South Prairie Creek Total Maximum Daily Load Phase II Evaluation

Quality Assurance Project Plan

by
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Table of Contents

Page

List of Figures

List of Tables

Introduction

Located in the South Puget Sound region, South Prairie Creek is a tributary to the Carbon River, which is a tributary to the Puyallup River. The watershed includes all or portions of the towns of Wilkeson, Buckley, South Prairie, and Burnett (Figure 1). Lower South Prairie Creek is the most important salmonid spawning area in the Puyallup River basin, with runs of fall chinook, pink, coho, chum, and winter steelhead. Lower South Prairie Creek exceeded water quality standards for fecal coliform bacteria, based on Ecology monitoring data from 1992-93, and a segment was placed on the 303(d) list. Upstream sections are listed for temperature, based on data collected by the Muckleshoot Tribe in 1997[1].

The purpose of the Total Maximum Daily Load (TMDL) is to determine contributors to the fecal coliform bacteria exceedences and to determine whether other nonpoint-source-related parameters meet water quality standards.

The monitoring will be conducted in two phases. The purpose of the initial monitoring described in the Phase I Assessment Quality Assurance Project Plan (QAPP) was to assess conditions in the lower South Prairie Creek watershed during summer 2000 (Roberts, 2000; http://www.ecy.wa.gov/biblio/0103064.html). The results were used to refine the detailed sampling program that will form the basis of the overall technical study. The present QAPP describes the Phase II monitoring program.

The 1998 303(d) listings addressed in this study:

Water Body	T	R	S	New ID	Old WBID	Parameter
South Prairie Creek	19N	06E	14	VC19MO	WA-10-1085	Fecal Coliform

Project Description

Study Area

The 90.7-square-mile watershed varies in elevation from 5,933 (Pitcher Mountain) to 285 ft MSL at its confluence with the Carbon River (Mastin, 1998). Mean annual average precipitation over the watershed is 61 in/yr but varies from 85 in/yr at the higher elevations to 38 in/yr at the mouth. Geology of the basin includes well compacted glacial till and stratified drift deposits. The lower valley was impacted by the Osceola mudflow from Mt. Rainier. The United States Geological Survey (USGS) has operated stream gage 12095000 (79.5 square miles, 430 ft NGVD) continuously since 1988; the gage was also in operation from 1950 to 1979.

[1] One reach each on South Prairie Creek and Wilkeson Creek are currently 303(d)-listed for temperature, based on continuous temperature monitoring (Stevens, 1997). However, the segments were mistakenly listed based on the Class AA standard of 16^{o}C (Beckett, written comm.), and the reaches could be delisted unless additional information indicates otherwise.

The river flows 21.65 miles from its headwaters in the Snoqualmie National Forest, near the northwest corner of Mount Rainier National Park. The upper watershed is characterized by steep gradients and high velocities not conducive to salmonid spawning, and the Buckley diversion dam at river mile 15.7 blocks upstream fish migration. Land cover is predominantly forested, with logging activity throughout the region (Lund, 1994).

The lower watershed provides more moderate to gentle gradients, with good gravel substrate and pool/riffle proportions providing excellent salmon habitat (Lund, 1994). Land cover is a mix of deciduous and evergreen forest, with agricultural and residential land use (Figure 2).

Towns in and near the watershed rely on local water resources for drinking water and wastewater needs. The town of Wilkeson owns and operates a wastewater treatment plant that discharges to Wilkeson Creek (WC river mile 4.0). Its drinking water supply consists of local springs. Burnett residents replaced many onsite disposal systems in 1998 following problems with poor soils (Hanowell, pers. comm.). South Prairie, which relies on two wells for drinking water, also discharges treated wastewater to South Prairie Creek at river mile 5.8. Buckley diverts a portion of upper South Prairie Creek for its drinking water supply, but wastewater discharges are external to South Prairie Creek. The Buckley diversion also provides drinking water to the Rainier State School and Washington State University Dairy Forage Facility[2]; both discharge wastewater to the adjacent White River system. Other scattered residential developments rely on private wells and septic systems. The Pierce County Watershed Ranking Committee, a temporary group, determined that most of the undeveloped sections of land in the Puyallup River watershed are generally not suitable for septic systems.

Much of Spiketon Creek (referred to as Spiketon Ditch in the Phase I Assessment) is an artificial channel that served local forestry needs historically. At present, Spiketon Creek serves to convey stormwater from a part of Buckley as well as receive local surface water runoff. The tributary area contains good riparian shading (Ladley, pers. comm.).

USGS completed a flood study of the South Prairie Creek watershed in 1998, following several destructive floods, including January 1990 and February 1996. Local citizens were concerned that timber harvesting and road construction had increased the potential for flooding. The study found no statistically significant trend in increased peak runoff (Mastin, 1998).

The Soil Survey of Pierce County (USDA SCS, 1979) included the lower half of South Prairie Creek watershed. The areas impacted by the Osceola mudflow have low permeabilities (0.6 to 2 in/hr) and include the developed areas of Buckley, Burnett, South Prairie and Wilkeson. Upland areas south of Wilkeson Creek and north of lower South Prairie Creek have highly permeable soils (6 to 20 in/hr). The lower South Prairie Creek valley has moderately permeable soils (2 to 6 in/hr). Upper South Prairie Creek watershed soils were not included in the soil survey.

The Pierce County Conservation District identified two dairies in the South Prairie Creek Watershed (PCCD, 1992) that had farm plans in place as of 1994 but had not implemented best

[2] The WSU facility ceased dairy operations as of July 2000, but will continue farming operations (Clowers, written comm.).

management practices (BMPs). By August 2000, both should have updated and approved farm plans in accordance with the Dairy Waste Management Act (Abbott, pers. comm.) Several small farms, some with horses, are also located adjacent to South Prairie Creek.

Wilkeson was a mining center, and coal waste products have been reported (Lund, 1994). An unconfirmed report presented in Lund (1994) describes 100% coho salmon fry mortality due to sulfur-laden water from the Wilkeson coal mines. However, salmon have been sighted spawning in active mine seeps, and pH is not believed to be a problem (Ladley, pers. comm.).

Previous forest practices impacted South Prairie Creek (Schuett-Hames, 1994). New forestry regulations developed as part of the 1999 Washington State Forest and Fish Agreement, have been adopted by the Washington State Legislature and the State Forest Practices Boards. These laws provide for stronger riparian protection, road management, and mass wasting practices in addition to an upgraded monitoring program and adaptive management. Operations active in the South Prairie Creek watershed met in January 2000 and discussed the possibility of a monitoring program for assessing the effectiveness of best management practices, although a pilot program would not begin before summer 2001 (Light, pers. comm.). Plum Creek has deployed Onset StowAway Tidbits in upstream reaches of Wilkeson Creek, Gale Creek, and/or the East Fork of South Prairie Creek in the past and anticipates deploying units in summer 2001 (Light, pers. comm.). Champion/IP Pacific Timberlands monitored stream temperature in the upper watershed (Liquori, pers. comm.) and anticipates additional monitoring in summer 2001.

Project Objectives

Overall project objectives include the following:

- Determine sources of bacteria to lower South Prairie Creek contributing to the exceedence of the fecal coliform water quality standard
- Determine whether other water quality standards are being met
- Develop TMDL allocations for bacteria, temperature and related parameters

The objectives of the Phase II monitoring are to quantify sources of fecal coliform bacteria and Enterococci; identify and quantify factors affecting temperature; and quantify related parameters such as flow.

Sources of Pollution

Potential sources of fecal coliform bacteria and/or Enterococci include both point and nonpoint sources. Both the Wilkeson and South Prairie wastewater treatment plants discharge upstream of lower South Prairie Creek. South Prairie effluent fecal coliform bacteria levels and temperature are monitored regularly, as are flow, 5-day biochemical oxygen demand (BOD5), copper, cadmium, lead, ammonia-nitrogen, nitrate, nitrite, pH, settleable solids, suspended solids, and zinc. At the Wilkeson plant, effluent is monitored for fecal coliform bacteria, temperature, flow, BOD5, chlorine, total suspended solids, pH, copper, mercury, ammonia, zinc, and ultraviolet intensity.

Potential nonpoint sources of fecal coliform bacteria and other pathogens include the following:

- Wildlife
- Septic systems
- Human recreation
- Domestic animals (dogs, horses, cats)
- Agriculture operations (cattle, field applications of manure)

Potential contributors to elevated instream temperatures include the following:

- Upper watershed impairments due to historical riparian cover removal
- Loss of riparian cover in lower watershed associated with agricultural, residential, and recreational development
- Variations in groundwater inflows to surface water
- Surface water withdrawals
- Point source discharges
- Modifications to high- and low-flow regimes due to changes in watershed or river channel characteristics

Additional potential nonpoint sources of pollution include the following:

- Sediments from land cover disturbance (residential, agricultural or recreational practices)
- Sediments from bank erosion
- Sediments and nutrients from residential, forestry, or agricultural practices

Water Quality Standards

The water quality standards, set forth in Chapter 173-201A of the Washington Administrative Code, include designated beneficial uses, classifications, numeric criteria, and narrative standards for surface waters of the state.

South Prairie Creek discharges to the Carbon River, which is a tributary to the Puyallup River. Neither South Prairie Creek nor the Carbon River are classified separately from the Puyallup River. Because they discharge to the Class A portion of the Puyallup River (WAC 173-201A-030), South Prairie Creek and its tributaries are considered Class A (excellent) water bodies. Characteristic uses for Class A water bodies include water supply (domestic, industrial, agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning, harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, aesthetic enjoyment), and commerce and navigation. Numeric criteria for particular parameters are intended to protect designated uses. For Class A freshwater bodies,

> *"…fecal coliform organism levels shall both not exceed a geometric mean[3] value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL"*

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

[3] The geometric mean is calculated as the n^{th} root of the product of n numbers.

Fecal coliform bacteria, while not disease-causing organisms, have been adopted as indicator organisms for other pathogens with a fecal pathway that could impact human health.

The water quality standards are currently under revision. Changes have been suggested for microbial pathogens (currently represented by the fecal coliform group), temperature, and dissolved oxygen numerical standards.

The current preferred alternative is to change the indicator organism from the fecal coliform group to the Enterococcus group of bacteria. The Enterococcus group is a subset of the fecal coliform group and includes several *Streptococcus* species, including *S. faecalis*. Draft language proposes that the geometric mean value of samples collected at a site not exceed 33/100 mL with not more than 10% of the samples exceeding 61/100 mL (Hicks, 2000).

The water quality standards also state that temperature shall not exceed 18.0^{o}C due to human activities for Class A water bodies. When natural conditions exceed 18.0^{o}C (freshwater only), no temperature increases will be allowed which will raise the receiving water temperature by more than 0.3^{o}C. If natural conditions are below 18.0^{o}C, incremental temperature increases resulting from nonpoint source activities shall not exceed 2.8^{o}C or bring the temperature above 18.0^{o}C at any time. Temperature is of greatest concern to salmonid species, and temperature can reduce the area available for spawning and rearing habitat for steelhead trout and other species.

The alternatives under consideration for temperature standards are based on the presence or absence of particular species. South Prairie Creek and its tributaries fall under the Salmon Spawning, Rearing, and Adult Holding categories. The following are the current options (Hicks, 2000):

- Human-caused conditions and activities are not to cause temperatures to exceed either of the following: (a) 15^{o}C as a moving 7-day average of the daily maximum temperatures, with no single daily maximum temperature greater than 17.5^{o}C from June 1 to September 14, (b) 12^{o}C as a 7-day average of the daily maximum temperatures, with no single daily maximum temperature exceeding 14.5^{o}C during the period from September 15 through May 31.
- Temperatures shall be maintained below 15^{o}C as a moving 7-day average of the daily maximum temperatures, with no single daily maximum temperature greater than 20^{o}C.
- Temperatures shall not exceed 17.5^{o}C as a single daily maximum.

Dissolved oxygen must exceed 8.0 mg/L, while pH must be within the range 6.5 to 8.5 for freshwater bodies, with human-caused variation within the range of less than 0.5 units. Turbidity increases due to human activities shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or exceed 10 percent of the background turbidity when the background turbidity is more than 50 NTU.

Finally, toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health.

Historical Data Review

Organizations that have collected data on South Prairie Creek include the Department of Ecology, USGS, Pierce County, Pierce County Conservation District, Muckleshoot Tribe, Puyallup Tribe, the Federal Emergency Management Agency (FEMA), and private timber companies.

Washington Department of Ecology

- Ecology conducted the Phase I Assessment (Roberts, 2000) to determine current conditions and to refine the Phase II monitoring program. Samples collected from seven locations were analyzed for fecal coliform bacteria, *E. coli*, Enterococci, nutrients, dissolved oxygen and suspended solids; temperature and pH were measured *in situ*. Table 1 summarizes the results. Results indicate that geometric mean fecal coliform concentrations at sites SD165, SPCB4 and SPCM exceed 100/100 mL. Limited sampling suggests that the proposed Enterococci standard also may be violated in the South Prairie Creek system. Figure 3 summarizes fecal coliform and Enterococci bacteria loads. In addition, six probes were installed to record temperature at 15-minute intervals from July through mid-October. Temperatures at all but the most upstream station (SPCSR) violate the existing water quality standard, and all stations would violate any of the proposed temperature standards, as shown in Figure 4. Other parameters met water quality standards, and nutrients were relatively low.

- Ecology is conducting an assessment of copper concentrations in Wilkeson Creek and the Wilkeson WWTP effluent to determine whether recent upgrades have reduced copper sufficiently or whether further actions are needed to protect water quality (Johnson, 2000). Field sampling includes flow, temperature, pH, conductivity, total suspended solids, and hardness; sampling began in August 2000 and will continue through November 2000, with the final report due in April 2001.

- Ecology conducted a 1997 macroinvertebrate and habitat assessment study, including a site on South Prairie Creek (Plotnikoff, written comm.). Data include canopy cover, flow, temperature, pH, velocity, DO, and bottom materials size fractions (cobble, gravel, sand, silt/clay) for a site just downstream of Burnett.

- Ecology conducted a one-year survey of wastewater treatment plant effluent metal concentrations within the Puyallup River watershed, including the Wilkeson WWTP (Hoyle-Dodson, 1997). The study found that copper and zinc were associated with TSS concentrations, and Wilkeson flows and 24-hour sample effluent TSS loads were greater than NPDES permitted monthly average limits. Effluent parameters measured included hardness, TSS, zinc, copper, mercury, temperature, pH, and conductivity.

Table 1
Phase I Assessment Water Quality Data

	Date	Station	Fecal Coliform (#/100 ml)	*E. coli* (#/100 ml)	Entero-cocci (#/100 ml)	TPN (mg/L)	Ammonia (mg/L)	Nitrite/ Nitrate (mg/L)	Nitrite (mg/L)	Total Phos (mg/L)	Ortho-phos (mg/L)	TSS (mg/L)	Calc. Organic Nitrogen (mg/L)	pH	Temp (C)	DO (mg/L)
Main Stem Stations	7/19/00	SPCSR	8												13.65	
	8/1/00	SPCSR	20	20	4	0.255	.010U	0.201	.010U	0.015	.005U	1U	0.044	7.56	14.6	9.9
	8/21/00	SPCSR	1											7.89	10.95	
	9/5/00	SPCSR	2	2	44	0.208	0.010 U	0.179	0.010 U	0.017	0.005 U	2	0.019	8.31	9.9	10.8
	9/19/00	SPCSR	22											8.05	12.4	
	10/24/00	SPCSR	1	1	NA										6.2	11.7
	7/19/00	SPCLB	11												14.65	
	8/1/00	SPCLB	21	20	10	0.273	.010U	0.207	.010U	0.013	.010U		0.056	7.8	15.35	10
	8/21/00	SPCLB	6											7.67	12.4	
	9/5/00	SPCLB	4	4	32	0.225	0.010 U	0.19	0.010 U	0.018	0.005		0.025	7.5	11	10.8
	9/19/00	SPCLB	26											7.64	12.85	
	10/24/00	SPCLB	1	1	NA										6.4	11.65
	7/19/00	SPCSP	20												14.55	
	8/1/00	SPCSP	49	45	24	0.305	.010U	0.239	.010U	0.02	0.006		0.056	8.1	16.85	10.25
	8/21/00	SPCSP	22											7.68	13.75	
	9/5/00	SPCSP	29	23	89	0.248	0.010 U	0.204	0.010 U	0.02	0.007		0.034	7.95	12.4	10.9
	9/19/00	SPCSP	50											7.64	14.05	
	10/24/00	SPCSP	8	8	NA										7.4	11.5
	7/19/00	SPCB4	120												13.85	
	8/1/00	SPCB4	140	130	19	0.523	0.013	0.426	.010U	0.028	0.012		0.084	8.26	19	9.4
	8/21/00	SPCB4	120											7.86	15.8	
	9/5/00	SPCB4	760J	740	73	0.504	0.010 U	0.461	0.010 U	0.029	0.013		0.033	7.77	12.7	10.7
	9/19/00	SPCB4	300											7.62	14.7	
	10/24/00	SPCB4	29	17	NA										8.1	11.45
	7/19/00	SPCM	65												13.6	
	8/1/00	SPCM	110	92	20	0.493	.010U	0.398	.010U	0.026	0.009	2	0.085	7.87	19.3	9.7
	8/21/00	SPCM	77											7.55	16.05	
	9/5/00	SPCM	160J	140	86	0.498	0.010 U	0.432	0.010 U	0.028	0.01	2	0.056	7.65	13	10.5
	9/19/00	SPCM	240											7.37	15.2	
	10/24/00	SPCM	23	14	NA										8.4	11.15
Tributary Stations	7/19/00	SD165	800												15.05	
	8/1/00	SD165	760	760	130	0.287	0.01	0.143	.010U	0.029	0.01		0.134	7.32	16.1	9.3
	8/21/00	SD165	670											7.35	11.6	
	9/5/00	SD165	240	210	260	0.153	0.010 U	0.089	0.010 U	0.022	0.007		0.054	7.9	10.1	10.7
	9/19/00	SD165	880											7.37	13.55	
	10/24/00	SD165	40	37	NA										6.4	11.05
	7/19/00	WCM	29												16.45	
	8/1/00	WCM	41	39	37	0.441	0.011	0.356	.010U	0.029	0.011	1	0.074	8.02	17.8	9.5
	8/21/00	WCM	37											7.99	13.75	
	9/5/00	WCM	76	73	88	0.391	0.010 U	0.328	0.010 U	0.028	0.011	1	0.053	7.82	11.9	10.85
	9/19/00	WCM	170											7.6	15	
	10/24/00	WCM	29	26	NA										6.6	11.4
Field Replicates and Lab Duplicates	10/24/00	SPCFR/SPCM	17	14	NA											
	8/21/00	SPCFR/SPCB4	76													
	9/5/00	SPCFR/SPCB4	2100J	2100J	85	0.533	0.010 U	0.462	0.010 U	0.028	0.013					
	9/19/00	SPCFR/SPCB4	330													
	8/1/00	SPCFR/SPCM	51	44	27	0.499	.010U	0.395	.010U	0.021	0.008		0.094			
	7/19/00	SPCFR/WCM	33													
	7/19/00	LAB DUP	23													
	8/21/00	LAB DUP/SD1	46													
	8/1/00	LAB DUP/SD165								0.026						
	8/1/00	LAB DUP/SPCFR/S	60	56	33	0.495	0.011	NA	.010U		0.008	2				
	9/5/00	LAB DUP/SPCSR	7	7	34	0.207				0.016						
	9/19/00	LAB DUP/SPCSR	29													
	10/24/00	LAB DUP/SPCSR	1													
	9/5/00	LAB DUP/WCM									0.011					
	8/1/00	LAB MSD				96.40%	96.70%	90%	107%	NA	95%					
Miscellaneous Locations	8/21/00	SD1	39													
	8/21/00	SD2	680													
	9/5/00	SDSR	59													
	9/5/00	SDSR	59													
	9/19/00	SPC246	57													
	11/1/00	SPCUS	7													
	9/19/00	14309	1400													
	10/24/00	EMERY1	8													

U Not detected at or above the reported detection limit.
J Estimated values; very high density of organisms on plate, and actual concentration may be greater than or equal to reported results.
LAB DUP indicates Laboratory duplicate sample; the sample which was split is indicated after the slash.
LAB MSD indicates Laboratory matrix spike.
SPCFR is used to indicate field replicates; the station from which the replicate was collected is indicated after the slash.
NA Not Analyzed

- Ecology monitored flow and water quality in South Prairie Creek in 1992-93 under the Ambient Monitoring Program. AMS station 10F090 (Route 162 Bridge 4, 2.8 miles north of the Carbon River bridge; included in the TMDL monitoring as station SPCB4) exceeded the fecal coliform standard for a Class A water body, as evident in Table 2. All other parameters met water quality standards.

- Ecology conducted total maximum daily load studies for the entire Puyallup River system for BOD, ammonia, and residual chlorine (Pelletier, 1993). Data include total organic carbon, chlorophyll a, BOD5 and ultimate BOD for point source discharges and instream conditions. The Wilkeson wastewater treatment plant was monitored, as were three stations along South Prairie Creek (SPR07.2, SPR05.8, and SPR01.1); hydraulic parameters were estimated for South Prairie Creek for modeling purposes.

- In 1987, Ecology completed a limited Class II inspection of the Wilkeson Wastewater Treatment Plant, evaluating the effects of infiltration and inflow – http://www.ecy.wa.gov/biblio/87e22.html. High infiltration and inflow caused hydraulic overload of the treatment processes, and significant raw sewage was bypassed to Wilkeson Creek (Kendra, 1987). Data include effluent and receiving water quality, as well as stormwater outfall water quality. Effluent fecal coliform levels exceeded permit limits, and stormwater contributed very high concentrations.

USGS

- USGS maintains a gaging station on South Prairie Creek at the town of South Prairie. Gage 12095000 (79.5 square miles) lies just upstream of the lower floodplain area. Flow varies from 24 cfs to 6700 cfs, with an annual average flow of 229 cfs and a median of 159 cfs[4]. Daily flow statistics are available from water year 1950 to 1972 and from 1988 to present. From 1972 to 1979, a crest-stage gage was operated. A meteorology station was added recently, and the station records precipitation and temperature. While not available as part of the real-time streamflow network, gage data may be accessed through the USGS ADAPS system through a cooperator agreement with the Department of Ecology.

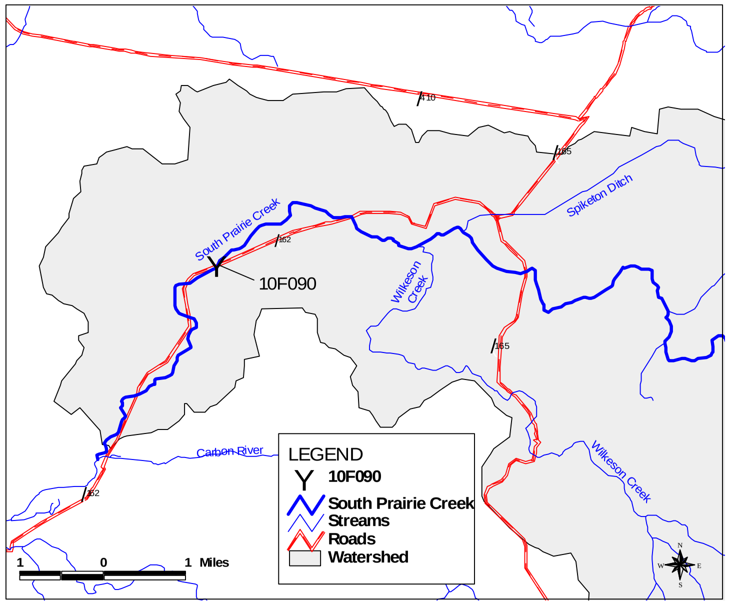
- USGS evaluated the flood potential of South Prairie Creek, in cooperation with Pierce County Surface Water Management, following several large floods (Mastin, 1998). The study evaluated the increase in cleared area and logging road construction using historical aerial photos, evaluated flooding trends, and mapped expected inundation zones for 100- and 500-year floods. While cleared areas increased from 11.2 percent of the watershed area in 1965 to 34.5 percent in 1990, and road length increased from 119.6 miles to 237.0 miles, the study found no statistically significant trend in flood potential over time. The study included 28 floodplain and channel cross sections near the same locations as the FEMA 1976-77 cross sections in 1994-95, and an additional 13 sections in 1996. Comparisons among the cross sections showed no significant channel fill. Finally, a backwater hydraulic model was used to delineate flood zones. Portions of Route 162, Spring Site Road, South Prairie Road, and the Town of South Prairie lie within the 100- and 500-year inundation zones, which includes most of the lower valley.

[4] For the period 10/1/87 through 9/30/98, including some estimated values for water year 1998.

Table 2
Ecology Ambient Monitoring Station 10F090 Water Quality Data

Date	Time	Flow (cfs)	Temperature (°C)	Conductivity (umhos/cm)	DO (mg/l)	DO (%sat)	pH	FC (#/100 ml)	TSS (mg/l)	NH3 (mg/l)	TP (mg/l)	Dissolved Soluble Phosphorus (mg/l)	Turbidity (NTU)	NO23N (mg/l)
10/27/92	1020	226	7.8	95	12.2	102.1	7.7	13	1	0.010k	0.010k	0.010k	0.4	0.3
11/22/92	1100	876	2.1	53	11.6	84.8	7.3	67s	22	0.014	0.024	0.010k	5.2	0.9
12/21/92	1035	346	4.5	57	12.2	94.4	7.5	84	4	0.011	0.014	0.010k	2.4	0.9
1/26/93	950	1590	6	32	12.1	97	7.0	110	65	0.033	0.049	0.010k	18	0.7
2/23/93	910	74	1	78			7.5	40	1	0.015	0.011	0.010k	0.7	0.6
3/23/93	945	1770	6.4	35	11.5	94.3	6.9	800s	100	0.022	0.089	0.010k	33	0.7
4/27/93	1035	361	7.5	56	11.6	95.9	7.7	2400s	4	0.021	0.02	0.010k	1.9	0.4
5/25/93	940	211	11.5	58	10.3	94.7	7.3	28s	2	0.052	0.013	0.010k	1	0.3
6/29/93	1045	388	10.6	53	10.9	97.7	7.3	1000	12	0.012	0.029	0.010k	3.8	0.3
7/27/93	1000	263	11.5	57	11	101	7.4	43	2	0.010k	0.01	0.010k	1.5	0.3
8/24/93	1015	88	12	98	10.6	97.4		88	5	0.013	0.021	0.010k	1.1	0.4
9/28/93	1115	45	10.6	108	11.2	100.1	7.6	440	2	0.010k	0.017	0.011	0.7	0.5

Flags:
u, j — estimated value
s — spreader
k — actual value known to be less



FEMA

- The Flood Insurance Study of 1981 included 51 floodplain and channel cross sections from the mouth to upstream of South Prairie in 1976 and 1977 (FEMA, 1981; FEMA, 1987). The studies were conducted to identify 100-year flood zones.

Muckleshoot Indian Tribe

- The Muckleshoot Indian Tribe installed continuous temperature monitors at several locations in the South Prairie Creek watershed during the summer of 1997. Temperatures in Gale Creek, above the confluence with Wilkeson Creek, exceeded the 18^{o}C standard for Class A water bodies, while temperatures in South Prairie Creek at RM 11.0, upstream of Page Creek, and Wilkeson Creek at RM 7.1, near confluence with Gale Creek, exceeded 16^{o}C but not the 18^{o}C standard (Stevens, 1997). Beaver Creek did not exceed 16.0^{o}C. Figure 5 presents the thermographs.

Puyallup Tribe

- The Puyallup Tribe has monitored temperature, pH, and dissolved oxygen at three locations along lower South Prairie Creek since 1999 (Naylor, pers. comm.). Data are collected using a YSI probe. Data show high dissolved oxygen levels throughout the year, somewhat low pH in the spring, and somewhat elevated temperature in the summer.

- During the fall, Fisheries staff float lower South Prairie Creek identifying salmonid redds.

Pierce County

- Pierce County Department of Public Works initiated a fecal coliform bacteria source investigation along Spiketon Creek in summer 2000 following early Phase I sampling results (Collins, 2000). Pierce County Public Works recommended that a property owner contact the Conservation District regarding funding fencing options for livestock.

- Pierce County does not own or maintain any levees along lower South Prairie Creek (Kibbey, pers. comm.).

Pierce County Conservation District

- Pierce County Conservation District conducted a culvert inventory of the Puyallup River Watershed/WRIA 10 in 1999 and 2000, and published an interim status report via CD-ROM with each culvert identified and coded based on fish passage feasibility (Pierce County Conservation District, 2000). The South Prairie Creek watershed contains 59 culverts, many of which represent barriers to fish passage. Project partners included the Puyallup Tribe, Washington Trout, South Puget Sound Salmon Enhancement Group, Natural Resources Conservation Service, Northwest Indian Fisheries Commission and the Washington Department of Fish and Wildlife.

- The Conservation District also administers a volunteer water quality monitoring program, including one site on South Prairie Creek, at Fettig Road and Lower Burnett Road downstream of the bridge (Udd, written comm.). Data for temperature, dissolved oxygen, pH and nitrate, available for spring 1999, show neutral waters with high DO. Nitrate is determined with a field kit made by InQuest. While the group conducts macroinvertebrate characterization, no data were available for South Prairie Creek. Volunteer monitoring is ongoing.

- The District has been working with two dairies in the watershed, Soler Dairy and Bert Inglun Dairy, to develop farm plans and implement BMPs. The files include the number of livestock on site over time as well as site-specific soils information and recommendations for waste management (Abbott, pers. comm.). The Soler Dairy plan has been accepted, and the Inglun plan is being finalized.

Plum Creek

- Plum Creek deployed temperature probes for two months in upstream reaches of Wilkeson, Gale and South Prairie Creeks in July 2000 (Light, pers. comm.). Figure 6 presents provisional results of the 2000 monitoring program as the instantaneous daily maximum temperature recorded hourly from mid-July to mid-September. South Prairie Creek station 3, approximately seven miles upstream of the Spiketon Road crossing, peaked at 15^{o}C, cooler than predicted based on the elevation and canopy cover.

Champion/IP Pacific Timberlands

- Champion/IP has monitored temperature at several locations in the upper South Prairie Creek watershed in the past and may install continuous temperature monitors in summer 2001 (Liquori, pers. comm.). Data were not available at the time of publication.

Study Design

The Phase II detailed monitoring includes several programs. Baseline monitoring will be conducted monthly and will include flow, fecal coliform and Enterococci. Continuous temperature monitoring will follow the Phase I assessment results and will focus on areas with elevated temperatures in summer 2000. Additional temperature parameters, such as canopy cover, will be assessed in accordance with the TFW Monitoring Program Method Manual (Schuett-Hames *et al.*, 1999). In addition, South Prairie Creek stream geomorphology will be assessed using the Rosgen stream classification system (Rosgen, 1996) to develop parameters important to instream temperatures. Travel times will be estimated for lower South Prairie Creek to understand flow regimes and to develop site-specific bacterial die-off rates. Finally, a fine-scale bacteria survey will be conducted to inventory sources on key reaches.

Figure 7 presents the locations of the 13[5] water quality stations plus one flow-only station to be monitored, including one point source. Table 3 describes monitoring station locations. Stations were selected to distinguish upstream and tributary contributions from main stem contributions, and to further distinguish among residential, agricultural and recreational contributions. Ecology will continue to monitor the seven stations from the Phase I Assessment.

Table 3
South Prairie Creek and Tributaries Phase II Monitoring Stations

ID	Water Body	Description
SPCM	South Prairie Creek	Near the mouth, from South Prairie Creek Rd
SPCB1	South Prairie Creek	At Route 162, first bridge north of Carbon River
SPCB2	South Prairie Creek	At Route 162, second bridge north of Carbon River
SPCB4	South Prairie Creek	At Route 162, fourth bridge north of Carbon River
WTPSP	WWTP Effluent	At South Prairie WWTP
SPCWTP	South Prairie Creek	From end of Emery Street, downstream of outfall
T1	Unnamed Tributary	At Route 162, tributary from town of South Prairie
SPCSP	South Prairie Creek	At Route 162, downstream of bridge near fire station
SPCWC	South Prairie Creek	Upstream of Wilkeson Creek, near Lower Burnett Rd
WCM	Wilkeson Creek	At mouth, near Lower Burnett Rd
SKTM	Spiketon Ditch/Creek	Near mouth, from Lower Burnett Rd
SKT165	Spiketon Ditch/Creek	At Route 165, near 128th St. East (flow only)
SPCLB	South Prairie Creek	At Lower Burnett Rd, downstream of Rte. 165 bridge
SPCSR	South Prairie Creek	At Spiketon Rd, from Ryan Rd in Buckley

Baseline Monitoring

Monthly field surveys will be conducted in calendar year 2001. Parameters include flow, fecal coliform, Enterococci, and discrete temperature. Table 4 lists parameters by station.

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[5] Flows in Spiketon Ditch/Creek will be measured at the Route 165 culvert, the location used in the Phase I sampling program. Water quality samples will be collected from the Lower Burnett Road culvert, where flows cannot be measured adequately.

Table 4
Baseline Monitoring Parameters by Station

Station	Flow	Fecal Coliform	Enterococci	Temperature
SPCM	♦	♦	♦	♦
SPCB1		♦	♦	♦
SPCB2		♦	♦	♦
SPCB4	♦	♦	♦	♦
WTPSP		♦	♦	♦
SPCWTP		♦	♦	♦
T1		♦	♦	♦
SPCSP	♦	♦	♦	♦
SPCWC				♦
WCM	♦	♦	♦	♦
SKTM		♦	♦	♦
SKT165	♦			
SPCLB	♦	♦	♦	♦
SPCSR		♦	♦	♦

Continuous Temperature Monitoring

Water temperature will be monitored continuously using Onset StowAway Tidbits (-5°C to +37°C), installed in the active stream channel and shaded from direct sunlight. The temperature monitors will be installed at approximately mid-depth, close to the thalweg[6] and away from potentially stratified pools. Each of the monitoring locations is free flowing without pooling immediately upstream. The monitors will log temperatures at 15-minute intervals to provide sufficient information to characterize peak temperatures and diurnal variations.

Continuous temperature monitors will be installed from July through October 2001 at the following locations:

- SPCSR
- SPCWC
- SPCSP
- SPCB4
- SPCM
- SKT165 or SKTM
- WCM

Upstream of Burnett, the creek lies within steep-sided canyons and is subject to steep gradients and a series of cascades. Riparian vegetation and runoff characteristics are influenced by

[6] The thalweg is the deepest part of the reach and the primary flow conduit.

logging activities. Two tributaries, Spiketon Creek and Wilkeson Creek, reach South Prairie Creek between Burnett and South Prairie. The South Prairie USGS gage lies near the widening of the valley floor and reduction in riparian width. During the Phase I program, significant warming occurred between SPCSR and SPCSP. However, SPCLB receives moderate recreational use, and no temperature monitor could be installed. The next accessible location is SPCWC, just upstream of the Wilkeson Creek confluence in an area of minimal activity. Bridge 4, the Route 162 bridge over South Prairie Creek approximately 2.8 miles north of the Carbon River, lies near the middle of the prime spawning areas. Finally, the mouth of South Prairie Creek is the downstream extent of the present project.

Rosgen Stream Classification

The Rosgen stream classification will be conducted in summer 2001 in accordance with the methods prescribed in Rosgen (1996). The objectives are to understand the creek's hydraulic and sediment regimes based on the type of channel present. Level I provides a geomorphic characterization based on channel slope, shape and patterns, where reaches are characterized as types A through G. Level II provides a morphological description based on site-specific measurements, including entrenchment ratio, width/depth ratio, sinuosity, channel slope and channel materials; channel segments will be further categorized as type A1 through G6. Level III describes the existing conditions and overall stability inferred from riparian vegetation, sediment transport and flow regime. Finally, portions of the Level IV assessment will be applied as needed to refine key parameters.

Intensive Bacterial Survey

In addition to the bacterial samples collected at the baseline monitoring stations, up to 20 grab samples will be collected between SPCSP and SPCM on a stream walk during the low flow period. Simultaneous flows will provide a highly detailed distribution of loads.

Travel Time Estimates

Travel time will be estimated at three locations in the lower reaches during low and moderate flows. Travel time can be estimated using several methods, from dye studies to passive tracers. One simple means is to release neutrally buoyant drogues (like oranges) and record the time each takes to arrive at a point downstream, where they are recovered and removed from the system. Drogues provide estimates for advection and dispersion, which are necessary to describe how bacteria respond in the system.

Approximately 50 oranges will be released at stations SPCSP, SPCB4 and SPCB1 in early summer and late summer. Table 5 summarizes estimated arrival times at various points downstream depending on the average velocity in the system. If average velocities between the three release stations and the downstream bridge or sampling location are moderate, travel time can be monitored over the entire length in a reasonable amount of time. However, if average velocities are very low, time scales on the order of one day would be needed to monitor arrival times 2000 to 3000 ft downstream. Therefore, arrival times at an intermediate station 1000 feet downstream of the release point will be recorded. These arrival times will be used to estimate average velocities in the section to determine whether the drogues should continue to the lower removal location. If the time of travel is too long, the drogues will be removed at the 1000-foot station.

Table 5
Estimated Travel Times for Varying Distance and Average Sectional Velocity

Distance (ft)	Time (hrs) of travel for various velocities (fps)				Notes
	0.05	0.1	0.5	1	
200	1.1	0.6	0.1	0.1	May not include pools and riffles
500	2.8	1.4	0.3	0.1	May not include pools and riffles
1000	5.6	2.8	0.6	0.3	Optimal distance for system velocities
2300	12.8	6.4	1.3	0.6	Distance between SPCB4 and bridge 3
3100	17.2	8.6	1.7	0.9	Distance between SPCSP and SPCOF
3800	21.1	10.6	2.1	1.1	Distance between SPCB1 and SPCM

Project Organization

The roles and responsibilities of Ecology staff are as follows:

- ***Mindy Roberts*** *(Project Lead, Environmental Assessment Program, Watershed Studies Unit)*: Responsible for managing and implementing TMDL technical study. Defines project objectives, scope, and study design.   Manages data collection program, and conducts data quality review and analysis. Writes TMDL technical study report.
- ***Greg Pelletier*** *(Technical Review, Environmental Assessment Program, Watershed Studies Unit)*: Provides technical review of interim products as well as QAPPs and final TMDL report.
- ***Jeannette Barreca*** *(TMDL Regional Office Project Lead, Water Quality Program, Southwest Regional Office)*: Acts as point of contact between Ecology technical study staff and interested parties and coordinates information exchange and meetings. Supports, reviews and comments on QAPPs and technical reports. Coordinates implementation planning and preparation of TMDL documents for submittal to EPA.
- ***Chris Hempleman*** *(Public Involvement Coordinator, Water Quality Program, Southwest Regional Office)*: Coordinates public participation.
- ***Kelly Susewind*** *(Section Supervisor, Water Quality Program, Southwest Regional Office)*: Responsible for approval of TMDL submittal to EPA.
- ***Will Kendra*** *(Section Supervisor, Environmental Assessment Program, Watershed Ecology Section)*: Responsible for approval of project QAPP and final TMDL report.
- ***Karol Erickson*** *(Unit Supervisor, Environmental Assessment Program, Watershed Studies Unit)*: Reviews project QAPPs, final TMDL report, and technical study budget.

- ***Field Assistant*** *(Environmental Assessment Program, Watershed Studies Unit)*: Conducts monitoring program under the supervision of Project Lead.
- ***Cliff Kirchmer*** *(Quality Assurance Officer, Environmental Assessment Program)*: Reviews QAPP and all Ecology quality assurance programs. Provides technical assistance on QA/QC issues during the implementation and assessment of project.

Data Quality Objectives

The data quality objectives are presented in Table 6. The laboratory's data quality objectives and quality control procedures are documented in the Manchester Environmental Laboratory (MEL) Lab Users Manual (MEL, 1999).

Accuracy includes both precision and bias. Precision is a measure of data scatter due to random error, while bias is a measure of differences between a parameter value and the true value due to systematic errors. Precision can be quantified using a number of parameters, including relative percent difference (RPD)[7], standard deviation (s)[8], pooled standard deviation (s_p)[9], or percent relative standard deviation (%RSD)[10]. For paired results, %RSD = RPD/√2. The %RSD will be used to assess data quality, as listed in the table. Since random error affects the determination of bias, bias quantification is very difficult. Adherence with established protocols will eliminate most sources of bias (QAS, 1991). A bias of 10% is acceptable, for a total accuracy[11] of approximately 70%.

Table 6
Data Quality Objectives

Parameter	Accuracy (2*precision + bias)	Precision (%RSD)	Bias	Lowest Level of Interest
Velocity	N/A	N/A	N/A	N/A
Temperature (discrete)	N/A	N/A	N/A	N/A
Temperature (continuous)	N/A	N/A	N/A	N/A
Fecal Coliform Bacteria	66	28*	10%	10/100 mL
Enterococci	70	30	10%	5/100 mL

%RSD = Percent Relative Standard Deviation = 100 * s / avg(x_1,x_2) = RPD / √2
* Based on Manchester Environmental Lab RPD < 40% for fecal coliform analyses.

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7 Calculated for a pair of results, x_1 and x_2, as $200*(x_1 – x_2) / (x_1 + x_2) = 100*(x_1 – x_2) / (avg [x_1 \text{ and } x_2])$.
8 Calculated for a pair of results, x_1 and x_2, as $(x_1 - x_2) / \sqrt{2}$, or for ≥3, $\sqrt{((\Sigma x_i^2-(\Sigma x_i)^2/n) / (n-1))}$
9 Calculated for a group of paired results as $s_p = \sqrt{(\Sigma D^2 / 2 m)}$, where ΣD^2 is the sum of the square of the differences between each pair and m is the number of pairs.
10 Calculated for a pair of results, x_1 and x_2, as $100*s / (avg [x_1 \text{ and } x_2])$, where s is the standard deviation.
11 accuracy = bias + 2*precision for 95% confidence limits

Analytical and Sampling Procedures

Laboratory methods available from MEL are appropriate for the data quality objectives and expected concentrations. Clean techniques or low-detection-limit methods are unwarranted.

Analytical methods, sample containers, volumes, preservation and hold time are listed in Table 7. Field sampling and measurement protocols will follow those described in the Field Sampling and Measurements Protocols for the Watershed Assessments Section (WAS, 1993). Samples for laboratory analysis will be stored on ice and delivered to MEL within 24 hours of collection. While the hold time for fecal coliform samples will meet the 30-hour limit specified in the Watershed Assessment Section Protocols (WAS, 1993), samples will exceed the 6-hour hold time recommended in Standard Methods (Greenberg, *et al.*, 1992) for legal actions. However, samples could meet the 24-hour hold time recommended in Standard Methods for samples collected for purposes other than legal actions.

Grab samples will be collected directly into pre-cleaned containers supplied by MEL and described in MEL (1999). An extra set of sample containers will be available should any of the bottles be lost or contaminated.

Table 7
Summary of Field and Laboratory Measurements,
Target Precision and Reporting Limits, and Methods

Parameter	Precision Target (Field Meas)	Reporting Limit (Lab Meas)	Method	Equipment	Container	Volume	Preser-vation	Hold Time
Velocity	+/- 0.5 ft/s	N/A	N/A	Marsh-McBirney Model 2000 Flow Meter	N/A	N/A	N/A	N/A
Temp (discrete)	+/- 0.2°C	N/A	N/A	Brooklyn Thermo. Co., Inc., Alcohol, -5°C to +37°C	N/A	N/A	N/A	N/A
Temp (contin.)	+/- 0.2°C	N/A	N/A	Onset StowAway Tidbit	N/A	N/A	N/A	N/A
Fecal Coliform Bacteria	N/A	1/100 mL	MF 9222D [1]	(grab sample)	Sterile polypro-pylene or glass	250 mL[3]	Cool to 4°C	as soon as possible [2,3]
Entero-cocci	N/A	1/100 mL	MF 9230C [1]	(grab sample)	Sterile polypro-pylene or glass	250 mL[3]	Cool to 4°C	as soon as possible [3]

1 Standard Methods, membrane filter method
2 30 hours maximum; 24 hours recommended
3 Fecal coliform and Enterococci samples collected in one 500-mL bottle.

Quality Control Procedures

Total variation for field sampling and analytical variation will be assessed by collecting replicate samples in addition to lab duplicates and comparing to data quality objectives. Replicate samples will be collected at a rate of 10%, with at least one site per survey. Microbiological samples will be analyzed at MEL. The laboratory's data quality objectives and quality control procedures are documented in the MEL Lab Users Manual (MEL, 1999). MEL will follow standard quality control procedures (MEL, 1999). Field sampling and measurements will follow quality control protocols described in WAS (1993).

Continuous temperature monitor variations will be checked using the calibrated field thermometer upon deployment and retrieval, and periodically during the sampling season. Field sampling and measurement procedures will follow quality control protocols described in the WAS protocol manual (WAS, 1993). The Onset StowAway Tidbits will be pre- and post-calibrated in accordance with TFW Stream Temperature Survey protocols (Schuett-Hames, *et al.*, 1999) to document instrument bias and performance at representative temperatures. A certified reference thermometer (HB Instrument Co., -8^{o}C to +32^{o}C, ISO9000, part 61099-035, serial 2L2087) will be used to calibrate the field thermometer (Brooklyn Thermometer Co., Inc., Safety Red Liquid Thermometer, -1^{o}C to +50^{o}C, +/-0.2^{o}C). At the completion of the monitoring, the raw data will be adjusted for instrument bias based on the pre- and post-calibration results in accordance with the TFW Stream Temperature Survey protocols (Schuett-Hames, *et al.*, 1999). If the field thermometer demonstrates greater than 0.2^{o}C temperature difference, the field thermometer's temperature readings will be adjusted by the mean difference.

Replicate field temperature readings will not be recorded, because previous Ecology experience has demonstrated that the thermometers consistently show a high level of precision, rarely varying by more than 0.2^{o}C.

Data Analysis and Use

Data reduction, review, and reporting will follow the procedures outlined in MEL's Lab Users Manual (MEL, 1999). In addition, lab results will be checked for missing and/or improbable data. Variability of field replicates and lab duplicates will be quantified using the methods described above. Should concentrations vary over an order of magnitude during the study at any given station, standard deviation and other parameters may be analyzed using the logarithms of concentration. If lab blanks show levels of analyte above reporting limits, the resulting data will be qualified and their use restricted as appropriate.

The bacteria water quality standard is based on the geometric mean, which will be calculated for both fecal coliform and Enterococci. Temperature data will be reported as raw (15-minute) values as well as peak daily values. Should the revision to the temperature water quality standard incorporate a moving average, the appropriate averages will be calculated.

Data will be used to develop TMDLs for fecal coliform bacteria and temperature, and possibly for Enterococci. Data will be evaluated according to the data quality objectives described above.

Reporting Schedule

The project reporting schedule includes the following documents:

August 2000	Phase I QAPP	Covers Phase I assessment monitoring
December 2000	Phase II QAPP	Covers Phase II 12-month monitoring program scheduled for 2001
May 2002	Draft Technical Report	Summarizes technical studies
July 2002	Final Technical Report	Summarizes technical studies
October 2000 and ongoing	Quarterly Technical Memos	Summarize work completed, including provisional data collected, by quarter

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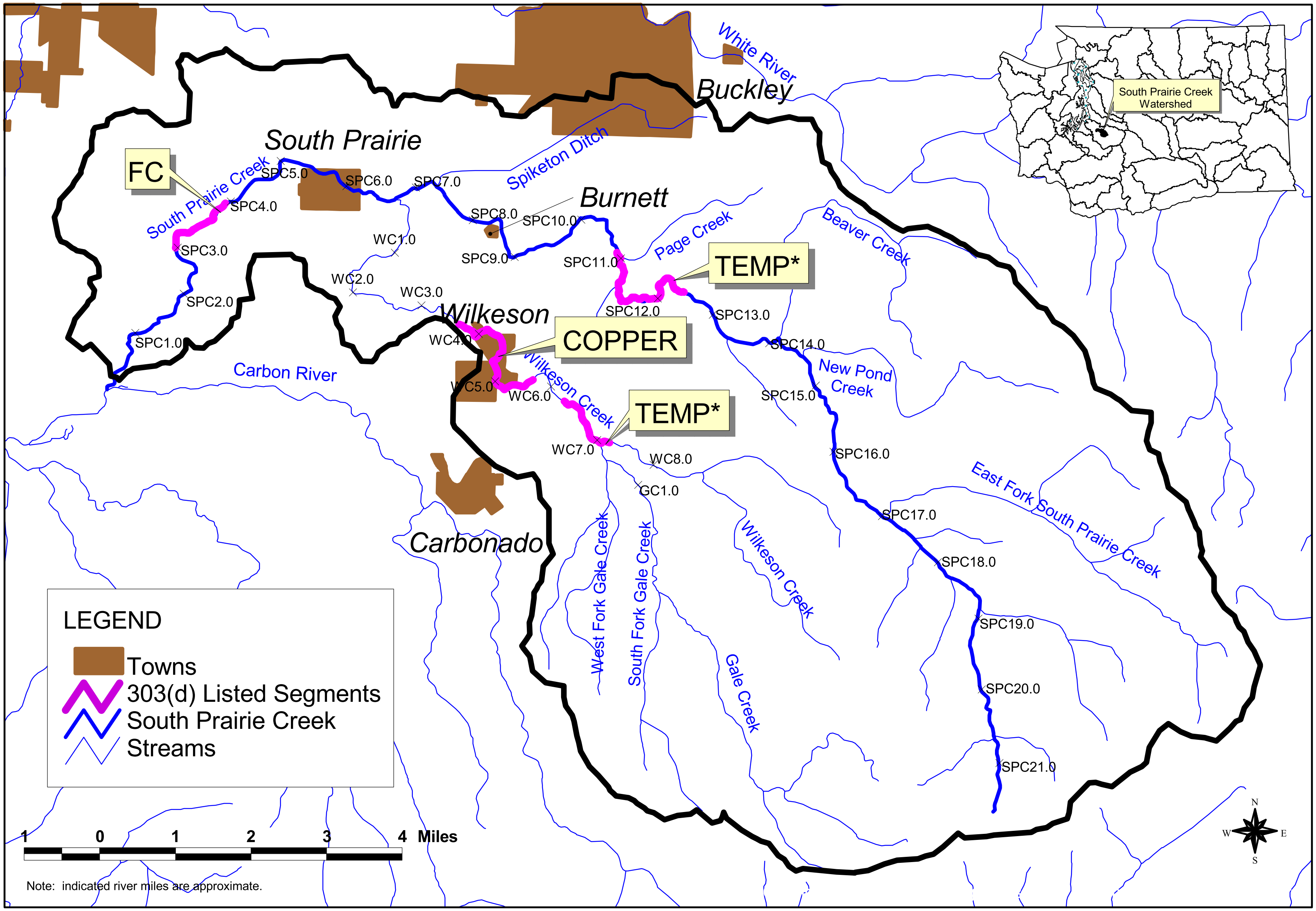
Figure 1
South Prairie Creek Watershed with 303(d) Listed Water Bodies



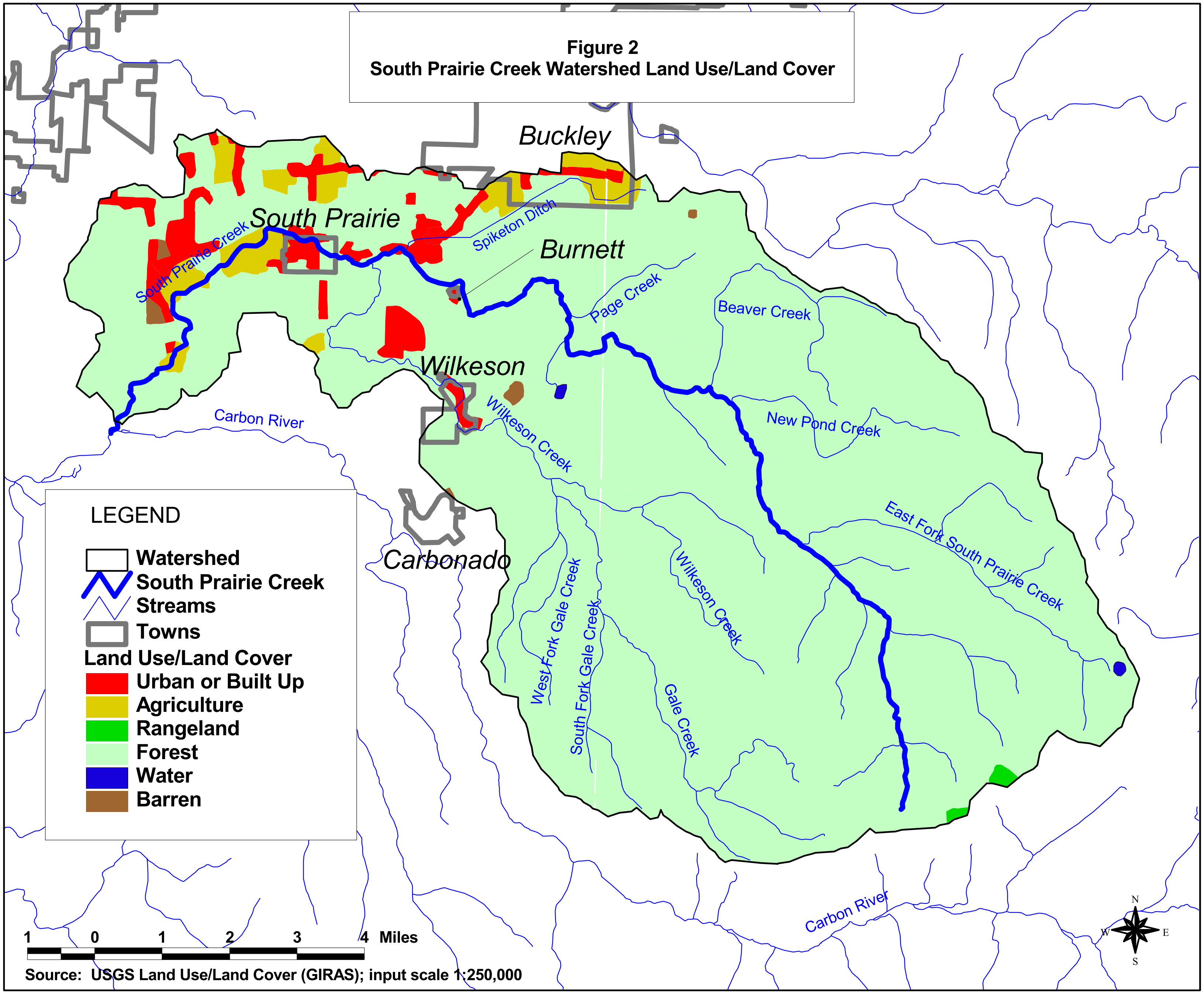
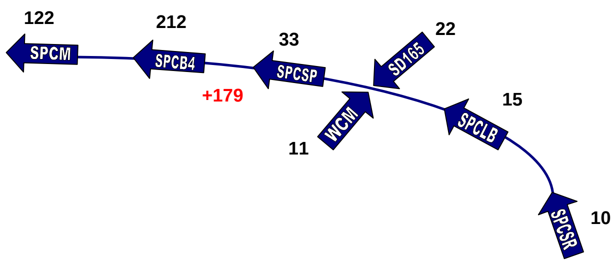


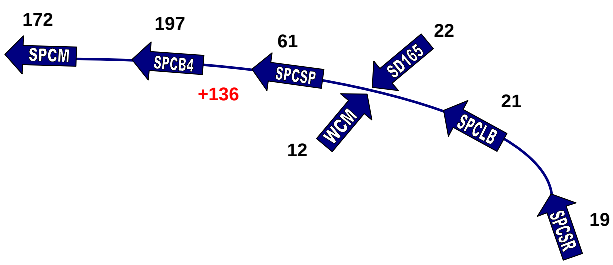
Figure 2
South Prairie Creek Watershed Land Use/Land Cover

Figure 3
Fecal Coliform and Enterococci Loads

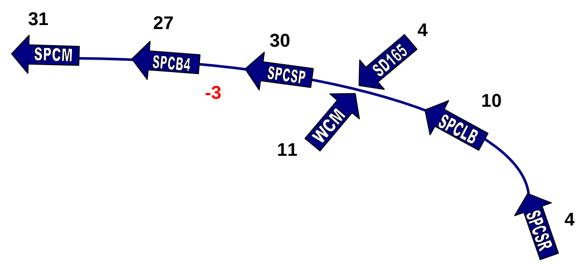
July 19, 2000 Fecal Coliform Loads
(billion FC per day)



August 1, 2000 Fecal Coliform Loads
(billion FC per day)



August 1, 2000 Enterococci Loads
(billion enterococci per day)



August 21, 2000 Fecal Coliform Loads
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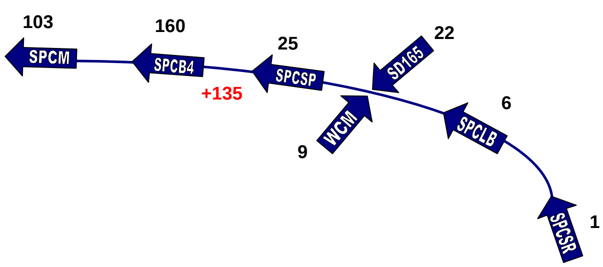

September 5, 2000 Fecal Coliform Loads
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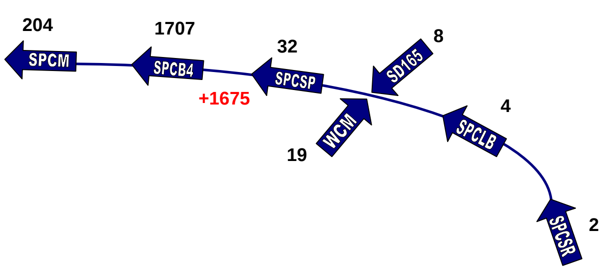
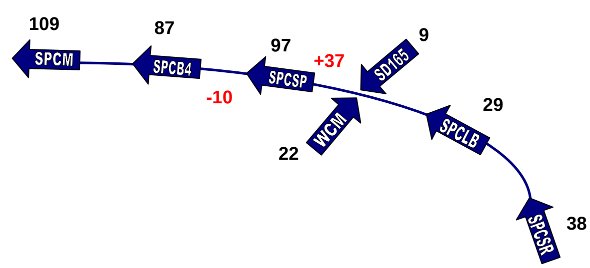
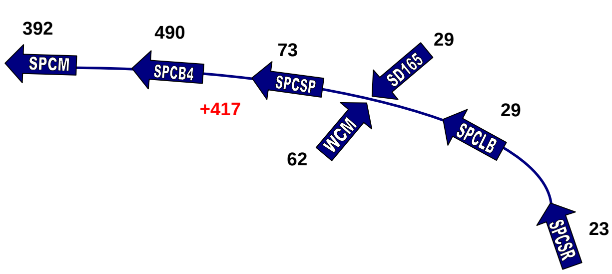
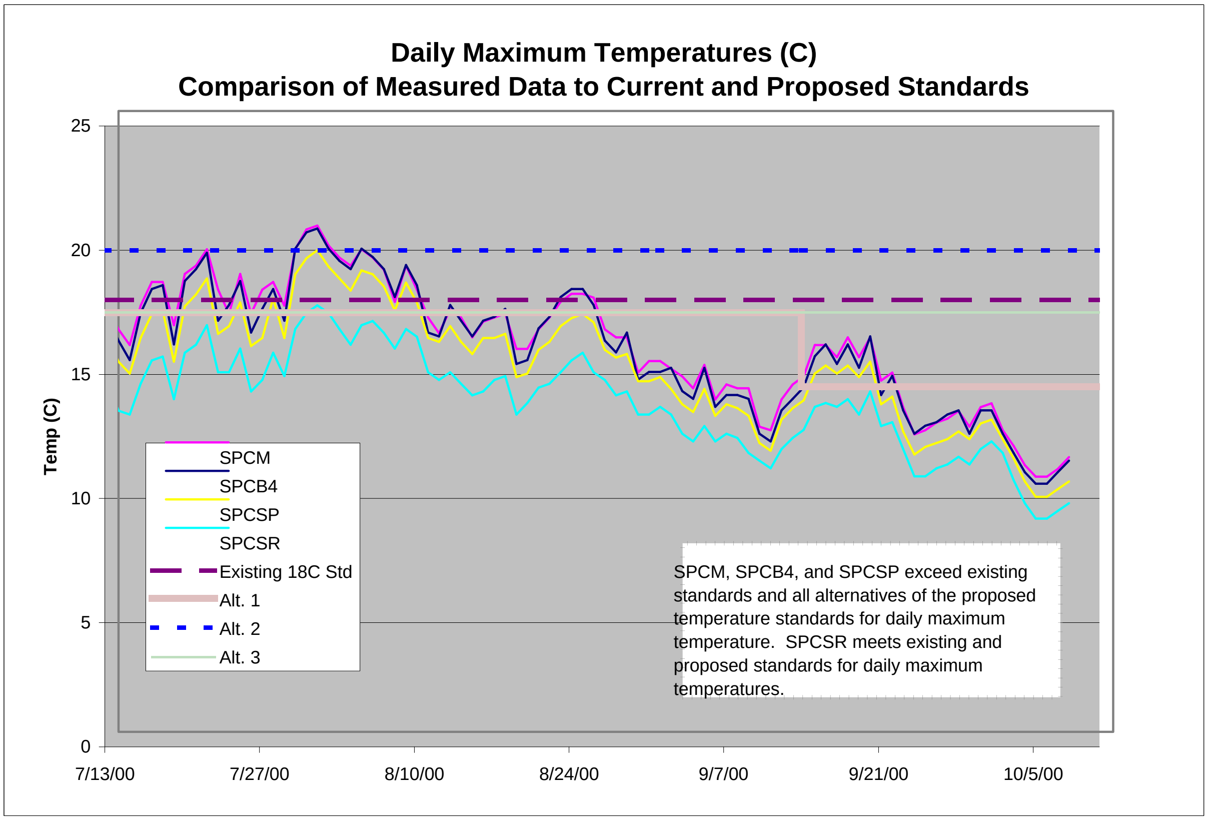


September 5, 2000 Enterococci Loads
(billion enterococci per day)

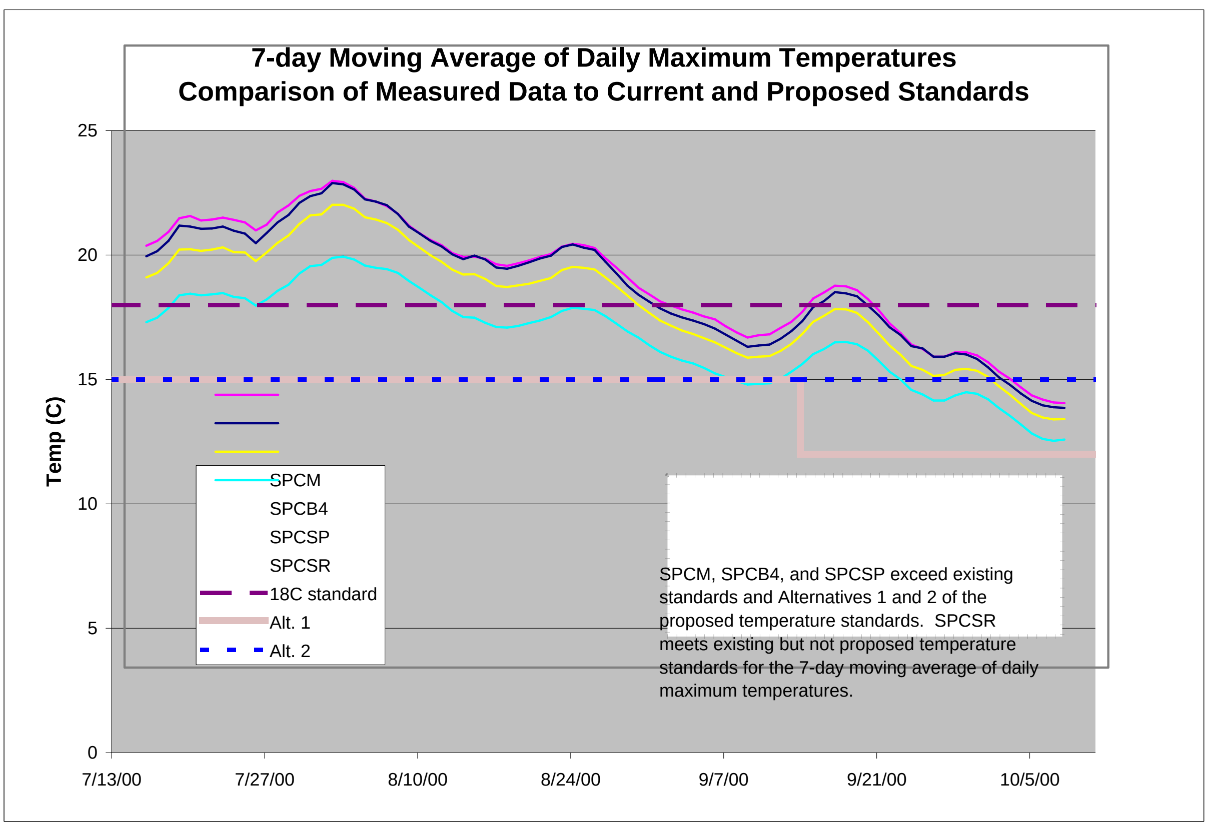


September 19, 2000 Fecal Coliform Loads
(billion FC per day)





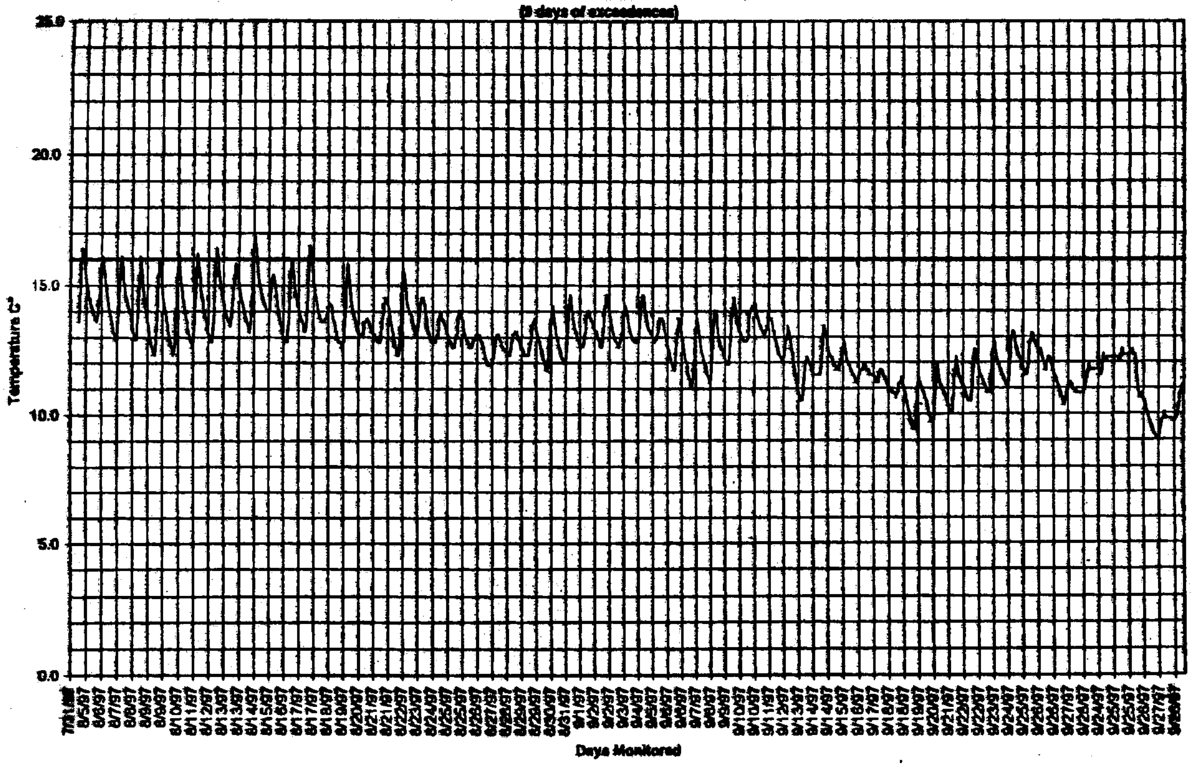
Daily Maximum Temperatures (C)
Comparison of Measured Data to Current and Proposed Standards
Temp (C)
25
20
15
10
5
0
7/13/00
7/27/00
8/10/00
8/24/00
9/7/00
9/21/00
10/5/00
SPCM
SPCB4
SPCSP
SPCSR
Existing 18C Std
Alt. 1
Alt. 2
Alt. 3
SPCM, SPCB4, and SPCSP exceed existing standards and all alternatives of the proposed temperature standards for daily maximum temperature. SPCSR meets existing and proposed standards for daily maximum temperatures.



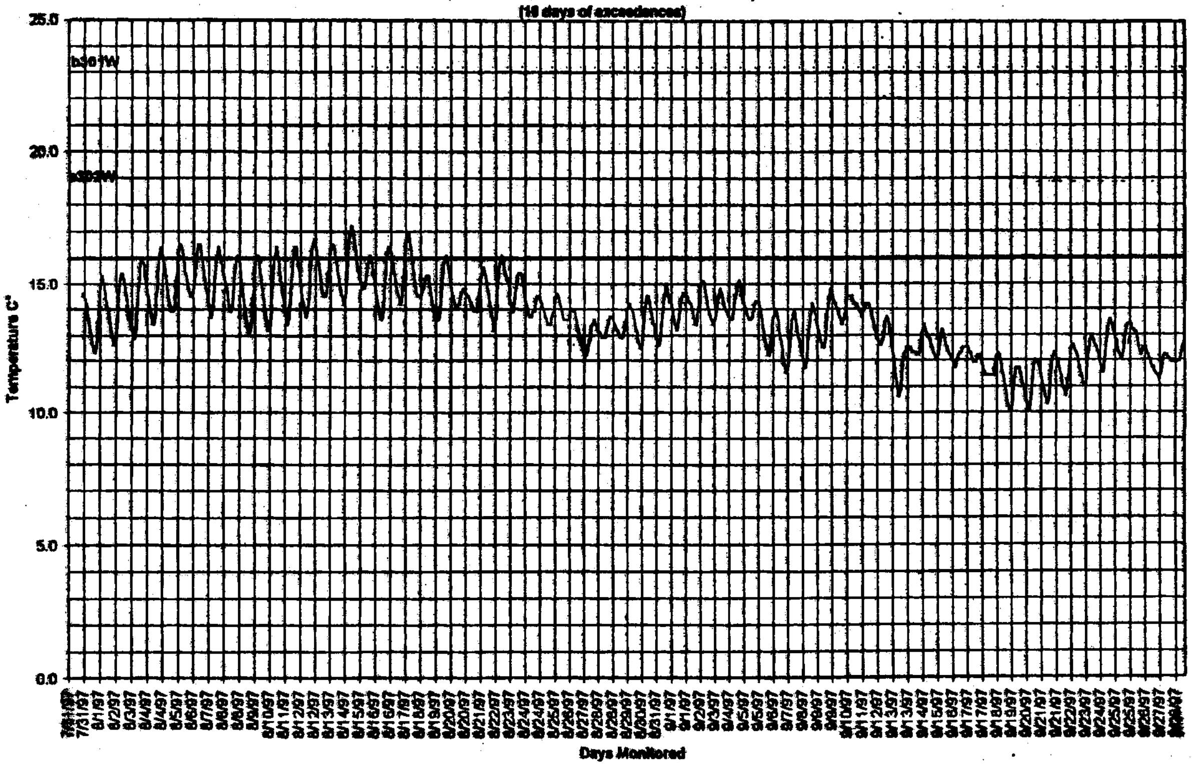
7-day Moving Average of Daily Maximum Temperatures
Comparison of Measured Data to Current and Proposed Standards
Temp (C)
25
20
15
10
5
0
7/13/00
7/27/00
8/10/00
8/24/00
9/7/00
9/21/00
10/5/00
SPCM
SPCB4
SPCSP
SPCSR
18C standard
Alt. 1
Alt. 2
SPCM, SPCB4, and SPCSP exceed existing standards and Alternatives 1 and 2 of the proposed temperature standards. SPCSR meets existing but not proposed temperature standards for the 7-day moving average of daily maximum temperatures.

Figure 5
Muckleshoot Tribe Temperature Monitoring

South Prairie Cr. (RM 11.0)
(WRIA 10.0466 - trib. to Carbon R. at RM 21.0)
(9 days of exceedences)



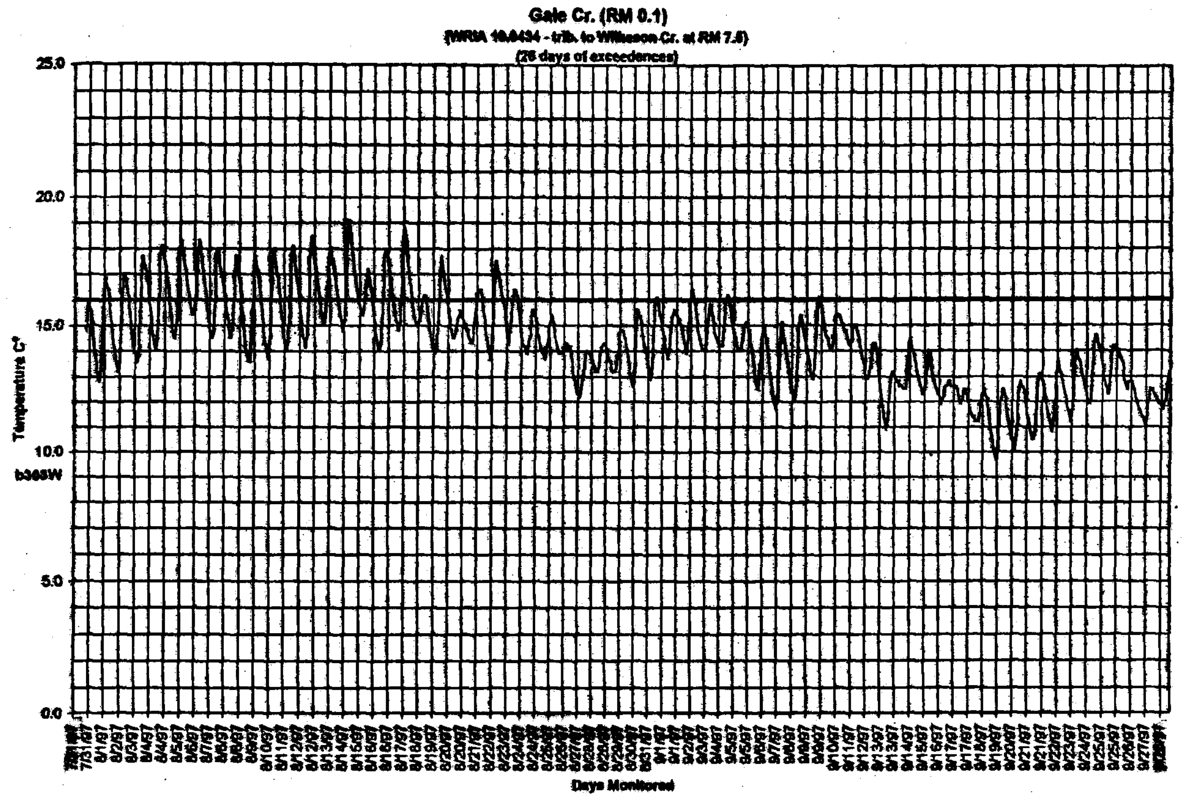
Wilkeson Cr. (RM 7.1)
(WRIA 10.0432 - trib. to S. Prairie Cr. at RM 5.7)
(18 days of exceedences)

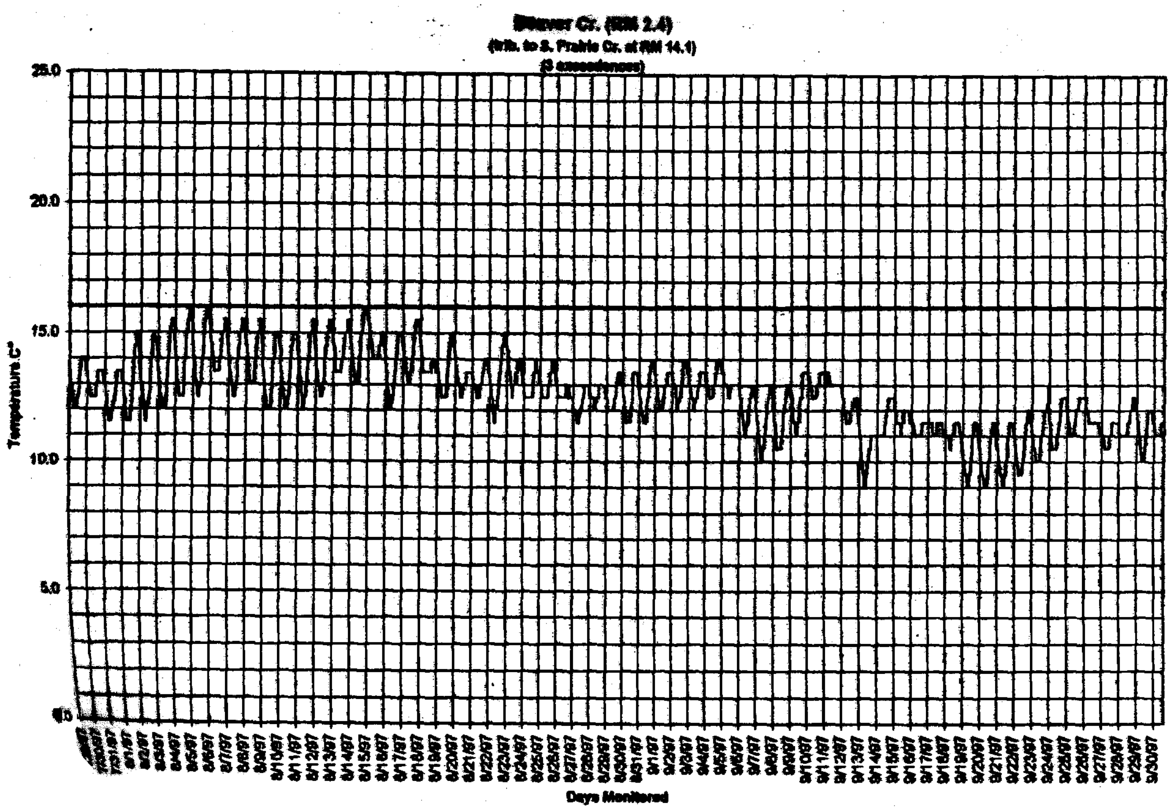


x axis tick marks
represent 12:11 AM

Muckleshoot Tribe Fisheries Dept.
October 24, 1997

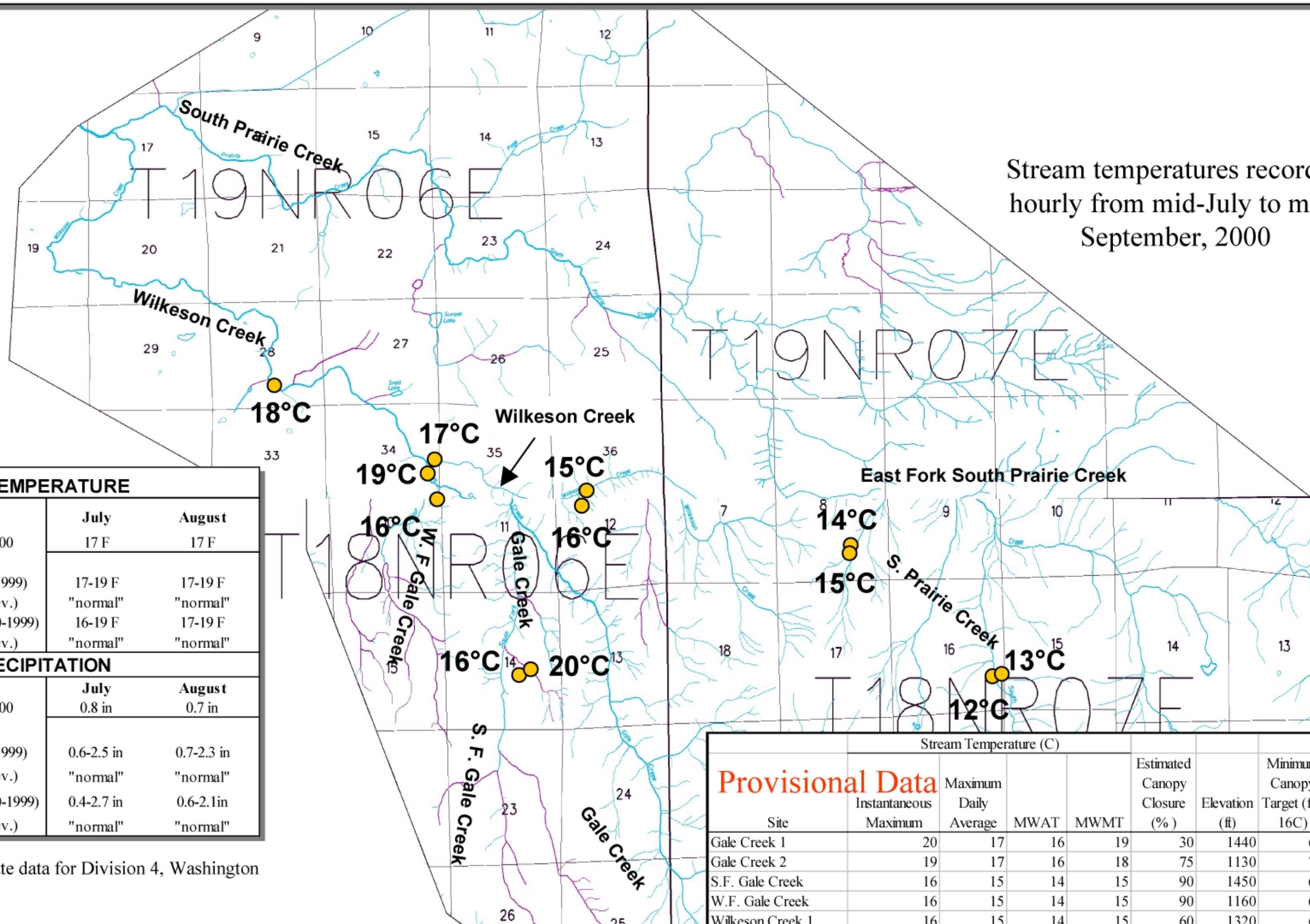
Figure 5 (cont'd)
Muckleshoot Tribe Temperature Monitoring





Muckleshoot Tribe Fisheries Dept.
October 24, 1997

Figure 6
Wilkeson Creek and South Prairie Creek Stream Temperature Monitoring, 2000



Stream temperatures recorded hourly from mid-July to mid-September, 2000

AIR TEMPERATURE	July	August
2000	17 F	17 F
Ten-Year Average (1990-1999)	17-19 F	17-19 F
(mean +- 1 Std. Dev.)	"normal"	"normal"
Twenty-Year Average (1980-1999)	16-19 F	17-19 F
(mean +- 1 Std. Dev.)	"normal"	"normal"

PRECIPITATION	July	August
2000	0.8 in	0.7 in
Ten-Year Average (1990-1999)	0.6-2.5 in	0.7-2.3 in
(mean +- 1 Std. Dev.)	"normal"	"normal"
Twenty-Year Average (1980-1999)	0.4-2.7 in	0.6-2.1in
(mean +- 1 Std. Dev.)	"normal"	"normal"

Source: NOAA climate data for Division 4, Washington

Provisional Data

Site	Stream Temperature (C) Instantaneous Maximum	Maximum Daily Average	MWAT	MWMT	Estimated Canopy Closure (%)	Elevation (ft)	Minimum Canopy Target (for 16C)	Conforms to TFW Temperature Screen?
Gale Creek 1	20	17	16	19	30	1440	60	yes
Gale Creek 2	19	17	16	18	75	1130	70	no *
S.F. Gale Creek	16	15	14	15	90	1450	60	yes
W.F. Gale Creek	16	15	14	15	90	1160	60	yes
Wilkeson Creek 1	16	15	14	15	60	1320	60	yes
Wilkeson Creek 2	15	14	13	14	80	1320	60	yes
Wilkeson Creek 3	17	16	15	16	75	1130	70	no *
Wilkeson Creek 4	18	16	15	17	55	810	70	yes
South Prairie Creek 1	12	12	11	12	90	1880	50	yes
South Prairie Creek 2	13	13	12	12	90	1880	50	yes
South Prairie Creek 3	15	13	13	14	55	1630	60	no **
E. F. South Prairie Cr.	14	12	11	13	55	1640	50	yes

* observed temperature higher than elevation/canopy combination would suggest
**observed temperature lower than elevation/canopy combination would suggest

Plum Creek
16 November 2000

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Figure 7
Phase II Baseline Monitoring Stations