Assessment Report: Biological Impairment in the West Fork French Broad Watershed

French Broad River Basin
Transylvania County, NC

North Carolina Division of Water Quality
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Collaborative Assessment for Watersheds and Streams (CAWS) Project
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1.0 Study Purpose

The West Fork French Broad River assessment is part of the Collaborative Assessment of Watersheds and Streams (CAWS) project, a study of four watersheds across the state being conducted by DWQ between 2001 and 2003. The goal of the project is to provide the foundation for future water quality restoration activities in each watershed by:

1. Identifying the most likely **causes** of biological impairment. Examples of such causes include degraded habitat or specific pollutants;
2. Identifying the major watershed activities and **sources** of pollution contributing to those causes. Examples of sources include streambank erosion or stormwater runoff from a particular location;
3. Outlining a watershed **strategy** that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

2.0 Study Approach

The general conceptual approach used to determine the causes of impairment in West Fork French Broad River was as follows:

1. Identify the most plausible potential causes of impairment in the watershed, based on existing data and initial watershed reconnaissance activities;
2. Collect a range of data bearing on the nature and impacts of those potential causes; and
3. Characterize the causes of impairment by evaluating all available information using a strength of evidence approach. The strength of evidence approach involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

3.0 The Setting

The West Fork French Broad River is located in southwest Transylvania County and is part of DWQ subbasin 040301. The West Fork is impaired near its headwaters in the vicinity of the Whitewater Trout Farm. The trout farm is located just upstream from the stream's intersection with S.R. 1306. Prior to this study, the impairment extent was not known; the 2000 303(d) list simply says 'From above to below trout farms'.

The West Fork French Broad is located in mountainous terrain with flood plains on its main stem, but not on its tributaries (V-shaped valleys). It is a relatively high gradient stream with a variety of riparian cover. The land cover is predominantly forested though there are residences on large plots scattered throughout the region, as well as pasture for cattle grazing. The area is sparsely populated.

4.0 Biological Conditions and Stream Habitat

Biological assessment (bioassessment) involves the collection of stream organisms and the evaluation of community composition and diversity to assess water quality and ecological conditions. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

This section describes the results of the benthic invertebrate and fish community surveys completed for this project. More detailed analyses may be found in Appendix A (invertebrates) and B (fish).

4.1 Approach to Biological and Habitat Assessment

4.1.1 Benthic Community Sampling and Rating Methods

When surveying the benthic community, DWQ followed its general procedures outlined in the standard operating procedures (NCDWQ, 2001). Reaches approximately 100 meters long were targeted, although the actual reach length sampled varied with site conditions. DWQ used standard qualitative sampling for most sites. This method included ten samples: two kick-net samples, three bank sweeps, two rock or log washes, one sand sample, one leaf pack sample and visual collections from large rocks and logs.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrates is evaluated using EPT taxa richness counts; while the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an acronym for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), which are insect groups that generally do not tolerate much or many kinds of pollution. A *higher* EPT number represents a healthier benthic macroinvertebrate community. A *lower* BI score represents a more balanced and diverse benthic community.

Biotic index ratings and EPT taxa richness rating are combined to produce a final bioclassification, such as Excellent, Good, Good-Fair, Fair or Poor. These final bioclassifications are used to determine if a stream is impaired. The cutoff for this decision is between Good-Fair and Fair, with Fair and Poor considered to be impaired. Under current DWQ policy, streams with a drainage area of less than three square miles are generally not formally rated, but are evaluated based on professional judgment. Small streams sampled using the Qual 5 method that have scores consistent with a Good-Fair or better rating are labeled as 'not impaired'.

4.1.2 Fish Community Assessment Methods

A distance of 600 ft. was sampled at each site on August 27 or 28, 2003 following all methods (including physical-chemical and habitat assessments) in the existing North Carolina Index of Biotic Integrity (NCIBI) protocols (NCDWQ, 2001). The fish within the delineated stretch were collected using two backpack electrofishing units with each unit accompanied by one person netting fish. A seine was used where appropriate. After collection, all readily identifiable fish were examined for sores, lesions, fin damage, and skeletal anomalies, measured (total length (TL) to the nearest 1 mm), and then released. Once the first 50 specimens of each species were measured, the remaining fish of each particular species were just counted and then also released. Those fish that were not readily identifiable in the field were preserved in 10% formalin and returned to the laboratory for identification, examination, and total length measurement. These fish were then deposited as voucher specimens with the North Carolina State Museum of Natural Science in Raleigh. All young-of-year fish were excluded from the data analyses. Fish were considered young of year if less than 100 mm TL for Rainbow trout and Brown trout and less than 50 mm TL for Blacknose dace.

4.1.3 Habitat Assessment Methods

When DWQ conducted benthic community sampling stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for mountain streams (NCDWQ, 2001). This subjective protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from zero (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- in-stream habitat variety and area available for colonization (20);
- riffle habitats (16);
- bottom substrate type and embeddedness (15);
- bank stability and vegetation (14);
- pool variety and frequency (10);
- light penetration/canopy coverage (10);
- riparian zone width and integrity (10); and
- channel modification (5).

4.2 Benthic Survey Results

DWQ's Biological Assessment Unit has sampled 3 sites on the West Fork French Broad since 1990:

Station 1: West Fork French Broad River off NC 281 above trout farm, Transylvania County. The exact location of the upstream site has varied over the course of this study, with a resultant variation in stream size. The upstream site sampled in September 2000 was very small, with a width of only one meter during the dry summer months. The upstream site was 3 meters wide in October 2001; this site is on the West Fork approximately 0.6 miles above the confluence with Mill Branch, which carries the trout farm effluent.

Station 2: West Fork French Broad River, SR 1306, Transylvania County. This site is less than 1/8th mile below all trout farms.

Station 3: West Fork French Broad River, NC 281, Transylvania County. Recovery site about 1 mile further downstream from the trout farm.

In 1990, DWQ surveyed all three sites in May and again in August. The results were Excellent both times at the upstream site, Good-Fair (in May) and Fair (in August) at SR 1306, and Good and Good-Fair at NC 281. During the 2000 sampling, the upstream site maintained its Excellent rating, the downstream site at SR 1306 remained Fair, and the third site at NC 281 was not re-sampled. In October 2001, the Biological Assessment Unit returned to the area to sample all three sites. Again, the upstream site rated Excellent, the SR 1306 site was Fair, and the downstream, NC 281 site received a Good rating. Summaries of the benthic invertebrate results are provided below in Table 1.

Table 1. Taxa richness by group and summary parameters, West Fork French Broad River, Transylvania County.

	5/90			8/90			9/00		10/01		
Parameter Station:	1	2	3	1	2	3	1*	2	1*	2	3
Ephemeroptera	23	15	20	17	5	10	11	4	11	5	11
Plecoptera	14	7	10	9	2	6	6	2	8	4	7
Trichoptera	18	11	14	19	8	16	12	9	9	10	23
Coleoptera	3	1	4	2	3	4	2	3	1	2	6
Odonata	2	2	6	3	2	4	1	5	1	4	5
Megaloptera	2	0	1	2	1	1	0	1	0	0	2
Diptera: Chironomidae	22	22	26	21	17	22	4	25	6	20	26
Misc. Diptera	8	8	7	5	4	7	7	10	5	5	8
Oligochaeta	3	4	4	1	5	2	1	6	2	5	3
Crustacea	1	0	1	1	1	1	1	1	0	0	0
Mollusca	0	1	2	1	2	2	0	2	0	2	2
Other	0	1	2	1	1	2	0	1	0	2	0
Total Taxa Richness	96	72	97	82	51	78	45	69	43	59	93
EPT Richness	55	33	44	45	15	32	29	15	28	19	41
Seasonal corrected	47	30	41						28	19	38
Small stream correction							42		35		
Biotic Index	2.68	4.95	4.55	2.68	5.97	4.95	2.13	6.47	2.46	5.83	4.46
Seasonally corrected	3.18	5.45	5.04						2.86	6.22	4.86
Rating	Ex	G-F	Good	Ex	Fair	G-F	Ex	Fair	Ex	Fair	Good
Width	5	5	7	5	5	7	1	5	3	4	6
Average Depth	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.3	0.1	0.3	0.3
Canopy	90	70	80	90	80	80	90	50	100	40	40
Aufwuchs	Slight	Ab	Ab	None	Ab	Ab	None	Ab	Mod	Ab	Mod
Bank Erosion	None	Slight	Slight	None	Slight	Slight	None	Slight	None	None	None
Substrate (%)											
Boulder	20	20	10	30	15	10	10	20	40	0	10
Rubble	40	25	25	40	20	20	30	30	25	25	35
Gravel	25	25	30	10	20	15	30	20	25	40	40
Sand	15	30	35	20	45	55	30	25	10	25	10
Silt	0	0	0	0	0	0	0	5	0	10	5

*Qual 4 sample, rating based on different EPT criteria
Ab=Abundant

Based on the 2001 survey at SR 1306, the dominant taxa indicated high inputs of organic material, low dissolved oxygen concentration and some toxicity. Substantial recovery was observed at the NC 281 site about one mile downstream, although this site still showed some enrichment. The NC 281 site is expected to receive a Good-Fair rating during summer months and a Good rating at other times of the year.

DWQ observed sewage fungus at the SR1306 during the 2001 invertebrate survey. Also, abundant growths of both moss (*Fissidens*) and periphyton covered much of the substrate.

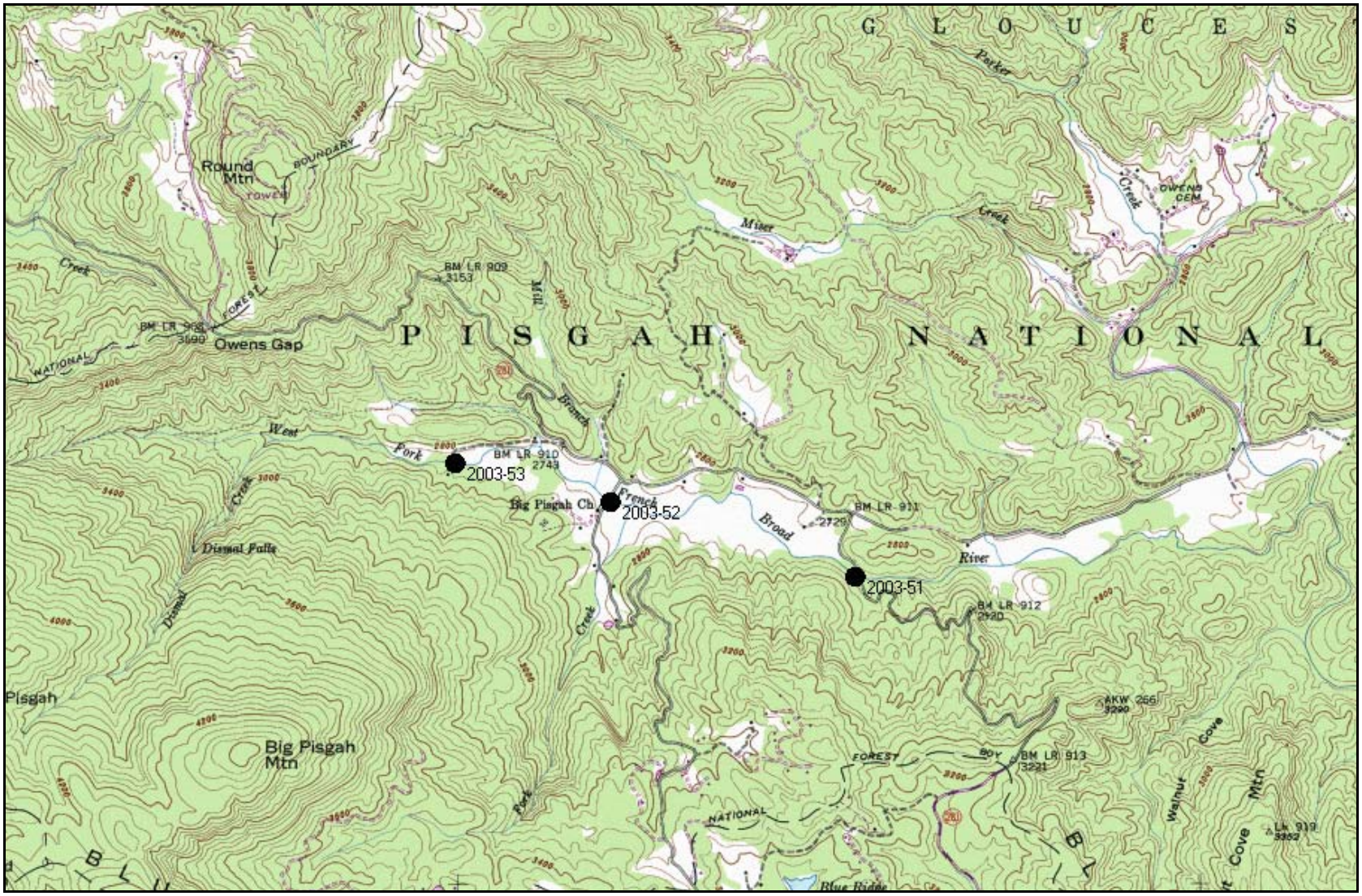

Figure 1. Sampling Stations on West Fork French Broad River. (2003-53 = Station 1; 2003-52 = Station 2; 2003-21 = Station 3)

4.3 Fish Survey Results

Fish Community

DWQ sampled the fish communities at all three sites on August 27 and 28, 2003. As was the case in 1990, the impact of the discharge from the trout farm on the receiving stream was to clearly artificially enhance and stimulate upper trophic level fish production in the river at and below the discharge (Table 2). For example, piscivorous Brown trout were 15 times more abundant below the than above the trout farm. Prey species also increased in numbers below the trout farm. No Blacknose dace were collected at Site No. 1, but were abundant at Site Nos. 2 and 3.

Enhancement extended downstream to Site No. 3 where the total number of fish was still 11 times greater than at Site No. 1. Not only were there more fish at and below the discharge than above it, but many of the Brown trout were greater than 300 mm TL and several were as long as 550 mm TL. These large piscivores undoubtedly influenced the structure of the fish community. Although individual weights and standing crop estimates were not made, the number and size of fish (as shown in Figure 3) were a common occurrence at Site No. 2 and to a lesser extent at Site No. 3.

Table 2. Abundance and catch per unit effort (CPUE) of fish collected from three sites along the W. Fork French Broad River, Transylvania Co., August 27 and 28, 2003.

	Station Number		
	1	**2**	**3**
Abundance			
Rainbow trout	10	44[1]	4[1]
Brown trout	12	180	68
Blacknose dace	0	93	160
Total number	22	317	232
Shocking time (seconds)	4,863	4,814	5,357
CPUE (No. of fish/100 seconds shocking)			
Rainbow trout	0.21	0.91[1]	0.07[1]
Brown trout	0.25	3.74	1.27
Blacknose dace	0.00	1.93	2.99
Total CPUE	0.5	6.6	4.3

[1]Includes fish that appeared to be stocked as well as wild fish.

Fish communities in streams such as the West Fork French Broad River are currently not rated with the NCIBI. The diversity was low in this trout stream; however, all the fish appeared healthy, and species at all the sites were represented by multiple age groups, indicating successful reproductive efforts.

The West Fork French Broad River at SR 1306 was sampled in October 1997 as part of the 1997 French Broad River Basinwide Assessment Program (NCDEHNR 1998). Based on data collected by DWQ in 1997 and 2003, and by the NCWRC in 1990, the fish

community in the lower part of this watershed (from NC 281 to SR 1306) seems to have been altered by the nonnative trout species and by the long-term management of the stream as a popular trout stream. Only six species (Rainbow trout, Brown trout, Blacknose dace, Redbreast sunfish (also an exotic), Greenside darter, and Swannanoa darter) have been collected from these sites. There were at least 15 additional native species previously known in this watershed: Mountain brook lamprey, Brook trout, Central stoneroller, Saffron shiner, Mirror shiner, Warpaint shiner, Telescope shiner, Longnose dace, Northern hogsucker, White sucker, Rockbass, Fantail darter, Redline darter, Greenfin darter, Gilt darter, and Mottled sculpin (Menhinick 1991). Many of these species should have been collected downstream at the NC 281 and SR 1306 sites.

Figure 2. Left - Whitewater Trout Farm located just above SR 1306 off NC 281 at the confluence of Mill Branch and the West Fork French Broad River, Transylvania County. The farm raises Rainbow trout.

Figure 3. Right - healthy, 200 mm long Brown trout collected from West Fork French Broad River at SR 1306 below the Whitewater Trout Farm, Transylvania County.

4.4 Habitat

DWQ assessed the instream habitat while conducting the fish community surveys in August, 2003. Instream and riparian habitats were of extremely high quality above the trout farm, rather low quality at the farm, and of moderate quality below the farm (Table 3). The major causes of the degraded habitats at Site No. 2 were the loss of riparian habitats, bank stability, and an embedded substrate.

Table 3. Habitat assessment scores at three fish community sites along the West Fork French Broad River, Transylvania County, August 2003.

	Site No.			
	1	2	3	**Maximum**
Location	off NC 281	SR 1306	NC 281	**Possible**
Date	08/28/03	08/27/03	08/27/03	**Score**
Habitat characteristics				
Channel modification	5	5	5	5
Instream habitat	20	14	18	20
Bottom substrate	15	8	10	15
Pool variety	8	6	7	10
Riffle habitats	16	9	7	16
Bank stability & vegetation				
Left bank	7	3	7	7
Right bank	7	3	5	7
Light penetration	8	5	8	10
Riparian vegetative zone width				
Left bank	4	2	5	5
Right bank	4	2	2	5
Total Habitat Score	94	57	74	100

4.4.1 Habitat Descriptions

Site No. 1, off NC 281

Site No. 1 is off NC 281 approximately 0.6 miles above the Whitewater Trout Farm and at the entrance to Camp Winding Gap. The river has wide forested riparian zones along both banks above the culvert and an overgrown Christmas tree farm and a youth camp below the culvert (Figure 4). The river is a typical high gradient, cold water mountain stream heavily shaded by Eastern hemlock and *Rhododendron*. Instream habitats consisted of riffles, runs, pools, snags, and the macrophyte *Podostemum* (river weed).

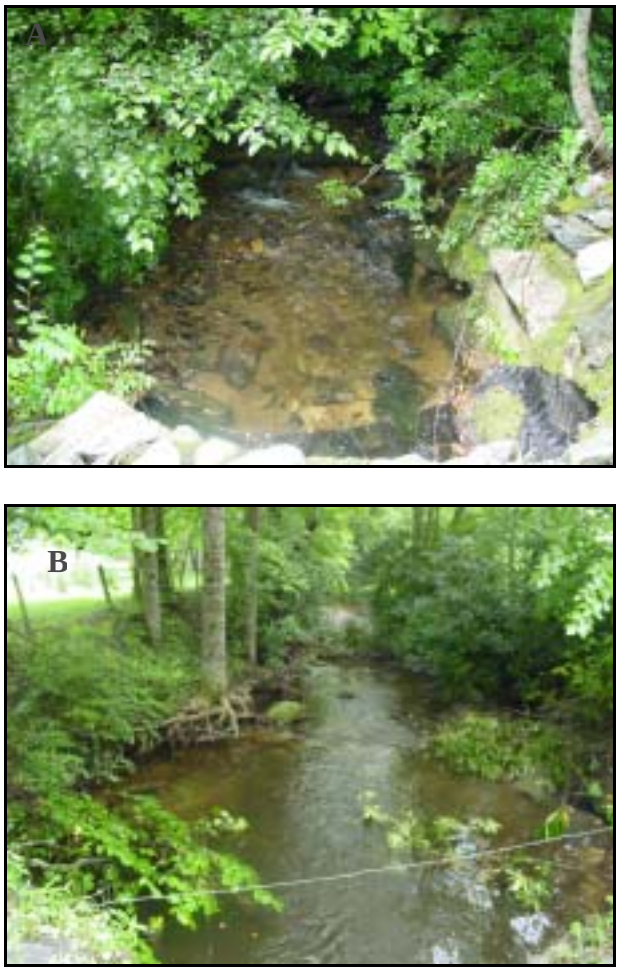

Figure 4. Upstream (A) and downstream (B) views of Site No. 1 on the West Fork French Broad River off NC 281 at Camp Winding Gap, Transylvania County.

Site No. 2, SR 1306 281

Site No. 2 was at SR 1306 immediately below the trout farm (Figure 5). Fish were sampled from a reach extending from 360 ft. above to 240 ft. below the culvert (i.e., from the mouth of Mill Branch to the mouth of Fork Creek). Between Site Nos. 1 and 2 and extending to Site No. 3, the riparian zones are narrow, shrubby, and the surrounding lands have been converted to active pastures and row crops. The open canopy and the nutrients in the trout farm discharge stimulated the production of the benthic periphyton and algae *Vaucheria* (water felt); *Podostemum* was also wide spread and abundant on the rocks in the current (Figure 6). Instream habitats consisted of riffles, runs, pools, and snags.

Figure 5. Upstream (A) and downstream (B) views of Site No. 2 on the West Fork French Broad River at SR 1306, Transylvania County.

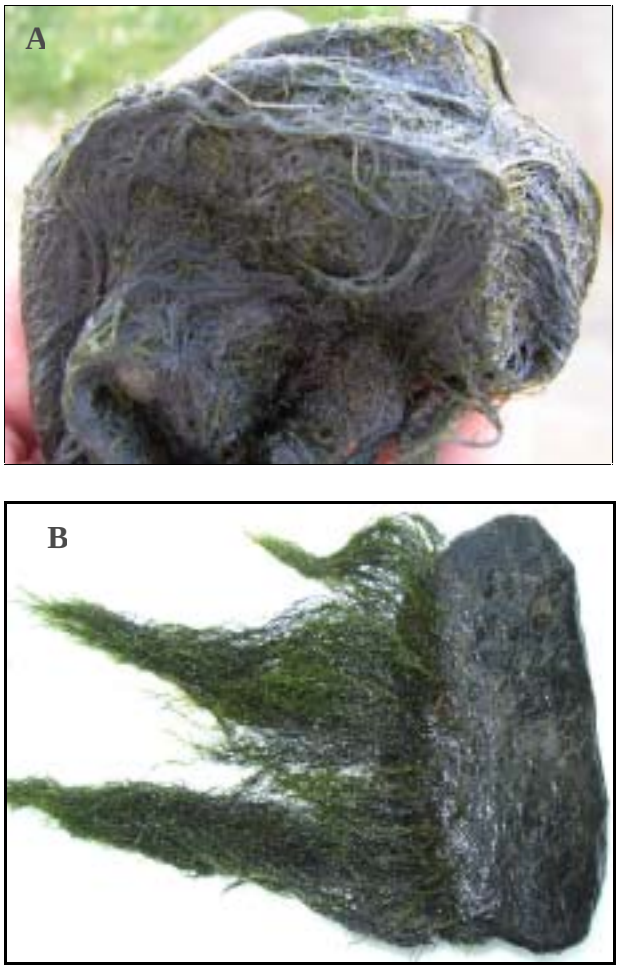

Figure 6. ***Vaucheria*** **(water felt) (A) and** ***Podostemum*** **(river weed) (B) found growing in the West Fork French Broad River at SR 1306 and NC 281, Transylvania County.**

Site No. 3, NC 281

Site No. 3 was located 1.2 miles below the trout farm and the sample reach extended 600 ft. upstream from the bridge crossing (Figure 7). Unlike Site No. 2, the riparian zone along the left shore was forested with Eastern hemlock and *Rhododendron*. However, the riparian along the right shoreline was very narrow and bordered the road and an active pasture. The cattle were excluded from the stream but they had direct access to tributaries between Site Nos. 2 and 3. *Potamegeton* (pond weed), *Vallisneria* (eel grass), and *Podostemum* were wide spread and abundant; excessive periphyton and filamentous algal growths (*Vaucheria*) also grew in places. Instream habitats consisted of runs, snags, deadfalls, and pools.

Figure 7. Upstream views of Site No. 3 on the West Fork French Broad River at NC 281, Transylvania County.

4.5 Physical and Water Quality Characteristics

There is not a DWQ ambient monitoring site on the West Fork French Broad River. All sampling was performed as part of the biological assessments. Results presented in Table 4 come from the August, 2003 fish community surveys.

The drainage areas of the three sites ranged from 2.1 to 6.0 square miles and the stream widths ranged from 3 to 8 meters. The conductivity (specific conductance) was extremely low at all sites, although the discharge from the trout farm increased the conductivity by 175% between Site No. 1 and Site No. 2. By the time the flow had reached Site No. 3, the conductivity had returned to background levels. Dissolved oxygen concentration and percent saturation also sagged and rebounded slightly below the farm. The pH however did not return to background levels by Site No. 3; instead, it continued to decrease. Even though the water was clear at all the sites below the trout farm there were deposits of organic silt, which had settled out in the low flow areas and

which easily became suspended, rendering the water very turbid. Flows during the sampling period were slightly greater than the historical median flows for that period.

Table 4. Physical and water quality characteristics of three fish community sites along the West Fork French Broad River, Transylvania County, August 2003.

	Site No.		
	1	2	3
Location	off NC 281	SR 1306	NC 281
Latitude	351051	351104	351110
Longitude	825609	825659	825730
Date	08/28/03	08/27/03	08/27/03
Physical and water quality characteristics			
Drainage area (mi^2)	2.1	3.3	6.0
Temperature (°C)	17.3	18.6	18.0
Conductivity (µmhos/cm)	8	14	8
Dissolved oxygen (mg/L)	7.6	6.8	7.2
Dissolved oxygen saturation (%)	79	73	76
pH (s. u.)	6.9	6.2	6.0[1]
Average width (m)	3	5	8
Average depth (m)	0.3	0.3	0.4
Water clarity	Clear	Clear[2]	Clear[2]
Substrate	Cobble, boulder, gravel	Cobble, gravel, silt	Cobble, gravel, silt
Estimated flow (cfs)[3]			170
Historical median flow (cfs)[3]			140

[1]The pH meter was calibrated and was operating correctly.
[2]Silt deposits were easily suspended causing the water to become very turbid.
[3]The flow was based on the USGS gauge at the French Broad River at Rosman (Transylvania County).

4.6 Summary of Bioassessments

The impacts of a trout farm discharge upon the aquatic communities in the West Fork French Broad River have been documented since 1990. The discharge, along with degraded riparian habitats in the vicinity of the farm, has affected the water chemistry, enriched periphytic growths, degraded the benthic community, and artificially stimulated the fish community. Although the sites evaluated were in the upper part of the watershed, management of the stream as a popular trout stream has possibly displaced several native species. Enrichment and degradation of the stream by cattle wastes also cannot be ruled out as a factor affecting the aquatic communities of the upper West Fork French Broad River. DWQ's biologist estimated that less than 25% of the organic loading comes from cattle, and more than 75% from the trout farm (Tracy, 2003).

5.0 Potential Causes of Biological Impairment

The study identified those factors that were plausible causes of biological impairment in the West Fork French Broad watershed using both biological assessment and watershed-based approaches. An evaluation of the aquatic macroinvertebrate community data, as well as habitat and land use activities, can point to the general types of impacts that may impact the stream's biological integrity. These stressors were flagged for further investigation, which DWQ conducted in this study.

Key Stressors Evaluated in the West Fork French Broad watershed:

1. *Nutrient/organic enrichment*. Organic enrichment can affect stream biota in two ways. First, it can deplete dissolved oxygen to harmful levels. Second, it can favor pollution tolerant species that filter their food from the water column. Trout farm effluent and cattle grazing in the area contribute to nutrient enrichment.

2. *Habitat degradation—sedimentation*. Sedimentation impacts habitat through loss of pools, burial or embedding of riffles, and high levels of substrate instability.

3. Toxicity. DWQ observed some evidence of toxicity through the results of the benthic invertebrate community survey.

6.0 Analysis and Conclusions – Causes and Sources of Impairment

This section analyzes the likely causes of impairment in the West Fork French Broad River watershed, drawing on information presented earlier in this report. The sources or origin of these key stressors are also discussed.

Admittedly, the project focused more on causes than on sources. The goal is to move West Fork French Broad River to the appropriate part of the 303(d) list, and then later, with more data on sources, develop a TMDL, or implement a management strategy.

6.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to candidate causes of impairment in order to determine whether that information provides evidence that each particular stressor plays a substantial role in causing the observed biological impacts. A strength of evidence approach is used to assess the evidence for or against each stressor, and draw conclusions regarding the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. [See the Background Note "Identifying Causes of Impairment", presented in Section 1, for additional discussion.] Acknowledgement for significant assistance on this section is owed to DWQ's Watershed Assessment and Restoration Project, which preceded this project and had the same objectives (NCDWQ, 2003).

6.1.1 A Framework for Causal Evaluation—the Strength of Evidence Approach

A 'strength of evidence' approach or 'lines of evidence' approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000).

This section considers all lines of evidence developed during the course of the study using a logical process that incorporates existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses and pollutant sources. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor that has an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing the impairment, the primary cause is the one that is most critical or limiting. Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment.
- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively cause impairment. A primary cause of impairment will generally not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process.
- **Contributing stressor.** A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.
- **Potential cause or contributor.** A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely

to impact stream biota in some fashion but are not important enough to be considered the causes of or contributors to impairment.

6.1.3 Candidate Stressors

As outlined in Section 5, the primary stressors evaluated were:

- Nutrient enrichment.
- Habitat degradation—sedimentation;
- Toxicity.

6.1.4 Review of Evidence

West Fork French Broad River is impaired between SR 1306 and NC 281, a condition that has been evident since 1990. It is not known when the last time the creek was unimpaired (had a balanced aquatic community).

Organic/nutrient enrichment. DWQ considered organic enrichment as a cause of impairment because the initial benthic community surveys reported potential impacts from organic loading. The three relevant lines of evidence in this case are habitat surveys, benthic community data and water quality monitoring data.

Recent benthic community surveys included organic enrichment indicator species. Abundant periphyton growth supports this assertion.

The nature of the organic enrichment seen in West Fork French Broad River does not seem to extend to low dissolved oxygen (DO), as that parameter was never measured below 5.0 mg/L at any of the sites. This may not be the whole story, however, as DWQ did not take DO measurements at night, or during the early morning, when the diurnal cycle of photosynthesis would produce the lowest levels of DO. Also, it may be possible that low dissolved oxygen occurs in organic-rich, periphyton-covered sediment.

Another impact of high nutrients and subsequent algal growth is the advantage gained by aquatic insects that prefer organic particles or algae as their food sources. These organisms tend to be placed in the pollution tolerant class of insects.

The strength of evidence regarding organic/nutrient enrichment points to this as a primary cause of impairment.

Habitat degradation—sedimentation. Sedimentation is evident over much of the course of West Fork French Broad River. Relevant lines of evidence include benthic macroinvertebrate community data, habitat and geomorphic evaluations, and watershed characteristics.

Stream surveys and habitat assessments indicate that sedimentation is occurring, but has probably not yet reached a point where it can be considered a primary cause of

impairment. Every reach below the trout farm has considerable amounts of fine-grained (e.g., sand and silt) sediment; fine-grained sediment comprises 35 percent of the substrate at Station 2, and 15 percent of the substrate at Station 3 (see Table 1).

Sedimentation in West Fork French Broad River causes unstable habitat for the benthic macroinvertebrate community. However, since it is not that extensive, **this probably means that sedimentation is a cumulative cause of impairment**. Since pockets with less sediment accumulation exist, some habitat remains, so DWQ does not believe sedimentation is a primary cause of impairment.

Toxicity. Unfortunately, DWQ does not have much evidence to evaluate to determine if toxicity is a factor in the stream's impairment. Toxicity was only evident at the SR 1306 site (Site 2), so whatever caused it is likely to be in the small area between the upstream site and SR 1306. The trout farm is a leading candidate. Another possibility may be chemicals (e.g., pesticides, herbicides) used by the few residences between Sites 1 and 2.

Toxicity may be further investigated through sediment chemical analyses and a sediment bioassay. Until this has been done, however, toxicity should be considered as only a potential cause of impairment.

6.1.5 Conclusion

Multiple stressors impact aquatic organisms in West Fork French Broad River. The watershed is highly developed, and characteristic of such urbanizing area, multiple stressors are evident. The leading stressors, in decreasing order of impact, are:

- Nutrient enrichment. Primary cause of impairment.
- Habitat degradation--sedimentation. Cumulative cause of impairment.
- Toxicity. Potential Cause of Impairment.

7.0 Improving Stream Integrity in West Fork French Broad River: Recommended Strategies

As discussed in the previous section, the West Fork French Broad is impaired primarily by organic enrichment, and also by the cumulative impacts of habitat degradation (sedimentation) and perhaps toxicity. This section considers how these problems can be addressed. A summary of recommendations is included at the end of the section.

The bioassessment of the fish community mentions the possibility that cattle may contribute to the organic enrichment problem in the stream. Certainly, an alternative water source should be provided and the stream should be fenced to keep out cattle. However, without these measures, the biologists estimated that less than 25% of the organic loading comes from cattle, while greater than 75 percent of the organic loading comes from the trout farm (Tracy, 2003). Consequently, the management strategy discussion below will focus on the trout farm.

7.1 Other Research on Impacts from Trout Farms

Research supports the claim that trout farm effluent can adversely affect benthic macroinvertebrates (Richards et al. 1993, Loch et al. 1996, Selong and Helfrich 1998).

Selong and Helfrich studied five trout farms on different streams in Virginia headwater catchments. They found that the key factor in determining how a trout farm impacts downstream benthos is substrate embeddedness (degree to which fine sediment covers normal coarse sediment).

Selong and Helfrich found few instances of unacceptable levels of solids, ammonia, dissolved oxygen, water temperature and pH. However, Bergheim et al. (1984) observed that 46% of total solids exported from a trout farm occurred during weekly one hour cleaning events. Also, presence of sewage fungus below some trout farms indicates that organic enrichment may cause anaerobic conditions within the microhabitat scale of the benthos (Loch et al., 1996).

The net result of excessive organic and solids loading is that it can create conditions that favor non-EPT taxa, such as chironomids and oligochaetes (Loch et al., 1996). Essentially, pollution intolerant EPT are out-competed by species that can feed on fine, suspended or deposited organic material, and which may tolerate occasionally anaerobic conditions and saprophytic fungi.

Factors that can mitigate the impact of organic solids loading include: (1) Trout farms that have settling ponds and are characterized by low pollutant concentrations and high flow rates (Cripps, 1994); ponds promote optimal settlement when the ratio of pond length to retention time is maximized and fluid velocity are less than 0.7 m/s (Henderson and Bromage, 1988); (2) Adjust production annually and seasonally when greater streamflow allows increased carrying capacity and greater feed loading (Selong and Helfrich, 1998).

7.2 Management Recommendations

This section will include a discussion of what can be done to better manage the trout farm effluent, so that the downstream benthic invertebrate community improves to meet the biological integrity designated use.

To reduce solid waste loading from a trout farm, some combination of the following must occur:

- reduce the number of trout raised;
- reduce the amount of food used;
- better contain or remove the solid waste that is created by the trout farm.

There are a number of options available to achieve these measures. Managing the amount and type of feed, as well as the amount of fish manure that enters the stream can have a big impact on the number of fish in the trout farm that the stream can tolerate.

NCDWQ has worked with trout farms in the mountains in the past and has had success in improving the stream health, while a trout farm continues operation. The management changes that NCDWQ has used in previous cases include the following:

- Use hand feeding as much as possible. This reduces the amount of food that enters the raceways and stream. It may not be possible to do this all of the time, but hand feeding regularly has shown benefits.
- Use high quality food. The fish receive the same amount of essential nutrients with less food, which results in less manure production. Estimates are that during the 1990s it took 1.7 lbs of feed to produce 1.0 lb of fish, while today it takes only 1.1 lbs of feed to produce 1.0 lb of fish (Tracy, 2003).
- Clean the raceways regularly and land apply the manure as fertilizer. This may be a challenging task as trout manure and the stringy sewage sludge that grows in the settling basin can be hard to collect, but improvement may be possible. Once collected, the sludge and manure may be applied to crops or pasture, as it is a good fertilizer.
- Another option is to grow a smaller amount of fish, measured in weight not count. A stream has a given capacity for assimilating waste, and that can be exceeded if a trout farm has too many fish.

The trout farm may adopt some or all of our recommendations. The goal is to improve the biological community downstream of the trout farm, such that it meets the stream's designated use for biological integrity. It is not clear what that will require, so making gradual improvements in managing the farm will be necessary.

Non-cooperation by the trout farmer could prompt DWQ to change the farm's NPDES permit to an individual one (versus the current general permit that applies to many trout farms in the state). An individual permit could require additional monitoring, which would provide data to set an allowable amount of fish. DWQ believes a better alternative would be to work with the trout farmer to find the right balance of BMPs and trout in the farm.

References Cited

Bergheim, A., H. Hustveit, A. Kittelsen, and A.R. Selmer-Olsen. 1984. Estimated loadings from Norwegian fish farms. II. Investigations 1980-1981. Aquaculture 86:359-368.

Cripps, S.J. 1994. Minimizing outputs: treatment. Journal of Applied Ichthyology 10:284-294.

Henderson, J.P. and N.R. Bromage. 1988. Optimizing the removal of suspended solids from aquacultural effluents in settlement lakes. Aquacultural Engineering 7:167-181.

Loch, D.D., West, J.L., and D.G. Perlmutter. 1996. The effect of trout farm effluent on the taxa richness of benthic macroinvertebrates. Aquaculture 147: 37-55.

NCDWQ. 2001. Standard operating procedure. Biological monitoring. Benthic invertebrate and fish community assessments. Biological Assessment Unit. North Carolina Department of Environment and Natural Resources. Division of Water Quality. Water Quality Section. Environmental Sciences Branch. Raleigh, NC. http://www.esb.enr.state.nc.us/BAU.html

NCDWQ. 2003. Special Watershed Protection Unit's Watershed Assessment and Restoration Project. Assessment Report: Biological Impairment in the Upper Swift Creek Watershed. Neuse River Basin. Wake County, NC. June 2003. http://h2o.enr.state.nc.us/swpu/

Richards, C., G.E. Host, and J.A.W. Arthur. 1993. Identification of predominant factors structuring stream macroinvertebrate communities within a large agricultural catchment. Freshwater Biology 29: 285-294.

Selong, J.H. and L.A. Helfrich. 1998. Impacts of Trout Culture Effluent on Water Quality and Biotic Communities in Virginia Headwater Streams. Progressive Fish Culturist, Volume 60, Number 4, pp. 247-262.

Tracy, B.H. 2003. NCDWQ Biological Assessment Unit. Personal communication.

USEPA. 1998. Guidelines for Ecological Risk Assessment. EPA 630-R-95-002F.

USEPA. 2000. Stressor Identification Guidance Document. EPA 822-B-00-025. December.

APPENDIX A.
HISTORICAL DATA

DWQ's interests in the effects upon the aquatic community from trout farm discharges along the upper West Fork French Broad River began in 1989. Prior to the implementation of Best Management Practices (BMPs), the discharges from trout farms were high in suspended solids, dissolved and particulate organics, and nutrients. In May and August 1990, September 2000, and October 2001, studies of the impact of these discharges upon the benthic macroinvertebrate community were conducted prior to and after implementation of BMPS (Biological Assessment Unit Memoranda B-900720, B-901029, 20000925, and 20020125).

Three sites (one above and two below the trout farm) were evaluated. [Note: the uppermost site in the 1990 and 2000 study was on an unnamed tributary to the West Fork French Broad River and not the West Fork French Broad River *per se*. The 2001 site was on the West Fork French Broad River just above Camp Winding Gap] These studies determined that the site above the trout farms was rated either Excellent or Not Rated, the site immediately below the trout farm (at SR 1306) was generally Fair, and the site below the farm at NC 281 was Good-Fair or Good (NCDENR 2003b). The effects of the discharge on the benthic fauna were similar to that of sewage effluents – an abundance of pollution tolerant, nutrient enrichment indicative, and filter feeding benthic macroinvertebrates. The discharges also stimulated production of benthic periphyton, sewage fungus, and bacteria. In Transylvania County alone in 2000 there were 18 such discharges from trout farms. (NCDA&CS 2001).

In 1990 to complement the DWQ benthic macroinvertebrate study, the North Carolina Wildlife Resources Commission sampled four sites along the river during May, August, and October to determine what impacts the discharge had upon the fish community (Doug Besler, Jim Borawa, and Scott Loftis, NCWRC, pers. com., unpublished data).[1] The trout farm discharge greatly stimulated fish production (density and biomass of three species) in the receiving stream (Table 1). For example, Total Density was 15 to 44 times greater below than above the discharge; likewise Total Standing Crop was 9 to 12 times greater below than above the discharge. The stimulated production was generally greatest immediately below the discharge and declined with distance downstream.

[1] The four sites sampled were: Site Nos. 1A and 1B on US Forest Service land above the trout farms, Site No. 3 below the trout farms at SR 1306, and Site No. 4 approximately 0.5 mile below SR 1306 where an unnamed tributary joins the river on the north side of the river and roughly one-half the way between SR 1306 and NC 281. The fish were collected using a three-pass depletion back pack electrofishing technique over a distance of approximately 90 to 100 meters.

Table 1. Fish data collected by the North Carolina Wildlife Resource Commission from three sites along the West Fork French Broad River, Transylvania County, 1990. See text for explanation of location of sites.

Month	May			Aug			Oct		
Location	Above	Below		Above	Below		Above	Below	
Site	1[1]	3	4	1[1]	3	4	1[1]	3	4
Density (No./ha)									
Rainbow trout	288	725	421	1,098	621	439	116	766	116
Brown trout	200	1,906	1,103	632	3,460	2,539	410	4,185	1,146
Blacknose dace	89	2,652	7,647	111	14,936	23,753	11	18,810	8,996
Redbreast sunfish	0	21	0	0	0	0	0	0	0
Total	577	5,304	9,171	1,841	19,017	26,731	537	23,761	10,258
Standing Crop (Kg/ha)									
Rainbow trout	13.54	84.43	37.04	14.97	44.10	56.56	11.20	44.1	56.56
Brown trout	11.75	216.11	53.05	29.56	323.60	125.5	22.95	323.60	125.15
Blacknose dace	0.27	6.29	19.69	0.33	32.65	41.63	0.06	36.56	14.18
Redbreast sunfish	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	25.56	306.87	109.78	44.86	400.35	223.69	34.21	404.26	195.89

[1]Averages of two sites located above the trout farms on US Forest Service lands.

These two 1990 biological studies (DWQ's and NCWRC's) along with a water chemistry study were part of a larger study on the impacts of trout farms coordinated by Drs. James Rice and Jeffery Hinshaw of North Carolina State University (Jim Rice, pers. com.). Since these early studies were conducted, operators at the aquaculture facility have attempted to do a better job of capturing the waste solids on the farm rather than being discharged into the stream. Beginning in the early 2000s, the trout chow diet has also changed so there is more efficient food conversion from feed to fish flesh. The feed is also now more water stable and floats atop the raceways until eaten rather than settling out in the bottom of the tanks (Jeffrey Hinshaw, NCSU, pers. com.)