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DEPARTMENT OF
ECOLOGY

Watershed Briefing Paper for the Upper and Lower Snake River Water Quality Management Area

September 1995
Publication No. 95-346

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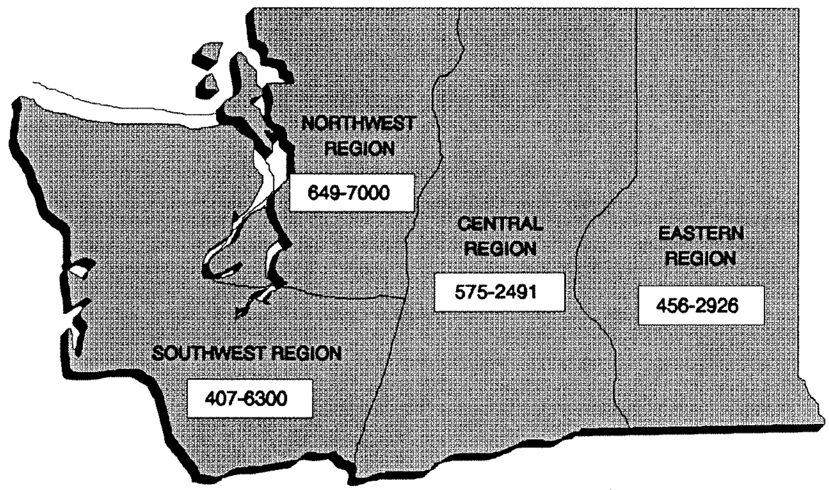

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Watershed Briefing Paper for the Upper and Lower Snake River Water Quality Management Area

by

Greg Pelletier, Dave Hallock, Dave Serdar,
Robert Garrigues, and Guy Hoyle-Dodson

Washington State Department of Ecology
Environmental Investigations and Laboratory Services Program
P.O. Box 47600, 300 Desmond Drive
Olympia, Washington 98504-7600

WRIAs 32, 33, 34, and 35

September 1995
Publication No. 95-346

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Executive Summary

This Consolidated Briefing Paper incorporates all of the information from the Environmental Investigations and Laboratory Services Program (EILS) into one briefing paper for the Watershed Workgroup for the Upper and Lower Snake River Water Quality Management Area (WQMA). Five individual chapters were prepared by EILS to include all aspects of EILS involvement for the Consolidated Briefing Paper as follows:

- Intensive Surveys and Total Maximum Daily Loads
- Ambient Rivers, Streams, and Lakes
- Toxics Investigations
- Ground Water Investigations
- Compliance Monitoring

Intensive Surveys and TMDLs

Several waterbody segments of the WQMA are considered to be impaired because of point sources of pollution. Three Total Maximum Daily Load (TMDL) projects have been approved by EPA. However, six segments of the WQMA remain on the 303(d) list partly because of point sources. Future TMDL studies by EILS should focus on the following unresolved point source problems:

- *Snake River.* Discharges by Potlatch Corporation, and to a lesser extent, the cities of Clarkston and Lewiston are suspected of contributing to dissolved oxygen problems in the Lower Granite Reservoir. An EILS project is in progress to use available information to develop a water quality model and evaluate the sensitivity of the reservoir to point and nonpoint loading sources of oxygen demanding materials and nutrients. Preliminary results from this project suggest that nonpoint sources of nutrients may exert a major influence on dissolved oxygen. Future TMDL efforts by Ecology should include consideration of the sensitivity and loading capacity of the reservoir and WLAs for dischargers in Washington. Additional involvement by EPA Region 10 and the state of Idaho is also needed to address point and nonpoint source loading from upstream of the Washington border.

- *South Fork Palouse River and Paradise Creek.* Waste Load Allocations (WLAs) for ammonia from the cities of Pullman and Albion have been developed and approved by EPA. These WLAs are planned to be incorporated into discharge permits in the near future. WLAs for ammonia loading from the Moscow Wastewater Treatment Plant (WTP) still need to be developed by EPA and Idaho. Future TMDL efforts should address the influence of point sources on dissolved oxygen and increase the involvement of EPA and Idaho for regulation of loading from Moscow.

- *Silver Creek.* Dissolved oxygen, ammonia, and chlorine have been identified as water quality problems that are influenced by point sources. Future TMDL efforts should develop WLAs to meet water quality criteria.

- *Rebel Flat Creek.* Fecal coliform and chlorine have been identified as water quality problems. Future TMDL efforts should develop WLAs to meet water quality criteria.

Most of the identified water quality problems in the WQMA have been attributed to nonpoint sources from agriculture and silviculture. Natural causes have also been identified as a major contributor to observed violations of water quality standards. Temperature, fecal coliform, and pH were the parameters with the most frequently observed violations of water quality standards in the WQMA. Several management activities are available to address nonpoint source problems in the WQMA and may be used as the functional equivalent of TMDLs:

- *Watershed Analysis.* Watershed Analysis is a process developed by the Timber, Fish, and Wildlife (TFW) cooperators to address the cumulative effects of forest practices on fish, water, and capital improvements. Waterbody segments that are listed under 303(d) and are identified as impaired by silviculture should be considered candidates for Watershed Analysis. The highest priority segments for Watershed Analysis include the following (because of listing under Sections 303(d) and 305(b) of the federal Clean Water Act with silviculture identified as a contributing cause):

- Touchet River	(segment 32-1020/1025)
- Snake River	(35-1010)
- Tucannon River	(35-2010/2030)
- Pataha Creek	(35-2013)
- Cummings Creek	(35-2024)
- Grande Ronde River	(35-3010)

- *Centennial Clean Water Funded Projects.* Ecology provides grants from the Centennial fund to local governments and other groups to complete a wide variety of water pollution control projects (e.g., watershed plans developed in accordance with the nonpoint rule [Chapter 400-12 WAC]). In evaluating whether a proposed project receives funding in the WQMA, highest priority should be given to projects that will improve or protect a waterbody on the Section 303(d) list. Funded projects should also be required to meet the major requirements for TMDL approval, including problem formulation, TMDL calculations and supporting studies, control actions and implementation schedules, public participation, and follow-up monitoring. All of the listed waterbody segments in the WQMA should be considered candidates for surrogate TMDLs conducted by Centennial Clean Water funded projects.

- *Farm Plans.* The state's local conservation districts work with individual farmers to develop water quality management (farm) plans. Development of these plans may be voluntary, required under the statewide NPDES Dairy Waste General Discharge Permit, or initiated by an agricultural water quality complaint to Ecology. These plans may be included as part of a basin-wide TMDL. A single farm plan or set of plans could also contain all of the components of a complete TMDL if farm management is the primary cause of water quality problems. The highest priority segments for farm plans include the following (because of listing under Sections 303(d) and 305(b) of the federal Clean Water Act with agriculture identified as a contributing cause):

- Walla Walla River	(segment 32-1010)
- Touchet River	(32-1020/1025)
- Snake River	(35-1010, 35-1010/1020)
- Palouse River	(34-1010/1030)
- Rock Creek	(34-1015)
- South Fork Palouse River	(34-1020)
- Missouri Flat Creek	(34-1024)
- Paradise Creek	(34-1025)
- Silver Creek	(34-1032)
- Tucannon River	(35-2010/2030)
- Pataha Creek	(35-2013)
- Cummings Creek	(35-2024)
- Grande Ronde River	(35-3010)

Ambient Monitoring

The recommended stations discussed below are in addition to the following seven core stations (sampled every year by Ecology's Ambient Monitoring Section) on rivers and streams in the Snake watershed:

32A070	Walla Walla River near Touchet	(river mile 15.3)
33A150	Snake River near Pasco	(2.2)
34A070	Palouse River at Hooper	(19.5)
34A170	Palouse River at Palouse	(121.2)
34B110	South Fork Palouse River at Pullman	(22.2)
35A150	Snake River at Interstate Bridge	(139.6)
35B060	Tucannon River at Powers	(2.3)

Up to five additional river and stream stations ("basin stations") may be monitored in water year (WY) 1997 (October 1996 through September 1997). We may also be able to monitor up to three "basin lakes," in addition to lakes with active volunteers. At this time, the only lake in the Snake River Basin with an active volunteer is Silver Lake.

- *Walla Walla/Touchet.* One potential area of focus for basin stations is the Walla Walla/Touchet sub-basin. Water quality in the Touchet River is significantly degraded in the 50 miles between Dayton and Touchet. Intermediate stations will help partition the source(s). Water quality in the upper Walla Walla has not been monitored, but the situation is probably similar to the Touchet. Up to six stations are desirable to cover both the Touchet and Walla Walla Rivers; *two to three stations on the lower Touchet River are recommended.*

- *South Fork Palouse River.* Monitoring should be conducted as a follow-up to the SFPR ammonia TMDL. The TMDL goal is dependent on an ammonia-nitrogen criterion being met in Paradise Creek at the Idaho border. *Two stations are recommended, one below the city of Albion discharge (river mile 21.3) and one at Paradise Creek at the Border.*

- *Asotin.* The high bacteria and occasionally high sediment concentrations in Asotin Creek should be confirmed with additional monitoring. One to two stations are desirable; none are recommended.

- *Tucannon.* The increasing trend in sediment concentrations in the lower Tucannon River should be confirmed by continued monitoring and more detailed statistical analysis. Additional stations are needed to partition source areas. Up to two stations are desirable, in addition to the core station; *one to two stations are recommended.* (Pataha Creek below river mile 23.0 could be monitored for dissolved oxygen only as a TMDL follow-up without counting as one of the five "basin stations.")

- *Discharge Trends.* The basin-wide decreasing trend in discharge should be confirmed and characterized in more detail. Continuous discharge data for major streams should be investigated, if available, rather than the monthly instantaneous discharge evaluated in this report. (No stations needed.)

- *Williams Lake.* Because of the indications of a declining trend in water clarity, monitoring on Williams Lake should continue. Unfortunately, at present we do not have a volunteer on Williams Lake to collect regular water clarity measurements.

- *Miscellaneous Lakes.* Other potential basin lakes with public access but no recent water quality data include Sprague, Fishtrap, Badger, Chapman, and Rock Lakes.

Toxics Investigations

- *Monitoring of pesticides in water, sediment, and fish in surface waters should continue at Washington State Pesticide Monitoring Program (WSPMP) stations.* Land-use in this area (largely agricultural) and the prevalence of pesticides in major waterbodies indicates the potential for more widespread contamination. Strategies to identify potential problem areas have been well-developed by Dale Davis (WSPMP). Sampling techniques and analytical procedures used in the WSPMP have been standardized and are therefore useful in obtaining data which can be compared to other WSPMP data collected in Washington State.

- *The load of 2,3,7,8-TCDD entering the Columbia River from the Snake River should be determined.* Data collected in 1988 indicated that Snake River (at Idaho border) dioxin levels were ten times the EPA water quality criterion. Major improvements have since been made at the Potlatch Lewiston pulp mill, the major historical source of dioxin, yet there are no recent data on 2,3,7,8,-TCDD loads in the Snake River. The load of 2,3,7,8-TCDD could be determined by the analysis of suspended particulate matter and the dissolved component of Snake River water in the vicinity of Ice Harbor Dam. EILS has been refining their ability to conduct such studies during the past few years. 2,3,7,8-TCDD loads could be compared to the Snake River loading capacity detailed in EPA's Columbia River TMDL.

- *A screening survey of dioxin/furan concentrations in edible fish tissue from the Snake River should be conducted.* This survey should include data on at least two species from each of the Snake River pools in Washington (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite).

Ground Water

Conclusions

- The USGS Regional Aquifer-System Analysis Program (RASA) studies have provided a wealth of data and analyses for the Columbia Plateau, including the Snake River watershed. Available ground-water data has also been compiled and published as part of the RASA effort.

- Ground-water quality is generally good throughout the watershed.

- There is widespread concern about nitrate concentrations in ground water. Historic data seems to support this concern. Nitrate sources are related to septic tank effluent, agricultural fertilizers, feed lots, effluent spray irrigation, and industrial waste.

- Ground-water availability and hydraulic connection between ground water and surface water is a prominent ground-water issue in the Snake River watershed.

- Information about ground-water quality trends seems to be lacking. There do not appear to be any follow-up studies which evaluate trends in nitrate concentrations for the watershed--or even for specific areas of high nitrate concern such as the Burbank-Wallula area.

Recommendations

- There is a serious need for follow-up ground water monitoring in the watershed. Areas of known historic nitrate contamination should be identified and ranked according to susceptibility for contamination and ground water use. Areas with important shallow aquifers upon which a population is dependent for water supplies should be looked at first. Priorities should be based on demand for ground water, potential sources of ground water contamination, growth projections, land use patterns and projections, and historic ground water quality data.

- Upon identification of priority areas, a schedule of sampling should be identified and implemented. The primary object would be to identify nitrate contamination trends or new contamination problems. Sampling should concentrate on previously sampled wells as much as possible. Each area should be re-sampled, where appropriate, at regularly occurring intervals, such as every 3-5 years, to establish data for trend analyses.

Compliance Monitoring

Conclusions

- Major municipal dischargers that have not received an Enhanced Class II Inspection during the last five years include Walla Walla WTP and Pullman WTP.

- Industrial waterbody and land application dischargers who have not received an Enhanced Class II Inspection during the last five years *or* whose NPDES or State Discharge permits have either expired or are near expiration include: Boise Cascade Pulp & Paper Mill, Stokely-USA, and Port of Whitman Company. The latter two have never been inspected.

- Minor municipal dischargers who have not received a Class II Inspection during the last five years and whose NPDES or State discharge permits have either expired or are near expiration include: Farmington, College Place, Dayton, Colfax, Asotin, Clarkston, St. John, Albion, Rosalia, Oakesdale, and Palouse.

- The contribution of Potlatch Corporation Lewiston Pulp & Paper and Saw Mill to the Upper Snake is a concern. Discharge constituents of concern include BOD5, TSS, pH, ammonia, phosphorus, temperature, chloroform, AOXs, furans, 2,3,7,8-TCDD (Dioxin), and metals.

Recommendations

Enhanced Class II Inspections are recommended for the following facilities:

- *Industrials*. Boise Cascade Pulp & Paper Mill (Major), Stokely-USA, and Port of Whitman Company.

- *Municipals*. Walla Walla (major), Pullman (major), Clarkston, Asotin, Garfield, Endicott, Palouse WTP, and Colfax WTP.

Introduction

The Upper and Lower Snake River Water Quality Management Area (WQMA) includes four Water Resource Inventory Areas (WRIAs):

- WRIA 32: Walla Walla
- WRIA 33: Lower Snake
- WRIA 34: Palouse
- WRIA 35: Middle Snake

Table 1 presents a river mile index of significant features in the WQMA. Most of the drainage areas in the WQMA are tributary to the Snake River. WRIA 32 contains a major portion of the drainage area of the Walla Walla River (including all of the Washington portion of the watershed).

The Snake River is the largest tributary to the Columbia River. The Snake River originates in Yellowstone National Park in northwestern Wyoming. It flows south into Idaho, west across the broad Snake river plain of southern Idaho, north to the Clearwater River confluence near Lewiston and Clarkston, then west to join the Columbia River near Pasco, Washington. The Snake River drainage basin covers an area of approximately 109,000 square miles. The mean annual flow near the mouth is approximately 51,000 cubic feet per second. The Snake River is approximately 1,000 miles long from the headwaters to the Columbia River. Approximately 180 miles of the lower Snake River are located in Washington.

The Snake River contains a series of reservoirs in Washington that are operated primarily for power production, recreation, and navigation (Lower Granite, Little Goose, Lower Monumental, and Ice Harbor). Each pool is approximately 130 feet maximum depth and 29 to 37 miles in length (Funk, Falter, and Lingg, 1979). The reservoirs are considered to be flow-through rather than storage pools. The pools were filled between 1962 and 1975.

The Walla Walla River is also a tributary to the Columbia River. The watershed area of the Walla Walla River is approximately 1,760 square miles. Mill Creek is the largest of the continuously flowing tributaries, all of which rise in the Blue Mountains (Newcomb, 1965). The Touchet River is formed by the confluence of several large creeks draining the northern part of the Walla Walla River basin. Creeks with headwaters in the lower part of the Blue Mountains are mostly non-perennial.

At intermediate elevations in the WQMA (about 2,000 to 3,000 feet) annual precipitation ranges from 15 to 25 inches, and vegetation of both grasslands and forests are typical of the semi-arid climate (Steinkampf, 1989). Precipitation in the lower central part of the plateau ranges from 7 to 15 inches per year. The lower precipitation in this part of the plateau results in an arid environment characterized by sage and grasslands and the presence of few perennial streams. Most of the annual precipitation occurs between October and March.

The purpose of this Consolidated Briefing Paper is to incorporate all of the information from the Environmental Investigations and Laboratory Services Program (EILS) into one briefing paper for the Watershed Workgroup for the Upper and Lower Snake River WQMA. Five individual chapters were prepared by the EILS sections to include all aspects of EILS involvement for the Consolidated Briefing Paper as follows:

- Intensive Surveys and Total Maximum Daily Loads
- Ambient Rivers, Streams, and Lakes
- Toxics Investigations
- Ground Water Investigations
- Compliance Monitoring

References

Funk, W.H., C.M. Falter, and A.J. Lingg. 1979. Limnology of an impoundment series in the Lower Snake River. Final Report submitted to US Army Corps of Engineers. Contract Nos. DACW 68-75-C-0143 and 0144. (Revised October, 1985).

Newcomb, R.C. 1965. Geology and Ground-Water Resources of the Walla Walla River Basin Washington-Oregon. State of Washington, Department of Conservation, Division of Water Resources. Water Supply Bulletin No. 21.

Steinkampf, W.C. 1989. Water-Quality Characteristics of the Columbia Plateau Regional Aquifer System in Parts of Washington, Oregon, and Idaho. US Geological Survey. Water Resources Investigations Report 87-4242. Tacoma, WA. 37 pp.

Table 1. River Mile Index for the Snake River from River Mile 0 to 176.1 (mouth to southern border of Washington) and Walla Walla River, including locations of major tributaries, Ecology core stations, USGS stations, dams, and other landmarks

Snake River Mile Location	Tributary River Mile Location		Tributary or Dam	Watershed Area (square miles)	Water Surface Elevation (feet)
0.0			Mouth of Snake River	109,000	340
2.2			USGS water quality station at Burbank (13353200); Ecology 33A150	108,800	
9.7			Ice Harbor Dam	108,500	440
41.6			Lower Monumental Dam	108,500	540
59.5			Palouse River	3,283	540
	19.5		USGS gage at Hooper, WA (13351000); Ecology 34A070	2,500	1,060
	41.0		Rock Creek	954	1,270
	49.4		Rebel Flat Creek		
	89.5		USGS gage at Colfax, WA (13349210)	796	1,936
	89.6		S.F. Palouse River	297	
		22.1	Missouri Flat Creek		
		22.2	USGS gage 13348000; Ecology 34B110	132	2,327
		23.6	Paradise Creek		
	103.8		Silver Creek		
	121.2		Ecology 34A170		
62.2			Tucannon River	504	540
	2.3		Ecology 35B060		
	11.2		Pataha Creek	185	
	34.8		Cummings Creek		
70.3			Little Goose Dam	103,900	638
107.5			Lower Granite Dam	103,500	738
139.3			Clearwater River	9,640	738
139.6			Clarkston/Lewiston, Interstate Bridge; Ecology 35A150	93,400	
145.3			Asotin Creek	323	
	0.0		USGS gage at Asotin, WA (13335050)	323	
	5.3		USGS gage near Asotin, WA (133334700)	170	
167.2			USGS gage at Anatone (13334300)	92,960	812
168.7			Grande Ronde River	3,950	
	45.2		USGS gage at Troy, OR (13333000)	3,275	1,590

Walla Walla River Mile Location	Tributary River Mile Location	Tributary or Dam	Watershed Area (square miles)	Water Surface Elevation (feet)
0.0		Mouth of the Walla Walla River	1,758	
15.3		Ecology 32A070		
18.2		USGS gage near Touchet, WA (13018500)	1,657	405
21.6		Touchet River	721	
	54.8	East Fork Touchet River	102	
33.6		Mill Creek		
	10.5	USGS gage at Walla Walla, WA (14015000)	96	1,167
	21.2	USGS gage near Walla Walla, WA (14013000)	60	2,016

Intensive Surveys and Total Maximum Daily Loads

by

Greg Pelletier
Watershed Assessments Section

Introduction

Waterbodies that were listed in 1994 under Section 303(d) of the federal Clean Water Act are shown in Table 1. Listed violations of water quality standards in waterbody segments of the WQMA include the following:

• temperature	(15 segments listed)
• fecal coliform	(12)
• pH	(7)
• ammonia	(5)
• dissolved oxygen	(5)
• chlorine	(2)
• total dissolved gas	(2)
• fish heptachlor	(1)
• total N and P	(1)

Causes of water quality impairment in waterbody segments of the WQMA have been identified in the 1994 Section 305(b) list as follows (includes waterbodies not listed under 303(d)):

• Agriculture (all categories)	(97 segments listed)
- *unspecified*	*(71)*
- *pasture land*	*(19)*
- *irrigated crop*	*(5)*
- *non-irrigated crop*	*(1)*
- *animal holding/management*	*(1)*
• Silviculture (all categories)	(43)
- *unspecified*	*(24)*
- *logging road construction/maintenance*	*(18)*
- *harvesting, restoration, residue management*	*(1)*
• Natural Sources	(42)
• Point Sources	(6)
- *municipal*	*(4)*
- *industrial*	*(2)*
• Flow Regulation/Modification	(3)

• Upstream Impoundment	(3)
• Removal of Riparian Vegetation	(1)
• Streambank Modification/Destabilization	(1)

Most of the identified water quality problems in the WQMA have been attributed to nonpoint sources from agriculture, silviculture, and natural sources. Six segments of the WQMA are considered to be impaired because of point sources of pollution.

Water quality problems associated with point sources were identified in the following waterbody segments (the largest municipalities and industries are shown in parentheses):

• Snake River	(33-1010/35-1020)	(Potlatch Inc., Clarkston, Lewiston)
• South Fork Palouse R	(34-1020)	(Moscow, Pullman, Albion)
• Paradise Creek	(34-1025)	(Moscow)
• Silver Creek	(34-1032)	(Garfield)
• Rebel Flat Creek	(34-4010)	(Endicott)

Ecology Studies: Intensive Surveys and Total Maximum Daily Loads

Three Total Maximum Daily Loads (TMDLs) have been approved by EPA as of June 1, 1996:

- *Mill Creek Ammonia.* The goal of this TMDL is to meet ammonia criteria between October and April downstream from the city of Walla Wall at river mile 5.4.

- *Pataha Creek Biochemical Oxygen Demand.* The goal of this TMDL is to meet the dissolved oxygen criterion downstream from the city of Pomeroy discharge at river mile 23.0.

- *South Fork Palouse River Ammonia.* The goal of this TMDL is to meet ammonia criteria downstream from the city of Pullman discharge at river mile 21.3 and the city of Albion at river mile 14.1. A revision of the TMDL was proposed by Ecology in 1995 and has not yet been approved by EPA. The water quality goals also depend on future development of water quality-based limits for the city of Moscow, Idaho, so that ammonia criteria will be met in Paradise Creek at the Idaho border.

Recent Projects by EILS (1989-present)

Total maximum daily loads (TMDLs) for ammonia were established for critical points in the South Fork Palouse River (Pelletier, 1993; Pelletier, 1995). Basin Class II inspections were also performed as part of the TMDL study (Glenn, 1992). Waste load allocations for Publicly Owned Treatment Works (POTWs), load allocations for nonpoint sources, and a margin of safety were factored into the analysis. Four alternatives were considered for evaluating TMDLs: monthly and semi-annual limits, each with and without mixing zone size exemptions. Semi-annual limits were recommended instead of monthly limits for administrative simplicity. An engineering analysis of the treatment process was recommended to determine feasibility of operational changes or improvements required to meet the proposed ammonia limits. Comparison of proposed limits with 1991 data from Pullman POTW suggests that the proposed limits could be achieved without significant capital improvements. Permit limits for effluent ammonia for the Albion POTW may be unnecessary during February and March, but may be required during April and May.

A Limited Class II inspection and receiving water survey was conducted at Pomeroy Wastewater Treatment Plant (WTP) on October 15-16, 1991 (Cusimano, 1992). The purpose of the study was to determine WTP efficiency and assess impacts of effluent discharge on Pataha Creek. Biochemical oxygen demand 5-day (BOD5), total suspended solids (TSS), total residual chlorine (TRC), pH, and fecal coliform were found to be within permit limits at the WTP. The receiving water study identified an effluent dilution of about 12:1 for the survey. Fecal coliform concentrations were found to exceed the water quality criteria above the WTP. The WTP effluent did not affect downstream temperature, however, dissolved oxygen, pH, and nutrient concentrations were altered by the effluent. In addition, instream ammonia concentrations below the plant exceed the chronic water quality criterion. Worst-case modeling predicted water quality violations for ammonia and dissolved oxygen under selected design conditions. Recommendations include improving treatment for ammonia and land application of effluent during summer conditions to mitigate the effects of ammonia and BOD on creek water quality.

A modeling analysis of dissolved oxygen in the Snake River is currently in progress. The objective of the project is to evaluate the sensitivity of dissolved oxygen in the Lower Granite reservoir to point and nonpoint sources of oxygen-demanding materials and nutrients. A water quality model based on existing data is being developed. Recent data collected by Potlatch, Inc. and by the U. S. Army Corps of Engineers will be used to develop the water quality model. Preliminary modeling suggests that dissolved oxygen deficits in the river are controlled mainly by algal productivity and respiration, which are controlled mainly by nonpoint sources of nutrients.

Older EILS Projects (1975-1989)

Touchet River and Tributaries

- A water quality investigation was conducted on the Touchet River on September 15, 1986 (Joy, 1986a). The objective of the survey was to identify possible sources of wastes being discharged into the river. Joy (1986b) also conducted a receiving water study at Waitsburg WTP. Yake (1979) had previously conducted Class II inspections and receiving water studies in this area.

- A water quality investigation was conducted on the Touchet River below the Dayton WTP on December 22, 1983 (Yake, 1984). The objective of the survey was to determine the potential impacts of chlorine and ammonia from the Dayton WTP on the Touchet River.

- A Class II inspection and receiving water study at Dayton WTP and the Touchet River was conducted by Chase and Cunningham (1981). The objective of this investigation was to determine if the plant was meeting its NPDES permit limitations, and to determine the effect of the effluent on the receiving waters of the Touchet River.

- A receiving water survey was conducted on Coppei Creek below the Waitsburg WTP on September 10 and 11, 1979 (Yake and Cloud, 1979). The objective of the study was to determine the effects of the effluent on Coppei Creek.

Mill Creek and Tributaries

- Class II Inspection and receiving water study were performed at the Walla Walla WTP and Mill Creek, on February 11 and 12, 1986 (Joy, 1987a). The objective of the survey was to document the water quality of Mill Creek since the upgrade of Walla Walla WTP, and to compare current conditions to 1981 pre-upgrade water quality conditions.

- Joy (1985) and Singleton and Cunningham (1985) developed a water quality model for dissolved oxygen simulation in Mill Creek using 1983-84 data from the Walla Walla WTP. The objective of the survey was to represent the dissolved oxygen cycle of Mill Creek using a Streeter-Phelps dissolved oxygen computer simulation model.

- Singleton (1982) evaluated Mill Creek discharge limitations during October and November. This document is a memorandum dated August 12, 1982. The author's main concern is improving the water quality of Mill Creek, especially during low flow months.

- A receiving water survey was conducted on Mill Creek on February 3 and 4, 1981 (Singleton and Joy, 1982). The primary purpose of the receiving water survey was to evaluate the Walla Walla WTP impact upon Mill Creek low flow conditions and determine the sources of any other inputs which may affect water quality.

Palouse River and Tributaries

- A Limited Class II Inspection and receiving water survey was conducted at the Endicott WTP on October 11-13, 1988 (Willms and Kendra, 1990). The purpose of the study was to determine the wastewater plant efficiency and assess effects of effluent discharge on Rebel Flat Creek.

- A Limited Class II Inspection and receiving water survey was conducted at Palouse WTP from September 28 to October 1, 1987 (Kendra, 1988). The objective of the investigation was to measure treatment efficiency provided by the process units, estimate loads to parallel streams of the treatment process, and to compare survey results to NPDES permit limits.

- Determan (1987) conducted an abbreviated Class II inspection of Garfield WTP and receiving water study of Silver Creek. This study evaluated the performance of the Garfield WTP and measured the effect of the discharge on Silver Creek. The report concluded that water quality in Silver Creek can be improved by eliminating direct discharge of the WTP to the creek, preventing livestock access, and eliminating an unknown upstream source.

- A Class II Inspection and receiving water survey was conducted at Colfax WTP on August 30 - September 1, 1982 (Yake, 1983a). The objective of the investigation was to determine if the upgraded plant was complying with NPDES permit limits, review and evaluate laboratory procedures, and assess the impact at Colfax WTP effluent on the water quality in the Palouse River.

South Fork Palouse River and Tributaries

- A water quality survey and Class II Inspection was conducted at the Pullman WTP on September 16-17, 1986 (Joy, 1987b). The objectives of the receiving water survey were to assess a current water quality of the south fork of the Palouse River from Paradise Creek to 2.5 miles below the Pullman WTP during low-flow conditions; to collect water quality and benthic invertebrate samples for comparison to the 1978 survey; to monitor Pullman WTP effluent impact with respect to NPDES permit limits, especially nitrogen and chlorine; and to assess current water quality of other sources within the study area, including those identified in the 1978 survey (Palouse Producers, Inc., Moscow WTP, Paradise Creek, and storm drains or other unknown sources between Thatuna Park and the Pullman WTP).

- A prototype method for evaluating permit limits for ammonia was developed and applied to the Pullman WTP (Yake, 1983b). The objective of this report was a first stage prototype for allocating effluent ammonia from point sources in the state, predicting the instream concentrations of unionized ammonia nitrogen. This report deals with how pH and temperature affect the concentrations of ammonia nitrogen.

- A Class II Inspection and water quality survey was conducted at the South Fork of the Palouse River, at Pullman WTP (Bernhardt and Yake, 1979). The report was published February 1979. The objective of this report was to provide a baseline of data which could be used for comparison after the Pullman WTP was upgraded.

- A receiving water investigation was conducted at Palouse Producers, Inc. in Pullman on September 13-15, 1978 (Bernhardt and Yake, 1978). The objective of the survey was to determine the source of high ammonia in the south fork of the Palouse River.

- A Class II Inspection was conducted at Pomeroy WTP, in conjunction with a receiving water study conducted on Pataha Creek on July 8-9, 1980 (Chase, Egbers, and Rob, 1980). The objective of the study was to measure treatment provided by the process units, review analytical procedures, evaluate sampling and analytical accuracy of both the Pomeroy Laboratory and Washington State Department of Ecology, and compare survey results with NPDES permit limits.

Non-Ecology Studies

US Army Corps of Engineers Studies in the Snake River

Several studies related to water quality in the Snake River system have been funded by the U. S. Army Corps of Engineers (ACOE) for management of the dams in Washington. A major focus of current studies by the ACOE is a proposal to seasonally draw down the reservoir water levels as part of a recovery plan for endangered species of salmon.

- Several studies of the Lower Granite Reservoir are ongoing. The purpose of the studies is to collect comprehensive environmental baseline data to estimate the effects of drawdown on the physical, chemical, and biological attributes of the affected reservoirs. Water quality sampling was initiated in 1994 and may continue for several more years. Data from this study are not yet available from ACOE.

- Greene (1995) conducted an assessment of nutrient pollution in the Lower Snake River using *Selenastrum capricornatum* to measure algal growth potential. This report concludes that water quality has been significantly degraded by increased nutrient loading compared with results of a similar study in 1974. The algal growth potential in Snake River samples was found to range from moderately to extremely productive.

Potlatch Corporation NPDES Permit Fact Sheet

Potlatch Corporation discharges wastewater from a kraft pulp and paper mill at the confluence of the Clearwater and Snake Rivers. The most recent NPDES permit fact sheet for the Potlatch Corporation includes calculations by Yearsley (1985) for effluent limits of BOD5. A one-dimensional steady-state model was used. Dissolved oxygen was predicted by accounting for carbonaceous BOD (CBOD) and nitrogenous BOD (NBOD) decay from point sources, and reaeration. Rate constants for CBOD and NBOD decay, and reservoir depth and width were estimated from data collected during August 1977 by EPA (Howard and Yearsley, 1977). Allowable BOD5 loading from Potlatch was calculated using the assumption that Potlatch would be allowed the difference between existing permit loads from Lewiston and Clarkston and total loading which would cause a 0.2 mg/L deficit. Allowable BOD5 loading from Potlatch was calculated for different river flows in the range of 14,000 to 20,000 cfs based on the load which would cause a 0.2 mg/L deficit at each combination of flow and temperature.

Washington State standards (WAC 173-201A) do not provide for allowing a 0.2 mg/L deficit from human-caused sources when the dissolved oxygen in fresh water does not meet the Class A standard of 8 mg/L. The EPA analysis is based on the assumption that a 0.2 mg/L deficit would be allowed if it could be considered immeasurable. Since occasional measurements of dissolved oxygen below 8 mg/L have been reported in the reservoir, the alternative to EPAs approach would be to not allow any discharges of wastes that would further suppress dissolved oxygen. The EPA approach in the Potlatch permit is similar to Washington State standards for marine water, which allow a 0.2 mg/L deficit from human caused sources when the natural condition is less than the standard.

Studies of the Snake River by Potlatch Corporation

Falter (1990) studied temperature and dissolved oxygen patterns in Lower Granite Reservoir during summer low flow in 1988 and 1989. The investigators also measured conductivity and pH profiles. This study found vertical differentiation of Clearwater and Snake River waters to river mile 109. Mixing of these two rivers occurred over most of the reservoir length. Colder water from the Clearwater River was most concentrated at lower depths in the reservoir and gradually mixed with warmer overlaying water from the Snake River. Dissolved oxygen concentrations as low as 6.3 mg/L were observed in deeper waters of the reservoir. The author hypothesized that oxygen deficits were due mostly to settling algae. Lowest dissolved oxygen concentrations were typically near the bottom. Concentrations near the surface were typically greater than 8 mg/L. Diel ranges of dissolved oxygen (differences between maximum and minimum over the course of a day) were typically 2 to 3 mg/L near the surface and less than 1 mg/L near the bottom.

Potlatch is currently conducting field studies during September and October 1995 (personal communication with Alan Prouty, Potlatch Corporation). Water column measurements of nutrients, chlorophyll, dissolved oxygen, temperature, and conductivity will be made at seven sampling sites between the Clearwater River and Lower Granite Dam. Ten sampling events are planned over an 8-week period.

1979 Study of Limnology of Lower Granite Reservoir

An investigation of limnology in the reservoir was sponsored by the U. S. Army Corps of Engineers and conducted by Washington State University and University of Idaho following construction of the dam (Funk, Falter, and Lingg, 1979). Data were collected during April 1975 through October 1977. Pronounced thermal and chemical stratification of the reservoirs was not observed. This study found the Snake and Clearwater flows to be incompletely mixed as far downstream as river mile 122. Algal biomass and nutrients indicated a mesotrophic condition. Both phosphorus and nitrogen were found to limit algal productivity at times during summer. Higher algal biomass levels were observed after impoundment compared with pre-impoundment data.

EPA 1977 Modeling Study of Lower Granite Reservoir

Howard and Yearsley (1977) developed a steady-state one-dimensional model to predict dissolved oxygen in the Lower Granite reservoir. Calibration data were collected during August 1977. The model results were not published in a final report or technical memorandum, but a draft memo was obtained from John Yearsley at EPA Region 10. The model results showed that the most important factors affecting dissolved oxygen were CBOD loading from the Potlatch Corporation, CBOD decay, and photosynthesis. The model was judged to provide conservative results of time- and vertically-averaged water quality. The authors expressed reservations about the accuracy of the model and attributed difficulty in fitting observed data to lack of vertical resolution and inadequate calibration data. The model was not used as the basis of determining NPDES permit loads.

Timber, Fish, and Wildlife Projects

Timber, Fish, and Wildlife (TFW) Cooperative Monitoring, Evaluation, and Research (CMER) committee has been involved in two projects that have include some studies in the WQMA:

- *Ecoregion Bioassessment Pilot Project.* A project was initiated to evaluate the usefulness of a monitoring protocol to detect water resource impacts due to forest practices. Plotnikoff (1992) conducted a biological assessment of benthic macroinvertebrate communities at unimpacted forested stream reference sites in three ecoregions of Washington: Columbia Basin, Cascades, and Puget Lowlands. The Columbia Basin study sites included two stations in the WQMA: Cummings Creek (tributary to Tucannon River and Snake River), and North Fork Asotin Creek (tributary to Asotin Creek and Snake River). The study results recommend evaluation methods and provide a data reference for evaluation of impacted sites in the Columbia Basin Ecoregion, which includes the WQMA. Plotnikoff (1993) continued and expanded the bioassessment study to include additional sites in the WQMA, including sites in Cummings Creek, North Fork Asotin Creek, Tucannon River, South Fork Palouse River, and Palouse River.

- *Stream Temperature Project.* Sullivan *et al.* (1990) evaluated models to predict the effects of forest practices on stream temperature. Study sites throughout the state included nine locations in the Tucannon River watershed. Data from the study sites were used to test various models to predict stream temperature. The study recommended a method for evaluation of temperature impacts by forest practices.

Watershed Analysis is a process developed by the TFW cooperators to address the cumulative effects of forest practices on fish, water, and capital improvements. A TFW Watershed Analysis has recently been started in the Touchet River basin. The study is being sponsored by the Ellensburg office of the Department of Natural Resources. The study is expected to be finished in late 1995 or early 1996.

U. S. Geological Survey Projects in the WQMA

The U. S. Geological Survey (USGS) is conducting a study of the Central Columbia Plateau. The Central Columbia Plateau study unit encompasses a large portion of the Upper/Lower Snake Basin and also extends into other WRIAs.

The long-term goals of the Central Columbia Plateau National Water Quality Assessment (NAWQA) study are to describe the status and trends in the quality of the surface and ground water resources of this study unit and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources. In meeting these goals, the study will produce water quality information that will be useful to policy-makers and managers at the national, state, and local levels.

The study unit is an important area to study because the water that flows out of the area, both on the surface and underground, ends up in the Columbia River, a major river resource of the United States. It is also important because of large-scale agricultural activities, which use both ground water and surface water from the Columbia Basin Irrigation Project (CBIP) of the U. S. Bureau of Reclamation. Persistent declines of ground water levels have occurred in areas of sizable pumping for irrigation. In other areas of the basin, water levels have risen hundreds of feet because of the large amounts of surface water applied for irrigation, requiring drains to be installed beneath the fields. Therefore, the different irrigation and farming practices in the area have a major impact on both ground and surface water quality. In areas where water levels are declining, agricultural practices may have less of a near-term effect on ground water quality because of increased distance between the water table and land surface. In areas with installed drains, shallow ground water containing large concentrations of nitrate is intercepted and routed to parts of the CBIP drainage system. Most of the drain water eventually reaches the Columbia River, but in transit, some of it moves through tributary water bodies where large nutrient concentrations may cause excessive plant growth and related problems.

To adequately address water quality issues at the national scale, an integrated program of water resources investigations that is consistent at all scales is required. In contrast with many previous water quality studies, the USGS NAWQA project will analyze loads as well as concentrations of chemical constituents in order to help assess the impact of the chemicals resulting from natural processes or manmade effects. The study will consider seasonal variations both from the standpoint of climate and agricultural practices. In order to determine the mechanisms causing water quality degradation, the study will search for areas with nearly homogeneous land use and hydrologic conditions where the incoming and outflowing water quality can be compared.

Reports by the USGS that are related to NAWQA and other projects in the Upper/Lower Snake Basin are listed in Appendix A.

Conclusions and Recommendations

Several segments of the WQMA are considered to be impaired because of point sources of pollution. Three TMDL projects have been approved by EPA. However, six segments of the WQMA remain on the 303(d) list partly because of point sources. Future TMDL studies by EILS should focus on the following unresolved point source problems:

- *Snake River.* Discharges by Potlatch Corporation, and to a lesser extent, the cities of Clarkston and Lewiston are suspected of contributing to dissolved oxygen problems in the Lower Granite Reservoir. An EILS project is in progress to use available information to develop a water quality model and evaluate the sensitivity of the reservoir to point and nonpoint loading sources of oxygen demanding materials and nutrients. Preliminary results from this project suggest that nonpoint sources of nutrients may exert a major influence on dissolved oxygen. Future TMDL efforts by Ecology should include consideration of the sensitivity and loading capacity of the reservoir and WLAs for dischargers in Washington. Additional involvement by EPA Region 10 and the state of Idaho is also needed to address point and nonpoint source loading from upstream of the Washington border.

- *South Fork Palouse River and Paradise Creek.* Waste Load Allocations (WLAs) for ammonia from the cities of Pullman and Albion have been developed and approved by EPA. These WLAs are planned to be incorporated into discharge permits in the near future. WLAs for ammonia loading from the Moscow WTP still need to be developed by EPA and Idaho. Future TMDL efforts should address the influence of point sources on dissolved oxygen and increase the involvement of EPA and Idaho for regulation of loading from Moscow.

- *Silver Creek.* Dissolved oxygen, ammonia, and chlorine have been identified as water quality problems that are influenced by point sources. Future TMDL efforts should develop WLAs to meet water quality criteria.

- *Rebel Flat Creek.* Fecal coliform and chlorine have been identified as water quality problems. Future TMDL efforts should develop WLAs to meet water quality criteria.

Most of the identified water quality problems in the WQMA have been attributed to nonpoint sources from agriculture and silviculture. Natural causes have also been identified as a major contributor to observed violations of water quality standards. Temperature, fecal coliform, and pH were the parameters with the most frequently observed violations of water quality standards in the WQMA. Several management activities are available to address nonpoint source problems in the WQMA and may be used as the functional equivalent of TMDLs:

- *Watershed Analysis.* Watershed Analysis is a process developed by Timber, Fish, and Wildlife (TFW) cooperators to address the cumulative effects of forest practices on fish, water, and capital improvements. Waterbody segments that are listed under 303(d) and are identified as impaired by silviculture should be considered candidates for Watershed Analysis. The highest priority segments for Watershed Analysis include the following (because of listing under Sections 303(d) and 305(b) of the federal Clean Water Act with silviculture identified as a contributing cause):

- Touchet River (in progress)	(32-1020/1025)
- Snake River	(35-1010)
- Tucannon River	(35-2010/2030)
- Pataha Creek	(35-2013)
- Cummings Creek	(35-2024)
- Grande Ronde River	(35-3010)

- *Centennial Clean Water Funded Projects.* Ecology provides grants from the Centennial fund to local governments and other groups to complete a wide variety of water pollution control projects (e.g., watershed plans developed in accordance with the nonpoint rule [Chapter 400-12 WAC]). In evaluating whether a proposed project receives funding in the WQMA, highest priority should be given to projects that will improve or protect a waterbody on the Section 303(d) list. Funded projects should also be required to meet the major requirements for TMDL approval, including problem formulation, TMDL calculations and supporting studies, control actions and implementation schedules, public participation, and follow-up monitoring. All of the listed waterbody segments in the WQMA should be considered candidates for surrogate TMDLs conducted by Centennial Clean Water funded projects.

- *Farm Plans.* The state's local conservation districts work with individual farmers to develop water quality management (farm) plans. Development of these plans may be voluntary, required under the statewide NPDES Dairy Waste General Discharge Permit, or initiated by an agricultural water quality complaint to Ecology. These plans may be included as part of a basin-wide TMDL. A single farm plan or set of plans could also contain all of the components of a complete TMDL if farm management is the primary cause of water quality problems. The highest priority segments for farm plans include the following (because of listing under Sections 303(d) and 305(b) of the federal Clean Water Act with agriculture identified as a contributing cause):

- Walla Walla River	(32-1010)
- Touchet River	(32-1020/1025)
- Snake River	(35-1010, 35-1010/1020)
- Palouse River	(34-1010/1030)

- Rock Creek (34-1015)
- South Fork Palouse River (34-1020)
- Missouri Flat Creek (34-1024)
- Paradise Creek (34-1025)
- Silver Creek (34-1032)
- Tucannon River (35-2010/2030)
- Pataha Creek (35-2013)
- Cummings Creek (35-2024)
- Grande Ronde River (35-3010)

References

Bernhardt, J., and W. Yake, 1978. Water Quality Violation at Palouse Producer's Inc. Memo to Claude Sappington. 4 pp.

------, and W. Yake, 1979. Assessment of Wastewater Treatment and Receiving Water Quality - South Fork of the Palouse River at Pullman, Washington. 47 pp.

Chase, S. and D. Cunningham, 1981. Dayton Class II Inspection and Touchet River Receiving Water Study. Memo to Claude Sappington. 16 pp.

Chase, S., E. Egbers, and S. Robb, 1980. Pomeroy Class II and Pataha Creek Receiving Water Study. Memo to Phil Williams. 33 pp.

Cusimano, B., 1992. Pomeroy Wastewater Treatment Plant Limited Class II Inspection and Receiving Water Study on Pataha Creek. Ecology Report, Olympia, Washington, 25 pp. + appendices.

Determan, T.A., 1987. Garfield Abbreviated Class II Inspection and Silver Creek Receiving Water Study. Ecology Report. 20 pp.

Falter, C.M., 1990. Temperature and Oxygen Patterns in the Lower Granite Pool, Snake River, Idaho-Washington, During Low Flows, 1988-89. Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID. Prepared for Potlatch Corporation, Lewiston, ID. 61 pp.

Funk, W.H., C.M. Falter, and A.J. Lingg. 1979. Limnology of an impoundment series in the Lower Snake River. Final Report submitted to US Army Corps of Engineers. Contract Nos. DACW 68-75-C-0143 and 0144. (Revised October, 1985).

Glenn, N., 1992. South Fork Palouse River Basin Class II Inspections at Pullman and Albion, July 23-25 and October 1-3, 1991. Ecology Technical Document, Olympia, Washington, 20 pp. + appendices.

Greene, J.C., 1995. An assessment of nutrient pollution in the Lower Snake River Using *Selenastrum capricornatum* to Measure Algal Growth Potential. Department of the Army. Walla Walla District, Corps of Engineers. Environmental Resources Branch. Walla Walla, WA.

Howard, D. and Yearsley, J. 1977. Untitled. Draft results of water quality modeling of Lower Granite Reservoir. US Environmental Protection Agency. Region 10. Seattle, WA.

Joy, J., 1985. Dissolved Oxygen Simulation for Mill Creek Using 1983-84 Walla Walla STP Effluent Data. Memo to Carl Nuechterlein.

------, 1986a. Results of September 15, 1986, Touchet River Survey in Waitsburg. Memo to Carl Nuechterlein and Larry Peterson. 12 pp.

------, 1986b. Waitsburg Wastewater Treatment Plant Receiving Water Study. Memo to Carl Nuechterlein. 28 pp.

------, 1987a. Walla Walla Wastewater Treatment Plant/Mill Creek Receiving Water Survey, February 12-13, 1986 and TMDL Evaluation. Ecology Report. 27 pp.

------, 1987b. A Water Quality and Receiving Water Survey of the South Fork of the Palouse River at Pullman, September 1986. Ecology Report. 46 pp.

Kendra, W., 1988. Quality of Palouse Wastewater Treatment Plant Effluent and Impact of Discharge to the North Fork Palouse River. Ecology Report. 36 pp.

Pelletier, G., 1993. South Fork Palouse River Total Maximum Daily Load of Ammonia. Ecology Report, 49 pp. + appendices.

Pelletier, G., 1995. South Fork Palouse River Total Maximum Daily Load for Ammonia, Addendum to the 1993 Report. Ecology Report No. 95-329. 8 pp. + appendices.

Plotnikoff, R. 1992. Timber/Fish/Wildlife Ecoregion Bioassessment Pilot Project. Washington State Department of Ecology. Environmental Investigations and Laboratory Services Program. Olympia, WA. 57 pp. + appendices.

Plotnikoff, R. 1993. Ambient Monitoring Instream Biological Assessment: Progress Report of 1993 Pilot Survey. Washington State Department of Ecology. Environmental Investigations and Laboratory Services Program. Olympia, WA. 31 pp. + appendices.

Singleton, L., 1982. Mill Creek Discharge Limitations During October and November. Memo to Carl Nuechterlein. 1 pp.

------, and D. Cunningham, 1985. Dissolved Oxygen Simulations for Mill Creek Using 1983-84 Walla Walla STP Effluent Data. Memo to Carl Nuechterlein. 7 pp.

------, and J. Joy, 1982. Mill Creek Receiving Water Survey. Memo to Carl Nuechterlein. 53 pp.

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

Willms, R. and W. Kendra, 1990. Endicott Wastewater Treatment Plant Limited Class II Inspection and Impact of Discharges on Rebel Flat Creek. 26 pp.

Yake, W., 1979. Waitsburg Class II Inspection. Memo to Phil Williams. 9 pp.

------, 1983a. Colfax Class II and Receiving Water Survey. Memo to Carl Nuechterlein. 23 pp.

------, 1983b. Permit Conditions for Ammonia, Pullman STP - A Prototype Method for Allocating Ammonia using Ambient Monitoring Data. Memo to Files. 14 pp.

------, 1984. Assessment of Potential Impact of Dayton STP Effluent on the Touchet River, with Recommended Permit Limits for Ammonia and Chlorine. Memo to Carl Nuechterlein. 11 pp.

------, and G. Cloud, 1979. The Effects of Waitsburg Wastewater Treatment Plant Effluent on Coppei Creek. Memo to Phil Williams. 17 pp.

Yearsley, J. 1985. Water Quality Related Effluent Limitations for Potlatch Corporation-Lewiston. Memorandum to Danforth G. Bodien. US Environmental Protection Agency, Region 10. Seattle, WA. 12 pp.

Table 1. Waterbodies in the Upper and Lower Snake River Water Quality Management Areas, including 1994 303(d) listings and high-priority TMDL projects (shading indicates high priority for TMDL, circles indicate parameters removed from the proposed 1996 303(d) list because of completed TMDLs).

				1994 Section 303(d) List Submitted to EPA (bold shading indicates high priority for TMDL)								
Waterbody ID Number	Waterbody Name	River Mile Range	Freshwater Classification	Temp-erature	Fecal Coliform	pH	Ammonia	Dissolved Oxygen	Chlorine	Total Dissolved Gas	Fish Hepta-chlor	Total N and P
WA-32-1010	Walla Walla River	0-21.6	A	X	X	X					X	
WA-32-1020	Touchet River	0-54.8	A	X	X	X						
WA-32-1025	Touchet River, N.F. (E.F.)	0-20.4	AA	X								
WA-32-1060	Mill Creek	0-6.4	B									X
WA-32-1070	Mill Creek	6.4-11.5	A	X	X							
WA-33-1010	Snake River	0-59.3	A	X				X		X		
WA-34-1010	Palouse River	0-89.6	B	X	X	X						
WA-34-1015	Rock Creek		A	X	X	X						
WA-34-1020	Palouse River, S.F.	0-31.8	A	X	X	X	(X)	**X**				
WA-34-1024	Missouri Flat Creek		A					X				
WA-34-1025	Paradise Creek		A	X	X		**X**	**X**				
WA-34-1030	Palouse River	89.6-123.4	A	X	X	X	X					
WA-34-1032	Silver Creek		A				X	X	X			
WA-34-4010	Rebel Flat Creek		A		X				X			
WA-35-1010	Snake River	59.5-139.3	A							X		
WA-35-1020	Snake River	139.3-176.1	A	X		X						
WA-35-2010	Tucannon River	0-32.7	A	X	X							
WA-35-2013	Pataha Creek	0-headwater	AA		X		(X)					
WA-35-2024	Cummings Creek	0-3.4	A	X								
WA-35-2030	Tucannon River	38.1-53.4	AA	X								
WA-35-3010	Grande Ronde River	0-36.8	A	X	X							
Numbers of Waterbody Segments Listed:				15	12	7	5	5	2	2	1	1

Appendix A: US Geological Survey Reports Related to the Upper/Lower Snake Basin

Published Abstracts Related to NAWQA

Ebbert, J.C., 1995. Inputs of nitrogen and changes of nitrate concentrations in ground water underlying irrigated cropland in parts of eastern Washington:, in Nitrogen Environment and People Conference, Everett, Washington, February 1995, p. 52.

Jones, J.L., and Ebbert, J.C., 1994, Comparison of water-quality information from shallow piezometers and domestic wells:, in Gary L. Pederson, American Water Resources Association, National Symposium on Water Quality, p. 249.

Jones, J.L., and Ebbert, J.C., [In Press], Comparison of pesticide and nitrate data from shallow piezometers and domestic wells.

Jones, J.L., Ebbert, J.C., and Williamson, A.K., 1994, Water quality under potato rotations: Columbia basin irrigation project:, in 34th Annual Washington Potato Conference and Trade Show, Moses Lake, Washington, February 7-9, 1995, p. 13.

Williamson, A.K., 1991, National water quality assessment (NAWQA), central Columbia plateau study unit -- Overview:, in 38th Annual Pacific Northwest Regional Meeting of the American Geophysical Union, Richland, Washington, September 18-20, 1991.

Published Reports Related to NAWQA

Bortleson, G.C., 1991, Water fact sheet, National Water-Quality Assessment Program Mid-Columbia River Basin, Washington and Idaho: US Geological Survey Open-File Report 91-164, p. 2.

Greene, K.E., Ebbert, J.C., and Munn, M.D., 1994, Nutrients, suspended sediment, and pesticides in streams and irrigation systems in the Central Columbia Plateau, in Washington and Idaho, 1959-1991: US Geological Survey Water-Resources Investigations Report 94-4215. 64+p.

Jones, J.L., and Wagner, R.J., [In Press], Ground-water quality of the Central Columbia Plateau in Washington and Idaho: Analysis of available nutrient and pesticide data, 1942-1992: US Geological Survey Water-Resources Investigations Report 94-4258. __p.

Williamson, A.K., and Bortleson, G.C., 1993, National water-quality assessment program central Columbia plateau, Washington and Idaho:, in Jones M.E., and Laenen, Antonius, American Institute of Hydrology, Interdisciplinary Approaches in Hydrology and Hydrogeology, Portland, Oregon, October 18-20, 1993, p. 338-349.

Other USGS Reports Related to the Upper/Lower Snake Basin

Palouse River Basin

- Boucher, P.R., 1970 (Sediment Transport By Streams)
- Nassar, E.G., Other, 1975 (General Water Resources)

Snake River Basin

- Ebbert, J.C., 1991 (Potential Effects of Lining Irrig Cnls On NO3 Conc In Gw)
- Laird, L.B., 1964 (Surface Water Quality)

Walla Walla River Basin (Also See Walla Walla County)

- Barker, R.A., Other, 1976 (Gravel-Aquifer Model)
- Darling, M.E., Other, 1994 (Appl GIS Rgrdng Gw Flw Sys Col Plateu Rasa)
- Garrett, A.A., 1962 (Artificial Recharge, Basalt)
- Mac Nish, R.D., Others, 1973 (Gw Availability, Management Model)
- Mac Nish, R.D., Other, 1976 (Basalt-Aquifer Model)
- Mapes, B.E., 1969 (Sediment Transport By Streams)
- Newcomb, R.C., 1965 (Gw Resources)
- Piper, A.M., Others, 1933 (Gw Resources)
- Price, C.E., 1961 (Artificial Recharge, Basalt)

Ambient Rivers, Streams, and Lakes

by

Dave Hallock
Ambient Monitoring Section

Introduction

The Ambient Monitoring Section (AMS) has collected over 3,000 river and stream samples in the Snake River Basin in the last 37 years. Thirty-five stations have been sampled since 1959 and 17 stations have been monitored during the last five years (Table 1). Six stations have been sampled long enough for statistical trend analyses to be meaningful (Walla Walla, Touchet, Snake, Palouse, SF Palouse, and Tucannon Rivers). Generally, 14 parameters were measured at each station (Table 2). We have also monitored three lakes in the basin (Silver, Sprague, and Williams; Table 3).

Some preliminary trend analyses are reported, below. The seasonal Kendall test for trend in WQHYDRO (Aroner, 1995) was used for the analysis. Trends were corrected for autocorrelation but the analysis did not consider the effects of trends in discharge on other parameters, or the potential affects of analytical methods changes. However, only trends considered to be real and significant were reported. More detailed analyses may reveal additional trends not reported here.

In general, conventional water quality at downstream stations in the Snake River Basin is poor. Suspended solids and total phosphorus concentrations tend to be high (Figure 1). Temperatures and pH are often high as well, and fecal coliform bacteria is a problem at a few stations.

Walla Walla River Basin

Lower stations in the basin (Walla Walla near Touchet (32A070) and Touchet near Touchet (32B070) tend to have poor water quality in general. Temperatures, in particular, are often well above water quality standards. The 90th percentile temperature at both stations was about 25°C. Conductivity, pH, sediments, and nutrients all tend to be high as well, though not as high as stations in the Palouse River Basin.

Water quality at Touchet River at Dayton (32B130), upstream of many agricultural impacts, was as good as that measured anywhere in the Snake River Basin in the last five years, although even this station had high temperatures.

A cursory trend analysis of data from the Walla Walla near Touchet indicated a statistically significant ($p < 0.001$) declining trend in discharge over the last 17 years, especially from August through April. (All trends in discharge are based on monthly instantaneous flows at the time of sampling.) Total suspended solids concentrations also decreased ($p = 0.070$).

Snake River

Water quality at both mainstem Snake River stations was generally good, often markedly better than the quality of water entering the system from tributary streams. Temperature and pH occasionally exceeded water quality criteria and conductivities were high. These results may be attributable to a heavily impounded system in an arid region. Nutrients and suspended solids were low, probably due to settling behind upstream impoundments.

The most significant trend noted was a decreasing trend in discharge ($p = 0.010$) amounting to 2,000 cfs, or 4.4 percent of the median flow annually for WY 1978 through WY 1994. Total suspended solids also decreased ($p = 0.076$).

Palouse River

Water quality in the Palouse River system is severely degraded. Fecal coliform bacteria, summer temperature, and pH frequently exceeded water quality criteria at mainstem, South Fork, and Paradise Creek stations. Nutrient and sediment concentrations were high at all stations.

The South Fork Palouse River (SFPR) in Pullman (34B110) has long had water quality as poor as any station monitored by AMS with respect to conventional parameters. At the request of the Eastern Regional Office, AMS monitored two stations on the South Fork of the Palouse River and two on Paradise Creek near Pullman, Washington, monthly during WY 1992. The objective was to partition sources of nutrients and bacteria upstream from the SFPR at Pullman. The primary source of nutrients was determined to be from Idaho via

Paradise Creek (presumably from the Moscow WTP). Sources of fecal coliform bacteria and suspended sediments were basin-wide. Findings are presented in detail in Hallock (1993).

Total suspended solids concentration has decreased in the SFPR since WY 1977 ($p = 0.010$) based on preliminary trend analyses. August discharge (the lowest-flow month) has also been decreasing ($p = 0.058$). Discharge also decreased in the main stem Palouse River ($p = 0.004$).

Tucannon River

Compared to the Palouse and Walla Walla systems, water quality in the Tucannon River was good (Table 4). Water quality criteria exceedences were far less common. However, while good relative to other stations in the Snake River Basin, temperatures as well as nutrient and sediment concentrations were high relative to conditions statewide.

Suspended sediment concentrations increased during the period evaluated, although the preliminary trend was not highly significant ($p=0.17$). Nevertheless, this may be cause for concern, since all other stations exhibited decreasing trends in sediment (with probabilities ranging from 0.010 to 0.78). Like other stations in the Snake River Basin, discharge in the Tucannon River decreased ($p=0.017$).

Southeast Washington: Grand Ronde River and Asotin Creek

Southeast Washington streams were monitored during WY 1993. Conventional water quality in the Grande Ronde River was good with no samples exceeding water quality standards. Water quality was generally good in Asotin Creek as well; however, 50% of samples exceeded the fecal coliform bacteria geometric mean criteria and one sample (May 4, 1993) had very high suspended solids (1,110 mg/L).

Sprague Lake

Sprague Lake was sampled by the Lake Water Quality Assessment (LWQA) program in 1989, both for a general trophic state assessment and for chemical contamination. The lake was considered eutrophic by Brower and Kendra (1990). Norton and Johnson (1990) found very low concentrations of metals and organic contaminants in Sprague Lake.

Williams Lake

Williams Lake (Spokane County) has been sampled for the LWQA program every year since 1989. Most recently, Rector (1995, in draft) assessed Williams Lake as mesotrophic. An analysis of trend in Secchi disk data indicated that the water clarity decreased during the six years AMS has been monitoring the lake, although the statistical significance was not high ($p=0.14$).

Silver Lake

Silver Lake was monitored by AMS in 1994 and 1995. Rector (1995, in draft) assessed the lake as meso-eutrophic. This assessment was based primarily on high phosphorus and chlorophyll concentrations; summer average Secchi depths indicated relatively good water clarity.

Conclusions and Recommendations

The recommended stations discussed below are in addition to the following seven core stations (sampled every year by AMS) on rivers and streams in the Snake River watershed:

32A070	Walla Walla River near Touchet	(river mile 15.3)
33A150	Snake River near Pasco	(2.2)
34A070	Palouse River at Hooper	(19.5)
34A170	Palouse River at Palouse	(121.2)
34B110	South Fork Palouse River at Pullman	(22.2)
35A150	Snake River at Interstate Bridge	(139.6)
35B060	Tucannon River at Powers	(2.3)

Up to five additional river and stream stations ("basin stations") may be monitored in WY 1997. We may also be able to monitor up to three "basin lakes," in addition to lakes with active volunteers. At this time, the only lake in the Snake River Basin with an active volunteer is Silver Lake.

- *Walla Walla/Touchet.* One potential area of focus for basin stations is the Walla Walla/Touchet sub-basin. Water quality in the Touchet River is significantly degraded in the 50 miles between Dayton and Touchet. Intermediate stations will help partition the source(s). Water quality in the upper Walla Walla has not been monitored, but the situation is probably similar to the Touchet. Up to six stations are desirable to cover both the Touchet and Walla Walla Rivers; *two to three stations on the lower Touchet River are recommended.*

- *South Fork Palouse River.* Monitoring should be conducted as a follow-up to the SFPR ammonia TMDL. The TMDL goal is dependent on an ammonia-nitrogen criterion being met in Paradise Creek at the Idaho border. *Two stations are recommended, one below the City of Albion discharge (river mile 21.3) and one at Paradise Creek at the Border.*

- *Asotin.* The high bacteria and occasionally high sediment concentrations in Asotin Creek should be confirmed with additional monitoring. One to two stations are desirable; none are recommended.

- *Tucannon.* The increasing trend in sediment concentrations in the lower Tucannon River should be confirmed by continued monitoring and more detailed statistical analysis.

Additional stations are needed to partition source areas. Up to two stations are desirable, in addition to the core station; *one to two stations are recommended.* (Pataha Creek below river mile 23.0 could be monitored for dissolved oxygen only as a TMDL follow-up without counting as one of the five "basin stations.")

- *Discharge Trends.* The basin-wide decreasing trend in discharge should be confirmed and characterized in more detail. Continuous discharge data for major streams should be investigated, if available, rather than the monthly instantaneous discharge evaluated in this report. (No stations needed.)

- *Williams Lake.* Because of the indications of a declining trend in water clarity, monitoring on Williams Lake should continue. Unfortunately, at present we do not have a volunteer on Williams Lake to collect regular water clarity measurements.

- *Miscellaneous Lakes.* Other potential basin lakes with public access but no recent water quality data include Sprague, Fishtrap, Badger, Chapman, and Rock Lakes.

References

Aroner, E.R., 1995. WQHYDRO. WQHYDRO Consulting, Portland, OR.

Brower, C. and W. Kendra, 1990. Water Quality Survey of 25 "Citizen-Volunteer" Lakes From Washington State. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA, 114 pp.

Hallock, D. 1993. South Fork Palouse River, Analysis of Ambient Monitoring Data. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Norton, D. and A. Johnson. 1990. 1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Rector, J., 1995 (In draft). Washington's Lake Water Quality Assessment Program, 1994 Data Summary: Williams Lake, Spokane County. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Rector, J., 1995 (In draft). Washington's Lake Water Quality Assessment Program, 1994 Data Summary: Silver Lake, Spokane County. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Olympia, WA.

Table 1. Stations and monitoring history for Ambient Monitoring Section river and stream stations in the Snake watershed. A "*" indicates current "core" stations (sampled every year).

Station Number	Name	Water Year Sampled 59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
*32A070	Walla Walla R nr Touchet	X	X	X	X	X	X	X	X					X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
32A090	Walla Walla R nr Lowden													X	X																							
32A110	Walla Walla R @ College Pl													X	X		X	X																				
32B070	Touchet R @ Touchet														X		X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
32B100	Touchet R @ Bolles																X	X																				
32B120	Touchet R nr Dayton																X	X																				
32B130	Touchet R @ Dayton	X	X																															X	X			
32C070	Mill Cr @ Mission St														X		X	X																				
32C110	Mill Cr @ Tausick Way														X		X																			X		
33A010	Snake R nr Mouth										X																											
*33A050	Snake R nr Pasco		X	X	X	X	X	X	X		X					X																		X	X	X	X	X
33A070	Snake R blw Ice Harbor Dam											X			X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
*34A070	Palouse R @ Hooper	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
34A085	Palouse R @ Shields Rd Bridge																																		X			
34A090	Palouse R nr Diamond													X			X																					
34A110	Palouse R abv Buck Canyon													X			X	X																				
*34A170	Palouse R @ Palouse																	X																	X	X	X	X
34B070	SF Palouse R nr Colfax													X			X	X																				
34B090	SF Palouse R nr Pullman													X			X																					
*34B110	SF Palouse R @ Pullman													X			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
34B130	SF Palouse R blw Sunshine																	X																				
34B140	SF Palouse R @ Busby																																		X			
34C060	Paradise Cr at Mouth																																		X			
34C070	Paradise Cr nr Pullman																				X																	
34C100	Paradise Cr @ Border																																		X			
34D070	SF Palouse Trib Whitman Fm																	X																				
34E070	Rock Creek at Revere																																		X			
35A100	Snake R blw Lwr Granite Dam																				X																	
*35A150	Snake R @ Interstate Br				X	X	X	X	X		X	X																						X	X	X	X	X
35A200	Snake R nr Anatone														X	X	X	X	X	X	X	X																
*35B060	Tucannon R @ Powers																X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
35B110	Tucannon R nr Delaney	X	X																																			
35C070	Grande Ronde R nr Anatone																			X			X	X	X											X		
35D070	Asotin Cr @ Asotin																			X																X		

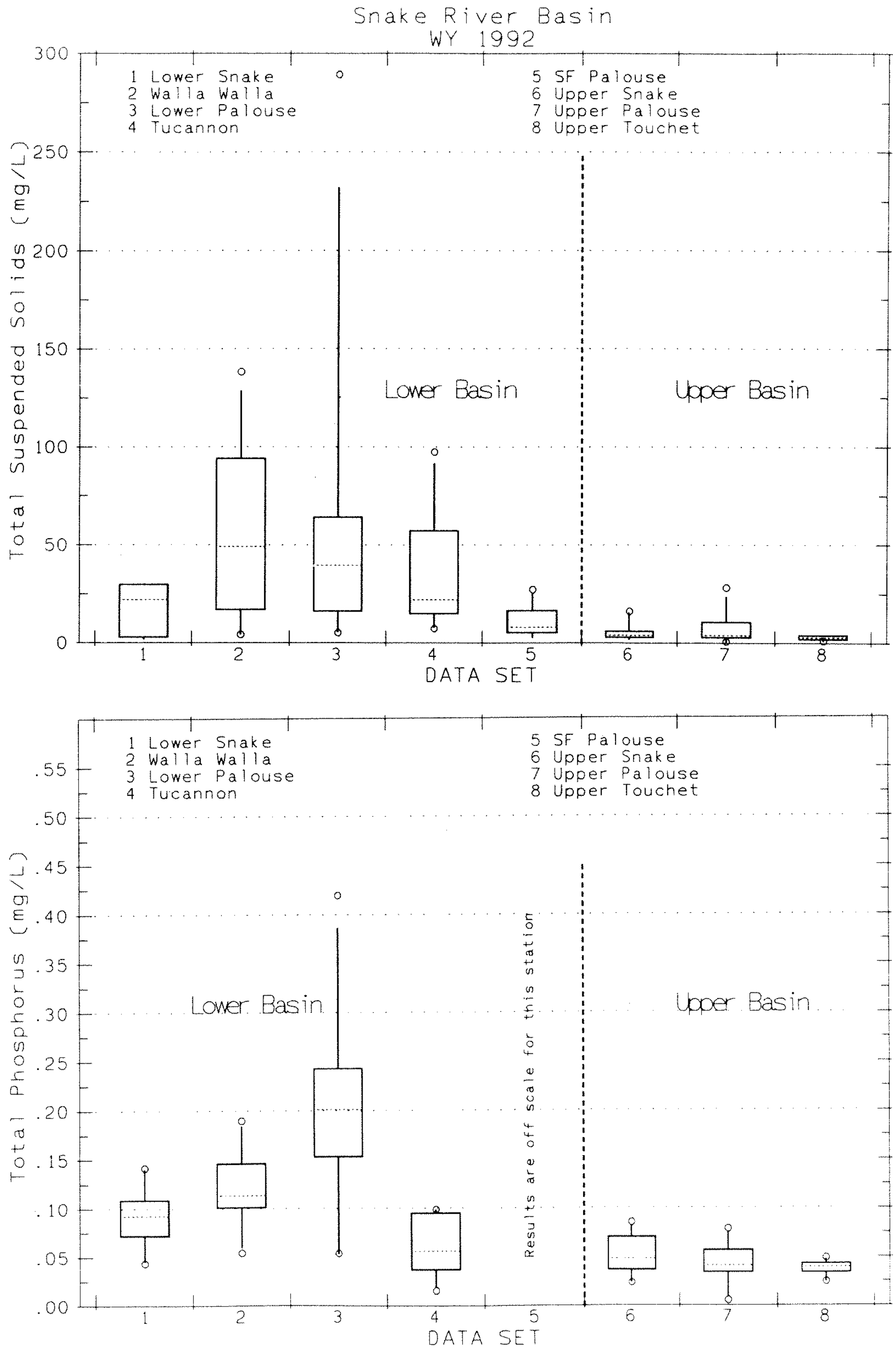
Table 2. Parameters routinely monitored by AMS in rivers and streams. Additional parameters may be available for some stations.

Barometric Pressure	NH_3	Total Suspended Sediment
Conductivity	NO_2	Fecal Coliform
Oxygen	NO_2+NO_3	Turbidity
pH	Ortho-phosphate	Discharge
Temperature	Total phosphate	

Table 3. Lakes monitored by AMS's Lake Water Quality Assessment Program in the Snake River watershed.

Lake	County	Years Monitored	Trophic State (Year of Assessment)
Sprague	Adams	89	Eutrophic (89)
Williams	Spokane	89-95	Mesotrophic (94)
Silver	Spokane	93-95	Meso-eutrophic (94)

Figure 1. Distribution of ambient monitoring suspended sediment data (top) and total phosphorus data (bottom) at several stations in the Snake River basin.



Toxics Investigations

by

Dave Serdar
Toxics Investigations Section

What We Know/Data Gaps

A literature search on environmental toxic contamination in the Snake River Water Quality Management Area indicates two issues that warrant consideration: 1) the apparent widespread presence of agricultural pesticides, and 2) potential chlorinated dioxin/furan contamination from the Potlatch bleached kraft pulp mill in Lewiston, Idaho. Overall, there has been little data generated on toxic environmental contaminants in the watershed, possibly due to the relatively small number of point sources in this area. Pesticides and dioxin/furan contamination are discussed below.

Agricultural Pesticides in Surface Waters

The majority of Ecology data on pesticides comes from the Washington State Pesticide Monitoring Program (WSPMP) begun in 1992. Table 1 list waterbodies and types of samples analyzed for the WSPMP. Although the number of sites monitored in the Snake River area is limited, it is the only ongoing program that routinely measures environmental pesticide levels in this area. There are also data from one-time sampling efforts as part of surveys conducted statewide (Hopkins *et al.*, 1985; Johnson and Norton, 1990; Hopkins, 1991) and nationwide (Schmitt *et al.*, 1990; EPA, 1992).

Data from these studies do not suggest severe pesticide contamination in any of the waterbodies sampled. The only instance of potentially serious pesticide contamination is described in a 1979 report of chlorinated pesticides in water, sediment, and fish tissue in a drainage ditch leading to the Palouse River (Yake, 1979). The ditch sampled was adjacent to the Palouse Producers' agricultural chemicals distribution site in Colfax. No record of follow-up to this problem was found.

Although concentrations of pesticides found in water, sediment, and fish tissue have generally been low, the Snake, Walla Walla, and Palouse Rivers are candidates for 303(d) listing based on pesticide residues in edible fish tissue (Table 2). Segments of these rivers are listed based on exceedence of conventional water quality standards such as DO, temperature and fecal coliform.

Only results from the WSPMP were considered in Table 2 because they reflect current conditions and are of defensible quality.

Table 1. WSPMP Samples Collected in the Snake River Basin Planning Area

	1992	1993	1994
Snake River (Lake Sacajawea) near Ice Harbor Dam			Fish fillet Whole fish
Walla Walla River near mouth	Water column Fish fillet Whole fish	Water column (4X) Bottom sediment Fish fillet Whole fish	
Palouse River at Winona			Water column (3X) Fish fillet Whole fish

Table 2. Snake River Planning Area Waterbodies on the 303(d) List as a Result of WSPMP Findings

	1992	1993	1994
Snake River (Lake Sacajawea)			4,4'-DDE, chlordane, dieldrin, and PCB-1260 in fish fillet
Walla Walla River	Heptachlor epoxide in fish fillet	4,4'-DDE, 4,4'-DDD, chlordane, dieldrin, heptachlor epoxide, hexa-chlorobenze, and PCB-1260 in fish fillet	
Palouse River			4,4'-DDE, heptachlor epoxide, and PCB-1260 in fish fillet

Chlorinated Dioxins and Furans in the Snake River

Potential dioxin/furan contamination of the Snake River was first addressed in 1988 as a result of findings from a joint EPA/industry survey of 104 pulp mills nationwide. This survey (commonly referred to as the "104 Mill Study") targeted mills bleaching pulp with chlorine after it was discovered that this process leads to the formation of polychlorinated dioxins and furans including 2,3,7,8-TCDD, the most toxic of these compounds and the only one for which a water quality criterion exists. Included among the facilities sampled during the 104 Mill Study was the Potlatch Corporation pulp mill in Lewiston, ID. The concentration of 2,3,7,8-TCDD in Potlatch's final effluent was 75 parts per quadrillion (ppq)(EPA, 1990). Based on the average discharge from the Potlatch facility of 38.6 MGD, and a harmonic mean flow of the receiving water (Snake River) of 35,700 cfs, the 2,3,7,8-TCDD concentration in the receiving water was calculated to be ten times above the EPA water quality criterion of 0.013 ppq.

Table 3 summarizes the results of samples collected from Potlatch effluent and from the Snake River at Lewiston. Aside from 2,3,7,8-TCDD, a substantial concentration of 2,3,7,8-TCDF was found in Potlatch effluent (2,3,7,8-TCDF has one-tenth the toxicity of 2,3,7,8-TCDD but is generally more prevalent in pulp mill effluent). Concentrations of both 2,3,7,8-TCDD and 2,3,7,8-TCDF in fish were relatively low compared to fish sampled below other chlorine-bleached pulp mills (EPA, 1992). However, the concentrations of 2,3,7,8-TCDD in bass fillet are above the human health criteria (National Toxics Rule) of 0.07 ppt.

During 1991, the EPA established a Columbia River TMDL for 2,3,7,8-TCDD. This included allocating loads for the Snake River. EPA estimated that the Snake River has a loading capacity of 1.18 mg 2,3,7,8-TCDD/day. A waste load allocation (WLA) of 0.39 mg 2,3,7,8-TCDD/day for the Potlatch mill was included in the TMDL. Other potential sources of 2,3,7,8-TCDD to the Snake River were considered too small to warrant separate WLAs.

Table 3. Dioxin/Furan Data from Potlatch Effluent and Snake River Fish Collected near Lewiston

	Source of Data	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ*
Potlatch final effluent (ppq)	104 Mill Study	75	340	109
Bass fillet (ppt)	National Bioaccumulation Study (EPA, 1992)	0.74	2.75	1.02
Whole sucker (ppt)	"	0.46	2.62	0.72

*TEQ or Toxic Equivalent is used to express the total toxicity of chlorinated dioxins and furans into the equivalent toxicity of 2,3,7,8-TCDD.

Since these data (Table 3) were collected, Potlatch has made a number of modifications designed to reduce their discharge of chlorinated dioxins and furans (EPA, 1990). However, there are no recent data available to evaluate the efficacy of these changes (a request for data on recent dioxin/furan concentrations in Potlatch effluent has been made to EPA). There are also no data available to determine if the Snake River is within its loading capacity for 2,3,7,8-TCDD as detailed in the Columbia River TMDL (it is noteworthy that the Snake River has been removed from the 303(d) list for dioxin because there is a TMDL in place, although there is no evidence that the TMDL has been met). Perhaps most important, there are no recent data nor has anyone conducted a meaningful survey of dioxins/furans in Snake River fish.

Cross Program Considerations

For pesticide issues, EILS staff informally coordinate field activities with other agencies such as the Department of Agriculture and the Natural Resource Conservation Service.

Summary of Issues, Threats, and Priorities

Widespread nonpoint contamination from agricultural pesticides is a potential concern. There are few data, especially recently, on dioxin/furan contamination of the Snake River. The major source of dioxin/furans has historically been the Potlatch Corporation pulp mill in Lewiston, ID.

Recommendations

- *Continue to monitor pesticides in water, sediment, and fish of watershed surface waters.* Land-use in this area (largely agricultural) and the prevalence of pesticides in major waterbodies indicates the potential for more widespread contamination. Strategies to identify potential problem areas have been well-developed by Dale Davis (WSPMP). Sampling techniques and analytical procedures used in the WSPMP have been standardized and are therefore useful in obtaining data which can be compared to other WSPMP data collected in Washington State.

- *Conduct a screening survey of dioxin/furan concentrations in edible fish tissue from the Snake River.* This survey should include data on at least two species from each of the Snake River pools in Washington (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite).

- *Determine the daily load of 2,3,7,8-TCDD entering the Columbia River from the Snake River.* This could be accomplished by the analysis of suspended particulate matter and the dissolved component of Snake River water in the vicinity of Ice Harbor Dam. EILS has been refining their ability to conduct such studies during the past few years. 2,3,7,8-

TCDD loads could be compared to the Snake River loading capacity detailed in EPA's Columbia River TMDL.

References

Davis, D., 1993. Washington State Pesticide Monitoring Program - Reconnaissance Sampling of Surface Water (1992). Washington State Department of Ecology, Olympia, WA.

Davis, D. and A. Johnson, 1994a. Washington State Pesticide Monitoring Program: Reconnaissance Sampling of Fish Tissue and Sediments 1992. Ecology Pub. No. 94-194, Washington State Department of Ecology, Olympia, WA.

Davis, D. and A. Johnson, 1993b. Washington State Pesticide Monitoring Program: 1993 Surface Water Sampling Report. Ecology Pub. No. 94-164, Washington State Department of Ecology, Olympia, WA.

EPA, 1990. Fact Sheet - Proposed Reissuance of a National Pollutant Discharge Elimination System (NPDES) Permit to Discharge Pollutants Pursuant to the Provisions of the Clean Water Act. Permit No. ID-000116-3 (Potlatch Corp.). U.S. Environmental Protection Agency, Region X, Seattle, WA.

EPA, 1992. National Study of Chemical Residues in Fish, Volumes I and II. EPA 823-R-92-008a and b, U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C.

Hopkins, B.S., D.K. Clark, M. Schlender, and M. Stinson, 1985. Basic Water Monitoring Program Fish Tissue and Sediment Sampling for 1984. Ecology Pub. No. 85-7, Washington State Department of Ecology, Olympia, WA.

Hopkins, B., 1991. Basic Water Monitoring Program Fish Tissue and Sediment Sampling for 1989. Washington State Department of Ecology, Olympia, WA.Washington State Department of Ecology, Olympia, WA.

Johnson, A. and D. Norton, 1990. 1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Olympia, WA.

Schmitt, C.J., J.L. Zajicek, and P.H. Peterman, 1990. National Contaminant Biomonitoring Program: Residues of Organochlorine Chemicals in U.S. Freshwater Fish, 1976-1984. Arch Environ. Contam. Toxicol. 19(748-781).

Yake, B., 1979. Toxic Substances: Analytical Results of Samples from Palouse Producers (Colfax) Drainage Ditch and Fish Collected from the Palouse River at Hooper. Memorandum *to* Claude Sappington, Washington State Department of Ecology, Olympia, WA.

Ground Water Investigations

by

Robert Garrigues
Toxics Investigations Section

Ground Water Characteristics

Introduction

The Snake River watershed lies entirely within the Columbia Plateau and includes parts of the Walla Walla-Tucannon, Blue Mountains, Palouse, Spokane, and Columbia Basin aquifer regions (Turney, 1986a & 1986b). In a hydrogeologic sense, the watershed contains a diverse selection of aquifers including Holocene alluvial deposits, Quaternary lacustrine and loess deposits, Pleistocene glacial-flood deposits of sand and gravel, the Columbia Plateau basalt aquifers, and older sedimentary, igneous, and metamorphic rock units.

Bedrock Aquifers

The basalt flows of the Columbia River Basalt Group are the primary source of ground water in the Snake River watershed. Ground water is generally produced from the fractured zones at the tops and bottoms of individual basalt flows. The sedimentary units deposited between basalt flows also act as aquifers, depending upon the presence of porous materials at specific sites. This group of basalt aquifers is comprised of, in descending order, the Saddle Mountains Basalt, the Mabton sedimentary interbed, the Wanapum Basalt, the Vantage sedimentary interbed, and the Grande Ronde Basalt. One or more of these basalt aquifers underlie nearly all of the watershed and have historically been the principle source of ground water for irrigation, stock, rural domestic, and municipal uses.

Fractured crystalline bedrock outcrops in various areas of the watershed (Walters & Glancy, 1969; Waggoner, 1990). This fractured bedrock locally yields water to springs and wells, but is a relatively unimportant source of water in the watershed.

Alluvial and Glacial-Flood Aquifers

Glacial-flood sands and gravels, are scattered throughout the watershed and are important aquifers locally (Balmer & Carr, 1980; Newcomb, 1965). These deposits occur mostly in and adjacent to the major valleys of the Columbia, and Snake Rivers. Alluvial aquifers are confined to valley flood plains and yield moderate amounts of water to wells, but tend to be relatively unimportant as aquifers in the region.

Surface Water/Ground Water Interaction

Ground water within the alluvial and glacial-flood deposits is, for the most part, in direct hydraulic continuity with surface water (Balmer & Carr, 1980). Surface-water/ground-water interaction within the basalt aquifers is well documented in parts of the watershed where irrigation from surface-water sources has raised the water table over 300 feet (Steinkampf, 1989). Hydraulic continuity between aquifers, caused by wells completed across aquifer boundaries, is a definite problem in much of the watershed. These wells allow rapid vertical movement of ground water across aquifer boundaries and can have significant effects on aquifer water levels and can enhance the effects of ground-water withdrawals on surface-water flows.

Ground Water Quality

Ground-water quality in the Snake River watershed is generally good and suitable for most purposes (Steinkampf, 1989; Turney, 1986a & 1986b). Calcium bicarbonate water is the most common water type throughout the watershed and predominates in the unconsolidated deposits and basalt aquifers of the Walla Walla-Tucannon sub-region. Calcium bicarbonate and calcium-magnesium bicarbonate water is common in the Palouse subregion (Turney, 1986b). According to Steinkampf (1989), calcium-magnesium bicarbonate water tends to predominate in the shallowest basalt units, and the water type evolves to sodium bicarbonate water in the deepest units.

TDS concentrations in 1982 were generally less than 250 mg/L in the Palouse and Blue Mountains regions. While in the Walla Walla - Tucannon region TDS generally ranged between 250 and 500 mg/L with some wells exceeding 500 mg/L (Turney, 1986b).

In 1982, ground water in the Palouse region had a median iron concentration of 200 μg/L. This concentration is substantially higher than in all of the other regions, which all had median iron concentrations of less than 20 μg/L. The Palouse region also had a median manganese concentration of 45 μg/L while all other regions exhibited concentrations of less than 10 μg/L (Turney, 1986b).

The Walla Walla-Tucannon region has a history of high nitrate levels in ground water. Turney's (1986b) data shows that nitrate concentrations in ground water range from moderate to high concentrations (where "moderate" levels are from 1 to 5 mg/L and "high" values are above 5 mg/L). Balmer & Carr (1980) state that "significant areas" of the shallow, unconsolidated water-table aquifer in the Burbank - Wallula area contain nitrates above the 10 mg/L maximum contaminant level (MCL) specified by the U.S. Environmental Protection Agency (EPA). This aquifer, according to Balmer & Carr (1980), is the primary water supply for the area. Permeable sediments, combined with a shallow aquifer allow for good recharge and transport of contaminants to the water-table aquifer. The primary nitrate sources in this area are septic tank effluent and agricultural fertilizers. Secondary nitrate sources include animal waste (particularly feed lots, both active and abandoned), industrial waste, and effluent spray irrigation (Balmer & Carr, 1980).

Ground Water Issues

The presence of elevated nitrate concentrations in ground water is the main ground-water issue identified. Although nitrate concentrations are worse in some areas than in others, nitrate in ground water can be considered a regional problem since it seems to be a concern in all areas. The sources of contamination are of local origin such as un-sewered development, failing septic systems, and agricultural practices. Nitrate contamination is a concern in: the Burbank-Wallula area; irrigated agricultural areas, areas of un-sewered, high-density development, and areas near feedlots. Irrigated agriculture seems to be a particular problem where ground water is the water source, according to Balmer & Carr (1980). This is due to the tendency for the water to be recycled -- it is withdrawn from the aquifer, used for irrigation where it picks up nutrients, recharged to the aquifer, and then withdrawn again. Nitrate levels tend to rise in this situation (Balmer & Carr, 1980).

Other ground water issues are:

- Declining water levels in the basalt aquifers has been a problem for many years.
- Possible pesticide contamination associated with the farming practices and with chemicals applied to lawns and gardens as populations increase.
- About half of the Snake river watershed is included in a proposal to designate part of the Columbia Plateau basalt aquifers as a sole-source aquifer. The area proposed for designation includes all of the area east and south of the Columbia River and north of the Snake River.

Conclusions and Recommendations

Conclusions

- There is an adequate amount of published geologic information for the Wenatchee watershed.
- The USGS Regional Aquifer-System Analysis Program (RASA) studies (i.e., Drost et al., 1990; Lane, 1988; Lane *et al.*, 1989; and Steinkampf, 1989) have provided a wealth of data and analyses for the Columbia Plateau, including the Snake River watershed. Available ground water data has also been compiled and published as part of the RASA effort.
- Ground water quality is generally good throughout the watershed.

- There is widespread concern about nitrate concentrations in ground water. Historic data seem to support this concern. Nitrate sources are related to septic tank effluent, agricultural fertilizers, feed lots, effluent spray irrigation, and industrial waste.

- Ground water availability and hydraulic connection between ground water and surface water is a prominent ground water issue in the Snake River watershed.

- Information about ground water quality trends seems to be lacking. There do not appear to be any follow-up studies which evaluate trends in nitrate concentrations for the watershed--or even for specific areas of high nitrate concern such as the Burbank-Wallula area studied by Balmer & Carr (1980).

Recommendations

- There is a serious need for follow-up ground water monitoring in the watershed. Areas of known historic nitrate contamination should be identified and ranked according to susceptibility for contamination and ground-water use. Areas with important shallow aquifers upon which a population is dependant for water supplies should be looked at first. Priorities should be based on: demand for ground water, potential sources of ground water contamination, growth projections, land use patterns and projections, and historic ground water quality data.

- Upon identification of priority areas, a schedule of sampling should be identified and implemented. The primary object would be to identify nitrate contamination trends or new contamination problems. Sampling should concentrate on previously sampled wells as much as possible. Each area should be re-sampled, where appropriate, at regularly occurring intervals, such as every 3-5 years, to establish data for trend analyses.

References

Balmer, D.K., and Carr, J.R., 1980, Evaluation of Nitrate and Fluoride in the ground water of the Burbank - Wallula area, Walla Walla County, Washington: Robinson, Noble, & Carr, Inc., Tacoma Washington, 107 p, 3 plates.

Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 11 maps.

Drost, B.W., Whiteman, K.J., and Gonthier, J.B., 1990, Geologic framework of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 87-4238, 10 p. & 10 plates.

Lane, R.C., 1988, Selected ground-water information for the Columbia Plateau Regional Aquifer System, Washington and Oregon, 1982 - 1985: Volume I. Geohydrology: U.S. Geological Survey Open-File Report 88-182, 236 p.

Lane, R.C., and Whiteman, K.J., 1989, Ground-water levels spring 1985, and ground-water level changes spring 1983 to spring 1985, in three basalt units underlying the Columbia Plateau, Washington and Oregon: U.S. Geological Survey Water-Resources Investigations Report 88-4018, 4 plates.

Molenaar, D., 1968, A geohydrologic reconnaissance of northwestern Walla Walla County, Washington: State of Washington Department of Water Resources Monograph No. 1, 1 sheet.

Molenaar, D., Grimstad, P., and Walters, K.L., 1980, Principal aquifers and well yields in Washington: U.S. Geological Survey and Washington State Department of Ecology Geohydrologic Monograph 5, 1 sheet.

Newcomb, R.C., 1965, Geology and ground-water resources of the Walla Walla River basin, Washington - Oregon: State of Washington Department of Water Resources Water-Supply Bulletin No. 21, 151 p., 3 plates.

Steinkampf, W.C., 1989, Water-quality characteristics of the Columbia Plateau Regional Aquifer System in parts of Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 87-4242, 37 p.

Turney, G.L., 1986a, Quality of ground water in the Columbia Basin, Washington, 1983: U.S. Geological Survey Water-Resources Investigations Report 85-4320, 172 p, 5 plates.

------, 1986b, Quality of ground water in southeastern and south-central Washington, 1982: U.S. Geological Survey Water-Resources Investigations Report 84-4262, 158 p., 5 plates.

Waggoner, S.Z., 1990, Geologic map of the Rosalia 1:100,000 quadrangle, Washington - Idaho: Washington State Department of Natural Resources, Division of Geology and Earth Resources Open-File Report 90-7, 20 p., 1 map.

Walters, K.L., and Glancy, P.A., 1969, Reconnaissance of geology and of ground-water occurrence and development in Whitman County, Washington: State of Washington Department of Water Resources Water-Supply Bulletin No. 26, 169 p., 4 plates.

Compliance Monitoring

by

Guy Hoyle-Dodson
Toxics Investigations Section

Lower Snake Water Resource Inventory Area (WRIA)

In the Lower Snake, there are currently four dischargers that have permits under the National Pollution Discharge Elimination System (NPDES) and seven dischargers that are permitted under the State Waste Discharge Permit Program (WAC 173-216). These include:

NPDES Major Permits - 1 Industrial, 1 Municipal
NPDES Minor Permit - 2 Municipal
State Discharge to Publicly Owned Treatment Works (POTW) - 4 Industrial
State Discharge to Ground Permits - 3 Industrial, 1 Municipal

The following summarizes the information from one industrial and three municipal discharge facilities that have had EILS Class II Inspections over the last ten years. All other facilities have either not been inspected or were inspected more than ten years ago. Data from studies more than ten years old are considered unrepresentative of current treatment facility effluent characteristics and these studies are not referenced. It should be noted that data from Class II Inspections more than five years old may also be non-representative of current facility effluent and should be viewed with caution.

- The one industrial facility, Boise Cascade Pulp & Paper Mill actually discharges directly to the Columbia River just upstream of the Snake River confluence, but it is included in the Lower Snake WRIA. A 1993 inspection of this facility found the plant's discharge to be in compliance with NPDES permit limits. Trace concentrations of bioaccumulative dioxins, furans, and phenolics were detected in the effluent.

- A 1985 Class II Inspection at the Waitsburg Wastewater Treatment Plant (WTP) suggested that the system, which discharges to an infiltration basin/marsh, seemed to be providing good treatment during the inspection.

- A 1986 Class II Inspection of the Walla Walla WTP found that most permitted parameters in the effluent were within NPDES permit limits. BOD_5 and TSS percent removals exceeded permit limits. Total residual chlorine exceeded permit limits.

- A 1987 Class II Inspection of the College Place WTP found all permitted parameters within permit limits, with the exception of fecal coliform which exceeded both monthly and weekly averages.

Upper Snake Water Resource Inventory Area (WRIA)

In the Upper Snake there are currently 13 dischargers that have permits under the National Pollution Discharge Elimination System (NPDES) and 8 dischargers that are permitted under the State Waste Discharge Permit Program (WAC 173-216). These include:

NPDES Major Permits -1 Municipal
NPDES Minor Permit - 12 Municipal
State Discharge to Publicly Owned Treatment Works (POTW) - 3 Industrial
State Discharge to Ground Permits - 1 Industrial, 4 Municipal

Following is a list of six municipal discharge facilities, where over the last ten years EILS has performed enhanced or limited Class II Inspections in conjunction with receiving water studies. All other facilities have either not been inspected or were inspected more than ten years ago.

- An abbreviated Class II Inspection of the Garfield WPT conducted in October 1986 found final effluent exceeded permit limits for BOD_5. Water quality violations in the receiving water (Silver Creek) included DO, TSS, un-ionized ammonia, and chlorine. TSS removal efficiency was below the permit requirement.

- A Limited Class II Inspection and receiving water survey conducted at the Palouse Wastewater Treatment Plant (WTP) in October 1987 found high ammonia and chlorine. It is believed that the most adverse impact will be limited to the near-field effluent plume.

- A Limited Class II Inspection and receiving water survey conducted at the Endicott WTP on October 11-13, 1988, found final effluent exceeded permit limits for fecal coliform and chlorine. Chlorine was found at toxic levels in the creek.

- A Limited Class II inspection and receiving water survey conducted at Pomeroy Wastewater Treatment Plant (WTP) on October 15-16, 1991, found ammonia concentrations below the plant that exceeded the chronic water quality criterion.

- An Enhanced Class II Inspection conducted at the Pullman WTP in September 1986, found ammonia concentrations exceeded the monthly average permit limit. Hydraulic and waste loads to the plant were approaching design criteria.

- A Limited Class II Inspection conducted at Albion WTP October 1-3, 1991, found the treatment plant was violating permit limits for TSS and pH.

Conclusions

- Major municipal dischargers that have not received an independent Enhanced Class II Inspection during the last five years include: Walla Walla WTP, and Pullman WTP.

- Industrial waterbody and land application dischargers who have not received an Enhanced Class II Inspection during the last five years or whose NPDES or State Discharge permits have either expired or are near expiration include: Boise Cascade Pulp & Paper Mill, Stokely-USA, and Port of Whitman Company. The latter two have never been inspected.

- Minor municipal dischargers who have not received a Class II Inspection during the last five years and whose NPDES or State discharge permits have either expired or are near expiration include: Farmington, College Place, Dayton, Colfax, Asotin, Clarkston, St. John, Albion, Rosalia, Oakesdale, and Palouse.

- The contribution of Potlatch Corporation Lewiston Pulp & Paper and Saw Mill to the Upper Snake. Discharge constituents of concern include BOD_5, TSS, pH, ammonia, phosphorus, temperature, chloroform, AOXs, furans, 2,3,7,8-TCDD (Dioxin) and metals.

Recommendations

Enhanced Class II Inspections are recommended for the following facilities:

- *Industrials*. Boise Cascade Pulp & Paper Mill (Major), Stokely-USA, and Port of Whitman Co.

- *Municipals*. Walla Walla (major), Pullman (major), Clarkston, Asotin, Garfield, Endicott, Palouse WTP, and Colfax WTP.

References

Cusimano, R., 1992a. Pomeroy Wastewater Treatment Plant Limited Class II Inspection and Receiving Water Study on Pataha Creek. Ecology Report, Olympia, Washington, 25 pp. + appendices

Determan, T.A., 1987. Garfield Abbreviated Class II Inspection and Silver Creek Receiving Water Study. Ecology Report. 20 pp.

Glen, Norm, 1992d. South Fork Palouse River Basin Class II Inspections at Pullman and Albion, July 23-25 and October 1-3, 1991. Ecology Technical Document, Olympia, Washington, 20 pp. + appendices.

Heffner, M., 1986. Waitsburg Sewage Treatment Plant Class II Inspection, September 24-25, 1985. Memo to Carl Nuechterlein and Larry Peterson. 15 pp.

Heffner, M., 1988. College Place STP Class II Inspection. Ecology Report. 19 pp.

Heffner, M., 1987. Pullman Sewage Treatment Plant Class II Inspection; September 16-17, 1986. Ecology Report. 38 pp.

Heffner, M., 1986. Walla Walla Sewage Treatment Plant Class II Inspection, February 12-13, 1986. Memo to Carl Nuechterlein and Larry Peterson. 14 pp.

Heffner, M., 1987. Pullman Sewage Treatment Plant Class II Inspection; September 16-17, 1986. Ecology Report. 38 pp.

Johnson, A. and M. Heffner, 1993. Class II Inspection of the Boise Cascade Pulp & Paper Mill, Wallula, Washington - April 1992. 29 pp. + appendices.

Kendra, W., 1988. Quality of Palouse Wastewater Treatment Plant Effluent and Impact of Discharge to the North Fork Palouse River. Ecology Report. 36 pp.

Pelletier, Greg, 1993c. South Fork Palouse River Total Maximum Daily Load of Ammonia. Ecology Report, 49 pp. + appendices.

Willms, R. and W. Kendra, 1990. Endicott Wastewater Treatment Plant Limited Class II Inspection and Impact of Discharge on Rebel Flat Creek. 26 pp.