South Fork Palouse River
Analysis of Ambient Monitoring Data

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ABSTRACT

The South Fork of the Palouse River (SFPR) at Pullman has long exhibited extremely poor water quality due to high concentrations of bacteria, nutrients, turbidity, and suspended solids. Ecology's Ambient Monitoring Section monitored water quality monthly at four stations in the SFPR drainage in Wateryear 1992 (October 1991-September 1992). These four stations were SFPR at Pullman (a long-term monitoring station upstream of the Pullman wastewater treatment plant), SFPR at Busby, Paradise Creek at the mouth, and Paradise Creek at the Idaho Border. The Moscow wastewater treatment plant is indicated as the primary source of nutrients to the SFPR, upstream of the long-term monitoring station. Bacteria and suspended sediment sources are basin-wide. Results from the long-term monitoring station indicate that concentrations of suspended solids, turbidity, and summer ammonia, while still high, decreased in the 1980s. Concentrations of other constituents remained unchanged.

INTRODUCTION

The South Fork of the Palouse River (SFPR) is consistently listed on Ecology's 303(d) list (e.g., Ecology, 1992) as Water Quality Limited. (This assessment is based predominately on data from Ecology's Ambient Monitoring Station 34B110, just above the Pullman Publicly-Owned Treatment Works (POTW), river mile 22.2) The Water Quality Index analysis (e.g., Hallock, 1990) has routinely assigned the SFPR the worst water quality score in the state. The primary parameters contributing to poor water quality were fecal coliform bacteria, nutrients (phosphorus and inorganic nitrogen), turbidity, and suspended solids (Table 1).

Table 1. Results of the Water Quality Index analyses from 1980 to 1990. Results over 20 indicate water quality inconsistent with assigned beneficial uses.

Year	Temp.	Oxygen	pH	Bacteria	Nutrients	Turbidity	Suspended Solids	Ammonia Toxicity	Overall
1980	11	11	16	65	100	70	81	12	98
1981	12	12	12	71	100	59	74	9	100
1982	11	12	8	66	100	52	30	6	97
1984	20	8	16	62	100	59	34	11	94
1986	25	7	27	63	100	55	28	18	97
1988	24	7	28	74	100	41	19	16	100
1990	19	7	19	76	100	25	21	23	100

Temperature, pH, and ammonia concentration also violate water quality standards periodically. In response to these water quality problems, Washington recently completed an ammonia total maximum daily load (TMDL) for SFPR (Pelletier, 1993) and EPA Region X is developing a demonstration TMDL for Paradise Creek, a major tributary to the SFPR, for nitrogen, phosphorus, and suspended particulates (Limno-Tech, 1993).

Others have also included dissolved oxygen as a problem in the SFPR system (e.g, Joy, 1987; Moore, 1991; Pelletier, 1993). Dissolved oxygen (as well as pH and temperature) varies dielly, with lowest values occuring in the early morning. Our sampling program is designed to sample at about the same time every day (late morning in the case of SFPR stations). As a result, our data would not necessarily detect chronically low dissolved oxygen.

Joy (1987) conducted an intensive survey of the SFPR on September 16-17, 1986. This survey identified several sources of water quality impairment in the SFPR drainage upstream of Ecology's ambient monitoring station. Paradise Creek was identified as the main source of nutrients, and the Moscow POTW and nonpoint sources were identified as contributors. (The Pullman POTW is also a source of nutrients to the SFPR system downstream of stations monitored during this study.) Joy also identified an unknown source of fecal coliform loading between Paradise Creek and Thatuna Park in Pullman. However, these evaluations were based on a low-flow survey and do not necessarily reflect sources at other times of the year. Pelletier (1993) concluded that effluent from Moscow and Pullman POTWs comprises most of the river flow from July through November in a typical year and are major contributors of nutrients, although nonpoint sources also contribute to water quality problems.

Ecology's Eastern Regional Office requested that the Ambient Monitoring Section (AMS) monitor three stations upstream of Station 34B110 (SFPR at Pullman) to partition sources of water quality problems based on annual data as well as to provide data for TMDL development. The purpose of this report is to review long-term water quality at Ecology's monitoring station on the SFPR at Pullman and to evaluate the results from one year of monitoring at upstream stations.

METHODS

Stations and Schedule

Three stations were identified upstream of our long-term monitoring station on the SFPR at Pullman (Table 2 and Figure 1). These stations were selected to identify contributions to water quality problems from the following areas:

1. Paradise Creek in Washington;
2. Paradise Creek upstream of the Idaho border;
3. SFPR upstream of Busby; and
4. SFPR between Busby and the Pullman station.

Table 2. Stations on the SFPR monitored during this study and other points of interest.

Station No.	Name	River Mile	Latitude	Longitude	Comments
34B110	SFPR at Pullman	22.2	46 43 58	117 10 48	Long-term station above Pullman treatment plant and Missouri Flat Creek
--	SFPR at mouth of Paradise Creek	23.6			
34C060	Paradise Creek at Mouth	0.1	46 43 14	117 09 47	Where creek crosses under Johnson (Busby) Road (below Best Western)
34C100	Paradise Creek at Border	5.8	46 43 57	117 02 35	At culvert at upstream end of Wilber-Ellis fertilizer company
--	Paradise Creek at Idaho Border	6.1			
34B140	SFPR @ Busby	25.8	46 41 28	117 09 03	Just past intersection of Johnson (Busby) and Sand Roads
--	SFPR at Idaho Border	32.4			

Samples were collected monthly on the first or second Tuesday from October 1991 through September 1992. All four stations were sampled within 1 hour and 25 minutes, beginning at about 10:30 a.m. The SFPR at Pullman has been monitored approximately monthly since 1978.

Parameters

Thirteen conventional water quality constituents were measured at each station (Table 3). Temperature and barometric pressure were measured *in situ*, other analyses were conducted on aliquots from a grab sample. Conductivity and pH were analyzed and oxygen was fixed immediately after collection. Other analyses were performed by Ecology's environmental laboratory at Manchester. Collection and analytical methods are described in detail in Hopkins (in press).

Instantaneous discharge for SFPR at Pullman (Station 34B110) was provided by the United States Geological Survey (USGS) based on wire-weight gage stage measurements at the time of sampling. Discharge was estimated for SFPR at Busby (34B140) and Paradise Creek at the mouth (34C060) based on a mass-balance analysis using conductivity (C):

C x Discharge at SFPR at Pullman =
(C x Discharge at SFPR at Busby) + (C x Discharge at Paradise Creek)

and

Discharge at SFPR at Pullman = Discharge at SFPR at Busby +
Discharge at Paradise Creek

This method ignores the impact of Sunshine Creek (Figure 1), an intermittent tributary 0.4 miles upstream of Paradise Creek, and assumes there were no significant water or conductivity sources or losses between stations.

Discharge at Paradise Creek at the border was calculated as the sum of the discharge in Paradise Creek above the Moscow, Idaho POTW outfall (provided by USGS) and the outfall discharge (Haselhuhn, pers. comm.). Assumptions were evaluated by comparing calculated discharges to stage height measurements made with a weighted tape from a reference point at each station.

Loads were calculated by multiplying concentration by discharge and a unit conversion factor.

Data Analysis

Trends at Ecology's long-term monitoring station at SFPR at Pullman were analyzed using WQHYDRO (Aroner, 1993). The Seasonal Kendall test for trend with correction for autocorrelation was used to test for the presence of a linear trend in parameters exhibiting

Table 3. Parameters measured at monitoring sites.

Parameter	Method	Units
Fecal Coliform Bacteria	Membrane Filter	colonies/100 mL
Temperature	Mercury Thermometer	°C
Dissolved Oxygen	Modified Winkler	mg/L
pH	Orion Model 250A	Std Units
Conductivity	Beckman Model RB5	µmhos/cm
Barometric Pressure	Aneroid Barometer	inches Hg
Total Phosphorus	Ascorbic Acid	mg/L
Ortho-phosphorus	Ascorbic Acid	mg/L
Nitrate Nitrogen	Cadmium Reduction	mg/L
Ammonia Nitrogen	Phenate	mg/L
Nitrate+Nitrite Nitrogen	Cadmium Reduction	mg/L
Total Suspended Solids	Gravimetric	mg/L
Turbidity	Nephelometric	NTU

autocorrelation (Hirsch *et al.*, 1982 and Hirsch and Slack, 1984). Slope was determined using the seasonal Sen slope. Both tests are non-parametric and are, therefore, independent of the distribution of the data. Trends were initially evaluated using all data between Wateryear (WY) 1980 and WY 1992 (wateryears begin in October). Trends were also evaluated for specific seasons where seasonality of the trend was indicated. Data were evaluated for correlation with discharge and, where significant, the effects of discharge were removed and the trend re-evaluated. The effect of discharge is removed in order to reduce variability in the data and thus improve the probability of trend detection.

Quality Assurance/Quality Control

The quality of Manchester Laboratory's data was evaluated through Manchester's continuing quality assurance/quality control (QA/QC) program which includes QC charts, check standards, in-house matrix spikes, laboratory blanks and duplicates, and regular performance evaluation standards. In addition, AMS maintains its own QA/QC program which includes standard sampling protocols, annual methods audits, and blind field duplicates. These QA/QC procedures and QC results for AMS in general are discussed in more detail in Hopkins (in press).

RESULTS AND DISCUSSION

Temporal Trends in the South Fork Palouse River at Pullman

Trends in parameters most responsible for water quality impairment in the SFPR at Pullman are shown in Table 4. Autocorrelation was present in all of the evaluated parameters and corrected for in the trend analyses.

Table 4. Trends in selected water quality constituents of the SFPR at Pullman. Trends are based on the period between WY 1980 and 1992. (Significance: * = 90%, ** = 95%, *** = 99%)

Parameter (Units)	Season	Mean Annual Slope	Percent of median	Median	Trend Probability
Temperature (°C)	All months	-0.014	0.16%	9.1	p=0.86
	Jun - Sept	+0.10	0.57%	17.4	p=0.53
Fecal Coliform (cfu/100 mL)	All months	+12.4	1.77%	700	p=0.41
Turbidity (NTU)	All months	-1.34	9.23%	14.5	p=0.01 **
Suspended Solids (mg/L)	All months	-0.61	4.03%	15.0	p=0.04 **
Total Phosphorus (mg/L)	All months	+0.13	1.03%	1.30	p=0.55
Effect of discharge removed	All months	-0.02	--[a]	--[a]	p=0.18
Ammonia Nitrogen (mg/L)	All Months	-0.001	0.81%	0.135	p=0.41
	Jun - Sept	-0.005	8.14%	0.06	p=0.004 ***
Nitrate+Nitrite Nitrogen (mg/L)	All Months	-0.010	0.18%	5.43	p=0.89
	Oct - Nov	-0.226	3.6%	6.28	p=0.05 *
Discharge (cfs)	All Months	-0.112	0.93%	12.0	p=0.27
	Jan - May	-2.49	7.65%	32.5	p=0.05 *
	Jun - Sept	0.00	0.00%	6.0	p=0.76

[a]Statistics are not reported because removing the affects of discharge adjusts the data to a mean of 0.

Turbidity and Suspended Solids

Both turbidity and suspended solids concentrations have decreased significantly at rates of nine and four percent of the median per year, respectively, during the last 10 years (Figures 2 and 3). However, neither parameter exhibited a significant trend between 1986 and 1992. This may indicate improved nonpoint source management in the basin in the early 1980s.

Both turbidity and suspended solids were correlated with discharge ($r=0.69$ and 0.77, respectively). As expected, both parameters increased with increasing discharge. Removing the effects of discharge did not have a major affect on trend significance for either turbidity or suspended solids.

Ammonia

Ammonia, while not exhibiting a trend overall, decreased 8.1% per year in the June to September period (Figure 4). Although median ammonia levels were lower during this period, ammonia toxicity (due to unionized ammonia) is most common in the summer because temperature and pH tend to be higher which leads to a higher unionized fraction. Nitrite plus nitrate also shows no trend overall and a decline of 3.6% per year in October and November (Table 4). The reasons for the decline in inorganic nitrogen are unknown. Either loading to the system from point or nonpoint sources has declined, or losses of inorganic nitrogen from the system through uptake by plants or nitrification (of ammonia to nitrate) and subsequent denitrification (of nitrate to nitrogen) by bacteria has increased. Wastewater treatment procedures have not changed at the Moscow POTW during the trend period (R. Haselhuhn, pers. comm.) and it seems unlikely that effluent ammonia levels have declined. Changes in loading from nonpoint sources is unknown. Pelletier (pers. comm.) has suggested that nitrification upstream of the Pullman station may have increased resulting in decreased ammonia levels. Nitrification is affected by residence time (e.g., discharge) and temperature. However, neither of these parameters exhibited a significant trend for the June through September period (Table 4). It would be interesting to know if plant growth in the SFPR has increased in the last 10 years--indicating increased uptake of nutrients--possibly as a response to the decrease in turbidity discussed above.

Other Parameters

Total phosphorus (Figure 5), nitrate plus nitrite, and fecal coliform bacteria were all extremely high throughout the trend period in comparison to stations outside the Palouse Basin, and did not exhibit significant trends over time (Table 4). Nitrate plus nitrite declined slightly in October and November for unknown reasons.

Of these three parameters, phosphorus was the only one strongly correlated with discharge ($r = 0.71$). Phosphorus concentrations tend to be high when discharge is low, indicating the concentration is affected more by point sources rather than by runoff. Removing the effects of discharge improved the probability of an increasing trend in phosphorus, although the trend was still not significant ($p>0.1$).

Concentrations of inorganic nitrogen at SFPR at Pullman tend to be higher during the higher-flow winter months (November - March) while concentrations of total phosphorus were higher in the low-flow summer months (Figures 6 - 8). As already discussed, an inverse relationship between concentration and discharge is indicative of point source loading. Failure to find this relationship for inorganic nitrogen could indicate nonpoint sources of nitrogen, but may also result from uptake by plants and nitrification/denitrification during the low-flow growing season.

Discharge

Instantaneous discharges are shown in Table 5. Discharges calculated using conductivity mass-balance equations correlated strongly with stage height measurements at both SFPR at Busby and Paradise Creek at the mouth (r = 0.99 and 0.98, respectively). Discharge versus stage height in November did not fit the relationship between discharge and stage height developed from other dates at either station (November data are not included in the above correlations). Pullman received 0.49 inches of rain on the day I sampled in November and field notes indicate that precipitation and runoff were observed during sampling. This probably resulted in a violation of the assumption of no significant water sources between stations. As a result, discharges for November were calculated from regression equations between stage height measurements and discharge based on other months.

Discharges at Paradise Creek at the border were similar to those at the mouth (Table 5). However, discharges at the border (calculated as the sum of discharges from the Moscow POTW and Paradise Creek upstream of the POTW) did not correlate with stage height measurements as strongly as at other stations (r=0.62). Withdrawal of POTW effluent by the University of Idaho for irrigation is one explanation.

When discharge at SFPR at Pullman was above 10 cfs, about half of the volume came from the SFPR at Busby (Figure 9). At lower discharges, however, the majority (to nearly all) of the discharge was from Paradise Creek. This was a result of the stabilizing influence of the Moscow POTW which, from June to October, provided 87 percent of the discharge to Paradise Creek at the Border, based on monthly instantaneous measurements (data from R. Haselhuhn, pers. comm.).

Load Partitioning and General Discussion

Load is the amount of a water quality constituent passing a given point per unit of time (e.g., kg/day). There are several potential sources of error in load estimates:

1. Error inherent in the measurement of the water quality constituent.
2. Error inherent in the measurement or calculation of discharge.
3. Instantaneous samples may not be representative of an extended time period (e.g., month).

Table 5. Instantaneous discharge (cfs) at the SFPR at Pullman (34B110), the SFPR at Busby (34B140), Paradise Creek at the Mouth (34C060), and Paradise Creek at the Border (34C100). (NA=Not Available.)

Date	34B110[a]	34B140[b]	34C060[b]	34C100[c]
91/10/08	5	0.8	4	4
91/11/05	14	2.6[d]	11[d]	6
91/12/03	12	6	6	6
91/01/07	8	3	5	NA
91/02/04	21	11	10	NA
91/03/03	35	20	15	NA
91/04/07	9	5	4	NA
91/05/05	9	5	4	NA
91/06/02	6	0.7	5	5
91/07/07	5	3	2.2	4
91/08/04	4	0	4	4
91/09/09	6	1.3	5	5

[a]Data source: USGS; stage-discharge taken at time of sampling.
[b]Data source: Calculated from conductivity mass-balance (except as noted).
[c]Date source: Routed from Moscow POTW and USGS measurements.
[d]Data source: Stage-discharge developed from conductivity mass-balance.

The third source of error is potentially the most critical in assessing loads from monthly monitoring data. Assessing annual loading requires more intensive sampling during runoff events. Johnson *et al.* (1973) reported that half of the annual sediment load in the SFPR may pass during one week or even a single day. For this reason, most of the following discussion refers to loading at upstream stations as a percent of the load passing SFPR at Pullman rather than to actual loads. This procedure avoids the question of whether a single sample is representative of the month. Reporting relative rather than absolute loading also eliminates error from bias in the measurement of concentration.

Annual representativeness is also of interest. Much of the discussion, below, is based on a single year of monthly sampling. WY 1992 received less rainfall than normal (17.98 inches campared to an average of 21.55 inches; Earthinfo, 1992). Whether or not WY 1992 was typical with respect to the relationships between stations is unknown. However, the median results in 1992 at SFPR at Pullman for the parameters discussed in this report were generally similar to median results for the last 12 years with the exception of the fecal coliform bacteria median which was somewhat lower than usual (Appendix A). Suspended solids, turbidity, and ammonia medians were also relatively low in WY 1992, but this is to be expected given the decreasing trends described above.

Nutrients

Loads of ammonia, nitrate plus nitrite, and total phosphorus during WY 1992 were greater (often much greater) at Paradise Creek at the mouth than at SFPR at Busby during almost every month sampled (Table 6, Figures 10 - 12). (Median concentrations were also higher at Paradise Creek at the mouth than at Busby (Appendix A)). Total phosphorus loads from Paradise Creek were high all year, but inorganic nitrogen loads tended to be higher in the fall and winter. During high-load periods, with the exception of phosphorus in November, Paradise Creek was consistently the dominant source of nutrients to SFPR at Pullman.

Although nutrient concentrations were high at Paradise Creek at the mouth, they were even higher at the border (Table 7). Given that the majority of the flow at the border was from the Moscow POTW, it is likely that the predominant source of high nutrients at the SFPR at Pullman was the Moscow POTW. This is almost certainly true during the summer, when discharge at Busby was very low. It is probably also true at other times of year, given the high nutrient concentrations in Paradise Creek relative to SFPR at Busby. This is consistent with the findings of others (e.g., Joy, 1987). Interestingly, summer ammonia levels, although still high at the border, were relatively low at the mouth. This was probably due to nitrogen uptake and nitrification/denitrification in Paradise Creek during the summer months.

The "difference" column in Table 6 indicates that concentrations of ammonia in December and April at SFPR at Pullman were much lower than expected given the concentrations at Busby and Paradise Creek at the mouth. Uptake and nitrification/denitrification are unlikely explanations given the time of year and the short distance between Paradise Creek at the mouth and SFPR at Pullman. It may be that the high load in Paradise Creek on these dates was the result of a pulse that had not reached the SFPR station at the time of sampling. Nitrate plus nitrite and total phosphorus concentrations at the Pullman station were about what one might expect given the upstream concentrations.

Ammonia concentrations were high (>4.0 mg/L; Appendix B) at both SFPR and both Paradise Creek stations in October. Phosphorus concentrations were also higher than usual on this date. The concentration of unionized ammonia in October at SFPR at Pullman was much higher than usual (Figure 13). A single point source cannot be the cause because there are two separate basins involved--the upper South Fork and Paradise Creek. Laboratory QC results were good and results for other samples in the same batch were not high. There was no precipitation during the preceding week (Earthinfo, 1992). Fall application of fertilizers on winter wheat fields is one possible source of nutrients. Whatever the cause of the high nutrients, all stations except Paradise Creek at the border exceeded acute criteria for unionized ammonia in October (Table 8). The acute criteria was not exceeded at the border station because pH was low relative to other stations. (Both the fraction of total ammonia which is unionized and the criteria are a function of pH and temperature.) After October, no station exceeded even the chronic criteria except the border station, which exceeded chronic criteria 9 of 12 times in spite of the relatively low pH (Figure 14).

Table 6. Load at SFPR at Busby (34B140) (Busby) and Paradise Creek at Mouth (34C060) (Para) as a percent of the load at SFPR at Pullman (34B110). The difference ("Diff") column is the load at Pullman not accounted for by Busby and Paradise loads. A positive difference may indicate a source between the above stations, a negative difference a sink. (NA = Not available)

Month	Solids			NH_3-N			NO_2+NO_3-N			Total Phos			Fecal Coliform			Discharge		Discharge at Pullman (CFS)
	Busby	Para	Diff	Busby	Para	Diff	Busby	Para	Diff	Busby	Para	Diff	Busby	Para	Diff	Busby	Para	
Oct	6%	56%	39%	30%	92%	-22%	5%	87%	9%	32%	63%	5%	3%	653%	-557%	17%	83%	5
Nov	69%	28%	3%	33%	80%	-13%	35%	42%	23%	70%	39%	-9%	35%	193%	-128%	78%	22%	14
Dec	34%	16%	50%	20%	540%	-460%	34%	59%	7%	18%	78%	3%	0%	0%	99%	51%	49%	12
Jan	56%	19%	25%	54%	44%	2%	22%	88%	-10%	11%	98%	-10%	7%	5%	88%	42%	58%	8
Feb	79%	189%	-168%	6%	93%	1%	34%	68%	-2%	12%	92%	-4%	NA	NA	NA	53%	47%	21
Mar	108%	12%	-20%	5%	133%	-38%	46%	58%	-4%	23%	97%	-20%	11%	3%	86%	57%	43%	35
Apr	234%	17%	-151%	67%	468%	-435%	19%	63%	18%	7%	73%	20%	42%	3%	55%	53%	47%	9
May	70%	20%	10%	25%	79%	-4%	4%	72%	24%	8%	84%	8%	44%	23%	33%	50%	50%	9
Jun	32%	44%	24%	24%	95%	-18%	0%	99%	1%	2%	131%	-34%	30%	32%	39%	12%	88%	6
Jul	42%	22%	36%	47%	30%	23%	0%	86%	14%	16%	59%	25%	6%	9%	85%	56%	44%	5
Aug	0%	100%	0%	0%	96%	4%	0%	111%	-11%	0%	116%	-16%	0%	63%	37%	0%	100%	4
Sep	14%	52%	33%	12%	78%	9%	0%	115%	-15%	1%	78%	21%	1%	14%	85%	22%	78%	6
Annual	84%	57%	-41%	19%	114%	-34%	30%	68%	3%	21%	80%	-1%	53%	48%	0%	50%	50%	

Table 7. Concentrations at Paradise Creek at Mouth (34C060) and Paradise Creek at Border (34C100) during WY 1992.

Month	NH_3-N (mg/L)		NO_2+NO_3-N (mg/L)		Total Phos (mg/L)		Fecal Coliform (cfu/100 mL)		Solids (mg/L)		Turbidity (NTU)	
	Mouth	Border	Mouth	Border	Mouth	Border	Mouth	Border	Mouth	Border	Mouth	Border
Oct	4.67	5.33	3.18	9.49	3.99	4.54	5100	440	6	4	5	7
Nov	1.05	1.61	6.79	2.99	2.68	1.50	25000	580	34	63	24	32
Dec	1.26	3.00	10.00	12.20	2.10	2.96	14	4	4	14	5	11
Jan	0.02	1.75	8.18	9.40	2.21	3.18	15	2	2	9	5	10
Feb	0.98	3.70	9.75	8.39	1.68	2.32			80	23	7	15
Mar	1.07	2.42	8.11	8.38	1.28	1.67	23	52	5	23	6	18
Apr	0.23	2.87	7.69	9.78	2.30	3.00	8	9	3	10	2	5
May	0.09	4.41	5.55	9.49	2.44	3.38	110	57	2	10	2	5
Jun	0.03	2.33	5.42	7.92	2.68	3.28	360	4100	3	15	2	8
Jul	0.03	1.91	5.18	7.97	2.07	3.14	220	1300	4	30	2	15
Aug	0.03	0.83	4.36	5.55	2.07	2.07	270	470	3	21	3	6
Sep	0.04	3.49	7.58	9.85	3.11	4.10	40	140	2	5	3	5

Table 8. Ammonia concentrations (unionized ammonia calculated from total ammonia, pH, and temperature) and acute and chronic criteria for unionized ammonia in October 1991.

Station	Total Ammonia (mg/L)	Unionized Ammonia (μg/L)	Acute Criteria (μg/L)	Chronic Criteria (μg/L)
SFPR at Pullman	4.24	135	97	19
SFPR at Busby	7.67	235	93	18
Paradise Cr at mouth	4.67	147	96	18
Paradise Cr at border	5.33	26	83	7.7

Fecal Coliform Bacteria

The fecal coliform bacteria load was similar at both Busby and Paradise Creek at the mouth (Table 6 and Figure 15). The "difference" column in Table 6 indicates that bacteria concentrations in October and November at SFPR at Pullman were much lower than expected given the concentrations at Paradise Creek at the mouth. The difference may be due to die-off of bacteria between stations, or, as discussed above, the extremely high concentrations at Paradise Creek at the mouth on these dates (5100 and 25,000 cfu/100 mL, respectively; Table 7) may be the result of a pulse that had not reached the SFPR station at the time of sampling. For all other samples (December through September) concentrations were higher at SFPR at Pullman than expected given upstream concentrations. This may indicate a consistent bacteria source to the SFPR between the Pullman station and the Busby and Paradise Creek stations.

Water quality standards for the SFPR require that a geometric mean of fecal coliform bacteria counts shall not exceed 100 cfu/100 mL and 10 percent of all samples shall not exceed 200 cfu/100 mL. Both of these criteria were exceeded at all stations during this study. Bacteria concentrations at Paradise Creek at the mouth were much higher than at the border in October and November, and concentrations at the border were much higher in June through August (Table 7). This could indicate runoff to Paradise Creek between the two stations as the dominant bacteria source in the fall, and an upstream source (and die-off between stations) during the summer months. Concentrations at both stations tended to be lower during high runoff months and higher during low-flow periods. This seasonal pattern was similar at the other stations monitored (Figure 16 and Appendix B) while the loads were generally constant (Figure 15). This pattern is generally typical of a point source, however, I know of no point sources upstream of the Busby station. Another explanation is that high concentrations in October and November and relatively low concentrations through the remainder of the high run-off period were a result of the "first flush" effect where fall rains clear out the summer's accumulation of bacteria. High concentrations in June and July may be related to stream access patterns of livestock in the watershed (however, this is purely speculative).

Regardless of the explanation for the patterns observed, the high fecal coliform concentrations at all stations monitored indicates a need for basin-wide management of potential bacteria sources.

Suspended Solids

SFPR upstream of Busby contributed the majority of suspended solids to the system, particularly during the higher discharge months of November to May (Table 6 and Figure 17). February was a notable exception; the suspended solids concentration was unusually high in Paradise Creek at the mouth (Table 7). Solids concentrations were generally high at both stations, particularly in February and March when discharge was also high. The "difference" column in Table 6 shows a small net loss of solids between monitored stations during low-discharge months but a large addition of solids during February through April. This may be due to scouring of deposited sediments, but may also reflect the impact of Sunshine Creek during high runoff periods, which enters the SFPR just upstream of Paradise Creek.

Solids concentrations were generally higher at Paradise Creek at the border than at the mouth (Table 7). The high suspended solids from several areas in the basin indicate that the SFPR system would benefit from basin-wide watershed and riparian management.

Temperature, Dissolved Oxygen and pH

Water quality standards for the SFPR require that temperature not exceed 18°C due to human activities. Even though we sampled well before temperature would be expected to peak in the afternoon, temperature at every station except Paradise Creek at the mouth exceeded 18°C at least once (Appendix B). Riparian management in the SFPR Basin would reduce summer temperatures.

Water quality standards for the SFPR require that oxygen shall exceed 8.0 mg/L. We sampled well after oxygen concentrations would be expected to be lowest (in the early morning). None of our samples indicated oxygen standards violations at any station except for Paradise Creek at the border where every sample violated standards (Appendix B). The median at this station was 3.8 mg/L (Appendix A). Moore (1991) also reported oxygen concentrations below standards in Paradise Creek on three dates in October 1991. His data show a classic oxygen sag-recovery below a BOD source (Moscow POTW) with the lowest concentrations near our border station. Standards were still violated as far downstream as river mile 1.6.

Water quality standards for the SFPR require that pH be within the range of 6.5 to 8.5. The pH slightly exceeded standards twice at the Pullman station; violations were more pronounced at SFPR at Busby, particularly in August and September. The pH was strongly correlated with discharge ($r = 0.63$) with higher pHs occuring during periods of low flow. The highest pH at Busby, 9.4, occured when there was essentially no flow. Riparian management would also decrease pH by reducing primary productivity and increasing discharge at low-flow.

CONCLUSIONS AND RECOMMENDATIONS

1. Turbidity and suspended solids concentrations declined in the SFPR at Pullman between 1980 and 1992; however, concentrations are still high. Summer ammonia concentrations also declined during the 1980s, although concentrations overall (all months) exhibited no significant trend.

2. There were no notable trends in temperature, fecal coliform bacteria, total phosphorus, nitrate plus nitrite nitrogen, or discharge.

3. Nutrient loads to the SFPR were primarily from Paradise Creek. The primary source of nutrients to Paradise Creek was most likely the Moscow POTW.

4. Paradise Creek at the border exceeded the chronic unionized ammonia criteria during 9 of 12 sampling events. Other stations exceeded the acute criteria in November, but otherwise did not exceed criteria.

5. Fecal coliform bacteria loading was indicated from all areas evaluated: upstream of SFPR at Busby, upstream of Paradise Creek at the border, between Paradise Creek at the border and the mouth, and between SFPR at Busby and SFPR at Pullman. The SFPR would benefit from basin-wide management to control bacteria sources.

6. Suspended solids loading was indicated primarily from SFPR upstream of Busby, but also from Paradise Creek upstream of the border. Occasional additional sources were indicated between these stations and SFPR at Pullman. Sunshine Creek is a potential source during high-flows that was not evaluated. The SFPR would benefit from basin-wide management to control sediment sources.

7. Temperature, dissolved oxygen, and pH all exceeded standards at one or more stations, even though samples were not collected at the time of day most likely to detect violations. The oxygen standard was exceeded only at Paradise Creek at the border where 12 of 12 sampling events exceeded standards.

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FIGURES

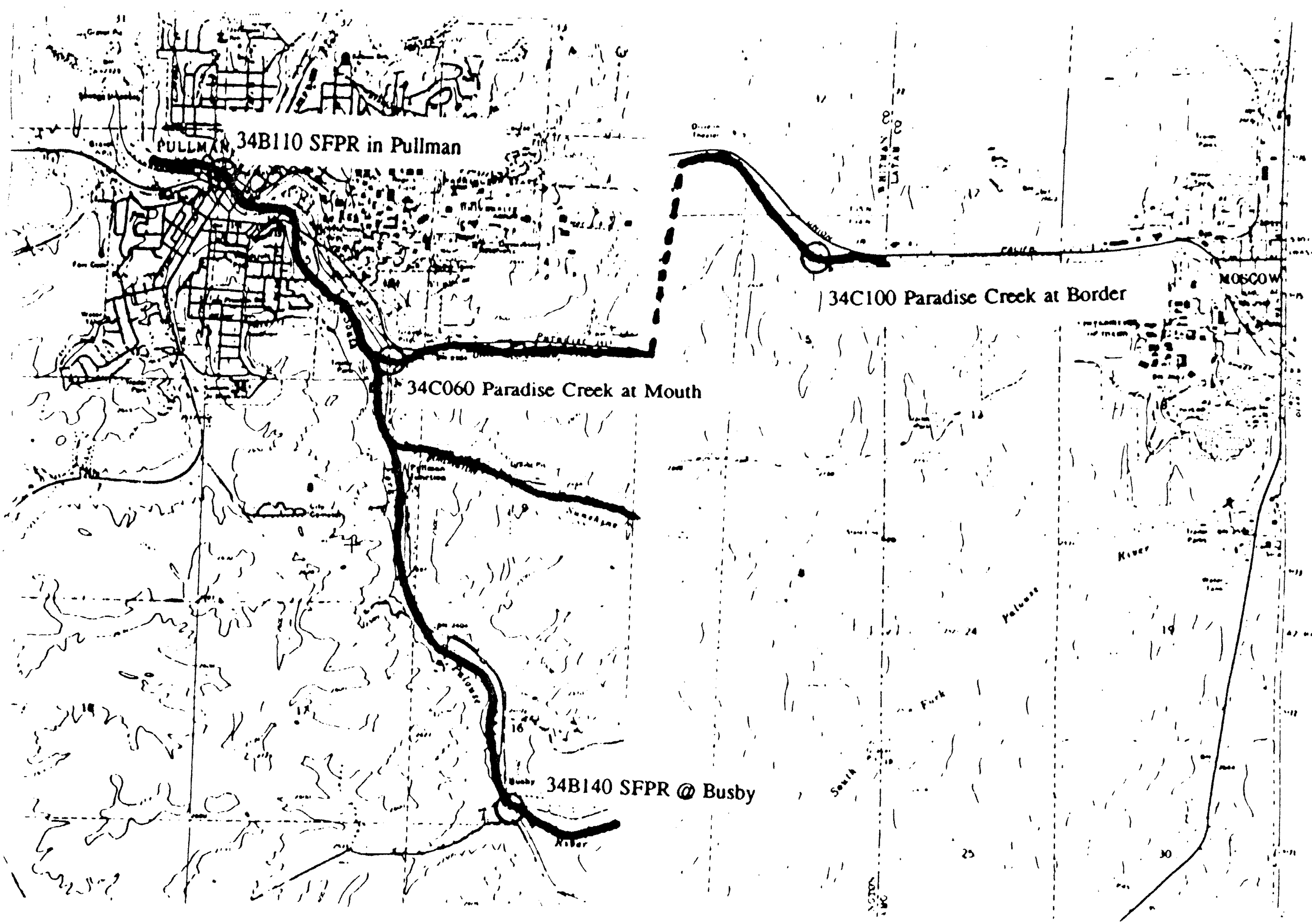


Figure 1. Map of study area. (Photocopy of USGS 1:24,000 "Pullman" and "Moscow West" guadrangle maps. Note discontinuity between Paradise Creek at the Border and other stations.)

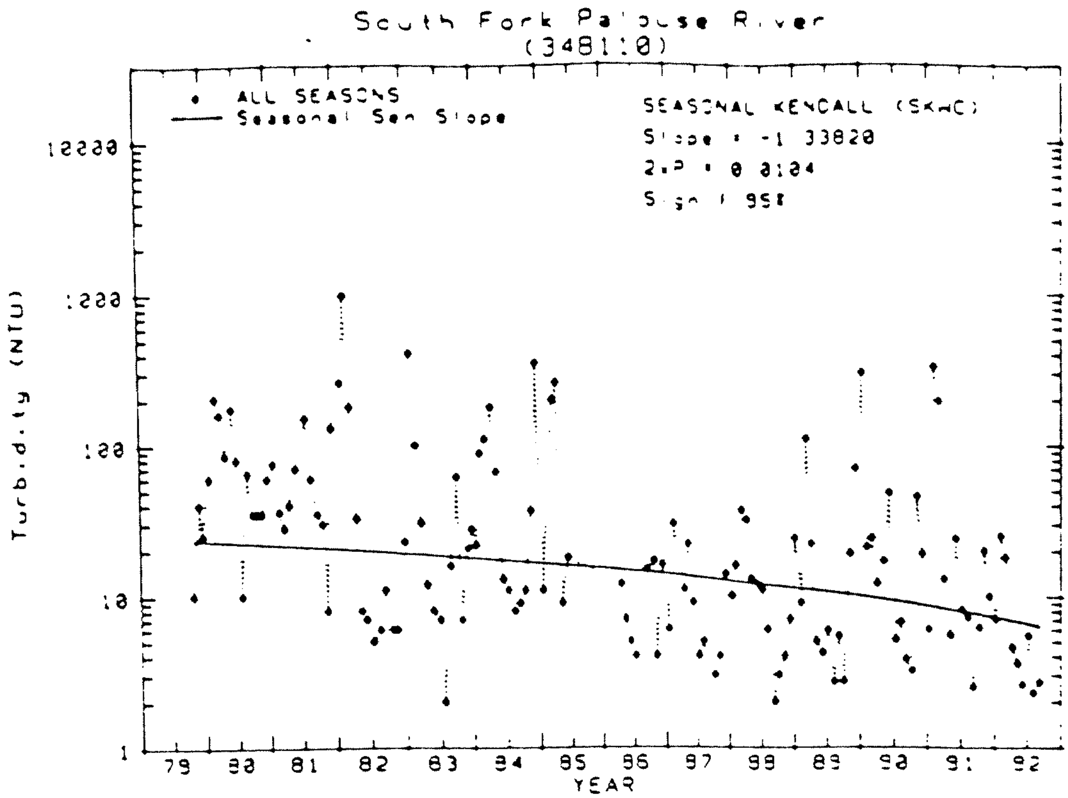


Figure 2. Trend in turbidity (NTU) at the South Fork Palouse River at Pullman between WY 1980 and WY 1992.

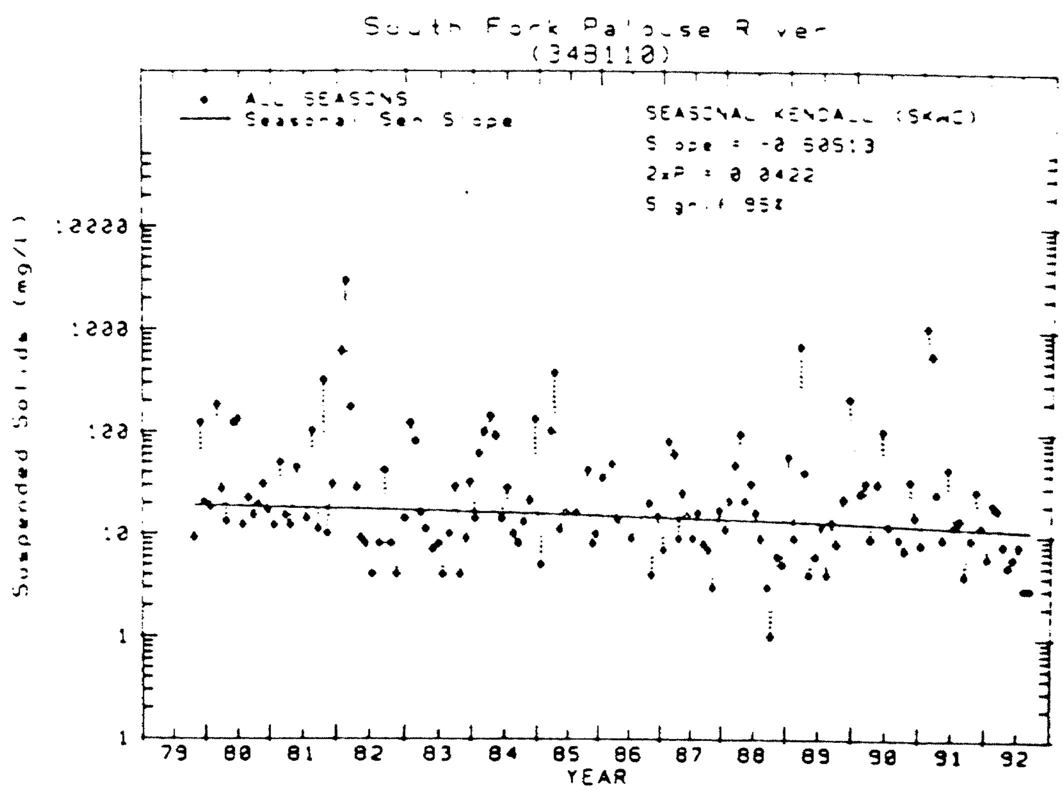


Figure 3. Trend in suspended solids (mg/L) at the South Fork Palouse River at Pullman between WY 1980 and WY 1992.

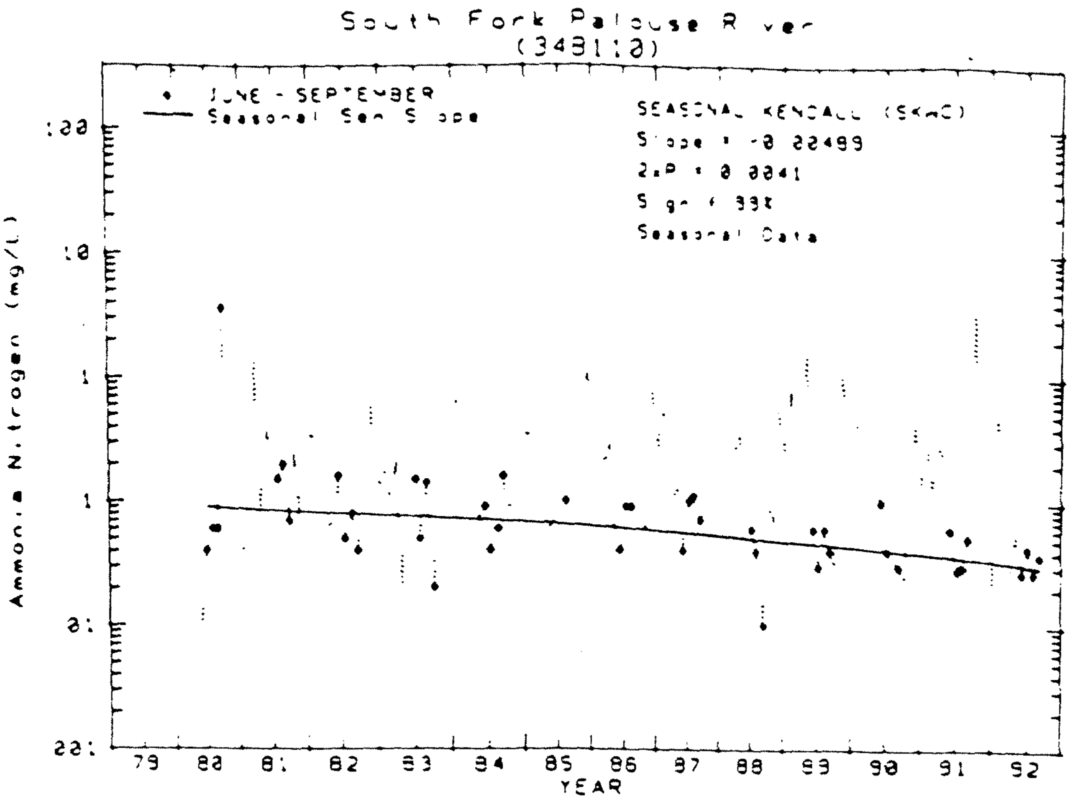


Figure 4. Trend in June through September ammonia nitrogen (mg/L) at the South Fork Palouse River at Pullman between WY1980 and WY 1992.

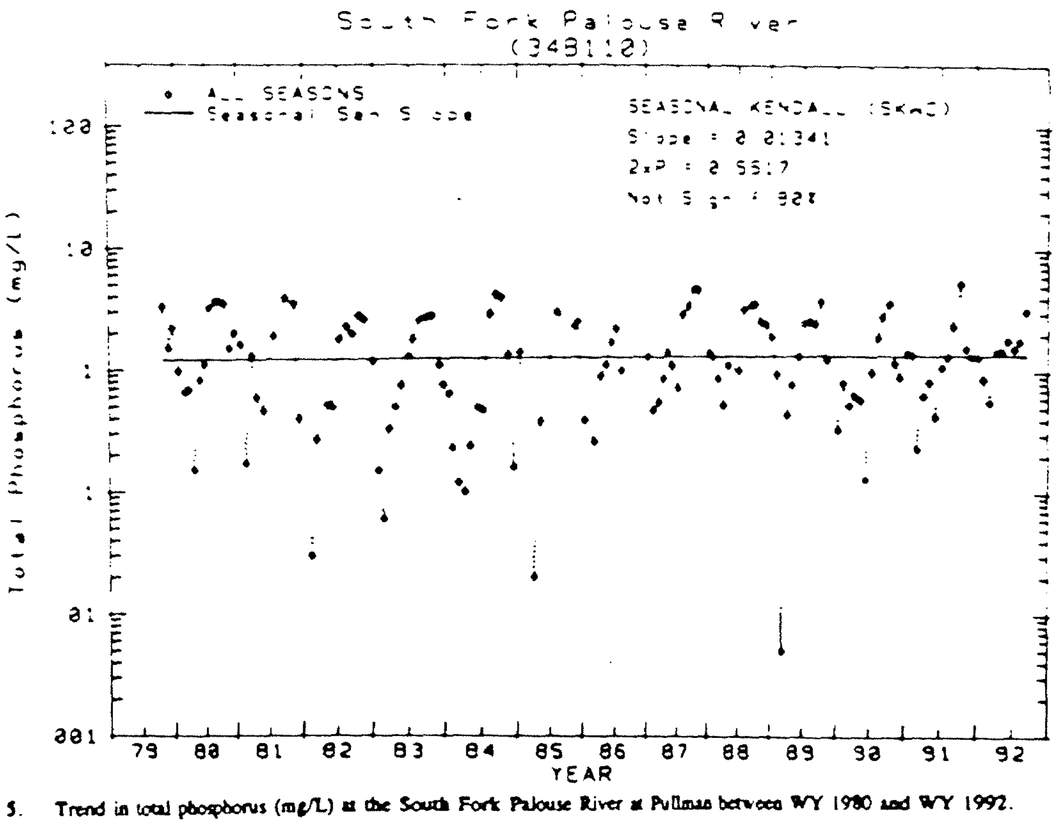


Figure 5. Trend in total phosphorus (mg/L) at the South Fork Palouse River at Pullman between WY 1980 and WY 1992.

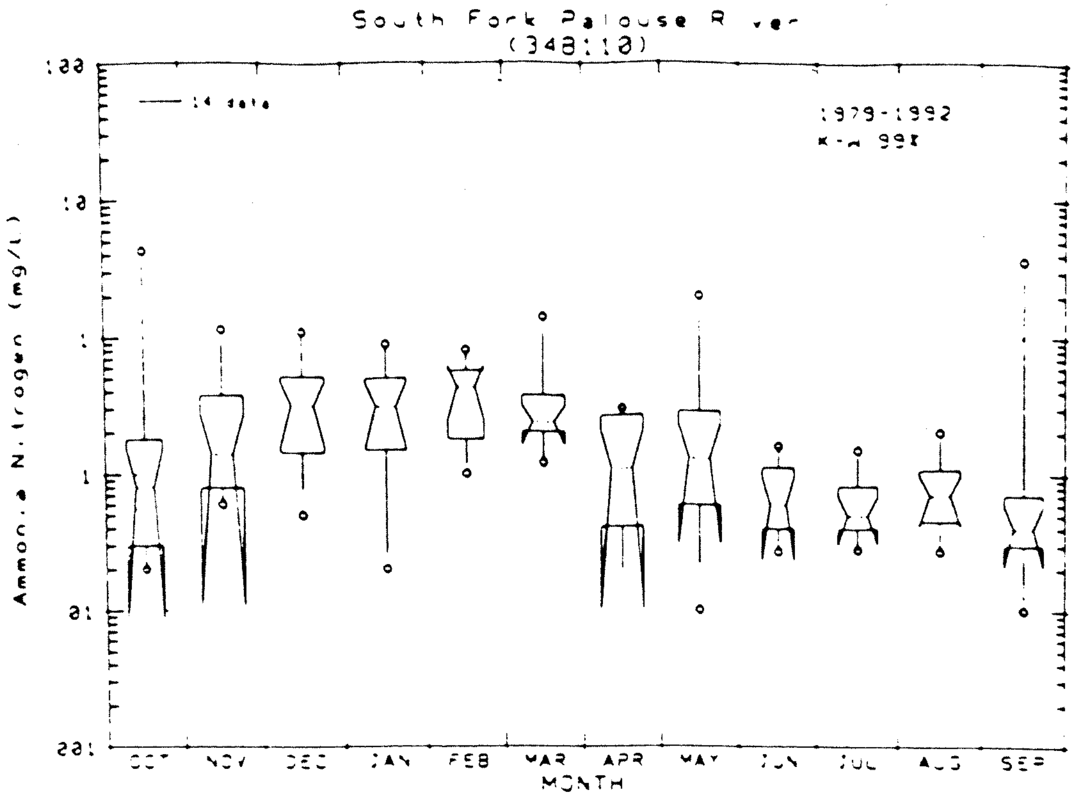


Figure 6. Seasonal variability in ammonia nitrogen concentrations in the SFPR at Pullman (WY 1980-1992). Box plots are explained in Appendix C.

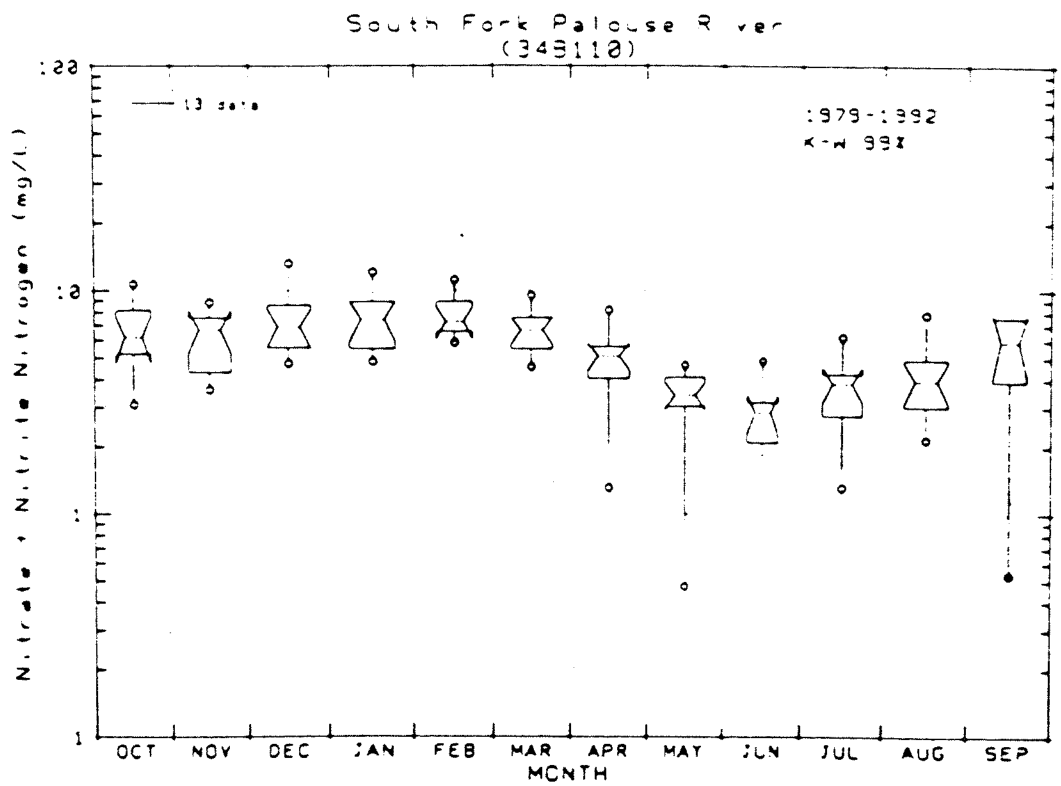


Figure 7. Seasonal variability in nitrate plus nitrite nitrogen concentrations in the SFPR at Pullman (WY 1980-1992). Box plots are explained in Appendix C.

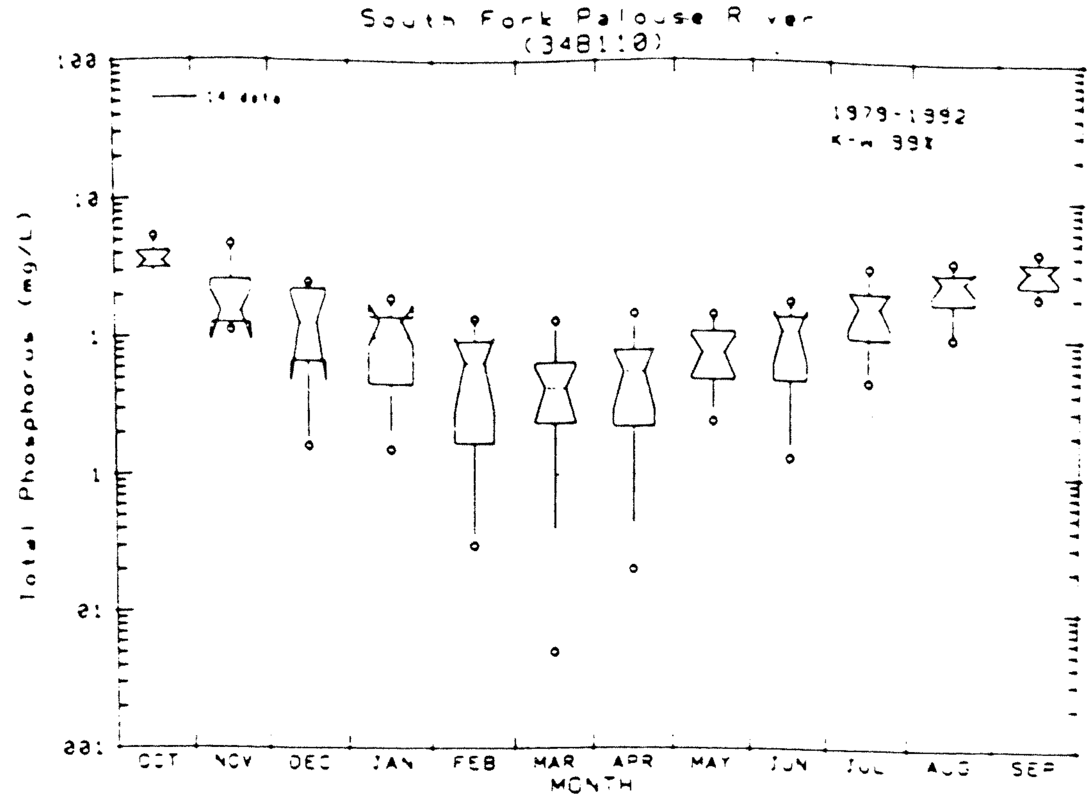


Figure 8. Seasonal variability in total phosphorus concentrations in the SFPR at Pullman (WY 1980-1992). Box plots are explained in Appendix C.

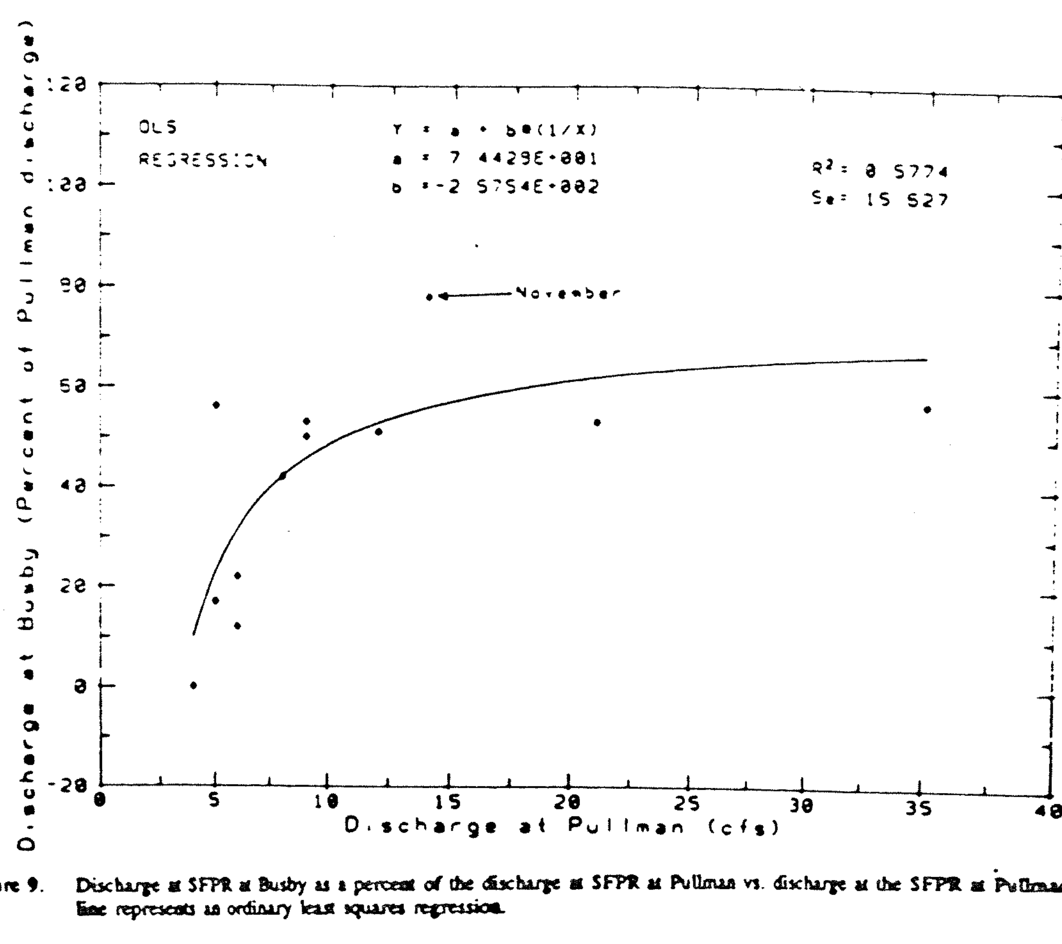


Figure 9. Discharge at SFPR at Busby as a percent of the discharge at SFPR at Pullman vs. discharge at the SFPR at Pullman. The line represents an ordinary least squares regression.

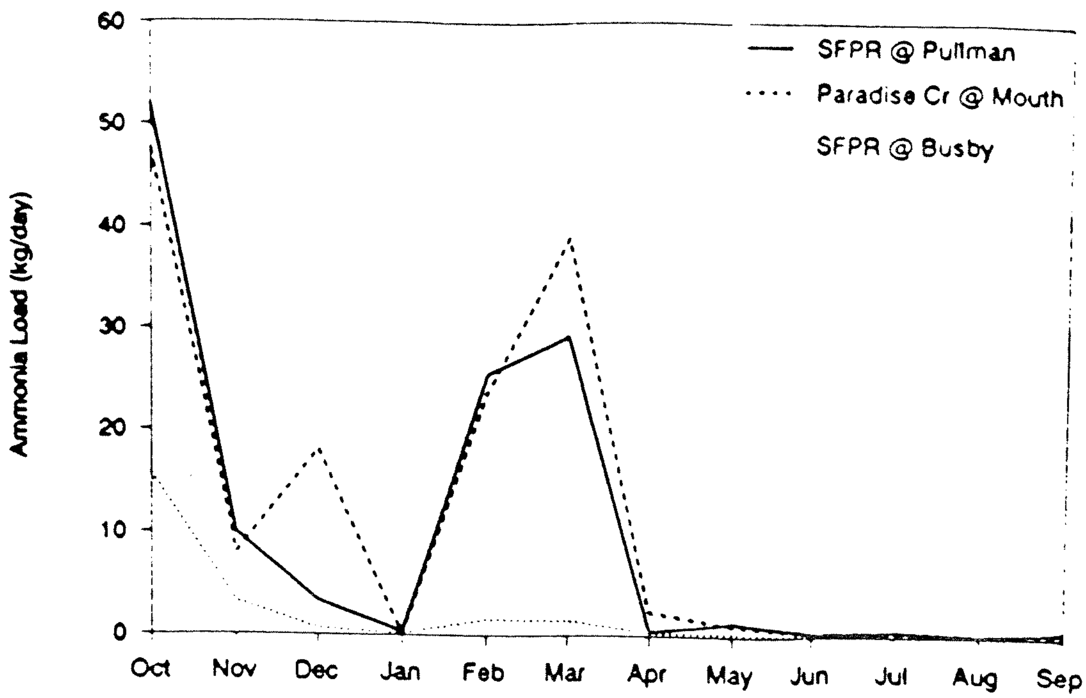


Figure 10. Load (mass per unit time) of ammonia nitrogen by month in WY 1992.

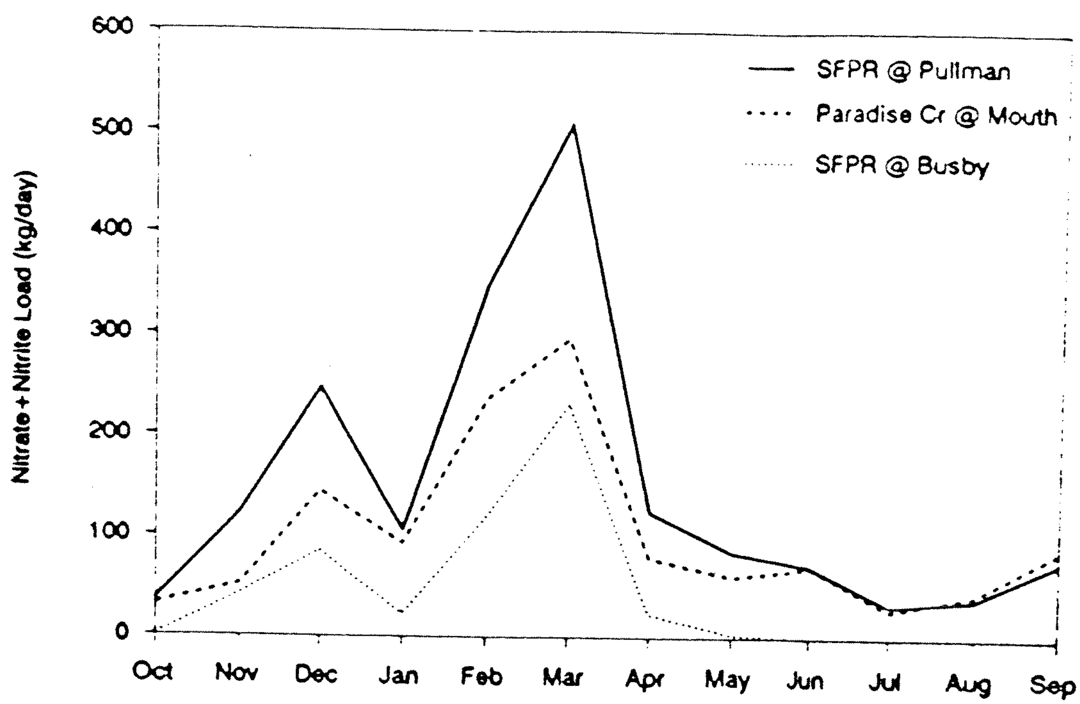


Figure 11. Load (mass per unit time) of nitrate plus nitrite nitrogen by month in WY 1992.

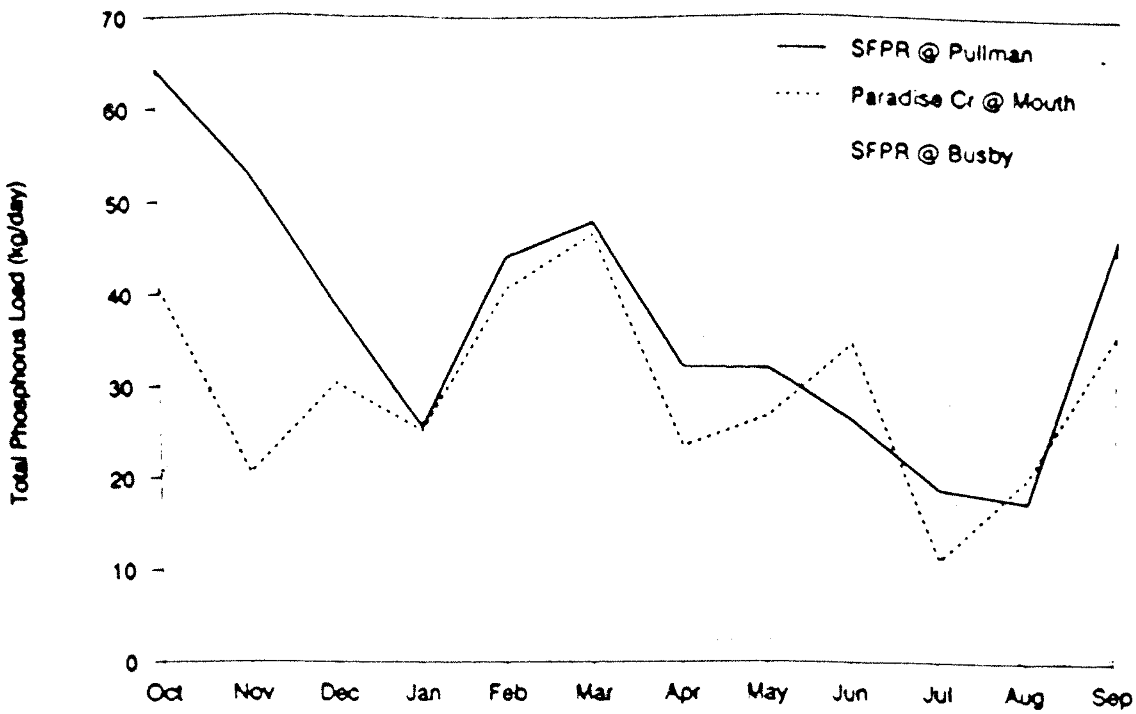


Figure 12 Load (mass per unit time) of total phosphorus by month in WY 1992.

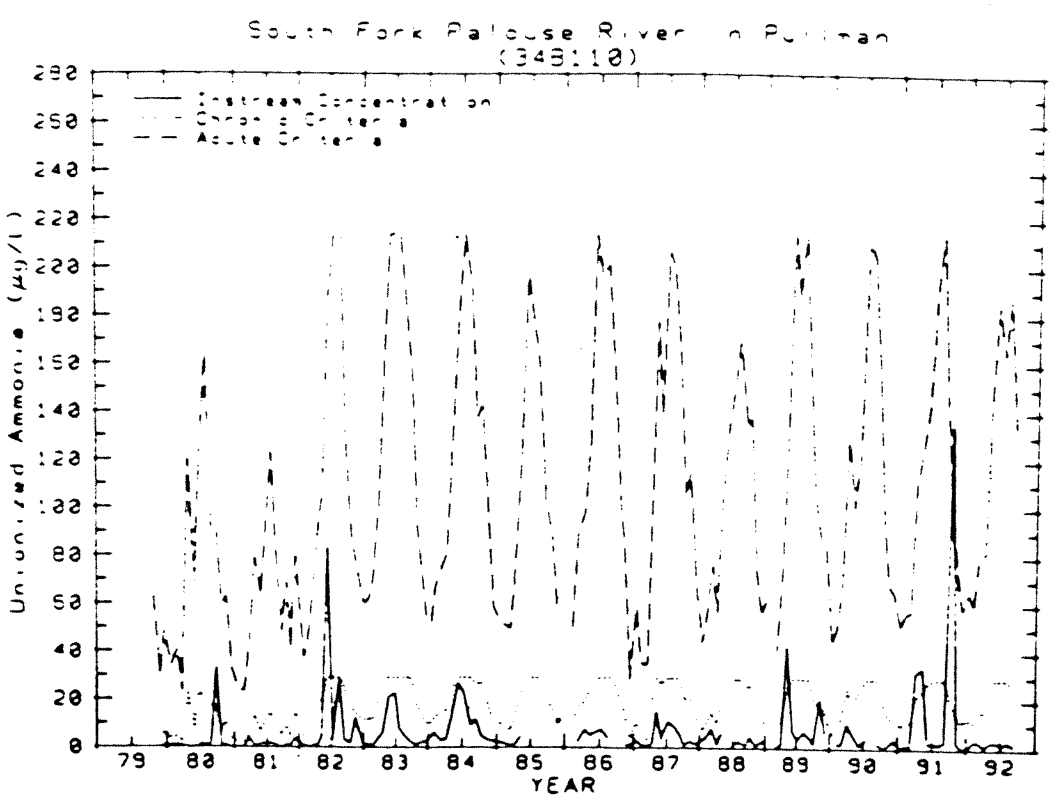


Figure 13. Unionized ammonia concentrations and chronic and acute criteria at the SPFR at Pullman from WY1980 through WY1992.

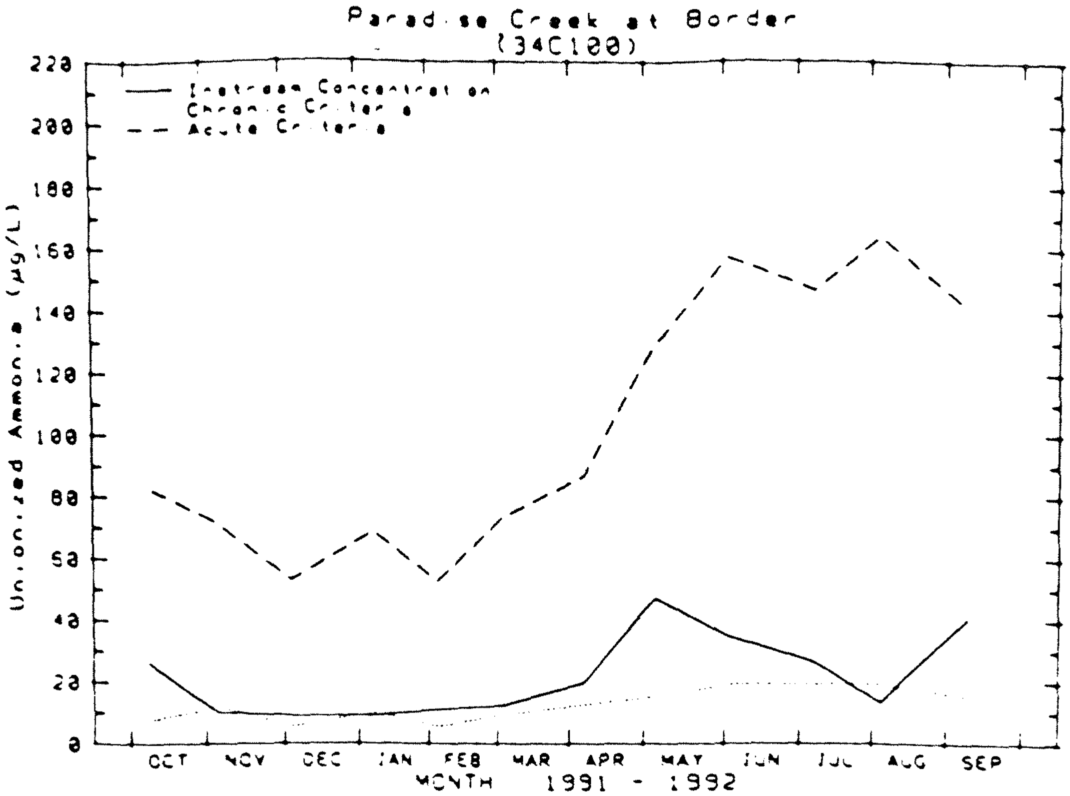


Figure 14. Unionized ammonia concentrations and chronic and acute criteria at Paradise Creek at the border in WY1992.

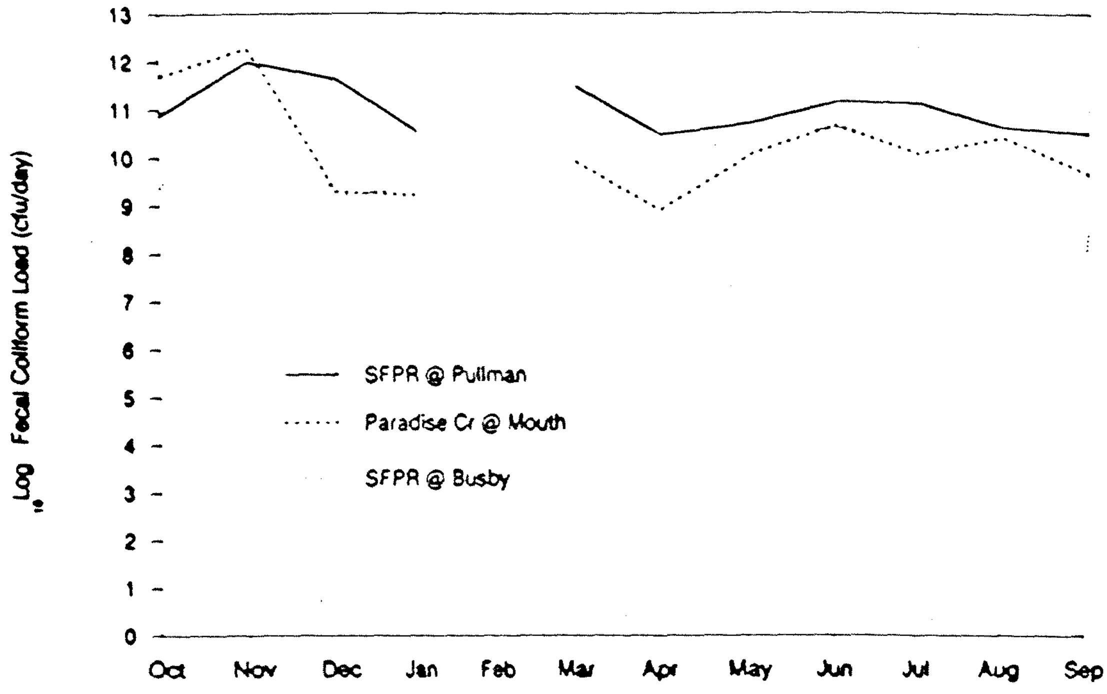


Figure 15. Load (number per unit time) of fecal coliform bacteria by month in WY 1992. (The August load at SFPR at Busby of 0 cfu/day is a consequence of flow being 0 cfs; concentrations were actually quite high.)

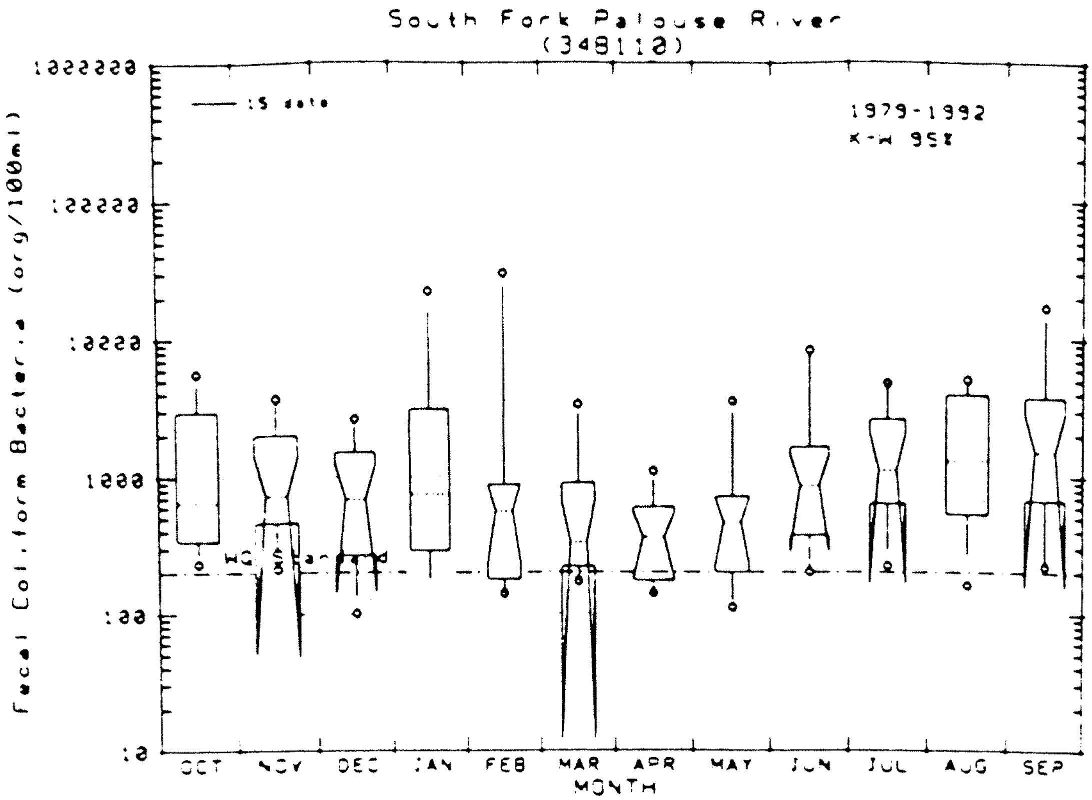


Figure 16. Seasonal variability in fecal coliform bacteria concentrations in the SFPR at Pullman (WY 1980-1992). Box plots are explained in Appendix C.

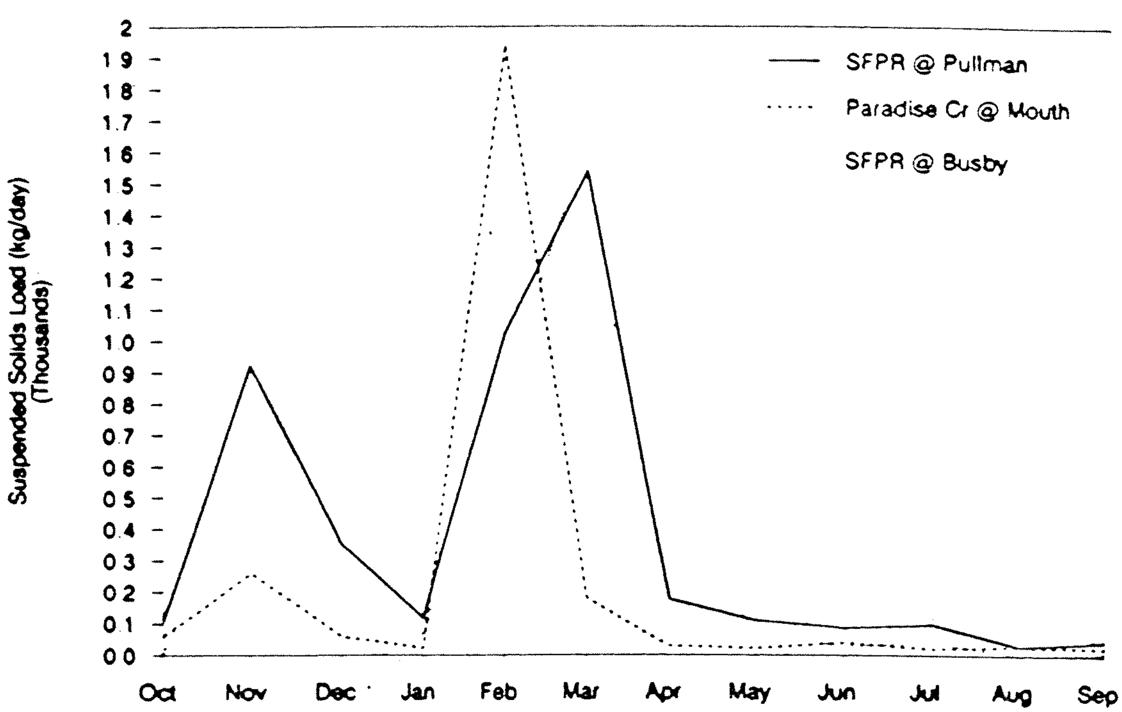


Figure 17. Seasonal variability in suspended solids concentrations in the SFPR at Pullman (WY 1980-1992). Box plots are explained in Appendix C.

APPENDIX A

Appendix A. Distribution of data collected from the South Fork of the Palouse River drainage. The first entry for the station in Pullman includes data from WY 1980 through WY 1992; subsequent entries are for WY 1992 only.

Station name	Number of samples	Min	PERCENTILES 10	25	50 (median)	75	90	Maximum
Temperature (°C)								
SF Palouse R in Pullman	152	0.4	1.7	4.3	9.1	15.1	19.1	22.2
SF Palouse R in Pullman	12	2.8	2.8	4.4	7.9	15.8	18.0	18.1
SF Palouse R @ Busby	12	1.5	1.6	2.2	7.3	16.3	19.8	19.9
Paradise Ck @ Mouth	12	4.0	4.2	5.3	8.5	15.8	17.7	17.8
Paradise Ck @ Border	12	8.0	8.2	10.2	14.5	19.0	20.1	20.4
Conductivity (µmhos/cm)								
SF Palouse R in Pullman	153	160.	237.	320.	420.	525.	600.	720.
SF Palouse R in Pullman	12	372.	377.	400.	445.	543.	622.	645.
SF Palouse R @ Busby	12	223.	236.	267.	292.	338.	391.	400.
Paradise Ck @ Mouth	11	465.	475.	570.	590.	620.	691.	700.
Paradise Ck @ Border	12	309.	366.	542.	585.	640.	775.	795.
Oxygen (mg/L)								
SF Palouse R in Pullman	153	8.0	9.2	10.3	11.5	12.6	13.2	19.2
SF Palouse R in Pullman	12	9.2	9.2	10.3	11.5	12.2	14.9	15.8
SF Palouse R @ Busby	12	9.2	9.2	10.3	11.8	12.8	13.8	14.2
Paradise Ck @ Mouth	12	8.6	8.8	9.2	9.9	11.1	13.3	13.6
Paradise Ck @ Border	12	0.5	1.0	2.9	3.8	5.1	5.9	6.1
Percent Saturation (%)								
SF Palouse R in Pullman	151	64.4	87.0	93.8	101.4	118.1	138.3	236.8
SF Palouse R in Pullman	12	80.0	84.0	94.4	102.3	129.1	139.5	140.5
SF Palouse R @ Busby	12	85.5	87.5	95.4	102.2	109.3	158.1	168.4
Paradise Ck @ Mouth	12	80.5	83.2	91.8	96.2	105.8	117.6	119.5
Paradise Ck @ Border	12	5.5	10.8	30.4	41.8	51.9	60.2	60.7
pH (standard units)								
SF Palouse R in Pullman	152	6.9	7.3	7.7	8.0	8.4	8.6	9.5
SF Palouse R in Pullman	12	7.7	7.7	7.8	8.3	8.4	8.6	8.6
SF Palouse R @ Busby	12	7.7	7.7	7.9	8.3	8.6	9.3	9.4
Paradise Ck @ Mouth	12	7.6	7.7	7.8	8.2	8.4	8.5	8.5
Paradise Ck @ Border	12	7.2	7.2	7.3	7.5	7.6	7.6	7.6
Total Suspended Solids (mg/L)								
SF Palouse R in Pullman	145	1.	5.	9.	15.	34.	120.	2900.
SF Palouse R in Pullman	12	3.	3.	5.	8.	17.	25.	27.
SF Palouse R @ Busby	12	2.	2.	5.	8.	29.	35.	35.
Paradise Ck @ Mouth	12	2.	2.	2.	4.	6.	66.	80.
Paradise Ck @ Border	12	4.	4.	9.	15.	23.	53.	63.
Ammonia Nitrogen (mg/L)								
SF Palouse R in Pullman	144	0.010	0.030	0.060	0.135	0.297	0.585	4.240
SF Palouse R in Pullman	12	0.020	0.021	0.027	0.051	0.330	3.118	4.240
SF Palouse R @ Busby	12	0.021	0.023	0.027	0.033	0.057	5.406	7.670
Paradise Ck @ Mouth	12	0.015	0.018	0.029	0.162	1.065	3.647	4.670
Paradise Ck @ Border	12	0.829	1.063	1.790	2.645	3.648	5.054	5.330
Nitrate+Nitrite Nitrogen (mg/L)								
SF Palouse R in Pullman	133	0.470	2.856	3.863	5.430	7.220	8.560	13.150
SF Palouse R in Pullman	12	2.670	2.787	3.640	4.990	5.868	7.940	8.420
SF Palouse R @ Busby	12	0.005	0.005	0.025	1.219	4.023	5.417	5.720
Paradise Ck @ Mouth	12	3.180	3.534	5.240	7.185	8.163	9.925	10.000
Paradise Ck @ Border	12	2.990	3.758	7.932	8.895	9.707	11.495	12.200

Appendix A.

Station name	Number of samples	Minimum	Percentiles 10	25	50 (median)	75	90	Maximum
Nitrite Nitrogen (mg/L)								
SF Palouse R in Pullman	47	0.005	0.014	0.030	0.050	0.090	0.163	0.180
SF Palouse R in Pullman	12	0.005	0.008	0.017	0.036	0.084	0.171	0.179
SF Palouse R @ Busby	12	0.005	0.005	0.005	0.009	0.015	0.072	0.093
Paradise Ck @ Mouth	12	0.005	0.005	0.021	0.111	0.194	0.392	0.398
Paradise Ck @ Border	12	0.141	0.162	0.303	0.434	0.815	0.983	1.030
Total Phosphorus (mg/L)								
SF Palouse R in Pullman	137	0.005	0.238	0.570	1.300	2.385	3.500	5.250
SF Palouse R in Pullman	12	0.560	0.650	1.313	1.500	1.797	4.617	5.250
SF Palouse R @ Busby	12	0.186	0.189	0.207	0.358	0.586	7.378	9.940
Paradise Ck @ Mouth	12	1.280	1.400	2.070	2.255	2.680	3.726	3.990
Paradise Ck @ Border	12	1.500	1.551	2.132	3.070	3.355	4.408	4.540
Ortho Phosphorus (mg/L)								
SF Palouse R in Pullman	126	0.005	0.257	0.553	1.260	2.385	3.500	5.200
SF Palouse R in Pullman	12	0.232	0.309	0.780	1.260	1.587	3.719	4.550
SF Palouse R @ Busby	12	0.099	0.106	0.147	0.320	1.010	5.602	7.120
Paradise Ck @ Mouth	12	0.751	0.771	1.220	2.000	2.385	3.623	4.070
Paradise Ck @ Border	12	0.845	0.845	1.158	2.560	2.903	3.982	4.360
Turbidity (NTU)								
SF Palouse R in Pullman	142	2.0	4.0	6.1	14.5	37.8	157.0	980.0
SF Palouse R in Pullman	12	2.3	2.4	2.9	5.8	16.0	23.5	25.0
SF Palouse R @ Busby	12	1.7	2.3	3.8	9.5	23.1	28.4	29.0
Paradise Ck @ Mouth	12	1.7	1.8	2.1	3.8	5.8	18.4	23.5
Paradise Ck @ Border	12	4.7	4.8	5.6	9.1	15.0	27.4	31.5
Fecal Coliform Bacteria (colony forming units/100ml)								
SF Palouse R in Pullman	147	100.	188.	330.	700.	1500.	4180.	30000.
SF Palouse R in Pullman	11	140.	148.	220.	430.	1100.	2620.	2900.
SF Palouse R @ Busby	11	8.	9.	29.	120.	1300.	2380.	2500.
Paradise Ck @ Mouth	11	8.	9.	15.	110.	360.	21020.	25000.
Paradise Ck @ Border	11	2.	3.	9.	140.	580.	3540.	4100.
Discharge (cfs)								
SF Palouse R in Pullman	153	2.0	5.0	6.0	12.0	31.5	90.0	750.0
SF Palouse R in Pullman	12	4.0	4.3	5.3	8.5	13.5	30.8	35.0

APPENDIX B

348110 75348110 13348000
SF PALOUSE RIVER AT PULLMAN
46 43 58.0 117 10 48.0 2F 0 Elev= 0 ft
53075 Washington Whitman Co. PACIFIC NORTHWEST
LOWER SNAKE (Palouse-34) 130834
21540000 Reach= 0.000 Org= 0 sqmi
Seg ID= 16-34-02 Class= A Miles= 0.00 to 0.00
AMBNT/STREAM/RMP

INDEX 1310001 002740 00290 0680
MILES 0324.30 0059.50 089.60 022.20 . . . .

DATE FROM TO	TIME	DEPTH FEET	8 LAB IDENT. NUMBER	10 WATER TEMP CENT	25 BAROMTRC PRESSURE MM OF HG	60 STREAM FLOW CFS	80 COLOR PT-CO UNITS	95 CNDUCTVY LAB @ 25C UMHO	300 DO MG/L	301 DO SATUR PERCENT	400 PH SU
91/10/08	1135		416161	8.5	709	5		645	10.5	96.3	8.30
91/11/05	1045		456161	6.2	706	14		388	9.2	80.0	7.80
91/12/03	1030		496161	3.8	708	12		435	11.5	93.8	7.70
92/01/07	1100		26161	2.8	706	8		455	12.9	102.7	8.20
92/02/04	1040		66161	2.9		21		394	11.9	96.0	7.80
92/03/03	1030		106161	7.4	699	35		372	10.3	93.2	7.80
92/04/07	1100		156161	6.2	707	9		425	15.8	137.2	8.50
92/05/05	1020		196161	14.6	703	9		418	10.3	109.1	8.30
92/06/02	1055		236161	17.9	702	6		493	11.7	133.0	8.60
92/07/07	1100		286161	16.2	704	5		484	9.3	101.8	8.20
92/08/04	1145		326161	18.1	701	4		570	12.3	140.5	8.60
92/09/09	1045		376161	13.2	708	6		560	11.5	117.3	8.30

DATE FROM TO	TIME	DEPTH FEET	440 HCO3 ION HCO3 MG/L	530 RESIDUE TOT-NFLT MG/L	610 NH3+NH4- N TOTAL MG/L	613 NO2-N DISS MG/L	615 NO2-N TOTAL MG/L	620 NO3-N TOTAL MG/L	630 NO2+NO3 N-TOTAL MG/L	665 PHOS-TOT MG/L P	671 PHOS-DIS ORTHO MG/L P
91/10/08	1135			9.0	4.240	0.076			3.060	5.250	4.550
91/11/05	1045			27.0	0.292J	0.087			3.580J	1.550	1.490
91/12/03	1030			12.0	0.115	0.059			8.420	1.320	1.140
92/01/07	1100			6.0	0.020	0.010K			5.430	1.310	0.232
92/02/04	1040			20.0	0.499	0.154			6.820	0.861	0.772
92/03/03	1030			18.0	0.343	0.179			5.940	0.560	0.488
92/04/07	1100			8.0	0.023	0.025			5.650	1.460	1.390
92/05/05	1020			5.0	0.059	0.031			3.820	1.450	1.380
92/06/02	1055			6.0	0.027	0.041			4.820	1.800	1.780
92/07/07	1100			8.0	0.043	0.014			2.670	1.540	1.620
92/08/04	1145			3.0	0.027	0.014			3.940	1.790	0.806
92/09/09	1045			3.0	0.037	0.030			5.160	3.140	0.844

DATE FROM TO	TIME	DEPTH FEET	902 MC HARD CACO3 MG/L	915 CALCIUM CA,DISS MG/L	925 MGNSIUM MG,DISS MG/L	930 SODIUM NA,DISS MG/L	935 PTSSIUM K,DISS MG/L	940 CHLORIDE CL MG/L	945 SULFATE SO4-TOT MG/L	31504 TOT COLI MFIM LES /100ML	31616 FEC COLI MFM-FCBR /100ML	31… FECSTR PC M-E /100

MORE DATES NEXT PAGE

DATE FROM TO	TIME	DEPTH FEET	902 MC HARD CACO3 MG/L	915 CALCIUM CA,DISS MG/L	925 MGNSIUM MG,DISS MG/L	930 SODIUM NA,DISS MG/L	935 PTSSIUM K,DISS MG/L	940 CHLORIDE CL MG/L	945 SULFATE SO4-TOT MG/L	31504 TOT COLI MFIM LES /100ML	31616 FEC COLI MFM-FCBR /100ML	3167 FECSTRE PC M-EN /100M
91/10/08	1135										650	
91/11/05	1045										2900	
91/12/03	1030										1500	
92/01/07	1100										180S	
92/03/03	1030										360	
92/04/07	1100										140	
92/05/05	1020										240	
92/06/02	1055										1000	
92/07/07	1100										1100J	
92/08/04	1145										430	
92/09/09	1045										220	

DATE FROM TO	TIME	DEPTH FEET	38260 MBAS MG/L	50066 CHLORINE COMB AVL MG/L	82079 TURBIDTY LAB NTU
91/10/08	1135				6.2
91/11/05	1045				20.0
91/12/03	1030				10.0
92/01/07	1100				7.0
92/02/04	1040				25.0
92/03/03	1030				18.0
92/04/07	1100				4.6
92/05/05	1020				3.6
92/06/02	1055				2.6
92/07/07	1100				5.5
92/08/04	1145				2.3
92/09/09	1045				2.7

348140   75348140
SF PALOUSE RIVER AT BUSBY
46 41 28.0 117 09 03.0   2F000   Elev=   0 ft
53075 Washington   Whitman Co.   PACIFIC NORTHWEST
LOWER SNAKE (Palouse-34)   130834
21540000   Reach=17060108017   0.000   Drg=   0 sqmi
AMBNT/STREAM/RMP

INDEX   1310001 002740 00290 0680
MILES   0324.30 0059.50 089.60 025.80 . . . .

DATE FROM TO	TIME	DEPTH FEET	8 LAB IDENT. NUMBER	10 WATER TEMP CENT	25 BAROMTRC PRESSURE MM OF HG	95 CNDUCTVY LAB @ 25C UMHO	300 DO MG/L	301 DO SATUR PERCENT	400 PH SU	530 RESIDUE TOT-NFLT MG/L	610 NH3+NH4- N TOTAL MG/L	6.. NO2..
91/10/08	1220		416163	8.0	707	371	11.3	102.5	8.30	3.0	7.670	[illegible]
91/11/05	1120		456163	2.9	705	311	10.7	85.5	7.90	24.0	0.123J	[illegible]
91/12/03	1115		496163	1.9	709	265	12.3	95.1	7.80	8.0	0.045	[illegible]
92/01/07	1130		26163	1.5	705	280	12.8	98.5	8.10	8.0	0.026	[illegible]
92/02/04	1130		66163	1.7		223	12.3	96.3	7.90	30.0	0.058	[illegible]
92/03/03	1105		106163	6.6	699	303	10.4	92.2	7.70	34.0	0.030	[illegible]
92/04/07	1145		156163	5.0	705	268	12.8	108.0	8.20	35.0	0.029	[illegible]
92/05/05	1055		196163	15.2	701	267	10.2	109.7	8.50	7.0	0.029	[illegible]
92/06/02	1140		236163	19.5	700	330	9.2	108.2	8.50	16.0	0.054	[illegible]
92/07/07	1150		286163	16.7	703	400	9.2	101.9	8.60	6.0	0.036	[illegible]
92/08/04	1220		326163	19.9	699	276	14.2	168.4	9.40	4.0	0.026	[illegible]
92/09/09	1120		376163	13.6	707	341	13.0	134.0	9.00	2.0	0.021	[illegible]

DATE FROM TO	TIME	DEPTH FEET	630 NO2+NO3 N-TOTAL MG/L	665 PHOS-TOT MG/L P	671 PHOS-DIS ORTHO MG/L P	31616 FEC COLI MFM-FCBR /100ML	82079 TURBIDTY LAB NTU
91/10/08	1220		0.838	9.940	7.120	120	4.1
91/11/05	1120		1.600J	1.400	1.160	1300J	14.5
91/12/03	1115		5.720	0.480	0.370	11	14.0
92/01/07	1130		2.830	0.359	2.060	29	12.0
92/02/04	1130		4.420	0.201	0.136		26.0
92/03/03	1105		4.710	0.225	0.123	69	27.0
92/04/07	1145		1.970	0.186	0.099	110	29.0
92/05/05	1055		0.298	0.228	0.178	210	4.4
92/06/02	1140		0.063	0.356	0.270	2500J	7.0
92/07/07	1150		0.012	0.442	0.417	120	3.6
92/08/04	1220		0.010K	0.622	0.562	1900J	3.7
92/09/09	1120		0.010K		0.208	8	1.7

34C060 7534C060
PARADISE CREEK AT MOUTH
46 43 14.0 117 09 47.0 2F000 Elev= 0 ft
53075 Washington Whitman Co. PACIFIC NORTHWEST
LOWER SNAKE (Palouse-34) 130834
21540000 Reach=17060108022 0.000 Drg= 0 sqmi
AMBNT/STREAM/RMP

INDEX 1310001 002740 00290 0680 0230
MILES 0324.30 0059.50 089.60 023.60 000.10 . . . .

DATE FROM TO	TIME	DEPTH FEET	8 LAB IDENT. NUMBER	10 WATER TEMP CENT	25 BAROMTRC PRESSURE MM OF HG	95 CNDUCTVY LAB @ 25C UMHO	300 DO MG/L	301 DO SATUR PERCENT	400 PH SU	530 RESIDUE TOT-NFLT MG/L	610 NH3+NH4- N TOTAL MG/L	6[illegible] NO2 DI[illegible] MG
91/10/08	1150		416162	8.4	708	700	10.2	93.4	8.30	6.0	4.670	0.0[illegible]
91/11/05	1105		456162	6.8	705	655	9.1	80.5	7.80	34.0	1.050J	0.[illegible]
91/12/03	1050		496162	4.9	710	610	10.9	91.3	7.60	4.0	1.260	0.[illegible]
92/01/07	1115		26162	4.0	705	580	12.5	102.9	8.20	2.0	0.015	0.0[illegible]
92/02/04	1110		66162	4.6		585	11.1	93.8	7.80	80.0	0.979	0.3[illegible]
92/03/03	1050		106162	8.7	699	465	9.6	89.6	7.90	5.0	1.070	0.3[illegible]
92/04/07	1130		156162	6.6	706	605	13.6	119.5	8.40	3.0	0.231	0.[illegible]
92/05/05	1040		196162	15.3	702	570	10.5	113.1	8.40	2.0	0.094	0.[illegible]
92/06/02	1110		236162	17.8	701	515	9.4	106.7	8.50	3.0	0.029	0.[illegible]
92/07/07	1130		286162	16.0	704	590	8.6	93.8	8.20	4.0	0.029	0.[illegible]
92/08/04	1205		326162	17.6	701		9.1	102.8	8.40	3.0	0.026	0.[illegible]
92/09/09	1105		376162	13.0	708	620	9.7	98.6	8.20	2.0	0.037	0.[illegible]

DATE FROM TO	TIME	DEPTH FEET	630 NO2+NO3 N-TOTAL MG/L	665 PHOS-TOT MG/L P	671 PHOS-DIS ORTHO MG/L P	31616 FEC COLI MFM-FCBR /100ML	82079 TURBIDTY LAB NTU
91/10/08	1150		3.180	3.990	4.070	5100J	4.7
91/11/05	1105		6.790J	2.680	2.580	25000J	23.5
91/12/03	1050		10.000	2.100	2.010	14	5.0
92/01/07	1115		8.180	2.210	1.250	15	5.0
92/02/04	1110		9.750	1.680	1.640		6.6
92/03/03	1050		8.110	1.280	1.210	23	6.0
92/04/07	1130		7.690	2.300	1.990	8	2.0
92/05/05	1040		5.550	2.440	2.440	110	1.7
92/06/02	1110		5.420	2.680	2.220	360	1.9
92/07/07	1130		5.180	2.070	2.150	220	2.3
92/08/04	1205		4.360	2.070	0.817	270	2.6
92/09/09	1105		7.580	3.110	0.751	40	2.9

34C100 7534C100
PARADISE CREEK AT IDAHO BORDER
46 43 57.0 117 02 35.0 2F000 Elev= 0 ft
53075 Washington Whitman Co. PACIFIC NORTHWEST
LOWER SNAKE (Palouse-34) 130834
21540000 Reach=17060108022 0.000 Drg= 0 sqmi
AMBNT/STREAM/RMP

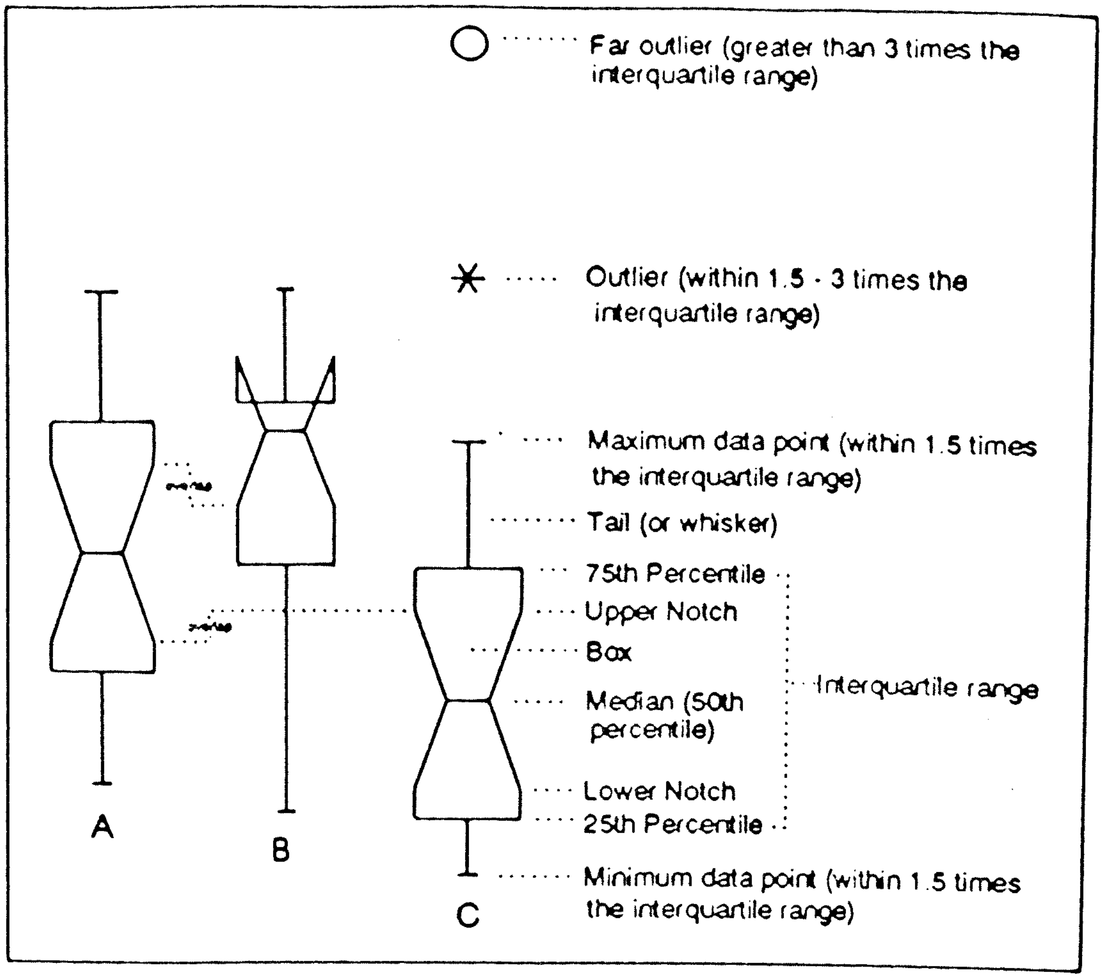
INDEX 1310001 002740 00290 0680 0230
MILES 0324.30 0059.50 089.60 023.60 006.50 . . . .

DATE FROM TO	TIME	DEPTH FEET	8 LAB IDENT. NUMBER	10 WATER TEMP CENT	25 BAROMTRC PRESSURE MM OF HG	95 CNDUCTVY LAB @ 25C UMHO	300 DO MG/L	301 DO SATUR PERCENT	400 PH SU	530 RESIDUE TOT-NFLT MG/L	610 NH3+NH4- N TOTAL MG/L	[illegible]
91/10/08	1245		416164	16.8	704	795	0.5	5.5	7.20	4.0	5.330	[illegible]
91/11/05	1150		456164	8.0	702	309	5.5	50.2	7.60	63.0	1.610J	[illegible]
91/12/03	1140		496164	10.3	706	590	3.7	35.5	7.20	14.0	3.000	[illegible]
92/01/07	1205		26164	8.8	703	540	3.2	29.8	7.50	9.0	1.750	[illegible]
92/02/04	1155		66164	10.2		590	4.6	44.8	7.20	23.0	3.700	[illegible]
92/03/03	1135		106164	11.3	696	500	6.1	60.7	7.40	23.0	2.420	[illegible]
92/04/07	1225		156164	12.2	702	650	5.2	52.4	7.50	10.0	2.870	[illegible]
92/05/05	1120		196164	18.0	698	610	3.4	38.9	7.50	10.0	4.410	[illegible]
92/06/02	1205		236164	19.4	725	548	4.0	45.3	7.60	15.0	2.330	[illegible]
92/07/07	1220		286164	18.4	699	552	2.8	32.3	7.60	30.0	1.910	[illegible]
92/08/04	1250		326164	20.4	697	580	4.9	59.0	7.60	21.0	0.829	[illegible]
92/09/09	1150		376164	19.2	704	730	2.0	23.3	7.50	5.0	3.490	[illegible]

DATE FROM TO	TIME	DEPTH FEET	630 NO2+NO3 N-TOTAL MG/L	665 PHOS-TOT MG/L P	671 PHOS-DIS ORTHO MG/L P	31616 FEC COLI MFM-FCBR /100ML	82079 TURBIDTY LAB NTU
91/10/08	1245		9.490	4.540	4.360	440	6.8
91/11/05	1150		2.990J	1.500	1.070	580	31.5
91/12/03	1140		12.200	2.960	2.670	8K	11.0
92/01/07	1205		9.400	3.180	2.940	2	10.0
92/02/04	1155		8.390	2.320	2.070		15.0
92/03/03	1135		8.380	1.670	1.420	52	18.0
92/04/07	1225		9.780	3.000	2.770	9	5.3
92/05/05	1120		9.490	3.380	3.100	57X	5.2
92/06/02	1205		7.920	3.280	2.450	4100J	8.1
92/07/07	1220		7.970	3.140	2.790	1300J	15.0
92/08/04	1250		5.550	2.070	0.845	470	6.3
92/09/09	1150		9.850	4.100	0.846	140	4.7

APPENDIX C

Appendix C. Box Plot Explanation.



Interpretation: Boxplots graphically display the distribution and characteristics of sample data. 50% of the sample data lie within the box. The rest of the data, except outliers, lie within the upper and lower tails. Symmetrical plots (like A) suggest that sample data are normally distributed. Asymmetrical plots (like B - long tail and 75th quartile close to median) may indicate a skewed distribution. Notched boxplots are useful for finding differences between two groups. The upper and lower notches designate the 95% Confidence Interval (CI) around the median. If the notches around two boxplot medians do not overlap, as in B and C above, the two population medians are significantly different at approximately the 95% confidence level (SYSTAT, 1990). In the figure above, the medians of populations A and B, and A and C, are not different, even though their sample medians are different. In plot B, the upper confidence limit extends beyond the 75th percentile, making the upper part of the plot appear as if it has folded over. The CI is dependent upon sample size and the variability of the data: a small sample size or highly variable data tend to result in a larger CI.