# TRIBUTARY WATER QUALITY ANALYSIS UPDATE 2002

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## ABSTRACT

*A 10-year study was conducted in tributaries in Travis County, Texas of five different wastewater treatment/disposal strategies. Contributing watersheds were categorized by predominant strategy into golf course effluent irrigated (GEI), residential septic (RS), residential central (RC), residential effluent irrigated (REI) and rural /undeveloped (UD). Parameters analyzed were nitrate/nitrite, orthophosphate, ammonia, fecal coliform bacteria, conductivity, pH and temperature. Overall, GEI and RC site types were shown to be significantly higher in nutrients and GEI was significantly higher in other physiochemical parameters. The UD site type was significantly lower in most parameters measured. The variation in concentrations of all parameters was most extreme in the GEI and RC site types. The undeveloped/rural site types had the lowest concentrations and the smallest variation in all parameters measured.*

## INTRODUCTION

Barton Creek is a gaining waterway in the contributing zone and a losing waterway in the recharge zone of Barton Springs segment of the Edwards Aquifer. The tributaries flowing into the mainstem are contributors and indicators of impacts on baseflow conditions. Monitoring water quality on a local level in Barton Creek tributaries was instituted to identify local effects of different land use types. Effects can be observed earlier in tributaries, whereas mainstem dilution can potentially mask effects until cumulative impacts are irreversible. Sites on tributaries in west Austin were added to obtain additional data on wastewater strategies and/or land uses that were not well represented in the Barton Creek watershed.

The Barton Creek Canyon Study (COA 1997) was initiated to determine how urbanization and wastewater disposal is affecting tributary water quality and how tributary water chemistry is affecting Barton Creek water chemistry and algae growth. The first objective was addressed by examining statistical differences between water chemistry parameters collected in 30 tributaries over the ten-year period between 1992- 2001. Based on preliminary tributary monitoring between 1990 and 1993, (COA 1997) Environmental Resource Management (ERM) staff designed a monitoring study to determine if significant water quality differences exist between the five different wastewater categories represented in this study. (Table 1)

Table 1. Land Use and Wastewater Strategy Categories and their abbreviations

| Group Abbreviations | Land Use Type | Wastewater Strategy |
|---|---|---|
| GEI | Golf | Effluent Irrigated |
| REI | Residential | Effluent Irrigated |
| RC | Residential | Central System |
| RS | Residential | Septic system |
| UD | Rural or undeveloped | None/Septic |

## METHODS

Site Selection

During the 10-year study period, ERM personnel sampled 74 sites on tributaries in various locations and for various periods of time in the Barton Creek watershed and west Austin. For the purposes of this update, data from 30 sites collected monthly or quarterly between 1992 and 2001 were used (Figure 1). The 30 sites were selected based on watershed type, perennial baseflow and the amount of regular monitoring data available. Appendix 1 contains the site names, locations and landuse designations for the tributaries chosen. Sites were grouped into wastewater strategy groups (Table 1) using best professional judgement and primary development type. Undeveloped sites were determined using GIS and the City of Austin's (COA) landuse coverage analysis with aerial photo interpetation, including only sites with less than 5% impervious cover. Exceptions to this categorization include:

1. Crenshaw Tributary 1 @ Barton Creek- This site has low impervious cover (1.1%), however the entire watershed is a golf course and uses effluent irrigation.(GEI)
2. Leif Johnson Spring Trib- Low impervious cover (4.6%), however, this tributary is fed by a spring where a large percentage of the springshed is in a golf course using effluent irrigation.(GEI)
3. Short Spring Branch Trib in LC Estates- Due to golf course construction that was initiated in 1997, causing frequent sediment spills through 2001, the data used in this analysis was limited to the pre-construction period (1992 – 1997) and the watershed was classified as undeveloped.

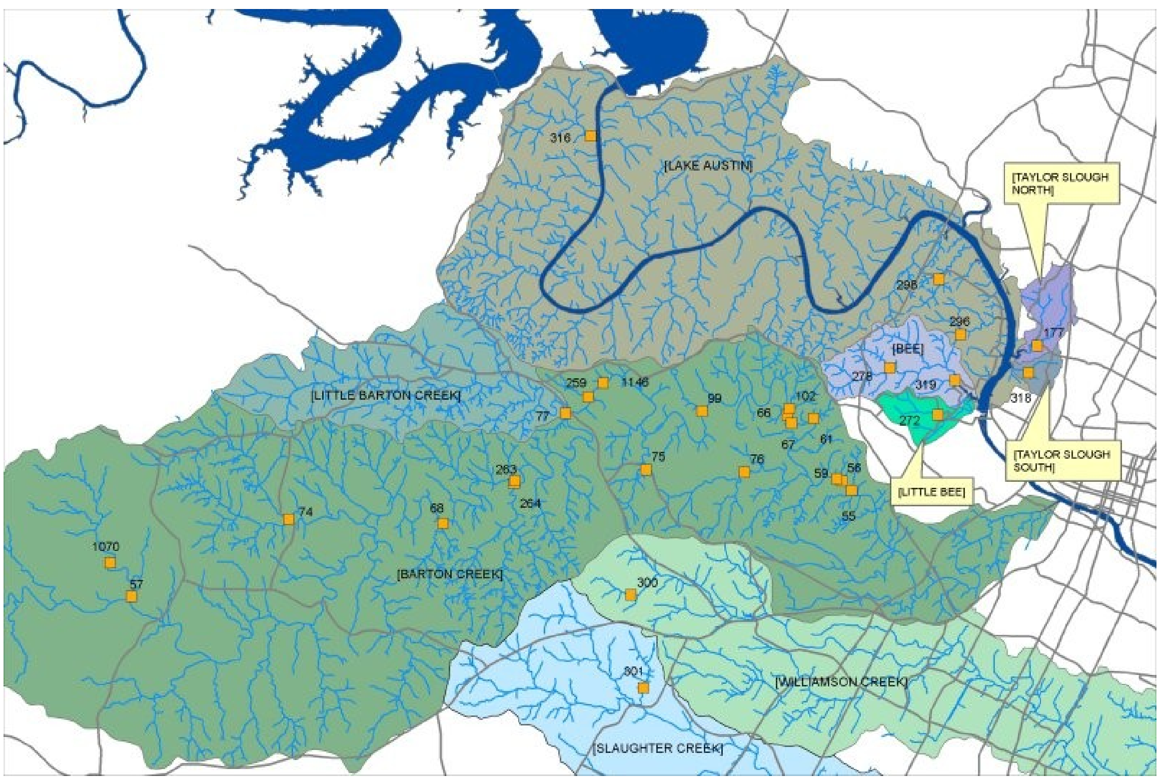


Figure 1. Canyon Tributary site locations 1992-2001.

Sampling Protocol

Monthly or quarterly baseflow surface water samples were collected by ERM personnel from the mouth of each stream or at an upstream site which represents the drainage of a particular land use. Standard collection methods were employed to prevent contamination and insure proper preservation of samples for analysis.

Previous to April of 1999, staff performed water chemistry analysis in ERM's laboratory, conducted in accordance with standard methods (American Health Institute 1995) (See appendix 2 for a list of methods and units of ERM lab analyses). Constituents measured in ERM's laboratory included nitrate nitrogen, ammonia nitrogen, orthophosphate, fecal coliform, turbidity in Formazin Turbidity Units (FTUs), total suspended solids (TSS), pH and total dissolved solids (TDS) (COA, 1997). TSS and TDS were dropped from the parameter list in 1995 (TDS was replaced by conductivity). Beginning in April of 1999 through December 2001, samples collected were submitted to Walnut Creek Water and Wastewater Laboratory (WCWWW) an EPA approved water quality lab for analysis. Laboratory parameters analyzed include turbidity (NTU), nitrate/nitrite- nitrogen, ammonia-nitrogen, orthophosphate and fecal coliform. (See Appendix 3 for methods and units of WCWWW Laboratory analyses). Field parameters during this period were pH, conductivity and water temperature. Conductivity, pH and temperature were measured using several different instruments over the 10-year period (see Appendix 4 for a table of instruments and use periods). Flow was measured using a Marsh McBirney Model 2000 velocity meter with methods recommended by TNRCC's 1993 *Water Quality Monitoring Procedures Manual*.

All samples were collected during baseflow conditions, which were defined as follows: From 1992 to 1999, baseflow conditions were met after at least 12 hours following measurable precipitation of less than 0.5", at least 24 hours following a rainfall of between 0.5" to 1.0", and at least 48 hours following a rainfall of greater than 1.0". Starting in April of 1999, baseflow conditions were redefined to be at least 24 hours following measurable precipitation of 0.1"to 0.25", 48 hours following rainfall of 0.25"to 1.0" and 72 hours or greater following a rainfall of greater than 1.0". This criteria change may have affected the decision to sample on a particular day, but is not anticipated to have biased results toward storm influenced conditions in the earlier period.

Data analysis was performed using the Statistica software package (Statsoft 1997). For normally distributed data, Analysis of variance (ANOVA) was used to determine statistical differences among sites with error levels of less than 5% (p values $<0.05$). Post Hoc comparison tests were then used to evaluate the results of the ANOVA (Scheffe and Tukeys Honest Significant Difference (HSD) tests). For data not normally distributed, non parametric tests were run, using ANOVA on ranked data and the Mann Whitney U test, error levels less than 5% ($p<0.05$). Values far from the middle of the distribution (outlier coefficient >1.5, extreme>3.0) are referred to as outliers and extremes and were included in analyses. For simplification purposes they are deleted from graphical displays, however, they are listed in footnotes below each graph. All data points below detection limits were set to the detection limits for analyses. Although substitution is not normally an optimal method of handling data below detection, it was accepted by TCEQ and other regulatory agencies during this period. Storm and special event data were excluded from analyses.

## RESULTS

Orthophosphorous

Analysis was performed on 1262 data points collected at the 30 sites over a ten-year period between 1992- 2001. Detection limits for analyses range from <0.01 to <0.02 mg/L. As illustrated in Figure 2, orthophosphorous concentrations appear higher in the site categories Golf Effluent Irrigated (GEI) and Residential Central (RC).

Because the data was not normally distributed, ANOVA was run on the ranked data. All site types are statistically different from GEI in this non-parametric analysis; The Undeveloped or Rural (UD) site type had the least variation in baseflow concentrations of orthophosphate. GEI and RC had the highest variation in baseflow concentrations (Figure 2).

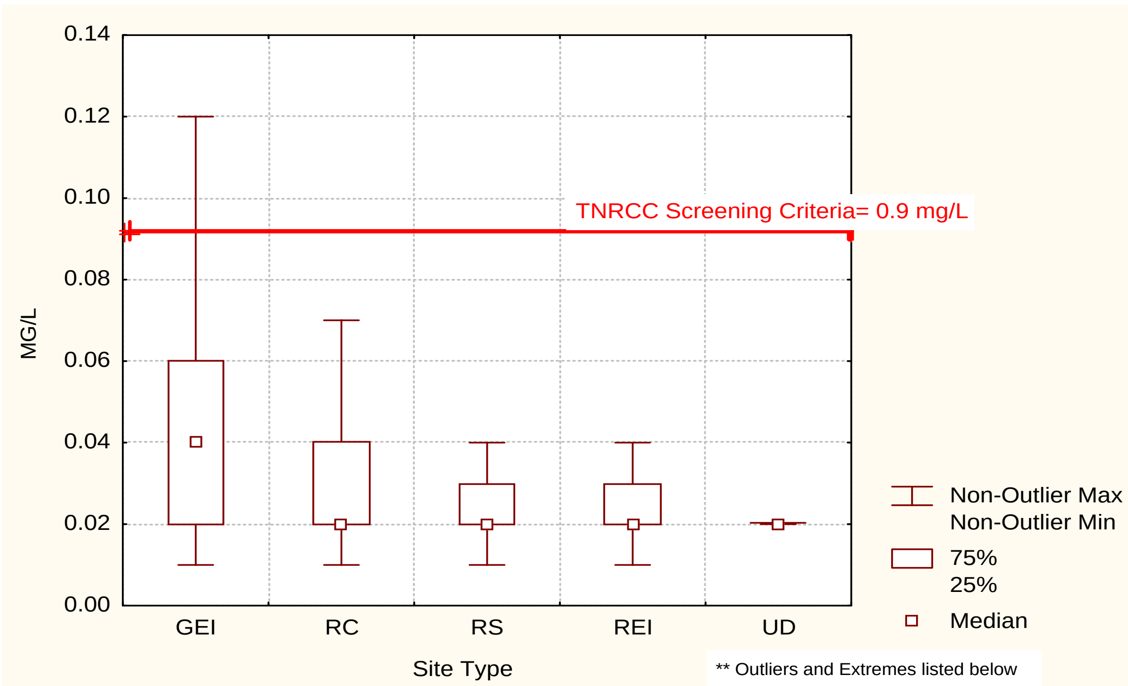


Figure 2. Orthophosphate concentration in Canyon Tributaries groups during study period (1992-2001). **Outliers and extremes- GEI- >2.5, >2.5, 0.24, 0.17, 0.14 mg/l- RC- 1.3,1,0.44, 0.32, 0.31,0.17, 0.17, 0.14 mg/l- RS- 0.18, 0.18, 0.15 mg/l REI- 0.18mg/l, -UD- 0.52,0.18, 0.14 mg/L

The undeveloped (UD) type had the lowest overall mean concentration of orthophosphate (below 0.025 mg/L). REI and RS had mean concentrations similar to the undeveloped sites, between 0.025 and 0.030 mg/L (Appendix 2).

<u>Nitrate/Nitrite as Nitrogen</u>

Analysis was performed on 1330 data points from the 30 selected sites over the 10-year period from 1992- 2001. Detection limits range from 0.02 to 0.1 mg/L. As illustrated in Figure 3, nitrate concentration medians appear to be higher in GEI, RC and RS watershed types

Non-parametric analyses show statistical differences between site types. These differences were supported with both ranked and unranked data. Additional Post Hoc Comparison tests were run using the Mann Whitney U test: the GEI site type showed significant differences with RC, REI, RS and UD. The actual difference between GEI and RC mean concentrations was 0.2 mg/l, which is relatively small. The mean concentration of nitrates in UD site types is graphically lower than all others, however, the mean is similar to REI (Fig. 3), with only a 0.2 mg/l difference. The most visible difference is the lack of variation in concentrations in the Undeveloped or rural (UD) site type. Variation in nitrate concentrations is most extreme in the Golf Effluent Irrigated and Residential Central site types.

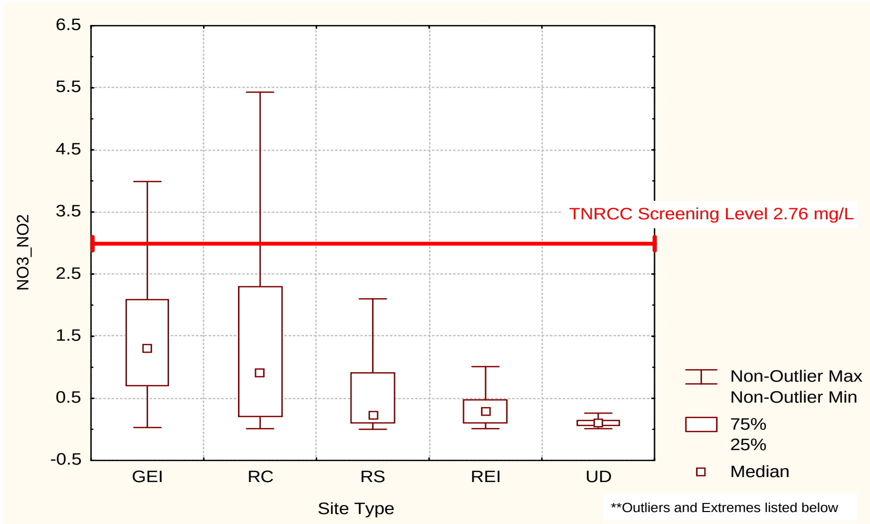


Figure 3. Nitrate/Nitrite as N concentrations within the five site types in Canyon Tributaries during the study period (1992-2001).
** Outliers and Extremes- GEI- 6.66, 7.28 mg/l- RS- 32.8 mg/l

<u>Ammonia as Nitrogen</u>
Ammonia analyses were conducted with 1337 samples collected at 30 sites over the 10-year period from 1992 through 2001. Detection limits range from <0.1 to <0.02 mg/L, with one month of data (11/98) with detection limits <0.001 mg/L. The five watershed types show similar concentrations, with the values ranging from a minimum of <0.01 mg/l at all sites and maximum values ranging from 0.1 to 0.483 mg/L found at the Golf effluent irrigation (GEI), Residential Central (RC) and Undeveloped (UD) watershed types. Graphically, the differences between watersheds are evident, (Fig. 4) with GEI and RC showing higher maximum concentrations and more variation. However, median concentrations between GEI, RC, REI and RS are similar. The Undeveloped or Rural (UD) site type appears graphically to have lower median concentrations of ammonia; however, statistically there are no differences between site types. Residential septic (RS) and Residential effluent irrigated (REI) site types had higher median concentrations than the UD site type, although due to variation in data collected there were no statistical differences.

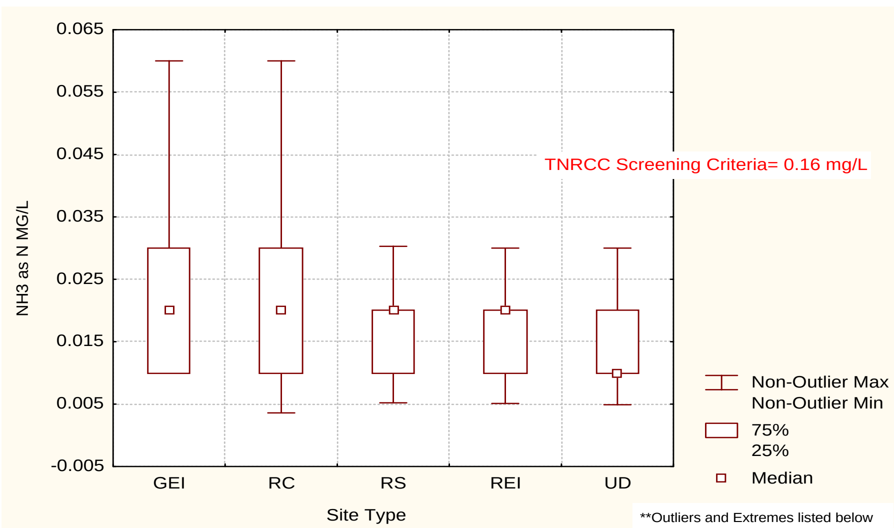


Figure 4. Ammonia as N concentrations in Canyon Tributaries within the five site types during the study period (1992-2001).
**Outliers and Extremes- GEI-0.16,0.13mg/L- RC-0.1, 0.11 0.36,0.37 mg/L- UD- 0.1,0.1,0.1,0.09,0.12,0.17,0.483 mg/L

Turbidity

Turbidity analyses were conducted on 1301 samples collected at 30 sites over the 10-year period between 1992-2001. From 1992 – 1999, turbidity analysis was conducted in ERM's laboratory and measured in FTU's.  In April of 1999, analysis of turbidity was performed at Walnut Creek Water and Wastewater laboratories and measured in NTUs. There is no conversion factor between the different units of measurement; therefore, the analyses were treated separately. When measured in FTUs, the mean for all samples was higher than when measured in NTUs. Otherwise, the site types appear to follow the same general pattern as with the nutrient results. The GEI site type showed the highest mean turbidity values and the undeveloped or rural site type showed the lowest mean turbidity values (Fig. 5). Statistical analyses were run separately on FTUs and NTUs, with results indicating the GEI site type is statistically higher than all other site types. There were no statistical differences between other site types.

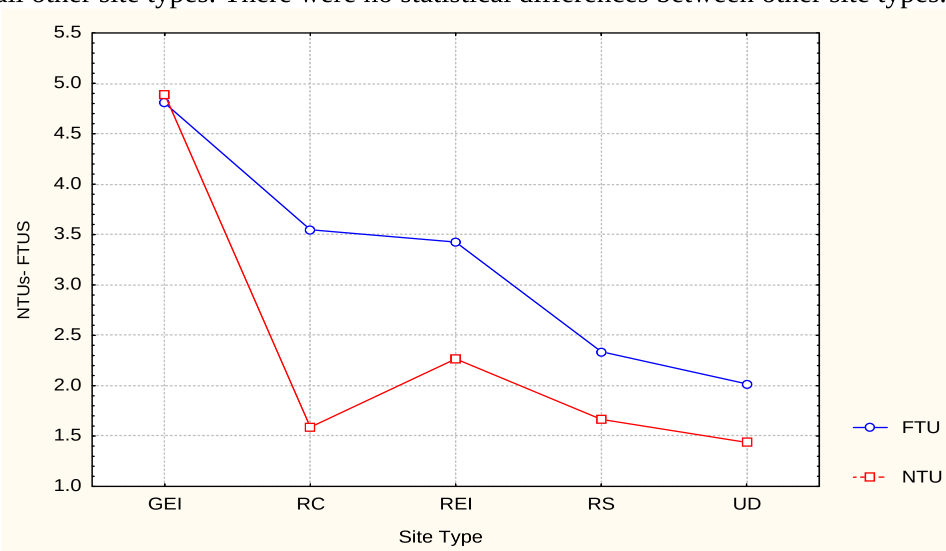


Figure 5. Mean Turbidity values in FTUs and NTUs within each site type for Canyon Tributaries during study period (1992-2001).

Conductivity

Conductivity analysis was conducted on 864 data points collected at 30 sites over the 10-year period between 1992- 2001. (Appendix 2) The data collected for conductivity were normally distributed; therefore, parametric Analysis of variance and Post hoc comparison tests were performed. Analyses showed significant differences between GEI and all other site types, with GEI being higher, and UD lower than all other site types. The residential site types were similar to each other with no significant differences among them (Fig. 6).

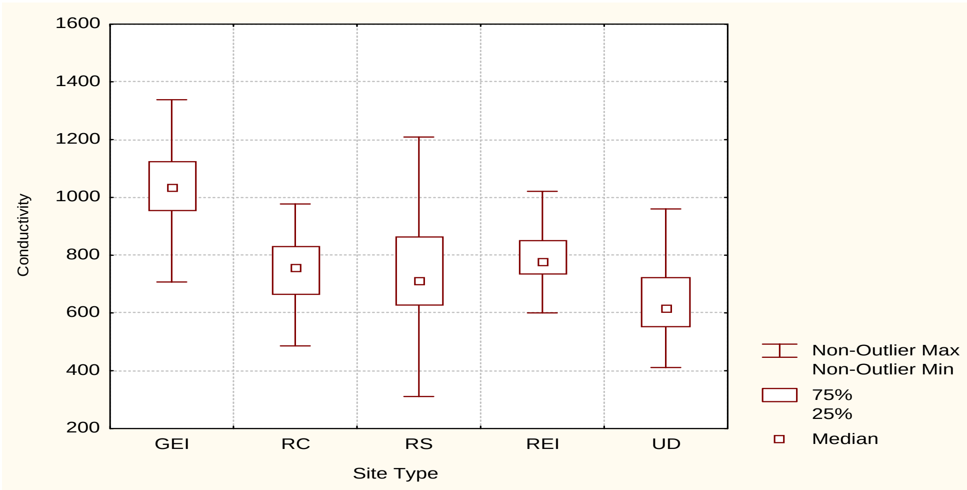


Figure 6. Conductivity values within site types in Canyon Tributaries during study period (1992-2001)

pH and Temperature

Water pH was analyzed with a total of 1063 data points collected from 30 sites over a 10-year period from 1992-2001. The median for all sites is 7.8 and the mean is 7.757, a minimum of 6.39 and a maximum of 8.75 were recorded. Statistical analyses were not performed on pH values, due to the low level of variation between sites (Appendix 2). Temperature was obviously related to season with the highest temperatures recorded in summer months and the lowest temperatures recorded in winter months with a range of 8 to 31 degrees centigrade.

Fecal Coliform

Fecal coliform was analyzed using 1008 data points from the 30 sites over the 10-year period from 1992 - 2001. Due to non-normally distributed data and wide variations in concentrations at all sites, statistical differences were determined using the nonparametric Mann Whitney U test on ranked data. The site type UD, with the lowest mean and median concentrations, is significantly different (lower) from RC, REI, and RS site types. The RC site type, (highest median with extreme variations in concentrations), is significantly different (higher) from all other site types. Residential Central has the highest potential for spills and wastewater leaks and fecal contamination from pet waste. (Gregory 2000), this can lead to higher overall baseline concentrations. The means of the individual sites follow the same pattern as the other parameters, with GEI and RC site types showing higher mean concentrations and UD site type with the lowest mean concentrations (Figure 8).

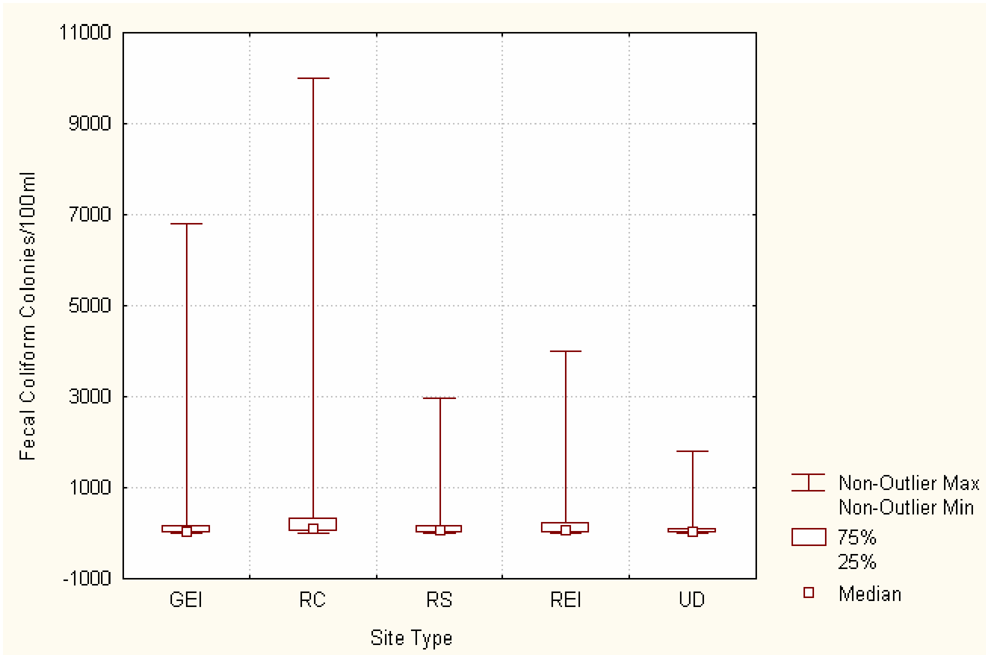


Figure 7. Fecal Coliform bacteria values at five site types in Canyon Tributaries during study period (1992-2001). Extremes & Outliers- GEI- (4) 10000-28100, RC- (1)-55,000, UD- (1)-6000

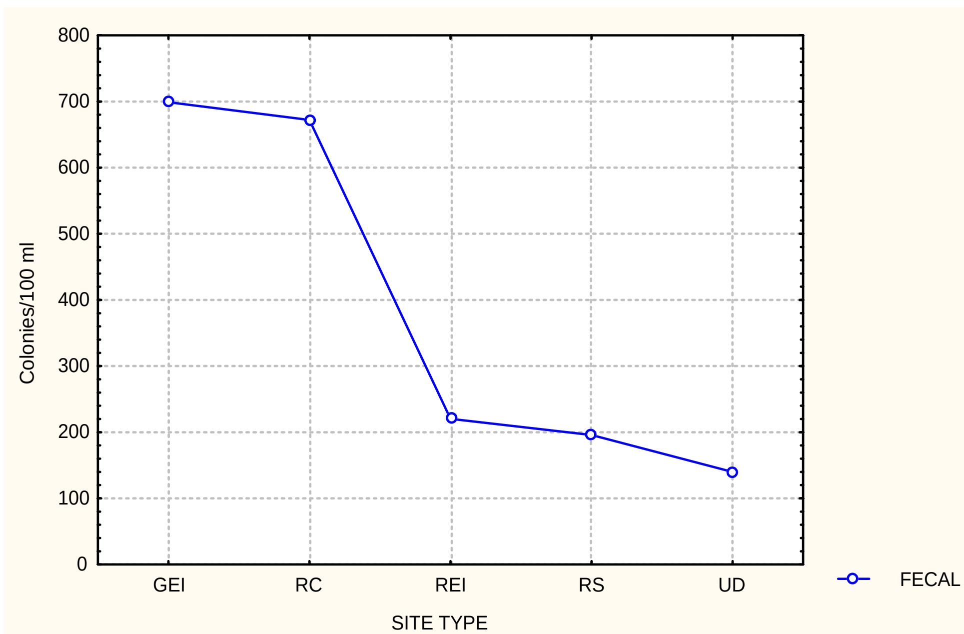


Figure 8. Fecal Coliform bacteria means at five site types in Canyon Tributaries during study period (1992-2001).

## DISCUSSION

The creeks and rivers flowing over the Balcones Escarpment of central Texas are characterized as having relatively clear waters with low nutrient concentrations. Although phosphorous is a necessary nutrient for all life, enriched phosphate levels can accelerate the growth of algae and other plants that impair water systems for municipal, recreational and fishery use. TNRCC Screening Criteria for orthophosphate is 0.9

mg/L (TNRCC 2002). The mean and median concentrations in these tributaries did not exceed the screening criteria; however, several individual points in the GEI site type exceed 0.9 mg/L (Figure 2). The USEPA has established a recommended limit of 0.05 mg/L for total phosphorous in streams that enter lakes and 0.1 mg/L for total phosphorous in flowing waters. Studies of phosphorous concentrations in pristine areas show medians of only 0.016mg/L. Dissolved phosphate occurs in small concentrations because it has low solubility, is readily taken up by biota and adsorbs to metals oxides in the soils (USGS 1999). The undeveloped watershed (UD) type has the lowest overall mean concentration of orthophosphate, below 0.025 mg/L. REI and RS have mean concentrations between 0.025 and 0.030 mg/L (Appendix 2). Slight increases in orthophosphate in these small tributaries can lead to eutrophication and increased loading into area streams and lakes. In freshwater systems, phosphorous is often found to be the growth-limiting nutrient (occurring at the lowest concentration in relation to the needs of the plants). If excessive amounts are added to the system, algae blooms can result. Loading estimates indicate that the largest anthropogenic sources of phosphorous are fertilizer application, manure application, wastewater treatment plant discharges and other nonpoint sources. (USGS 1999)

As with phosphorous, nitrate nitrogen is necessary for all life. However, increased nitrate concentrations can accelerate productivity and ultimately impair a water systems health. A USGS study of 85 undeveloped stream basins across the United States show a flow weighted median concentration of nitrate at 0.087 mg/L (Clark 2000). The median concentration for undeveloped tributaries in this study was less than 0. 25 mg/L, although higher than the USGS median, this is a relatively low concentration. Since there are little or no anthropogenic inputs, nitrate levels remain low and stable. TNRCC has established a Screening Level of 2.76 mg/L for nitrate/ nitrite as nitrogen for identifying secondary concerns in ambient waters (TNRCC 2002). The mean and median concentrations for nitrates in the Canyon watersheds did not exceed screening levels, (Appendix 2, Figure 3) although there are individual data points in site types GEI and RC which exceeded the screening level of 2.76 mg/L (Fig. 3).

Ammonia is normally found in low levels, rapidly oxidizing into nitrites then nitrates by nitrifying bacterium. Ammonia is the primary nitrogen product produced and released by most biological waste treatment processes. It is very expensive to aerate sewage sufficiently to oxidize the ammonia to nitrate (Manahan 2001). TNRCC screening criteria for ammonia in surface water is 0.16 mg/L (TNRCC 2002). At no time did any site exceed this limit. Although statistically there are no differences in ammonia among the site types, graphically there were visible differences (Fig. 4). GEI and RC site types have the highest variation in ammonia concentrations. Residential Central water quality may be influenced primarily by tap water runoff; especially during baseflow conditions (lawn irrigation, etc.). Examples of average ammonia concentrations in tapwater from the three treatment plants in the Austin area from 4/1/99-6/30/99 are 0.49, 0.42 and 0.46 mg/l. Examples of ammonia concentrations in natural waters entering the system are <0.03, 0.04 and 0.03 mg/l respectively. (Water Quality Summary 1999).

Overall, nutrient concentrations are higher and have increased variation in the GEI and RC site types. UD site type had the lowest nutrient concentrations with the least variation. For the most part, RS and REI site types had lower concentrations and less variability than GEI and RC site types, but higher nutrient concentrations and more variability than the UD site type. Increasing variability in nutrient concentrations can be an indicator of degradation in water quality. It is likely that land use practices in the GEI and RC site types are causing eutrophication in these streams.

Conductivity is a measure of dissolved ions in the water. Measurements of conductivity can be used as an initial alert of changing water chemistry in natural and wastewaters. The GEI site type is statistically higher than all others and UD site type is statistically lower than all others. There are no statistical differences between residential site types. Higher values of conductivity in the GEI site type indicate that irrigation practices are increasing ionic concentration in the tributaries that drain these watersheds. This parameter is a good indicator that dissolved pollutants in the wastewater effluent are most likely entering these waterbodies.

Presence of fecal coliform bacteria in streams indicates that contamination by fecal material from human or animal sources has occurred and contact with these waters can result in exposure to pathogenic bacteria often associated with fecal contamination (Gregory 2000). Fecal coliform results show UD site type to be statistically lower than all other site types and RC site type is statistically higher than all other site types. Residential central watersheds appear to have a greater impact on water quality than residential septic development, with increased bacterial (fecal coliform) and nutrient loading. Large variations in fecal numbers in the RC site type could be the result of leaks and spills from central sewer lines, pet manure washing into creeks or illegal sanitary connections to storm drains (Gregory 2000). Again, this is an indicator that RC streams are being degraded by watershed practices.

Overall, results for nutrients and other constituents show Golf Effluent Irrigated (GEI) and Residential Central (RC) tributary types with higher baseline concentrations for all parameters measured but few significant differences between the two site types. Both site types have significantly higher concentrations for nutrient parameters analyzed than the Undeveloped (UD) site type. Residential Effluent Irrigated (REI) and Residential Septic (RS) have similar concentration means for nutrients, possibly due to lot size and buffer requirements imposed when developing these types of residential communities. Several studies have shown vegetated buffer zones to be one of the best management practices for maintaining stream ecological integrity (Horner 1999).

## CONCLUSIONS

The major conclusions of this study are as follows:

- Golf courses using effluent irrigation negatively impact water quality in small tributaries where they are located and thus, have a detrimental impact on the water quality in larger creeks downstream.
- Residential central watersheds appear to have a greater impact on water quality than residential septic development through increased bacterial (fecal coliform) and nutrient loading. The increased variation of baseline concentrations for all parameters in GEI and RC site types can also be an indication of water quality degradation
- Undeveloped or rural watersheds result in the least variability in tributary concentrations of all constituents measured.

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# Appendix 1
## Land Use

| | | Site Type | LLSF | SF | Mobile Homes | mf | com | off | ind | civ | park | trans | util | undev | unknown | total ac | %IC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **site** | **Site Name** | | **50** | **100** | **113** | **200** | **300** | **400** | **500** | **600** | **700** | **800** | **870** | **900** | **999** | | |
| 67 | Leif Johnson Tributary (LJST) @ Barton Creek | GEI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.9 | 12.6 | 0.0 | 0.0 | 11.0 | 0.0 | 30.5 | 0.0 |
| 72 | Crenshaw Tributary 1 (CRT1) @ Barton Creek | GEI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.7 | 0.0 | 0.0 | 0.0 | 0.0 | 14.7 | 0.0 |
| 66 | Fazio Tributary @ Barton Creek | GEI | 0.0 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.0 | 48.0 | 7.6 | 0.0 | 35.1 | 0.0 | 123.1 | 0.1 |
| 56 | Lost Creek Waterfalls Tributary @ Barton (LCW) | RC | 0.0 | 17.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 2.3 | 0.0 | 0.0 | 0.0 | 19.7 | 0.2 |
| 59 | Ringtail Ridge Canyon Tributary @ Barton (RRC) | RC | 0.0 | 51.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.2 | 9.4 | 0.0 | 1.8 | 0.0 | 71.6 | 0.2 |
| 55 | Lost Creek Residential Tributary @ Barton (LCR) | RC | 0.0 | 53.7 | 0.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 92.3 | 11.0 | 0.0 | 14.9 | 0.0 | 172.9 | 0.1 |
| 318 | Taylor Slough South @ Reed Park (TSS) | RC | 0.0 | 140.7 | 0.0 | 5.3 | 4.1 | 0.0 | 0.0 | 104.0 | 1.4 | 40.4 | 0.0 | 1.8 | 0.0 | 297.8 | 0.3 |
| 177 | Taylor Slough North @ Pecos St (TSN) | RC | 0.0 | 152.0 | 0.0 | 6.4 | 12.9 | 12.2 | 0.0 | 227.7 | 10.8 | 74.6 | 0.7 | 1.6 | 0.0 | 498.9 | 0.3 |
| 298 | Westlake Davenport Trib 1 (WDT1) @ Westlake Drive | REI | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.2 | 0.0 | 2.8 | 0.0 | 3.4 | 0.1 |
| 99 | Barton Creek West Tributary 1 @ Barton Creek (BCW) | REI | 0.0 | 37.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 13.8 | 0.0 | 109.0 | 0.0 | 161.9 | 0.1 |
| 259 | Bee Cave Tributary (BCT) @ Barton Creek | REI | 0.0 | 0.0 | 0.0 | 0.0 | 23.2 | 0.0 | 0.0 | 0.0 | 51.9 | 8.5 | 0.0 | 183.9 | 0.0 | 267.5 | 0.1 |
| 296 | Small Toro Canyon Tributary @ Toro Canyon Rd (STC) | RS | 0.0 | 61.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.1 | 0.0 | 7.1 | 0.0 | 79.0 | 0.2 |
| 61 | Camelot Tributary @ Barton Creek (CAM) | RS | 0.0 | 77.4 | 0.0 | 0.0 | 2.1 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 0.0 | 44.3 | 0.0 | 134.8 | 0.1 |
| 102 | Rob Roy Tributary @ Barton Creek | RS | 0.0 | 81.5 | 0.0 | 0.0 | 0.0 | 12.2 | 0.0 | 8.0 | 0.0 | 43.4 | 1.1 | 134.1 | 0.0 | 280.3 | 0.1 |
| 272 | Little Bee Creek @ Laurel Valley Rd (LVT) | RS | 0.0 | 302.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 31.5 | 0.0 | 99.6 | 0.0 | 435.3 | 0.2 |
| 300 | Williamson Creek @ Mowinkle Drive (MOW) | RS | 425.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 37.2 | 0.0 | 34.9 | 0.0 | 497.5 | 0.1 |
| 301 | Granada Hills Trib Upstrm of Slaughter Creek (GHT) | RS | 300.5 | 9.9 | 0.0 | 0.0 | 1.6 | 0.0 | 3.4 | 0.0 | 0.0 | 43.2 | 0.0 | 197.9 | 0.0 | 556.5 | 0.1 |
| 319 | Bee Creek @ Lake Austin | RS | 0.0 | 631.1 | 0.0 | 2.5 | 15.8 | 46.6 | 7.1 | 14.9 | 169.4 | 130.6 | 4.8 | 442.4 | 0.0 | 1465.3 | 0.1 |
| 316 | Unnamed Trib @ Running Deer Trail (AST) | RS | 0.0 | 83.6 | 14.0 | 0.0 | 4.6 | 0.0 | 6.7 | 1.4 | 0.2 | 113.4 | 0.0 | 1319.8 | 37.0 | 1580.6 | 0.1 |
| 1146 | Headquarters Tributary @ Barton Creek | UD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.7 | 3.7 | 0.0 | 60.8 | 0.0 | 79.2 | 0.0 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 278 | Wild Basin Park Trib @ Bee Creek (WBP) | UD | 0.0 | 17.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 123.5 | 20.9 | 0.0 | 24.1 | 0.0 | 186.0 | 0.1 |
| 264 | Little Paisano Tributary (LPT) @ Barton Creek | UD | 0.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 222.7 | 0.0 | 223.6 | 0.0 |
| 276 | Stark Tributary @ Barton Creek (STT) | UD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 727.7 | 0.0 | 727.7 | 0.0 |
| 68 | White Branch Creek (WHC) @ Barton Creek | UD | 5.3 | 18.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 713.3 | 0.0 | 737.4 | 0.0 |
| 75 | Upland Tributary 1 @ Southwest Parkway (UPTS) | UD | 0.0 | 75.3 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 658.6 | 13.3 | 0.2 | 199.7 | 0.0 | 949.5 | 0.0 |
| 76 | Short Spring Branch Trib in LC Estates (SSBE) | UD | 50.3 | 140.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.9 | 0.0 | 618.0 | 47.1 | 0.0 | 1062.4 | 0.0 | 1927.7 | 0.0 |
| 77 | Little Barton Creek @ Barton Creek (LBC) | UD | 12.6 | 135.0 | 0.0 | 0.0 | 20.7 | 4.6 | 20.9 | 84.0 | 29.2 | 79.2 | 0.0 | 1707.5 | 0.0 | 2093.7 | 0.0 |
| 74 | Rocky Creek (ROC) @ Crumley Ranch Road | UD | 0.0 | 35.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.8 | 0.0 | 0.0 | 2364.8 | 0.0 | 2422.2 | 0.0 |
| 263 | Grape Creek @ Barton Creek (GMC) | UD | 157.0 | 115.9 | 0.0 | 0.0 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 6.4 | 0.0 | 2627.6 | 0.0 | 2908.9 | 0.0 |
| 1070, 57 | Fitzhugh Creek @ CR101/Fitzhugh Rd/ mouth | UD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3123.5 | 0.0 | 3123.5 | 0.0 |

## Appendix 2
## Environmental Resource Management Laboratory Methods

| Parameter | Method | Earliest | Latest | Count |
|---|---|---|---|---|
| | HACH 8038 | 15-Jan-93 | 20-Apr-94 | 7 |
| | HACH 8041 | 29-Sep-98 | 29-Sep-98 | 1 |
| | HACH 8155 | 8-Apr-92 | 29-Oct-98 | 589 |
| AMMONIA AS N | SM 4500-NH3 D E (ORION) | 1-May-98 | 25-Mar-99 | 147 |
| NITRATE/NITRITE AS N | HACH 8038 | 20-Jul-95 | 20-Jul-95 | 1 |
| | HACH 8038 | 24-Jan-94 | 24-Aug-95 | 130 |
| | HACH 8048 | 1-Feb-95 | 5-May-95 | 13 |
| | HACH 8171 | 8-Apr-92 | 27-Oct-98 | 428 |
| | HACH 8192 | 1-Feb-93 | 29-Oct-98 | 39 |
| | OHMICRON NO3 SCREENING | 26-Aug-98 | 30-Jan-02 | 129 |
| NITRATE AS N | SM 4500-NO3 D G (ORION) | 1-May-98 | 29-Sep-98 | 21 |
| ORTHOPHOSPHORUS AS P | HACH 8048 | 8-Apr-92 | 30-Jan-02 | 737 |
| TOTAL SUSPENDED SOLIDS | SM 2540 D | 24-Jan-94 | 9-May-97 | 93 |
| FECAL COLIFORM BACTERIA | SM 9221 E | 8-Apr-92 | 30-Jan-02 | 583 |
| | HACH 16800 | 1-Feb-93 | 30-Jan-02 | 337 |
| TURBIDITY | HACH 8237 | 20-Apr-92 | 27-Oct-98 | 501 |

## Appendix 3
## Walnut Creek Water/Wastewater Laboratory Methods

| Parameter | Method | Earliest | Latest | Count |
|---|---|---|---|---|
| | SM 4500-NH3 D | 14-Jan-02 | 1-May-02 | 31 |
| AMMONIA AS N | SM 4500-NH3 F | 19-Apr-99 | 17-Oct-01 | 432 |
| NITRATE/NITRITE AS N | EPA 353.2 | 19-Apr-99 | 1-May-02 | 461 |
| NITRATE AS N | EPA 353.2 | 19-Apr-99 | 2-Aug-99 | 51 |
| ORTHOPHOSPHORUS AS P | SM 4500-P E | 19-Apr-99 | 1-May-02 | 464 |
| TOTAL SUSPENDED SOLIDS | SM 2540 D | 23-Jul-01 | 1-May-02 | 15 |
| FECAL COLIFORM BACTERIA | SM 9222 D | 19-Apr-99 | 1-May-02 | 442 |
| TURBIDITY | SM 2130B | 19-Apr-99 | 24-Apr-02 | 455 |

Appendix 4
Field Equipment

| Parameter | Description | Earliest | Latest | Count |
|---|---|---|---|---|
| DISSOLVED OXYGEN | CORNING M90 | 28-Mar-96 | 28-Mar-96 | 5 |
| | HYDROLAB | 21-Jan-94 | 2-Aug-02 | 68 |
| | Quanta Probe | 12-Sep-00 | 16-Oct-01 | 7 |
| WATER TEMPERATURE | COLE PARMER PHCON10 | 20-Apr-99 | 30-Jan-02 | 331 |
| | CORNING M90 | 6-May-97 | 15-Jul-99 | 14 |
| | EPA 220.2 | 26-Jan-95 | 26-Jan-95 | 1 |
| | EPA 351.3 | 22-Sep-99 | 22-Sep-99 | 1 |
| | HACH | 1-Feb-93 | 24-Jul-97 | 44 |
| | HORIBA WATER QUALITY METER | 29-May-97 | 30-Oct-00 | 30 |
| | HYDROLAB | 21-Jan-94 | 2-Aug-02 | 72 |
| | Quanta Probe | 12-Sep-00 | 16-Oct-01 | 7 |
| | THERMOMETER (ALCOHOL) | 25-Feb-94 | 25-Jan-96 | 48 |
| PH | COLE PARMER PHCON10 | 20-Apr-99 | 30-Jan-02 | 336 |
| | CORNING M90 | 20-Apr-92 | 27-Oct-98 | 296 |
| | HACH | 21-Jan-94 | 18-Dec-97 | 155 |
| | HORIBA WATER QUALITY METER | 29-May-97 | 30-Oct-00 | 30 |
| | HYDROLAB | 21-Jan-94 | 2-Aug-02 | 78 |
| | Oakton pH Tester 2 | 2-Mar-98 | 15-Jul-99 | 6 |
| | Oakton pH Tester 3 | 18-Sep-97 | 25-Mar-99 | 190 |
| | Quanta Probe | 12-Sep-00 | 16-Oct-01 | 7 |
| FLOW | CALCULATION | 23-Jun-94 | 25-May-95 | 11 |
| | MARSH McBIRNEY METER | 23-Jun-94 | 1-May-02 | 980 |
| | STOPWATCH | 24-Jul-01 | 24-Jul-01 | 1 |
| | VISUAL ASSESSMENT | 22-Aug-96 | 10-Apr-00 | 19 |
| | VISUAL FLOW ESTIMATION | 28-Jan-99 | 24-Apr-02 | 30 |
| CONDUCTIVITY | COLE PARMER PHCON10 | 20-Apr-99 | 30-Jan-02 | 342 |
| | CORNING M90 | 22-Feb-96 | 15-Jul-99 | 435 |
| | EPA 245.2 | 24-Apr-97 | 24-Apr-97 | 1 |
| | HORIBA WATER QUALITY METER | 29-May-97 | 30-Oct-00 | 25 |
| | HYDROLAB | 21-Jan-94 | 2-Aug-02 | 78 |
| | Quanta Probe | 12-Sep-00 | 16-Oct-01 | 7 |
| | SM 2510B | 24-Jun-99 | 22-Sep-99 | 6 |