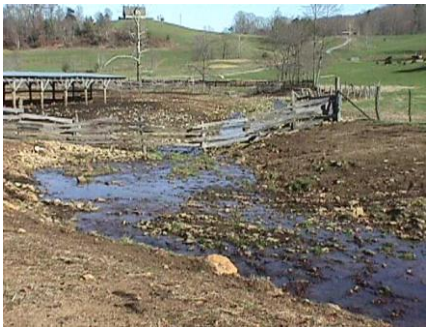
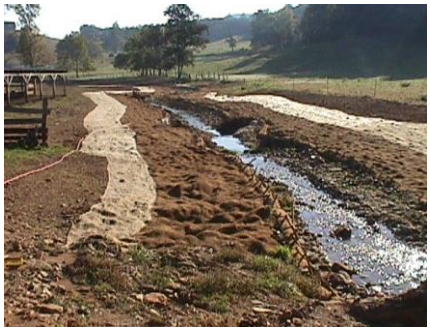
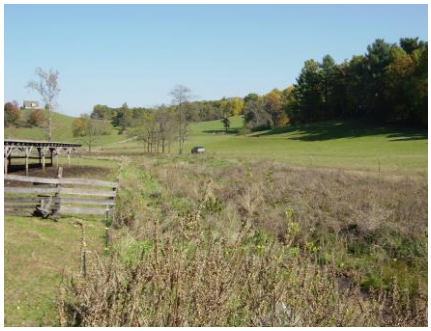
# 2003 Summary Addendum

Ecological Functions of Restored Stream Systems
Benthic Macroinvertebrates

March 2004

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## Introduction and Background

In December 2002 a final report was submitted to EPA summarizing benthic macroinvertebrate information collected from 50 stream restoration projects in North Carolina. These 50 projects and their collection schedules are listed in this memorandum as appendix 1. At that time, this report satisfied the conditions of the 3-year Wetland Program Development Grant CD984487-98. However, in many instances these data were preliminary, collected only prior to construction or immediately following construction and were considered by the Division of Water Quality (DWQ) to be incomplete. Additional data were collected from many of these projects in 2003 to build upon the initial investigations and are also currently scheduled for future investigations. This memorandum summarizes the biological data collected by the DWQ from stream restoration projects during 2003. The DWQ has assumed responsibility for collection and analyses of these data in a cooperative effort with the Wetlands Restoration Program (now the Ecosystem Enhancement Program) and the NC Department of Transportation. The overall intent of this summary is to initialize the use DWQ data only to begin review of success criteria. Data collected by consultants are listed and may be used to corroborate DWQ information. However, many other stream restoration projects have also had biological monitoring as a condition of the 401 Certification. Monitoring reports are submitted to DWQ for review and comment as part of the 401-review process. These data are listed in an introductory table but do not have detailed summaries in this memorandum. Table 1 lists all of the stream restoration projects that have a biological monitoring component to them and had data collected (or were scheduled for collection) in 2003.

*Technical Guidance Manual:* Prior to the implementation of monitoring programs to determine how streams were responding to restoration practices the Division of Water Quality produced a technical guidance manual that included survey protocols, including sample collection. These protocols mimic those developed by the Biological Assessment Unit of the DWQ. Standard qualitative collection methods were recommended for surveys conducted in all wadable streams that are 3rd order or larger. This collection method consists of two kick net samples, three sweep net samples, one leaf-pack sample, two fine-mesh rock and/or log wash samples, one sand sample, and visual collections. Insects are separated from the rest of the sample in the field ("picked") using forceps and white plastic trays, and preserved in glass vials containing 95% ethanol. Organisms are picked roughly in proportion to their abundance, but no attempt is make to remove all organisms from the samples. If an organism can be reliably identified as a single taxon in the field (an example would be Isonychia), then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples. These include colonial species (Bryozoa, Porifera), Nematoda, Collembola, semiaquatic Coleoptera, and all Hemiptera except Naucoridae, Belostomatidae, Corixidae and Nepidae. These are not picked either because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. The hemipteran families that are included can spend long periods below the water surface.

Stream mitigation projects are frequently conducted in small perennial streams having catchment sizes of less than one square mile (640 acres). Standard qualitative collection methods for these small 1st and 2nd order streams are inappropriate. Therefore, an abbreviated collection technique used (EPT collection method). This technique is a modification of the standard method in which only four samples are collected (rather than ten): one kick net sample, one sweep net sample, one leaf-pack and "visuals" and only Ephemeroptera, Plecoptera and Trichoptera (EPT) are collected and identified. However, during these surveys which assess the colonization of new habitat, all organisms are collected and processed not just EPT taxa. This collection method is referred to in this guidance as a Qual-4 technique. Analytical methods include the comparisons of taxa richness (total and EPT), abundance and NC biotic index values (lower biotic index values indicate better water quality) between investigations. It is recognized that Ephemeroptera, Plecoptera and Trichoptera are generally not considered early colonizers and would not be appropriate indicator organisms for restoration projects.

*Collection Protocol Training:* In many instances, biological monitoring was written into the conditions of a 401 Certification, which necessitated the use of private consulting firms to collect the data. To ensure consistency in the data collection, a series of two-day training sessions were conducted during 2001 and 2002 in the Raleigh area to instruct individuals in standard operating procedures recommended by the Division of Water Quality for the collection of benthic macroinvertebrates. DWQ-certified laboratories conducted taxonomic identification of specimens collected from private firms

## Collection Methods and Metrics

*Collection Methods:* All samples were collected using protocols developed by the North Carolina Division of Water Quality. Full-scale surveys (2 kick nets, 3 sweep nets, a leaf pack, 3 epifaunal collections and visuals) were used at projects that had catchments of 1.0 square mile or more and Qual-4 surveys (1kick net, 1 sweep net, 1 leaf pack and visuals) were used in smaller catchments. All specimens were preserved in the field using standard protocols and identified to the lowest practical level in the laboratory. During many surveys conducted in 2003, an attempt was also made to

differentiate between the inorganic (kicks and visuals) and organic (sweeps and leaf packs) components of the surveys. This type of sampling was conducted to determine what habitat types were most productive following restoration and how these habitats change with time.

*Metrics:* Analytical methods that were used to compare population structures between locations included taxa richness (EPT and total) and EPT (Ephmeroptera, Plecoptera and Trichoptera) abundance. Biotic indices would be an appropriate tool for comparisons; however, at the current time analytical programs were not available to calculate these metrics. Subjective values of 1, 3 and 10 were given for rare (1-2 specimens), common (3-9 specimens) and abundance (10 or more specimens) using the protocols developed by the DWQ. However if the samples were collected and separated by organic and inorganic components the actual abundance values were given to each taxa. Also a Dominant in Common (DIC) Index was used. This is a very simple comparison of the dominant taxa from a reference area (Common and Abundant taxa were used for this comparison) to the restored area. The hypothesis is that a high Dominant in Common value (percent) would be expected between the reference and the test site if all habitat and water quality parameters were similar. In many of the restoration projects summarized in this report the initial values are expected to be very low and improve as the new channel matures. In addition to the DIC, we also looked at the number of keystone species present at reference and compared those numbers to the restored channels. A keystone taxa is one that has a biotic index value of 2.0 or less (as defined by the DWQ) or has specific habitat requirements that are indicative of a stable channel. An example would be the presence of Serratella deficiens, which isn't necessarily an intolerant taxa, but is found primarily in macrophytes, which grow on stable habitat. Keystone taxa also include some elmidae because of their preference for woody material in the stream.

*Stream Flow Variability:* Many of these restoration projects had pre-construction data collected in 2001 and the first post-construction survey in 2003. All efforts were made to collect both sets of data from similar seasons; however, there were huge differences in stream flow between years. Drought, or near drought, conditions were experienced in 2001 and in many small catchments, flow ceased. This, of course, negatively affects the benthic insect populations of these small streams. Normal or high flow conditions were common in 2003.

## Results and Discussion

Table 1 lists all of the projects (30 projects in 2003) from which biological data were collected (or were scheduled to be collected) in 2003. However, this report only summarizes data collected from stream restoration projects that DWQ conducted cooperatively with either the Wetlands Restoration Program (now the Ecosystem Enhancement Program) or DOT. These data will be used to develop and test potential biological success criteria for stream restoration projects in North Carolina. No attempt was made to summarize all of the biological data collected by private consulting firms as part of stream mitigation projects, although these data may be used to corroborate DWQ information. Reports from private consultant firms will continue to be submitted to the Wetlands Unit of DWQ for review as part of the 401 Certification process. Appendix 1 is the original list of stream restoration projects summarized in the EPA grant (December 2002). Some of these projects have not been constructed and other new projects have been added to this original list.

*Potential Success Criteria*. One of the key recommendations of the 2002 report to EPA was a list of draft criteria that were proposed that might be used to determine project success. These criteria will be further tested and modified as more data are collected. These draft criteria are listed below and are based on the type of reference information collected (i.e. upstream site, ecoregional reference or neither).

I. Upstream Reference Data are Available:

- Biological success can be defined as occurring when the benthic macroinvertebrate community within the restored channel includes a viable population (common or abundance specimens) of keystone species. Keystone aquatic insect species are those taxa whose presence in the restored stream are dependent upon stable microhabitats. The presence of keystone species, or habitat specialists, is an indication that the restored stream channel contains productive microhabitats. These taxa must be collected from the upstream reference site and during any of the post-construction investigations from within the restored reach. Examples of keystone species include Tallaperla (leafpack), leptocerid caddisflies (streambank root hairs), elmid beetles or some limnephilid caddisflies (large woody material), heptageniid mayflies and hydropsychid caddisflies (flow).

And

- The composition of the dominant taxa between the reference reach and the restored channel must be at least 75% similar. The dominants in common (DIC) is defined as the number of dominant taxa common to the reference and restored reach regardless of their order of their abundance. Dominants are defined as all abundant or common taxa if use DWQ collection criteria are use or the ten most dominant taxa if quantitative methods or complete counts are used in the analyses. The 75% similarity criteria can be demonstrated during any of the post-construction investigations.

II. Ecoregional Reference Data are Available:

- Comparisons between the restored channel and the ecoregional reference location must be made between similar catchment types and stream order. The composition of the benthic fauna must be at least 50% similar (using a dominants in common analyses) between the ecoregional reference location and the restored channel. The 50% similarity criteria can be demonstrated during any of the post-construction investigations. The 50% similarity threshold is less restrictive than projects with upstream reference reaches because it is assumed that the biological integrity of the ecoregional reference streams is greater than streams selected for restoration. Staff of the DWQ must approve the ecoregional reference location.

III. Neither Upstream Reference nor Ecoregional Reference Data are Available:

- These types of monitoring projects are strongly discouraged by the DWQ and will not be approved for all future projects. The value of having reference data is critical for the determination of success. Unfortunately, some earlier projects were approved using this approach. If comparisons between pre- and post-construction investigations within restored channels are done, biological success is defined as having at least a 25% increases in taxa richness of EPT or 25% increase in the abundance of intolerant taxa (as defined by having a NC Biotic Index value of 3.50 or less), or a decrease in the NC Biotic Index value of one pollution category (excellent, good, good-fair, fair or poor) during any post-construction survey.

Table 1. Summary of Benthic Macroinvertebrate data collected from stream restoration sites in 2003. DWQ projects are in bold.

| Ecoregion | Project Name/County | Collecting Agency | No. of Years Post-constr. | Notes |
|---|---|---|---|---|
| Mountains | **High Vista - Buncombe** | **DWQ** | 1 | Restoration of Country Line Creek has not improved the biological integrity of this stream. The DIC index is well below the proposed criteria and the restored stream is dominated by tolerant taxa. Potential enrichment from golf course runoff remains an issue. |
| | Dowdle Mt. - Macon | Fish and Wildlife Associates | 2 | Benthic samples were collected prior to construction (2002) and during post-construction surveys in 2001 and 2002. Data indicate an initial decline in taxa richness following construction, and moderate increases in biological integrity in 2002. 2003 samples have been collection, but at this point the data haven't been analyzed. |
| | Warren Wilson - Buncombe | AES, Wisconsin | Not constructed | Pre-construction samples were collected as part of the mitigation for the Canton Motor Speedway. |
| New River | **Brush and L Pine - Alleghany** | **DWQ** | 1 | Data from this project question the validity of selecting this stream for restoration if the justification was to improve the biological health of the stream. There were more taxa and a higher DIC (78%) prior to construction within the restored reach. An increase in EPT abundance was note at Brush 2 following enhancement of a severely eroding bank. |
| | Lynn Haven - Watauga | Appalachian Environmental Services | 2 | Monitoring reports have been sent to DWQ that summarize data collected during the first year following construction. These data indicate that some recovery following construction has taken place. EPT taxa richness values of 14 were collected in the restored reach. However, data were not collected during 2003. |
| | Trillium - Watauga | Environmental Consulting Services | 1 | The first year of post-construction data has been collected from this project and the report submitted to DWQ for review. These data indicated that post-construction conditions didn't improved at all from pre-construction conditions at the restored reach. The report illustrated that the substrate conditions have improved (increase in the D50 values) at the restored location. |
| | Charleston Forge - Watauga | Environmental Consulting Services | 1 | The first year of post-construction samples has been collected and the report has been submitted to DWQ for review. These data note that upstream perturbations (construction of a dormitory, detention pond and culverts) impacted both reference and restored locations. |
| Western Piedmont | **Stone Mt. State Pk. - Wilkes** | **DWQ** | 3 | These data suggest that some improvement in the biological condition of the East Prong of the Roaring River is occurring, but not to pre-construction levels. DIC numbers remain relatively similar at site 2, but increase progressively at site 3 following construction. |
| | Concord Mills - Cabbarus | EcoScience | 3 | The annual monitoring report (year 4) has been submitted to DWQ for review and comment. This report notes that the benthic fauna has changed significantly between surveys and may be due to channel oversizing, channel evolution or the effects of sedimentation from upstream sources. Differences in collection techniques and location between surveys has complicated the analyses of these data. |
| | **Starmount Park - Guilford** | **DWQ** | 2 | Poor pre- and post-construction water quality conditions are evident at this project. Headwater reaches are stormwater driven and susceptible to drought conditions as noted during the 2003 survey. However some keystone taxa are consistently collected from the upstream reach and not from the restored reaches. Stormwater and/or nonpoint source runoff from the golf course is potentially impacted water quality at sites 2 and 3, within the restoration reach. |
| | **Payne Dairy - Alexander** | **DWQ** | 2 | Following construction the DIC, number of taxa and EPT abundance values declined dramatically at the restored site. Keystone taxa were eliminated. The most abundant taxa at this site following restoration was a very tolerant midge (Cricotopus bicinctus). This decline in integrity was also noted at site 3 during this survey. Conditions improved during the 2003 survey and now mimic to some extent the pre-construction conditions. |
| | **Big Warrior Crk. - Wilkes** | **DWQ** | 2 | Biological data from this project continue to improve from pre-construction conditions, particularly at sites 2 and 3. Increases in DIC numbers and keystone species are noted from these two locations in 2003. Data from Little Warrior Creek (relatively recent construction) note very little improvement to date, although EPT taxa richness (mostly Baetidae) did increase at this site in 2003. |

| Ecoregion | Project Name/County | Collecting Agency | No. of Years Post-constr. | Notes |
|---|---|---|---|---|
| | **Price Park - Guilford** | **DWQ** | 1 | Water quality conditions declined at both locations during the 2003 investigation, apparently responding to increases in stormwater. During both surveys keystone taxa were collected from the upstream reference and not from the restored reach suggesting that the habitat at the reference site is more stable. |
| | Hickory Quarry - Catawba | Fish and Wildlife Associates | 3 | Monitoring Complete, report submitted by F&WA. The information from this project showed an initial decline in the taxa richness following construction and an improvement the second year. They also noted a significant decline in the health of this stream the third year of analysis due to massive amounts of sediment released above the project. |
| | Edsel Place - Mecklenburg | Charlotte Stmw. Serv. - Mactech | 2 | Pre-construction data collected in 2000 and two years of post-construction data have also been collected (2002, 2003). The monitoring report has been sent to Charlotte for review, but at this point DWQ hasn't received this report. |
| | **Lyle Creek - Alexander** | **DWQ** | 1 | Significant reductions in taxa richness and EPT abundance values were recorded from site 2 within the restoration reach following construction. DIC values and the number of keystone taxa declined as well. |
| | Pott Creek- Lincoln | RKK | 1 | Benthic macroinvertebrate samples have been collected from two three monitoring locations prior to construction (2002) and for one year post-construction (2003). Summary reports note that instream conditions have declined following restoration, but the designers expect conditions to improve following channel stabilization. |
| | Meridian Drive - Mecklenburg | Charlotte Stmw. Serv. - Mactech | 2 | Pre-construction surveys were conducted in 1999 and 2000, post-construction surveys were also conducted in 2002 and 2003. The City of Charlotte is reviewing a draft report. |
| | Magnolia/Kirkwood/Sedgefield Park - Mecklenburg | Charlotte Stmw. Serv. - Mactech | 2 | Surveys have been conducted in 2001 (pre-construction), 2002 and 2003 (post-construction). A draft report summarizing these data has been sent to the City of Charlotte for review. |
| | Hope Park Branch - Mecklenburg | Charlotte Stmw. Serv. - Mactech | 1 | A draft report has been sent to the City of Charlotte for review. Pre-construction data were collected in 2001 and one year of post-construction data was collected in 2003. |
| Triassic Basin | Anson County Landfill | EcoScience | 1 | The second year monitoring report from this project has been completed and sent to DWQ for review. However, no biological data were collected the first year following construction due to lack of flow in the new channel. Data were collected the second year following construction and the fauna was dominated by enrichment tolerant taxa (esp. Chironomus) |
| Eastern Piedmont | Chavis Park - Wake | G. Pasacreta | 1 | Biological data were collected from 3 sites in August 2002. |
| | Rochester Heights - Wake | City of Raleigh – Ellis Aquatic Serv. | 3 | Data were initially collected in 1999 and post-construction in 2001, 2002, and 2003. The benthic macroinvertebrate community has hd very low taxa richness and diversity during all investigations, but these data indicate a minor improvement in the structure of the community following construction of the new channel. |
| | **Rocky Branch - Wake** | **DWQ** | 1 | Construction at this project is being conducted in phases and these data only summarize results following phase 1. The data from this project suggest that the overall biological integrity of the stream hasn't improved following restoration (tolerant taxa still dominate the fauna); however, the benthic fauna at site 2 (which is within the phase 1 construction) shifted from toxic tolerant chironomidae in 2000 to tolerant hydropsychidae in 2003. This observation may be result of stormwater treatment within this reach of Rocky Branch. |
| | **Hominy Swamp - Wilson** | **DWQ** | 1 | This urban Wilson stream is stormwater driven. It's evident that catchment-wide water quality issues control the biological integrity of the restored reach. Interestingly very tolerant taxa were collected from the reference reach in 2003 and not from site 2 within the restored reach. Likewise more EPT taxa (3) were collected from the restored reach than the upstream reference. |
| | **Smith/Austin Crks. - Wake** | **DWQ** | 1 | Data suggest that water quality conditions have improved at all locations in 2003, including data from the reference reach (much less so for Smith Creek 2). At this point it's difficult to say how much of this improvement is due to low flow conditions pre-construction compared to high flow conditions following construction. DIC values are much lower than the proposed success criteria. |

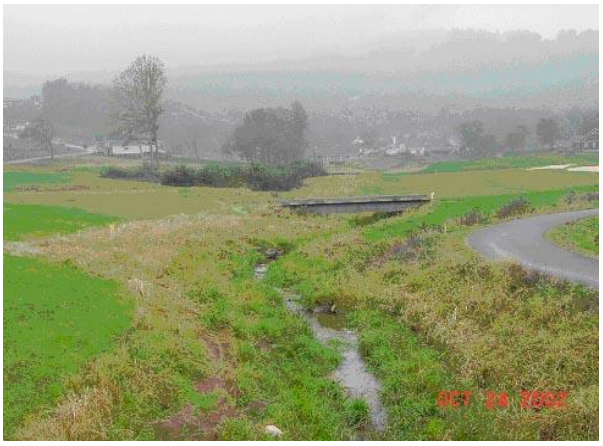
| Ecoregion | Project Name/County | Collecting Agency | No. of Years Post-constr. | Notes |
|---|---|---|---|---|
| | **Murphy Farm - Franklin** | **DWQ** | 1 | Some improvements were noted in the benthic macroinvertebrate fauna of UT Bear Swamp Creek following restoration. Increases were noted in the taxa richness and abundance of EPT taxa. DIC values were also higher in 2003 at site 2, but not at site 3. Many of the EPT taxa collected in the restored reach are tolerant (note the low numbers of keystone taxa in these sections) and may be a response to continued enrichment of this feature. |
| | **Yates Mill - Wake** | **DWQ** | 1 | Taxa richness and abundance values are lower in a previously restored reach (completed in 2000) than upstream reference conditions suggesting that biological condition haven't improved within this reach. In addition taxa richness values and DIC numbers were lower at the newly restored reach following construction. |
| Coastal Plain | Crescent Road - Lenoir | NC DOT - Buck Engineering | 1 | Pre-construction monitoring was conducted in 2002 by Biologists at Buck Engineering. All post-construction work is being coordinated by the NC DOT. |

# 1. High Vista Estates and Golf Course (Buncombe County)

Country Line Creek at High Vista Estates is a small (0.35 square mile), relatively steep tributary of the French Broad River. The land uses within the drainage area primarily consist of single family residential, and golf course (greens, ponds and golf cart paths) land cover. The stream originates at the base of a small pond although perennial spring seeps are common in the catchment. The restoration appears to be laterally confined due to limitations of the golf course resulting in very little sinuosity and nutrient management of nonpoint source runoff seems to be problematic in the catchment. Algae blooms in the downstream pond are common. Construction was completed in July 2002 at this project and biological data were collected in December 2001 (pre-construction) and December 2003 (first year of post-construction data).

Table 2. Summary statistics from the stream restoration project at High Vista Estates:

| **Site Location** | **Reference** | | | | **Country Line Creek Site 1** | | | | **Country Line Creek Site 2** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metric/Survey | Pre-C | Post 1[1] | Post 2 | Post 3 | Pre-C | Post 1 | Post 2 | Post 3 | Pre-C | Post 1 | Post 2 | Post 3 |
| Total Taxa Richness | 34 | 34 | | | 34 | 31 | | | 29 | 22 | | |
| EPT Taxa Richness | 21 | 19 | | | 19 | 15 | | | 5 | 5 | | |
| EPT Abundance | 85 | 87 | | | 62 | 55 | | | 18 | 25 | | |
| Dominant in Common Index (%) | - | - | | | 24% | 5% (14%) | | | 28% | 17% (36) | | |
| # Keystone species | 16 | 13 | | | 12 | 9 | | | 0 | 1[2] | | |



The reference reach was moved during the 2003 survey to a nearby catchment that appeared to be a better comparison to the data collected from Country Line Creek. These two reference reaches did have many similarities (taxa richness and abundance values are very similar). Dominant in Common numbers for both Country Line Creek locations when compared to reference reach conditions were 24% and 28% respectively during the pre-construction survey. This information suggests that catchment-wide perturbations are affecting the water quality of Country Line Creek and that the upstream site on Country Line Creek (site 1) may not be an appropriate reference. Dominant in Common numbers were low when compared to the ecoregional reference site in 2003 following construction (5 and 17%, respectively) and site 1 (14 and 36%, respectively). The number of keystone species was compared only to the upstream location on Country Line Creek rather than to a reference reach in another catchment.

It is evident that, at the current time, restoration of Country Line Creek has not improved the biological condition above proposed criteria. Taxa richness numbers remain low (EPT taxa richness was 5 both surveys at site 2) and dominated by fairly tolerant taxa (primarily Hydropsyche betteni) at this lower site (see table 3). Typically the abundance of filter-feeders, such as H. betteni, suggest autotrophic conditions and an abundance of fine particulate material. These data suggest that enrichment of the catchment for because of the golf course has overwhelmed the attempt to restore the channel to date. A comparison of the numbers of insects collected from the inorganic fraction of the sample and compared to the organic fraction in 2003 illustrate that Plecoptera (stoneflies) dominate both inorganic and organic components of the sample at the reference reach, but that their numbers are quickly reduced at site 1 and are completely eliminated at site 2. Filter-feeding Trichoptera were collected from the inorganic component of the sample suggesting that the riffle areas are stable enough to support this population of tolerant insects.

[1] The ecoregional reference reach for the first post-construction survey was move to a nearby neighboring catchment as the upstream reference may not be appropriate.

[2] There was only one "keystone" species collected from this location during this survey, however the number of Diplectona modesta (which has a biotic index value of 2.2) also increased in abundance during the first follow-up investigation.

Table 3. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples from Country Line Creek.

| | **Reference** | | **Site 1, upstream** | | **Site 2, downstream** | |
|---|---|---|---|---|---|---|
| | inorganic | organic | inorganic | organic | inorganic | organic |
| Ephemeroptera | 54 | 12 | 13 | 3 | 3 | 2 |
| Plecoptera | **81** | **39** | 4 | 1 | 0 | 0 |
| Trichoptera | 28 | 18 | 59 | 8 | 34 | 3 |
| Total | 163 | 69 | 76 | 12 | 37 | 5 |

# 2. Little Pine and Brush Creek Project (Alleghany County)

Little Pine Creek is a third order tributary of Brush Creek with a catchment size of 4.3 square miles at the confluence. The project/construction site is the lower reach of Little Pine Creek before it flows into Brush Creek. This reach was artificially straightened in 1969 and 950 linear feet of the channel was restored to original pattern, dimension and profile in July 2001. However, this reach appeared to be relatively stable at the time of restoration (although some bank instability was noted) and cattle had been previously excluded from this lower reach. It appeared that Little Pine Creek above the restoration reach (station 1) has also been straightened in the past and, unlike station 2, cattle have access to the stream in this reach. The aquatic insect data from Little Pine Creek reflects the water quality conditions of the entire catchment. Other investigations conducted in small stressed streams in the New River Basin by the Environmental Sciences Branch have indicated that the biological integrity is unusually high.

Brush Creek near the confluence of Little Pine Creek has a substrate dominated by sand and various reaches of Brush Creek above and below the confluence with Little Pine Creek have experienced significant streambank collapse. A large eroding streambank was found below the confluence with Little Pine Creek and may have been partially related to the channelization of Little Pine. Part of this project included an enhancement of the 2,640 linear feet of this streambank. Biological samples were collected from sites above and within the restoration reach of Little Pine (Stations 1 and 2) and above, within and below the enhancement reach of Brush Creek (Stations 1,2 and 3). Data from these surveys are summarized in Table 4.

Table 4. Summary statistics from the stream mitigation project at Little Pine and Brush Creeks.

| | **Little Pine 1** | | **Little Pine 2** | | **Brush Crk. 1** | | **Brush Crk. 2** | | **Brush Crk. 3** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Restoration | | | | Enhancement | | | | | |
| Metric/survey | Pre C | Post 1 | Pre C | Post 1 | Pre C | Post 1 | Pre C | Post 1 | Pre C | Post 1 |
| Total Taxa Richness | 47 | 66 | 64 | 52 | 75 | 56 | 63 | 60 | 79 | 74 |
| EPT taxa Richness | **22** | **29** | **29** | **27** | 38 | 36 | 38 | 34 | 39 | 40 |
| EPT abundance | 110 | 184 | 135 | 138 | **166** | **150** | **129** | **162** | **199** | **221** |
| Biotic Index | 4.28 | n/a | 3.66 | n/a | 2.50 | n/a | 3.39 | n/a | 3.58 | n/a |
| EPT Biotic Index | 2.88 | n/a | 2.52 | n/a | 2.50 | n/a | 2.66 | n/a | 2.41 | n/a |
| Dominant in Common Index (%) | - | - | 78% | 60% | - | - | 50% | 68% | 75% | 87% |
| # Keystone Species | 14 | 18 | 8[3] | 11 | 23 | 22 | 21 | 19 | 22 | 20 |

Benthic macroinvertebrates have been collected at five locations prior to construction and once following construction from this project. These data are summarized on table 4. Interestingly taxa richness and EPT abundance values were greater at station 2 (downstream) than station 1 on Little Pine Creek before restoration and these numbers declined only slightly following construction of the new channel. The Dominant Taxa Index was 78% at station 2 compared to station 1 prior to construction and declined to 603% following construction. The number of keystone taxa, primarily EPT taxa or other taxa commonly collected from stable habitat, was slightly higher following channel restoration. These observations suggest that there are watershed wide conditions affecting the water quality of this reach of Little Pine Creek and that the restoration has to date a minor improvement, to the benthic fauna. It is apparent that fencing cattle from the stream helped to stabilize the channel and allowed the restored reach prior to construction to provide riparian habitat for the aquatic insects. The habitat was removed following construction and the number of EPT taxa and DIC numbers

[3] Keystone species at this project represent intolerant EPT taxa (having a biotic index value of less than 2.00) and other taxa that are typically found on stable substrate (i.e. elmid beetles).

declined following restoration. These data question the validity of selecting this stream for restoration, as it appeared that biological conditions were better prior to construction.

Data from the Brush Creek enhancement effort illustrate a slight improvement in the biological condition at station 2 (which is the reach of Brush Creek that had a major sediment source/bank failure stabilized). The benthos in the immediate area of this part of the project may be responding to the elimination of the sediment source. Whereas prior to construction the EPT abundance values were lowest at station 2 (129), these numbers were slightly higher than station 1 (162 vs. 150) following enhancement of this eroding bank. Station 3 remains the most stable/diverse reach of Brush Creek. Dominant Common Taxa were higher following construction at stations 2 and 3 and the number of keystone taxa was very high at these two locations as well.

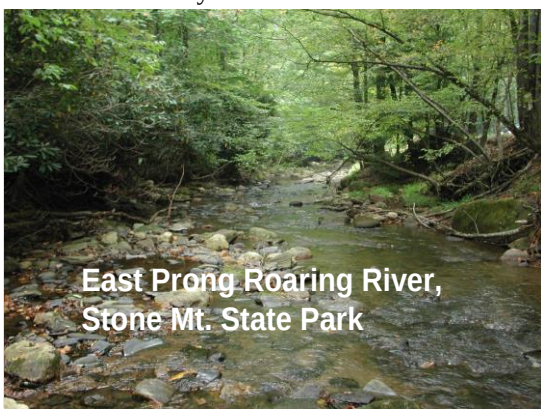
## 3. Stone Mountain State Park (Wilkes County)

Studies have indicated that stream bank erosion along downstream reaches of the East Prong of the Roaring River was severe due to past agricultural practices. Restoration of the East Prong, within Stone Mountain State Park, included stabilization of the eroding banks and the provision of instream habitat as well as reestablishment of pattern, dimension and profile. The total length of the project was 10,633 linear feet in two major reaches of the river. Biological samples were collected from three locations. Reference data (site 1) were collected from a site above both restoration reaches within a stable section of the East Prong. Two downstream stations were also sampled. Site 2 is within a stable reach of the East Prong but below a section of the East Prong that was restored; this reach was not manipulated during the construction. Site 3 is within the downstream restoration section and within a reach that was restored and is essentially a new channel. Data (table 5) were collected during the months of September or October during all surveys.

Table 5. Summary statistics from the stream restoration project at Stone Mountain State Park.

| **Site Location** | **Site 1, upstream reference** | | | | **Site 2** | | | | **Site 3** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metric/Survey | Pre-C | Post 1 | Post 2 | Post 3 | Pre-C | Post 1 | Post 2 | Post 3 | Pre-C | Post 1 | Post 2 | Post 3 |
| Survey year | 1998 | 2001 | 2002 | 2003 | 1998 | 2001 | 2002 | 2003 | 1998 | 2001 | 2002 | 2003 |
| Total Taxa Richness | 73 | 61 | 73 | 73 | 75 | 67 | 75 | 88 | 66 | 61 | 73 | 79 |
| EPT Taxa Richness | 39 | 37 | 37 | 41 | 38 | 36 | 35 | 41 | 36 | **28** | 32 | 40 |
| EPT abundance | 165 | 173 | 202 | **215** | 170 | 154 | 183 | **219** | 194 | 109 | 126 | **180** |
| Biotic Index Values | 4.05 | n/a | n/a | n/a | 3.97 | n/a | n/a | n/a | 4.38 | n/a | n/a | n/a |
| Dominants in Common Index (%) | - | - | - | - | 67% | 76% | 78% | 73% | 74% | 34% | 48% | 64% |
| Number of Keystone Species | 31 | 23 | 26 | 28 | 20 | 14 | 15 | 21 | 19 | 8 | 11 | 18 |

Relatively stable conditions were noted at the reference reach during these investigations; however, total taxa richness was lower during the survey conducted in 2001 and much lower EPT abundance values were noted in 1998 and 2001. This site is dominated by intolerant taxa. Slightly lower taxa richness values were recorded from all of the locations during the first post-construction survey, although the differences in EPT taxa richness between the pre and post construction surveys was larger at the most downstream location (site 3). EPT abundance values increased progressively downstream during the pre-construction survey: however this trend was reversed during all of the post-construction investigations. Note however, that these differences are much smaller during the most recent survey (in bold). Dominants in Common index values remain relatively similar at site two (range from 67 to 78%), but increase progressively at station 3 following construction. In addition the number of keystone species in common with the reference reach has increased during all surveys. These data suggest that improvement in the biological condition of the East Prong of the Roaring River is occurring, but that DIC numbers do not approach the proposed success criteria.




Data in table 6 illustrate that there continue to be some significant differences in the numbers of EPT taxa between the reference reach and the two downstream restoration sites. Note that the number of stoneflies collected from the organic

component of the samples was much higher at the reference reach and that the percentage of stoneflies decline in this organic fraction at the downstream locations. We noted during the 2003 survey that the number of large (mature) stoneflies was much lower at site number 3. In addition we also noted that many of the rocks at station 3 had not yet developed periphytic material, which would support a grazing community of insects (Elimia for example was not collected at the downstream location).

Table 6. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples during the 2003 investigation from East Prong Roaring River at Stone Mountain State Park.

| | **Reference** | | **Site 2** | | **Site 3** | |
|---|---|---|---|---|---|---|
| | inorganic | organic | inorganic | organic | inorganic | organic |
| Ephemeroptera | 149 | 46 | 179 | 101 | 145 | 60 |
| Plecoptera | 69 | **121** | 73 | 70 | 44 | 52 |
| Trichoptera | 91 | 52 | 74 | 26 | 91 | 32 |
| SubTotal | 309 | 219 | 326 | 197 | 280 | **144** |
| Total Abundance | 528 | | 523 | | 424 | |

# 4. Starmount Park, Guilford County (Greensboro)

Two stations were sampled prior to construction and as construction proceeded downstream, a third biological site was sampled. This restoration project is within the Starmount Country Club and had severe limitations to design due to lateral constraints of the golf course. Stormwater was not treated as part of the project. Very little new sinuosity was added to this reach during restoration and very little new habitat was constructed. There were no undercut banks, riffle material appeared to be undersized and the banks consisted exclusively of coconut matting logs. In addition to these observations, there also appeared to be some nutrient enrichment, perhaps from runoff from the golf course. Site 3 is located above Market Street at the lower end of this project. This reach was recently constructed approximately one month before the March 2001 investigation and, as expected, very little recolonization has occurred at this site to date. Banks were constructed exclusively of coir-fiber logs and the bottom of the stream was lined with large rocks. The substrate was unstable (fine sand/clay material was immediately below the rocks) and very little sweep areas were found for collection. No riparian canopy was noted at this station as well.

Table 7. Summary statistics from the stream restoration project at Starmount Country Club.

| | **Site 1 Upstream Reference** | | | **Site 2** | | | **Site 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| Year of Survey | 2000 | 2001 | 2003 | 2000 | 2001 | 2003 | 2000 | 2001 | 2003 |
| Metric/Survey | Pre C | Post 1 | Post 2 | Pre C | Post 1 | Post 2 | Pre C | Post 1 | Post 2 |
| Total Taxa Richness | 26 | 24 | 5 | 31 | 25 | 21 | - | 6 | 20 |
| EPT taxa Richness | 2 | 2 | 0 | 3 | 2 | 1 | - | 1 | 3 |
| EPT Abundance | 13 | 13 | 0 | 21 | 20 | 1 | - | 1 | 12 |
| Dominant Taxa in Common Index (%) | - | - | - | 27% | 71% | 50% | - | 18% | 50% |
| # Keystone Species | 2 | 2 | 0 | 0 | 0 | 0 | - | 0 | 0 |

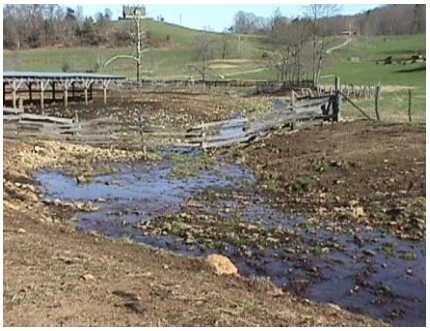
Pre-construction water quality conditions of this stream were poor, although Perlesta (a stonefly) and Stenelmis (an elmid beetle) were collected at site 1 suggesting that this reach of stream has good habitat and supported a relatively intolerant community. Water quality conditions of the reference reach declined during surveys conducted in 2001 and 2003. Many more tolerant taxa were collected at this site in 2001 (Hydropsyche betteni, Cricotopus/Orthocladius sp. 1 and 6, and Physella) and very few taxa were collected at this site in 2003. The 2003 collection may be a response to the severe drought conditions during the previous year (this section of stream may have dried up). Poorer water quality conditions may have been responsible for a higher DIC index value (71%) at site 2. However during the 2001 survey we did collect Ectopria nervosa (a beetle) and Ferrissia (a snail), which are taxa that are commonly collected from stable habitats. Keystone species were not collected at either of the downstream locations.

# 5. A, H and W Farm Site, Big Warrior Creek (Wilkes County)

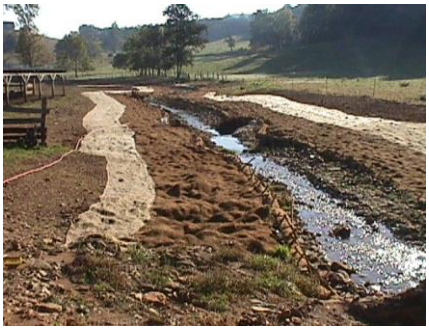
Benthic macroinvertebrates were collected from four monitoring locations to assess the effectiveness of this stream restoration project. The reference site is located on the test stream above the farm property and in a relatively undisturbed forest. The Big Warrior stations at 1 and 2 are located below a feedlot and near the lower reach of the restoration project on Big Warrior, respectively. The canopy at these two downstream locations is open and cattle had direct access to the stream prior to restoration. Filamentous algae and streamside grasses were very prolific at both locations. Data from Little Warrior Creek were collected from a site approximately ¼ mile below NC 18 and within the restoration reach of this catchment. The construction of this project has been conducted in stages and during the last survey (2003), the most upstream reach had matured approximately one year, site 2 was relatively new constructed approximately 6 months since the survey and Little Warrior Creek was only about 3 months old. Additional surveys should be conducted to assess the maturity of the two lower reaches of this project.

Table 8. Summary statistics from the stream restoration project at A, H and W Farm site (Wilkes County).

| | **Upstream Reference** | | | **Site 1** | | | **Site 2** | | | **Little Warrior Cr.** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metric/Survey | Pre C | Post 1 | Post 2 | Pre C | Post 1 | Post 2 | Pre C | PreC | Post 1 | Pre C | Pre C | Post 1 |
| Year of Survey | 2000 | 2002 | 2003 | 2000 | 2002 | 2003 | 2000 | 2002 | 2003 | 2000 | 2002 | 2003 |
| Total Taxa Rich. | 42 | 30 | 43 | 46 | 27 | 44 | 39 | 26 | 37 | 28 | 24 | 32 |
| EPT Taxa Rich. | 23 | **18** | 30 | 14 | 13 | 26 | 15 | 13 | 19 | 8 | 9 | 16 |
| EPT Abundance | 95 | 75 | 132 | 38 | 59 | 132 | 77 | 64 | 111 | 46 | 31 | 54 |
| Dominants in Common Index | - | - | - | 18% | 27% | 48% | 14% | 13% | **48%** | 4% | 0% | 9% |
| #Keystone Taxa | 17 | 11 | 21 | 3 | 3 | 9 | 0 | 1 | 5 | 0 | 0 | 1 |



Pre-Construction site 2



During Construction

One year Post-Construction

The above series of photographs were taken from Big Warrior Creek at site 2. Taxa richness and abundance values from the reference reach are extremely variable and may be a response to very low flow at this location during 2001. This variability does make between year comparisons in the data somewhat more difficult. Note the low numbers of EPT taxa from this location during the 2002 survey (in bold). However the effects of the low flow were not noticed during the 2003 investigation. Prior to restoration, intolerant insects were quickly eliminated at site 2 and recovery was not noted at downstream locations. Note in particular, the low number of keystone species at the downstream locations. Following restoration, the Dominant In Common index increased at site 2 from 27% to 48% in 2002 and 2003 suggesting that conditions have improved at this location. A surprising increase in the DIC was also noted at site 3 during the 2003 investigation; however, the numbers of keystone taxa are still very low at this location. Both the DIC and the number of keystone taxa are low at the Little Warrior Creek location. At the current, time these numbers do not meet the proposed success criteria for biological recovery. Additional surveys should be conducted at these locations.

During the 2003 survey, samples were collected and preserved in organic and inorganic fractions (essentially the kicks and visuals were kept separate from the sweeps and leaf packs) to attempt to determine if there were differences in colonization rates between the habitat types available in the restored stream (table 9). These data illustrate that fewer number of organisms were collected from the organic fraction at the downstream locations compared to the reference reach and that higher number were collected from the inorganic fractions (in bold). These data suggest that many more grazer organisms were collected (primarily Heptageniidae and Baetidae mayflies) from riffles and that the organic habitats such as leaf packs and bank areas have not fully developed and that more organisms are colonizing the riffles. A shift to a more balanced community is expected to occur as the stream matures.

Table 9. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples during the 2003 investigation from Big and Little Warrior Creeks (Wilkes County).

| | **Reference** | | **Site 2** | | **Site 3** | | **Little Warrior** | |
|---|---|---|---|---|---|---|---|---|
| Sample Type | inorg | organic | inorg | organic | inorg | organic | inorg | organic |
| Ephemeroptera | **54** | 24 | **133** | 59 | **162** | 85 | 92 | 58 |
| Plecoptera | 67 | **165** | 15 | **8** | 1 | 43[4] | 1 | 0 |
| Trichoptera | 31 | 15 | 71 | 3 | 74 | 15 | 122 | 32 |
| Subtotal | 152 | 204 | 219 | 70 | 237 | 143 | 215 | 90 |
| Total Abundance | 356 | | 289 | | 380 | | 305 | |

# 6. Payne Dairy, Alexander County

Benthic macroinvertebrates samples were collected from three locations in this project to assess the restoration of Jumping Run Creek. Qual-4 collections were used at all locations and the organic/inorganic fractions of the collections were kept separate during the 2003 investigation. Station 1 is located above the restoration project in a relatively stable reach of Jumping Run Creek (approximately 3-4 riffles above the fence that marks the property line), although there is some sedimentation and bank erosion at this location. The catchment above this location contains mostly pasture and has some stormwater from residential development. Station 2 is located approximately 50 meters above SR 1614 and is within the reach of Jumping Run Creek that was restored. The stream was very unstable at this point with cattle access prior to construction. Sand and silt dominated the substrate at this location, bank erosion was severe and the canopy has been reduced or eliminated in some places. Also it appears that this reach of Jumping Run Creek has been channelized in the past. Station 3 is below a UT of Jumping Run Creek which drains the farm property. Jumping Run Creek at this point appeared to be more stable and had a much wider riparian zone. Cattle had access to this reach prior to restoration and Physella, suggesting accumulation of fine particulate organic material (FPOM) and occasional low DO values dominated the benthos prior to restoration. The data in table 10 summarize the data from these three locations during pre-construction (2000) and two post-construction surveys (2002 and 2003).

Table 10. Summary statistics from the stream restoration project at Payne Dairy (Alexander County).

| | **Upstream Reference** | | | **Site 2** | | | **Site 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| Year of Survey | 2000 | 2002 | 2003 | 2000 | 2002 | 2003 | 2000 | 2002 | 2003 |
| Total Taxa Richness | 43 | 37 | 44 | 38 | 12 | 20 | 31 | 28 | 44 |
| EPT Taxa Richness | 19 | 20 | 19 | 8 | 3 | 12 | 9 | 7 | 16 |
| EPT Abundance | 67 | 88 | 87 | 39 | 7 | 34 | 47 | 28 | 71 |
| Dominants in Common Index (%) | - | - | - | 25% | 5% | 28% | 19% | 16% | 50% |
| # Keystone Species | 10 | 12 | 14 | 2 | 0 | 5 | 4 | 0 | 6 |

Taxa richness and EPT abundance values from the upstream reference site indicate relatively stable conditions and a surprising number of intolerant (keystone) species during surveys conducted in 2002 and 2003. Many of these taxa were completely eliminated downstream of this location prior to construction and replaced by tolerant filter-feeding taxa, presumably responding to the input of fine particulate organic matter. Following construction, the number of taxa and EPT abundance values declined dramatically at site 2. The Dominant in Common Index and the number of keystone species also declined at this site following restoration and this decline was also noted at site 3 near the lower end of the project. Interestingly the most dominant taxa at site 2 in 2002 following restoration was a very tolerant chironomidae (Cricotopus bicinctus). The abundance of these taxa may be a response to the presence of coir-matting in this reach used for bank stabilization. Recovery from this initial impact to Jumping Run Creek appears to be occurring as taxa richness, EPT abundance have increased from data collected in 2002 and now mimic, to some extent, pre-construction conditions.

Table 11 summarizes the number of animals collected from organic (leaf packs and sweeps) and inorganic (kicks and visuals) components of the collection. During this investigation, we noted that there was a great deal of organic material in the stream at site 2, primarily decomposing grasses that were planted near the stream to stabilize the new banks as well as coir-matting. However, this material didn't provide a productive habitat for organisms that would normally be found in the organic component of the collection. Note overall the decline in abundance values at this site compared to

[4] Forty one specimens of Allocapnia were collected at this site accounting for the relatively high number in this sample.

those found at the reference location and the numbers found in the organic fraction (in bold). The abundance values increased at site 3.

Table 11. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples during the 2003 investigation from Payne Dairy (Alexander County).

| | **Upstream Reference** | | **Site 2** | | **Site 3** | |
|---|---|---|---|---|---|---|
| | inorganic | organic | inorganic | organic | inorganic | organic |
| Ephemeroptera | 32 | **60** | 24 | **25** | 81 | 65 |
| Plecoptera | 20 | **20** | 0 | **3** | 8 | 10 |
| Trichoptera | 21 | 15 | 5 | 11 | 32 | 5 |
| Subtotal | 73 | **95** | 29 | **39** | 121 | 80 |
| Total Abundance | 168 | | 68 | | 201 | |

# 7. Price Park, Guilford County (Greensboro)

This restoration project is in a small, stormwater driven stream in Greensboro. The reference site was selected above the proposed restoration and station 1 is within the restoration reach just below a walkway/road over the stream. The reference site is located at the end of a paved walkway at a fence line marking a property line. The stream at this point appeared relatively stable with good habitat. Rocky riffles and undercut banks provided good habit. A few relatively intolerant taxa were collected from this site and not at the downstream location (Paraleptophlebia, Triaenodes tardus, Brillia, Stylogomphus and Gomphus) and many more taxa were abundant here and reduced in abundance at the downstream site during the pre-construction survey. Part of the difference in taxa richness between these two sites is likely due to the lack of riparian canopy and habitat at the downstream location (both prior and following construction) compared to riparian density upstream within the reference reach. Taxa richness values did not change between sites (EPT and total), although there was a shift in the composition of the fauna and EPT abundance was much lower at station 1 as noted above.

The results of the first survey following construction illustrate that water quality conditions at both sites declined. Note significantly lower taxa richness values and fewer keystone species at both sites. This may be a response to flow conditions prior to the investigations, since a small urban streams will receive more stormwater during wet years (i.e. 2003) than during dry years (i.e. 2001). Despite these catchment wide conditions, there were differences in the fauna at these two sites in 2003. Principle among these differences is the presence of keystone taxa (intolerant taxa or those taxa that represent stable habitat) at the upstream site and not at the restored location. These taxa include the mayfly Paraleptophlebia, the Dipteran Dixa and the snail Ferrissia. The two EPT taxa that accounted for the increase in EPT abundance are tolerant taxa (Baetis flavistriga and Cheumatopsyche). Success at this project may approach proposed DIC criteria with more time during which stabilization may occur and some of the keystone species may start to inhabit the downstream reach of this stream.

Table 12. Summary statistics from the stream restoration project at Price Park (Guilford County)

| | **Upstream Reference** | | **Site 2** | |
|---|---|---|---|---|
| Survey Year | 2001 | 2003 | 2001 | 2003 |
| Total Taxa Richness | 35 | 22 | 37 | 18 |
| EPT Taxa Richness | 7 | 3 | 7 | 2 |
| EPT Abundance | 27 | 5 | 13 | 20 |
| Dominant in Common Index (%) | - | - | 40% | 64% |
| Keystone Taxa | 5 | 3 | 1 | 0 |

# 8. Lyle Creek (Wike Property), Alexander County.

Reference reach data were collected from two sites for this project (table 13). UT Catawba River is a very small tributary of the Catawba River near Lookout Shoal Lake. Despite the fact that this reach of stream is completely wooded the substrate was mostly unstable shifting sand. This observation suggests that there have been disturbances in the past or that there are sources on nonpoint runoff in the catchment that are affecting this reach. Reference data also were collected from a reach of Lyle Creek above the restoration site. The catchment is mostly forested at this location. The stream at this point was fairly incised but had some decent habitat including some bank habitat and stable gravel/cobble riffles. Taxa richness values were somewhat similar between these two sites both years of collection; however, EPT abundance and EPT taxa richness were greater at the Lyle Creek location. The Dominants in Common Index between these two sites was very

similar both years suggesting that water quality conditions haven't changed. Because of these similarities all future collections can be eliminated from the UT Catawba River reference location. Site 2 is located near transect 110 at the lower reach of the restoration section and within a modified pasture. Cattle obviously had access to this reach of the stream as the banks were eroding and the substrate was more sandy/muddy. Site 3 is a very small tributary of Lyle Creek that hasn't receive any mitigation work to date. Data were collected from this site in anticipation of future construction. During the 2001 survey at this tributary site very few taxa were collected compared to the data from this site in 2003. This observation may be a result of very low flow during drought conditions prior to the 2001 survey.

Table 13. Summary statistics from the stream restoration project at Wike Property (Alexander County).

| **Metric/location** | **UT Catawba** | | **Upstream Reference** | | **Site 2** | | **Site 3 (UT)** | |
|---|---|---|---|---|---|---|---|---|
| Year of Survey | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 |
| Total Taxa Richness | 39 | 42 | 44 | 45 | 51 | 30 | 18 | 40 |
| EPT Taxa Richness | 18 | 17 | 16 | 22 | 17 | 9 | 3 | 16 |
| EPT Abundance | 66 | 101 | 94 | 114 | 84 | 33 | 30 | 62 |
| Dominants in Common Index (%) | - | - | 61% | 62% | 72% (72%)[5] | 33% (34%) | n/a | n/a |
| # Keystone Species | 6 | 10 | 10 | 10 | 7 | 4 | 0 | 9 |

Significant reductions in taxa richness and EPT abundance values were recorded from Site 2 within the restoration reach following construction. In addition, the Dominants in Common Index fell from 72% to 34% using the upstream reach of Lyle Creek as reference. Many of the intolerant or keystone species were either completely eliminated or reduced in numbers at this location following restoration. During the survey, we noted that many of the outside bends were failing and sediment was being reintroduced into the stream.

Table 14 lists the number of specimens collected from inorganic and organic components of the collection. These data illustrate the very low number of specimens collected from site 2 within the newly restored reach. Unlike many other streams studied in this report, the organic component of samples from the Lyle Creek catchment, including the reference reach, have much lower EPT abundance values than the inorganic component.

Table 14. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples during the 2003 investigation from Payne Dairy (Alexander County).

| | **UT Catawba R.** | | **Upstream Reference** | | **Site 2** | | **Site 3 (UT)** | |
|---|---|---|---|---|---|---|---|---|
| | inorganic | organic | inorganic | organic | inorganic | organic | inorganic | organic |
| Ephemeroptera | 53 | 67 | 59 | 36 | 4 | 2 | 27 | 5 |
| Plecoptera | 33 | 26 | 46 | 16 | 17 | 12 | 26 | 8 |
| Trichoptera | 52 | 23 | 131 | 32 | 36 | 6 | 54 | 6 |
| Subtotal | 138 | 116 | 236 | 84 | 57 | 20 | 107 | 19 |
| Total Abundance | 254 | | 320 | | 77 | | 136 | |

[5] DIC numbers are compared to the UT Catawba River and the upstream reference reach (in parentheses) at this location.

## 9. Hominy Swamp, Wilson County

Hominy Swamp is an urban channel that drains much of the city of Wilson. Site 1 was located above the restoration project near the intersection of Canal and Pine Wood streets and selected as the reference location. The stream at this point has been channelized and appears to be stormwater driven. Riffle areas at this site are comprised primarily of chunks of asphalt. However root mats were common and provided some limited habitat for the benthos. Site 2 is within the restoration reach near a city park and near the lower end of the project. The stream at this point was much less stable prior to construction; bank failures were common along the restored reach. Root mats that were common at the upstream location have been eliminated at station 2 and replaced by emergent vegetation due to the lack of canopy at the lower site. Benthic macroinvertebrate faunas at both locations are very depauperate and represent poor water quality conditions. These data are illustrated in table 15.

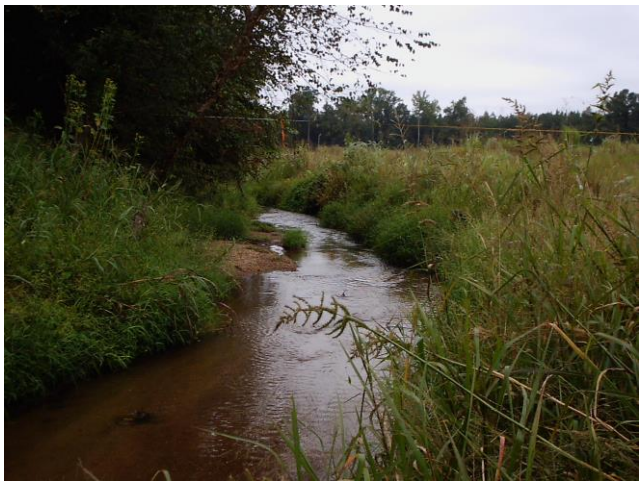
Table 15. Summary statistics from the stream restoration project in Wilson, North Carolina.

| | **Upstream Reference Site 1** | | **Site 2** | |
|---|---|---|---|---|
| Year of Collection | 2001 | 2003 | 2001 | 2003 |
| Total Taxa Richness | 26 | 19 | 23 | 23 |
| EPT Taxa Richness | 1 | 1 | 1 | **3** |
| EPT Abundance | 10 | 10 | 10 | 12 |
| Dominant in Common Index (%) | - | - | 50% | 64% |
| #Keystone species | 0 | 0 | 0 | 0 |

Despite the stable habitats found at the upstream reference reach, it is evident from these data that there are water quality issues in this catchment that control the biological integrity of this stream. The Division of Water Quality should conduct an inventory of these perturbations. Some differences in the fauna were noted following the restoration (2002) that are interesting, although no keystone taxa were collected at either site. The upstream reference location was dominated by very tolerant organisms (specifically Sphaerium, Physella and Dugesia tigrina), whereas these organisms were not collected at the restored reach. In addition two tolerant mayfly species were also collected from the restoration reach (in bold) and not collected from the upstream reference. These data may suggest that the benthic fauna of this stream are recovering from perturbations above the reference location but that the newly restored reach is provided enough stable habitat and downstream distance from the perturbation that some recovery is noted.

## 10. Smith/Austin Creeks – Wake Forest (Wake County)

Biological samples were collected from four locations to assess this restoration project. Because of the relatively large size of these streams, full scale samples were collected prior to construction (2001) and, at this point, one year following construction (2003). Two stations were established on Austin Creek: station 1 at Jones Dairy Road was used as the upstream reference reach for this project and station 2 was within the restoration reach. The stream at station 1 appears to be relatively stable. Triaenodes and Serratella were collected at this site which probably is related to the microhabitat requirements for these two taxa (stable banks and moss on rocks). This was the only site with any stoneflies during the pre-construction survey. Station 2 on Austin Creek is within the restoration reach of this feature. Prior to construction it had a relatively wide riparian zone with some instream habitat, although much of the substrate was shifting sand. EPT taxa richness and abundance values were much lower at this site than all others during the pre-construction survey.



Two stations were also established on Smith Creek. Smith Creek #1, which is within the restoration reach, is very unstable and had a substrate composed primarily of shifting sand. Macrophytes along the bank were very common. Smith Creek #2 is below the confluence with Austin Creek. Smith Creek at this point also was channelized in the past and had

excessive amounts of sediment. Despite some fairly, decent habitat EPT numbers were low (12 taxa during both surveys) and dominated by tolerant taxa (S. modestum, Cheumatopsyche and Tricorythodes). Table 16 summarizes the data from both surveys.

Table 16. Summary statistics from the stream restoration project at Smith/Austin Creeks, Wake Forest.

| | Austin Creek 1 (Reference Site) | | Austin Creek 2 | | Smith Creek 1 | | Smith Creek 2 | |
|---|---|---|---|---|---|---|---|---|
| Year of Collection | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 |
| Total Taxa Richness | 35 | 49 | 26 | 54 | 34 | 48 | 42 | 41 |
| EPT Taxa Richness | 11 | 15 | 7 | 14 | 11 | 13 | 12 | 12 |
| EPT Abundance | 55 | 70 | 29 | 83 | 68 | 64 | 43 | 52 |
| Dominant in Common Index (%) | - | - | 33% | 63% | 48% | 60% | 48%[6] | 37% |
| #Keystone Species | 5 | 8 | 1 | 4 | 2 | 4 | 5 | 4 |

The data summarized in table 16 suggest that water quality conditions improved at all of the locations in 2003, including data from the reference reach (much less so at the Smith Creek 2 location). Note the increase in the DIC index and the number of keystone species at the two restoration reaches (Austin Creek 2 and Smith Creek 1) at this point in time. It is difficult to say how much of this improvement are due to low flow conditions during the pre-construction survey compared to high flow conditions following construction. Substrate composition within the restoration reaches appears to be unchanged following construction (primarily shifting sand). Additional investigations should be conducted at these locations.

# 11. Rocky Branch, North Carolina State University – Raleigh

Three collection locations were selected to assess the biological recovery of Rocky Branch following restoration. The upstream reference location (Station 1) is located just below Gorman Road. The stream at this point is perennial and has a width of 1-2 meters. The riparian zone was fairly mature and the canopy was nearly complete. This reach of Rocky Branch appears to be relatively stable although there are sources of stormwater and other nonpoint source runoff above this location. The substrate was coated with iron oxidizing bacteria suggesting a fairly strong groundwater influence at this site. Prior to construction, the benthic macroinvertebrate fauna was dominated by tolerant chironomidae primarily Conchapelopia and Cricotopus varipes group. The abundance of these taxa and very little else suggests the effects of toxicity, most likely from stormwater runoff. Station 2 is located above the bridge at Dan Allen Drive. This reach is within the Phase I portion of the project and was constructed prior to the 2003 survey. Rocky Branch at this point was very deeply entrenched and had severe problems with bank erosion. The steep banks were cut back allowing the stream to access a modified floodplain and then the riparian zone was revegetated. The effects of stormwater and nonpoint source runoff exasperated the water quality problems at this location. Again the benthos was very depauperate dominated primarily by tolerant chironomidae. Station 3 is the most downstream location for this project and is located above Pullen Road near the athletic fields at North Carolina State University. The stream at this point again was deeply entrenched although there are numerous grade control structures that may be forcing the stream here to widen. This reach of Rocky Branch had very deep pools although fish were not observed. There also appeared to be a stable riffle/pool sequence. This reach is part of the Phase II construction and, at the time of the 2003 survey, was not constructed.

Table 17. Summary statistics from the stream restoration project at Rocky Branch, North Carolina State University - Raleigh.

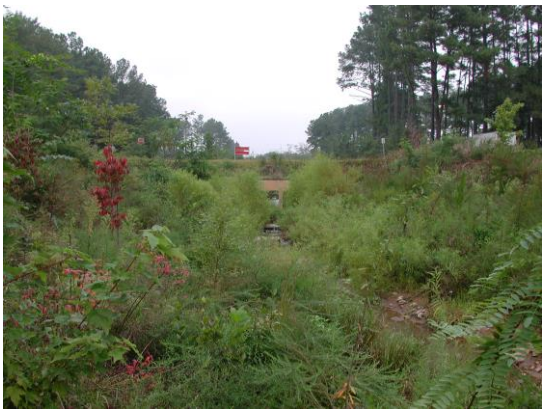
| | Upstream Reference | | Site 2 | | Site 3 | |
|---|---|---|---|---|---|---|
| Year of Collection | 2000 | 2003 | 2000 | 2003 | 2000 | 2003 |
| Total Taxa Richness | 13 | 18 | 15 | 20 | 13 | 16 |
| EPT Taxa Richness | 1 | 1 | 1 | 2 | 1 | 0 |
| EPT Abundance | 1 | 3 | 1 | 13 | 1 | 0 |
| Dominant in Common Index (%)[7] | - | - | 75% | 38% | 50% | 25% |
| # Keystone species | 0 | 1[8] | 0 | 1 | 0 | 1 |

[6] A comparison of dominants in common for this site may be inappropriate because of the size difference between this location and the reference reach at Austin #1.

[7] Because very taxa collected were collected from the reference reach (all were tolerant), the use of DIC index may inappropriate.

[8] This keystone taxa is Ferrissia, which is a very tolerant mollusk, however it is commonly collected on stable habitat.

Data from all three of the Rocky Branch locations suggest very poor water quality, with minor improvements in the biological health of the stream following restoration, particularly at site 2. Taxa richness and EPT abundance values increased at Site 2 during the 2003 survey, but the increase was due to the presence of tolerant hydropsychid caddisfly (Cheumatopsyche and Hydropsyche betteni). Tolerant taxa dominate all locations and EPT taxa were not collected at all at Site 3 in 2003. The poor water quality conditions were, in part, due to the effects of stormwater runoff.



An attempt to determine the composition of the fauna between its organic and inorganic components was conducted (table 18). These data illustrate that the fauna are dominated by toxic-tolerant chironomidae at sites 1 and 3 (in bold) regardless of the organic/inorganic fraction, and hydropsychid caddisfly at site 2. This may be due to the restoration (i.e. stormwater treatment) as the fauna at site 2 was also dominated by toxic-tolerant chironomidae prior to construction. A study conducted at the University of California Berkerley Campus demonstrated that if stormwater is removed from urban streams the biological health can improve (Charbonneau and Resh 1992[9]). In this study the bioclassification of the urban stream improved from Poor to Good/Fair (using NC classification criteria) following stormwater treatment. The development of a tolerant hydropsychidae fauna at Rocky Branch 2 is an apparent improvement in water quality.

Table 18. Abundance values of Ephemeroptera, Plecoptera, Trichoptera, Chironomidae, Mollusca and all other groups collected from inorganic and organic components of samples during the 2003 investigation from Rocky Branch – North Carolina State University, Raleigh.

| | **Upstream Reference** | | **Site 2** | | **Site 3** | |
|---|---|---|---|---|---|---|
| | inorganic | organic | inorganic | organic | inorganic | organic |
| Ephemeroptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Plecoptera | 0 | 0 | 0 | 0 | 0 | 0 |
| Trichoptera | 7 | 0 | **58** | **15** | 0 | 0 |
| Chironomidae | **17** | **19** | 10 | 16 | **57** | **27** |
| Mollusca | 2 | 14 | 11 | 3 | 1 | 9 |
| All Other Groups | 7 | 21 | 6 | 13 | 6 | 26 |
| Subtotal | 33 | 54 | 85 | 47 | 64 | 62 |
| Total Abundance | 87 | | 132 | | 126 | |

## 12. Murphy Farm, Louisburg (Franklin County)

Approximately 1800 linear feet of this UT to Bear Swamp Creek in Franklin County was restored in July 2002. Qual-4 samples were collected from three reaches of this tributary prior to and following construction to assess the recovery of this stream following restoration. Site 1 is above the 1800 linear foot reach on the UT to be restored. The stream at this point is stable with good instream and riparian habitat. The site was selected as an upstream reference reach and receives flow from a series of springs immediately above the site as well as overflow from an instream pond. Two sites were selected within the restoration reach. Site 2 is a midreach location approximately 50 meters below a bridge crossing. The stream at this point was severely degraded with very little riparian canopy and cattle did have direct access. Site 3 is located within a minimally forested reach of the stream at the lower end of the restoration project and appears to be aggrading. Abundance of benthic organisms at this location is much greater than at site 2 and many tolerant organisms were collected at this site (i.e. Chirononmus sp.) during the initial survey. Additional samples were collected from a UT to Crooked Creek, which was selected as the ecoregional reference site and used for the design of the new stream at Murphy Farm. The reference reach at the UT to Crooked Creek appears to be very stable and has a diverse benthic macroinvertebrate population.

[9] Charbonneau, R. and V. H. Resh. 1992. Strawberry Creek on the University of California, Berkelely Campus: a case history of urban stream restoration. Aquatic conservation: marine and freshwater ecosystems 2:293-307.

Table 19. Summary statistics from the stream restoration project at Murphy Farm, Louisburg (Franklin County)

| | **UT Crooked Creek Ecoregional Ref.** | | **UT Bear Swamp Upstream Ref., site 1** | | **UT Bear Swamp, Site 2** | | **UT Bear Swamp, Site 3** | |
|---|---|---|---|---|---|---|---|---|
| Year of Collection | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 | 2001 | 2003 |
| Total Taxa Richness | 50 | 51 | 48 | 43 | 36 | 39 | 46 | 40 |
| EPT Taxa Richness | 21 | 24 | 16 | 14 | 4 | **8** | 8 | 11 |
| EPT Abundance | 100 | 107 | 69 | 67 | 8 | **48** | 23 | 44 |
| Dominant in Common Index (%) | - | - | 59% | 50% | 11%[10] (22%) | 33% (45%) | 33% (48) | 29% (35%) |
| # Keystone Species | 12 | 14 | 6 | 7 | 2 | 1 | 3 | 2 |

Table 19 summarizes the data from this project. A very rapid change in the composition of the benthic fauna occurred between the upstream reference site and station 2 during the pre-construction survey. The upstream reference was dominated by fairly intolerant taxa including Diplectrona and Chimarra, but their numbers fall off drastically at station 2 and these conditions suggest a shift in energy sources from heterotrophic to autotrophic. Many organisms that are abundant or common upstream were not collected at the downstream location during this survey. Abundance and taxa richness increase slightly at station three in 2001, perhaps responding to the increase in canopy cover. However tolerant fauna (Chironomus and Physella) dominated the benthic community at this most downstream location. Conditions improve somewhat the first year following restoration. Note particularly the increase in EPT taxa richness and abundance values (in bold) during the 2003 survey at station 2. However, many of the EPT taxa collected at this site are tolerant. Also note the decline in the number keystone taxa between years at this site. Slightly higher EPT values were also found at station 3 and many of the very intolerant taxa collected during the 2001 survey were reduced in abundance. These data suggest that UT Bear Swamp has improved slightly from pre-construction conditions, but that this improvement to date doesn't meet proposed success criteria. During a March 2004 inspection of this project, enrichment indicators (primarily filamentous algae) were noted from this reach of UT Bear Swamp, suggesting that nutrient laden runoff is entering the stream. Additional information should be collected from this project. Data also were collected from UT Crooked Creek that was selected as the reach for design. Taxa richness and abundance values were higher at this location. Many more mayflies and stoneflies were collected from this location than the upstream reference reach of UT Bear Swamp.

During the 2003 survey data from organic and inorganic components of the collection were kept separate in an attempt to assess differences in habitat structure (table 20). These data illustrate that there were very few taxa collected from station 2 (relative to reference stations), and that there is a shift in the abundance values in habitat types. At the two reference reaches, both mayflies and stoneflies were much more numerous in the organic component of the collection (in bold) and that caddisflies were more abundant in the inorganic fraction. These conditions shift at the restored reaches. As we would expect, few number of benthic organisms were collected compared to reference reach conditions and the organic fraction was dominated by caddisflies. Unlike the reference reaches, the majority of the mayflies and some stoneflies (although the number of stoneflies are limited) were collected from the inorganic fraction and the majority of the caddisflies were collected from the organic fraction. This reversal of habitat fecundity may be due to the immaturity or lack of the leaf pack habitat from this reach of stream and that the riffle habitat is the only one that is stable enough to support benthic macroinvertebrates. These numbers should shift to more reference-like conditions as the habitat stabilizes.

Table 20. Abundance values of Ephemeroptera, Plecoptera and Trichoptera collected from inorganic and organic components of samples during the 2003 investigation from Murphy Farm, Louisburg (Franklin County).

| | **UT Crooked Creek Ecoregional Ref** | | **UT Bear Swamp Upstream Ref** | | **UT Bear Swamp 2** | | **UT Bear Swamp 3** | |
|---|---|---|---|---|---|---|---|---|
| | inorgan | organic | inorgan | organic | inorgan | organic | inorgan | organic |
| Ephemeroptera | 44 | **86** | 23 | **53** | 12 | 42 | **36** | 11 |
| Plecoptera | 13 | **89** | 12 | **27** | 0 | 1 | **6** | 4 |
| Trichoptera | **32** | 25 | **58** | 32 | 17 | **54** | 35 | **50** |
| Subtotal | 89 | 200 | 93 | 112 | 29 | 97 | 77 | 65 |
| Total Abundance | 289 | | 205 | | 126 | | 142 | |

[10] DIC comparisons were made between the ecoregional reference and the upstream reference (in parentheses) at these two locations.

# 13. Yates Mill, Raleigh (Wake County)

Qual-4 samples (or slight modifications because of the very small size of some sites) were collected from four locations associated with this project. Station 1 is located above a road and culvert and also above an earlier restoration project. The stream at this point is very small bordering on intermittent. A good population of limnephilid caddisfly were collected at this location (plus some Pisidium) which suggests that the stream at this point is perennial. The riparian zone is

mostly forested above this location and there did not appear to be obvious sources of enrichment. Riffle pool sequences appear to be normal at this location with substrate materials that would support a benthic fauna. Station 2 is located within the lower reach of an earlier restoration project that was completed in 2000. This station is approximately 20 yards above the more recent (2002) stream restoration. The stream at this point was heavily enriched with very thick mats of Aufwuchs material. Also it appeared that the riffles were poorly developed in that they did not have the proper materials to support fauna. The substrate appeared to mostly clay-like material rather than rocks. Chironomids dominated the fauna. Station 3 is within the more recent stream restoration segment and near transect 24 00. The stream at this point had good habitat (rocky riffles, and some undercut banks), but the fauna seemed depauperate. Again, there were lots of Aufwuchs material on the substrate materials and the pools looked greenish. Because of the very small size of the upstream reference location, an ecoregional reference site also was sampled as part this project. The site, Sals Branch, is near the US 70 entrance to Umstead State Park and behind the visitor's center. The stream at this point was stable with a population of benthos dominated by intolerant taxa (esp. Neophylax).

Construction was complete in April 2002 at site 3. Samples were collected pre-construction and a single survey following construction (2003). Table 21 summarizes the benthos data from this project. Despite its very small size, the upstream reference site had higher EPT abundance values than either of the downstream restored sites, particularly during the 2003 survey (in bold). Low taxa richness and abundance values at this reference reach in 2002 may have been an artifact of drought conditions prior to this survey. Lower EPT taxa richness and Dominants in Common numbers at Site 3 following restoration suggest that biological integrity hasn't improved within this reach. The occurrence of prolific growths of Aufwuchs material at these two downstream locations suggests that there may be some nutrient laden runoff from nearby land uses. These numbers suggest that the restoration project has not yet successfully restored the biological components of this stream.

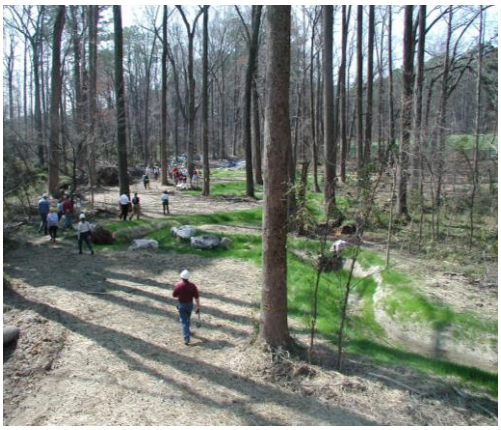


Table 21. Summary statistics from the stream restoration project at Yates Mill, Raleigh (Wake County)

| | **Sals Branch Ecoregional Ref.** | | **Upstream Ref. Site 1** | | **Site 2 (within earlier restoration)** | | **Site 3 (more recent restoration)** | |
|---|---|---|---|---|---|---|---|---|
| Year of Collection | 2002 | 2003 | 2002 | 2003 | 2002 | 2003 | 2002 | 2003 |
| Total Taxa Richness | 26 | 25 | 15 | 23 | 3 | 14 | 24 | 17 |
| EPT Taxa Richness | 9 | 10 | 3 | **7** | 1 | 2 | 4 | 2 |
| EPT Abundance | 26 | 38 | 12 | **33** | 3 | 4 | 4 | 4 |
| Dominant in Common Index (%) | - | - | 8% | 17% | 8% (37%)[11] | 17% (28%) | **33% (37%)** | **8% (17%)** |
| # Keystone Species | 4 | 6 | 1 | 2 | 0 | 0 | 1 | 0 |

[11] DICs were calculated from the ecoregional reference location and the upstream reference reach (in parentheses) because of the very small catchment size of the upstream reference.

## Summary

This report is intended as an addendum to the final grant report submitted to EPA in December 2002 that summarized biological information from 50 stream restoration projects in North Carolina. This addendum summarizes the information collected by the Division of Water Quality from thirteen stream restoration projects during 2003. Much of this information remains preliminary in that 9 of these thirteen projects have only one year of post-construction information (and three projects have only two years of post-construction data). These thirteen projects are all associated with work coordinated by the Wetlands Restoration Program (now the Ecosystem Enhancement Program or EEP) or the NC Department of Transportation. Biological information has also been collected in 2003 by consultants at stream restoration projects. These projects are listed is this report, and may be used to corroborate DWQ data; however, the primary intent of this summary is to discuss the potential use of biological data to determine success criteria. Table 22 summarizes the biological data from projects from which data were collected in 2003. The observations in this table note changes in the biological communities of streams following restoration and comparisons (improvement, no change or declines in biological integrity) are made to pre-construction conditions. In many instances the data noted that there were initial declines in biological integrity immediately following construction, but that these conditions improved during the second and third years of investigation.

Table 22. Changes in biological integrity following restoration from 2003 investigations.

| **Number of years following construction** | **Number surveys conducted in 2003** | | **Projects with <u>improved</u> biological integrity** | | **Projects with <u>no change</u> in biological integrity** | | **Projects at which biological integrity <u>declined</u>** | | **Projects meeting potential success criteria** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Urban | Rural | Urban | Rural | Urban | Rural | Urban | Rural | Urban | Rural |
| 1 | 3 | 6 | - | 2 | 2 | 2 | 1 | 2 | none | none |
| 2 | 1 | 2 | - | 2 | - | - | 1 | - | none | none |
| 3 | - | 1 | - | 1 | - | - | - | - | - | none |

Data in table 22 only summarize information up through the 2003 collection season. It's evident that these data are still preliminary and that additional surveys should be conducted at these projects in 2004 as well as other EEP/DOT stream restoration projects. Table 22 notes that the biological integrity either remains unchanged or declines in integrity following the first year after construction and that biological integrity improves with project maturity. Note also that none of these projects meet potential biological success criteria. Appendix 1 lists 18 DWQ investigations currently scheduled for the 2004 collection season. These data will add a significant amount of information to these results.

Preliminary biological data from these stream restoration projects suggest that if streams have access to stable upstream reference reaches the recovery is much more likely to occur. Improvements (subtle in some instances) in the biological conditions following restoration were noted at Stone Mountain State Park, Big Warrior Creek, Smith/Austin Creeks and Murphy Farm, and in each of these projects the streams had access to a stable upstream reference. However, other than for the data from Stone Mountain State Park (which is the only project that has three years of post-construction data in this review) potential biological success criteria have not been met at any of the projects and, in many instances, tolerant EPT taxa become dominant initially in restored streams. In several projects adequate upstream reference reaches were found and used for comparison to the restored reach, yet biological integrity declined following restoration (Payne Dairy, Lyle Creek and Yates Mill). The reduction in biological health of these streams may have been due to system disturbance during construction or project failure following construction. Biological data need to be collected from these projects to assess recovery and more holistic approaches to stream restoration is encouraged in these instances. Stream restoration projects in urban catchments are complicated due to the potential effects of stormwater. Biological recovery may occur only if intense stormwater management is part of the restoration process. For example, data from the Rocky Branch project indicates that toxic tolerant midges (which were dominant prior to construction and stormwater treatment) were replaced by tolerant hydropsychid caddisflies following phase one construction. Also data from some urban stream restoration projects have noted that stable urban stream will have keystone taxa (i.e. <u>Perlesta</u>, <u>Stenelmis</u>, <u>Ectopria</u> <u>nervosa</u>, <u>Ferrissia</u>, <u>Paraleptophlebia</u>) and that these taxa are perhaps good indicators of restoration success and might be more useful that the Dominant in Common metric in these streams.

Benthic macroinvertebrate data also have been collected as part of stream restoration projects for mitigation as part of the 401 Certification Program. Data from these projects are submitted to the Wetlands Unit of the Division of Water Quality as part of their review process and may be used to corroborate the testing of biological success criteria. Appendix 1 lists all of the stream restoration projects that are currently scheduled for collection during 2004 and Appendix 2 is the collection schedule for all 50 stream restoration projects initially selected in the 2002 grant report to EPA.

Appendix 1. **2004 Benthic Macroinvertebrate Collection Schedule**

| **Month of Collection** | **Project Name** | **Collecting Agency** |
|---|---|---|
| January | 3M, Moncure | KCI |
| February | Crescent Road | Buck Engineering |
| March | Tallula Creek | DOT |
| | Trilluim | ENV-John Vilas |
| | Starmount Park | DWQ |
| | Anson County Landfill | EcoScience |
| | Yates Mill, Steepbank Cr. | DWQ |
| April | Brush and Little Pine Crks | DWQ |
| | Brown Branch | DWQ |
| | Beaver Creek | DWQ |
| May | Hanging Rock Creek | Buck Engineering |
| | Price Park | DWQ |
| | Edsel Place | MacTec |
| | Morrisville Comm. Park | S & EC |
| | Hominy Swamp | DWQ |
| | Marks Creek | Stantec |
| June | TC Roberson | Appalachian Environ. |
| | Meridan Drive | MacTec |
| | Magnolia/Kirkwood | MacTec |
| July | Edwards Branch | MCDEP |
| | Sheppards Tree, Statesville | DWQ |
| | Mt. Vernon Springs | S & EC |
| August | Kings Creek, Brevard | DWQ |
| | Bare Enhancement Site | DWQ |
| | Charleston Forge | S & EC |
| | Randolph/Chatham Co. | DWQ/DOT |
| | Chavis Park | G. Pasacreta |
| | Smith Austin Creeks | DWQ |
| September | Hope Park | MacTec |
| October | Payne Dairy | DWQ |
| | Big Warrior Creek | DWQ |
| November | Pott Creek | RKK |
| December | High Vista | DWQ |
| | Wike Property | DWQ |
| | Rocky Branch | DWQ |
| | Murphy Farm | DWQ |

**Need to check on the construction status of the following projects:**

- **Randolph Park (Enfield) – Buck Engineering**
- **Mill Branch (Greenville)**
- **Global Transpark (Kinston) – EcoScience**
- **Adkins Branch (Kinston) - EcoScience**

**Appendix 2.**

**Mountain Ecoregion**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency* | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Reed Cr., Asheville | Large | Urban | DOT | Jan-98 | Mar-98 | Oct-98 | Oct-99 | Oct-00 |
| Tallula Cr., Murphy | Large | Rural | DOT | Mar-98 | Aug-02 | Mar-04 | Mar-05 | Mar-06 |
| High Vista, Asheville | Small | Rural | DWQ | Dec-01 | Jul-02 | Dec-03 | Dec-04 | Dec-05 |
| TC Roberson, Hendersonville | Small | Rural | Appalachian Env. | Jun-02 | Not Completed | Jun-04 | Jun-05 | Jun-06 |
| Warren Wilson College | Small | Rural | AES, Wisconsin | Sep-02 | Nov-Dec 02 | Sep-03 | Sep-04 | Sep-05 |
| Kings Creek, Brevard | Large | Urban | DWQ | Aug-02 | Aug-02 | Aug-04 | Aug-05 | Aug-06 |

**New River Ecoregion**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Lynnhaven, Boone | Small | Rural | Appalachian Env. | Sept-97 | Dec-01 | Nov 02 | | |
| Trillium, Boone | Small | Rural | ENV | Mar-01 | May-01 | Mar-03 | Mar-04 | Mar-05 |
| Brush and Little Pine, Sparta | Small | Rural | DWQ | Apr-01 | Jul-01 | Apr-03 | Apr-04 | Apr-05 |
| Bare Site (enhancement only) | Small | Rural | DWQ | Aug-01 | Sep-01 | Aug-02 | Aug-03 | Aug-04 |
| Charleston Forge, Boone | Small | Urban | S & EC | Aug-01 | ? | Aug-03 | Aug-04 | Aug-05 |
| Hanging Rock Cr., Banner Elk | Small | Rural | Buck Eng. | Apr 01, May 02 | Not Completed | May-04 | May-05 | May-06 |

**Western Piedmont**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Stone Mt. State Park | Large | Rural | DWQ | Oct-98 | Nov-00 | Sep-01 | Sep-02 | Sep-03 |
| Concord Mills | Small | Rural | EcoScience | Apr-99 | Jul-99 | Jul-01 | Jul-02 | Jul-03 |
| Fiddlers Branch, Winston-Salem | Small | Rural | KCI | May-99 | May-99 | May-00 | May-01 | May-02 |
| Starmount Pk, Greensboro | Small | Urban | DWQ | Mar-00 | Feb-01 | Mar-01 | Mar-03 | Mar-04 |
| Edwards Br., Charlotte | Small | Urban | MCDEP | Jul-01, Jul-02 | Phase 1 only | Jul-04 | Jul-05 | Jul-06 |
| Payne Dairy, Taylorsville | Small | Rural | DWQ | Oct-00 | Feb-01 | Oct-02 | Oct-03 | Oct-04 |
| Big Warrior Cr., Boomer | Small | Rural | DWQ | Oct-00 | Nov-01 | Oct-02 | Oct-03 | Oct-04 |
| Price Park, Greensboro | Small | Urban | DWQ | May-01 | Jul-01 | May-03 | May-04 | May-05 |
| Sheppard's Tree, Statesville | Small | Rural | DWQ | Jul-01 | Apr-03 | Jul-04 | Jul-05 | Jul-06 |
| Edsel Place, Charlotte | Small | Urban | Law Engineering | May 00 | May-01 | May-03 | May-04 | May-05 |
| Lyle Creek (Wike Prop), Newton | Small | Rural | DWQ | Dec-01 | Jun-02 | Dec-03 | Dec-04 | Dec-05 |
| Brown Branch, Lenoir | Small | Rural | DWQ | Apr-02 | Sep-02 | Apr-04 | Apr-05 | Apr-06 |
| Beaver Creek, Surry County | Large | Rural | DWQ | Apr-02 | Jul-02 | Apr-04 | Apr-05 | Apr-06 |
| Pott Creek, Lincoln County | Small | Rural | RKK | Nov-01 | Mar-02 | Nov-03 | Nov-04 | Nov-05 |
| Meridan Drive, Charlotte | Small | Urban | Law Engineering | Sept99, Apr00 | Jul-00 | Jun-02 | Jun-03 | Jun-04 |
| Magnolia/Kirkwood, Charlotte | Small | Urban | Law Engineering | 5-01, 6-01,7-02 | Phase 1 complete | Jun-04 | Jun-05 | Jun-06 |
| Hope Park Branch, Charlotte | Small | Urban | Law Engineering | Sept-01 | Sept-02 | Sept-03 | Sept-04 | Sept-05 |

**Slate Belt Ecoregion**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Randolph/Chatham County Sites | Small | Rural | DWQ | Aug-01 | Oct-02 | Aug-04 | Aug-05 | Aug-06 |
| Mt. Vernon Springs | Small | Rural | S & EC | Jul-01 | Jul-02 | Jul-04 | Jul-05 | Jul-06 |

**Triassic Basin**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Anson County Landfill, Monroe | Small | Rural | EcoScience | Mar-01 | Apr-01 | Mar-03 | Mar-04 | Mar-05 |
| 3M, Moncure | Small | Rural | KCI | Sep-01 | Jul-02 | Sep-03 | Sep-04 | Sep-05 |
| Morrisville Community Park | Large | Rural | S and EC | May-02 | Jun-02 | May-04 | May-05 | May-06 |

**Eastern Piedmont**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Chavis Park, Raleigh | Small | Urban | G. Pasacreta | Aug-99 | Jul-02 | Aug-03 | Aug-04 | Aug-05 |
| Rochester Heights, Raleigh | Small | Urban | City of Raleigh | Sep-99 | Apr-00 | Sep-01 | Sep-02 | Sep-03 |
| Rocky Branch, Raleigh | Small | Urban | DWQ | Dec-00 | Spring 03? | Dec-04 | Dec-05 | Dec-06 |
| Randolph Park, Enfield | Small | Rural | Buck Eng. | Jan-01 | Not Completed | | | |
| Hominy Swamp, Wilson | Small | Urban | Buck Eng. | May-01 | Jan-02 | May-03 | May-04 | May-05 |
| Smith-Austin Crks., Wake Forest | Small | Urban | DWQ | Aug-01 | Jul-02 | Aug-03 | Aug-04 | Aug-05 |
| Murphy Farm, Louisburg | Small | Rural | DWQ | Dec-01 | Jul-02 | Dec-03 | Dec-04 | Dec-05 |
| Yates Mill, Raleigh | Small | Rural | DWQ | Mar-02 | Apr-02 | Mar-03 | Mar-04 | Mar-05 |
| Marks Creek, Knightdale | Small | Rural | Stantec | May-02 | Sept 02 | May-04 | May-05 | May-06 |

**Sand Hills Ecoregion**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Buckhead Cr., Fayetteville | Large | Urban | BLWI | Sep-99 | Jul-00 | Oct-00 | Oct-01 | Oct-02 |

**Coastal Plain Ecoregion**

| | | | | | | Post-Construction Monitoring | | |
|---|---|---|---|---|---|---|---|---|
| Project or Stream Name, location | Catchment Size | Rural or Urban | Collection Agency | PreC - Survey | Constr Date | Year 1 | Year 2 | Year 3 |
| Whitehurst Cr., Aurora | Large | Rural | CZR | w & s 92 | Oct 92 & 95 | w & s 93 | w & s 94 | w & s 95 |
| Bailey Cr., Aurora | Small | Rural | CZR | Jul-95 | Sep-96 | w & s 97 | w & s 98 | w & s 99 |
| Mill Branch, Greenville | Small | Rural | DWQ | Jul-01 | Not Completed | | | |
| Global Transpark, Kinston | Large | Rural | EcoScience | Jun-02 | Not Completed | | | |
| Adkins Branch, Kinston | Large | Urban | DWQ | Apr-02 | Not Completed | | | |
| Crescent Road, Kinston | Large | Rural | Buck Engin. | none done | Apr-02 | Feb-02 | Feb-03 | Feb-04 |