Executive Summary

Assessment Report: Biological Impairment in the Upper Cullasaja River Watershed

Little Tennessee River Basin
Macon County, N.C.

November 2002

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Planning Branch

Prepared for the Clean Water Management Trust Fund

Introduction

This report presents the results of the upper Cullasaja River water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). The upper Cullasaja River and Mill Creek are considered impaired by the DWQ because they are unable to support acceptable communities of aquatic organisms. The goal of the assessment is to provide the foundation for future water quality restoration activities in the upper Cullasaja River watershed by: 1) identifying the most likely causes of biological impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

The upper Cullasaja River and Mill Creek are tributaries of the Little Tennessee River located in southeastern Macon County, in the community of Highlands (see Figure 2.1). The study area of the Cullasaja River is the first 4.8 miles of the river, from its source at Ravenel Lake to Mirror Lake; the entire 1.4-mile length of Mill Creek is considered in this study. The watershed drains approximately six square miles, ending in Mirror Lake. The watershed is developed in golf courses, residences, and an urban center. The upper Cullasaja River and its tributaries are impounded numerous times in three golf course communities. Mill Creek drains half of the town of Highlands. The study area is described in more detail in Section 2. The study was limited to the stream sections described above and did not address water quality issues in Mirror Lake or Lake Sequoyah.

Benthic macroinvertebrate communities are impaired throughout the mainstem of the upper Cullasaja River and Mill Creek.

Approach

A wide range of data was collected to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology, and riparian zone condition; water quality sampling to evaluate stream chemistry and toxicity; analysis of stream bed sediment for chemistry and toxicity; and characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 2, 4, 5 and 6 of the report.

Conclusions

Although excess sedimentation was historically listed as a problem parameter on the 303(d) list, it is not a current cause of impairment for either Mill Creek or the upper Cullasaja River. Sedimentation is a notable problem for some tributaries and many impoundments in the watershed, however. The most probable causes and sources of impairment, based upon an evaluation of all available data, are the following (see Section 7 for additional discussion):

Upper Cullasaja River:

1) A number of dam-related issues are considered cumulative causes of impairment, including the prevention of downstream colonization of benthic macroinvertebrates and fish and upstream migration of fish by dams on the mainstem and its tributaries, lower water levels, increased temperature for localized areas below dams, and change in food type due to the trapping of coarse particulate organic matter and input of phytoplankton from impoundments.
2) The lack of organic microhabitat in the form of leafpacks, sticks, and large wood is a cumulative cause of impairment.
3) Pesticides, high levels of cadmium, and low dissolved oxygen in localized areas due to dams are considered potential causes or contributors, although limited data from this study provide insufficient evidence that they are problematic.

Mill Creek: Based on the information available, a number of stressors likely act in concert to impact the biological community. These stressors cumulatively cause impairment to the stream, but information collected does not identify any single stressor as a primary cause of impairment. The following stressors are believed to cumulatively cause impairment:

1) Scour of benthic macroinvertebrates and organic microhabitats from urban stormflows for areas downstream of Highlands' town center.
2) The lack of upstream colonization sources for the benthic community after storms and other impacts due to toxicants and in-stream impoundments in tributaries.

The lack of organic microhabitat (leafpacks, sticks) is also a contributing stressor for Mill Creek above the town center. Toxicants are a potential cause or contributor for the Mill Creek mainstem.

Recommendations

The most important factors leading to impairment in the study area are systemic in nature. Addressing these problems will require actions that are similarly broad in scope. The following actions are necessary to address current sources of impairment in the upper Cullasaja River and Mill Creek and to help prevent future degradation (see Section 8 for additional details). For the upper Cullasaja River, action one is essential to the restoration of aquatic communities, and actions two and three are secondary but important watershed-wide solutions. For Mill Creek, actions one through four are of primary importance at this time. Because there are a number of unresolved issues for Mill Creek, further monitoring to identify specific toxicants and their sources will be performed by project staff in 2002. Determination of specific activities taken for action five (stormwater retrofits) should be identified as part of the development of a restoration plan for the Mill Creek watershed, developed with the input of a broad set of stakeholders. Action six should also be implemented as part of a long-term strategy to restore and protect stream integrity.

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1) A strategy to reduce the impacts of dams in Wildcat Cliffs Country Club, the Cullasaja Club, and Highlands Falls Country Club should be developed, including a plan for access to unimpounded colonization sources. *If the problems associated with dams are not addressed, then the recovery potential for the Cullasaja River is limited and other strategies listed below will have limited impacts.*

2) Golf course communities (residential areas and golf courses) should plant wooded buffers along cleared streams, and large woody debris and rock clusters should be placed in the stream channel where wooded buffers are not planted.
3) Pesticide and nutrient management programs at the golf courses should be evaluated to determine ways to further decrease the use of these materials and their potential to enter lakes and streams. Homeowners and landscapers should also be educated about the responsible use of pesticides, fertilizers, and hydroseed mix.
4) Developers should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas and limiting development of steeper areas. New road construction projects should use appropriate stormwater controls to reduce velocities and sediment impacts. Macon County and the Town of Highlands should continue to examine the issue of construction on steep slopes and insure that policies provide adequate protection to streams and lakes from erosion and sedimentation.

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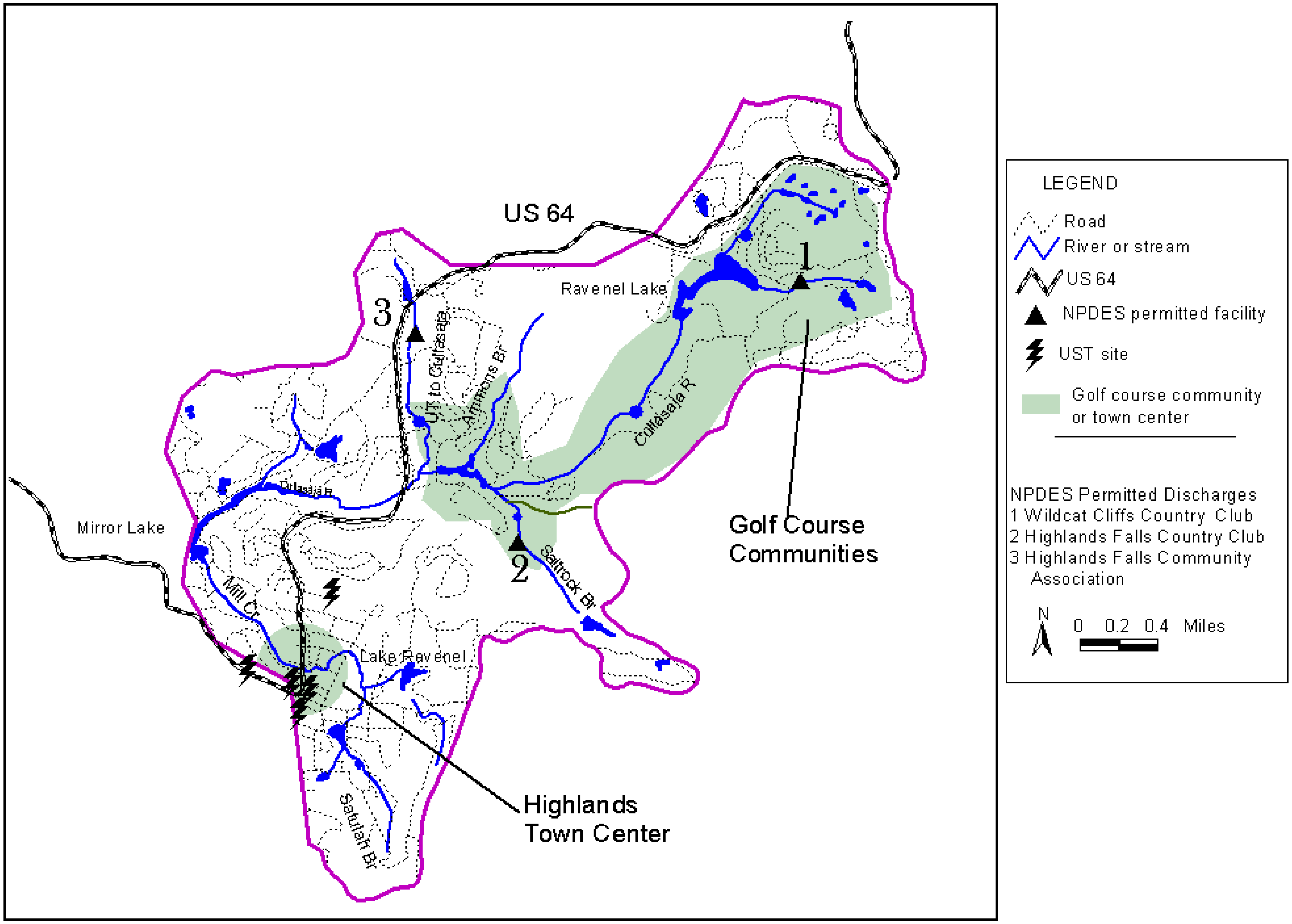
    a) Importance of riparian vegetation. Landowners should be encouraged to plant native woody riparian vegetation along stream banks and protect current riparian vegetation.
    b) Responsible use of pesticides, fertilizers, and hydroseed mix.
    c) Ideas for residents and businesses to reduce their contribution to stormwater volumes—e.g., redirection of downspouts to pervious areas rather than to driveways or gutters.
    d) The impacts of in-stream dams.
2) The source of high levels of semi-volatile organic contaminants in the main stormwater tributary to Mill Creek should be determined and remediated.
3) Pending results from the Town of Highlands' study of groundwater contamination near the town's maintenance facility, sources of contamination should be remediated, if appropriate.
4) Unauthorized discharges to the stormwater system of Mill Creek should be pinpointed and eliminated.
5) Stormwater retrofits should be constructed to control the quantity and quality of stormwater delivered to Mill Creek. Highlands' town center should be given top priority for retrofits.
6) Developers should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas and limiting development of steeper areas. New road construction projects should use appropriate stormwater controls to reduce velocities and sediment impacts. Macon County and the Town of Highlands should continue to examine the issue of construction on steep slopes and insure that policies provide adequate protection to streams and lakes from erosion and sedimentation.

Figure 2.1. Upper Cullasaja River Watershed



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Section 1
Introduction

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Part of a larger effort to evaluate impaired streams across North Carolina, this study was intended to evaluate the causes of biological impairment and to suggest appropriate actions to improve stream conditions. The CWMTF, which allocates grants to support voluntary efforts to address water quality problems, is seeking DWQ's recommendations regarding the types of activities it could fund in these watersheds to improve water quality. Both the DWQ and the CWMTF are committed to encouraging locally based initiatives to protect streams and to restore waters that are degraded.

1.1 Study Area Description

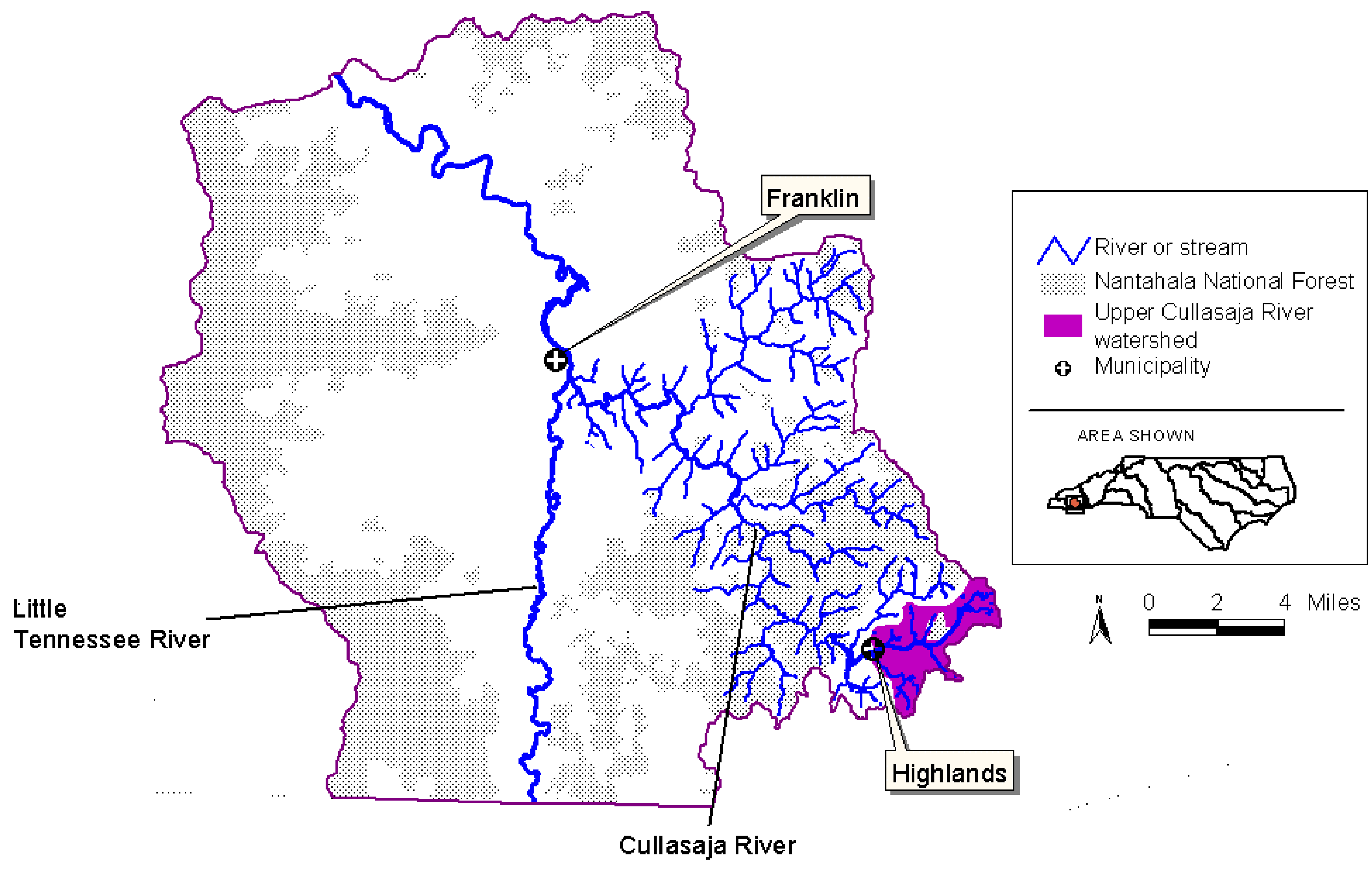
The upper Cullasaja River (defined here as from its source to Mirror Lake) and Mill Creek are small tributaries of the Little Tennessee River located in southeastern Macon County, in the community of Highlands (Figure 1.1). The upper Cullasaja River watershed includes both the upper Cullasaja River and Mill Creek drainages and drains approximately six square miles, ending in Mirror Lake. North Carolina's 2000 303(d) list designates the Cullasaja River as impaired from its source to Mirror Lake (4.8 miles) and Mill Creek as impaired for its entire length, from its source to Mirror Lake (1.4 miles). This watershed is on the Highlands Plateau, a high (approximately 4,000 ft in elevation) area contained by ridges on three sides. The watershed is developed in golf courses, residences, and an urban center, and there is pressure to build within remaining undeveloped ridges and valley areas. The upper Cullasaja River watershed makes up a portion of hydrologic unit 06010202030010, which includes the upper half of the entire Cullasaja River watershed.

1.2 Study Purpose

The upper Cullasaja River watershed assessment is part of the Watershed Assessment and Restoration Project (WARP), a study of eleven watersheds across the state being conducted during the period from 2000 to 2002 with funding from the CWMTF. A list of watersheds included in the project is shown in Table 1.1. The goal of the project is to provide the foundation for future water quality restoration activities in the eleven watersheds by:

1. Identifying the most likely causes of biological impairment (such as degraded habitat or specific pollutants).

Figure 1.1. Upper Cullasaja River Watershed in Little Tennessee River Subbasin 01



2. Identifying the major watershed activities and sources of pollution contributing to those causes (such as stormwater runoff from particular urban or rural areas or stream bank erosion).
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.

This investigation focuses primarily on aquatic life use support issues (biological impairment). It was intended to be as comprehensive as possible in order to assess the major water quality concerns that exist in the upper Cullasaja River watershed. While the study was not designed to address important issues such as bacterial contamination, water supply or flooding, we have made an effort to discuss these concerns where existing information allows.

Table 1.1 Study Areas Included in the Watershed Assessment and Restoration Project

Watershed	**River Basin**	**County**
Toms Creek	Neuse	Wake
Upper Swift Creek	Neuse	Wake
Little Creek	Cape Fear	Orange, Durham
Horsepen Creek	Cape Fear	Guilford
Little Troublesome Creek	Cape Fear	Rockingham
Upper Clark Creek	Catawba	Catawba
Upper Cullasaja River/ Mill Creek	Little Tennessee	Macon
Morgan Mill/Peter Weaver Creeks	French Broad	Transylvania
Mud Creek	French Broad	Henderson
Upper Conetoe Creek	Tar-Pamlico	Edgecombe, Pitt, Martin
Stoney Creek	Neuse	Wayne

1.3 Study Approach and Scope

Of the study's three objectives, identification of the likely causes of impairment is a critical building block, since addressing subsequent objectives depends on this step. Determining the primary factors causing biological impairment is a significant undertaking that must address a variety of issues (see background note, "Identifying Causes of Impairment", for additional details). While screening level assessments can be used to attempt to identify potential causes of impairment, we have taken a more detailed approach in order to maximize the opportunity to reliably and defensibly identify causes and sources of impairment within the time and resource framework of the project. This provides a firmer scientific foundation for the collection and evaluation of evidence, better enables us to prioritize problems for management, and offers a more robust basis for the commitment of resources. EPA's recently published guidance for stressor identification envisions that causes of impairment be evaluated in as rigorous a fashion as is practicable (USEPA, 2000b).

Background Note: Identifying Causes of Impairment

Degradation and impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function well ecologically. When monitoring indicates that degradation has become severe enough to significantly interfere with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the State's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of fish or benthic macroinvertebrates (aquatic bugs visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases, a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at that time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient inputs, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as "those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody." (USEPA, 1997, pp 1-10). When a stream or other waterbody is unable to support an adequate population of fish or macroinvertebrates, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions which impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at an intensity, frequency and duration that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases, a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over other causes. In other situations, several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000b). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors which are present, but not of primary importance, and those which appear to be the underlying causes of impairment. Following are examples of issues which must often be addressed.

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses upon aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to 'bounce back' from disturbances.

For further information on use support and stream impairment issues, see the web site of DWQ's Basinwide Planning Program at http://h2o.enr.state.nc.us/basinwide/index.html; A *Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); EPA's *Stressor Identification Guidance Document* (USEPA, 2000b).

1.3.1 Study Approach

The general conceptual approach used to determine causes of impairment in the upper Cullasaja River and Mill Creek was as follows (see USEPA, 2000b; Foran and Ferenc, 1999).

- *Identify the most plausible potential (candidate) causes* of impairment in the watershed, based upon existing data and initial watershed reconnaissance activities.
- *Collect a wide range of data* bearing on the nature and impacts of those potential causes.
- *Characterize the causes of impairment* by evaluating all available information using a *strength of evidence approach*. The strength of evidence approach, discussed in more detail in Section 7, 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.

Project goals extend beyond identifying causes of impairment, however, and include the evaluation of source activities and the development of recommendations to mitigate the problems identified. In order to address all three objectives, activities conducted in the upper Cullasaja River watershed during this study were divided into three broad stages:

1. An initial *reconnaissance stage*, in which existing information was compiled and watershed reconnaissance conducted. At the conclusion of this stage, the most plausible candidate causes of impairment were identified for further evaluation.
2. A *stressor-source evaluation stage* that included: collection of information regarding candidate causes of impairment; evaluation of all available information using a strength of evidence approach; investigation of likely sources (origins) of the critical stressors.
3. The *development of strategies* to address the identified causes of impairment.

A schematic diagram of project activities is shown in Figure 1.2.

1.3.2 Approach to Management Recommendations

One of the goals of this assessment is to outline a course of action to address the key problems identified during the investigation, providing local stakeholders, the CWMTF and others with the information needed to move forward with water quality improvement efforts in this watershed. It is our intent that the recommendations included in this document provide guidance that is as specific as possible given available information and the nature of the issues to be addressed. Where problems are multifaceted and have occurred over a long period of time, the state of scientific understanding may not permit all actions necessary to mitigate those impacts to be identified in advance with any certainty. In such situations, an iterative process of adaptive management is required (Reckhow, 1997; USEPA, 2001), in which those committed to water quality improvement begin by implementing an initial round of management actions, monitor the results of those activities over time, use the resulting information as the basis for planning subsequent efforts, and then implement additional measures as needed. Under these circumstances we will recommend an initial set of actions that should be undertaken and discuss a framework for evaluating and implementing additional measures.

Protection of streams from the imposition of additional damage from future watershed development or other planned activities is a critical consideration. In the absence of such protection, efforts to restore water quality by mitigating existing impacts will often be ineffective or have only a temporary impact. These issues will be examined during the course of the study and addressed in the management recommendations.

Management recommendations included in this document are not intended to be institutionally prescriptive. That is, it is not the intent of DWQ to specify particular administrative or institutional mechanisms for implementing remedial practices, but only to describe the types of actions that must be taken to place the upper Cullasaja River and Mill Creek on the road to improvement. It is our hope that local governments and other stakeholders in the upper Cullasaja River watershed will work cooperatively with each other and with state agencies to implement these measures.

The study will not develop TMDLs (total maximum daily loads) or to establish pollutant loading targets. For many types of problems (e.g., most types of habitat degradation) we do not believe that TMDLs, which are based on pollutant loading calculations and thresholds, are an appropriate mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs may be appropriate and necessary if the problem is not otherwise addressed. In any case, TMDL development is beyond the scope of this investigation.

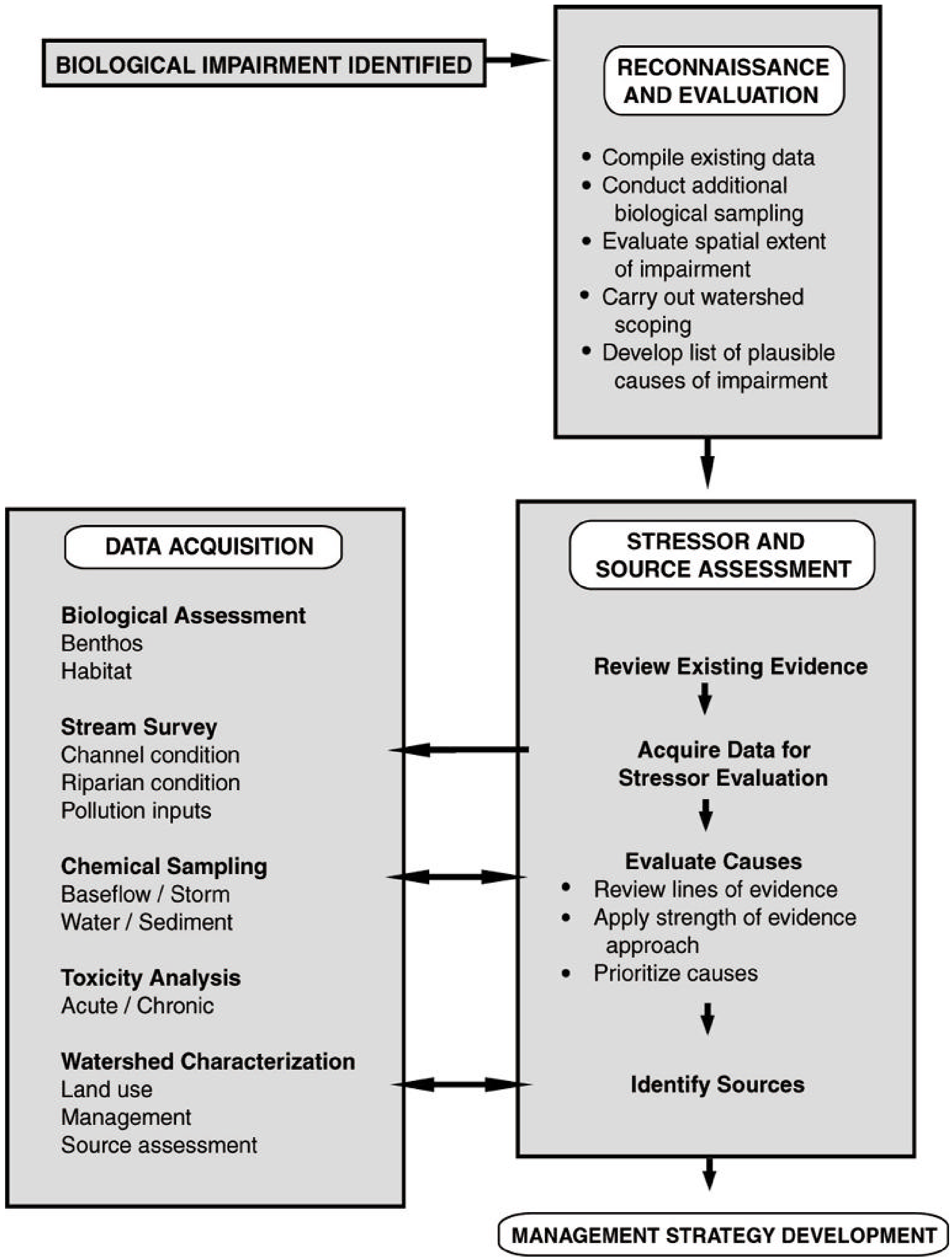
1.3.3 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not adequate to address the goals of the investigation. Extensive data collection was necessary in order to develop a more adequate base of information. The types of data collected during the study included:

1. Macroinvertebrate sampling.
2. Assessment of stream habitat, morphology, and riparian zone condition.
3. Stream surveys--walking stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition.
4. Chemical sampling of stream water quality.
5. Analysis of bed sediment for toxicity and chemistry.
6. Watershed characterization--evaluation of watershed hydrologic conditions, land use, land management activities, and potential pollution sources.

These activities are discussed further in subsequent sections of this report.

Figure 1.2 Overview of Study Activities



Section 2
Description of the Upper Cullasaja River Watershed

2.1 Introduction

The Cullasaja River headwaters are in a relatively flat area on the western side of the Tennessee Valley Divide, which marks the division between waters that drain to the Mississippi River and those that drain to the Atlantic coast. They flow through three golf courses and are impounded multiple times. Past the golf courses, the river flows under US 64 and courses through a narrow, forested valley to Mirror Lake. The headwaters of Mill Creek are in forested ridges. Mill Creek flows through a small, flat valley in a residential and commercial area of Highlands. It then flows under US 64 and drops down into a tight, forested valley until it meets the Cullasaja River in Mirror Lake.

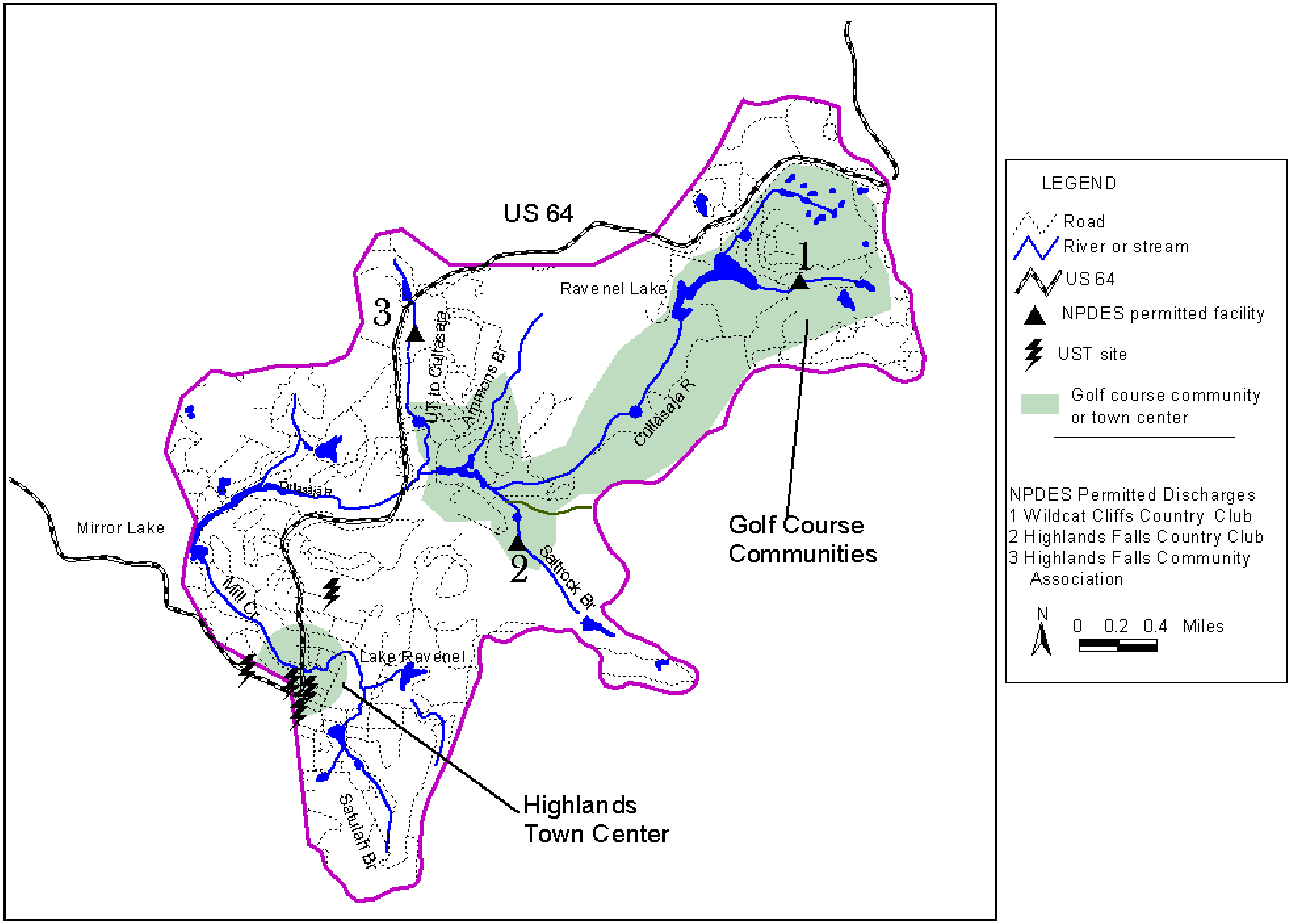
This section summarizes watershed hydrography and topography, describes current and historical land use, and discusses potential pollutant sources. Stream and riparian conditions will be addressed in subsequent sections.

2.2 Streams

The Cullasaja River is a 25-mile mountain stream that begins on the Highlands Plateau, courses through the Cullasaja Gorge, and meanders through a broad agricultural valley before it joins the Little Tennessee River in Franklin. The upper Cullasaja River watershed is defined as the eastern headwaters section, bounded by the Tennessee Valley Divide on the east and Mirror Lake on the west (Figure 2.1). This approximately six-square mile area is bounded by a high ridge to the south (also marking the Tennessee Valley Divide) and a set of lower rolling ridges to the north.

The impaired section of the Cullasaja River (above Mirror Lake) is 4.8 miles long and classified as Water Supply-III Trout (WS-III Tr). Its headwaters flow through the golf course community of Wildcat Cliffs and meet in Ravenel Lake, which is in another golf course community, the Cullasaja Club. The river then flows through the Cullasaja Club and drops over Highlands Falls into a third golf course community, the Highlands Falls Country Club. As it flows through these country clubs, it is dammed several times to create ponds, which are used to irrigate the country club properties (e.g., in the summer, approximately 400,000 gallons of water is withdrawn from impoundments in the Cullasaja Club each night). The two larger impoundments have passive top-spill dams, over which there is little or no flow during dry periods according to residents and country club staff. Ammons Branch, classified as WS-III and a tributary of the Cullasaja River, begins in a small patch of national forest and then flows through Highlands Falls Country Club, where it is impounded before it meets the Cullasaja River. Saltrock Branch (WS-III) also flows through Highlands Falls Country Club and is impounded before it meets the Cullasaja River. Once it leaves the country clubs, the Cullasaja River flows through wooded residential land until it meets Mirror Lake.

Figure 2.1. Upper Cullasaja River Watershed



Mill Creek (WS-III Tr) is 1.4 miles in length and begins at the Highlands Biological Station, where it is dammed to form Lake Ravenel (not to be confused with Ravenel Lake of the Cullasaja River). Satulah Branch, which is WS-III and drains a greater area than Mill Creek above their confluence, joins Mill Creek in a marshy area above the business district of Highlands. Satulah Branch drains a residential area and is dammed to form a small lake above its confluence with Mill Creek. Below the confluence of Mill Creek and Satulah Branch, a beaver dam impounds Mill Creek. Below this, the stream flows through a marshy area and then picks up gradient through a residential and commercial section of Highlands. Mill Creek drains the eastern half of the Town of Highlands. Below the town center, it drops down into a residential wooded gorge and empties into Mirror Lake.

The watershed is located within hydrologic area HA10, the mountain region. USGS regional low flow equations for this area (Giese and Mason, 1991) predict a 7Q10 flow of approximately 2.2 cubic feet per second (cfs) on the Cullasaja River at US 64 (approximately 3.9 mi^2 drainage area) and 0.8 cfs on Mill Creek at Brookside Lane (approximately 1.5 mi^2 drainage area) (locations are the lowest benthic monitoring locations in this study). Typical mean annual flows in this part of the state are approximately 3.5 cfs/square mile.

The watershed has not been continually gauged; a gauge was present at the head of the Cullasaja River gorge downstream of the study area from 1933 to 1971, and a gauge was installed further down in the gorge in 2001. Precipitation in Highlands averages 87 inches per year (using data collected by the Highlands Biological Station from 1962 to 2001). Western North Carolina has been in drought conditions since mid-1998; in Highlands, 2000 and 2001 have been the driest years for the entire 40-year dataset, with rainfall of both years only 69% of the annual average. Stream channel and riparian area conditions are described in more detail later in this report.

2.3 Topography and Geology

The Highlands Plateau is a relatively flat area at high elevation (3600-5000 feet above mean sea level (msl)) and consists of the Cullasaja watershed above the dam at Lake Sequoyah. The headwaters of the Cullasaja River begin at 4000-4200 feet msl and those of Mill Creek begin at 4000-4500 feet msl. The streams join at Mirror Lake, which is at approximately 3700 feet msl. The impaired section of the Cullasaja River drops 67 feet per mile, and Mill Creek drops 114 feet per mile. Much of this elevation loss is in short drops and waterfalls; in many areas, the gradient of these streams is atypically low for mountain streams. The low gradient sections of these streams often flow through relatively wide valleys of thick organic soils; many wetland areas along these creeks have been drained and developed.

The Highlands Plateau is underlain by gneiss bedrock covered with schist. Its soils are in the Edneyville-Plott-Chestnut-Cullasaja series, which are rock outcrop and loamy soils that formed in material weathered from high-grade metamorphic or igneous rocks or in colluvium (USDA, 1996). These soils are well-drained, sandy, and erodable; as a consequence, sand is a dominant substrate in many streams on the plateau.

2.4 Land Use in the Watershed

Note: Much of the following text has been gleaned from conversations with local residents and Shaffer (2001) and Zahner (1994).

2.4.1 Present Day

The upper Cullasaja River watershed is largely developed. More than half of the watershed above US 64 (the lowermost benthic monitoring site on the Cullasaja River) is in three golf course communities. The golf courses themselves are in the river valleys, and much of the Cullasaja River and its tributaries have been cleared of woody riparian vegetation. Many home sites and roads are located on the steep ridges, which are largely wooded. Below US 64, there is continued residential development. Mill Creek's watershed is in forested residential use in the steeper sloped areas above and below the town center. In the valley area of Mill Creek in central Highlands, there is dense housing and the town center, which in 2000 hosted 222 businesses. Most houses in the upper Cullasaja River watershed are served by city sewer or golf community package plants.

Present day land use on the Highlands Plateau is primarily residential, with the majority of houses serving as vacation homes. It is difficult to obtain an estimate of the area's population due to its seasonal fluctuations; population of the larger Highlands community is estimated to be 3,000 in the winter and 30,000 in the summer (Shaffer, 2001). Large areas were cleared for its golf courses, and development of land for house sites continues at a fast pace.

The landcover Geographic Information Systems dataset developed via 1993-95 LANDSAT imagery by the NC Center For Geographic Information Analysis classifies 86 percent of the land in the study area as forest, nine percent as managed herbaceous cover, and three percent as developed. However, this classification underestimates the amount of developed land due to the large amount of residential areas with tree cover that fall into the "forest" category. Currently, approximately 35 percent of the watershed is in the city limits of Highlands, and most of this is in the Mill Creek watershed.

2.4.2 History

Early Highlands. Much of the Highlands Plateau was logged in the 1870s and then divided into parcels for family farms. The Town of Highlands, which is the only town on this small plateau, was incorporated in 1879 as a resort town for wealthy travelers. In 1910, the headwaters of the Cullasaja River were dammed to form Ravenel Lake as a fishing and picnicking spot. In the 1920s, many roads were built and subsequent economic growth occurred. Once the Cullasaja River was dammed to create Lake Sequoyah in 1925, development of the surrounding land began. Highlands Country Club was sited on the lake in 1928, becoming the first golf course community in the area and spurring widespread popularity for Highlands as a summer retreat.

Development of the upper Cullasaja River watershed. In the 1940s, land was cleared for the Skylake community (now Highlands Falls Country Club). In the same time period, Champion Lumber bought and clearcut 2-3000 acres of virgin forest (called Ravenel Forest) in the headwaters of the upper Cullasaja River (part of which is now the Cullasaja Club). In the 1960s, Wildcat Cliffs Country Club was constructed above Lake Ravenel. In 1978, the Skylake community was sold, a golf course developed, and the area was reopened as Highlands Falls Country Club. In 1987, Champion Lumber land was bought and developed into the Cullasaja Club. Numerous impoundments were built on tributaries and the Cullasaja River mainstem during the construction of the golf courses. Large-scale logging for timber sale, development of golf courses, and construction of residential areas likely resulted in massive erosion of uplands and subsequent sedimentation of area streams. In addition, construction of impoundments and channelization of streams also destabilized streams and impacted stream function.

Natural disturbance. Throughout the recorded history of Highlands, droughts, flooding, and hurricanes have shaped the area's landscape. Heavy rainfall is characteristic of the area, at times bringing with it drastic consequences such as dam breaches and bridge destruction. In 1995, Hurricane Opal brought severe flooding and high winds that felled many trees. Drought has periodically lowered water levels in streams, as well as in drinking water wells and reservoirs, causing much concern to area residents.

2.5 Sources of Pollution

2.5.1 Wastewater Discharges

There are three wastewater treatment plants (WWTPs) permitted by the National Pollutant Discharge Elimination System (NPDES) in the upper Cullasaja River watershed. Wildcat Cliffs Country Club (NPDES permit NC0051381), a residential golf community, is permitted to discharge 0.05 millions of gallons per day MGD to an unnamed tributary (WS-III Tr) of the Cullasaja River. At the point the tributary enters the Cullasaja River, the river is impounded as Ravenel Lake. This facility received Notices of Violation (NOVs) for operation and maintenance issues observed during facility inspections performed in November and December 2001, but according to the monthly discharge monitoring reports no effluent violations occurred in 1999, 2000, or 2001. Wildcat Cliffs Country Club is currently building a new facility that should provide better treatment and solve problematic maintenance issues.

Highlands Falls Community Association (permit NC0059552) is permitted to discharge 0.003 MGD to another unnamed tributary (WS-III Tr) to the Cullasaja River. This is a sandfilter system that rarely discharges due to the low volume of flow and the high hydraulic potential of soils beneath the system.

Highlands Falls Country Club (permit NC0075612), a residential golf community, is permitted to discharge 0.135 MGD to Saltrock Branch (WS-III). This WWTP uses ultraviolet light for disinfection rather than chlorination. This facility received two NOVs for monthly average ammonia nitrogen effluent violations in July and October 2000. The monthly limits for ammonia nitrogen are 2.0 mg/L in the summer and 5.0 mg/L in the winter, and monthly average effluent concentrations for July and October 2000 were 3.6 mg/L and 16.75 mg/L, respectively.

2.5.2 Nonpoint Source Inputs

Recent development

As mentioned above, the soils on the Highlands Plateau are very sandy and erodable. Land disturbance often results in erosion; build-up of coarse sand in streams below disturbed areas has been observed frequently (Figure 2.2). Development for home sites and commercial ventures is the main source of sedimentation in the watershed. Many homes are built on steep ridges, and driveways and construction sites without proper erosion control on these slopes are significant sources of sediment. When construction is sited on a creek, creek banks are sometimes cleared of vegetation, exposing bare soil and causing future bank instability.

Figure 2.2 Build-up of coarse sand in East Fork Salt Rock Branch below recent construction.

Golf courses

Golf courses of the upper Cullasaja River watershed are sited in stream valleys, with fairways built adjacent to stream banks. Woody riparian vegetation has been removed, and banks of these streams are often unstable and a source of sediment; riprap has been used to stabilize collapsing banks. Some areas of the Cullasaja River and its tributaries in the golf courses have been channelized (straightened and/or dredged) or piped, compounding system instability.

Golf courses are intensive users of nutrients, insecticides, herbicides, and fungicides, and runoff of these pollutants can reach streams. Ponds in the golf courses are often controlled for aquatic plants and algal blooms with herbicides and algacides. However, the golf courses in the watershed use a number of methods to lessen the impacts of pesticides and nutrients on surface waters. Each course maintains a pesticide-free buffer of at least 15 feet around waterways and efforts are made to reduce the amounts of pesticides and fertilizers used. Efforts are underway to become certified under the Audubon International Cooperative Sanctuary Program, which promotes a range of practices to reduce impacts of golf courses on natural resources.

Highlands town center

Half of Highlands' central business district drains to Mill Creek. Stormwater is directed to the creek, carrying with it pollutants from parking lots, roads, roofs, and other impervious surfaces. Metals, hydrocarbons, road salt, and fecal contaminants are common in urban stormwater (Center for Watershed Protection, 2000). In addition to stormwater, city storm sewers often have unauthorized discharges, which are illegal under the Clean Water Act and include a wide range of sources, including connections of piped waste from a business or residence, leaky sewage pipes, and misuse of storm drains.

There is one groundwater contamination incident (incident 15218, DWQ groundwater incident management database) on record for the upper Cullasaja River watershed. A significant spill of fuel oil and other petroleum products occurred in March 1996 at the former Duncan Oil Bulk Storage Facility on US 64, approximately 100 m from Mill Creek at its closest point. Petroleum was observed in storm ditches near the spill, and 384 tons of contaminated soils were taken from the site. This file was closed and the contamination site considered clean in February 1997.

Many of the older homes and businesses in Highlands use heating oil during the winter months. Heating oil is typically stored in steel tanks above or below ground and the potential for leaks is significant. It is possible that there are unidentified current or historical leaks from these tanks, impacting groundwater that flows to Mill Creek. There are five underground storage tank (UST) incidents (or leaks) on record for the watershed.

- A leaking heating oil tank was pinpointed at Dun Fergots Store, located upgradient of Mill Creek near Spring Street (incident 11455, DWQ UST incident management database). The file was closed and the site considered clean in December 1993.
- When a UST at the Town of Highlands' maintenance facility on Poplar Street was removed in December 1993, contamination was discovered (incident 11894). According to the Town of Highlands, the tank was in an old dump that used to be sited at the subject property. Groundwater monitoring wells, an adjacent storm drain inlet, and a location on an adjacent tributary to Mill Creek upstream of the site were monitored quarterly until the site was ranked as low priority in July 1996. Due to this ranking, the site will not be monitored until the state UST trust fund can support monitoring on low priority sites. Monitoring data do suggest that the site may still be a source of contamination. In October 95, benzene was measured at 1.53 mg/L in the storm drain inlet. In January 1996, vinyl chloride was measured at 0.7 mg/L (the DWQ standard is 2.0 μg/L for WS classified streams) in the tributary upstream of the site, but the source of this contaminant remains unknown.
- A leaky petroleum UST was found at the Farmers Market convenience store on the corner of Hwy 106 and Main Street during the tank removal in July 1994 (incident 13062). The site was ranked a low priority in July 1996. Due to this ranking, the site will not be monitored until the state UST trust fund can support monitoring on low priority sites.
- A spill of fuel oil occurred in November 1993 at Suzettes Boutique on Main Street (incident 11610) when the vent pipe to the UST was knocked off and heavy rains inundated the tank, displacing the fuel oil on the ground. Approximately 24 tons of contaminated soil were removed and the file was closed and the incident site considered clean in February 1994.

- Significant fuel oil odors and stains were discovered around a fuel oil tank in the basement of the Highland Inn on the corner of Main Street and US 64 in November 1988 (incident 4077). The tank was abandoned in place by filling it with concrete and capping all lines. Some contaminated soils were removed, but structural supports for the building did not allow for all of the soils to be removed. The file was closed in March 1989.

<u>Other sources</u>
Activities near streams by residential landowners are also a source of nonpoint source pollution. The use of pesticides to control stream bank vegetation and in gardens can be problematic. Homes are sited along the streams, and runoff from roofs, driveways, and lawns are a source of nutrients, fecal contamination (from pets), and other pollutants. House construction near streams can be a source of contaminants, as well; substances such as those used for foundation treatments can end up in stormwater runoff, and equipment is sometimes cleaned in adjacent creeks.

2.6 Trends in Land Use and Development

As mentioned previously, the Highlands area has experienced intense pressure for home and resort development during the past twenty years. This pressure continues due to the popularity of the area for vacation and retirement homes. Much of the study watershed has been developed, and most of the current development is occurring on steeper ridges. The flatter area of downtown Highlands is built-out, but some older residential space is being converted to retail uses.

2.7 Regulatory Issues and Local Water Quality Activities

2.7.1 Applicable Local Regulations

The Town of Highlands adopted an erosion and sediment control ordinance in 1992 and a watershed buffer plan and ordinance in 1994. The erosion and sediment control ordinance applies to many land-disturbing activities regardless of size, sets rules to reduce site erosion, has special plan requirements for development on steep slopes, and stipulates revegetation of exposed slopes. Highlands is delegated to enforce erosion and sediment control regulations usually enforced by the NC Division of Land Resources, and its program is more stringent than that of the state. Buffer zones are required for any land-disturbing activity adjacent to waterbodies, requiring control of sediment movement within the buffer. A buffer width of at least 25 feet is required for disturbance near classified trout waters. The ordinances also include requirements for stormwater outlet protection, borrow and waste areas, access and haul roads, operations in lakes or natural watercourses, existing uncovered areas, and design and performance standards for activities adjacent to high quality waters.

The Town of Highlands has also developed regulations that apply to its water supply watershed. The upper Cullasaja River watershed is in a WS-III watershed with no critical area (the area within one half mile of the water intake in the Big Creek arm of Lake Sequoyah). Minimum lot size for single family residences and cluster development is one half acre, and other residential development and non-residential development cannot exceed a maximum of 24 percent built upon area. A 30-foot vegetative buffer is required.

As previously noted, only approximately 35 percent of the watershed is in the city limits of Highlands. Highlands' residents have long complained of poor erosion and sedimentation control practices on construction sites outside of Highlands. In 2001, Macon County adopted an erosion and sediment control ordinance, which builds on the current state-wide Erosion and Sediment Control Program administered by the NC Division of Land Resources (DLR). As of April 2002, Macon County has been delegated to enforce erosion and sediment control regulations usually enforced by the NC DLR. Under Macon County's ordinance, several provisions are more strict than or in addition to those of NC DLR's program, including the following: 1) an erosion and sediment control plan must be submitted if one half of an acre or more is disturbed; 2) incentives are provided for contractors to attend a Clean Water Contractor class; 3) a plan must be approved for a project with a slope greater than 1:1; and 4) maximum road grades are set for paved and unpaved roads.

2.7.2 Watershed Initiatives

The Little Tennessee Watershed Association, Inc. (LTWA) is a citizen-based organization of Macon County actively engaged in public education, public service, and in studying, monitoring, and improving the Little Tennessee River watershed from its headwaters to Lake Fontana. LTWA monitored total suspended sediment via multi-stage samplers in the Cullasaja River watershed for one year; four sediment monitoring stations were on the Highlands Plateau. Fish and benthic macroinvertebrate communities in the Cullasaja River watershed are monitored for LTWA and the Tennessee Valley Authority. Fish data for the upper Cullasaja River watershed are summarized in Section 4 of this report.

As part of a semester research project through the Highlands Biological Station, a University of North Carolina at Chapel Hill student studied aquatic macroinvertebrate communities of several area streams. Two small creeks in the upper Cullasaja River watershed, including a tributary to Ravenel Lake that flows through Wildcat Cliffs Country Club and a tributary that runs by the Highlands' maintenance shed on Poplar Street, were sampled in November 2001.

The Upper Cullasaja Watershed Association, Inc. (UCWA) is a citizen-based organization engaged in public education, public service, and in studying, monitoring, and improving the Cullasaja River watershed upstream of Lake Sequoyah dam. At the request of Macon County, the LTWA and UCWA formed the Macon County Watershed Council in 2000 for the purpose of advising the Board of Commissioners and the county's municipal governments on watershed protection and water resource management planning. The Council drafted the County's erosion and sedimentation control ordinance passed in 2001.

Section 3
Potential Causes of Biological Impairment

Factors that were plausible causes of biological impairment in the upper Cullasaja River watershed were identified using both bioassessment and watershed-driven approaches. An evaluation of benthic community data and other biological and habitat indicators can point toward general types of impacts that were likely impacting aquatic biota. These stressors were flagged for further investigation. The nature of land uses and activities in the watershed were also considered to identify likely stressors that should be evaluated. The specific stressors identified in this fashion are discussed in this section.

3.1 Key Stressors Evaluated in the Upper Cullasaja River Watershed

The following stressors were evaluated as the most plausible candidate causes of impairment in the upper Cullasaja River and Mill Creek.

3.1.1 Upper Cullasaja River

1. Dam impacts. There are numerous impoundments in the upper Cullasaja River watershed, including the 24-acre Ravenel Lake in the headwaters area and a 10-acre lake just 1/5 mile upstream of the DWQ monitoring site. Dams can impact downstream aquatic communities in a number of ways: 1) prevent downstream colonization of benthic and fish populations; 2) lower water levels below dams; 3) cause changes in temperature and dissolved oxygen; and 4) change available food type.

2. Habitat degradation due to sedimentation. Habitat degradation due to sedimentation manifests itself in the loss of pools, burial of riffles, and high levels of substrate instability. Excess sedimentation was historically listed as a problem parameter for the Cullasaja River on the 303(d) list.

3. Habitat degradation due to lack of key microhabitat. Preliminary watershed investigations pinpointed a potential problem with absence of key microhabitats, such as woody debris and leafpacks.

4. Pesticides. Pesticides used on residential gardens and lawns, on golf courses, and in ponds could impact benthic communities.

3.1.2 Mill Creek

1. Toxicants. Half of Highlands' town center and a large portion of its residential area drain to Mill Creek, so there is significant potential for a wide variety of toxicants to enter streams during storm events, from spills, unauthorized discharges to the stormwater system, or contaminated groundwater. A number of problematic underground storage tanks have been documented in the Highlands area, and residents suspect that there may be additional tanks

with problems. Due to the wide range of potential toxicants and source activities in this watershed, toxicity merits further evaluation as a potential cause of impairment.

2. Habitat degradation due to sedimentation. Excess sedimentation was historically listed as a problem parameter for the Cullasaja River on the 303(d) list.

3. Habitat degradation due to lack of key microhabitat. Preliminary watershed investigations pinpointed a potential problem with absence of key microhabitats, such as woody debris and leafpacks.

Section 4
Biological Conditions and Stream Habitat

Bioassessment involves the collection of stream organisms and the evaluation of community diversity and composition in order to assess water quality and ecological conditions in a stream. Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

DWQ's Biological Assessment Unit has collected biological data from the upper Cullasaja River watershed since 1990. The Cullasaja River was sampled at US 64 in 1990, 1991, 1996, and 1999, and the benthic community was rated Fair for all dates except in 1991, when it was rated Poor. The benthic macroinvertebrate community was characterized by low diversity and few intolerant taxa.

Intensive monitoring of Mill Creek took place in the 1990s due to problems associated with Highlands' old wastewater treatment plant (WWTP), which was below the town center on Mill Creek. Mill Creek was sampled by DWQ at two sites—above and below the old WWTP. In 1990 and 1991, both sites were rated Fair with benthic community data. The WWTP was moved to the Cullasaja River below Lake Sequoyah in 1994, and Mill Creek was again sampled in 1999 below the old WWTP. The community was rated Good-Fair, but it was still characterized by low diversity and a limited number of intolerant taxa.

McLarney (2000) monitored fish and benthic communities in both the Cullasaja River and Mill Creek in 1999, and these streams were rated with an Index of Biological Integrity modified for high elevation streams. The Cullasaja River was sampled at US 64 and scored 36 (out of a possible 60 points), or Poor-Fair. The fish community consisted of one species—the tolerant redbreast sunfish. Using two different scoring systems, the Mill Creek sample scored 34 and 28, or Poor. The community was characterized by two classic features of a polluted stream--a high proportion of pollution tolerant species (chiefly redbreast sunfish and creek chub) and omnivores (bluehead and creek chub). McLarney noted that lack of recruitment sources due to impoundments is a persistent problem for fish communities in this watershed.

Additional benthic community sampling was conducted during the present study to serve several purposes:

- To account for any changes in biological condition since the Cullasaja River and Mill Creek were last sampled in 1999.
- To obtain more specific information on the actual spatial extent of impairment than is possible with existing data.
- To better understand which portions of the watershed may be contributing to biological impairment and which areas are in good ecological condition.
- To collect additional information to support a biologically driven identification of likely stressors.

In this section, we describe the approach to bioassessment used during the study and summarize the results of this work. A more detailed analysis of the condition of aquatic macroinvertebrate communities in the upper Cullasaja River watershed may be found in Appendix A.

4.1 Approach to Biological and Habitat Assessment

Benthic macroinvertebrate community samples were collected at seven sites in the watershed, with five locations on the Cullasaja River and its tributaries above US 64 (one of which was a reference stream) and two locations on Mill Creek. In order to compare study streams to relatively unimpacted streams, reference sties were chosen in adjacent watersheds. These reference streams were of similar gradient and watershed size, but drained primarily forested catchments. Benthic macroinvertebrates were collected at three reference sites in adjacent Big Creek and Skitty Creek watersheds. All sampling was performed in May and August 2000 and July 2001. Sample sites are shown in Figure 4.1 and listed in Section 4.2.

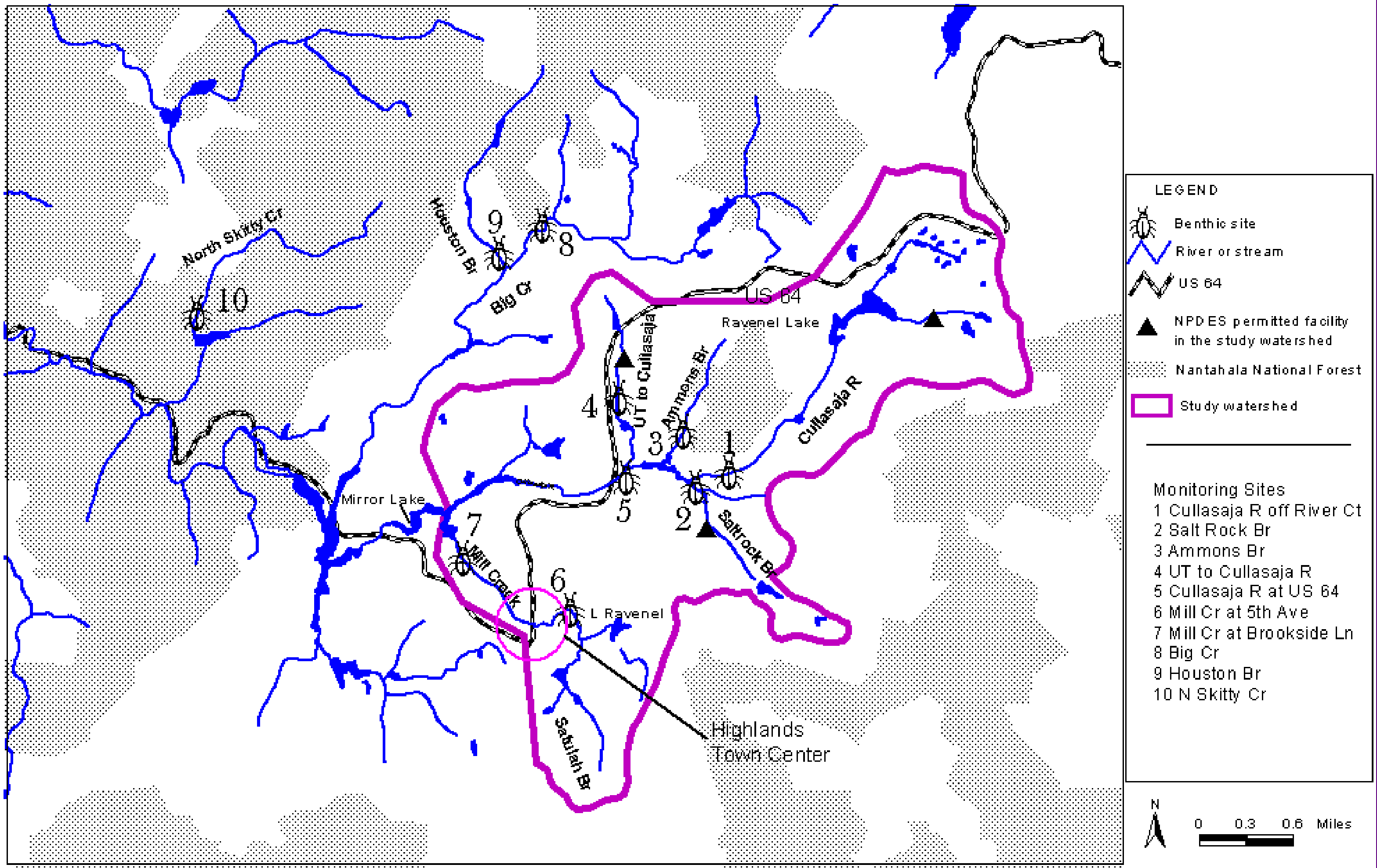
4.1.1 Benthic Community Sampling and Rating Methods

Macroinvertebrate sampling was carried out using the general procedures outlined in the Division's standard operating procedures (NCDWQ, 2001). Standard qualitative methods were used for streams with a width of at least 4 meters. This method includes 10 composite samples: 2 kicks, 3 sweeps, 1 leafpack, 1 sand sample, 2 rock/log washes, and a visual collection. The Qual 4 sampling procedure was used for sites under 4 m wide in 2000. This procedure involves four composite samples: 1 kick, 1 sweep, 1 leafpack sample and visual collections. The Qual 5 method was used for sites under 4 m wide in 2001 and includes the four composite samples collected with a Qual 4 plus a rock/log wash, which was added to obtain a better sample of the midge community. Organisms were identified to genus and/or species. Sampled reaches were approximately 100 meters in length. Details of the methods used at each sampling station are included in Appendix A.

Two primary indicators or metrics are derived from macroinvertebrate community data: the diversity of a more sensitive subset of the invertebrate fauna is evaluated using EPT taxa richness counts; the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), insect groups that are generally intolerant of many kinds of pollution. *Generally, the higher the EPT number, the more healthy the benthic community*. Low BIs indicate a community dominated by taxa that are relatively sensitive to pollution and other disturbances (*intolerant*). High BIs indicate greater dominance by organisms that are pollution and disturbance insensitive (*tolerant*). *Thus, the lower the BI number, the more healthy the benthic community.* Biotic index numbers were combined with EPT taxa richness ratings to produce a final bioclassification (Good, Fair, Poor, etc.).

Streams that are at least four meters wide are formally rated with standard qualitative criteria. Streams less than four meters wide may be rated if certain conditions are met. If an unimpacted, high quality stream is sampled with Qual 4 procedures, a size correction factor is applied and a rating given. If a stream is sampled using Qual 4 procedures but is impacted by human disturbance, it is rated as Not Impaired (NI) if it meets the criteria for a Good-Fair or higher

Figure 4.1. Benthic Invertebrate Monitoring Sites in the Upper Cullasaja River Watershed



rating using the standard qualitative criteria. If this stream would not be Good-Fair or higher using standard qualitative criteria, it is listed as Not Rated (NR) and evaluated qualitatively using BI and EPT numbers, based on staff experience and professional judgment. All streams sampled with Qual 5 methods are considered NR because Qual 5 rating methods are still being developed.

Final bioclassifications are used to determine if a stream is impaired. Streams with bioclassifications of Excellent, Good, and Good-Fair are all considered unimpaired. Those with Fair and Poor ratings are considered impaired and likely placed on the 303(d) list.

4.1.2 Habitat Assessment Methods

At the time benthic community sampling was carried out, stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for piedmont streams (NCDWQ, 2001). This 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):

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

4.2 Results and Discussion

4.2.1 Description

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.1. Some streams were too small to be given a formal rating (bioclassification). A narrative summary of conditions at each current site follows. In July 2001, benthic monitoring was performed during or just after heavy rains. See Appendix A for additional details.

<u>Upper Cullasaja River and its tributaries</u>

- *Cullasaja River off River Court* (CUCR11). This reach is in a golf course at the Highlands Falls Country Club and is upstream of Salt Rock Branch and the large impoundment above US 64. This reach is bordered by grass, and it may have been channelized in the past. Riffles were infrequent, but embedded with fine sediment. Wood and leafpacks were rare, and undercut banks were isolated by low flows. This site was characterized by an abundance of taxa tolerant of habitat and water quality impacts, including possible toxicity. It had 25 EPT taxa before seasonal corrections and a Not Impaired rating (at least Good-Fair) in 2000. However, in 2001, the number of EPT taxa dropped to 16 and its EPT biotic index (BI) increased almost one full point; the community could no longer be rated unimpaired and is Not Rated.

- *Salt Rock Branch at Falls Drive East* (CUSB03). This reach is also within the golf course at Highlands Falls Country Club, below the club's wastewater treatment plant and an impoundment. This reach is also bordered by grass within the golf course, and it has high and vertical banks. In-stream habitat was very poor here (scoring 37 out of 100), with virtually no organic microhabitat (leafpacks, wood). Edge habitat consisted of grass banks. Riffles were infrequent and very embedded, and sand and silt comprised 85 percent of the bottom substrate. This site had the lowest number of EPT taxa (5) of all study streams and a high EPT BI (5.52), indicating a very impacted benthic community. The community was dominated by taxa tolerant of numerous types of stress, including possible toxicity. This stream is Not Rated due to the use of Qual 5 sampling methods.
- *Unnamed tributary off US 64* (CUCR04). This stream runs along US 64 behind residences and businesses before it is impounded in the Highlands Falls Country Club and then converges with the Cullasaja River above US 64. It was sampled to determine its possible contributing impacts to the impaired site on the Cullasaja River at US 64. The lower part of this reach is steep and bedrock-bottomed, running through a *Rhododendron* thicket. The upper part of the reach flows through a grassed residential area, has much lower gradient, and is quite sandy. Habitat was quite good (scoring 87 out of 100); leafpacks and large wood were rare but sticks were abundant. As in other streams, undercut banks were unavailable due to low water. This stream was characterized by a community typical of a healthy small mountain stream. It hosted a number of intolerant EPT taxa (EPT BI = 2.38) and a good number of EPT taxa (23). This stream is Not Rated due to the use of Qual 5 sampling methods.
- *Cullasaja River at US 64* (CUCR01). This is the site historically sampled for benthos by DWQ and fish by Bill McLarney. It is below all golf course communities in the upper Cullasaja River watershed and is a slowly flowing reach in a steep wooded valley. Riffles were infrequent and often comprised of woody debris. Silt and sand were significant portions (55 percent) of the bottom substrate, and boulder and cobble substrate was quite embedded by fine sediment. Large wood and sticks were common, but leafpacks were uncommon. Undercut banks were present but isolated due to low flows. A slick covering of silt and attached algae was present on the hard inorganic substrate. As in the past, this site was rated Fair with samples from 2000 and 2001, characterized by some of the highest EPT BIs (5.12 and 5.92) of all study streams. It hosted a tolerant benthic community and a limited number of EPT taxa (18 in 2000 and 10 in 2001). The community was indicated the presence of stressors, including possible toxic inputs.

<u>Mill Creek</u>

- *Mill Creek at 5th Avenue* (CUMC14). This reach is in a residential section of Highlands but above the town center. It was sampled in order to measure conditions in Mill Creek above stormwater inputs from the town center. This reach is bordered by a thin wooded riparian area on the left bank, but a large house was being constructed along the edge of the right bank where no woody vegetation was present. It is a slowly flowing section of Mill Creek, just below a swampy area and beaver dam. This reach was characterized by little microhabitat, with no leafpacks and little woody substrate. Undercut banks were unavailable due to low water. Riffles were infrequent and embedded with fine sediment. This stream site was sampled in the spring and summer of 2000 and characterized by a tolerant community, including some taxa that can be indicative of toxicity, and few EPT taxa (13 in spring and 11 in summer). This community could not be considered unimpaired and is Not Rated.

- *Mill Creek at Brookside Lane* (CUMC02). This reach is in approximately the same location as that sampled by DWQ in the 1990s (below the old wastewater treatment plant). It is in a residential area below Highlands' town center, bordered by a wooded riparian area on the right bank and residential lawn on the left bank. Cobble and boulder riffles were frequent and somewhat embedded. Although large woody debris was common, leafpacks and sticks were rare, and undercut banks were unavailable for colonization due to low flows. Like the upstream site at 5th Avenue, this site was characterized by an impacted benthic community. It was dominated by tolerant taxa (EPT BI = 4.51). It had more EPT taxa than the upstream site (17), but overall richness was still low. This community could not be considered unimpaired and is Not Rated.

<u>Reference Sites</u>

- *Ammons Branch off Spruce Lane* (CUAB15). This small stream is above all residences and golf course areas at Highlands Falls Country Club and drains an old growth section of Nantahala National Forest. It was sampled as a reference for other small tributaries in the area, including Salt Rock Branch and the unnamed tributary off US 64. This stream is bordered by a wooded riparian zone and had the best habitat of all study streams (scoring 93 out of 100). It had a nice mix of cobble, gravel, boulder, and fine sediment, and riffles were frequent and well defined. Although undercut banks were isolated by low flows, other microhabitats were abundant, including leafpacks and wood. This small stream was characterized by a very intolerant benthic community, with an EPT BI of 1.15, the lowest of all study streams. EPT taxa richness was 20. Ammons Branch had only one mayfly taxon, which is likely due to the low pH of the site (5.4). Apart from the lack of mayflies, the community was typical of a high quality mountain stream. This stream is Not Rated due to the use of Qual 5 sampling methods.
- *Big Creek at Buck Creek Road (SR 1538*) (CUBC16). This reach was a reference site for the Cullasaja River above US 64. Most of the watershed is residential or Nantahala National Forest. This reach is just below a high gradient drop and flows through a steep wooded valley, which is bordered by Buck Creek Road about 10 meters from the right bank. It had good habitat (average score of 86 out of 100 points) and was characterized by diverse microhabitat; sticks, leafpacks, and large woody debris were abundant, although undercut banks were isolated by low flows. Sand and silt was dominant in 2000 (80 percent of bottom substrate), but in 2001, much of this fine sediment had moved downstream and was no longer predominant (comprising 25 percent of the substrate). Riffles were frequent and well-defined. This site hosted a diverse and intolerant community. It was rated as Excellent in 2000; it was not rated in 2001 due to the use of Qual 5 sampling methods, but the community was still indicative of a high quality mountain stream. It had the highest number of EPT taxa in the study (41 in 2000 and 29 in 2001).
- *Houston Branch at Simon Speed Road* (CUHB17). This small creek was a reference site for small tributaries in the upper Cullasaja River watershed. It drains a forested watershed and has two impoundments 0.5 mi above the sampling site. This small creek had very low flow and no access to undercut banks when sampled. It was bordered by a nice riparian buffer, although horses have periodic access further upstream. It was characterized by finer substrate, with gravel, sand, and silt comprising 75 percent of the bottom. Leafpacks were rare, but sticks and large wood were abundant. Although this creek was very shallow, it had a frequent and well-defined riffles and pools. Overall, it had good habitat, scoring 82 out of

100 points. This very small creek was rated as Excellent, hosting a high number of EPT taxa for a small stream (25). It had a very low EPT BI (1.97), and a number of intolerant taxa typical of clean mountain streams were abundant.

- *North Skitty Creek at Cliffside Recreation Area* (CUSC18). This was a reference site for Mill Creek and drains Nantahala National Forest. This stream was characterized by excellent habitat, scoring 92 out of 100 points, and flows through National Forest. Like Houston Branch, it had well-defined and frequent riffles and pools. Sticks and large wood were abundant, leafpacks rare, and undercut banks isolated due to low flows. This small creek was also rated as Excellent, and it had a community typical of a clean mountain stream. It hosted a number of intolerant taxa and had a very low EPT BI (1.61). It was diverse, as well, with 28 EPT taxa.

4.2.2 Summary of Conditions and Nature of Impairment

The Cullasaja River and Salt Rock Branch, which drain golf communities, and Mill Creek, which drains Highlands, host severely impacted benthic communities. The Cullasaja River hosts a community that is indicative of multiple types of stress, but it is healthier at the upstream location at River Court. The benthic community in Salt Rock Branch is severely impacted, hosting a community that is very tolerant to stress. Mill Creek is characterized by a benthic community that is also tolerant of stress, and there is little change from its upstream location at 5th Avenue to Brookside Lane, which is below the town center. Streams that drain forested land (Ammons Branch, North Skitty Creek, Houston Branch) or less developed land (Unnamed tributary to the Cullasaja River, Big Creek) are characterized by healthy benthic communities that are able to withstand natural stresses such as drought.

Due to long-term drought, edge habitat (undercut banks, root mats) was unavailable to benthic communities in reference and study watershed streams. Other organic microhabitats, such as wood and leafpacks, were more abundant in reference streams and study watershed streams with wooded riparian areas. Sand was a significant habitat component in some study watershed and highly rated reference streams. It is unlikely that sedimentation is a cause of impairment for Mill Creek and the Cullasaja River.

Although Big Creek, a reference stream, was sampled during a heavy storm in 2001, it still hosted a healthy benthic community. There was a loss of EPT richness (29 taxa instead of 2000's 41 taxa), but the community's EPT biotic index (a measure of tolerance to stress) was stable. The Cullasaja River was also sampled during this period of heavy storms, and EPT richness dropped as well. This loss of taxa, however, was also accompanied by an increase in the EPT biotic index by almost a full point at both the River Court and US 64 sites.

Table 4.1 Selected Benthic Community and Habitat Characteristics at Study Sites in the Upper Cullasaja River Watershed

Site	Date	Stream Width (m) [1]	Avg. Depth (m)	Substrate % sand and silt [2]	In-stream Structure Score (of 20) [3]	Embeddedness Score (of 15) [4]	Habitat Score Total (of 100) [5]	EPT Richness [6]	EPT Biotic Index [6]	Bioclassification [6]
Cullasaja R. off River Ct.	5/16/00	3	0.1	30	10	11	38	25	3.72	Not Impaired (at least Good-Fair)
	7/26/01	3	0.2	40	14	6	60	16	4.63	Not Rated**
Salt Rock Br. at Falls Dr. E	7/26/01	1	0.3	85	10	4	37	5	5.52	Not Rated**
Unnamed tributary off US 64	7/25/01	3	0.2	20	16	13	87	23	2.38	Not Rated**
Cullasaja R. at US 64	8/28/00	5	0.3	55	14	8	69	18	5.12	Fair
	7/25/01	5	0.6	55	14	10	69	10	5.92	Fair
Mill Cr. at 5th Ave.	5/17/00	3	0.3	45	9	8	70	13	4.51	Not Rated*
	8/29/00	2	0.1	60	10	5	49	11	5.36	Not Rated*
Mill Cr. at Brookside Ln.	8/28/00	3	0.2	20	14	12	76	17	4.51	Not Rated*
Reference Streams										
Ammons Br. off Spruce Ln.	7/25/01	2	0.1	30	13	15	93	20	1.15	Not Rated**
Big Cr. at Buck Cr. Rd.	8/29/00	4	0.1	80	16	8	83	41	2.48	Excellent
	7/25/01	3.5	0.5	25	17	13	89	29	2.22	Not Rated**
Houston Br. at Simon Speed Rd.	8/29/00	1	0.1	50	14	9	82	25	1.97	Excellent
North Skitty Cr. at Cliffside Recreation Area	8/29/00	2	0.1	30	16	12	92	28	1.61	Excellent

[1] Wetted channel width at times of sampling.
[2] Based on visual estimate of substrate size distribution.
[3] Visual quantification of the of in-stream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats.
[4] Estimation of riffle embeddedness.
[5] See text for a list of component factors.
[6] See text for description.
* Sampled with Qual 4 method. Impacted, but too small to rate.
** Sampled with Qual 5 method, which currently has no rating method.

Section 5
Chemical and Toxicological Conditions

Water quality assessment provides information to evaluate whether chemical and physical conditions contribute to suboptimal benthic communities. DWQ does not have an ambient station in this watershed, and historical data on stream chemistry are extremely limited. In this study, ambient conditions were assessed in the field and surface water samples were collected for laboratory analysis to evaluate water quality. Two broad purposes of this monitoring were:

1. To provide a synoptic characterization of water quality conditions in the watershed.
2. To collect a range of chemical, physical and toxicity data to help evaluate the specific causes of impairment and to help identify the sources.

This section summarizes the sampling and data collection approach used and discusses key monitoring results. See Appendix B for a more detailed discussion of methodological issues and a more comprehensive presentation of results.

5.1 Approach to Chemical, Physical, and Toxicity Sampling

During the study period, project staff collected grab samples in the upper Cullasaja River watershed on 18 dates between August 2000 and November 2001, four of which were storm samples. Semi-permeable membrane devices were used to document contaminants over longer periods of time (one to two weeks). Sediments were sampled from Mill Creek and the Cullasaja River in August 2001. Dissolved oxygen and temperature were monitored with data sondes over the course of a week above and below dams. Sampling locations are summarized in Section 5.1.2.

5.1.1 General Approach

General water quality characterization. One station at the downstream end of the study area on both the Cullasaja River and Mill Creek was sampled multiple times over 16 months to characterize water quality conditions. These locations were chosen as integrator sites for the two streams. A standard set of parameters similar to those evaluated at DWQ ambient stations was analyzed (Appendix B, Table B.1). Samples were collected during both baseflow and stormflow periods. Baseflow periods were defined as those in which no measurable rain fell in the watershed during the 48-hour period preceding sampling. Storm samples were collected on the rising stage of the hydrograph. Fecal coliform samples were collected only under baseflow conditions. For additional details, refer to Appendix B.

Stressor and source evaluation. Samples were collected at a variety of locations in order to identify major chemical/physical stressors to which aquatic biota are exposed and assess major sources. Station locations for stressor identification sampling were linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities believed to represent potential sources of impairment.

In addition to standard parameter sampling, the water column of the upper Cullasaja River and its tributaries was sampled for dissolved oxygen and temperature above and below dams and analyzed for acid herbicides, organochlorines, organophosphates, and nitrogen pesticides by the DWQ laboratory. In Mill Creek, the water column was analyzed for semi-volatile organics (EPA method 625) and volatile organic pollutants (EPA method 624) in baseflows and stormflows. Mill Creek baseflows were analyzed for a suite of pesticides, including organochlorines, organophosphates, and acid herbicides by the DWQ laboratory. Mill Creek stormflows were analyzed for a broader set of pesticides by the NCSU Department of Environmental and Molecular Toxicology. Dissolved oxygen and temperature were studied in Mill Creek to determine possible impacts of a beaver dam below the confluence of Satulah Branch and Mill Creek.

In Mill Creek and the Cullasaja River, semi-permeable membrane devices and stream sediments were used to measure long-term stream exposure to pollutants. Semi-permeable membrane devices (SPMDs), passive artificial samplers that accumulate hydrophobic organic pollutants, were used during a six-day stormflow/baseflow period in Mill Creek and 17-day baseflow periods in Mill Creek and the Cullasaja River. The SPMDs were analyzed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated pesticides, and selected current use pesticides.

Hydrolab data sondes, multiparameter probes with a data logging capability, were used to measure dissolved oxygen, temperature, specific conductance, and pH levels in-stream during seven-day periods. These instruments were deployed at three locations in the upper Cullasaja River watershed in September 2001 to determine the differences in dissolved oxygen above and below dams on the Cullasaja River. They were also deployed in Mill Creek in October 2001 both below the beaver dam at 5th Avenue and at the integrator location further downstream in order to determine whether dissolved oxygen levels were impacted by the beaver dam.

Ambient acute and chronic toxicity tests (bioassays) were conducted on water samples to evaluate potential toxic impacts in Mill Creek below Highlands' town center. Laboratory bioassays provide a method of assessing the presence of toxicity to aquatic organisms from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. One chronic toxicity test was performed during baseflow and acute toxicity tests were performed for two storm events. The North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NCDWQ, 1998) was used for chronic toxicity determination. Acute toxicity was determined using protocols defined by USEPA using *Ceriodaphnia dubia* with a 48-hour exposure (USEPA, 1993).

Stream sediments of the Cullasaja River and Mill Creek were collected in August 2001 and then analyzed for pesticides, metals, and a suite of organic pollutants, including PAHs, PCBs, and other semi-volatile compounds. Chronic toxicity tests were conducted on these sediments to evaluate potential toxic impacts. Forty-two day tests were performed with the test organism *Hyallela azteca*, using methods described in ASTM (2000) and USEPA (2000a).

Field measurements (pH, dissolved oxygen, specific conductance and temperature) were taken on multiple occasions at various locations throughout the watershed to further characterize water quality conditions and to investigate potential stressor source areas.

Water and sediment benchmarks. In order to help evaluate whether a significant likelihood existed that observed concentrations may have a negative impact on aquatic life, measured concentrations were compared to EPA's National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999b) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where appropriate (USEPA, 1999b). For chromium, the NAWQC for Cr VI was used. The use of NAWQC and other benchmarks is discussed in more detail in Appendix B. Since NAWQC are for dissolved metals and samples of the upper Cullasaja River watershed were analyzed for total metals, these criteria are conservative.

Sediment data were compared to a set of sediment benchmarks used by the DWQ Aquatic Toxicology Unit (Appendix B, Table B.2). They were grouped into conservative and non-conservative ranges in the manner of MacDonald et al. (2000). Conservative ranges are sets of threshold values, below which there is low probability of toxicity to aquatic organisms. Region 4 USEPA values are included in the set of conservative values, but they are also presented by themselves because the DWQ Aquatic Toxicology Unit uses these as initial screening benchmarks. Non-conservative ranges are sets of values above which there is a high probability of toxicity to aquatic organisms. If a measured value falls within the conservative range, it is possible but not probable that it is toxic. If the value falls within the non-conservative range, it is possible that it is toxic, and the higher the concentration, the more probability of toxicity.

Benchmarks were used for initial screening of potential impacts. Final evaluation of the likely potential for metals, and other analytes, to negatively impact aquatic biota, considered all lines of evidence available, including toxicity bioassays and benthic macroinvertebrate data, in addition to data on analyte concentrations.

5.1.2 Site Selection

Sampling stations were chosen based on several criteria: accessibility, proximity to benthic sampling sites, and proximity to potential contributing land use activities. Sampling sites are summarized in Table 5.1 and shown in Figure 5.1. Data and samples were collected at the following sites.

Watershed integrator sampling

- Cullasaja River upstream of US 64 (CUCR01). This location is the historic benthic sampling location. It is downstream of the Cullasaja Club and Highlands Falls golf course communities and is the most downstream monitoring location that is accessible. It integrates most of the nonpoint and point source influences in the watershed. Dissolved oxygen was measured here with a continuous data logging device to determine the influence of the lowest impoundment in the Highlands Falls golf community on oxygen. An SPMD was deployed here for 17 days during baseflows in November 2001. Sediment was sampled and analyzed for toxicity and contaminants.

Figure 5.1. Physical/Chemical and Benthic Monitoring Sites
in the Upper Cullasaja River Watershed

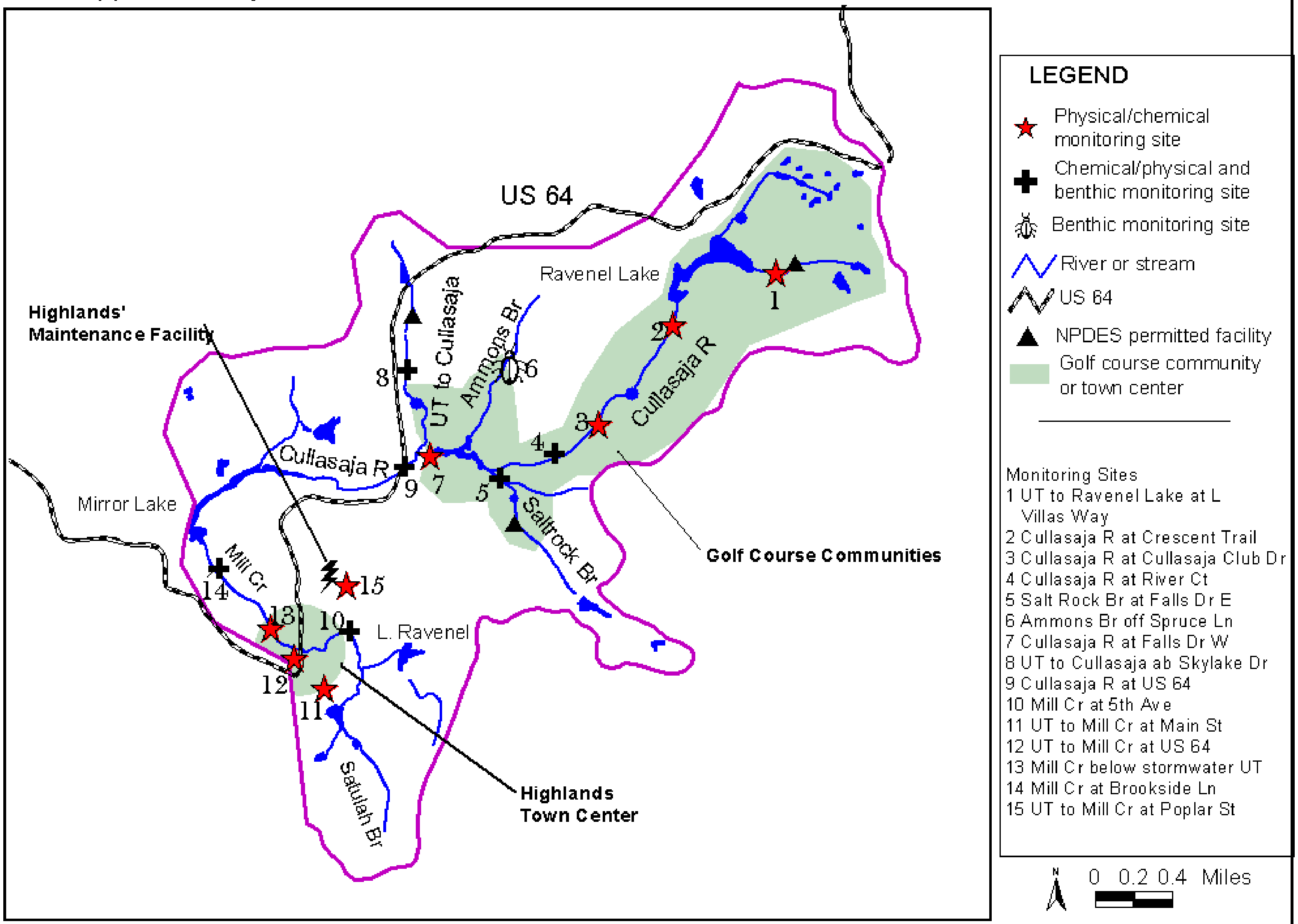


Table 5.1 Summary of Monitoring Approaches Used at Primary Sampling Sites, Upper Cullasaja River Study Area

			Monitoring Approach					
	Station Code	**Location**	**Benthos**	**Water Chemistry[1]**	**Toxicity (water)**	**Bed Sediment**	**SPMD [2]**	**Data Sonde**
Upper Cullasaja River	CUCR01	Cullasaja R. at US 64	✔	✔+		✔	✔	✔
	CUSB03	Salt Rock Br. at Falls Dr. East	✔	✔				
	CUCR04	Unnamed tributary to the Cullasaja R. above Skylake Rd.	✔	✔				
	CUCR05	Cullasaja R. at Falls Dr. West						✔
	CUCR10	Cullasaja R. at Cullasaja Club Dr.		✔				
	CUCR11	Cullasaja R. at River Ct.	✔	✔				
	CUCR12	Unnamed tributary to Ravenel Lake at Lake Villas Way						✔
	CUCR13	Cullasaja R. at Crescent Trail						✔
	CUAB15	Ammons Br. off Spruce Ln.	✔					
Mill Creek	CUMC02	Mill Creek at Brookside Ln.	✔	✔+	✔	✔	✔	✔
	CUMC06	Main stormwater tributary to Mill Cr.		✔				
	CUMC08	Mill Cr. downstream of CUMC06		✔	✔			
	CUMC09	Unnamed tributary to Mill Cr. at Main St.		✔				
	CUMC14	Mill Creek at 5th Avenue	✔	✔				✔
	CUMC19	Unnamed tributary to Mill Cr. at Poplar St.		✔				
Reference	CUBC16	Big Cr. at Buck Cr. Rd.	✔					
	CUBC17	Houston Br. at Simon Speed Rd.	✔					
	CUSC18	N. Skitty Cr. at Cliffside Recreation Area	✔					
	MRSM01	South Fork Mills R. off USFS Rd.				✔		

1 Grab samples and/or repeated field measurements.
2 SPMD--semipermeable membrane device.
+ Integrator station.

- Mill Creek at the end of Brookside Lane (CUMC02). This location is the lowest benthic sampling location. It is downstream of Highlands and is the most downstream monitoring location that is accessible. It integrates most of the nonpoint source influences in the watershed. Dissolved oxygen was measured here with a continuous data logging device to compare to upstream oxygen levels. SPMDs were deployed here for a 17-day baseflow period and a six-day stormflow/baseflow period in November 2001. Sediment was sampled and analyzed for toxicity and contaminants.

Stressor and source identification sampling locations

- Saltrock Branch at Falls Drive East (CUSB03). This sampling location is downstream of the main wastewater treatment plant for the Highlands Falls golf course community.
- Unnamed tributary to the Cullasaja River at Skylake Road (CUCR04). This sampling location is downstream of the smaller wastewater treatment plant for the Highlands Falls golf course community and was sampled for metals and nutrients.
- Cullasaja River at Falls Drive West (CUCR05). Dissolved oxygen was measured here with a continuous data logging device to determine the influence of the lowest impoundment in the Highlands Falls golf community on oxygen.
- Unnamed tributary to Mill Creek (CUMC06). This sampling location is where a small tributary that drains approximately half of the town center empties into Mill Creek. This is referred to as the "main stormwater tributary" throughout this document. Petroleum odors were observed here during dry periods.
- Mill Creek downstream of the stormwater culvert at the CUMC06 location (CUMC08). This sampling location was used to determine if contaminants measured at CUMC06 were at measurable levels in Mill Creek. Chronic toxicity was also performed on water from this site.
- Unnamed tributary to Mill Creek (CUMC09). This sampling location is at the end of a culvert across from the Mountain Fresh grocery store on Main Street where sewage smells and fungus were observed.
- Cullasaja River at Cullasaja Club Drive (CUCR10). This sampling location is downstream of most of the Cullasaja Club golf course.
- Cullasaja River at River Court (CUCR11). This sampling location is located on the edge of one of the fairways in the Highlands Falls golf course; pesticide analysis was performed on samples collected here.
- Cullasaja River at Cresent Trail (CUCR13). Dissolved oxygen was measured here with a continuous data logging device to determine the influence of Ravenel Lake on oxygen.
- Mill Creek at 5th Avenue (CUMC14). This sampling location is above Highlands' town center but below a residential neighborhood and a beaver impoundment. Dissolved oxygen was measured here with a continuous data logging device to determine the influence of the beaver impoundment on oxygen. This is below the confluence of the unnamed tributary that flows through the Highlands' maintenance facility, and a sample from this site was analyzed for a suite of organic contaminants.
- Unnamed tributary to Mill Creek at Poplar Street (CUMC19). This is located just downstream of Town of Highlands' maintenance facility, where there is documented contamination from a leaky underground storage tank. A sample from this site was analyzed for suite of organic contaminants and metals.

Sediment reference location

- South Fork Mills River (MRSM01) at end of USFS Road 476 near Pink Beds in Pisgah National Forest. This site drains a low gradient forested catchment on the Pink Beds plateau and was chosen as a reference site for sediment analysis.

5.2 General Water Quality Characterization

Concentrations of nutrients and other conventional parameters for the Cullasaja River at US 64 and for Mill Creek at Brookside Lane are listed in Tables 5.2 and 5.3. Metal concentrations of interest are discussed in Section 5.3.

Cullasaja River

- Median baseflow concentrations of total phosphorous and total nitrogen were 0.03 mg/L and 0.58 mg/L, respectively. These are somewhat elevated above background levels (Simmons and Heath, 1982), but are not extraordinary when compared to levels in other mountain streams. Salt Rock Branch, a tributary, was sampled once, and it had higher nutrient levels, with a total phosphorous concentration of 0.08 mg/L and total nitrogen concentration of 1.06 mg/L.
- Dissolved oxygen levels at US 64 ranged from 6.0 to 11.3 mg/L. Continuous data loggers were deployed in a tributary to Ravenel Lake and below the two largest impoundments on the upper Cullasaja River during seven days in September 2001. There was water flow over the dams during this period. There were no problematic levels of dissolved oxygen, with concentrations ranging from 7.4 to 9.2 mg/L (Appendix B, Table B.3). There was an increase in mean temperature of about 3 degrees Celsius downstream of Ravenel Lake.
- Fecal coliform levels were low, ranging from 1 to 20 colonies/100 mL, with a geometric mean of 6 col/100 mL. The North Carolina standard for fecal coliform in these waters is a geometric mean of 200 col/100 mL.

Mill Creek

- Median baseflow concentrations of total phosphorous and total nitrogen were 0.04 mg/L and 0.38 mg/L, respectively. These are somewhat elevated above background levels (Simmons et al., 1982), but are not extraordinary when compared to levels in other mountain streams.
- Dissolved oxygen levels ranged from 8.3 to 11.5 mg/L. Continuous data loggers deployed below the beaver dam at 5th Avenue and at Brookside Lane during a week in October 2001 demonstrated no problematic levels of dissolved oxygen, with concentrations ranging from 6.8 to 9.7 mg/L (Appendix B, Table B.3). Temperature measured during the same week showed little difference in mean temperature between the site below the beaver dam on 5th Avenue and that at Brookside Lane.
- Fecal coliform levels were low, ranging from 11 to 84 colonies/100 mL, with a geometric mean of 25 col/100 mL.

Table 5.2 Water Quality Results for the Cullasaja River at US 64 (CUCR01)

PARAMETER	BASEFLOW					STORMFLOW	
	N	Max	Min	Median	Mean	N	Value
Nutrients (mg/L)							
Ammonia Nitrogen	5	0.60	<0.1	<0.1	0.17	1	0.10
Total Kjeldahl Nitrogen	5	0.80	<0.1	0.40	0.49	1	0.80
Nitrate+Nitrite Nitrogen	5	0.28	0.12	0.18	0.20	1	0.20
Total Phosphorus	5	0.30	<0.02	0.03	0.10	1	0.08
Total Nitrogen	5	1.0	0.3	0.6	0.7	1	1.0
Other Conventional							
DO (mg/L)	9	80.0	6.0	8.0	16.3	1	10.6
pH (Standard Units)	9	7.6	5.1	6.9	6.7	1	5.4
Specific Cond (µS/cm)	9	44	29	38	38	1	40
Total Hardness(mg/L)	5	18.0	9.0	10.0	11.9	1	9.0
Residue, T. Suspended (mg/L)	5	7.0	1.3	1.8	2.8	1	7.0
Total Dissolved Solids (mg/L)	5	85	27	38	52	1	32
Turbidity (NTU)	5	2.9	1.5	2.6	2.3	1	11.1
Calcium (mg/L)	4	3.25	1.98	2.28	2.45	1	2.24
Magnesium (mg/L)	4	0.69	0.59	0.64	0.64	1	0.671

Table 5.3 Water Quality Results for Mill Creek at Brookside Lane (CUMC02)

PARAMETER	BASEFLOW					STORMFLOW				
	N	Max	Min	Median	Mean	N	Max	Min	Median	Mean
Nutrients (mg/L)										
Ammonia Nitrogen	5	0.3	<0.1	<0.1	0.1	2	0.9	<0.1	0.5	0.5
Total Kjeldahl Nitrogen	5	0.7	<0.1	0.3	0.4	2	0.7	0.5	0.6	0.6
Nitrate+Nitrite Nitrogen	5	0.28	0.18	0.22	0.22	2	0.31	0.20	0.26	0.26
Total Phosphorus	5	0.07	<0.02	0.02	0.03	2	0.08	0.04	0.06	0.06
Total Nitrogen	5	0.9	0.2	0.5	0.6	2	0.9	0.8	0.9	0.9
Other Conventional										
DO (mg/L)	5	11.5	8.3	10.6	10.2	1			10.9	
pH (Standard Units)	5	7.5	6.8	7.2	7.2	1			7.2	
Specific Cond (µS/cm)	5	58	32	42	43	1			43	
Total Hardness(mg/L)	5	20.0	9.5	10.0	12.1	1			14.0	
Residue, T. Suspended (mg/L)	4	1.8	1.1	1.5	1.5	1			8.8	
Total Dissolved Solids (mg/L)	5	40	24	36	34	1			29	
Turbidity (NTU)	5	2.9	0.9	1.7	1.7	1			10.6	
Calcium (mg/L)	4	3.36	2.14	2.42	2.58	1			2.47	
Magnesium (mg/L)	4	0.73	0.41	0.48	0.52	1			0.51	

5.3 Stressor and Source Identification—Cullasaja River

Sediments from the Cullasaja River at US 64 tested negative for chronic toxicity using *Hyallela azteca*. However, chemistry analysis on these sediments revealed high levels of metals and chlorinated pesticides, but no other organic pollutants were detected. Sediment and water physical/chemical data are described below.

5.3.1 Pesticides and Other Organic Contaminants

Acid herbicides, organochlorines, organophosphates, and nitrogen pesticides were analyzed on baseflow samples taken from the Cullasaja River at River Court and at Cullasaja Club Drive on one date. At Cullasaja Club Drive, bentazon was detected at 0.908 µg/L, a concentration considerably lower than published effects thresholds (USEPA Pesticide Ecotoxicity Database) and at River Court, bentazon was detected at levels too low to quantify. At both locations, ten or greater unidentified organochlorine peaks, which may have been breakdown products, were identified in the pesticide analysis. No other pesticides were detected in water samples.

A number of organic contaminants, including polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and organochlorine pesticides were sampled by a semi-permeable membrane device deployed in the Cullasaja River for 17 baseflow days (Appendix B, Table B.4). All levels were below published acute and chronic screening levels.

Table 5.4 lists pesticides found in depositional sediment that were (1) found at levels above screening benchmarks or (2) found at detectable levels, but do not currently have published screening benchmarks. Sediment analysis for pesticides identified the insecticide gamma chlordane at 0.8 ppb, which falls within the conservative benchmark range for chlordane; thus, it is possible, but not probable, that this pesticide was present at concentrations that can cause sediment toxicity to aquatic organisms (see benchmark discussion in Appendix B). Other chlorinated pesticides were found at concentrations below sediment screening benchmarks. Trans-nonachlor was measured at 0.20 ppb, but there is no published benchmark for this pesticide. Other than chlorinated pesticides, no organic compounds were detected in sediments.

Table 5.4 Selected Pesticides in the Depositional Sediment of Cullasaja River (CUCR01), Mill Creek (CUMC02), and a Reference Stream, South Mills River (MRSM01)[1]

Pesticide (ppb)	**Sample Site**			**Benchmark Reference[2]**		
(Dry Weight)	CRCR01	CRMC02	MRSM01	EPA Region 4	Conservative	Non-conservative
alpha chlordane[3]	0.15	bdl	bdl	0.5	0.5 to 7	4.79 to 147
gamma chlordane[3]	**0.80**	bdl	0.74	0.5	0.5 to 7	4.79 to 147
trans-nonachlor	0.20	bdl	bdl			
dieldrin	bdl	**0.72**	bdl	0.02	0.02 to 3.3	4.3 to 2229.5
4,4'-DDE	0.85	**2.30**	0.91	2.07	1.42 to 5	6.75 to 465.5
Sum of DDTs	0.85	**2.30**	0.91	1.58	1.58 to 7	46.1 to 4450

1 Values in bold are greater or equal to at least one benchmark. Bdl = below detection limit.
2 Where appropriate, non-conservative benchmarks were adjusted for the lowest total organic carbon value—2.45% (the TOC for CUMC02).
3 Benchmark values are for chlordane.

5.3.2 Metals

Table 5.5 provides a comparison of selected metal concentrations measured in water on specific sampling dates to the chronic and acute EPA NAWQC criteria (screening values) that were adjusted for site-specific hardness. Only those metals with measured values at or above NAWQC criteria are listed. Although pH is also a major factor in a metal's bioavailability, no adjustment calculations were necessary because readings at sites in the upper Cullasaja River watershed were generally circumneutral.

The stormflow sample had a copper and cadmium level at least two times the acute screening level. Baseflow concentrations were not as notable--the median copper and cadmium concentrations of six samples collected are below the detection limit (1 µg/L) and the screening level. However, it is important to note that the lead detection limit (1 µg/L) is above the chronic benchmark (0.1 µg/L).

Table 5.5 Selected Metals in the Cullasaja River and Mill Creek and Comparison Values of the Tuckasegee River and EPA Screening Levels[1]

Site	Total metal concentration (µg/L)				Calculated
	Cadmium	Copper	Lead	Zinc	Hardness (mg/L)[2]
Cullasaja R. at US 64 (CUCR01)					
3/15/2001--stormflow	**0.8**	**3**	<1	10.3	8.36
Adjusted chronic benchmark	0.4	1.4	0.1	15.0	
Adjusted acute benchmark	0.4	1.1	3.5	15.0	
Baseflow median	<0.1	<1	<1	9.5	8.44
Adjusted chronic benchmark	0.4	1.4	0.1	15.0	
Adjusted acute benchmark	0.4	1.1	3.5	15.0	
Mill Cr. at Brookside Ln. (CUMC02)					
3/15/2001--stormflow	<0.1	**2**	2	**18.7**	8.28
Adjusted chronic benchmark	0.3	1.1	0.1	14.5	
Adjusted acute benchmark	0.3	1.3	3.4	14.5	
11/23/2001--stormflow	**0.4**	**9**	**5**	**125.3**	8.28[3]
Adjusted chronic benchmark	0.3	1.1	0.1	14.5	
Adjusted acute benchmark	0.3	1.3	3.4	14.5	
11/29/2001--stormflow	0.2	**2**	3	**27.0**	8.28[3]
Adjusted chronic benchmark	0.3	1.1	0.1	14.5	
Adjusted acute benchmark	0.3	1.3	3.4	14.5	
Baseflow median	0.1	<1	<1	10.5	8.54
Adjusted chronic benchmark	0.4	1.1	0.1	15.0	
Adjusted acute benchmark	0.4	1.4	3.6	15.0	
Tuckasegee R. at Bryson City					
Median for monthly data collected 9/94-8/99		**3**		**12.0**	7.0[4]
Adjusted chronic benchmark		1.2		11.1	

[1] Bold values are those greater or equal to chronic screening levels if from baseflow and greater or equal to acute screening levels if from stormflow.
[2] Hardness calculation = ([Ca^{2+}] X 2.497) + ([Mg^{2+}] X 4.118).
[3] Hardness value is calculated hardness from 3/15/01 stormflow cation data.
[4] Hardness is median hardness for all samples from the Tuckasegee River.

Data from the Tuckasegee River at Bryson City (DWQ station number G8600000) provide a comparison for copper and zinc in the upper Cullasaja River watershed. Detection limits for lead and cadmium are too high to provide a dataset for comparison. Benthic macroinvertebrates in the lower Tuckasegee River were monitored in 1999 and rated as Good; thus, metals concentrations here likely do not negatively impact the macroinvertebrate community. Median copper in the Tuckasegee River is similar to that of the Cullasaja River (3 µg/L vs. 2-3 µg/L), and it also exceeds its site-specific benchmark of 1 µg/L.

Sediment collected in depositional areas in the Cullasaja River had high levels of aluminum, cadmium, iron, and zinc (Table 5.6). Concentrations of these metals are within the conservative benchmark range; thus, it is possible, but not probable, that these metals are toxic to aquatic organisms. Mercury was found at a concentration that is half the lowest conservative benchmark.

Table 5.6 Metals Detected in the Depositional Sediment of Cullasaja River (CUCR01), Mill Creek (CUMC02), and a Reference Stream, South Mills River (MRSM01)[1]

Metal Total (ppm)	**Sample Site**			**Benchmark Reference**		
dry weight units	CUCR01	CRMC02	MRSM01	EPA Region 4	Conservative	Non-conservative
Aluminum	**25900**	15300	9160		25500	58030 to 73160
Cadmium	**1.610**	**1.140**	**0.596**	0.676	0.583 to 1.2	3 to 41.1
Copper	12.7	13.0	4.2	18.7	16 to 35.7	54.8 to 270
Iron	**20200**	14600	7600		20000 to 188400	40000
Lead	8.67	13.90	<2.78	30.2	30.2 to 46.7	68.7 to 396
Manganese	414	306	107		460 to 1673	819 to 11000
Mercury	0.0755	<0.0374	<0.0396	0.13	0.13 to 0.2	0.486 to 2
Nickel	11.60	8.83	4.69	15.9	15.9 to 39.6	35.9 to 75
Zinc	**104**	**104**	24	124	98 to 159	271 to 1532

[1] Values in bold are greater or equal to at least one benchmark.

5.4 Stressor and Source Identification—Mill Creek

Monitoring in Mill Creek focused on impacts from Highlands' town center. Using *Cerodaphnia dubia*, toxicity was measured in water samples collected below the town center. Two acute toxicity tests performed on stormflows and one chronic toxicity test performed on baseflow passed, with no associated mortality or observed reduction in reproduction. Toxicity tests performed on the depositional sediment from Mill Creek did not provide any conclusive evidence of toxicity. There was no statistically significant difference ($p<0.05$) between the control and Mill Creek sediments for any toxicity endpoints except for the 28-day survival of *Hyallela azteca*, and this is not considered evidence of toxicity due to extremely high survival of test organisms in control sediments.

5.4.1 Pesticides and Other Organic Contaminants

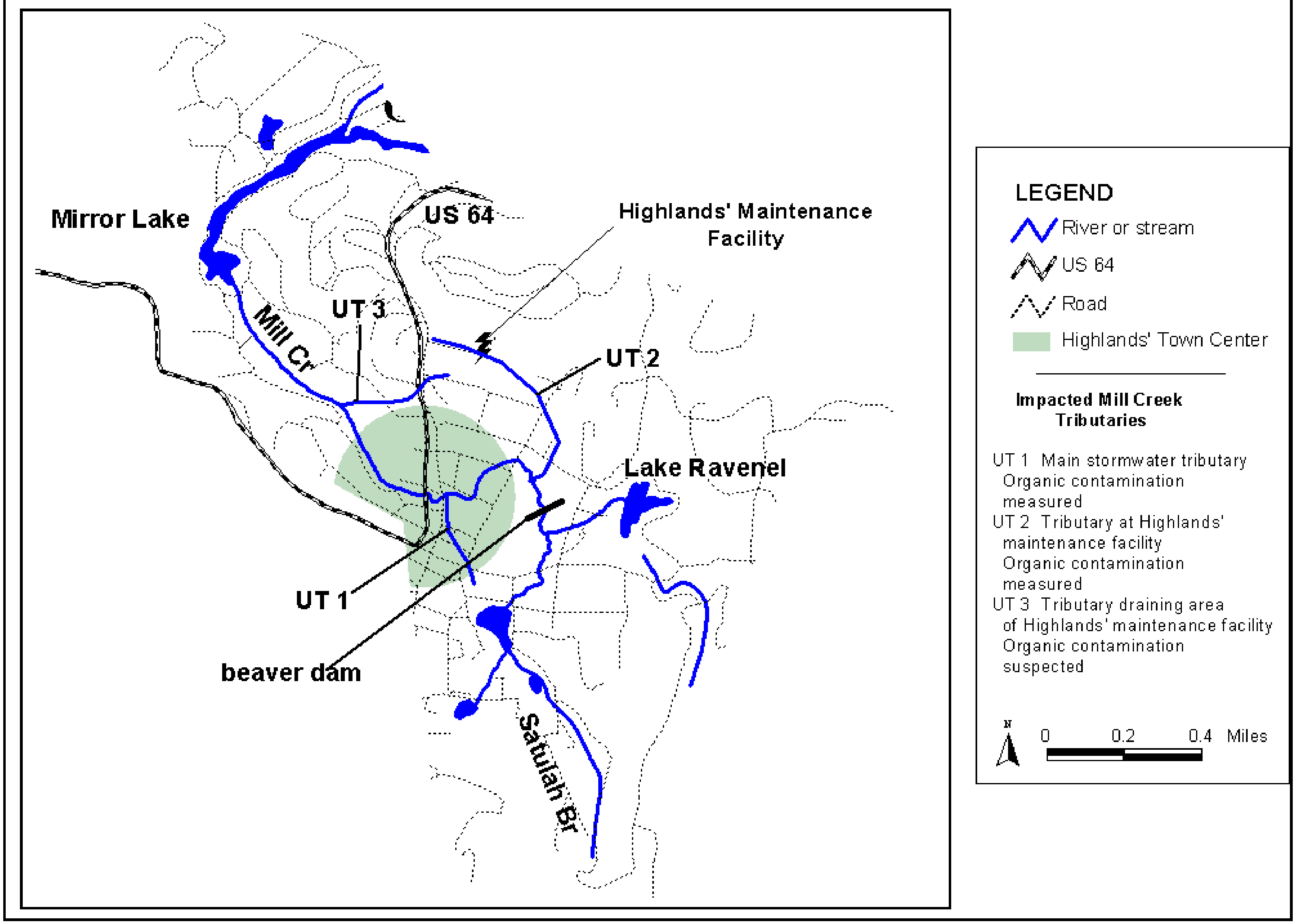
There were three chlorinated pesticides measured in depositional sediments of Mill Creek at concentrations that were above published screening benchmarks—dieldrin, total DDTs (a measure of DDT and its breakdown products), and DDE (Table 5.4). DDE, a breakdown product of DDT, and the total DDTs concentrations were the same; therefore, DDE accounts for the total DDTs. All of these concentrations fall within the conservative benchmark range. The one baseflow sample that was analyzed for chlorinated pesticides, organophosphates, and acid herbicides had two unidentified chlorinated pesticide peaks, which may have been breakdown products of these pesticides.

Semi-permeable membrane devices (SPMDs) placed in Mill Creek during a six-day baseflow and stormflow period and a seventeen-day baseflow period collected a large number of organic contaminants, including chlorinated pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons (Appendix B, Table B.4). Concentrations of most contaminants were higher from the SPMD that sampled both baseflows and stormflows than the SPMD that sampled baseflows only. All levels were below published acute and chronic screening levels. SPMD concentrations represent an average concentration over the entire deployment period and can be used to determine what has passed through the stream. They do not represent actual concentrations of pulse events such as stormflows. The storm event that occurred during the SPMD deployment period was also sampled with an automatic sampler, which collected and composited four subsamples over the course of 45 minutes. There were no notable levels of semi-volatile or volatile organic contaminants (including PAHs), chlorinated or other pesticides, or acute toxicity in this sample. PCBs were not analyzed. This composite sample provides only a snapshot of 45 minutes during the storm and does not reflect the concentrations of pollutants during the entire storm event, so it is possible that the contaminants measured by the SPMD entered the stream at some other time during the storm or during baseflow.

Water samples were tested for semi-volatile organic contaminants in the main stormwater tributary to Mill Creek that drains Highlands' town center (UT 1 in Figure 5.2) and in Mill Creek below the confluence with this tributary. A number of compounds were detected during baseflow in the main stormwater tributary (Appendix B, Table B.13). There are no NAWQC benchmarks available for these compounds. However, two out of twelve compounds detected have published Tier II chronic screening levels, and they were exceeded; this tributary had 17 μg/L of naphthalene (Tier II value: 12 μg/L) and an estimated 57 μg/L of p-xylene (Tier II value for xylene: 13 μg/L). The two baseflow samples taken in Mill Creek below this tributary did not have measurable levels of semi-volatile compounds, however, and a chronic toxicity test performed here passed, with no associated mortality or observed reduction in reproduction.

A strong petroleum odor was observed in a tributary to Mill Creek (UT 2 in Figure 5.2) that flows from the Town of Highlands' maintenance facility, where there is a documented leaking underground storage tank incident (see Section 2.5.2). A sample from this tributary (specific conductance = 101 μS/cm) was analyzed for volatile and semi-volatile organics, phenols, PAHs, and metals; only volatile organics (Table 5.7) and metals were detected in the sample. The zinc level (22.7 μg/L) was above the chronic NAWQC screening level (15.0 μg/L, adjusted for median watershed baseflow hardness). Two isomers of xylene (m and p) could not be separated in analysis and are reported together. The Tier II screening level for m-xylene is much lower

Figure 5.2. Mill Creek and Its Tributaries



than that for xylene, and the stream's concentration of m + p-xylene is almost three times the screening level for m-xylene, but below that of xylene. Levels of other volatile organics were below Tier II screening levels, but additive effects of these contaminants may be problematic. Mill Creek was sampled just below this tributary (above 5th Avenue), but no organic contaminants were detected and metal concentrations were below screening levels. Another tributary to Mill Creek that drains an area near the maintenance facility but merges with Mill Creek below US 64 (UT 3 in Figure 5.2) also smelled of petroleum and had high specific conductance (162 µS/cm); however, no analysis for organic contaminants or metals was performed on water from this stream.

Table 5.7 Volatile Organic Contaminants in a Tributary to Mill Creek Draining the Highlands' Maintenance Facility and Corresponding EPA Tier II Surface Water Chronic Benchmarks (µg/L)

Contaminant	Site Concentration	Tier II Benchmark
Benzene	1.03	130
Toluene	1.40	9.8
Ethylbenzene	1.84	7.3
M+P-Xylene[1]	4.92	1.8; 13
O-Xylene[2]	1.92	13

[1] The Tier II benchmark for m-xylene is 1.8 µg/L, and the benchmark for xylene is 13 µg/L.
[2] There is no Tier II benchmark for o-xylene; the benchmark for xylene was used.

5.4.2 Metals

Stormflow metals in the water column sometimes exceeded EPA NAWQC values (Table 5.5). One of three stormflow cadmium and lead concentrations were greater than the acute screening levels. Three of three stormflow copper and zinc concentrations exceeded the acute screening levels (including zinc for one storm at 125.3 µg/L, with a comparative acute benchmark of 14.6 µg/L). Two of the three storm events, including one with the high zinc concentration, were tested for acute toxicity, but neither event demonstrated mortality of the test organisms. Median baseflow metal concentrations were below chronic screening levels. Again, it is important to note that the lead detection limit (1 µg/L) is above the chronic benchmark (0.1 µg/L).

Using data from the fully supporting Tuckasegee River at Bryson City as a comparison for Mill Creek data can provide perspective on zinc and copper levels. Median copper in the Tuckasegee River is above that of Mill Creek for all but one storm sample, and it also exceeds its site-specific benchmark of 1 µg/L. However, zinc levels in the Tuckasegee River are much lower than those of Mill Creek.

Both cadmium and zinc concentrations in Mill Creek sediments fell within the conservative benchmark range (Table 5.6); thus, it is possible, but not probable, that they can cause toxicity to aquatic organisms. Mill Creek sediments had both metals and chlorinated pesticides above screening benchmarks; additive effects of these contaminants could cause toxicity.

5.4.3 Other Concerns

Multiple problems with runoff from Highlands' town center were observed. During snowmelt in December 2000, high specific conductance was measured in several storm drains and ditches that flow to Mill Creek, and the one storm drain tested for chloride had a concentration of 94 mg/L; road salt was the likely cause of these high values. A very high fecal coliform bacteria count (estimated 90,000 colonies/100 mL) was noted from a storm drain on Main Street across from the Mountain Fresh grocery store in December 2000, and it was evident that there was an unauthorized discharge of sewage to the storm drain.

Residents have observed periodic occurrences of suspicious substances in the stormwater drainage network of Highlands. Soapy substances, milky white discharges, and petroleum smells have been noted.

Section 6
Channel and Riparian Conditions

The characterization of stream habitat and riparian area condition at benthic macroinvertebrate sampling sites, described earlier, provides information essential to the assessment of conditions in the upper Cullasaja River watershed. However, a perspective limited to a small number of locations in a watershed may not provide an accurate picture of overall channel conditions, nor result in the identification of pollutant sources and specific problem areas. This study therefore undertook a broader characterization of stream condition by examining large sections of the channel network of the upper Cullasaja River and Mill Creek in the field. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities. The results of these efforts are summarized in this section. See Appendix C for a more detailed description.

6.1 General Approach

During the course of this study project, staff walked almost the entire channel of the Cullasaja River from Ravenel Lake to Mirror Lake (approximately 4 miles). Mill Creek was walked from Lake Ravenel to Mirror Lake (approximately 1.4 miles), and much of its main tributary, Satulah Branch (approximately 1 mile), was also walked. A few other tributaries of the upper Cullasaja River and Mill Creek were also walked.

Project staff walked the identified sections of channel while carrying out the following tasks:

- Observing overall channel stability, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization and similar attributes.
- Observing overall riparian area condition and the nature of surrounding land use.
- Identifying wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows.
- Observing visual water quality conditions (odors, surface films, etc.).
- Noting specific areas where pollutants are or may be entering the stream (livestock access areas, dump sites, land clearing adjacent to the stream, etc.).
- Identifying specific areas that may be candidates for channel restoration or best management practices.
- Providing digital photo documentation of key features.

6.2 Channel and Riparian Area Summary

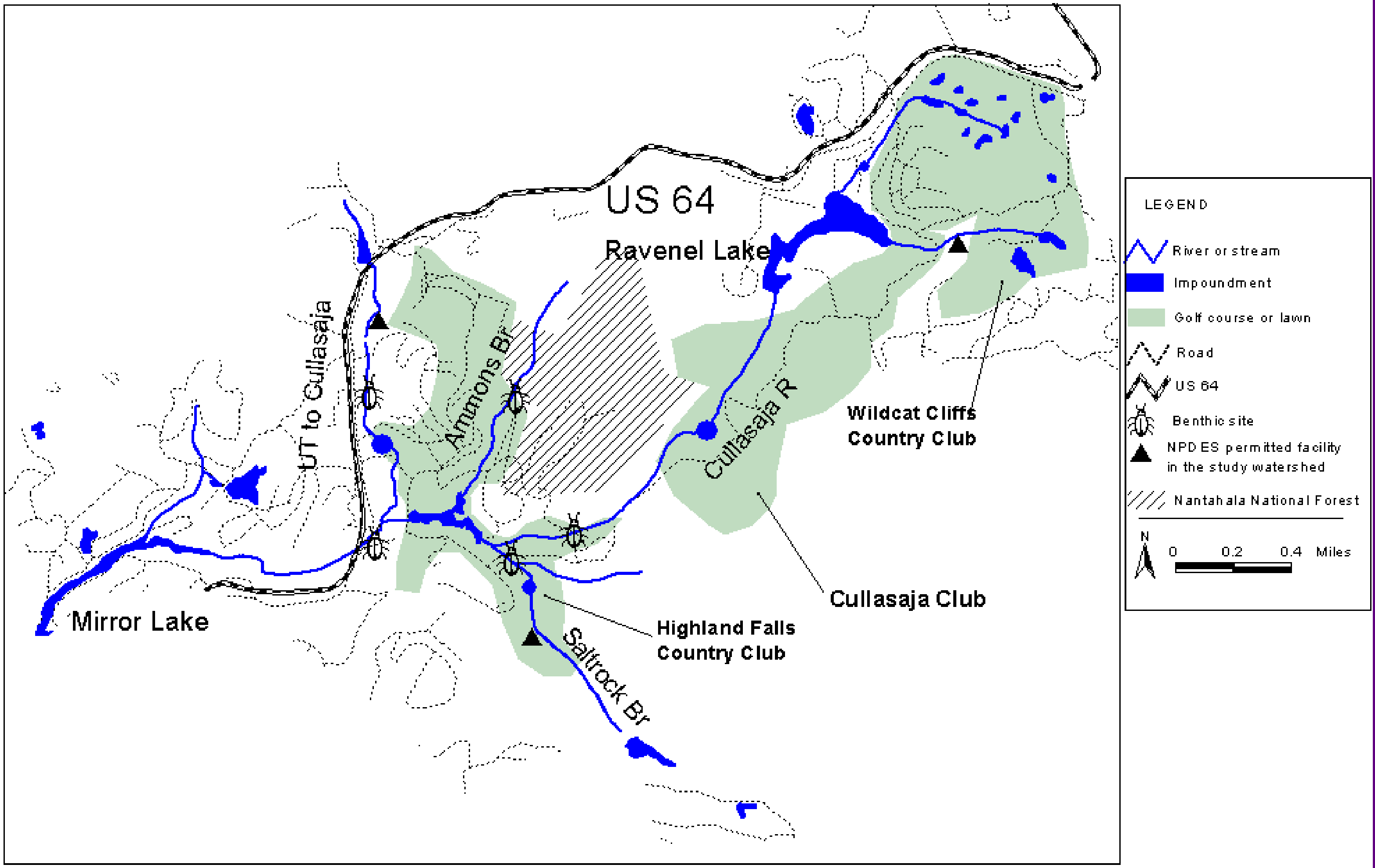
Half of the length of the impaired section of the Cullasaja River flows through golf course communities (Figure 6.1). Here, the mainstem of the Cullasaja is impounded three times, and much of the free-flowing section of the stream runs through golf courses, where it is sometimes channelized and has no woody riparian vegetation. The lack of woody vegetation impacts in-stream habitat in several ways. There is less source of organic microhabitat, such as large wood, sticks, and leafpacks, and there is less roughness in the stream channel, which can catch sticks and leafpacks from upstream sources. Woody vegetation also stabilizes stream banks, and where there is only grass, banks are often unstable, providing a source of sediment to the creek. Tributaries to the Cullasaja River in the golf course communities are also often impounded and have the same problems with in-stream habitat within the manicured stream sections.

Like the Cullasaja River, Mill Creek is impounded several times, with one beaver-made and two human-made impoundments in the low gradient area upstream of US 64. It has very low gradient, cutting through organic soils, above the upper benthic monitoring site. Below US 64, most tributaries are small and impounded upstream of their confluence with Mill Creek. Although woody riparian vegetation has been removed in some areas, a much greater length of Mill Creek has some riparian forest.

Colonization sources are limited below the beaver pond on Mill Creek (see Figure 5.2). Of the two largest tributaries, one is impacted by organic pollutants likely coming from the UST site at the Town of Highlands' maintenance facility (see Section 5.4.1) and the other may also be impacted by this site. Another tributary serves as the town's main stormwater channel and carries high levels of organic pollutants. Most of the other smaller tributaries are impounded above their confluences with Mill Creek.

Excess sedimentation is seen in low gradient areas of both Mill Creek and the Cullasaja River and in their tributaries. Although there are some unstable sections of the Cullasaja River in the golf courses, the banks are generally not a substantial source of in-stream sediment. It is evident that upland construction is the source of some of this sediment seen in Mill Creek and the Cullasaja River. However, sediment deposition is not a problem for higher gradient areas in either stream where aquatic invertebrates were sampled. Numerous in-stream impoundments on the tributaries and mainstems serve as sinks for incoming sediment.

Figure 6.1. Upper Cullasaja River, In-stream Impoundments, and Golf Course Areas



Section 7
Analysis and Conclusions

This section presents our analysis of the causes of impairment in the upper Cullasaja River watershed. It discusses the available evidence, based upon information presented earlier in this report, and provides our evaluation of the most probable reasons for the inadequate biological conditions in the streams assessed. The sources or origin of these key stressors are also discussed.

7.1 Analyzing Causes of Impairment

The following analysis summarizes and evaluates the available information related to each candidate cause of impairment in order to determine whether that information provides evidence that particular stressors play a substantial role in causing observed biological impacts. A strength of evidence approach is used to weigh the evidence for or against each stressor in order to draw conclusions regarding which are 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.

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

A 'strength of evidence' 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, 2000b). The term 'weight of evidence' is sometimes used to describe this approach (Burton and Pitt, 2001), though this terminology has gone out of favor among many in the field because it can be interpreted as requiring a mathematical weighting of evidence.

We consider all lines of evidence developed during the course of the project 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 to be 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 ecoepidemiological approach described by Fox (1991) and USEPA (2000b) provides a useful set of concepts to help structure the review of evidence. 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 having an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing 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 generally will 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 causes of or contributors to impairment.

7.1.2 Review of Candidate Stressors

The key stressors evaluated during this study of the upper Cullasaja River watershed were:

<u>Upper Cullasaja River</u>

- Dam impacts, including (1) prevention of downstream colonization of aquatic populations, (2) lower water levels below dams, (3) changes in temperature and dissolved oxygen, and (4) change in food type;
- Habitat degradation due to sedimentation;
- Habitat degradation due to lack of key microhabitat; and
- Pesticides.

<u>Mill Creek</u>

- Toxicants;
- Habitat degradation due to sedimentation; and
- Habitat degradation due to lack of key microhabitat.

Additional potential stressors, including metals, were identified during the course of watershed investigations and will be discussed in the following section.

The extended drought that began mid-1998 has decreased flows in the upper Cullasaja River watershed, with rainfall only two-thirds of the annual mean in 2000 and 2001. Low flows themselves can stress aquatic invertebrate communities by shrinking aquatic habitat (e.g., isolating edge habitat) and changing energy dynamics (e.g., slowing riffle current). Low flows impacted both watershed and reference streams; edge habitat was unavailable in all streams. Reference streams were not sorely impacted by this stress, since they still maintained diverse and intolerant benthic communities. It might be expected that already impacted benthic communities would be further impacted by this natural stress. However, there was no notable change in community composition between non-drought and drought years that could be attributed to drought.

7.1.3 Review of Evidence--Upper Cullasaja River

The Cullasaja River from its source at Ravenel Lake to Mirror Lake is considered impaired by DWQ, and data collected during this study confirms this. The benthic community in Salt Rock Branch is also severely impacted, but this stream cannot be rated due to its small size. Each stressor investigated during this study is evaluated below.

<u>Dam impacts</u>

1) *Prevention of downstream colonization of aquatic populations*. Invertebrate and fish communities depend on upstream-downstream movement for colonization. Downstream drift is a key mechanism for aquatic invertebrate community maintenance (Waters, 1972; Williams and Hynes, 1976). There are two main types of drift—one is *continuous* and can be due to chance (like an invertebrate becoming dislodged from its niche) or part of a regular pattern of movement. The other type of drift is *catastrophic*, which is a response to abiotic factors, such as high flows, pesticides, heated waters, and drought (Brittain and Eikeland, 1988). Stormflows can scour benthic invertebrates from the substrate and send them drifting downstream; some flood events can cause the loss of a majority of individuals within a stream reach (e.g., Ryck, 1975). Recolonization after catastrophic events occurs through a number of mechanisms, with drift considered the most important method of colonization (Smock, 1996). If drift sources are present, recolonization can occur quickly; recovery from floods in a small stream in Missouri occurred within one month (Ryck, 1975).

In-stream impoundments serve as a barrier to downstream drift. Drifting invertebrates encounter a much different environment in a pond. With no flow, many invertebrates sink to the bottom, where the habitat is inappropriate for stream-adapted species, and it is unlikely that they are able swim up and over a top-spill dam. Within a pond, the water is warmer during the summer, and fish are a constant source of predation.

The benthic monitoring site at US 64 is less than 1/6 of a mile below the 10-acre impoundment in the Highlands Falls Country Club. An unnamed tributary with a healthy benthic community converges with the Cullasaja River between the dam and the sampling location; however, this tributary is also impounded 1/4 of a mile above the sampling location on the Cullasaja River. Any drift colonization must come from the small stream segments between the dams and the sampling site. If the benthic communities in these streams are severely impacted due to scour from storms, other catastrophic drift events, or some toxic event, then recolonization depends on mechanisms other than downstream drift, such as aerial dispersal by adult insects, which can take a long period of time.

Dams also stop both upstream and downstream migration of fish. The fish community, which consists of only one tolerant, non-native species, the redbreast sunfish (McLarney, 2000), is essentially isolated between the dams and a large drop below the US 64 culvert, and there is no source of recruitment of other species. It is likely that the block to colonization is a significant stressor for this section of the Cullasaja River.

Many of the Cullasaja River's tributaries in the three golf course communities are impounded. Therefore, this issue of lack of unimpounded colonization sources is a wide-reaching issue for the upper Cullasaja River watershed. (See background note, "The Stress-Recovery Cycle"). The Cullasaja River at River Court, which is above the large impoundment in Highlands Falls Country Club and more than 1/2 of a mile below the closest upstream impoundment, was sampled in 2000 and 2001. Its community was consistently more diverse than that of US 64, although it was still dominated by taxa tolerant of stress. A notable decrease in taxonomic richness was seen in 2001 at River Court, and this could be due to the scour of recent heavy stormflows. Recolonization of this site is likely hampered by the lack of unimpounded colonization sources.

2) *Lower water levels below dams.* There were periods of time during the summers of 2000 and 2001 when there was no flow over the dam at Ravenel Lake. At times, there was very little to no flow coming from the Cullasaja Club into Highlands Falls Country Club, as well. Water is pulled daily from some of the golf course impoundments to irrigate the courses; this lengthens the amount of time that there is no outflow and decreases the amount of water that does flow over the dams.

A dry stream bed is an extremely stressful situation for aquatic invertebrates and fish. Many studies have demonstrated substantial changes in benthic community composition due to the lower water levels of drought (e.g., Canton et al., 1984; Cowx et al., 1984). Lowered water levels below dams are likely a stressor to biological communities in the Cullasaja River. This stress is localized below dams that are not releasing water; groundwater and tributaries below the dam eventually provide flow in the stream. However, this decrease in outflow artificially lowers the flow throughout the stream and can stress aquatic invertebrate communities by shrinking aquatic habitat and changing energy dynamics.

3) *Change in temperature and dissolved oxygen*. Continuous data loggers were placed above and below the two largest impoundments on the Cullasaja River during a warm week in September 2001 while there was flow over the dams. Temperature did increase below the dams, but there were no notable differences in dissolved oxygen. An increase in temperature below impoundments has been associated with benthic community shifts (e.g., Fraley, 1979), and it is considered a contributing stressor for the upper Cullasaja River. Benthic community analysis of samples collected at least 1/5 of a mile below any impoundment demonstrates little indication of low dissolved oxygen impacts. However, low dissolved oxygen levels may occur periodically in short stretches of the river (such as pools) below dams, especially when there is little or no flow over the dams. Although there is no evidence that it is a system-wide stressor, low dissolved oxygen is a potential stressor for local sections of the stream.

4) *Change in food type*. Change in food type available to biological communities is likely another important impact from the dams in the upper Cullasaja River watershed. Numerous studies have documented a distinct change in the benthic community to dominance by organisms that feed on small particulate organic matter and algae below dams (e.g., Ward and Stanford, 1979). Dams hold back coarse particulate organic matter (leaves, sticks, large wood), an

important food source for benthic invertebrates. Impoundments produce planktonic algae, which serve as a very different food type for downstream benthic invertebrates.

Habitat degradation due to sedimentation

Although historically listed as a problem parameter on the 303(d) list, there is little evidence that sedimentation is a current cause of impairment for the upper Cullasaja River. Reference streams (e.g., Big Creek) that hosted diverse benthic communities were often characterized by comparable amounts of sand and silt, providing evidence that sedimentation did not severely limit benthic macroinvertebrates in these streams. Historic logging and construction activities almost certainly produced sediment inputs that resulted in the degradation of stream habitat of the Cullasaja River. The role of these inputs in past impairment cannot be determined with the limited historic information now available.

"Impairment" in this document is gauged by benthic macroinvertebrate communities. DWQ benthic collection and analytical methods are geared towards detecting water quality impacts, not sedimentation impacts. Biologists collect organisms in select habitats (e.g., riffles, edge habitat, leafpacks) that have varying degrees of sensitivity to sedimentation (see Appendix A for details on methods). Although sedimentation is reflected by the composition of the benthic community, sedimentation seen by the public as deleterious may not "impair" the benthic macroinvertebrate community.

Although excess sediment does not cause impairment in the Cullasaja River mainstem, sedimentation is clearly a watershed-wide problem. Tributaries below road or homesite construction (e.g., East Fork Salt Rock Branch) are often highly sedimented, and impoundments fill at an accelerated rate with sand and silt from upstream sources. It is likely that sedimentation was a greater problem for the Cullasaja River in the past due to large-scale clearing of the valley and upland areas for the timber industry and for golf course and homesite development.

Habitat degradation due to lack of key microhabitat

Organic microhabitat (leafpacks, sticks, and large wood) and edge habitat (root mats and undercut banks) play very important roles in a stream ecosystem. Organic matter in the form of leaves, sticks, and other materials provide a food source for microbes in streams and serve as the base of the food web for many small streams. When microbes feed on organic matter, they consume oxygen in the process and make nutrients available to primary producers such as plants and algae. Macroinvertebrates feed on the microbial community and algae and are, in turn, consumed by fish.

Certain types of microhabitat serve as special niches for aquatic invertebrate species, providing food and/or habitat; for example, many stoneflies are found almost exclusively in leafpacks and on small sticks, and some beetle species prefer edge habitat such as undercut banks. If these habitat types are not present, there is no place for these specialized invertebrates to live and feed.

Background Note: The Stress-Recovery Cycle

Even in relatively pristine streams, aquatic organisms are exposed to periods of stress. Natural stresses due to high flows during storms, low flows during hot dry summer periods or episodic large sediment inputs (e.g., from slope failures in mountain areas or breaching of beaver dams) can have significant impacts on stream communities. Although aquatic communities in high quality streams may be impacted by such disturbances, and some species may be temporarily lost from particular sites, populations are able to reestablish themselves--often very quickly--by recolonization from less impacted areas or refugia (see Yount and Niemi, 1990; Niemi et al., 1990). This process can involve recolonization from backwater areas, interstitial zones (spaces between the cobble and gravel substrate), the hyporheic zone (underground habitats just below the stream bed surface layer) or other available microhabitats. Repopulation from headwaters or tributary streams not impacted by the disturbance can also occur. For insects, aerial recolonization is important as well.

Without robust mechanisms of recovery, even streams subjected to relatively modest levels of disturbance would be unable to support the diversity of aquatic organisms that they often do (Sedell et al., 1990; Frissell, 1997). This balance between local elimination followed by repopulation is critical to the persistence of fish, macroinvertebrates and other organisms in aquatic ecosystems, and is part of what we mean when we say that these creatures are “adapted” to their environment.

It is now commonly recognized that as watersheds experience increased human activity, stream biota are subjected to higher levels of stress. This can include both an increased frequency, duration or intensity of ‘natural’ types of disturbance, such as high flows, as well as completely new stresses, such as exposure to chlorinated organic chemicals. We less often realize, however, that many of these same activities often serve to inhibit those mechanisms that allow streams to recover from disturbances--in particular movement and recolonization (Frissell, 1997). For example, as watersheds develop:

- Channel margin and backwater refugia may be eliminated as bank erosion or direct channel modification (channelization) make channel conditions more uniform and habitat less diverse;
- Edge habitat, such as root mats, may be unavailable to biota due to lowered baseflows;
- Access to interstitial and hyporheic areas may be limited by sediment deposition;
- Impoundments may limit or eliminate drift of organisms from upstream and fish migration from downstream;
- Small headwater and tributary streams may be eliminated (culverted or replaced with storm drain systems);
- Remaining headwater and tributary streams may be highly degraded (e.g., via channelization, removal of riparian vegetation, incision and widening due to increased stormflows, or decreased baseflows);
- Aerial recolonization of macroinvertebrates may be diminished by the concomitant or subsequent degradation of streams in adjacent watersheds; and
- Fish migration is often limited by culverts or other barriers.

As human activity intensifies, aquatic organisms are thus subjected to more frequent and more intense periods of stress, while at the same time their ability to recover from these stresses is severely compromised. It is the interaction between these two processes that results in the failure of many streams to support an acceptable population of fish or macroinvertebrates.

Efforts to restore better functioning aquatic communities in degraded streams must consider strategies to both reduce the stresses affecting stream biota and to protect and restore potential refugia and other sources of colonizing organisms. Under some conditions, the lack of adequate recolonization sources may delay or impede recovery. Protecting existing refugia and those relatively healthy areas that remain in impacted watersheds should be an important component of watershed restoration efforts (McGurrin and Forsgren, 1997; Frissell, 1997).

Due to drought, edge habitat was unavailable to aquatic communities in reference and upper Cullasaja watershed streams. Reference streams still hosted very healthy and diverse benthic communities, despite this lack of edge habitat. Organic microhabitat, however, was abundant in all reference streams and watershed streams with wooded riparian areas (except Mill Creek).

Lack of these microhabitats is an important stressor for the upper Cullasaja River site at River Court and in Salt Rock Branch.

Pesticides

Chemical analysis of baseflow samples from one date and sediment samples did not pinpoint any problematic pesticide levels. Gamma chlordane, an isomer of a chlorinated pesticide, was found in sediment at a level that is probably not toxic to aquatic organisms. Bentazon, a herbicide, was detected at two locations, but at levels that are not toxic. Benthic community data do not point to definite toxic impacts. Impoundments likely serve to mitigate pesticide toxicity; pollutant concentrations are diluted in the ponds. However, available data are not adequate to fully characterize pesticide levels in the Cullasaja River. Due to this limitation and the nature of the watershed's land use (half of the watershed above US 64 is in golf course), pesticides cannot be ruled out as a problem without further sampling. Therefore, they are considered a potential stressor.

Metals

Notable levels of cadmium were found in stormflows and sediment; the stormflow sample had four times the benchmark concentration, and the sediment sample was above the conservative screening range. Because the sediments passed the sediment toxicity test, with no associated mortality or depressed growth, it is unlikely that cadmium levels in the sediments are toxic. Benthic data from the Cullasaja River do not pinpoint toxicity as an overwhelming factor. The US Forest Service found similar cadmium levels in sediments in nearby Scotsmans Creek, which has a largely forested watershed and hosts a healthy aquatic invertebrate community (Richard Burns, personal communication). It is difficult to determine if the high cadmium concentration in the storm sample is problematic, since only the total cadmium concentration was analyzed and bioavailability could not be evaluated. Therefore, cadmium is a potential stressor.

Nutrients

Evidence of high inputs of nutrients has been noted in the East Fork Salt Rock Branch. Heavy growths of epiphytic algae were noted in the winter of 2001 in this tributary. The benthic community in Salt Rock Branch was very tolerant to stress, and although habitat quality was a major stressor for this community, it is likely that water quality impacts were also important.

Conclusion

Based on the information collected during this study, a number of dam-related impacts are considered cumulative causes of impairment for the biological community of the upper Cullasaja River: 1) the prevention of downstream colonization of aquatic organisms and upstream migration of fish by dams on the Cullasaja River and its tributaries; 2) lower water levels; 3) increased temperature for localized areas below dams; and 4) change in food type due to the trapping of coarse particulate organic matter and input of phytoplankton from impoundments Lack of organic microhabitat is a cumulative cause of impairment, as well. Although historically listed as a problem parameter on the 303(d) list, sediment is not considered a cause of impairment for the Cullasaja River. It is a notable problem for some tributaries and many impoundments in the watershed, however. Pesticides, high levels of cadmium, and low dissolved oxygen in localized areas due to dams may contribute to the degradation of the biotic community and are considered potential causes or contributors.

7.1.4 Review of Evidence--Mill Creek

Mill Creek from its source at Lake Ravenel to Mirror Lake is considered impaired. Although there may be a small unimpaired section of Mill Creek below Lake Ravenel that runs through a forested riparian area in the Highlands Biological Station, data collected during this study confirm that most of Mill Creek is impaired.

<u>Toxicants</u>

Although there were some benthic taxa tolerant of toxicants, analysis of the benthic community did not strongly indicate that toxicity was a problem in the Mill Creek mainstem. However, a wide range of contaminants was found in the water column and sediment, sometimes at levels exceeding published benchmarks.

Cadmium, lead, and zinc were found above screening levels in stormflow samples from Mill Creek taken below the town center. However, storm samples with these metal concentrations passed acute toxicity tests. It is likely that these high metal concentrations were not bioavailable, perhaps bound to particulate matter. The sediment sample also had levels of cadmium and zinc that fall within the conservative range of sediment benchmarks, which signifies that it is possible, but not probable, that these concentrations alone cause toxicity to aquatic organisms.

Two tributaries to Mill Creek—the main stormwater tributary from Highlands' town center and a tributary near Highlands' maintenance facility—that were tested for organic pollutants had levels of semi-volatile or volatile contaminants exceeding levels set by EPA for the protection of aquatic life. However, grab samples from Mill Creek immediately below these tributaries did not have not have any detectable levels of organic contaminants.

Although baseflow and stormflow water samples from the Mill Creek mainstem did not have measurable levels of semi-volatile organic contaminants or pesticides, both the sediments and semi-permeable membrane devices (SPMDs) provide a record that these contaminants do come through Mill Creek. Two chlorinated pesticides that are likely from past use—dieldrin and DDE (a breakdown product of DDT)—were found at levels that exceed conservative benchmark levels for the protection of aquatic life.

Mill Creek at 5th Avenue (above the town center) was also characterized by a tolerant and limited benthic community. This site was sampled twice in the summer of 2000, when a large house was being constructed several meters from the stream bank (Figure 7.1). Staff observed small drainage trenches that were dug to the creek from the house. It is possible that runoff or direct inputs from this construction site impacted the benthic community. Staff noted evidence of paint dumping at other house sites along the creek. This site is also below one of the larger tributaries that is likely impacted by the UST at the Town of Highlands' maintenance facility.

Toxic impacts, especially if caused by storm inputs, can be very episodic and difficult to identify. Although evidence suggests that toxicants may be a problem for Mill Creek (e.g., the urban nature of the watershed, resident complaints about chemical odors in Mill Creek, sediment and SPMD data), further monitoring must be performed to determine if toxicants are periodically at high enough levels in the Mill Creek mainstem to be a direct cause of impairment. Toxicants are considered a potential cause or contributor for the Mill Creek mainstem.

The impact of toxicants on tributaries likely plays an indirect role in impairment of the mainstem as well. Pollutant levels appear to be high enough to cause toxicity in these tributaries, limiting their ability to serve as colonization sources for Mill Creek.

Figure 7.1 Construction of house on Mill Creek at 5th Avenue.

Habitat degradation due to sedimentation

Although historically listed as a problem parameter on the 303(d) list, habitat and benthic data from reference streams and Mill Creek provide no evidence that sedimentation is a current cause of impairment for Mill Creek. Reference streams (e.g., Houston Branch) that hosted diverse benthic communities were often characterized by comparable amounts of sand and silt, providing evidence that sedimentation did not severely limit benthic macroinvertebrates in these streams. See discussion on sedimentation in Section 7.1.3.

Habitat degradation due to lack of key microhabitat

Like in the Cullasaja River, organic microhabitat was limited in Mill Creek (see discussion on microhabitat above). This important habitat type was abundant in all reference streams and watershed streams with healthy benthic communities. Due to a healthy forested riparian area above Brookside Lane, there are sources of leafpacks, sticks, and large wood; large wood was common at the monitoring site, but the smaller habitat types were rare.

Stormflow scour

Mill Creek drains much of Highlands, which has a high proportion of impervious cover. This imperviousness increases the volume and energy of stormflows, which can scour aquatic macroinvertebrates and their associated microhabitats (sticks and leafpacks) from the stream.

Lack of colonization sources

Mill Creek has very limited colonization sources. It is dammed below the confluence with Satulah Branch and upstream of the town center. The two larger tributaries below this are likely impacted by the UST site at Town of Highlands' maintenance facility. Another tributary that receives much of the stormflow from the town center is also impacted by organic pollutants. The small tributaries, that feed Mill Creek below the town center flow through residential areas, are often impounded to create small ponds. These tributaries likely have limited value as colonization sources of benthic macroinvertebrates.

Since Mill Creek is exposed to high energy stormflows that likely scour benthic organisms from the stream bed and possibly to toxicants from urban runoff, downstream drift of benthic organisms is a very important mechanism for the maintenance of benthic populations. The lack of quality upstream sources is likely a key stressor for the biological community of Mill Creek.

Conclusion

A primary cause of impairment was not identified for Mill Creek and may not exist. However, the available data point to the cumulative impacts of several stressors. Scour from stormflows and the lack of upstream colonization sources due to toxicants and in-stream impoundments in tributaries are considered cumulative causes of impairment. The lack of organic microhabitat is considered a contributing stressor, as well. Toxicants are a potential cause or contributor for the Mill Creek mainstem. Stormflows may be responsible for scouring benthic macroinvertebrates and organic microhabitat from Mill Creek downstream of the town center, and recolonization of the benthic community after storms and other catastrophic events is limited due to the lack of upstream sources. It is possible that with further study, these stressors could be prioritized and a key stressor isolated. Although sedimentation has been historically listed as a problem parameter on the 303(d) list, it is not considered a stressor for Mill Creek. It is a notable problem for some tributaries and many impoundments in the watershed, however.

7.2 Sources of Impairment

7.2.1 Upper Cullasaja River

Dam impacts

There are three in-stream impoundments in the Cullasaja River and many impoundments along tributaries in the watershed. The two larger in-stream impoundments (Ravenel Lake and the 10 acre impoundment above US 64) likely have the biggest impact on the biological community.

Lack of organic microhabitat

The lack of key microhabitats is an important stressor for Salt Rock Branch and the Cullasaja River at River Court. The removal of the wooded riparian buffer at and upstream of these sites is the source of this problem. There is no local source of leafpacks and wood, since grass borders both of these sites. Although there are some limited upstream sources of organic matter, there is little roughness in these stream channels to catch and hold these key microhabitats. Roughness, provided by boulders, channel sinuousity, and edge vegetation plays the important role of catching leaves and wood from upstream sources. In addition, dams likely serve as a barrier to the downstream movement of organic matter such as leaves and wood.

Pesticides
Gamma chlordane was sampled in sediments, but chlordane, a highly toxic pesticide, has not been allowed for general use since 1988. This is likely a legacy contaminant and its presence from past use. Golf courses can be heavy users of pesticides, using insecticides, fungicides, and herbicides on their greens and fairways. Herbicides and algacides are used in ponds in the golf courses, as well. Residential areas in the golf course communities are also a source of pesticides.

Cadmium
The sources of cadmium have not been determined. Atmospheric sources of cadmium are likely, since cadmium is a product of fuel oil and coal combustion; local residents use fuel oil to heat their homes and in-state and out-of-state power plants burn coal. Cadmium is often associated with phosphate fertilizers (USEPA, 1999a), and fertilizer is used on lawns, golf courses, and in hydroseed mix placed on bare slopes and roadsides. It is also possible that there are natural sources of some of cadmium; mineralization of watershed rock can provide concentrated sources of some metals.

7.2.2 Mill Creek

Pesticides
Both dieldrin and DDT (of which DDE is a breakdown product) are chlorinated pesticides that were banned in the early 1970s. Those measured in the Mill Creek sediments are likely from past use.

Other organic contaminants
Runoff from Highlands' town center and residential areas is one likely source of organic contaminants, including polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and other contaminants. Pollutants build up on roads, parking lots, sidewalks, and roofs and are washed off into storm drains and eventually into Mill Creek during storms. Unauthorized discharges to the storm drain system are also a possible source of contamination.

Based on the information collected during this study, groundwater is impacting Mill Creek tributaries. In the main stormwater tributary from Highlands' town center, semi-volatile organic compounds are likely from one or more leaky underground storage tanks (USTs). These leaky USTs may be undocumented. The larger Mill Creek tributary at the Town of Highlands' maintenance facility is likely impacted by the site of a former leaky UST at the facility.

Metals
Cadmium, zinc, and lead are all common components of urban stormwater (Center for Stormwater Protection, 2000). These metals are found in fertilizers (USEPA, 1999a), which are used in residential landscaping. Metal roofs and pipes can serve as sources of zinc and perhaps cadmium. Car exhaust, tires, and brakes are sources of metals, as well. Atmospheric sources are also likely for both cadmium and lead, since they are by-products of fuel oil and coal combustion. It is also possible that there are natural sources of some of these metals; mineralization of watershed rock can provide concentrated sources of some metals.

Scour

Scour of stream invertebrates and their stream habitat by increased stormflow volume and energy is due to the high proportion of impervious cover in the Mill Creek watershed.

Lack of organic microhabitat

The lack of organic microhabitat (mainly sticks and leafpacks) may be due to two issues—high gradient and stormwater force. Mill Creek below the town is relatively high gradient, and this naturally pushes small organic debris through the system. Reference streams are also high gradient, however, and these small microhabitats were present in these streams. Since Mill Creek receives half of Highlands' stormwater, it has stormflows with much higher volume and energy, which can push sticks and leafpacks through the system with more force.

The lack of organic microhabitat at the upstream site (5^{th} Avenue) is likely due to limited upstream sources and lack of in-stream roughness to catch leaves and sticks.

7.3 Other Issues of Concern

Excess nutrients are a problem in the watershed. Heavy algal growths were noted by staff in East Fork Salt Rock Branch, and intense pond management is needed to control aquatic plants and algal blooms in some impoundments in the upper Cullasaja River watershed. Staff and other observers have noted algal problems stemming from the use of hydroseed mix along roads and other areas. The absence of forested buffers along streams increases incoming light, likely further encouraging algal growth. Fertilizer use by residents and golf courses can also contribute to excess nutrients.

Section 8
Improving Stream Integrity in the Upper Cullasaja River Watershed: Recommended Strategies

As discussed in the previous section, a number of stressors are considered contributing causes of impairment for the Cullasaja River, including lack of organic microhabitat and a number of dam-related impacts. Low dissolved oxygen in localized areas, cadmium, and pesticides are potential causes or contributors to impairment. Mill Creek is likely impacted by a set of cumulative factors, including scour associated with high stormflows and lack of colonization sources due to toxicants and in-stream impoundments in tributaries. A contributing stressor may be lack of organic microhabitat. Toxicants are a potential cause or contributor for the Mill Creek mainstem. This section discusses how these problems can be addressed. A summary of recommendations is included at the end of the section.

8.1 Addressing Current Causes of Impairment

The objective of stream quality improvement efforts is to create water quality and habitat conditions that can support a diverse and functional biological community in this area. While the upper Cullasaja River watershed contains densely populated areas and high impact land use, the watershed has not been so highly modified as to preclude potential for some improvements in stream integrity. A return to pristine conditions that existed prior to human influence is not feasible, but the Cullasaja River and Mill Creek can potentially support much healthier communities than they do today.

8.1.1 Upper Cullasaja River

Dams

The numerous dams on the Cullasaja River and its tributaries impact biological integrity in a number of ways: 1) prevention of downstream colonization of aquatic populations and upstream migration by fish; 2) change in temperature; 3) artificially lower water levels; 4) change in food type; and 5) possible lowered dissolved oxygen in localized areas.

In order to allow downstream colonization, free flow is required in a stream. Beginning at Ravenel Lake, there are three in-stream impoundments on the Cullasaja River above US 64, and many small tributaries that feed this stream section are impounded, as well. The most obvious solution is to remove the dams along the Cullasaja mainstem and some of the dams on the feeding tributaries in order to allow free movement through the river and provide some tributary sources of colonization. This solution would be costly, difficult, and impractical. Preventing the downstream movement of large amounts of sediment that have been trapped in the impoundments would be important. Other solutions could be considered, such as rerouting streams around in-stream impoundments.

By allowing for free flow, the other dam-related issues, such as temperature, change in food type, lowered water levels, and possible dissolved oxygen would be addressed, as well. If free flow around the dams is not attained on the upper Cullasaja River, minimum releases from impoundments could be required in order to assure some minimum flow in the river bed. This would at least lessen low flow-related impacts. However, retrofitting dams to allow for minimum releases would be costly and would not address other significant stressors, such as the prevention of downstream colonization, change in food type, and increases in temperature.

A design incorporating dam removal or other options to allow downstream colonization for the upper Cullasaja River above US 64 and its tributaries is beyond the scope of this study. It should be developed by a group of stakeholders, including golf course representatives and the Division of Water Quality.

Due to the impacts of in-stream impoundments on aquatic communities, the NC Department of Environment and Natural Resources (NCDENR) should reexamine its policy regulating in-stream impoundments. Dams on small streams often do not require notification of or approval from DWQ under the 401 Certification Program if total fill and flooding associated with the pond does not exceed 150 feet of stream. Some small stream impoundments are likely constructed without any DWQ oversight or knowledge. DWQ currently does not require stream mitigation for flooding associated with a dam; if the affected stream length is greater than 150 feet, mitigation is required for filling only. NCDENR should develop a dam policy that protects the aquatic life in small streams and considers the cumulative impacts of multiple dams in a watershed.

The Division of Land Resources regulates dam construction and maintenance with their Dam Safety Program, which has the mission of safeguarding human life and property from damage. Biological integrity of stream communities is not a focus of their program, and small dams are generally not regulated unless they cause a potential hazard downstream. Jurisdictional dams (more than 15 feet in height and impounding at least ten-acre feet) under the Dam Safety Law can be required to maintain minimum flows, and dams that were built before 1967 are not exempt from this requirement.

Habitat degradation due to lack of organic microhabitat

A local source of organic microhabitat can be provided by planting a buffer of native woody species along the Cullasaja River and its tributaries in the golf course communities above US 64 (see Section 6). This wooded buffer will provide edge habitat (root mats, undercut banks) and a source of organic matter, including leaves, sticks, and larger wood. The edge habitat and larger wood will provide roughness to catch the smaller organic microhabitat (leaves and sticks). This solution will benefit the Cullasaja River in the golf course areas, including the monitoring site at River Court.

Within the golf courses, some of the stream sections that have been cleared of woody vegetation are within fairways, where a woody buffer may not be possible. In these areas, it is recommended that large woody debris or boulder clusters be placed in the channel in order to provide some channel roughness to catch smaller organic microhabitat.

Pesticides and nutrients

The limited pesticide analysis that was performed does not provide evidence that pesticides occur at toxic levels in the Cullasaja River. However, the nature of the watershed's land use (half of the watershed above US 64 is in golf course) implies that pesticides have the potential to be a problem. Area golf courses already use management practices to lessen the impacts of pesticides and fertilizers on surface waters (e.g., integrated pest management, untreated buffer zones along waterways). It is important that the golf courses diligently implement these programs and continue to incorporate new methods to prevent pesticide and fertilizer impacts. Because fertilizer can be a source of heavy metals, reduction of its use may reduce the amount of metals entering waterways. Becoming fully certified through the Audubon Cooperative Sanctuary Program for golf courses may be an excellent way to develop a more conservation-oriented management plan.

Further chemical monitoring will be performed by project staff in 2002 to determine the potential impacts of these chemicals.

Watershed residents and grounds staff of the golf course communities should be educated about conservative pesticide and fertilizer use. Conservative use of hydroseed mix should be encouraged.

8.1.2 Mill Creek

Based on the information available, we conclude that scour from stormflows and lack of colonization sources are the key problems for Mill Creek biota. The lack of organic microhabitat is a contributing stressor, as well. Toxicants are an indirect cause of impairment due to their impacts on tributaries and may directly impact Mill Creek, as well. The relative importance and interrelation of these stressors are unclear, however. There are a number of measures that can be taken to improve the quality of Mill Creek, including (1) education, (2) identification and remediation of groundwater and underground storage tank problems, (3) identification and elimination of unauthorized discharges to the stormwater drain network, (4) further monitoring, and (5) stormwater retrofits.

<u>Education</u>
In order to control sources of pollutants, a community education program should be developed, educating Highlands' business owners and homeowners about responsible fertilizer and pesticide use. The construction of in-stream ponds should be strongly discouraged and landowners should be encouraged to replant stream buffer vegetation along Mill Creek and its tributaries.

<u>Groundwater and underground storage tank issues</u>
To reduce the input of toxicants, the source of the semi-volatile organic pollutants in the town's main stormwater tributary should be pinpointed and remediated. The Town of Highlands is currently reexamining possible groundwater and surface water contamination near the leaky underground storage tank (UST) site at the town's maintenance facility. Remediation of contamination sources may be needed to lessen impacts on local streams.

<u>Unauthorized discharges to the stormwater network</u>
Another important component of a strategy to reduce input of toxicants from Highlands will be to identify and remove unauthorized stormwater discharges. These discharges can be quite variable, ranging from a business floor drain to a sewage pipe connection.

Further monitoring
Since monitoring in this watershed has only provided limited information on potential toxicants and their sources, an essential first step in restoring Mill Creek is further sampling and source identification. More surface water monitoring will be performed by project staff in 2002 in tributaries and mainstem creeks to further isolate problem areas.

Stormwater retrofits
Stormwater retrofits are structural stormwater measures (best management practices or BMPs) for urban watersheds intended to lessen accelerated channel erosion, promote conditions for improved aquatic habitat, and reduce pollutant loads (Claytor, 1999). They lessen the volume and energy of stormwater flow, thus, reducing the potential for scour of aquatic organisms and their habitat. A range of practices, including a variety of ponds and infiltration approach may be appropriate depending on specific local needs and conditions. A key design challenge is to maximize hydrologic mitigation and/or pollution removal potential while limiting impacts to infrastructure and existing structures. Highlands' town center should be the priority area for stormwater retrofits due to its high imperviousness.

The suite of available structural and nonstructural retrofit practices to reduce hydrologic impacts have been discussed widely in the literature (e.g., ASCE, 2001; Horner et al., 1994) and in state BMP manuals (e.g., NCDWQ, 1999; Maryland Department of the Environment, 2000). Some of these include:

- detention ponds;
- retention (wet) ponds;
- stormwater wetlands;
- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- 'run on' approaches (regrading) to promote infiltration;
- reducing hydrologic connectivity (e.g., redirecting of downspouts);
- education to promote hydrologic awareness; and
- changes in design/construction standards.

Determining which BMPs (or which combination of practices) are most feasible and effective for a particular catchment depends on numerous site-specific and jurisdictional specific issues, including: drainage patterns, size of potential BMP location, size needed given catchment size, soils, location of existing infrastructure. Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999).

Recommendations for specific stormwater retrofit projects are beyond the scope of this investigation. Specific projects should be identified as part of the development of a restoration plan for the Mill Creek watershed. This plan should be developed with the input of a broad based stakeholder group and should consider water quality goals, other water resource concerns (e.g., flooding), and local infrastructure issues. Since stormwater retrofits are complex and expensive, it is important that further sampling be performed in Mill Creek in order to identify specific toxicants and their sources.

EPA has developed a Phase II stormwater program, mandating that small communities not previously subject to federal stormwater requirements apply for permit coverage. Designated jurisdictions will be required to develop and implement a comprehensive stormwater management program, which must include six minimum measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) unauthorized discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater management for new development and redevelopment; and 6) pollution prevention/good housekeeping for municipal operations. In October 2002, the NC Environmental Management Commission passed a temporary rule governing the implementation of the Phase II program in the state. Under this rule, the designation process will be implemented in accordance with the schedule for development of the Division's basinwide water quality plans. The Little Tennessee River Basinwide Water Quality Plan will next be revised in 2007. At that time DWQ will evaluate whether jurisdictions in the Little Tennessee River Basin, including Macon County and Highlands, should be reviewed for inclusion in the Phase II program. Regardless of whether Highlands is eventually included in the program, it would be useful for the Town to consider developing a stormwater management program that addresses the issues included in the minimum program measures listed above.

8.2 Addressing Future Threats to Stream Integrity

Although excess sediment is not considered a cause of impairment for Mill Creek and the Cullasaja River, it is still a watershed-wide problem (see Section 6 and 7.1.3). Home building will continue in steeper areas of the watershed, and roads, driveways, and construction sites will likely provide a significant source of sediment to streams.

Through ordinances, both Macon County and the Town of Highlands have taken significant steps to control sedimentation and erosion from development (see Section 2.7.1). Regardless of project size, developers of roads and building sites should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas with vegetation and limiting development of steeper areas. Roads and driveways with steep grades (>12%) are difficult to maintain and erode easily (Western North Carolina Tomorrow, 1999); their construction should be discouraged. Eroding road banks can also be a significant source of sediment, and developers should ensure that these are quickly stabilized with vegetation. New road construction projects should use appropriate stormwater controls to reduce velocities and sediment impacts. Macon County and the Town of Highlands should continue to examine the issue of construction on steep slopes and insure that policies provide adequate protection to streams and lakes from erosion and sedimentation. Both of these local programs should be well-funded to insure adequate enforcement of regulations.

8.3 A Framework for Improving and Protecting Stream Integrity

Restoring and protecting streams is not a one shot proposition, but requires an iterative process in which sequential actions are taken over time in conjunction with an effort to monitor changes in stream condition. An organizational framework for ongoing watershed management in the upper Cullasaja River drainage is essential in order to provide oversight for the implementation of projects, evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies can play an important role in this undertaking, planning can be much more effectively initiated and managed at the local level. Coordination between Highlands and Macon County and involvement of a broad range of stakeholders are important components of this process. The Upper Cullasaja Watershed Association, a diverse group of stakeholders involved in water supply and quality issues, could play a key role in designing and coordinating a framework to restore and protect streams in the upper Cullasaja River watershed.

8.4 Summary of Recommendations

The following actions are recommended to address current sources of impairment in the upper Cullasaja River watershed, and to prevent future water quality degradation in the watershed:

Upper Cullasaja River:

1) A strategy to reduce the impacts of dams in Wildcat Cliffs Country Club, the Cullasaja Club, and Highlands Falls Country Club should be developed, including a plan for access to unimpounded colonization sources. *If the problems associated with dams are not addressed, then the recovery potential for the Cullasaja River is limited and other strategies listed below will have limited impacts.*
2) Golf course communities (residential areas and golf courses) should plant wooded buffers along cleared streams, and large woody debris and rock clusters should be placed in the stream channel where wooded buffers are not planted.
3) Pesticide and nutrient management programs at the golf courses should be evaluated to determine ways to further decrease the use of these materials and their potential to enter lakes and streams. Homeowners and landscapers should also be educated about the responsible use of pesticides, fertilizers, and hydroseed mix.
4) Developers should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas and limiting development of steeper areas. New road construction projects should use appropriate stormwater controls to reduce velocities and sediment impacts. Macon County and the Town of Highlands should continue to examine the issue of construction on steep slopes and insure that policies provide adequate protection to streams and lakes from erosion and sedimentation.

Mill Creek:

1) A watershed education program should be developed and implemented with the goal of targeting homeowners, business owners, and local landscapers in order to reduce impacts on local streams. At a minimum the program should include elements to address the following issues:
    a) Importance of riparian vegetation. Landowners should be encouraged to plant native woody riparian vegetation along stream banks and protect current riparian vegetation.
    b) Responsible use of pesticides, fertilizers, and hydroseed mix.
    c) Ideas for residents and businesses to reduce their contribution to stormwater volumes—e.g., redirection of downspouts to pervious areas rather than to driveways or gutters.
    d) The impacts of in-stream dams.
2) The source of high levels of semi-volatile organic contaminants in the main stormwater tributary to Mill Creek should be determined and remediated.

3) Pending results from the Town of Highlands' study of groundwater contamination near the town's maintenance facility, sources of contamination should be remediated, if appropriate.
4) Unauthorized discharges to the stormwater system of Mill Creek should be pinpointed and eliminated.
5) Stormwater retrofits should be constructed to control the quantity and quality of stormwater delivered to Mill Creek. Highlands' town center should be given top priority for retrofits.
6) Developers should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas and limiting development of steeper areas. New road construction projects should use appropriate stormwater controls to reduce velocities and sediment impacts. Macon County and the Town of Highlands should continue to examine the issue of construction on steep slopes and insure that policies provide adequate protection to streams and lakes from erosion and sedimentation.

Section 9
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Appendix A

Benthic Macroinvertebrate Sampling

Division of Water Quality

Watershed Assessment and Restoration Project

March 11, 2002

MEMORANDUM

To:	Jim Blose
Through:	Trish MacPherson
From:	John Giorgino
Subject:	Macroinvertebrate sampling of the Cullasaja River, Mill Creek and selected tributaries, Macon County.

BACKGROUND

The Cullasaja River is located in Macon County in the Little Tennessee River (LTN) subbasin 01. The Cullasaja River, Tuckasegee River and Cartoogechaye Creek are the major tributaries (tribs) to the Little Tennessee River. Although the water quality of streams and rivers in this subbasin is generally rated Good-Excellent based on benthos data, parts of the LTN basin are being rapidly developed with resultant water quality problems.

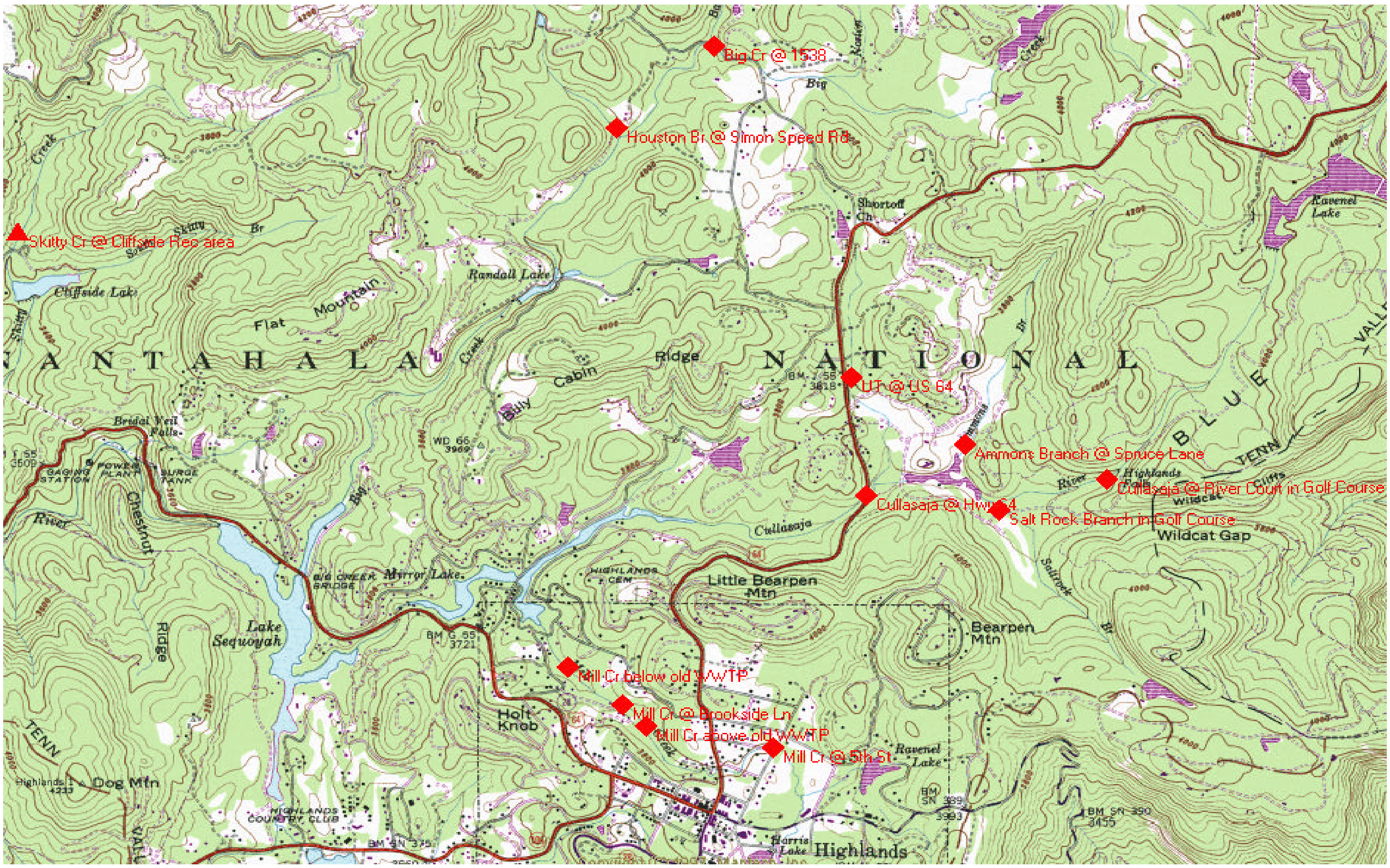
This survey of the Cullasaja River focuses around the town of Highlands, a popular summer retreat for out-of-state visitors. According to the chamber of commerce, the population increases from 3,000 people in winter to 20,000 people in summer. Because of the aesthetic attraction, a large portion of the development is along stream corridors. The impacts to the Cullasaja River and its main tributary, Mill Creek, are prime examples of how development is affecting water quality. The Cullasaja and its tributaries become turbid with sediments after rainfall (personal observation). The soil that is found on the Highlands plateau is very fragile and easily erodable with only minimal disturbance. Its soils are in the Edney-Plott-Chestnut-Cullasaja series, which are rock outcrop and loamy soils that formed in material weathered from high-grade metamorphic or igneous rocks or in colluvium (USDA 1996).

The Cullasaja River flows through two country clubs (Cullasaja Club and Wildcat Cliffs) in the headwaters and then through another country club (Highland Falls) before crossing US 64 just north of Highlands. The river then empties into Mirror Lake (a run of the river lake) and Lake Sequoyah to the west. The impaired section of the Cullasaja River is its headwater section – 4.8 miles from its source to Mirror Lake.

Mill Creek begins at the Highlands Biological station and flows through the town center of Highlands. Before it empties into Mirror Lake, it courses through a wooded residential area. The entire length of Mill Creek is listed as impaired - 1.4 miles from its source to Mirror Lake.

The impaired sections of these two streams drain a developed watershed of approximately 6 square miles.

MAP OF THE CULLASAJA RIVER AND MILL CREEK STUDY SITES



LIST OF THE CULLASAJA RIVER AND MILL CREEK WATERSHED HISTORIC AND CURRENT SAMPLE STATIONS

Cullasaja River Sites

Cullasaja River at River Court (CUCR11). This is the uppermost site sampled on the Cullasaja and is located within the Highlands Falls Country Club. Prior to this survey, the River Court site had never been sampled. At this point, the river is 3 meters wide and is bordered by the playing green within the golf course. The substrate is mostly gravel, with some rubble and sand. Pools and riffles in this reach are considered infrequent. There are no snags or logs and very little detritus. Because this reach is located in the golf course, there are no trees nearby to provide leaf packs. There were no undercut banks or root mats that would be considered suitable habitat for benthic organisms. When visited in 2001, there was a significant increase in silt from the previous survey in 2000. Although there is no wooded riparian zone, the banks are stable and are held by

grass. It is likely that the stream has been moved or channelized to accommodate the golf course.
Cullasaja River at US 64 (CUCR01). This is the historic sampling site on the Cullasaja, located just north of Highlands. At this point, the Cullasaja has flowed through 3 golf courses with numerous residential areas. There are no more golf courses downstream from US 64, but low-density residential areas can be found in this forested area. Here, the river is 5 meters wide and about 0.5 meters deep. When last sampled in 2000 and 2001, there were significant amounts of sand and silt at this location. Root mats were out of the water and undercut banks were non-existent. Some leaf packs were available for colonization, pools, riffles and snags were present. The riffles were primarily formed from organic debris, and not from rocks. The riparian zone was intact on both banks with diverse trees and shrubs. The habitat score was 69 in 2000 and 2001.

Mill Creek Sites
Mill Creek at 5th Avenue (CUMC14). This site was sampled in May and August 2000 and is located at the eastern edge (beginning) of the Highlands business district and is downstream from the confluence of Satulah Branch. Below the confluence there is a beaver pond and swampy area. Immediately upstream from this site are mostly residential areas with some housing very close to the creek. At the site, a house was being constructed / remodeled within 10 feet of the water. The creek was only 2-3 meters wide when sampled, due to the low water conditions for both sampling events. When sampled for the second time in August, the water was lower than the May survey. The riffle area was man-made by the placement of small boulders and rubble to create a pooled area. Leaf packs, snags, logs and undercut banks were scarce. Some root mats were present, but were unavailable for colonization because of the low water. When sampled in August, sand and silt comprised 60% of the substrate and had a habitat score of 49. The habitat score in May was 70. The higher score was probably due to the higher flow than the August survey.

Mill Creek above the old WWTP. This site was sampled in 1990 and 1991 by the Biological Assessment Unit (BAU) to assess the effects of the (old) Highlands WWTP on Mill Creek and the upper reaches of the Cullasaja. At this point, the creek is about 3 meters wide and about 0.1 meters deep. In 1991, the substrate mix consisted of 45% boulder, 25% rubble, 10% gravel and 20% sand. There were good riffle areas here and pools, snags, undercut banks and root mats were considered common. A green tinge to the water was noted and nutrient enrichment was suspected.

In 1985, the town of Highlands applied for an increase in its discharge from its wastewater treatment plant and a relocation of the discharge to the Cullasaja River below Lake Sequoyah. The plant was relocated in 1994 and is currently permitted for 0.5 million gallons per day (MGD).

Mill Creek below the WWTP. The Biological Assessment Unit sampled this reach in 1990, 1991 and again in 1999. In 1990 and 1991 the habitat appeared to be similar to the reach above the WWTP. Substrate composition was also similar. When sampled in 1999, riffles were not as abundant as in 1990 and 1991, and snags and root mats were not present.

Mill Creek at Brookside Lane (CUMC02). This site, also below the old WWTP, was sampled as part of the Watershed and Restoration Project. It is located just downstream of the BAU site mentioned above, and was chosen because the habitat appeared more suitable for benthic colonization and had better flow. While there is a wooded area upstream from the site, the sample reach itself is bordered by a residence and a house under construction. There was a good mix of substrates with 60% rubble and gravel. There were 2 small tributaries present within the sample reach, which was approximately 3 meters wide. There is a common practice in the area of developing pools in streams behind homes by stacking small boulders and rubble (as mentioned in the 5th Street site). This site was not an exception. The manmade pools were quite sandy while the natural pools were not, probably due to the better flow within the natural pools. Although snags and logs were common, sticks and leafpacks were considered rare. There were some undercut banks and root mats, but most were unavailable for colonization by benthic organisms because of low flow. Overall, erosion was considered moderate, but was more severe where the new construction was taking place. The overall habitat score was 76.

Selected Tributaries Sampled

UT Cullasaja at US 64 (CUCR04). This site is located approximately 1 mile north of where the Cullasaja crosses under US 64. It is a small tributary (3.0 meters) that generally flows south, parallel to US 64 and drains an area less than 1 square mile. At first glance, the habitat appeared to be very good, despite its location near the road and a store. However, at the upper end of the sample reach the habitat changed significantly. A private driveway crossed the stream over bedrock, and the stream grade became much flatter. Above the driveway, there were grass banks on both sides of the stream. The sample reach had a habitat score of 87.

Saltrock Branch at Falls Drive (CUSB03). This site is located in Highland Falls Country Club just above the confluence with the Cullasaja River. The habitat here is poor. The substrate was dominated by silt with some sand and sparse gravel. This tributary has a small drainage area and is only 1 meter wide at the sample site. Although it flows through the playing greens and golf course residence yards, the banks are stable with grass down to the waters edge.

Reference Sites (4 meters wide)

Big Creek at SR 1538 (CUBC16). This reference site is located north of the Cullasaja River and drains a forested area that contains an occasional residence. The station is located just below the confluence with Bad Branch. Big Creek eventually drains into Lake Sequoyah, west of the Cullasaja River. The width at the sample site was about 4 meters and the average depth was 0.5 meters when sampled in 2001. The habitat was considered diverse and scored 89. There was a mix of boulders, rubble, gravel and sand. The 2001 survey took place during a rain event, which brought flow conditions up to what was thought to be normal levels. In 2000, low flow conditions made root mats and undercut banks unavailable for benthic colonization.

Reference Sites (less than 4 meters wide)

Houston Branch at Simon Speed Road (CUHB17). This site is located downstream of the Big Creek site, just before Houston Branch drains into Big Creek. Similar to the Big Creek drainage, Houston Branch flows through a heavily forested area with few residences. When sampled in 2000, this small stream (1 meter) had very low flow conditions. Although there were a good mix of substrates and good instream habitat, undercut banks and root mats were often not available for colonization by benthic organisms because of the low water. The average midstream depth was only 0.1 meters and the maximum depth was 0.2 meters. The habitat scored 82, which was considered very diverse.

North Skitty Creek at Cliffside Recreation Area (CUSC18). This site is heavily forested and located within a federally operated recreation area in the Nantahala National Forest. There are no residences in the immediate area. Downstream, the creek flows into Cliffside Lake and then into the Cullasaja River, well below Lake Sequoyah. The creek was about 2 meters wide with an average depth of 0.1 meter. The sample reach was located off the parking area, downstream from the forest service road. Although upstream sites are usually selected to eliminate any affect from the road, the reach above the road culvert was considered too sandy, with less than ideal habitat. This site was also sampled in 2000 when low-flow conditions prevailed. Even though undercut banks and root mats were not available for benthic colonization, the instream habitat was diverse and the stream had a good mix of substrates. The habitat score was 92.

Ammons Branch at Spruce Lane (CUAB15). This site is located in the Highlands Falls Country Club. Ammons Branch flows into the north side of the same golf course lake that the Cullasaja River flows into from the east. The reach surveyed is just above the impoundment in a heavily forested catchment. There was a good mix of substrates that was dominated by gravel and rubble. This small 2 meter wide stream had an average depth of 0.1 meter. The flow was considered low despite rain the night before it was sampled. Undercut banks and root mats could generally not be colonized by benthic organisms because of the depth. Overall, the habitat was diverse and scored a 93.

METHODS

Benthic macroinvertebrates were collected using the Division of Water Quality's (DWQ) standard qualitative sampling procedure at the Cullasaja River, US 64 site in 1999, 2000 and 2001. It was also used at Mill Creek, above the WWTP and below the WWTP in 1991 and 1999 and also at the Big Creek and SR 1538 site in 2000. This method includes 10 composite samples: 2 kick-net samples, 3 bank sweeps, 2 rock or log washes, 1 sand sample, 1 leafpack sample, and visual collections from large rocks and logs. The purpose of these collections is to inventory the aquatic fauna and produce an indication of relative abundance for each taxon.

The Cullasaja River at River Court in 2000, Mill Creek at 5th Street, Mill Creek at Brookside Lane, Houston branch and North Skitty Creek were sampled using a modification of the Division of Water Quality's standard qualitative sampling procedure called a Qual 4. This type of collection is intended to assess between-station differences in water quality. Four composite samples were taken at each of these sites: 1 kick, 1 sweep, 1 leafpack and 1 visual collections. All taxa were collected and identified at the above Qual 4 sites.

Qual 5 samples were done at the Cullasaja River at River Court, Big Creek at SR 1538, Ammons Branch at Spruce Lane and Salt Rock Branch at Falls Drive in 2001. It differs from a Qual 4 by adding a rock and log wash.

EPT samples were collected from the Cullasaja River at US 64 site in 1990, 1991 and 1996. The same sampling technique as a Qual 4 was used, however only EPT taxa were collected.

Several data-analysis summaries (metrics) can be produced from standard qualitative samples to detect water quality problems. These metrics are based on the idea that unstressed streams and rivers have many invertebrate taxa and are dominated by intolerant species. Conversely, polluted streams have fewer numbers of invertebrate taxa and are dominated by tolerant species. The diversity of the invertebrate fauna is evaluated using taxa richness counts; the tolerance of the stream community is evaluated using a biotic index. EPT taxa richness (EPT S) is used with DWQ criteria to assign water quality ratings (bioclassifications). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera, insect groups that are generally intolerant of many kinds of pollution. Higher EPT taxa richness values usually indicate better water quality. Water quality ratings also are based on the relative tolerance of the macroinvertebrate community as summarized by the North Carolina Biotic Index (NCBI). Both tolerance values for individual species and the final biotic index values have a range of 0-10, with higher numbers indicating more tolerant species or more polluted conditions. Water quality ratings assigned with the biotic index numbers were combined with EPT taxa richness ratings to produce a final bioclassification, using criteria for mountain streams.

With Qual 4 procedures, the rating of small streams using a size correction factor is reserved for unimpacted high quality waters. Other streams that are too small to rate, but meet the criteria for a Good-Fair or higher rating using the EPT criteria are given a designation of NI for Not Impaired. Any small stream site that would not be Good-Fair or higher is listed as Not Rated. Because Qual 5 rating methods are still being developed, any stream sampled with Qual 5 procedures is Not Rated.

EPT abundance (EPT N) and total taxa richness calculations also are used to help examine between-site differences in water quality. When the EPT taxa richness rating and the biotic index differ by one bioclassifaction, the EPT abundance value was used to produce the final site rating

RESULTS AND DISCUSSION

All data is summarized in the attached appendices. Appendix AA is the summary of all sites on the Cullasaja River and Appendix AB is the taxa list for those sites. Appendix AC is the summary of all sites on Mill Creek and Appendix AD is the taxa list for those sites. Appendix AE is the summary for reference sites and tributaries and Appendix AF is the taxa list for those sites.

Reference Sites

Big Creek at SR 1538. This site was sampled in the summer of 2000 and 2001 as a reference for the Cullasaja. This reach is heavily wooded with minimal disturbance in the catchment. When sampled in 2000, low flow conditions all but eliminated undercut bank and root mat habitats. Despite the low water, the habitat score was 83. Sand comprised 75% of the substrate. Although this can be considered somewhat high, this region has soils that are well drained, sandy and erodable. The EPT richness was 41 and the EPT abundance was very high at 208 (see Table 7 below). The BI was 3.55. This site yielded an Excellent bioclassification.

When sampled in 2001, habitat conditions changed significantly. Sampled during an all day rain, flow conditions were elevated compared to the previous sample. Sand now comprised only 25% of the substrate. The EPT richness dropped to 29 and EPT abundance also dropped to 104 (Table 1), the BI was 2.86.

The 2001 sample was not rated because there are no criteria to rate Qual 5 samples, including high quality unimpaired mountain streams. However, the community is still typical of a high quality mountain stream.

Some indicator species found in abundance at each survey were the mayflies *Baetis pluto* and *Stenonema meririvulanum*, the stoneflies *Acroneuria abnormis*, *Leuctra* and *Malirekus hastatus*, and the caddisfly *Dolophilodes* spp. These organisms are predominately intolerant.

Of importance here, is the abundance of sand and low water conditions at the first survey. Sand, and the lack of some instream habitat did not in itself yield a bioclassification that suggests an impacted community. The fragile soil in this region often naturally contributes to large sand deposits in streams.

Table 1. Big Creek at SR 1538

Location	Big Creek SR 1538	Big Creek SR 1538
Date	8/29/00	7/25/01
Total Taxa Richness	103	49
EPT Richness	41	29
EPT Abundance	208	104
Biotic Index	3.55	2.86
EPT BI	2.48	2.22
Bioclassification	Excellent	Not Rated
Sample Type	Full Scale	Qual 5
Width (meters)	4	4

Houston Branch at Simon Speed Road. This one meter wide reference stream is a tributary to Big Creek and located just downstream from Big Creek at 1538. This site on Houston Branch only drains about a one half-square mile catchment and flows through a heavily forested area with little disturbance. When sampled, very low flow conditions existed. The maximum depth was only 0.2 meters. The substrate consisted mostly of gravel (25%), sand (30%) and silt (20%). Despite its small size, the EPT richness was 25 and the EPT abundance was 122 (Table 2).

Some indicator species found here in abundance were the mayflies *Baetis brunneicolor* and *Isonychia* spp., the stoneflies *Leuctra* spp., *Malirekus hastatus* and *Tallaperla* spp., and the caddisflies *Diplectrona modesta*, *Parapsyche cardis* and *Pycnopsyche* spp.

Using the stream size correction factor (1.45) for EPT taxa for unimpaired high quality mountain streams 1-2 meters wide, the bioclassification is Excellent.

This is another example of an undisturbed stream with half of its substrate in sand and silt that is able to maintain a viable and diverse benthic community because of minimal disturbance in the watershed.

<u>North Skitty Creek at Cliffside Recreation Area.</u> This is a small 2-meter wide stream located within a heavily forested recreation area. When visited in 2000, low flow conditions prevailed. The average depth was only 0.1 meters. This site was sampled downstream from the road crossing because of the upstream sandbars. At the survey site, sand made up for 30% of the substrate, gravel 15%, rubble 30% and boulders 25%. Taxa values were very similar to the Houston Branch site. EPT Richness was 28, and the EPT abundance was 102 (Table 2). The bioclassification was Excellent.

Unimpaired water indicator species found here in abundance were the mayflies *Stenonema meririvulanum* and *Stenonema pudicum*, the stoneflies *Leuctra* spp. and *Tallaperla* spp., and the caddisfly *Diplectrona modesta*.

This is another example of an undisturbed site with large amounts of sand deposition that appear to be a natural occurrence.

<u>Ammons Branch at Spruce Lane.</u> Located within another heavily forested catchment, the Ammons Branch site drains an area under 0.5 square miles and is 2 meters wide. This station had a slightly lower EPT richness value than the other reference sites primarily because of the lack of mayflies found here (*Stenonema meririvulanum* was the only species found). The EPT richness was 20 and the EPT abundance was 104 (Table 2). The lack of mayflies was probably due to the low pH at the site (5.4). At the other reference sites, pH values ranged from 7.2 to 6.6 units. The low value could be attributed to acid precipitation or a naturally occurring state due to the local geology and vegetation. The substrate consisted of boulders (10%), rubble (30%), gravel (30%), sand (15%) and silt (15%).

Some high quality water indicator species found here in abundance were the mayfly *Stenonema meririvulanum*, the stoneflies *Leuctra* spp. and *Tallaperla* spp., and the caddisflies *Lepidostoma* spp., *Neophylax mitchelli* and *Pycnopsyche* spp.

Table 2 below shows a comparison between the 3 small reference streams (2 meters or less). Mean EPT and BI values were calculated to establish expected values from small unimpaired streams in the area.

Table 2. Comparison between Houston Branch, North Skitty Creek and Ammons Branch including mean EPT values.

Location Date	Houston Branch Simon Speed Rd 8/29/00	N Skitty Creek Cliffside Rec Area 8/29/00	Ammons Branch Spruce Lane 7/25/01	Mean Values
Total Taxa Richness	47	45	47	46
EPT Richness	25	28	20	24
EPT Abundance	122	102	104	109
Biotic Index	2.70	2.35	2.94	2.66
EPT BI	1.97	1.61	1.15	1.58
Bioclassification	Excellent	Excellent	Not Rated	
Sample Type	Qual 4	Qual 4	Qual 5	
Width (meters)	1	2	2	

Cullasaja River Sites

Cullasaja River at River Court. This uppermost site on the Cullasaja was sampled in 2000 (spring) and 2001 (summer). The spring sample had significantly more mayflies than the summer sample. Table 3 gives the EPT values and compares them to North Skitty Creek and Big Creek reference sites. This site exhibited an abundance of species tolerant of low quality water or poor habitat. Some examples are the chironomids *Conchapelopia* group (abundant in the spring sample and common in the summer sample), *Polypedilum illinoense* (common in the summer sample) the caddisfly *Hydropsyche betteni* (abundant in the spring sample and common in the summer sample) and the gastropod *Physella* spp. Additionally, *Cricotopus bicinctus*: C/O sp1 (abundant at both samples) and *Conchapelopia* group (abundant in 2000) can be indicators of toxicity.

Although the River Court site was sampled at two different seasons (spring usually has a greater abundance of the short lived mayflies), it does not account for the significant drop in EPT abundance from 121 in the spring of 2000 to 44 in the summer of 2001. Additionally, a Qual 5 sample was conducted in 2001, which added a rock and log wash that was not done with the Qual 4 sample in 2000. As mentioned in the reference stream section, there was a dramatic drop in EPT abundance at the Big Creek site when sampled during the same time in 2001, compared to the summer of 2000. The higher flows in 2001 may have been one factor in the reduced number.

The EPT richness at the River Court site indicates a not impaired rating (Good-Fair) in 2000. It was Not Rated in 2001. If this reach of the stream was wooded and had an intact riparian zone, overall rating values might increase.

Table 3. Cullasaja River at River Court, North Skitty Creek and Big Creek

Location	Cullasaja R River Court	Cullasaja R River Court	N Skitty Cr Cliffside Rec Area	Big Creek SR 1538	Big Creek SR 1538
Date	5/16/00	7/26/01	8/29/00	8/29/00	7/25/01
Total Taxa Richness	61	56	45	103	49
EPT Richness	25	16	28	41	29
Seasonal Correction	20				
EPT Abundance	121	44	102	208	104
Biotic Index	4.85	5.77	2.35	3.55	2.86
EPT BI	3.72	4.63	1.61	2.48	2.22
Bioclassification	NI (Good-Fair)	Not Rated	Excellent	Excellent	Not Rated
Sample Type	Qual 4	Qual 5	Qual 4	Full Scale	Qual 5
Width (meters)	3	3	2	4	4

Cullasaja River at US 64. This station, located downstream from River Court is significantly different from that site. Here, the Cullasaja is about 5 meters wide with better overall habitat. The Biological Assessment Unit (BAU) first began sampling this site in 1990 (Table 4). It was again sampled by BAU (because of its impaired status in 1990) in 1991, 1996 and 1999. The Watershed Assessment and Restoration Project (WARP) sampled this site in 2000 and 2001. In 1990, this reach was given a Fair bioclassification. In 1991, the bioclassification dropped to Poor and then increased to Fair for subsequent surveys. The 1991 and 1996 surveys were both done during the fall sample season (October). The EPT richness and abundance values increased significantly enough from 1991 (9 and 38 respectively) to 1996 (18 and 66 respectively) to help upgrade the bioclassification. The surveys in 1999, 2000 and 2001 were conducted during the summer sampling season using DWQ's standard sampling procedure (Full Scale). The summer surveys show very little change over the last 3 years. When comparing this site to the upstream site (River Court), the benthic data shows that the upstream site appears to have slightly better water quality despite poorer habitat.

The low EPT richness and abundance values and the Biotic Index values for all surveys indicate a tolerant benthic community. In general, the community composition is indicative of poor habitat and possible toxic stress. For example, the species assemblage of the Chironomids *Cricotopus bicinctus*: C/O sp1, *Cricotopus varipes* C/O sp 6 and *Conchapelopia* group are tolerant to a variety of toxicants. A possible source could be anything from pesticides and herbicides (as used on golf courses or residential yards) to treating new construction foundations for termites.

An area of concern is the amount of silt that has increased over the past 3 years. Prior to 1999, silt was not a significant component of the substrate, but increased to 25% in 2001. Rubble decreased from being 30% of the substrate in 1996 to 10% in 2001.

Approximately 1/5 of a mile upstream from the US 64 site, the Cullasaja is dammed to form a golf course impoundment. The dam would likely cause flow irregularities, which would severely limit any downstream drift of benthic organisms that could provide the US 64 site with recolonization if communities get decimated from scouring or any possible chemical slugs from the impoundment in the golf course. Although aerial dissemination will readily occur, it is a slower and more seasonal process than downstream drift. This might help explain the lower values at this site.

Table 4. Cullasaja River at US 64

Location	Cullasaja R US 64	Cullasaja R US 64	Cullasaja R US 64	Cullasaja R US 64	Cullasaja R US 64	Cullasaja R US 64
Date	12/11/90	10/16/91	10/14/96	6/23/99	8/28/00	7/25/01
Total Taxa Richness				47	65	41
EPT Richness	14	9	18	14	18	10
EPT Abundance	72	38	66	66	57	43
Biotic Index				5.7	6.34	6.55
EPT BI	4.87	5.59	4.82	4.97	5.12	5.92
Bioclassification	Fair	Poor	Fair	Fair	Fair	Fair
Rubble %	25	25	30	10	15	10
Silt %	0	0	5	0	15	25
Sample Type	EPT	EPT	EPT	Full Scale	Full Scale	Full Scale

Mill Creek Sites

Mill Creek at 5th Street. This is the most upstream site sampled on Mill Creek. When sampled in May and August of 2000, low flow conditions existed. As a result, this small 2-3 meter wide stream had no undercut banks or root mats available for colonization. A large part of the substrate consisted of sand. This area is in a residential section of Highlands. There was an abundance of tolerant benthic organisms collected at both surveys, which included the mayfly *Stenonema modestum*, the caddisflies *Cheumatopsyche* and *Hydropsyche betteni*, and the chironomid *Conchapelopia*. The EPT richness in May was 13 and in August it was 11 (see Table 5 below). One winter stonefly (*Amphinemura*) was collected in May. Total taxa richness values remained about the same with dipterans being the predominant taxa. EPT abundance values dropped from 57 in May to 42 in August. This was probably due to the seasonal change (short-lived spring species) and to the lower water levels in August.

The low EPT richness and abundance values and the Biotic Index values for both surveys indicate a tolerant benthic community, and do not indicate a single specific problem. The abundance of the *Conchapelopia* group at both surveys may indicate some toxicity, although this taxon is tolerant of many kinds of stress. Low water levels during both surveys (resulting in poor flow) probably helped reduce EPT richness and abundance values. Additionally, there was a significant lack of leafpacks that not only provide refugia, but also food for shredder macroinvertebrates. Small streams are generally driven by leaf input. Considering the location of this site and the proximity of human disturbance along the reach, there are probably multiple sources of runoff that can be toxic to the benthic community.

When comparing this site to the North Skitty Creek reference site (which was sampled on the same day in August 2000) total taxa richness, EPT richness and EPT abundance values were about double Mill Creek values (Table 8). Using the rating system for unimpacted high quality small streams; the bioclassification for N Skitty Creek is considered Excellent.

The North Skitty Creek catchment is virtually free from any human disturbance. Although North Skitty Creek was also sampled late in the summer when most sticks and leafpacks from the fall have flushed through the system, they were still found to be common. Another major difference from Mill Creek was the well-defined riffle and run sections and frequency of pools despite low water. North Skitty Creek is about 2 meters wide and Mill Creek varied from 2-3 meters wide.

Table 5. Mill Creek at 5th Street and North Skitty Creek

	Mill Cr	Mill Cr	N Skitty Creek
Location	5th Street	5th Street	Cliffside Rec Area
Date	5/17/00	8/29/00	8/29/00
Total Taxa Richness	37	41	45
EPT Richness	13	11	28
EPT Abundance	57	42	102
Biotic Index	5.54	6.14	2.35
EPT BI	4.51	5.36	1.61
Bioclassification	Not Rated	Not Rated	Excellent
Sample Type	Qual 4	Qual 4	Qual 4
Width (meters)	3	2	2

Mill Creek above the old wastewater treatment plant (WWTP). This site was surveyed in 1990 (winter) and 1991 (fall) by BAU to assess the impact of the WWTP (Table 6). An EPT sample was used in 1990 and a Full-Scale sample was used in 1991. Both investigations would result in a Fair bioclassification if using large stream criteria with the impairment being due to "runoff from the highly urbanized Town of Highlands" as reported in the 1997 LTN River basinwide management plan.

Only 2 plecoptera were found in 1990, *Leuctra/Allocapnia* spp. and the winter stonefly *Taeniopteryx*. The 2 ephemeroptera that were abundant were *Stenonema modestum* and *Stenonema pudicum*. In 1991 there were no stoneflies found and the full scale survey yielded an EPT abundance of 50 and a BI of 5.47 indicating an impacted site.

As early as 1989, Highlands recognized the need to maintain the integrity of their surface waters and developed a land use plan that addressed the need to "maintain or improve the present quality of the natural environment". Additionally, in 1992 a Soil Erosion and Sedimentation Control Ordinance was enacted followed by a Watershed Buffer Plan in 1994.

Mill Creek at Brookside Lane. This site is just downstream from the previous site (Table 6) and was chosen because of the better habitat and flow conditions than the old site. There was a good mix of substrates at this site with over half being rubble and gravel. The habitat score was 76 despite the stream side houses (one under construction) located on the right bank. When comparing this site to the Mill Creek at 5th Street site sampled the prior day, there was an improvement in habitat here. There was an abundance of the

Conchapelopia group indicating the possibility of some toxicity and a water quality problem.

EPT richness at Brookside Lane was 17 and EPT abundance was 77. The BI was 5.48. The biotic index for this reach on Mill Creek would be indicative of a Fair rating if using criteria for a larger stream (not a high quality water small stream).

Mill Creek below the old WWTP. This site was part of the WWTP impact study mentioned above. In 1990 the width at this station was recorded at 3 meters. Using criteria for a larger stream, the bioclassification would be Fair. In 1991 and 1999, the width was recorded as 5 and 4 meters respectively and yielded a Fair and Good-Fair bioclassification.

It was sampled in 1990, 1991 and again in 1999 to see if any improvement or recovery had taken place. When sampled in 1990 and 1991, there was no significant difference between the sites above and below the WWTP, suggesting the WWTP itself was not further impacting the creek. This indicates that an impact was being delivered above the WWTP. During the 1999 survey, EPT abundance rose to 91 and the BI was 4.53 (Table 6). This change and the appearance of the plecopterans *Allocapnia/Leuctra* spp. and *Malirekus hastatus* and the reappearance of the 2 ephemeroptera *Stenonema modestum* and *Stenonema pudicum* shows some downstream recovery over time not necessarily related to the WWTP. The bioclassification rose to Good-Fair.

Table 6. Comparison of sites immediately above and below the old WWTP on Mill Creek

Location	Mill Cr Above WWTP	Mill Cr Above WWTP	Mill Cr Brookside Lane	Mill Cr Below WWTP	Mill Cr Below WWTP	Mill Cr Below WWTP
Date	12/12/90	10/16/91	8/28/00	12/12/90	10/16/91	6/22/99
Total Taxa Richness		36	47		50	44
EPT Richness	15	12	17	17	12	15
EPT Abundance	59	50	77	50	40	91
Biotic Index		5.47	5.48		5.49	4.53
EPT BI	4.25	4.41	4.51	3.14	3.90	3.69
Bioclassification	Not Rated	Not Rated	Not Rated	Not Rated	Fair	Good-Fair
Sample Type	EPT	Full Scale	Qual 4	EPT	Full Scale	Full Scale
Width (meters)	3	3	3	3	5	4

Selected Tributaries Sampled

Unnamed Tributary (UT) to the Cullasaja at US 64. This small tributary parallels US 64 and has limited commercial and residential property within its drainage (less than one square mile). Located north of Highlands's business district, development is restricted to roadside stores and homes. Although the habitat score was 87 at the immediate survey site, just upstream from the sample reach the habitat degraded because of a change in stream morphology. Upstream, the grade flattened out and had grassy banks with few trees. There was also a bedrock driveway across the stream with a residence within 30 meters. The sample site was at a parking area for commercial property (Gourmet

Central) where the stream entered a culvert and flowed under the bridge/driveway to the store.

When sampled in the summer of 2001, EPT richness was 23, total taxa richness was 46 and the BI was 3.32 (Table 7). Some intolerant stoneflies that are predominately found in high quality water streams, such as *Malirekus hastatus* and *Tallaperla* spp. were found here. If rated using criteria for a large stream, the bioclassification would be Good.

This tributary is a good representation of a small mountain stream with good habitat and marginal disturbance in the catchment that is able to maintain some intolerant benthic communities. What makes this stream different from the in town areas sampled is the limited disturbance within its watershed. For example, when comparing this site to Mill Creek at Brookside Lane the overall habitat (and habitat score) is very similar but taxa values and the BI are very different. The Mill Creek catchment has more impervious surface, which may or may not affect habitat but is affecting water quality.

Table 7. UT to the Cullasaja at US 64 and Mill Creek at Brookside Lane

Location	UT Cullasaja US 64	Mill Creek Brookside Lane
Date	7/25/01	8/28/00
Total Taxa Richness	46	47
EPT Richness	23	17
EPT Abundance	125	77
Biotic Index	3.32	5.48
EPT BI	2.38	4.51
Bioclassification	Not Rated	Not Rated
Sample Type	Qual 5	Qual 4
Width (meters)	3	3

Saltrock Branch at Falls Drive. This site in Highlands Falls Country Club is within the actual playing area so there are no trees or shrubs along either bank. The drainage area is about 1.5 square miles. Saltrock Branch courses through a forested area before it meets the Cullasaja above an impoundment in the golf course. This is a highly impacted reach, only 1 meter wide with 60% of the substrate composed of silt, 25% sand and 15% gravel. No stoneflies were found here. *Baetis pluto*, the only mayfly found, is a common mountain and piedmont species. Three caddisfly taxa were found: *Cheumatopsyche* spp. (very tolerant), *Hydropsyche betteni* (very tolerant) and *Pycnopsyche* spp. (a ubiquitous species). The BI was 6.54. Table 8 compares Saltrock Branch with the Houston Branch and North Skitty Creek reference sites of similar width.

Considering the size and drainage area of Saltrock Branch, it is not likely to be a major contributing factor to the impairment of the Cullasaja. Very poor habitat appears to be a limiting factor for benthic colonization along this reach.

Table 8. Saltrock Branch at Falls Drive (Highlands Falls Country Club), Houston Branch and North Skitty Creek

	Saltrock Branch	Houston Branch	N Skitty Creek
Location	Falls Drive	Simon Speed Rd	Cliffside Rec Area
Date	7/26/01	8/29/00	8/29/00
Total Taxa Richness	43	47	45
EPT Richness	5	25	28
EPT Abundance	36	122	102
Biotic Index	6.54	2.70	2.35
EPT BI	5.52	1.97	1.61
Bioclassification	Not Rated	Excellent	Excellent
Sample Type	Qual 5	Qual 4	Qual 4
Width (meters)	1	1	2

SUMMARY AND CONCLUSIONS

The Cullasaja River and Mill Creek have been considered impaired by the Biologic Assessment Unit as early as 1990 when first evaluated using benthic communities. Follow up sampling through 1999 continued to show impairment with little change between stations for both water bodies. In 2000 and 2001, a more intensive survey was launched by the Watershed Assessment and Restoration Project to narrow down some specific causes for the impairment.

Tables 9 and 10 summarize EPT richness and abundance values for all sites on the Cullasaja River and Mill Creek.

Table 9. Comparison of sites on the Cullasaja River.

Location	Cullasaja River River Court	Cullasaja River River Court	Cullasaja River US 64	Cullasaja River US 64	Cullasaja River US 64	Cullasaja River US 64	Cullasaja River US 64	Cullasaja River US 64
Date	5/16/00	7/26/01	12/11/90	10/16/91	10/14/96	6/23/99	8/28/00	7/25/01
EPT Richness	25	16	14	9	18	14	18	10
EPT Abundance	121	44	72	38	66	66	57	43
EPT BI	3.72	4.63	4.87	5.59	4.82	4.97	5.12	5.92
Bioclassification	Not Impaired	Not Rated	Fair	Poor	Fair	Fair	Fair	Fair

Table 10. Comparison of sites on Mill Creek.

Location	Mill Cr 5th Street	Mill Cr 5th Street	Mill Cr Above WWTP	Mill Cr Above WWTP	Mill Cr Brookside Lane	Mill Cr Below WWTP	Mill Cr Below WWTP	Mill Cr Below WWTP
Date	5/17/00	8/29/00	12/12/90	10/16/91	8/28/00	12/12/90	10/16/91	6/22/99
EPT Richness	13	11	15	12	17	17	12	15
EPT Abundance	57	42	59	50	77	50	40	91
EPT BI	4.51	5.36	4.25	4.41	4.51	3.14	3.90	3.69
Bioclassification	Not Rated	Not Rated	Fair	Fair	Not Rated	Fair	Fair	Good-Fair

On the Cullasaja River, the upstream River Court site appears to be better than the downstream US 64 site. Ammons Branch, which flows into the same golf course impoundment as the Cullasaja and the unnamed tributary to the Cullasaja, do not appear to be contributing to any impairment. Salt Rock Branch, a highly impacted site is not likely contributing to the Cullasaja's impairment due to its small size.

In Mill Creek, the 5th Street site (both surveys) and Brookside Lane had an abundance of the *Conchapelopia* group indicating the probability of some toxicity. Impairment to Mill Creek was noted as early as 1990 when a study was done above and below the old WWTP. That study, and subsequent sampling below the WWTP site indicates an impact above the plant. Some downstream recovery was evident by the appearance of the plecopterans *Allocapnia/Leuctra* spp. and *Malirekus hastatus* and the reappearance of the 2 ephemeroptera *Stenonema modestum* and *Stenonema pudicum* in 1999.

Reference

USDA Natural resources Conservation. 1996. Soil Survey of Macon County, North Carolina.

cc: Jimmie Overton

NOTE: The addendum to Appendix A, Appendices AA-AF, is available from DWQ upon request. These Appendices contain macroinvertebrate station summaries and complete taxa lists for the Cullasaja River, Mill Creek and reference sites.

Appendix B

Water Quality Conditions

Appendix B
Water Quality Conditions

A wide range of chemical, physical and toxicological analyses were conducted in the upper Cullasaja River watershed during the course of this study. This appendix describes the approach and methods used, discusses sampling locations, and summarizes monitoring results. Specific sampling methods are documented in the project's *Standard Operating Procedures for Chemical/Physical Toxicity Monitoring* (NCDWQ, 2001a) and are not described here.

Section 1 Approach and Methodology

Chemical-physical and toxicity monitoring conducted during the project had two broad goals:
1. General water quality characterization. This goal involved developing a synoptic picture of the chemical and physical water quality characteristics of a particular study area, based upon a standard set of parameters.
2. Stressor-source area identification. Identifying the causes of biological impairment and the sources of these causal factors is a primary goal of the project and the major focus of the monitoring effort. As it relates to chemical-physical and toxicity monitoring of the water column, this goal involves:
   --identifying the major chemical/physical stressors to which aquatic biota (benthos in particular) in a stream are exposed;
   --providing information on the nature of exposure to these stressors (e.g. concentration and timing);
   --evaluating the toxicity of waters of concern and determining the pollutants causing any toxicity identified;
   --determining major sources or source areas.

The nature of stressor-source identification demands a monitoring approach that is dynamic and flexible, changing over time as new information regarding biological condition, stream chemistry, and watershed activities becomes available.

1.1 General Water Quality Characterization

Routine sampling was conducted at two integrator stations located toward the downstream end of the study areas--the Cullasaja River upstream of US 64 and Mill Creek at the end of Brookside Lane. Surface grab samples (depth of 0.15 meters, or approximately six inches) were collected during both baseflow and storm conditions. Baseflow periods were defined as those in which no measurable rain fell in the watershed during the 48 hour period preceding sampling, based on staff judgment utilizing available information. A standard set of parameters, similar to the parameters used by DWQ at ambient stations, was used. A listing of these parameters is included in Table B.1. Fecal coliform samples were collected on five occasions under baseflow conditions during August and September 2001.

Table B.1. Parameters for Water Quality Characterization, Cullasaja River at US64 and Mill Creek at Brookside Lane

Field Parameters	Laboratory Parameters	
Dissolved Oxygen	Turbidity	Metals:
Air Temperature	Total Dissolved Solids	Aluminum
Water Temperature	Total Suspended Solids	Arsenic
Specific Conductance	Hardness	Cadmium
pH	Fecal Coliform	Chromium
	Total Phosphorus	Copper
	Ammonia-N	Iron
	Nitrate/nitrite-N	Lead
	Total Kjeldahl Nitrogen	Manganese
	Calcium	Mercury
	Magnesium	Nickel
	Potassium	Silver
	Sodium	Zinc

1.2 Stressor-Source Identification—Water Column

1.21 Chemical/Physical Monitoring

Several types of water column sampling were conducted, reflecting the needs for both stressor identification and the determination of sources. Stressor identification sites were selected to identify chemical stressors present in study waters and to provide information for evaluating whether those stressors contribute to biological impairment. Source identification sites were chosen to identify source areas or individual pollutant sources. While stressor and source identification can be separated conceptually, in practice stressor and source determination were sometimes carried out jointly.

The sampling effort was intended to provide information relevant to the evaluation of causal relationships by tying selection of sampling sites, parameters and timing of sampling to available information on stressors and sources, e.g. biological information and watershed activities. This approach differs from many commonly used sampling frameworks because the goal was not to characterize typical conditions or to estimate pollutant loads, but to provide information to help evaluate whether particular stressors are likely contributors to biological impairment. The timing and location of sampling were selected to identify critical conditions such as periods of low dissolved oxygen or exposure to high levels of toxicants.

Station location. The number and location of sites was determined based upon the size of the watershed, the location and degree of biological impairment, the nature and spatial distribution of watershed activities, and existing chemical data. Station locations for stressor identification purposes were generally linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities believed to represent potential sources of impairment. Sites are listed in section 5.12 and mapped in Figure 5.1.

Parameter selection. Monitoring focused primarily on candidate stressors initially identified based upon watershed reconnaissance and a review of existing information. Additional parameters were added as necessary. Aside from the standard parameters listed in Table B.1, pesticides were monitored in the Cullasaja River and methylene blue active substances (MBAS, an indicator of anionic surfactants) were monitored in Saltrock Branch.

A diverse set of parameters was sampled in Mill Creek. Given the complex nature of land use in many urban areas, and the inability to rule out many parameters from consideration in the initial stages of the sampling effort, the number of candidate parameters in streams draining developed areas is significant. The approach was also shaped by a tension between the need to use project laboratory resources efficiently and the limited time frame available for identification of the causes of impairment. Parameter selection was subject to review on an ongoing basis. Total concentration was measured for all analytes. The dissolved fraction was not analyzed.

In order to assess potential toxicants, the following analytes and parameter groups were sampled in the Mill Creek watershed, including:

- metals;
- chlorinated pesticides and polychlorinated biphenyls (PCBs) (EPA 608);
- current use pesticides (quantitative and broad scan GC/MS);
- acid herbicides (EPA 615), organophosphate pesticides (EPA 614/622), and nitrogen pesticides (EPA 619/630);
- volatiles/methyl tertiary-butyl ether (MTBE) (EPA 602);
- phenols (EPA 604);
- polycyclic aromatic hydrocarbons (PAHs) (EPA 610);
- semi-volatile organics (EPA 625);
- volatile organics (purgeables) (EPA 624);
- semipermeable membrane device (SPMD) chlorinated pesticides (modified EPA 8081A);
- SPMD PCBs (modified EPA 8082); and
- SPMD PAHs (modified EPA 8270C).

Pesticides were analyzed using a variety of methods. A quantitative gas chromatograph/mass spectrophotometer (GC/MS) technique tested for a set list of 37 current use pesticides. A broad scan GC/MS technique tested for a list of more than 300 current and legacy-use pesticides. Section 3 lists the pesticides analyzed in each method.

Type and number of samples. Manual grab sampling was used for nonstorm sampling. Storm samples were generally collected as grab samples during the rising limb, using either manual collection or automatic samplers. The use of automatic sampling equipment was limited by budgetary constraints. On occasion chemical analyses were conducted on multiple grabs from different portions of the rising limb, but project resources limited this option.

The number of samples collected was variable, depending on analytical results to date, the occurrence of appropriate conditions for sampling (e.g., rainfall or rain free periods) and the outcome of other components of the study. Where sampling was not tied to very specific watershed activities but targeted at more general source areas, staff generally attempted to collect repeated samples (at least 2-3) under the relevant conditions (e.g., baseflow or stormflow, seasonal).

Timing of sampling. Whenever feasible the timing of sampling was based upon available information on likely pollutants, the timing of source activities in the watershed, and knowledge of watershed hydrology. Baseflow, storm event or other samples were collected as appropriate to the particular stressors and sources. Such linkage is difficult in large watersheds or in urban areas where the timing of multiple activities in a given drainage is difficult to discern. The suspected seasonality of inputs was also considered.

Semipermeable membrane devices (SPMD). SPMDs were used on a limited basis at the integrator locations. The devices used consist of a pre-extracted polyethylene membrane deployed in the stream inside a plastic mesh enclosure. SPMDs collect hydrophobic organic compounds to which the device is exposed during the deployment period (e.g., Huckins et al 1993; Hofelt and Shea, 1997; Meadows et al, 1998). Laboratory analysis of SPMDs was conducted for PAHs, PCBs, chlorinated pesticides, and selected current use pesticides. These devices were deployed in cooperation with the NCSU Department of Environmental and Molecular Toxicology. Average concentrations over the deployment period were calculated by the NCSU Department of Environmental and Molecular Toxicology assuming a set sampling rate by the SPMDs.

Multiparameter data loggers. Hydrolab data sondes, multiparameter probes with a data logging capability, were deployed for seven-days in September and October 2001. Dissolved oxygen (DO), pH, water temperature, and specific conductance (SC) were recorded continuously, usually on a quarter-hourly basis. The multiprobes were deployed simultaneously in the Cullasaja River drainage above and below golf course impoundments and in the Mill Creek drainage above and below the town center of Highlands in order to evaluate daily patterns in those parameters.

1.22 Toxicity Assessment

Ambient toxicity tests were conducted where toxicity was considered a potential cause of biological impairment. Laboratory bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. Acute tests were conducted on storm samples, while chronic tests were conducted on samples collected during nonstorm periods. The following specific tests were used:

- Ambient tests for acute toxicity using protocols defined in USEPA document EPA/600/4-90/027F (USEPA 1993) using *Ceriodaphnia dubia* with a 48-hour exposure.
- Ambient tests for chronic toxicity using the North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NC Division of Water Quality, 1998).

Acute toxicity analyses were conducted at the downstream benthic sampling location on Mill Creek (Brookside Lane) and chronic toxicity was conducted below the main stormwater tributary from Highlands' town center on Mill Creek.

1.3 Stressor-Source Identification—Bed Sediment

Analysis of stream bed sediments was conducted at the integrator locations and on a reference stream for the purpose of evaluating whether sediment toxicity was a likely contributor to degradation of the benthic macroinvertebrate community.

Analysis was conducted on composites of multiple grab samples collected from the top 5 cm of the substrate. In each target reach, sediment was collected for analysis from two distinct substrate areas related to those sampled for benthos: at sand sample locations, and in depositional areas, as described below: (1) sand substrate locations of the type sampled by DWQ during standard macroinvertebrate sampling (NCDWQ, 2001b); (2) fine depositional areas such as pools, backwaters, and channel margins. Sediment collected from sand sampling and depositional sampling areas was analyzed separately. For more details on methods, see the project standard operating procedures document for additional details (NCDWQ, 2001a).

Toxicity was evaluated using long term (42 day) laboratory bioassays using the amphipod *Hyalella azteca*, conducted according to the procedures outlined by USEPA (2000). Chemical analyses conducted included chlorinated pesticides (modified EPA method 8081A), PCBs (modified EPA method 8082), PAHs (modified EPA method 8270C), semivolatile organics (EPA method 8270C), metals, current use pesticides (broad scan GC/MS), total organic carbon (TOC), and particle size distribution.

1.4 Toxicity Benchmarks

When performing ecological risk assessments and water quality evaluations, contaminants are often compared to screening benchmarks to determine if the reported concentrations of those contaminants are high enough to warrant further consideration. In this study, toxicological benchmarks derived for the protection of aquatic life were used to screen observed contaminant concentrations for potential aquatic ecological effects. Laboratory detection limits were also compared to benchmark values.

Benchmark screening values denote thresholds of elevated risk, but do not predict actual impacts in particular situations. Actual site-specific and event-specific impacts depend upon the interaction of numerous factors, including the level, timing and duration of exposure; the form and bioavailability of the particular chemicals (often dependent on pH or other variables); and simultaneous exposure to other stressors.

Many different sources of screening benchmarks exist, with differing levels of conservatism. A detailed discussion of these can be found in Suter and Tsao (1996). The primary screening benchmarks used in the upper Cullasaja River watershed assessment were 1) EPA's acute and chronic National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999) and 2) EPA's Tier II values (USEPA, 1995). The acute NAWQC were established by EPA to correspond to concentrations that would cause less than 50% mortality in 5% of the exposed populations in a brief exposure. The chronic NAWQC are the acute values divided by the geometric mean of at least three median lethal concentrations (LC50). Tier II values were developed by EPA as part of the Great Lakes Program (USEPA, 1995) for use with chemicals for which NAWQC are not available. They are based on fewer data than are required to establish NAWQC.

In this study NAWQC for priority pollutants were taken from EPA's online Water Quality Standards Database (http://www.epa.gov/wqsdatabase/). NAWQC for nonpriority pollutants, which are not included in the online database, were taken from USEPA (1999). Tier II values and other benchmarks, such as EPA Region 4 benchmarks, were obtained from the ecological benchmark listing available through the Risk Assessment Information System operated by the Oak Ridge National Laboratory (http://risk.lsd.ornl.gov/homepage/eco_tool.shtml).

Where no benchmarks were available, a search of the toxicological literature was performed using EPA's online ecotoxicology database, ECOTOX (http://www.epa.gov/ecotox/). Observed concentrations were compared to effects level values for freshwater aquatic animals.

NAWQC for many metals (cadmium, chromium III, copper, lead, nickel, silver and zinc) are a function of water hardness. NAWQC are reported by EPA for a hardness of 100 mg/L and must be adjusted for site specific hardness levels. In this study benchmarks for all of the above metals except chromium were adjusted for hardness using the formulas recommended in USEPA (1999). The NAWQC for chromium VI (which does not require hardness adjustment) was used instead of chromium III, since the former provides a more conservative screening level. Since hardness variability is low in the Cullasaja River and Mill Creek, the average calculated hardness (8.6 mg/L) level from calcium and magnesium concentrations reported for Mill Creek at Brookside Lane and the Cullasaja River at US 64 was used to calculate benchmarks for reported samples that were not also analyzed for calcium and magnesium.

NAWQC for many metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc) are calculated as the concentration of dissolved metals in the water column. Comparison of the ambient total metals concentrations measured in this study to dissolved metals criteria is a conservative approach in that less than 100% of a metal in any particular ambient sample may be in dissolved form. This approach is appropriate for initial screening purposes. Final evaluation of the likely potential for metals and other analytes to negatively impact aquatic biota considered all lines of evidence available, including toxicity bioassays and benthic macroinvertebrate data, in addition to data on analyte concentrations.

Sediment data were compared to a set of sediment benchmarks used by the DWQ Aquatic Toxicology Unit and included those of Region 4 USEPA (Waste Management Division Sediment Screening Values for Hazardous Waste Sites, available at http://www.epa.gov/region04/waste/ots/ecolbul.htm#tbl3), Florida Department of Environmental Protection (McDonald, 1994), Ontario Ministry of the Environment (MOE) (1993), Long et al. (1995), NOAA's Screening Quick Reference Tables (SquiRT) (Buchman 1999), and Oak Ridge National Laboratory's toxicological benchmarks document (Jones et al., 1997). They were grouped into conservative and non-conservative ranges in the manner of MacDonald et al. (2000) (Table B.2). Conservative ranges are sets of threshold values, below which there is low probability of toxicity. Region 4 USEPA values are included in the set of conservative values, but they were also individually used for comparison because the DWQ Aquatic Toxicology Unit uses these as initial screening benchmarks. Non-conservative ranges are sets of values above which there is a high probability of toxicity to aquatic organisms. If a measured value falls within the conservative range, it is possible but not probable that it is toxic. If the value falls within the non-conservative range, it is possible that it is toxic, and the higher the concentration, the more probability of toxicity.

Both the Upper Effects Threshold (UET) values (NOAA SquiRT) and Ontario Severe Effects Levels (SEL) for organic contaminants were adjusted for site-specific total organic carbon (TOC)). Published UET values were listed for sediments with 1% TOC; a site-specific UET was derived by multiplying the published value by the site-specific percent TOC as in Jones et al. (1997). Published SEL values are in µg/g organic carbon. To derive a site-specific benchmark in mg/kg sediment (dry weight), the SEL was adjusted with site-specific TOC as described in the Ontario Ministry of the Environment's sediment benchmark document (1993).

Table B.2. Sources of Sediment Benchmarks for Conservative and Non-conservative Screening Ranges

Conservative	**Non-conservative**
Region 4 EPA Ecological Screening Values	
Hyallela Threshold Effects Levels (via NOAA SquiRT[1])	Upper Effects Threshold (via NOAA SquiRT[1])
Threshhold Effects Levels (via NOAA SquiRT[1])	Apparent Effects Thresholds (via NOAA SquiRT[1])
	Probable Effects Levels (via NOAA SquiRT[1])
No Effects Levels (Ontario MOE)	Severe Effects Levels (Ontario MOE)
Low Effects Levels (Ontario MOE)	
Effects Range-Low (MacDonald & Long)	Effects Range-Median (MacDonald & Long)
Threshhold Effects Levels (FL DEP)	Probable Effects Levels (FL DEP)
	Apparent Effects Thresholds (WA State) [3]
Threshold Effects Concentrations (EPA ARCS[2]) [3]	Probable Effects Concentrations (EPA ARCS[2]) [3]
No Effects Concentrations (EPA ARCS[2]) [3]	
NOAA Effects Range-Low[3]	NOAA Effects Range-Median[3]

[1]SQuiRT=Screening Quick Reference Tables
[2]ARCS=Assessment and Remediation of Contaminated Sediments Program
[3]via Oak Ridge National Laboratory's toxicological benchmarks document

1.5 Laboratories

This study utilized a number of laboratories in order to obtain services for the necessary range of chemical, physical and biological analyses.

- Environmental Chemists (Wilmington, NC)--chemical/physical analysis;
- Paradigm Analytical Laboratory (Wilmington, NC)--chemical analysis;
- Southern Testing (Rocky Mount, NC)--chemical analysis;
- Division of Water Quality Laboratory (Raleigh and Asheville, NC)--chemical and biological analysis;
- NCSU Department of Environmental and Molecular Toxicology (Raleigh, NC)—pesticides (broad scan and qualitative GC/MS), PCBs (sediment), SPMDs;
- Simalabs International (Burlington, NC)--toxicity bioassay (water);
- and USGS Columbia Environmental Research Center (Columbia, MO)--toxicity bioassay (sediment).

Consult the project standard operating procedures document for additional details (NCDWQ, 2001a).

Section 2 Results

Key chemical, physical and toxicity monitoring results are discussed in Section 5 of the text. Here we present supplemental information on selected issues, followed by a summary of analytical results for all sampling stations and water column bioassay results.

2.1 Data Sonde Deployments

Hydrolab data sondes were deployed for seven days at four locations on the Cullasaja River mainstem and a tributary and two locations on Mill Creek during baseflow periods in September and October 2001. Units were programmed to monitor water temperature, specific conductance, DO, and pH every fifteen minutes. From these deployments, we summarize below (Table B.3) the daily patterns at sites where equipment was simultaneously deployed—in the Cullasaja River Headwater Creek to Ravenel LakeCUCR12, at Crescent Trail Rd. CUCR13, at Falls Drive West CUCR05, and at US 64 CUCR01—in Mill Creek at 5th Ave. CUMC14 and at Brookside Lane CUMC02.

Water temperature, pH, dissolved oxygen, and specific conductance levels were fairly stable over the deployment period, and there was little variability among the group of Cullasaja sites and Mill Creek sites.

Table B.3. Parameter Summary for Hydrolab Data Sonde Deployment in Cullasaja River Mainstem and Tributary and Mill Creek, September and October 2001

Parameter		Headwater Creek to Lake Ravennel CUCR12	CULLASAJA River at Cresent Trail Rd. CUCR13	CULLASAJA River at Falls Drive West CUCR05	CULLASAJA River at US 64 CUCR01	Mill Creek at 5th Ave CUMC14	Mill Creek at Brookside Lane CUMC02
		9-28-01 thru 10-05-01				10-16-01 thru 10-23-01	
Temperature Degrees Celsius	Mean	12.4	15.2	14.2	13.8	10.5	9.7
	Max	14.1	17.6	16.1	15.6	12.8	12.4
	Min	10.7	13.6	12.7	12.1	8.1	7.1
Specific Conductance µS/cm	Mean	31.0	29.0	19.0	29.0	21.7	33.5
	Max	32.0	30.0	20.0	30.0	23.4	35.8
	Min	30.0	28.0	18.0	27.0	19.6	28.8
Dissolved Oxygen %Sat	Mean	84.4	79.6	89.5	84.8	74.0	71.6
	Max	88.5	85.3	92.3	88.8	83.4	77.7
	Min	79.2	74.1	86.8	80.9	64.5	65.6
Dissolved Oxygen mg/L	Mean	9.0	8.0	9.2	8.8	8.3	8.2
	Max	9.6	8.7	9.5	9.2	9.7	9.2
	Min	8.4	7.4	8.8	8.3	6.8	7.1
pH units	Mean	6.7	6.7	6.2	6.5	6.2	6.7
	Max	6.7	6.7	6.4	6.6	6.5	6.8
	Min	6.6	6.6	5.9	6.4	6.0	6.6

2.2 Semipermeable Membrane Devices (SPMD)

Estimated average concentrations of detected contaminants from SPMD deployments during baseflows and stormflows in Mill Creek at Brookside Lane and baseflows in the Cullasaja River at US 64 are reported in Table B.4. None of the reported concentrations are in the range of any acute or chronic toxicological benchmarks.

Reported concentrations are average concentrations over the entire deployment period. Therefore, if a pulse event (e.g., a storm) contributed a high concentration of a pollutant, this high level would be averaged with lower concentrations to which the SPMD was exposed during the rest of the deployment period. Only parameters that had concentrations above the detection limits are reported in the table. See Tables B.32, B.33, and B.34 for a list of all parameters that were analyzed by each analytical method.

Table B.4. Estimated Water Concentrations of Compounds Detected on SPMDs from Mill Creek at Brookside Lane (CUMC02) and the Cullasaja River at US 64 (CUCR01)*

Sample ID	**CUMC02**	**CUMC02**	**CUCR01**
Date Collected	**11/19/01-11/25/01**	**11/2/01-11/19/01**	**11/2/01-11/19/01**
Predominant flow type during period	Stormflow & Baseflow	Baseflow	Baseflow
Parameter (ng/L)			
Pesticides: Quantitative GC/MS			
chlorpyrifos	0.14	0.15	0.06
Pesticides: Broad Scan GC/MS	<0.025	<0.025	<0.025
Chlorinated Pesticides			
hexachlorobenzene	0.11	<0.025	<0.025
heptachlor	0.14	<0.025	<0.025
alpha chlordane	<0.025	0.06	0.06
gamma chlordane	<0.025	0.04	<0.025
trans-nonachlor	0.18	0.08	0.04
methoxychlor	0.26	<0.025	<0.025
DDTs			
4,4'-DDE	0.38	0.08	<0.025
Sum of DDTs	0.38	0.08	0.00
PCBs			
PCB 28	0.18	<0.025	<0.025
PCB 52	0.13	<0.025	<0.025
PCB 44	0.10	<0.025	<0.025
PCB 66	0.06	<0.025	<0.025
PCB 101	0.09	<0.025	0.05
PCB 118	0.06	<0.025	<0.025
PCB 153	0.07	0.02	0.11
PCB 138	<0.025	0.01	0.08
PCB 187	0.04	<0.025	<0.025
Sum of PCBs	0.73	0.03	0.23
PAHs			
Napthalene	0.25	0.13	0.22
2-Methylnapthalene	0.35	0.15	0.09
1-Methylnapthalene	0.22	0.17	0.14
Biphenyl	0.30	<0.025	<0.025
2,6-Dimethylnapthylene	0.48	0.24	<0.025
Acenapthylene	0.07	<0.025	<0.025
Acenapthene	<0.025	0.50	0.25
Dibenzofuran	0.07	<0.025	<0.025
2,3,5-Trimethylnapthalene	0.93	0.43	0.15
C1 - Napthalenes	0.27	0.39	0.28
C2 - Napthalenes	1.96	2.06	1.15
C3 - Napthalenes	5.20	2.16	0.88
C4 - Napthalenes	9.12	0.83	0.27
Fluorene	0.21	0.42	0.15

Table B.4. Cont.

Sample ID Date Collected Predominant flow type during period	CUMC02 11/19/01-11/25/01 Stormflow & Baseflow	CUMC02 11/2/01-11/19/01 Baseflow	CUCR01 11/2/01-11/19/01 Baseflow
Parameter (ng/L)			
PAHs			
1-Methylfluorene	0.45	0.21	0.07
C1 - Fluorenes	1.53	0.93	0.37
C2 - Fluorenes	7.93	1.55	0.65
C3 - Fluorenes	9.38	<0.025	<0.025
Dibenzothiophene	0.21	<0.025	<0.025
C1 - Dibenzothiophenes	1.01	<0.025	<0.025
C2 - Dibenzothiophene	2.87	<0.025	<0.025
C3 - Dibenzothiophene	2.29	<0.025	<0.025
Phenanthrene	1.40	3.65	1.99
Anthracene	0.24	0.17	0.35
1-Methylphenanthrene	1.08	0.44	0.21
C1 - Phenanthrenes/Anthracenes	9.08	2.39	1.25
C2 - Phenanthrenes/Anthracenes	8.73	1.56	0.62
C3 - Phenanthrenes/Anthracenes	4.83	0.96	0.36
C4 - Phenanthrenes/Anthracenes	3.45	<0.025	<0.025
Fluoranthrene	7.70	6.82	2.61
Pyrene	9.44	4.85	2.26
C1 - Fluoranthenes/Pyrenes	4.30	1.26	0.80
Retene	1.27	0.53	0.53
Benz[a]anthracene	0.63	0.49	0.40
Chrysene	3.80	2.01	0.60
C1 - Chrysenes	0.83	0.31	0.15
C2 - Chrysenes	<0.025	0.22	<0.025
Benzo[b]fluoranthene	1.33	<0.025	<0.025
Benzo[k]fluoranthene	0.51	<0.025	<0.025
Benzo[e]pyrene	1.48	0.47	0.12
Benzo[a]pyrene	0.23	<0.025	<0.025
Perylene	0.74	0.22	0.08
Indeno[1,2,3-c,d]perylene	0.24	<0.025	<0.025
Dibenz[a,h]anthracene	0.06	<0.025	<0.025
benzo[g,h,i]perylene	0.39	<0.025	<0.025
Coronene	0.07	<0.025	<0.025
Sum PAH	106.94	36.50	16.99

*All results are reported in ng/L as the average concentration over the deployment period

2.3 Stream Bed Sediments

Stream bed sediments (dry weight) of the Cullasaja River, Mill Creek, and a reference site, South Fork Mills River, were analyzed for metals, acid and base/neutral extractable organics, PAHs, PCBs, chlorinated pesticides, and selected current use pesticides (Table B.5). Results from depositional sediments are reported here only, since the sand sediments had contaminant concentrations at much lower levels. No acid and base/neutral extractable organics or PAHs were detected, and these results are not included in Table B.5. However, the detection limits for a number of acid and base/neutral extractable organic contaminants were greater than published screening benchmarks (Table B.6), and it is possible that these contaminants were present at levels above screening benchmarks. No other analytes had detection limits above sediment screening benchmark ranges. There are also a number of analytes with no screening benchmarks (e.g., many current use pesticides and some acid and base/neutral extractable organics), but with the exception of trans-nonachlor (a chlorinated pesticide) there were no contaminants with concentrations measured above detection limits that did not have screening benchmarks.

Concentrations of aluminum, cadmium, iron, zinc, and gamma chlordane were found in depositional sediments of the Cullasaja River above conservative screening benchmarks. Cadmium, zinc, dieldrin, DDE, and total DDTs were found in the depositional sediments of Mill Creek at levels above conservative screening benchmarks. Cadmium was also found at the lower end of the conservative benchmark range in reference depositional sediments of the South Fork Mills River. No other metals or chlorinated pesticides were found at levels at or above sediment benchmarks. See Section 5 of this report for comparative benchmark ranges.

Sediment toxicity tests were performed on Mill Creek, Cullasaja River, and South Fork Mills River sediments (Table B.7). The results demonstrate no toxicity in Cullasaja River or South Fork Mills River sediments. Although 28 day survival of *Hyallela azteca* in the Mill Creek sediment was significantly less than that of a control ($p<0.05$), control survival was too high for this test to provide conclusive evidence of toxicity (USEPA 2000). The other toxicity endpoints, including 28 day growth, 35 day survival, 42 day growth, 42 day survival, and number of offspring per female, were not significantly different from those of the control.

See Section 3 for a list of pesticides analyzed for with the broad scan and quantitative GC/MS methods. Analytes 2,4-D and dicamba were analyzed using a quantitative GC/MS method separate from that described by Table B.22; they are listed in Table B.5 separately. Values that were below detection limits are reported as less than the specified detection limit (e.g., “<5.0”).

Table B.5. Pollutant Concentrations[1] in Depositional Sediment Samples from the Integrator Locations on the Cullasaja River (CUCR01) and Mill Creek (CUCR02), and the Reference Location, South Mills River (MRSM01)

Parameter	MRSM01D 08/10/01	CUCR01D 08/13/01	CUMC02D 08/13/01
Total Organic Carbon (%)	1.55	2.85	2.45
Particle Size (%)			
Sand	75	66	70
Silt	14	16	19
Clay	11	18	11
Pesticide: Broad Scan GC/MS (ng/g)	<0.5	<0.5	<0.5
Pesticide: Quantitative GC/MS (ng/g)			
2,4-D	<0.5	<0.5	<0.5
dicamba	<0.5	<0.5	<0.5
Pesticide: HPLC[2] (ng/g)			
azoxystrobin	<0.5	<0.5	<0.5
esfenvalerate	<0.5	<0.5	<0.5
Pesticide: ELISA[3] (ng/g)			
paraquat		<0.5	<0.5
Chlorinated Pesticides (ng/g)			
hexachlorobenzene	<0.5	0.30	<0.5
alpha chlordane	<0.5	0.15	<0.5
gamma chlordane	0.74	0.80	<0.5
trans-nonachlor	<0.5	0.20	<0.5
dieldrin	<0.5	<0.5	0.72
DDTs (ng/g)			
4,4'-DDD	0.26	0.20	0.58
4,4'-DDE	0.91	0.85	2.30
Sum of DDTs	1.17	1.05	2.88
PCBs (ng/g)			
PCB 101	0.51	<0.5	<0.5
PCB 118	0.74	<0.5	<0.5
PCB 153	1.08	<0.5	<0.5
PCB 138	1.02	<0.5	<0.5
PCB 187	0.25	<0.5	<0.5
Sum of PCBs	3.60	<0.5	<0.5
Total Organic Carbon (TOC) mg/kg	16700	19500	16700
Metals, Total (mg/kg)			
Aluminum	9160	25900	15300
Antimony	<1.85	<2.72	<1.89
Arsenic	<9.26	<13.6	<9.43
Beryllium	<0.926	<1.36	<0.943
Cadmium	0.596	1.61	1.14
Chromium	8.63	17.3	12.5
Copper	4.2	12.7	13
Iron	7600	20200	14600

Table B.5. Cont.

Parameter	MRSM01D 08/10/01	CUCR01D 08/13/01	CUMC02D 08/13/01
Lead	<2.78	8.67	13.9
Manganese	107	414	306
Mercury	<0.0396	0.0755	<0.0374
Nickel	4.69	11.6	8.83
Selenium	<9.26	<13.6	<9.43
Silver	<0.926	<1.36	<0.943
Thallium	<1.85	<1.36	<1.89
Zinc	24	104	104

[1]Detection limit (0.5 ng/g, dry weight), for pesticides and PCBs
[2]HPLC: High Performance Liquid Chromatography
[3]ELISA: Enzyme-Linked Immunosorbent Assay

Table B.6. Base-neutral and Acid Extractable Organic Analytes with Detection Limits above Sediment Benchmark Concentrations

Analyte	Range of Detection Limits (ug/kg)			Range of Sediment Benchmarks (ug/kg)[1]		
Butylbenzylphthalate	183	to	448	63		
2-Chlorophenol	183	to	448	8		
Di-n-Butylphthalate[3]	183	to	448	184		
Di-n-octylphthalate	183	to	448	61		
1,2-Dichlorobenzene	183	to	448	13		
1,4-Dichlorobenzene	183	to	448	110		
2,4-Dichlorophenol	183	to	448	5		
Diethylphthalate	183	to	448	6		
2,4-Dimethylphenol	366	to	896	18	to	29
Dimethylphthalate	183	to	448	6		
Hexachlorobenzene[2]	183	to	448	10	to	400.8
Hexachlorobutadiene	183	to	448	1.3		
Hexachloroethane	183	to	448	73		
2-Methylphenol	183	to	448	8	to	63
N-Nitrosodiphenylamine	183	to	448	28		
Nitrobenzene	183	to	448	21		
Pentachlorophenol	366	to	896	17	to	360
Phenol[2]	183	to	448	80.16	to	420
1,2,4-Trichlorobenzene	183	to	448	4.8		
2,4,5-Trichlorophenol	183	to	448	3		
2,4,6-Trichlorophenol	183	to	448	6		
Selenium	6.03	to	9.26	1		

[1]Using sediment screening benchmark sources in Table B.2. Selenium is in mg/kg.
[2]Only MRMS01D and CRCR01D samples had detection limits above the sediment benchmark range.
[3]Only the MRMS01D sample had a detection limit above the sediment benchmark range.

Table B.7. Response of *Hyalella azteca* in 42 Day Exposures to Depositional Sediment Samples from Mill Creek (CUMC02), the Cullasaja River (CUCR01), Reference South Fork Mills River (MRSM01), and Control Sediment [1]

Sample	28-d Survival (%)	28-d Length[2] (mm)	35-d Survival (%)	42-d Survival (%)	42-d Length (mm)	42-d: # of young Per Female
control	98 (1.01)	4.49 (0.05)	98 (1.64)	95 (1.80)	5.25 (0.06)	8.28 (1.11)
MRSM01	98 (1.64)	4.74 (0.07)	98 (2.50)	98 (2.50)	5.16 (0.08)	8.38 (0.43)
CUMC02	89 (2.27)*	4.66 (0.06)	95 (2.89)	98 (2.50)	5.49 (0.10)	5.80 (0.76)
CUCR01	96 (2.63)	4.43 (0.06)	88 (9.46)	88 (9.46)	5.07 (0.07)	4.68 (0.74)

[1] Means (standard error of the means in parentheses). Asterisk signifies that test sediment endpoint is significantly different than that of the control ($p < 0.05$). n= 8.
[2]Starting body length of amphipods = 2.10 (0.07) mm

2.4 Toxicity Bioassay Results for Water Samples

Results of one chronic bioassay from baseflows and two acute bioassays from stormflows at Mill Creek are shown in Table B.8.

Table B.8. Results of Acute and Chronic Toxicity Bioassays Conducted on Water Column Samples

Site	Sample Date	Test	LC_{50} pass/fail	COMMENTS
CUMC02	11/23/01	ACUTE	>100%	
CUMC02	11/29/01	ACUTE	>100%	
CUMC08	5/3/01	CHRONIC	pass	average reproduction (# of young)--25.3 control, 30.0 treatment; control CV -11.6%

2.5 Summary of Physical/Chemical Data for Water Column Samples Collected at all Sampling Locations

Tables B.9 through B.19 summarize physical and chemical data for water column samples collected at all sampling locations in the Cullasaja River and Mill Creek, and are listed below:

- Table B.9. Summary of water quality results for the Cullasaja River at US64, integrator location.
- Table B.10. Summary of water quality results for Mill Creek at Brookside Lane, integrator location.
- Table B.11. Summary of nutrient, metal, and MBAS results from Saltrock Branch at Falls Dr. West.
- Table B.12. Summary of metal and nutrient results for UT to Cullasaja at Skylake Rd.
- Table B.13. Summary of semi-volatile organic results for UT to Mill Creek at US 64 (Highlands' main stormwater tributary).
- Table B.14. Summary of semi-volatile organic results for Mill Creek below US 64 and below Highlands' main stormwater tributary.

- Table B.15. Summary of fecal coliform results for UT to Mill Creek at Main St.
- Table B.16. Summary of pesticide results for Cullasaja River at Cullasaja Club Dr.
- Table B.17. Summary of pesticide results for Cullasaja River at River Court.
- Table B.18. Summary of organic and metal results for a tributary to Mill Creek at the Town of Highlands Warehouse Facility.
- Table B.19. Summary of organic and metal results for Mill Creek at 5th Avenue.

For discussion of certain water quality results see section five of this report. Column headings are given below:

#Sam   number of samples or measurements
#Det   number of samples at or above the minimum analytical reporting level
Max   maximum value
Min   minimum value
Med   median
Mean   mean (geometric mean, in the case of fecal coliform)
Value   reported concentration for each parameter
NA   not applicable/analyzed

For each analysis for pesticides or other organics (broad scan GC/MS, quantitative GC/MS, or EPA Method) only the compounds measured at or above the minimum analytical detection limits are shown in the following tables. See Section 3 for lists of compounds analyzed in each organic and pesticide analytical method.

For parameter groups other than pesticides and organics, a value below the minimum analytical detection limit is listed as less than the specified detection limit (e.g., "<5.0"), and this value is centered in the table's group of Max, Min, Med, and Mean fields. If the detection limits for a parameter varied, the value is reported as a range (e.g., "<5.0-10"). In calculating means, values below detection limits were assigned a value of half the detection limit. Where all samples for a parameter were below the detection limit for a parameter, the maximum, median and mean values were not calculated. Where there was only one sample, the value was placed in the median column.

Table B.20 lists all organic and pesticide analytes for water samples that had detection limits above the chronic and/or acute screening benchmarks. The lead detection limit (1 μg/L) was above the chronic benchmark (0.1 μg/L) (Section 5, Table 5.5).

Table B.9. Summary of Water Quality Results for the Cullasaja River at US64--CUCR01

PARAMETER	BASEFLOW						STORMFLOW	
	#SAM	#DET	MAX	MIN	MED	MEAN	#SAM	VALUE
Field Parameters								
Air Temperature (°C)	8	NA	26.0	0.6	19.2	15.6	1	7.5
Water Temperature (°C)	9	NA	21.6	3.9	19.1	14.9	1	7.2
Stage (m below mark)	3	NA	1.45	1.37	1.37	1.40	1	1.3
Specific Cond (µS/cm)	9	NA	44	29	38	38	1	40
DO (mg/L)	9	NA	11.3	6.0	8.0	8.4	1	10.6
DO (% saturation)	4	NA	89.0	80.0	84.0	84.3	1	88.0
pH (Standard Units)	9	NA	7.6	5.1	6.9	6.7	1	5.4
Nutrients (mg/L)								
Ammonia Nitrogen	5	2	0.6	0.1	0.1	0.2	1	0.1
Total Kjeldahl Nitrogen	5	4	0.8	0.1	0.4	0.5	1	0.8
Nitrate+Nitrite Nitrogen	5	5	0.28	0.12	0.18	0.20	1	0.20
Total Phosphorus	5	4	0.30	0.01	0.03	0.10	1	0.08
Total Nitrogen	5	5	0.98	0.28	0.63	0.68	1	1.00
Other Parameters (mg/L)								
Hardness, total	5	5	18.0	9.0	10.0	11.9	1	9.0
Residue, T. Suspended	5	5	7.0	1.3	1.8	2.8	1	7.0
Total Dissolved Solids	5	5	85	27	38	52	1	32
Turbidity (NTU)	5	5	2.87	1.46	2.60	2.35	1	11.10
Metals, Total (µg/L)								
Aluminum	6	6	238	142	187	187	1	456
Arsenic	6	0			<5		1	<5
Cadmium	6	0			<0.1		1	0.8
Chromium	6	0			<1		1	<1
Copper	6	1			<1		1	3
Iron	6	6	1030	309	541	590	1	497
Lead	6	0			<1		1	<1
Manganese	6	6	61	34	44	45	1	32
Mercury	6	0			<0.2		1	<0.2
Nickel	6	0			<1		1	<1
Silver	6	1	11.3	0.3	0.3	2.1	1	<0.5
Zinc	6	5	10.9	0.1	9.5	7.5	1	10.3
Ions (mg/L)								
Calcium	4	5	3.25	1.98	2.28	2.45	1	2.24
Magnesium	4	5	0.69	0.59	0.64	0.64	1	0.67
Potassium	4	5	1.38	0.82	0.94	1.02	1	1.15
Sodium	4	5	3.54	2.31	3.01	2.97	1	2.8
Fecal Coliform Bacteria (colonies per 100/ml)	5	5	20	1	6	6	0	
Pesticides (µg/L)								
Quantitative GC/MS	1	0			<0.005		0	
Broad Scan GC/MS	1	0			<0.10		0	

Table B.10. Summary of Water Quality Results for Mill Creek at Brookside Lane--CUMC02

PARAMETER	BASEFLOW						STORMFLOW					
	#SAM	#DET	MAX	MIN	MED	MEAN	#SAM	#DET	MAX	MIN	MED	MEAN
Field Parameters												
Air Temperature (°C)	5	NA	20.0	0.6	9.8	10.6	1	NA			8.0	
Water Temperature (°C)	5	NA	18.0	3.2	6.3	9.1	1	NA			7.3	
Stage (m below mark)	4	NA	0.65	0.60	0.60	0.61	0					
Specific Cond (μS/cm)	5	NA	58	32	42	43	1	NA			43	
DO (mg/L)	5	NA	11.5	8.3	10.6	10.2	1	NA			10.9	
DO (% saturation)	4	NA	92	81	87	86	1	NA			91	
pH (Standard Units)	5	NA	7.5	6.8	7.2	7.2	1	NA			7.2	
Nutrients (mg/L)												
Ammonia Nitrogen	5	2	0.3	0.1	0.1	0.1	2	1	0.9	0.1	0.5	0.5
Total Kjeldahl Nitrogen	5	4	0.7	0.1	0.3	0.4	2	2	0.7	0.5	0.6	0.6
Nitrate+Nitrite Nitrogen	5	5	0.28	0.18	0.22	0.22	2	2	0.31	0.20	0.26	0.26
Total Phosphorus	5	3	0.07	0.01	0.02	0.03	2	2	0.08	0.04	0.06	0.06
Total Nitrogen	5	5	0.9	0.2	0.5	0.6	2	2	0.9	0.8	0.9	0.9
Other Parameters (mg/L)												
Hardness, total	5	5	20.0	9.5	10.0	12.1	1	1			14.0	
Residue, T. Suspended	5	5	1.8	0.5	1.4	1.3	1	1			8.8	
Total Dissolved Solids	5	5	40	24	36	34	1	1			29	
Turbidity (NTU)	5	5	2.9	0.9	1.7	1.7	1	1			10.6	
Organics (μg/l)												
Phenols (604)	0						2	0			<5.0	
Polycyclic Aromatic Hydrocarbons (610)	0						2	0			<5.0	
Purgeable Organics (624)	0						2	0			<1.0	
Base/Neutral & Acid Organics (625)	0						3	0			<5.0-10.0	
Metals, Total (μg/L)												
Aluminum	5	5	136	49	105	97	4	4	573	382	445	461
Arsenic	5	0			<5		4	0			<5	
Cadmium	5	2			<0.1		4	0			<0.1	
Chromium	5	0			<1		4	0			<1	
Copper	5	0			<1		4	0			<1	
Iron	5	5	521	142	201	289	4	4	2250	456	925	1139
Lead	5	0			<1		4	3	5	1	3	3
Manganese	5	5	23.7	9.4	18.2	17.2	4	4	475.0	22.1	68.0	158.3
Mercury	5	0			<0.2		4	0			<0.2	
Nickel	5	1			<1		4	0			<1	
Silver	5	1			<5.0		4	0			<5.0	
Zinc	5	5	10.9	5.8	10.3	9.0	4	4	125.3	14.0	22.9	46.3
Ions (mg/L)												
Calcium	4	4	3.36	2.14	2.42	2.58	1	1	2.47	2.47	2.47	2.47
Magnesium	4	4	0.73	0.41	0.48	0.52	1	1	0.51	0.51	0.51	0.51
Potassium	4	4	1.00	0.57	0.69	0.74	1	1	0.87	0.87	0.87	0.87
Sodium	4	4	4.30	3.38	3.59	3.71	1	1	3.80	3.80	3.80	3.80
Fecal Coliform Bacteria (colonies per 100/ml)	5	4	84	11	24	25	0					

Table B10. Cont.

PARAMETER	BASEFLOW						STORMFLOW					
	#SAM	#DET	MAX	MIN	MED	MEAN	#SAM	#DET	MAX	MIN	MED	MEAN
Pesticides (µg/L)												
Chlorinated Pesticides	1	0		<0.01-1.50			0					
Organophosphate Pesticides	1	0		<0.4-20.0			0					
Nitrogen Pesticides	1	0		<0.5-20.0			0					
Acid Herbicides	1	0		<0.05-3.20			0					
Quantitative GC/MS	0						2	0		<0.005		
Broad Scan GC/MS	0						2	0		<0.10		

Table B.11. Summary of Water Quality Results for Saltrock Branch at Falls Drive West--CUSB03

PARAMETER	Baseflow	
	#SAM	8/16/01
Field Parameters		
Air Temperature (°C)	1	20.0
Water Temperature (°C)	1	18.0
Specific Cond (µS/cm)	1	28
DO (mg/L)	1	7.8
DO (% saturation)	1	82
pH (Standard Units)	1	7.3
Nutrients (mg/L)		
Ammonia Nitrogen	1	<0.1
Total Kjeldahl Nitrogen	1	0.8
Nitrate+Nitrite Nitrogen	1	0.26
Total Phosphorus	1	0.08
Total Nitrogen	1	0.3
Metals, Total (µg/L)		
Aluminum	1	212
Arsenic	1	<5
Cadmium	1	<0.1
Chromium	1	<1
Copper	1	<1
Iron	1	496
Lead	1	<1
Manganese	1	37.0
Mercury	1	<0.2
Nickel	1	<1
Silver	1	<0.5
Zinc	1	3.2
MBAS (mg/L)	1	<0.03

Table B.12. Summary of Water Quality Results for UT to Cullasaja at Skylake Road--CUCR04

PARAMETER	Baseflow	
	#SAM	**8/16/01**
Field Parameters		
Air Temperature (°C)	1	20.0
Water Temperature (°C)	1	17.0
Specific Cond (µS/cm)	1	52
DO (mg/L)	1	7.8
DO (% saturation)	1	82
pH (Standard Units)	1	7.8
Nutrients (mg/L)		
Ammonia Nitrogen	1	<0.1
Total Kjeldahl Nitrogen	1	0.8
Nitrate+Nitrite Nitrogen	1	0.11
Total Phosphorus	1	<0.02
Total Nitrogen	1	0.2
Metals, Total (µg/L)		
Aluminum	1	310
Arsenic	1	<5
Cadmium	1	<0.1
Chromium	1	<1
Copper	1	<1
Iron	1	652
Lead	1	<1
Manganese	1	<0.5
Mercury	1	<0.2
Nickel	1	5
Silver	1	6.8
Zinc	1	<0.1
MBAS (mg/L)	1	0.12

Table B.13. Summary of Water Quality Results for UT to Mill Creek at US 64--CUMC06

PARAMETER	Baseflow	
	#SAM	**12/6/00**
Organics: Base/Neutral & Acid Organics (625) (µg/L)		
NAPTHALENE	1	17
Other Peaks Detected		
2-METHYLNAPTHALENE	1	4 D
P-XYLENE	1	57 T
ETHYL METHYL BENZENE	1	70 T
TRIMETHYL BENZENE	1	180 T
DIETHYL BENZENE	1	17 T
METHYL PROPYL BENZENE	1	22 T
TETRA METHYL BENZENE	1	26 T
TETRAMETHYL TETRAHYDRO FURANE ONE	1	6 T

Table B.13. Cont.

PARAMETER	Baseflow	
	#SAM	12/6/00
Other Peaks Detected		
DIHYDROMETHYL H-INDENE	1	6 T
DIMETHYLBENZOIC ACID PROPYL BENZENE	1	6 T
INDAN	1	23 T

D=Detected below the quantitation limit
T=Tentatively identified, estimated concentration

Table B.14. Summary of Water Quality Results for Mill Creek below US 64--CUMC08

PARAMETER	BASEFLOW					
	#SAM	#DET	MAX	MIN	MED	MEAN
Field Parameters						
Air Temperature (°C)	1	NA			11.4	
Water Temperature (°C)	2	NA	13.7	12.4	13.1	13.1
Specific Cond (µS/cm)	2	NA	40	13	27	27
DO (mg/L)	2	NA	9.7	8.6	9.1	9.1
DO (% saturation)	2	NA	92	81	87	87
pH (Standard Units)	2	NA	7.4	6.8	7.1	7.1
Organics (µg/l)						
Base/Neutral & Acid Organics (625)	2	0		<5.0-10.0		

Table B.15. Summary of Water Quality Results for UT to Mill Creek at Main Street--CUMC09

PARAMETER	Baseflow	
	#SAM	12/6/00
Fecal Coliform Bacteria	1	>6000/90000*

*reported/estimated

Table B.16. Summary of Water Quality Results for Cullasaja River at Cullasaja Club Drive --CUCR10

PARAMETER	Baseflow	
	#SAM	8/29/00
Field Parameters		
Water Temperature (°C)	1	21.7
Specific Cond (µS/cm)	1	44
DO (mg/L)	1	5.4
pH (Standard Units)	1	6.5
Pesticides (µg/l)		
Chlorinated Pesticides (608)	1	>10 unidentified peaks detected
Organophosphate Pesticides (614/622)	1	0 peaks detected
Nitrogen Pesticides (619/630)	1	0 peaks detected
Acid Herbicides (615)	1	>10 unidentified peaks detected
-Bentazon	1	0.908

Table B.17. Summary of Water Quality Results for Cullasaja River at River Court--CUCR11

PARAMETER	Baseflow	
	#SAM	8/29/00
Field Parameters		
Water Temperature (^oC)	1	22.5
Specific Cond (µS/cm)	1	37
DO (mg/L)	1	8.6
pH (Standard Units)	1	6.9
Pesticides (µg/L)		
Chlorinated Pesticides (608)	1	10 unidentified peaks detected
Organophosphate Pesticides (614/622)	1	0 peaks detected
Nitrogen Pesticides (619/630)	1	0 peaks detected
Acid Herbicides (615)	1	>10 unidentified peaks detected
-Bentazon	1	D<0.8*

*detected below the quantification limit

Table B.18. Summary of Water Quality Results for Mill Creek at 5th Avenue--CUMC14

PARAMETER	BASEFLOW	
	#SAM	2/1/02
Organics (µg/l)		
Volatiles (602)	1	<0.5-1.0
Phenols (604)	1	<5.0
Chlorinated Compounds (608)	1	<0.2-2.5
Polycyclic Aromatic Hydrocarbons (610)	1	<5.0
Purgeable Organics (624)	1	<1.0
Base/Neutral & Acid Organics (625)	1	<5.0-10.0
Metals, Total (µg/L)		
Aluminum	1	207
Arsenic	1	<5
Cadmium	1	<0.1
Chromium	1	<1
Copper	1	<1
Iron	1	431
Lead	1	<1
Manganese	1	38.0
Mercury	1	<0.2
Nickel	1	<1
Silver	1	<0.5
Zinc	1	9.3

Table B.19. Summary of Water Quality Results for Tributary to Mill Creek by the Town of Highlands Warehouse Facility—CUMC19

PARAMETER	BASEFLOW	
	#SAM	2/1/02
Field Parameters		
Water Temperature (°C)	NA	11.0
Specific Cond (µS/cm)	NA	107
DO (mg/L)	NA	8.1
DO (% saturation)	NA	74
pH (Standard Units)	NA	6.4
Organics (µg/l)		
Volatiles (602)	1	
Benzene	1	1.03
Toluene	1	1.40
Ethylbenzene	1	1.84
M+P Xylene	1	4.92
O Xylene	1	1.92
Phenols (604)	1	<5.0
Polycyclic Aromatic Hydrocarbons (610)	1	<5.0
Purgeable Organics (624)	1	<1.0
Base/Neutral & Acid Organics (625)	1	<5.0-10.0
Metals, Total (µg/L)		
Aluminum	1	172
Arsenic	1	<5
Cadmium	1	<0.1
Chromium	1	<1
Copper	1	<1
Iron	1	924
Lead	1	<1
Manganese	1	45.0
Mercury	1	<0.2
Nickel	1	<1
Silver	1	<0.5
Zinc	1	22.7

Table B.20. Analytes with Detection Limits above Acute and/or Chronic Screening Benchmarks*

Chemical	Analytical Method	Detection Limit (µg/L)	Acute Benchmark (µg/L)	Chronic Benchmark (µg/L)
BHC, gamma- (Lindane)	GC/MS Broad Scan	0.1	0.95	0.08
Chlordane	GC/MS Broad Scan	0.1	2.4	0.0043
Chlordane	EPA 608	0.01	2.4	0.0043
Chloropyrifos	GC/MS Broad Scan	0.1	0.083	0.041
Demeton	GC/MS Broad Scan	0.1		0.1
Diazinon	GC/MS Broad Scan	0.1	0.17	0.043
Dieldrin	GC/MS Broad Scan	0.1	0.24	0.056
Endrin	GC/MS Broad Scan	0.1	0.086	0.036
Heptachlor	GC/MS Broad Scan	0.1	0.52	0.0038
Heptachlor	EPA 608	0.01	0.52	0.0038
Malathion	GC/MS Broad Scan	0.1		0.1
Methoxychlor	GC/MS Broad Scan	0.1		0.03
Parathion	GC/MS Broad Scan	0.1	0.065	0.013
4,4'-DDT	GC/MS Broad Scan	0.1	1.1	0.001
Toxaphene	EPA 608	1.5	0.73	0.0002
Anthracene	EPA 610/625	5	13	0.73
Benzo(a)anthracene	EPA 610/625	5	0.49	0.027
Benzo(a)pyrene	EPA 610/625	5	0.24	0.014
4-Bromophenyl Phenyl Ether	EPA 625	5		1.5
2,4-Dinitrophenol	EPA 625	10	62	6.2
Hexachlorobutadiene	EPA 625	5	9	0.93
Hexachlorocyclopentadiene	EPA 625	5	0.7	0.07
2,4,6-Trichlorophenol	EPA 625	10	32	3.2
PCBs	EPA 608	0.5		0.014

*The sources of actue and chronic benchmarks are EPA NAWQC (primary source) and EPA Tier II (secondary source). If neither of these sources had benchmarks, then EPA Region 4 benchmarks were used.

Section 3 Pesticides and Organic Analyses: Analyte Lists

Lists of analytes for pesticide and organic analyses used in this study are presented in Tables B.21 through B.34.

Table B.21. Pesticides Analyzed by NCSU Broad Scan GC/MS Method*

ACEPHATE	BUTYLATE	CYCLURON	DINOSEB
ACETOCHlOR	CAPTAFOL	CYPROFURAM	DINOSEB ACETATE
ALACHLOR	CAPTAN	D (2,4) METHYlESTER	DINOTERB
ALDRIN	CARBARYL	DDD-O,P'	DIOXATHION
ALLETHRIN	CARBETAMIDE	DDD-P,P'	DIPHENAMID
AMETRYN	CARBOFURAN	DDE-O,P'	DIPROPETRYN
AMIDITHION	CARBOPHENOTHION	DDE-P,P'	DISULFOTON
AMINOCARB	CARBOXIN	DDT-O,P'	DITALIMPHOS
AMITRAZ	CHLORANIFORMETHAN	DDT-P,P'	DNOC
ANILAZINE	CHLORBENSIDE	DEMEPHION	DODEMORPH
ANTHRAQUINONE	CHLORBROMURON	DEMETON	ENDOSULFAN SULFATE
ARAMITE	CHLORBUFAM	DEMETON-S-METHYL	ENDOSUlFAN-ALPHA
ATRAZINE	CHLORDANE	DESMETRYN	ENDOSULFAN-BETA
ATRAZINE DESETHYL	CHLORDIMEFORM	DIALIFOS	ENDRIN
ATRAZINE DESISOPROPYL	CHLORFENPROP-METHYL	DI-ALLATE	EPN
AZ0BENZENE	CHLORFENSON	DIAZINON	ETACONAZOLE
AZAMETHIPHOS	CHLORFENVENPHOS	DICHLOBENIL	ETHALFLURALIN
AZINPHOS-ETHYL	CHlORFLURECOL-METHYL	DICHLOFENTHION	ETHIOFENCARB
AZINPHOS-METHYL	CHLORIDAZON	DICHLOFLUANID	ETHIOLATE
AZIPROTRYNE	CHLORMEPHOS	DICHLONE	ETHION
BARBAN	CHLOROBENZILATE	DICHLORO(4,4')DIBENZOPHENONE	ETHOFUMESATE
BENALAXYL	CHLORONEB	DICHLOROANILINE (2,3-)	ETHOPROPHOS
BENDIOCARB	CHLOROPROPYLATE	DICHLOROANILINE (2,5-)	ETRIDIAZOLE
BENFLURALIN	CHLOROTHALONIL	DICHLOROBENZENE (1,2-)	ETRIMFOS
BENODANIL	CHLORPROPHAM	DICHLOROPHENOL (2,4-)	FENAMIPHOS
BENTAZONE	CHLORPYRIFOS	DICHLORPROP METHYLESTER	FENARIMOL
BENZOYLPROP-ETHYL	CHLORPYRIFOS-METHYL	DICHLORVOS	FENAZAFLOR
BIFENOX	CHLORTHAL-DIMETHYL	DICLOBUTRAZOL	FENCHLORPHOS
BIPHENYL	CHLORTHIAMID	DICLOFOP-METHYl	FENITROTHION
BITERTANOL	CHLORTHION	DICLORAN	FENPROPlMORPH
BROMACIL	CHlORTHIOPHOS	DICOFOL	FENSON
BROMOCYLCLEN	CHLOZOLINATE	DICROTOPHOS	FENSULFOTHION
BROMOPHOS	COUMAPHOS	DIELDRIN	FENTHION
BROMOPHOS-ETHYL	CROTOXYPHOS	DIMEFOX	FENVALERATE
BROMOPROPYLATE	CRUFOMATE	DIMETHACHLOR	FLAMPROP-ISOPROPYL
BUPIRIMATE	CYANAZINE	DIMETHAMETRYN	FLUAZIFOP-P-BUTYL
BUTACHLOR	CYANOFENPHOS	DIMETHIPIN	FLUBENZIMINE
BUTRALIN	CYANOPHOS	DIMETHOATE	FLUCHLORALIN
BUTURON	CYCLOATE	DINOBUTON	FLUMETRALIN

Table B.21. CONT.

FLUOMETURON	METHACRIPHOS	PHORATE	SWEP
FLUORODIFEN	METHAMIDOPHOS	PHOSALONE	T (2,4,5..) METHYLESTER
FLURECOL-BUTYL	METHAZOLE	PHOSMET	TEBUTAM
FLURIDONE	METHIDATHION	PHOSPHAMIDON	TECNAZENE
FLUROCHLORIDONE	METHOPROTRYNE	PHOXIM	TEPP
FOLPET	METHOXYCHLOR	PINDONE	TERBAZIL
FONOFOS	METOBROMURON	PIPERONYL BUTOXIDE	TERBUMETON
FORMOTHION	METOLACHLOR	PIRIMICARB	TERBUTHYLAZINE
HCH-ALPHA	METRIBUZIN	PIRIMIPHOS-ETHYL	TERBUTRYN
HCH-BETA	MEVINPHOS	PIRrMIPHOS-METHYL	TETRACHLORVINPHOS
HCH-DELTA	MIREX	PROCHLORAZ	TETRADIFON
HEPTACHLOR	MOLINATE	PROCYMIDONE	TETRAMETHRIN
HEPTACHLOREPOXID-CIS	MONALIDE	PROFENOFOS	TETRASUL
HEPTACHLOREPOXID-TRANS	MONOCROTOPHOS	PROFLURALIN	THIABENDAZOLE
HEPTENOPHOS	MONOLINURON	PROMECARB	THIOBENCARB
HEXABROMOBENZENE	NALED	PROMETON	THIOMETON
HEXACHLOROBENZENE	NAPROPAMIDE	PROMETRYN	THIONAZIN
HEXACHLOROPHENE	NITRALIN	PROPACHLOR	THIOQUINOX
IMAZILIL	NITRAPYRIN	PROPANIL	TIOCARBAZIL
IODOFENPHOS	NITROFEN	PROPARGITE	TOLCLOFOS-METHYL
IOXYNIL	NITROTHAL-ISOPROPYL	PROPAZINE	TOLYLFLUANID
IPRODIONE	NORFLURAZON DESMETHYL	PROPETAMPHOS	TRI-ALLATE
ISAZOPHOS	NUARlMOL	PROPHAM	TRIADIMEFON
ISOCARBAMID	OMETHOATE	PROPICONAZOLE	TRIADIMENOL
ISOFENPHOS	OXADIAZON	PROPOXUR	TRIAMIPHOS
ISOMETHIOZIN	OXADIXYL	PROPYZAMIDE	TRIAZOPHOS
ISOPROPALIN	OXYCARBOXIN	PROTHIOPHOS	TRICHLORFON
LANDRIN (3,4,5-)	OXYDEMETON-METHYL	PROTHOATE	TRICHlOROACETOPHENON (1,2,4-)
LENACIL	PARAOXON	PYRAZOPHOS	TRICHLOROBENZENE (1,2,4-)
LINDANE	PARATHION	PYRIDATE	TRICHLORONAT
MALAOXON	PARATHION-METHYL	PYROQUILON	TRICHLOROPHENOL (2,3,5-)
MALATHION	PEBULATE	QUINALPHOS	TRICHLOROPHENOL (2,3,6-)
MCPA	PENCONAZOLE	QUINOMETHIONATE	TRICHLOROPHENOL (2,4,5-)
MCPA METHYLESTER	PENDIMETHALIN	QUINTOZENE	TRIDIPHANE
MECARBAM	PENTACHLOROBENZENE	SECBUMETON	TRIETAZINE
MECOPROP	PENTANOCHLOR	SIMAZINE	TRIFLURALIN
MECOPROP METHYLESTER	PERTHANE	SIMETRYN	VAMIDOTHION
METAMITRON	PHENKAPTON	SULFOTEPP	VERNOLATE
METAZACHLOR	PHENTHOATE	SULPROFOS	VINCLOZOLIN

*Note: Detection limits for Broad Scan GC/MS compounds are 0.10 ug/L

Table B.22. Pesticides Analyzed by NCSU Quantitative GC/MS Method*

2,6-DIETHYLANALINE	DACTHAL	FLUMETRALIN	PERMETHRIN
ALACHLOR	DEETHYLATRAZINE	FONOFOS	PROMETON
ATRAZINE	DEISOPROPYLATRAZINE	MALATHION	PROMETRYN
BENFLURALIN	DIAZINON	METHYL PARATHION	SIMAZINE
BUTYLATE	DIMETHOATE	METOLACHLOR	TEBUTHIURON
CARBARYL	DISULFOTON	METRIBUZIN	TERBUFOS
CARBOFURAN	EPTC	MOLINATE	TRIFLURALIN
CHLOROTHALONIL	ETHALFLURALIN	NAPROPAMIDE	
CHLORPYRIFOS	ETHOPROP	PEBULATE	
CYANAZINE	FENAMIPHOS	PENDIMETHALIN	

*Note: Detection limits for quantitative GC/MS compounds are 0.005 µg/L

Table B.23. Volatile Organics and their Quantitation Limits (EPA Method 602) (µg/L)

Benzene	0.5	O-Xylene	0.5
Toluene	0.5	1,3-Dichlorobenzene	0.5
Chlorobenzene	0.5	1,4-Dichlorobenzene	0.5
Ethyl Benzene	0.5	MTBE	0.5
M + P Xylene	1.0		

Table B.24. Phenols and their Quantitation Limits (EPA Method 604) (µg/L)

4-Chloro-3-methylphenol	5.0	2-Nitrophenol	5.0
2-Chlorophenol	5.0	4-Nitrophenol	5.0
2,4-Dichlorophenol	5.0	Pentachlorophenol	5.0
2,4-Dimethylphenol	5.0	Phenol	5.0
2,4-Dinitrophenol	5.0	2,4,6-Trichlorophenol	5.0
2-Methyl-4,6-dinitrophenol	5.0		

Table B.25. NCDWQ Chem Lab Chlorinated Pesticides and their Quantitation Limits Analyzed by Electron Capture Detection (EPA Method 608) (µg/L)

ALACHLOR	< 0.08	DDD, PP	< 0.01	METHOXYCHLOR, PP	< 0.05
ALDRIN	< 0.01	DDE, OP	< 0.02	MIREX	< 0.02
ATRAZINE	< 1.50	DDE, PP	< 0.01	TRANS-NONACHLOR	< 0.01
BHC-ALPHA	< 0.01	DDT, OP	< 0.02	OXYCHLORDANE	< 0.03
BHC-BETA	< 0.01	DDT, PP	< 0.01	MIXED-PERMETHRIN	< 0.60
BHC-DELTA	< 0.01	DIELDRIN	< 0.01	PROPACHLOR	< 0.15
BHC-GAMMA(LINDANE)	< 0.01	ENDOSULFAN I	< 0.01	TECNAZENE	< 0.01
CHLORDANE, TECHNICAL	< 0.30	ENDOSULFAN II	< 0.01	TOXAPHENE	< 1.50
CHLORDANE-ALPHA	< 0.01	ENDOSULFAN SULFATE	< 0.01	TRIFLURALIN	< 0.02
CHLORDANE-GAMMA	< 0.02	ENDRIN	< 0.01	AROCLOR 1016	< 0.50
CHLORDENE	< 0.01	ENDRIN ANDEHYDE	< 0.01	AROCLOR 1221	< 0.50
CHLORNEB	< 0.10	ENDRIN KETONE	< 0.02	AROCLOR 1232	< 0.50
CHLOROBENZILATE	< 0.30	ETHAZOLE	< 0.03	AROCLOR 1242	< 0.50
CHLORPYRIFOS	< 0.03	HEPTACHLOR	< 0.01	AROCLOR 1248	< 0.50
CHLOROTHALONIL	< 0.01	HEPTACHLOR EPOXIDE	< 0.01	AROCLOR 1254	< 0.50
DCPA	< 0.01	HEXACHLOROBENZENE	< 0.01	AROCLOR 1260	< 0.50
DDD, OP	< 0.03	MALATHION	< 0.10	AROCLOR 1262	< 0.50

Table B.26. NCDWQ Chem Lab Acid Herbicides and their Quantitation Limits Analyzed by Electron Capture Detection (EPA Method 615) (µg/L)

ACIFLUORFEN (BLAZER)	< 0.10	DICHLORPROP	< 0.60
BENTAZON	< 0.80	DINOSEB	< 0.20
CHLORAMBEN	< 0.20	5-HYDROXYDICAMBA	< 0.10
2,4-D	< 0.40	4-NITROPHENOL	< 3.20
2,4-DB	< 0.80	PENTACHLOROPHENOL (PCP)	< 0.05
DCPA (ACID METABOLITES)	< 0.10	PICLORAM	< 0.20
DICAMBA	< 0.10	2,4,5- T	< 0.10
3,5 DICHLOROBENZOIC ACID	< 0.60	2,4,5-TP (SILVEX)	< 0.10

Table B.27. NCDWQ Chem Lab Organophosphate Pesticides and their Quantitation Limits Analyzed by Flame Photometric Detection (EPA Method 614/622) (µg/L)

CARBOPHENOTHION	< 0.8	FENTHION	< 0.4
CHLORPYRIFOS	< 0.4	FENSULFOTHION	< 4.8
DEF (OXIDIZED MERPHOS)	< 0.4	FOLEX (MERPHOS, TRIBUFOS)	< 20.0
DEMETON	< 0.8	MEVINPHOS	< 0.4
DIAZINON	< 0.4	MONOCROTOPHOS	< 0.8
DICHLORVOS	< 0.4	NALED	< 0.8
DIMETHOATE	< 0.4	ETHYL PARATHION	< 0.4
DISULFOTON	< 0.8	METHYL PARATHION	< 0.4
DISULFOTON SULFONE	< 1.0	PHORATE	< 0.4
DISULFOTON SULFOXIDE	NE*	RONNEL	< 0.4
EPN	< 0.4	SULFOTEPP	< 0.4
ETHION	< 0.4	TERBUFOS	< 0.4
ETHOPROP	< 0.4		

*no established target quantitation limit

Table B.28. NCDWQ Chem Lab Nitrogen Pesticides and their Quantitation Limits Analyzed by Nitrogen Phosphorous Detection (EPA Method 619/630) (µg/L)

ALACHLOR	< 5.0	DIPHENAMID	< 5.0	PROMETON	< 1.5
AMETRYN	< 1.5	EPTC (EPTAM)	< 1.5	PROMETRYN	< 1.5
ATRAZINE	< 1.5	FENAMIPHOS	< 5.0	PRONAMIDE	< 5.0
BROMACIL	< 10	HEXAZINONE	< 5.0	PROPAZINE	< 1.5
BUTACHLOR	< 10	METOLACHLOR	< 5.0	SIMAZINE	< 1.5
BUTYLATE	< 1.5	METRIBUZIN	< 5.0	SIMETRYN	< 1.5
CARBOXIN	< 10	MGK 264	< 20.0	TEBUTHIURON	< 5.0
CHLORPROPHAM	< 5.0	MOLINATE	< 1.5	TERBACIL	< 20.0
CHLORPYRIFOS	< 0.5	NAPROPAMIDE	< 10.0	TERBUFOS	< 0.5
CYANAZINE	< 2.5	NORFLURAZON	< 5.0	TERBUTRYN	< 1.5
CYCLOATE	< 1.5	PEBULATE	< 1.5	VERNOLATE	< 1.5
DIAZINON	< 0.5				

Table B.29. Polycyclic Aromatic Hydrocarbons and their Quantitation Limits (EPA Method 610) (µg/L)

ACENAPHTHENE	<5.0	CHRYSENE	<5.0
ACENAPHTHYLENE	<5.0	DIBENZO(A,H)ANTHRACENE	<5.0
ANTHRACENE	<5.0	FLUORANTHENE	<5.0
BENZO(A)ANTHRACENE	<5.0	FLUORENE	<5.0
BENZO(A)PYRENE	<5.0	INDENO(1,2,3-C,D)PYRENE	<5.0
BENZO(B)FLUORANTHENE	<5.0	NAPHTHALENE	<5.0
BENZO(K)FLUORANTHENE	<5.0	PHENANTHRENE	<5.0
BENZO(G,H,I,)PERYLENE	<5.0	PYRENE	<5.0

Table B.30. Volatile Organics (Purgeables) and their Quantitation Limits (EPA Method 624) (µg/L)

BENZENE	<1.0	1,2-DICHLOROBENZENE	<1.0	METHYLENE CHLORIDE	<1.0
BROMODICHLOROMETHANE	<1.0	1,3-DICHLOROBENZENE	<1.0	1,1,2,2-TETRACHLOROETHANE	<1.0
BROMOFORM	<1.0	1,4-DICHLOROBENZENE	<1.0	TETRACHLOROETHENE	<1.0
BROMOMETHANE	<1.0	1,1-DICHLOROETHANE	<1.0	TOLUENE	<1.0
CARBON TETRACHLORIDE	<1.0	1,2-DICHLROROETHANE	<1.0	1,1,1-TRICHLOROETHENE	<1.0
CHLOROBENZENE	<1.0	1,1-DICHLORORETHENE	<1.0	1,1,2-TRICHLOROETHENE	<1.0
CHLOROETHANE	<1.0	TRANS-1,2-DICHLOROETHENE	<1.0	TRICHLOROETHANE	<1.0
2-CHLOROETHYLVINYL ETHER	<1.0	1,2-DICHLOROPROPANE	<1.0	TRICHLOROFLUOROMETHANE	<1.0
CHLOROFORM	<1.0	CIS-1,3-DICHLOROPROPENE	<1.0	VINYL CHLORIDE	<1.0
CHLOROMETHANE	<1.0	TRANS-1,3-DICHLOROPROPENE	<1.0		
DIBROMOCHLOROMETHANE	<1.0	ETHYL BENZENE	<1.0		

Table B.31. Base/Neutral and Acid Organics and their Quantitation Limits (EPA Method 625) (µg/L)

ACENAPHTHLENE	<5.0	CHRYSENE	<5.0	HEXACHLOROBENZENE	<5.0
ACENAPHTHYLENE	<5.0	DI-N-BUTYLPHTHALATE	<5.0	HEXACHLOROBUTADIENE	<5.0
ANTHRACENE	<5.0	DI-N-OCTYLPHTHALATE	<5.0	HEXACHLOROCYCLOPENTADIENE	<5.0
BENZO(A)ANTHRACENE	<5.0	DIBENZO(A,H)ANTHRACENE	<5.0	HEXACHLOROETHANE	<5.0
BENZO(A)PYRENE	<5.0	1,2-DICHLOROBENZENE	<5.0	INDENO(1,2,3-C,D)PYRENE	<5.0
BENZO(B)FLUORANTHENE	<5.0	1,3-DICHLOROBENZENE	<5.0	ISOPHORONE	<5.0
BENZO(G,H,I,)PERYLENE	<5.0	1,4-DICHLOROBENZENE	<5.0	N-NITROSODI-N-PROPYLAMINE	<10.0
BENZO(K)FLUORANTHENE	<5.0	3,3'-DICHLOROBENZIDINE	<10.0	N-NITROSODIPHENYLAMINE	<10.0
BIS(2-CHLOROETHOXY)METHANE	<10.0	2,4-DICHLOROPHENOL	<10.0	NAPHTHALENE	<5.0
BIS(2-CHLOROETHYL)ETHER	<10.0	DIETHYLPHTHALATE	<5.0	NITROBENZENE	<10.0
BIS(2-CHLOROISOPROPYL)ETHER	<10.0	2,4-DIMETHYLPHENOL	<5.0	2-NITROPHENOL	<10.0
BIS(2-ETHYLHEXYL)PHTHALATE	<5.0	DIMETHYLPHTHALATE	<5.0	4-NITROPHENOL	<10.0
4-BROMOPHENYL PHENYL ETHER	<5.0	4,6-DINITRO-2-METHYLPHENOL	<10.0	PENTACHLOROPHENOL	<10.0
BUTYLBENZYLPHTHALATE	<5.0	2,4-DINITROPHENOL	<10.0	PHENANTHRENE	<10.0
4-CHLOROANILIME	<5.0	2,4-DINITROTOLUENE	<5.0	PHENOL	<10.0
4-CHLORO-3-METHYLPHENOL	<10.0	2,6-DINITROTOLUENE	<5.0	PYRENE	<5.0
2-CHLORONAPHTHALENE	<5.0	FLUORANTHENE	<5.0	1,2,4-TRICHLOROBENZENE	<5.0
2-CHLOROPHENOL	<10.0	FLUORENE	<5.0	2,4,6-TRICHLOROPHENOL	<10.0
4-CHLOROPHENYL PHENYL ETHER	<5.0				

Table B.32. SPMD Chlorinated Pesticides analyzed by Modified EPA Method 8081A*

alpha BHC	beta endosulfan
beta BHC	endosulfan sulfate
gamma-BHC (lindane)	endrin
delta BHC	endrin aldehyde
hexachlorobenzene	endrin ketone
heptachlor	methoxychlor
heptachlor epoxide	mirex
alpha chlordane	4,4'-DDT
gamma chlordane	4,4'-DDD
trans-nonachlor	4,4'-DDE
aldrin	2,4'-DDT
dieldrin	2,4'-DDD
alpha endosulfan	2,4'-DDE

*Note: Detection limit=2 ng

Table B.33. SPMD PCBs Analyzed by Modified EPA Method 8082*

PCB 8	PCB 105
PCB 18	PCB 138
PCB 28	PCB 126
PCB 52	PCB 187
PCB 44	PCB 128
PCB 66	PCB 180
PCB 101	PCB 170
PCB 77	PCB 195
PCB 118	PCB 206
PCB 153	PCB 209

*Note: Detection limit=2 ng

Table B.34. SPMD PAHs Analyzed by Modified EPA Method 8270C*

Napthalene	1-Methylphenanthrene
2-Methylnapthalene	C1 - Phenanthrenes/Anthracenes
1-Methylnapthalene	C2 - Phenanthrenes/Anthracenes
Biphenyl	C3 - Phenanthrenes/Anthracenes
2,6-Dimethylnapthylene	C4 - Phenanthrenes/Anthracenes
Acenapthylene	Fluoranthrene
Acenapthene	Pyrene
Dibenzofuran	C1 - Fluoranthenes/Pyrenes
2,3,5-Trimethylnapthalene	Retene
C1 - Napthalenes	Benz[a]anthracene
C2 - Napthalenes	Chrysene
C3 - Napthalenes	C1 - Chrysenes
C4 - Napthalenes	C2 - Chrysenes
Fluorene	C3 - Chrysenes
1-Methylfluorene	C4 - Chrysenes
C1 - Fluorenes	Benzo[b]fluoranthene
C2 - Fluorenes	Benzo[k]fluoranthene
C3 - Fluorenes	Benzo[e]pyrene
Dibenzothiophene	Benzo[a]pyrene
C1 - Dibenzothiophenes	Perylene
C2 - Dibenzothiophene	Indeno[1,2,3-c,d]perylene
C3 - Dibenzothiophene	Dibenz[a,h]anthracene
Phenanthrene	benzo[g,h,i]perylene
Anthracene	Coronene

Note: Detection limit=2 ng

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Appendix C
Stream and Riparian Area Surveys

This study undertook a broad characterization of stream condition by examining large sections of the channel network of the upper Cullasaja River and Mill Creek in the field. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities. The results of these efforts are summarized in this appendix.

During the course of this study, project staff walked the channel of the upper Cullasaja River from Ravenel Lake to approximately one-half mile above Mirror Lake, where the creek became too difficult to walk. The entire channel of Mill Creek was walked from Lake Ravenel to Mirror Lake. A few tributaries of these streams were also walked. All photos (Figures C.1 through C.4) are included at the end of this appendix.

Upper Cullasaja River and Its Tributaries

Cullasaja River: Ravenel Lake to Mirror Lake (stream benthos sampled at US 64 and in Highlands Falls Country Club at River Court)

The impaired section of the Cullasaja River runs through three golf courses in its upper half, then flows through a steep wooded valley to Mirror Lake (Section 6, Figure 6.1). Throughout this 4.8 mile section, the river is often a low gradient system, flowing very slowly over bedrock or boulder. Long low gradient sections are broken up by bedrock falls and short cobble-gravel runs.

Two main headwater tributaries are dammed to form Ravenel Lake. One tributary flows through Wildcat Cliffs Country Club, where it is dammed numerous times and runs through the golf course before it flows into Ravenel Lake. The other tributary flows through a forested area and receives the discharge from Wildcat Cliff's wastewater treatment plant.

From Ravenel Lake to US 64, the river runs through two golf communities—the Cullasaja Club and Highlands Falls Country Club. The majority of this two-mile section flows through golf courses, where it often has no wooded buffer and is instead bordered by short grass (Figure C.1). In many areas, the playing area of the golf course is within two meters of the river, and holes are arranged so that golfers must hit balls over the river. In other areas, the golf course is oriented so that the playing area is not so close to the river. Here, a buffer of native vegetation, primarily *Rhododendron maximum*, is sometimes present (Figure C.2). Some of these riparian buffers have been recently cleared in the Cullasaja Club.

In some areas, the river has been channelized, and there are some areas where the banks are unstable. In the Cullasaja Club, riprap has been used to hold unstable banks in place along much of the river that has no woody riparian buffer (Figure C.3). There is no massive bank failure in the upper Cullasaja River, however, and unstable banks are likely a less significant source of sediment than upland sources. Where a buffer of native vegetation exists, stream banks are generally stable.

The golf community section of the Cullasaja River runs through a wide valley. There are three in-stream impoundments along the river itself and many more on its tributaries. These impoundments were usually built to create water hazards and irrigation sources for the golf courses. Ravenel Lake is the largest impoundment (24 acres), and passively releases water over its top. Due to this design, when water is low in the lake, no water flows out of the lake; in the dry summer of 2000, there were periods of up to 6 weeks with no release. There is an off-line impoundment below Ravenel Lake, where a low dam diverts part of the stream flow to a pond but still allows some flow to continue in a channelized section of the Cullasaja River. The second in-stream impoundment is formed by a low riprap dam on the river, but it is likely that this structure allows continuous water release. The last impoundment is large (10 acres), and is formed by damming the confluence of Ammons Branch and the Cullasaja River. Like Ravenel Lake, water in this impoundment is released over the top of the dam, and there are times when water within the impoundment is so low that there is very little release below the dam.

Below US 64, the Cullasaja runs though a steep and primarily forested valley. Again, it alternates between slow flowing areas of bedrock and bedrock-boulder drops. For the most part, the valley is steep enough to preclude construction along the river, although there is one landowner who has cleared a large area of riparian forest (approximately 1 acre) and built near the river. Houses dot the ridges above the valley.

Excess sediment deposition is present in some locations in the 4.2 mile impaired section of the Cullasaja River, but it does not seem to be a gross problem. The biggest sources of sediment are upland construction along the ridges. Slugs of sand move into the Cullasaja River, but these are stopped eventually by one of the impoundments.

The greater habitat quality issue in the golf community reach of the Cullasaja River is lack of organic microhabitat. Due to the lack of woody riparian vegetation, there are no undercut banks or woody root mats in the areas that have been cleared in the golf courses (such as the reach that was sampled for benthos at River Court). Here, there is no large wood, and there are few leafpacks and sticks. Since roughness within the channel is minimal (no edge vegetation, little sinuosity, and few large boulders), organic debris like leafpacks and sticks that come from wooded areas upstream is less likely to collect in these manicured areas. Habitat complexity has been reduced.

Salt Rock Branch (stream benthos sampled at lower end)

Salt Rock Branch begins up on a steep forested ridge, but crosses into a manicured area of Highlands Falls Country Club. At first, a forested buffer of at least five meters on each side runs along the creek within this residential area. The country club's wastewater treatment plant discharges within this section. For the last 600 m of the creek above its confluence with the Cullasaja River, it has no woody vegetation along its banks and is impounded once. Just before it meets the Cullasaja River, it joins with the East Fork Salt Rock Branch. East Fork Salt Rock Branch is not impounded along its length, but it runs along a new road in its headwaters, where heavy deposits of sand choke the creek. In the winter of 2001, it had heavy growths of epiphytic algae, apparently resulting from hydroseed mix used along the road (Figure C.4). Once it crosses into the manicured area of the country club, it has no forested buffer.

Unnamed tributary to Cullasaja River (stream benthos sampled along US 64)
Unlike Salt Rock Branch, this creek runs along US 64, where it flows past retail businesses, an autobody shop, and residences before it enters the Highlands Falls Country Club. Along most of its length, it has a forested buffer. It alternates between a high gradient bedrock-boulder stream type and a very low gradient type, where there are heavy deposits of sand. Once it enters the country club, it is impounded in a two acre pond. Below this, it enters a steep wooded valley, where it becomes a sequence of riffles and pools. The maintenance area of the country club is sited along the left bank, and here the buffer is non-existent, with construction debris pushed against the stream banks.

Mill Creek and Its Tributaries

Mill Creek: From Lake Ravenel to US 64 (stream benthos sampled at 5th Avenue)
Mill Creek begins up on a forested ridge and is impounded at the Highlands Biological Station as Lake Ravenel. Between Lake Ravenel and US 64 (approximately 1,100 meters), the land is relatively flat, and the stream has relatively low gradient. Mill Creek flows through an intact riparian forest in the biological station, and here it has good in-stream habitat. Mill Creek is impounded again as soon as it enters the residential area of Highlands. Below this pond, it enters a very flat and wet area; the stream banks are organic, and the upland area is pocketed with wetlands. The stream has very low gradient, and the bottom substrate is a mix of silt-covered cobble, gravel, and sand. It has little forested riparian area. Within this low gradient area Mill Creek's major tributary, Satulah Branch, enters. Below this confluence, beavers have dammed the creek. This dam is approximately 350 meters upstream of the benthic sampling location at 5th Avenue.

Once the creek crosses 5th Avenue, its gradient increases. As it flows past residences, it sometimes has a thin (five meter) forested buffer and is other times bordered by grassy banks. Bottom substrate is a mix of bedrock, boulder, cobble, gravel, and sand; finer substrate is less dominant here than in the upper low gradient section. As it flows through commercial Highlands, it has no wooded buffer and is held in place by rock walls. Parking lots and businesses border the creek to US 64.

Mill Creek: From US 64 to Mirror Lake (stream benthos sampled at Brookside Lane)
This section of Mill Creek (1,300 meters) is that below the town center. It is surprisingly lovely, typified by bedrock slides, drop-pool sections of boulder and cobble, and pools. It courses through a forested ravine for most of its length; where the creek is bordered by wider floodplain, houses have been built and riparian areas heavily landscaped.

Just below US 64, the stormwater pipe that carries much of Highlands' town center stormwater enters Mill Creek. This pipe often carries water with a petroleum odor. Below this input, Mill Creek drops quickly over a bedrock slide. Below this slide area, Mill Creek is characterized by boulder-cobble riffles, bedrock slides, and pools. It runs through a forested ravine, but where the ravine widens to provide an apron of dry land, there is residential development and Highlands' old wastewater treatment plant (WWTP). At the old WWTP, the creek has been channelized for approximately 20 meters, and vegetation on the left bank has been managed. A sewer line runs along the left bank until from US 64 to the old WWTP. In the small area where residential development borders the creek, riparian vegetation on the left bank has been cut down to scrubby shrubs.

Sediment moves through lower Mill Creek and ultimately ends up in Mirror Lake. Landowners around Mirror Lake have seen a gradual conversion from lake to vegetated wetland due to continual deposition of sand. In Mill Creek itself, fine sediment accumulates only in lower gradient sections where sand accumulates in pools and mid-channel and side bars. However, excess sedimentation is not a significant problem for this section of Mill Creek. In-stream habitat is very good in most areas of this section of Mill Creek, although leafpacks and sticks are not frequently observed.

Although lower Mill Creek receives stormwater from half of Highlands, the channel is very stable. Streams subjected to high volumes of urban stormwater often compensate for the larger volume and higher energy flows by channel downcutting and/or widening. There is no downcutting in Mill Creek due to its bedrock bottom. Stream banks seem relatively stable, as well, and many of them are rock.

Epiphytic algae are often seen on stream substrate in lower Mill Creek; higher nutrients may be a problem. One tributary below the WWTP that begins near the Town of Highlands' maintenance facility (where there was a leaking underground storage tank) and then flows through a residential area had high specific conductance (103 uS/cm) and algae at the foot of the pipe.

Tributaries to Mill Creek

Satulah Branch is the main tributary to Mill Creek, and it begins up on a ridge and courses through a wooded valley, where it usually has a forested riparian area. As the land flattens out closer to central Highlands, the stream's gradient lessens, and its bottom substrate changes from cobble and boulder to mostly sand. In this flat area, the stream flows past a school and several residences, where it has little forested buffer. It flows into a beaver-created wetland and then into Harris Lake, which is bordered by manicured lawn used by humans and geese. Below Harris Lake, it flows slowly through flat, wet land, until it converges with Mill Creek.

Other tributaries that flow into Mill Creek are very small and often very sandy. Tributaries below US 64 flow through densely built residential land, many of them are impounded to form small decorative ponds near houses. The two main tributaries that enter Mill Creek below the last impoundment (beaver pond above 5th Avenue) flow from the area of the Town of Highlands' maintenance facility, where there is contamination from a leaky underground storage tank (UST). Both of these tributaries have a strong petroleum smell and high specific conductance near the maintenance facility (107 and 162 uS/cm).

Figure C.1. The Cullasaja River running through a golf course.

Figure C.2. Cullasaja River with forested buffer in golf course community.

Figure C.3. Riprapped banks on the Cullasaja River in a golf course.


Figure C.4. Heavy growths of algae in East Fork Salt Rock Branch.