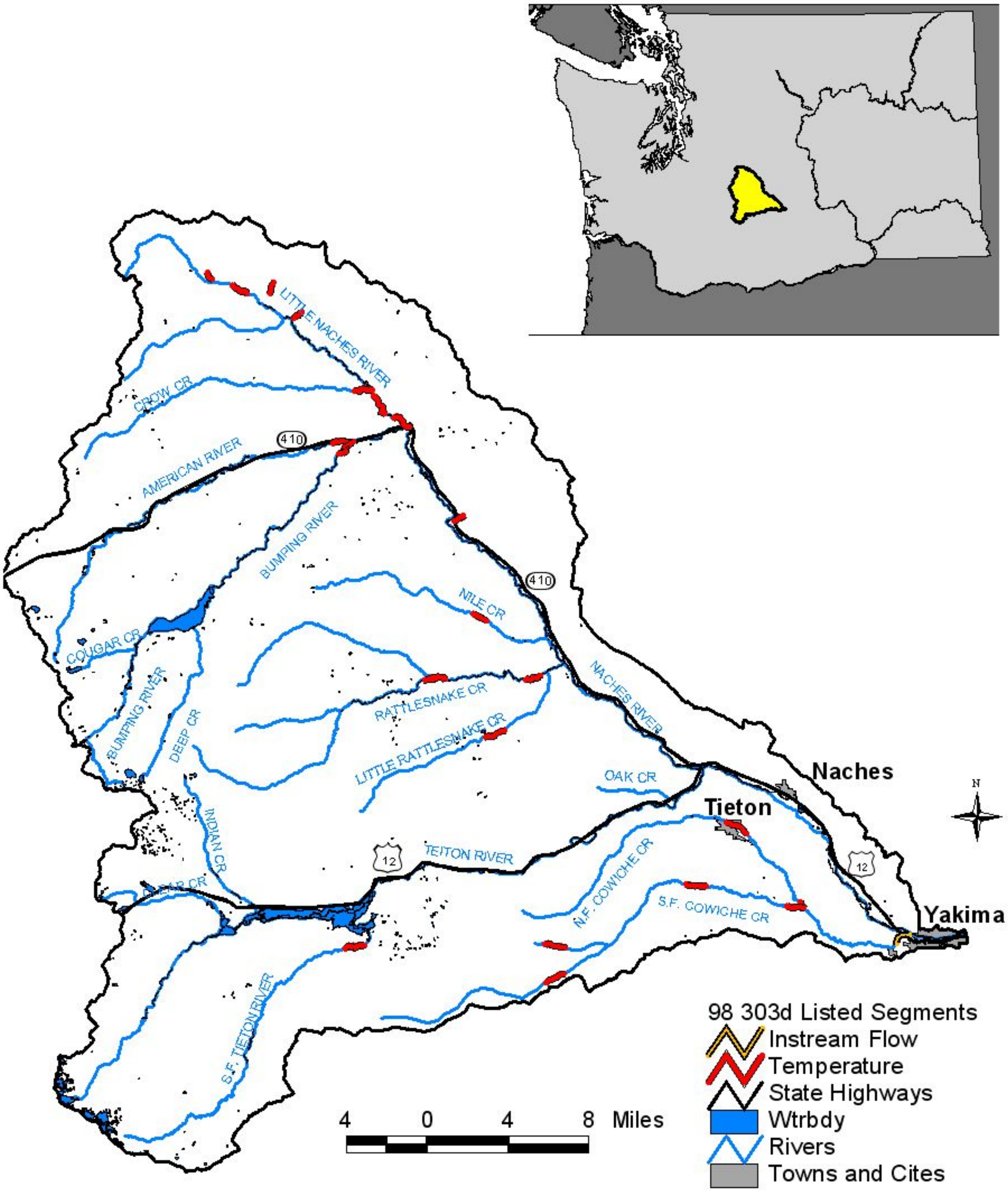

Figure 1: 1998 303d Listings for Temperature in the Naches River Basin (WRIA 38).

Project Description

Study Area

The study area includes all major tributaries of the Naches River from the confluence of the Yakima River to the USFS boundary. Load allocations will be developed for Cowiche Creek, Tieton River, Rattlesnake Creek, and the Mainstem Naches River. The Wenatchee National Forest has developed a temperature TMDL that established load allocations for shade on USFS designated lands in WRIA 38 (Whiley, 2004). Private timberlands fall under the jurisdiction of the Forests and Fish Agreement, which establishes riparian vegetation density targets for these lands (DNR, 1999). Because land use in the basin consists of a mix of public and privately managed timberlands, small private resorts and cabins, and irrigated agriculture, the basin is considered a mixed use watershed. In accordance with the section of Forests and Fish Agreement titled *TMDLs Produced Prior to 2009 in Mixed Use Watersheds*, load allocations will be developed in this TMDL for forest lands in the Naches River Watershed. Also consistent with the Forests and Fish Agreement, implementation of the load allocations established in this TMDL for private and state forestlands will be accomplished via implementation of these forest practice regulations (DNR, 1999). Therefore, this temperature TMDL will develop load allocations for all land within the Naches River Watershed, excluding Wenatchee National Forest land.

Watershed Description

The Naches River Subbasin, Watershed Resource Inventory Area (WRIA) 38, is part of the Yakima River drainage basin. The Naches River flows east from the Cascades to the city of Yakima where it converges with the Yakima River. The Naches River has four major tributaries: Bumping, American, Tieton, and Little Naches Rivers. There are two reservoirs located within the basin: Rimrock Lake (approximately 198,000 acre-feet) is located on the Tieton River and Bumping Lake (approximately 33,700 acre-feet) is located on the Bumping River. The Bureau of Reclamation manages the Yakima reservoirs system, which includes the reservoirs located within the Naches Watershed, using a management policy termed “flip-flop.”

In practice, flip-flop, which was conceived and initiated in 1981, consists of releasing virtually all water needed by the Wapato Irrigation Project and the Sunnyside Valley Irrigation District from the upper Yakima reservoirs until September. During this time, releases from Rimrock and Bumping Reservoirs are minimized. In early September, the release pattern reverses and the majority of the flow is provided from Rimrock and Bumping Reservoirs and the upper Yakima releases are curtailed (YSFWPB, 2004). The purpose of the flip-flop operation is to encourage chinook, returning to the upper Yakima in the fall, to spawn at lower river stages. This ensures that the flows required to keep the redds watered and protected during the incubation period (November through March) are minimized; it is also consistent with the “normative” flow concept for the upper Yakima arm of the basin (Bureau of Reclamation, 2004). Based on historical records, flip-flop will actually occur sooner than normal this year with release of storage flows from the Naches reservoir system increasing in late August to early September.

The climate of the basin ranges from cool and moist in the mountains to warm and dry in the valleys. Most of the precipitation falls during November to January. Annual precipitation in the mountains ranges from 80 to 140 inches at the cascade crest to less than 10 inches in the eastern part of the basin. Average summertime temperatures range from 55°F in the mountains to 82°F in the Valleys. These conditions are formed by predominately westerly winds coming over the cascade crest and the rain shadow effect in the valleys below.

The Naches Basin mainly lies in the Cascade Mountain province with only a small portion near the mouth falling in the Columbia Plateau. The Cascade Mountains consists of continental formations of Eocene-age sandstone, shale, and some coal layers, and pre-Miocene volcanic, intrusive, and metamorphic formations. Tertiary and quaternary andesite and dacitic lavas, tuff, and mudflows form a broad north-south arch (Tri-County, 2000). The Columbia Plateau is a series of basalt flows that cover older rock of the Cascade Mountains. Much of the fertile soils in the basin come from glacier and river transported soils.

The vegetation of the basin is a complex blend of forest, shrub steppe, and grasslands. The forests are located in the mountainous areas where precipitation is greater, and along the riparian edges of streams and rivers. Ponderosa pine, Douglas fir, and Grand and Noble fir form the majority of complex heterogeneous forests at the higher elevations (Haring, 2001). White oak, cottonwood, birch, and alder are found along the riparian zones in the valleys (Haring, 2001). Most of the land in the lower reaches is populated with fragile shrub and grassland that is highly erodeable if disturbed.

Land ownership in WRIA 38 is predominantly public. The USFS owns and manages the majority of land in the basin. The Washington State Department of Natural Resources and Washington State Department of Fish and Wildlife own and manage the next largest proportion of public lands. The private lands of the upper watershed consist of small recreational cabins and small resorts. The valleys of the Mainstem Naches River and Cowiche Creek are predominantly irrigated agriculture croplands. The major crops raised in the basin are apples, pears, and cherries. There are three municipalities located within the lower Naches Watershed: Naches, Tieton, and Yakima.

Project Objectives

Characterize summer (June-October) stream temperature of the Tieton River, Naches River Rattlesnake Creek, and Cowiche Creek (WRIA 38).

- Compile existing data, including:
  - Data collected by USFS, Washington State Department of Fish and Wildlife, United States Bureau of Reclamation, United States Geological Survey, and other potential data sources found during the study.
  - Qualitative historical data on stream temperature, stream channel characteristics, and riparian vegetation.

- Collect additional data in cooperation with USFS, Washington State Department of Fish and Wildlife, and other watershed groups.

Develop a predictive computer temperature model for the Mainstem Naches River from the mouth to the Wenatchee National Forest Boundary, Tieton River, Cowiche Creek, and selected Naches River tributaries not located on USFS lands.

- Model the stream temperature regime at average and critical conditions.
- Evaluate the ability of various watershed *Best Management Practices* (BMPs) to reduce water temperature to meet water quality standards.

Establish a TMDL for temperature in the Naches River Watershed.

- Develop the loading capacity for thermal load to the stream (usually expressed as incoming solar radiation in units of Langleys/day).
- For ease of implementation, load allocations may be reported in terms of surrogates 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

Environmental variables that affect water temperature include (Brown, 1969):

- Solar Radiation.
- Air Temperature.
- Stream width, depth, and velocity.
- Tributary and groundwater influence.

The city of Naches Wastewater Treatment Plant (WWTP), Cowiche/Tieton WWTP and the Apple-Packers are the registered NPDES Phase I permit holders within the Naches Basin. The impacts of these three point sources on the receiving water temperature will be analyzed and wasteload allocations developed as part of this TMDL. Other potential point sources in the basin include the Naches Hatchery, Nelson Springs Raceway, and Yakama Nation acclimatization ponds. Methodology for addressing each of the point sources will be developed and sent out for peer review during this TMDL.

Sources of nonpoint thermal pollution may be:

- Riparian vegetation disturbance and loss of shade due to:
    - Removal of trees and shrubs for pasture, crops, timber harvest, roads, or buildings.
    - Heavy grazing by livestock.
    - Conversion of forest to pasture land.
    - Alteration of the hydrograph to such an extent that riparian vegetation cannot complete its life history requirements.

- Channel morphology impacts resulting from:
    - Removal of large, woody debris by commercial harvest, agriculture, and flood control.
    - Increased sediment loading from agriculture, timber harvest, and roads.
    - Channel constraint/diking for agriculture, flood control, and roads.
    - Bank instability/erosion and sedimentation from removal of root structure and increased land-use practices in the watershed.
    - Altered sediment/energy regimes that result in channel incision or aggradation.

- Hydrologic changes influenced by:
    - Extraction and return of water for irrigation or other purposes.
    - Discharge management with reservoirs maintaining artificially high flows.
    - Altered stream flow patterns from urbanized and timber harvest areas resulting in increased spring runoff and decreased summer base flows.
    - Altered sediment/energy regimes that result in channel incision or aggradation.

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, reduction (or loss of) groundwater inputs, and increased water surface area from sedimentation, making the channel wider and shallower.

Beneficial Uses

The Naches River, its tributaries, and Cowiche Creek are classified as Class AA (extraordinary) and Class A (excellent), as defined by Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A-0303 WAC) (Table 2). The water quality 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. The beneficial uses of the waters in this specific area are:

- *Recreation*: Fishing, Swimming, and Rafting.

- *Fish and Shellfish*: Spring Chinook Salmon (*Oncorhynchus tshawytscha*), Rainbow/Steelhead Trout (*Oncorhynchus mykiss*), and Bull Trout (*Salvelinus confluentus*) are the salmonid species in the Naches Basin. The lower reaches of the basin are mainly used by these species for migration, rearing, and spawning habitat. Pacific lamprey, kokanee salmon, cutthroat trout, and mountain whitefish have also been documented within the basin (YSFWPB, 2004).

- *Industrial, Municipal and Agricultural Water Supply and Stock Watering*: Agriculture extracts water for irrigation and stock watering, and the city of Yakima uses the Lower Naches as a drinking water source.

- *Miscellaneous Uses (Wildlife Habitat)*: Riparian areas are used by a variety of wildlife species, which are dependent on the habitat.

Numeric freshwater water quality criteria state that temperature shall not exceed the following:

Table 2: Stream Classifications of Naches River and its Tributaries as Defined by Water Quality Standards for Surface Waters of the State of Washington.

Classification	Temperature Not to Exceed (Degrees C)
Class AA (extraordinary)	16.0
Class A (excellent)	18.0

When natural conditions exceed the temperature criterion, no temperature increases will be allowed, which will raise the receiving water temperature by greater than 0.3°C. If natural conditions are below the temperature standard, incremental temperature increases, resulting from nonpoint source activities, shall not exceed 2.8°C or bring the stream temperature above the specified standard of the class at any time (Chapter 173-201A-030 WAC).

An alternative to the current temperature standard is under development and currently being reviewed by the United States Environmental Protection Agency (EPA). This alternative is based on the presence, or absence, of particular fish species and their temperature needs at various life-history stages. The most current information on this alternative can be found at http://www.ecy.wa.gov/programs/wq/swqs/rev_rule.html.

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, habitat, and floodplain connectivity are major concerns in the Naches River and its tributaries because of the use of its waters by steelhead and bull trout and their listing as a threatened species under the Endangered Species Act. Elevated temperature and altered channel morphology, resulting from various land-use activities such as timber harvest, flood control, and agriculture, limit available spawning and rearing habitat for salmonids (Haring, 2001).

Historical Data Review

WRIA 38 is rich in published literature directly applicable to the Naches Temperature TMDL. A thorough historical data review will be conducted as part of this study. A bibliography of known publications to date is presented in Appendix A.

Study Design

Approach

The Naches River 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 relative 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 streamflow patterns due to land-use practices that increase runoff instead of storage.

The sources of increased stream temperatures will be examined as part of the Naches River temperature TMDL to produce a loading capacity and load and wasteload allocations for the heat 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 (Table 3).

Table 3: Model Data Requirements and Collection Source.

		MODEL		Collection By				
	PARAMETER	**Effective shade**	**Qual2K**	**TIR**	**USBR**	**USFS**	**WDFW**	**Ecology**
Flow	discharge - tributary		x		x			x
	discharge (upstream & downstream)		x					x
	flow regression constants		x					x
	flow velocity		x		x			x
	groundwater inflow rate/discharge		x					x
	travel time		x					x
General	calendar day/date	x	x	All Data Collected Primarly from USGS or GIS Maps				
	duration of simulation	x	x					
	elevation - downstrean	x	x					
	elevation - upstream	x	x					
	elevation/altitude	x	x					
	latitude	x	x					
	longitude	x	x					
	time zone	x						
Physical	channel azimuth/stream aspect	x						
	cross-sectional area	x	x					x
	Manning's n value	x	x					x
	percent bedrock	x	x					x
	reach length	x	x					x
	stream bank slope	x						x
	stream bed slope	x	x	Collect from USGS or GIS Maps				
	width - bankfull	x						x
	width - stream	x	x					x
Temperature	temperature - ground		x					x
	temperature - groundwater		x					x
	temperature - water downstream		x	x	x	x	x	x
	temperatures - water upstream		x	x	x	x	x	x
	temperature - air		x	x	x	x	x	x
	thermal gradient		x					
Vegetation	% forest cover on each side	x						x
	canopy-shading coefficient/veg density	x						x
	diameter of shade-tree crowns	x						x
	distance to shading vegetation	x						x
	topographic shade angle	x						x
	vegetation height	x						x
	vegetation shade angle	x						x
	vegetation width	x						x
Weather	relative humidity		x	Weather Staion/RH meters				
	% possible sun/cloud cover		x	Weather Station				
	solar radiation		x	Weather Station				
	temperature - air		x	Field check/Weather Station				
	wind speed/velocity		x	Weather Station				

Data Collection and Ecology Field Surveys

Data collection, compilation, and assessment will be governed by the data set requirements of the computer temperature model (Table 3). The data will be assembled from local third-party studies and Ecology field surveys. Local third-party studies include investigations by USFS, Washington State Department of Fish and Wildlife (WDFW), Bureau of Reclamation (USBR), United States Geologic Survey (USGS) and other potential data sources.

Five types of Ecology field surveys will be conducted: 1) continuous flow monitoring at selected gaging stations, 2) continuous monitoring of water and air temperature and relative humidity, 3) riparian surveys of the streams and rivers in the study area, 4) groundwater monitoring, and 5) remote sensing of surface temperatures using thermal infrared (TIR) technology.

Stream Flow Monitoring

Three on-site, continuous-flow monitoring stations will be established by Ecology's Environmental Assessment Program's Stream Hydrology Unit in the study area for the duration of the sampling season, June through October (Figure 2). The standard protocols for the on-site, continuous data loggers will follow those currently established by the Stream Hydrology Unit (Ecology, 2000). There are two USGS continuous flow monitoring stations located on the Mainstem Naches River and one located on the American River. The USBR maintains ten stations throughout the basin to monitor their flow management operations. USFS operates one station on the Little Naches River and one on Oak Creek. All flow monitoring stations located within the Naches Basin are shown on Figure 2.

Ecology, in cooperation with USGS, WDFW, and USFS, will perform a seepage run on the Naches River in July. The seepage run consists of manual flows taken on specific reaches over short periods of time, typically two-to-three days. The Naches Watershed has been split into four reaches (Table 4). Six teams will be assembled to conduct the seepage run. Replicate flows will be taken at three sites by different teams and each team will take at least one replicate flow at a site to account for between-team error and within-team error.

Table 4: Proposed Seepage Run Reaches for the Naches River Temperature TMDL.

Reach #	***Description***
1	Cowiche Creek including NF Cowiche to French reservoir and SF Cowiche to Reynolds Creek
2	Naches River from Mouth to Wapatox Diversion
3	Naches River from Wapatox Diversion to American River and Little Naches River
4	Tieton River from Mouth to Rimrock Reservoir

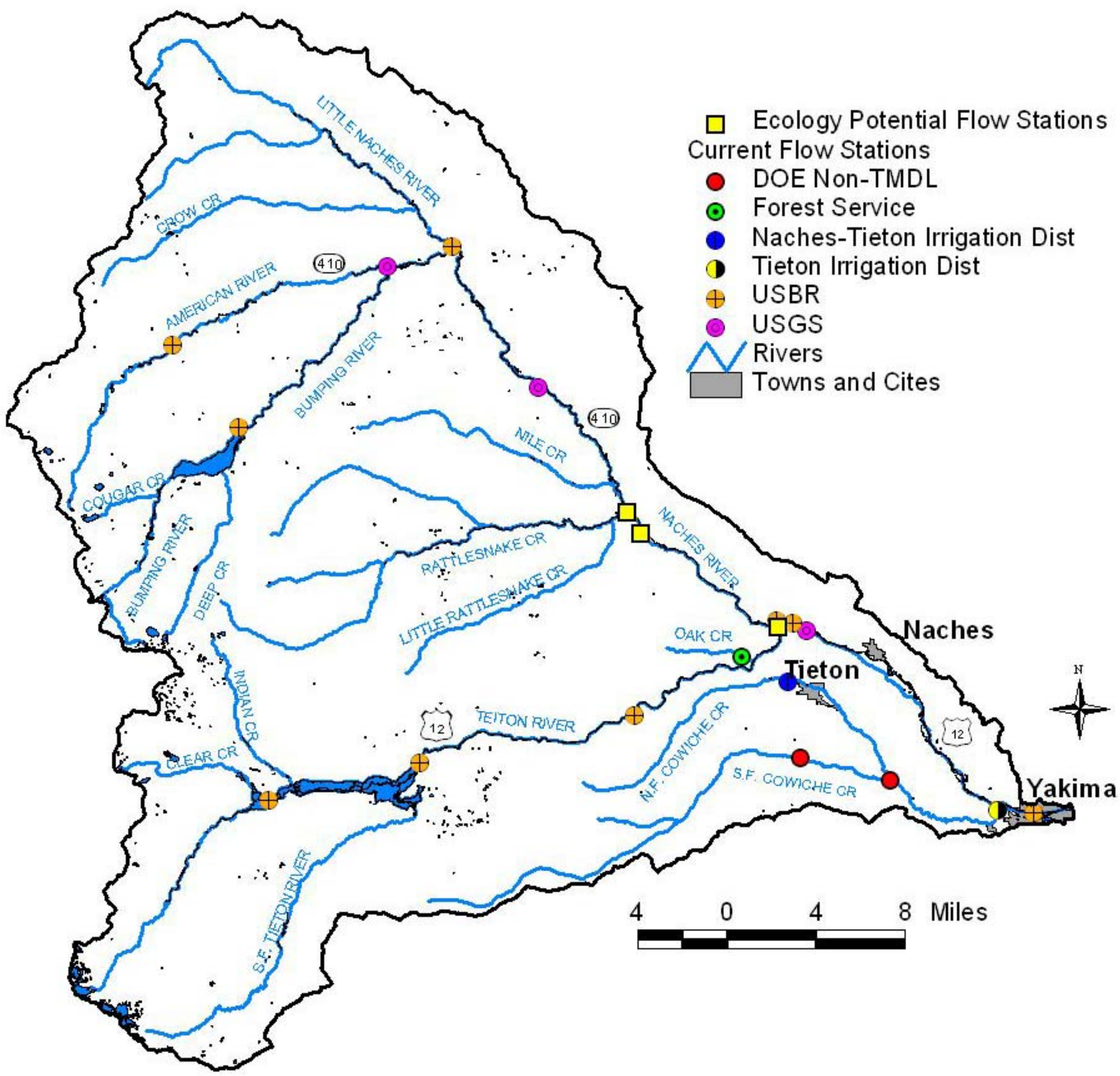

Figure 2: Proposed Continuous Flow Stations for the Naches River Temperature TMDL.

Temperature Sites

Water temperature sites will be established at 37 locations (Figure 3) throughout the study area. Air temperature will be monitored at 25 of these sites, and relative humidity will be monitored at five of these sites (Figure 3 and Table 5). 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 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.

Table 4: Potential Temperature Monitoring Stations for the Naches River Temperature TMDL.

Station ID	Temperature Station Description	Lattitude	Longitude
38-COW-00.5	Cowiche Creek @ S. Naches Rd.	46 37 39.2	120 34 35.2
38-NFC-00.0	N.F. Cowiche Creek near Confluence with S.F. Cowic	46 38 51.1	120 40 50.7
38-REY-00.2	Reynolds Creek near Mouth	46 37 12.0	120 53 10.7
38-SFC-12.6	S.F. Cowiche Creek 0.1 River Miles above Confluence	46 37 00.0	120 53 11.1
38-NAC-00.5	Naches River near Mouth @ Yakima County Greenway	46 37 37.8	120 31 17.7
38-COW-05.9	Cowiche Creek above Cowiche Canyon	46 37 52.4	120 39 46.2
38-COW-02.7	Cowiche Creek Below Cowiche Canyon	46 37 18.6	120 36 46.3
38-NFC-06.3	N.F. Cowiche Creek @ Noye Road	46 42 40.8	120 46 35.5
38-NAC-03.7	Naches River @ S. Naches Rd Bridge	46 37 53.7	120 35 08.1
38-NAC-10.5	Naches River Downstream from Town of Naches @ Publ	46 42 11.3	120 39 34.6
38-NAC-17.6	Naches River @ Hwy 12 abv Confluence with Tieton R	46 44 46.6	120 47 14.8
38-TIE-00.4	Tieton River near Mouth	46 44 29.0	120 47 07.9
38-NAC-08.5	Naches River @ Eschbach Park	46 40 38.3	120 38 54.0
38-NAC-12.8	Naches River @ Naches Tieton Rd	46 43 10.0	120 41 55.5
38-NAC-23.9	Naches River 2.5 Road Miles down from Nile Road	46 47 23.2	120 52 14.2
38-RAT-00.2	Rattlesnake Creek @ Nile Road	46 49 09.8	120 55 58.6
38-NAC-26.8	Naches River @ Lower Nile Road	46 48 23.9	120 55 09.3
38-NIL-00.9	Nile Creek @ Nile Road	46 50 18.1	120 56 59.6
38-NAC-31.1	Naches River @ Upper Nile Rd	46 51 23.1	120 57 20.6
38-NAC-36.0	Naches River @ Forest Service Cottonwood Work Camp	46 54 03.0	121 01 00.8
38-NAC-41.1	Naches River @ Boulder Cave Road	46 56 54.8	121 04 11.3
38-TIE-06.5	Tieton River @ Hwy 12 above Oak Creek	46 42 33.3	120 53 01.1
38-TIE-09.0	Tieton River @ Hwy 12 near Windpoint Campground	46 40 53.8	120 57 18.0
38-SFT-02.6	S.F. Tieton River above Rimrock Lake	46 37 07.0	121 08 10.8
38-NFC-03.5	N.F Cowiche Creek @ Danner Road	46 40 51.6	120 43 10.5
38-NAC-20.8	Naches River above Horseshoe Bend	46 45 58.9	120 49 49.9
38-SFC-06.1	S.F. Cowiche Creek @ Beaver Complex	46 39 44.8	120 47 43.7
38-REY-02.0	Upper Reynolds Creek past VAn Wyke Property	46 36 59.0	120 55 15.8
38-SFC-15.4	Upper S.F. Cowiche past Van Wycke Property	46 35 51.8	120 56 03.8
38-TIE-01.5	Tieton Input into the French Reservoir	46 42 44.4	120 47 59.6
38-RAT-07.3	Rattlesnake Creek near FS Road 119	46 48 32.3	121 03 11.7
38-LIT-00.1	Little Naches River @ Hwy 410	46 59 21.4	121 05 47.3
38-BUM-00.2	Bumping River @ FS Road 1700	46 59 16.7	121 05 51.4
38-NAC-38.8	Naches River @ Old River Road	46 55 22.8	121 02 58.3
38-NFC-05.5	N.F. Cowiche @ Naches Tieton Rd	46 42 08.0	120 44 36.8
38-SFC-04.6	S.F. Cowiche Creek @ First WDFW Boundary	46 39 38.	120 45 54.6
38-TIE-16.2	Tieton River @ Willows Campground	46 40 15.4	121 05 05.2
Lat/Longs were taken in NAD 27 Washington South Zone Datum			

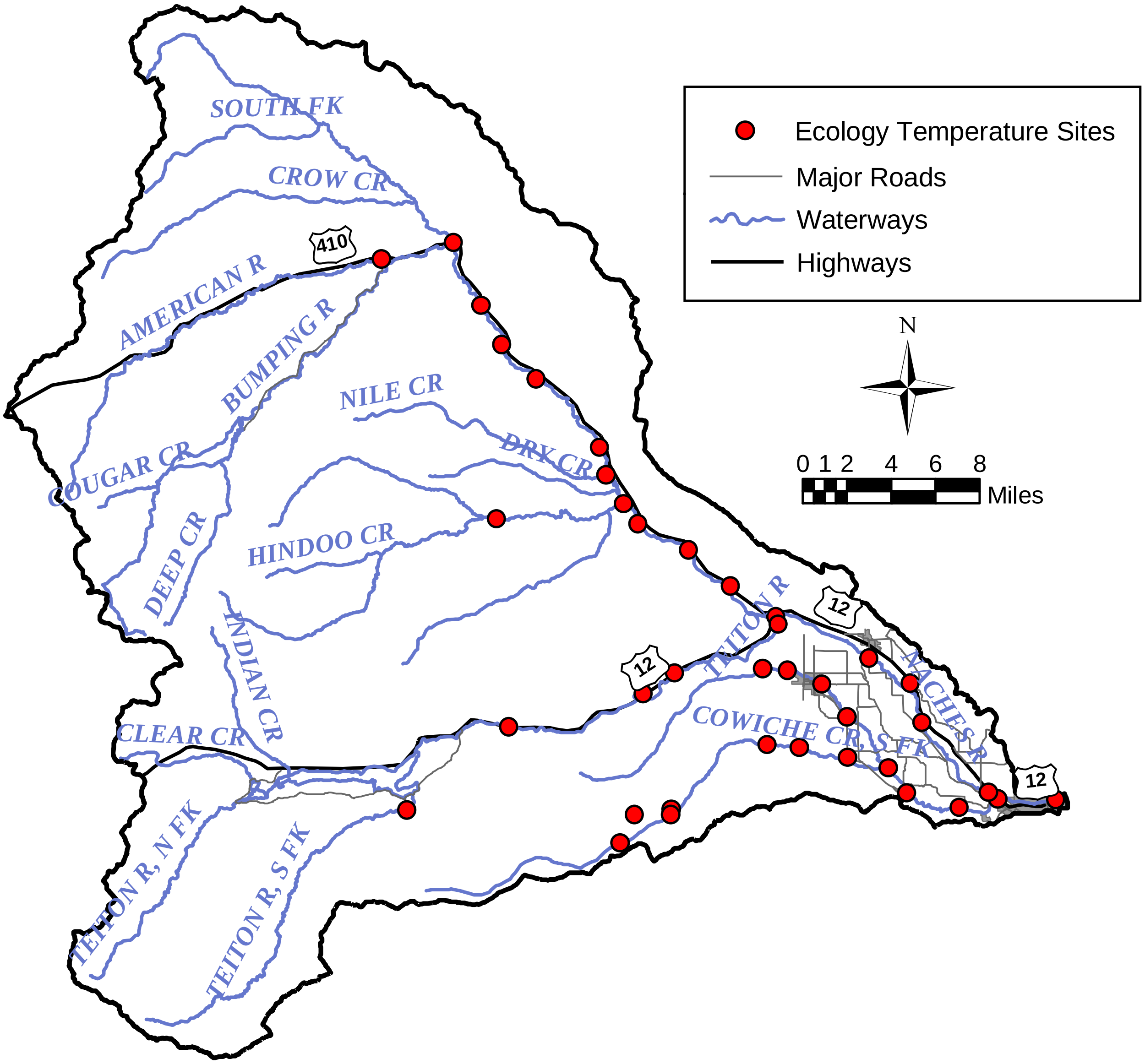

Figure 3: Potential Temperature Monitoring Stations for the Naches River Temperature TMDL.

Riparian Stream and Habitat Surveys

An adapted form of the Timber-Fish-Wildlife Stream Temperature Survey methodology will be followed for the collection of data during thermal reach surveys (Schuett-Hames et al., 1999). The surveys will be conducted July to August 2004 at the temperature sites established by Ecology (Table 4). Field measurements will be taken longitudinally on the Naches and Tieton Rivers. Sites will be dispersed evenly from the USFS boundary to the mouth of the Naches River, and will consist of bankfull width and depth, wetted width and depth, effective shade (using hemispherical photography and a Solar Pathfinder), and channel type. The Wapatox Reach will not be surveyed because of instream safety hazards from water diversions. Also, large amounts of data from habitat surveys exist for this reach from multiple agencies. Riparian Management Zone (RMZ) characteristics, such as active channel width, cover, size, density, and bank erosion, will also be recorded during the surveys. Hemispherical photography will be used to measure effective shade and canopy density at all water temperature stations to ground-truth the range of vegetation classes digitized from inspection of digital orthophotos.

Groundwater Survey

Mini-instream piezometers will be installed near 17 temperature stations on the Tieton River and Naches River to define the vertical hydraulic gradient between area streams and the water-table aquifer (Figure 4). The piezometers consist of a seven-foot length of one-half inch diameter galvanized pipe, one end of which is crimped and slotted. The piezometers will be hand driven into the stream bed to a depth of approximately five feet. The piezometers will be used to classify groundwater influences within the watershed.

Water levels in the piezometers will be measured monthly, between July and Sept 2004, using a calibrated electric well probe or steel tape in accordance with standard USGS methodology (Stallman, 1983). The head difference between the internal piezometer water level and the external creek stage provides an indication of the vertical hydraulic gradient and the direction of flow between the creek and groundwater. When the piezometer head exceeds the creek stage, groundwater discharge into the creek can be inferred. Similarly, when creek stage exceeds the head in the piezometer, loss of water from the creek to groundwater storage can be inferred.

Surface and groundwater temperatures and conductivity will be measured during each of the monthly piezometer surveys. Stream reaches with significant groundwater input (especially during low flow periods) should exhibit similar water conductivity and temperature to the groundwater in the vicinity. Measurements will be made with properly maintained and calibrated field meters in accordance with standard USGS methodology.

Hyporheic tidbits, placed at a depth of one-foot and three-feet below the river bottom, will be installed to measure thermal transfer of heat through the surface and hyporheic zones. The hyporheic tidbits will log temperatures every one-half hour to measure changes in hyporheic temperatures. In addition, temperature will be measured during the habitat surveys to assess the presence, or absence, of groundwater discharge longitudinally along the Naches and Tieton Rivers.

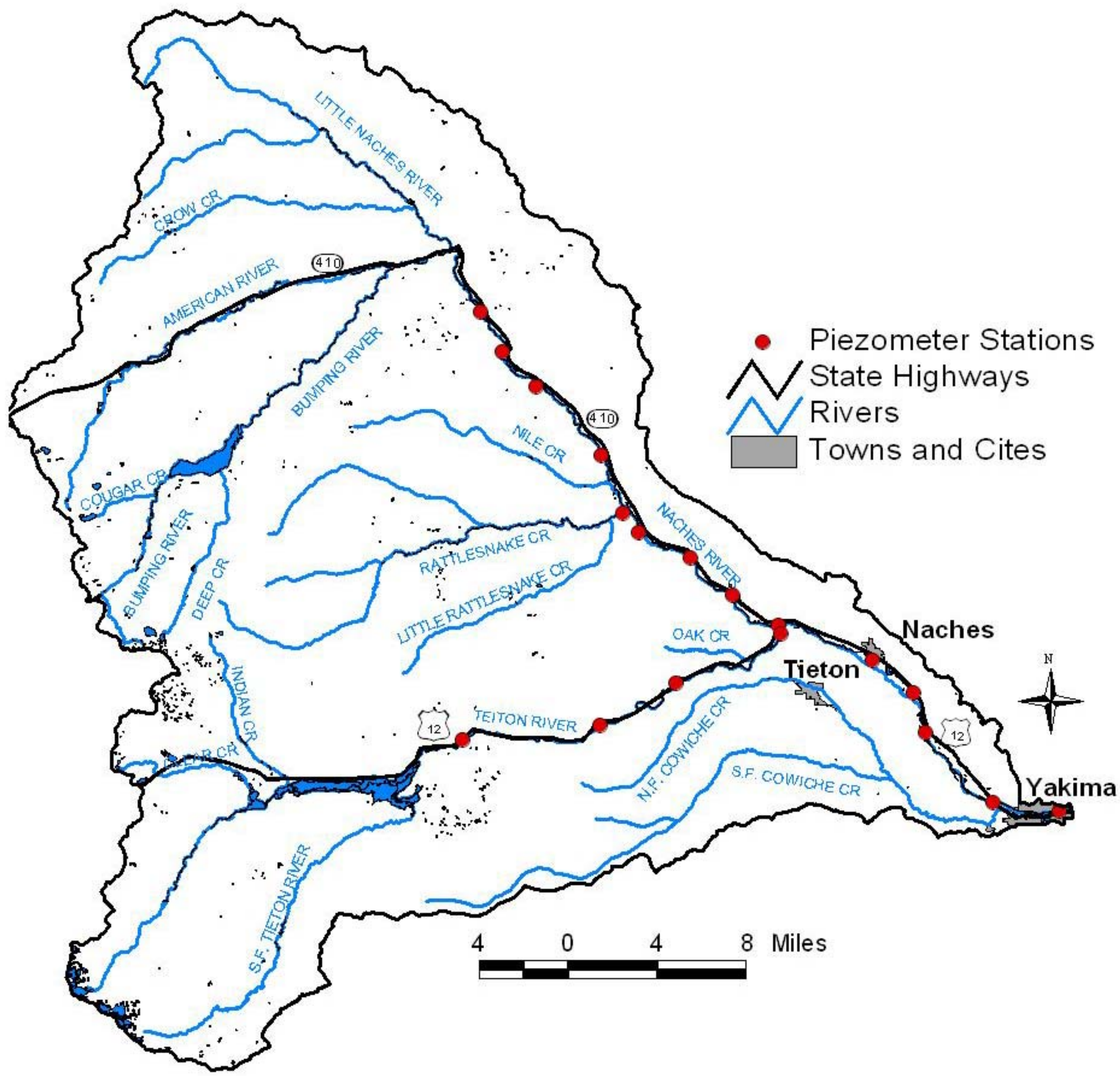

Figure 4: Proposed Groundwater Monitoring Locations for the Naches River Temperature TMDL (WRIA 38).

Thermal Infrared Surveys

Approximately 45 miles of the Naches River (Figure 5) will be flown to provide simultaneous TIR 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 by 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°C. The TIR survey will occur sometime between July 20 and August 20. Data collection will be timed to capture the maximum daily stream temperatures, which typically occur between 14:00 and 17:00 hours.

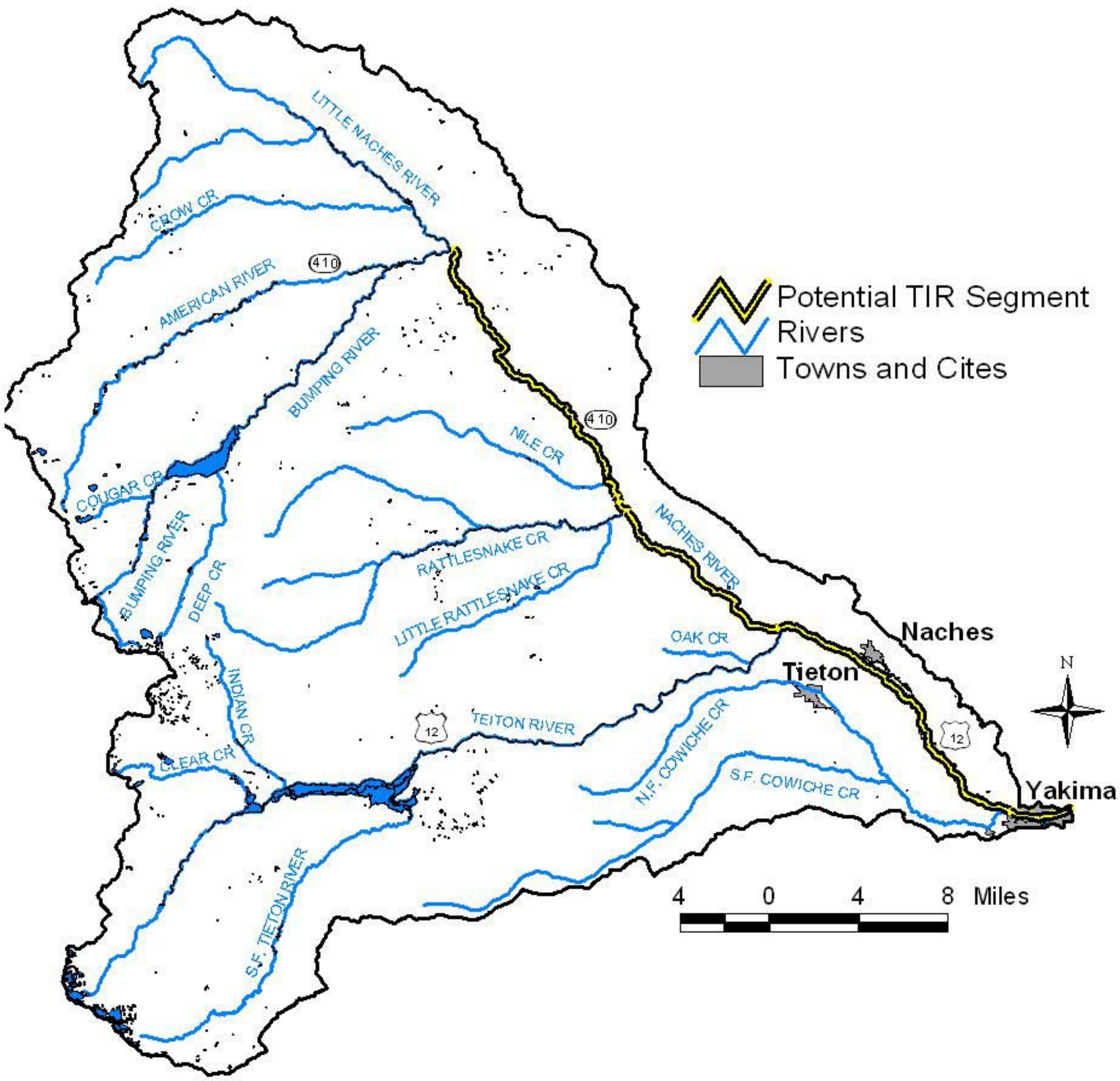

Figure 5: Planned TIR Sampling for the Naches River Temperature TMDL.

Data Collection Timeline

The following field schedule for 2004 shows approximate dates of datalogger installation, data download, and stream surveys:

June 1-20	Continuous-flow monitoring devices installed and launched.
June 1-30	Reconnaissance temperature data loggers (tidbit) installed.
June1- Oct 30	Instantaneous flow measurements taken for rating curves.
June 18-30	Temperature data from loggers downloaded and instantaneous flow measurements taken.
June 30	Quality Assurance (QA) Project Plan approved for sampling and comments addressed.
July 1-15	Core Temperature data loggers (tidbit) installed.
July 18- Aug 15	TIR survey (schedule depends on TIR contractor and weather).
July 1- Aug 31	Stream and habitat surveys.
July 18- Aug 15	Synoptic flow measurements taken on tributaries and mainstem, and temperature data downloaded 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 all field equipment.

To ensure data quality, this timeline may change due to irregularities in stream discharge and/or weather.

Project Organization

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

Stephanie Brock: Temperature Study Project Manager, Watershed Ecology Section, Environmental Assessment (EA) Program. Responsible for overall project management of this study. Defines project objectives, scope, and study design. Responsible of the project QA Project Plan and final technical report. Manages data collection program. Communicates study status and findings to the regional office TMDL lead, the Yakama Nation, and other interested parties.

Michael LeMoine: Temperature Study Field Lead, Watershed Ecology Section, EA 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 the quality assurance project plan QA Project Plan and portions of the final report relating to data collection, field methods, and data quality review and analysis.

Mark Peterschimdt: TMDL Lead, Water Quality Program, Eastern Regional Office (ERO). Reviews and comments on QA Project Plan 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.

Chuck Springer: Stream Hydrology Unit, Environmental Monitoring and Trends Section, EA 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.

Jeff Lewis: Unit Supervisor, Water Quality Program, ERO. Reviews and comments on QA Project Plan and reports. Responsible for approval of TMDL submittal to EPA.

Tom Tebb: Section Supervisor, Water Quality Program, ERO. Reviews and comments on QA Project Plan and reports. Responsible for approval of TMDL submittal to EPA.

Will Kendra: Section Manager, Watershed Ecology Section, EA Program. Responsible for approval of the project QA Project Plan and final technical report.

Karol Erickson: Unit Supervisor, Water Quality Studies Unit, Environmental Assessment Program. Responsible for approving the technical study budget, approval QA Project Plan and final technical report.

Cliff Kirchmer: EA Program, Quality Assurance Unit. Reviews and comments on the draft QA Project Plan and will be available for technical assistance on QA during the implementation and assessment phases of the project.

Data Quality Objectives

Accuracy objectives for field measurements are presented in Table 5. 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 and the field thermometers will be maintained through pre- and post-calibration 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. 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 (NIST) traceable equipment. The field thermometer is a Brooklyn Alcohol Thermometer (Model No. 67857). 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.

Table 5: Summary of Field Measurements, Target Accuracy or Reporting Values, and Methods.

Parameter	**Accuracy or Reporting Values**	**Method**
Air Temperature Water Temperature	± 0.4°C ± 0.2°C	Onset Stowaway Tidbit Onset Stowaway Tidbit
Relative Humidity	± 3 %	Onset RH
Velocity	± 2 % of reading	Marsh-McBirney Model 201 current Meter

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 NIST 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 0.2°C. 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 0.2°C.

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 representative of the surrounding environment and 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, and channel type. Riparian Management Zone (RMZ) characteristics, such as width, cover, size, density, and windthrow, will also be recorded during the surveys. (Schuett-Hames et al., 1999).

Quality Control Procedures

The following quality control procedures have been described previously: 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.

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 (16°C for Class AA and 18°C for Class A). Estimates of groundwater inflow will be calculated by constructing a water mass balance from continuous and instantaneous streamflow data, a piezometer network, and a time-of-travel study.

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 analyses will be run to assess the reliability of the model results.

Data collected during this TMDL effort will allow the development of a temperature simulation methodology that is both spatially continuous and which spans full-day lengths. The GIS and modeling analysis will be conducted using three specialized software tools:

- ODEQ's Ttools extension for Arcview (ODEQ, 2001) will be used to sample and process GIS data for input to the QUAL2K model.

- ODEQ's HeatSource/Shadealator model (Ecology, 2003a) will be used to estimate effective shade along the mainstems of the Naches River, Tieton River, Rattlesnake Creek, and Cowiche Creek. Effective shade will be calculated at 50 to 100-meter intervals along the streams and then averaged over 500 to 1000-meter intervals for input to the QUAL2K model.

- The QUAL2Kw model (Chapra, 2001, Ecology 2003b) will be used to calculate the components of the heat budget and simulate water temperatures. QUAL2Kw simulates diurnal variations in stream temperature for a steady flow condition. In summary, QUAL2Kw is a steady-state, one-dimensional model that simulates diurnally varying water temperature using a finite-difference numerical method. Therefore, a single flow condition is selected to represent a given condition, such as a seven-day average flow. QUAL2Kw uses the kinetic formulations for the components of the surface water heat budget that are described in Chapra (1997). For temperature simulation, data collected in the field (such as solar radiation, air temperature, relative humidity, headwater temperature, and point source/tributary water temperatures) are specified as diurnally varying functions with a minimum and maximum value and time of the maximum value. QUAL2Kw will be applied by assuming that flow remains constant for a given condition such as a seven-day or one-day period, but key variables are allowed to vary with time over the course of a day. Diurnally varying water temperatures will be simulated at 500 to 1000-meter intervals along the basin. The water temperature model will be calibrated to in-stream data collected along the Naches River, Tieton River, Rattlesnake Creek, and Cowiche Creek. Modeling of other selected reaches may occur depending on data availability, flow conditions, and desire of the watershed technical group. A more detailed discussion of model assumptions, calibaration, and limitations is available in the QUAL2Kw users manual (Chapra 2001, Ecology 2003b).

At this point, Qual2Kw and Shade model are the preferred tools to model temperature. Shade model has a proven history in calculating effective shade in both Oregon and Washington temperature TMDLs. Qual2Kw can model various water quality parameters thus incorporating temperature modeling with other TMDL efforts.

Reporting Schedule

The reporting schedule for this project is as follows:

October 2005	Draft report due to Nonpoint Studies Unit Supervisor.
November 2005	Draft report due to clients.
December 2005	Draft report out for external review.
March 2006	EIM data entered.
March 2006	Final report completed.

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Appendix A
Naches Basin Bibliography

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