WATER QUALITY STATUS REPORT NO. 95

HANGMAN CREEK
POST-BEST MANAGEMENT PRACTICES IMPLEMENTATION STUDY

Benewah County, Idaho

1989 - 1990

Idaho Department of Health and Welfare

Division of Environmental Quality

1991

WATER QUALITY STATUS REPORT NO. 95

HANGMAN CREEK POST-BEST MANAGEMENT PRACTICES IMPLEMENTATION STUDY Benewah County, Idaho 1989 - 1990

Prepared by
Bill Fortis
and
Mike Hartz

Coeur d'Alene Field Office
2110 Ironwood Parkway
Coeur d'Alene, ID 83814

Idaho Department of Health and Welfare
Division of Environmental Quality
1410 North Hilton Street
Boise, Idaho 83720-90000

1991

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

(figures cont.)

ABSTRACT

Hangman Creek originates in Benewah County in northern Idaho. It drains a forest and nonirrigated cropland watershed of approximately 83,000 acres, of which about 33,000 acres are in dry cropland production. The soils are typical of the Palouse region and are highly erosive with an annual erosion rate between 30 and 50 tons/acre.

A study completed in 1982 established the baseline water quality status of Hangman Creek and recommended land management changes for the watershed. The main objective of this follow-up study was to evaluate differences in water quality in Hangman Creek for the 1981-1982 baseline study and the 1989-1990 post-best management practices (BMP) implementation study. Suspended sediment concentrations decreased in the upper Hangman Creek watershed and increased in the lower portion. This paper discusses factors responsible for water quality changes in an attempt to assess BMP effectiveness on critical areas.

The same 16 stations, 12 on tributaries and 4 on the main stream, were sampled during both studies. BMP contracts were completed in the upper Hangman Creek watershed prior to the follow-up study. Both surveys covered approximately an 18 month period. Sampling began in January and was completed in May or June of the following year. Samples were primarily analyzed for sediment, nutrients, and bacteria.

Suspended sediment is the main pollutant in Hangman Creek and the BMPs (ie. conservation tillage and grassed waterways) are directed at reducing the amount of soil entering the stream during the spring runoff period. In order to identify changes in suspended sediment concentrations in Hangman Creek, sediment discharge rating curves were established for both study periods. Comparing post-implementation curves with the 1981-1982 baseline sediment rating curves shows that suspended sediment concentrations in the upper Hangman Creek watershed have decreased. Stations on the main stem above and below Sanders, near DeSmet, Smith Creek, and on the west tributary of Sheep Creek, all have post-implementation curves that plot below those from 1981-1982.

The post-implementation curves for Lolo Creek, Andrews Springs' Creek, State Park tributary and the Clay Pit tributary however, show an increase in suspended sediment concentrations. These drainages comprise the lower Hangman Creek watershed. Lack of improvement with regard to sediment in lower Hangman Creek, can be attributed to the following: 1) BMP implementation on critical areas in the lower Hangman Creek watershed began four to five years later than implementation in the upper watershed areas. BMPs were implemented approximately one year before the 1989-1990 study. As a result, newly established BMPs in lower Hangman Creek, may not have been effective during the 1989-1990 study. 2) In comparison

to the upper Hangman Creek watershed, BMPs were implemented on a smaller percentage of critical area in lower Hangman Creek. 3) large differences in 1981-1982 and 1989-1990 water years and storm events increase variability in water quality data interpretation. 4) a larger percentage of cropland versus woodland acres in the lower watershed in comparison to the upper portion, may result in more pronounced cumulative effects, especially with regard to sediment transport. 5) unstable stream banks and inadequate riparian zones along lower Hangman Creek probably result in significant sediment inputs to the stream.

Average total phosphorus concentrations at the monitoring sites in 1989-1990 were 19-75 percent less than those registered in 1981-1982. Means ranged from 0.09 mg/L at Hangman Creek above Sanders to 0.3 mg/L at Middle Andrew Springs' Creek. Phosphorus discharge rating curves also indicated a reduction in total phosphorus levels at most stations.

Inorganic nitrogen concentrations, on the other hand, increased at most of the stations. The Clay Pit tributary had the highest mean concentration at 14.38 mg/L. This is a 53 percent increase from the 1981-1982 survey. A peak of 48.94 mg/L was recorded here on January 5, 1989.

Idaho Water Quality Standards protect Hangman Creek for use as an agricultural water supply and secondary contact recreation. State fecal coliform standards of 200/100 ml were not exceeded at any of the sample stations. This was violated in the pre-implementation study at both the Hangman Creek stations above and below Sanders. Fecal coliform-fecal streptococcus ratios indicate that bacterial contamination in these upper Hangman drainages is primarily from human sources.

Dissolved oxygen and temperature levels were in compliance with accepted standards in the follow-up study, indicating that the criteria for the future beneficial use of Hangman Creek for cold water biota are currently being met. Hydrogen ion concentrations or pH levels were at the low end of the pH scale (6.5-9.0) accepted as the standard for waters protected for cold water fisheries, however, no violations were recorded. These findings are consistent with those of the 1981-1982 study indicating that future fisheries would not be hampered by inadequate temperature, dissolved oxygen, or pH levels.

Future monitoring of lower Hangman Creek, Lolo Creek, Andrews Springs' Creek, Mission Creek, and Clay Pit Tributary is advised. This will provide better documentation of changes in suspended sediment concentrations in the watershed.

INTRODUCTION

BACKGROUND

The 1979 Idaho Agricultural Pollution Abatement Plan (IDL-SCC 1979) identified Hangman Creek as severely affected by sediment due to erosion. As a result, the Division of Environmental Quality (DEQ) conducted a water quality study of the watershed in 1981-1982 to establish baseline data and to locate the critical erosion areas to which best management practices should be applied.

The results and conclusions of this study were presented in Water Quality Status Report No. WQ-51 (Bauer and Wilson 1983). Beginning in 1982, the Benewah Soil and Water Conservation District (SWCD) began an extensive effort to implement BMPs on the critical areas as identified by Bauer and Wilson (1983).

The University of Idaho investigated macroinvertebrate populations in Hangman Creek and its' tributaries (Personal communication, Dr. Brusven, University of Idaho 1991). Preliminary monitoring of macroinvertebrates show differentials in species diversity and densities throughout the watershed. In general, upper Hangman Creek and its tributaries show the greatest species diversity and highest densities with regard to macroinvertebrates. Species diversity decreases in lower Hangman Creek and its tributaries. The University of Idaho macroinvertebrate baseline data is apparently the only bioassessment information on Hangman Creek available to date. This information has not been formally documented.

OBJECTIVES

The Idaho Water Quality Standards and Wastewater Treatment Requirements (IDHW 1985) (See Appendix A) designate Hangman Creek as:

1) Protected for general use as an agricultural water supply;

2) Protected for general use as secondary contact recreation; and

3) Protected for future usage of cold water biota.

The following specific objectives reflect the protected uses of Hangman Creek, its designation as a high priority stream segment in the Idaho Agricultural Pollution Abatement Plan (IDL-SCC 1979) and the recognition of the significant expenditure of public and private funds for water quality enhancement.

1) Evaluate changes in Hangman Creek water quality by comparing present water quality data with baseline water quality status.

2) Compare water quality in Hangman Creek to state water quality standards and historical data.

3) Adapt "EPA's "Bioassessment" procedure as a means of obtaining trend analysis to augment laboratory data.*

4) Prioritize Hangman Creek sub-watersheds for future monitoring and to recommend BMP implementation.

* The third objective in this study related to bioassessment was not able to be addressed due to constraints of manpower and time. Also, no baseline bioassessment data was available from the original study. Therefore, identifying trends in water quality, the main focus of this study, would not have been possible.

WATERSHED DESCRIPTION

Hangman Creek is a part of the Spokane River drainage system (Figure 1) and has its headwaters in the mountains 10 miles southeast of Tensed, Idaho. The creek flows northwestward and enters Washington seven miles northwest of Tensed. The watershed has a classic dendritic pattern and eight major sub-drainages including: Mission Creek, Sheep Creek, Andrew Springs' Creek, Mineral Creek, Hangman Creek, Indian Creek, Squaw Creek and Lolo Creek. The sampling station near DeSmet on the main stem, is considered to divide upper Hangman Creek from the lower portion (Figure 2). The watershed area of Hangman Creek in Idaho is approximately 83,000 acres. Of this, about 53,000 acres are forest land and about 33,000 acres are non-irrigated cropland, hayland and pasture.

Elevations range from 4,949 feet at the top of Moses Mountain to about 2,500 feet at the Idaho-Washington border. Land forms and soil types are generally those characteristic of the Palouse region. Three major soil divisions are found within the watershed (Figure 3). Type 1 is mainly silt and loam and is found on flood plains and low stream terraces. Though this makes good cropland, it is frequently flooded and poorly drained. Type 2 soil occurs on the steep to mildly sloped loess covered hills. This Palouse soil is also a silt-loam and is easily eroded. Soil loss in the area has often reached 40-50 tons/acre/year. Most of this erosion occurs in February and March and is associated with early spring rains on snow-covered ground. Type 3 soil, a gravelly loam, is considered highly erodible. Approximately 43 percent of the land under production is of the original prairie type and 57 percent is cut-over (once forested) soil (USDA-SCS 1981).

Precipitation in the watershed ranges from 40 inches on Mineral Mountain to 20 inches at Tensed. This 20 inch variation occurs over a distance of only nine miles and accounts for much of the variability in stream flow from drainage to drainage, and year to year. Average annual precipitation over the last eight years at the Plummerosa Tree Farm, two miles south of Plummer, was 32 inches (Wetter 1989).

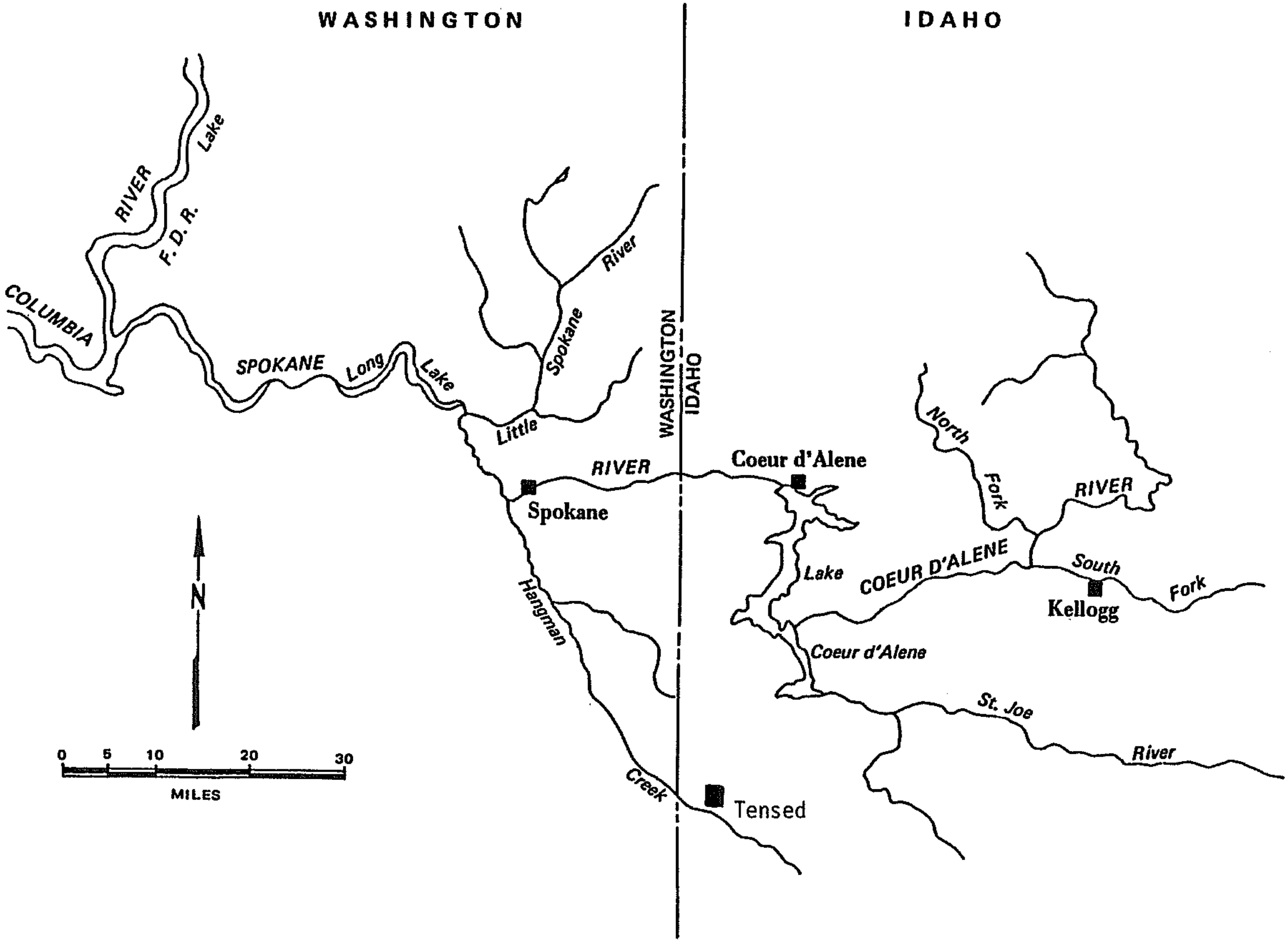

Figure 1. Spokane River Drainage System. Hangman Creek is located in the south central portion of this map.

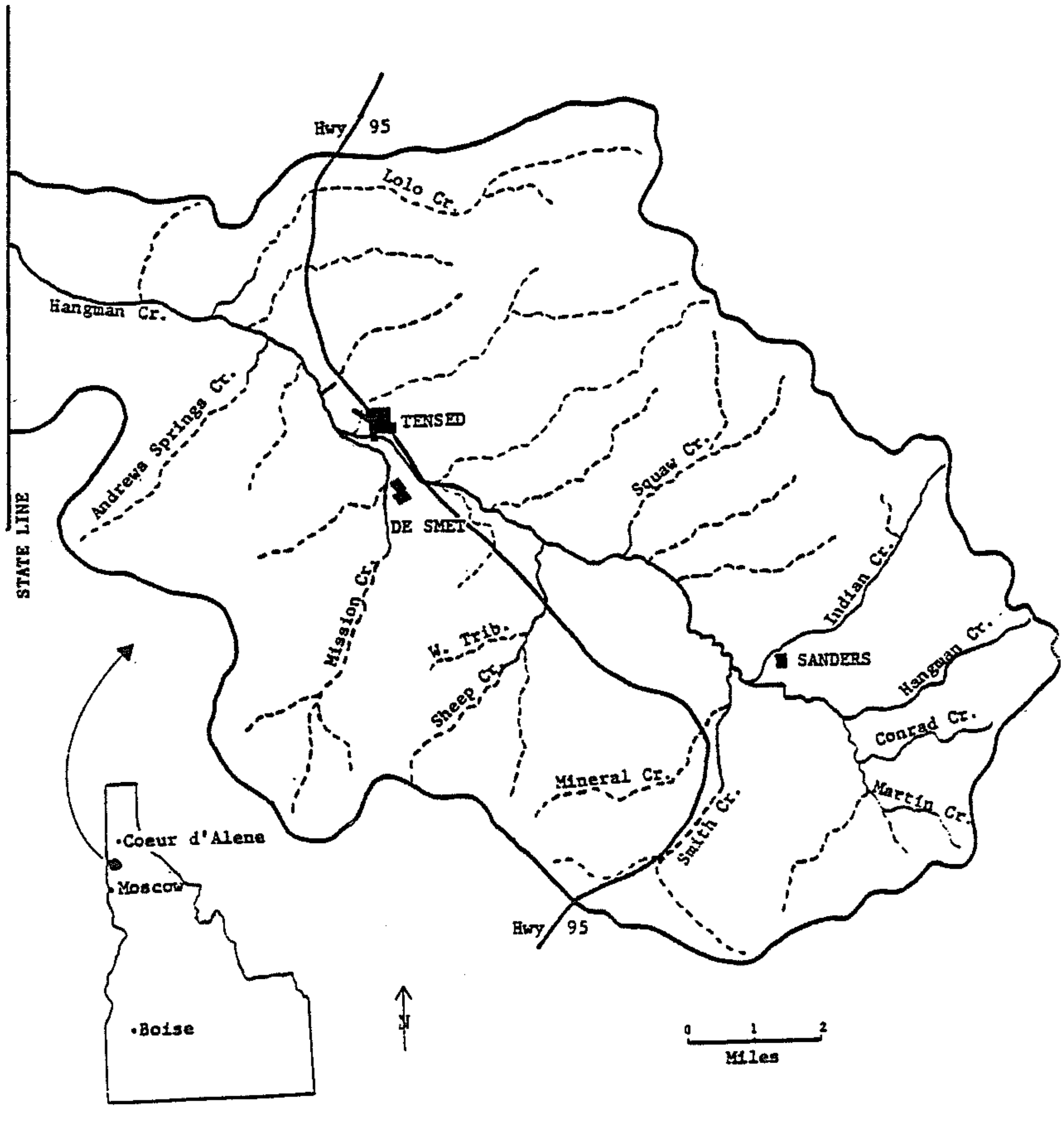

Figure 2. Hangman Creek Watershed. Bauer and Wilson (1983).

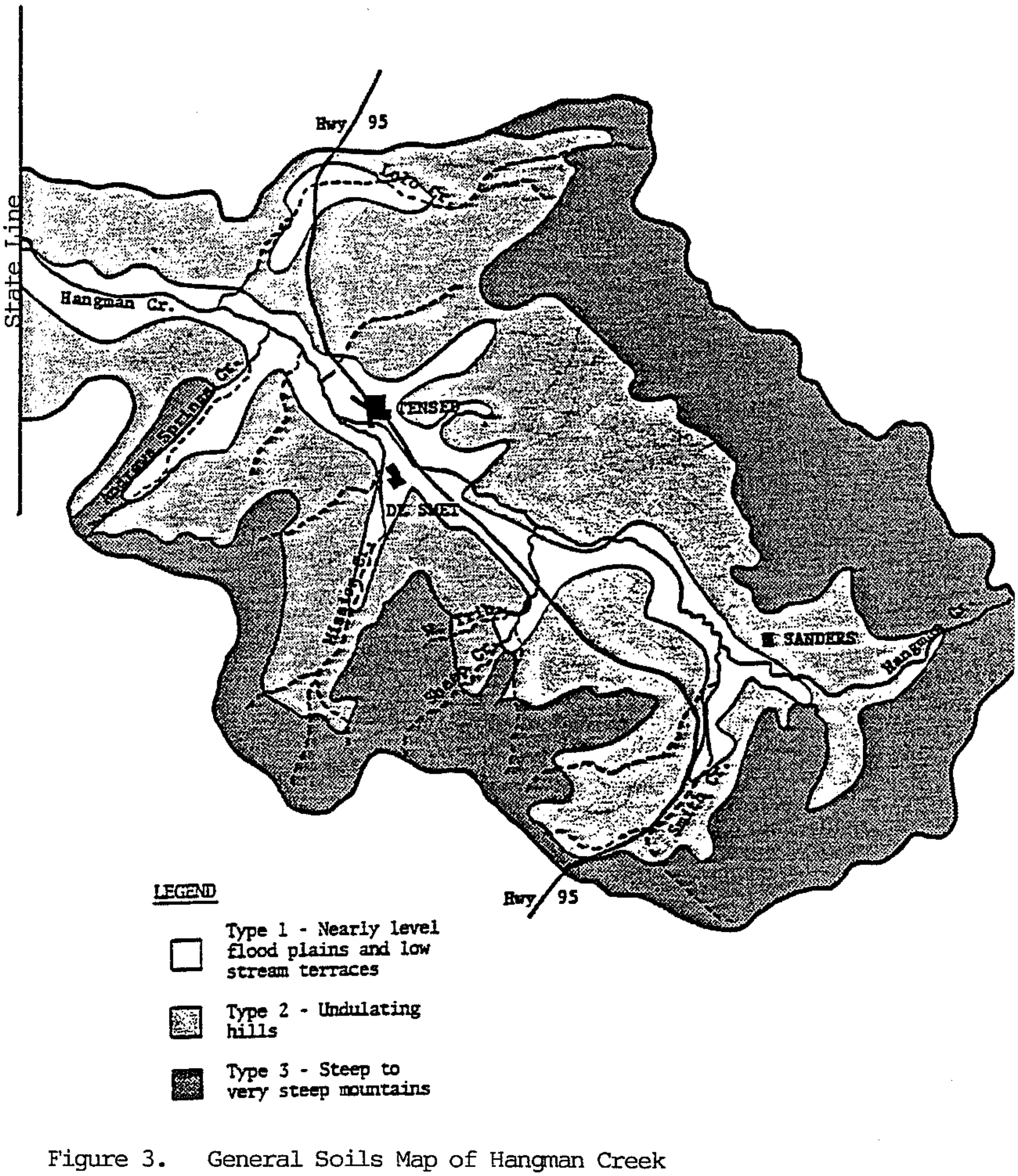

Figure 3. General Soils Map of Hangman Creek Watershed From SCS Soil Survey Bauer and Wilson (1983)

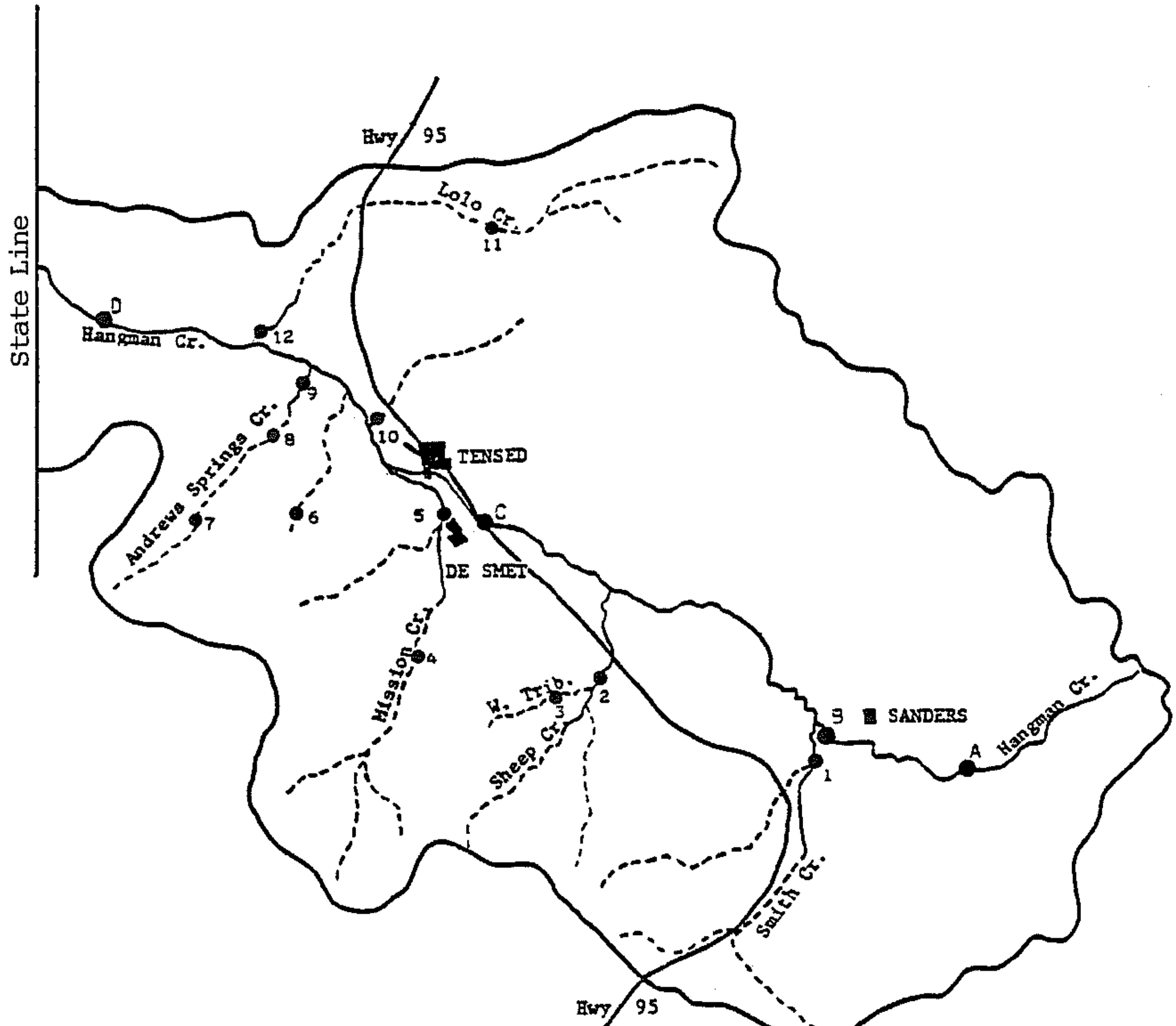

Figure 4. Sampling Station Locations, Hangman Creek.
Ambient A-D, Intensive 1-12.
Bauer and Wilson (1983)

TABLE 2. Location and Description of Stations Sampled and Numbers of Samples Collected During 1981-82 and 1989-90.

STATION	LOCATION	COMMENTS	# SAMPLES 81-82	89-90
A	Hangman Creek above Sanders (A)	drains woodland area, above cropland	25	29
B	Hangman Creek below Sanders (A)	drains woodland and cut-over cropland	24	28
1	Smith Creek near mouth (I)	cut-over soils	15	17
3	Western tributary of Sheep Cr. (I)	cut-over soils	15	17
2	Sheep Creek near mouth (I)	cut-over soils	14	21
C	Hangman Creek at DeSmet (A)	divides Hangman Creek into upper segment	23	27
4	Upper Mission Creek (I)	below woodland and cut-over soils	12	21
5	Mission Creek near mouth (I)	drains critical area on Palouse soils	15	21
6	State Park tributary (I)	drains entirely woodland	10	6
7	Upper Andrew Springs Creek (I)	drains woodland and cut-over soils	11	19
8	Middle Andrew Springs Creek (I)	cut-over and Palouse soils	12	20
9	Andrew Springs Cr. at mouth (I)	Palouse soils	14	20
10	Clay Pit tributary (I)	Palouse soils Fertilizer Plant	14	22
11	Upper Lolo Cr.(I)	cut-over soils	11	21
12	Lolo Creek near mouth (I)	below Palouse soils	13	20
D	Hangman Creek at stateline (A)	measures water quality at border	36	30

I = Indicates Intensive Stations, A = Ambient Stations with USGS gage and discharge data. Both methods however, had high correlation values. Discharge near the Idaho-Washington border was recorded by a continuous recording gage under contract by the USGS. Field parameters were analyzed on site with portable meters, calibrated prior to each survey. Conductivity as measured with a YSI Model 33 meter, dissolved oxygen and temperature with a YSI Model 50 meter, turbidity with a portable HACH Model 16800 meter, and pH was determined with a Corning Model 610-A meter.

Water samples were collected according to procedures outlined in IDHW-DEQ Technical Procedures Manual (Ralston and Browne 1976). All samples were placed on ice, cooled to 4 degrees centigrade and then analyzed according to Methods for Chemical Analysis of Water and Waste (EPA 1979).

RESULTS AND DISCUSSION

STREAM FLOW

Hangman Creek followed a similar flow pattern during both study periods. The high flow period occurs from January through May, corresponding with heavy rains and snow melt. It is during this period that most erosion takes place as the ground has little or no vegetative cover. While not intermittent, Hangman Creek has very low base flows (1.0 cfs). These occur during the summer months. Figure 5 demonstrates the flow characteristics of Hangman Creek as a hydrograph of monthly means for both study periods. The hydrograph covers the entire 18 month time span of each study period from beginning to end.

While the general pattern of monthly flows is similar, Figure 5 shows the variation in averages from year to year. In the most recent study, the highest monthly average flow was 411 cfs in March, 1990, while in the original study the highest monthly average was 626 cfs in February, 1982. The peak flow in the post-implementation study was 1360 cfs on February 10, 1990. This contrasts with a peak flow in the 1981-1982 study of over 2,600 cfs. Figure 6 shows the highest monthly peak flows for both study periods. Discharges during 1989-1990 generally averaged much lower than those of the first study.

During the high runoff season, Hangman Creek floods its banks two or three times per year. Generally the flooding occurs below DeSmet and throughout the lower drainage. It is at these times that tremendous amounts of sediment enters the stream from the fields and the easily eroded stream banks. During the February, 1990 storm event, roads were flooded throughout the lower drainage. Major storm events during both studies took place in February and March. Snowpack has increased until this time and then warm chinook winds and heavy rains combine to rapidly melt the snow, creating a major runoff event. The variations in average daily flows point out the difficulty in using storm events to establish trends in water quality in a dryland agricultural type environment.

Low base flows occurring from July to November of both studies averaged between 0.25 and 8 cfs. Although the main stem is perennial, most of the tributaries dry up by June. Heavy precipitation occasionally occurs during the summer-fall months. However, this does not necessarily result in higher discharges, because the rainfall is easily absorbed by the dry, heavily covered fields at this time.

Total monthly precipitation varies greatly from year to year as demonstrated in figure 7. The general pattern remains the same as with stream flow, with heaviest precipitation occurring from January through May during both periods of study. Heavy rainfalls in February and March contributed to high runoff events in 1982 and

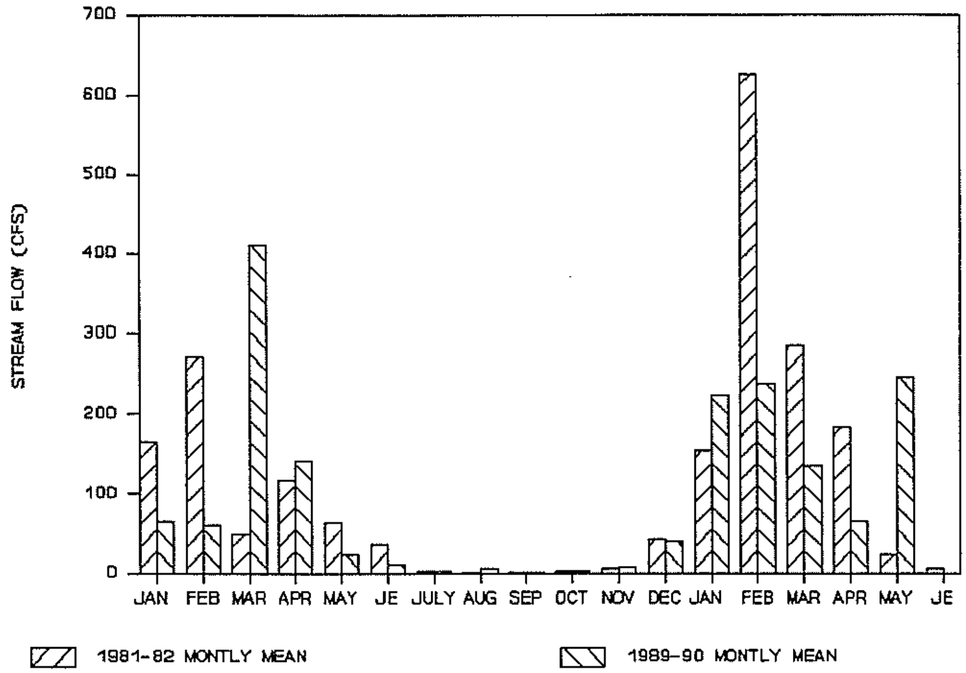

Figure 5. Hangman Creek Monthly Mean Flows From the USGS Station near Stateline.

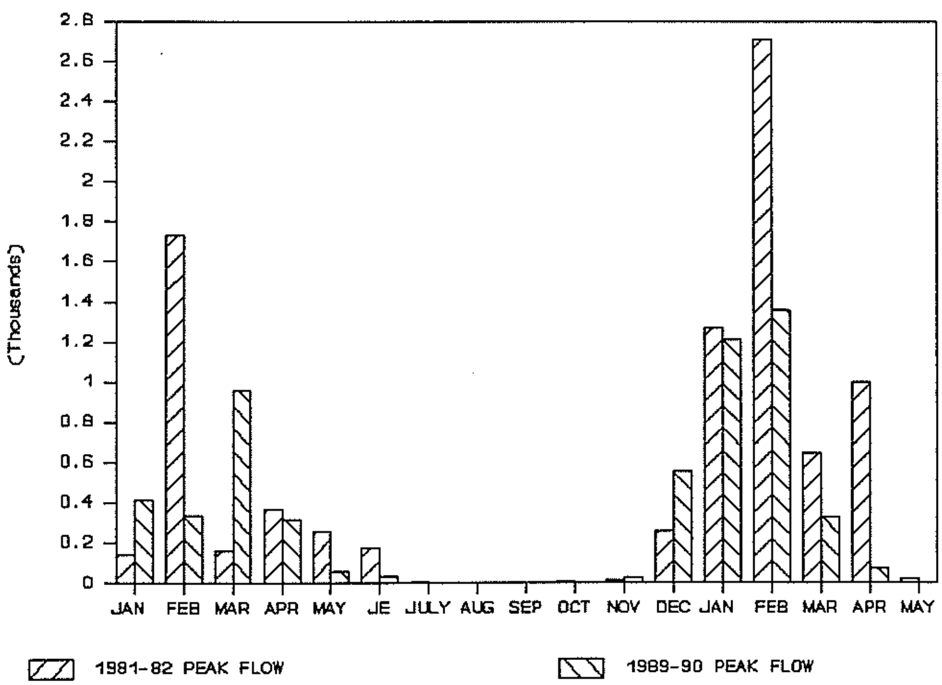

Figure 6. Peak Flows at Hangman Creek Recorded at USGS Gaging Station.

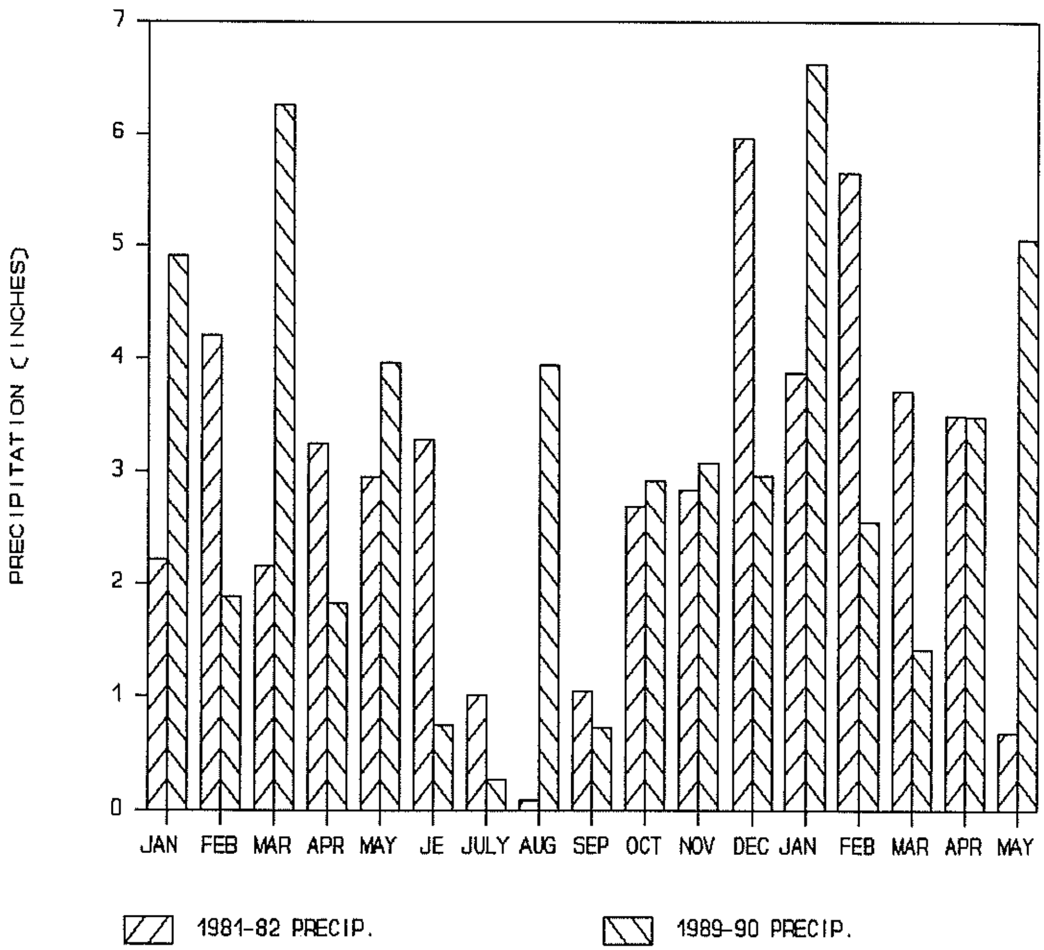

Figure 7. Total Monthly Precipitation Monitored Two Miles South of Plummer.

1990. However, no storms in the follow-up study compared with the 10 day event sampled in February, 1982, when almost five inches of rain fell.

Figure 8 is a diagram of the water budget of the Hangman Creek watershed during the storm seasons of both studies. Percentages indicate contributions by each sub-watershed to the total water budget. Percentage discharge for each of the three storm months (February, March and April) was calculated and then averaged. Most of the watersheds had similar percentages of the total flow, except for Hangman Creek below Sanders. Differences can be accounted for in the different rainfall patterns within each sub-watershed.

SUSPENDED SEDIMENT

1. Water Year Basis

   As the linear regressions from both studies show, in most cases there is a high correlation between stream discharge and suspended sediment concentrations (Figures 16 through 31). The highest flows occur from January to March and this is also the time of the heaviest sediment levels. During a relatively short period of time, over 90 percent of the sediment from land erosion is flushed into the stream. In both studies, this occurred in February and March. Following the high runoff period, sediment concentrations drop off rapidly and are low the remainder of the year. The sediment entering the stream is deposited in low gradient stretches and is eventually carried out of the system.

2. Sediment Rating Curves

   The main focus of the post-implementation study on Hangman Creek was to determine if sediment entering the stream had been reduced. Bauer and Wilson (1983), created sediment rating curves that through regression analysis expressed the relationship between discharge and suspended sediment concentration as linear regression lines. The regressions in both studies were generated from flow (independent variable) versus suspended sediment (dependent variable). For the purposes of this paper, sediment rating curves will also be referred to as sediment regression graphs. The 1981-1982 regression lines, when compared with the regressions established from the current data, will show a trend of increasing, decreasing or unchanged suspended sediment concentrations at each station.

   Most of the regression lines from both studies had coefficients of determination values (r^2) greater than 0.60, as seen in Appendix E. However, some of the 1981-82 r^2 values were low (<0.50). In both studies, it was found that original measurement units gave higher r^2 values in most cases then using a logarithmic transformation.

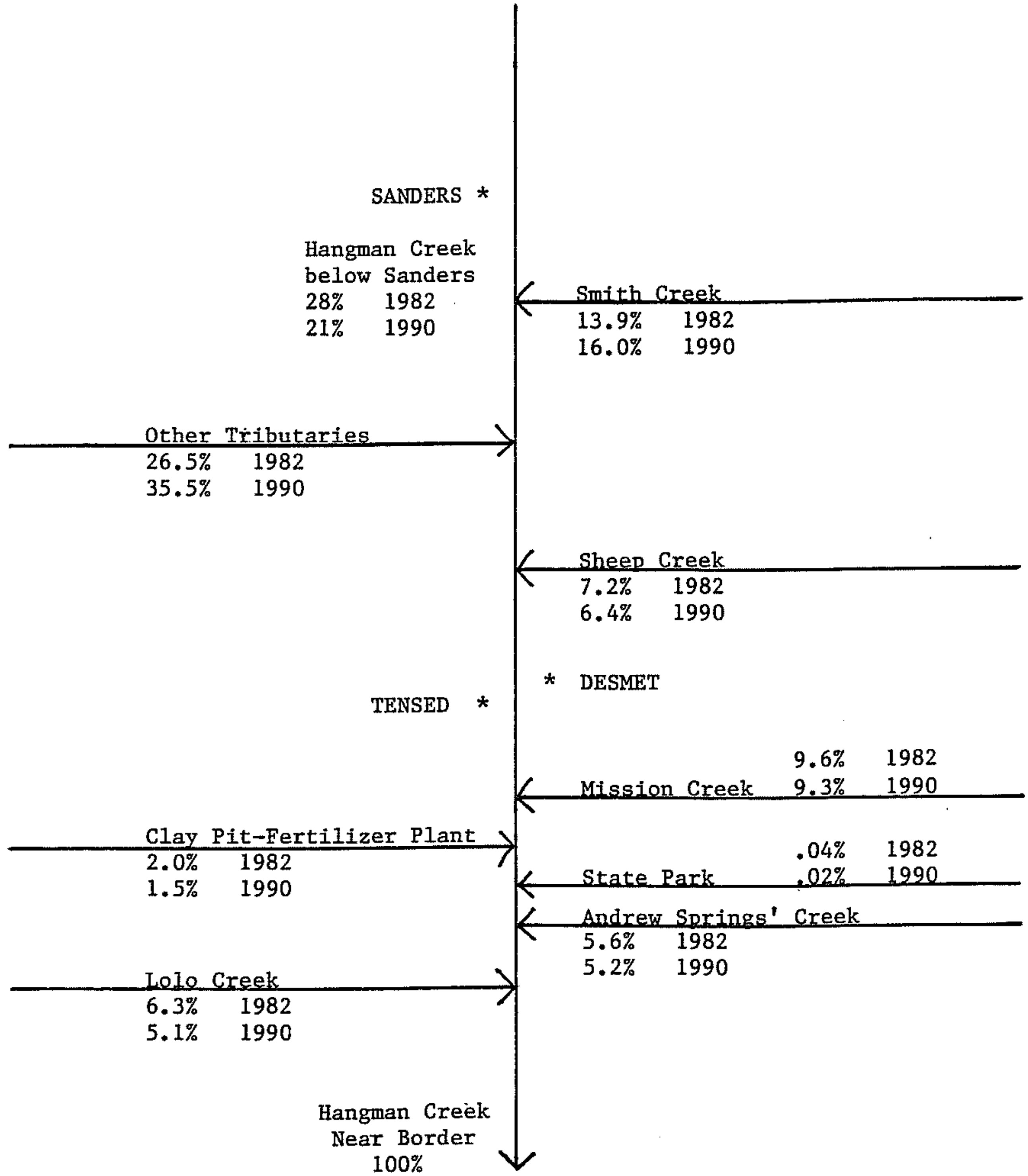

Figure 8. Water Budgets for the 1982 and 1990 Storm Seasons (February, March, April), Hangman Creek. (%= the relative percentage of the total discharge for the specified year. Arrow indicates direction of water flow).

The premise in using regression line comparison is that if a successful management change has occurred, then the post-implementation regression line will plot below the pre-implementation baseline regression. The graphs in Appendix E show a general trend of decreasing suspended sediment concentrations in the upper Hangman Creek stations, particularly at Hangman Creek above and below Sanders, Smith, and Sheep Creeks. We would expect improvements in water quality in the upper Hangman Creek sub-watersheds to be reflected at DeSmet. For Hangman Creek at Desmet, the 1989-90 regression line falls below the line generated from 1981-82. This suggests BMPs implemented upstream have been successful in reducing sediment delivery to Hangman Creek above DeSmet. These improvements are also supported by storm event and sediment loading data, as will be discussed in the next section.

For each of the 16 sampling sites, the 1981-82 and 1989-90 regression data were tested for homogeneity of regression coefficients (slopes) using a students t-test between two *b*'s (Steel and Torrie, 1960). In 4 out of the 16 stations, the t-test showed statistically significant differences between regression coefficients ($P<0.05$). The following upper Hangman Creek stations: S2-Hangman Creek below Sanders (figure 17), HC1-Smith Creek (figure 20), and HC3-west tributary of Sheep Creek (figure 22) all showed statistically valid reductions in regards to sediment. The lower Hangman Creek station, HC9-Andrew Springs Creek near mouth (figure 28), also showed a statistical difference in regression slopes. The graph configuration at this site indicates increased suspended sediment concentrations.

For the other 12 stations which did not show statistical differences in slopes, there were either low r^2 values and/or small slope differences. However the intuitive trend of sediment reduction in Hangman Creek above DeSmet and increased sediment concentrations below DeSmet is still evident (see appendix E).

Sediment regression lines for the lower Hangman Creek watershed fail to show significant improvements in water quality, and this is reflected in the Hangman Creek at Stateline graph which shows a degradation of water quality at higher flows. The Andrew Springs' Creek and Lolo Creek regressions show that BMPs have apparently failed to reduce suspended sediment concentrations. Indeed, the graphs reflect a degradation of water quality at the mouths of these drainages. Andrew Springs' Creek with only 50 percent implementation apparently shows the worse degradation in water quality. The graph for Andrew Springs' in Appendix E, indicates significantly higher concentrations of suspended sediment within the stream, especially at higher flows.

Failure to show water quality improvements in the lower Hangman Creek watershed, can be attributed to the timing of BMP implementation with respect to the 1989-1990 sampling period. BMP implementation contracts were completed one year before the post-implementation study. As a result, BMPs implemented in the Lolo and Andrew Springs' sub-drainages, may not have been properly established during the 1989-1990 study.

Lack of water quality improvement in lower Hangman Creek, can also be attributed to insufficient treatment of critical areas within the Lolo and Andrews Springs drainages. Lolo Creek and Andrew Springs' Creek received only 65 and 50 percent BMP implementation respectively, on critical areas (Table 1). Significant portions of land in these drainages were not improved. In addition, various intermittent tributaries to lower Hangman Creek, such as State Park tributary were not treated with BMPs. Cumulative effects from these areas will also mask improvements in lower Hangman Creek.

Finally, there were large differences between the 1981-1982 and 1989-1990 studies with regard to water years and storm events. These factors cause increased variability in water quality data. In addition, topographical variation and differences in land use activity between the upper Hangman Creek watershed and the lower portion are important factors responsible for suspended sediment concentration differentials throughout the watershed. The flood prone areas of Hangman Creek below DeSmet may contribute more sediment to the stream than those areas above DeSmet. In general, stream banks become less stable and riparian zones less significant along Hangman Creek below DeSmet.

3. Storm Events and Sediment Loading

It is difficult to compare the sediment loadings of different storm events to determine improvements or degradation of water quality. Each storm event is unique in its duration and intensity. The condition of the soil, its cover, its temperature, its water content, also will affect the amount of soil delivered to the stream during each storm. However, Figure 9 shows that during the February and March 1982 storm events, the highest sediment load (43,891 tons in February, 2,960 tons in March) was recorded at Hangman Creek at DeSmet. Much of this sediment must have been deposited in the channel before Hangman Creek at Stateline as the total loads recorded at Stateline for these two storm events were lower (27,982 tons in February, 1,876 tons in March). This contrasts with the total loads carried past DeSmet and Stateline in the follow-up study. In the three day February, 1990 storm event, the total load at Stateline was 5,917 tons while the total at DeSmet was only 2,069 tons. This suggests an improvement in water quality at DeSmet and in the upper Hangman Creek drainage.

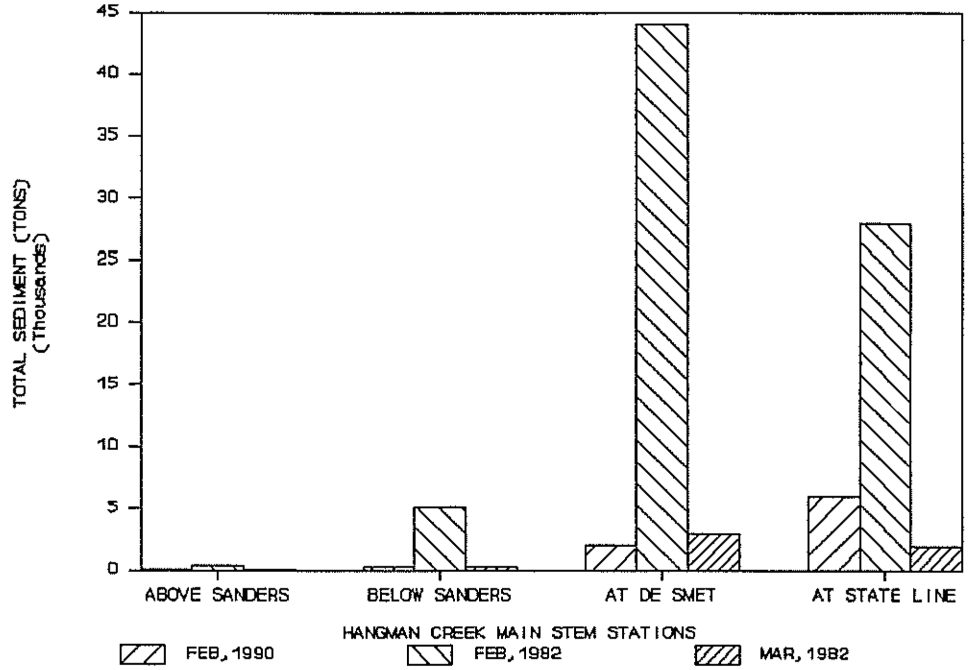

Figure 9. Comparison of Storm Event Sediment Load for Three Storm Events in 1982 and 1990.

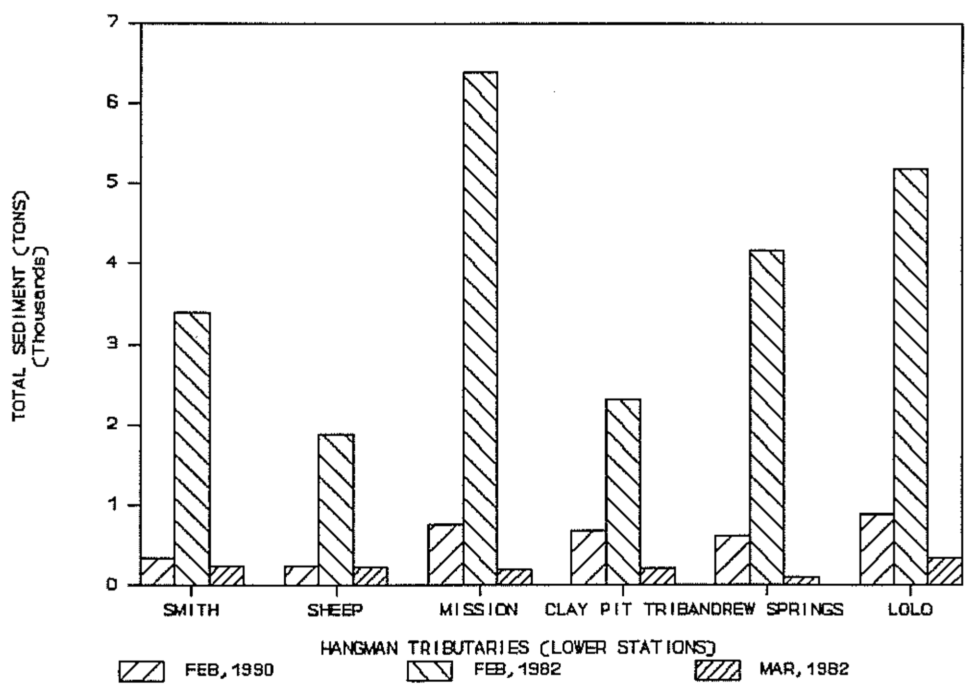

Figure 10. Comparison of Storm Event Sediment Load for Three Storm Events in 1982 and 1990.

Table 3 is a sediment loading budget for the three storm events. In February 1990, Hangman Creek at DeSmet carried 35 percent of the total sediment load passing by Stateline. This is in sharp contrast to February and March 1982 storm events during which it carried approximately 158 percent of the total load. This indicates a significant decrease in the amount of sediment entering Hangman Creek above DeSmet and re-enforces conclusions from the sediment rating curves that show improvements in the upper Hangman drainages. Hangman Creek below Sanders, Smith and Sheep Creeks each carried 4 percent, 6 percent and 4 percent respectively of the total load passing Stateline. In 1982, they carried an average of 16 percent, 13 percent and 9 percent respectively. The lower stations on Mission, Lolo, Andrew Springs' and the Clay Pit Tributary show little or no improvements in the percentage of total load carried. This corresponds to the sediment discharge regression graphs which also indicated little or no decrease in suspended sediment concentrations for the lower tributaries.

4. Critical Areas

One of the original survey objectives in 1982 was to identify critical areas within the Hangman Creek Watershed. Using suspended sediment concentrations as a criteria, Bauer and Wilson (1983) identified Lolo Creek, the west tributary of Sheep Creek, Mission Creek and Andrew Springs' Creek as critical drainages. With priority placed on tons of sediment delivered to the creek, he identified Mission Creek, Lolo Creek, Upper Hangman Creek, Andrew Springs' Creek and Smith Creek as the critical watersheds.

In looking at the mean concentrations of suspended sediment in Figure 11, one can see a general increase in the concentrations in the tributaries as one proceeds downstream. This reflects a general land use change toward increases in cropland acreage in the lower tributaries. Based on sediment concentrations from the 1989-1990 data, the following drainages in order of priority, would require further land management changes to improve water quality:

1. Clay Pit Tributary
2. Lolo Creek
3. Andrew Springs' Creek
4. Mission Creek

Using sediment load as a criteria, those drainages in order of priority, needing management changes would appear to be:

1. Lolo Creek
2. Mission Creek
3. Clay Pit Tributary

TABLE 3. Sediment Loading Budget for 3 Storm Events (February & March, 1982 and February, 1990).

Tributary	Sediment Producing Acres	Sediment Loading (% of total passing by Hangman Creek at Stateline)		
		Feb 82	Mar 82	Feb 90
Hangman Creek at Stateline	100%	100%	100%	100%
Hangman Creek below Sanders	10.6%	18%	14%	4%
Smith Creek	4.5%	12%	13%	6%
Sheep Creek	4.6%	7%	12%	4%
Mission Creek	6.6%	23%	10%	13%
Clay Pit Trib.	4.6%	8%	11%	12%
Andrew Springs	7.4%	15%	5%	10%
Lolo Creek	12%	19%	18%	15%
Hangman Creek at DeSmet	-	157%	158%	35%
Unaccounted for acres during monitoring	49.7			

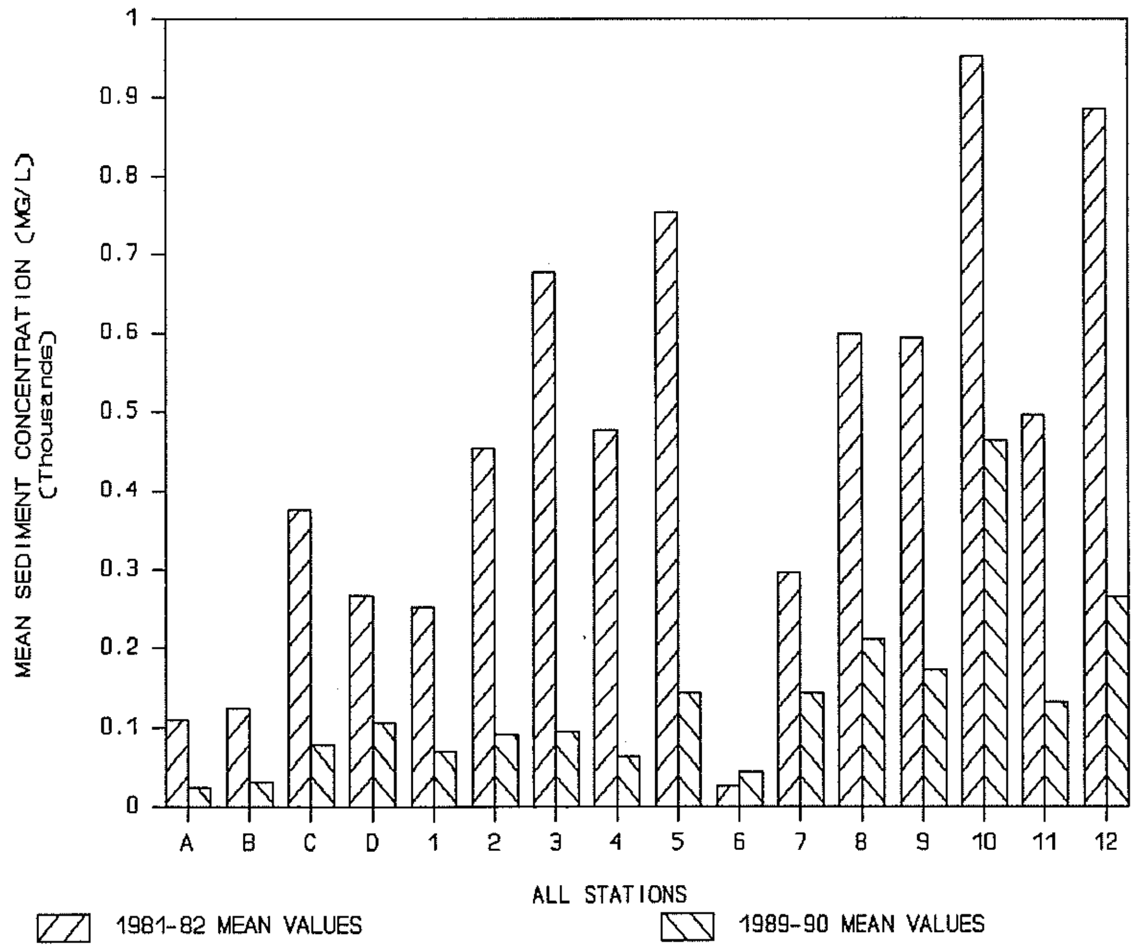

Figure 11. Mean Sediment Concentrations. A Comparison of 1981-'82 and 1989-'90 Data.

4. Andrew Springs' Creek

Note that compared with the 1981-1982 critical areas, all upper Hangman drainages (upper Hangman Creek, Sheep Creek and Smith Creek) have been removed from the list indicating significant improvements in water quality as a result of BMPs. The Clay Pit Tributary which drains only 4.6 percent of the total critical areas contributed 12 percent of the total sediment load in the 1989-1990 study. It apparently has had no BMPs implemented on its acreage and appears to need land management changes. Andrew Springs', Mission and Lolo Creeks, as part of the "Feedback Loop" process (IDHW 1985), also need further changes in land use practices in order to improve water quality with regard to suspended sediment.

NUTRIENTS

The major nutrients of concern in water are forms of nitrogen and phosphorus. In high concentrations they can cause nuisance algal blooms and excessive aquatic plant growth. Upon decay, these can lower dissolved oxygen levels to a point that impairs beneficial uses.

PHOSPHORUS

Phosphorus availability is a critical factor in the eutrophication (enrichment) of water bodies. To restrict excess primary productivity, the recommended concentration for total phosphorus in streams is 0.1 mg/L (EPA 1986). Table 4 summarizes phosphorus data for both studies. It shows that in 1989-1990, only the Hangman Creek stations above and below Sanders met this criteria. The highest total phosphorus levels were recorded at the lower Hangman Creek tributary stations on Mission Creek (1.11 mg/L), Andrew Springs' Creek (1.60 mg/L) and Lolo Creek (1.80 mg/L). The highest levels of total phosphorus carried in the tributaries and main stem corresponded with the highest runoff periods during storm events.

The summary of data in Table 4 shows significant improvements in mean concentrations for total phosphorus at all the stations. The upper range of concentrations is also significantly less during the storm events. Whereas upper ranges in the 1981-1982 study were 1.06 mg/L for Smith Creek, 2.28 mg/L for Mission Creek, 3.10 mg/L for Andrew Springs', 5.87 mg/L for Lolo Creek and 2.61 mg/L for Stateline, they were only 0.44 mg/L, 1.11 mg/L, 0.77 mg/L, 1.80 mg/L and 0.58 mg/L respectively for these same stations in 1989-1990. Total phosphorus measures the phosphorus dissolved in the water plus the phosphorus contained on the soil particles suspended in the water column. Ortho-phosphorus measures only the dissolved portion. Comparing the two forms indicates how much of the phosphorus is washed into the streams with sediment. As can be seen by studying Table 4, generally more that two-thirds of the total phosphorus entering the stream was associated with sediment.

TABLE 4. Summary of Total Phosphorus and OrthoPhosphate Data for Hangman Creek, 1981-1982 and 1989-1990.

Station		Ortho Phosphate (mg/L) 1981-82	1989-90	Total Phosphorus (mg/L) 1981-82	1989-90	Total Phosphorus (% change)
Hangman Creek	Mean	0.11	0.03	0.17	0.09	
above Sanders	Range	0.01-0.73	0.01-0.05	0.02-1.06	0.04-0.26	-47%
Hangman Creek	Mean	0.11	0.03	0.16	0.10	
below Sanders	Range	0.01-0.56	0.01-0.07	0.02-0.82	0.03-0.33	-37%
Smith Creek	Mean	0.27	0.03	0.23	0.15	
near Mouth	Range	0.02-1.40	0.01-0.08	0.03-1.06	0.05-0.44	-35%
Western Trib.	Mean	0.24	0.07	0.74	0.25	
Sheep Creek	Range	0.03-1.23	0.02-0.17	0.05-3.75	0.10-0.71	-66%
Sheep Creek	Mean	0.24	0.04	0.32	0.17	
near Mouth	Range	0.03-1.40	0.02-0.13	0.02-0.98	0.05-0.42	-33%
Hangman Creek	Mean	0.16	0.04	0.21	0.14	
at DeSmet	Range	0.01-1.39	0.01-0.09	0.03-0.82	0.04-0.47	-19%
Upper Mission	Mean	0.37	0.06	0.38	0.19	
Creek	Range	0.03-1.87	0.02-0.13	0.03-1.06	0.07-0.58	-50%
Mission Creek	Mean	0.50	0.10	0.70	0.28	
near Mouth	Range	0.04-2.12	0.02-0.54	0.02-2.28	0.08-1.11	-60%
Clay Pit	Mean	0.99	0.10	1.32	0.25	
Tributary	Range	0.03-9.85	0.06-0.50	0.03-6.19	0.085-0.62	-81%
State Park	Mean	0.23	0.09	0.30	0.28	
Tributary	Range	0.03-0.82		0.02-0.57	0.20-0.35	- 7%
Upper Andrews	Mean	0.22	0.11	0.42	0.28	
Springs Creek	Range	0.03-0.90	0.04-0.21	0.05-1.47	0.04-0.85	-33%
Mid. Andrews	Mean	0.42	0.09	0.63	0.31	
Springs Creek	Range	0.04-1.79	0.03-0.20	0.03-3.1	0.03-1.6	-51%
Andrews Spr.	Mean	0.22	0.10	0.72	0.27	
Cr. at Mouth	Range	0.07-0.57	0.04-0.25	0.02-3.10	0.03-0.77	-62%
Upper Lolo	Mean	0.17	0.06	0.58	0.19	
Creek	Range	0.02-0.90	0.03-0.23	0.02-2.45	0.04-0.74	-67%
Lolo Creek	Mean	0.55	0.08	1.12	0.28	
near Mouth	Range	0.02-2.45	0.01-0.27	0.02-5.87	0.04-1.8	-75%
Hangman Creek	Mean	0.18	0.05	0.38	0.15	
near ID/WA Stateline	Range	0.01-0.90	0.01-0.24	0.01-2.61	0.04-0.58	-60%

Figure 14 illustrates the daily main stem total phosphorus loadings for the February 10-12, 1990 storm event. Note how the loadings follow the same pattern of increasing amounts as one proceeds downstream, as the sediment loading charts in Figure 12.

Regression graphs relating discharge with total phosphorus are shown in Appendix F. Note the consistently high correlation between discharge and total phosphorus in the 1989-1990 study. As most of the phosphorus is attached to the sediment, this would suggest that decreases in sediment delivery as a result of BMPs would also decrease phosphorus concentrations in the water. In general, the phosphorus regression graphs follow the same pattern of improvement or degradation in stream water quality as the corresponding sediment regression graphs. However, the differences between the two phosphorus regression slopes is not as great as with the two sediment slopes.

NITROGEN

Inorganic nitrogen is the sum of nitrite (NO_2), nitrate (NO_3) and ammonia (NH_3). In comparison to phosphorus, inorganic nitrogen is not generally associated with soil particles. It is rather, carried dissolved in the water column. Fertilizer is usually applied in the form of inorganic nitrogen and leaches easily through the soil and into the stream. BMPs, while reducing levels of sediment and phosphorus in waterways, often have no effect on inorganic nitrogen levels.

Table 5 shows that most average inorganic nitrogen concentrations actually increased during the post-implementation survey. Means range from 0.23 mg/L at Upper Hangman and the State Park Tributary (the two background stations) to 14.37 mg/L at the Clay Pit Tributary. Only Lolo Creek at the mouth and upper Andrew Springs' Creek show any improvement in inorganic nitrogen concentrations. The instream criteria for inorganic nitrogen is generally accepted to be 0.3 mg/L. As can be seen in Table 5, this is exceeded at all but the two background stations.

Peak concentrations were also much higher in the post-implementation study. The Clay Pit Tributary had the highest concentration recorded at 48.94 mg/L on January 5, 1989. Peak concentrations were never related to peak discharge rates and often occurred during the times of lowest flows. The Clay Pit Tributary also had the highest mean concentration in the 1989-1990 study (14.37 mg/L). The stream flows by a fertilizer plant and the high concentrations may be attributed to runoff from this plant.

The increased inorganic nitrogen concentrations during the 1989-1990 study period could be associated with the following factors: cropping changes, changes in fertilizing practices, and changes in animal grazing activities. Similar cropping changes occurred

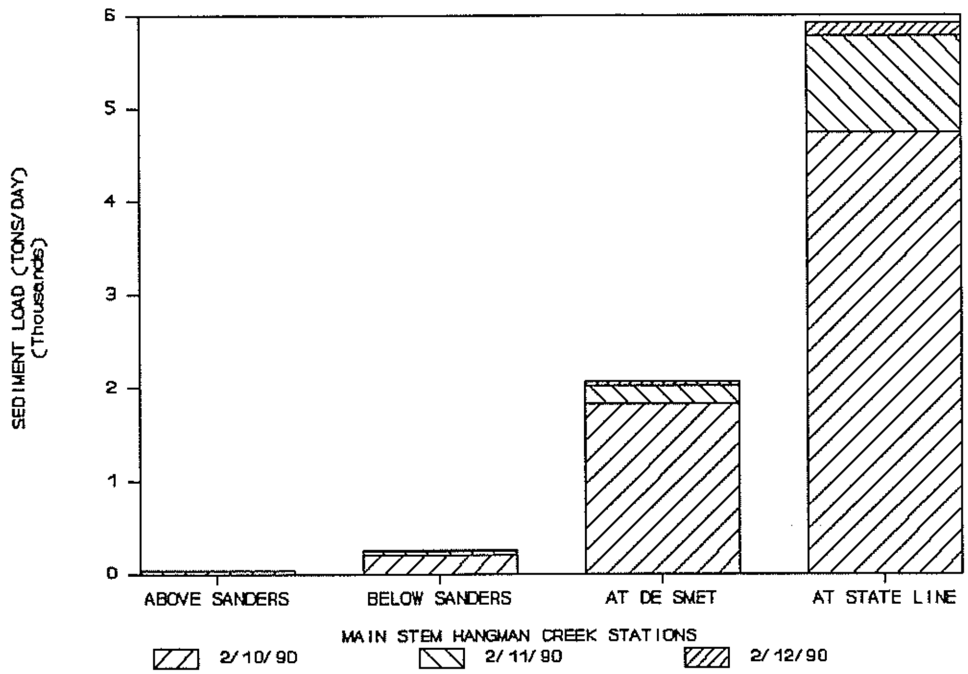

Figure 12. Daily Main Stem Sediment Loadings for a Three Day Storm Event (Feb. 1990).

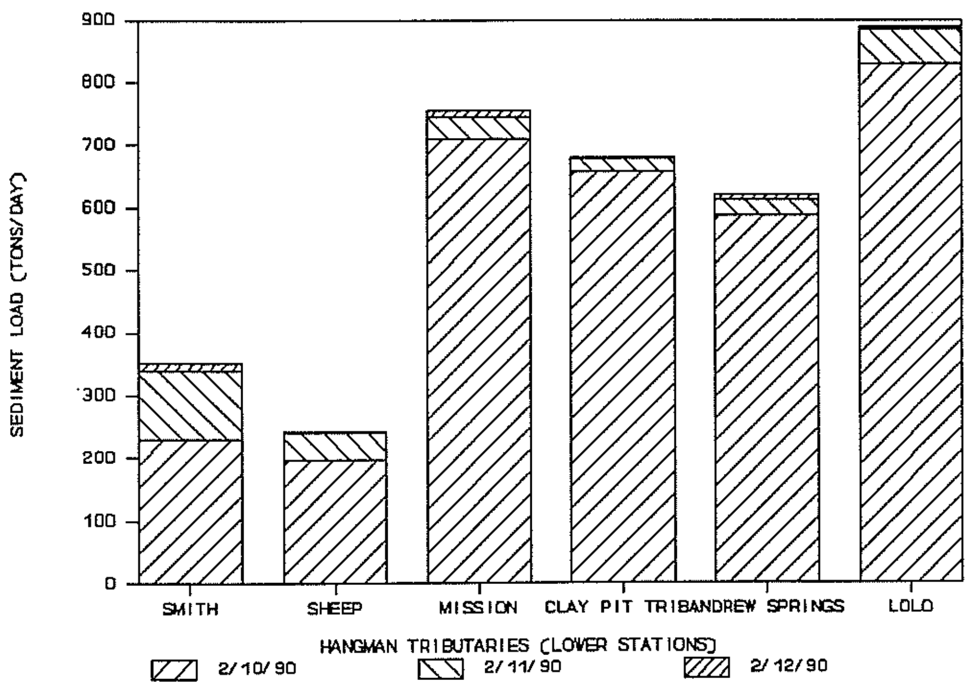

Figure 13. Daily Tributary Sediment Loadings for a Three Day Storm Event (Feb. 1990).

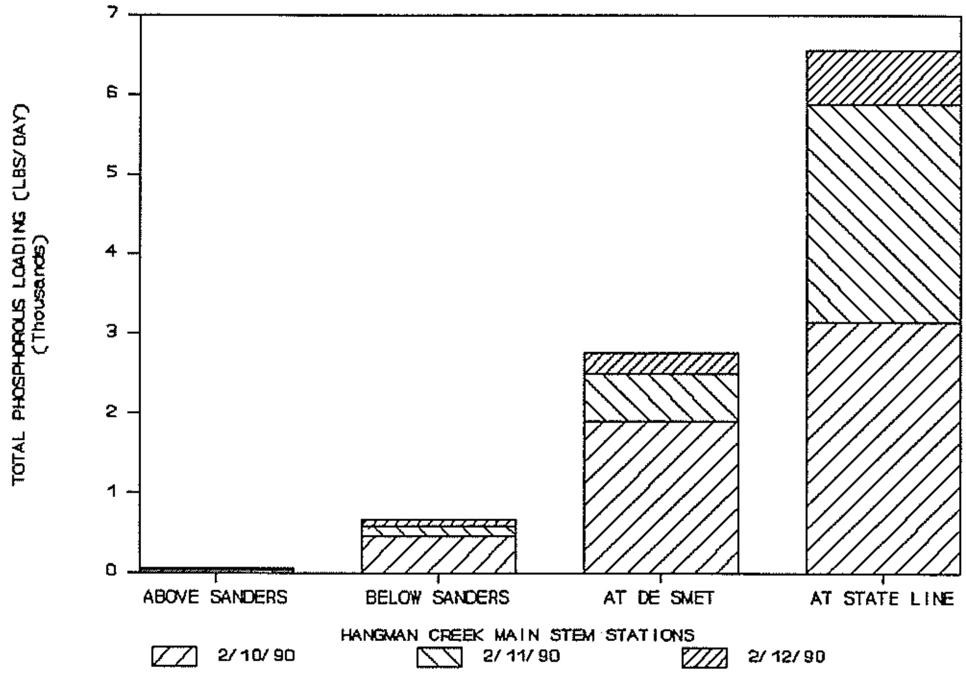

Figure 14. Daily Main Stem Phosphorus Loadings for a Three Day Storm Event (Feb. 1990).

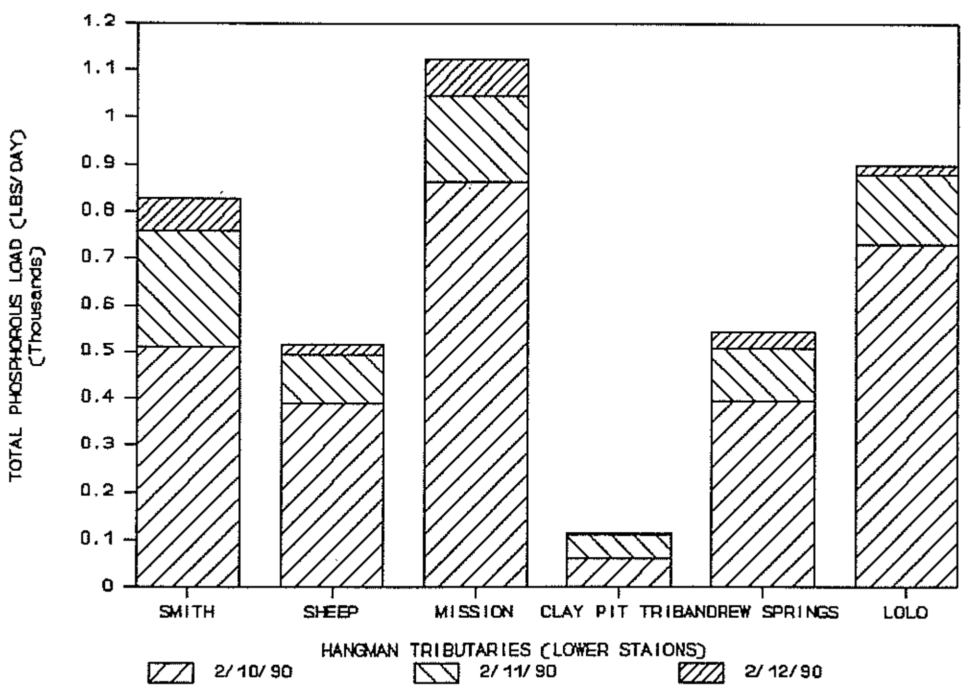

Figure 15. Daily Tributary Phosphorus Loadings for a Three Day Storm Event (Feb. 1990)

TABLE 5. Summary of Inorganic Nitrogen* Data for Hangman Creek, 1981-1982 and 1989-1990.

Station		Inorganic Nitrogen* 1981-82	1989-90	% Change
Hangman Creek above Sanders	Mean	0.23	0.23	0
	Range	0.02-0.61	0.01-0.73	
Hangman Creek below Sanders	Mean	0.42	0.46	+ 9%
	Range	0.01-1.60	0.01-1.60	
Smith Creek near Mouth	Mean	0.83	0.86	+ 3%
	Range	0.02-2.81	0.02-4.65	
Western Tributary of Sheep Creek	Mean	1.62	2.24	+28%
	Range	0.11-4.79	0.28-6.10	
Sheep Creek near Mouth	Mean	0.75	0.92	+18%
	Range	0.04-1.73	0.02-4.86	
Hangman Creek at DeSmet	Mean	0.75	1.25	+40%
	Range	0.002-2.70	0.025-5.14	
Upper Mission Creek	Mean	0.99	1.31	+24%
	Range	0.55-2.21	0.02-5.85	
Mission Creek near Mouth	Mean	1.56	1.88	+17%
	Range	0.16-3.05	0.04-6.31	
Clay Pit tributary	Mean	6.80	14.37	+53%
	Range	2.71-12.75	5.33-48.94	
State Park tributary	Mean	0.10	0.23	+57%
	Range	0.002-0.17	0.01-0.58	
Upper Andrews Springs Creek	Mean	4.01	3.69	- 8%
	Range	0.03-13.41	0.03-12.98	
Middle Andrews Springs Creek	Mean	3.45	4.92	+30%
	Range	1.65-4.66	0.92-12.69	
Andrews Springs Creek near Mouth	Mean	3.58	5.53	+35%
	Range	1.75-5.33	1.26-11.25	
Upper Lolo Creek	Mean	2.20	3.94	+44%
	Range	0.67-3.57	0.44-15.01	
Lolo Creek near Mouth	Mean	3.68	3.58	- 3%
	Range	1.66-4.98	0.17-9.47	
Hangman Creek at Stateline	Mean	1.53	2.05	+25%
	Range	0.01-5.53	0.12-6.49	

*Inorganic Nitrogen = Nitrite (NO_2) + Nitrate (NO_3) + Ammonia (NH_3)

throughout the watershed as a result of BMP implementation. Increased inorganic nitrogen could result from substituting legumes with wheat. In addition, planting permanent grass on steep slopes or in side draws, sometimes requires the use of fertilizers containing nitrogen.

BACTERIA

The presence of fecal coliform and fecal streptococcus bacteria are used as indicators of fecal contamination. Hangman Creek is protected for secondary contact recreation which may include fishing, boating, wading and other activities where ingestion of raw water is not probable. Idaho Water Quality Standards (IDHW 1985) specify that fecal coliforms not exceed 800/100 ml at anytime or exceed a geometric mean of 200/100 ml.

Table 6 shows the results of bacterial sampling in both Hangman Creek surveys. The table shows that significant improvements appear to have occurred as a result of established BMPs. The geometric mean criteria for secondary contact recreation is currently met at all main stem stations. It was exceeded in 1981-1982 at Hangman Creek stations both above and below Sanders. The instantaneous criteria of no more than 800 per 100 ml at anytime was still violated 20 percent of the time at Hangman Creek above Sanders in 1989-1990. However, there was a 36 percent violation of this criteria in the 1981-1982 study. There was an 8 percent violation rate at Hangman Creek below Sanders in the 1989-1990 survey. This is significantly reduced from the 25 percent violation rate in 1981-1982. There is a slight increase of violations, however, at the Stateline station from 0 percent to 8 percent.

There is no specific standard for fecal streptococcus bacteria. However, this species can be used as an indicator of the sources of contamination. Animal feces contain a greater number of streptococci, such that the ratio of fecal coliform to fecal streptococcus is always less than 0.7. Human feces contains a greater number of coliform, causing the FC/FS ratio to exceed 4.0 (Clausen, et al. 1977). These ratios suggest that bacterial contamination is primarily from human sources above and below Sanders and of mixed animal and human sources at DeSmet and Stateline.

DISSOLVED OXYGEN AND TEMPERATURE

Dissolved oxygen and temperature were examined in the four main stem stations during both studies to ascertain if criteria were met in regards to possible future uses of fish and aquatic life. In both studies, no problems with dissolved oxygen or temperature were detected. Table 7 summarizes data from both studies for dissolved oxygen and temperature.

Table 6. Fecal Coliform Bacteria in Hangman Creek, 1981-1982, + 1989-1990.

Station	Number of Samples		Fecal Coliform /100 ml (log mean)		Minimum-Maximum /100 ml		% Violation*	
	81-82	89-90	81-82	89-90	81-82	89-90	81-82	89-90
Hangman Creek above Sanders (S-1)	14	26	334	176	5-8300	20-7000	36%	20%
Hangman Creek below Sanders (S-2)	12	24	226	113	15-8500	10-820	25%	8%
Hangman Creek at DeSmet (S-3)	14	23	169	67	18-2800	5-2700	7%	7%
Hangman Creek Idaho/WA State Line (S-4)	17	26	43	47	7-260	1-4500	0%	8%

*% violation based on 800/100 ml. water quality standard.

TABLE 7. Summary of Dissolved Oxygen, pH, Conductivity and Temperature in Hangman Creek, 1981-1982 and 1989-1990.

Parameter	Hangman Creek Above Sanders 1981-82	Hangman Creek Above Sanders 1989-90	Hangman Creek Below Sanders 1981-82	Hangman Creek Below Sanders 1989-90	Hangman Creek at DeSmet 1982-82	Hangman Creek at DeSmet 1989-90
Mean Dissolved Oxygen (mg/l)	12.1 (21)	12.7 (25)	12.1	12.7	12.8	13.0
Dissolved Oxygen Range (mg/l)	9.6-14.6	9.1-14.5	10.8-15	8-13.8	9.2-14.7	9.9-14.5
Mean Conductivity (micromho)	32	43	37 (22)	47	55	50
pH Range	6.7-9.5	6.5-7.6	6.4-7.9	6.6-7.4	6.7-8.9	6.6-7.3
Mean Temperature (C)	6.1 (24)	5.1	5.7 (23)	5.5	7.8	7.6
Temperature Range (C)	0-14.5	0.4-14.5	0-14.6	0.2-21.5	0-18	0.2-14.7

NOTE: () denotes number of samples used to calculate mean value.

Dissolved oxygen concentrations were well above the minimum standard of 6 mg/L at all stations. Temperatures also were generally well below 22°C, the maximum temperature set for waters protected for cold water biota. Table 7 shows no significant in oxygen or temperature ranges and means from one study to the other. As Hangman Creek meets the criteria for cold water biota for temperatures and oxygen, it is possible that it eventually could maintain a viable fishery if sediment levels continue to be reduced.

pH AND CONDUCTIVITY

The Idaho water quality standards (IDHW 1985) specify that pH be within the range of 6.5 to 9.0 for cold water biota. As can be seen in Table 7, the lowest values for pH fall well within this range. Hangman Creek therefore meets the state pH criteria for freshwater aquatic life.

Conductivity, a measure of the dissolved solids in water, is also shown in Table 7. The data range from 43 micromhos/sec/cm^2 at Hangman Creek above Sanders to 97 micromhos/sec/cm^2 at Stateline. This range of means is similar to those found in the pre-implementation study. There is an increase in conductivities as one proceeds downstream, however, the mean concentration of 97 micromhos/sec/cm^2 found at the lower-most station is still considered very low (IDHW 1985).

CONCLUSIONS AND RECOMMENDATIONS

Analysis of data from the post-implementation survey suggests improvements in water quality in regards to sediment, phosphorus, and bacterial contamination in the upper Hangman Creek drainage areas above DeSmet. Sediment graphs and storm event sediment loading figures show reductions in the amount of sediment carried past Hangman Creek at DeSmet when compared with the 1981-1982 data. Best management practices designed to reduce soil erosion appear to have been effective in these upper drainages.

Although assessment of BMP effectiveness was in the scope of this water quality follow-up study, it was not adequately achieved. Water quality changes indicated by comparing baseline and post-BMP implementation regression slopes cannot be attributed solely to SAWQP land treatment. Other sources of sediment and nutrient variation such as precipitation differences, climatic differences, possible land use changes, unaccounted for pollution sources, and federal agricultural program shifts could also contribute to the differences seen in the data. Without a reliable "on the ground" BMP assessment system to augment our short term water quality studies, we have no way to discern which factor(s) is most responsible for differentials in the preliminary and post data sets.

The 1981-1982 and 1989-1990 study periods had significantly different water years. Differences in water years will increase variability in water quality data. Errors as a result of sampling, experimental design and laboratory analysis are additional causes of water quality data variability. A combination of these factors probably account for the low r^2 values calculated from many of the 1981-82 data set regressions. Low r^2 values and/or slight slope differences resulted in students t-test failure, further illustrating the variability of the data base.

Water quality improvement as a result of BMP implementation is not apparent for the lower Hangman Creek watershed below DeSmet and eight miles downstream to the Idaho-Washington border. Furthermore, Lolo Creek, Andrew Springs' Creek, and the Clay Pit Tributary show degradation in water quality with regard to sediment. Lack of water quality improvement in the lower Hangman Creek watershed can be attributed to the following factors: 1) BMP implementation on critical areas in the lower Hangman Creek watershed began four to five years later than implementation in the upper watershed areas. BMPs were implemented approximately one year before the 1989-1990 study. As a result, newly established BMPs in lower Hangman Creek, may not have been effective during the 1989-1990 study. 2) In comparison to the upper Hangman Creek watershed, BMPs were implemented on a smaller percentage of critical areas in lower Hangman Creek. 3) large differences in 1981-1982 and 1989-1990 water years and storm events increase variability in water quality data interpretation. 4) the larger percentage of cropland versus woodland acres in the lower watershed in comparison to the upper portion, will result in more pronounced cumulative effects, especially with regard to sediment transport. 5) unstable stream banks and inadequate riparian zones along lower Hangman Creek contribute significant sediment inputs to the stream.

The following recommendations are made:

1) Changes in land use activity in sub-watersheds not included in the study, should be encouraged. Tributaries in these watersheds drain 16,743 acres (Table 1) or 49.7 percent of the critical acres in the entire Hangman Creek drainage and contribute 30 percent to the total water budget. Sediment delivery to Hangman Creek from these acres most likely masks many improvements from BMPs implemented in other areas.

2) Though best management practices appear to have been effective in the upper Hangman Creek drainages above DeSmet, the current study, as part of the "Feedback Loop" indicates further land management changes are needed in the sub-watersheds of Lolo, Mission, and Andrew Springs' Creeks and the Clay Pit Tributary. Priority for implementing continuing cost-share programs based on sediment loading should be placed on these tributaries in the following order: Lolo Creek, Andrews Springs' Creek , Clay Pit Tributary, and Mission Creek.

3) Suspended sediment and discharge monitoring would ideally be continued at the mouths of Mission, Lolo, and Andrew Springs' Creeks and the Clay Pit Tributary, especially at high flow periods. Suspended sediment regression graphs could continue to be used to track trends in water quality in these highly impacted watersheds. Continued monitoring in the main stem at DeSmet and Stateline would also be useful in assessing the overall effect of BMPs on the main waters of Hangman Creek. This could possibly be accomplished through a volunteer effort.

4) Bank stabilization and the better establishment of permanent riparian zones need to be emphasized in the lower Hangman area. Unstable banks along lengthy stretches of the main stem below DeSmet contribute large amounts of sediment to the stream during the high spring runoff period. Riparian zones in general are much better established and maintained in the upper Hangman drainage.

5) Macroinvertebrate surveys in Hangman Creek should be considered in the future, especially in the Tensed-Lolo project area. This information could provide a useful indicator of water quality and bed load reduction in Hangman Creek. Macroinvertebrate baseline data in Hangman Creek from 1987 is available through the University of Idaho (Brusven, personal Communication, 1991).

6) Rapid bioassessment of stream segments under water quality investigation should be better emphasized in the future. Personnel and financial requirements need to be considered throughout the planning process. This information could provide a useful indicator of bed load status, as well as beneficial use status. Baseline biological data would make the use of rapid bioassessment in follow-up studies an effective means to track trends in bed load. Rapid bioassessment information would augment water quality data and help minimize problems associated with water quality data variability.

Literature Cited

Bauer, S.B. and T. Wilson. 1983. Assessment of Non-irrigated Crop land Runoff, Hangman Creek (Benewah County) 1981-1982. Water Quality Status Report #W-51 IDHW Division of Environment, Boise,ID. 124 p.

Bauer, S.B. 1986. Pilot Study of Quality Assurance Sample Procedures. IDHW, DEQ, Boise, Idaho.

Environmental Protection Agency (EPA). 1976. Quality Criteria for Water. EPA, Wash.,D.C. 256 p.

EPA. 1979. Methods for Chemical Analysis of water and wastes. EPA, Wash.,D.C.

EPA. 1986. Quality Criteria for Water. EPA, Wash.,D.C. Inorganic Nitrogen.

Idaho Department of Health and Welfare (IDHW). 1985. Idaho Water Quality Standards and Wastewater Treatment Requirements. IDHW, Division of Environment, Boise, ID. 56p.

Idaho Department of Lands-Soil Conservation Commission (IDL-SCC). 1979. Idaho Agricultural Pollution Abatement Plan.

Ralston, G.L. and M. Browne. 1976. Technical Procedures Manual for Water Quality Monitoring. IDHW, Division of Environment, Boise, ID.

Rosgen, D.C. 1986. A Stream Classification System. Riparian Ecosystems and Their Management. Procedures of Riparian Symposium. Tucson, Arizona.

Steel, R.G. and Torrie J.H. 1960. Principles and Procedures of Statistics. 175 p.

United States Department of Agriculture-Soil Conservation Service (USDA-SCS). 1981. Soil Survey of Benewah County Area. 255 p.

United States Geological Survey (USGS). 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. USGS, Geological Survey Water Supply Paper 1473. 363 p.

Wetter, F. 1980. Hangman Creek Conservation Act Project. (1973). USDA-SCS. 15 p.

Wetter, F. 1989. Benewah Soil and Water Conservation District.

APPENDIX A

Idaho Water Quality Standards and Wastewater Treatment Requirements (1985) designate the waters of Hangman Creek as: (1-2110.01)

1. Protected for general use as an agricultural water supply. Waters which are suitable or intended to be made suitable for the irrigation of crops or as drinking water for livestock. (1-2100.01)

2. Protected for future use as a cold water biota. Waters which are suitable or intended to be made suitable for protection and maintenance of viable communities of aquatic organisms and populations of significant aquatic species which have optimal growing temperatures below 18°C. (1-2100.03)

   Waters designated for cold water biota are to exhibit the following characteristics:

   a. Dissolved oxygen concentrations exceeding 6 mg/l at all times.

   b. Hydrogen ion concentration (pH) values within the range of 6.5 and 9.0.

   c. Water temperatures of 22°C or less with a maximum daily average of no greater than 19°C.

   d. The total concentration of dissolved gas not exceeding one hundred ten percent (110%) of saturation at atmospheric pressure at the point of sample collection.

   e. Mean concentration of unionized ammonia at a level of 0.04 mg/l or less as based on a minimum of five (5) samples taken over a thirty (30) day period if water quality characteristics are near optimal for the protected use. In all other cases, the mean concentration of unionized ammonia is to be 0.02 mg/l or less as based on a minimum of five (5) samples taken over a thirty (30) day period. (1-2250.04)

3. Protected for general use as a secondary contact recreation. Surface waters which are suitable or intended to be made suitable for recreational uses on or about the water and which are not included in the primary contact category. These waters may be used for fishing, boating, wading, and other activities where ingestion of raw water is not probable. (1-2100.07)

APPENDIX A (continued)

Water designated for secondary contact recreation are not to contain fecal coliform bacteria significant to the public health in concentrations exceeding:

a. 800/100 ml at any time; and

b. 400/100 ml in more than ten percent (10%) of the total samples taken over a thirty (30) day period; and

c. A geometric mean of 200/100 ml based on a minimum of five (5) samples taken over a thirty (30) day period. (1.2250.02)

APPENDIX B

SURVEY STATIONS, STORET DESCRIPTION

Station #	Description	Latitude	Longitude	River Mile*	Elevation	Storet #
Ambient						
A	Hangman Creek above town of Sanders	47°06'00"	116°45'10"	643.0/72.4/74.2	2880	2000170
B	Hangman Creek below town of Sanders	47°07'10"	116°48'20"	643.0/72.4/71.4	2640	2000171
C	Hangman Creek at De Smet, Highway 95	47°09'00"	116°54'30"	643.0/72.4/65.4	2550	2000172
D	Hangman Creek at USGS gaging station near Idaho/Washington state line	47°12'10"	117°02'25"	643.0/72.4/57.4	2500	2000173
Intensive						
I 1	Smith Creek near mouth	47°05'55"	116°48'45"		2640	2000177
I 3	West Tributary of Sheep Creek	47°06'50"	116°53'00"		2630	2000178
I 2	Sheep Creek, Sections 31/32	47°08'18"	116°52'25"		2570	2000189
I 4	Mission Creek at bridge, Section 26/35	47°07'15"	116°55'40"		2600	2000179
I 5	Mission Creek near town of De Smet	47°08'55"	116°55'10"		2550	2000180
I 6	Tributary below state park, 1 1/2 miles west of De Smet	47°08'55"	116°56'50"		2720	2000181
I 7	Andrews Springs Creek below headwaters, Section 17/20	47°08'50"	116°59'40"		2640	2000182
I 8	Andrews Springs Creek, Section 9	47°10'00"	116°58'10"		2580	2000183
I 9	Andrews Springs Creek near mouth, Section 3	47°10'40"	116°57'20"		2540	2000184
I 10	Small tributary draining clay pit and fertilizer plant, Section 10	47°10'10"	116°56'30"		2550	2000186
I 11	Lolo Creek, Section 36	47°12'25"	116°54'10"		2680	2000187
I 12	Lolo Creek near mouth, Section 4	47°11'15"	116°58'10"		2530	2000188

*Columbia River/Spokane River/Hangman Creek

APPENDIX C

Water Quality Parameters

A = Ambient station sampled
I = Intensive station sampled

		Storet Code
Flow		
A-I	flow, instantaneous in CFS	00061
Temperature		
A-I	temperature Deg-C	00010
Oxygen		
A-I	dissolved oxygen mg/l	00300
pH		
A-I	field	00400
Bacteria		
A	fecal coliform	31616
A	fecal streptococci	31679
Nutrients		
A-I	total ammonia as N	00610
A-I	total NO_2 + NO_3 as N	00630
A-I	total Kjeldahl nitrogen	00625
A-I	total phosphorus as P	00665
A-I	orthophosphate as P	70507
Solids		
A-I	turbidity NTU	00076
A-I	suspended sediment as nonfilterable residue	80154
A	specific conductance micromhos/cm	00095

APPENDIX C (Continued)

Minerals - Common Ions		Storet Code
A	hardness as $CaCO_3$	00900
A	total alkalinity as $CaCO_3$	00410
A	calcium	00916
A	magnesium	00927
A	sodium	00929
A	potassium	00937
A	chloride	00940
A	floride	00951
A	sulphate as SO_4	00945
A	Silica as SiO_2	00956

Total Metals - Inorganic Toxicity		
A	arsenic, total	01002
A	boron, total	01022
A	cadmium, total	01027
A	chromium, total	01034
A	copper, total	01042
A	iron, total	01045
A	lead, total	01051
A	mercury, total	71900
A	zinc, total	01092

APPENDIX D

HANGMAN CREEK PRECIPITATION* AND STREAM FLOW** SUMMARY

	1981-1982		1989-1990	
MONTH	TOTAL PRECIPITATION (INCHES)	AVERAGE DAILY STREAM FLOW (CFS)	TOTAL PRECIPITATION (INCHES)	AVERAGE DAILY STREAM FLOW (CFS)
JAN	2.21	165	4.92	65
FEB	4.21	271	1.88	60
MAR	2.15	50	6.26	411
APR	3.25	117	1.82	141
MAY	2.95	64	3.97	23
JUNE	3.28	37	0.76	11
JULY	1.02	3.0	0.28	2.0
AUG	0.10	0.6	3.94	5.0
SEP	1.05	0.2	0.73	1.0
OCT	2.69	2.0	2.92	2.0
NOV	2.84	5.0	3.08	8.0
DEC	5.96	42	2.97	39
JAN	3.88	153	6.62	222
FEB	5.66	626	2.56	238
MAR	3.72	285	1.42	134
APR	3.50	183	3.49	65
MAY	0.69	24	5.06	245

*Precipitation from Plummerosa Tree Farm.
**Stream Flow from USGS gaging station on Hangman Creek near Idaho/Washington state line.

APPENDIX E

Comparison of regression lines for 1981-1982 and 1989-90 sediment versus flow data.

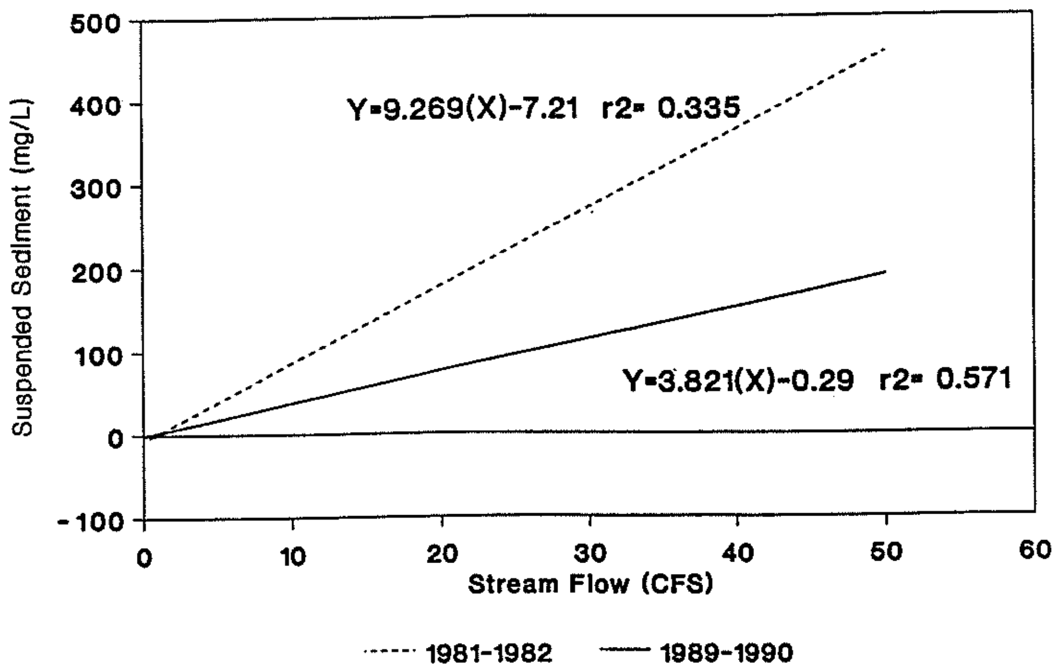

Figure 16. Regression of station S1, flow vs. sediment.

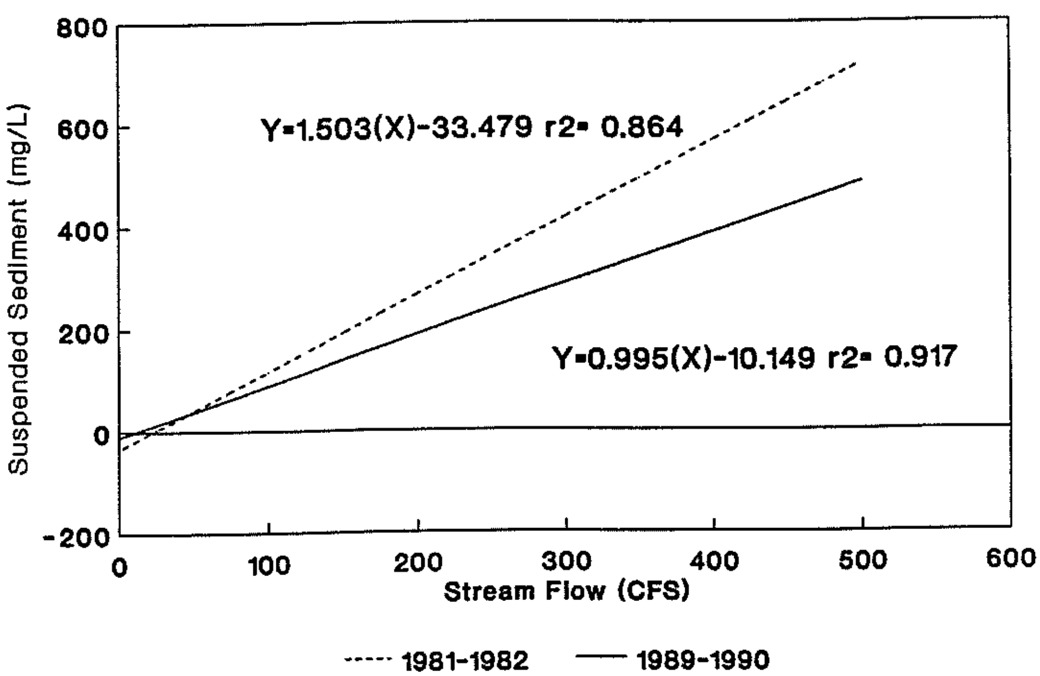

Figure 17. Regression of station S2, flow vs. sediment.

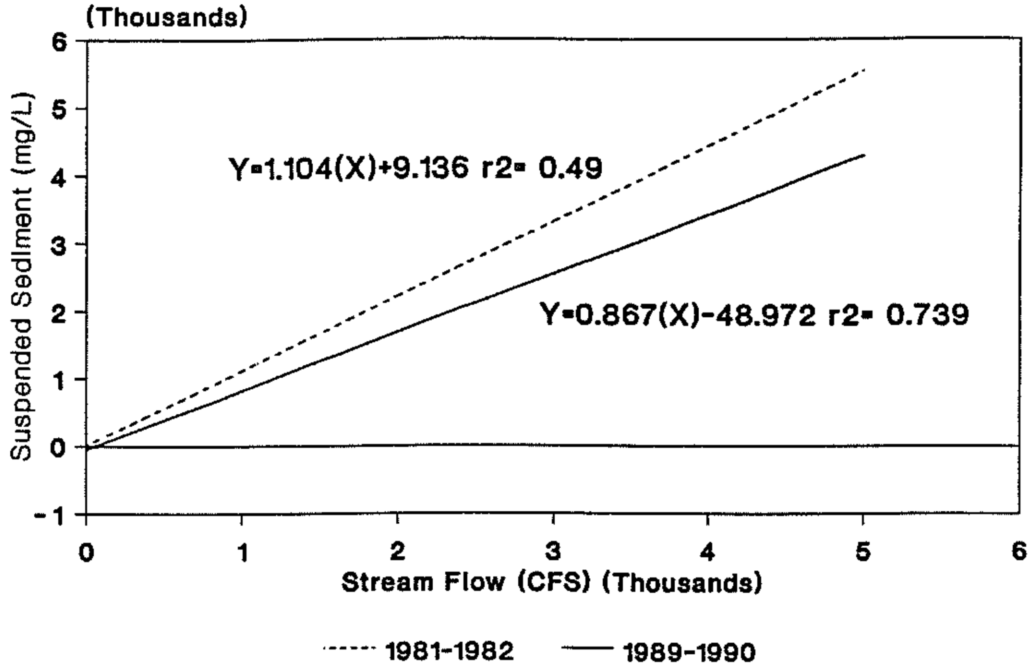

Figure 18. Regression of station S3, flow vs. sediment.

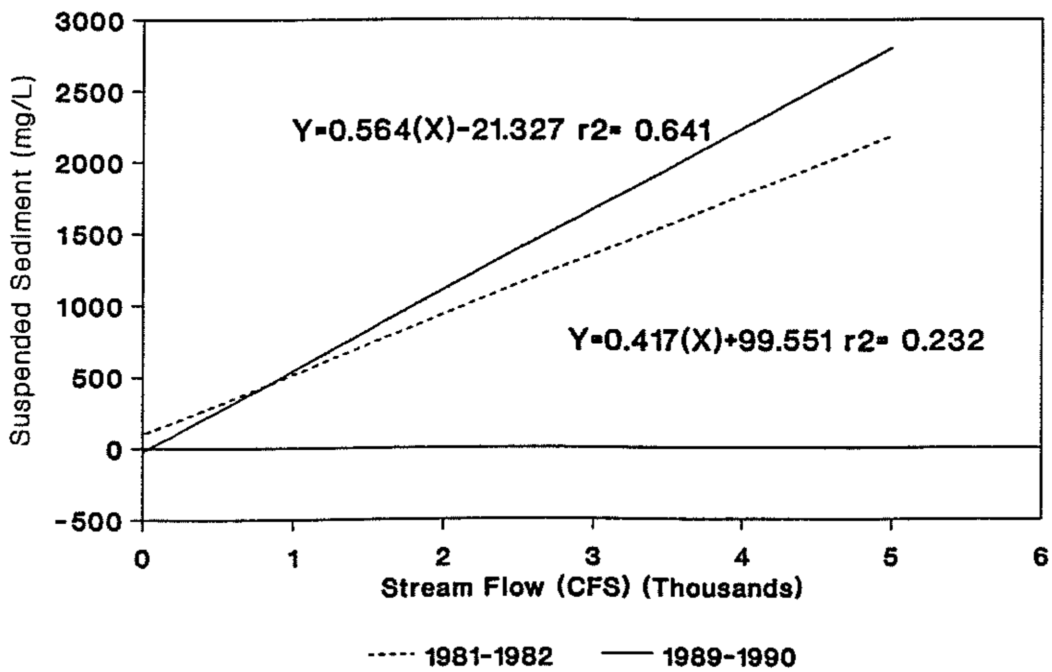

Figure 19. Regression of station S4, flow vs. sediment.

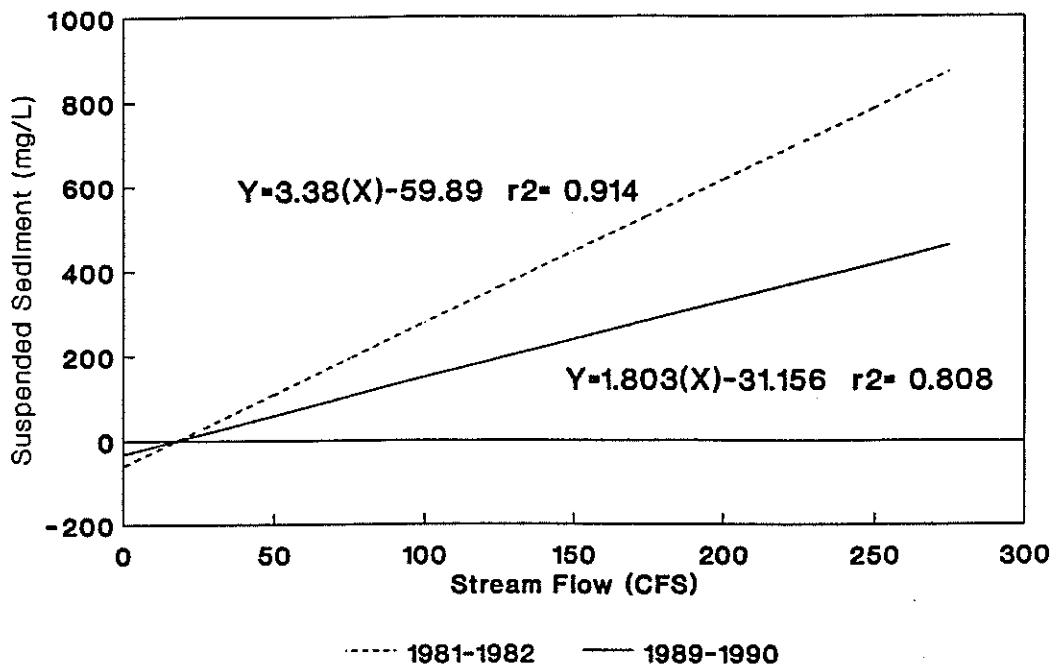

Figure 20. Regression of station HC1, flow vs. sediment.

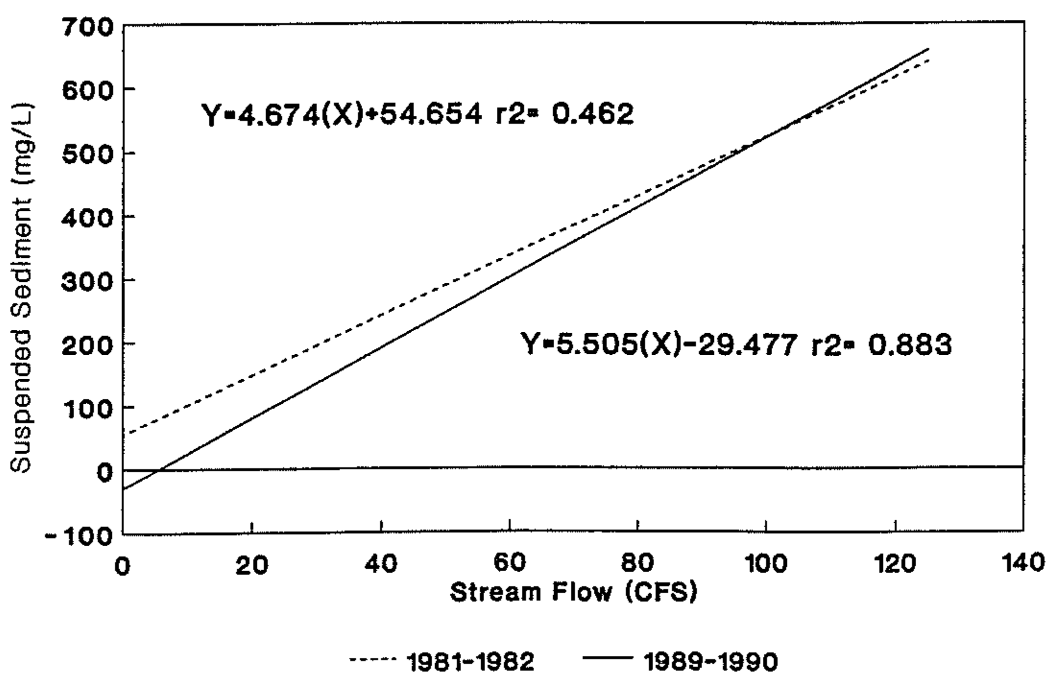

Figure 21. Regression of station HC2, flow vs. sediment.

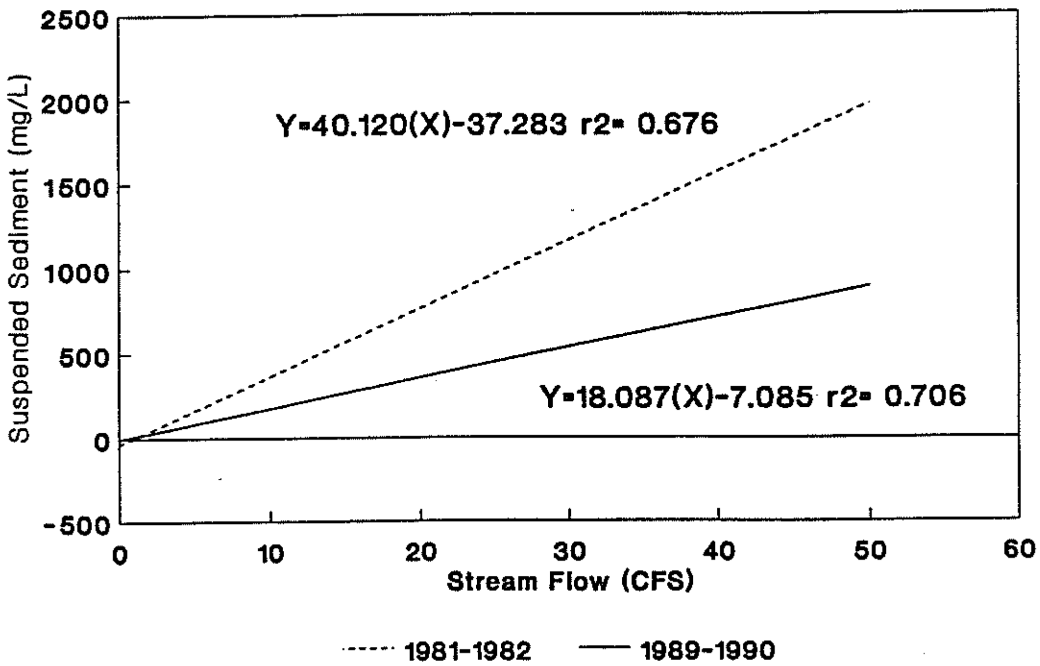

Figure 22. Regression of station HC3, flow vs. sediment.

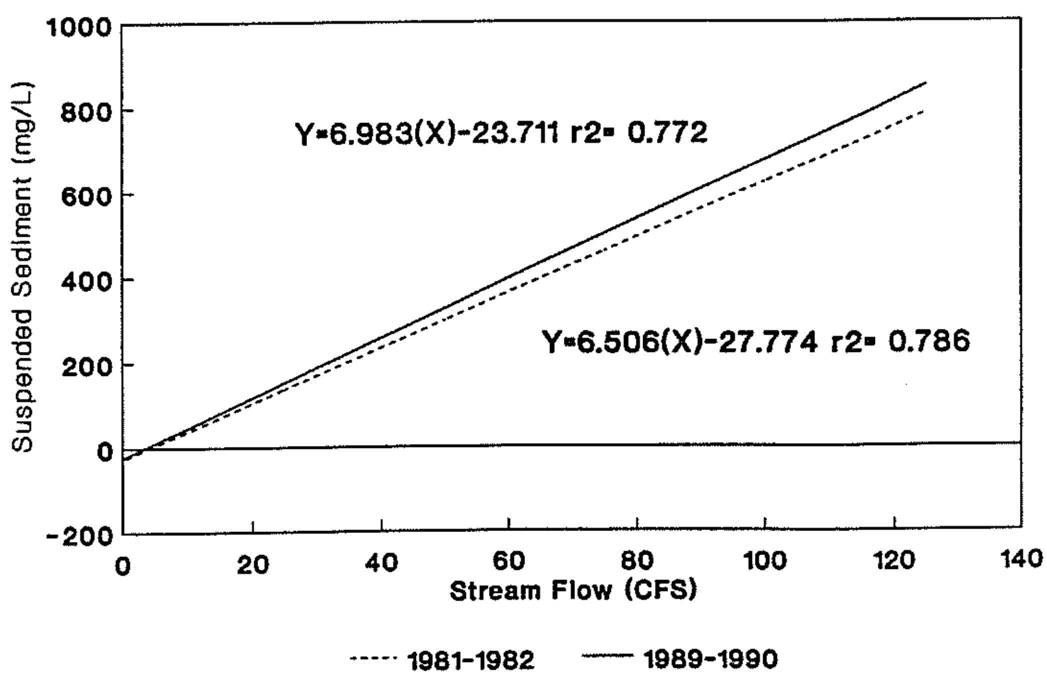

Figure 23. Regression of station HC4, flow vs. sediment.

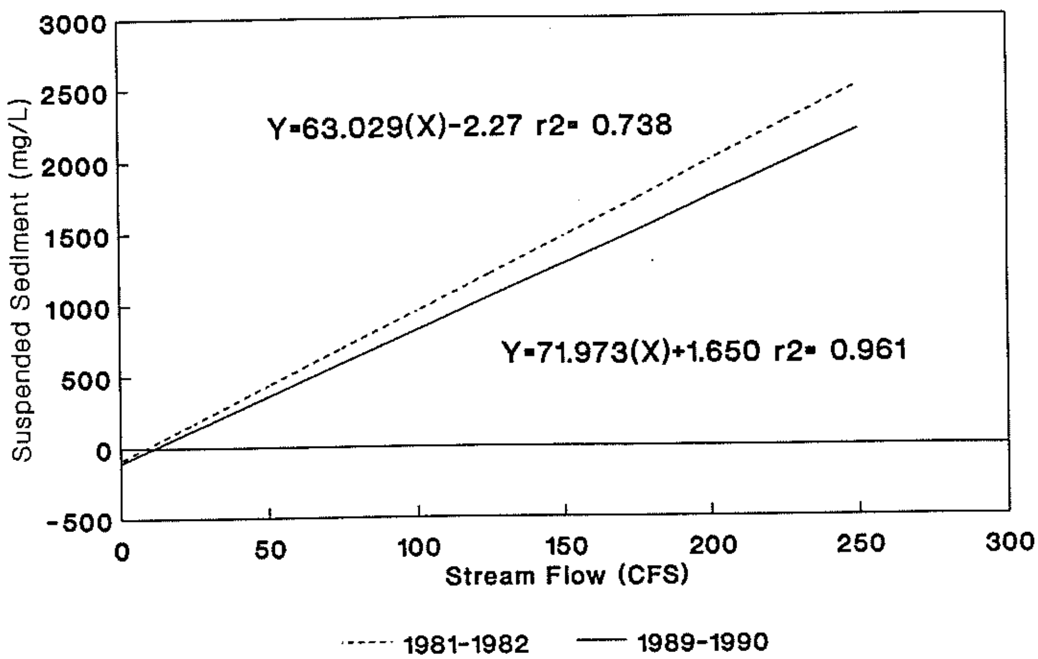

Figure 24. Regression of station HC5, flow vs. sediment.

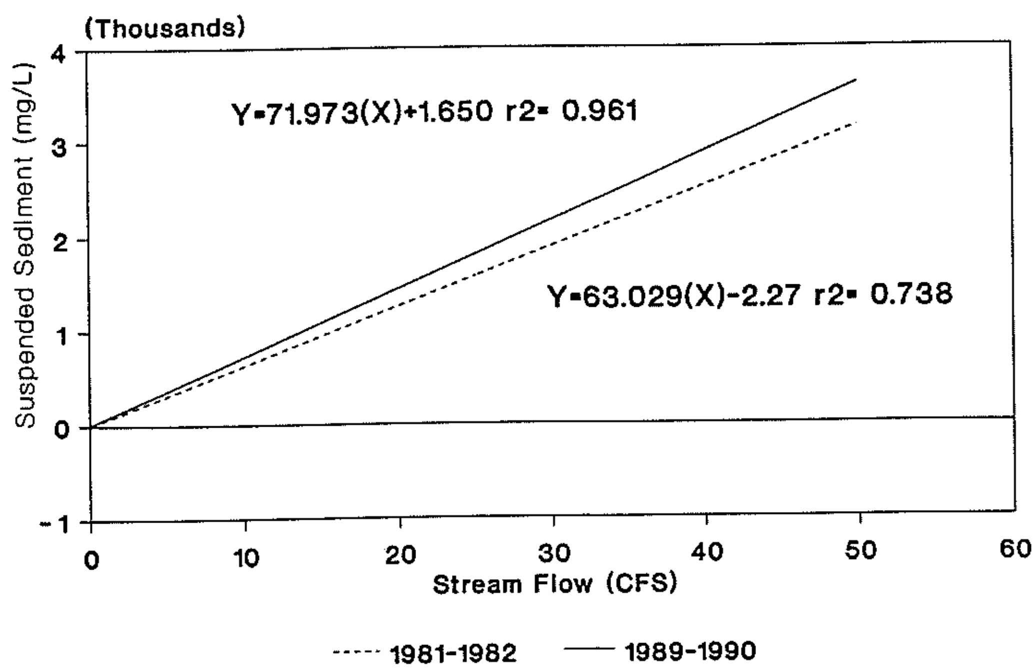

Figure 25. Regression of station HC6, flow vs. sediment.

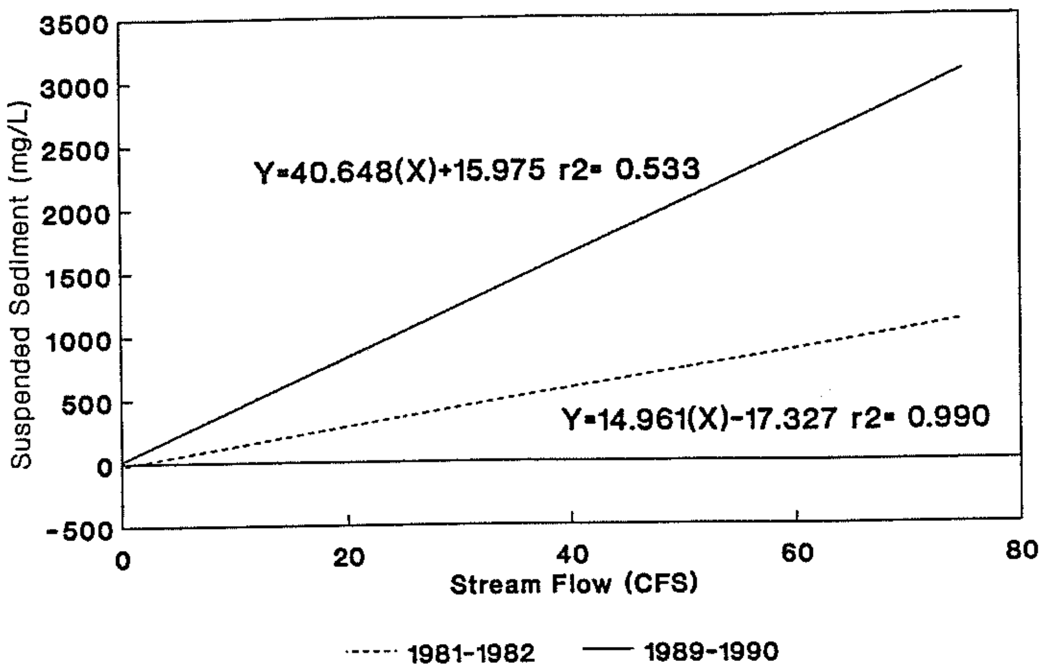

Figure 26. Regression of station HC7, flow vs. sediment.

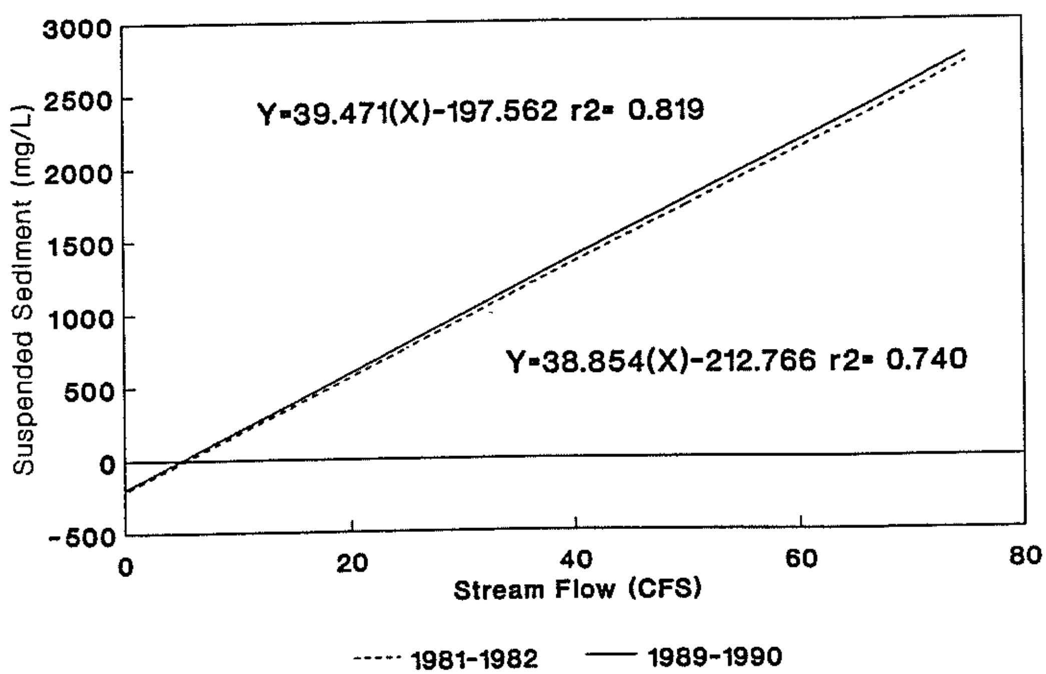

Figure 27. Regression of station HC8, flow vs. sediment.

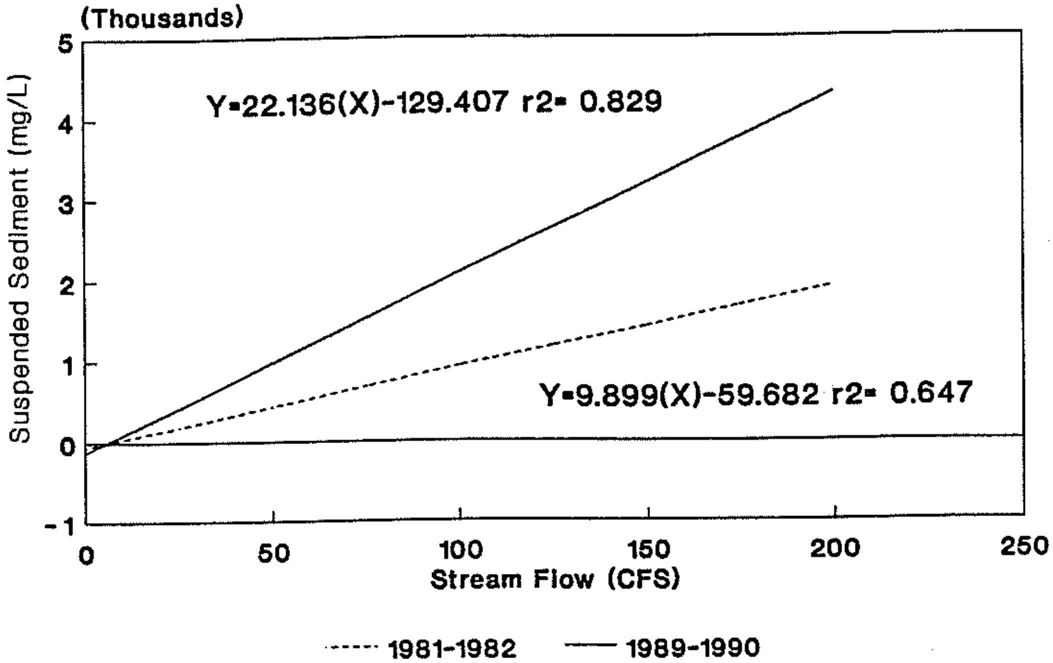

Figure 28. Regression of station HC9, flow vs. sediment.

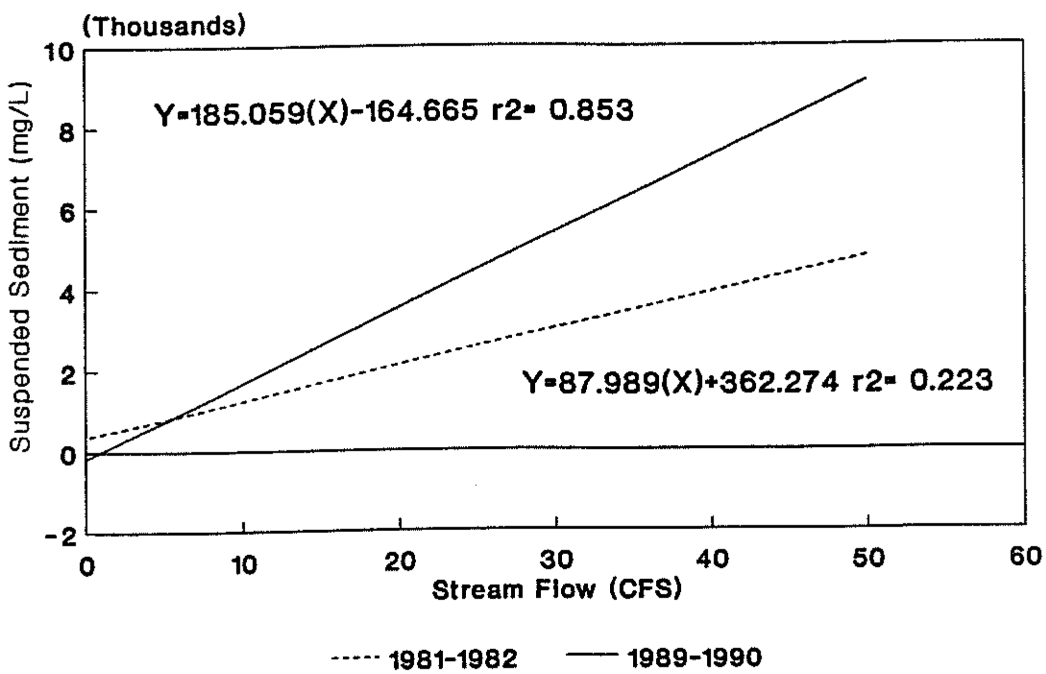

Figure 29. Regression of station HC10, flow vs. sediment.

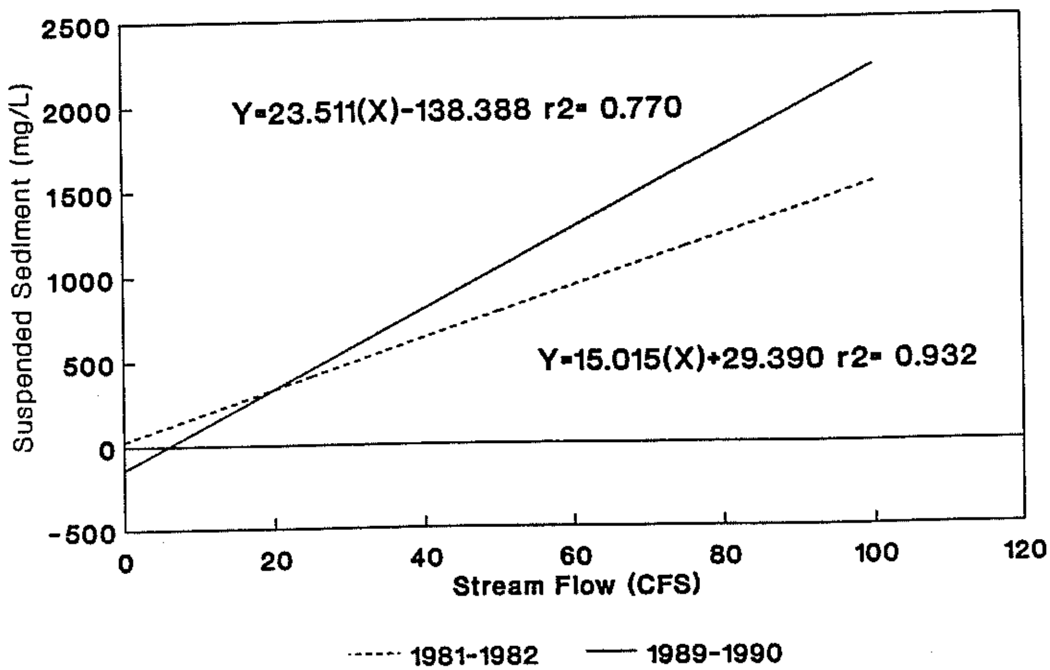

Figure 30. Regression of station HC11, flow vs. sediment.

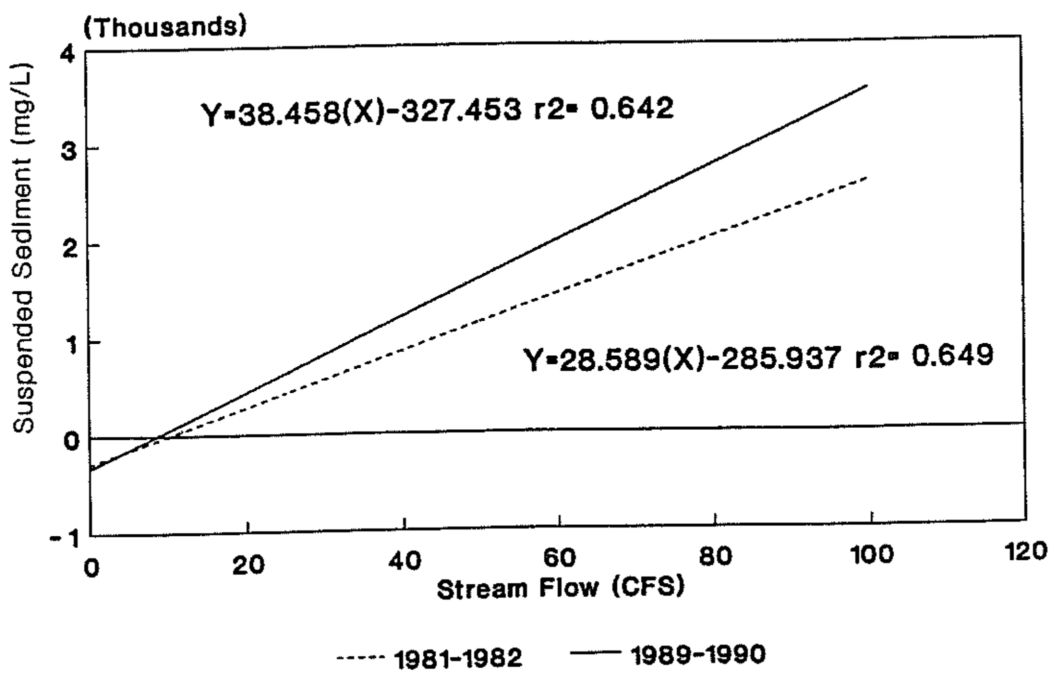

Figure 31. Regression of station HC12, flow vs. sediment.

APPENDIX F

Comparison of regression lines for 1981-1982 and 1989-1990 Total phosphorus versus flow data.

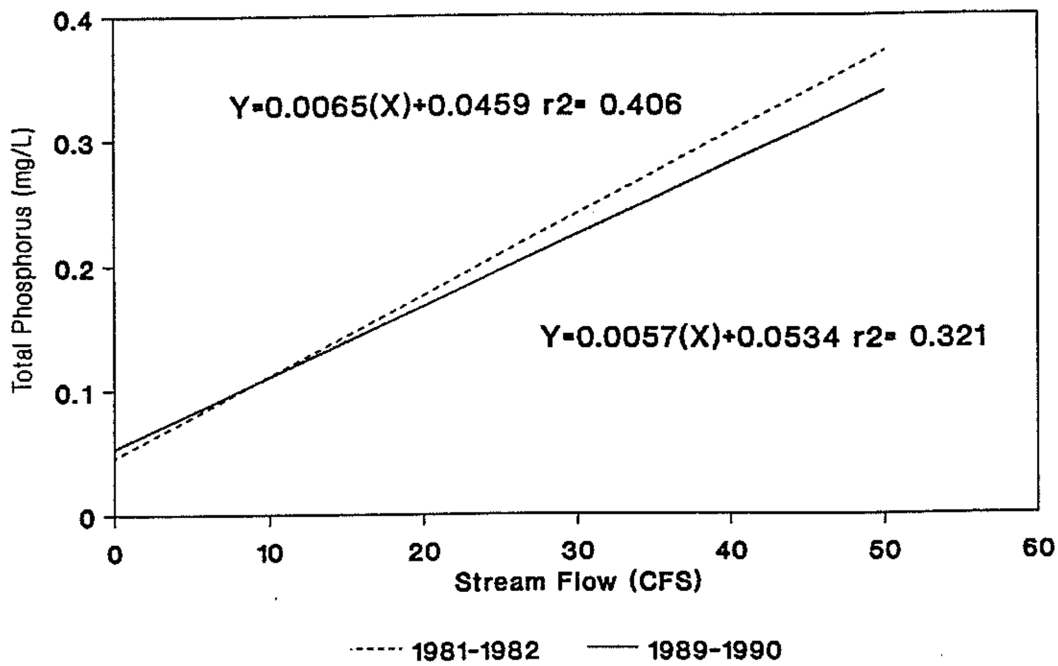

Figure 32. Regression of station S1, flow vs. total P.

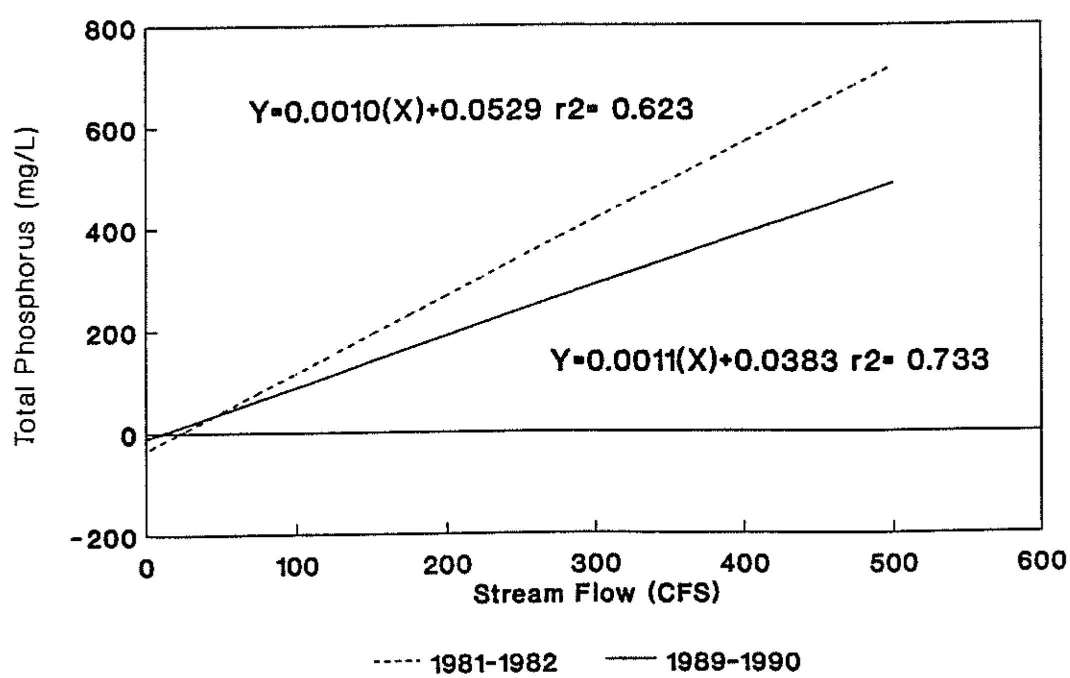

Figure 33. Regression of station S2, flow vs. total P.

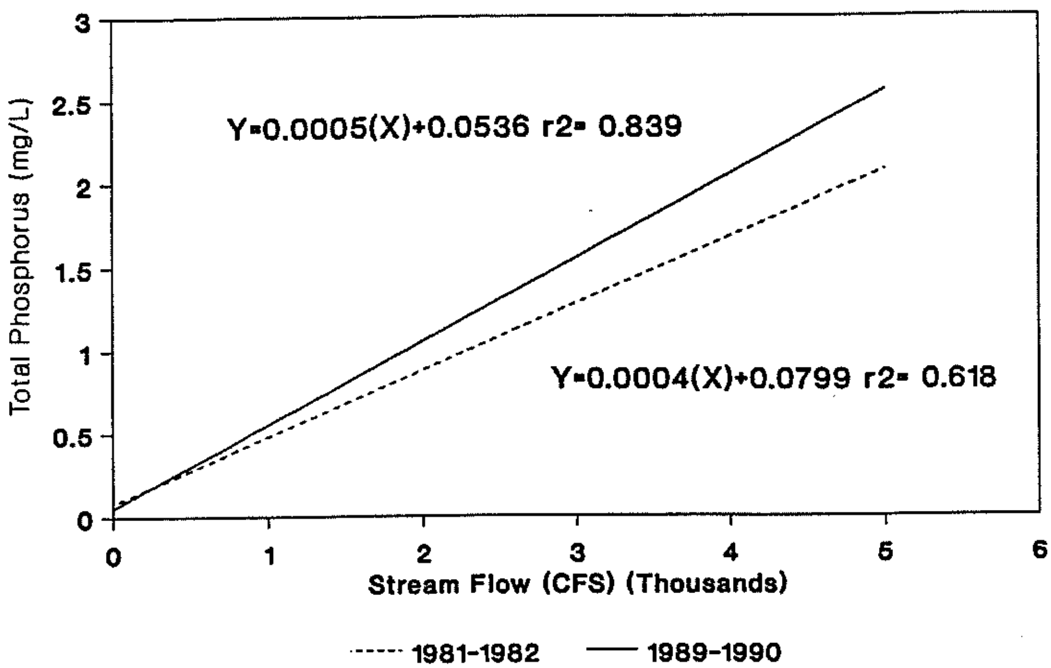

Figure 34. Regression of station S3, flow vs. total P.

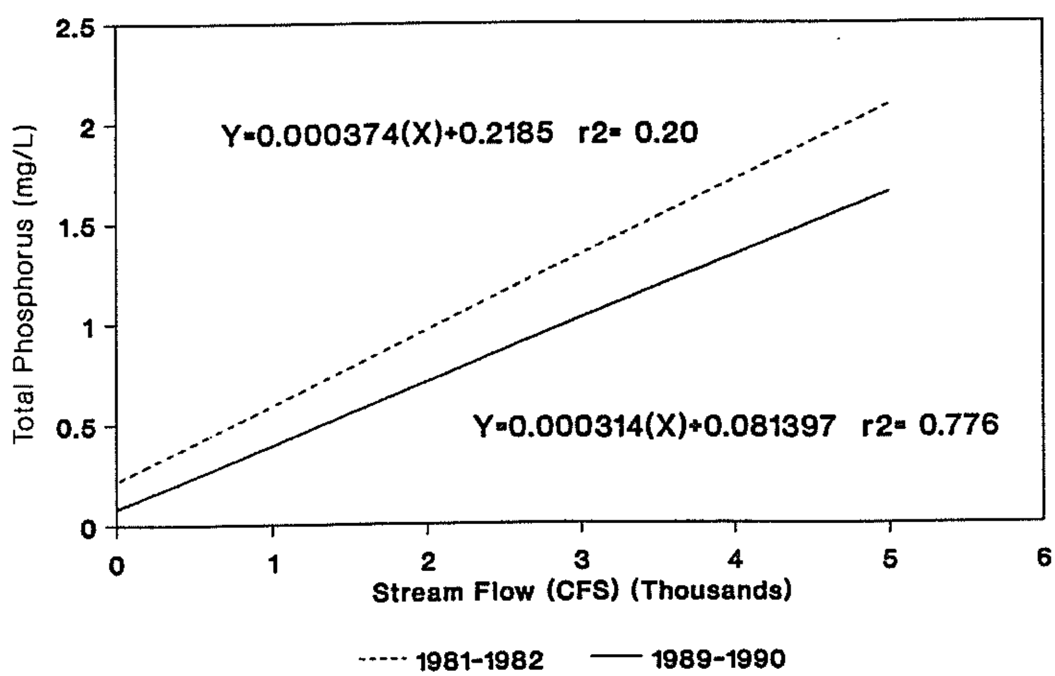

Figure 35. Regression of station S4, flow vs. total P.

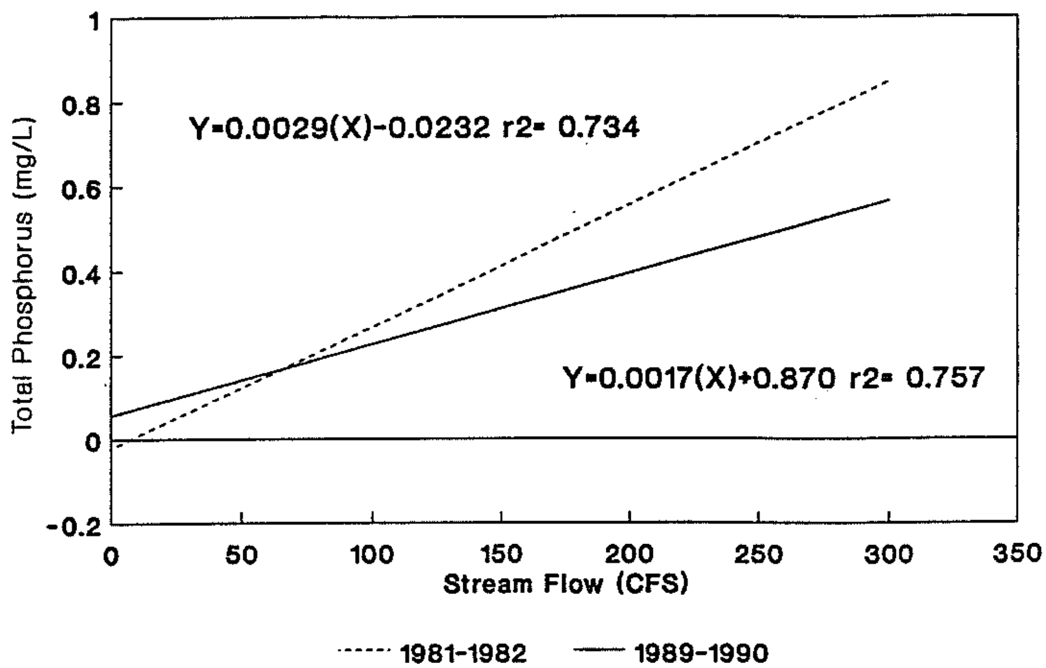

Figure 36. Regression of station HC1, flow vs. total P.

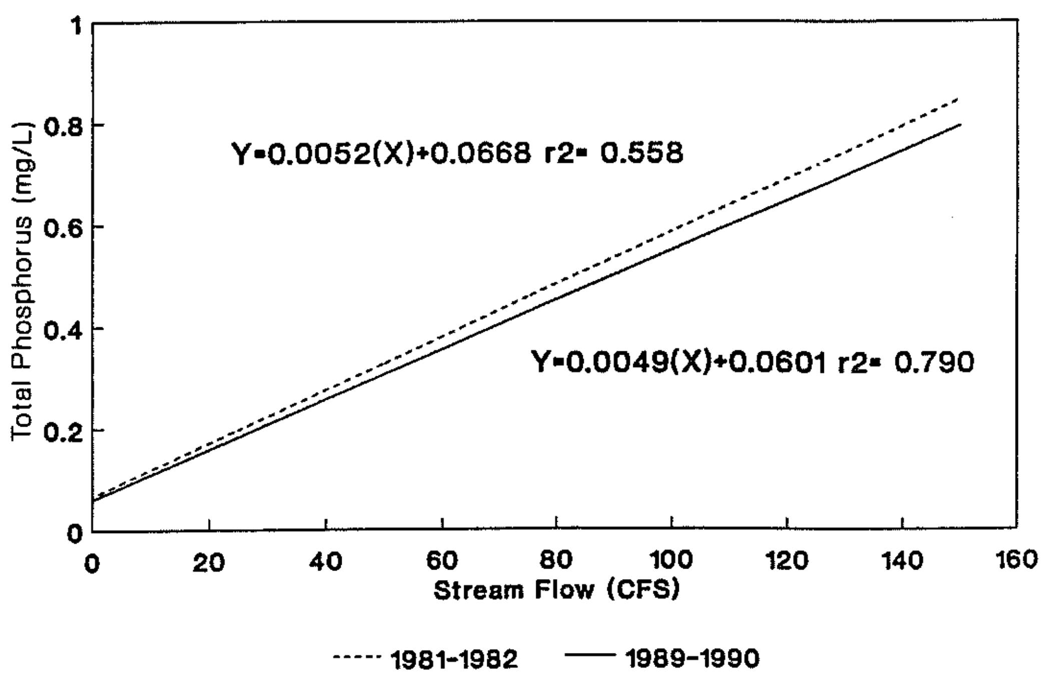

Figure 37. Regression of station HC2, flow vs. total P.

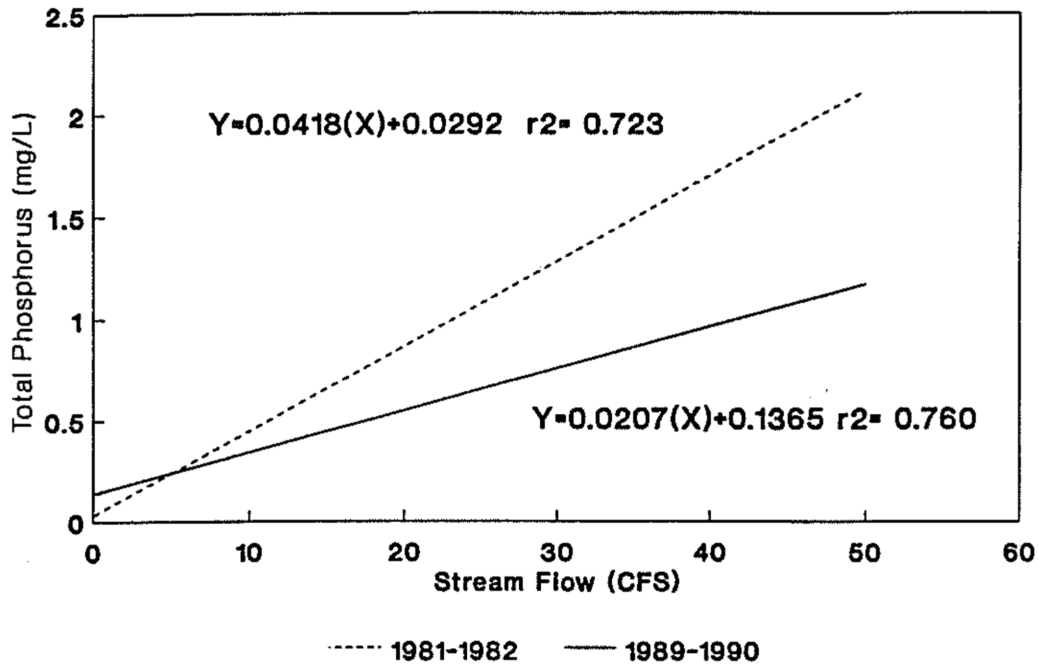

Figure 38. Regression of station HC3, flow vs. total P.

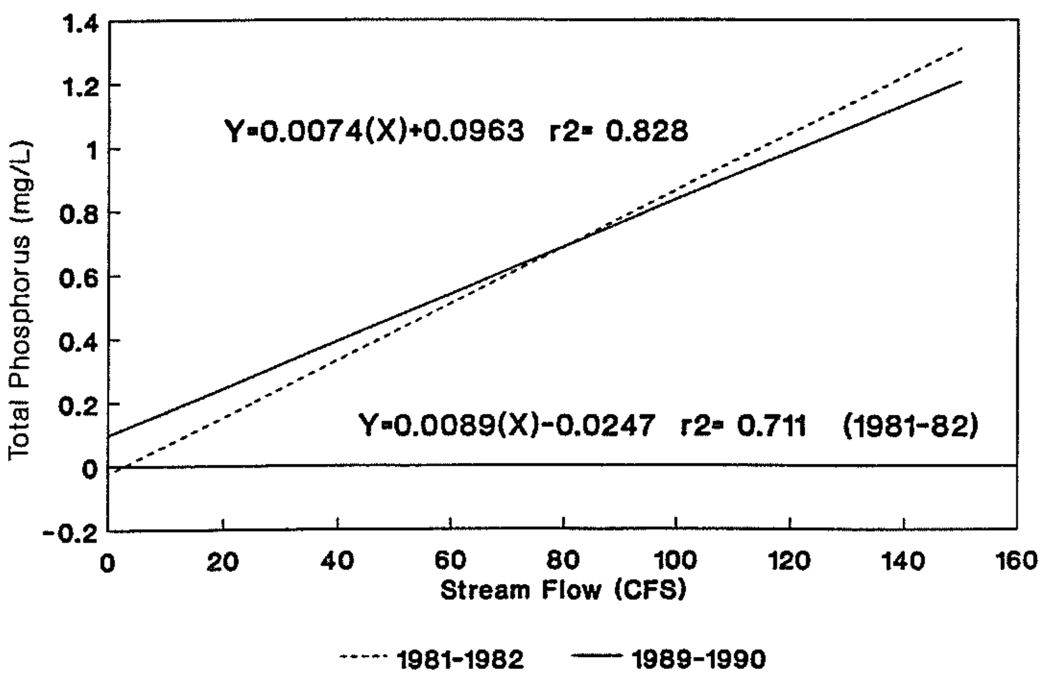

Figure 39. Regression of station HC4, flow vs. total P.

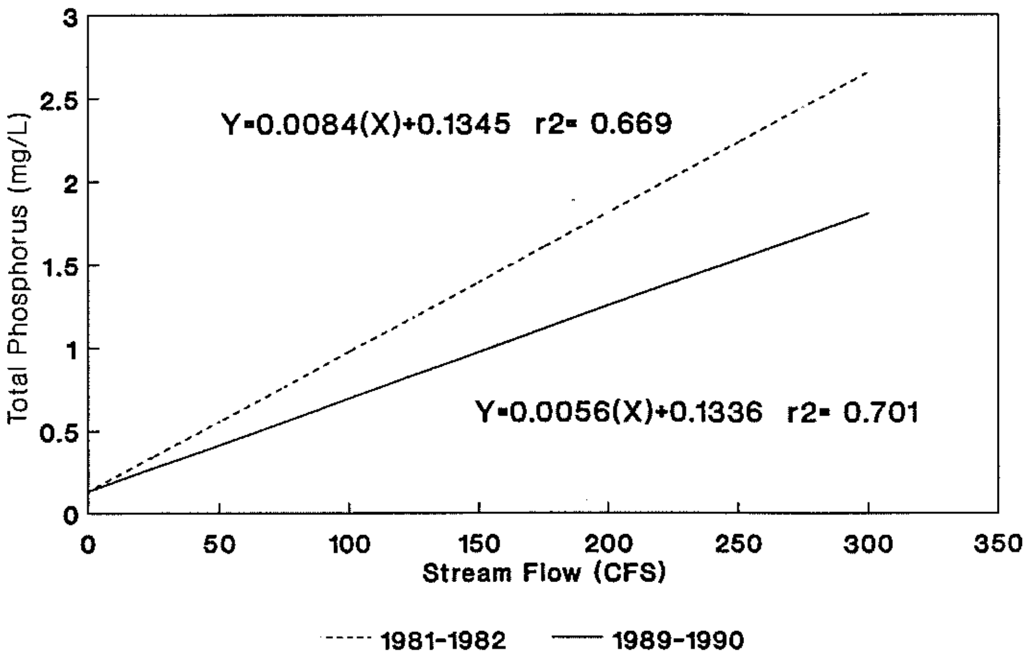

Figure 40. Regression of station HC5, flow vs. total P.

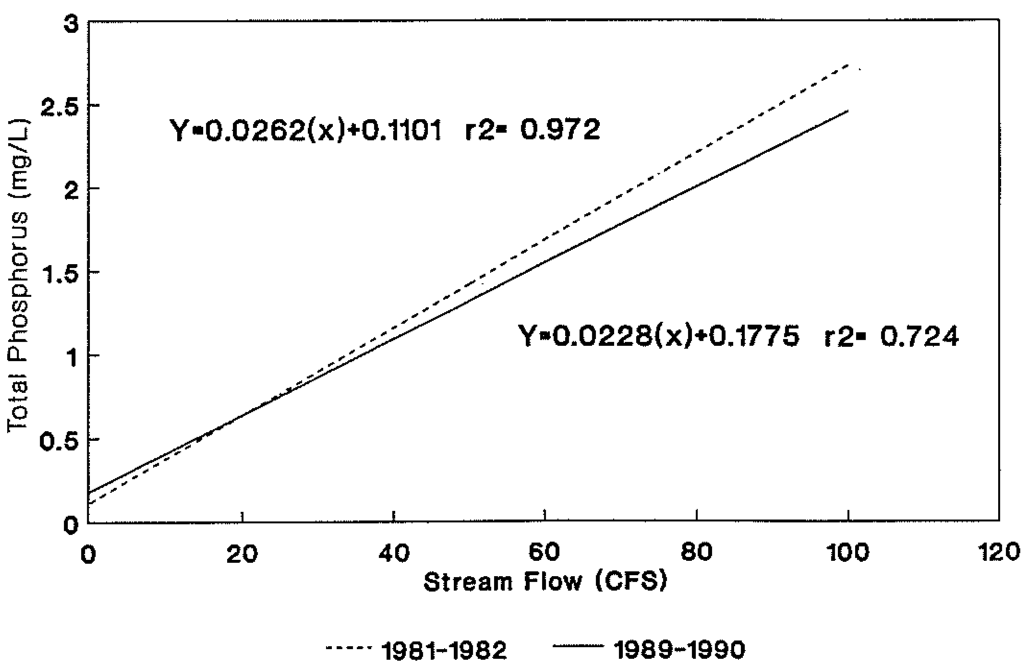

Figure 41. Regression of station HC7, flow vs. total P.

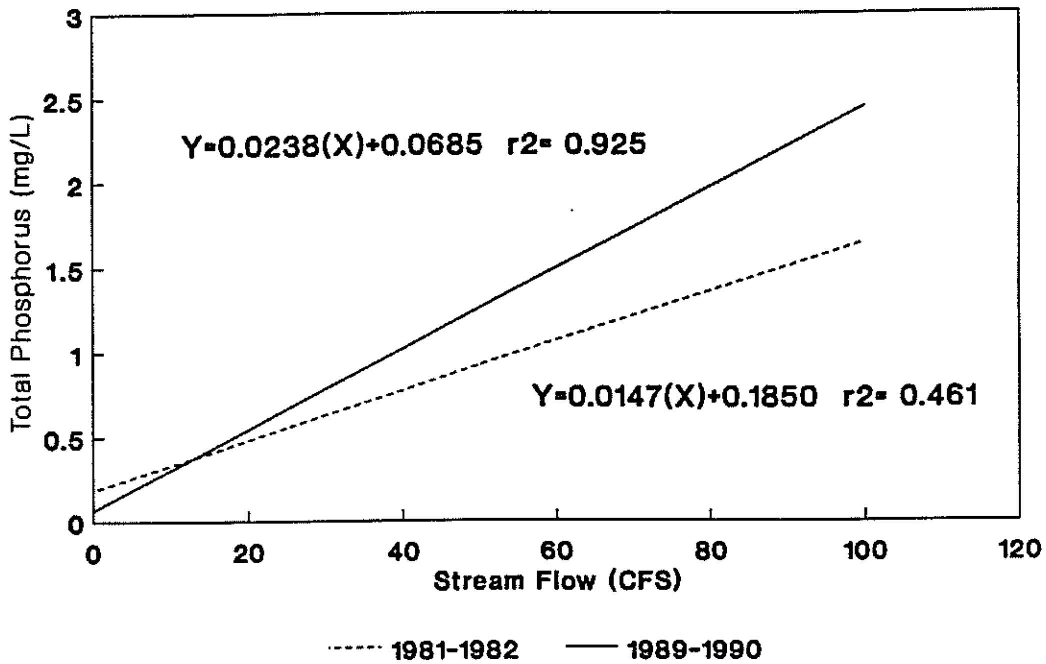

Figure 42. Regression of station HC8, flow vs. total P.

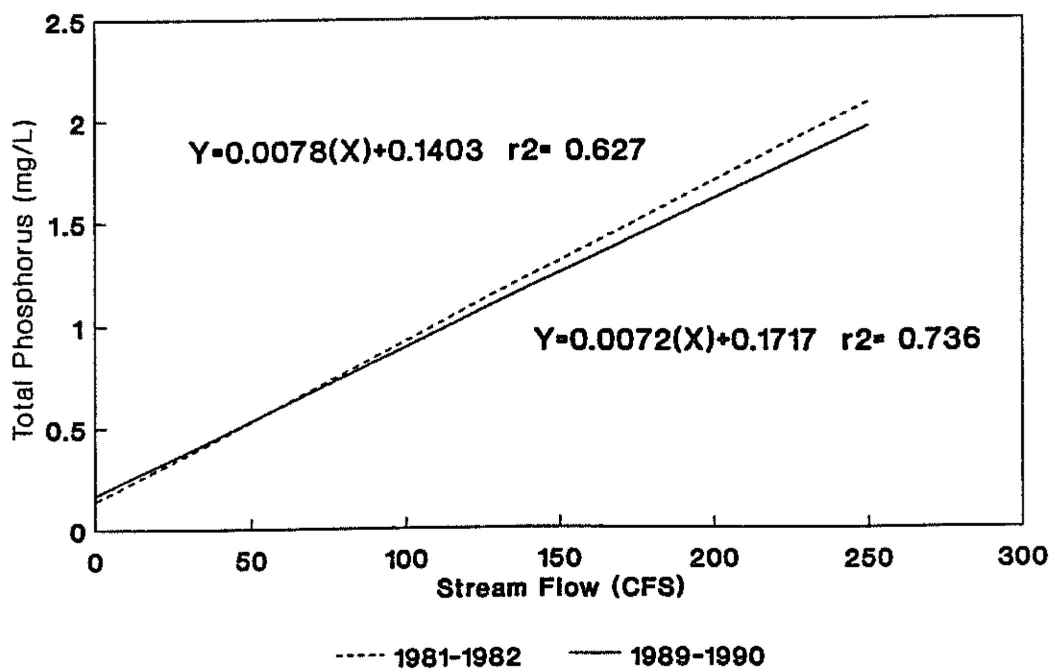

Figure 43. Regression of station HC9, flow vs. total P.

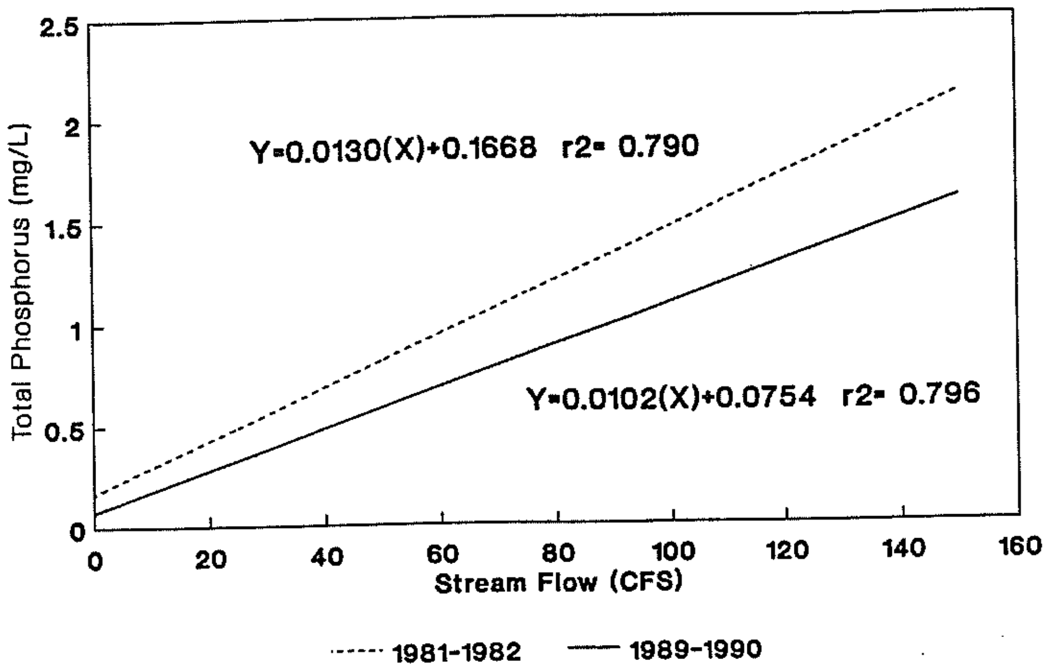

Figure 44. Regression of station HC11, flow vs. total P.

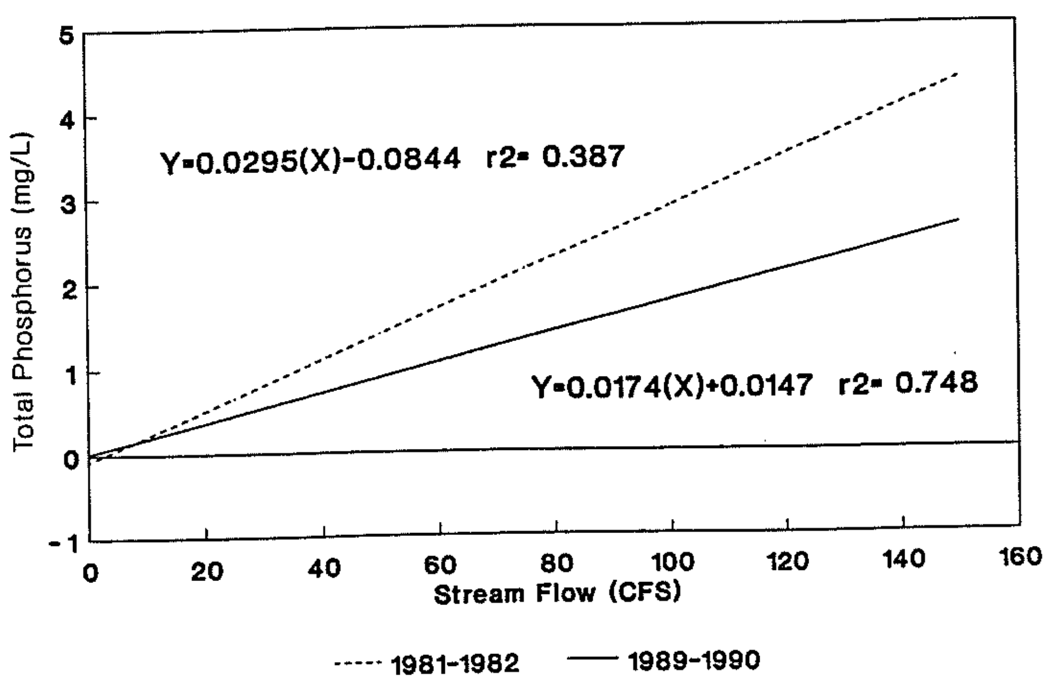

Figure 45. Regression of station HC12, flow vs. total P.