# BIG CREEK SUB-WATERSHED STUDY: WATER AND BED SEDIMENT QUALITY RELATIONAL TO PESTICIDE AND NUTRIENT CONCENTRATIONS

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**Abstract.** The City of Alpharetta, Georgia was awarded a 319(h) grant in 1999 for the study of water and bed sediment quality relational to pesticide and nutrient concentrations in the Big Creek sub-watershed. After changes in personnel and the work plan, monitoring began on the project in April 2004. Big Creek has a watershed area of 103 square miles and is a major sub-watershed of the Chattahoochee River. The Big Creek watershed lies north of Atlanta and includes portions of Cherokee, Fulton and Forsyth Counties, as well as the Cities of Alpharetta, Cumming and Roswell. Twenty-four square miles or 23% of the watershed is within the City limits of Alpharetta and well over half of the watershed drains through Alpharetta. The majority of Alpharetta is within a seven-mile upstream radius of the City of Roswell's drinking water intake on Big Creek.

Pesticides to be addressed during this study included chlorpyrifos and degradate 3,5,6-trichloropyridinol, diazinon, malathion, oxadiazon, chlorothalonil and degradate 4-OH chlorothalonil, trifluralin, dithiopyr, and pendimenthalin. Pesticides were chosen based on widely available insecticides, herbicides and fungicides in the area. Nutrients monitored included nitrate, ammonia, various forms of phosphate, total phosphorous, and biologically available and soluble phosphorous.

The purpose of the study was to conduct an assessment of pesticide and nutrient concentrations in the water and bed sediment of Big Creek and its tributary Foe Killer Creek. The final goal was to determine if there are unusually high concentrations of specific pesticides, fungicides or fertilizers in order to more accurately pinpoint the sources of the pollutants and recommend public education strategies to target the known pollutants in the Big Creek Watershed.

Often times, pesticide and insecticide contamination in surface waters and stream sediment can be attributed to applications on private lawns. Compared to professional landscape companies, private homeowners tend to apply more chemicals than are necessary. Subsequently, when a storm event occurs, the excess chemicals will runoff and flow into local waterways. Applying chemicals shortly before rain events can also cause increased runoff of the chemicals.

This paper will outline the background of the project, Phase I and Phase II monitoring, and final conclusions and recommendations. Overall goals for the 319(h) grant were to:

- Monitor basic water quality parameters, including dissolved oxygen, pH, turbidity, total dissolved solids, fecal coliform, fecal strep, temperature, depth, stream flow, copper, and fluoride
- Monitor nutrient concentrations in water
- Monitor pesticide concentrations in water and sediment
- Assess water and sediment quality in the Big Creek Sub-Watershed
- Develop a Sub-Watershed Implementation Strategy
- Educate stakeholders

Monitoring results were somewhat surprising. Half of the pesticides analyzed were not found in a single water or bed sediment sample over the two-year monitoring period. The only pesticide found consistently was chlorothalonil and its degradate 4-OH chlorothalonil. Basic water quality parameters such as temperature, pH, dissolved oxygen and turbidity were consistently in the acceptable range. However, the fecal coliform counts consistently exceeded EPA guidelines for swimming, often by several orders of magnitude. During Phase I, the average fecal coliform reading was 10,000 cfu/100mL which is 50 times the EPA guideline of 200 cfu/100 mL.

Overall, this study showed a direct link between pesticide use in the watershed and pesticide presence in Big Creek. Many instances of pesticide presence were downstream of a local golf club. Fortunately, only a few pesticides were found in the water or bed sediment samples. Chlorothalonil was the only pesticide found on a consistent basis and should be addressed in any public education efforts.

## BACKGROUND

In metro Atlanta, watershed urbanization has caused widespread degradation of water quality and aquatic communities in streams, lakes and reservoirs. Most of the stream reaches in metro Atlanta do not fully meet their designated uses because of high concentrations of indicator bacteria and other aquatic toxicity of unknown origin (Georgia DNR, 1997). Nonpoint sources of pollution in storm water runoff are the most commonly identified cause of this degradation (Frick et al, 1998; Georgia DNR, 1997). Big Creek is a 303(d) listed stream just downstream of Alpharetta because it only partially meets the designated uses of fishing and drinking water due to violating the fecal coliform criterion. The City of Roswell's drinking water intake is downstream of Alpharetta on Big Creek near its confluence with the Chattahoochee River. There has been historic detection of some of the targeted pesticides in Big Creek, but at the time of grant application, insufficient data existed to provide scientific indication of appropriate daily loads of specific pesticides and nutrients.

Of the toxic compounds present in metro Atlanta streams, pesticides are unique in that their primary mode of release to the environment is intentional use as a poison. Most organic compounds and toxic trace elements are released as air emission or as solid waste. The presence of one or more organophosphate or carbamate insecticides (part of the "pesticide" group) in urban stream water is of particular concern because these compounds are toxic to aquatic life at very low concentrations (some at 50 to 60 parts per trillion) relative to most other types of pesticides. Serious impacts may be exacerbated when other pesticide chemicals become mixed in the same streams and rivers. The presence of mixtures in water samples collected by the U.S. Geological Survey (USGS) show that aquatic biota in the Chattahoochee River and its tributaries are commonly exposed to mixtures of these products at levels approaching acutely toxic values. Research suggests that when fresh water ecosystems are exposed to both nutrients and insecticides, algae blooms are larger and more persistent than in the presence of nutrients alone. The increase in perphytic algae in the presence of insecticides was attributed to a decrease in populations of arthropod grazers that would normally regulate algae populations (Brook et al, 1995).

In metro Atlanta, nitrate and phosphate are commonly measured in watersheds as a result of storm water runoff. Few data, however, are available to indicate which sources are responsible for the loading (i.e., fertilizer runoff from turf, sewage, industrial wastewater). Many of these same products can be found and persist in higher concentrations in bed sediments, dramatically affecting benthic organisms. As nutrients and pesticides have both separate and combined effects on ecosystems, more data is needed on the temporal patterns and sources of pesticide and nutrient loading in local waterways.


**Figure 1 Location of Big Creek Watershed.**

In the past, the City of Alpharetta has cooperated with State agencies in investigations of stream and lake fish kills that have been traced to pesticide runoff; however, existing information is insufficient to determine the appropriate pesticide and nutrient loading for in-stream water and bed sediment quality. In addition, there is no real knowledge of the short- and long-term implications of specific concentrations. Impacts on aquatic environments, public safety for recreation and local drinking water quality are all concerns. Without a solid base of local data, local policy makers have no scientific guide for developing regulations and public education programs to improve and protect water resources in the Big Creek Watershed, and to allocate appropriate resources to alleviate pesticide and nutrient nonpoint source pollutants.

In order to determine the source and levels of pollutants in Big Creek water and bed sediment, routine and storm event monitoring were performed in the Big Creek Watershed over the course of two years in two separate phases. Grab samples and storm event samples were analyzed for specific pesticides, nutrients and basic water quality parameters. Sediment samples were analyzed for targeted pesticides.

## MONITORING

Phase I concentrated on gathering baseline in-stream data to determine the presence and concentration of target constituents in Big Creek. Water samples (grab samples) were taken every two weeks at all of the six sampling locations. Water samples were analyzed by the City of Alpharetta Water Resources Technician for basic water quality parameters such as temperature, pH, dissolved oxygen, turbidity, total dissolved solids, copper, fluoride, fecal coliform and fecal strep. Grab samples were then sent to Mississippi State and, under the supervision of Dr. Kevin L. Armbrust, were analyzed for nutrients (such as phosphorus and nitrogen) and common pesticides. The sampling locations can be seen in Figure 2 and include:

A. Segment #3 – Foe Killer Creek at Rucker Road. Drains residential areas and older farms. Less development exists in this segment than other areas of Alpharetta.

B. Segment #16 – Big Creek at McGinnis Ferry Road at the Forsyth County line. Monitoring at this site prior to initiation of the grant had determined that some in-stream nutrient problems could be traced back to a poultry-processing plant in Cumming and to landscaping fertilization in newly developed areas north of Alpharetta.

C. Segment #5 – Big Creek at Old Milton Parkway. This location is downstream of Caney Creek and Lake Windward and receives storm water runoff from upscale residential neighborhoods, a major golf course and well-maintained corporate campuses.

D. Segment #28 – Big Creek at Kimball Bridge Road. This is the location of a USGS stream gauging station. Contributing land use includes residential and heavy office development.

E. Segment #47 – Big Creek near Mansell Road. This location is adjacent to the City of Alpharetta greenway downstream of intense retail development. The location is at the confluence with Long Indian Creek, which drains approximately 3.6 square miles of residential land.

F. City of Roswell site – Foe Killer Creek northeast of Mansell Road, near Rock Mill Road. There is a current Real Time Monitoring Station operated by the City of Roswell near this site. No sediment samples were taken at this site due to the rocky nature of the creek bed.

Sediment samples were collected once a month at five of the six sites. The initial work plan included bed sediment at Site 6 (Roswell site). However, in the field it was determined that this was not possible due to the bed of the creek being rocky in that location. Sediment samples were sent to Mississippi State where they were analyzed for pesticide concentrations.

Phase II monitoring primarily provided confirmatory data and continued sediment, nutrient, pesticide and basic water quality parameter monitoring. Grab samples were taken once a month at all six sampling locations and sediment samples were taken monthly at five of the six locations. The City of Alpharetta continued monitoring for basic water quality parameters throughout the two-year period at all six sampling locations.

Storm event sampling was completed during Phase II. The City of Alpharetta contracted out the storm event sampling to Russell Engineering. Three Isco samplers for storm event sampling were placed at three selected monitoring sites. Storm even sampling took place at an upstream site (Big Creek at McGinnis Ferry Road), a mid-point site (Big Creek at Old Milton Parkway), and a downstream site (Big Creek near Mansell Road). Two storm events were sampled at each of these locations, one in October 2005 and one in April 2006. The purpose of the storm event sampling was to compare pollutant concentrations during runoff events to dry weather events. It was expected that pollutant loadings would be higher during runoff events.

Phase I monitoring began in April 2004 and was completed April 2005. In-stream water samples were taken at six sites every two weeks for a total of 138 samples. Several samples were missed over the course of the year which extended the timeframe for Phase I by one month. Sediment samples were taken at five sites monthly for a total of 60 samples.

Phase II monitoring began in May 2005 and was completed in April 2006. In-stream water samples for basic water quality parameters were taken at six sites every month for a total of 66 samples. Sediment samples were taken at five sites for a total of 40 samples. Due to human error, sediment samples were not sent to Mississippi State for analysis during July and August 2005. Two storm event samples were taken at three sites (12 samples each) for a total of 72 samples.

Pollutants addressed included chlorpyrifos and degradate 3,5,6-trichloropyridinol, diazinon, malathion, oxadiazon, chlorothalonil and degradate 4-OH chlorothalonil, trifluralin, dithiopyr, and pendimenthalin. All water samples were analyzed for insecticides (chlorpyrifos and its degradation product 3,5,6-trichlorpyridinol, diazinon, and malathion), herbicides (oxadiazon), fungicides (chlorothalonil and its degradation product 4-OH chlorothalonil), nutrients (nitrate, ammonia, phosphorus), and basic water quality parameters (dissolved oxygen, pH, turbidity, total dissolved solids, copper, fluoride, fecal coliform and fecal streptococcus bacterial counts). Bed sediment samples were analyzed for all insecticides, herbicides and fungicides.

Sources of the studied pollutants include herbicides used for selective or post emergent weed control on turf, ornamentals and gardens; herbicides used for nonselective weed control on transportation and utility rights-of-way; insecticides used for structural and indoor pest control around homes, apartments and other buildings; and fungicides for lawn and turf control of fungal diseases.

## BASIC WATER QUALITY PARAMETERS

Results of the basic monitoring parameters mirrored values and concentrations previously seen in the watershed. The City of Alpharetta has been monitoring sites along Big Creek monthly for over 10 years.

### pH

The pH of Big Creek and Foe Killer Creek was consistently at acceptable levels throughout the grant. pH levels ranged from 6.33 to 7.55 during Phase I with average pH levels very close to 7. During Phase II, pH levels ranged from 6.15 to 7.98 with an average pH level of 6.96. A pH of 6.5 to 8.2 is considered acceptable by EPA standards.

### Dissolved Oxygen

Dissolved oxygen concentrations were consistently at acceptable levels throughout the grant monitoring period. The average dissolved oxygen value during Phase I was 7.88 mg/L and during Phase II was 7.45 mg/L. These concentrations fall in the acceptable range, and are consistent with previously recorded values in the watershed. EPA standards consider dissolved oxygen concentrations of at least 5 mg/L to be acceptable for fresh water.

The only date which showed concentrations below 5 mg/L was September 28, 2005. The lowest concentration for dissolved oxygen for the entire grant monitoring period was recorded at every site on that date. It is most likely that these low results were the result of a calibration problem with dissolved oxygen meter on that day which was resolved before the next monitoring date.

### Turbidity

Turbidity ranged from 4-282 NTU during both Phases I and II, with the values usually falling below 50 NTU. This was an expected range. There is no EPA guideline for turbidity, but measured values were considered by staff to be acceptable. In general, turbidity was found to increase after heavy rainfall events. Higher turbidity can be caused by large amounts of rainfall, sediment buildup and erosion.

### Fluoride

Fluoride was only found in two samples during the entire monitoring period, both during Phase I. Fluoride is generally associated with potable water or sewage entering the creek. The fluoride was found at the Foe Killer Creek at Rucker Road site on October 27, 2004 and again on January 11, 2005. Due to the isolated nature of these readings, it is likely that the source was local due to a water main or sewer line leak which was later repaired. Based on EPA maximum contaminant levels, fluoride should be below 2 mg/L. The highest concentration of fluoride found was 0.28 mg/L.

### Copper

Copper concentrations were consistently found to be under 0.25 parts per billion (ppb). Based on EPA maximum contaminant levels, copper concentrations should be below 1.3 parts per million, therefore, monitoring results showed extremely low copper concentrations. Copper found in the samples can have several sources. It can be a natural occurrence based on mineral content in the area or a result of treated lumber used around open waterways.

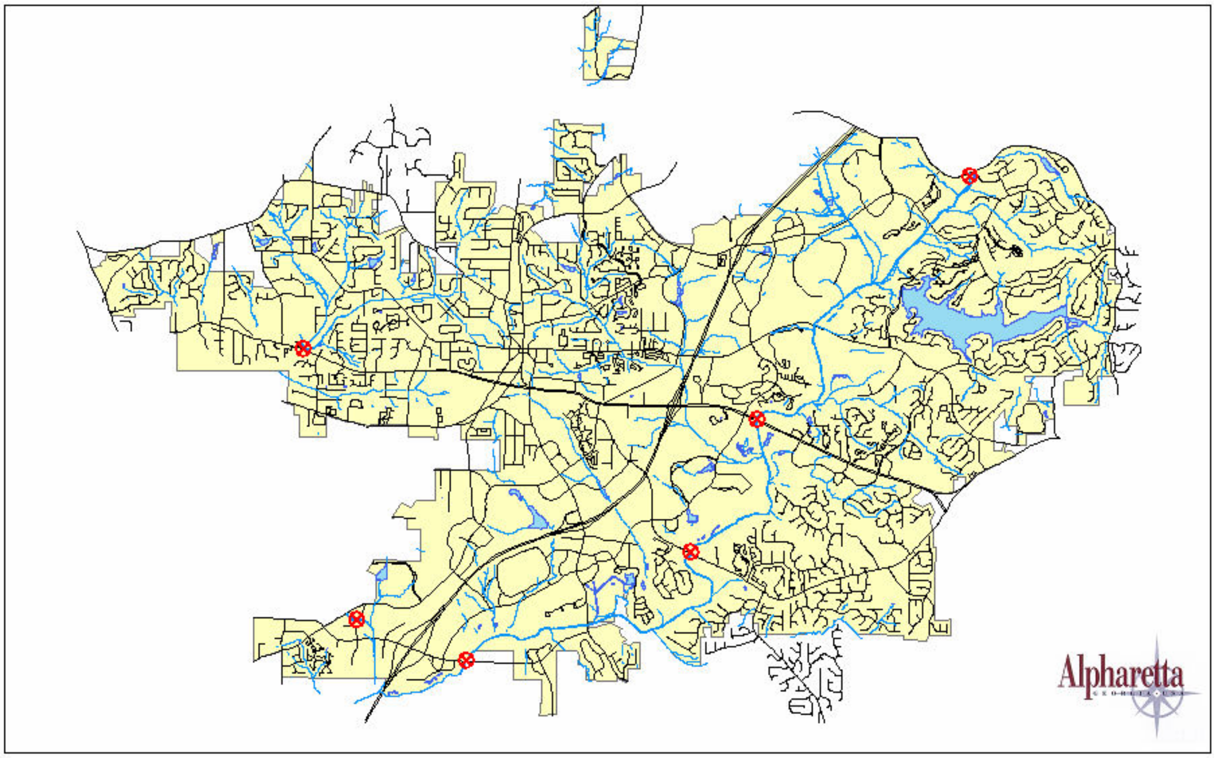


**Figure 2 Monitoring locations.**

**Fecal Coliform and Fecal Streptococcus**

Fecal coliform and fecal strep counts were consistently high with occasional spikes. These spikes occurred in the warm summer months when bacteria can easily multiply in the hot temperatures. The fecal coliform range was 500 – 182,000 cfu/100mL during Phase I. Average values were around 10,000 cfu/100ml during Phase I. The fecal strep range during Phase I was 40-2060 cfu/100mL. Average values for fecal strep during Phase I were around 400 cfu/100mL. Finally, the fecal coliform to fecal strep ratio consistently exceeded 4. This can be a possible indication that the source of contamination is human waste entering the waterways. The City of Alpharetta has actively investigated to determine the source of the high fecal coliform and fecal strep readings, but has so far been unsuccessful in determining a source.

During Phase II monitoring, fecal coliform and fecal strep counts continued to be consistently high with occasional spikes. The fecal coliform counts, compared to Phase I, were lower. Even though the level of fecal contamination was lower, the counts still significantly exceeded the EPA guidelines of 200 cfu/100ml. Therefore, the overall water quality was better, but still significantly exceeded EPA standards. Some spikes occurred again in the warm summer months. The fecal coliform range during Phase II was 0-13,900 cfu/100mL. This range is significantly lower than the range of 500 – 182,000 cfu/100mL found during Phase I monitoring. Average counts were approximately 2,000 cfu/100mL which is also down from the Phase I average of 10,000 cfu/100mL. The fecal strep range during Phase II was 0-2890 cfu/100mL. This range is comparable to the range of 40-2060 cfu/100mL measured during Phase I. Average counts for Phase II fecal strep were similar to Phase I at approximately 400 cfu/100mL. Finally, the fecal coliform to fecal strep ratio continued to consistently exceed 4 during Phase II.

NUTRIENTS

Nutrients tested at Mississippi State included total phosphorus, orthophosphate, polyphosphate, nitrate and ammonia. In general, concentrations of all nutrients tested were very low and usually did not exceed EPA guidelines. A slight correlation was seen between antecedent rainfall within two to five days of the sampling event and spikes in phosphorus and nitrate concentrations.

**Phosphorus**

The total phosphorous and orthophosphate (reactive or biologically available phosphorus) concentrations were insignificant and consistently <0.10 mg/L during both Phase I and Phase II. No polyphosphate (organic phosphorus) concentrations were identified due to the extremely low concentrations of phosphorus in the samples. The highest value of total phosphorous was 0.69 mg/L on July 2, 2004 during Phase I and 0.77 mg/L on September 1, 2005 during Phase II. Monitoring data was compared to rainfall data to determine if there was a correlation between antecedent rainfall and unusually high concentrations of nutrients. In both cases of high phosphorus concentrations, significant rainfall (over 0.5 inch) had occurred within 48 hours prior to the sampling date. This indicated that nutrient concentrations can spike after a rainfall event. However, there were many instances of over 0.5 inch of antecedent rainfall where the nutrient concentrations did not spike. Therefore, all spikes occurred after rainfall, but not all rainfall caused spikes.

A significant source of phosphorus in water bodies can be attributed to runoff containing fertilizers, detergents, or cleaning chemicals. These products can contain phosphorous and commonly end up in the local waterways. According to the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA) has recommended that total phosphorus should not exceed 0.1 mg/L in streams (USGS, 2001).

**Nitrate**

The levels of nitrate were generally in the 1.5 – 6 mg/L range during both Phase I and Phase II and averaged about 4 mg/L. The highest concentration of nitrate was 14 mg/L during Phase I and 6.7 mg/L during Phase II. Only two samples exceeded the EPA Primary Drinking Water Standard of 10 mg/L. Both samples were taken on January 28, 2005. During analysis of the data, it was noted that nitrate values were consistently high on that date. Further investigation showed that there was no rainfall within two weeks prior to that day, and no extreme or unexpected values were found for any other water quality or nutrient parameters. Temperatures had varied widely that month from around 70 degrees Fahrenheit during the first half of January to near 30 degrees Fahrenheit on the date of the sample. Currently, the only explanation for the high values is possible sampling or analysis error on that day.

According to the EPA, drinking water standards can serve as guidelines for surface water goals (Maidment, 1993). Common sources of increased values for nitrate can be fertilizer runoff, sewage seepage, chicken facility discharges, a localized source (such as a home garden next to a creek), and sampling error. There is a chicken processing facility which discharges into a tributary to Big Creek upstream in Forsyth County. Although historical documentation shows this plant used to be a significant contributor of pollutants to Big Creek, the plant has improved operations over the years and is no longer considered a significant threat to the health of Big Creek. EPA data from the chicken plant for the year 2004 show that the plant released 276,891 pounds of nitrate into surface waters over the course of the year. This amount certainly had an impact on the baseline nitrate concentrations found in Big Creek. It was noted during data analysis that, on average, sampling sites on Big Creek had about 3 mg/L more nitrate than sampling sites on Foe Killer Creek. However, the concentration of nitrate in Big Creek was still consistently within EPA guidelines.

**Ammonia**

The average level of ammonia was 0.024 mg/L during Phase I, with values exceeding 0.2 mg/L only three times during Phase I. In all three cases, there had been a significant rainfall event within 48 hours prior to the sample being taken. The levels of ammonia ranged from below the detectable limit of 0.10 mg/L to 0.13 mg/L during Phase II, with values exceeding 0.1 mg/L only three times. The average level of ammonia was 0.007 mg/L during Phase II. The EPA has established criteria for the maximum ammonia concentrations allowable in surface waters. This maximum limit is based on danger to aquatic organisms, such as fish. In most natural surface waters, ammonia values greater than 2 mg/L exceed the chronic exposure criteria for fish (USGS, 2001). The concentrations obtained through sampling show that the values in Big Creek were well below the maximum limit and were similar to previously sampled concentrations in the watershed. Concentrations varied throughout the different sites and were not consistently higher at any one monitoring location within the sampled area.

PESTICIDES

The only pollutants found in water samples during Phase I were chlorothalonil, 4-OH chlorothalonil, dithiopyr, and oxadiazon. The only pollutants found in bed sediment during Phase I were 4-OH chlorothalonil and oxadiazon. Both were only found in bed sediments sampled on April 1, 2005. The only pollutants found in the water samples during Phase II were chlorothalonil, 4-OH chlorothalonil, oxadiazon and malathion. The only pollutant found in bed sediment during Phase II was oxadiazon, which was only found on October 11, 2005.

Big Creek runs through the center of a major golf course in the northern portion of Alpharetta. Occasionally when pollutants were present, the concentration was higher downstream of this area. It appears from Phase I and II monitoring that Big Creek is highly susceptible to receiving pollutant runoff after pesticide applications. The golf club is also surrounded by heavily landscaped homes, as is typical for golf courses. The combination of the golf course and the surrounding homes could be a contributing factor to the levels of pesticide and nutrient concentrations in Big Creek within the City limits of Alpharetta.

The monitoring results were compared to rainfall data and it was found that there was not a direct correlation between pesticide presence and antecedent rainfall. However, if the pesticides were present, there was a direct correlation between higher concentrations and antecedent rainfall between June and September both years. In addition, pesticides were only found in bed sediment on April 1, 2005 and October 11, 2005. In both cases, antecedent rainfall exceeded 3.5 inches over the five-day period prior to the sampling date.

**Chlorothalonil and 4-OH chlorothalonil**

4-OH chlorothalonil is a metabolite of chlorothalonil which is a commonly used fungicide on lawns. It is used most commonly by golf courses. Bravo is a common brand name of this fungicide sold at stores such as Home Depot and Lowes. Chlorothalonil is also present in paints and deck stains. It is highly water soluble so it is very susceptible to runoff. Higher levels of concentration were recorded during the summer and early fall of 2004 during Phase I. During Phase II, concentrations were consistent throughout the year, with spikes during the fall season. These values were obtained from all sample locations and could be attributed to localized application throughout the Alpharetta area. However, it was noted that the majority of the samples containing chlorothalonil and 4-OH chlorothalonil were downstream of the golf club and could be a result of fungicide application in the area. City staff checked with the golf club and found that chlorothalonil is used during the spring and summer. According to Dr. Armbrust of Mississippi State, it is not surprising to find chlorothalonil and 4-OH Chlorothalonil in these samples. Small amounts of fungicide are not uncommon in Georgia's waterways due to the fact that the state accounts for the most pounds of chlorothalonil used per year in the United States (Cox, 1997).

**Dithiopyr**

Dithiopyr is a commonly used herbicide that is found in the product Dimension. Dimension is a specialty herbicide that provides control of crabgrass and twenty-five other annual grassy and broadleaf weeds. This product is used to control weeds on public and private landscaping projects, at nurseries, and in other applications (Dowagro, 2006). Trace values found in samples during the spring of 2005 can likely be attributed to runoff from landscaped areas during a storm event. The golf club has indicated that they no longer use dithiopyr, but commonly used it in the spring until 2005.

**Malathion**

Malathion is an organophosphate insecticide that is used widely on agricultural crops, in residential gardens, pest eradication programs (mosquito control), golf courses, nurseries, uncultivated nonagricultural areas, outdoor garbage dumps, sewage systems, and pastures (USEPA, 2005). The insecticide was detected in three water samples from Big Creek during June 2005. Concentration levels in the samples ranged from 0.13 – 0.14 ppb. In subsequent samples throughout the year, the insecticide was not detected. Due to the wide range of uses, the exact source of the pollutant can not be determined. However, due to the surrounding land use, likely sources are use on residential gardens, on the golf course and for mosquito control.

**Oxadiazon**

Oxadiazon is a herbicide registered for commercial use on golf courses, as well as in apartment/condominium complexes, parks, athletic fields, sod farms, nurseries, and landscapes (USEPA, 2006). Trace amounts were only found in samples from March 22, 2005 during Phase I. During Phase II, trace amounts were only found in samples taken on October 11, 2005. In October, the oxadiazon was only found in one sample, and could be a result of runoff from a private or commercial herbicide application in the area. In both cases oxadiazon was found to be in samples downstream of the golf club and could be a result of herbicide application in the area. The golf club indicated that they no longer use oxadiazon, but commonly used oxadiazon in the winter until 2005.

## STORM EVENTS

The storm event sampling was completed during Phase II. Three Isco samplers for storm event sampling were placed at three selected monitoring sites. Storm event sampling took place at an upstream site (Big Creek at McGinnis Ferry Road), a mid-point site (Big Creek at Old Milton Parkway), and a downstream site (Big Creek near Mansell Road). Two storm events were sampled at each of these locations, one in October 2005 and one in April 2006. The purpose of the storm event sampling was to compare pollutant loadings during runoff events to loadings during dry weather events. It was expected that pollutant loadings would be higher during runoff events.

Nitrate levels were consistently below 4 mg/L. Ammonia was consistently below detectable limits (0.10 mg/L). Total phosphorus was present at McGinnis Ferry Road and near Mansell Road in concentrations of 0.26 mg/L and 0.16 mg/L, respectively, in October 2005. Total phosphorus was below detectable limits (0.10 mg/L) at all sites in April 2006. Oxadiazon and dithiopyr were found at the Old Milton Parkway site in April 2006. 4-OH chlorothalonil was found at all three sites in October 2005. The concentrations were 0.028, 0.25 and 0.10 upstream to downstream. The highest concentration was at the site downstream of the golf club. No other pesticides were found during either storm event.

## CONCLUSIONS

Based on the sampling, most pesticides were not detected in the bed sediment and water samples. Only 63% of water samples contained traces of any of the pesticides assessed. The levels of pesticides that were detected were usually measured at very low concentrations. When sampling data was compared to rainfall data, a correlation was found between antecedent rainfall and higher concentrations of pesticides in the creek. The pollutants assessed were chosen based on their expected use in the watershed on the surrounding land use. It was a positive surprise that no trace of chlorpyrifos and degradate 3,5,6-trichloropyridinol, diazinon, trifluralin, and pendimenthalin were found in any water samples. Malathion, oxadiazon, and dithiopyr were found occasionally. However, traces of chlorothalonil and/or its degradate 4-OH chlorothalonil were found in 55% of water samples.

Chlorothalonil and its degradate 4-OH chlorothalonil were the only pesticides regularly found in water samples. It was determined that the golf club regularly uses this pesticide in the spring and summer. However, chlorothalonil and its degradate 4-OH chlorothalonil were found at all times throughout the year. Often, when 4-OH chlorothalonil was present, its concentration increased as sampling went downstream. Therefore, it appears there are sources in the area other than the golf course. Pesticides were found both in wet and dry weather, possibly indicating that sprinklers are used in the area adding pesticides even during dry weather conditions. Research has shown that more chlorothalonil is used in Georgia than any other state (Cox, 1997). Therefore, chlorothalonil should be a focus of public education.

In general, the concentrations of nutrients and pesticides were similar for storm events and dry weather events. However, when the increased flow in the stream is taken into account, it is clear that the pollutant loadings do increase even though the concentrations may not increase. In addition, the highest readings for both total phosphorus and ammonia were in water samples taken after significant rainfall within the previous 48 hours. Therefore, while rainfall did not always produce a spike in the nutrient and pesticide concentrations, occasional spikes after rainfall events did occur.

Basic monitoring results were consistent with previous monitoring results on Big Creek. The fecal coliform and fecal strep counts were relatively high, but followed trends that were previously seen in the Big Creek watershed. Overall, basic water quality parameters were consistently within EPA guidelines for temperature, pH, dissolved oxygen, turbidity, total dissolved solids, copper, and fluoride. Only fecal coliform and fecal strep consistently exceeded EPA guidelines. More focus on sources of fecal coliform may be needed throughout the watershed or more in-depth testing, possibly for E. coli, should be completed.

## RECOMMENDATIONS

At the beginning of the grant, the City of Alpharetta expected to find results that could pinpoint sources of pesticides and nutrients entering the local waterways. Due to the low levels of pesticides, herbicides and fungicides that were detected, the only possible source that could be pin-pointed was the golf club. However, the pollutants found are as likely to come from the well-maintained homes surrounding the golf course as from the golf course itself. The best way to deal with pollution due to runoff is public education. In the future, public education should continue to focus on informing the community on correct pesticide, herbicide, and fungicide application. Public education specifically addressing golf courses and their surrounding neighborhoods should be developed. Public education should include instruction to homeowners which informs them of correct application of chemicals on their properties. Education to golf courses should include proper application and reminders not to spray pesticides when rain is in the forecast.

The Clean Water Campaign, coordinated by the Atlanta Region Commission, has already created public education materials related to landscaping, pesticide application, and stormwater runoff. They have also created brochures targeting commercial landscapers in both English and Spanish. Local governments should continue to distribute these materials and participate in local workshops designed for homeowners and professional landscapers.

One form of public education could be to reach homeowners and landscapers through homeowners associations. Distributing materials to active homeowners associations that can then include the materials in newsletters to their homeowners could cost-effectively reach a significant number of homeowners. If information is included to explain to homeowners how to tell their landscapers they want pesticides applied, landscapers can be reached as well.

The City of Alpharetta already has an active storm drain stenciling program. In addition, the Clean Water Campaign has available storm drain markers and stencils. Local governments should be encouraged to use these resources to educate citizens that what they put in storm drains (including nutrient and pesticide laden leaves and grass clippings) ends up in local waterways.

The Clean Water Campaign and local governments could work with the Metro Atlanta Landscape and Turf Association (MALTA) to help educate landscapers. Local governments could also check for landscaper certification when commercial landscapers apply for business licenses.

A possible subsequent research project could be to work with golf courses to test the impacts of stream buffers and water quality devices on downstream nutrient and pesticide loadings to determine if there is a simple or cost-effective way to reduce loadings from golf courses into streams.

A recent statistically valid survey by the Atlanta Regional Commission showed that the percentage of people correctly identifying stormwater runoff as most responsible for pollution of rivers and streams has risen by 64 percent since the 2001 inception of the Clean Water Campaign (ARC, 2006). This confirms that public education is key to improving water quality in the future. Implementation strategies were sought from stakeholders and published in a brochure for local governments.

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