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Rocky Ford Creek TMDL Study

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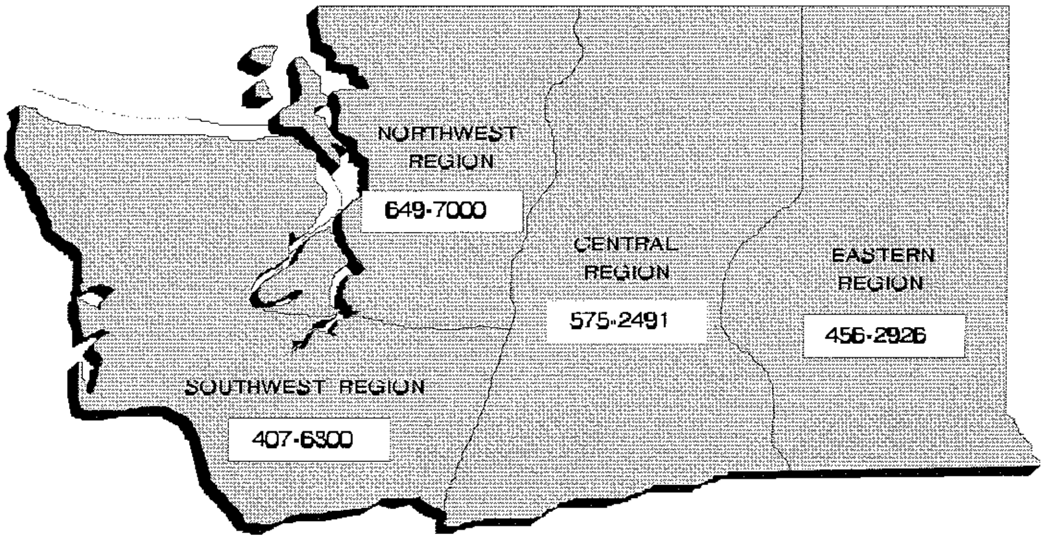

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Rocky Ford Creek TMDL Study

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Abstract

Rocky Ford Creek is a Class A surface water currently listed as violating water quality standards numeric criteria for temperature, pH, and dissolved oxygen. It is suspected that criteria violations are due to excessive primary productivity caused by nutrient loading to the creek. The survey data collected for this project support the 303(d) listings for dissolved oxygen and temperature, and suggest that primary productivity and decomposition in Rocky Ford Creek and its adjacent wetlands are the cause for dissolved oxygen criteria violations and also may be the cause of reported pH violations. The temperature violations are due to natural conditions and it is recommended that the creek be delisted for this parameter.

Historical and survey data collected for this project show that the concentration of nutrients are high in Rocky Ford Creek. The source of the high phosphorus and nitrogen concentrations in the creek is mostly from groundwater feeding Rocky Ford Creek. Agricultural land management practices in upper Crab Creek are the most likely source of the high nutrient concentration in the groundwater.

A direct quantitative link between nutrient loading, concentrations in the water column, and dissolved oxygen (or pH) levels in Rocky Ford Creek may not be possible to establish, because of the nature of wetlands and rooted submerged plant processes. However, setting qualitative nutrient loading limits to protect the creek are recommended. In addition, nutrient allocations based on the upcoming Moses Lake nutrient TMDL recommendations may be necessary to ensure that the nutrient contributions from Rocky Ford Creek do not cause an adverse impact on lake water quality. These allocations may require that both groundwater and fish hatchery nutrient contributions be reduced.

Introduction

Problem Statement

Ecology's Eastern Regional Office (ERO) is concerned about pollutant loading in Rocky Ford Creek and Moses Lake. They requested that the Watershed Assessment Section (WAS) in Ecology's Environmental Investigations and Laboratory Services Program evaluate the water quality of the creek with respect to 303(d) listed parameters and impaired uses. The creek is a Class A surface water currently listed as violating water quality standards numeric criteria for temperature, pH, and dissolved oxygen.

Figure 1 is a map of the study area with sampling stations annotated. The Rocky Ford Creek basin drains only about 40 square miles and is approximately 8 miles long. The creek obtains most of its flow from springs that are its headwaters. Rocky Ford Creek flows south from the springs and discharges to the north end of the main arm of Moses Lake. The elevation of the creek at the springs is 1,080 feet, dropping to 1,046 feet at the lake. The creek has a dense growth of macrophytes, and supports a well developed wetlands from about river mile 2 to its confluence with Moses Lake. The wetlands extend about 100-500 feet from either side of the main channel.

There are two privately operated trout hatcheries that discharge to the creek, known as Troutlodge #1 and #2, which are located at the springs and about 2 miles downstream of the springs. The water discharged from these facilities is regulated under the upland fin-fish hatching and rearing general waste discharge permit. The permit requires hatchery operators to prevent nutrient impacts to the creek through the use of best management practices and wastewater treatment processes.

The most likely causes of pH and dissolved oxygen violations in the creek are the excessive growth of aquatic plants and their seasonal die off. The growth of aquatic plants in Rocky Ford Creek and its adjacent wetlands are likely due to the high levels of nutrients in the source water for the springs and to the pollutant loading from the two fish hatcheries. The major source of nutrients found in the springs is believed to be the Columbia Basin Irrigation Project irrigation water return flow impoundments (Brooks and Round Lakes), located in the upper Crab Creek watershed near Adrian and Stratford. These lakes are believed to act as nutrient sinks for the agricultural activities in the watershed. Another nutrient source for the springs, of secondary importance, appears to be the irrigated cropland located just north of the springs (Bain, 1985). The only other known sources of nutrients to the creek are the fish hatcheries and a feeding/watering area for about 50 cattle located about river mile 5.

Historical Data Review

Hydrology

Rocky Ford Creek has an annual average flow of 78.2 cfs, with a standard deviation of 19.8 cfs, and an annual 7Q10 of 39.6 cfs. Figure 2 shows a line graph of the monthly mean flows from USGS station 12470500 located about 1.5 miles downstream of the springs above Troutlodge Hatchery #2. The monthly mean flows were calculated from daily flow records from 1942 through September 1991, and estimated from October 1991 through February 1998 from bi-monthly USGS flow measurements. Figure 3 shows box plots of the daily flow records by month (each box represents the interquartile range or the 50% of the data between the 25th and 75th percentiles; the end of the whiskers are the minimum and maximum data point within 1.5 times the interquartile range; cross-hatches represent outliers between 1.5 and 3 times the interquartile range; and the notch in the box shows the 95% confidence limit about the median). The statistically significant changes in monthly medians (i.e., notches that do not overlap) are most likely due to differences in annual and seasonal irrigation practices in the upper Crab Creek Watershed. For example, the highest monthly median flows correspond to the irrigation season. The flows in the creek are relatively stable (day-to-day) and most of the time range between 30 and 100 cfs.

Most of the irrigated cropland in the upper Crab Creek drainage was developed between 1952 and the mid 1960s (Bureau of Reclamation, 1989). The flows in Rocky Ford Creek from 1991 through 1996 appear to be similar to the flows before the development of irrigated cropland; which may indicate that less water was available during those years for irrigation (i.e., less precipitation and winter snowpack). There is a large well-field located just north of the creek. The impact of the wells on water quantity in the creek are unknown.

Water Quality

Welch et al. (1973) estimated that Rocky Ford Creek contributed between 22-28 and 37-38 percent of the load of total phosphorus and nitrogen to Moses Lake, respectively. At the time of their study, only one fish hatchery was operating on the creek. They noted that ortho-phosphate, total phosphorus, nitrate-nitrite nitrogen, ammonia nitrogen, and total nitrogen all showed a mean increase below the hatchery. They also noted that the hatchery may have contributed 66 percent of the phosphorus loading to the creek. However, they questioned the accuracy of their nutrient estimates for the fish hatchery because they were based on only a few samples.

Since the late 1960s, most of the water quality data from Rocky Ford Creek was collected to assess nutrient loading to Moses Lake. Figure 4-6 summarizes some of the nutrient data collected on the creek from a number of different projects (Welch et al., 1973; EPA, 1977; Kendra, 1986; Welch et al., 1989; and Bain, 1993). The historical data in Figure 4 were grouped to approximate the sampling locations shown in Figure 1. Table 1 lists some basic statistics for the pooled historical data by sampling station. The most consistent sampling location has been at the new or old highway 17 bridges (i.e., approximately station ROC6). Figures 5 and 6 show the historical data by year and month for ROC6. No statistical evaluation of trends in these data was attempted because of the different data sources and temporal disparity, and because of the discontinuous nature of the combined data set. It should be noted that the 1991-1992 data collected by Bain (1993) were collected during a period when the creek flows were well below the historical average.

As part of the Moses Lake restoration project, a detention pond structure was constructed at the lower end of Rocky Ford Creek in 1987. The detention pond was designed to trap nutrients associated with suspended sediments entering the pond. Nutrient removal was hoped to be accomplished by sediment settling and plant uptake. A secondary benefit of the detention pond structure was to prevent carp from migrating into the creek from Moses Lake. In 1988, the Department of Wildlife removed the carp from the creek in order to improve aquatic plant growth in the creek and stabilize sediments. Welch et al. (1989) noted that the nutrient content of samples collected upstream and downstream of the detention pond in 1987-1988 showed little or no effect of the pond. However, the samples collected in this study were taken just after the pond was constructed and before the carp were removed. They also noted that the nutrient concentrations in the creek did not reveal any significant changes from the historical data, and attributed a decrease in nutrient loading from the creek to lower flows and not real decreases in concentrations. In July 1989, the Moses Lake Irrigation and Rehabilitation District (Bain, 1990) reported that nitrate nitrogen levels fell from 2.4 mg/L near the springs to 0.2 mg/L at the detention pond spillway and that total phosphorus levels fell from 0.14 to 0.04 mg/L. In addition, it was noted that aquatic plants and benthic algae increased in the area upstream of the detention pond. Bain (1993) noted that average nitrate and total phosphorus concentrations during the low flow years of 1991-92 were lower than the historical averages.

A t-test ($\alpha = 0.05$) comparison of the historical data corresponding to sample sites ROC6 and ROC8 (above and below the detention pond) showed no significant difference for ortho-phosphorus and total phosphorus, but did show a difference for nitrate-nitrite nitrogen. However, the pre- and post-1987 nitrate-nitrite data for ROC6 (above detention pond station) were also significantly different (i.e., post 1987 data were lower). Therefore, it is unclear whether the detention pond has had any effect on reducing the nutrient concentrations of the creek or the nutrient loading being discharged to Moses Lake from the creek.

The historical hydrologic and water quality data will be discussed further in the results section.

Project Goals

Rocky Ford Creek has been identified as a major source of nutrients to Moses Lake. In addition, the creek often violates water quality criteria for temperature, dissolved oxygen, and pH. The major goal of this project is to understand the conditions and causes of water quality violations in the creek and assess the nutrient loads the creek discharges to Moses Lake. Another goal of the project is to evaluate the need for establishing a Total Daily Maximum Load (TMDL) for the Rocky Ford Creek basin as required under Section 303(d) of the Federal Clean Water Act for waterbodies not meeting water quality criteria. A TMDL may need to be established to regulate problem pollutants.

Project Objectives

Objectives for the study include:

1. Conduct water quality sampling investigations of Rocky Ford Creek with emphasis on 303(d) listed parameters.

2. Assess the water quality of the springs feeding Rocky Ford Creek.

3. Assess the impact of the two fish hatcheries, located in the upper reach of Rocky Ford Creek, on water quality.

4. Estimate the loading of nutrients from Rocky Ford Creek to Moses Lake.

5. Determine the potential for the creek to violate numeric criteria of the water quality standards; recommend wasteload allocations (WLAs) for the fish hatcheries and load allocations (LAs) for nonpoint and background sources to meet the standards.

Methods

Study Design

The project objectives were met by collecting and reviewing prior investigators' data (see Historical Data Review section), conducting field sampling and analysis of new data, and using dissolved oxygen concentrations in the creek to estimate primary productivity.

Two synoptic field surveys were conducted on August 19-20 and November 3-4, 1997 to provide data for meeting the project objectives. These sampling dates were chosen to represent the summer plant productivity and fall plant die-off periods, respectively. The sampling stations are shown in Figure 1 and the schedule for field measurements and sample collection for laboratory analyses are listed in Table 2

The sampling stations were chosen to represent the spring headwater and source water for Troutlodge #1 (SPR1), the creek downstream of each fish hatchery (FSH2 and FSH4), the source water for Troutlodge #2 (ROC3), two stream reach sites (ROC5 and ROC6), and locations above and below the detention pond (ROC7 and ROC8).

On the first day of the August survey, composite samplers were placed to sample the discharge from the two fish hatcheries for 24 hrs. In addition, during each survey and on September 23, an *in situ* monitor (Datasonde 3) was mounted to collect pH, temperature, conductivity, and dissolved oxygen for 24 hours at ROC6. The September data were collected to provide information on the transition period between summer and winter conditions. On the second day of each survey, samples were collected at all sites in the morning and then again in the late afternoon.

Flow data were collected from the USGS station located just upstream of Troutlodge #2 and at the detention pond weirs.

Two additional data collection surveys were conducted to (1) identify plant species in the creek and the wetlands, and (2) determine nutrient concentrations in the sediment and soil of the creek and wetlands, respectively. The plant surveys were conducted in August 1997 by Jenifer Parsons, Ecology aquatic plant specialist; and by Dennis Beich, Ecology wetlands specialist. The soil survey was conducted on November 11, 1997 by Dennis Beich, Ecology Wetlands Specialist and Ron Rainy, NRCS Wetlands Specialist. The sediment and soil survey involved collecting 28 samples; 3 samples from the upland Ephratic soils, 9 samples from the near shore area of the creek (referred to as the Cattail Zone); 10 samples from the transition area between the Cattail zone and the Ephratic soil (referred to as the Rush Zone). The samples were collected along 3 transects near the Highway 17 bridge and represent the upper 17 inches of soil or sediment.

Data Quality Objectives and Analytical Procedures

The analytical methods and the reporting or precision limits for the field measurements and laboratory analyses are listed in Table 3. The plant survey was conducted to provide qualitative information about the major plant species growing in the creek and in the adjacent wetland. The soil survey data were collected to provide information about the relative concentrations of nutrients in the sediments and soils of the creek channel and in the adjacent wetlands relative to the Ephratic soils of the general area. Although data quality objectives were not set for the soil data, the analyses were conducted by Best-Test Analytical Services, Moses Lake, WA, using standard soil and plant analytical methods (Gaviak et al., 1994).

The data generated from the laboratory analyses of the water samples met the Manchester Environmental Laboratory (MEL) quality assurance requirements and were considered acceptable for use.

Quality Control Procedures and Sampling Procedures

Total variation for field sampling and laboratory analysis was assessed by collecting replicate samples. At least 10% of the total number of laboratory samples per parameter were replicate samples. The replicate precision was within the limits established for past studies conducted by these investigators.

All samples for laboratory analysis were preserved as specified by the laboratory users manual (MEL, 1994) and delivered to MEL within 24 hours of collection. Laboratory analyses listed in Table 3 were performed in accordance with MEL (1994). Field sampling and measurement protocols followed those specified in the WAS field sampling and measurement protocol manual (WAS, 1993) for temperature (alcohol thermometer), pH (Orion Model 250A meter and Triode™ pH electrode and/or pH paper), conductivity (Beckman Model RB-5 and YSI 33), dissolved oxygen (Winkler titration), streamflow (Marsh-McBirney 201 & 2000), and *in situ* temperature, dissolved oxygen, pH and specific conductance (Hydrolab7 multi-parameter meters). All meters were calibrated and post-calibrated per manufacturer's instructions.

Data Assessment Procedures

Laboratory data reduction, review, and reporting followed procedures outlined in MEL's Users Manual (MEL, 1994). All water quality data were entered into an EXCEL5 spreadsheet. Data were verified, and 100% of the entered data were reviewed for errors.

Estimation of univariate statistical parameters and graphical presentation of the data were made using SYSTAT/SYGRAPH8 or EXCEL5 computer software.

Data from sampling stations SPR1, ROC6, and ROC8 were used to assess the source (spring) and discharge water quality of the creek to Moses Lake, respectively. These data were also compared to historical data. The fish hatchery data from site FSH2 and FSH4 were used together with SPR1 and ROC3 data to estimate the loading of the hatcheries to the creek based on fish production (or feeding) levels on the sampling dates. The spring and creek stations SPR1, ROC3, ROC5, ROC6, ROC7, and ROC8, were used to assess water quality changes along the creek's length. Together with the *in situ* monitoring data, these data were also used to assess the creek diel and diurnal changes, respectively.

Results and Discussion

Hydrology

The creek flow during the August and November surveys at the USGS gauging station (ROC3) was estimated to be 142 and 88 cfs, respectively. The discharge at the detention pond (ROC8) was estimated to be 168 and 110 cfs. These measurements suggest that the flow increases about 20% from the springs downstream to the lake. Flows in the creek during the summer of 1997 were higher than they have been since the late 1950s which may indicate that more water was used for irrigation (see Figure 2).

Diurnal Data

Figures 7 and 8 show the results of the *in situ* continuous monitoring data at ROC6. The data show that the creek dissolved oxygen level was below the 8 mg/L water quality standard criteria most of the time. The water quality standard temperature criteria of 18°C was also exceeded during the August survey. The diurnal dissolved oxygen curves for August and September indicate that primary productivity was affecting the dissolved oxygen concentrations (e.g., the range on August 19-20 was 3.6 to 9.2 mg/L). Primary productivity can be estimated from the diurnal measurements by applying the Delta Method described in Chapra (1997). Appendix B contains the results of fitting the Delta Method dissolved oxygen curve to the August data. The method provides a primary productivity estimate of 12.9 $gO\ m^{-2}\ d^{-1}$ or 4.81 $gC\ m^{-2}\ d^{-1}$ for the August data, which suggests that the creek is a highly productive system (Chapra, 1997). Most of the productivity is likely in the macrophyte plant community with some unknown contributions from benthic algae. It should be noted that August 19 was a sunny day and August 20 a cloudy day. The productivity estimate is based on the data collected from 1430 on August 19 to 0830 on August 20.

The November data suggest that plant decomposition and sediment oxygen demand depresses dissolved oxygen below 8 mg/L in the fall-winter period (estimated average saturation of dissolved oxygen for the period was 10.8 mg/L). In general, the diurnal data show that plant productivity (and decay) is causing the system to be listed on the 303(d) list for dissolved oxygen. However, corresponding changes in pH were not found. This could be because the flows in the creek were high and the water is likely well buffered (conductivity in the creek was ≥370 $\mu mhos\ cm^{-1}$). At lower flows (such as occurred during the early 1990s) the plant community may have an even greater impact on water quality in the creek (including changes in pH).

Field and Laboratory Data

The field and laboratory survey data are listed in Appendix A. Figures 9-12 show the results of the survey data for selected variables from the spring headwaters (SPR1) downstream to the detention pond (ROC8). Overall, the phosphorus and nitrogen data are within the range of the historical data. The survey and historical data results also suggest that dissolved phosphorus and ammonia increase below the fish hatcheries. In addition, nitrogen decreases further downstream from the hatcheries. Seasonal changes for nitrogen are indicated by the data. These changes are especially noticeable for ammonia. Also, as other investigators have noted, most of the phosphorus is dissolved (i.e., ortho-phosphate). No significant differences were found in the nutrient concentrations above and below the detention pond. The maximum chlorophyll concentrations found during the August survey was <3 μg/L which suggest that water column algal productivity was low during the survey. Generally, surface waters with <4 μg/L of chlorophyll are usually considered unproductive (McNeely *et.al.*, 1979). However, because of the high nutrient concentrations in the water column, algal productivity could be high. The creek temperature violated the Class A criteria during the August survey. The temperature violation appears to be due to natural conditions (i.e., warm air temperature, little stream shading). Finally, the fish hatcheries appear to contribute a negligible amount (<1mg/L) of biochemical oxygen demanding substances (BOD) to the creek. However, the impact of the periodic cleaning of fish rearing ponds on creek dissolved oxygen concentrations is unknown.

Based on the survey data, Table 4 lists the estimated pounds per day and percent contribution of the fish hatcheries to the nutrient and total organic carbon (TOC) concentrations in the creek below the fish hatcheries (FSH4) and the nutrient contributions to Moses Lake (ROC8). The estimated loading to the creek at FSH4 was based on the average survey flow measured at the USGS gauging station. The loading to Moses Lake was based on average survey flows measured at ROC8. The creek showed a net increase in TOC export to Moses Lake; however, it does not appear that the hatcheries are a significant contributor of TOC to the creek. The fish hatcheries contributed about 21% of the total phosphorus and 7% of the total nitrogen to the upper creek at FSH4. As a percent of the loading to Moses Lake, these values were estimated to be 10% and 9%, respectively. The most significant nutrient loads to the creek are coming from the spring source water.

Troutlodge estimated that each hatchery used approximately 60,000 pounds of feed per month in 1997 (facsimile transmittal from Jim Barfoot). In addition, Troutlodge also estimated that the tonnage of fish raised during 1997 was below normal and expect that in the next few years the production levels should increase (facsimile transmittal from Jim Barfoot). Table 5 lists the estimated contributions of nutrients to the creek based on 1997 fish production and maximum fish production levels as represented by the maximum permitted feed. The estimates are presented for the historical mean, 90^{th}, and 10^{th} percentile creek flows at the USGS gauging station and the discharge from the detention pond, assuming a 20% increase in flow from the gauging station to the detention pond. These estimates indicate that the percent contribution of nutrients by the fish hatcheries to the creek and ultimately to Moses Lake could become significantly higher do to changes in creek flow and fish hatchery production levels.

Table 6 is an estimated annual total nitrogen and total phosphorus budget for Rocky Ford Creek based on the average 1997 chemistry data and the annual average flow of 78.2 cfs at ROC3 (93.8 cfs discharging to Moses Lake at ROC8). The atmospheric nutrient contributions are based on areal deposition rates measured in the Lake Chelan basin (28 ± 11 kg P/km^2-yr and $1,100 \pm 140$ kg N/km^2-yr) (Patmont *et al.*, 1989). The budget suggests that on an annual basis, the creek (and wetlands) retains nitrogen but exports phosphorus. The additional phosphorus may be from nonpoint sources (e.g., the cattle feeding/watering area).

Impact of Nutrient Loading on Productivity

One of the objectives of this study is to assess the impact the Troutlodge fish hatcheries are having on Rocky Ford Creek water quality. As noted above, the primary productivity in the system is causing violations of the dissolved oxygen criterion and probably has caused past violations of the pH criterion. The historical data, the results of the 1997 water quality survey, and the estimated maximum contribution of nutrients by the hatcheries suggest that they can contribute a significant amount of nutrients to the creek. However, the major question is whether the nutrient contributions of the hatcheries are causing an adverse impact on creek water quality. A review of the general characteristics of wetlands, including the effects of macrophytes on water quality, may help answer this question.

General Characteristics of Wetland Productivity

In streams and lakes, rooted submerged macrophytes are known to draw their nutrient needs from sediments, not from the water column. The submerged macrophytes provide substrate for periphyton, recycle and store nutrients, accumulate sediments (including particulate organic matter), and may create nuisance biomass levels (Carpenter and Lodge, 1986; Welch, 1992). In general, most of these macrophyte characteristics are also true of a wetland system (Howard-Williams, 1985; Johnston, 1991). However, the emergent macrophytes in wetlands carry on photosynthesis in the atmosphere while the photosynthesis processes of submergent macrophytes occur in water. As a result, submergent macrophytes have a direct effect on water quality while emergent macrophytes have only an indirect effect.

Wetlands have been shown to retain and store nutrients. Wetland soils (including stream sediments) contain by far the largest standing stock of nutrients of any of the wetland storage compartments (Johnston, 1991). Phosphorus turnover time in wetland soils has been estimated to be about 100 years, while the nitrogen turnover may be much longer (Johnston, 1991). Wetland succession leads to the accumulation of detritus, filling-in (loss) of open water channels, and expansion of the shoreline emergent plant communities (Howard-Williams, 1985; Carpenter and Lodge, 1986; Johnston, 1991).

Emergent macrophytes have been found to respond positively to eutrophication, but fertilization experiments have shown that nitrogen rather than phosphorus may be the key element limiting productivity (Graneli and Solander, 1988) In waters with dense submerged macrophyte stands, diel changes in dissolved oxygen can be as large as 8 mg/L. In addition, decaying macrophytes will also consume large amounts of oxygen (Carpenter and Lodge, 1986).

With respect to water quality, both natural and constructed wetlands have been used to mitigate the impact of point and nonpoint sources of pollutants. This is because of the ability of wetlands to remove pollutants by (1) ion exchange/nonspecific adsorption; (2) specific adsorption/ precipitation; and (3) complexation (Hammer, 1989). Studies have shown that wetlands receiving anthropogenic inputs of nutrients had no decrease in nitrogen retention capacity over time but can loose their capacity to retain phosphorus (Johnston, 1991).

Impact of Nutrient Loading to Rocky Ford Creek

Rocky Ford Creek and its riparian area is a well developed wetland system with dense stands of emergent and submergent macrophytes. The large diel changes in dissolved oxygen in the creek are likely due to the dense submergent macrophyte stands growing throughout the length of the creek. However, although the effects of benthic algae are unknown, the hatcheries contribution of ammonia to the creek may cause increased algal and periphyton growth because their growth is known to be promoted by inorganic nitrogen (Johnston, 1991). In addition, decomposition of the wetland plants also probably contributes to year-round depressed dissolved oxygen concentrations in the creek. Although the wetlands retain a portion of the nitrogen entering the system, a significant amount of both nitrogen and phosphorus is exported to Moses Lake. In the summer, the wetland retains nitrogen, but appears unable to retain phosphorus. During winter, neither nutrient is retained.

Table 7 lists the results of the wetland sediment/soil survey. The average concentrations of total nitrogen and total phosphorus for organic wetland soils have been reported as 17.1 mg/g (range 1.8-30.0 mg/g) and 0.64 mg/g (range .003-1.3 mg/g), respectively (Johnston, 1991). The Rocky Ford Creek wetland total nitrogen concentrations are low (4-6 mg/g) and the total phosphorus concentrations high (0.92-1.41 mg/g) with respect to these average values. The estimated wetland area is 395 acres, including the area of the main creek channel. The estimated area of the creek channel is 52 acres. (Estimates were made by digitizing the area of the wetland from Department of Natural Resources arial photographs.)

Table 8 lists the current estimated nutrient storage of the wetland in years, calculated as the pounds in the wetland and creek sediments divided by the annual estimated input listed in Table 6. Relative to the annual nutrient loading to the creek, the wetlands do not appear to have a large amount of storage. However, given the ability of wetland systems to recycle nutrients, the existing storage may be adequate to allow the rooted macrophyte production to continue at current levels even if nutrient loads to the creek are reduced.

Appendix A contains a memo from Dennis Beich, ERO wetlands specialist, summarizing the plant species found in the wetlands. The plants are listed as submersed, immediate shoreline, and transitional to upland area. (The plant species were identified by Dennis Beich and Jenifer Parsons, EILS aquatic plant specialist.) Although most of these plants are rooted and draw their nutrients from the sediments, one of the dominant submerged macrophytes, *Ceratophyllum demersum* (Coontail), is not a rooted plant and draws its nutrients directly from the water. Of the plants listed, *Lythrum salicaria* (Purple Loose Strife), is the only "nuisance" species. As an emergent plant, Purple Loose Strife thrives along shorelines and may become one of the dominant plants in the wetland as successional processes increase emergent habitat (i.e., the creek channel becomes filled-in and braided).

Landowners in the basin are concerned about flooding and the expansion of the wetlands. The landowners are also concerned that nutrient loading from the fish hatcheries are causing expansion of the wetlands which, in turn, cause flooding. However, given the characteristics of the wetland system and historically high nutrient levels in Rocky Ford Creek, together with the recent increase in creek flow, the expansion of the wetlands is probably more likely due to increased water availability than additional nutrient inputs. In addition, flooding in the areas along the creek is probably due to a combination of wetland successional processes and increased flows in the creek.

Nutrient TMDLs

The Clean Water Act (CWA) Section 303(d) requires states to effect pollution controls on waterbody segments where technology-based controls are insufficient to reach water quality standards. To meet this requirement, a TMDL must be established for each pollutant violating water quality criteria. The TMDL is the sum of point and nonpoint sources as wasteload (WLA) and load (LA) allocations, respectively. However, although it is clear that primary productivity in Rocky Ford Creek is causing violations of the dissolved oxygen criteria, Ecology has not adopted nutrient criteria or recommended procedures for protecting streams and rivers from excessive nutrient loading. Since no site-specific or numeric nutrient criteria exist that can be applied to Rocky Ford Creek, nutrient criteria would need to be developed by linking measured nutrient concentrations (or loads) and an endpoint indicator (i.e., dissolved oxygen concentrations). This implies that it is possible to link (through understanding and quantifying mechanistic processes) the effects of nutrient addition (loading) to the water column, the effects of nutrients in the water column on plant productivity, and the impact of plant productivity on dissolved oxygen concentrations in the creek.

Although it is possible to establish nutrient loadings and estimate the impact of plant productivity on the dissolved oxygen concentrations in Rocky Ford Creek, it is not possible to establish a cause and effect relationship between the concentrations of nutrients in the water column and plant productivity because the soil/sediment is the main nutrient source for the dominant rooted plants. It may be possible to develop a computer model of the system with more detailed data on the productivity processes. The model could be used to simulate plant productivity and assess changes in plant production due to changes in water column nutrient concentrations. However, these investigators believe that an intensive sampling and modeling effort would not yield any more information on the impact of nutrients or their control than can be drawn from the information already presented in this report. There is probably little or no quantitative link between the current water column nutrient and dissolved oxygen concentrations in the creek. These investigators believe it will require dramatic, long-term decreases in nutrient loading to reduce the effects of plant productivity on water quality in the creek.

At this time, it is probably not possible to set a quantitative nutrient TMDL for Rocky Ford Creek as an individual waterbody. However, it will be possible to set quantitative nutrient limits for the creek based on the effect of nutrients in Moses Lake by using the water quality standards for lake numeric nutrient criteria (Chapter 173-201A-030 (5)). The investigators are currently preparing a report summarizing the historical data for Moses Lake and assessing the impact of nutrient loading to lake water quality. This analysis will lead to recommendations for nutrient load allocations for sources to the lake, including Rocky Ford Creek, which can then be allocated to the fish hatcheries and ground water nutrient sources. An alternative approach would be to set qualitative goals for reducing the concentration of nutrients in Rocky Ford Creek (e.g., reduce groundwater and hatchery nutrient concentrations by 60-80 percent, or use reported literature values for controlling nuisance algal growth in streams and rivers to set loading limits), with the hope that water quality will improve and that wetland successional processes will be slowed. In either case, groundwater contributions must be controlled before there will be any possibility of mitigating the effects of nutrient loading in Rocky Ford Creek or Moses Lake.

Beneficial Uses

This report was prepared to evaluate the creek with respect to its Class A waterbody designation. The characteristic uses for Class A waters include water supply (domestic, industrial, and agriculture), fish and wildlife habitat, and recreation (primary contact, sport fishing, and aesthetic enjoyment). Currently, the major uses of the creek are for aquaculture, fish and wildlife habitat, trout fly fishing, and agriculture water supply.

An important first step for managing the water quality of Rocky Ford Creek will be to establish specific beneficial uses for the creek, and establish an appropriate designation (i.e., should it be considered a wetland system and not subject to Class A waterbody criteria). The beneficial uses of the wetlands are not considered in the evaluation. The primary means for protecting water quality in wetlands is through implementing the antidegredation procedures (WAC 173-070), which may be in conflict with the current uses of the creek. For example, in order to protect the creek's use as a trout fly fishery, it should meet the Class A waterbody criteria. However, management actions to achieve this goal would not be compatible with protecting a naturally eutrophic wetland system.

EPA (1990) published national guidance for water quality standards for wetlands that includes guidance for use designation. These guidelines together with antidegredation procedures could be used to classify and protect the water quality of Rocky Ford Creek.

Conclusions and Recommendations

- Rocky Ford Creek is listed on the 303(d) list as not meeting Class A water quality criteria for dissolved oxygen, pH, and temperature. The survey data collected for this project support the listings for dissolved oxygen and temperature.

- Plant productivity and decomposition in Rocky Ford Creek and its adjacent wetlands are the cause for dissolved oxygen criteria violations and also may be the cause of reported pH violations. Temperature violations are due to natural conditions (i.e., warm air temperatures and little stream shading). As a result, the creek should be delisted for temperature.

- Historical and survey data collected for this project show that the concentration of nutrients are high in Rocky Ford Creek. The source of the high phosphorus and nitrogen concentrations in the creek are mostly from groundwater feeding Rocky Ford Creek. Agricultural land management practices in upper Crab Creek are the most likely source of the high nutrient concentration in the groundwater.

- The percent nutrient contribution of the fish hatcheries to Rocky Ford Creek and to Moses Lake can vary significantly based on the creek flow, the creek nutrient concentration, and the feed pounds fed to the hatchery fish.

- A direct quantitative link between nutrient loading, concentrations in the water column, and dissolved oxygen (or pH) levels in Rocky Ford Creek may not be possible to establish because of the nature of wetlands and rooted submerged plants. However, setting qualitative nutrient loading limits should be considered.

- Nutrient allocations based on the Moses Lake nutrient TMDL recommendations may be necessary to ensure that the nutrient contributions from Rocky Ford Creek do not cause an adverse impact on lake water quality. This potential allocation should require that both groundwater and fish hatchery nutrient contributions be reduced. (The Moses Lake TMDL report is scheduled to be completed by December 30, 1998.)

- Nutrient limits for the fish hatcheries may need to be established to protect creek water quality. One possible way to establish these limits may be through hatchery production limits based on creek flow and pounds of fish food fed at the hatcheries.

- The expansion of the wetlands and recent flooding in the areas along the creek are more likely due to increased water availability and wetland successional processes rather than additional nutrient inputs. One method for controlling the expansion of the wetlands would be to maintain the integrity of the creek channel (e.g., dredging, re-introduce carp, remove detention pond)

- This report was prepared to evaluate the creek with respect to its Class A waterbody criteria designation. An important first step for managing the water quality of Rocky Ford Creek will be to establish specific beneficial uses for the creek, and establish an appropriate designation (i.e., should it be considered a wetland system and not subject to Class A waterbody criteria). The beneficial uses of the wetlands are not considered in the evaluation. The primary means for protecting water quality in wetlands is through implementing the antidegredation procedures (WAC 173-070), which may be in conflict with the current uses of the creek. For example, in order to protect the creek's use as a trout fly fishery, it should meet the Class A waterbody criteria. However, management actions to achieve this goal would not be compatible with protecting a wetland system which are naturally eutrophic.

- Violations of water quality criteria could be considered natural conditions if the system is considered and protected as a wetlands system.

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Figures

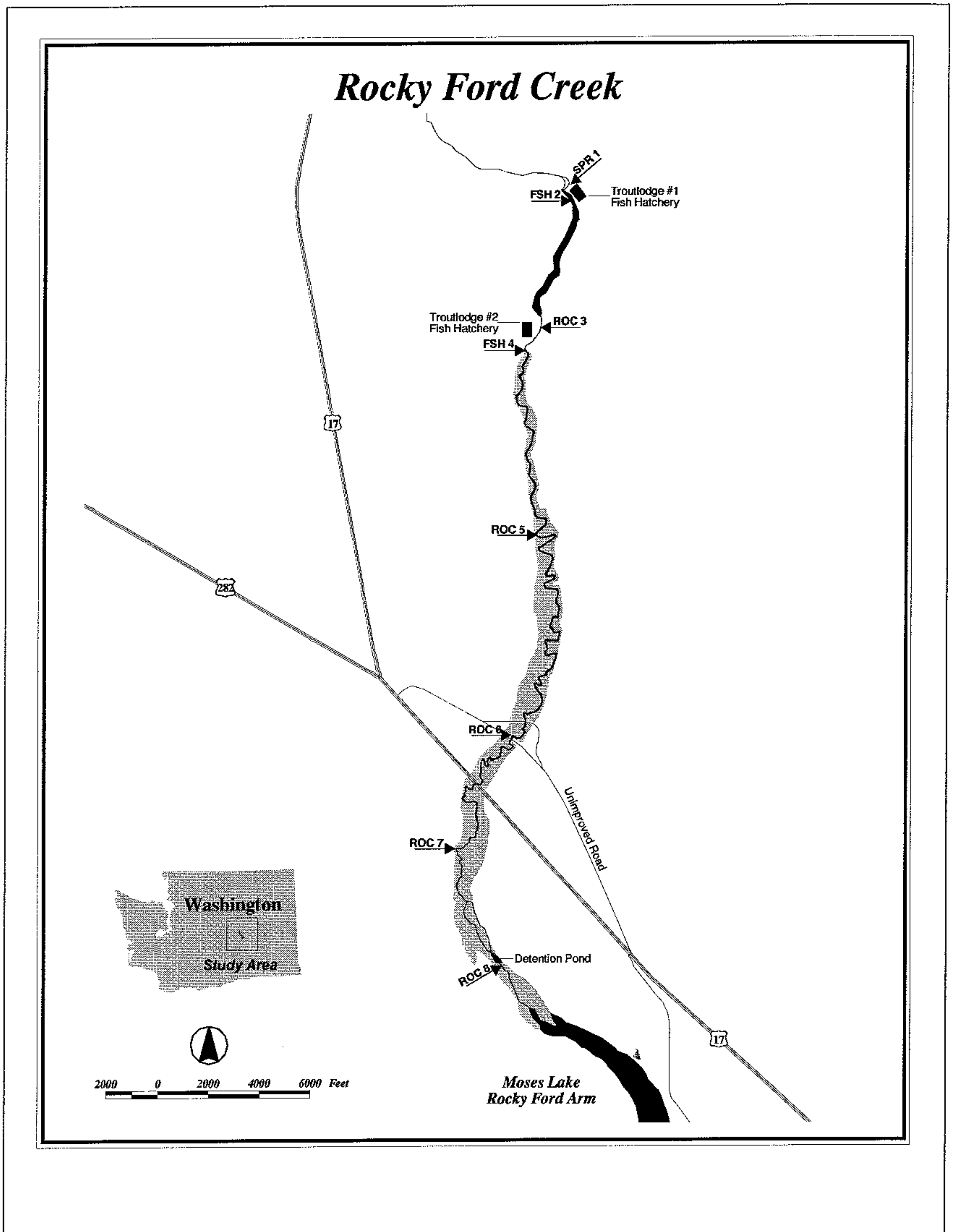


Figure 1. Study area map with sampling stations identified.

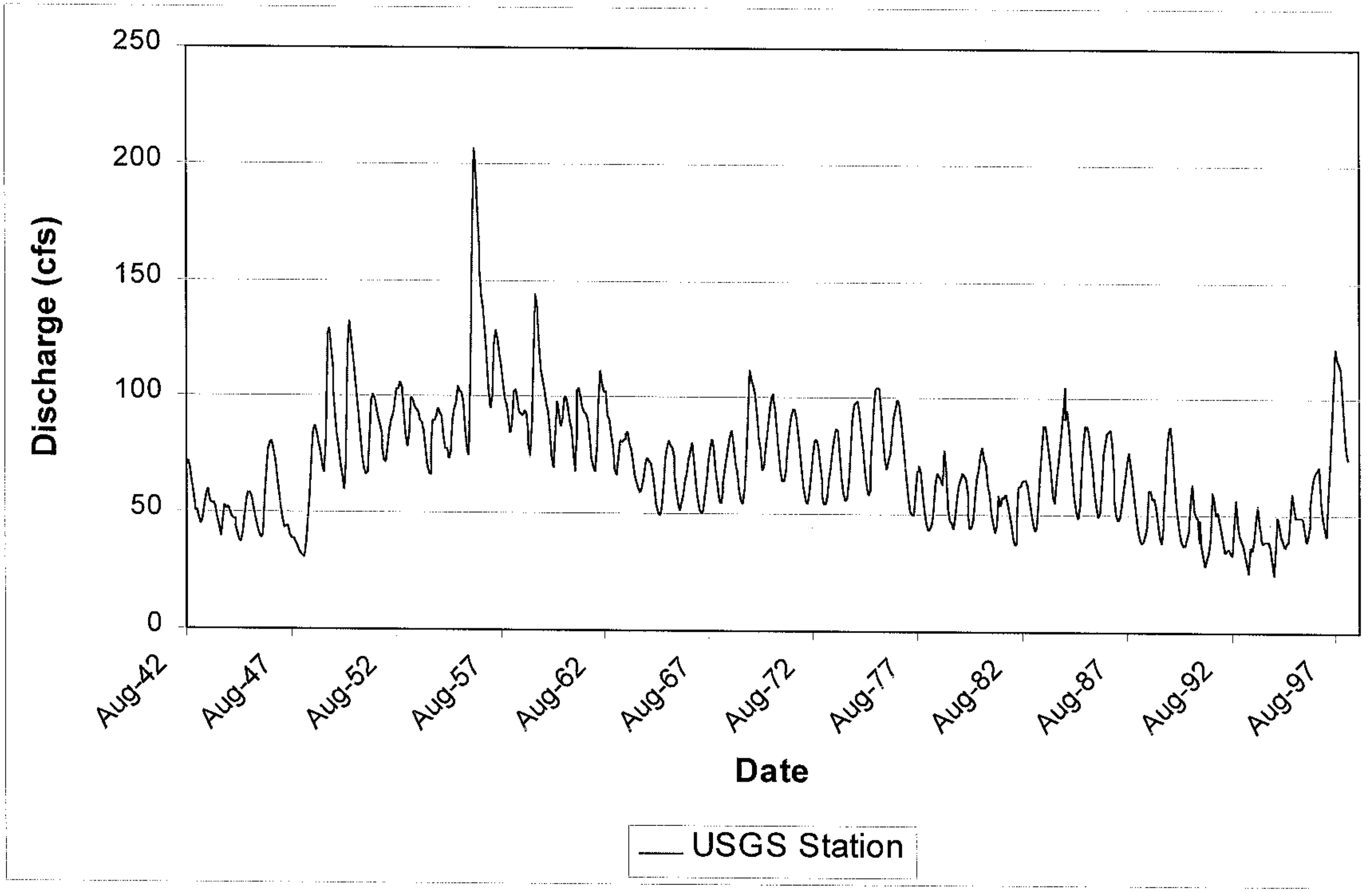


Figure 2. Rocky Ford Creek monthly mean flows from USGS station 12470500 data (from October 1991 through February 1998 monthly mean flows were estimated from bi-monthly data.

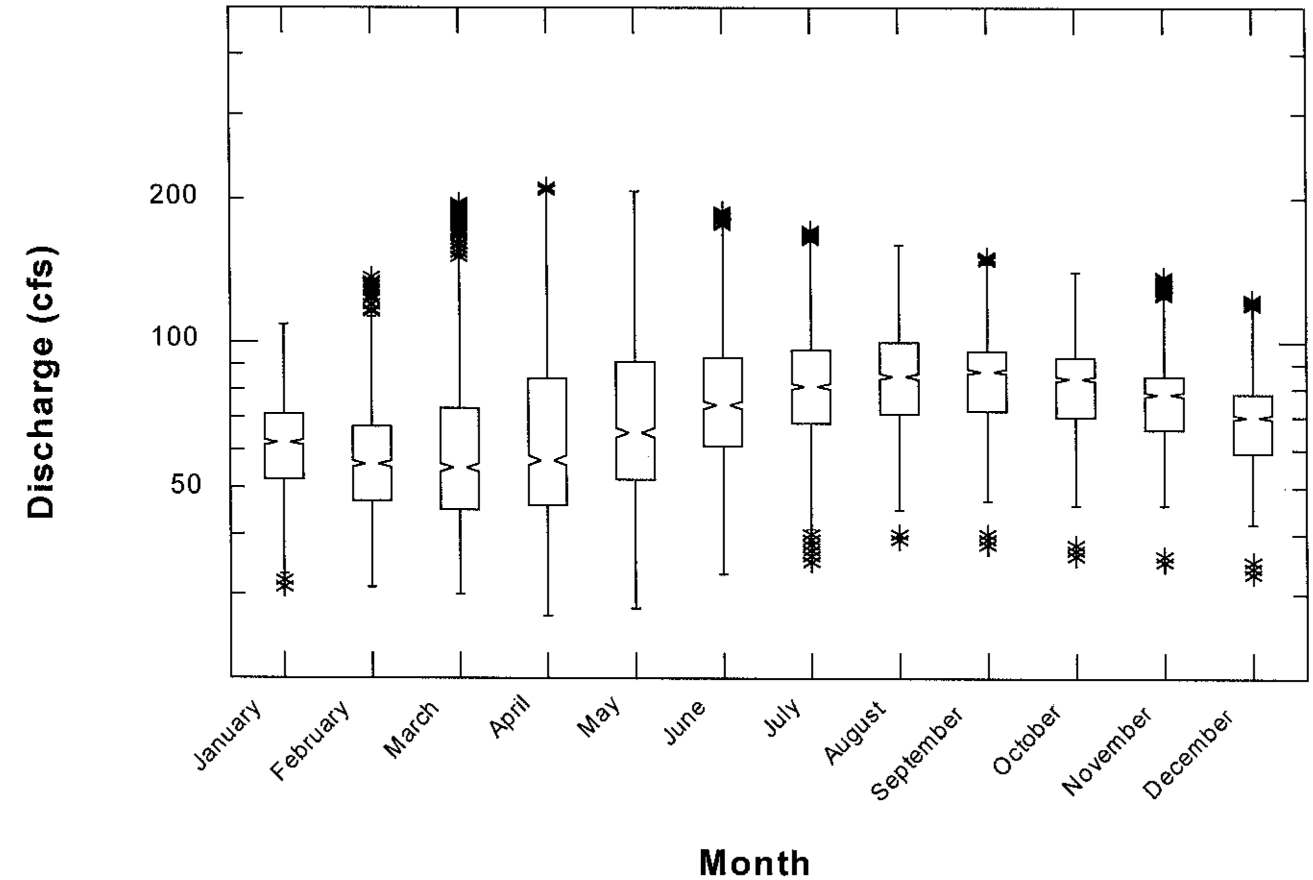


Figure 3. Box plots of daily flow for Rocky Ford Creek from USGS Station 127470500 data.

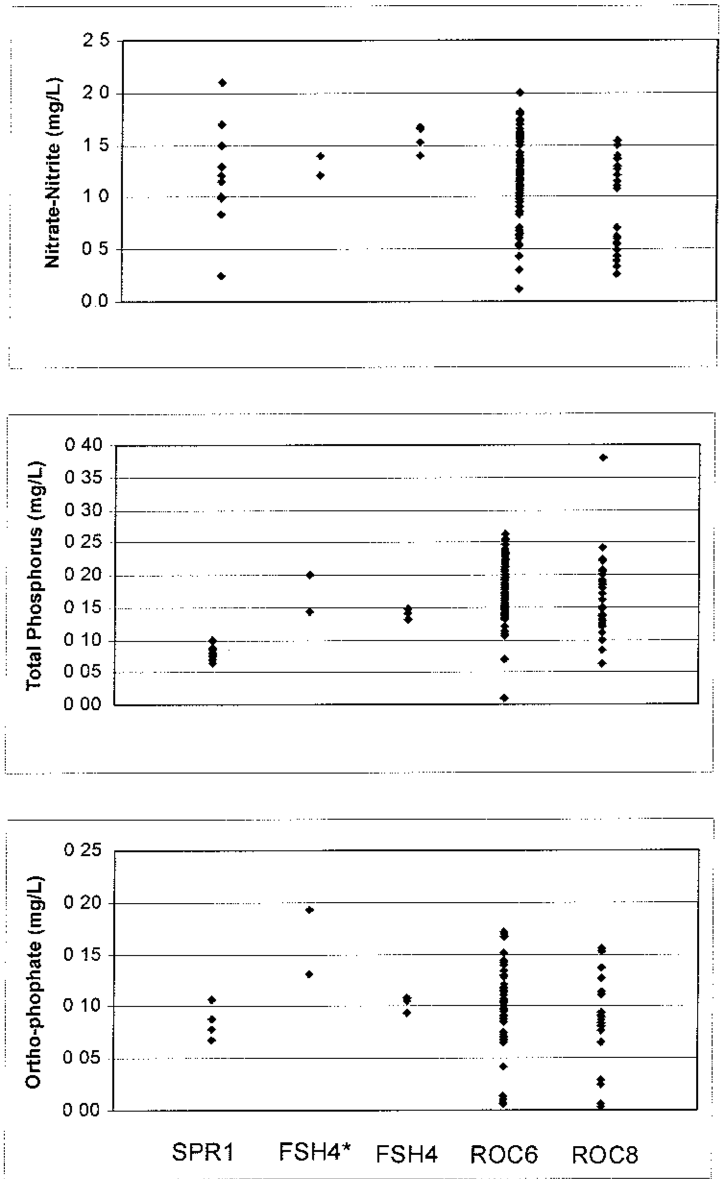


Figure 4. Historical nutrient data (Welch *et al.*, 1973; EPA, 1977; Kendra, 1986; Welch *et al.*, 1989; and Bain, 1993). (The FSH4* data was collected from the fish hatchery discharge.)

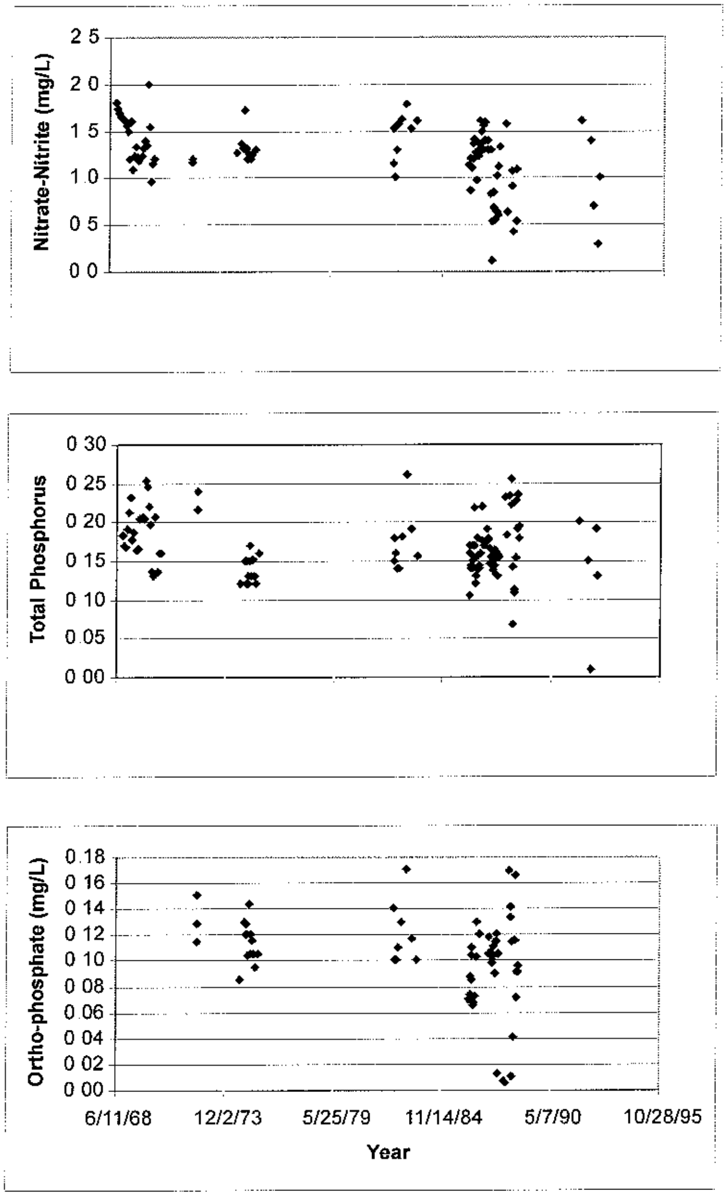


Figure 5 Historical nutrient data for ROC6 (Welch *et al.*, 1973; EPA, 1977; Kendra, 1986; Welch *et al.*, 1989; and Bain, 1993)

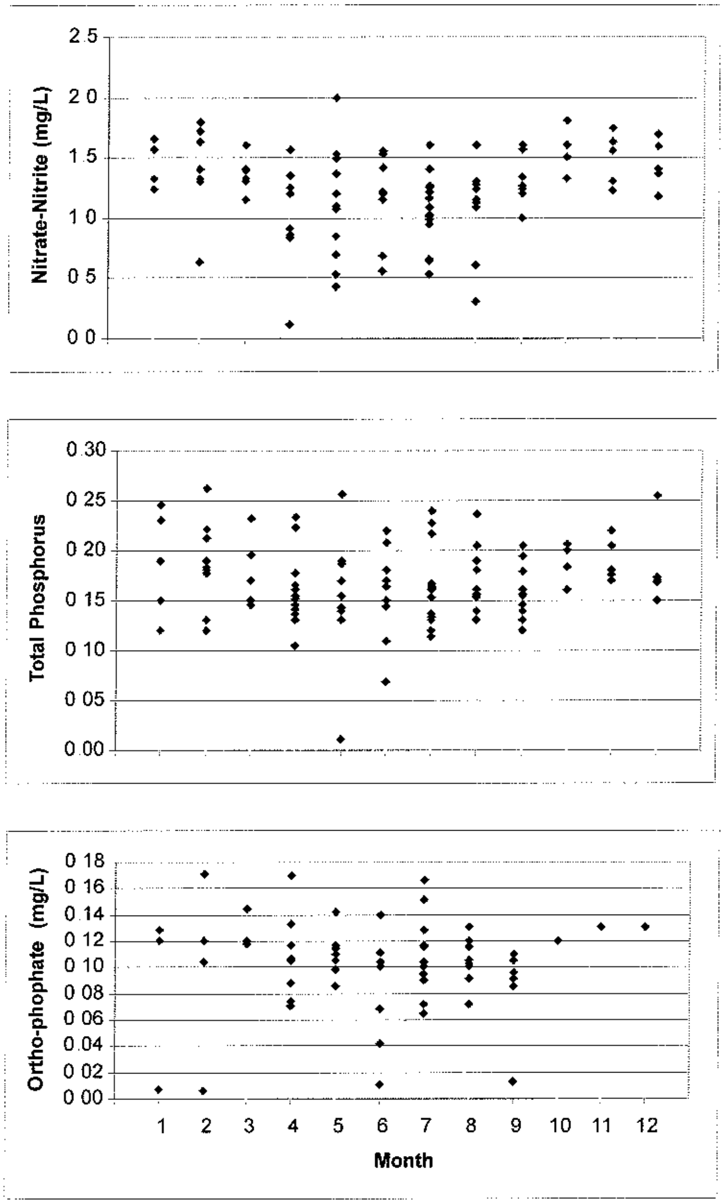


Figure 6 Historical nutrient data for ROC6 by month (Welch *et al*, 1973; EPA, 1977; Kendra, 1986; Welch *et al.*, 1989; and Bain, 1993).

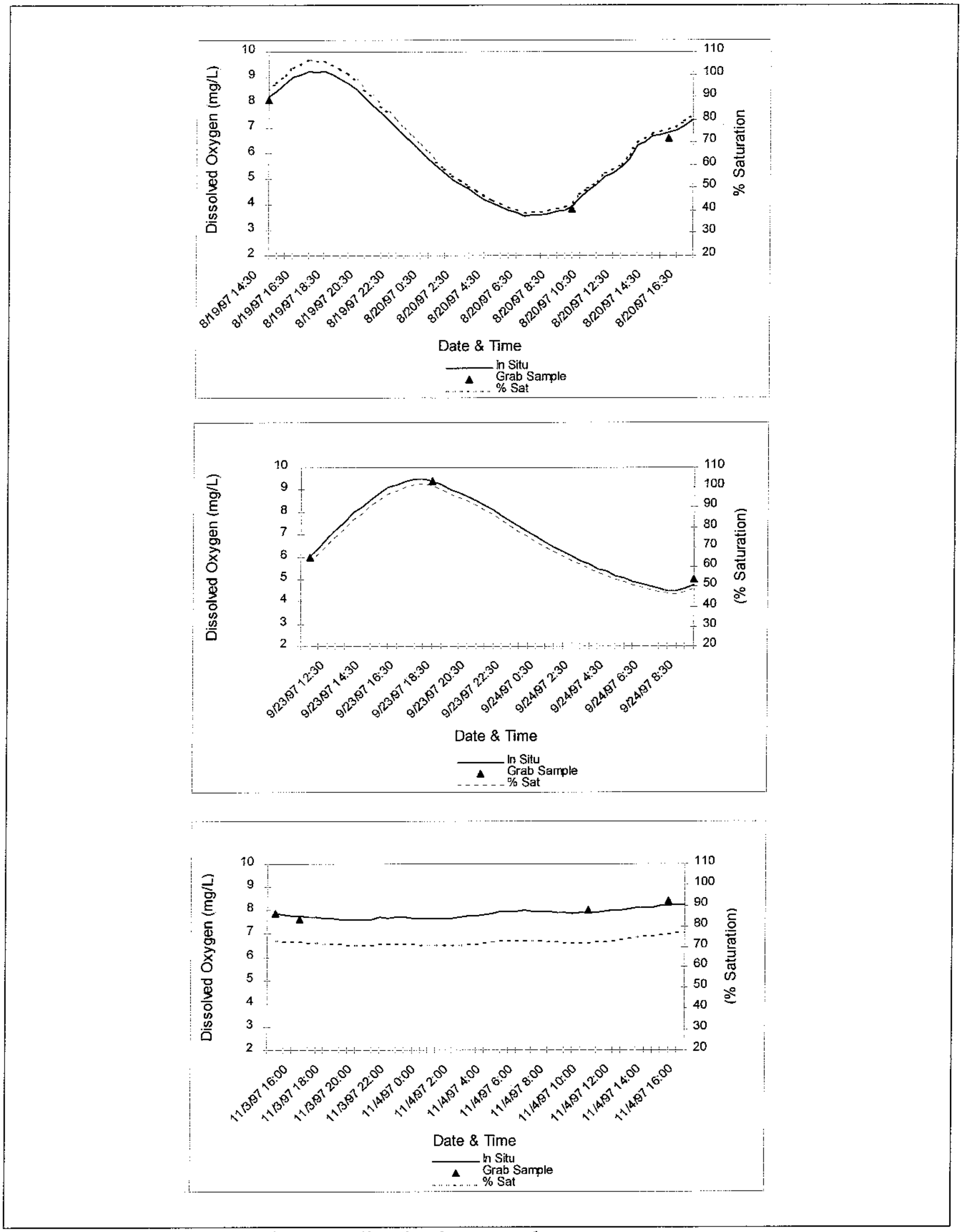


Figure 7. Rocky Ford Creek *in situ* dissolved oxygen data.

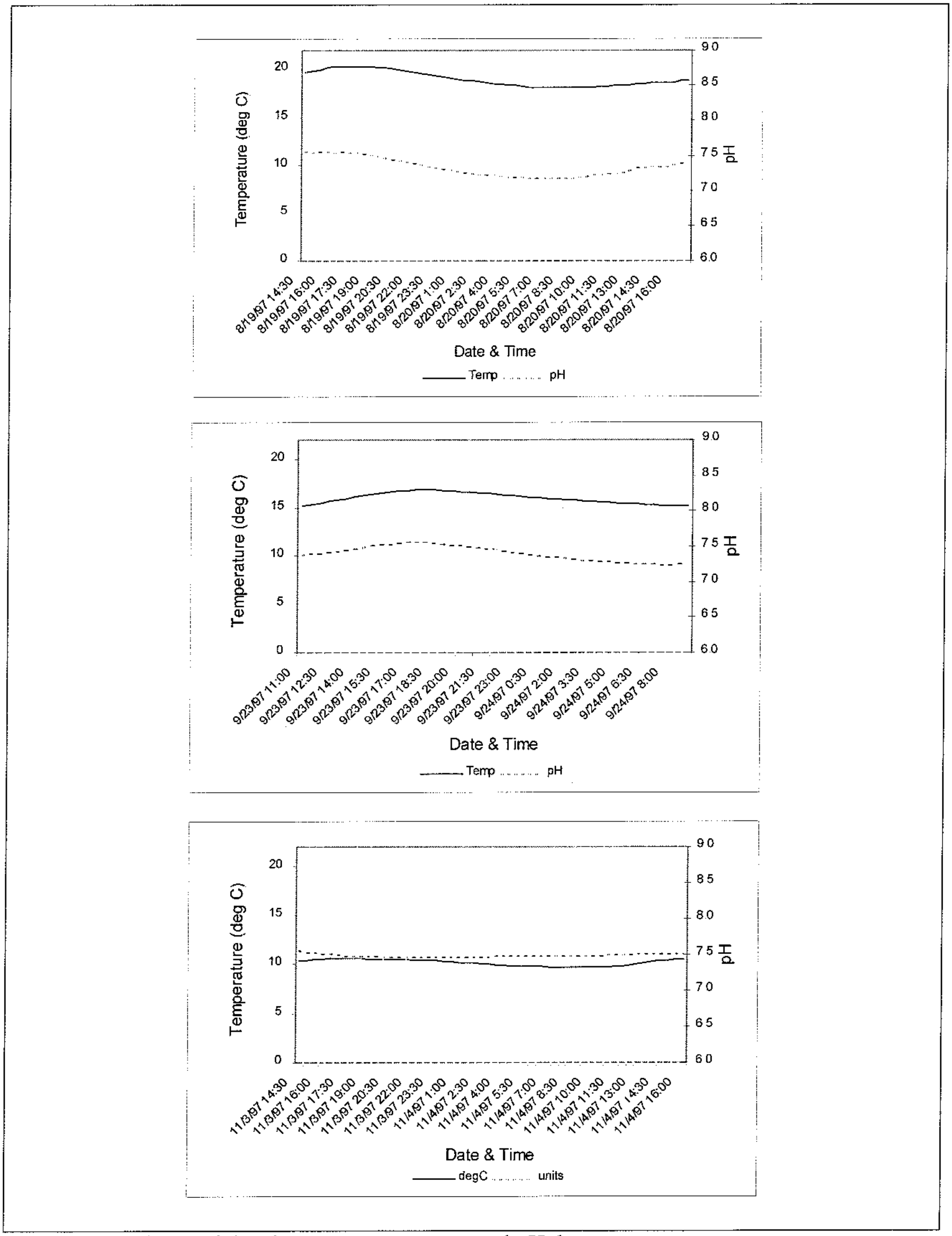


Figure 8. Rocky Ford Creek *in situ* temperature and pH data

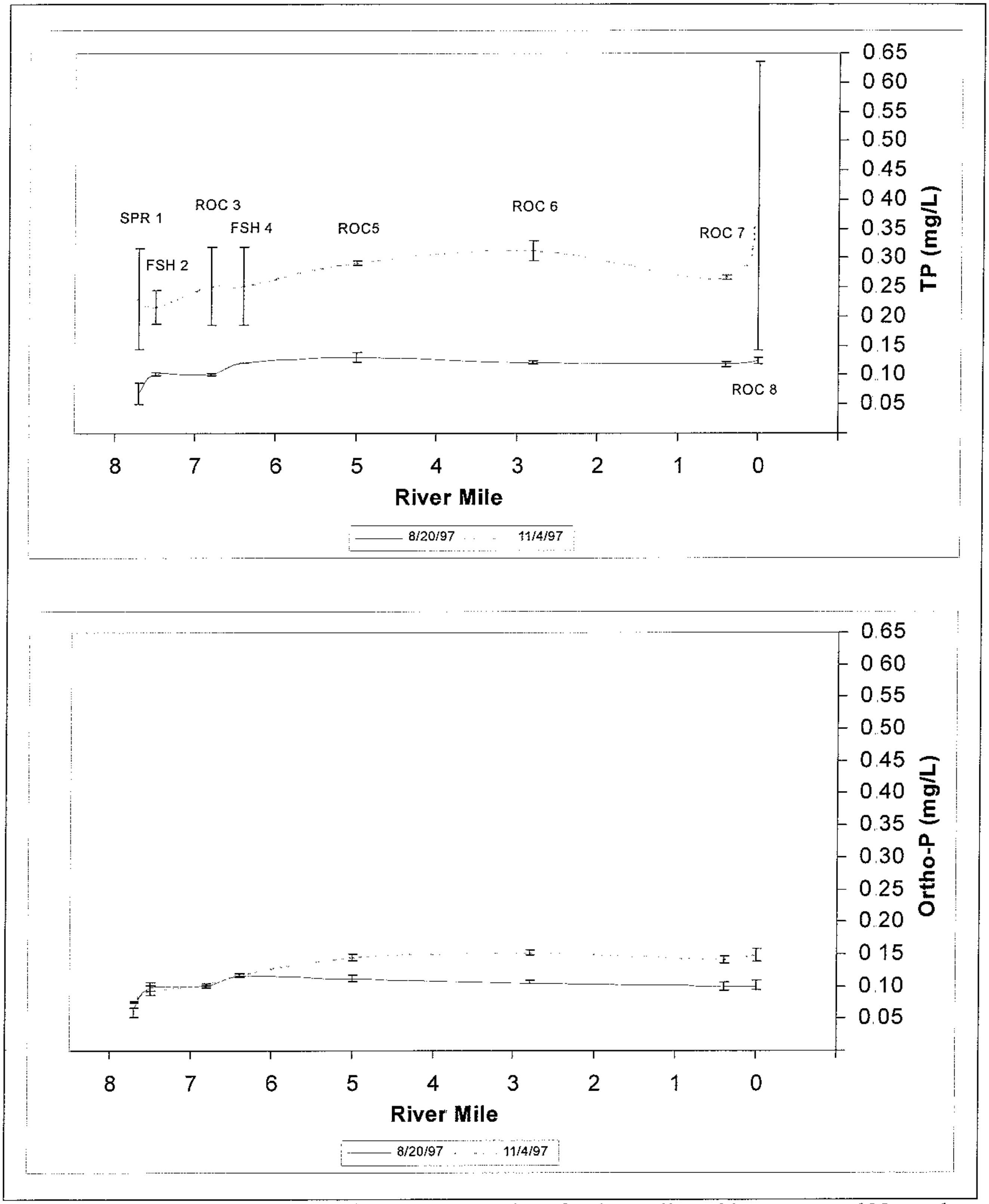


Figure 9. Rocky Ford Creek phosphorus concentrations for data collected in August and November 1997.

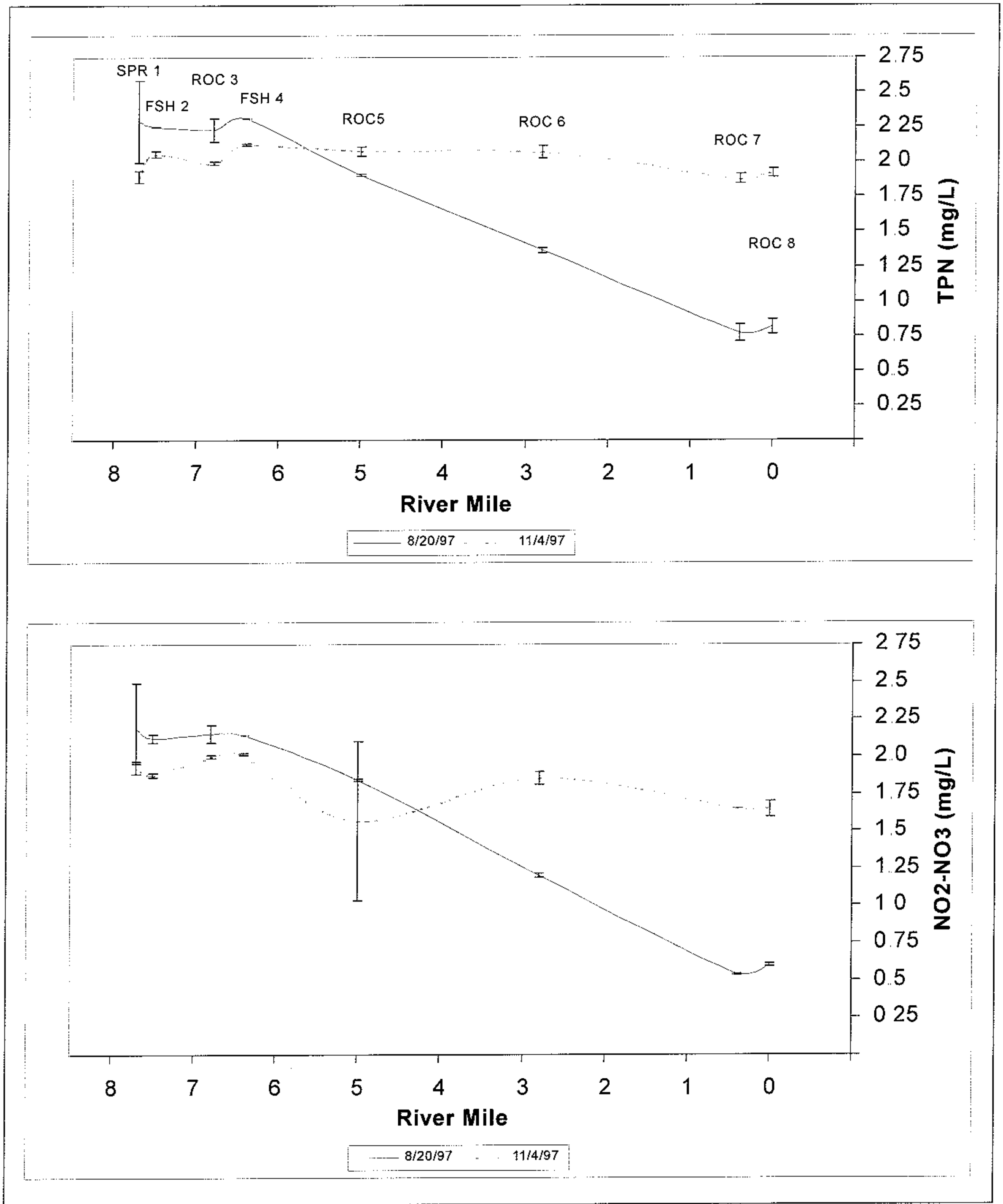


Figure 10. Rocky Ford Creek nitrogen concentrations for data collected in August and November 1997.

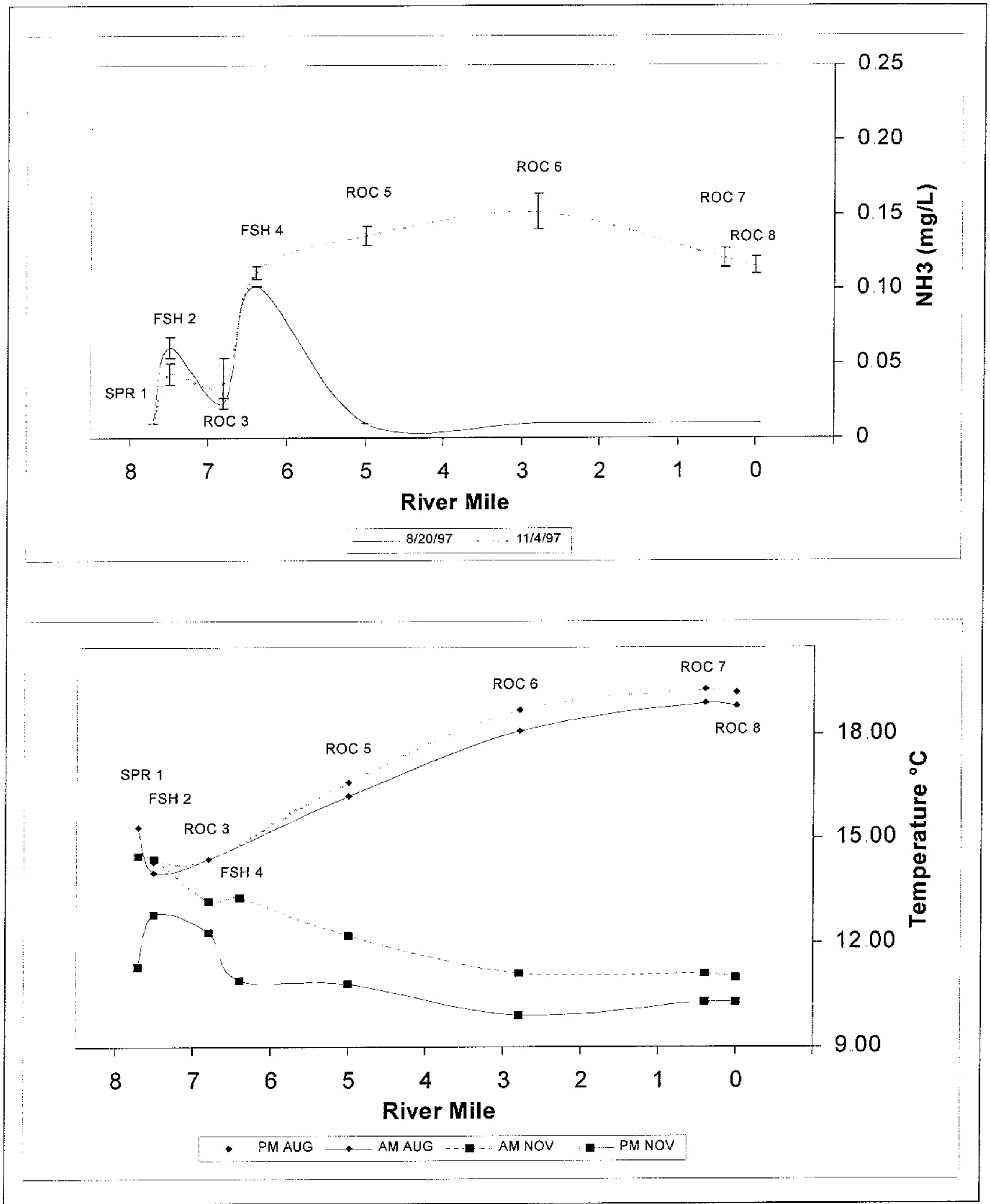


Figure 11 Rocky Ford Creek ammonia concentrations and temperature for data collected in August and November 1997

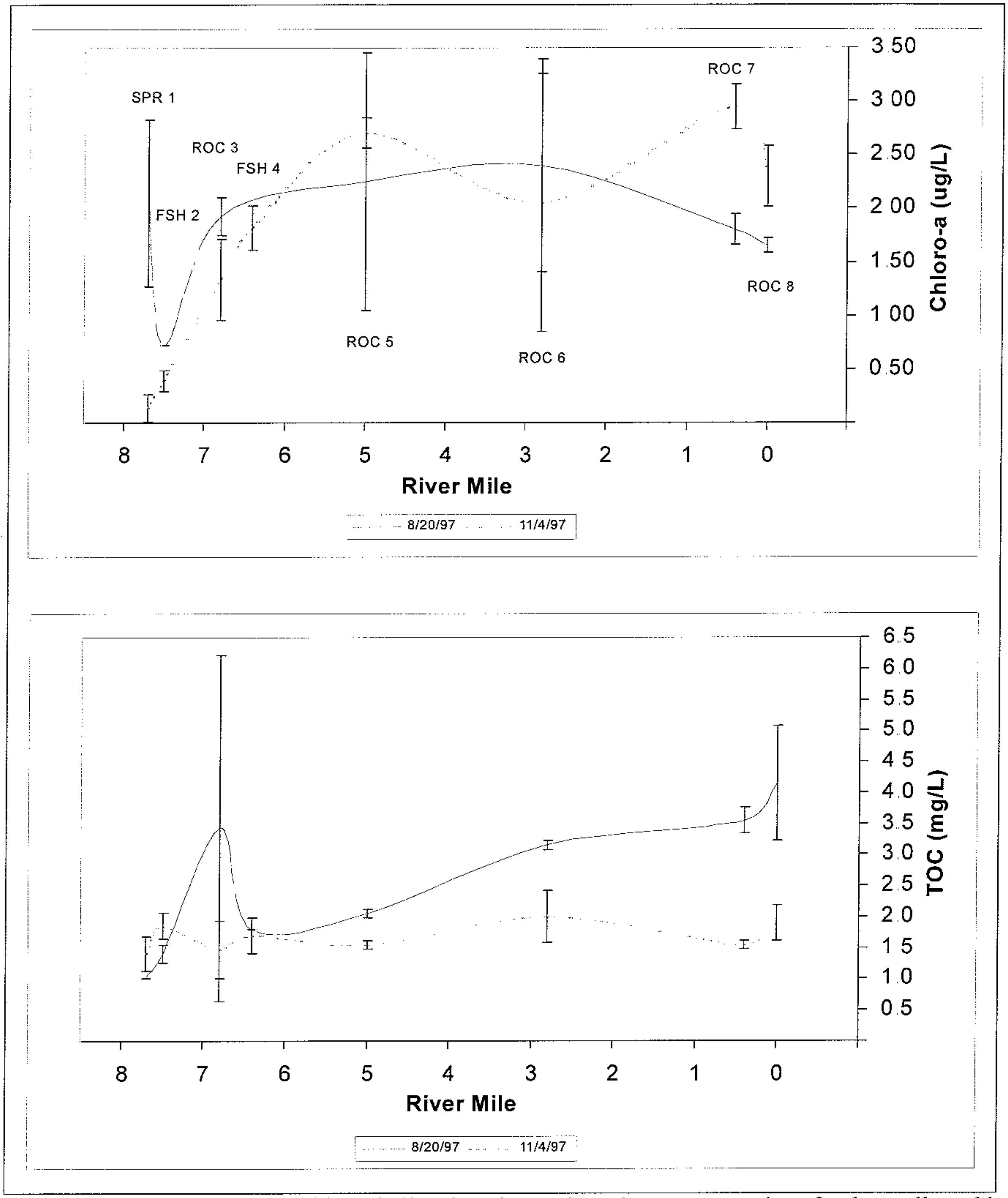


Figure 12. Rocky Ford Creek chlorophyll and total organic carbon concentrations for data collected in August and November 1997

Tables

Table 1. Statistics for historical data

The following results are for: SPR1

	ORTH-P	TP	NO3NO2
N of cases	5	11	11
Minimum	0.067	0.065	0.025
Maximum	0.106	0.100	2.100
Mean	0.085	0.079	1.209
95% CI Upper	0.103	0.086	1.568
95% CI Lower	0.067	0.073	0.850
Standard Dev	0.015	0.009	0.534

The following results are for: FSH4*

	ORTH-P	TP	NO3NO2
N of cases	2	2	2
Minimum	0.131	0.142	1.208
Maximum	0.193	0.199	1.400
Mean	0.162	0.170	1.304
95% CI Upper	0.556	0.533	2.524
95% CI Lower	-0.232	-0.192	0.084
Standard Dev	0.044	0.040	0.136

The following results are for: FSH4

	ORTH-P	TP	NO3NO2
N of cases	4	4	4
Minimum	0.093	0.132	1.399
Maximum	0.108	0.148	1.672
Mean	0.100	0.142	1.562
95% CI Upper	0.112	0.154	1.767
95% CI Lower	0.088	0.130	1.356
Standard Dev	0.008	0.007	0.129

The following results are for: ROC6

	ORTH-P	TP	NO3NO2
N of cases	65	109	96
Minimum	0.006	0.010	0.118
Maximum	0.171	0.262	2.000
Mean	0.103	0.167	1.230
95% CI Upper	0.112	0.175	1.301
95% CI Lower	0.095	0.160	1.159
Standard Dev	0.034	0.040	0.350

The following results are for: ROC8

	ORTH-P	TP	NO3NO2
N of cases	24	35	27
Minimum	0.003	0.061	0.264
Maximum	0.155	0.380	1.542
Mean	0.085	0.162	0.994
95% CI Upper	0.101	0.182	1.159
95% CI Lower	0.068	0.141	0.830
Standard Dev	0.040	0.059	0.415

Table 2. Sampling schedule for synoptic sampling surveys on August 19-20 and November 4-5, 1997.

Station	Temp.	pH	Cond.	D.O.	FC	Nut 5[a]	TPN	TOC	Cl	Chloro *a*[b]	UBOD[b]
SPR1	X	X	X	X	X	X	X	X	X	X	
FSH2	X	X	X	X	X	X	X	X	X	X	X
ROC3	X	X	X	X	X	X	X	X	X	X	
FSH4	X	X	X	X	X	X	X	X	X	X	X
ROC5	X	X	X	X	X	X	X	X	X	X	
ROC6	X	X	X	X	X	X	X	X	X	X	
ROC7	X	X	X	X	X	X	X	X	X	X	
ROC8	X	X	X	X	X	X	X	X	X	X	

[a]Nut 5 = Ammonia, Nitrate-Nitrite, Nitrite, Ortho-Phosphate, Total Phosphorus

[b]Collected during the August survey, and during a high fish production period at the hatcheries (not yet determined)

Table 3. Summary of field and laboratory measurements of water and sediment, target detection limits, and methods.

Parameter	Precision Limit (for field measurements and turbidity) or Reporting Limit (all others)	Method[a]
Field Measurements		
Velocity	±0 05 f/s	Current Meter
pH	±0 1 SU	Field Meter/Electrode
Temperature	±0 2 °C	Alcohol Thermometer
Dissolved Oxygen	±0.06 mg/L	Gas Probe/Winkler Titration
Specific Conductivity	±20 µmhos/cm	Field Meter/Conductivity Bridge
General Chemistry		
Fecal coliform	2 cfu/100 Ml	SM 18 Membrane Filter 9222D
Ammonia nitrogen	0.01 mg/L	EPA 350.1
Nitrate + nitrite nitrogen	0 01 mg/L	EPA 353 2
Total persulfate nitrogen	0.01 mg/L	SM 4500 NO3-F Modified
Orthophosphate	0.01 mg/L	EPA 365.3
Total phosphorus	0 01 mg/L	EPA 365.3
Chloride	0 1 mg/L	EPA 300 0
Chlorophyll *a*	0.05 µg/L	SM 10200H(3), Fluorometer
Ultimate Biochemical Oxygen Demand (UBOD)	2 mg/L	NCASI

[a] For method reference see MEL 1994.

Table 4. The total phosphorus and nitrogen contributions of the spring and fish hatcheries to Rocky Ford Creek, and the contribution of the creek to Moses Lake based on average 1997 survey data.

Station Location	Creek Flow	Total Phosphorus		Total Persulfate Nitrogen		Total Organic Carbon	
	ft^3/sec	lb./day	%[a]	lb./day	%[a]	lb./day	%[a]
Spring Concentration at SPR1	115	81.2	NA	1326.5	NA	712.8	NA
Combined Hatchery Contribution (FSH2 + FSH4)	115	16.7	21	86.8	7	-309.9	-44
Total Creek Contribution to Moses Lake (at ROC8)	138	168.1	10	922.2	9	2447.2	-13

[a]Percent contribution of hatcheries

Table 5. The total phosphorus and nitrogen contributions of the fish hatcheries based on estimated 1997 and maximum fish production levels.

Location	Creek flow	1997 Production[a]				Maximum Production[b]			
		Total Phosphorus		Total Persulfate Nitrogen		Total Phosphorus		Total Persulfate Nitrogen	
Hatchery Contribution at FSH4	ft^3/sec	%	lbs/day	%	lbs/day	%	lbs/day	%	lbs/day
90% Flow	103	23.0	16.7	7.3	86.8	80.1	58.3	25.4	302.3
50% Flow	78.2	30.3	16.7	9.4	86.8	105.5	58.3	32.7	302.3
10% Flow	52.8	44.9	16.7	14.2	86.8	156.4	58.3	49.5	302.3
Hatchery Contribution at ROC8									
90% Flow	123.6	11.1	16.7	10.5	86.8	38.6	58.3	36.6	302.3
50% Flow	93.8	14.7	16.7	13.8	86.8	51.0	58.3	48.0	302.3
10% Flow	64.4	21.5	16.7	20.2	86.8	74.9	58.3	70.2	302.3

[a]Based on a 60,000-lbs/month Troutlodge estimate of the amount of fish food fed at each hatchery in 1997.
[b]Based on a monthly average of the estimated yearly pounds of fish food fed at each hatchery at maximum production. Information was taken from NPDES waste discharge permit application forms.

Table 6. Estimated annual total phosphorus and nitrogen budget for Rocky Ford Creek based on 1997 survey data and annual average creek flow.

Location	Total Phosphorus Annual Budget (lbs/year)			Total Nitrogen Annual Budget (lbs/year)		
	Inputs	Exported	Retained	Inputs	Exported	Retained
Spring	20,154			329,232		
Hatcheries	6,096			31,682		
Atmosphere	110			4,473		
Ground Water	4,031			65,846		
Total	30,391	41,723	-11,332	431,233	228,923	202,310

Table 7. Soil/Sediment mean nutrient data.

Soil Sediment Zone	Bulk Density		Dissolved Nutrients							Total Nutrients				
				NH3		NO3		Ortho-P			TN		TP	
	n	(g/ml)	n	(mg/g)	(lbs/ft^3)	(mg/g)	(lbs/ft^3)	(mg/g)	(lbs/ft^3)	n	(mg/g)	(lbs/ft^3)	(mg/g)	(lbs/ft^3)
Ephratic[a]	3	0.970	3	0.0025	0.00015	0.0016	0.000096	0.0263	0.00157	2	1.7361	0.096	0.735	0.043
Rush[b]	10	0.751	10	0.0051	0.00021	0.0072	0.000314	0.0279	0.00132	3	5.8889	0.227	1.41	0.057
Cattail[b]	9	0.466	9	0.039	0.00106	0.0027	0.000078	0.0157	0.00045	3	6.74	0.192	0.92	0.027
Creek[c]	6	0.504	6	0.0883	0.00240	0.0029	0.000100	0.0403	0.00131	3	4.0518	0.133	1.0466	0.038

[a]Soil samples were taken from the upland area adjacent to the Rocky Ford Creek wetland.
[b]Sediment samples were taken from the identified macrophyte zones of the Rocky Ford Creek wetland.
[c]Sediment samples were taken from the stream channel of Rocky Ford Creek located within the wetland.

Table 8. Estimated storage of nutrients in the wetland and creek channel.

Location	Storage/Soil-Sediment	Annual Input	Storage/Input
	(lbs.)	(lbs.)	(years)
TP in Wetland	1,018,951	41,723	33.5
TP in Creek Channel	121,365	41,723	4.0
TN in Wetland	5,082,625	228,923	11.8
TN in Creek Channel	424,778	228,923	1.0

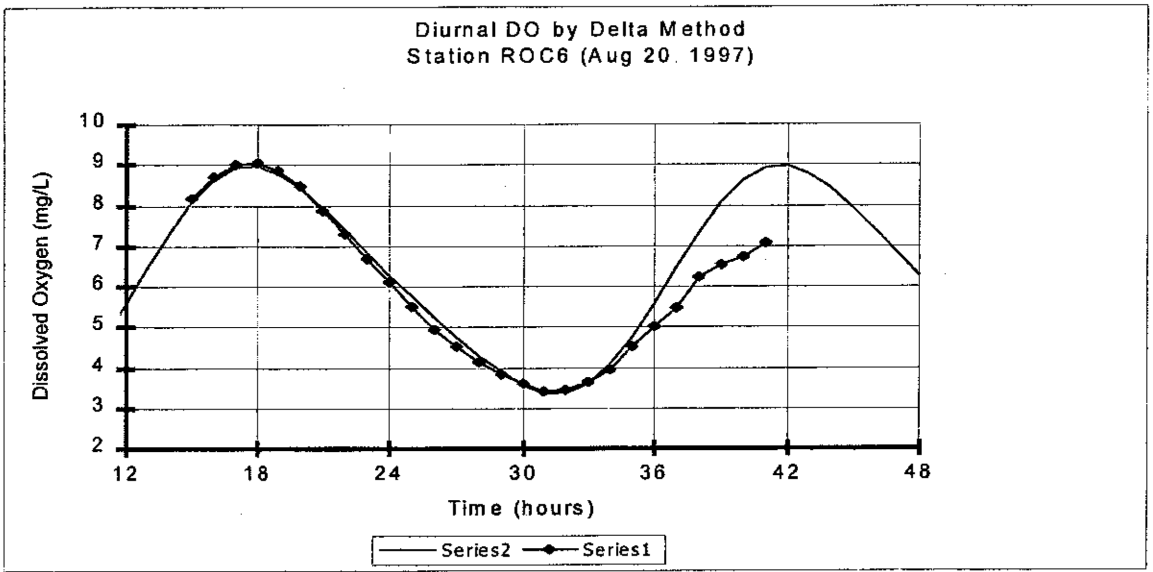
Appendices

Appendix A. Laboratory and field measurements for samples collected August 20 and November 4, 1997

Date	LAB ID	Station ID	Time (Hour)	Cond (umhos/cm)	Temp (C°)	DO (mg/L)	DO Sat'n %	pH (S.U.)	TPN (mg/L)	NH3 (mg/L)	NO2 (mg/L)	NO2-NO3 (mg/L)	TP (mg/L)	Ortho-P (mg/L)	TOC (mg/L)	BOD 35 (mg/L)	Chloro-a (ug/L)	Chloride (mg/L)	Pheo a (ug/L)	E coli (#/100mL)	F C (#/100mL)
8/20/97	97348130	SPR1	07:30	230	15.3	-		7.24	2.08	0.01 U	0.01 U	1.97	0.081	0.075	1 U	-	2.6	5.7	1.5	-	-
8/20/97	97348131	SPR1	12:45	270	-	9.49	-	7.63	2.50	0.01 U	0.01 U	2.40	0.056	0.056	1 U	-	1.5	4.79	0.44	170	170
8/20/97	97348132	FSH2	07:45	285	14.0	8.01	80.8	7.42	2.25	0.066	0.01 U	2.14	0.103	0.103	1.5	0.85	-	6.1	-	-	-
8/20/97	97348133	FSH2	14:30	380	14.3	8.98	91.1	7.76	2.25	0.056	0.01 U	2.10	0.10	0.094	1.3		0.72	6.46	0.77	10	10
8/20/97	97348134	ROC3	08:22	350	14.4	7.34	78.8	7.49	2.29	0.021	0.01 U	2.19	0.10	0.101	5.4	-	1.8	6.88	2	-	-
8/20/97	97348135	ROC3	13:45	370	14.9	10.67	108.5	7.83	2.15	0.026	0.01 U	2.16	0.099	0.102	1.5	-	1.9	6.71	1.9	6	6
8/20/97	97348136	ROC3	13:55	-	-	-	-	-	2.19	0.026	0.01 U	2.05	0.104	0.094	1.4	-	2.2	6.42	1.7	8	8
8/20/97	97348137	FSH4	12:00	-	-	-	-	-	2.50	0.20	0.01 U	2.09	0.148	0.13	2.1	0.85	-	6.38	-	-	-
8/20/97	97348138	FSH4	12:45		-	-	-	-	-	-	-	-	-	-	-	0.85	-	-	-	-	-
-	-	FSH4*	-	-	-	-	-	-	2.31	0.102	0.0102	2.138	0.121	0.115	1.8		-	6.59		-	-
8/20/97	97348139	ROC5	09:10	370	16.2	6.43	71.6	7.55	1.91	0.01 U	0.032	1.83	0.136	0.109	2		3.1	6.46	3.6	-	-
8/20/97	97348140	ROC5	15:15	360	16.6	12.09	128.9	8.1	1.90	0.01 U	0.032	1.84	0.125	0.113	2.1	-	1.4	6.43	1.6	13	13
8/20/97	97348141	ROC6	09:47	370	18.1	3.88	42.7	7.51	1.38	0.01 U	0.01 U	1.21	0.12	0.104	3.1	-	3.1	6.59	3.2	-	-
8/20/97	97348142	ROC6	15:50	390	18.7	6.73	74.9	7.68	1.35	0.01 U	0.01 U	1.19	0.123	0.105	3.2	-	1.7	6.59	3	53	53
8/20/97	97348143	ROC7	10:15	395	18.9	3.98	44.5	7.54	0.811	0.01 U	0.01 U	0.538	0.115	0.104	3.7	-	1.7	6.29	2.6	-	
8/20/97	97348144	ROC7	16:35	375	19.3	4.9	55.2	7.55	0.728	0.01 U	0.01 U	0.536	0.121	0.095	3.4	-	1.9	6.47	2.9	37	43
8/20/97	97348145	ROC8	10:30	385	18.8	5.2	58.0	7.61	0.853	0.01 U	0.01 U	0.605	0.128	0.103	4.8	-	1.7	6.17	3.4	-	-
8/20/97	97348146	ROC8	16:55	380	19.2	5.81	65.3	7.73	0.766	0.01 U	0.01 U	0.591	0.123	0.101	3.7	-	1.7	6.16	3.1	-	-
8/20/97	97348147	ROC8	17:00	-	-	-	-	-	0.785	0.01 U	0.01 U	0.598	0.119	0.092	3.3	-	1.5	6.43	3.3	27	27
11/4/97	97458080	SPR1	07:30	355	11.9	9.55	91.9	7.57	1.86	0.01 U	0.01 U	1.96	0.292	0.076	1.6	-	0.05 UJ	3.96	0.05 UJ	2	2
11/4/97	97458081	SPR1	12:45	380	14.5	9.5	96.8	7.55	1.92	0.01 U	0.01 U	1.95	0.169	0.075	1.2	-	0.23	4.09	0.14	1	1
11/4/97	97458082	FSH2	08:00	335	12.8	8.7	85.4	7.7	2.04	0.038	0.01 U	1.88	0.237	0.088	2	-	0.46	6.09	0.58	-	-
11/4/97	97458083	FSH2	13:35	370	14.4	9.6	97.6	7.79	2.07	0.05	0.01 U	1.86	0.196	0.099	1.7	-	0.32	5.49	0.48	0	1 U
11/4/97	97458084	ROC3	08:40	370	12.3	8.6	83.5	7.64	1.98	0.049	0.012	2.00	0.30	0.106	1.8	-	1.6	6.29	2.6	-	-
11/4/97	97458085	ROC3	08:40	-	-	-	-	-	2.02	0.026	0.01 U	1.93	0.182	0.101	1.2	-	1.2	6.28	2	1	1
11/4/97	97458086	ROC3	13:05	390	13.2	10.45	103.5	7.81	1.98	0.024	0.011	2.04	0.229	0.101	1.1	-	0.94	6.26	1.9	3	3
11/4/97	97458087	FSH4	08:30	355	10.9	7	65.8	7.49	2.30	0.197	0.03	2.00	0.296	0.137	2		2.4	6.36	3.2	-	-
-	-	FSH4*	-	363	11.7	7.9	75.7	-	2.130	0.114	0.0199	2.010	0.299	0.120	1.9	-	1.96	6.35	2.87	-	
11/4/97	97458088	FSH4	13:45	380	13.3	8.55	84.9	8.04	2.29	0.215	0.014	2.00	0.175	0.132	2		2.6	6.32	3	2	2
-	-	FSH4*	-	386	13.24	9.62	95.4	-	2.116	0.108	0.0123	2.02	0.205	0.115	1.5		1.67	6.29	2.38	-	
11/4/97	97458089	ROC5	09:45	375	10.8	8.3	77.9	7.92	2.05	0.131	0.022	1.19	0.294	0.149	1.6	-	2.6	6.57	3.5	-	-
11/4/97	97458090	ROC5	14:35	390	12.2	9.55	92.5	8.04	2.10	0.14	0.018	1.94	0.289	0.141	1.5	-	2.8	6.47	3 J	5	5
11/4/97	97458091	ROC6	10:10	380	9.9	8	73.5	7.89	2.10	0.143	0.023	1.82	0.301	0.155	2.3	-	1.2	6.71	2.2	-	-
11/4/97	97458092	ROC6	15:15	390	11.1	8.4	79.3	7.85	2.04	0.16	0.022	1.88	0.325	0.149	1.7	-	2.9	6.7	4.8	16	21
11/4/97	97458093	ROC7	10:35	385	10.3	8.9	82.5	7.86	1.90	0.116	0.035	1.65	0.269	0.145	1.6	-	2.8	6.22	4.5	-	-
11/4/97	97458094	ROC7	15:35	385	11.1	9	85.0	7.92	1.85	0.125	0.034	1.65	0.264	0.137	1.5	-	3.1	6.3	5.7	13	17
11/4/97	97458095	ROC8	10:55	380	10.3	9.15	84.8	7.88	1.97	0.112	0.032	1.70	0.191	0.14	1.9	-	2.5	6.3	4.5	-	
11/4/97	97458096	ROC8	10:50	-	-	-	-	-	1.91	0.112	0.036	1.67	0.238	0.143	1.5	-	2.5	6.28	4.8	-	-
11/4/97	97458097	ROC8	15:55	395	11.0	9.4	88.6	7.9	1.90	0.12	0.038	1.61	0.564	0.155	2.1	-	2.1	6.15	3.8	11	14

J The analyte was positively identified. The associated numerical result is an estimate.
U The analyte was not at or above the reported limit.
UJ The analyte was not detected

Appendix B. **Estimated productivity based on diurnal dissolved oxygen concentrations.**



Model Values	
24	Enter period (24 hr)
6.100	Enter daily average DO (mg/L)
5.70	Enter Delta DO (mg/L)
4.00	Enter phi (time lag in hours from solar noon to max DO)
14.10	Enter photoperiod (hours)
0.9	Enter reaeration coeff (ka) from Figure 24.5 in Chapra text
0.47	Enter Delta/P from Figure 24.6 in Chapra text
6.00	Enter sunrise (hr)
13.1	Enter solar noon (hr)
20.3	Enter water temperature (degC)
1050	Enter elevation (ft NGVD)

Terms of equation 24.29 in Chapra (1997):

bn1 =	0.53
bn2 =	0.14
denom1 =	6.35
denom2 =	12.60
arctan1 =	1.43
arctan2 =	1.50
term1 =	6.28
term2 =	12.57

Appendix C.

Department of Ecology

September 28, 1997

TO: Bob Cusimano, HQ

FROM: Dennis Beich

SUBJECT: Rocky ford Creek

As promised, following is a list of the most common plants found proximate to the Rocky Ford Creek system. I've broken the vegetation list into three categories within the landscape. The first category would be open water (list compiled by Jenifer Parsons). Obviously, some of these plant communities will cross over

1. Open water
   - *Rorippa nastortiuva* - water cress
   - *Lemna minor* - duckweed
   - *Ceratophyllum demersum* - coontail
   - *Zannichellia palustris* - horned pondweed
   - *Sparganium* sp. - bur-reed (this ID is tentative, plants were not blooming)
   - *Potamogeton* sp. - thin leaved pondweed, no seeds for ID to species
   - *Polygonum* sp. - probably *P. amphibium,* (waterpepper) no flowers
   - *Carex* sp. - sedge, on shore
   - *Typha latifolia* - cattail, on shore
   - *Scirpus* sp. - bulrush, on shore

2. Immediate Shoreline
   - *Salix* sp. - willow
   - *Mimulus* sp. - monkey flower
   - *Polygonum* sp.
   - *Typha latifolia* - cattail
   - *Lythrum salicaria* - purple loose strife
   - *Oenanthe sarmantosa* - water parsley
   - *Atropa belladonna* - night shade
   - *Bidens cernoa* - nodding beggarticks
   - *Scirpus acutus* - hardstem bullrush

3. Wetland transition area to upland
   - *Scirpus pungens* - 3 square bullrush
   - *Scirpus maritimus*
   - *Juncus effusus*
   - *Juncus balticus*

Appendix C. (Cont'd)

Eleocharis palustris - spike rush
Lamiaceae uniflorus - water horehound
Carex sp. - two carex sp. that I have not had the time to identify to species;
Phalaris arundinacea - reed canary grass
Spartina gracilis - Alkali cordgrass
Muhlenbergia asperifolia - Alkali muhly
Polypogon monspeliensis - rabbit foot grass
Hordeum brachyantherum

This is by no means a complete plant list, but should give you a good grasp of the majority of the plant community.

One final note, when I went to have lunch out at the fish hatchery in their little park area, I noted some Phragmites communis growing in that area. If you get the opportunity you might ask them to kill it, as it has a tendency to take over the plant community once it gets started.

Stay in touch, and call me if you have any questions.

DB:sb
rockyfd.doc