# 1996 Analysis of Changes in Creek Water Quality with Construction Activity and Increased Development

By Martha Turner, P.E., Project Coordinator, Environmental Resources Division, Watershed Protection Department, City of Austin. (Appendix A - Updated with Data through 2000)

*Water quality monitoring data from City of Austin creeks discharging to Town Lake were examined for trends related to building permit data, periods of intense construction, and comparison of a recent period (1991-1995) to historical averages. USGS stations for five Austin Creeks were used along with city-wide building permit data. The recent period shows lower concentrations of pollutants on average potentially related to lower level of construction activity in this period than times previous or the increased regulation on construction activities. However, average annual flow is higher in the recent period which may be offsetting the decrease in concentrations and resulting in an estimated increase in pollutant loads carried by the creeks. Total suspended solids, Kjeldahl nitrogen, total phosphorus and fecal coliform bacteria are significantly directly related to the number of building permits issued during the year*

## Introduction

The Town Lake Report investigated water quality in Town Lake primarily through 1990. In preparation for an update report, changes in water quality in Town Lake were examined using data from 1991-1995. Some improvements in Town Lake water quality were noted. Since the water quality in Town Lake is directly affected by the creeks within its watershed, the changes in water quality and quantity throughout area creeks were investigated.

## Methods

### Data Obtained

USGS water quality and flow data from 1975 through 1995 was available for five (5) Austin Creek sites; Barton Creek at Loop 360, Bull Creek at Loop 360, Shoal Creek at 12th Street, Walnut Creek at FM 969, and Williamson Creek at Oak Hill. These sites do not all have complete records for the entire period, but they have the longest records available. Other USGS monitoring sites were maintained for much shorted time periods and were not used in the analysis. Of these five creeks, Shoal Creek and Barton Creek flow directly into Town Lake.

Annual rainfall at the Austin Airport was obtained from data provided by the National Weather Service.

The number of building permits issued by the City of Austin was obtained for the years 1975-1995 from the City's Growth Watch Report currently published by the Transportation, Planning, and Sustainability Department's Spatial Analysis Group. The total number of building permits is the sum of the single family, duplex, multi-family and commercial building permits. Since reliable annual impervious cover data is not available over this time period, the annual number of building permits is used as an indicator of potential construction period impacts.

**Estimates of Pollutant Levels in Shoal and Barton Creek for Two Time Periods**

Analysis of variance on the pollutant levels for Shoal Creek and Barton Creek for the two time periods (1975-1990 and 1991-1995), was performed to compare average values historically to recent period data. The flow at the time the sample was collected was used as a covariate, if the relationship between flow and the specific pollutant was significant as determined by regression analysis. The flow weighted means for nine parameters and the two periods were determined. The parameters selected from the USGS water quality data were TSS, TP, TKN, Nitrate/Nitrite, NH3, BOD, TOC, Fecal Coliform and Fecal Streptococci. The flow weighted means are the least-squares means from the analysis of variance with period as a class variable and flow as a covariate. Least-squares means, or population marginal means, are the expected value of the class means with all covariates at their mean value. Flow was used as a covariate to subtract out the effects of sampling under different flow levels during different years. The annual flow weighted means of several pollutant parameters for the two time periods for Shoal Creek and Barton Creek were plotted for visual comparison to building permit data.

**Estimates of Yearly Pollutant Levels in Area Creeks - Comparison of Pollutant Levels with Building Permit Data**

Analysis of Variance on the nine pollutants from all five creek sites was performed with site and year as class variables and flow at the time the sample was collected as a covariate. The yearly flow weighted means for all five creeks were plotted along with the number of building permits issued during the year. Data from all the creeks was included since at the time of the analysis, the building permit data was not available by watershed. Building permit data was only available from the City of Austin's jurisdiction and covers all of four of the creeks with corresponding flow and water quality data, but only 29% of the Barton Creek watershed. However, from development trends during this period, it is probable that the majority of the construction activity in the Barton Creek watershed from 1975-1995 would probably have been within the City's jurisdiction.

Linear regressions of building permits on flow weighted pollutant means were performed to determine if a significant relationship existed between a construction indicator and surface water quality. For parameters which showed a significant relationship with the permits, the residuals from the regressions, which have both the effects of flow and construction removed, were plotted for examination.

**Town Lake Creeks Compared to All Five Creeks**

Shoal Creek and Barton Creek pollutant level patterns were compared with the patterns determined from combining all the creek data together.

**Estimates of Annual Flow in Area Creeks for Two Time Periods**

The average annual flows in four creeks, with rainfall as a covariate, were compared for two time periods, 1975-1983 and 1984-1995. Rainfall was used as a covariate to remove the effect of differing rainfall amounts during different years. The earlier period was before the major impact of building construction while the later period was during and after the construction boom as indicated by the number of building permits issued. An ANOVA on annual average flow, with the time period as the class variable and the annual rainfall as a covariate, was done for each creek except Shoal Creek. Flow data from Shoal Creek was not analyzed since the continuous flow record for Shoal Creek at 12th Street does not start until 1985. Changes in both flow and concentration are needed to estimate differences in annual pollutant loads. However, when the same amount of rainfall produces a larger volume of runoff due to increases in impervious cover, even a constant concentration can be said to indicate an increase in loading.

## Results

**Pollutant Levels in Shoal and Barton Creek are Lower during the More Recent Time Period**

Analysis of variance results indicated that almost all the parameters are lower during the update period (1991-1995) and many are significantly lower. The flow weighted means of several pollutant parameters for the two time periods for Shoal Creek and Barton Creek, and the percent change are shown in Table 1. It should be noted that all the pollutant levels in Shoal Creek are higher than those in Barton Creek. All of the investigated parameters were significantly different at different flow levels, except nitrate/nitrite in both creeks, and fecal coliform bacteria counts in Shoal Creek, demonstrating the need for acknowledging and removing the effects of flow in the analyses.

**Four of Nine Pollutant Levels in Area Creeks show a strong relationship with Building Permits.**

The yearly flow weighted means (least-squares means from ANOVA with site and year as class variables and flow as a covariate) for all five creeks for the parameters TSS, TP, TKN, and Fecal Coliform, show a strong relationship with the number of building permits issued by the City. Figure 1 shows the flow weighted pollutant means for these four parameters for all five creeks from 1975-1995 along with the number of building permits issued during the year

The regressions of pollutant levels on building permits were significant with R-squared values of .57, .45, .32, and .20 for TP, Fecal Coliform, TSS, and TKN, respectively. The plots of the residuals from these regressions show no significant trends over time.

During the building boom in the 80's pollutant levels increased dramatically. The most recent years of the analysis (1994-95) represent another construction boom period, and pollutant levels are increasing again, but examination of the building permit plots indicates that the pollutant constituent levels are not increasing as fast as in the past.

The yearly flow weighted means of Nitrate/Nitrite, NH3, BOD, TOC and Fecal Streptococci do not exhibit a significant relationship with the number of building permits. Nitrate/Nitrite appears visually to be gradually declining over time, while Ammonia shows a sudden decrease in the last four years. TOC, BOD and Fecal Streptococci appear to be exhibiting normal variation over time. Figure 2 shows the flow weighted pollutant means for these five parameters for all five creeks from 1975-1995 along with the number of building permits issued during the year

**Town Lake Creeks Pollutant Level Patterns Similar to All Five Creeks**

Shoal Creek and Barton Creek pollutant level patterns were compared with the patterns determined from combining all the creek data together. The patterns are similar from one creek to the next, but the levels of pollutants are not. Some differences in the Barton Creek watershed data include bimodal pollutant peaks in the early 1980's, and a stronger upturn in pollutant levels in recent years than is observed in other creeks.

**Annual Flow in Area Creeks Increases during the Second Time Period**

Barton Creek, Bull Creek, Walnut Creek, and Williamson Creek all showed increased weighted annual average flow during the later period. The weighed annual average flows are the least-squares means from the ANOVA and are the expected annual average flows with annual rainfall, from the airport, at its mean value. These increases were not statistically significant but were close to the 0.05 significance level. It is probable that if rainfall in the individual watersheds were available to use instead of the airport data, the results would be significant.

| Creek | Ratio of Weighted Annual Average Flows in 1984-1995 to those in 1975-1983 |
|---|---|
| Barton Creek at Loop 360 | 164% |
| Bull Creek at Loop 360 | 169% |
| Walnut Creek at FM 969 | 130% |
| Williamson Creek at Oak Hill | 105% |

## Discussion

**Water Quality Improvement in Area Creeks**

Analysis of the creek data indicated that water quality in the more recent update time period (1991-1995) was better than during the entire preceding period monitored (1975-1990) for Shoal and Barton Creeks. The next step was to try to determine the causes for this improvement.

**Potential Causes of Creek Improvement**

The timing of the improvement, determined from the yearly flow weighted pollutant means, suggested a relationship with construction activity as measured by the number of building permits issued by the City of Austin.

It should be noted that the building permit data is not ideal. Construction does not necessarily occur during the year that the permit is issued, and indeed may not occur at all. The locations of the construction sites relative to the creek monitoring stations are not known. It is likely that many of the construction sites were not in the subwatersheds of the USGS monitoring stations and thus had no impact on the measured pollutant levels. Permit numbers were available for both single-family, duplex, multi-family and commercial construction. However no information is available on the expected differences in pollutant loads from the various different types of construction sites; therefore, grouping by type of construction was not investigated. In the following paragraphs, the relationship between building permits and pollutant levels is discussed. However the nature of the permit data makes it possible that the relationship suggested by the statistics is neither real nor causal.

**The Relationship between Construction and Pollutant Levels**

For four parameters, TP, TSS, TKN , and Fecal Coliform , the regressions of building permits on the pollutant levels were significant. The correlation between building permits and these five pollutant levels implies that enhanced control of runoff from building sites may be warranted. However, the need for more detailed watershed scale analysis of this data is also suggested.

Pollutant levels do not appear to be increasing as fast in the current (1994-95) building boom as they did during the 1980's boom. It is possible that controls on runoff from construction sites are better that they were in the previous intense construction period. A complicating factor in interpreting this result is the notable changes in regulation of sedimentation and erosion controls in the COA during the monitoring period. In 1986, the first comprehensive construction controls were mandated throughout the City and in 1991, the interim Barton Springs Zone ordinance required additional enhanced controls in this portion of the City.

The yearly flow weighted means of Nitrate/Nitrite, NH3, BOD, and TOC do not exhibit a significant relationship with construction activity. Other potential reasons for creek improvement in these parameters will have to be sought. Nitrate/Nitrite appears to be gradually declining over time, while Ammonia shows a sudden decrease in the last four years. TOC, BOD and Fecal Streptococci may not be declining, but rather just varying over time. The number of years in the later period is much smaller than in the first period, so that it is possible to have an apparent decline which might be just noise in the data record.

**Impact on Town Lake**

Clearly, construction related activity can have a major impact on area creeks and thus on the lake. However, the long term effects of development are less certain. The residuals from the regressions have both the effects of flow and construction removed. The residuals show no significant trends over time. This indicates that at the same flows and with the effect of construction removed, pollutant concentrations in the creeks have not changed significantly over time. It is possible that with increased data collection the relationship may become significant since many studies have shown a consistent positive relationship between impervious cover and pollutant levels. Also determining, if possible, the exact location of the building permits would enable us to look at this issue more closely. In addition, the changes in annual flow indicate an increase in total pollutant load regardless of the absence of a discernable increase in concentration.

**Changes in Annual Flow**

While concentrations at the same flow levels may not have increased, the (rainfall weighted) annual average flows have significantly increased. In both local and nationwide watershed monitoring data, with increasing development, the amount of baseflow tends to decrease and the amount of stormwater runoff increases. From this data analysis, it is significant that higher flows are present for the same intensity of rainfall events due to increased impervious cover. This would have the effect of increasing the yearly load to the Lake, even if the concentrations at the same flows have not changed following construction.

**Loads to Lake**

In order to estimate the increased load to the lake from these increased flows, the changes in the frequency distributions of flows need to be investigated.

## Recommendations

This analysis could be further refined by determining the locations of the building sites and repeating the analysis on a watershed basis using only constructions sites upstream of the water quality stations. The analysis could then be updated periodically to determine if the observed trends persist.

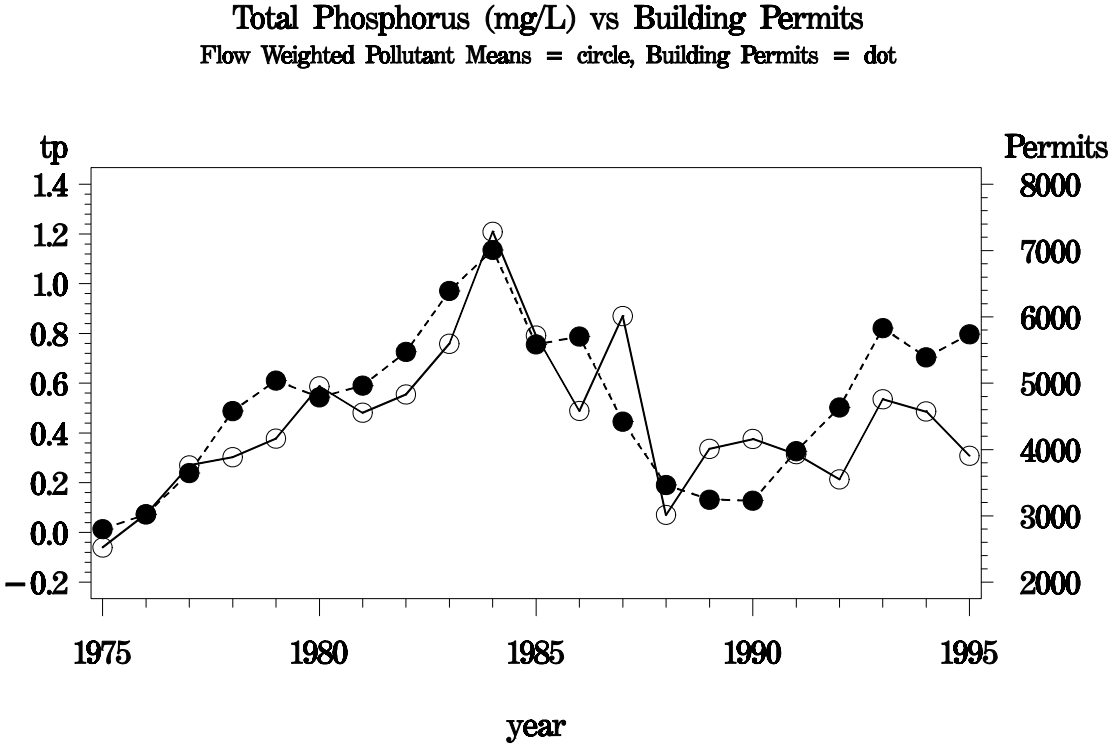
## Conclusions

- Most pollutant concentrations in Shoal and Barton Creeks, which flow into Town Lake, are significantly lower in 1991-1995 than in 1975-1990. This improvement appears to be related to both decreases in construction activity and decreases in recent years in the effects of construction activity.
- Construction activity as measured by building permits is directly related to some pollutant concentrations in the creeks.
- Total suspended solids, total Kjeldahl nitrogen, total phosphorus and fecal coliform bacteria are significantly directly related to the number of building permits issued by the City.
- With the increase in the number of building permits in 1994 and 1995, pollutant levels are increasing again, but not as fast as in past construction booms. Increased enforcement and improvements in requirements for erosion and sedimentation controls (Comprehensive Watershed Ordinance 1986, Interim Barton Springs Ordinance 1991) are possible reasons for the decline in the rate of increase.
- Average annual flows appear to be increasing at the same intensity of rainfall events although the increase is not yet significant. Thus pollutant load may be increasing.

**Table 1. Flow weighted pollutant means for Shoal and Barton Creeks for two time periods, 1975-1990 and 1991-1995, and the percent decrease in levels during the second period**

| | Units | mg/L | | | | | | | | col/100mL | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SITE** | **PERIOD** | **TP** | **TKN** | **TN** | **BOD** | **NH3** | **TOC** | **TSS** | **NO23** | **FCOL** | **FSTR** |
| Shoal | 1975-1990 | 1.07 | 3.34 | 3.95 | 12.36 | 0.18 | 35.93 | 1450 | 0.62 | 252718 | 170879 |
| Shoal | 1991-1995 | 0.68 | 1.63 | 2.06 | 6.33 | 0.09 | 23.71 | 995 | 0.42 | 74661 | 98248 |
| Barton | 1975-1990 | 0.17 | 1.58 | 1.99 | 3.87 | 0.07 | 22.45 | 639 | 0.36 | 23483 | 27478 |
| Barton | 1991-1995 | 0.11 | 0.78 | 1.05 | 3.03 | 0.03 | 15.82 | 349 | 0.29 | 14501 | 24346 |
| **Percent (2nd Period/1st Period)** | | | | | | | | | | | |
| Shoal | | 63 | 49 | 52 | 51 | 52 | 66 | 69 | 68 | 30 | 57 |
| Barton | | 61 | 49 | 53 | 78 | 37 | 70 | 55 | 81 | 62 | 89 |
| Significant differences (α=0.05) between periods are highlighted | | | | | | | | | | | |

Figure 1. Pollutant Flow Weighted Means vs Building Permits for Constituents with Significant Relationships between Pollutant Concentrations and the Annual Number of Building Permits.



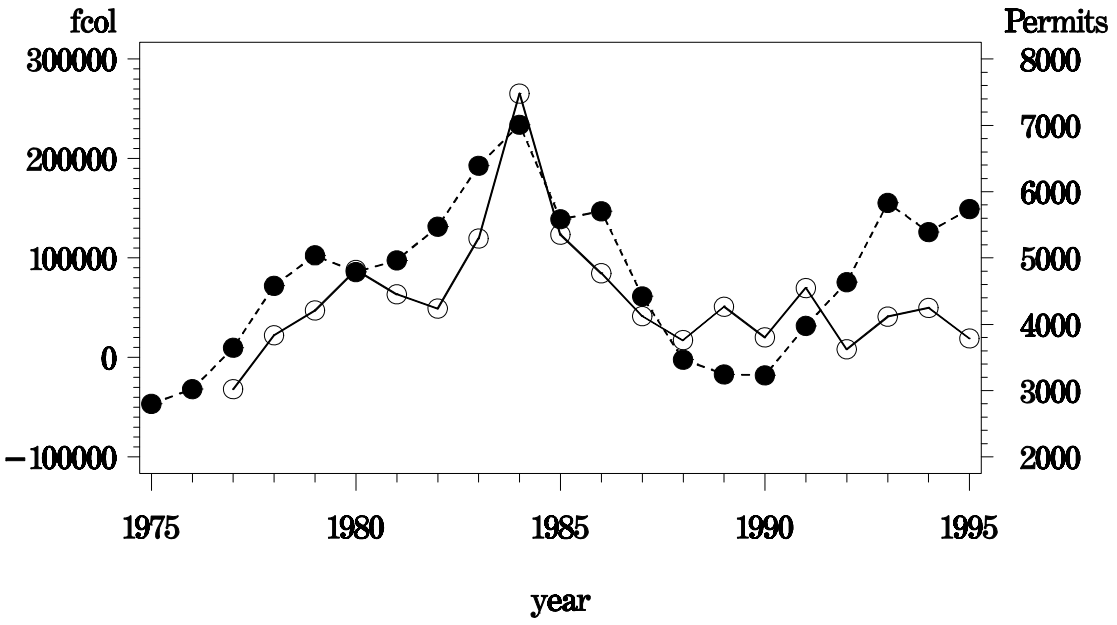
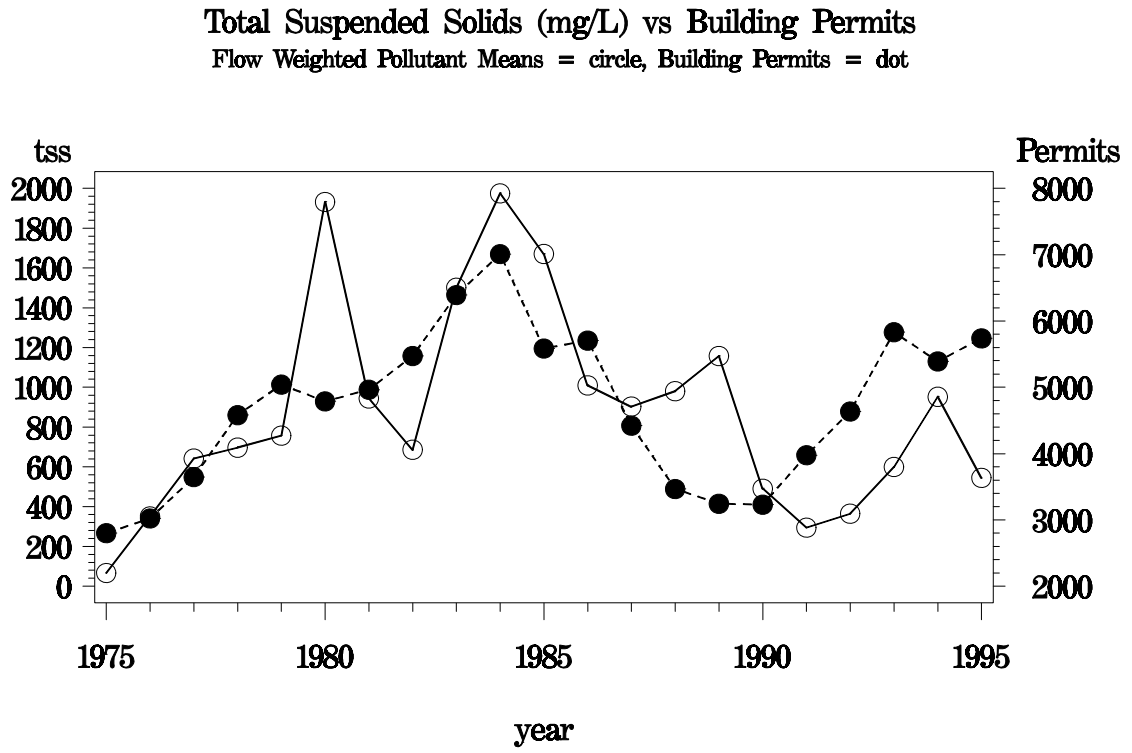



**Figure 1. Continued.**



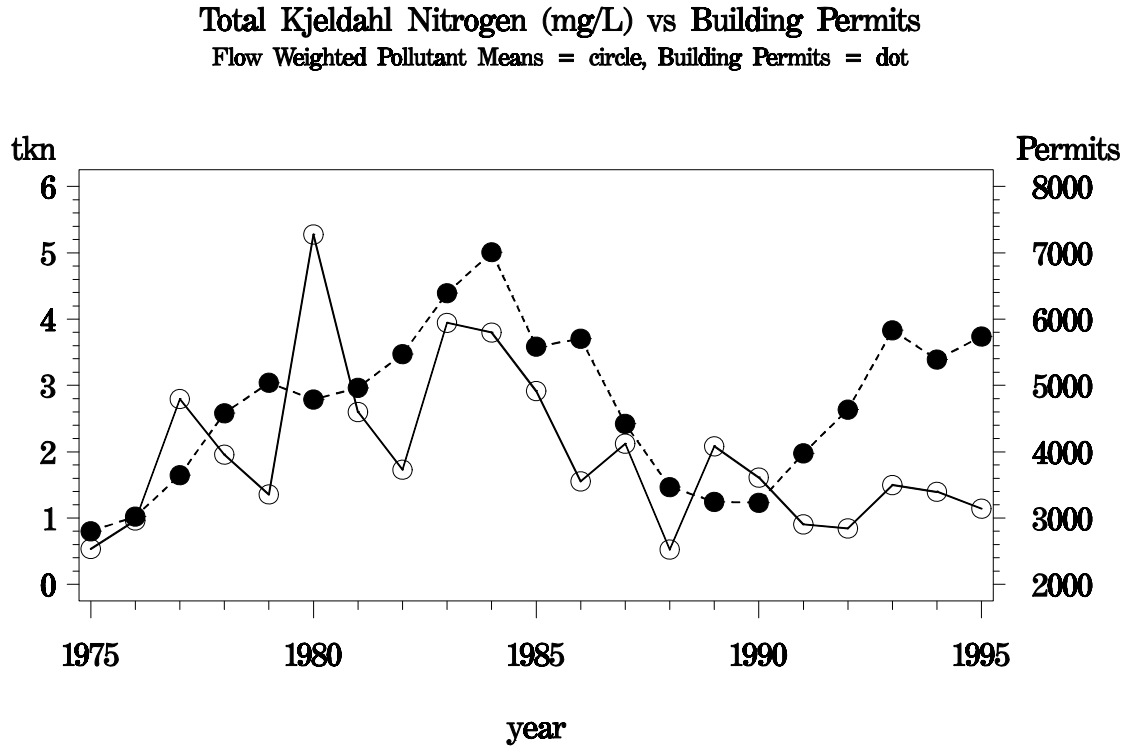
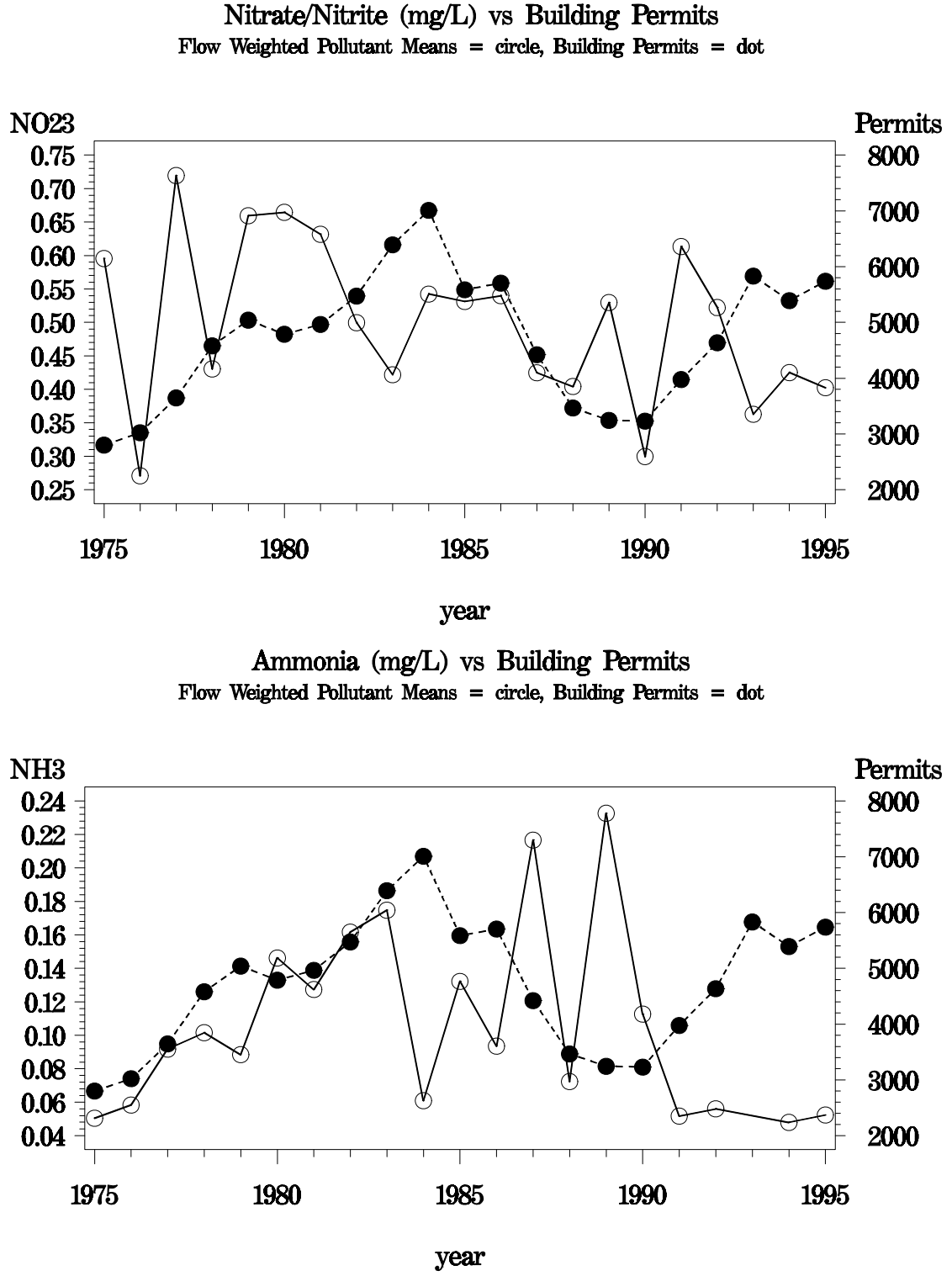



**Figure 2. Pollutant Flow Weighted Means vs Building Permits for Constituents without Significant Relationships between Pollutant Concentrations and the Annual Number of Building Permits.**



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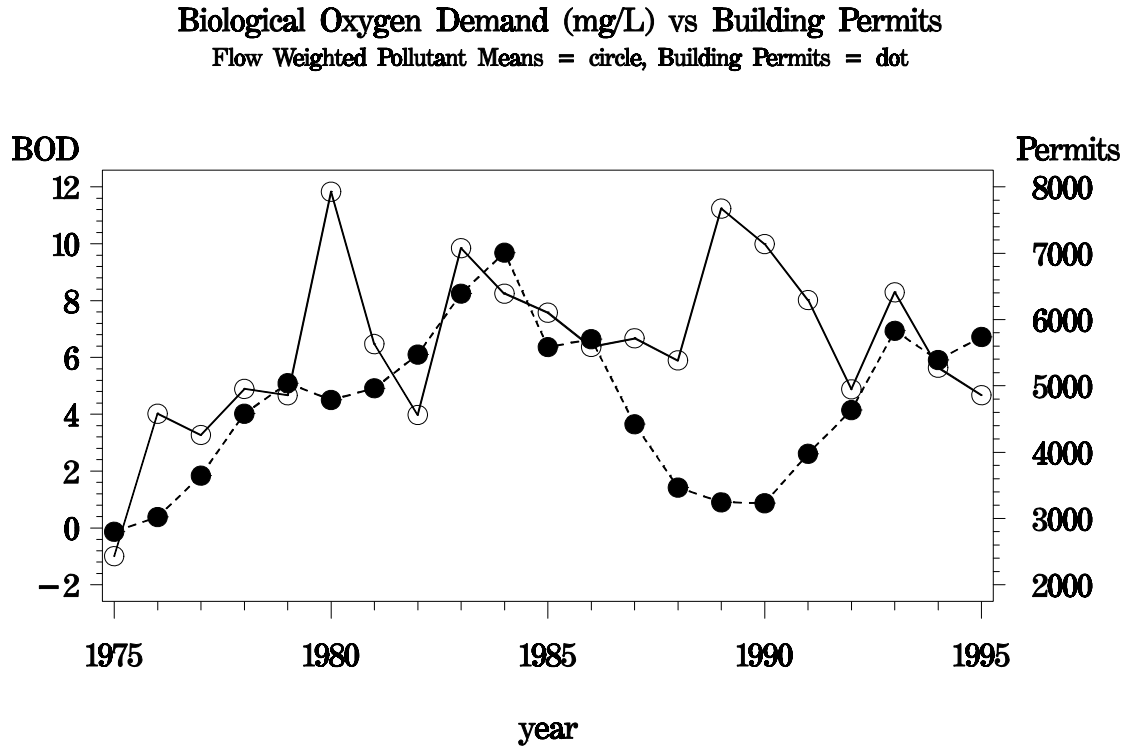


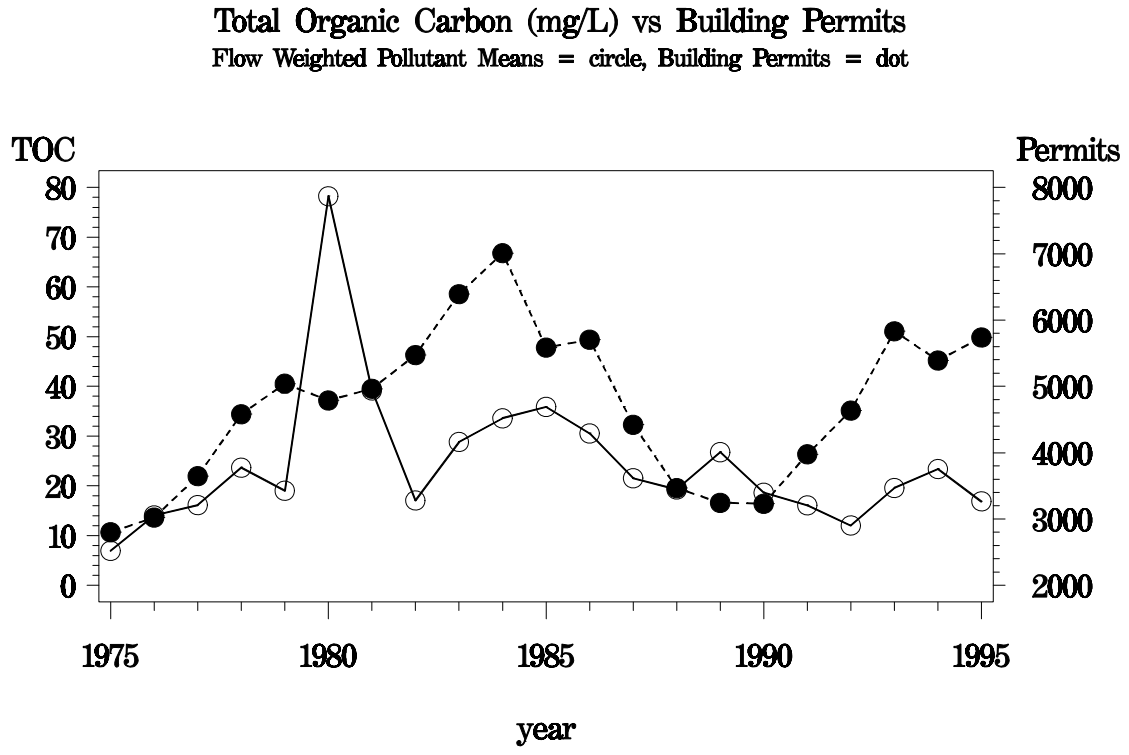

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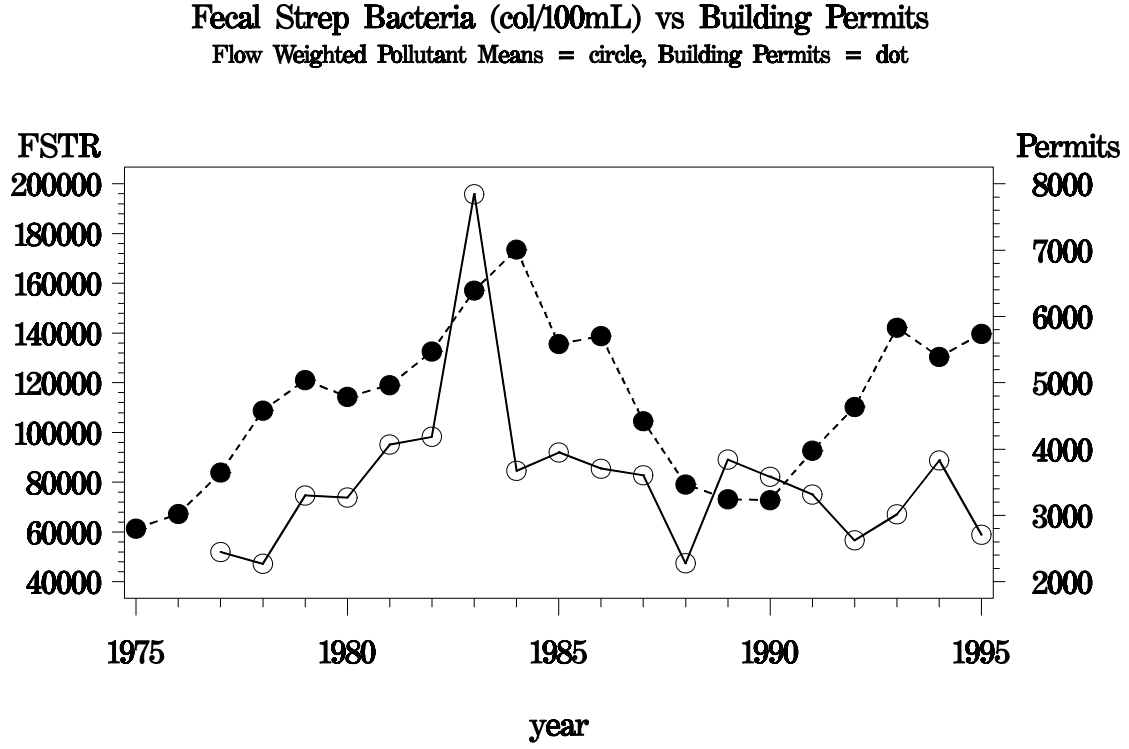

# Appendix A
# Addendum to: "1996 Analysis of Changes in Creek Water Quality with Construction Activity and Increased Development" using 1996 – 2000 Data

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## Introduction

The 1996 analysis of changes in creek water quality with construction activity and increased development used building permit data for 1975 through 1995 obtained from the City of Austin's Growth Watch Report. Additional permit data, for 1996 through 2000 is now available from more recent Growth Watch Reports. One of the conclusions from the 1996 analysis was that "with the increase in the number of building permits in 1994 and 1995, pollutant levels are increasing again, but not as fast as in past construction booms. Increased enforcement and improvements in requirements for erosion and sedimentation controls (Comprehensive Watershed Ordinance 1986, Interim Barton Springs Ordinance 1991) are possible reasons for the decline in the rate of increase." Examination of the 1996 to 2000 data strengthens this conclusion.

## Methods

### Data Obtained

USGS water quality for four parameters, TP, TSS, TKN and Fecal Coliform, and flow data from 1996 through 2000 was obtained for five (5) Austin Creek sites; Barton Creek at Loop 360, Bull Creek at Loop 360, Shoal Creek at 12th Street, Walnut Creek at FM 969, and Williamson Creek at Oak Hill. This more recent data was combined with the data used in the 1996 analysis. These four creek water quality parameters were significantly related to construction activity during the 1975 through 1995 period. The natural logarithm of the flow was calculated for use in the analyses since the relationship between concentration and flow is not linear

The number of building permits issued by the City of Austin was obtained for the years 1996-2000 from the City's Growth Watch Report and added to the 1975 through 1995 data used in the 1996 analysis. The total number of building permits is the sum of the single family, duplex, multi-family and commercial building permits. In 1996, the Growth Watch data for commercial building was changed from number of permits to total square feet. However for three years, 1993-1995 both the number of permits and the total square feet were reported. During those three years, the average number of square feet per commercial building permit was 1334 $ft^2$. Using this information the number of building permits for 1996 through 2000 was estimated from the total square feet.

**Estimates of Yearly Pollutant Levels in Area Creeks from 1975 through 2000. Comparison of Pollutant Levels with Building Permit Data.**

Analysis of Variance on the four pollutants from all five creek sites was performed with site and year as class variables and the logarithm of the flow at the time the sample was collected as a covariate. The yearly flow weighted means for all five creeks were plotted along with the number of building permits issued during the year. Data from all the creeks was included since the building permit data was not available by watershed.

## Results

**Increase in Yearly Pollutant Levels was Much Lower than in the Previous Booms.**

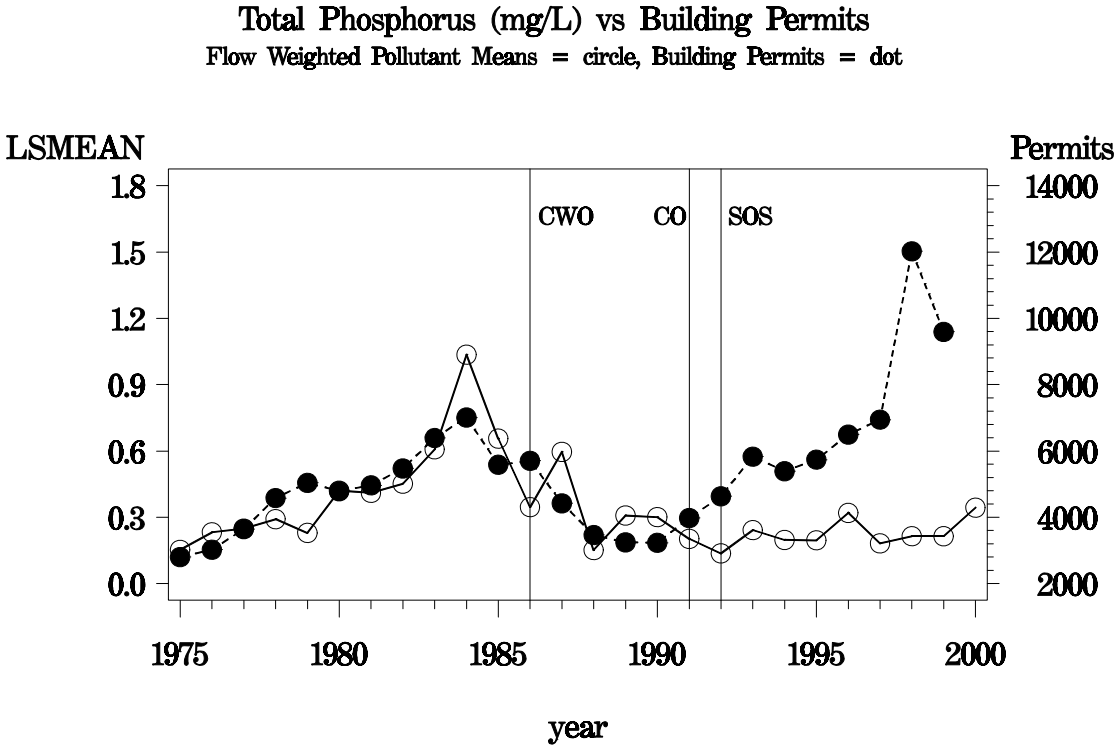
Figure 1 shows the change in the relationship between pollutant concentrations and the number of building permits in recent years. From 1975 through 1990 pollutant concentrations and building permits increase and decrease simultaneously. However the increase in permits during the 1990s is not mirrored by a matching increase in pollutant levels. The building permits increase much faster than the pollutant concentrations. Marked on the time axis are the dates when the City enacted ordinances controlling runoff from construction sites.

## Discussion

**City Ordinances Probably Responsible for Reduced Pollutant Runoff from Construction Sites into Area Creeks**

In 1986 the City enacted the Comprehensive Watershed Ordinance for non-urban watersheds, including Barton, Bull, Walnut, and Williamson, but not Shoal. This ordinance regulated construction activities in an effort to reduce the pollutant load to area creeks. In 1991 the Comprehensive Ordinance was enacted for the Barton Springs Zone which includes Baron and Williamson Creeks. In 1992 the SOS ordinance took effect for the Barton Springs Zone, but due to assorted lawsuits was not enforced for most of the nineties. These ordinances all addressed the problem of runoff from construction sites, and are postulated to be the reason the pollutant concentrations per building permit were so much lower in the nineties than in the eighties.

**Figure 1. Pollutant Flow Weighted Means vs Building Permits.**



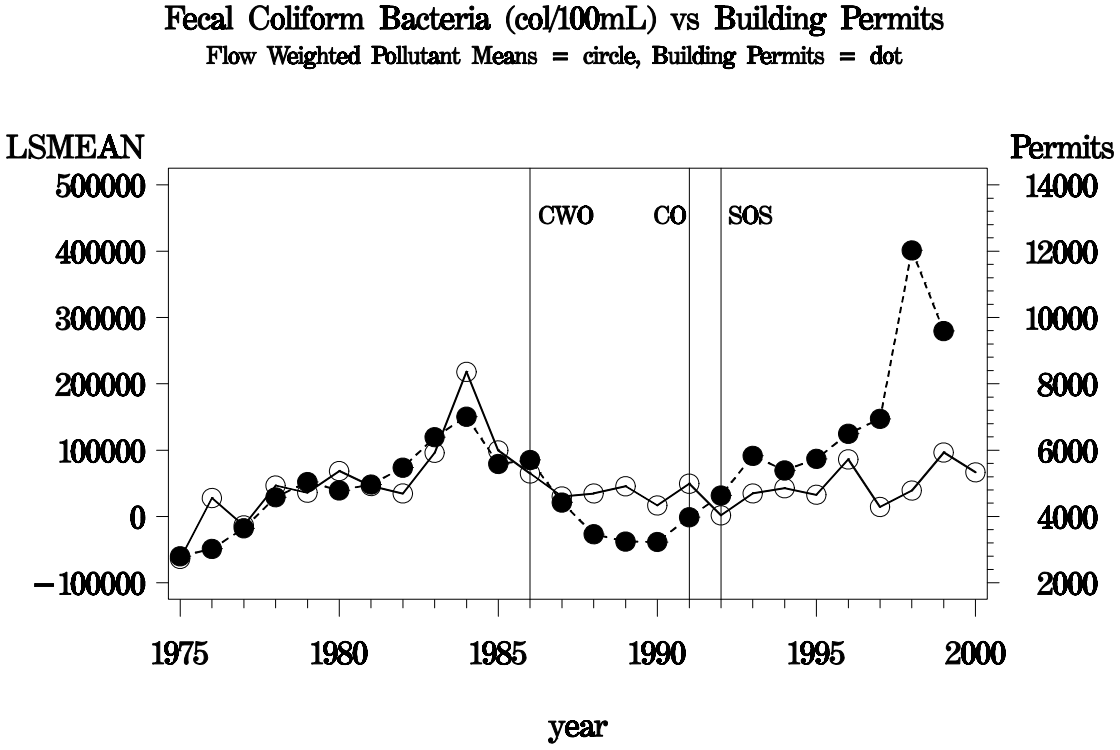



**Figure 1. Continued**