Results

I. Seasonal Variability

Figure 14 showed the monthly rainfall for three weather stations located on the Eastern Shore of Virginia over the course of the study. These three stations were chosen because they cover the geographical scope of Virginia's Eastern Shore. This figure clearly illustrated the difference between the rainfall totals for the 1996 growing season and 1997 growing season. The total for the 1996 season was higher than average, with over fourteen inches of rainfall falling at the *Painter* station in July, the rainfall for the 1997 season was much less, with the *Painter* station receiving only five inches of rain in July, approximately a three-fold decrease in total accumulated rainfall for the month. The typical profile of monthly rainfall sums on the Eastern Shore would lie somewhere between the 1996 and 1997 values (US Department of Commerce, 1996c; US Department of Commerce, 1997c).

Other variations existed between the growing seasons of 1996 and 1997. The location of fields engaged in plasticulture changed significantly in the Gargathy Creek watershed. At least one field was taken out of tomato production and planted in soybeans. This was the field located on Kegotank Road and planted in tomatoes in 1996. Several fields in the Gargathy Creek watershed were put into tomato plasticulture in 1997, such as one field on Metompkin Road, and a field on Kegotank Road, across the road from the previous year's. All of these 1997 fields were located at least 100 yards farther away from Gargathy Creek's borders than the field that had been planted in 1996.

II. Time-independent Results

Figure 15 demonstrated the relationships between total copper, dissolved copper, total suspended solids, and rainfall for the Gargathy Creek sampling site at the Clam Company for all samples collected. Although these six plots could have been generated for all of the stations, only one station was necessary to illustrate the following point. Of the six relationships, only one appeared to exhibit a trend, the relationship between total

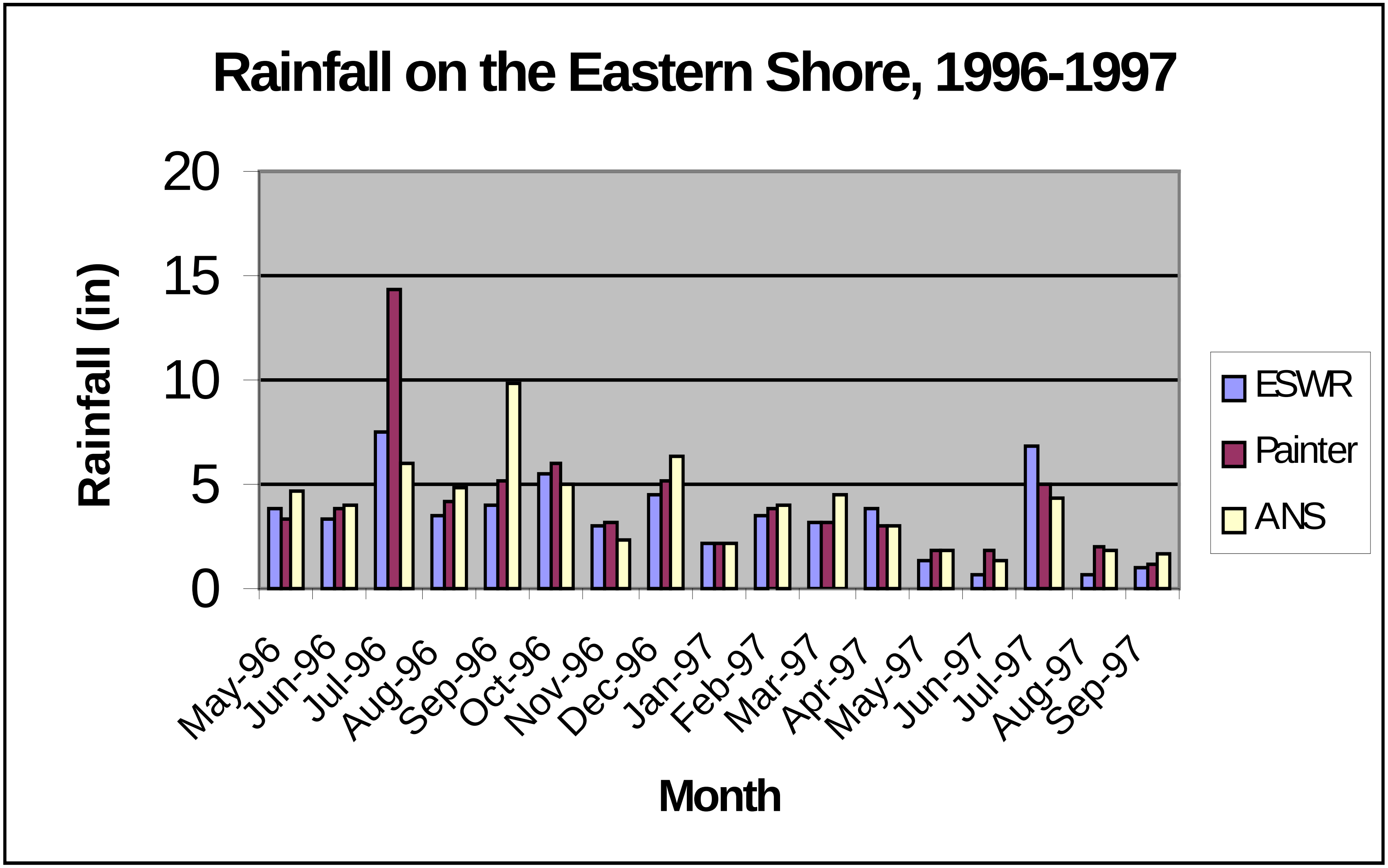

Figure 14. Monthly summed rainfall for three weather stations on the Eastern Shore. *ESWR*= Eastern Shore Wildlife Refuge, *Painter*= Painter Agricultural Extension Office, and *ANS*= Assateague National Seashore.

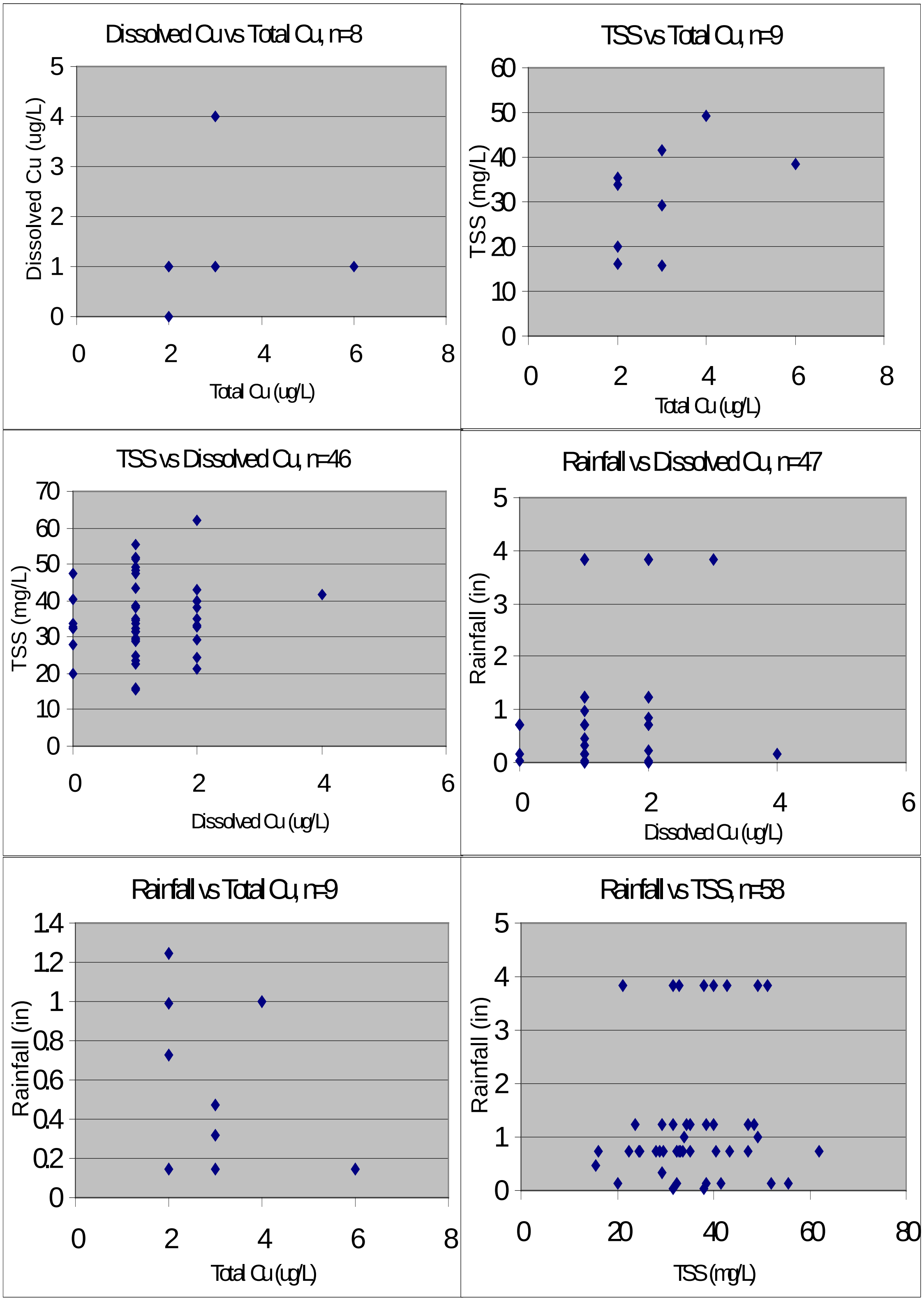

Figure 15. Relationships between rainfall, total copper, dissolved copper, and total suspended solids for Gargathy Creek at the Clam Company. No trend is evident in five of the graphs, but total copper may exhibit a trend when compared to total suspended solids.

copper and total suspended solids. The other five appeared scattered, and exhibited little detectable trend.

The rainfall measurement used throughout this study was a sum of the rainfall falling on the day of sampling and the two days before the day of sampling. The sum was used rather than a single day's rainfall for two reasons. First, runoff only occurred when the ground was already wet, so the rain falling several days before a sampling event had an effect on the amount of runoff generated, and therefore the amount of copper carried to the tidal creek or estuary. In addition, copper in runoff sometimes had to travel overland some distance, and even farther in the waterway, before being sampled. This travel took time depending on the distance from the source to the sampling site. Attempting to relate copper concentrations to a single day's rainfall would not have accurately portrayed the relationship between rainfall and concentration.

The closest weather station provided the rainfall data for each sampling site. In the event that two weather stations were approximately equidistant to the sampling point, an average of the two three-day sums was used. In Figure 15, an average of the *Painter* and *ANS* weather stations was used, as it was for all sampling sites within the Gargathy Creek and Parker's Creek watersheds. For the Queen's Sound site, *ANS* data were used. For all sites within The Gulf watershed, an average of *Painter* and *ESWR* data were used. Lastly, *ESWR* data were used for determining the rainfall at Raccoon Creek. This was true for all figures and calculations presented in this report.

Figures 16 and 17 demonstrated the two relationships between water quality parameters that were found statistically significant from the data collected. Figure 16 illustrated the relationship between total suspended solids and total copper, from every sample and every site that was measured for both characteristics. The regression equation had an R^2 of 0.50 with the following relationship. The concentration of total suspended solids in mg/L was equal to the total copper concentration in ug/L multiplied by 6.4 mg/ug plus a constant 7.92 mg/L. The overall regression was significant at a 95% confidence interval. The slope estimate of 6.4 mg/ug was significantly different from zero at the 95% confidence interval. The intercept 7.92 mg/L was not significantly different from zero at the 95% confidence interval. This relationship implied that the waterways were likely to contain suspended solids even when no copper was present,

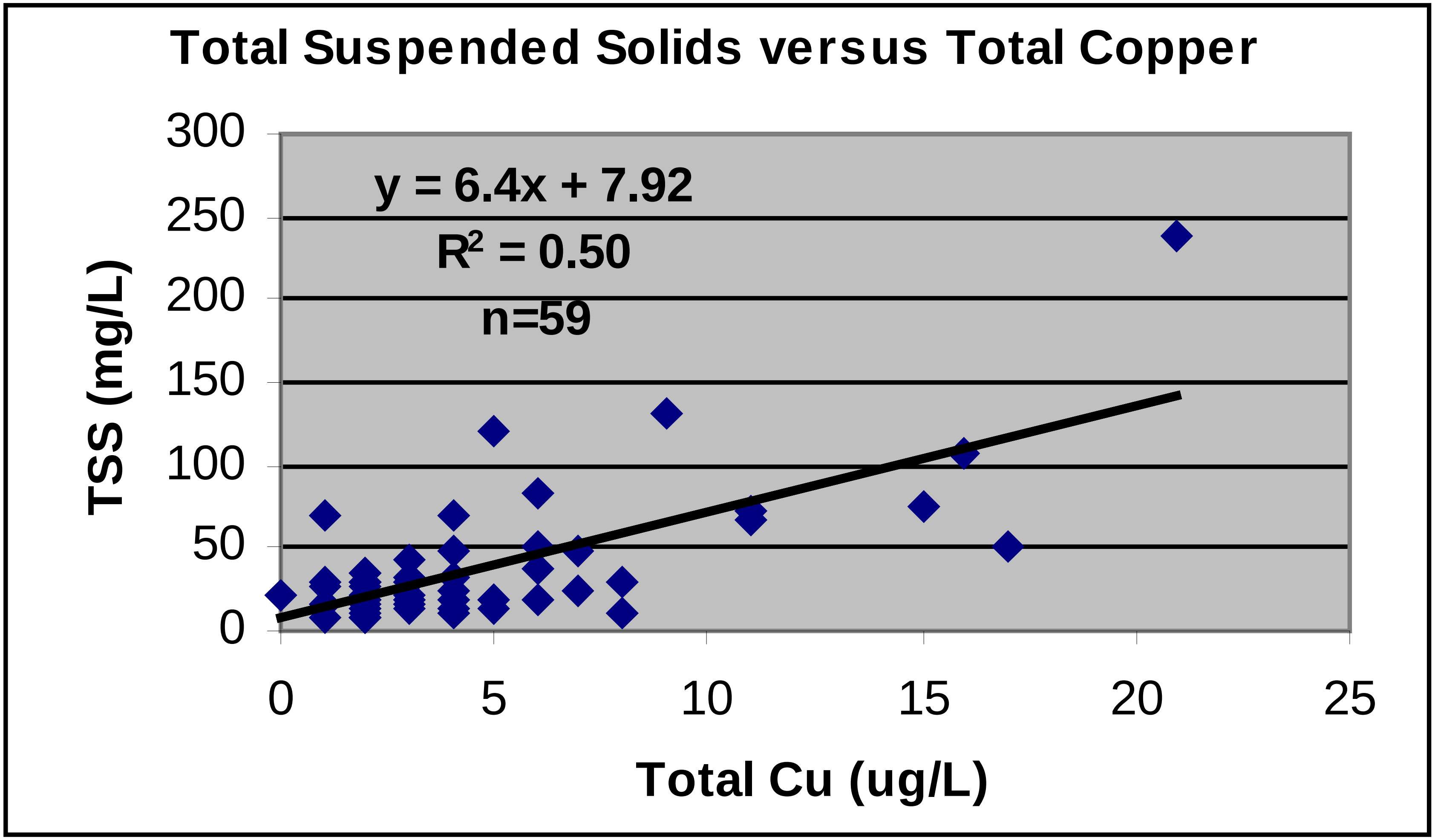

Figure 16. The relationship between total suspended solids and total copper for all water samples for which both parameters were measured. Fifty-nine data points were used to generate the regression equation that shows a positive relationship between the two parameters.

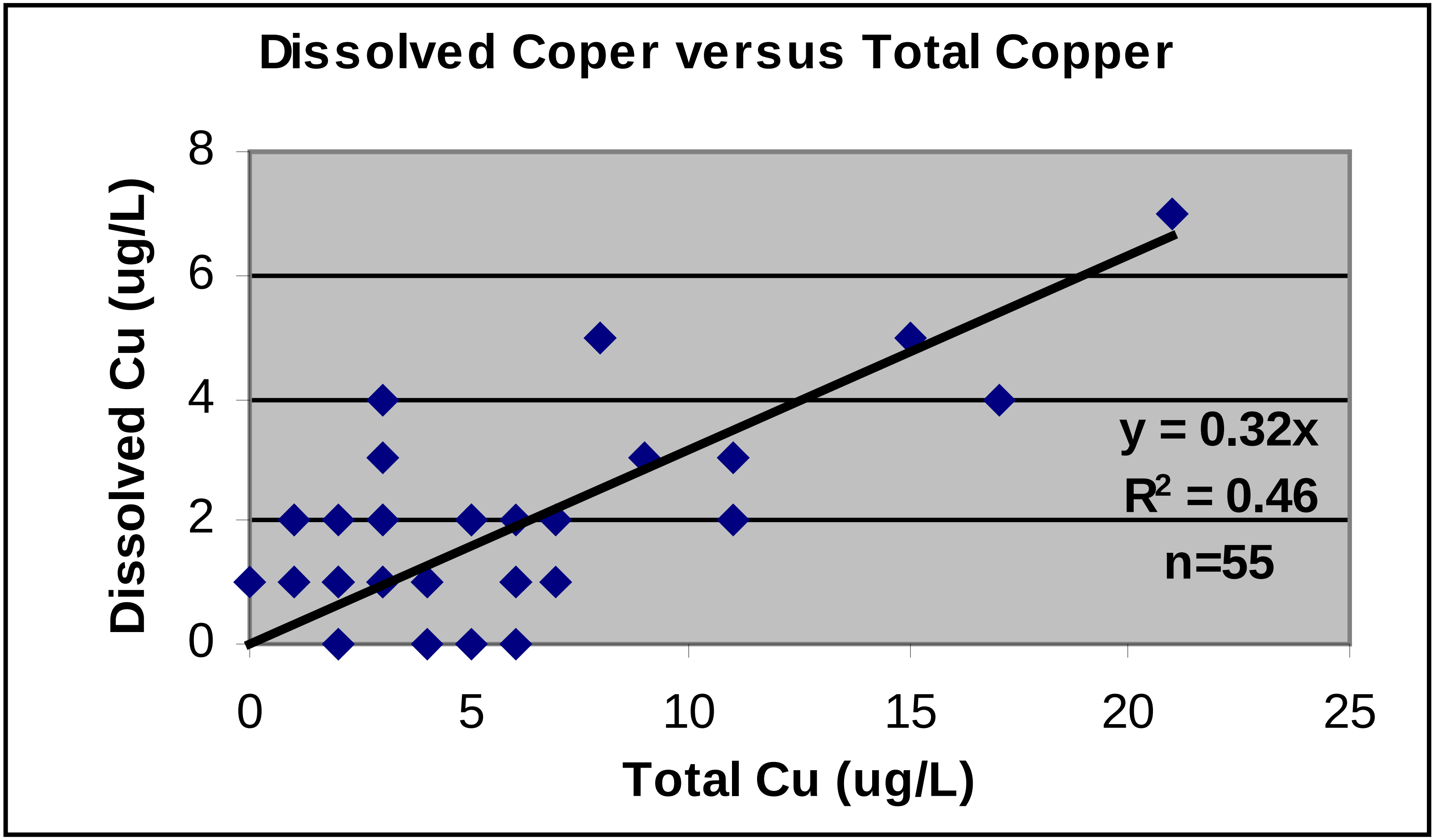

Figure 17. The relationship between dissolved copper and total copper for all water samples for which both parameters were measured. Fifty-five data points were used to generate the regression equation that shows 0.32 for the ratio of dissolved copper to total copper for the watersheds tested.

and that there is a correlation between increasing total copper and increasing suspended solids.

Figure 17 similarly illustrated the relationship between total copper and dissolved copper. The regression line in Figure 17 was forced to travel through the origin with the idea that both total and dissolved copper must be zero at the same time. Therefore the relationship between the two could have been written as dissolved copper in ug/L was equal to 0.32 multiplied by the concentration of total copper in ug/L. This time the regression equation had an R^2 of 0.46. The overall regression was significant at the 95% confidence interval. The slope estimate of 0.32 ug/ug was significantly different from zero with a 95% confidence interval between 0.27 and 0.36 ug/ug.

This relationship allowed for a rough estimation of dissolved copper from total copper concentrations, by illustrating that the average ratio between the two was a simple 0.32, over all of the watersheds that had been studied. Later, this ratio was used to estimate dissolved copper when only total copper was measured, as in the September 1996 samples.

III. Time-dependent Results

Figures 18 through 26 illustrated the water quality results from each of nine different sampling locations over the thirteen months of the study. Graphs of total suspended solids, rainfall, total copper and dissolved copper versus month were shown for each of the sites selected. Zero values were indicated by a 0 above the month, whereas missing data were left blank. In the case that a total copper measurement was taken and the corresponding dissolved copper was not, the dissolved copper measurement was estimated from the regression equation in Figure 17. Values determined in this way were indicated by a light yellow color. Rainfall was generated in the same manner as was described earlier. Therefore, the rainfall measurement on the graph is the three-day sum prior to the date the sample was collected. If no sample was collected, then the rainfall measurement is left blank, because there would be no indication of which three-day sum to use for that particular month.

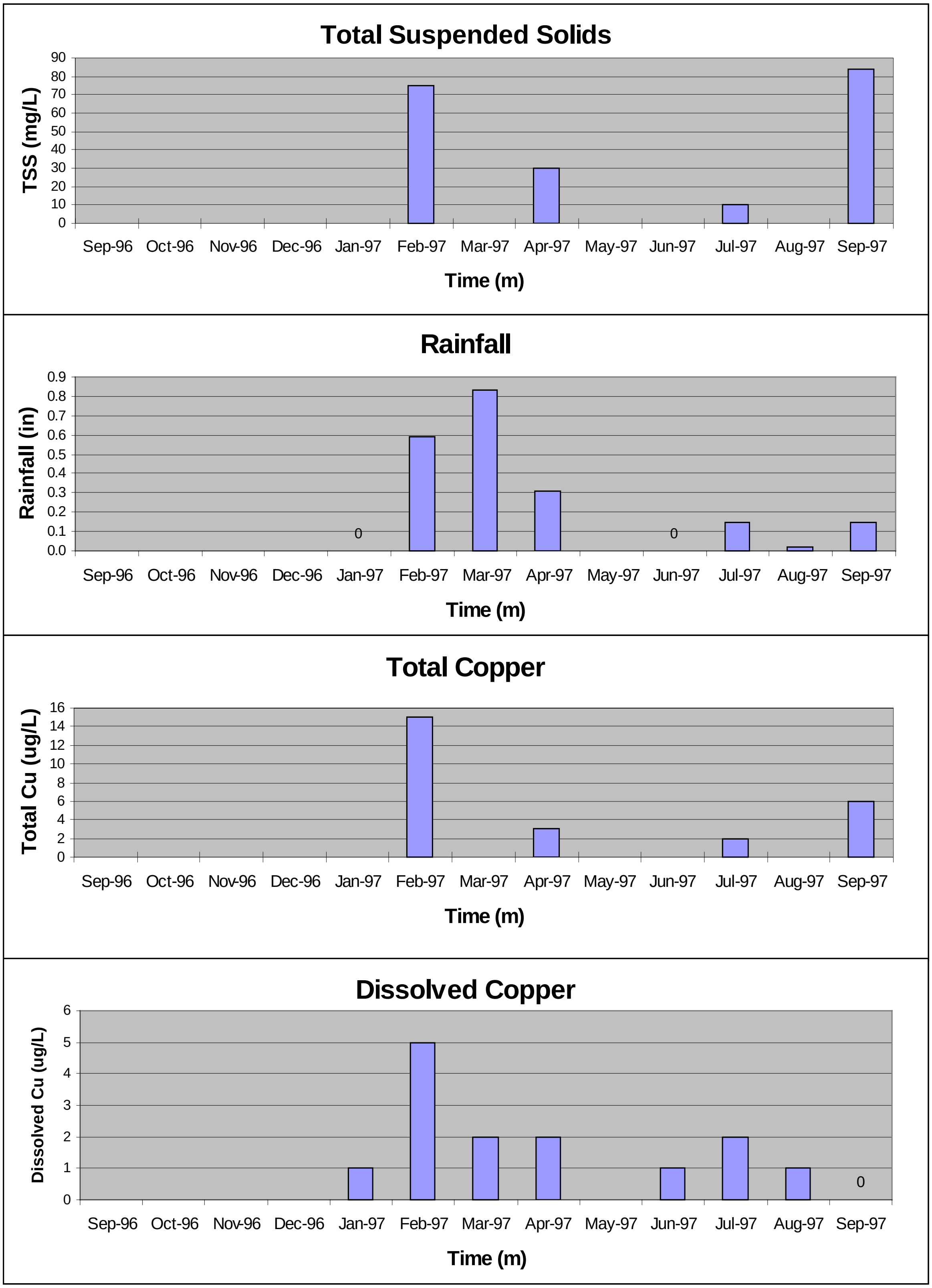

Figure 18. Water quality data for monthly grab samples from the freshwater creek that feeds Gargathy Creek.

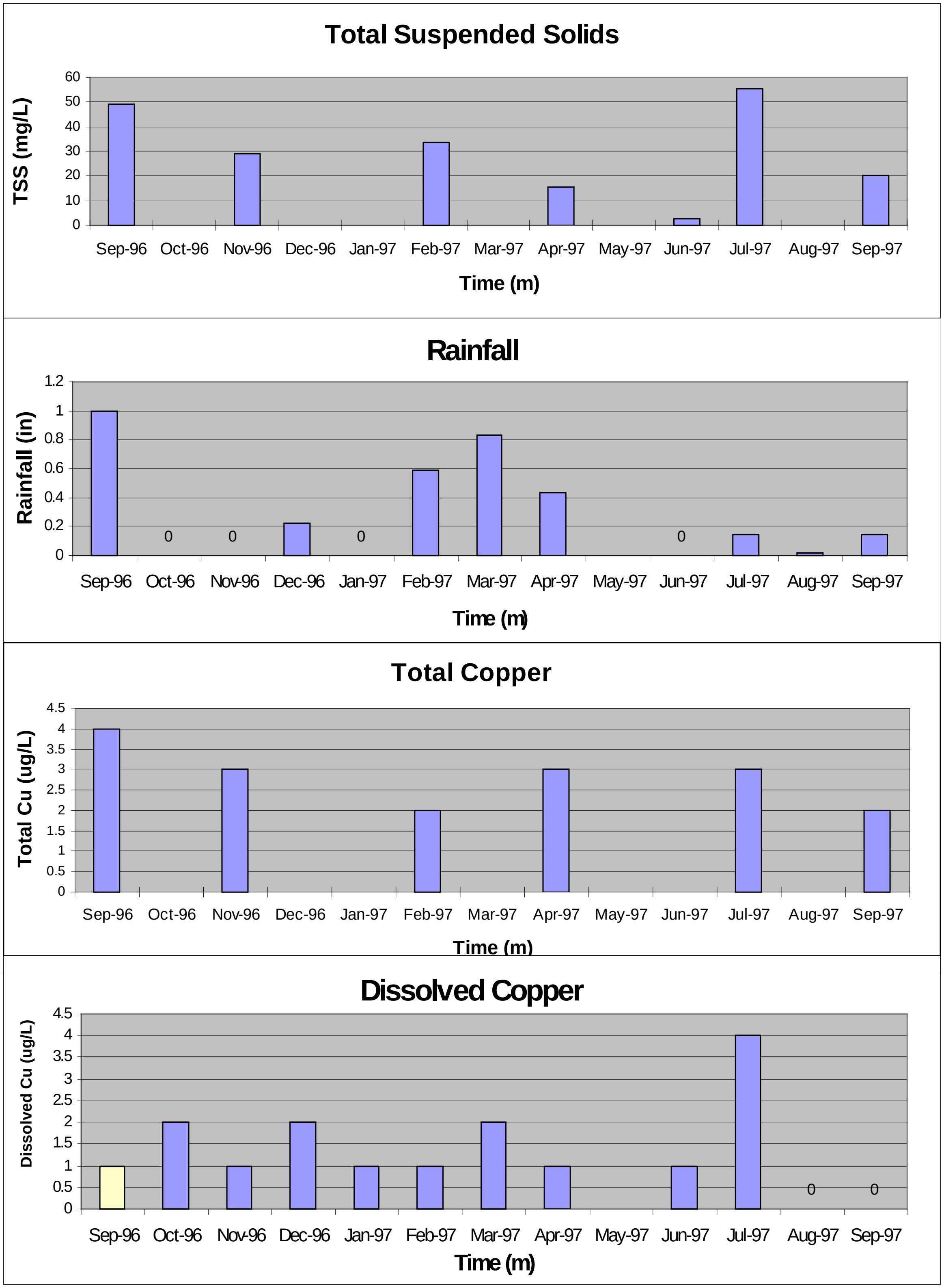

Figure 19. Water quality data for monthly grab samples from Gargathy Creek at the Clam Company site.

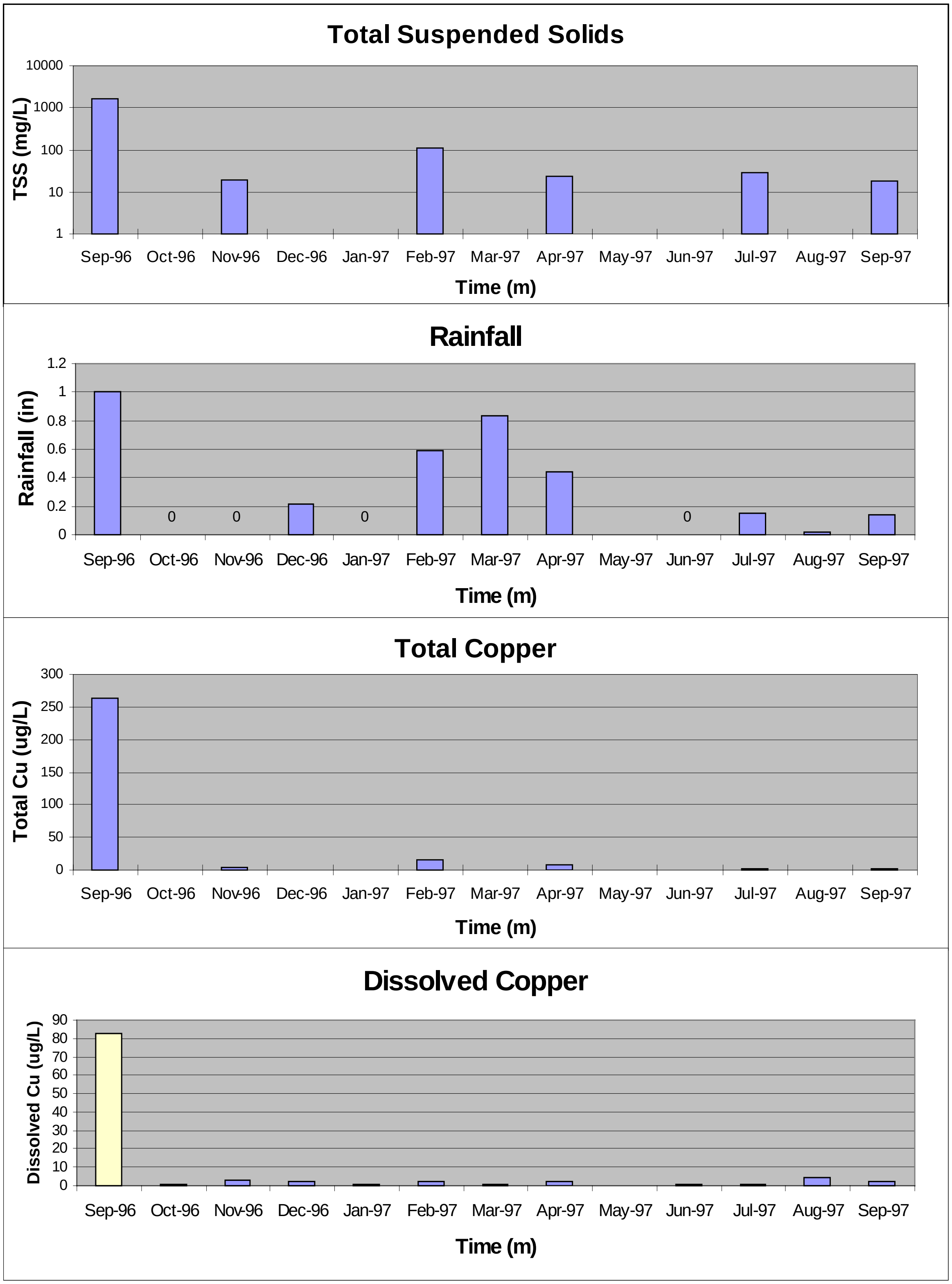

Figure 20. Water quality data for monthly grab samples from Gargathy Creek at the Kegotank Public Landing.

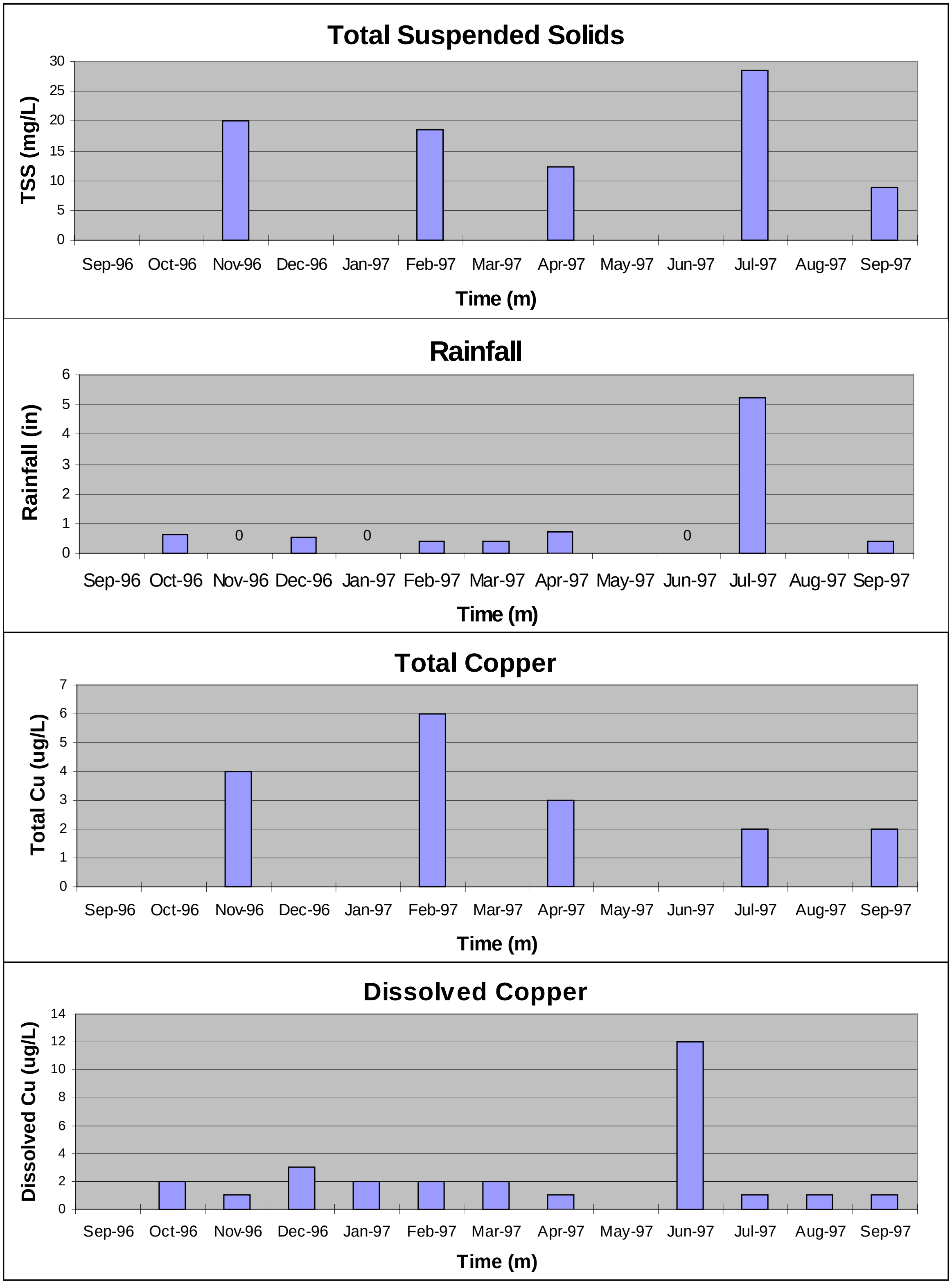

Figure 21. Water quality data for monthly grab samples from The Gulf from the Clam Company site.

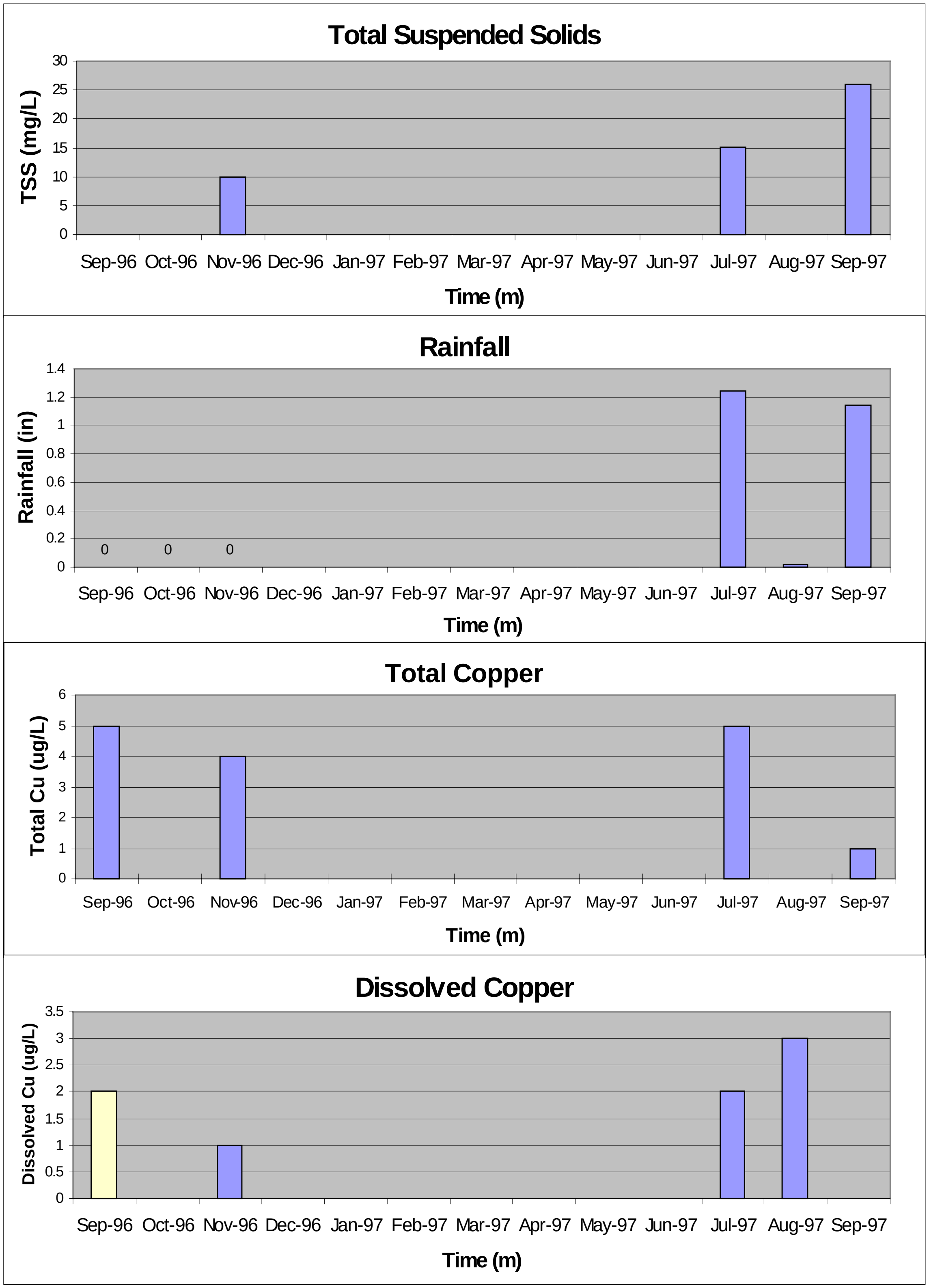

Figure 22. Water quality data from monthly grab samples from Parker's Creek.

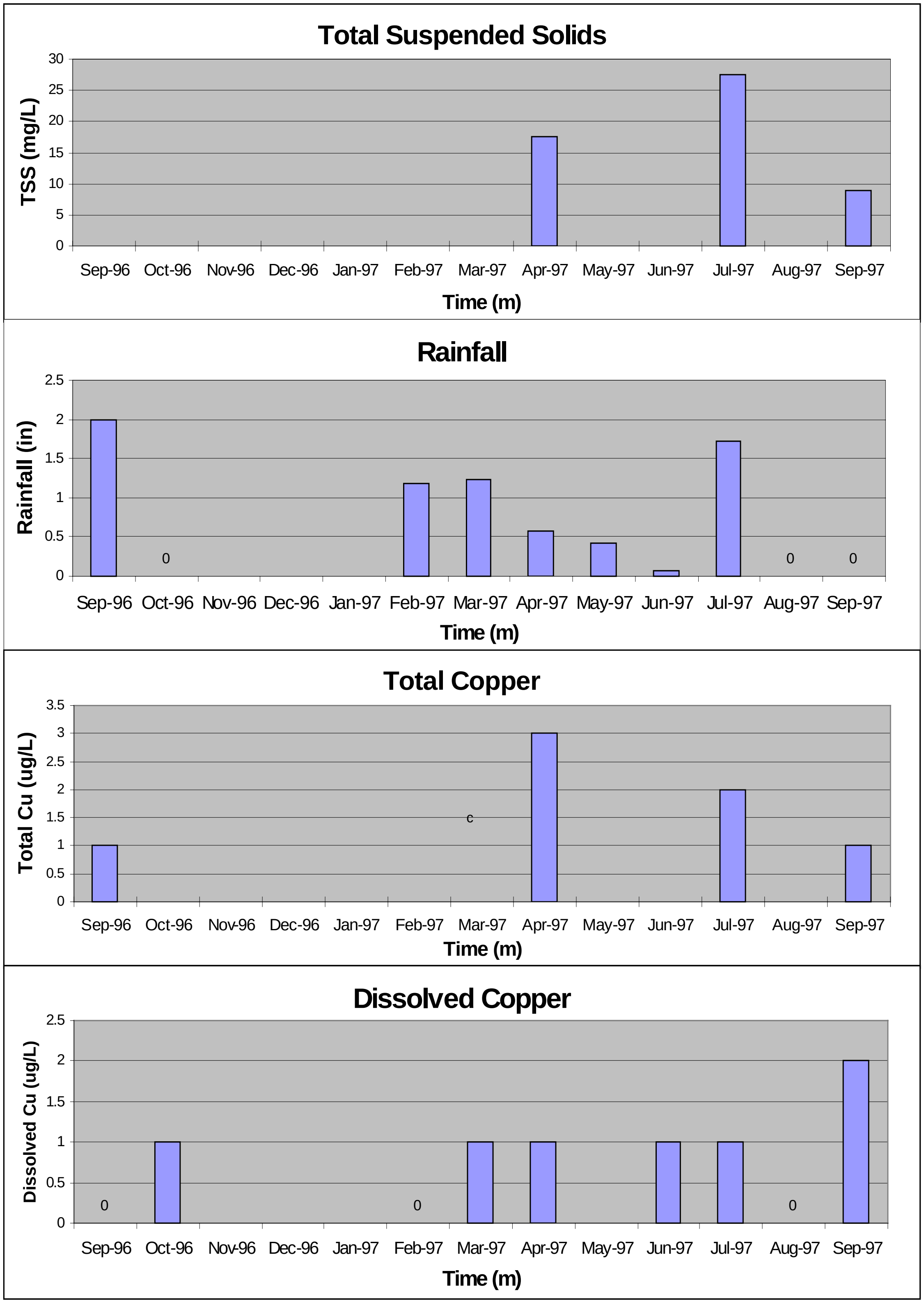

Figure 23. Water quality data from monthly grab samples from Queen’s Sound, off the coast of Chincoteague.

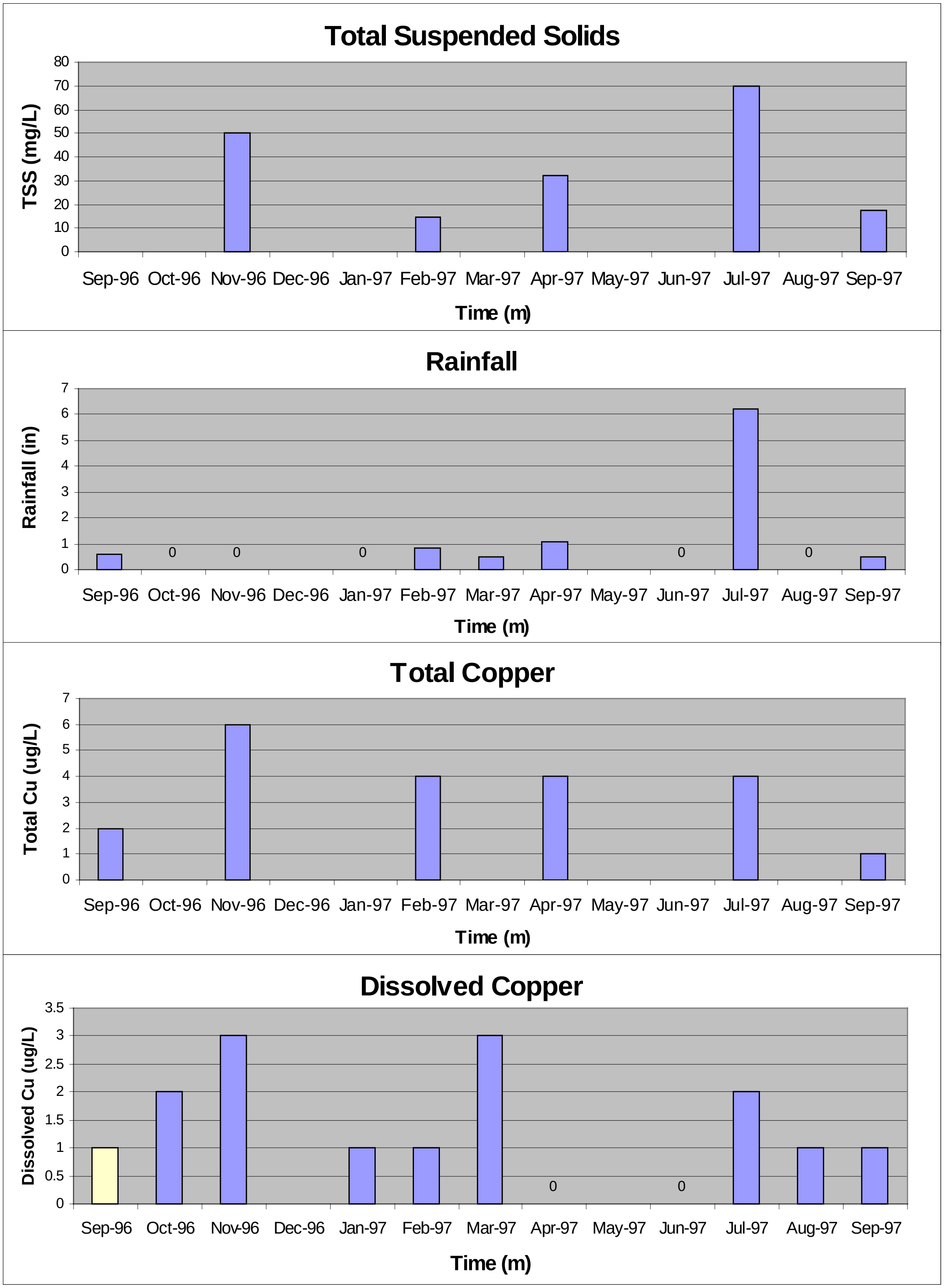

Figure 24. Water quality data from monthly grab samples from Raccoon Creek in the Eastern Shore Wildlife Refuge.

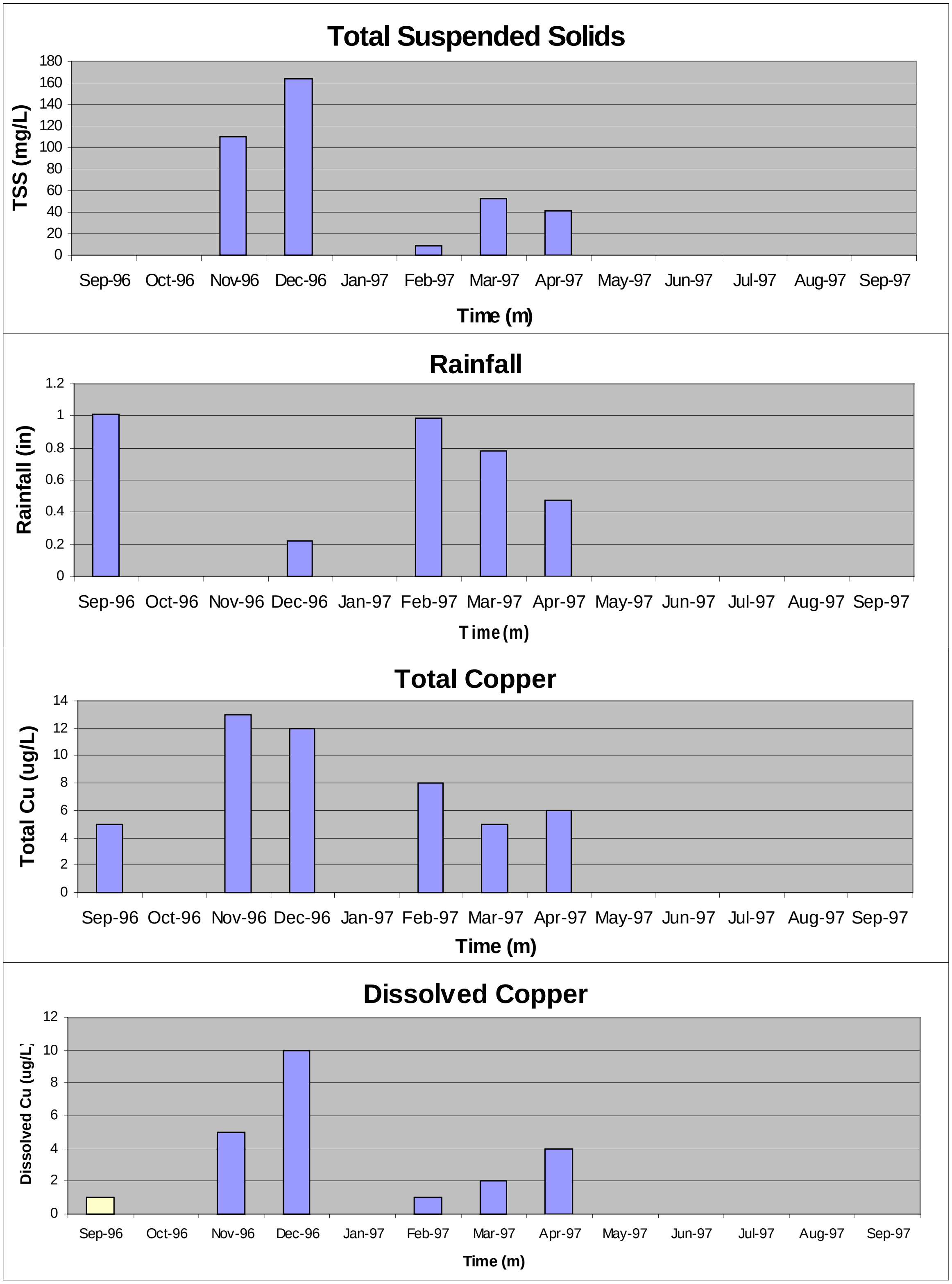

Figure 25. Water quality data from monthly grab samples from a residential roadside puddle on Gargatha Road.

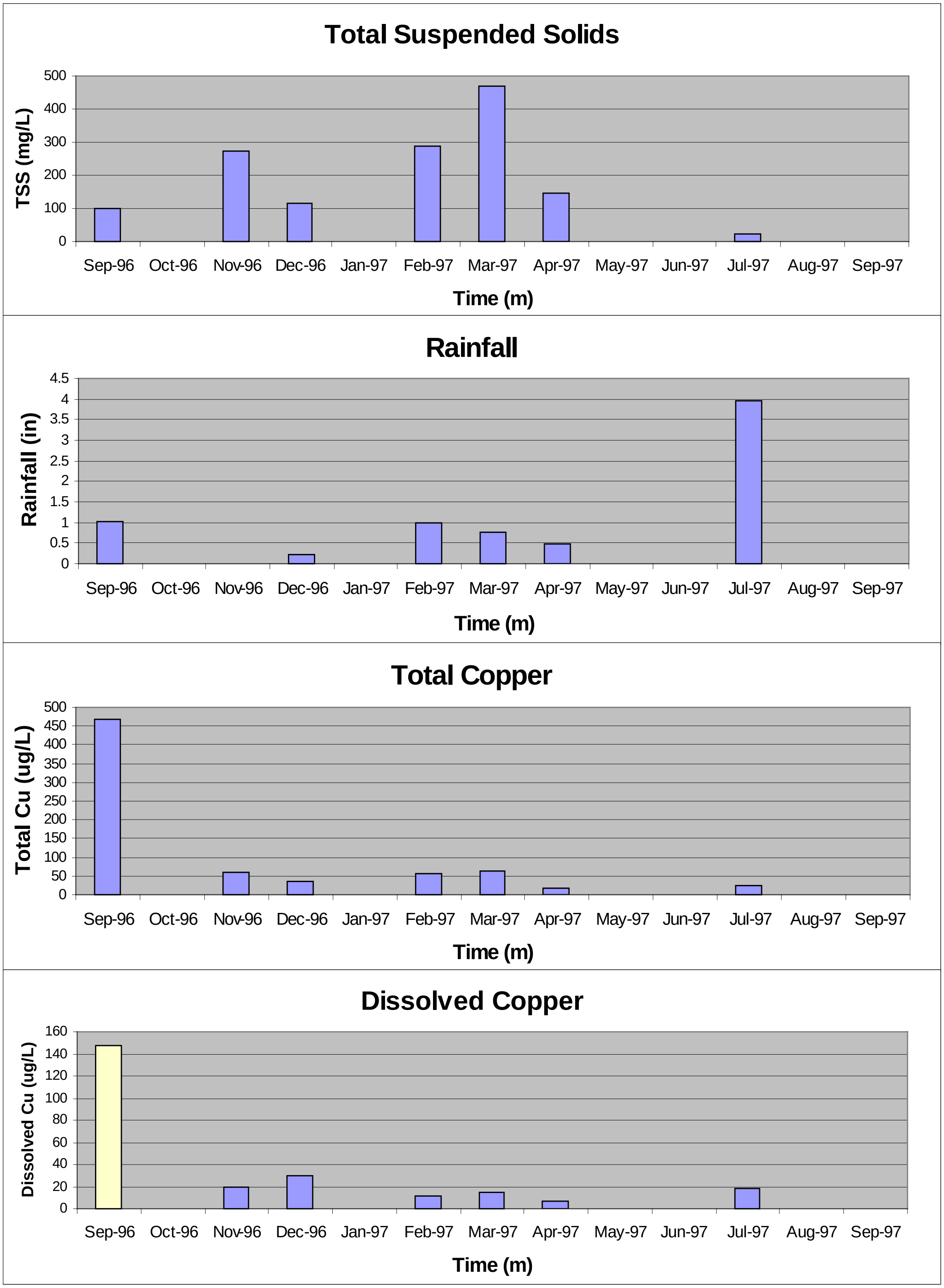

Figure 26. Water quality data from monthly grab samples from the 1996 Kegotank Road Tomato Field Roadside Puddle

The Gargatha Road Roadside Puddle, adjacent to a residential area, showed some copper contamination with total copper values from 5 to 13 ug/L, the higher values likely caused by worn brake linings eroding on a reasonably well-traveled road (Novotny and Olem). The copper concentrations at the 1996 Kegotank Road Tomato Field Puddle were consistently higher, with total copper values between 19 and 468 ug/L. The highest value was measured in September 1996, when the field was still in tomato production. After the field was put into a cover crop of grain, the runoff from the field continued to register very high copper concentrations. Even as far into the future as July 1997, when the field was in soybeans, total copper measured from that particular location was nearly 20 ug/L. These high concentrations were not identical to the concentrations of copper found at the non-agricultural rain puddle on Gargatha Road, and were influenced by copper left from the previous year's crop.

Figure 27 illustrated the differences between sampling sites for the dissolved copper concentrations from end of the wet 1996 growing season through the non-growing season. Again, all dissolved copper concentrations from September 1996 were estimated from the regression equation in Figure 17.

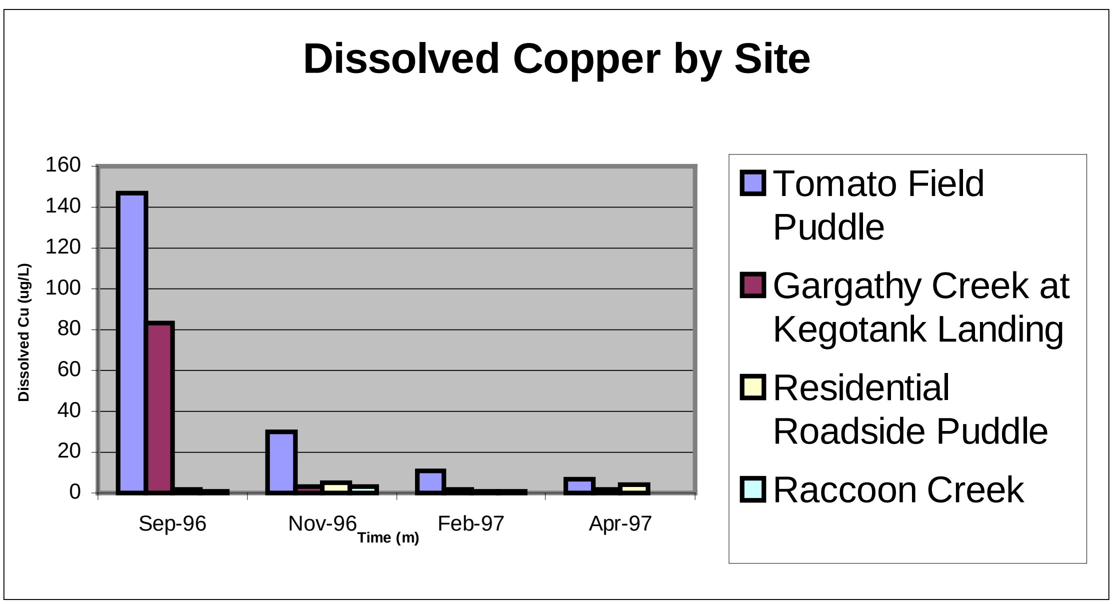

Figure 27. Comparison of dissolved copper concentrations at different sampling sites