WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Review Draft
Assimilative Capacity Study for Nutrient Loading in the Lower White River

December 1999

Publication No. 00-03-001
printed on recycled paper

For additional copies of this publication, please contact:

Department of Ecology
Publications Distributions Office
P. O. Box 47600
Olympia, Washington 98504-7600
(360) 407-7472

Refer to Publication Number 00-03-001

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Review Draft
Assimilative Capacity Study for Nutrient Loading in the Lower White River

by
Karol Erickson

Washington State Department of Ecology
Environmental Assessment Program
Watershed Assessment Section
PO Box 47710
Olympia, Washington 98504-7710

December 1999

Water Body No. WA-10-1040

Publication No. 00-03-001
printed on recycled paper

Table of Contents

List of Appendices

List of Figures and Tables

Page

Figures

Tables

Abstract

The White River, a tributary of the Puyallup River in western Washington State, exhibits high pH values, in exceedence of the state criterion of 8.5 standard units. The high pH is caused by periphytic algae growth, which in turn is related to excessive nutrient concentrations. An assimilative capacity study was undertaken to determine the maximum amount of inorganic nitrogen and orthophosphate that could be discharged to the river, and still maintain pH below 8.5. The largest contributor of pollutant loading for both nitrogen and phosphorus is from the Enumclaw wastewater treatment plant. The Buckley wastewater treatment plant also contributes a significant amount of phosphorus, and nonpoint sources contribute a significant amount of nitrogen. Based on an upstream/downstream nutrient-vs.-pH comparison, there does not appear to be significant nutrient loading capacity for the White River downstream of river mile 25. However, there is uncertainty in the assimilative capacity estimate. Recommendations are made for an adaptive management approach for reducing phosphorus loadings to the White River, starting with reductions of at least 50 percent. If follow-up monitoring determines that pH continues to exceed standards, additional reductions will be required. The Department of Ecology will be working with the cities of Enumclaw and Buckley, Rainier School, the Muckleshoot and Puyallup Tribes, EPA, and other stakeholders to identify alternative adaptive management strategies for reducing phosphorus inputs to the lower White River. The preferred alternative will include specific wasteload allocations for the existing point sources and load allocations for the nonpoint sources in the study area, to be included in the final TMDL for the lower White River.

The final report on this study is in preparation. The public comment period for this draft document has closed.

Acknowledgements

The many people contributing to this study are appreciated and deserve recognition.

John Tooley conducted the groundwater component of the study.

Emmanuel Nocon, Glenn Merritt, Norm Glenn, Joe Joy, Dan Saul, Bob Duffy, John Tooley, and Will Kendra assisted with field work.

Randy Coots developed the maps.

Greg Pelletier provided guidance throughout the project.

Russ Ladley, Puyallup Tribe Fisheries Department, provided a boat and river rafting expertise for the tributary and spring sampling.

Leslie Groce and Rob Fritz, of the Muckleshoot Tribe, provided valuable comments on the project plan and assisted in defining sampling sites.

Review comments were provided by Dr. Eugene Welch, Ralph Vaga and Geoff Poole of U.S. EPA Region 10, Julie Rector of the Muckleshoot Tribe, representatives of the cities of Enumclaw and Buckley, Peter Leinenbach, Greg Pelletier, Will Kendra, Bill Ehinger, Anise Ahmed, and Bob Duffy.

Introduction

Background

The White River, located in the Puget Sound basin in western Washington, originates from glaciers on Mt. Rainier, flowing westerly until emptying into the Puyallup River near Sumner, Washington. The study area for this report extends from river mile 26 to river mile 4 (Figure 1).

High pH values, substantially exceeding the water quality criterion of 8.5, were observed in the lower White River in September and October of 1990 (Pelletier, 1993). The high pH values were suspected to be caused by excessive nutrient levels that were promoting benthic algae growth, which in turn raises pH. An assimilative capacity study was subsequently identified as a high priority in the basin scoping process for this geographic area (Emmett, 1995). An assimilative capacity study determines the maximum amount of a pollutant, in this case, nitrogen or phosphorus, that can be discharged to a river from both point and nonpoint sources and still maintain water quality standards.

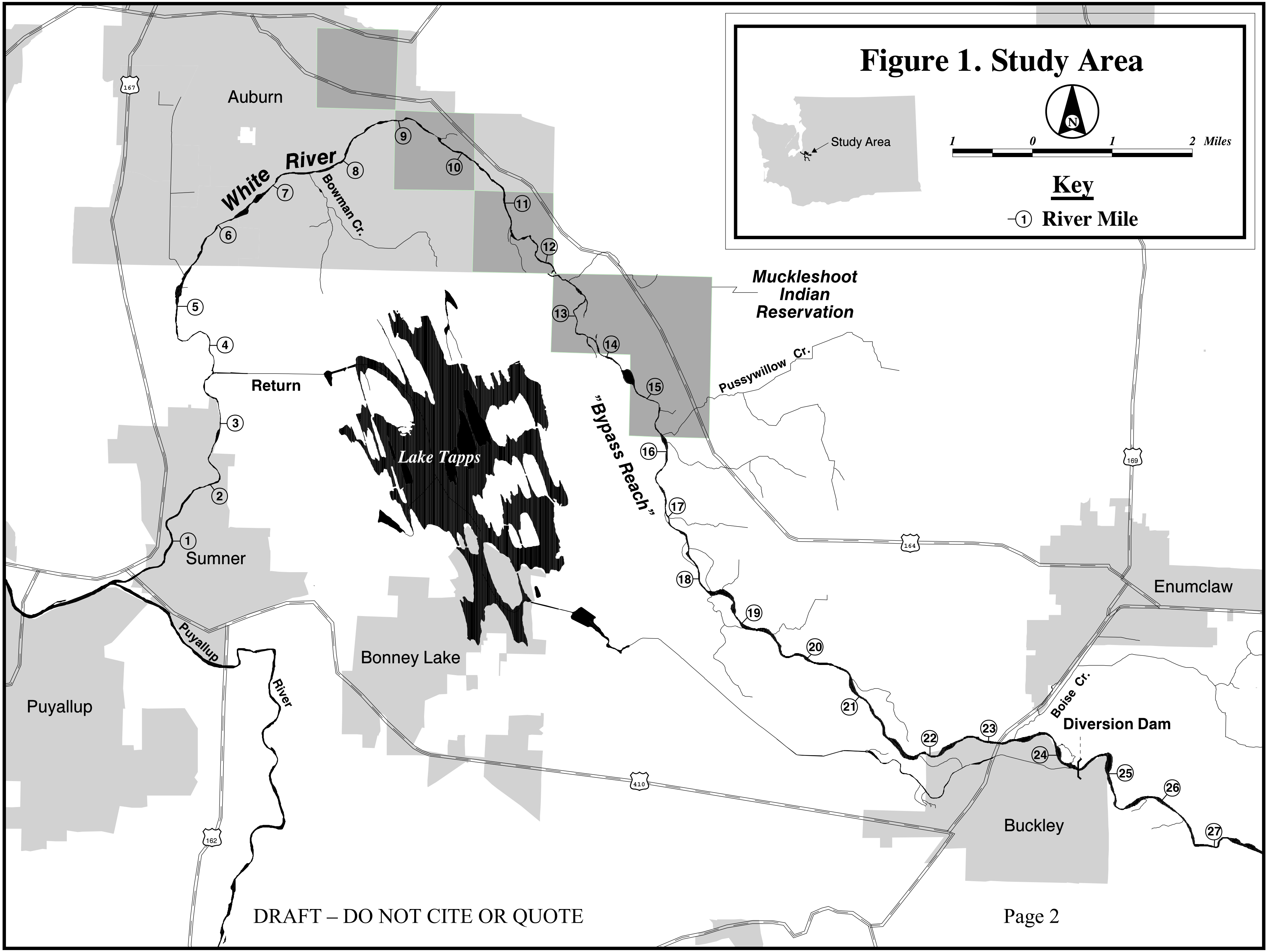
This study is the first step in developing a total maximum daily load (TMDL) for nutrients for the White River. TMDLs are required by the Clean Water Act when water quality does not meet standards after the application of technology-based controls (i.e., after pollutant sources have implemented the best available pollutant-control technology). TMDLs set limits for the pollutant(s) that are causing water quality standards to be violated. Subsequent steps will include development of a "Water Clean-up Plan" with recommended pollutant controls and revision of wastewater discharge permits. Interested and affected parties will have the opportunity to participate in development of the Water Clean-up Plan.

State water quality standards and an eventual TMDL for the White River apply to waters under the jurisdiction of the state of Washington. The White River flows through the Muckleshoot Indian Tribe reservation; waters within the reservation boundaries are not under the state's jurisdiction. The Muckleshoot Tribe is eligible to adopt tribal water quality standards; however, tribal standards have not been established to date. Because of jurisdictional issues, this study has been coordinated with the Muckleshoot Tribe.

Study Area

The White River drains a 494 square-mile basin with a total length of 68 miles. Streamflow during the summer months is turbid due to the river's glacial origin, which accounts for the river's namesake color. Land use in the study area is mixed urban/ residential (near Auburn, Sumner, Enumclaw, Buckley, highway corridors and surrounding Lake Tapps), agricultural (on the remaining uplands of the Enumclaw plateau), and forested (tree cover on the valley floor, upstream from Auburn). The area is experiencing rapid residential growth, generally into areas that were previously agricultural. The Muckleshoot Indian Reservation, shown in Figure 1, is

Figure 1. Study Area



located along the White River between river miles 16 and 9. (River miles used in this report are based on the catalog of Washington streams by the Department of Fisheries (Fisheries, 1975). The river miles are used as benchmarks for reference purposes, and may differ from other river mile measurements due to river channel changes, scale effects, and other factors.)

At river mile 24.3, Puget Sound Energy diverts most of the river flow to Lake Tapps for power generation, leaving only a minimum flow in the mainstem until the water is returned at mile 3.5 (Figure 1). This stretch of the river is known as the "bypass reach." The study area for this project is from river mile 25 to river mile 3.5.

Relationship of pH to Nutrient Levels

Although the water quality problem in the White River is high pH, the assimilative capacity study was done for nutrients (nitrogen and phosphorus). The reason for this is described below.

High pH in the White River is caused by photosynthesis of algae. In the case of the White River, the algae are attached to rocks on the stream bottom (periphyton) as opposed to free-floating in the water. The effect of photosynthesis on pH is well-documented in the literature and described in textbooks on aquatic systems (Welch *et al*., 1992; Stumm and Morgan, 1981). Photosynthetic algae consume CO_2 faster than it can be replenished from the atmosphere, resulting in a net loss of carbon to the system. As total carbon goes down (and alkalinity remains essentially constant), pH goes up. Because of this process, the diurnal change in pH can be used as a measure of photosynthetic rate (Hall and Moll, 1975).

Algae photosynthesis can be summarized as:

Light + nitrogen + phosphorus + carbon $\longrightarrow$ **Algae + oxygen**

Carbon uptake occurs simultaneously with nutrient uptake, according to a stoichiometric ratio that is similar to the carbon/nitrogen/phosphorus content of the algae. Therefore change in pH is directly related to nutrient uptake.

As depicted in the above equation, algae require nitrogen and phosphorus to grow. The purpose of this assimilative capacity study is to determine the maximum level of nutrients allowable in the river to keep algae levels low enough that pH will be in compliance with standards.

Many other factors also affect algae growth, including light, temperature, stream water velocity, grazing by invertebrates, substratum type, and suspended sediment (Welch *et al*., 1992). In addition, the change in pH that results from a given amount of change in carbon is dependent on the alkalinity of the water (also called buffering capacity). However, most of these factors are natural characteristics of the system and are not controllable. Nutrient levels in the White River have been increased over natural levels by human-related causes. Therefore, this assimilative capacity study is focused on nutrients. The sensitivity of pH to streamflow levels is also addressed in the *Assimilative Capacity Analysis* section.

Sources of Nutrients

There are four point sources of nutrients in the study area (river miles given in parentheses).

- Rainier School wastewater treatment plant (RM 25)
- The White River Hatchery, operated by the Muckleshoot Indian Tribe (RM 24)
- City of Enumclaw wastewater treatment plant (RM 23)
- City of Buckley wastewater treatment plant (RM 22)

There are numerous nonpoint sources of nutrients as well. In particular, about 20 dairies are located in the study area (Figure 2). In addition to dairies, other possible nonpoint sources of nutrients include on-site septic systems, fertilizers, and other animal wastes.

Project Objectives

The study objectives, as identified in the project plan (Erickson, 1996), were to:

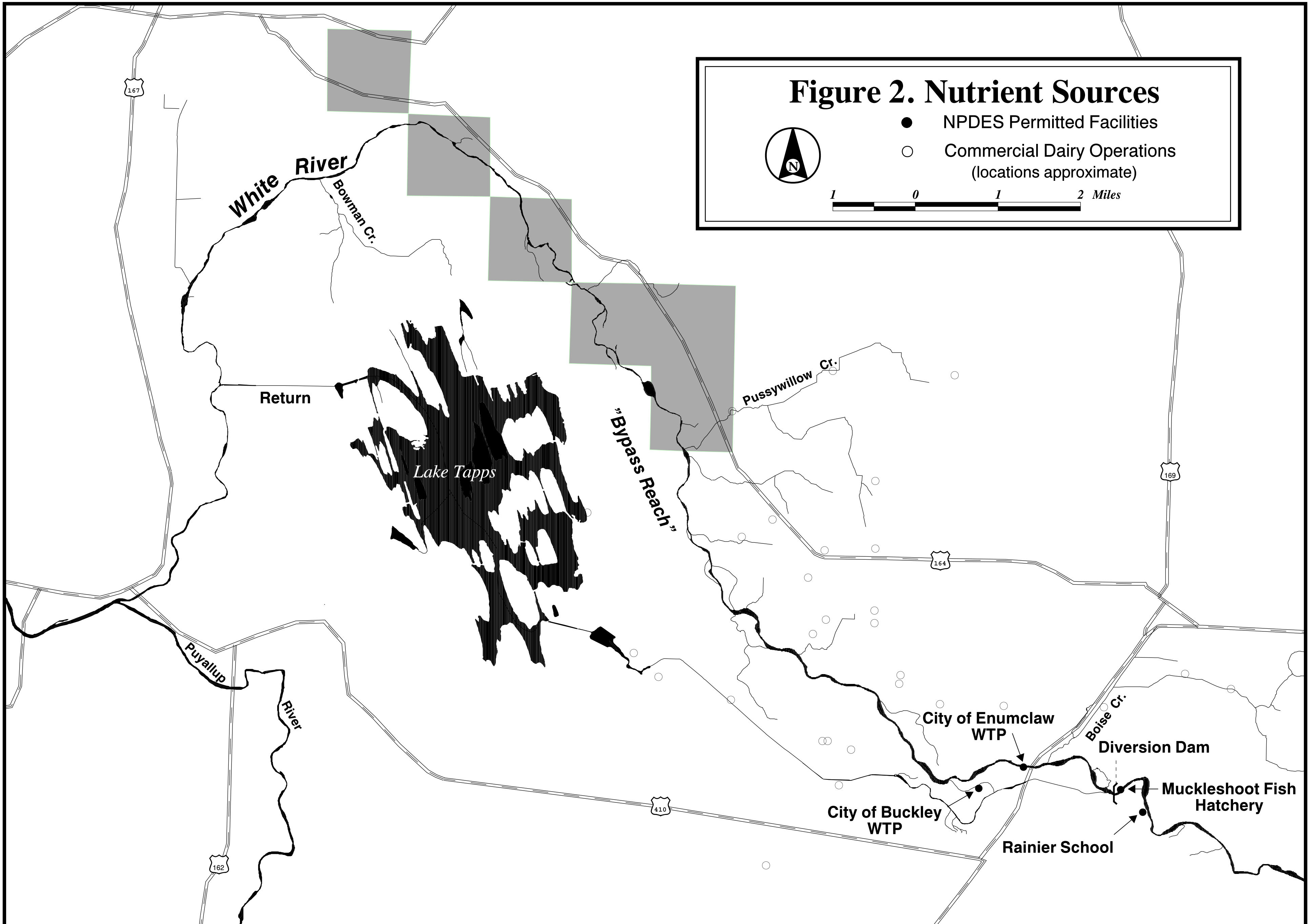
- Characterize the White River pH, nutrient concentrations, and periphyton communities, both longitudinally along the affected river reach, and temporally over the summer season (including diurnal pH changes).
- Assess the relationship between nutrient concentrations, algal growth, streamflow, and pH for the conditions observed.
- Assess nutrient loading from both point and nonpoint sources.
- Predict the effect of reduced nutrient loading on pH values.

Water Quality Standards and Beneficial Uses

The White River in the study area is classified as Class A, "excellent." Washington State's water quality standards specify that "pH shall be within the range of 6.5 to 8.5 (freshwater) with a human-caused variation within a range of less than 0.5 units" (Ch.173-201A-030 WAC). Characteristic uses for this class consist of water supply (domestic, industrial, and agricultural), stock watering, fish and shellfish (salmonid and other fish migration, rearing, spawning and harvesting), wildlife habitat, recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment), and commerce and navigation.

The pH of natural aquatic systems is important because the toxicity of many compounds is affected by the degree of association of weak acids or bases, which is affected by pH. The most obvious example of this for high pH is ammonia, which has been shown to be ten times as toxic at pH 8.0 as 7.0. On the other hand, metals, cyanide, and several other compounds are more toxic at low pH. The "gold book" on water quality criteria (U.S. EPA, 1986) discusses the potential impacts of pH on fishery resources:

There is no definite pH range within which a fishery is unharmed and outside of which it is damaged, but rather, there is gradual deterioration as the pH values are further removed from



DRAFT – DO NOT CITE OR QUOTE

the normal range. The pH range which is not directly lethal to fish is 5 - 9; however, the toxicity of several common pollutants is markedly affected by pH changes within this range, and increasing acidity or alkalinity may make these poisons more toxic (European Inland Fisheries Advisory Commission, 1969).

The U.S. Fish and Wildlife Service (Piper *et al.*, 1982), in discussing fish hatchery management, states:

Ninety percent of natural waters have pH values in the range 6.7 to 8.2 and fish should not be cultured outside the range of 6.5 to 9.0. Many fish can live in waters of more extreme pH, even for extended periods, but at the cost of reduced growth and reproduction. Fish have less tolerance of pH extremes at higher temperatures.

Even within the relatively narrow range of pH 6.5 to 9.0, fish species vary in their optimum pH for growth. Generally, those species that live naturally in cold or cool waters of low primary productivity (low algal photosynthesis) do better at pH 6.5-9. Trout are an example; excessive mortality can occur at pH above 9.0. The affected fish rapidly spin near the surface of the water and attempt to leave the water. Whitening of the eyes and complete blindness, as well as fraying of the fins and gills with the frayed portions turning white, also occur. Death usually follows in a few hours.

Of prime importance to the White River system is the White River spring chinook, the sole remaining spring chinook stock in South Puget Sound. The South Sound Spring Chinook Salmon Technical Committee (WDF&W *et al.*, 1996) reports that the White River spring chinook are among the most depressed salmon stocks in the Pacific Northwest outside of the Columbia River Basin.

An adult chinook tracking study was conducted in 1996 by the Puyallup Indian Tribe (Ladley *et al.*, 1996). This study found spawning areas in the upper range of the study area (upstream of river mile 21.0). Extended holding behavior was not observed anywhere in the bypass reach except at the Tacoma Public Utilities pipeline crossing (about 0.8 miles downstream of the diversion dam). This study did not address juvenile usage.

Spawning, holding, and rearing of spring chinook occur during the period high pH was measured (September and October). However, the exact effect of high pH on spring chinook is not known.

In addition to spring chinook, other important species of fish occur in the lower White River. A 1997 study by the Muckleshoot Indian Tribe documented coho, steelhead, spring and fall chinook, chum, sockeye, and pink salmon in the mainstem and tributaries within the bypass reach of the White River. Whereas most spawning occurred in the tributaries, spawner surveys found coho, chum, and chinook spawning in the mainstem White River.

Historical Data Summary

Puyallup River TMDL

Data on nutrients and pH were collected in September and October 1990 as part of the Puyallup River TMDL study. The data applicable to this study are listed in Appendix A.

Ecology's *Environmental Monitoring and Trends Section* has collected monthly water quality data on the White River, spanning the period from 1962 to the present, although not on a continuous basis; most of the data are more than 25 years old. These data are also presented in Appendix A, and data availability is summarized in Table 1. Parameters measured include temperature, pH, dissolved oxygen, nutrients, turbidity, and streamflow, although not all parameters are available for all dates and sites. Quality assurance protocols associated with ambient data have become increasingly sophisticated over time; therefore later data are more reliable than earlier data.

Table 1. Ambient monitoring data availability for the White River. RM = River Mile

		Water year (October through September)														
Station	RM	62	63	64	65	69	70	71	72	73	75	93	96	97	98	99
10C085	4.9					X	X				X		X			
10C090	6.3	X	X	X	X			X		X						
10C095	8.0															X
10C110	19.8									X						
10C130	23.1											X				

Methods

Field Surveys

Four types of field surveys were conducted. The first three were conducted in 1996:

1. Water column parameters and streamflow
2. Periphyton studies, and
3. Supplemental sampling of tributaries and springs.

In 1997, additional sampling was done for nutrients and pH at selected mainstem sites.

1. Water column parameters and streamflow

Six field surveys were conducted to collect physical and chemical water column data during the summer and early fall of 1996. The dates of the sampling surveys were June 25-27, July 30-August 1, August 21-23, September 10-12, September 23-25, and October 8-10.

Sampling sites are listed in Table 2 and shown in Figure 3. Sampling sites consisted of: 1) effluent outfalls from the four point sources, 2) eight mainstem sites, and 3) four tributary sites. The uppermost mainstem site was just above the Rainier School outfall at river mile (RM) 25.2 and the lower-most site was at RM 4.9. The remaining sites were chosen to represent the river between these sites, based on available access. The uppermost site (RM 25.2) is not affected by point sources.

During each survey, remote data collection equipment was deployed (Hydrolab® datasondes) that collected pH, temperature, dissolved oxygen, and conductivity data every 30 minutes. In general, the hydrolabs were set up the first day of each survey and set to run for 48 hours. Hydrolabs were used at three sites: WR25.2, WR14.9, and WR08.0. At the time the hydrolabs were deployed and retrieved, field measurements were taken of pH, temperature, and dissolved oxygen, for data quality assessment of the hydrolab data.

Grab samples and field measurements were collected from river sites on the second day. The parameters measured are shown in Table 2. Field measurements consisted of streamflow, temperature, dissolved oxygen, pH, and conductivity. Laboratory parameters for the grab samples consisted of ammonia, nitrate + nitrite, nitrite, orthophosphate, total phosphorus, total nitrogen, alkalinity, fecal coliform bacteria, turbidity, total suspended solids, chloride, and chlorophyll a in the water column.

Composite samplers also collected 24-hour effluent samples at the three wastewater treatment plants. Laboratory parameters for the composite samples consisted of the parameters listed above, excluding alkalinity, turbidity, and chlorophyll a.

Table 2. White River nutrient study sampling surveys in 1996.

I. Water Column and Streamflow (six surveys)			Number of field measurements per survey						Number of samples per survey for laboratory parameters								
Stn.	RM	Description	Hydrolab[1]	Flow	Temp.	Dissolved Oxygen	pH	Cond.	Nuts 5[2]	Total Pers. Nitrogen	Total Keld. Nitrogen	Alkalinity	Fecal Col. Bacteria	Turbidity	Total susp. Solids	Chloride	chl. a
A. Point Sources																	
RAINSC		Rainer School effluent		1	1	1	1	1	2		2		1		2	2	
MUCKLSH		Muckleshoot Hatchery		1	1	1	1	1	2		2		1		2	2	
BUCKLEY		Buckley WTP effluent		1	1	1	1	1	2		2		1		2	2	
ENUMCL		Enumclaw WTP effluent		1	1	1	1	1	2		2		1		2	2	
B. Mainstem sites																	
WR25.2	25.2	White R. upstream of Rainier School	(continuous)		1	1	1	1	1	1		1	1	1	1	1	1
WR23.1	23.1	White R. at Highway 410 crossing			1	1	1	1	1	1		1	1	1	1	1	1
WR21.2	20.4	White R. downstream of return flow from fish screen			1	1	1	1	1	1		1	1	1	1	1	1
WR14.9	14.9	White R. near SE 400th	(continuous)		1	1	1	1	1	1		1	1	1	1	1	1
WR10.3	10.3	White R. at power line crossing			1	1	1	1	1	1		1	1	1	1	1	1
WR8.0	8.0	White R. above Bowman Cr.	(continuous)		1	1	1	1	1	1		1	1	1	1	1	1
WR6.3	6.3	White R. at RR and "A" St. crossing			1	1	1	1	1	1		1	1	1	1	1	1
WR4.9	4.9	White R. at 8th St. bridge nr. Pacific			1	1	1	1	1	1		1	1	1	1	1	1
QA		Quality Assurance Samples			1	1	1	1	1	1		1	1	1	1	1	1
C. Tributaries																	
BOISE		Boise Creek near mouth			1	1	1	1	1	1		1	1		1	1	
TRIB15.4		Tributary at White RM 15.4		1	1	1	1	1	1	1		1	1		1	1	
TRIB15.5		Tributary at White RM 15.5		1	1	1	1	1	1	1		1	1		1	1	
BOWMAN		Bowman Creek near mouth		1	1	1	1	1	1	1		1	1		1	1	

II. Periphyton Survey (3 surveys)						
Stn.	RM	Description	velocity	depth	Chl a	ID[3]
WR25.2	25.2	White R. upstream of Rainier School	1	1	1	1
WR4.9	14.9	White R. near SE 400th	1	1	1	1
WR8.0	8.0	White R. above Bowman Cr.	1	1	1	1

III. Supplemental Tributaries and Springs (1 survey)							
Stn.	RM	Description	Flow	Temp.	pH	Nuts 5[2]	TPN
Trib/spring1		See Figure 3	1	1	1	1	1
Trib/spring2		See Figure 3	1	1	1	1	1
Trib/spring3		See Figure 3	1	1	1	1	1
Trib/spring4		See Figure 3	1	1	1	1	1
Trib/spring5		See Figure 3	1	1	1	1	1
Trib/spring6		See Figure 3	1	1	1	1	1
Trib/spring7		See Figure 3	1	1	1	1	1
Trib/spring8		See Figure 3	1	1	1	1	1
Trib/spring9		See Figure 3	1	1	1	1	1

[1] Remote data collection of temperature, pH, DO, and conductivity every 30 minutes for 48 hours per survey

[2] Nuts 5 = NH3, NO3+NO2, NO2, ortho-P, and total P

[3] One date only

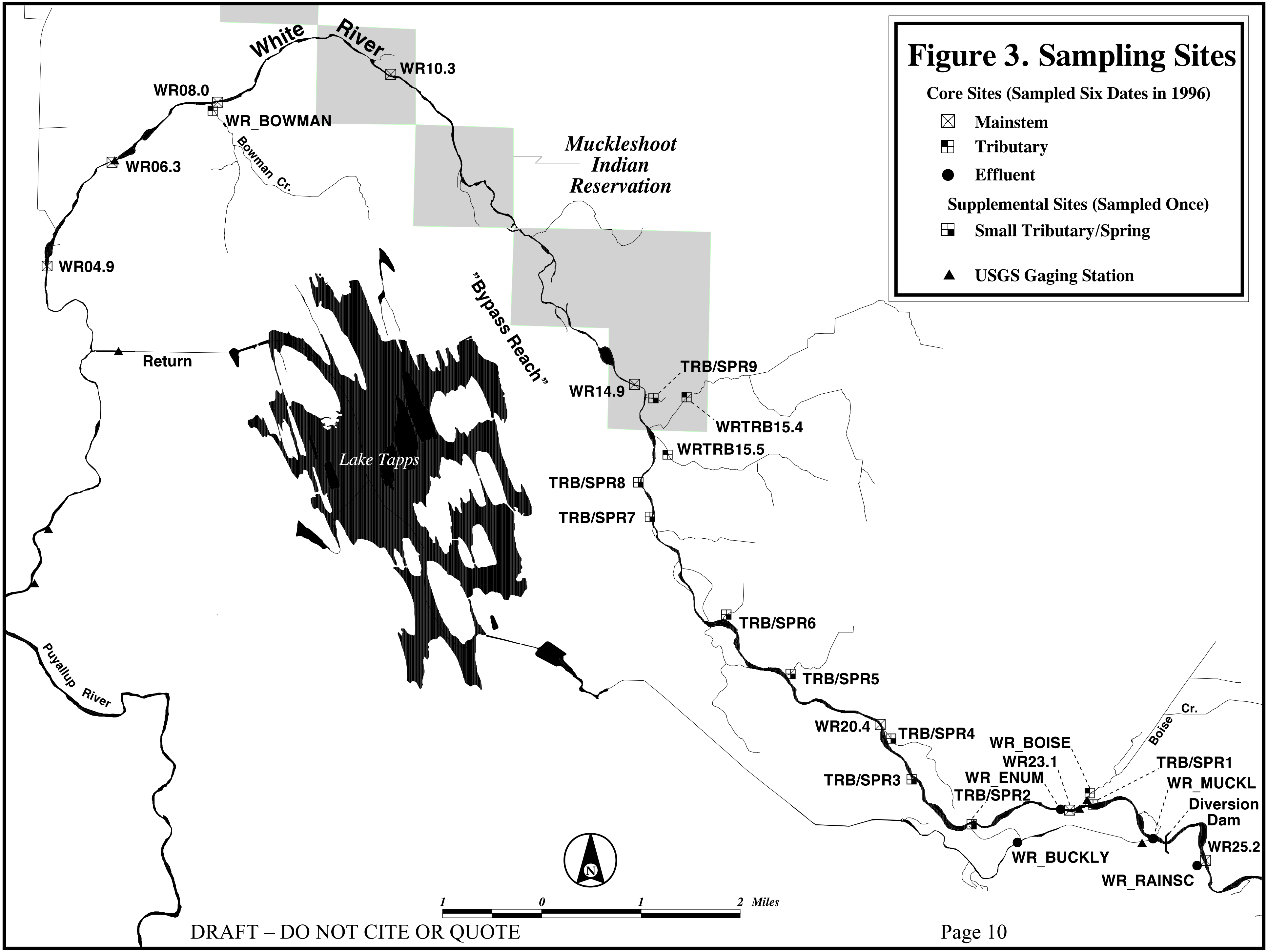


Figure 3. Sampling Sites
Core Sites (Sampled Six Dates in 1996)
Mainstem
Tributary
Effluent
Supplemental Sites (Sampled Once)
Small Tributary/Spring
USGS Gaging Station
White River
Muckleshoot Indian Reservation
"Bypass Reach"
Lake Tapps
Return
Bowman Cr.
Puyallup River
Boise Cr.
WR04.9
WR06.3
WR08.0
WR_BOWMAN
WR10.3
WR14.9
TRB/SPR9
WRTRB15.4
WRTRB15.5
TRB/SPR8
TRB/SPR7
TRB/SPR6
TRB/SPR5
WR20.4
TRB/SPR4
TRB/SPR3
TRB/SPR2
WR_ENUM
WR23.1
WR_BOISE
TRB/SPR1
WR_MUCKL
Diversion Dam
WR25.2
WR_BUCKLY
WR_RAINSC
1 0 1 2 Miles
N

All laboratory analyses were done by Manchester Environmental Laboratory. orthophosphate samples were filtered in the field, and the chlorophyll a samples were filtered by the laboratory. No other samples were filtered. (Additional details on field equipment used and laboratory methods are provided in the project plan, Erickson, 1996).

Total variation for field sampling and analytical variation was assessed by collecting replicate samples of all parameters at one site during each survey. Quality control procedures by the lab followed standard operating procedures described in MEL (1994). Field sampling and measurements followed quality control protocols described in the WAS protocols manual (WAS, 1993). The pH and conductivity meters and Hydrolab® datasondes were pre- and post-calibrated in accordance with the manufacturers' instructions. The pH probe was calibrated with low-ionic strength buffer which is closer to actual conditions than standard buffer solutions. Samples for laboratory analysis were stored on ice and delivered to MEL within 24 hours of collection.

United States Geological Survey (USGS) gages were used for obtaining flow data on the mainstem. Gaging stations are shown in Figure 3; a schematic diagram of the gaging stations is also shown in Figure 4. In addition, streamflow measurements were taken at each of the three remaining tributary sites during each survey, concurrent with the water quality sampling.

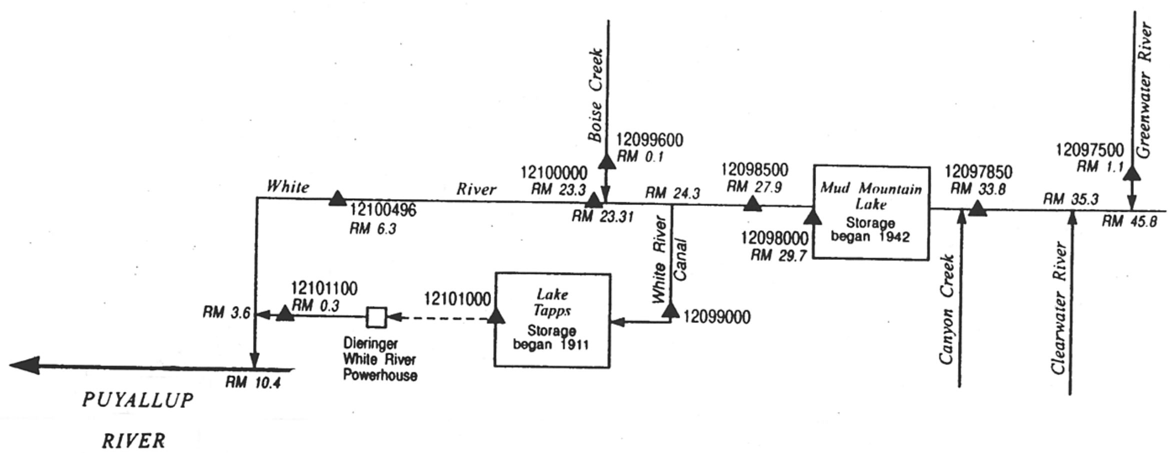


Figure 4. Schematic diagram of USGS gaging stations for the White River (USGS, 1995).

2. Periphyton analyses

Periphyton studies were conducted during three dates (September 11, September 24, and October 9) and at three sites each (RM 25.2, 14.9, and 8.0). The periphyton analyses consisted of identification, measurement of chlorophyll *a*, and measurement of average depth and water velocity at the site. Algae samples were obtained by scraping a prescribed area from six rocks taken randomly from along the stream cross section at that site and composited into two containers (three rocks per container, which provided one sample and one replicate). On the first date, de-ionized water was added to each container to reach a total volume of 550 mL. Of this, 50 mL of mixed solution was removed from each container and placed into a separate bottle for algae identification. The samples for identification were preserved by adding Lugol's solution. On subsequent dates, the bottles were filled to 500 mL and no algae ID was done. The conversions to mg/m^2 took into account the different quantities of dilution water.

3. Supplemental sampling of tributaries and springs

On the July 31 survey, in addition to the sampling described above, the river was floated in an inflatable boat between river miles 24 and 8 to visually inspect the river valley and to sample additional tributaries and springs that are not accessible by road. Nine additional sites were sampled. Field measurements and sample parameters consisted of temperature, pH, streamflow, nitrate+nitrite, ammonia, orthophosphate, and total phosphorus. The purpose of the float trip was to allow better quantification of nonpoint nutrient inputs. Site trib/spring2 is the Buckley effluent channel. Site trib/spring3 is the fish passage return flow.

In 1997, additional nutrient and pH data were collected weekly from August 1 to November 14, 1997, at four sites: river miles 25.2, 8.0, 6.3 and 4.9. pH was measured twice a day at each site, early in the morning and in mid-afternoon. Nutrient samples (ammonia, nitrate+nitrite, nitrite, orthophosphate, total phosphorus, and total nitrogen) were taken at river miles 25.2 and 8.0 in the afternoon.

Groundwater Study

A ground water study was undertaken to estimate groundwater nutrient loading to the White River in the study area. John Tooley of the Department of Ecology led this effort; the results are presented in Appendix B. The study concluded that nutrients in groundwater in the vicinity of the study area are likely being discharged laterally to White River tributary streams.

Results

Quality Assurance

A summary of the quality assurance review of the 1990, 1996, and 1997 sampling data is presented in Appendix C. Some data were rejected for failing quality assurance criteria. When the measured result was reported to be less than the detection limit, the value was assumed to be one-half of the detection limit. The Hydrolab® pH data were found to be biased low by an average of 0.15 pH units; however, the data were not adjusted. The final data are tabulated in Appendix D.

pH

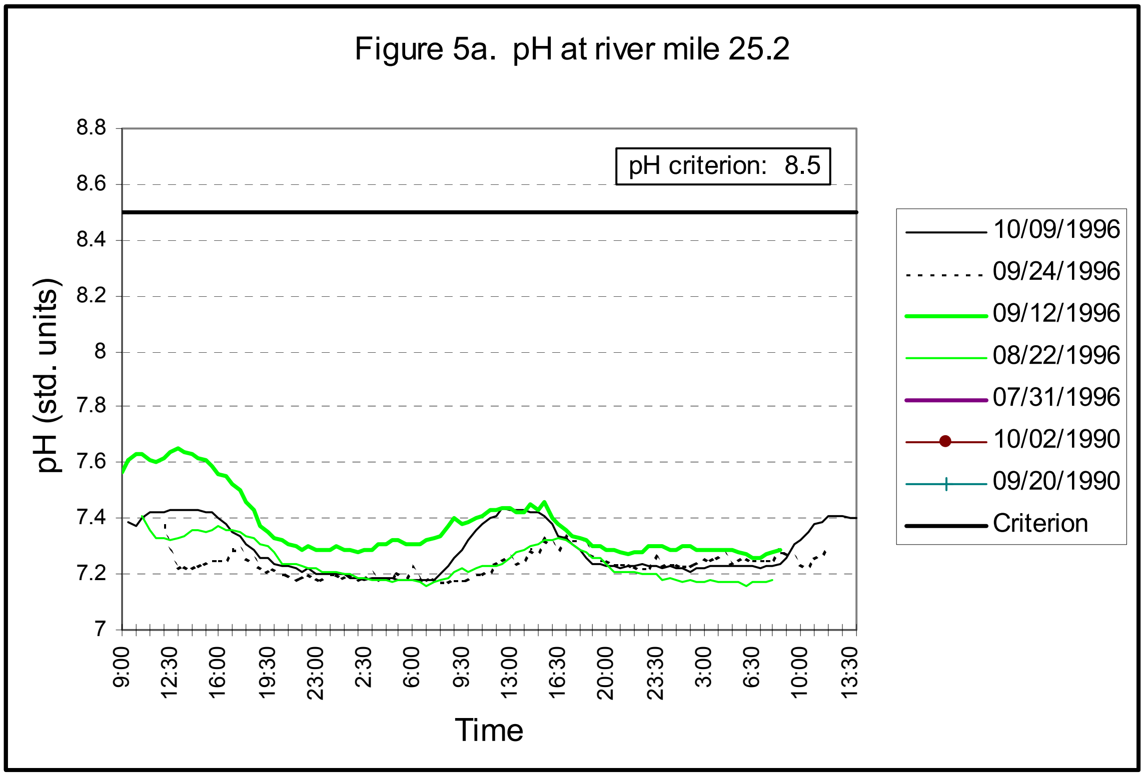
Figure 5 illustrates the pattern of pH found by the water quality surveys in 1996. Figure 5a shows pH at river mile 25.2, the uppermost site. Here pH varied only slightly over the course of a day, and varied little over the season. The pH stayed fairly constant in the range of 7.2 to 7.5.

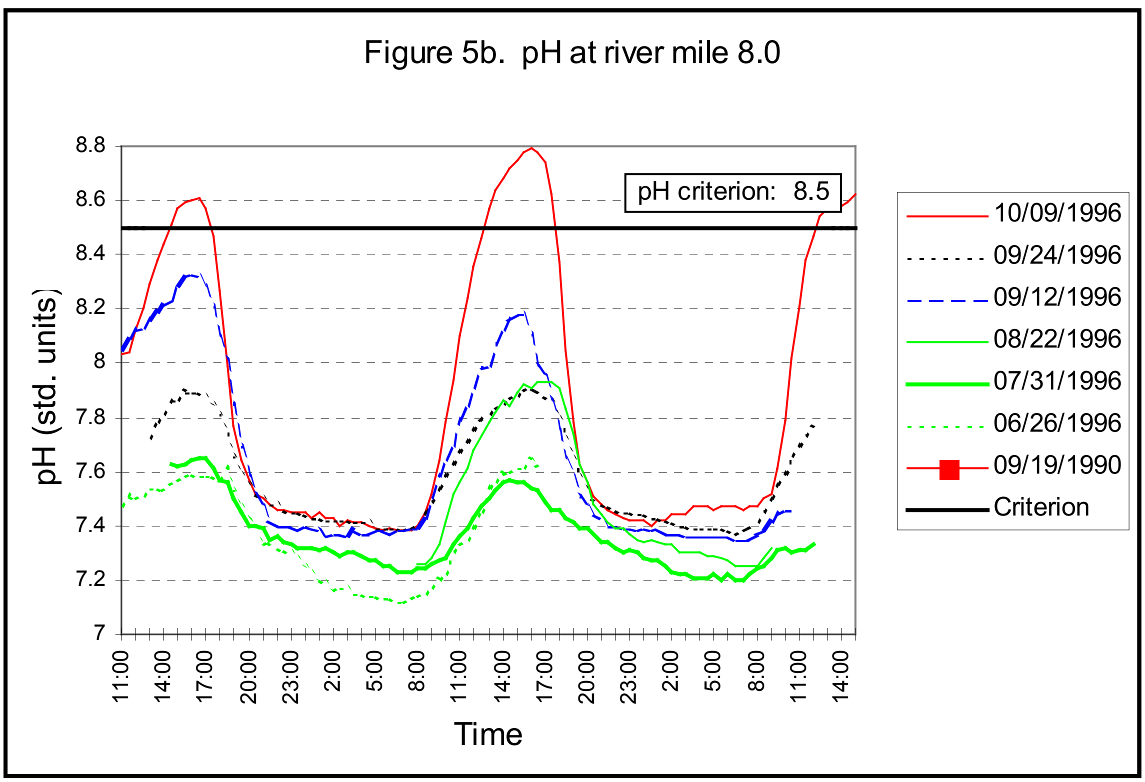
The pH pattern in the lower river is considerably different. Figure 5b illustrates pH at river mile 8.0. Here there is considerably more variation over the course of a 24-hour day, showing the effect of photosynthesis. In addition, there is more variation over the summer season, compared to the upper river site. The night pH was fairly constant at about 7.4. The mid-afternoon pH ranged from 7.6 in June and July to a high of 8.8 on October 9, 1996. This figure also illustrates that the pH violated the state water quality standard of 8.5 on October 7-9, 1996.

Figure 6 shows the Hydrolab® data for river mile 8.0 overlain with all of the measured pH values from 1990, 1996, 1997, and 1999, plotted by time-of-day. The measured values are consistent with the Hydrolab® data, showing a range of possible values in the mid-afternoon and lower values in the early morning. The 1990 and 1999 pH measurements were quite high (maximum of 9.6), and were significantly higher than the values measured in 1996 and 1997 (maximum of 8.8). These higher values cannot be explained by higher nutrient concentrations, differences in turbidity nor streamflow levels. The White River appears to have significant year-to-year variation in pH values.

Figure 7 shows all of the historical pH data for the study area by day of year to show seasonal variation. The ambient data were not collected at any particular time of the day, and therefore do not necessarily reflect the mid-afternoon maximum pH values for that day. Nevertheless, the ambient record is helpful to show a seasonal pattern of potentially high pH values. The results show that pH violations have been recorded as early as March 24 and as late as November 10.

Figure 5. White River pH at river miles 25.2 and 8.0, 1996 surveys.





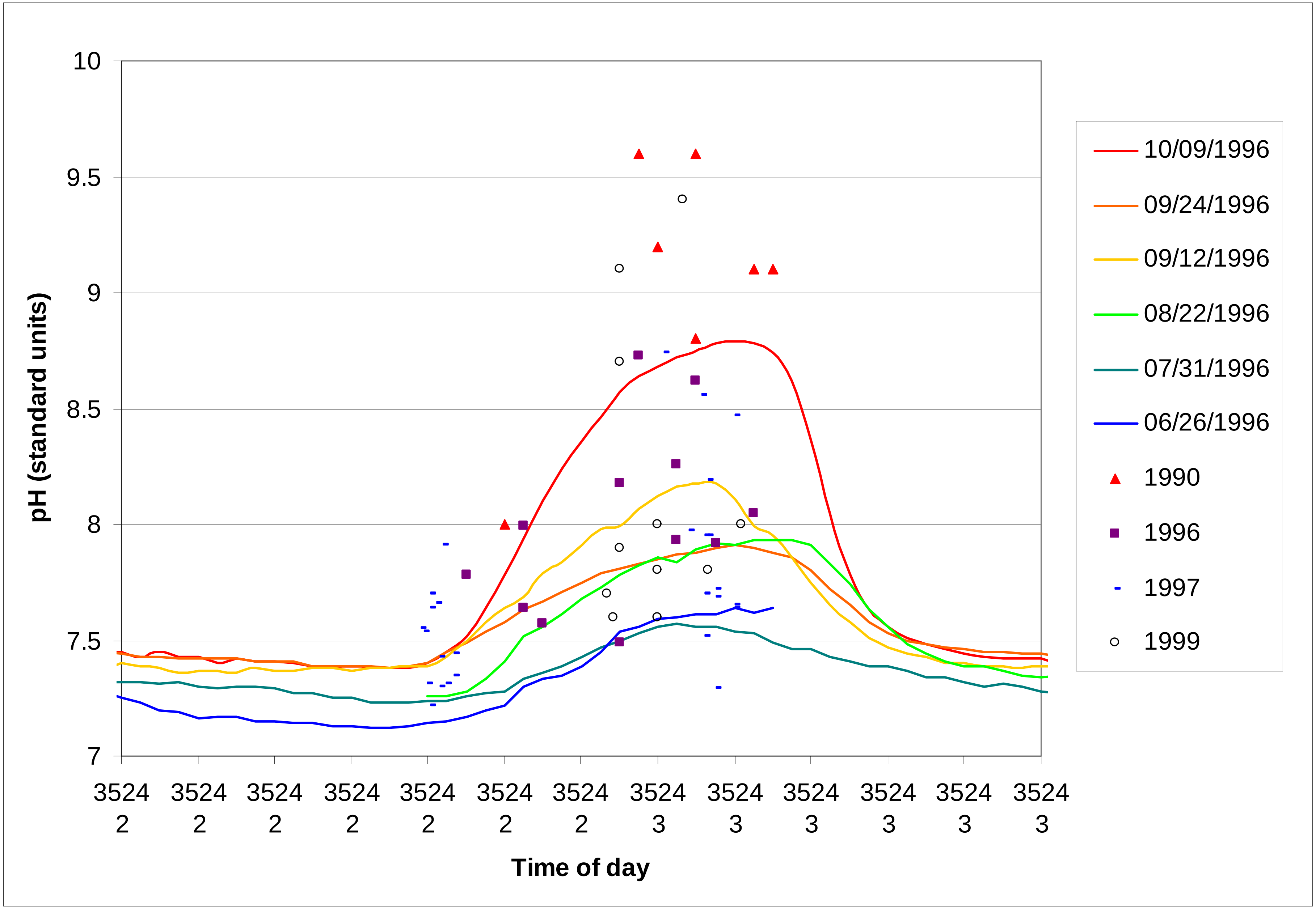


Figure 6. White River pH at river mile 8.0; 1990, 1996 and 1997 and 1999.

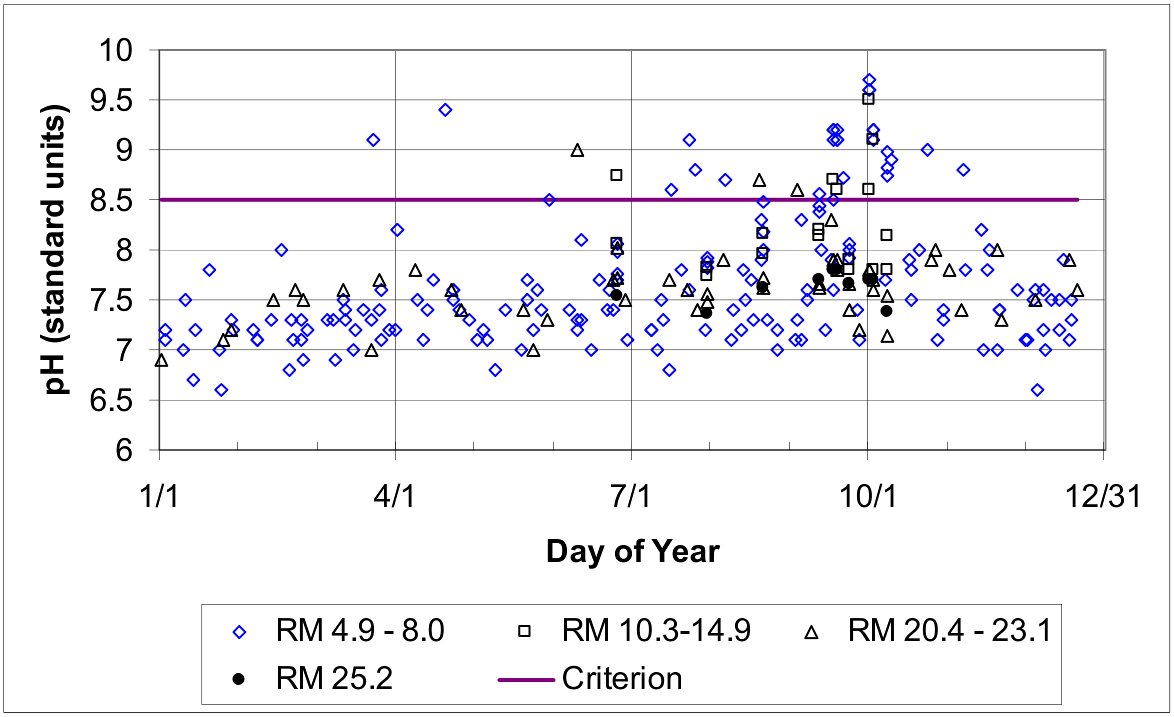


Figure 7. White River pH by day of year, all data within study area.

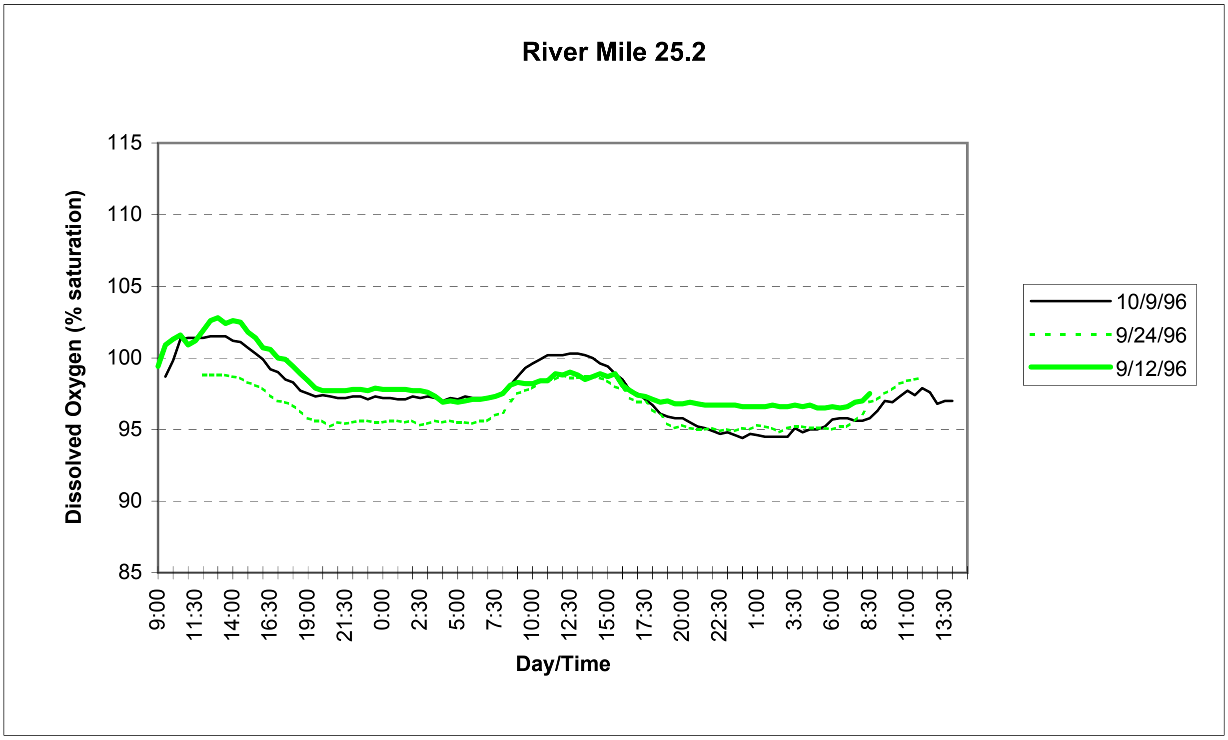
Dissolved Oxygen

The pattern for dissolved oxygen, illustrated in Figure 8 in terms of percent saturation, is similar. This is to be expected, since dissolved oxygen and pH both peak in the mid-afternoon as an effect of photosynthesis. However, dissolved oxygen did not fall below the state water quality criterion of 8.0 at any time during the study, and ranged from 8.8 to 11.5 over all river sites and dates.

Nutrients

Mainstem nutrient results from 1996 and 1997 are summarized in Figure 9 by river mile. Both nitrogen and phosphorus levels were relatively low at river mile 25.2, and then increased downstream. The nutrient concentrations were higher in 1997 than 1996. In 1997, there was a high measurement for both nitrogen and phosphorus on 10/31/97, which also corresponded to a high rainfall and streamflow event.

A comparison of nitrogen to phosphorus levels can indicate which nutrient may be most likely to limit algal growth. The average ratio of inorganic nitrogen to orthophosphate (on a mass basis) increased in a downstream direction in 1996, from 4.2 at the headwaters to 8.6 at the lower reach. A ratio less than 10 suggests nitrogen-limited waters (Thomann and Mueller, 1987). Concentrations of both nitrogen and phosporus are currently too high to limit growth; but the nutrient likely to deplete first would be nitrogen (which is typical in waters receiving sewage



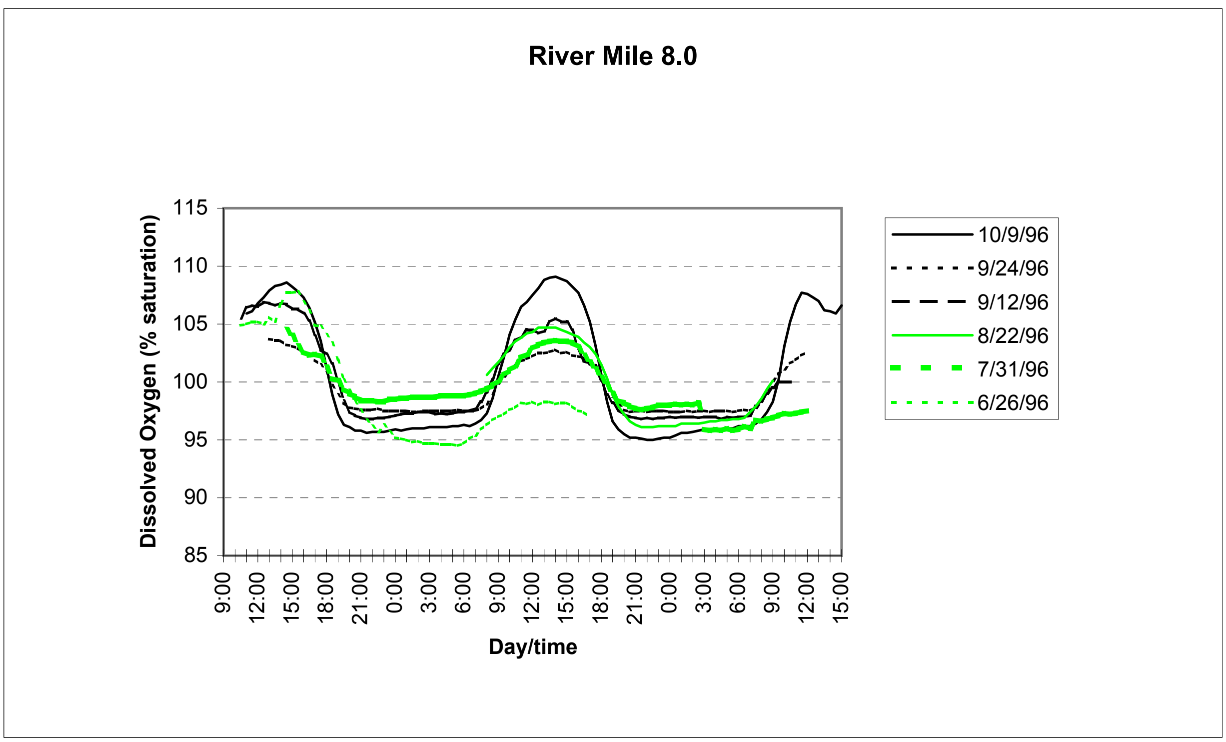
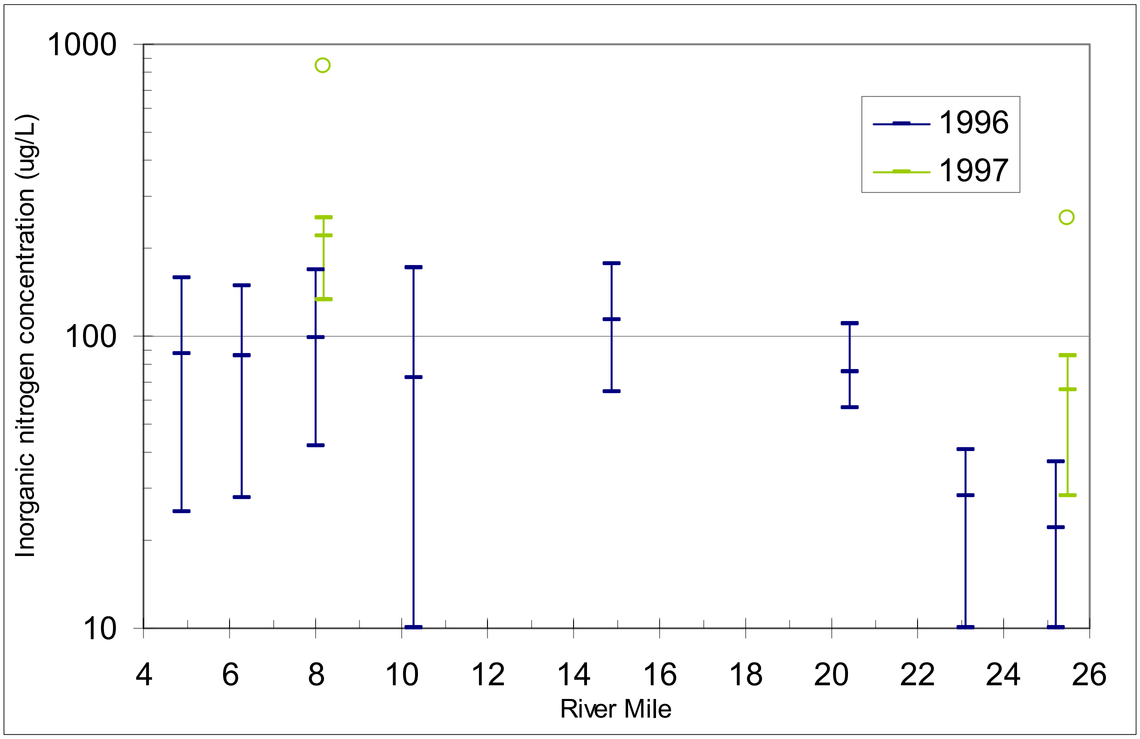


Figure 8. White River dissolved oxygen % saturation
at river miles 25.2 and 8.0, continuous data.



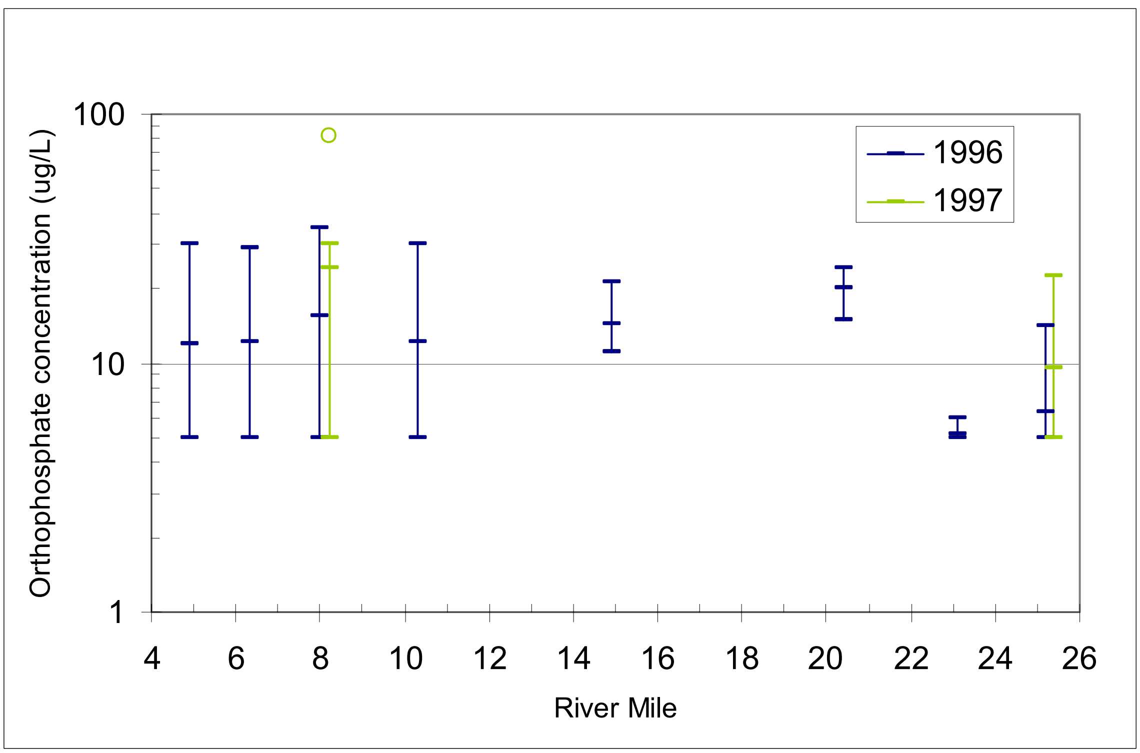


Figure 9. White River nutrient concentrations measured in 1996 and 1997, by river mile. Bars show mean, minimum, and maximum (except for outliers - circles) of data for each site.

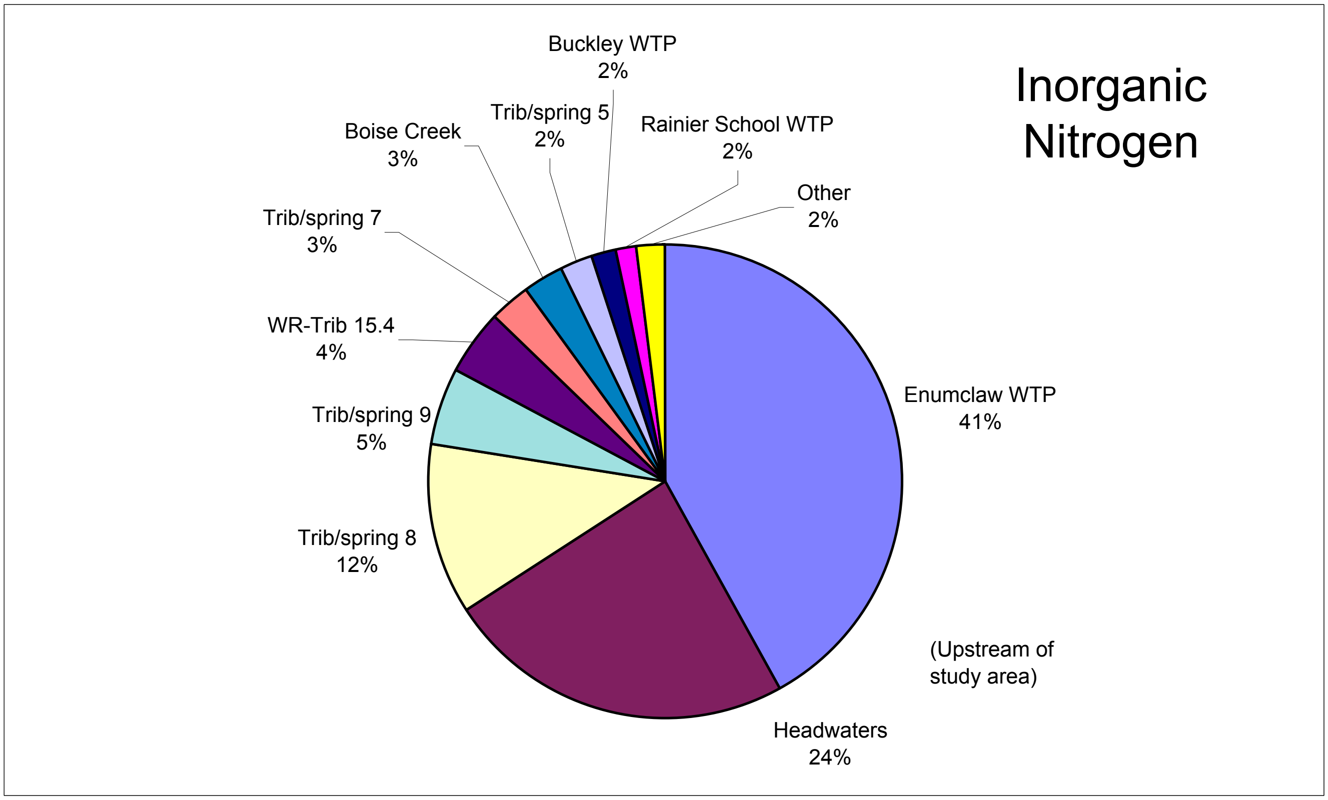
effluent). However, many factors go into determining what nutrient is most appropriate to target for reduction. Nitrogen is usually more naturally abundant and is very mobile in the environment. Also, nitrogen can be contributed to the river system from atmospheric sources. In low-nitrogen waters, nitrogen-fixing blue-green algae may become more predominant. Phosphorus is usually less abundant and more easily tied up in soil and sediments. Phosphorus is more commonly targeted for nutrient reduction to control algal biomass for fresh water systems.

The relative contributions of nutrients to the lower White River are shown in Figure 10, based on average loads for the six 1996 surveys. The tributary/spring loads are based on one set of samples from 7/31/96; therefore they may not be directly comparable to the other loads, and have a higher level of uncertainty. This figure shows that the largest contributor of both nitrogen and phosphorus is the Enumclaw wastewater treatment plant. The second largest contribution of nitrogen comes from sources upstream of the study area. Nonpoint sources of nitrogen (represented by tributaries) comprise about 31 percent of the total sources within the study area; Buckley and Rainier School wastewater treatment plants contribute only an additional 4 percent. For phosphorus, nonpoint sources in the study area are virtually absent. The Buckley wastewater treatment plant contributes about 9 percent of the total orthophosphate inputs, and Rainier School 2 percent.

Nutrient Profiles

To better understand the longitudinal pattern of nutrient concentrations, a mass balance model was used to simulate nutrient concentrations in the mainstem White River based on measured inputs. The model was developed by Greg Pelletier as part of the Puyallup Total Maximum Daily Load study (Pelletier, 1994), and divides the study area into 0.2 mile segments. The nutrient mass of each element is calculated based on the previous element concentration, plus pointload inputs, and minus nutrient uptake (set externally). The hydrodynamic elements were derived from the QUAL2E model described in Pelletier (1993). The purpose of the model was to simulate stream nutrient concentrations longitudinally based on nutrient inputs, nutrient uptake, and streamflow levels. Model calibration details are presented in Appendix E.

The result of modeling nitrogen and phosphorus for 9/24/96 is shown in Figure 11. The figure illustrates that between river miles 25 and 15, numerous sources contribute nitrogen to the river, the largest of which is the Enumclaw wastewater treatment plant. Other significant sources of nitrogen between river miles 25 and 15 include trib/spring 8, trib/spring 9, and tributary 15.4, all of which represent non-point sources. For phosphorus, only two sources are significant: Enumclaw and, to a much lesser extent, Buckley wastewater treatment plants. In contrast to the nitrogen situation, there are no significant nonpoint sources of phosphorus between river mile 25 and 15. Downstream of river mile 15, no additional sources of nutrients were observed. Nutrient concentrations declined from this point downstream due to algal uptake.



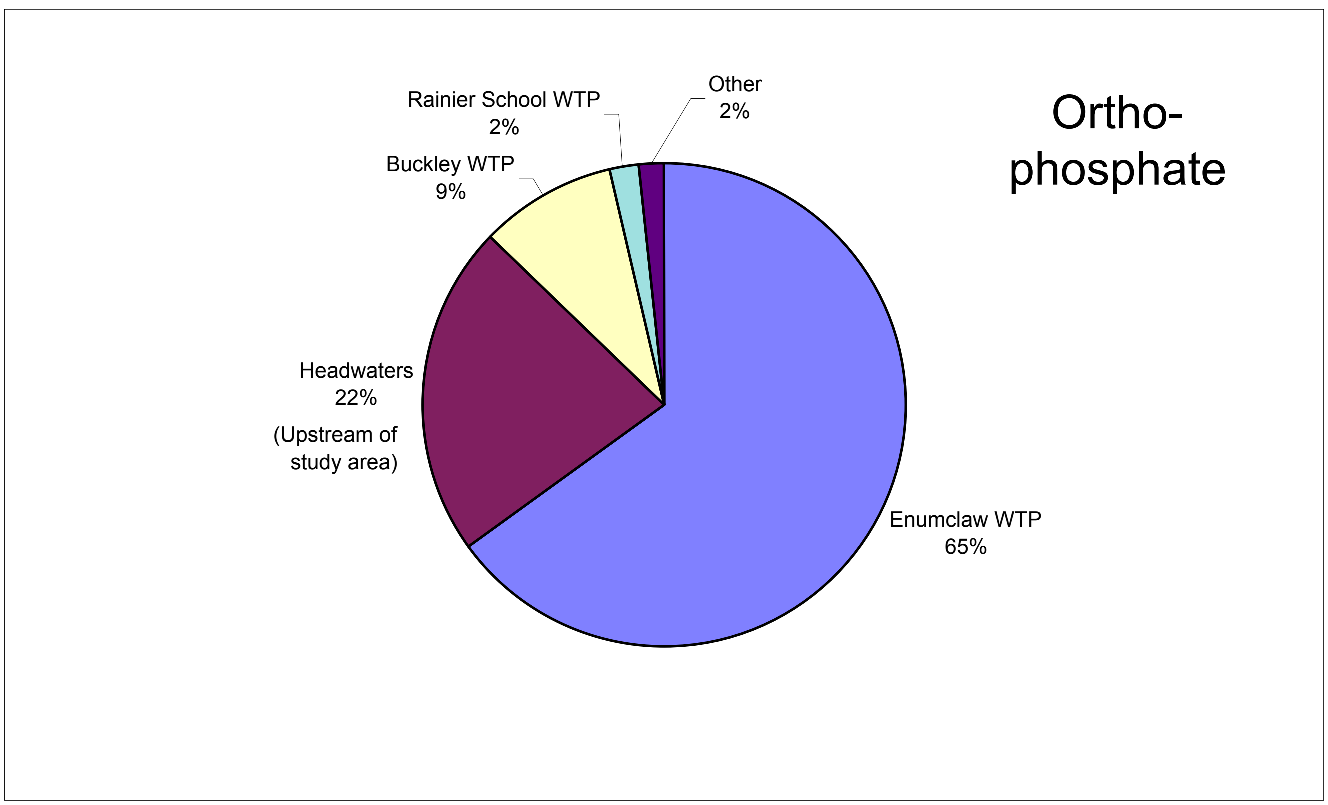


Figure 10. Relative contributions of nutrients to the lower White River. Average loads from 6 surveys in 1996 (tribs/springs one date only).

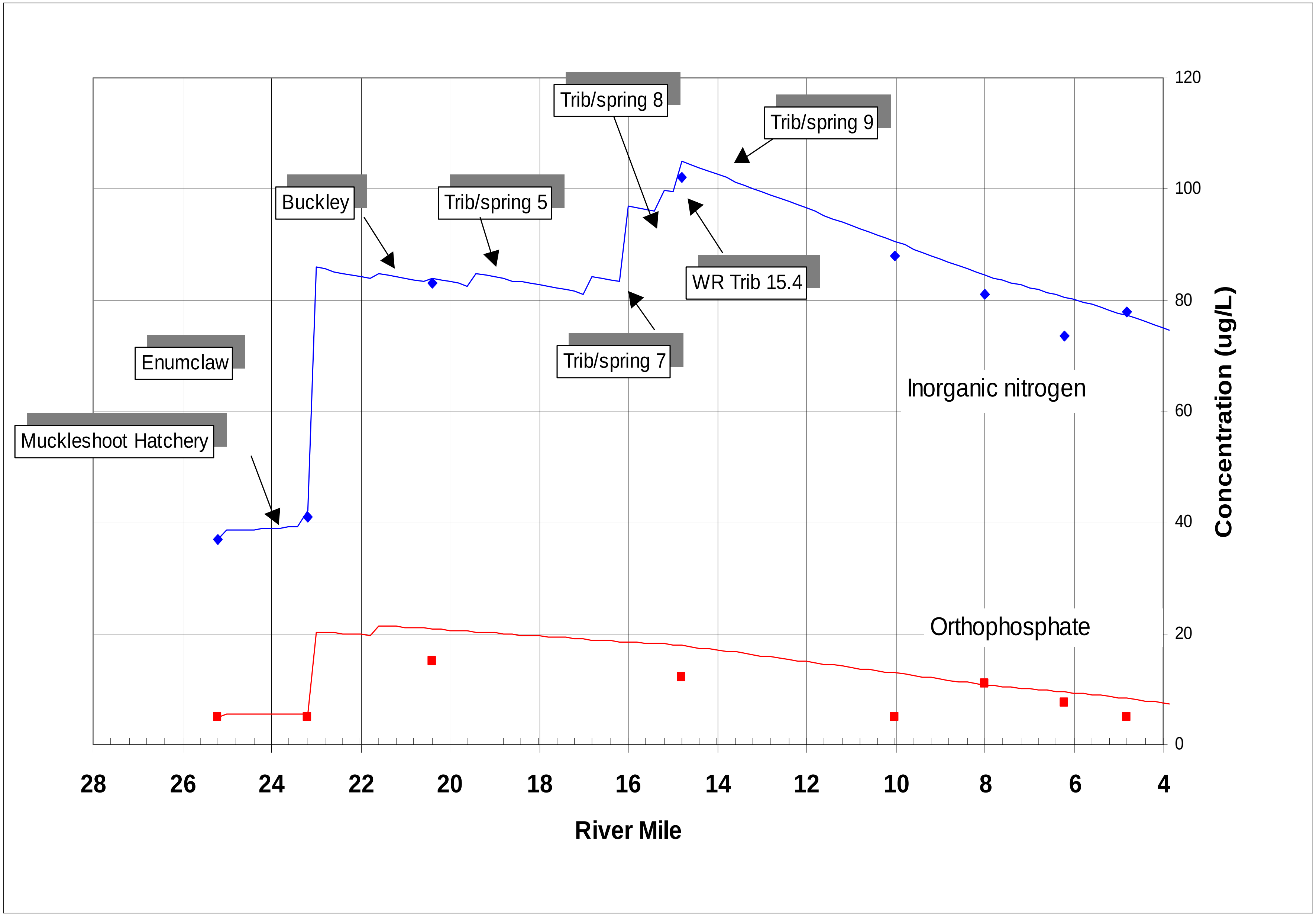


Figure 11. White River modeled (line) and measured (points) inorganic nitrogen orthophosphate for 9/24/96; streamflow = 512 cfs at river mile 23.3.

Historical Nutrient Concentrations

Figure 12 shows a time series plot of all available nitrate data for the lower White River (data combined for river miles 4.9, 6.3, and 8.0). Because much of the data is over 25 years old, comparisons between older and newer data need to be made with caution. Detection limits have decreased and quality control procedures have increased significantly over this time period.

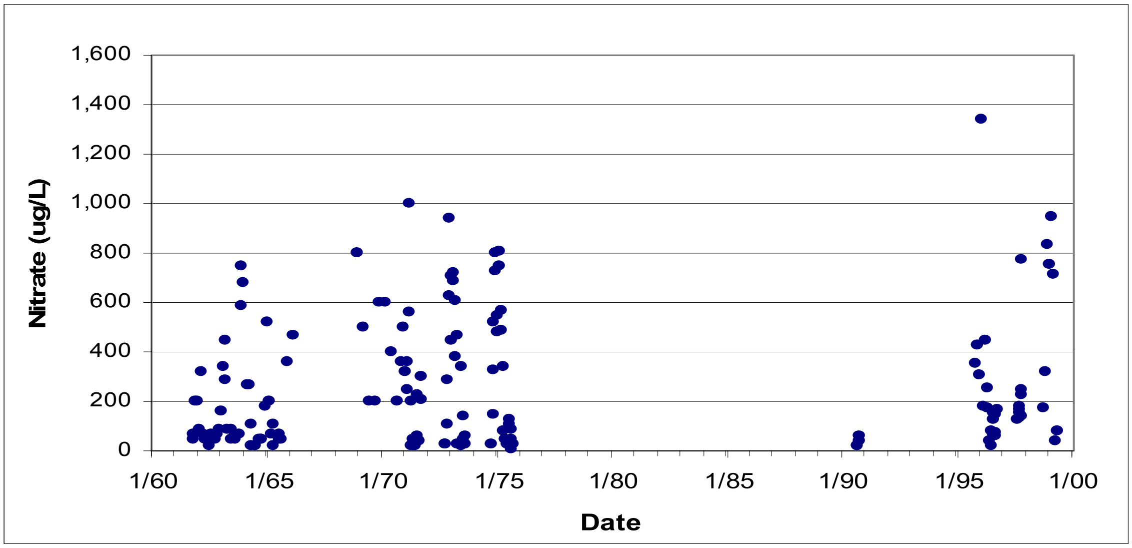


Figure 12. White River nitrate concentration time series for all available data, 1961 to 1999; combined data for river miles 4.9, 6.3, and 8.0.

Nitrate is presented here instead of inorganic nitrogen, because ammonia and nitrite values are not available for much of the period of record. However, nitrate is generally the majority of the inorganic nitrogen, averaging about 73 percent over the period of record. Figure 12 shows that the range of nitrate levels measured recently is consistent with the range of data measured in earlier years. The same comparison for phosphorus levels cannot be made because of the high number of values less than the detection limit, with decreasing detection limits over the period of record.

Figure 13 shows a box plot of the same nitrate data for the White River, grouped by month. The data show a distinct seasonal pattern, with higher nitrate values in the winter and lower values in the summer. The higher values in the winter are likely due to nutrients being washed off of the land surface by rainfall events. In the summer, uptake by periphyton contributes to lower nitrate levels.

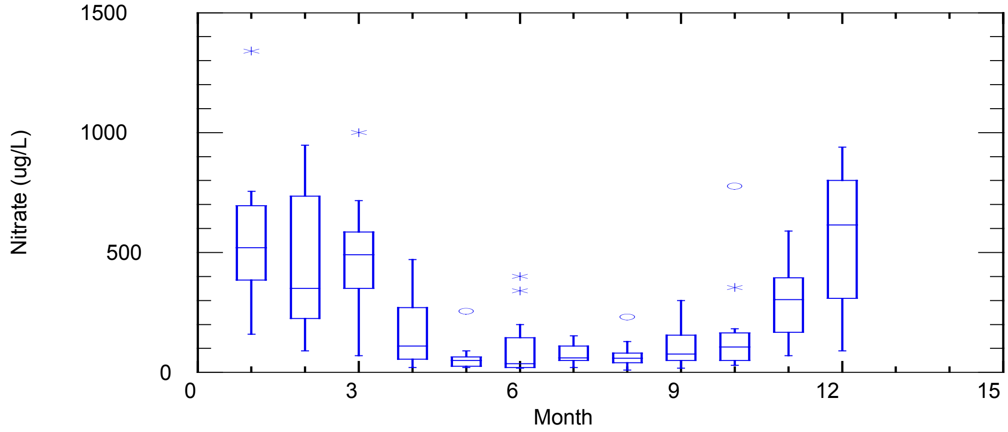


Figure 13. White River nitrate concentration box plots by month for all available data, 1961 to 1999; combined data for river miles 4.9, 6.3, and 8.0. Key to box plot on page 25.

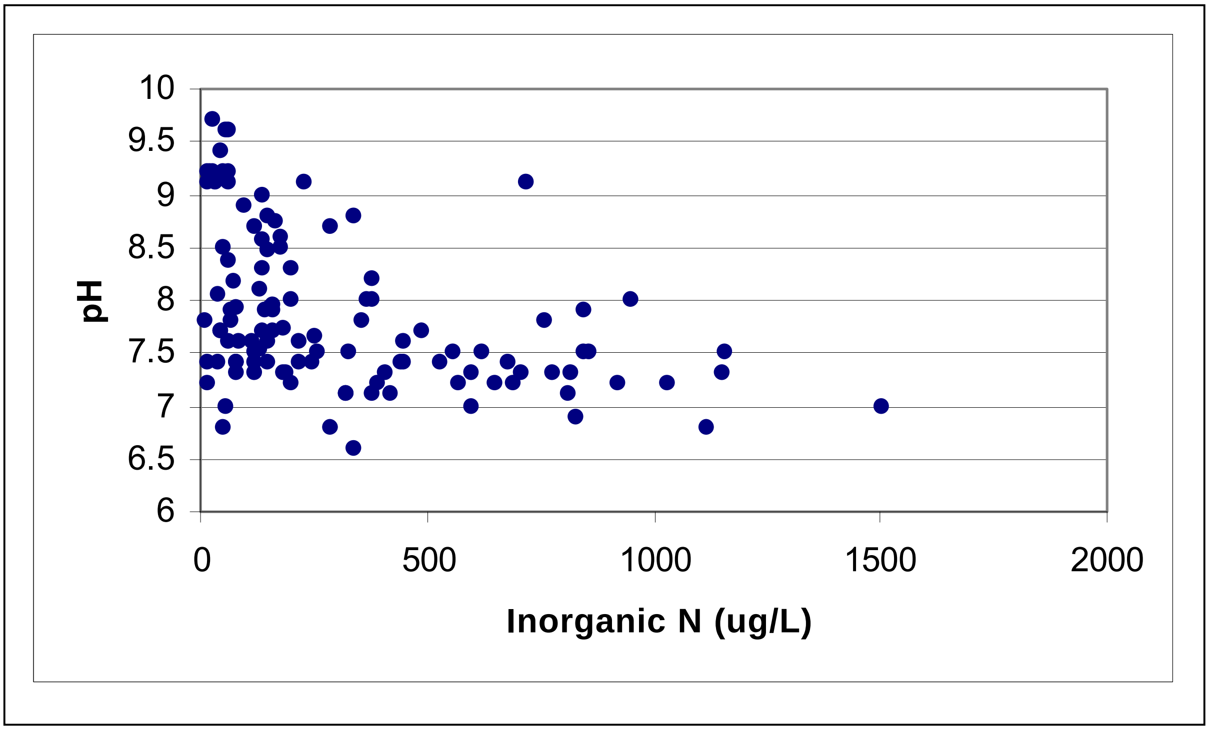
Nutrients vs. pH

pH is plotted against inorganic nitrogen and orthophosphate levels for all available data in the lower White River in Figure 14 (combined data for river miles 4.9, 6.3, and 8.0). An inverse relationship is seen: high pH corresponds generally to low nutrient values, and low pH corresponds generally to high nutrient values. When pH is high, the algae are taking up nitrogen at a relatively fast rate, depleting the available supply, thereby resulting in low concentrations in the water column. Conversely, when pH is low, nutrient uptake is also low, and water column concentrations are not reduced substantially from levels farther upstream. The relationship has a lot of scatter, however, showing that other factors in addition to nutrients are affecting pH.

Turbidity

Turbidity has the potential to influence algae growth by limiting light transmittance and, to a lesser extent, by a scouring effect (Horner *et al*., 1990). The White River, as its name implies, can be extremely turbid. Figure 15 shows historical turbidity data for the study area, as collected by Ecology's Ambient Monitoring Program (data are pooled from the four stations within the study area). A seasonal pattern of higher turbidity values in the summer months, during glacial melt, is evident. When the air temperature gets warm enough in the spring or early summer for the glaciers to start to melt, the turbidity rises. (Local residents talk about the day each June when the river "goes white".) Similarly, when cooler fall weather stops the glacial melt process, the turbidity falls again.

The turbidity readings from the 1996 survey (Figure 16) were relatively high compared to the historical range for all but the last two dates. The July reading of 250 NTU exceeded any previous value for that month. The turbidity data show a general pattern of decreasing turbidity in a downstream direction.



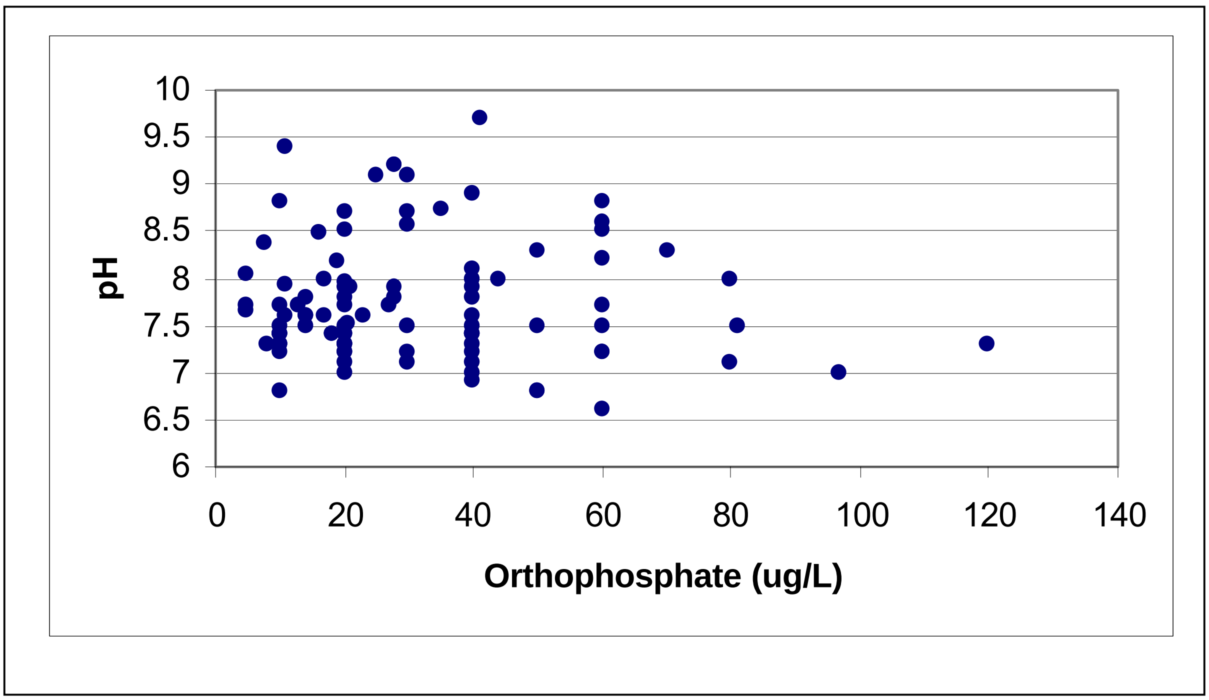


Figure 14. Lower White River pH vs. inorganic nitrogen and orthophosphate concentrations, combined data for river miles 4.9, 6,3, and 8.0.

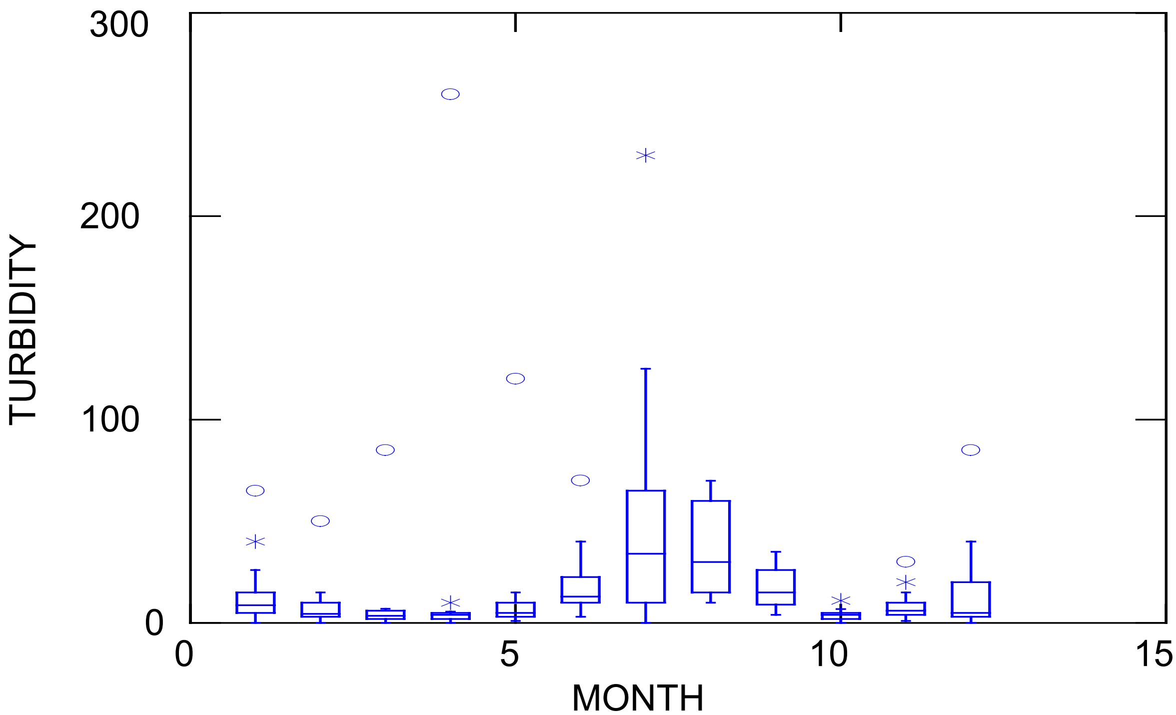
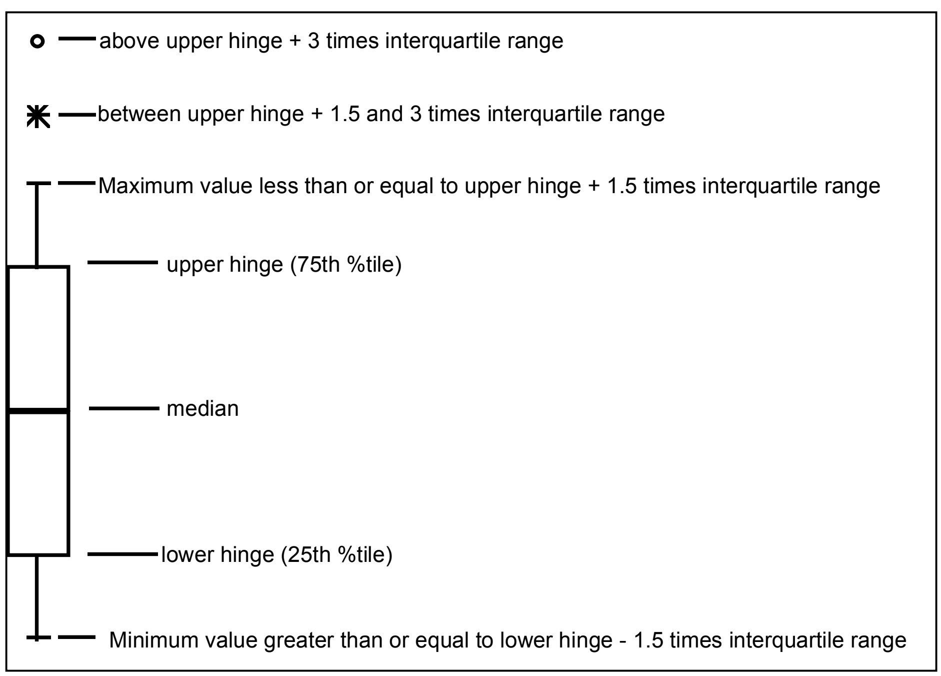


Figure 15. White River historical turbidity measurements (in NTU) within the study area, by time of year. Data from Ecology ambient stations 10C130 (river mile 23.1), 10C110 (RM 19.8), 10C090 (RM 6.3), and 10C085 (RM 4.9).

Key to box plots



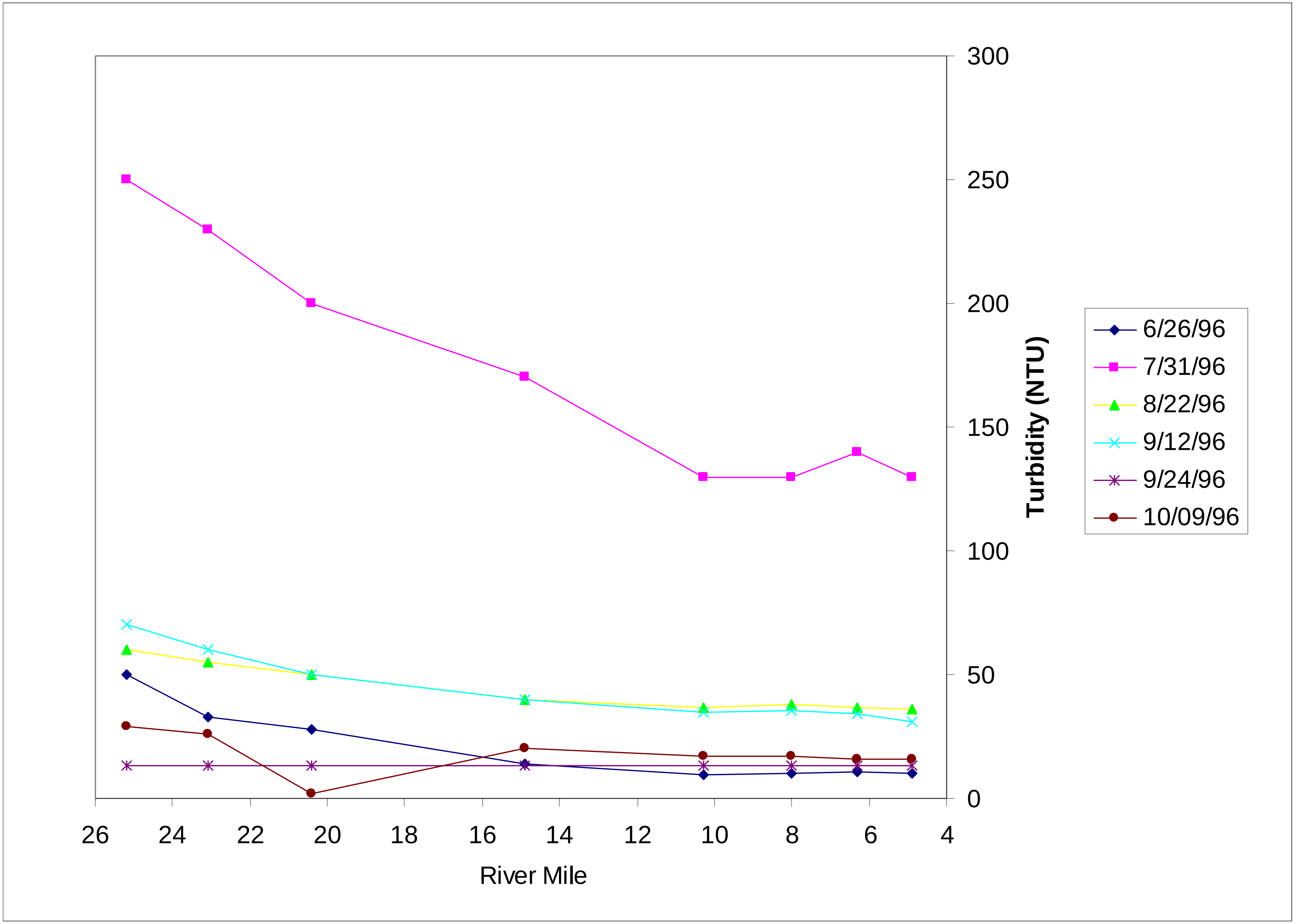


Figure 16. White River turbidity, 1996 surveys, by river mile.

The low turbidity values in October coincided with high pH readings. Conversely, in July, when the turbidity was very high, the pH levels were not elevated, despite warm and sunny conditions. Efforts to measure actual light transmittance were not successful with the available equipment; however, the light extinction coefficient can be estimated from turbidity (U.S. EPA, 1985). The critical depth, at which 1 percent of the surface radiation remains, (Thomann and Mueller, 1987) can be compared to the actual depth. Based on these relationships and an average depth, the critical turbidity is about 30 NTU. For turbidities greater than this, insufficient light would be expected to reach the benthic layer. This critical turbidity was exceeded during the July and August sampling dates at river mile 8.0.

A plot of turbidity vs. pH for all available data in the study area is shown in Figure 17, with older data (which may be less reliable) differentiated from more recent data. Based on this figure, it appears that elevated pH levels usually occur when turbidity is less than about 50 NTUs. Most occurrences of pH above the criterion of 8.5 corresponded to turbidities less than about 30 NTUs.

Alkalinity

Alkalinity affects how abruptly the pH will rise in response to carbon uptake from algae. If the alkalinity is high, the response will be muted. If the alkalinity is low, the pH rise will be magnified. Alkalinity values were consistently fairly low, ranging from 17 to 32 mg/L, with an average of 25 mg/L. The low alkalinity of these waters makes the lower White River more susceptible to pH increases as a result of carbon uptake from photosynthesis. Therefore it is also more sensitive to nutrient inputs.

Chlorophyll *a* and Periphyton

Chlorophyll *a* values in the water column were low, averaging 1.2 ug/L, indicating that phytoplankton was not a significant contributor to productivity in the study area.

Chlorophyll *a* measured in periphyton was used as the indicator of periphyton biomass (Figure 18). The figure illustrates that periphyton biomass increased downstream, from very low levels at river mile 25.2, increasing values at river mile 14.9, and the highest values at river mile 8.

Periphyton biomass was highest in October. These biomass figures are consistent with the pH results that show higher pH downstream, and higher pH in October. It should be noted that these levels of biomass are not considered high for streams in general. Periphytic algae is often considered to be at "nuisance" levels at 150 mg/m^2 (Welch *et al*., 1989), primarily due to filamentous green algae that break loose and clog water supply intake pipes and degrade the aesthetic environment. The levels in the White River are much lower than this threshold; however, they are high enough to cause elevated pH values in these low-alkalinity waters.

The periphyton community is comprised almost entirely of diatoms, with similar dominant taxa at all sites sampled (river miles 25.2, 14.9, and 8.0). Periphyton identification results are presented in Appendix F. No nuisance filamentous green algae were observed.

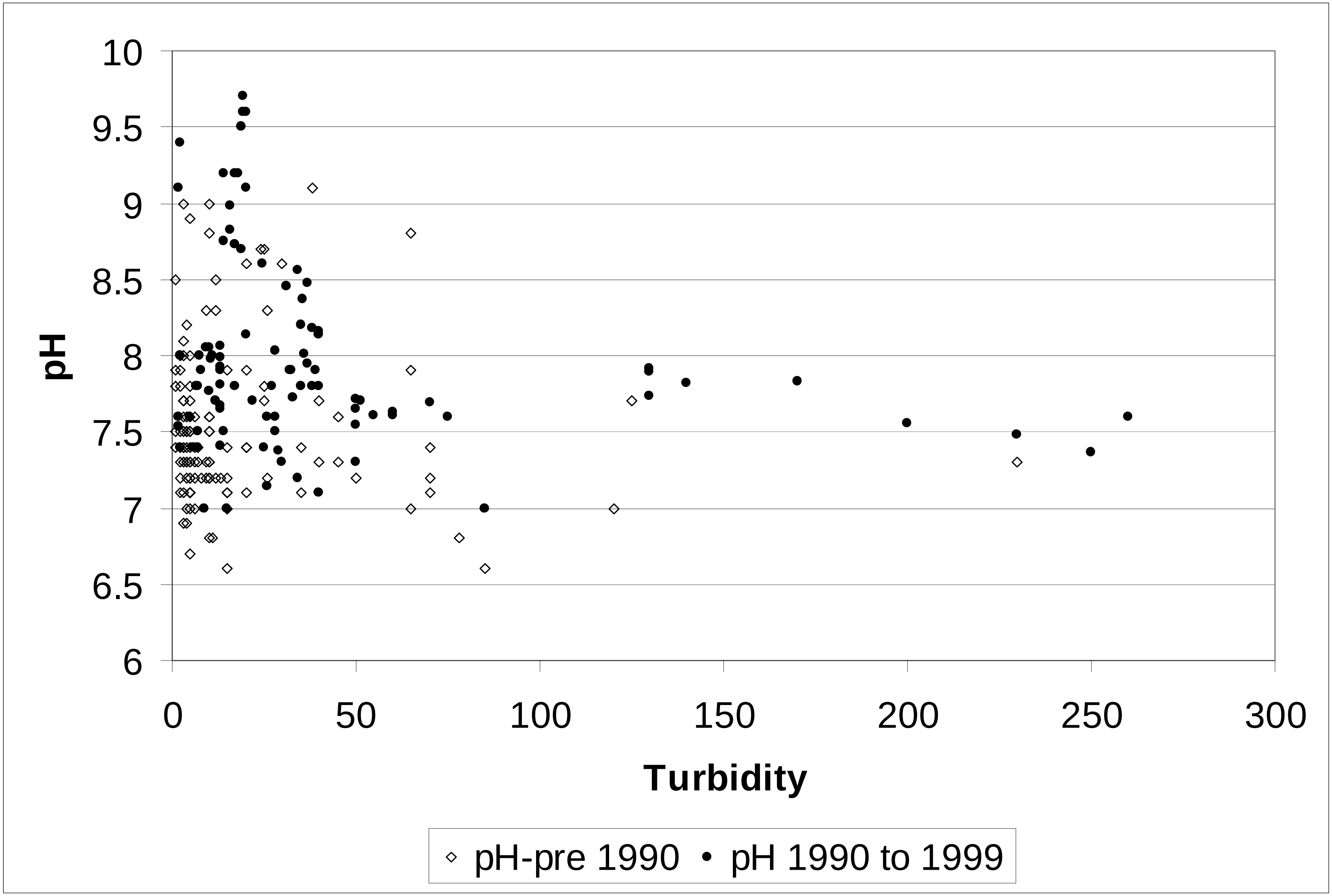


Figure 17. White River turbidity vs. pH for all available data in the study area.

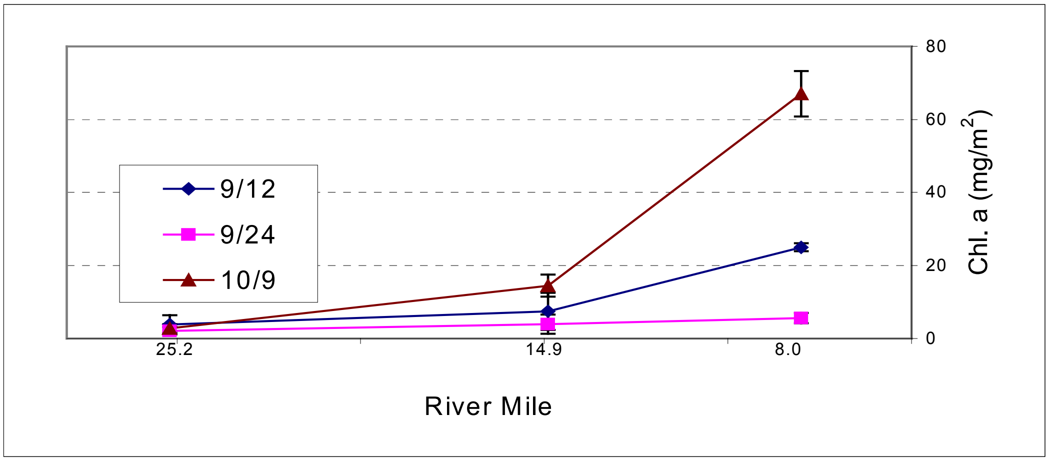


Figure 18. White River periphyton biomass (chl. a) at three sites, 1996. Graph shows mean of duplicates and one standard deviation.

Temperature

Temperature affects the rate of algae growth, with higher temperatures resulting in higher growth rates. However, the highest pH reading during the 1996 survey occurred on October 9, when the water temperature averaged 13.0° C, significantly lower that the average of 18.5° on July 31, when pH was low (and turbidity high). Therefore temperature does not appear to be the dominant factor in the pH problem. Temperature is an independent problem, however, adversely affecting aquatic life when it is too high. The temperature of the White River exceeded the state water quality standard of 18°C during the June, July, and August surveys in 1996. The lower White River is now proposed to be listed on the 1998 303(d) list for temperature.

Fecal Coliform Bacteria

The White River is listed on the 1996 and the proposed 1998 303(d) list for fecal coliform bacteria. This study was not designed to comprehensively address bacteria, because doing so would involve a different type of sampling plan, including stormwater sampling and sampling during the wet season. However, bacteria data were collected to add to the existing set of information.

The bacteria results, summarized in Table 3, show that for the mainstem and tributary sites, Boise Creek stands out as having significantly higher bacteria levels. This site did not meet the state criterion for Class A waters (geometric mean not to exceed 100 organisms/100 mL, and less than 10 percent of the samples not to exceed 200 organisms/100 mL). Of the mainstem sites, only WR23.1 violated the criterion. This site is just downstream of Boise Creek, and hence influenced by it.

Results for the point sources show that the Rainier School wastewater treatment plant was not effectively disinfecting their effluent, nor meeting their monthly and weekly permit limit of 200 and 400 organisms/100 mL, respectively. Results for the Enumclaw wastewater treatment plant ranged between 200 and 400 organisms/100 mL, with the exception of 9/24/96, when levels were 2,200 org./100 mL. The Buckley wastewater treatment plant and the White River Hatchery levels were consistently low.

Table 3. White River fecal coliform bacteria results.

Site	Geometric Mean (#/100 mL)	Percent over 100 org./200 mL	Water quality criterion violated?
Mainstem sites			
WR04.9	9	0%	
WR06.3	11	0%	
WR08.0	10	0%	
WR10.3	11	0%	
WR14.9	14	0%	
WR20.4	23	0%	
WR23.1	41	17%	Yes
WR25.2	11	0%	
Tributaries			
Boise Creek	284	83%	Yes
Bowman Creek	23	0%	
WRTRB15.4	17	0%	
WRTRB15.5	4	0%	
Point Sources			
Buckley WTP	4		
Enumclaw WTP	560		
Rainier School WTP	11954		
White River Hatchery	2		

Assimilative Capacity Analysis

As discussed in the introduction, this assimilative capacity study is the first step in developing a total maximum daily load (TMDL) for nutrients in the lower White River. The assimilative capacity defines the amount of nutrients that can be added to the White River without causing water quality standards to be violated.

The relationship between nutrients and pH is complex. The pH of the White River is determined by many factors, including the natural buffering capacity of the system (i.e. alkalinity levels) and the amount of periphyton biomass and its photosynthetic activity. On most days, natural factors limit photosynthesis so that pH does not exceed water quality standards. Those factors include: insufficient light reaching the river bottom (either due to clouds or turbidity), unsuitable temperatures for periphyton growth, or insufficient nutrients. In addition, grazing of the periphyton biomass or scouring by suspended sediment may keep periphyton biomass levels down to levels that do not cause significant pH problems. However, on some days, many or all of these factors are favorable for periphyton growth and its associated uptake of carbon, and the result is pH levels in exceedence of the standards.

Of all of the factors affecting pH, most of them are natural characteristics of the system and cannot be controlled. It is not possible to significantly change the alkalinity, incident sunlight, turbidity, water velocity, grazing by invertebrates, substratum type, or suspended sediment levels. However, if nutrient levels are kept below those needed for extensive mats of periphyton to develop, photosynthetic uptake of carbon will not cause pH to exceed standards. This assimilative capacity study determines the acceptable level of nutrients that will keep periphyton levels low enough that pH standards are not violated.

Ideally, a mathematical model would be available to make this prediction. The ideal model for this study would predict periphyton biomass over the course of the growing season and then translate that to changes in pH. Models have been developed to predict maximum biomass levels based on: nutrient concentrations, light, temperature, stream water velocity, grazing by invertebrates, substratum type, and suspended sediment (Welch *et al*., 1989). Actual biomass levels are usually lower than the predicted maximum due to less than optimum conditions in at least some of the factors influencing growth (as well as losses). Unfortunately, scientific understanding has not progressed sufficiently to be able to accurately model periphyton biomass and nutrient/carbon uptake rates for a situation such as the White River.

In the absence of an ideal model, the assimilative capacity was evaluated in two ways:

1. Comparison of upstream and downstream nutrient values and corresponding pH
2. Comparison to literature values.

1. Comparison of Upstream and Downstream Nutrient and pH Values

Figure 14, presented earlier, shows nutrient vs. pH data for the lower White River (combined data for river miles 4.9, 6.3, and 8.0). Figure 19 shows the same information for data from 1990 to 1999, focusing on the lower range of nutrient concentrations, and also includes the corresponding data for river mile 25. The tabular data corresponding to Figure 19 is presented in Appendix G, Table G-1. The figure shows that high pH can occur at relatively low nutrient concentrations, with many measurements of pH above 9.0 with inorganic nitrogen concentrations between 17 and 66 ug/L. Corresponding phosphorus data were not available for most of those same measurements, but Figure 19 shows that the orthophosphate concentration was 11 ug/L when the pH was 9.4.

These high pH readings on days with low nutrient concentrations show that there is not *evidence* of nutrient limitation at inorganic nitrogen levels as low as 17 ug/L and orthophosphate levels of 11 ug/L. This implies that nutrient concentrations would need to be lower than these levels before the lack of nutrients would be limiting periphyton growth. However, it should be noted that these high pH/low nutrient values are not *proof* that nutrient levels need to be lower than these thresholds before periphyton growth is limited. pH is representative of short-term carbon uptake and is a function of the periphyton biomass present at that time. It is possible that if nutrient concentrations were consistently low throughout the growing season, periphyton biomass would not build up sufficiently to cause pH exceedences. However, data are not available to test that scenario. Also, instantaneous photosynthetic rates are not always reflective of the corresponding instantaneous nutrient concentrations. Periphyton have been shown to be able to use previously-stored nutrients. Nevertheless, Figure 19 shows that with the existing nutrient regime in the lower White River, there is no evidence of nutrient limitation at inorganic nitrogen concentrations as low as 17 ug/L and orthophosphate concentrations as low as 11 ug/L.

Figure 19 also shows that upstream nutrient levels at river mile 25, the upstream point of the study area, are often above these indicated levels, with inorganic nitrogen often above 17 ug/L and orthophosphate often above 11 ug/L. Therefore, water coming into the study area is already at nutrient levels that have the potential to cause pH excursions in the lower portion of the river.

The implication of this figure is that there is little or no assimilative capacity for additional nutrients above the levels found at river mile 25.

2. Comparison to Literature Values

The literature shows that high biomass levels of periphyton, even mats of filamentous greens, can develop at orthophosphate concentrations as low as 10 ug/L (Welch *et al*., 1989; Welch *et al*., 1992) and substantial mats of diatoms at 1 ug/L (Bothwell, 1985. The literature shows that nutrient levels need to be very low before the growth of diatom-dominated periphyton mats is limited. These literature values also imply that there is very little, if any, assimilative capacity for additional nutrients above the levels found at river mile 25.

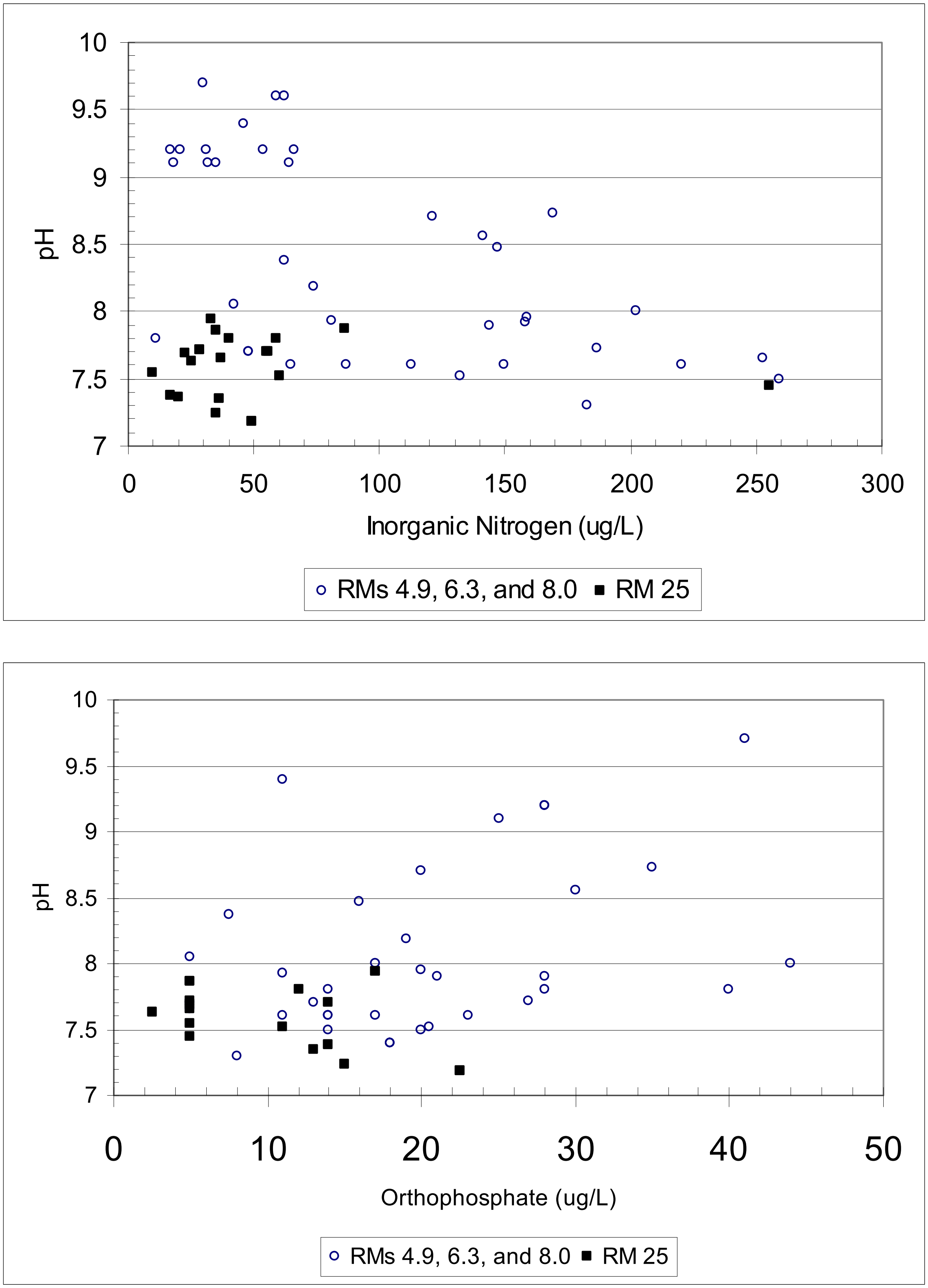


Figure 19. pH vs. inorganic nitrogen and orthophosphate concentrations for the lower White River (combined data for river miles 4.9, 6.3, and 8.0) and river mile 25.

The above analyses indicate a very limited assimilative capacity in the lower White River for nutrient inputs downstream of river mile 25. However, there is a high degree of uncertainty in determining the assimilative capacity because 1) all available data for the lower White River are for conditions where nutrients do not appear to be limiting, and 2) scientifically-proven models are not available to predict pH levels at lower nutrient levels. Therefore it is difficult to extrapolate to nutrient-limiting conditions.

Sensitivity to Streamflow Levels

As discussed in the introduction, most of the study area is located within the bypass reach of the Puget Sound Energy White River hydroelectric project. The future of the hydroelectric project, and associated minimum instream flows, is currently being debated. Higher streamflows in the bypass reach provide additional dilution of nutrient inputs from the wastewater treatment plants, tributaries, and other sources.

Unfortunately, the available evidence does not indicate that higher streamflows would be sufficient to keep pH from exceeding water quality standards. Figure 19 shows that nutrient concentrations at river mile 25, upstream of the diversion, are often about the same as those at river mile 8 where pH exceedences occur. In September 1990, when no streamflow diversion was occurring due to flume maintenance, pH was still above 9. It is possible that higher streamflows throughout the growing season would provide enough dilution that periphyton biomass would be reduced and therefore pH exceedences also reduced. Higher streamflows may also increase scour of periphyton. Higher streamflows would also result in deeper water, which would reduce light reaching the stream bottom, especially during turbid periods, perhaps impeding periphyton growth. However, these effects are speculative in nature and there are no data to substantiate them. The available data and literature values imply that, even with no diversion of streamflow, pH exceedences would still be likely to occur.

Conclusions

The lower White River experiences elevated pH, above the criterion of 8.5, at existing nutrient concentrations. pH excursions have been recorded as early in the spring as March 24 and as late as November 10. This sensitivity to nutrients is influenced by low alkalinity, which causes a more dramatic response of pH to carbon removal than in higher alkalinity waters.

For the purposes of limiting nutrients in the lower White River, either nitrogen or phosphorus can be targeted. As discussed earlier, the ratio of nitrogen to phosphorus levels indicates that nitrogen is likely to be depleted first. However, it is much more difficult to make nitrogen the limiting nutrient for reducing periphyton growth than it is for phosphorus. Nitrogen is usually more naturally abundant and is very mobile in the environment. Also, nitrogen can be contributed to the river system from atmospheric sources. In low-nitrogen waters, nitrogen-fixing blue-green algae may become more predominant. Phosphorus is usually less abundant and more easily tied up in soil and sediments. Phosphorus is the nutrient that should be targeted for nutrient reduction to address pH exceedences in the lower White River.

The largest contributor of pollutant loading for phosphorus is the Enumclaw wastewater treatment plant (65 percent). The Buckley wastewater treatment plant also contributes a significant amount of phosphorus (9 percent). Upstream sources contribute 22 percent of phosphorus. These upstream sources are a combination of natural and nonpoint sources.

The assimilative capacity for the White River downstream of river mile 25 is very low. The available data and scientific tools do not allow a precise loading capacity to be determined with certainty.

Recommendations

Phosphorus levels in the lower White River need to be reduced to the point that pH is no longer exceeding water quality standards. Available data and literature values indicate that very substantial reductions are necessary. The final TMDL for the lower White River, in order to be approved by the U.S. Environmental Protection Agency (EPA), must be protective of the state water quality standard for pH. The Clean Water Act states that technical uncertainty must be compensated with a higher margin of safety. One way to be compliant with the Clean Water Act would be to set the assimilative capacity for phosphorus inputs from human-related sources to zero, and allow no pollutant loadings from point and nonpoint sources in the study area.

Another option is to approach the necessary phosphorus reductions incrementally. For example, start by implementing substantial phosphorus reductions, and monitor resulting pH. If pH continued to exceed standards, additional reductions would be needed. This could be considered an example of using adaptive management in reaching the water quality standard. As a starting point, phosphorus loads should be reduced at least 50 percent from their current levels.

There are a variety of ways that phosphorus could be reduced incrementally in the Lower White River. The major stakeholders in the watershed should participate in developing and assessing alternative phosphorus reduction strategies.

The Department of Ecology will be working with the cities of Enumclaw and Buckley, Rainier School, the Muckleshoot and Puyallup Tribes, EPA, and other stakeholders to identify alternative adaptive management strategies for reducing phosphorus inputs by at least 50% to the lower White River. Alternatives will be evaluated in terms of feasibility, cost, and benefits. The analysis of alternatives will also need to take into account the uncertainty associated with the assimilative capacity estimate. For example, alternatives will be evaluated in terms of the risk associated with over or underestimating the assimilative capacity in terms of sunk costs, environmental harm, etc. The preferred alternative will be selected from the range of alternatives considered, and include specific wasteload allocations for the existing point sources and load allocations for the nonpoint sources in the study area. The allocations would be included in the final TMDL for the lower White River.

References

Bothwell, M., 1989. *Phosphorus-Limited Growth Dynamics Of Lotic Periphytic Diatom Communities: Areal Biomass And Cellular Growth Rate Responses*. Can. J. Fish Aquat. Sci. 46: 1293-1301.

Emmett, K., 1995. Needs Assessment for the South Puget Sound Water Quality Management Area. Washington Department of Ecology, Olympia, WA. Publication number WQ-95-64.

Erickson, K., 1996. Assessment of pH Response to Nutrient Loading in the White River, Final Quality Assurance Project Plan. Washington Department of Ecology, Olympia, WA.

European Inland Fisheries Advisory Commission, 1969. *Water Quality Criteria for European Freshwater Fish - Extreme pH Values and Inland Fisheries*. Prepared by EIFAC Working Party on Water Quality Criteria for European Freshwater Fish. Water Research, 3:593.

Fisheries, 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound Region. Washington Department of Fisheries, Olympia, WA.

Hall, C. and R. Moll, 1975. *Methods of Assessing Aquatic Primary Productivity*. In Primary Productivity of the Biosphere, edited by Helmut Lieth and Robert Whittaker. Pringer-Verlag New York Inc., New York, NY.

Horner, R., E. Welch, M. Seeley, and J. Jacoby, 1990. *Responses of Periphyton to Changes in Current Velocity, Suspended Sediments and Phosphorus Concentration*. Freshwater Biology, 24:215-232.

Ladley, R., B. Smith, and M. MacDonald, 1996. White River Spring Chinook Migratory Behavior Investigation. Puyallup Tribe Fisheries Division, Puyallup, WA.

MEL, 1994. Manchester Environmental Laboratory, Lab Users Manual. Washington Department of Ecology, Environmental Investigations and Laboratory Services, Manchester Environmental Laboratory, Port Orchard, WA.

Pelletier, G., 1993. Puyallup River Total Maximum Daily Load for Biochemical Oxygen Demand, Ammonia, and Residual Chlorine. Washington Department of Ecology, Olympia, WA.

Pelletier, G., 1994. Addendum to the 1993 Puyallup River TMDL Report. Memo from Greg Pelletier to Bill Backous, dated 7/22/94. Washington Department of Ecology, Olympia, WA.

Piper, R., I. McElwain, L. Orme, J. McCraren, L. Fowler, and J. Leonard, 1982. Fish Hatchery Management. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Stumm, W. and J. Morgan, 1981. Aquatic Chemistry; An Introduction Emphasizing Chemical Equilibria in Natural Waters. John Wiley & Sons, Inc., New York, NY.

Thomann, R. and J. Mueller, 1987. Principles of Surface Water Quality Modeling and Control. Harper Collins Publishers, New York, NY.

U.S. EPA, 1985. Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants, Part II, EPA/600/6-85/002b. United States Environmental Protection Agency, Office of Research and Development, Athens, Georgia.

U.S. EPA, 1986. Quality Criteria for Water, 1986. U.S. Environmental Protection Agency, EPA-440/5-86-001. United States Environmental Protection Agency, Division of Water, Washington, DC.

USGS, 1995. Water Resources Data, Washington, Water Year 1994. U.S. Geological Survey Water-Data Report WA-94-1. U.S. Department of the Interior, U.S. Geological Survey, Tacoma, WA.

WAS, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Washington Department of Ecology, Olympia, WA.

WDF&W, Puyallup Indian Tribe, and Muckleshoot Indian Tribe, 1996. Recovery Plan for White River Spring Chinook Salmon. Washington Department of Fish and Wildlife, Olympia, WA.

Welch, E., R. Horner, and C. Patmont, 1989. *Prediction of Nuisance Periphytic Biomass: A Management Approach*. Wat. Res. Vol. 23, pp. 401-405.

Welch, E., J. Quinn, and C. Hickey, 1992. *Periphyton Biomass Related to Point-Source Nutrient Enrichment in Seven New Zealand Streams*. Wat. Res. Vol. 26, No. 5, pp. 669-675.

Appendices

Appendix A

Historical Data

Table A-1. Puyallup River TMDL data in study area (does not include BOD and metals data).
Source: Pelletier, 1993.

Station Name	Date	Time	FLow cfs	Temp-erature degC	pH S.U.	Diss. Oxygen mg/L	Nitrate+ Nitrite-N mgN/L	Ammonia-N mgN/L	Total Persulf. N mgN/L	Soluble Reactive P mgP/L	Total P mgP/L	Alka-linity mgCaCO3/L	Fecal Coliform #/100mL	
WHI25.2	9/18/90	1330	----	13.1	7.8	10.6	0.041	0.018	0.065	0.012	0.108	21	6	
WHI23.1	9/18/90	1420	----	14	7.9	10.5	0.040	0.011	0.073	0.013	0.103	22	14	
BOWMAN	9/18/90	1420	0.55	14.9	7.9	9.6	0.052	0.012	0.191	0.011	0.022	26.9	46	
WHI20.4	9/18/90	1500	----	14.6	7.9	10.4	0.074	0.014	0.113	----	0.111	----	11	
WTR15.0	9/18/90	1510	0.33	10.3	6.5	8.8	7.508	0.005	7.595	0.043	0.058	46.1	3	
WHI10.3	9/18/90	1610	----	16.7	8.7	10.4	0.025	0.012	0.075	0.027	0.078	25.4	----	
BOI05.8	9/18/90	1625	1.8	12.9	7.3	9.8	0.278	0.004	0.331	0.011	0.012	22.8	29	
WHI08.0	9/18/90	1650	----	17.2	9.1	10.5	0.018	0.017	0.092	----	0.074	----	3	U
BOI00.1	9/18/90	1710	6.4	15.2	7.6	9.5	0.281	0.029	0.664	0.023	0.047	53.3	830	
WHI06.3	9/18/90	1720	----	17.4	9.2	10.5	0.016	0.015	0.072	----	0.076	----	11	
WHI04.9	9/18/90	1740	----	17.5	9.2	10.5	0.008	0.013	0.061	0.028	0.073	25.8	6	
BUCKLEY	9/18/90	COMP	0.35	----	----	----	0.183	0.624	1.663	6.591	6.633	110	3	
ENUMCLAW	9/18/90	COMP	1.1	----	----	----	14.820	0.608	16.780	5.696	6.440	114	700	H
RAINSCH	9/18/90	COMP	0.17	----	----	----	3.751	4.923	9.570	0.111	3.064	72	2900	H
BOI00.1	9/19/90	1025	6.4	12.4	8.4	10.4	0.247	0.010	0.338	----	0.033	----	----	
MUCTRBEFF	9/19/90	1125	1.9	11.5	7.5	10.8	0.224	0.099	0.451	0.026	0.038	31.1	----	
BOI05.8	9/19/90	1130	2.3	12	7.6	9.6	0.295	0.005	0.334	----	0.012	----	----	
WHI25.2	9/19/90	1440	----	12.7	7.8	10.6	0.033	0.007	0.060	----	0.114	20.6	----	
WHI23.1	9/19/90	1510	----	14.3	7.8	10.5	0.042	0.016	0.083	----	0.109	23	----	
WHI20.4	9/19/90	1540	----	14.2	7.9	10.5	0.074	0.013	0.104	----	0.112	----	----	
WHI10.3	9/19/90	1640	----	16.4	8.6	10.5	0.021	0.016	0.068	----	0.083	25.4	----	
WHI08.0	9/19/90	1700	----	16.8	9.1	10.5	0.017	0.015	0.065	----	0.079	----	----	
WHI06.3	9/19/90	1730	----	17	9.1	10.6	0.010	0.008	0.061	----	0.076	----	----	
WHI04.9	9/19/90	1750	----	16.8	9.2	10.5	0.003	0.014	0.056	0.028	0.068	25.6	6	
BUCKLEY	9/19/90	COMP	0.36	----	----	----	0.186	0.381	1.434	----	5.851	106	----	
ENUMCLAW	9/19/90	COMP	1.12	----	----	----	15.880	0.477	18.210	----	6.511	105	----	
RAINSCH	9/19/90	COMP	0.17	----	----	----	3.294	4.557	9.347	----	2.849	65.4	----	
BUCKLEY	9/19/90	COMP	0.36	----	----	----	0.480	0.016	1.153	----	6.243	----	----	
ENUMCLAW	9/19/90	COMP	1.1	----	----	----	15.130	0.309	17.160	----	7.258	----	----	
MUCTRBEFF	9/20/90	1400	2	12	7.5	10.6	0.232	0.127	0.473	----	0.029	30.9	----	
WHI25.2	10/2/90	820	----	8.7	7.7	11.3	0.040	0.016	0.064	0.014	0.161	21	3	
WHI23.1	10/2/90	840	----	9	7.8	11.4	0.045	0.008	0.088	0.015	0.106	26	34	S
WHI20.4	10/2/90	920	----	9.2	7.8	11.5	0.082	0.028	0.110	0.042	0.100	----	38	
WHI14.9	10/2/90	1020	----	9.9	8.6	12.3	0.110	0.019	0.155	----	0.087	----	35	
WHI10.3	10/2/90	1310	----	11.6	9.5	13.4	0.042	0.016	0.117	0.043	0.086	28	5	
WHI08.0	10/2/90	1340	----	12	9.6	12.4	0.041	0.021	0.111	----	0.086	----	3	
WHI06.3	10/2/90	1400	----	12.2	9.6	12.3	0.039	0.020	0.110	----	0.088	----	3	
WTR15.0	10/2/90	1410	1.4	10.3	6	9.5	7.331	0.003	7.508	0.038	0.064	----	1	
BOI05.8	10/2/90	1500	1.6	10.6	6.9	10.8	0.282	0.004	0.332	0.017	0.013	----	5	
BOI00.1	10/2/90	1600	5.3	11.4	7.9	10.4	0.219	0.006	0.331	0.015	0.027	----	260	
WHI04.9	10/2/90	1840	----	12.9	9.7	11.0	0.012	0.018	0.093	0.041	0.075	30	4	
BUCKLEY	10/2/90	COMP	0.35	----	----	----	1.455	0.212	3.600	6.424	6.680	90	3	
ENUMCLAW	10/2/90	COMP	1.1	----	----	----	15.500	1.154	18.880	7.743	7.729	----	110	
RAINSCH	10/2/90	COMP	0.22	----	----	----	3.201	4.527	9.803	2.737	3.099	60	100	
WHI25.2	10/3/90	800	----	9.2	7.7	11.1	0.043	0.012	0.158	----	0.078	22	17	
WHI23.1	10/3/90	830	----	9.6	7.7	11.1	0.062	0.018	0.121	----	0.056	26	52	
WHI20.4	10/3/90	900	----	9.8	7.6	11.0	0.102	0.013	0.268	----	0.081	----	43	
WHI14.9	10/3/90	1000	----	10.5	7.8	11.2	0.162	-0.001	0.248	----	0.085	----	16	
MUCTRBEFF	10/3/90	1105	1.6	11.1	7.6	10.9	0.235	0.062	0.383	0.018	0.029	30	----	
BOI00.1	10/3/90	1245	8.1	12.1	7.8	9.7	0.257	0.003	0.404	----	0.032	----	800	
BOI05.8	10/3/90	1330	4.2	11.3	7.8	10.7	0.266	0.003	0.327	----	0.023	----	170	S
WHI10.3	10/3/90	1345	----	12.1	9.1	12.3	0.071	0.001	0.153	----	0.071	30	10	
WHI08.0	10/3/90	1415	----	12.5	9.2	12.1	0.063	0.003	0.141	----	0.078	----	16	
WHI06.3	10/3/90	1430	----	12.8	9.1	11.6	0.051	0.013	0.124	----	0.072	----	40	
BOWMAN	10/3/90	1450	0.17	12.5	7.4	9.4	0.068	0.004	0.206	0.006	0.015	----	96	
WHI04.9	10/3/90	1645	----	13.5	9.2	11.3	0.046	0.009	0.156	----	0.070	32	24	
BUCKLEY	10/3/90	COMP	0.34	----	----	----	2.916	0.124	3.706	----	6.397	88	3	
ENUMCLAW	10/3/90	COMP	1.1	----	----	----	14.740	0.233	17.060	----	7.173	96	3000	J
RAINSCH	10/3/90	COMP	0.13	----	----	----	3.368	4.828	10.620	----	3.723	68	170	
MUCTRBEFF	10/4/90	1340	1.9	11.1	7.4	10.9	0.256	0.097	0.535	----	0.046	34	----	

Periphyton Data:		Depth (ft)	Vel. (fps)	TOC (mg/L)	TP (mg/L)	TN (mg/L)	Chl. A (ug/L)
WHI20.4	9/25/91	1.2	0.93	10.3	2.6	1.00	204
WHI20.4-rep	9/25/91	1.2	0.92	13.3	1.7	1.91	398
WHI23.3	9/25/91	0.9	1.18	20.2	2.5	3.39	374
WHI23.3-rep	9/25/91	0.9	1.25	17.4	2.8	3.04	264
WHI25.2	9/25/91	1.1	1.02	10.1	5.4	0.87	87.3
WHI25.2-rep	9/25/91	1.1	0.96	9.6	6.5	0.92	91.9

Table A-1. Puyallup River TMDL data in study area (does not include BOD and metals data).
Source: Pelletier, 1993.

Station Name	Date	Klebsiella % of FC	Turbidity NTU		Specific Conductance um/cm25C	Chloride mg/L	Total Susp. Solids mg/L		Total Organic Carbon mg/L	Chlorophyll A µg/L		Pheopigments µg/L	
WHI25.2	9/18/90	BDL	35		67	1.56	82		2.89	0.63		0.91	
WHI23.1	9/18/90	50	32		69	1.62	68		2.67	----		----	
BOWMAN	9/18/90	----	1.8	J	70	1.13	4		7.85	----		----	
WHI20.4	9/18/90	----	32.5		74	2.29	61		2.86	----		----	
WTR15.0	9/18/90	----	1	U	208	9.74	1	U	5.57	----		----	
WHI10.3	9/18/90	BDL	19		83	2.61	29		2.84	----		----	
BOI05.8	9/18/90	89	1	U	54	1.66	1	U	2.56	----		----	
WHI08.0	9/18/90	----	20		83	2.57	24		2.76	----		----	
BOI00.1	9/18/90	----	2		114	1.9	3		3.63	----		----	
WHI06.3	9/18/90	----	18		83	2.51	44		2.11	----		----	
WHI04.9	9/18/90	BDL	17		83	2.51	23		1.56	5.87		5.32	
BUCKLEY	9/18/90	----	1.4		736	32.9	2		13.6	----		----	
ENUMCLAW	9/18/90	----	4.9		894	149	7		21.9	----		----	
RAINSCH	9/18/90	----	6.7	J	274	15.4	5		27.6	----		----	
BOI00.1	9/19/90	----	----		116	----	1	U	3.98	----		----	
MUCTRBEFF	9/19/90	----	1	U	95	1.75	1		4.22	----		----	
BOI05.8	9/19/90	----	----		53	----	1		3.11	----		----	
WHI25.2	9/19/90	----	35		66	1.59	72		2.61	----		----	
WHI23.1	9/19/90	----	----		68	----	68		2.65	----		----	
WHI20.4	9/19/90	----	----		73	----	59		2.13	----		----	
WHI10.3	9/19/90	----	----		84	----	24		2.79	----		----	
WHI08.0	9/19/90	----	----		83	----	24		2.49	----		----	
WHI06.3	9/19/90	----	----		83	----	26		2.11	----		----	
WHI04.9	9/19/90	BDL	----		84	----	23		2.03	2.85	J	2.54	J
BUCKLEY	9/19/90	----	----		397	----	1	U	11.7	----		----	
ENUMCLAW	9/19/90	----	----		1132	----	8		20.6	----		----	
RAINSCH	9/19/90	----	----		252	----	6		20.7	----		----	
BUCKLEY	9/19/90	----	----		----	----	----		----	----		----	
ENUMCLAW	9/19/90	----	----		----	----	----		----	----		----	
MUCTRBEFF	9/20/90	----	----		96	----	1		3.72	----		----	
WHI25.2	10/2/90	0	51.5		70.5	1.73	140		2.02	0.44		0.41	
WHI23.1	10/2/90	0	38		77.2	1.82	69		3.42	----		----	
WHI20.4	10/2/90	----	27		85.4	2.38	28		2.95	----		----	
WHI14.9	10/2/90	----	24.5		91.8	2.43	14		3.87	----		----	
WHI10.3	10/2/90	20	19		92.2	2.5	11		3.12	----		----	
WHI08.0	10/2/90	----	19.5		92.3	2.54	11		3.54	----		----	
WHI06.3	10/2/90	----	20		92.3	2.54	10		3.14	----		----	
WTR15.0	10/2/90	----	1	U	209	8.92	3		4.87	----		----	
BOI05.8	10/2/90	33	1	U	54.9	1.74	11		1.77	----		----	
BOI00.1	10/2/90	----	1	U	117	1.71	1		2.32	----		----	
WHI04.9	10/2/90	0	19.5		93.6	2.42	10		3.14	1.67		2.75	
BUCKLEY	10/2/90	----	1	U	391	33.4	1		13.1	----		----	
ENUMCLAW	10/2/90	----	4.2	J	739	99.4	8		22.9	----		----	
RAINSCH	10/2/90	----	7.1	J	262	15.7	11		26.6	----		----	
WHI25.2	10/3/90	6	22		78.3	1.78	53		1.88	----		----	
WHI23.1	10/3/90	3	----		82.6	----	29		2.62	----		----	
WHI20.4	10/3/90	----	----		88.8	----	19		2.52	----		----	
WHI14.9	10/3/90	----	----		97.2	----	13		2.93	----		----	
MUCTRBEFF	10/3/90	----	1	U	101	1.85	1	U	2.99	----		----	
BOI00.1	10/3/90	----	1		120	----	3		5.55	----		----	
BOI05.8	10/3/90	0	3.6		54.5	----	4		2.89	----		----	
WHI10.3	10/3/90	10	----		96.9	----	10		2.89	----		----	
WHI08.0	10/3/90	----	----		97.1	----	10		3.18	----		----	
WHI06.3	10/3/90	----	----		97.4	----	10		2.9	----		----	
BOWMAN	10/3/90	----	1	U	92.4	----	1		4.7	----		----	
WHI04.9	10/3/90	0	14		97.7	----	11		3.12	2.44	J	4.12	
BUCKLEY	10/3/90	----	----		390	----	1		8.02	----		----	
ENUMCLAW	10/3/90	----	----		1030	----	11		10.9	----		----	
RAINSCH	10/3/90	----	----		268	----	8		26.3	----		----	
MUCTRBEFF	10/4/90	----	----		102	----	1		2.67	----		----	

Periphyton Data:

WHI20.4	9/25/91
WHI20.4-rep	9/25/91
WHI23.3	9/25/91
WHI23.3-rep	9/25/91
WHI25.2	9/25/91
WHI25.2-rep	9/25/91

Table A-2. Department of Ecology Ambient Monitoring Data within the study area.

Station 10C085 White River, river mile 4.9

DATE	TIME	TEMP	FLOW	COND	DO	PH	SS	TPN	NH3	NO2	NO3	TP	OP	TURB	FC	COLOR
(units)		(° C)	(cfs)	(umhos/cm)	(mg/L)	(st. units)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(NTU)	(#/100 mL)	(Pt-Co)
02-Dec-68		5.0	-99.0	64	11.8	7.1	-99.0	-99.000	-99.000	-99.000	0.800	-99.000	-99.000	-99.0	-99	20
17-Mar-69		8.0	-99.0	76	11.6	7.2	-99.0	-99.000	-99.000	-99.000	0.500	-99.000	-99.000	-99.0	-99	5
16-Jun-69		17.0	-99.0	44	9.4	7.0	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	-99.0	-99	5
15-Sep-69		15.8	-99.0	67	9.0	7.2	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	-99.0	-99	0
08-Dec-69		6.1	-99.0	86	11.0	7.6	-99.0	-99.000	-99.000	-99.000	0.600	-99.000	-99.000	-99.0	-99	5
09-Mar-70		7.0	-99.0	66	11.9	6.9	-99.0	-99.000	-99.000	-99.000	0.600	-99.000	-99.000	-99.0	-99	10
08-Jun-70		10.7	-99.0	45	10.8	7.4	-99.0	-99.000	-99.000	-99.000	0.400	-99.000	-99.000	-99.0	-99	10
18-Aug-70		-99.0	-99.0	67	-99.0	7.3	-99.0	-99.000	-99.000	-99.000	0.000	-99.000	-99.000	-99.0	-99	5
08-Sep-70		14.5	-99.0	68	9.0	7.5	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	-99.0	-99	20
17-Oct-74	1200	11.6	65.0	120	11.8	7.9	-99.0	-99.000	0.040	0.000	0.030	0.040	0.020	2.0	12 J	16
30-Oct-74	1245	11.1	111.0	140	12.1	7.4	-99.0	-99.000	0.070	0.010	0.150	0.040	0.020	3.0	400 L	21
14-Nov-74	1255	10.4	98.0	120	12.5	8.2	-99.0	-99.000	0.050	0.020	0.330	0.070	0.060	4.0	10 J	30
20-Nov-74	1200	9.3	175.0	120	11.2	7.0	-99.0	-99.000	0.080	0.020	0.520	0.090	0.040	4.0	60	35
11-Dec-74	1110	8.8	104.0	140	12.8	7.5	-99.0	-99.000	0.060	0.010	0.800	0.060	0.050	2.0	30	40
18-Dec-74	1235	7.4	277.0	100	12.5	7.1	-99.0	-99.000	0.080	0.020	0.730	0.060	0.040	5.0	40	54
15-Jan-75	1315	4.9	2040.0	65	13.0	7.2	-99.0	-99.000	0.140	0.010	0.550	0.080	0.010	12.0	120	56
29-Jan-75	1105	3.2	404.0	81	13.2	7.3	-99.0	-99.000	0.120	0.010	0.480	0.050	0.010	6.0	60	34
20-Feb-75	1220	4.0	620.0	92	12.9	6.8	-99.0	-99.000	0.310	0.020	0.810	0.140	0.050	11.0	1100 J	88
26-Feb-75	1200	5.8	268.0	100	12.6	6.9	-99.0	-99.000	0.080	0.010	0.750	0.050	0.040	3.0	280 J	43
12-Mar-75	1110	6.5	200.0	100	12.0	7.5	-99.0	-99.000	0.050	0.010	0.570	0.040	0.030	1.0	6 J	28
26-Mar-75	1030	6.1	178.0	110	13.4	7.4	-99.0	-99.000	0.040	0.010	0.490	0.030	0.010	2.0	1 K	31
16-Apr-75	1145	8.6	193.0	100	11.4	7.7	-99.0	-99.000	0.060	0.010	0.080	0.020	0.010	3.0	22	27
30-Apr-75	1205	14.0	132.0	110	11.3	7.3	-99.0	-99.000	0.070	0.010	0.340	0.040	0.020	2.0	1 J	27
14-May-75	1150	12.4	3280.0	52	11.0	7.4	-99.0	-99.000	0.070	0.000	0.050	0.070	0.010	15.0	12 J	18
28-May-75	1200	13.0	939.0	61	11.2	7.4	-99.0	-99.000	0.030	0.000	0.050	0.020	0.010	3.0	3 J	21
11-Jun-75	1210	13.9	1330.0	54	10.7	7.3	-99.0	-99.000	0.050	0.000	0.030	0.040	0.010	9.0	6 J	32
25-Jun-75	1220	11.4	1640.0	32	11.7	7.4	-99.0	-99.000	0.050	0.010	0.030	0.070	0.040	20.0	44	42
16-Jul-75	1155	13.3	2340.0	66	10.4	6.8	-99.0	-99.000	0.160	0.020	0.130	0.050	0.010	78.0	40 J	58
30-Jul-75	1225	14.5	142.0	78	10.4	7.2	-99.0	-99.000	0.280	0.030	0.110	0.180	0.040	50.0	10 J	50
14-Aug-75	1120	18.0	53.0	96	10.7	7.8	-99.0	-99.000	0.060	0.010	0.010	0.080	0.020	25.0	10 J	33
27-Aug-75	1155	15.0	140.0	83	10.6	7.2	-99.0	-99.000	0.110	0.010	0.090	0.060	0.020	13.0	25 J	42
04-Sep-75	1205	16.6	65.0	117	11.4	7.3	-99.0	-99.000	0.070	0.010	0.050	0.030	0.020	4.0	12 J	33
17-Sep-75	1220	15.1	49.0	112	11.5	7.9	-99.0	-99.000	0.130	0.010	0.030	0.080	0.040	15.0	20 J	33
18-Oct-95	1300	10.3	234.0	99	11.8	7.8	4.0	0.489	0.010 U	-99.000	-99.000	0.049	0.028	6.8	27	-99
21-Nov-95	1400	8.1	557.0	86	11.6	7.4	20.0	0.540	0.013	-99.000	-99.000	0.046	0.018	6.9	18	-99
19-Dec-95	1255	6.0	330.0	60	12.2	7.5	155.0	0.508	0.018	-99.000	-99.000	0.113	0.014	28.0	74	-99
24-Jan-96	1350	5.5	325.0	111	11.9	7.0	12.0	2.200	0.163	-99.000	-99.000	0.150	0.097	8.7	1900 J	-99
21-Feb-96	1255	6.1	5600.0	47	9.5	7.3	118.0	0.328	0.010 U	-99.000	-99.000	0.142	0.008	50.0	300	-99
20-Mar-96	1300	9.0	270.0	92	12.5	7.4	2.0	0.579	0.010 U	-99.000	-99.000	0.030	0.018	2.0	33	-99
24-Apr-96	1215	7.9	4120.0	53	11.6	7.6	897.0	0.628	0.048	-99.000	-99.000	0.546	0.023	260.0	1000 J	-99
22-May-96	1320	10.5	670.0	71	11.4	7.5	27.0	0.348	0.010 U	-99.000	-99.000	0.033	0.020	7.0	34	-99
19-Jun-96	1220	13.1	813.0	59	11.0	7.7	26.0	0.123	0.010 U	-99.000	-99.000	0.043	0.005	12.0	2	-99
24-Jul-96	1245	20.9	354.0	75	9.8	7.6	35.0	0.167	0.010 U	-99.000	-99.000	0.066	0.017	28.0	26 X	-99
21-Aug-96	1245	15.2	348.0	85	10.7	7.9	31.0	0.186	0.016	-99.000	-99.000	0.088	0.028	39.0	10	-99
18-Sep-96	1250	10.8	709.0	79	11.4	7.6	59.0	0.227	0.010 U	-99.000	-99.000	0.063	0.014	26.0	49	-99

Station 10C090 White River, river mile 6.3

DATE	TIME	TEMP	FLOW	COND	DO	PH	SS	TPN	NH3	NO2	NO3	TP	OP	TURB	FC	COLOR
18-Oct-61		8.8	69.0	98	12.4	7.5	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	-99.0	-99	15
08-Nov-61		10.0	69.0	101	12.6	7.8	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	-99.0	-99	10
05-Dec-61		6.0	94.0	103	11.3	7.6	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	0.0	-99	10
10-Jan-62		5.1	1110.0	61	12.3	7.0	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	65.0	-99	10
08-Feb-62		7.8	104.0	91	11.4	7.1	-99.0	-99.000	-99.000	-99.000	0.090	-99.000	-99.000	5.0	-99	10
13-Mar-62		5.9	143.0	97	14.8	7.3	-99.0	-99.000	-99.000	-99.000	0.320	-99.000	-99.000	0.0	-99	10
02-Apr-62		10.8	118.0	92	13.2	8.2	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	0.0	-99	15
07-May-62		11.2	1710.0	56	11.6	7.1	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	5.0	-99	10
11-Jun-62		14.8	2040.0	53	11.5	7.2	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	10.0	-99	5
09-Jul-62		17.5	84.0	88	9.0	7.2	-99.0	-99.000	-99.000	-99.000	0.020	-99.000	-99.000	0.0	-99	5
15-Aug-62		26.0	61.0	93	8.9	7.5	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	10.0	-99	10
05-Sep-62		17.6	57.0	57	8.4	7.1	-99.0	-99.000	-99.000	-99.000	0.000	-99.000	-99.000	15.0	-99	10
08-Oct-62		11.9	119.0	96	10.1	7.7	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	5.0	-99	10
16-Nov-62		9.0	95.0	105	12.8	7.8	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	5.0	-99	10
06-Dec-62		7.0	3140.0	46	13.1	6.6	-99.0	-99.000	-99.000	-99.000	0.090	-99.000	-99.000	85.0	-99	15
03-Jan-63		7.5	1480.0	52	10.1	7.1	-99.0	-99.000	-99.000	-99.000	0.160	-99.000	-99.000	5.0	-99	10
06-Feb-63		6.7	1950.0	70	11.9	7.2	-99.0	-99.000	-99.000	-99.000	0.340	-99.000	-99.000	15.0	-99	20
06-Mar-63		5.3	175.0	83	12.2	7.3	-99.0	-99.000	-99.000	-99.000	0.290	-99.000	-99.000	5.0	-99	10
01-Apr-63		6.0	278.0	86	11.3	7.2	-99.0	-99.000	-99.000	-99.000	0.450	-99.000	-99.000	10.0	-99	20
03-May-63		11.1	221.0	83	11.3	7.1	-99.0	-99.000	-99.000	-99.000	0.090	-99.000	-99.000	5.0	-99	15
12-Jun-63		15.0	830.0	55	10.5	7.3	-99.0	-99.000	-99.000	-99.000	0.090	-99.000	-99.000	10.0	-99	5
09-Jul-63		17.2	196.0	78	9.3	7.2	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	5.0	-99	0
13-Aug-63		16.5	467.0	82	9.0	7.2	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	70.0	-99	10
03-Sep-63		16.0	97.0	87	10.7	7.1	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	35.0	-99	20
30-Oct-63		10.0	86.0	96	11.2	7.3	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	5.0	-99	15
15-Nov-63		8.9	226.0	96	11.2	7.0	-99.0	-99.000	-99.000	-99.000	0.590	-99.000	-99.000	15.0	-99	25

Table A-2. Department of Ecology Ambient Monitoring Data within the study area.

DATE	TIME	TEMP	FLOW	COND	DO	PH	SS	TPN	NH3	NO2	NO3	TP	OP	TURB	FC	COLOR
(units)		(° C)	(cfs)	(umhos/cm	(mg/L)	(st. units)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(NTU)	(#/100 mL)	(Pt-Co)
09-Dec-63		5.5	249.0	95	9.7	7.0	-99.0	-99.000	-99.000	-99.000	0.750	-99.000	-99.000	5.0	-99	25
14-Jan-64		6.0	319.0	90	11.4	6.7	-99.0	-99.000	-99.000	-99.000	0.680	-99.000	-99.000	5.0	-99	20
25-Feb-64		7.0	170.0	90	12.1	7.1	-99.0	-99.000	-99.000	-99.000	0.270	-99.000	-99.000	0.0	-99	5
27-Mar-64		13.0	139.0	95	11.8	7.1	-99.0	-99.000	-99.000	-99.000	0.270	-99.000	-99.000	5.0	-99	15
24-Apr-64		11.9	145.0	92	11.6	7.6	-99.0	-99.000	-99.000	-99.000	0.110	-99.000	-99.000	5.0	-99	10
20-May-64		10.4	3320.0	49	11.2	7.0	-99.0	-99.000	-99.000	-99.000	0.020	-99.000	-99.000	120.0	-99	5
30-Jun-64		10.9	2240.0	51	10.3	7.1	-99.0	-99.000	-99.000	-99.000	0.020	-99.000	-99.000	15.0	-99	5
14-Jul-64		13.9	2310.0	46	12.3	7.3	-99.0	-99.000	-99.000	-99.000	0.020	-99.000	-99.000	230.0	-99	5
27-Aug-64		16.5	118.0	58	9.1	7.0	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	15.0	-99	5
28-Sep-64		11.2	77.0	93	10.8	7.1	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	20.0	-99	5
28-Oct-64		9.0	-99.0	100	11.7	7.1	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	0.0	-99	5
28-Nov-64		3.7	-99.0	65	12.2	7.6	-99.0	-99.000	-99.000	-99.000	0.000	-99.000	-99.000	10.0	-99	10
08-Dec-64		6.5	-99.0	71	11.3	7.2	-99.0	-99.000	-99.000	-99.000	0.180	-99.000	-99.000	10.0	-99	10
11-Jan-65		4.0	-99.0	92	12.4	7.5	-99.0	-99.000	-99.000	-99.000	0.520	-99.000	-99.000	0.0	-99	5
25-Feb-65		7.8	-99.0	69	11.7	7.3	-99.0	-99.000	-99.000	-99.000	0.200	-99.000	-99.000	10.0	-99	5
30-Mar-65		7.1	-99.0	90	12.0	7.2	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	0.0	-99	5
14-Apr-65		9.2	-99.0	94	11.8	7.4	-99.0	-99.000	-99.000	-99.000	0.110	-99.000	-99.000	0.0	-99	5
05-May-65		7.8	-99.0	60	11.7	7.2	-99.0	-99.000	-99.000	-99.000	0.020	-99.000	-99.000	5.0	-99	5
13-Jul-65		16.0	-99.0	86	9.6	7.5	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	10.0	-99	5
10-Aug-65		19.2	-99.0	84	9.5	7.4	-99.0	-99.000	-99.000	-99.000	0.070	-99.000	-99.000	35.0	-99	5
08-Sep-65		17.5	-99.0	105	10.8	7.6	-99.0	-99.000	-99.000	-99.000	0.050	-99.000	-99.000	10.0	-99	5
14-Dec-65		3.4	-99.0	123	13.0	7.5	-99.0	-99.000	-99.000	-99.000	0.360	-99.000	-99.000	-99.0	-99	10
16-Mar-66		9.2	-99.0	97	11.0	7.0	-99.0	-99.000	-99.000	-99.000	0.470	-99.000	-99.000	-99.0	-99	20
17-Nov-70	1055	7.9	-99.0	112	9.2	8.0	-99.0	-99.000	0.010	0.010	0.360	0.090	0.080	3.0	-99	35
01-Dec-70	1325	4.5	-99.0	108	12.5	7.1	-99.0	-99.000	-99.000	-99.000	-99.000	-99.000	-99.000	3.0	270	24
14-Dec-70	1330	5.4	-99.0	97	12.3	7.2	-99.0	-99.000	0.070	0.000	0.500	0.060	0.060	2.0	40 K	14
25-Jan-71	1300	4.9	-99.0	53	12.5	6.6	-99.0	-99.000	0.020	0.000	0.320	0.090	0.060	15.0	400	66
08-Feb-71	1215	4.5	-99.0	70	13.2	7.1	-99.0	-99.000	0.070	0.000	0.250	0.100	0.080	5.0	100 K	7
22-Feb-71	1240	7.4	-99.0	71	11.8	7.1	-99.0	-99.000	0.020	0.000	0.360	-99.000	-99.000	2.0	40 K	22
08-Mar-71	1435	7.0	-99.0	92	11.9	7.3	-99.0	-99.000	0.150	0.010	1.000	0.070	0.040	4.0	30	54
23-Mar-71	1200	8.7	-99.0	94	11.2	7.3	-99.0	-99.000	0.150	0.010	0.560	0.170	-99.000	7.0	80 L	49
12-Apr-71	1300	8.8	-99.0	66	11.9	7.1	-99.0	-99.000	0.120	0.000	0.200	0.120	-99.000	5.0	20 K	26
26-Apr-71	1200	12.9	-99.0	61	11.6	7.4	-99.0	-99.000	0.020	0.000	0.020	0.080	0.040	1.0	20 K	24
10-May-71	1210	11.1	-99.0	52	11.3	6.8	-99.0	-99.000	0.000	0.000	0.050	0.120	0.050	10.0	20 K	19
25-May-71	1200	11.3	-99.0	50	11.0	7.2	-99.0	-99.000	0.000	0.000	0.020	0.100	0.030	8.0	20 K	18
22-Jun-71	1305	12.4	-99.0	47	10.4	7.4	-99.0	-99.000	0.000	0.000	0.020	0.020	0.010	70.0	90	32
12-Jul-71	1310	12.2	1900.0	48	11.0	7.0	-99.0	-99.000	0.000	0.010	0.060	0.020	0.020	6.0	20	4
26-Jul-71	1345	18.0	4350.0	74	10.3	8.8	-99.0	-99.000	0.100	0.010	0.050	0.010	0.010	65.0	120	68
09-Aug-71	1250	19.1	220.0	61	9.8	7.1	-99.0	-99.000	0.190	0.000	0.230	0.080	0.030	70.0	70	72
23-Aug-71	1410	17.5	155.0	59	10.2	7.3	-99.0	-99.000	0.150	0.010	0.040	0.120	0.120	45.0	50	31
13-Sep-71	1235	16.8	65.0	105	11.3	8.0	-99.0	-99.000	0.080	0.000	0.300	0.060	0.040	5.0	20 K	33
27-Sep-71	1230	12.6	215.0	108	10.8	7.4	-99.0	-99.000	0.040	0.000	0.210	0.070	0.040	4.0	20 K	28
10-Oct-72	1425	10.5	-99.0	97	12.3	8.9	-99.0	-99.000	0.070	0.010	0.030	0.060	0.040	5.0	-99	36
24-Oct-72	1350	9.7	-99.0	97	13.6	9.0	-99.0	-99.000	0.110	0.000	0.030	0.030	0.000	3.0	-99	73
07-Nov-72	1245	9.0	-99.0	104	12.9	8.8	-99.0	-99.000	0.050	0.010	0.290	0.070	0.060	10.0	-99	16
21-Nov-72	1145	5.5	-99.0	53	15.1	7.4	-99.0	-99.000	0.040	0.000	0.110	0.040	0.000	20.0	-99	2
04-Dec-72	1130	2.0	-99.0	100	14.7	7.5	-99.0	-99.000	0.220	0.020	0.940	0.100	0.040	5.0	-99	4
19-Dec-72	1115	5.4	-99.0	47	12.8	7.3	-99.0	-99.000	0.150	0.010	0.630	0.230	0.020	40.0	-99	186
03-Jan-73	1135	3.4	-99.0	58	13.3	7.2	-99.0	-99.000	0.200	0.000	0.450	0.230	0.000	26.0	-99	60
30-Jan-73	1200	5.4	-99.0	64	11.3	7.2	-99.0	-99.000	0.210	0.010	0.710	0.040	0.020	9.0	-99	41
13-Feb-73	1115	6.0	-99.0	120	13.1	7.3	-99.0	-99.000	0.130	0.010	0.690	0.040	0.010	3.0	-99	24
27-Feb-73	1300	9.7	-99.0	60	13.1	7.2	-99.0	-99.000	0.310	0.020	0.720	0.120	0.060	6.0	-99	40
13-Mar-73	1130	7.8	-99.0	68	14.5	7.4	-99.0	-99.000	0.070	0.010	0.610	0.040	0.020	7.0	-99	50
27-Mar-73	1200	9.7	-99.0	74	13.8	7.6	-99.0	-99.000	0.070	0.010	0.380	0.050	0.040	6.0	-99	16
10-Apr-73	1100	13.5	-99.0	83	13.7	7.5	-99.0	-99.000	0.090	0.010	0.030	0.030	0.010	4.0	-99	35
24-Apr-73	1130	10.4	-99.0	63	11.9	7.5	-99.0	-99.000	0.090	0.010	0.470	0.070	0.060	5.0	-99	40
22-May-73	1215	14.5	-99.0	76	11.6	7.7	-99.0	-99.000	0.130	0.000	0.030	0.040	0.020	3.0	-99	22
31-May-73	1330	16.5	-99.0	113	10.9	8.5	-99.0	-99.000	0.150	0.000	0.030	0.050	0.020	1.0	-99	39
12-Jun-73	1130	16.0	-99.0	115	10.4	8.1	-99.0	-99.000	0.110	0.010	0.020	0.040	0.040	3.0	-99	34
26-Jun-73	1145	15.5	-99.0	93	13.2	7.7	-99.0	-99.000	0.150	0.000	0.340	0.150	0.060	25.0	-99	102
17-Jul-73	1255	21.3	-99.0	130	10.2	8.6	-99.0	-99.000	0.040	0.020	0.140	0.200	0.060	30.0	-99	41
24-Jul-73	1145	15.6	-99.0	98	12.6	9.1	-99.0	-99.000	0.180	0.020	0.050	0.120	0.030	38.0	-99	19
07-Aug-73	1100	15.7	-99.0	118	11.5	8.7	-99.0	-99.000	0.250	0.010	0.040	0.080	0.030	25.0	-99	38
21-Aug-73	1030	14.7	-99.0	130	12.2	8.3	-99.0	-99.000	0.110	0.000	0.030	0.070	0.050	12.0	-99	23
05-Sep-73	1055	16.4	-99.0	140	10.1	8.3	-99.0	-99.000	0.140	0.000	0.060	0.080	0.070	9.0	-99	50
18-Sep-73	1115	15.4	-99.0	114	11.2	8.5	-99.0	-99.000	0.050	0.010	0.000	0.080	0.060	12.0	-99	34

Station 10C095 White River, river mile 8.0

DATE	TIME	TEMP	FLOW	COND	DO	PH	SS	TPN	NH3	NO2	NO3	TP	OP	TURB	FC	COLOR
21-Oct-98	1610	9.7	-99.0	110	11.8	8.0	12.0	0.199	0.026	-99.000	-99.000	0.016	0.017	7.3	6	-99
18-Nov-98	1440	6.6	-99.0	74	11.6	-99.0	76.0	0.378	0.021	-99.000	-99.000	0.047	0.015	15.0	14	-99
16-Dec-98	1300	5.6	-99.0	77	12.5	7.9	31.0	0.924	0.015	-99.000	-99.000	0.043	0.021	7.7	33	-99
20-Jan-99	1520	5.5	-99.0	76	11.6	7.8	35.0	0.955	0.010 U	-99.000	-99.000	0.063	0.040	6.5	260 J	-99
17-Feb-99	1400	5.8	-99.0	101	12.3	8.0	2.0	1.120	0.010 U	-99.000	-99.000	0.078	0.044	2.3	490 J	-99
24-Mar-99	1300	8.2	-99.0	65	13.6	9.1	2.0	-99.000	0.010 U	-99.000	-99.000	0.051	0.025	1.7	31	-99
21-Apr-99	1440	7.9	-99.0	88	12.5	9.4	4.0	0.484	0.010 U	-99.000	-99.000	0.030	0.011	2.0	5	-99

Table A-2. Department of Ecology Ambient Monitoring Data within the study area.

DATE (units)	TIME	TEMP (° C)	FLOW (cfs)	COND (umhos/cm)	DO (mg/L)	PH (st. units)	SS (mg/L)	TPN (mg/L)	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)	TP (mg/L)	OP (mg/L)	TURB (NTU)	FC (#/100 mL)	COLOR (Pt-Co)
26-May-99	1250	8.3	-99.0	45	11.4	7.6	239.0	0.192	0.035	-99.000	-99.000	0.104	0.011	75.0	15	-99
23-Jun-99	1400	8.7	-99.0	48	10.9	7.6	122.0	0.121	0.021	-99.000	-99.000	0.089	0.014	45.0	21	-99
21-Jul-99	1400	12.1	-99.0	54	10.6	7.8	87.0	0.183 J	0.030	-99.000	-99.000	0.112	0.014	40.0	18	-99
18-Aug-99	1240	14.8	-99.0	52	10.0	7.7	225.0	0.146	0.043	-99.000	-99.000	0.180	0.013	80.0	47	-99
22-Sep-99	1300	14.3	-99.0	76	10.7	8.7	24.0	0.143	0.043	-99.000	-99.000	0.094	0.020	40.0	6	-99
Station 10C110 White River, river mile 19.8																
26-Oct-72	1145	8.1	52.0	73	12.3	7.9	-99.0	-99.000	-99.000	-99.000	0.140	0.050	0.040	1.0	-99	48
02-Nov-72	1430	9.5	-99.0	85	-99.0	7.8	-99.0	-99.000	0.120	0.010	0.160	0.090	0.060	1.0	-99	51
06-Nov-72	1230	8.8	60.0	77	10.9	7.4	-99.0	-99.000	0.240	0.020	0.280	0.140	0.090	6.0	-99	150
20-Nov-72	1235	7.2	47.0	96	13.5	8.0	-99.0	-99.000	0.080	0.010	0.330	0.100	0.090	2.0	-99	0
05-Dec-72	1225	0.0	47.0	87	14.4	7.5	-99.0	-99.000	0.210	0.010	0.690	0.110	0.070	5.0	-99	0
18-Dec-72	1220	4.3	168.0	58	12.5	7.9	-99.0	-99.000	0.130	0.000	0.560	0.120	0.020	20.0	-99	102
02-Jan-73	1200	4.9	181.0	49	12.7	6.9	-99.0	-99.000	0.100	0.000	0.200	0.030	0.010	4.0	-99	24
29-Jan-73	1200	5.6	66.0	102	12.2	7.2	-99.0	-99.000	0.220	0.010	0.650	0.090	0.050	4.0	-99	21
14-Feb-73	1230	7.0	60.0	104	13.0	7.5	-99.0	-99.000	0.230	0.010	0.380	0.090	0.050	4.0	-99	33
26-Feb-73	1245	8.1	94.0	99	12.0	7.5	-99.0	-99.000	0.200	0.010	0.390	0.110	0.070	3.0	-99	37
12-Mar-73	1255	7.2	71.0	100	12.4	7.6	-99.0	-99.000	0.220	0.010	0.540	0.100	0.080	3.0	-99	49
26-Mar-73	1200	8.0	88.0	103	12.5	7.7	-99.0	-99.000	0.150	0.010	0.410	0.110	0.080	3.0	-99	18
09-Apr-73	1120	12.5	88.0	98	12.3	7.8	-99.0	-99.000	0.090	0.010	0.300	0.100	0.080	2.0	-99	27
23-Apr-73	1200	9.4	83.0	80	12.2	7.6	-99.0	-99.000	0.130	0.010	0.360	0.100	0.070	4.0	-99	47
21-May-73	1300	14.6	76.0	65	11.2	7.4	-99.0	-99.000	0.090	0.010	0.100	0.070	0.050	5.0	-99	21
30-May-73	1425	18.1	61.0	98	12.8	7.3	-99.0	-99.000	0.060	0.010	0.150	0.140	0.120	3.0	-99	22
11-Jun-73	1340	18.5	60.0	90	13.7	9.0	-99.0	-99.000	0.110	0.010	0.150	0.130	0.120	10.0	-99	38
25-Jun-73	1225	13.6	115.0	76	11.1	7.7	-99.0	-99.000	0.180	0.020	0.240	0.140	0.020	40.0	-99	76
16-Jul-73	1250	18.2	111.0	65	9.3	7.7	-99.0	-99.000	0.090	0.020	0.070	0.150	0.070	125.0	-99	90
23-Jul-73	1430	17.5	61.0	100	-99.0	7.6	-99.0	-99.000	0.240	0.030	0.170	0.190	0.010	45.0	-99	52
06-Aug-73	1335	15.7	47.0	88	12.6	7.9	-99.0	-99.000	0.100	0.020	0.180	0.140	0.090	65.0	-99	48
20-Aug-73	1210	15.3	10.0	99	12.8	8.7	-99.0	-99.000	0.150	0.020	0.130	0.160	0.130	24.0	-99	22
04-Sep-73	1305	16.8	60.0	99	10.3	8.6	-99.0	-99.000	0.150	0.020	0.170	0.190	0.150	20.0	-99	32
17-Sep-73	1215	13.1	58.0	120	12.3	8.3	-99.0	-99.000	0.120	0.030	0.220	0.170	0.120	26.0	-99	32
Station 10C130 White River, river mile 23.1 (at highway 410 bridge)																
27-Oct-92	1055	7.4	134.0	77	12.0	8.0	16.0	-99.000	0.014	-99.000	-99.000	0.011	0.010 K	11.0	16	-99
22-Nov-92	1145	-99.0	1160.0	45	11.9	7.3	474.0	-99.000	0.019	-99.000	-99.000	0.084	0.010 K	30.0	270 J	-99
21-Dec-92	1116	4.3	178.0	71	12.4	7.6	10.0	-99.000	0.102	-99.000	-99.000	0.068	0.033	4.8	910 S	-99
26-Jan-93	1025	5.7	2930.0	36	12.6	7.1	378.0	-99.000	0.046	-99.000	-99.000	0.175	0.010 K	40.0	150	-99
23-Feb-93	0940	1.5	134.0	58	13.5	7.6	2.0	-99.000	0.014	-99.000	-99.000	0.010	0.010 K	1.6	27	-99
23-Mar-93	1020	5.8	2420.0	39	12.2	7.0	737.0	-99.000	0.015	-99.000	-99.000	0.240	0.010 K	85.0	230 S	-99
27-Apr-93	1105	7.7	148.0	62	11.7	7.4	6.0	-99.000	0.039	-99.000	-99.000	0.054	0.025	5.5	1300	-99
25-May-93	1010	8.9	842.0	42	11.3	7.0	85.0	-99.000	0.013	-99.000	-99.000	0.038	0.010 K	15.0	14	-99
29-Jun-93	1110	10.9	131.0	117	11.0	7.5	15.0	-99.000	0.030	-99.000	-99.000	0.038	0.011	14.0	500 J	-99
27-Jul-93	1043	12.7	195.0	53	11.0	7.4	47.0	-99.000	0.027	-99.000	-99.000	0.048	0.010 K	25.0	130	-99
24-Aug-93	1110	11.1	213.0	60	10.9	-99.0	73.0	-99.000	0.015	-99.000	-99.000	0.040	0.019	60.0	71	-99
28-Sep-93	1145	11.2	478.0	70	10.6	7.2	41.0	-99.000	0.019	-99.000	-99.000	0.049	0.016	34.0	17	-99

Key to abreviations:

-99	No Data
COND	Conductivity
DO	Dissolved oxygen
%SAT	Dissolved oxygen, percent saturation
FLOW	Streamflow
NO3	Nitrate-Nitrogen
NH3	Ammonia-Nitrogen
TPN	Total persulfate nitrogen
OP	Ortho-phosphorus
Total P	Total phosphorus
TURB	Turbidity
SS	Suspended solids
FC	Fecal coliform bacteria
U,K	Below reporting limit
B	Analyte in blank
X	Background organisms
J	Estimate
S	Spreader colonies

Appendix B

Assessment of pH Response to Nutrient Loading in the Lower White River

Nutrient Loading from Groundwater

by John Tooley
January 1997

Objective

Estimate groundwater nutrient loading to the White River Bypass Channel.

Approach

Review historical groundwater water quality literature from projects in the White River drainage, King County and Pierce County.

Review any appropriate surface water/ground water interaction analyses for the White River area.

Compile available groundwater quality information in the area, and summarize nutrient characteristics from these data.

Geology

The geology around the bypass reach, like that of rest of the Puget Sound lowland, is greatly influenced by the Pleistocene glaciation of the Puget lobe of the Cordilleran Ice Sheet. The repeated invasion of the ice, with warm periods in between, resulted in a complex assemblage of coarse outwash gravels, finer alluvial sands, fine lacustrine sediments, and poorly sorted tills. This process formed broad outwash plains through which rivers have since down cut to their current locations.

In addition to repeated glaciation, this area was subjected to periodic eruptions of ash and debris flows from Mount Rainier. About 5700 years ago the Osceola mudflow originated on the summit of the northeastern side of Mount Rainier and flowed down the White River valley and spilled into the Puyallup and Green river basins. The composition of the clay content of the mudflow indicates that it originated as a huge deep-seated landslide which cut into the core of Mt. Rainier. The resulting mudflow had an estimated volume of 89 $mi.^3$ and covered an area of at least 195 $mi.^2$ with up to 100 ft. thick layer of clay rich sediments (Dragovich, 1994).

This mudflow covers the drift plains surrounding the White River bypass reach with mixture of clay-rich gravel, cobbles and boulders. The soils formed on these deposits are poorly drained and have a slow permeability. Ecology (1995) reports that these mudflow deposits create an aquitard that confines the underlying aquifers and perches water tables in the overlying aquifers.

Hydrologic Investigations

Dinicola (1990) found that glacial till and mudflow deposits produced recharge rates much less than outwash deposits. After initial infiltration water generally moves laterally along the top of the contact until it intercepts a stream channel of land surface. Such seeps were observed along the White River bluffs.

Rates of discharge to Soos Creek Basin in Southwest King County are reported as .3 to 3 ft^3/sec./mi. (Morgan and Jones, 1996). Unfortunately rates of discharge to major streams are not available.

In a setting quite similar to the White River bypass reach, hydraulic gradient showed an expected down-valley gradient, but not a strong gradient towards the river. Unfortunately this observation was during May 1980 and does not represent low flow conditions (Lum *et al*., 1984).

Groundwater Quality Information

There are over 180 public water supply wells within 2 miles of the White River bypass channel. Monitoring data from these wells should give and general indication of nitrate concentration in the deeper groundwater systems. 1994 data from twenty Class 1 & 2 public water supply wells showed nitrate concentration ranging from 0 to 4.8 mg/l Nitrate Nitrogen. More recent data from a larger sampling of wells is currently being acquired from Washington Department of Health.

Groundwater data from wells around the Muckleshoot Indian Reservation showed nitrate values ranging from 0 to 9 mg/l Nitrate Nitrogen. The highest values were reported in a well only 25 ft deep (Applied Geotechnology 1991).

Conclusions

Available information indicates that downward movement of nutrients from nonpoint sources (dairies, septic systems, fertilizers, etc.) surrounding the bypass reach is probably inhibited by the presence of the Osceola Mudflow aquitard which forces nutrients in the water table aquifer to be discharged laterally to tributary streams.

The rate of discharge of groundwater directly to the White River bypass reach is unknown and would probably be fairly difficult to measure.

References – Appendix B

Applied Geotechnology Inc. 1991. Supplemental Hydrogeologic Evaluation and Initial Groundwater Management Planning Muckleshoot Indian Reservation.

Dinicola, R. S., 1990. Characterization and simulation of rainfall-runoff relations for headwater basins in western King and Snohomish Counties, Washington: U.S. Geological Survey Water-Resources Investigations Report 89-4052, 52 p.

Dragonvich, J. D., P.T. Pringle, T. J. Walsh, 1994. Extent and Geometry of the Mid-Holocene Osceola Mudflow in the Puget Lowland--Implications for Holocene Sedimentation and Paleography. Washington Geology, Vol. 22, No. 3, p. 3-26.

Lum, W.E., R.C. Alvord, and B.W. Drost, 1984. Availability of Water from the Alluvial Aquifer in Port of the Green River Valley, King County, Washington. U.S. Geological Survey Water Resources Investigations Report 83-4178, Tacoma, WA.

Morgan, D.S., and J.L. Jones, 1996. Numerical Model Analysis of the Effects of Ground-Water Withdrawals On Discharge to Streams and Springs in Small Basins Typical of the Puget Sound Lowland, Washington, U.S. Geological Survey Open File Report 95-470, Tacoma, WA, 73 p.

Washington Department of Ecology, 1995. Draft Initial Watershed Assessment of Water Resources Inventory Area 10, Puyallup-White Watershed, Open-File Technical Report 95-08, Washington Dept. of Ecology, Olympia, WA, 69 p.

Appendix C

Quality Assurance Analysis

The quality of the data collected was assessed in the following ways:

1) Lab and field duplicates. Duplicate grab samples were collected at one mainstem site during each survey in 1996. Duplicate field measurements were also taken for temperature, dissolved oxygen, conductivity, and pH at these sites. For the 1997 supplemental nutrient data, duplicate grab samples were collected about 20 percent of the time. These duplicate pairs were analyzed for relative percent difference (RPD, difference divided by the mean, expressed as percent) to assess total field and laboratory variation. For results less than the detection limit, the value was assumed to be one-half of the detection limit. The results are presented below.

Parameter	Average Relative Percent Difference of duplicate pairs
Temperature	0.3%
Dissolved Oxygen	0.5%
Conductivity	2.4%
pH	0.2%
Alkalinity	0.2%
Chloride	0.3%
FC	38%
NH3	(SEE NOTE BELOW)
NO2	3.9%
NO2/NO3	5.2%
Orthophosphate	24%
Chl. a - water	16%
Chl. a - algae	55%
Pheopig. - water	13%
Pheopig. - algae	71%

For ammonia, all measurements were below the detection limit of 0.010 mg/L, except for one reading of 0.013 mg/L.

The RPD for fecal coliform, 38 percent, was relatively high. However, the readings tended to be low (between 2 and 31 organisms/100 mL), which will result in a high RPD.

The RPD for orthophosphate, 24 percent, appears high. If pairs with one value less than the detection limit and one higher are excluded, the RPD improves to 12 percent. Given that the orthophosphate measurements were also low (generally less than 30 ug/L), this RPD was deemed to be acceptable.

1) Comparison of total vs. sum of components for nitrogen and phosphorus. Total nitrogen was compared to the sum of ammonia and nitrate+nitrite. Total phosphorus was compared to orthophosphate. If the total was less than the sum of the components, the results were investigated further. This comparison revealed a problem with orthophosphate data from the 7/31/96 survey of mainstem sites: in each case, the orthophosphate was significantly higher than the total phosphorus. In addition, the orthophosphate values were much greater than any other date. Therefore, these orthophosphate values for the 7/31/96 data set were rejected.

2) Hydrolab® data – The hydrolabs were usually deployed for about 48 hours. The data were verified by the following QA checks:

   a) Pre-calibration of dissolved oxygen, temperature, conductivity, and pH prior to traveling to the site.

   b) Field measurements of dissolved oxygen and pH at the time of deployment and the time of retrieval.

   c) Field measurements of dissolved oxygen, temperature, conductivity, and pH during the normal water quality survey routine (usually roughly mid-way through the 48 hours).

   d) Post-calibration after traveling back from the site.

The results showed that some data sets needed to be rejected due to hydrolab drift for dissolved oxygen and pH. If the hydrolab pH measurement differed by more than 0.5 pH units compared to the field meter reading, the data set was rejected.

Of the remaining data sets, the average difference between the hydrolab and field meter reading for pH was 0.24 standard units. This comparison also showed that the hydrolab tended to be biased low, compared to the field meter reading, with an average bias of –0.15 standard units.

Data collected in 1990 was checked for adherence to quality assurance protocols. Three pH values were rejected due to lack of quality assurance documentation.

All of the data not rejected for reasons listed above were considered to be of acceptable quality for this study.

Appendix D

Project Data

Table D-1. 1996 White River Water Quality Sampling Results

Site ID	Date	Time	Temp ° C	PH SU	DO mg/L	Cond µmhos /cm	O-P mg/L	TP mg/L	NH3 mg/L	NO2/NO3 mg/L	TPN mg/L	TKN mg/L	TSS mg/L	Turb NTU	Alk mg/L	Cl mg/L	FC No./ 100 mL	Chl a µg/L	Pheopig. µg/L
WR25.2	6/26/96	0810	10.0	7.5	11.1	60	0.010 U	0.121	0.010 U	0.010 U	0.067		184	50	19.5	1.04	11	0.72	1.2
WR25.2	7/31/96	0800	13.0	7.4	10.1	50	0.126 R	0.015 R	0.010 U	0.015	0.031		399	250	16.7	1.1	29	1.3	2.1
WR25.2	8/22/96	0755	12.2	7.6	10.5	62	0.005 U	0.157	0.010 U	0.020	0.048		75	60	21.1	1.56	9	0.42	0.61
WR25.2	9/12/96	0750	13.5	7.7	10.2	74	0.010 U	0.094	0.010 U	0.018	0.047		64	70	20.5	1.54	29	0.57	0.59
WR25.2	9/24/96	0810	8.5	7.7	11.3	84	0.010 U	0.045	0.010 U	0.032	0.057		14	13	24.5	1.64	8	0.21	0.29
WR25.2	10/9/96	0740	10.3	7.4	10.7	82	0.014	0.049	0.010 U	0.012	0.111		10 J	29	23.8	1.8	3	0.65	0.93
WR23.1	6/26/96	1100	11.8	7.7	11.0	59	0.010 U	0.054	0.010 U	0.010 U	0.085		72	33	21.1	1.1	48	0.95	1.1
WR23.1	7/31/96	0930	14.0	7.5	10.3	45	0.106 R	0.018 R	0.010 U	0.033	0.054		326	230	18.6	1.2	54	1.0	1.9
WR23.1	8/22/96	0820	12.5	7.6	10.6	64	0.006	0.063	0.010 U	0.019	0.041		54	55	22.4	1.57	18	0.46	0.89
WR23.1	9/12/96	0850	13.7	7.6	10.2	78	0.010 U	0.078	0.010 U	0.022	0.060		46	60	21.9	1.55	140	0.55	0.80
WR23.1	9/24/96	0850	8.9	7.4	11.5	86	0.010 U	0.039	0.010 U	0.036	0.071		13	13	24.9	1.55	11	0.14	0.23
WR23.1	10/9/96	0840	10.4	7.1	11.1	82	0.010 U	0.041	0.010 U	0.024	0.047		11	26	25.3	1.71	68	2.0	1.1
WR20.4	6/26/96	1230	13.4	8.0	10.8	61	0.019	0.059	0.010 U	0.053	0.152		61	28	21.7	1.32	10	2.0	2.1
WR20.4	7/31/96	1045	15.5	7.6	10.0	53	0.128 R	0.032 R	0.010 U	0.105	0.114		271	200	19.4	1.91	23	1.2	2.3
WR20.4	8/22/96	0915	13.0	7.7	10.6	67	0.016	0.065	0.010 U	0.052	0.076		36	50	23.3	2.4	31	0.73	0.91
WR20.4-dp	8/22/96	0915	13.0	7.7	10.6	67	0.021	0.067	0.010 U	0.052	0.094		34	50	23.3	2.4	29	0.96 J	1.1 J
WR20.4	9/12/96	0940	13.8	7.7	10.4	85	0.024	0.086	0.010 U	0.055	0.091		28	50	23	2.78	64	0.86	0.76
WR20.4	9/24/96	0930	9.2	7.7	11.4	90	0.015	0.061	0.010 U	0.078	0.112		18	13	25.4	1.72	10	0.23	0.26
WR20.4	10/9/96	0925	10.7	7.5	11.0	90	0.024	0.069	0.010 U	0.081	0.157		14	1.6	25.9	1.51	36	0.78	0.95
WR14.9	6/26/96	1500	17.7	8.8	10.2	63	0.011	0.038	0.010 U	0.059	0.176		24	14	23.1	1.45	2	2.7	2.0
WR14.9	7/31/96	1400	19.6	7.8	9.4	60	0.137 R	0.029 R	0.010 U	0.171	0.185		143	170	21.9	1.69	22	3.1	3.3
WR14.9	8/22/96	1145	15.3	8.2	10.7	72	0.016	0.056	0.010 U	0.082	0.101		26	40	25.1	2.29	26	0.64	0.72
WR14.9	9/12/96	1205	14.8	8.1	10.5	90	0.012	0.059	0.010 U	0.091	0.158		19	40	24.8	2.45	62	1.2	0.94
WR14.9	9/24/96	1210	11.0	7.9	11.3	95	0.012	0.056	0.010 U	0.097	0.158		21	13	26.9	1.8	9	0.26	0.20
WR14.9	10/9/96	1140	12.5	8.1	11.3	102	0.021	0.060	0.010 U	0.150	0.196		9	20	28.6	2.25	10	0.95	1.1
WR10.3	6/26/96	1600	18.4	8.1	9.8	73	0.010 U	0.019	0.012	0.015	0.143		13	9.2	24.8	1.44	4	1.4	1.0
WR10.3	7/31/96	1520	21.3	7.7	9.3	70	0.104 R	0.026 R	0.010 U	0.010 U	0.188		206	130	23.3	1.63	16	3.9	2.7
WR10.3	8/22/96	1245	18.5	8.0	10.5	78	0.016	0.045	0.010 U	0.062	0.119		24	37	26.2	2.5	13	1.1	1.0
WR10.3	9/12/96	1345	15.4	8.2	10.5	93	0.010 U	0.060	0.010 U	0.067	0.124		17	35	26.1	2.64	31	1.1	1.0
WR10.3	9/24/96	1340	12.1	7.8	11.3	95	0.010 U	0.055	0.010 U	0.083	0.117		18	13	27.4	1.81	7	0.28	0.18
WR10.3	10/9/96	1250	14.3	7.8	11.3	110	0.030	0.056	0.010 U	0.165	0.247		6	17	31.7	2.51	10	0.91	1.2
WR08.0	6/26/96	1630	18.6	8.1	9.7	70	0.010 U	0.025	0.024	0.018	0.141		15	10	24.3	1.44	8	1.7	1.8
WR08.0	7/31/96	1545	21.1	7.9	9.2	72	0.109 R	0.019 R	0.010 U	0.155	0.168		202	140	23.3	1.63	22	4.1	2.8
WR08.0-dp	7/31/96	1600	21.1	7.9	9.2	73	0.100	0.032	0.010 U	0.151	0.155		153	120	23.3	1.63	14	2.9	2.5
WR08.0	8/22/96	1310	16.7	8.2	10.3	77	0.019	0.059	0.010 U	0.069	0.122		35	38	26	2.64	12	1.1	1.5
WR08.0	9/12/96	1435	16.0	8.4	10.4	96	0.010	0.062	0.010 U	0.058	0.107		17	35	26	2.78	25	1.2	1.1
WR08.0-dp	9/12/96	1500	16.0	8.4	10.5	92	0.010 U	0.061	0.010 U	0.057	0.113		18	36	26.1	2.77	24	1.1	1.1
WR08.0	9/24/96	1425	12.5	7.9	11.5	96	0.011	0.050	0.010 U	0.076	0.115		19	13	27.6	1.74	6	0.25	0.23
WR08.0	10/9/96	1340	14.9	8.7	11.2	107	0.035	0.051	0.010 U	0.164	0.198		8	17	30.5	2.66	5	1.3	1.3
WR06.3	6/26/96	1800	18.5	8.0	9.5	71	0.010 U	0.019	0.013	0.017	0.134		14	10	24.8	1.45	7	1.4	1.3
WR06.3-dp	6/26/96	1820	18.7	8.0	9.5	75	0.010 U	0.024	0.010 U	0.021	0.132		14	11	24.7	1.46	11	1.6	0.96
WR06.3	7/31/96	1715	22.0	7.8	9.0	64	0.117 R	0.031 R	0.010 U	0.144	0.165		124	140	23.8	1.69	44	2.4	1.5
WR06.3	8/22/96	1410	18.0	8.5	10.4	73	0.014	0.089	0.010 U	0.056	0.100		25	37	26.2	2.61	11	0.60	0.57
WR06.3	9/12/96	1555	16.0	8.6	10.3	94	0.010 U	0.059	0.010 U	0.045	0.099		19	34	26.3	2.73	21	1.3	0.94
WR06.3	9/24/96	1520	13.3	8.0	11.0	96	0.010 U	0.051	0.010 U	0.069	0.118		17	13	27.5	1.81	2	0.28	0.22
WR06.3-dp	9/24/96	1525	13.3	8.1	11.1		0.01	0.047	0.01 U	0.068	0.117		16	13	27.6	1.8	6	0.29	0.2
WR06.3	10/9/96	1435	15.5	9.0	11.4	109	0.029	0.055	0.010 U	0.142	0.199		5	16	30.9	2.75	6	1.4	1.4
WR04.9	6/26/96	1845	18.7	7.8	9.4	60	0.010 U	0.022	0.011	0.014	0.156		18	10	25.3	1.46	11	2.0	1.2
WR04.9	7/31/96	1730	22.2	7.9	9.9	53	0.117 R	0.033 R	0.014	0.143	0.189		103	130	24.2	1.62	33	2.3	1.8
WR04.9	8/22/96	1440	18.2	8.0	10.2	77	0.015	0.069	0.010 U	0.061	0.115		30	36	26.6	2.75	8	1.1	0.79
WR04.9	9/12/96	1620	16.2	8.5	10.3	95	0.010 U	0.064	0.010 U	0.042	0.107		17	31	26.7	2.88	22	1.2	1.1
WR04.9	9/24/96	1550	13.5	8.0	11.0	95	0.010 U	0.065	0.014	0.064	0.139		18	13	28.1	1.82	3	0.26	0.21
WR04.9	10/9/96	1455	15.2	8.8	11.4	109	0.032	0.057	0.010 U	0.147	0.212		7	16	31.5	2.77	3	1.4	1.3
WR04.9-dp	10/9/96	1500	15.3	8.8	11.5	108	0.028	0.073	0.010 U	0.137	0.228		6	16	31.4	2.76	4	1.3	1.4
WR_BOISE	6/26/96 1035		12.7	7.81	10.5	71	0.01 U	0.012	0.011	0.302	0.441		3		36.4	1.56	570		
WR_BOISE	7/31/96 1000		14.4	7.74	10	89	0.015	0.022	0.01 U	0.246	0.3		13		40.8	1.72	360		
WR_BOISE	8/22/96 0845		12.7	7.85	10.4	82	0.005 U	0.019	0.01 U	0.184	0.259		1		41.2	1.6	190		
WR_BOISE	9/12/96 0910		13.9	7.74	10	102	0.01 U	0.025	0.01 U	0.182	0.255		5		42.8	1.48	1000		
WR_BOISE	9/24/96 0900		9.5	7.71	11.2	89	0.01 U	0.049	0.01 U	0.249	0.345		3		37.2	1.36	140		
WR_BOISE	10/9/96 0900		10.5	7.53	10.5	90	0.01 U	0.025	0.01 U	0.195	0.306		2		41.1	1.51	96		
WR_BOWMAN	6/26/96 1700		16.7	7.49	8.6	96	0.01 U	0.01	0.01 U	0.135	0.312		5		33.2	1.63	32		
WR_BOWMAN	7/31/96 1615		18.1	7.28	8.2	79	0.01 U	0.075	0.01 U	0.097	0.182		7		31.6	1.51	69		
WR_BOWMAN	8/22/96 1340		15.9	7.41	8.7	68	0.005 U	0.025	0.01 U	0.053	0.159		5		28.6	1.43	57		
WR_BOWMAN	9/12/96 1523		16	7.3	8.3	105	0.01 U	0.027	0.01 U	0.055	0.191		8		33.4	2.39	40		
WR_BOWMAN	9/24/96 1450		11.9	7.61	9.5	106	0.01 U	0.032	0.01 U	0.047	0.168		5		35	2.5	11		
WR_BOWMAN	10/9/96 1400		13.2	7.56	8.9	107	0.01 U	0.015	0.01 U	0.052	0.146		6		35.6	1.99	3		
WRTRB15.4	6/26/96 1415		11.8	7.1	9.9	124	0.065	0.069	0.01 U	6.53	7.13		21		52.4	7.62	24		
WRTRB15.4	7/31/96 1245		12.2	7.31	10.5	199	0.058	0.054	0.01 U	6.87	6.92		27		50.6	8.04	55 J		
WRTRB15.4	8/22/96 1045		10.6	7.46	10.5	155	0.046	0.06	0.01 U	6.97	6.46		2		49.5	7.93	43		
WRTRB15.4	9/12/96 1115		11.1	7.32	10.1	208	0.01 U	0.227	0.085	6.29	6.9		837		51.4	8.52	34		
WRTRB15.4	9/24/96 1110		10	7.43	10.6	211	0.023	0.087	0.014	6.08	7.72		288		51.6	7.86	6		
WRTRB15.4	10/9/96 1040		10.4	7.27	10.4	210	0.044	0.104	0.01 U	6.01	8.03		8		54.2	8.1	2		
WRTRB15.5	6/26/96 1330		11.3	6.76	4.3	120	0.15	0.16	0.016	0.01 U	0.828		1		109	9.1	3		
WRTRB15.5	7/31/96 1200		12	6.7	4.7	270	0.14	0.151	0.01 U	0.01 U	0.273		1 U		105	8.77	4		
WRTRB15.5	8/22/96 1000		11.2	6.75	4.3	238	0.129	0.157	0.01 U	0.01 U	0.388		4		100	8.16	1 U		
WRTRB15.5	9/12/96 1030		11.2	6.71	4.4	260	0.147	0.165	0.01 U	0.035	0.338		10		93.7	8.23	14		
WRTRB15.5	9/24/96 1020		10.9	6.39	4.4	255	0.14	0.187	0.01 U	0.072	0.366		1 U		94.4	7.35	8		
WRTRB15.5	10/9/96 1005		10.9	6.52	4.2	241	0.134	0.169	0.01 U	0.097	0.377		1 U		92.1	7.36	11		

Table D-1. 1996 White River Water Quality Sampling Results

Site ID	Date	Time	Temp °C	PH SU	DO mg/L	Cond µmhos /cm	O-P mg/L	TP mg/L	NH3 mg/L	NO2/NO3 mg/L	TPN mg/L	TKN mg/L	TSS mg/L	Turb NTU	Alk mg/L	Cl mg/L	FC No./ 100 mL	Chl a µg/L	Pheopig. µg/L
WR_BUCKLY	6/26/96	0915	19.3	6.99	5.3	192	0.388	0.597	0.079	0.904		2.02	8			22.3	29		
WR_BUCKLY	7/31/96	1030	21.2	6.9	4	300	3.06	3.55	0.236	0.833		1.28	2			31.2	1		
WR_BUCKLY	7/31/96	24-hr.					3.3	3.68	0.631	0.883		1.87	3			29.9			
WR_BUCKLY	8/22/96	1320	21.2	6.93	4.1	363	4.02	3.71	0.311	2.4		1.29	3			36.2	3		
WR_BUCKLY	8/22/96	24-hr.					0.961	3.57	0.373	1.89		1.42	2			35.6			
WR_BUCKLY	9/12/96	1325	20	6.74	6.7	270	2.77	2.82	0.662	1.14		1.4	3			31.5	12		
WR_BUCKLY	9/12/96	24-hr.					2.82	2.92	0.88	0.353		1.59	2			32.5			
WR_BUCKLY	9/24/96	1115	17.5	6.77	5.9	270	2.52	2.32	0.194	1.51		1.04	3			29.1	1		
WR_BUCKLY	9/24/96	24-hr.					2.51	2.18	0.327	2		1.12	3			29.9			
WR_BUCKLY	10/9/96	1045	18.1	6.91	5.4	320	1.43	5.29	0.725	0.046		1.73	6			35.1	6		
WR_BUCKLY	10/9/96	24-hr.					2.54	3.8	2.34	0.015		2.88	3			35.6			
WR_ENUMCL	6/26/96	1130	21.1	7.01	3.6	392	3.44	3.56	0.415	12.4		2.46	3			24.4	320		
WR_ENUMCL	7/31/96	0945	20.3	6.88	4	900	3.78	4.5	0.746	11.2		3.27	5			34.7			
WR_ENUMCL	7/31/96	24-hr.					3.91	4.8	0.431	11.4		2.76	8			189			
WR_ENUMCL	8/22/96	1320	21.9	6.98	5.2	930	4.31	4.01	1.91	13		3.32	13			166	400		
WR_ENUMCL	8/23/96	24-hr.					4.36	2.25	1.17	7.32		3.59	13			90.3			
WR_ENUMCL	9/12/96	1105	20.4	6.94		960	3.77	4.45	0.896	9.94		2.24	11			259			
WR_ENUMCL	9/12/96	24-hr.					4.45	4.52	1.89	12.2		3.19	10			338			
WR_ENUMCL	9/24/96	1230	19.2	6.76	5.4	430	3.74	4.04	0.423	10.6		2.28	6			34.4	2200		
WR_ENUMCL	9/24/96	24-hr.					4.16	4.1	1.5	13.3		3.87	11			81.5			
WR_ENUMCL	10/9/96	0915	19.2	6.88	4.5	410	4.24	5.05	0.685	12		3.13	13			50.5	350		
WR_ENUMCL	10/9/96	24-hr.					3.95	4.57	1.79	13		3.62	6			84.9			
WR_MUCKLS	6/26/96	1010	10.4	7.9	10.2	73	0.093	0.104	0.092	0.065		0.48	7			1.21	1 U		
WR_MUCKLS	7/31/96	1225	13.2	7.38	9.4	50	0.014	0.102	0.023	0.08		1 U	115			1.22	6		
WR_MUCKLS	8/22/96	1215	14.8	7.1	9.2	71.6	0.037	0.042	0.01 U	0.074		1 U	17			1.48	3		
WR_MUCKLS	9/12/96	1220	13.1	6.35		65	0.01 U	0.051	0.061	0.072		1 U	21			1.43			
WR_MUCKLS	9/24/96	1410	11.9	6.37	10.5	80	0.01	0.037	0.032	0.082		1 U	5			1.45	4		
WR_MUCKLS	10/9/96	1330	12.6	7.36	9.7	100	0.015	0.031	0.047	0.094		1 U	4			1.86	1 U		
WR_RAINSC	6/26/96	0845	15.7	6.91	6.4	130	1.48	1.61	1.26	4.47		4.09	8			9.84	4700 J		
WR_RAINSC	7/31/96	840	19.3	6.66	6.4	135	1.26	1.88	0.992	3.26		2.51	5			10.2	13000 J		
WR_RAINSC	7/31/96	24-hr.					1.11	1.88	1.57	3.28		3.28	4			10			
WR_RAINSC	8/22/96	1055	17.7	6.6	5.8	174.3	1.67	1.76	2.34	5.09		3.62	6			10.6	7300		
WR_RAINSC	8/22/96	24-hr.					1.47	1.8	2.05	4.1		3.98	6			11.4			
WR_RAINSC	9/12/96	1430	19.1	6.69	6.7	178	1.13	1.49	2.86	3.74		4.36	8			12.6	74000		
WR_RAINSC	9/12/96	24-hr.					1.3	1.48	2.32	3.36		3.56	7			10.7			
WR_RAINSC	9/24/96	1000	15.3	6.78	6.8	260	1.44	1.88	1.69	3.71		3.36	6			10.3	5200		
WR_RAINSC	9/24/96	24-hr.					1.44	1.54	2.54	3.35		4.35	4			13.5			
WR_RAINSC	10/9/96	1130	17.2	6.7	6	220	1.45	2.9	2.17	4.32		4.29	14			13.6	17000		
WR_RAINSC	10/9/96	24-hr.					1.19	2.33	1.78	3.13		4.06	7			12.4			

Tributary/Spring Sampling

Site ID	Date	Time	Temp °C	PH SU	DO mg/L	Cond µmhos /cm	O-P mg/L	TP mg/L	NH3 mg/L	NO2/NO3 mg/L
WRTRB/SP1	31-JUL-96	0820	12.5	7.62	-----	-----	0.013	0.018	0.011	0.272
WRTRB/SP2	31-JUL-96	0942	19.5	7.32	-----	-----	2.82	3.58	0.195	0.778
WRTRB/SP3	31-JUL-96	1042	14.7	7.88	-----	-----	0.018	0.884	0.01 U	0.046
WRTRB/SP4	31-JUL-96	1115	10.8	7.23	-----	-----	0.012	0.05	0.01 U	0.839
WRTRB/SP5	31-JUL-96	1210	11.8	7.46	-----	-----	0.01 U	0.033	0.01 U	2.49
WRTRB/SP6	31-JUL-96	1250	16	7.5	-----	-----	0.01 U	0.022	0.01 U	0.197
WRTRB/SP7	31-JUL-96	1345	17.4	7.43	-----	-----	0.01 U	0.02	0.01 U	3.58
WRTRB/SP8	31-JUL-96	1440	15.4	8	-----	-----	0.031	0.058	0.01 U	13.3
WRTRB/SP9	31-JUL-96	1700	-----	-----	-----	-----	0.043	0.05	0.01 U	4.33

Periphyton Sampling

SITE ID	DATE	TIME	CHL. A mg/m^2	PHEOPIG mg/m^2
WR25.2	12-SEP-96	0750	6	0.3
WR25.2	12-SEP-96	0750	2	0.2
WR25.2	24-SEP-96	0810	3	0.3 J
WR25.2	24-SEP-96	0810	1	0.2
WR25.2	9-OCT-96	0740	4	0.6
WR25.2	9-OCT-96	0740	2	0.3
WR14.9	12-SEP-96	1205	11	0.5
WR14.9	12-SEP-96	1205	4	0.3
WR14.9	24-SEP-96	1210	6	1.0
WR14.9	24-SEP-96	1210	2	0.3
WR14.9	9-OCT-96	1140	17	1.9
WR14.9	9-OCT-96	1140	12	0.4
WR08.0	12-SEP-96	1435	26	2.1
WR08.0	12-SEP-96	1435	24	2.2
WR08.0	24-SEP-96	1425	7	2.0
WR08.0	24-SEP-96	1425	5	0.7
WR08.0	9-OCT-96	1340	71	1.0
WR08.0	9-OCT-96	1340	63	4.4

Key to abbreviations:

Abbreviation	Parameter
Temp	Temperature
PH	pH
DO	Dissolved oxygen
Cond	Conductivity
O-P	Ortho-phosphate
TP	Total phosphorus
NH3	Ammonia
NO2/NO3	Nitrite + Nitrate
TPN	Total persulfate nitrogen
TKN	Total Keldahl nitrogen
TSS	Total suspended solids
Turb	Turbidity
Alk	Alkalinity
Cl	Chloride
FC	Fecal coliform bacteria
Chl a	Chlorophyl *a*
Pheopig.	Pheopigments
R	Data rejected - did not meet quality assurance test (see Appendix C).
U	Data was not detected above this level.
J	Value is an estimate.

Continuous Hydrolab data available upon request in electronic and/or printed format. Continuous data sets consist of measurements every 15 minutes for temperature, dissolved oxygen, pH, and conductivity for the following sites and dates:

Site	Dates
RM 8.0	6/25-6/27; 7/30-8/1; 8/21-8/23; 9/11-9/13; 9/23-9/25; 10/8-10/10
RM14.9	9/11-9/13
RM 25.2	8/21-8/23; 9/11-9/13; 9/23-9/25; 10/8-10/10

TABLE D-2. 1997 PROJECT DATA.

Station Name	Date	Time	pH (std. Units)	NH3 (mg/L)	NO2+NO3 (mg/L)	NO2 (mg/L)	PO4 (mg/L)	TP (mg/L)	TPN (mg/L)
WR04.9	8/1/97	6:55	7.1						
WR04.9	8/1/97	15:20	9.0						
WR04.9	8/8/97	7:10	7.0						
WR04.9	8/8/97	16:00	7.7						
WR04.9	8/15/97	7:10	7.1						
WR04.9	8/15/97	15:25	7.9						
WR04.9	8/21/97	7:05	7.2						
WR04.9	8/21/97	16:10	8.0						
WR04.9	8/28/97	7:20	7.1						
WR04.9	8/28/97	15:55	7.7						
WR04.9	9/4/97	7:20	7.0						
WR04.9	9/4/97	16:40	7.6						
WR04.9	9/18/97	7:45	7.5						
WR04.9	9/24/97	7:25	7.0						
WR04.9	9/24/97	15:55	8.4						
WR04.9	10/2/97	16:15	7.7						
WR04.9	10/9/97	7:35	7.3						
WR04.9	10/9/97	15:55	8.1						
WR04.9	10/16/97	7:45	7.3						
WR04.9	10/16/97	16:40	8.4						
WR04.9	10/23/97	16:55	9.1						
WR04.9	10/30/97	7:45	7.2						
WR04.9	10/30/97	16:10	7.6						
WR04.9	10/30/97	16:10	7.2						
WR04.9	11/6/97	7:55	7.2						
WR04.9	11/6/97	7:55	7.2						
WR04.9	11/13/97	16:35	7.6						
WR04.9	11/13/97	16:35	7.8						
WR06.3	8/1/97	7:30	7.3						
WR06.3	8/8/97	7:40	7.6						
WR06.3	8/8/97	15:45	7.7						
WR06.3	8/15/97	7:40	7.5						
WR06.3	8/15/97	15:10	8.1						
WR06.3	8/21/97	7:35	7.5						
WR06.3	8/21/97	15:55	8.2						
WR06.3	8/28/97	7:45	7.3						
WR06.3	8/28/97	15:45	7.9						
WR06.3	9/4/97	7:40	7.1						
WR06.3	9/4/97	16:10	7.7						
WR06.3	9/18/97	8:05	7.7						
WR06.3	9/24/97	7:45	7.5						
WR06.3	9/24/97	15:35	8.7						
WR06.3	10/2/97	16:00	8.1						
WR06.3	10/9/97	7:55	7.6						
WR06.3	10/9/97	15:35	8.0						
WR06.3	10/16/97	8:00	7.5						
WR06.3	10/16/97	16:20	8.7						
WR06.3	10/23/97	16:40	9.5						
WR06.3	10/30/97	8:05	7.3						
WR06.3	10/30/97	15:55	7.7						
WR06.3	10/30/97	15:55	7.3						
WR06.3	11/6/97	8:15	7.3						
WR06.3	11/6/97	8:15	7.3						
WR06.3	11/13/97	16:20	7.7						
WR06.3	11/13/97	16:20	7.8						
WR08.0	8/1/97	8:20	7.3						
WR08.0	8/1/97	14:10	8.7						
WR08.0	8/8/97	8:05	7.6						
WR08.0	8/8/97	15:15	7.7						
WR08.0	8/15/97	7:55	7.5						
WR08.0	8/15/97	14:50	8.0						
WR08.0	8/21/97	7:50	7.6						
WR08.0	8/21/97	15:20	8.2						
WR08.0	8/28/97	8:00	7.3						
WR08.0	8/28/97	15:20	8.0						
WR08.0	9/4/97	8:05	7.2						
WR08.0	9/4/97	15:15	7.5	0.01 U	0.1245	0.01 U	0.023	0.1305	0.166
WR08.0-DUP	9/4/97	15:15		0.01 U	0.13	0.01 U	0.018	0.15	0.167
WR08.0	9/11/97	16:00		0.013	0.166	0.01 U	0.0225	0.13	0.179
WR08.0	9/18/97	8:25	7.9						
WR08.0	9/18/97	15:15		0.018	0.134	0.01 U	0.023	0.454	0.319
WR08.0	9/24/97	8:05	7.7						
WR08.0	9/24/97	15:10	8.6	0.01 U	0.136	0.01 U	0.03	0.068	0.156
WR08.0	10/2/97	15:30	7.7	0.01 U	0.1875	0.01 U	0.027	0.082	0.196

TABLE D-2. 1997 PROJECT DATA.

Station Name	Date	Time	pH (std. Units)	NH3 (mg/L)	NO2+NO3 (mg/L)	NO2 (mg/L)	PO4 (mg/L)	TP (mg/L)	TPN (mg/L)
WR08.0-DUP	10/2/97	15:30		0.01 U	0.176	0.01 U	0.027	0.08	0.188
WR08.0	10/9/97	8:15	7.7						
WR08.0	10/9/97	15:15	8.0	0.01 U	0.154	0.01 U	0.02	0.088	0.223
WR08.0	10/16/97	8:20	7.4						
WR08.0	10/16/97	16:00	8.5	0.01 U	0.142	0.01 U	0.016	0.069	0.178
WR08.0	10/23/97			0.01 U	0.141	0.01 U	0.0155	0.0425	0.166
WR08.0	10/30/97	8:30	7.3						
WR08.0	10/30/97	15:30	7.7	0.069	0.776	0.01 U	0.081	0.303	1.43
WR08.0	10/30/97	15:30	7.3						
WR08.0	11/6/97	8:40	7.4						
WR08.0	11/6/97	8:40	7.4						
WR08.0	11/6/97			0.01 U	0.228	0.01 U	0.013	0.072	0.2445
WR08.0-DUP	11/6/97			0.01 U	0.223	0.01 U	0.012	0.094	0.245
WR08.0	11/13/97	16:00	7.7	0.01 U	0.248	0.01 U	0.01 U	0.057	0.263
WR08.0	11/13/97	16:00	7.6						
WR25.2	8/1/97	9:15	7.6						
WR25.2	8/1/97	13:30	7.8						
WR25.2	8/8/97	8:55	7.6						
WR25.2	8/8/97	14:10	6.9						
WR25.2	8/15/97	8:35	7.5						
WR25.2	8/15/97	14:00	7.6						
WR25.2	8/21/97	8:30	7.6						
WR25.2	8/21/97	14:15	7.7	0.01 U	0.0235	0.01 U	0.01 U	0.145	0.0275
WR25.2	8/28/97	8:50	7.8						
WR25.2	8/28/97	14:20	7.2	0.01 U	0.030	0.01 U	0.015	0.099	0.072
WR25.2	9/4/97	9:10	7.1						
WR25.2	9/4/97	14:00	7.2	0.01 U	0.044	0.01 U	0.0225	0.225	0.129
WR25.2	9/11/97	15:10		0.01 U	0.041	0.01 U	0.011	0.203	0.026
WR25.2	9/18/97	9:20	8.1						
WR25.2	9/18/97	14:15		0.01 U	0.062	0.01 U	0.01 U	0.303	0.09
WR25.2	9/24/97	8:55	7.9						
WR25.2	9/24/97	14:10	7.9	0.01 U	0.028	0.01 U	0.017	0.055	0.029
WR25.2	10/2/97	14:25	7.4	0.01 U	0.031	0.01 U	0.013	0.119	0.017
WR25.2	10/9/97	14:20	7.5	0.01 U	0.055	0.01 U	0.011	0.118	0.095
WR25.2	10/16/97	9:20	8.0						
WR25.2	10/16/97	15:05	7.9	0.01 UJ	0.025	0.01 U	0.01 U	0.075	0.022
WR25.2	10/23/97	15:00		0.01 U	0.032	0.01 U	0.01 U	0.034	0.025
WR25.2	10/30/97	9:20	7.0						
WR25.2	10/30/97	14:35	7.5	0.01 U	0.25	0.01 U	0.01 U	0.339	0.472
WR25.2	10/30/97	14:35	7.1						
WR25.2	11/6/97	14:15		0.01 U	0.079	0.01 U	0.01 U	0.285	0.115
WR25.2	11/13/97	15:05	7.9	0.01 U	0.081	0.01 U	0.01 U	0.09	0.063
WR25.2	11/13/97	15:05	8.0						

Appendix E

Mainstem Nutrient Profile Modeling

Introduction

To better understand the nutrient dynamics, a mass balance model was used to simulate nutrient concentrations in the mainstem White River. The model was developed by Greg Pelletier as part of the Puyallup Total Maximum Daily Load study (Pelletier, 1994), and divides the study area into 0.2 mile segments. The nutrient mass of each element is calculated based on the previous element concentration, plus pointload inputs, and minus nutrient uptake (set externally). The hydrodynamic elements were derived from the QUAL2E model described in Pelletier (1993). The basic model structure is shown in Table E-1. The purpose of the model was to model stream nutrient concentrations longitudinally based on nutrient inputs, nutrient uptake, and streamflow levels.

Mass Balance Model Calibration

There were potentially six complete sets of data that could be used with the mass balance model, each collected in 1996. However, only one data set, from 9/24/96, had data that represented the same block of water as it traveled downstream. This is important because of the highly variable effluent characteristics of the Enumclaw discharge. In addition, streamflow can vary significantly over the course of a day due to natural variations, as well as operations at Mud Mountain dam and the diversion works. Therefore the 9/24/96 dataset was used to calibrate the mass balance model.

On 9/24/96, no water was being diverted to Lake Tapps (due to flume maintenance). Therefore, streamflow was relatively high on this date, and nutrient concentrations relatively low.

Hydrodynamics

The mass balance model was first checked for goodness-of-fit of the hydrodynamics. The 9/24/96 streamflow average daily values from USGS gages 12-1000-00, 12-0996-00 and 12-0990-00 and the measured tributary streamflows for 9/24/96 were input into the model. In addition, the small tributary/spring flows as measured or estimated on 7/31/96 were also entered into the model. The predicted streamflow was compared to USGS gage 12-1004-96. The fit was very good (Table E-2). This would indicate that there is not a lot of groundwater inflow to this stretch of the White River, or additional unmeasured tributaries. This is consistent with the conclusions of the ground water study (Appendix B), that suggested that groundwater is likely to discharge to tributaries of the White River, as opposed to flowing directly to the river.

Table E-1. Mass balance model structure.

RUN DESCRIPTION: 9/24/96

		DIN	O-P
Uptake rates (mg/m2/d):	RM 25.2 to RM23.0:	0	0
Uptake rates (mg/m2/d):	RM 23.0 to RM15.0:	29.5	10
Uptake rates (mg/m2/d):	RM15.0 to RM4.9:	59	20

Significant Feature	Up-stream River Mile	Down-stream River Mile	QUAL2E DATA10 Headwater Flow (cfs)	QUAL2E DATA11 Pointload Flow (cfs)	Headwater/ Pointload Chloride (mg/L)	Headwater/ Pointload DIN (mg/L)	Headwater/ Pointload O-P (mg/L)	Calculated Element Outflow (cfs)	QUAL2E hydraulics data: a for V= aQ^b	b for V= aQ^b	c for D= cQ^d	d for D= cQ^d	V= Velocity (ft/sec)	D= Depth (ft)	Width (m)	Bottom Area (m2)	Element Volume (L)	Element Initial DIN	Element Final DIN	Element Initial O-P	Element Final O-P
Headwater	25.4	25.2	494.57		1.64	0.037	0.005	494.57	0.095	0.56	0.19	0.3	3.07	1.22	132.04	42500	1.58E+07	0.037	0.037	0.005	0.005
Rainier School POTW	25.2	25.0		0.1400	10.3	5.4	1.44	494.71	0.095	0.56	0.19	0.3	3.07	1.22	132.05	42502	1.58E+07	0.039	0.039	0.005	0.005
	25.0	24.8						494.71	0.095	0.56	0.19	0.3	3.07	1.22	132.05	42502	1.58E+07	0.039	0.039	0.005	0.005
	24.8	24.6						494.71	0.095	0.56	0.19	0.3	3.07	1.22	132.05	42502	1.58E+07	0.039	0.039	0.005	0.005
White R Canal	24.6	24.4		0.00	1.642	0.039	0.005	494.71	0.095	0.56	0.19	0.3	3.07	1.22	132.05	42502	1.58E+07	0.039	0.039	0.005	0.005
Muckleshoot Hatchery	24.4	24.2		3.19	1.45	0.114	0.01	497.90	0.095	0.56	0.19	0.3	3.08	1.22	132.17	42540	1.59E+07	0.039	0.039	0.005	0.005
	24.2	24.0						497.90	0.095	0.56	0.19	0.3	3.08	1.22	132.17	42540	1.59E+07	0.039	0.039	0.005	0.005
	24.0	23.8						497.90	0.095	0.56	0.19	0.3	3.08	1.22	132.17	42540	1.59E+07	0.039	0.039	0.005	0.005
Trib/spring 1	23.8	23.6		0.50		0.28	0.013	498.40	0.095	0.56	0.19	0.3	3.08	1.22	132.19	42546	1.59E+07	0.039	0.039	0.005	0.005
Abv Junc. Boise Cr	23.6	23.4						498.40	0.095	0.56	0.19	0.3	3.08	1.22	132.19	42546	1.59E+07	0.039	0.039	0.005	0.005
Boise Cr	23.4	23.2		6.60	1.36	0.254	0.005	505.00	0.095	0.56	0.19	0.3	3.10	1.23	132.43	42625	1.60E+07	0.042	0.042	0.005	0.005
Enumclaw POTW	23.2	23.0		2.0200	34.4	11.023	3.74	507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.086	0.086	0.020	0.020
	23.0	22.8						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.086	0.086	0.020	0.020
	22.8	22.6						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.086	0.085	0.020	0.020
	22.6	22.4						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.085	0.085	0.020	0.020
	22.4	22.2						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.085	0.085	0.020	0.020
	22.2	22.0						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.085	0.084	0.020	0.020
	22.0	21.8						507.02	0.095	0.56	0.19	0.3	3.11	1.23	132.50	42649	1.60E+07	0.084	0.084	0.020	0.020
Buckley POTW	21.8	21.6		0.3800	29.1	1.704	2.52	507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.085	0.085	0.022	0.021
	21.6	21.4						507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.085	0.085	0.021	0.021
	21.4	21.2						507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.085	0.084	0.021	0.021
Fishpipe Return Flow	21.2	21.0		0.00	2.000	0.050	0.020	507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.084	0.084	0.021	0.021
	21.0	20.8						507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.084	0.084	0.021	0.021
	20.8	20.6						507.40	0.095	0.56	0.19	0.3	3.11	1.23	132.52	42653	1.60E+07	0.084	0.083	0.021	0.021
Trib/spring 4	20.6	20.4		0.50		0.84	0.012	507.90	0.095	0.56	0.19	0.3	3.11	1.23	132.54	42659	1.60E+07	0.084	0.084	0.021	0.021
	20.4	20.2						507.90	0.095	0.56	0.19	0.3	3.11	1.23	132.54	42659	1.60E+07	0.084	0.084	0.021	0.021
	20.2	20.0						507.90	0.095	0.56	0.19	0.3	3.11	1.23	132.54	42659	1.60E+07	0.084	0.083	0.021	0.021
	20.0	19.8						507.90	0.095	0.56	0.19	0.3	3.11	1.23	132.54	42659	1.60E+07	0.083	0.083	0.021	0.021
	19.8	19.6						507.90	0.095	0.56	0.19	0.3	3.11	1.23	132.54	42659	1.60E+07	0.083	0.083	0.021	0.020
Trib/spring 5	19.6	19.4		0.50		2.5	0.005	508.40	0.095	0.56	0.19	0.3	3.11	1.23	132.55	42665	1.60E+07	0.085	0.085	0.020	0.020
	19.4	19.2						508.40	0.095	0.56	0.19	0.3	3.11	1.23	132.55	42665	1.60E+07	0.085	0.084	0.020	0.020
	19.2	19.0						508.40	0.095	0.56	0.19	0.3	3.11	1.23	132.55	42665	1.60E+07	0.084	0.084	0.020	0.020
	19.0	18.8						508.40	0.095	0.56	0.19	0.3	3.11	1.23	132.55	42665	1.60E+07	0.084	0.084	0.020	0.020
	18.8	18.6						508.40	0.095	0.56	0.19	0.3	3.11	1.23	132.55	42665	1.60E+07	0.084	0.084	0.020	0.020
Trib/spring 6	18.6	18.4		0.50		0.2	0.005	508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.084	0.083	0.020	0.020
	18.4	18.2						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.083	0.083	0.020	0.020
	18.2	18.0						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.083	0.083	0.020	0.020
	18.0	17.8						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.083	0.082	0.020	0.019
	17.8	17.6						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.082	0.082	0.019	0.019
	17.6	17.4						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.082	0.082	0.019	0.019
	17.4	17.2						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.082	0.082	0.019	0.019
	17.2	17.0						508.90	0.095	0.56	0.19	0.3	3.11	1.23	132.57	42671	1.60E+07	0.082	0.081	0.019	0.019
Trib/spring 7	17.0	16.8		0.50		3.59	0.005	509.40	0.095	0.56	0.19	0.3	3.12	1.23	132.59	42677	1.60E+07	0.085	0.084	0.019	0.019
	16.8	16.6						509.40	0.095	0.56	0.19	0.3	3.12	1.23	132.59	42677	1.60E+07	0.084	0.084	0.019	0.019
	16.6	16.4						509.40	0.095	0.56	0.19	0.3	3.12	1.23	132.59	42677	1.60E+07	0.084	0.084	0.019	0.019
	16.4	16.2						509.40	0.095	0.56	0.19	0.3	3.12	1.23	132.59	42677	1.60E+07	0.084	0.083	0.019	0.019
Trib/spring 8	16.2	16.0		0.53		13.3	0.031	509.93	0.095	0.56	0.19	0.3	3.12	1.23	132.61	42683	1.60E+07	0.097	0.097	0.019	0.018
	16.0	15.8						509.93	0.095	0.56	0.19	0.3	3.12	1.23	132.61	42683	1.60E+07	0.097	0.097	0.018	0.018
Muckleshoot Boundary	15.8	15.6						509.93	0.095	0.56	0.19	0.3	3.12	1.23	132.61	42683	1.60E+07	0.097	0.096	0.018	0.018
WTrib 15.5	15.6	15.4		0.17	7.35	0.077	0.14	510.10	0.095	0.56	0.19	0.3	3.12	1.23	132.62	42685	1.60E+07	0.096	0.096	0.018	0.018
WTrib 15.4	15.4	15.2		0.35	7.86	6.094	0.023	510.45	0.095	0.56	0.19	0.3	3.12	1.23	132.63	42689	1.60E+07	0.100	0.100	0.018	0.018
	15.2	15.0						510.45	0.095	0.56	0.19	0.3	3.12	1.23	132.63	42689	1.60E+07	0.100	0.099	0.018	0.018
Trib/spring 9	15.0	14.8		0.74		4.34	0.043	511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.106	0.105	0.018	0.018
	14.8	14.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.105	0.104	0.018	0.018
	14.6	14.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.104	0.104	0.018	0.017
	14.4	14.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.104	0.103	0.017	0.017
	14.2	14.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.103	0.103	0.017	0.017
	14.0	13.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.103	0.102	0.017	0.017
	13.8	13.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.102	0.101	0.017	0.017
	13.6	13.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.101	0.101	0.017	0.016
	13.4	13.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.101	0.100	0.016	0.016
	13.2	13.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.100	0.100	0.016	0.016
	13.0	12.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.100	0.099	0.016	0.016
	12.8	12.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.099	0.098	0.016	0.016

RUN DESCRIPTION: 9/24/96

		DIN	O-P
Uptake rates (mg/m2/d):	RM 25.2 to RM23.0:	0	0
Uptake rates (mg/m2/d):	RM 23.0 to RM15.0:	29.5	10
Uptake rates (mg/m2/d):	RM15.0 to RM4.9:	59	20

Significant Feature	Up-stream River Mile	Down-stream River Mile	QUAL2E DATA10 Headwater Flow (cfs)	QUAL2E DATA11 Pointload Flow (cfs)	Headwater/ Pointload Chloride (mg/L)	Headwater/ Pointload DIN (mg/L)	Headwater/ Pointload O-P (mg/L)	Calculated Element Outflow (cfs)	QUAL2E hydraulics data: a for V= aQ^b	b for V= aQ^b	c for D= cQ^d	d for D= cQ^d	V= Velocity (ft/sec)	D= Depth (ft)	Width (m)	Bottom Area (m2)	Element Volume (L)	Element Initial DIN	Element Final DIN	Element Initial O-P	Element Final O-P
	12.6	12.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.098	0.098	0.016	0.015
	12.4	12.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.098	0.097	0.015	0.015
	12.2	12.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.097	0.097	0.015	0.015
	12.0	11.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.097	0.096	0.015	0.015
	11.8	11.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.096	0.095	0.015	0.015
	11.6	11.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.095	0.095	0.015	0.014
	11.4	11.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.095	0.094	0.014	0.014
	11.2	11.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.094	0.093	0.014	0.014
	11.0	10.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.093	0.093	0.014	0.014
	10.8	10.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.093	0.092	0.014	0.013
	10.6	10.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.092	0.092	0.013	0.013
	10.4	10.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.092	0.091	0.013	0.013
	10.2	10.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.091	0.090	0.013	0.013
	10.0	9.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.090	0.090	0.013	0.013
	9.8	9.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.090	0.089	0.013	0.012
	9.6	9.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.089	0.089	0.012	0.012
	9.4	9.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.089	0.088	0.012	0.012
	9.2	9.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.088	0.087	0.012	0.012
	9.0	8.8						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.087	0.087	0.012	0.012
	8.8	8.6						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.087	0.086	0.012	0.011
	8.6	8.4						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.086	0.086	0.011	0.011
	8.4	8.2						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.086	0.085	0.011	0.011
	8.2	8.0						511.19	0.095	0.56	0.19	0.3	3.12	1.23	132.66	42698	1.61E+07	0.085	0.084	0.011	0.011
Bowman Cr	8.0	7.8		0.56	2.5	0.052	0.005	511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.084	0.084	0.011	0.011
	7.8	7.6						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.084	0.084	0.011	0.010
	7.6	7.4						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.084	0.083	0.010	0.010
	7.4	7.2						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.083	0.083	0.010	0.010
	7.2	7.0						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.083	0.082	0.010	0.010
	7.0	6.8						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.082	0.082	0.010	0.010
	6.8	6.6						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.082	0.081	0.010	0.010
	6.6	6.4						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.081	0.081	0.010	0.010
	6.4	6.2						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.081	0.081	0.010	0.009
	6.2	6.0						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.081	0.080	0.009	0.009
	6.0	5.8						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.080	0.080	0.009	0.009
	5.8	5.6						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.080	0.079	0.009	0.009
	5.6	5.4						511.75	0.41	0.33	0.18	0.36	3.21	1.70	93.70	30160	1.56E+07	0.079	0.079	0.009	0.009
	5.4	5.2						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.079	0.078	0.009	0.009
	5.2	5.0						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.078	0.078	0.009	0.008
	5.0	4.8						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.078	0.077	0.008	0.008
	4.8	4.6						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.077	0.077	0.008	0.008
	4.6	4.4						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.077	0.076	0.008	0.008
	4.4	4.2						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.076	0.075	0.008	0.008
	4.2	4.0						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.075	0.075	0.008	0.007
	4.0	3.8						511.75	0.42	0.31	0.16	0.35	2.90	1.42	124.08	39938	1.73E+07	0.075	0.074	0.007	0.007

Table E-2. White River predicted streamflow vs. USGS gaged flow.

	Streamflow (cfs)	Comment
Model		
River Mile 23.3	505	Average daily streamflow at USGS gage 12-1000-00
River Mile 6.3	512	Model predicted flow
Gaged flows		
River Mile 23.3	510	USGS unit value for 9/24/96 at 08:00
River Mile 6.3	506	USGS unit value for 9/24/96 at 16:00 (0800 plus travel time predicted by model)
Difference		
River Mile 23.3	-5	-1%
River Mile 6.3	+7	+1%

Water Quality

The ability of the model to predict the fate and transport of water quality constituents was first checked with the conservative parameter chloride. The model prediction was good, as shown in Figure E-1.

For nutrient modeling, the target parameters were inorganic nitrogen (ammonia, nitrate, and nitrite) and orthophosphate. These forms of nutrients were selected instead of total nitrogen and total phosphorus, because they are the forms biologically available to algae.

To model the nutrient concentrations in the river, the rate of nutrient uptake by algae was needed. Three methods were used to estimate uptake rates: dissolved oxygen diurnal curve, pH diurnal curve, and measured nutrient profiles in the river. The diurnal curve methods used one station at RM 8.0, as described in Hall and Moll (1975) based on the method of Odum (1956). The nutrient profile rates were based on a linear regression of nutrient concentration vs. travel time for the reach between RM 14.9 and 4.9 (Figure E-2). The results of these analyses are shown in Table E-3. Of the three alternative methods, the nutrient profiles were estimated to be the most accurate. The dissolved oxygen (DO) and pH estimates are highly dependent on re-aeration estimates, which can be subject to significant error in the turbulent White River (although pH is slower to react to atmospheric exchange, and therefore is probably more accurate than the DO method).

Figure E-2. Inorganic nitrogen and orthophosphate vs. travel time.

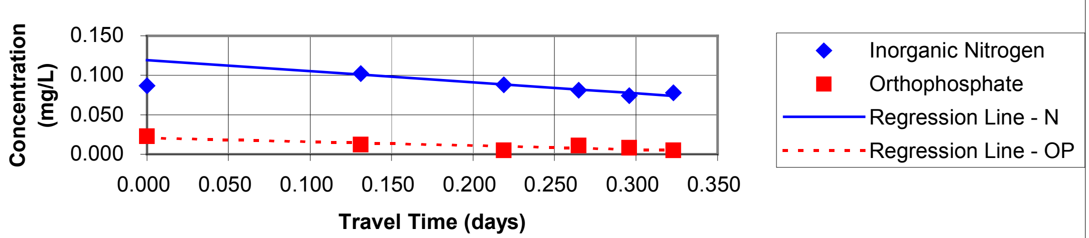


Figure E-1. White River chloride concentrations: modeled and measured, 9/24/96.

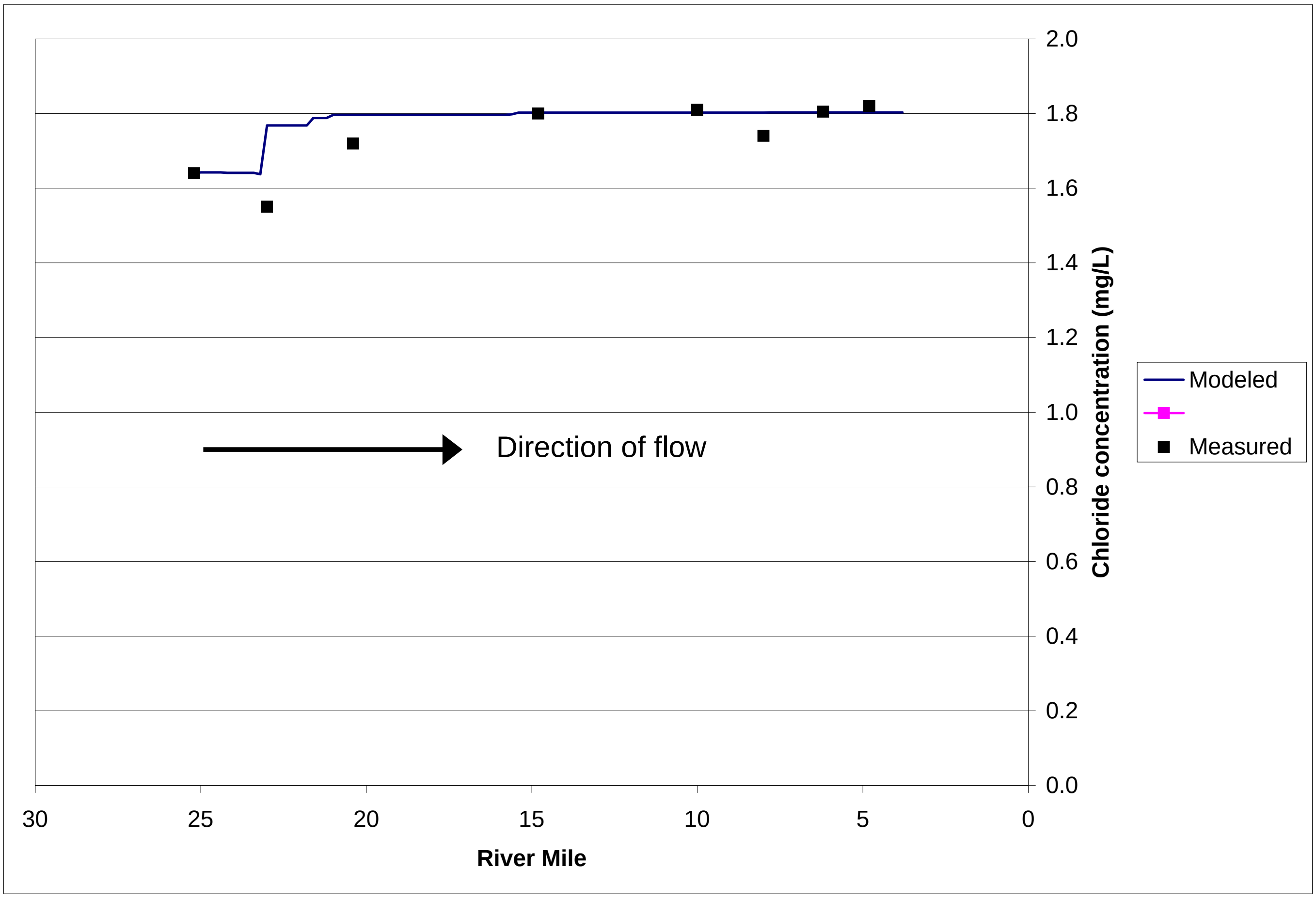


Table E-3. White River nutrient uptake rates for 9/24/96 based on three alternative methods.

Volumetric	Profile Method[1]		Diurnal DO method[2]	Diurnal pH method[2]
g-O2/m3-day	2.8	from N	1.5	4.0
	7.0	from P		
g-C/m3/day				1.2
mg-N/L-day	0.14		0.075	0.20
mg-P/L-day	0.049		0.011	0.028

Areal				
g-O2/m2-day	1.2	from N	0.77	2.1
	2.8	from P		
g-C/m2-day				0.6
mg-N/m2-day	59		39	105
mg-P/m2-day	20		5	15

Key:
- [solid box] direct calculation from method indicated
- [dotted box] converted from calculated value to give comparable units, based on assumed stoichiometric atomic ratio of O_2:C:N:P of 138:106:16:1

[1]Profile method based on linear regression of nutrient concentrations between river miles 14.9 and 4.9.
[2]Diurnal DO and pH methods based on Hall and Moll (1975) for data at river mile 8.0.

These nutrient uptake rates are appropriate for the reach from RM 14.9 to 4.9. The nutrient uptake rates upstream of RM 14.9 were estimated based on periphyton biomass and the measured concentrations. The periphyton biomass appeared to be negligible at river mile 25.2, and significantly lower at river mile 14.9 than at river mile 8 (Figure 12 in the main body of the report). This information, in combination with fitting the measured inorganic nitrogen levels, led to setting the nutrient uptake rates from RM 25.2 to RM 23.0 at 0, and from RM 23.0 to RM 14.9 at one-half the rate calculated downstream (29.5 and 10 mg N and P, respectively, per square meter per day).

The model did not include the process of organic nitrogen being converted to inorganic nitrogen. To test the significance of this process, the conversion of organic nitrogen to ammonia was included in the model for 9/24/96 at a rate of 0.1/day at 20° C, adjusted for actual measured temperatures (U.S. EPA, 1991). The resultant change in predicted inorganic nitrogen at the most downstream site was negligible (less than 1 ug/L). To check sensitivity to temperature, the modeled temperatures were raised to an average daily temperature higher than was observed during the 1996 season; the result was a change in inorganic nitrogen of 1 ug/L. The process of organic nitrogen conversion to inorganic nitrogen was therefore considered insignificant and was not included in subsequent model runs.

References – Appendix E

Hall, C. and R. Moll, 1975. *Methods of Assessing Aquatic Primary Productivity*. In Primary Productivity of the Biosphere, edited by Helmut Lieth and Robert Whittaker. Pringer-Verlag New York Inc., New York, NY.

Odum, H., 1956. *Primary Production of Flowing Waters*. Limnol. Oceanogr. 2:85-97.

Pelletier, G., 1993. Puyallup River Total Maximum Daily Load for Biochemical Oxygen Demand, Ammonia, and Residual Chlorine. Washington Department of Ecology, Olympia, WA.

Pelletier, G., 1994. Addendum to the 1993 Puyallup River TMDL Report. Memo from Greg Pelletier to Bill Backous, dated 7/22/94. Washington Department of Ecology, Olympia, WA.

U.S. EPA, 1991. Instruction materials for the workshop on "The Stream Water Quality and Uncertainty Model, QUAL2E", June 24-28, 1991. U.S. Environmental Protection Agency, Center for Exposure Assessment Modeling (CEAM) of the Office of Research and Development, Athens, GA.

Appendix F

Periphyton Identification

PERIPHYTON SAMPLE ANALYSIS

SAMPLE: White R, Algae 25.2

SAMPLE DATE: 96-09-12

TOTAL DENSITY (#/sq cm): 27505

TOTAL BIOVOL (cu uM/sq cm): 1.083213E+07

DIVERSITY INDEX: 4.12

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Nitzschia dissipata	5128	18.6	1379423	12.7
2	Achnanthes minutissima	2797	10.2	139854	1.3
3	Melosira varians	2331	8.5	3030162	28.0
4	Achnanthes linearis	1865	6.8	246142	2.3
5	Navicula gregaria	1865	6.8	326325	3.0
6	Navicula tripunctata	1399	5.1	2036269	18.8
7	Cymbella minuta	1399	5.1	517458	4.8
8	Fragilaria vaucheria	1399	5.1	402778	3.7
9	Surirella ovata	1399	5.1	405576	3.7
10	Gomphonema angustatum	932	3.4	167824	1.5
11	Cocconeis placentula	932	3.4	428885	4.0
12	Navicula cryptocephala	466	1.7	86243	0.8
13	Navicula cryptocephala veneta	466	1.7	44287	0.4
14	Achnanthes lewisiana	466	1.7	58272	0.5
15	Rhoicosphenia curvata	466	1.7	54543	0.5
16	Cymbella sinuata	466	1.7	65265	0.6
17	Navicula capitata	466	1.7	223766	2.1
18	Navicula graciloides	466	1.7	202788	1.9
19	Nitzschia clausii	466	1.7	149177	1.4
20	Gomphonema sp.	466	1.7	93236	0.9
21	Gomphonema tenellum	466	1.7	293693	2.7
22	Gomphonema subclavatum	466	1.7	279707	2.6
23	Surirella linearis	466	1.7	130530	1.2
24	Navicula sp.	466	1.7	69927	0.6

PERIPHYTON SAMPLE ANALYSIS

SAMPLE: White R, Algae 14.9

SAMPLE DATE: 96-09-12

TOTAL DENSITY (#/sq cm): 173796

TOTAL BIOVOL (cu uM/sq cm): 2.749809E+07

DIVERSITY INDEX: 3.25

	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Nitzschia communis	58431	33.6	3155292	11.5
2	Achnanthes minutissima	25470	14.7	1400854	5.1
3	Rhoicosphenia curvata	19477	11.2	3646115	13.3
4	Nitzschia frustulum	11986	6.9	1438310	5.2
5	Nitzschia dissipata	10488	6.0	2821185	10.3
6	Achnanthes linearis	7491	4.3	988838	3.6
7	Nitzschia paleacea	7491	4.3	734137	2.7
8	Nitzschia innominata	5993	3.4	287662	1.0
9	Navicula gregaria	5993	3.4	1048768	3.8
10	Nitzschia fonticola	4495	2.6	755113	2.7
11	Cocconeis placentula	4495	2.6	2067570	7.5
12	Navicula tripunctata	2996	1.7	3356056	12.2
13	Gomphonema ventricosum	1498	0.9	1273504	4.6
14	Cymbella affinis	1498	0.9	2696831	9.8
15	Achnanthes lanceolata	1498	0.9	269683	1.0
16	Diatoma hiemale mesodon	1498	0.9	1198592	4.4
17	Navicula cryptocephala	1498	0.9	277174	1.0
18	Navicula mutica	1498	0.9	82403	0.3

PERIPHYTON SAMPLE ANALYSIS

SAMPLE: White R, Algae 8.0

SAMPLE DATE: 96-09-12

TOTAL DENSITY (#/sq cm): 440221

TOTAL BIOVOL (cu uM/sq cm): 9.081262E+07

DIVERSITY INDEX: 3.47

--	SPECIES	DENSITY	PCT	BIOVOL	PCT
1	Achnanthes minutissima	102855	23.4	12342639	13.6
2	Nitzschia paleacea	78170	17.8	9958863	11.0
3	Nitzschia communis	61713	14.0	2777094	3.1
4	Rhoicosphenia curvata	28799	6.5	4380402	4.8
5	Nitzschia innominata	28799	6.5	1382376	1.5
6	Nitzschia fonticola	24685	5.6	2902988	3.2
7	Cocconeis placentula	20571	4.7	9462690	10.4
8	Nitzschia frustulum	16457	3.7	1974822	2.2
9	Gomphonema subclavatum	16457	3.7	9874111	10.9
10	Navicula tripunctata	12343	2.8	13823754	15.2
11	Cymbella affinis	8228	1.9	14811166	16.3
12	Cymbella sinuata	8228	1.9	1151980	1.3
13	Nitzschia dissipata	8228	1.9	2213447	2.4
14	Gomphonema angustatum	8228	1.9	1481117	1.6
15	Nitzschia amphibia	4114	0.9	394964	0.4
16	Achnanthes linearis	4114	0.9	543076	0.6
17	Navicula gregaria	4114	0.9	719987	0.8
18	Navicula sp.	4114	0.9	617132	0.7

Appendix G

Tabular Data for Figure 19

Table G-1. Inorganic nitrogen, orthophosphate and pH data for the White River at river miles 4.9, 6.3, 8.0, and 25.2 for the period 1990 through 1999. Measurements with pH above 9.0 are shaded.

River Mile	DATE	TIME	pH	Inorg. N (ug/L)	OP (ug/L)	NO3 (ug/L)	Site	Data Source
4.9	9/18/90	1740	9.2	21	28	8	WHI04.9	Puyallup R. TMDL
4.9	9/19/90	1750	9.2	17	28	3	WHI04.9	Puyallup R. TMDL
4.9	10/2/90	1840	9.7	30	41	12	WHI04.9	Puyallup R. TMDL
4.9	10/3/90	1645	9.2	54		46	WHI04.9	Puyallup R. TMDL
4.9	10/18/95	1300	7.8	359	28	354	10C085 (RM 4.9)	Ambient data
4.9	11/21/95	1400	7.4	443	18	430	10C085 (RM 4.9)	Ambient data
4.9	12/19/95	1255	7.5	327	14	309	10C085 (RM 4.9)	Ambient data
4.9	1/24/96	1350	7	1503	97	1340	10C085 (RM 4.9)	Ambient data
4.9	2/21/96	1255	7.3	183	8	178	10C085 (RM 4.9)	Ambient data
4.9	3/20/96	1300	7.4	451	18	446	10C085 (RM 4.9)	Ambient data
4.9	4/24/96	1215	7.6	220	23	172	10C085 (RM 4.9)	Ambient data
4.9	5/22/96	1320	7.5	259	20	254	10C085 (RM 4.9)	Ambient data
4.9	6/19/96	1220	7.7	48	5	43	10C085 (RM 4.9)	Ambient data
4.9	7/24/96	1245	7.6	87	17	82	10C085 (RM 4.9)	Ambient data
4.9	8/21/96	1245	7.9	144	28	128	10C085 (RM 4.9)	Ambient data
4.9	9/18/96	1250	7.6	150	14	145	10C085 (RM 4.9)	Ambient data
6.3	9/18/90	1720	9.2	31		16	WHI06.3	Puyallup R. TMDL
6.3	9/19/90	1730	9.1	18		10	WHI06.3	Puyallup R. TMDL
6.3	10/2/90	1400	9.6	59		39	WHI06.3	Puyallup R. TMDL
6.3	10/3/90	1430	9.1	64		51	WHI06.3	Puyallup R. TMDL
8.0	9/18/90	1650	9.1	35		18	WHI08.0	Puyallup R. TMDL
8.0	9/19/90	1700	9.1	32		17	WHI08.0	Puyallup R. TMDL
8.0	10/2/90	1340	9.6	62		41	WHI08.0	Puyallup R. TMDL
8.0	10/3/90	1415	9.2	66		63	WHI08.0	Puyallup R. TMDL
8.0	6/26/96	1630	8.1	42	5	18	WR08.0	White R. TMDL
8.0	7/31/96	1550	7.92	158		153	WR08.0	White R. TMDL
8.0	8/22/96	1310	8.2	74	19	69	WR08.0	White R. TMDL
8.0	9/12/96	1445	8.4	63	8	57.5	WR08.0	White R. TMDL
8.0	9/24/96	1425	7.9	81	11	76	WR08.0	White R. TMDL
8.0	10/9/96	1340	8.7	169	35	164	WR08.0	White R. TMDL
8.0	9/4/97	15:15	7.5	132	21	127	WR08.0	White R. TMDL
8.0	9/11/97	16:00		179	23	166	WR08.0	White R. TMDL
8.0	9/18/97	15:15		152	23	134	WR08.0	White R. TMDL
8.0	9/24/97	15:10	8.6	141	30	136	WR08.0	White R. TMDL
8.0	10/2/97	15:30	7.7	187	27	182	WR08.0	White R. TMDL
8.0	10/9/97	15:15	8.0	159	20	154	WR08.0	White R. TMDL
8.0	10/16/97	16:00	8.5	147	16	142	WR08.0	White R. TMDL
8.0	10/23/97			146	16	141	WR08.0	White R. TMDL
8.0	10/30/97	15:30	7.5	845	81	776	WR08.0	White R. TMDL
8.0	11/6/97			231	13	226	WR08.0	White R. TMDL
8.0	11/13/97	16:00	7.7	253	5	248	WR08.0	White R. TMDL
8.0	10/21/98	1610	8.0	202	17	176	10C095 (RM 8)	Ambient data
8.0	11/18/98	1440		339	15	318	10C095 (RM 8)	Ambient data
8.0	12/16/98	1300	7.9	849	21	834	10C095 (RM 8)	Ambient data
8.0	1/20/99	1520	7.8	760	40	755	10C095 (RM 8)	Ambient data
8.0	2/17/99	1400	8.0	953	44	948	10C095 (RM 8)	Ambient data
8.0	3/24/99	1300	9.1	721	25	716	10C095 (RM 8)	Ambient data
8.0	4/21/99	1440	9.4	46	11	41	10C095 (RM 8)	Ambient data
8.0	5/26/99	1250	7.6	113	11	78	10C095 (RM 8)	Ambient data
8.0	6/23/99	1400	7.6	65	14	44	10C095 (RM 8)	Ambient data
8.0	7/21/99	1400	7.8	11	14	80	10C095 (RM 8)	Ambient data
8.0	8/18/99	1240	7.7	48	13	50	10C095 (RM 8)	Ambient data
8.0	9/22/99	1300	8.7	121	20	78	10C095 (RM 8)	Ambient data

Table G-1. Inorganic nitrogen, orthophosphate and pH data for the White River at river miles 4.9, 6.3, 8.0, and 25.2 for the period 1990 through 1999. Measurements with pH above 9.0 are shaded.

River Mile	DATE	TIME	pH	Inorg. N (ug/L)	OP (ug/L)	NO3 (ug/L)	Site	Data Source
8.0	10/20/99	1530	8.0				10C095 (RM 8)	Ambient data
25.2	9/18/90	1330	7.8	59	12	41	WHI25.2	Puyallup R. TMDL
25.2	9/19/90	1440	7.8	40		33	WHI25.2	Puyallup R. TMDL
25.2	10/2/90	820	7.7	56	14	40	WHI25.2	Puyallup R. TMDL
25.2	10/3/90	800	7.7	55		43	WHI25.2	Puyallup R. TMDL
25.2	6/26/96	0810	7.5	10	5	5	WR25.2	White R. TMDL
25.2	7/31/96	0800	7.4	20		15	WR25.2	White R. TMDL
25.2	8/22/96	0755	7.6	25	2.5	20	WR25.2	White R. TMDL
25.2	9/12/96	0750	7.7	23	5	18	WR25.2	White R. TMDL
25.2	9/24/96	0810	7.7	37	5	32	WR25.2	White R. TMDL
25.2	10/9/96	0740	7.4	17	14	12	WR25.2	White R. TMDL
25.2	8/21/97	14:15	7.7	28.5	5	23.5	WR25.2	White R. TMDL
25.2	8/28/97	14:20	7.2	35	15	30	WR25.2	White R. TMDL
25.2	8/28/97	8:50	7.8				WR25.2	White R. TMDL
25.2	9/4/97	9:10	7.1				WR25.2	White R. TMDL
25.2	9/4/97	14:00	7.2	49	22.5	44	WR25.2	White R. TMDL
25.2	9/11/97	15:10		46	11	41	WR25.2	White R. TMDL
25.2	9/18/97	9:20	8.1				WR25.2	White R. TMDL
25.2	9/18/97	14:15		67	5	62	WR25.2	White R. TMDL
25.2	9/24/97	8:55	7.9				WR25.2	White R. TMDL
25.2	9/24/97	14:10	7.9	33	17	28	WR25.2	White R. TMDL
25.2	10/2/97	14:25	7.4	36	13	31	WR25.2	White R. TMDL
25.2	10/9/97	14:20	7.5	60	11	55	WR25.2	White R. TMDL
25.2	10/16/97	15:05	7.9	35	5	25	WR25.2	White R. TMDL
25.2	10/16/97	9:20	8.0				WR25.2	White R. TMDL
25.2	10/23/97	15:00		37	5	32	WR25.2	White R. TMDL
25.2	10/30/97	9:20	7.0				WR25.2	White R. TMDL
25.2	10/30/97	14:35	7.1				WR25.2	White R. TMDL
25.2	10/30/97	14:35	7.5	255	5	250	WR25.2	White R. TMDL
25.2	11/6/97	14:15		84	5	79	WR25.2	White R. TMDL
25.2	11/13/97	15:05	7.9	86	5	81	WR25.2	White R. TMDL