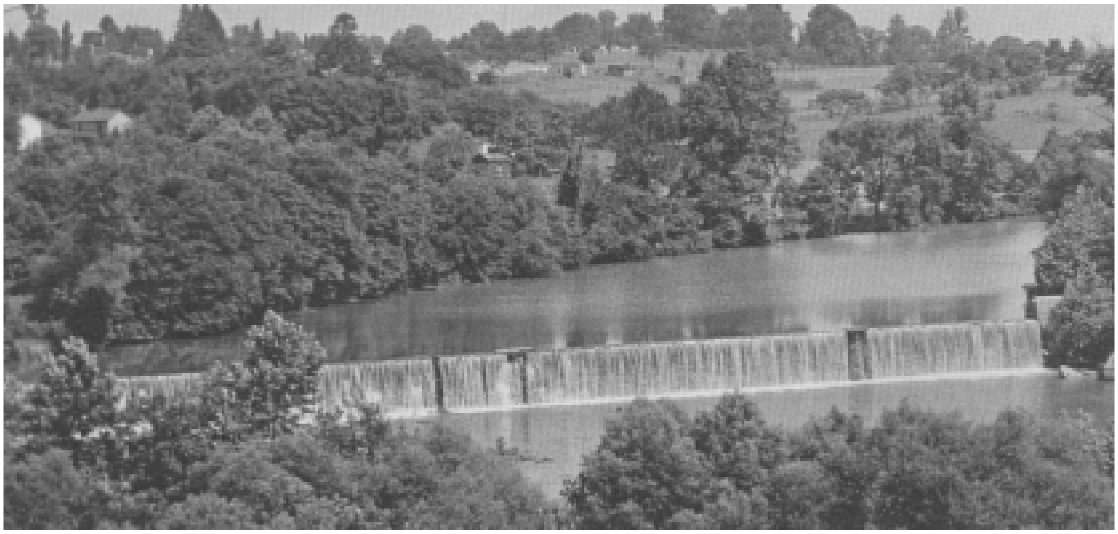
RIVANNA RIVER BASIN PROJECT



# STATE OF THE BASIN

# 1998

Thomas Jefferson Planning District Commission
Rivanna River Basin Roundtable
The Environmental Education Center
Albemarle County - City of Charlottesville Office of Water Resources Management
University of Virginia School of Architecture
Virginia Department of Mines, Minerals, and Energy

# Rivanna River Basin Project
# The State of the Basin: 1998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The Rivanna River Basin Roundtable

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May 20, 1998

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# I. Executive Summary

The Executive Summary distills the work of the Rivanna River Roundtable and the Environmental Education Center into key elements. Included in the Summary are the Project Goals and Objectives, the Vision Statement, significant findings, and major recommendations. The Roundtable presents them here as a way of introducing the community to the topic in general, with the hope and expectation that the reader will be enticed into a fuller reading of the Rivanna River Basin Project.

## Goals and Objectives

The Rivanna River Basin Project was initiated by the Thomas Jefferson Planning District Commission (TJPDC) to assess past and current conditions of the Rivanna River and its tributaries and to articulate desired future conditions. The Rivanna River Roundtable (RRR) was selected by the TJPDC to develop the project. The Roundtable included twenty-four members from all parts of the Rivanna Watershed, representing all the political jurisdictions and a wide variety of stakeholders - farmers, developers, designers, environmentalists, educators, scientists, preservationists, historians, and authors. In addition, the Environmental Education Center formed Field Teams of interested citizens to monitor water quality in the River and its tributaries.

The residents of the Rivanna Watershed collectively play a large role in determining the quality of the water in and the habitat of the Rivanna and its tributaries. To understand this collective role, the Rivanna River Basin Project addressed the Rivanna River as an ecological system encompassing its physical structure, connection to human history and culture, stream side habitat for birds and other wildlife, and, of course, its fish and aquatic habitat. Because land use impacts water quality, the community of people living within the watershed can, through individual actions and public policy, determine the nature of the river they share.

The overall goal of the project was to gather information that can be used to maintain and improve water quality and to provide this information to citizens and decision makers within the region. In addition to the Roundtable discussions and field team monitoring, the State Division of Mineral Resources completed a study showing how land in the watershed is currently used and what types of vegetation are present; a forecast of future residential development was not completed due to limitations in data.

The Roundtable reviewed these studies as well as assessing the chemical, biological, and streambank characteristics of the main stem of the Rivanna and its tributaries. As a result the Roundtable made a number of recommendations relating to water quality improvements. Finally, it has identified some strategies that will contribute to improving water quality and community enjoyment of the River.

## Vision Statement

The Rivanna River Roundtable has developed a vision for the future of the basin based on the understanding that a healthy landscape, diverse ecosystem, clean air, clean water, and beautiful scenery add value to the local economy, and sustain the quality of life.

We envision:

- a river treasured as an investment in the future of the region, a resource worthy protection;
- a river occupying a vital place in the continuing history of the region;
- creeks and rivers which define what it means to be part of a special place, reinforcing residents sense of place and community;
- streams and rivers as accessible recreational resources, providing inspiration and educational opportunities for future generations;
- a river closely integrated into the cultural life of the region;
- streambeds providing habitat for river life and containing less silt, more rocks and riffles;
- forests and trees providing habitat and shading the streams and rivers, thus providing a habitat for fish and birds;
- a landscape that allows rainwater to seep slowly through the ground, providing recharge for summer creeks, while limiting flooding;
- swimmable, fishable streams for our future generations;
- clear and clean waters bound by fully vegetated stream banks, with topsoil in place;
- a future created by interested citizens working together and celebrating our need to return to the river as a source of daily pleasure, a place of commerce, and a place of occupation, and as a reminder of our history.

## Significant Findings

Significant findings are summarized in relation to river history, hydrology, streambank structure, water quality, and land use.

**History**

The River and its environs have significant historical importance and have played a central role in the development of the region from the era of Indian pre-history, Colonial and Revolutionary times, and early industrial development.

The Community has not yet developed the means to connect with the River’s cultural heritage and its resources, including remnants of the Indian period, early mills, and the canal system.

**Hydrology**

The pattern of river discharge (water volume) shows undesirable changes associated with the early stages of urbanization, which result from increasing areas of hard surfaces (impervious to water). Stormwater run-off is rapid and contributes to bank erosion and stream side damage. Summertime low flows are getting lower because rainwater runs off rapidly into the stream rather than being stored as slowly-released groundwater.

If these trends continue, as they have in some cities, discharge will be increasingly destructive during high flows and reduced to a trickle at other times. This will eliminate much of the river s potential value for both people and wildlife.

Appropriate corrective techniques are available, and together with continued close monitoring, can stabilize or reverse these trends, retaining the river s economic and ecological value.

**Shape of the Stream Banks (Morphology)**

Stream banks along the Rivanna range from being unvegetated and highly unstable, with great potential for erosion and collapse, to recovering re-vegetated stream banks, to fairly stable, fully-vegetated stream banks.

The North Fork sites show the deteriorating water quality and poor aquatic habitat characteristic of areas with unstable, eroding banks. Eighteen areas exhibit conditions where streambank erosion is causing a diminished habitat for flora and fauna.

**Water Quality**

Water quality in the River is poor under high flow conditions. Storm water runoff carries high levels of pollutants, including nitrogen, phosphorus, silt (suspended solids), ammonia, and fecal coliform (from animal or human waste). In addition, relative pH is high. At least two of these conditions were found at each monitoring site, indicating that the quality of the River’s waters is periodically threatened during heavy rainfall.

Dissolved oxygen, necessary for all aquatic life, is low in the River in the segment from the South Fork Rivanna Reservoir dam to Route 29 due to discharge from the South Fork dam. This could be easily corrected.

The small number of water quality samples routinely collected by government agencies are not coordinated in time with flow conditions, thus, the deterioration of water quality at high flows was undetected until the field work of the Roundtable was done. Water quality and stream discharge volume are currently measured at different sites by different agencies, which, together with the small number of samples, makes interpretation of results and community planning difficult. We do not know when runoff reaches a critical volume, how long it takes the River to recover, or the effect of land uses and controls.

The streams closest to the urban area received the lowest scores under the Save Our Streams (SOS) protocol, which measures small streambottom-dwelling creatures. Meadow Creek, the only segment not achieving an excellent rating in the Save Our

Streams (SOS) protocol used for field-testing, presents an opportunity for rehabilitation and stream restoration.

Biological indicators of the river and river bank conditions yielded mixed results indicating early, but reversible, deterioration. Streambed insects were diverse and healthy at all but the most urban sites. Rivanna fish communities are generally in good condition, but with a few declining trends and species losses detectable in the somewhat patchy historic records. Bird species used to characterize healthy stream side forests were poorly represented, suggesting sub-optimal land use and erosion potential near streams.

**Land Use**

*Coverage.* Streams flowing out of forests provide very high quality water; approximately 64% of the watershed is now covered by forest.

The second largest land cover classification is pastureland, about 20% of the coverage. If highly grazed, pastureland can be ranked relatively impervious. Poorly managed stream banks adjacent to any land use, including agricultural land, have a very high erosion potential. Vegetated banks can slow topsoil loss. Vegetated buffer strips, anywhere along the River, can stabilize streamflow and stream banks, reduce sediment loading in streams and reservoirs, lower summer water temperatures, and filter chemical and organic pollution.

Highly impervious land uses contribute to runoff and loading of nutrients (nitrogen and phosphorus) into the River. These uses cover 15% of the drainage area.

*Risk Classifications.* The percentage of land cover which is impervious indicates a level of risk to the water quality and aquatic biology. The risk levels range from Healthy (0%-10% coverage)to Degraded (>25% coverage). Based on the percentage of impervious land coverage 75% of the basin is classified as healthy, 21% of the land is classified at risk, (11%-15% coverage), and 2% of the land is degrading (16%-25%) and 1% is degraded (>25%).

Degraded areas, are the 29 North and Free Bridge areas of Albemarle County and Lake Monticello. All Charlottesville watersheds are considered degraded.

## Recommendations

### Develop a Corridor Plan to guide decision making related to preservation and use of the Rivanna River.

The plan should be developed by an oversight group, possibly as continuation of the Rivanna River Roundtable, with a charge approved by the local jurisdictions and funds for development of the plan.

The plan should address mechanisms to incorporate watershed management planning into local land use plans; best management practices, including buffers, riparian owner and community issues; recreation areas, uses and access points; historic and archaeologically significant sites; redesign of commercial and industrial uses and other development; special designations of certain rivers and streams; integration of policies and ordinances to protect and preserve the River; exploration of the potential for a regional or state Rivanna River Corridor Linear Park.

**Develop a comprehensive, systematic and coordinated data base of all information related to the Rivanna River.**

Include consistent protocols for data collection and expand the Save Our Streams (SOS) protocol and monitoring by volunteers, work with the Department of Environmental Quality to develop multiple sample protocols and with the Department of Game and Inland Fisheries to collect more frequent fish and bird data; identify the nature and source of toxins, metals and non-point source pollution, and develop more complete information on hydrology and morphology.

**Establish a comprehensive, multi-disciplinary, interagency data collection and monitoring program, which brings together all interested parties under one umbrella, and names the responsible lead group charged with oversight and stewardship of the River and its Basin.**

Request state and federal agencies to co-locate sampling sites and coordinate sampling done at the sites, thus efficiently maximizing the amount of data.

Request Rivanna Water and Sewer Authority adopt biological and habitat goals in managing water resources and establish minimum instream flow to protect all uses, include that for fish and wildlife habitat.

Request local governments work together on streambank restoration, erosion control, storm water management, and education of themselves and the public.

**Implement design practices that promote, preserve, and protect the Rivanna River.**

Request local government to incorporate design practices into site plan review and other land use plans and incentives to use vegetated buffers and other best management practices; to mitigate impacts of existing impervious surfaces, and reduce impervious surfaces in new development; restore stream banks; reduce sedimentation. Review local ordinances and practices as well as work with the Virginia Department of Transportation toward the goal of stream protection.

**Expand stewardship of the River.**

Local governments should lead the way to involve the public in education and protection of the Rivanna River by providing information about best management practices and economic support such as cost share programs; developing a public education program and literature on the State of the River; and instituting water conservation practices and practicing water reclamation, and a watershed-based focus for stewardship.

Non-profit groups, such as the Environmental Education Center should be supported in their efforts to continue monitoring and providing a focus for stewardship.

# II. Acknowledgements

During a 15 month flurry of activity, hundreds of participants in the Rivanna River Basin Project, created, executed, and completed one of the most comprehensive efforts of its kind in the country, on time. The Roundtable, Field Teams, Explore Day, Land Cover/Impervious Surface Analyses, Water Quantity Analyses, Desired Future Conditions, and Recommendations were all completed for a single program by dedicated, highly organized teams of volunteers, private consultants, and government employees working in parallel.

From start to finish the project was guided by the Rivanna River Basin Roundtable. This group of individuals actually did more work in terms of research and writing, than any other groups of volunteers I have had the pleasure to staff. They poured their hearts and minds into this project and deserve the appreciation of every resident of the basin.

## Rivanna River Basin Roundtable: 1996-1997

Co-Chairs: Judy Bancroft and Russell Perry

Jennifer Ackerman
Marissa Bass
Arthur J Bulger
Mark C Burris
Ken Copper
R Reynolds Cowles Jr.
Tommy Darnell
Irene Feltner
James L Ford
Steve Helvin
Edgar A Imhoff
Patt Hart Keats
Frank Kessler
Michel A King
Chris McLean
Carter McNeely
Angus Murdoch
Bunny Murray
William K Norris
Richard A Park
John Schwab III
Kay Slaughter
Kelly Smith
Justin Wiley

Some of these folks in particular deserve the “Rivanna Stonefly” award. Strong and steady leadership was provided by Judy Bancroft and Russ Perry. From the development of consensus rules of order, to principles and recommendations, the two leaders moved the Roundtable along. Enough cannot be said about the contribution of the members of the Steering Committee; Ken Copper, Patt Keats, Carter McNeely, Bunny Murray, and Bill Norris. Countless meetings on a weekly basis were held to develop ways to hold the project together. Each contributed enormously to the its completion. Others including Art Bulger, Ed Imhoff, Mitch King, Chris McLean, Angus Murdoch, and Mayor of the City of Charlottesville, Kay Slaughter, provided unheard of effort to create texts and charts on a range of subjects from water quantity to legislation. The efforts of Justin Wiley are also appreciated to bring the Rivanna River Basin Project stationary to fruition.

The project was built on the work of John Hermsmeier, Projects Director of the Environmental Education Center, and Dave Hirschman, Water Resources Manager of Charlottesville-Albemarle County. They collected samples in wet weather and dry, worked many weekends to develop never before-attempted protocols for stream morphology, to coordinate volunteers, and write-up results. Both went way, way beyond the call of duty.

Much appreciation is extended to Payne, Ross and Associates for working with Justin Wiley for pro-bono work to design and print the logo.

Significant contributions were also provided by many folks at the University of Virginia, only a few of which include Beth Meyer, Kathy Poole, Dan Bluestone, Bob Dripps, and Tim Abrams. I think everyone associated with this project looks forward to future corridor design projects with the University of Virginia.

The basic framework for the project evolved through a series of meetings in August and September, 1996, attended by Art Bulger, Dave Hirschman, Mike Woodside from the U.S. Geological Survey in Richmond, Tom Gunter, William Trout, from the Virginia Canal Society, and Dan Hayes, a geo-archeologist interested in Native American sites along the river.

The project got off to a fabulous start thanks to the wise words of Jack Marshall, Chairman of the Rivanna Water and Sewer Authority and Sally Thomas, Chair of the Thomas Jefferson Planning District Commission. Also assisting with the kick-off was the University of Virginia School of Architecture, which donated space for the day-long event, Rising Sun Bakery for providing a break on food and drink, and Photoworks, for donating film development services for the slide show.

The morphology portion of the project would have failed were it not for the efforts of Dave Hirschman, Deb Mills at the Virginia Department of Conservation and Recreation, Sam Austin, from the Virginia Department of Forestry, Allyson Sappington at the Thomas Jefferson Soil and Water Conservation District, and Paul Muhlenberger at the Albemarle County Recycling Office.

The Chemistry and Biology Field Teams would have been completely unable to collect samples without the generosity of the many riverside landowners in the basin who granted access to the field team volunteers. This includes Mike Merrian and Monticello, for the shuttles to the river and the granting of easy access to one of the project's most important monitoring sites.

If this project is the foundation for future basin-wide initiatives, then it stands on the bedrock of regional capital consisting of 25 years of existence of the Thomas Jefferson Planning District Commission. No project is an island, and this one in particular stands on the shoulders of a quarter-century of work toward real regional cooperation in the areas of housing, transportation, and the natural environment. And for many of these years, projects and programs, of which this is just one part, have been guided by the tireless efforts of the Executive Director of the Planning District, Nancy O'Brien.

Finally, perhaps the most lasting aspects of the project was done by all the chemistry, biology, morphology, and explore day volunteers that contributed thousands of hours of documentation of the physical and spiritual elements of the waters of the basin. What a precious gift to the future and to the Explore Team members of 2097!

- Michael Collins

## Rivanna River Basin Field Team and Explore Team Members: 1997

David Carr
Will Carr
Thea Aldridge
Rosemary Balister
Ed Barbour
Liz Beckwith
Amy Birdwell
Scott Boven
Mecca Burns
Brad Stoller
Sherry Buttrick
Michael Collins
Logan Collins
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Patricia Dowd
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Karen Firehock
Nathan Kreuter
Donna Bennett
Jay Graves
Justine Taylor
Kim Korth
David DeViese
Matthew DeViese
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Pearce Johnson
Rochelle Garwood
Carla L. Myrtle
Adam Stevens
Ninni Baeckstrom
Andre A. Hakes
Laurie Peverill
Donna Shaunessy
CarrieWorrell
Carter McNeely
Wick McNeely
Elliewood Baxter
Betsy Lynn
Jesse Lynn
Cathryn McCue
Dan Sebring
Ralph Giannini
David Buchanan
Colin Gallahue
James Sturgill
Glen Metzler
Angus Murdoch
Kris Parker
Jay Gilliam
Ken Cooper
Teresa Luke
Steve Keach
Paul Brant
Scott Gall
Sara Greenfield
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Jim Pissot
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Kay Slaughter
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Sally Thomas
George Thomas
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Mark Debow
James Mosher
Paul Muhlberger
Jim Bennett
Phylis White
Bob Whaley
Andrea Craig
Shelby Earls
Judy La Chapelle
Steve Wells
Zak Worrell
Brian Cox
Alphonse Diaz
Rachel Evans
Casimir Kawecki
Daniel Perry
Russell Perry
Charles Rosenblum
Jacques Vinc

# III. Project Background

Perhaps the Rivanna River Basin Project began 25 or more years ago, as Fluvannian Minnie Lee McGee began to be concerned about summer-time low flows and started to try to talk to county officials, legislators, and government employees about the river. Others think the Rivanna River Basin Project began a few years ago, as concerned citizens in Albemarle County, Fluvanna County, and Charlottesville, began to consider the river as *the landscape feature* of this portion of Central Virginia, and the reason that Charlottesville was originally constructed, as *a town on a river*.

As if a collective light bulb went off, folks in Fluvanna started the Rivanna Conservation Society to catalogue old locks and canals. The Charlottesville Greenbelt was constructed, and with it, a new awareness of parking lots, sandmines, and backsides of shopping malls along the river. This seemed to coincide with the discovery of an old batteau stuck in a stream bank at Milton, and the Moores Creek and Meadow Creek Stormwater Studies done by Charlottesville, Albemarle County, and the University of Virginia.

In retrospect, it's not surprising that in the context of all this, citizens were concerned when the Virginia Department of Environmental Quality identified several sections of the Rivanna on the "303(d)" list, identifying them as polluted due to an impaired rating for benthic macro-invertebrates and for fecal coliform counts above state standards. Shortly after this, the Planning District Commission submitted a proposal to the Virginia Department of Environmental Quality to fund this project using Section 604 (b) Clean Water Act Funds in the amount of $48,100. The project was selected for one-year funding and officially began October 1, 1996. Due to bad weather the winter of 1996-1997, and the necessary cancellation of many meetings, the Planning District Commission asked for and received a three-month extension to December 31, 1997.

# IV. Project Organization

## Introduction

The major work of the project was accomplished by two groups of citizens who served either as members of the Rivanna River Basin Roundtable or as members of Field Teams directed by personnel from The Environmental Education Center. The Project Director provided staff support to both groups. Citizens were recruited via a notice published in local newspapers inviting the submission of letters of interest. In addition to these individuals, experts from state and local agencies and organizations also participated, either to provide information to the project groups, or to accomplish some of the actual work of the project. For example, students and faculty from the University of Virginia assisted in developing the historical description of the River and its Basin.

The aims of this organizational structure were to maximize resources and to develop a descriptive database, via field study, which would be used to inform the Roundtable about the current state of the River and its Basin. Communication between the Roundtable and the Field Teams was provided through periodic reports to the Roundtable from the Project Director and the Director of the Environmental Education Center.

## The Roundtable

Twenty-four individuals were appointed to the Roundtable. An attempt was made to appoint two individuals to represent each of the Basin's hydrologic units and to have representation from each of the counties, and the City of Charlottesville, through which the River flows. In addition, an attempt was made to diversify the Roundtable by appointing two secondary school students, and by selecting individuals with diverse interests and background. The Roundtable consisted of six women and eighteen men, whose backgrounds included hydrology, water resource management, architecture, systems engineering, fiscal management, human and animal health sciences, agriculture, land development, carpentry, law, bio-science, history, literature and public policy. Two of the members were also members of scenic river advisory boards.

The Roundtable started meeting in the fall of 1996, met twice a month, and developed a mission statement, guidelines for group process, and identified principles that the group agreed to use in guiding the substantive work of the Roundtable.

It was agreed that the major emphasis of the Roundtable in the early phase of its existence would be self-education. To this end, resource people were asked to make presentations to the Roundtable. This educative process was essential in assisting the members of the Roundtable to develop a common understanding. In addition to guest speakers, the Project Director and other members of the group distributed technical literature, and field trips were organized so that the Roundtable members could have first-hand knowledge of topics such as stream bed morphology, flood plains and macro-invertebrate sampling procedures. Among the people who came to the Roundtable to share their expertise were:

Sam Austin, Virginia Department of Forestry
Rod Bodkin, Department of Environmental Quality
David Bowerman, Albemarle County Board of Supervisors, Chair, Thomas Jefferson Sustainability Council
Treva Cromwell, former Chair Rivanna Water and Sewer Authority
Nick Evans, Virginia Division of Mineral Resources
Dick Gibbons, Virginia Department of Conservation and Recreation
David Hirschman, Charlottesville/Albemarle Water Resources Manager
John Kaufman, Virginia Department of Game and Inland Fisheries
Keith Klein, Virginia Department of Game and Inland Fisheries - bird surveys
Tayloe Murphy, Jr., Virginia House of Delegates
C.E. Stevens, noted botanist
Ray Tesh, Department of Environmental Quality
Steve Thomas, Soil Scientist, Virginia Tech

**Group Process**

Six working groups within the Roundtable were established. Members self-selected into a group. The six groups were 1) Water Quality/Quantity, 2) Habitat/Morphology, 3) Land Use, 4) Public Policy/Regulation, 5) History and 6) Steering Committee. Over the course of the project each group presented information to the Roundtable.

The role of the Steering Committee was to coordinate the other work groups, establish meeting agendas for work group reports and other presentations, prepare information for media releases, prepare draft mission statements for larger group discussion and input, identify the scope of the plan to be developed and assign work group tasks, propose strategies and timetables for meeting Roundtable goals and to monitor and assess the progress of the project as a whole. The Steering committee functioned with the sanction of the larger Roundtable and always brought its work to the Roundtable for discussion and approval. Some of the Steering Committee members also functioned as members of other work groups

In mid-September the Steering Committee recommended an agenda for the remainder of the project period that involved the reporting of each work group's findings, usually in written form, the development of recommendations and strategies, and the preparation of the final report. The absence of a well-developed database about the River, its morphology and its other hydrologic characteristics was a constant impediment to the work of the Roundtable. The project had to focus, to a great extent, on developing descriptive data that could then be used as part of the basis for continued planning. This was a time-consuming, though useful process. However, the time needed to analyze the data collected and then to thoughtfully develop recommendations and implementation strategies became very limited.

The final major role of the Steering Committee work group was to draft project recommendations for discussion by the Roundtable as a whole. Again the procedure was to identify which of those recommendations were acceptable via consensus of the group. Reports from the other work groups were the source of most of the recommendations eventually drafted by the Steering Committee. The Steering Committee also proposed that the Roundtable request continuation under the auspices of the Planning District during the early part of 1998. This proposal was approved by the Roundtable.

## The Field Teams

### Organizing Citizens for Participation: A Team Approach

The plan in preparation for the project kickoff was to have:

1) a biology/chemistry team of several volunteers that stayed with the same site,
2) a larger, roving morphology team to cover all of the sites, and
3) a huge exploration team made up of existing and to-be-recruited volunteers to document various additional sites across the basin.

While this basic framework was preserved, several adjustments needed to be made throughout the early stages of the project in order to match the needs of the monitoring plan with the role and schedule of the volunteers.

### Volunteer Recruitment And October 26, 1997 Kickoff

Dozens of potential volunteers responded to ads in local newspapers and other media coverage announcing the project and the need for help. All of these people were then called to inform them of the kickoff and to briefly describe the various roles for field team volunteers. Nametags showing the home watershed of each participant helped people congregate during the luncheon by the stream they had in common. During the kickoff, guest speakers explained each field component and described the role for volunteers in detail. Maps showing monitoring stations and sign-up sheets for each component were placed around the room. The group of 30 volunteers then divided themselves by task and location and selected dates when each team could meet. The monitoring plan for the entire project year was essentially solidified on the spot because the volunteers responded to the challenge of finding a role for themselves. This successful beginning was indicative of the quality of volunteer that stepped forward on this project; every single one of these 30 people actually participated after the kickoff, and they were later joined by many others who could not attend that day.

### Teams

*Biology Team*

A small team was established for each of the 14 sites to conduct seasonal measurements of macroinvertebrate diversity using the Izaak Walton League of America's Save Our Streams protocols. This particular protocol, while not as detailed as other rapid bio-assessment techniques, was selected because of the quality control achievable with its relative simplicity and its validity as a screening-level assessment that can trigger appropriate attention by government agencies when a more refined assessment is called for. While citizen volunteers can be trained to use dissecting microscopes and identify macroinvertebrates to the species level, this seemed unnecessary since the project focus was a general assessment of the Rivanna basin and not, for example, a targeted investigation of discharge permit compliance, etc.

Teams were designed to work at the same site because familiarity with the location is more important than with chemical grab samples, for example. Either the field team coordinator or a volunteer resource professional certified in SOS was present for each sampling event in order to ensure quality control. Since the macroinvertebrate samples reflect river conditions over a relatively long period of time, it is not necessary to coordinate them simultaneously across the basin as long as a general seasonal schedule is maintained.

*Chemistry Team*
Consultations with DEQ and USGS along with direct experience with volunteer chemical monitoring programs convinced project staff that field chemical kits were not the best approach for the project. Though there are certainly successful citizen monitoring programs that use field kits, they take tremendous energy to achieve an acceptable level of quality control. With a gracious offer by the Rivanna Water and Sewer Authority (RWSA) to conduct the analysis, the most appropriate role for volunteers appeared to be collecting and delivering the samples. This decision required the creation of a chemical sampling effort separate from the biology teams. Unlike the macroinvertebrate sampling, chemical sampling needs to be conducted for each of the 14 sites within a six-hour window. This scheduling requirement was further complicated by the short-notice nature of capturing storm events and the RWSA requirement that samples be collected on a Tuesday, Wednesday or Thursday. Most biology team volunteers are available on Saturdays or after work on weekdays. Flexibility of schedule on the part of chemistry volunteers was a critical factor for participation on this team.

Since sampling all of the sites required 170 miles of driving, the task was broken up into two or three teams each sampling 5-7 sites. RWSA provided the glass fecal bottles and the plastic bottles. The samples must be kept cool so the bottles were transported in coolers, with the fecal bottles stored in a small cooler with an ice pack. Although RWSA conducted the analysis, volunteers still needed to be trained in proper sampling techniques.

An additional component of the chemical sampling for two sites (#11 Mechunk Creek and #13 Cunningham Creek) was a field determination of discharge. There are no USGS gauging stations at these sites and it is not possible to interpolate between values at other stations, so measurements to determine discharge must be calculated at the time samples are taken. This is done by measuring the height of the water at the site and its velocity. Velocity is closely approximated using the “orange method,” where an orange is tossed into the creek and timed over a pre-measured course with at least 3 trials. Prior work to survey the stream channel and install a staff plate referenced to the bridge abutment meant that the volunteer simply needed to take a staff plate reading to obtain the cross-sectional area and then determine velocity. Tests of this method against a flow meter proved satisfactory.

One-time sediment samples were taken at each of the 14 monitoring sites and analyzed by DEQ for heavy metals. Resources were not available for additional testing of “hot spots” like drainage from parking lots.

*Morphology Team*
This team required the most equipment, training and volunteer professional input, but it also attracted great volunteer interest and the potential is strong over time to build a skilled, equipped team that can relieve professional volunteers of most of the work. Developing this team required several meetings and field tests to design a satisfactory methodology suitable for appropriate use of volunteer skills. The overall approach and data forms had to be developed from scratch since there were no known examples of citizen monitoring programs in this arena.

For this first project year, a “Morphology Weekend” was held in late July. Saturday was devoted to training and, on Sunday, 4 teams, each led by a mentor, conducted measurements at a total of 8 sites. The water at 6 of the sites is too deep to work with because the measurements of channel width and the pebble counts require wading across the river and reaching down to touch the streambed. (These sites can still be documented photographically). Prior work conducted by volunteer professionals consisted of determining the reach, calculating valley and stream slope and placing bankfull pins at each site. The volunteers determined entrenchment ratios, conducted pebble counts and photo-documented each site. In the future, the morphology team will continue to make annual (summer) measurements.

*Exploration Team*
Members of the general public joined existing project volunteers on May 24, 1997 for “Rivanna River Explore Day” to document the state of the basin at several locations. Volunteers registered in advance by going to the Thomas Jefferson Planning District Commission and planning their day using the large watershed map and registration materials. Approximately 100 people participated in this event that required a great deal of commitment and resourcefulness on the part of volunteers. The intent behind Explore Day was twofold. First, it allowed the project to connect with the public in a way that produced a creative, living archive of the basin in addition to written reports. Second, it provided a simple analysis of several parameters including:

- sediment and erosion
- wildlife
- vegetation
- human uses
- character of the water

Volunteers were recruited through radio and print media. The registration process was targeted yet also allowed each volunteer the flexibility to select a particular place or feature to document, if they were so inclined. Since it was impossible to know how many volunteers would step forward, areas to be documented were prioritized so that volunteers could fill the most pressing needs, yet also be guaranteed of a role in the project. The six categories for documentation included:

- pre-designated river stretches for coverage by canoe
- each of the 14 RRBP monitoring sites
- volunteer-selected sites
- reservoirs
- bridges and other public access points
- stretches of walking trails along creeks and rivers.

Products of Explore Day far exceeded expectations. 25 volumes of material have been submitted complete with:

- maps
- descriptive text
- photographs
- video and audio tapes
- sketches
- poetry

Plans are underway to formally establish an archive of Explore Day materials at the public library, and additional volunteers have offered to make the materials available through computer web technology.  On September 27, 1997, all participants were invited to an afternoon on the Rivanna to view the collective products of Explore Day.  As impressive as the materials were, perhaps the best part of the afternoon was the spontaneous sharing between explorers.  Although they had set out across the basin last May 24 alone or in small groups without any knowledge of other participants, their experiences produced a common bond that prompted discussion of building a coalition to watch over the river.

# V. Planning Positions

As the Roundtable and Field Teams began their work, it was important to identify and articulate basic positions about the River and its Basin in order to establish a work context. These positions were stated as principles and a vision. In addition, as the Project progressed a number of working assumptions emerged and criteria for evaluating the state of the River and its Basin were developed. In order to facilitate this work the Roundtable appointed an *ad hoc* committee, the Desired Future Conditions Committee, to clearly articulate the kind of rivers and streams that are desired and to develop parameters to measure this condition. These ideas helped direct the work of the project and helped define the nature of the data to be collected.

## Roundtable Principles

The principles adopted by the Roundtable are either positions taken by the group as true or value statements that the group agreed to which subsequently influenced the planning process. These statements indicate the perspective or the context established for the work of the Roundtable. They are as follows:

1) All resources are finite.
2) The basin is a living organism.
3) The "waters within the basin" include precipitation, surface water and ground water.
4) All living things with the basin are interconnected in complex and interdependent systems.
5) All living things within the basin are dependent on the quality and quantity of the basin's waters.
6) All human activities should be considered in terms of their potential impacts on waters of the basin.
7) It is both possible and desirable to conduct human activities in a manner which sustains the health of the waters of the basin.
8) It is both possible and desirable to restore the health of degraded waters in the Basin.
9) There are enough resources to support ideal future conditions of the basin.
10) Our vision of the future should not be limited to what is now perceived as possible.

Although many of the statements above reflect an optimistic view of the future, the Roundtable members were aware of the constraints that conflicting social values and current resource allocation pose. These principles resulted from a strategic planning position taken by the group that, unless "ideals" are expressed, decisions about the future will be limited by currently identified constraints. Much of the last work of the Roundtable was informed by the recognition of the interrelationships among diverse variables and the need to use systems models in future planning work to capture the holistic nature of the River and its Basin.

## Vision for the Future

The Rivanna River Roundtable has developed a vision for the future of the basin based on the understanding that a healthy landscape, diverse ecosystem, clean air, clean water, and beautiful scenery adds value to the local economy, and sustains the quality of life.

**We envision:**

- a river treasured as an investment in the future of the region, a resource worth keeping healthy;
- a river occupying a vital place in the continuing history of the region;
- creeks and rivers which define what it means to be part of a special place, reinforcing residents sense of place and community;
- our streams and rivers as accessible recreational resources, providing inspiration and educational opportunities for future generations;
- a river closely integrated into the cultural life of the region;
- streambeds providing habitat for river life and containing less silt, more rocks and riffles;
- forests and trees providing habitat and shading the streams and rivers;
- a landscape that allows rainwater to seep slowly through the ground, providing recharge for summer creeks, while limiting flooding;
- clear and clean waters bound by fully vegetated stream banks, with topsoil in place;
- swimmable, fishable streams for future generations;
- a future which celebrates our need to return to the river as a source of daily pleasure, a place of commerce, and a place of occupation brought about by interested citizens and groups working together.

# VI. Characteristics of the Rivanna River Basin

## Location

The Rivanna River Basin is a tributary of the James River located in the mountains and foothills of Central Virginia. The basin spans the Blue Ridge Mountains in the west to the James River in the east. The northern border of the basin is generally Route 33 in Greene County, and the southern border is the Albemarle-Nelson County line. The drainage area covered is approximately 490,000 acres or 766 square miles. The basin is entirely found within the Blue Ridge and Piedmont physiographic provinces. The Virginia Department of Conservation and Recreation has divided the Rivanna River Basin into ten sub-basins, or hydrologic units (H.U.). These sub-basins are the drainage area for the major tributaries of the Rivanna River and are shown in the following table.

| RIVANNA RIVER BASIN BY HYDROLOGIC UNIT (H.U.) | | |
|---|---|---|
| TOTAL ACRES | % OF THE BASIN | HYDROLOGIC UNIT NAME |
| 63,399 | 13.1 | Mechums River H.U. |
| 49,675 | 10.2 | Moormans River H.U. |
| 23,079 | 4.8 | Buck Mountain Creek H.U. |
| 34,836 | 7.2 | S. Fork Rivanna/Ivy Creek H.U. |
| 107,985 | 22.3 | N. Fork Rivanna/Swift Run/Preddy Creek H.U. |
| 37,757 | 7.8 | Upper Rivanna River H.U. |
| 45,491 | 9.4 | Middle Rivanna River/Buck Island Creek H.U. |
| 39,652 | 8.2 | Mechunk Creek H.U. |
| 60,147 | 12.4 | Lower Rivanna River/Ballinger Creek H.U. |
| 23,140 | 4.8 | Cunningham Creek H.U. |
| 485,160 | 100.0 | RIVANNA RIVER BASIN |

The major communities, subdivisions, and landmarks located within each of the H.U.s are the following:

| | |
|---|---|
| Mechums River: | Crozet, Batesville |
| Moormans River: | Doylesville, Brown’s Cove |
| Buck Mountain Creek: | Free Union, Boonesville |
| S. Fork Rivanna/Ivy Creek: | Along 29 north from Northfields to Forest Lakes subdivisions, South Fork Reservoir, and Ivy |
| N. Fork Rivanna/Swift Run/Preddy Creek: | Advance Mills, Dyke, Stanardsville |
| Upper Rivanna River: | Charlottesville and Ragged Mountain Reservoir |
| Middle Rivanna/Buck Island Creek: | Shadwell |
| Mechunk Creek: | Cismont, Cobham, Cash Corner |
| Lower Rivanna River/Ballinger Creek: | Lake Monticello, Palmyra, Carysbrook |
| Cunningham Creek: | Fluvanna Ruritan Lake |

Each of the sub-basins has been further divided into third-order watersheds (TOW) by the Thomas Jefferson Planning District Commission (TJPDC, 1994). A third-order watershed is the drainage area for the minor tributaries of the basin. There are a total of 236 TOWs in the basin, ranging from 12,303 acres to less than an acre in size. The average size of the TOWs is 2070 acres.

## Water Quality and Quantity

Water quality and quantity data for the Rivanna River Basin Project came from three separate agencies; Rivanna River Basin Project chemistry, biology, and morphology data developed in 1996-1997, Virginia Department of Environmental Quality (DEQ) biology and chemistry data, and U.S. Geological Survey (U.S.G.S.) water quantity data. The sampling location, type, and agency responsible for data analysis for the major streams and tributaries of the basin are also shown on Map 1.

## Morphology

The Rivanna River Basin Project's monitoring component included chemical, biological, and stream morphology monitoring. *Stream morphology refers to the physical and geometric properties of the stream channel, streambed, and surrounding flood plain area in relation to the watershed*. Fluvial geomorphology has only recently found its way into the tool kit of the planner and natural resources manager concerned with watershed health, water quality, and water policy. River morphology is a way to begin to diagnose how the life history of a river and its watershed has influenced current conditions.

For the Rivanna River Basin Project, river morphology became a topic of interest for those helping to plan the project through a series of courses sponsored by the Chesapeake Bay Program. Dave Rosgen was the instructor for these courses, and his ideas and techniques provided a compelling challenge to look within the Rivanna River Basin for indicators of stream stability and instability, especially in relation to the chemical and biological information that was also to be collected as part of the project.

Since these types of data have never been collected for the Rivanna Basin on a systematic basis, it was necessary to develop a methodology that could be employed for an assessment level program (a level that would allow general comparisons between tributaries) rather than an in-depth morphological study of each tributary. It was also imperative that this methodology employ volunteers, which was challenging since this line of inquiry was relatively new even to the professionals in the field of water resources. Volunteers were essential to the philosophy of the Rivanna River Basin Project, as well as a necessary human resource to get the job done.

### River Morphology Terminology

The following terms are discussed in order to provide an understanding of the stream morphology results obtained for the Rivanna River Basin Project.

> *Bankfull Discharge*: Bankfull discharge occurs when the stream just fills its banks; it occurs on the average once every 1.5 years in North American, but the range of values for recurrence is wide.
>
> Bankfull discharge provides the basis for other morphological measurements and indicators. A stream discharge, when the water is to the top of the bank, provides the force that moves stream bed materials (silt, sand, gravel, cobbles, and/or boulders) and deposits them downstream, changes meanders and streambanks, and generally produces

(and rearranges) the observable stream channel and flood prone area. Rosgen offers the following definition of bankfull discharge, which is attributable to Dunne and Leopold:

> The bankfull stage corresponds to the discharge at which channel maintenance is the most effective. That is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing the work that results in the average [Dave Rosgen, Applied River Morphology, p. 2-3, quoting from Dunne & Leopold, Water in Environmental Planning.]

It must be stressed that the bankfull discharge is not represented by the infrequent, morphologic characteristics of channels.

For the RRBP sites, bankfull stage is shown as a field-surveyed cross-section.

*Entrenchment Ratio*: This ratio expresses the relationship of a stream channel to its frequently inundated flood plain (flood prone area). An entrenched stream has cut down through its valley, abandoned its flood plain (which is now a terrace), tends to puts stress on its streambanks, and may have a sediment load/transport problem. A lower entrenchment ratio number indicates a stream that is more entrenched. The ratio is dimensionless.

*Width/Depth Ratio*: This is an index of cross-sectional shape, measured at bankfull level. It generally increases in the downstream direction, but is very much influenced by the bank material. Channels in easily worked sane beds are wide and shallow, whereas silt-clay beds yield steeper, deeper streams. Steams that are actively cutting down their beds tend to be deeper and narrower, and those that are depositing material tend to be shallow and wide.

*Sinuosity*: In simple terms, it is the “wiggliness of a stream”. Sinuosity is the relationship between stream length and valley length or stream slope and valley slope. A higher number (also dimensionless) indicates a stream that is more twisting, or sinuous. For instance if a stream is very straight, it will have the same length as distance. It a stream is wiggly, the sinuosity is high. A SI (sinuousity index measurement) of 4 is a very sinuous stream.

*Particle Size Distribution of Channel Materials*: A stream channel can be composed of a combination of silt/clay, sand, gravel, cobbles, boulders, and bedrock. The relative distribution of these materials indicates a lot about a stream’s soils and geology, stability, ability to transport bedload, and aquatic habitat. The “d50 particle” is the particle size in a channel that 50% of the particles counted are equal to or finer than. The d50 particle is a way to compare channel materials between different streams. The d50 particle is measured customarily in millimeters. For the RRBP sites, particle size distribution is illustrated as the number of particles of each size as well as a cumulative curve.

*Floodplain:* The relatively flat valley floor formed by floods, which extends to the valley walls and is adjacent to a stream, which becomes inundated at high flows.

*Flood:* Flow that goes beyond the bankfull stage into the adjacent land or valley.

## Hydrology

The hydrologic cycle is a continuous natural process by which water is transported from the oceans to the atmosphere, from the atmosphere to land, and from land back to the oceans. It consists of evaporation, infiltration, groundwater flow, precipitation, surface runoff, and transpiration.

## Indicators of Water Quality

Indicator species are those which, when present, are indicative of a set of environmental conditions. The status and trends in the populations of indicator species (or groups of species) can be used to monitor changes in ecosystem health, since they integrate multiple structural and functional aspects of the landscape which may be more difficult to measure on a regular basis. Thus, trends detected in species monitoring data might be interpreted as resulting from degradation or improvement in habitats.

The three types of water quality indicators used in this project are aquatic biota indicator species, terrestrial biota indicator species and physical indicators, which include water quality standards. In addition, related habitat, including closed canopy forest species and large area deciduous forests were also considered to be significant indicators.

It is often desirable to have information available on multiple indicator species because of natural variation in individual species numbers over which we have no control. Economists and newscasters do something similar in relying on the patterns in the "leading economic indicators" as opposed to only one of them. If, for example, one of the bird species we use to monitor the health of mature deciduous forests declines in a given year, while the other bird species that use that habitat remain stable, general habitat change is not necessarily indicated. If most of the birds that use mature forest decline over a decade, habitat disturbance is more likely.

Species counts can also be used as an indicator of disturbance, and perhaps the total number of species in an area is a candidate for one of the "leading ecological indicators." Whether we discuss fish, birds, or aquatic insects, the general pattern (with a few exceptions) is that highly modified areas support fewer species. As a consequence, we can interpret a decline in the number species (which is often easy to count) as an early indication of undesirable disturbance, which is sometimes more difficult to measure.

Indicator species can also be used, through their habitat associations, to measure environmental characteristics more subtle than the presence of disease or toxins. For example, the presence of nest-building chubs (fish in the genus Nocomis) in a stretch of river indicates that siltation has not progressed so far that they cannot find pebbles with which to build their nests, or sufficient nearby clean riffles in which to forage for aquatic insects.

Several long-term data sets of species counts exist for our area. Through species-habitat associations, these data can be used now and in the future to monitor the condition of desirable elements in our landscape.

Regardless of whether they are intrinsically desirable or not, indicator species are often chosen for monitoring because they demonstrate the presence of desirable or undesirable ecosystem conditions. Fecal coliform bacteria measurements are a good example. While not usually pathogenic in themselves, elevated counts indicate the potential presence of pathogenic organisms in contaminated water. Another example is fish eating bird species such as herons, ospreys and bald eagles. Recent increases in the number of these fish-eating birds (following an earlier decline) reflect a general decrease in the amount of toxic material discharged into water and concentrated in fish flesh. *Low fecal coliform counts and high osprey counts are two biological indicators of desirable conditions for water quality*.

## Aquatic Indicators

### Introduction

*Benthic macroinvertebrates*
A benthic macroinvertebrate is an animal without a backbone, that lives in streambeds, and that you can see with the naked eye.

*Use As an Indicator*
The Izaak Walton League's Save Our Streams (SOS) Program protocols, used for the biological sampling, are based on the premise that aquatic macroinvertebrates serve as indicator species for determining the health of a river both at the sampling site and as assessment of basin-wide water quality for the combined points upstream. Impaired streams do not contain animals that unaltered streams do contain. Animals known to live in clean streams that are not found in dirty streams can serve as indicators of water quality. As with other measures based on species counts, disturbance usually reduces the number of species

*Fish*
The James River basin as a whole contains fish fauna fairly rich in diversity for an Atlantic Coast drainage, with 109 species listed, 73 of which are native (3 endemic), 26 of which are introduced, and 10 are estuarine or diadromous species. Of these, striped bass ascended the James well into the Piedmont and American Shad migrated far into the Valley and Ridge (James River Fish Fauna from Jenkins and Burkhead. 1993)

Many fish species prefer stream bottoms of clean loose gravel, rubble, or boulder, which are assumed to have been the dominant substrate types (along with bedrock in many streams) from the fall line west before deforestation. Loose, coarse substrate has abundant spaces between and under stones to support the invertebrate foods of many fishes and to serve as egg deposition sites and cover from predators. Small species avoid open bedrock, where shelter is rare; irregular bedrock outcrops often serve as foraging and hiding places.

Siltation and turbidity are the most pervasive deleterious factors to Virginia fishes, as well as fishes elsewhere. Siltation occurs when suspended solids, which cause turbidity, settle from overlying water. Fine sediment smothers gravel and rubble, and fills interstices, reducing benthic, bottom dwelling biota and breeding sites. Turbidity reduces the food-finding ability of sight-feeding fishes, of which there are many in Virginia. Many pool and backwater species commonly occur over silt bottom, but the food for these is drift from harder substrate or terrestrial input, and most of such species spawn on hard substrate or attach eggs above the bottom.

A few species have specific substrate requirements; when the required substrate is hard or firm bottoms, such species are rare or localized. For example, Erimystax cahni (slender chub) and Etheostoma tippecanoe (tippecanoe darter) occur mainly on major beds of pea-sized gravel in runs of large streams and rivers; the burrowing Etheostoma vitreum may be an obligate sand dweller. Some fishes that live in swift mountain streams may spawn in scattered sandy patches (Jenkins, RE and NM Burkhead. 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD. p47)

Pebble nests, such as those constructed by chubs, are an excellent place for fish to lay eggs: the eggs filter in among the pebbles (and are also covered by the adults), where they are protected from predators, yet the large pore size of the nests lets oxygen-rich water flow through. Other fish have discovered this, and other fish species also spawn over the chub nests. So the absence of chubs means other species will have reduced spawning success; since chubs themselves are prey for larger game fish, their absence because of siltation can indicate the breakdown of a desirable aquatic community, not to mention the loss of topsoil from adjacent farms or excess sedimentation in reservoirs, which occur at the same time. In the case of nest-building chubs, their presence indicates that desirable conditions exist and that they are performing desirable functions. One criterion for choosing an indicator species can be that it performs important functions.

**Nest Building Chubs**

The North American fish genus Nocomis contains seven species, four of which occur in Virginia; the River chub (N. micropogon), Bull chub (N. Raneyi), and Bluehead chub occur in the Rivanna River; they could be used to characterize a healthy river in the Piedmont. Nocomis chubs are often common, and are probably important forage fishes for gamefishes. They are often used as bait. They are of great interest because of their nest building activities (Bulger, 1997). The three Rivanna species (River, Bull, Bluehead) overlap in some characteristics, but differ somewhat in body size, diet, and the range of stream sizes they occupy.

Males of all Nocomis species construct a nest by first excavating a pit on the stream bottom, then building a gravel mound over it. Spawning occurs at intervals in a trough in the top of the mound, which is filled after each episode. The nest is defended against males of the same species. Other stream fishes especially dace and shiners use chub nests for spawning, but male chubs typically ignore these “nest associates”. Thirteen species are known to spawn on Bluehead chub nests, so they play an important role in stream ecology. Male chubs frequently chase egg-foraging species such as suckers. Males on nests are wary (unless actually spawning) and often disappear at the approach of humans. The quiet observer may see them return. Several other Virginia fishes in this family build gravel nests, but are more tolerant of silt.

**River Chub**

Although the River chub extends up into the 10 meter-wide section of suitable tributaries, it is typically found in medium and large tributaries and mainstreams. It typically occupies clear, gravel and rocky streams of moderate gradient, from downstream habitats up to the lower end of wild-trout waters. Typical coastal plain habitat is unsuitable.

The River chub diet is primarily immature aquatic insects taken by sight feeding, but like most fish they are opportunistic and other items occur in the diet. Sexual maturity occurs at 2-3 years, at an average length (SL) of 160 mm for males and 108 mm for females. Maximum longevity is 5 years.

Mid-spring to early summer is nest-making time in runs and tails of pools at an average temperature of about 21 C. Typical gravel mounds are 33-102 cm in diameter and 3-33 cm in height; larger males construct the larger nests. They take 20-30 hours to complete, spread over 2-4 days in daylight hours. A large nest may contain 7000 stones and have a volume of 67 liters. After the nest is built, the male digs a trough in it; the female initiates spawning by entering the trough; spawning lasts about one second, and several spawnings may occur in quick succession. Afterwards the male chases the female from the nest and fills the trough.

**Bull Chub**

The Bull chub feeds chiefly on benthic and drifting insects, plus snails, by sight feeding. Mean size for males is about 220 mm (Bulger, 1997) for males and 135 mm for females. Maximum age is at least 5 years.

The Bull chub typically occupies major rivers and their larger tributaries in the Piedmont and Valley and Ridge Provinces, and occasionally 8-12 meter-wide tributaries as well. It is more common over gravel and rocky bottoms than sand. It occupies both fast and slow waters, and can be found occasionally in the Coastal Plain over gravel. It builds the largest nest of the chubs: up 110 cm in diameter and 35 cm high; it can push or tug stones as large as 10 cm to its nest.

**Bluehead Chub**

The Bluehead chub is an omnivore, feeding on a wide variety of aquatic insect and plant material, especially algae. Sexual maturity occurs within three years of life; mean size for males is about 134 mm, and 83 mm for females (Bulger, 1997). In Virginia, males construct gravel nests in riffles, runs and tails of pools, during May and early June, at a mean water temperature of about 20 C. The gravel nests of Bluehead chubs are common in many Virginia streams in spring and early summer, and are often attributed to crayfish or children.

Bluehead chubs occur farther upstream than Bull or River chubs, from headwaters downstream to streams 20-30 meters wide, and can coexist with brook trout populations. Bluehead chubs tolerate streams, which are occasionally turbid, but the strongest populations occur in clear streams over a wide substrate size from sand to boulder, but not silt.

**Acid Deposition**
The Mid-Atlantic Highlands (including the mountains in the western part of the Rivanna basin) has one of the highest rates of acid deposition in the country. Sulfur and nitrogen oxides are released into the atmosphere by fossil fuel powered industries and vehicles. These emissions react with atmospheric components to produce nitric and sulfuric acids; these are delivered to watersheds as rain, snow, fog, particulate mater, aerosol particles, and dust. Their presence can be measured in water as sulfates, nitrates and acidity.

The sensitivity of a landscape and its waterbodies to acid deposition is determined primarily by bedrock geology. Soils derived from quartz sandstone (siliciclastic) produce streams with little or no acid neutralizing capacity (ANC). Watersheds underlain by granite, basalt or limestone produce streams with ANC in an increasing sequence. Thus bedrock geology maps can be used to identify watersheds sensitive to acid deposition.

The Southern Appalachian Assessment (SAA) (SAMAB 2, 1996) classified about 54% of the total stream miles in the Southern Appalachians as highly sensitive to acid deposition. About 9% of all stream miles were of medium sensitivity, and about 27% of all stream miles were of low sensitivity. Approximately the same percentages of Virginia streams fall into these categories.

Since current projections indicate that the sensitive areas (mostly forested mountain areas) of the region are continuing to acidify, the Roundtable might consider using brook trout and associated species (other fish and aquatic insects) as indicators of acidification status.

**Wild Trout**
The western forested part of our region hosts cool-water fish communities typified by brook trout. Trout populations are regarded as one of the region's most valuable aquatic natural resources. The status of trout populations and trout habitat is a major concern to the public in the Southern Appalachians in general. Sources of concern generally fall into three categories: 1) fisheries for native brook trout and introduced rainbow and brown trout; 2) "existence value" for brook trout, regarded as a beautiful and intrinsically valuable native species; 3) the presence of trout as indicators of high water quality.

Shenandoah National Park (SNP) and the Virginia Department of Game and Inland Fisheries (VDGIF) monitor the health of these communities. The findings of the "Fish in Sensitive Habitats" Project clearly demonstrated that both chronic and episodic acidification are occurring in SNP streams. Biological effects are apparent in fish species richness, population density, condition factor, age, size, and bioassay survival. This study on the effects of acidification on fish was initiated as a result of a 14-year record of decreasing pH in some SNP streams.

## Indicator Species

Considering available information about fisheries in the Rivanna basin, the Desired Future Conditions Working Group initially selected the following species as aquatic biota indicator species for the project:

- Bluehead Chub
- River Chub

- Bull Chub
- Smallmouth Bass

After initial mapping efforts of these species revealed disappointing coverage within the basin, three additional species were selected. These demand similar habitat characteristics as the chub list above, with the exception of the sunfish, which is a nest builder, and requires adequate woody vegetation for spawning.

- Cutlips Minnow
- Redbreast Sunfish
- Fallfish

## Terrestrial Biota Indicator Species

**Introduction**

It has become very clear that the way we use land has a direct effect on water quality and aquatic habitats. We should be interested in the health of our forests from a water quality point of view, because water flowing out of healthy forests generally is of a higher quality and has a stable stream hydrology. We should be aware of how stream banks, especially near farms, are stabilized, because of the potential for erosion and siltation. We should be aware of the amount of impervious surface in developed areas, because water quality deteriorates as the amount of impervious surface increases.

**Bird Surveys Counts**

We have available long-term (30-50 years), high quality counts of bird populations in our area, for both winter and summer. Dedicated volunteers collect these data, and the collection is sponsored by government agencies. The motivation for collecting the data is often an intrinsic interest in birds (about 25% of American adults identify themselves as at least occasional birdwatchers) as well as an interest in the health of bird habitats.

*Breeding Bird Survey (BBS)*

The Breeding Bird Survey is the most comprehensive non-game biological monitoring program in North America (Greenberg and Reaser, 1995); it is a cooperative effort of the US Fish and Wildlife Service and the Canadian Wildlife Service. The value of the BBS should not be underestimated. The large sample sizes make the data set robust, and it is regarded as the best early warning system we have for detecting declines in bird populations.

*Christmas Bird Counts (CBC)*

Christmas Bird Counts take place between mid-December and early January, with volunteers recording all birds by species and number observed on a single day, in nearly 1600 local areas in every state and Canadian province, plus several localities in Central and South America, and the West Indies.

**Species-Habitat Associations**

The Southern Appalachian Assessment (SAA) (SAMAB 5, 1996) selected groups of terrestrial species as representatives of habitat types based on their strong associations with readily detected habitats. These were then analyzed using remote-sensing information. To avoid distortion, groups of species with either very narrow or very general habitat requirements were avoided.

The study encompassed the entire Southern Appalachian region, which includes parts of seven states and 37 million acres, including the Rivanna basin in Greene, Albemarle and Nelson counties. The mapped land-cover classes included: nine different forest types, agricultural cropland, agricultural pasture, grass-shrub-old fields, barren, water, wetlands, and developed land. Three of these groups and their associated habitats appear suitable for use by the Roundtable to determine trends in landscape unit health.

## Indicator Species by Habitat

**Forested streamsides**
Forested streamside habitat (also associated with springs and seeps) was defined as the area approximately 100 feet wide along each side of streams, and 100 feet wide around the edge of other water bodies.

This group included 12 plants, 13 salamanders, 3 birds, and 3 mammals. Only forested streamside habitat was quantified for the SAA. The Roundtable chose the following forested streamside species, primarily because long term data monitoring information was available:

- American woodcock
- Acadian flycatcher
- Louisiana waterthrush
- Beaver

**Closed canopy forests**
Closed canopy forests combine several healthy, mature-forest habitat sub-types, which are distinguishable in LANDSAT imagery. The primary forest types grouped here for the purposes of the Roundtable are mixed mesic (neither very wet nor very dry) hardwood, oak, bottomland hardwood, northern hardwood, and mixed hardwood-softwood forests. A large number of plants and insects are associated with these subtypes. The Roundtable chose two mammals and two bird closed canopy forest species:

- Eastern gray squirrel
- Eastern fox squirrel
- Eastern wood pewee
- Downy woodpecker

**Large-area, mature deciduous forests**
This forest group also combines several healthy, mature-forest habitat sub-types, which are distinguishable in LANDSAT imagery.

The primary forest types grouped here for the purposes of the Roundtable are similar to the previous category, with the exception that only larger tracts are considered, and the indicator species are those that are considered to be area-sensitive, requiring continuous forested tracts. The value of the SAA effort is a documented, published account of the strong association between large forest tracts and the 16 species chosen, many of which currently occur in our area in sufficient numbers to be useful indicators of continuous forest habitat.

The Roundtable chose the following large-area mature deciduous species species based on the SAA effort. All 16 species in the group are birds. Many are neotropical migrant species; many avoid forest edges during nesting, and may be considered forest-interior species. Continuous forested tracts were stratified into size categories for analysis, which is beyond the level of detail required for the purposes of the Roundtable.

- Kentucky warbler
- Northern parula
- Scarlet tanager
- Summer tanager
- Ovenbird
- Yellow-throated vireo
- Hooded warbler
- Pileated woodpecker
- Red-bellied woodpecker
- Hairy woodpecker

The Roundtable also chose the following10 Southern Appalachian Area game species indicators:

- White-tailed deer
- Black Bear
- Gray Squirrel
- Fox Squirrel
- Eastern Cottontail Rabbit
- Raccoon
- Ruffed Grouse
- Bobwhite Quail
- Eastern Wild Turkey
- American Woodcock.

Several of these species show strong habitat associations. Higher Fox Squirrel and Bobwhite Quail densities are associated with agricultural land. Grouse are associated with early-successional (sapling-pole) forests. High Turkey densities occur in counties with greater amounts of oak forest and cropland, versus counties with coniferous forests and developed land.

In addition to these specific habitat-associated species, the Roundtable also chose four "charismatic mega-fauna" to provide a focal point for the larger public concern:

- Shad
- Otter
- Humans
- Great Blue Heron

Blue Ridge-Piedmont species-specific habitat requirements were looked for and not found, indicating the forest is failing. Their lack should be noted.

## Physical Indicators/Water Standards

In addition to the aforementioned biological indicators, the following physical indicators and associated targets were also approved by the Roundtable. Research sources for the setting of the targets included Virginia Department of Environmental Quality standards and recommendations, T.E. Waters (1995) Sediment in Steams (Waters), Stoskopf (1993) Fish Medicine, Living Resources Subcommittee Chesapeake Bay Program (1991) Habitat Requirements for Chesapeake Bay Living Resources, and recommendations for standards by A. Bulger, University of Virginia Department of Environmental Sciences and member of the Rivanna River Roundtable. DEQ standards are regulatory unless otherwise noted.

**Fecal Coliform**
The first standards for drinking water were established in 1914 by the US Public Health Service, and were based on coliform contamination. The purpose of the testing was to screen for sewage contamination of the water supply, thus preventing outbreaks of enteric (gastrointestinal) disease. As testing has become more refined over the years, tests are now conducted for fecal coliform, as they are more specific to the intestinal tracts of warm-blooded animals.

It is important to note that individual pathogenic bacteria are not routinely tested for because it is far more difficult, time consuming, and expensive. Fecal coliforms, on the other hand, are not only more numerous (billions are present in each animal's intestinal tract), but are also easy to detect by routine culture. (Although if fecal contamination is present, it says nothing about the presence of human pathogens).

Traditionally, the concern in water contamination has been for human pathogens that live predominantly in human intestinal tracts, such as those causing typhoid fever, cholera, bacillary dysentery, hepatitis, and various parasitic diseases. However, in the past two decades, it has been recognized that some bacteria that live predominantly in animals are causing significant amounts of human disease. For example, enterohemorrhagic e. coli (strain 0157:H7) has received perhaps the most attention because of both its frequency (an estimated 10-20,000 cases/year) and its potential severity. These organisms live predominately in cattle, but rarely reach significant numbers outside overcrowded, epidemic-prone cattle fed lots. There have been several reported epidemics secondary to swimming in contaminated water (e.g. Illinois 1995) and three episodes in Virginia. All were in still bodies of water (lakes) and all involved children in diapers infecting other swimming children.

Cryptosporidia is a parasite that also has an animal reservoir, including cattle. This organism caused the large outbreak of gastrointestinal illness in Milwaukee several years ago, when the water purification systems were overwhelmed by heavy rainfall. Giardia is a common parasite that has been spread from man to many animals in our wilderness areas and contaminates many streams across the U.S.

**EPA Limits on Fecal Coliform (FC) Contamination**
The Environmental Protections Agency has set limits on safe levels of fecal coliform as follows:

*Human consumption*

- (unenforceable goal) 0 Fecal Coliform per 100 ml sample
- MLC for less than 40 samples/month: no more than 1% of samples may be positive for total coliform (TC)

*Primary contact (swimming, etc.)*

- based on a minimum of 5 samples taken over a 30-day period, the Fecal Coliform should be < a log mean of 200 per 100 ml, nor should more than 10% of samples taken during any 30 day period exceed 400 per 100 ml

*Secondary contact (fishing, boating, etc.)*

- Fecal Coliform shall not exceed a log mean of 1000 per 100 ml, nor more than 10% of the total samples during a 30 day period exceed 2000.

**Ammonia (Mg/L)**

| | |
|---|---|
| Cold Water Fish Species Target for acute exposures (DEQ): | 0.58-35 |
| Warm Water Fish Species Target for acute exposures (DEQ): | 0.82-35 |
| Cold Water Fish Species Target for chronic exposure (DEQ): | 0.09-3.02 |
| Warm Water Fish Species Target for chronic exposure (DEQ): | 0.13-3 |
| Trout (Stoskopf): | 0.03 |
| Smallmouth Bass (Bulger): | 0.7 |

**Nitrate Or Nitrite (Mg/L)**

| | |
|---|---|
| Public Water Supply (Nitrate) (DEQ): | 10 |
| Trout (Nitrate) (Stoskopf): | 0.55 |
| Trout (Nitrite) (Stoskopf): | 0.55 |
| Green Sunfish (Nitrite) (Bulger): | 86 |
| Bluegill (Nitrite) (Bulger): | 160 |

**Phosphorous (Mg/L)**

| | |
|---|---|
| Enrichment Trigger (advisory standard) (DEQ): | 0.2 |

**Total Suspended Solids (Mg/L)**

| | |
|---|---|
| Humans (advisory standard) (DEQ): | 500 |
| Shad (Ches. Bay Subcommittee): | 100 |
| Trout (Stoskopf): | 80 |
| Chubs (Bulger): | Need clear gravel and rocks |
| Fish in general (Waters): | 80-400 |

**Fecal Coliform (Cells/100 Mls)**

| | |
|---|---|
| Humans (DEQ): | 1000 |

**Dissolved Oxygen (Mg/L)**

| | |
|---|---|
| Natural Trout (DEQ): | min. 6, avg. 7 |
| Put & Take Trout (DEQ): | min. 5, avg. 6 |

| | |
|---|---|
| All other Fish: (DEQ): | min. 4, avg.5 |
| Trout (Stoskopf): | 5 |
| Shad (Ches. Bay Subcommittee): | 5 |

**Temperature (Degrees Centigrade)**

| | |
|---|---|
| Natural Trout (DEQ): | 20 |
| Put & Take Trout (DEQ): | 21 |
| All other Streams (DEQ): | 32 |
| Trout (Stoskopf): | 0.5-20 |
| Catfish (Stoskopf): | 0.5-35 |
| Shad (Ches. Bay Subcommittee): | 8-27 |

**pH**

| | |
|---|---|
| All life (DEQ): | 6-9 |
| Trout (Stoskopf): | 6-8 |
| Catfish (Stoskopf): | 4-10 |
| Shad (Ches. Bay Subcommittee): | 6-7.5 |

**Copper (Mg/L)**

| | |
|---|---|
| Human Health Public Water Supply (DEQ): | 1.3 |
| Trout (Stoskopf): | 0.014 |

**Zinc (Mg/L)**

| | |
|---|---|
| Human Health (DEQ): | 5 |
| Trout (Stoskopf): | 0.01-0.15 |

**Cadmium (Mg/L)**

| | |
|---|---|
| Human Health (DEQ) (PWS): | 0.016 |
| Human Health (DEQ): | 0.17 |
| Trout (Stoskopf): | 0.03 |

Noteworthy is DEQ's lack of regulatory standards for phosphorous and total suspended solids.

## Working Assumptions

As the work of the Project progressed, several assumptions emerged as central to identifying the kinds of data that needed to be collected. **The first of these assumptions is that the River can and should be returned to the desirable conditions of the past.** This assumption was reflected in the Roundtable's use of the slogan, "Put the Shad back in Shadwell", and pointed out the importance of developing an historical description of the River and its basin.

**A second assumption is that the River and its basin are parts of a larger dynamic and interrelated system including the human and animal residents of the area. A third assumption is that factors affecting one portion of the watershed have related effects on other parts of the basin.** These two assumptions underlie the need to establish baseline data about land use and land surfaces or cover, including both river buffers and impervious surfaces.

In addition, they highlight the importance of developing watershed-wide planning strategies amongst geographic areas that do not always share the same governmental boundaries.

**A fourth central assumption is that the efforts of an involved, informed citizenry, in addition to local and state government are required to safeguard the resources of the River.** This assumption is the basis for a number of the Project activities, including the River Explore Day and other efforts to enfranchise citizens.

**Field Team Assumptions**

The general role of Field Team Volunteers for the Rivanna River Basin Project (RRBP) was carefully developed over the summer months leading to the October 26, 1997 project kickoff. RRBP staff worked to define a middle ground between a top-down approach where professional scientists collect all of the data, ensuring quality control at the expense of citizen involvement, and a bottom-up approach where unaccompanied citizen volunteers, no matter how competent, collect data only to have it questioned and rendered unusable by recipient agencies. Recognition was given to the various ways people relate to a river, including not only the intellectual but the emotional and social as well. The goal for the field teams was to produce not only quantitative data, but also to create images of how we connect to the river and how it connects us. This goes beyond a basic understanding of belonging to, or living in, a specific watershed to a fuller understanding gained by being part of a team of people working together.

Project development was based on the premise that genuine, ongoing citizen involvement in the monitoring and stewardship of the Rivanna Basin is necessary for long term project success. Two major elements of the approach to volunteer network design resulted from this premise:

1*) The audience targeted to use project data is ultimately all of the residents of the Rivanna Basin*. While every effort was made to link monitoring locations and methodologies with those of the Virginia Department of Environmental Quality, the U.S. Geological Survey, etc., it was determined that the quality of data generated also needs to meet the needs and standards of the scientists, decision makers and citizens living within the basin. For example, the decision to correlate chemical data with discharge data was based on the need to evaluate the impact of storm events on chemical parameters.

2) The *project needs to continue indefinitely*. The challenge was to build a volunteer network of citizens and professional scientists that accomplished its tasks not only for the given project year, but which is designed to continue on well beyond the project year. The work put into building a permanent monitoring framework for each of the field team components added complexity to what could have been a one-year-only approach to the project, but this work has paid off as citizen and professional volunteers have expressed commitment to continuing with the project after the grant year.

# VII. Inquiry Approach and Project Methodology

## Introduction

The major portion of the inquiry conducted within the project was descriptive-analytic. Much of the methodology was directed toward the development of baseline data after initial searches disclosed a surprising dearth of systematically collected data about the River and its Basin. The data collected were primarily gathered by field study, especially those data related to water quality, hydrology and morphology. A second approach to inquiry in this Project involved the construction of maps that could be used to display data of relevance to the river by illustrating relationships. For example, the relationship of impervious surfaces to water quality is documented but had not been specifically mapped in relation to this river system.

Literature review was the primary method used to develop the historical description. The chapter describing this history was written by two students at the University of Virginia under the direction of Professor Beth Myers, in collaboration with the History subcommittee of the Roundtable. Additional document review was done to identify data sources used to construct maps such as the map of the percent of impervious surface in the Basin. Often a variety of sources were used to synthesize findings of particular interest in this Project. This methodology will be described in detail below.

The Project Field Teams under the direction of John Hermsmeier accomplished by far the most intense data collection. The current and historic water quality and stream flow data are primarily based on a combination of the monitoring done by these teams and historic data from the Virginia Department of Environmental Quality and the U. S. Geological Survey.
The field teams also monitored stream morphology (condition of stream banks and depth of channels) in addition to the chemical and biological composition of the water. The methodology used to describe the morphology and hydrologic characteristics of the River will be included in the following section. Data about stream hydrology were gathered from U.S. Geological Survey documentation, the U.S. Department of Commerce, and the University of Virginia Geographic Information center.

The following four major areas and subsets were selected for volunteer participation. The goal in selecting these parameters together was to build a comprehensive understanding of the river rather than studying its components in isolation.

*Biology*
type, number and diversity of benthic macroinvertebrates

*Chemistry/Bacteriology*
pH
Total Suspended Solids (mg/L)
Nitrate/Nitrite (mg/L)
TKN [total Kjeldahl nitrogen] (mg/L)
Total Nitrogen (mg/L)
Total Phosphorus (mg/L)

Fecal Coliform (colonies/100 ml)
Discharge (for sites without a USGS gage)

*Morphology*
Width at Bankfull
Flood Prone Area
Entrenchment Ratio
Pebble Counts
Photo documentation of site including permanent bankfull markers

*Exploration (Audio/Visual Documentation, Including Poetry, Sketches, Etc.)*
Sediment and Erosion
Vegetative Cover
Wildlife
Human Uses
Character of Water
Other notable features at discretion of explorer

## Characteristics of the Rivanna River and Basin

In addition to the historical description of the Basin, specific information about the morphology of the streams and their hydrology was collected. The study methods used to describe the latter two characteristics are presented below.

**Morphology**
One stream morphology team was trained to travel to each of the watersheds (same locations the chemistry/biology teams) to collect data on stream width, depth, sedimentation, and other characteristics useful in correlating historic land use with stream bed structure. The team visited each site at the beginning and end of the project period. The teams used one or all of the following techniques:

- Rosgen methodology
- Tree root cross sections
- Sediment deposition on clay

The protocol included using data collection sheets and the following steps:

1) Locate pre-flagged cross-section location and bankfull level, using station sheet. Do you agree with the bankfull level? Perhaps the flags have washed away in the recent storm. Test your bankfull skills!
2) Establish permanent monumentation at bankfull (one or both banks, depending on landowner permission) with rebar and flagging. On page 1 of data sheet, document location of cross-section to known reference points (e.g., 100’ downstream from downstream bridge abutment on right bank, 10;east of large sycamore, etc.)
3) Beginning at left bank (looking downstream), conduct measurements for bankfull cross-section and flood plain area; fill in data sheet.

4) Locate gauge reference (for gauged stations – see station sheet). Conduct measurement to reference bankfull elevation to gage, if applicable (may have to find new bankfull location close to gage area). Fill in data sheet.
5) Conduct pebble counts at 10 cross-sections within reach---approximately 100 pebble count readings (50/50 riffle/pool).
6) Take several photographs and describe photo locations on data sheet.

This information was then collated and analyzed by stream segment.

**Hydrology**
There is only one long-term gauging station measuring precipitation in the Basin. It is located at the University of Virginia's McCormick Observatory on Observatory Hill, near the Basin's geographic center. Precipitation data from this station was provided by the State Climatology Office, located at the University's Clark Hall. The data were used to represent the entire basin.

Data were reviewed for changes over the period of record and the trends charted. A statistical test was performed to determine the probability of the trends being significant.. The analysis was not used in developing this report due to stricter probability values acceptable to the PDC.

The rate of change and the magnitude of change were also reviewed in developing areas, which qualified for future monitoring.

## Water Quality Methodology

Water quality was measured by physical indicators, aquatic and terrestrial biota. The methods used are described below.

**Physical Indicators**
Water quality data for the Rivanna River Basin Project were developed from two sources:

*Current data* from the Rivanna River Basin Project Field Teams (see Rivanna River Basin Field Teams for information about methodology)

*Historic water quality and discharge data* from the ambient monitoring program at the Virginia Department of Environmental Quality and from the U.S. Geological Survey/Virginia Department of Environmental Quality. (Due to concerns about data validity, DEQ staff suggested that monitoring data recorded prior to 1990 not be used.)

Both sets of water quality data were analyzed using a "flow-based context" to consider the impact of increased and decreased flows on pollutant concentration. A flow-based context is an examination of water quality trends in relationship to discharge trends over time. Discharge data used for both current and historic data came from the U.S. Geological Survey. Additional data came from sediment samples collected and analyzed by the Virginia Department of Environmental Quality.

Staff identified the following five DEQ stations with water chemistry data which were co-located with USGS gauging stations:

- Mechums River at Rt. 614
- Moormans River at Rt. 601
- Buck Mountain Creek at Rt. 664
- North Fork of the Rivanna River at Rt. 606
- South Fork of the Rivanna River at Rt. 29
- Rivanna River at Rt. 15

**Definitions**
To assist the reader in understanding the morphology of the River, the following definitions are provided:

*Baseflow Concentration*: An amount of pollutant per volume of water sampled during low water.
*Coliform* are rod-shaped bacteria ubiquitous in nature, especially in soil and water.
*Fecal coliform* is a sub-group found in the intestines of warm-blooded animals, and is excreted in their feces.
*Concern:* Where an average concentration of pollutants is above recommended thresholds for fish in the Rivanna River Basin, or other tests are incompatible with continued water quality, the segment or area is noted to be "of concern"
*Maximum Storm/Baseflow Concentration*: The maximum concentration of pollutants of the four stormflow or baseflow samples.
*Mean Storm/Baseflow Concentration:* The average concentration of pollutants of the four stormflow or baseflow samples.
*Minimum Storm/Baseflow Concentration*: The minimum concentration of pollutants of the four stormflow or baseflow samples.
*Stormflow Concentration*: An amount of pollutant per volume of water sampled during high water.

## Aquatic Biota

Aquatic biota includes benthic macroinvertebrates and fish. A benthic macroinvertebrate is an animal without a backbone, that lives in streambeds, and that you can see with the naked eye.

**Benthic Macroinvertebrates Site Selection**
A total of 14 monitoring sites were selected for the 10 hydrologic units in the Rivanna Basin based on the following criteria:

1) proximity to existing and former DEQ monitoring sites and USGS gauging stations in order to complement historic data
2) proximity to mouth of hydrologic unit (one site each was added for this reason to H27, H29 and H31). The goal is to measure the impact of each sub-basin on the Rivanna. Future project plans call for the expansion of this approach upstream so that impacts on each tributary can be studied.
3) representation of a diversity (rural, urban, etc.) of land uses. The Meadow Creek site was added to H28 in order to capture an urban drainage.
4) ease of access for volunteers

5) permission by landowners for access

After parameters and sites were selected, the next step was to determine how to assign volunteers to a task, a location and a time schedule in a way consistent with project goals and each volunteer's interest, expertise and time constraints.

**Parameters for Benthic Macroinvertebrates Data Collection**
In the SOS methodology, macroinvertebrates are divided into categories of Pollution Sensitive, Somewhat Sensitive and Tolerant. Points are allotted for each type of animal found (3 points for each type in the sensitive range, 2 points for somewhat and 1 for tolerant). The sum of the points is the score for the segment.

Based on the overall score, the SOS protocol macroinvertebrates are divided into the following four ranges:

| | |
|---|---|
| Poor: | 10 or less |
| Fair: | 11-16 |
| Good: | 17-22 |
| Excellent: | >22 |

*Limitations.* Macroinvertebrate sampling is a subset of the overall biology of a given site. Biology, in turn, is only one of the many measures used in determining the health of a given river or river segment.

Stream samples are indicative of conditions at the site of the sample; other habitat conditions, such as an area of excess siltation may exist as close as the other end of a stream riffle for various reasons, including direction or rapidity of flow in relation to the sampling site chosen. The sampling location is intended to be the best square meter of habitat at the site, which may be better than the overall habitat conditions.

Analysis of overall scores may hide variations in components of the measurements, so a site with a lot of sensitive organisms with relatively few total organisms may have the same score as a site with more organisms overall, but with few sensitive ones.

Scores are affected by high water flows, which occurred several times during the project. The most meaningful information is the high score for the site over the project year.

Macroinvertebrate sampling provides a good idea of a site's ability to support different types of life over a period of time, going back at least as long as the life span of the organism found. By basing the assessment of each site and its comparison to other sites on annual high scores, rather than on each sampling event, factors such as variable flow conditions and even monitor error can be eliminated. If a single macroinvertebrate count indicates excellent water quality, one knows the water quality is not poor. However, if a macroinvertebrate count indicates poor water quality, factors like suitable flow conditions for monitoring, monitor error, and even variability in the distribution of populations might explain the result. If low scores persist over time, without any high scores, such as in Meadow Creek, there is increasing confidence it is an indication of poor water quality.

## Fish

Digital fisheries data from VDGIF were used to plot historic fish collection locations in the Rivanna River Basin and create maps showing the distribution of fish indicator species. The Desired Future Conditions Committee of the Rivanna River Basin Roundtable selected fish indicator species. The following species were selected (see Desired Future Conditions of this report for more detailed information):

- Bluehead Chub
- River Chub
- Bull Chub
- Cutlips Minnow
- Redbreast Sunfish
- Fallfish
- Smallmouth Bass

No information was available for this project from VDGIF concerning the probable locations of fish species based on habitat, only where they have been collected. (However, VDGIF biologist John Kaufmann did visit with the Roundtable to discuss findings and relate concerns about areas where small mouth bass species were expected, but not found). Data made available for this project from VDGIF were included the year the sample was collected, the location at which the sample was collected and the type of species found. No data were available on the number of fish found for each species, nor were data generally available in the same location over time (the one exception is some trout collection sites). Consequently, none of the warm water fish data can be used for trend analysis purposes. Because much of the data that is available were collected prior to recent urbanization of portions of the basin, only those collections of data sampled from 1980 to the present was used. These recent fish collection locations were "tagged" to third-order watersheds to produce watershed-based GIS maps of fish indicator species.

## Birds

Bird data examined in the project came from three sources:

- Virginia Department of Game and Inland Fisheries (VDGIF) Breeding Bird Atlas (BBA)
- National Biological Survey Breeding Bird Survey (BBS)
- Audubon Society Christmas Bird Counts (CBC)

BBA data were combined with maps for each of the habitat types linked to the production of good water quality and the results analyzed for species diversity. Historic trends for each of the indicator species identified through the BBS and CBC were analyzed. Analyzed data came from the *report Trends for Indicators of Sustainability* and *Trends for Indicators of Sustainability: Appendix* (Thomas Jefferson Planning District Commission, 1997). Taken together, the BBA, BBS, and CBC data sets comprise the first comprehensive examination of existing spatial and temporal bird data in the Rivanna River Basin.

**Breeding Bird Atlas**
The Breeding Bird Atlas was started in 1984 as a 5-year survey performed by the VDGIF and the Virginia Society of Ornithology (VSO). The purpose of the atlas is to evaluate the status and distribution of breeding birds within the state. The state is divided into quadrangles (the same size as an U.S. Geological Survey quadrangle, and each of these is divided into six blocks). "Atlasers", composed of volunteers and VDGIF staff, ensured that at least one block of each of the inventoried quadrangles was surveyed once during the 5-year project period. Thus, no data was available for this project from VDGIF about where bird species are expected to be found within the basin. However, VDGIF biologist Keith Klein did visit the Roundtable to discuss concerns about areas where species diversity was not as great as it might otherwise be.

Third order watersheds were tagged by Breeding Bird Atlas quadrangle to convert atlas data to watershed data. Maps of species diversity by habitat type were then created. These maps were then overlaid with the third-order watershed land cover map to identify the relationship between land cover and species diversity.

**Breeding Bird Survey**
The survey was begun in 1965 to establish long-term trends in numbers of birds that might result from environmental factors, such as the use of DDT. It is based on a continent-wide sampling design. During each nesting season (in May-June, when males are most vocal), volunteers survey one or more of the 1,800 predetermined routes that cover nearly 50,000 miles. The Breeding Bird Survey is conducted by volunteers during the peak of the nesting, primarily in June of every year. Each Breeding Bird Survey route is 24.5 miles long, with a total of fifty stops located at .5 mile intervals along the route. A three-minute count is conducted at each stop, during which the observer records all birds heard or seen within .25 mile. Surveys last about 4.5 hours. There are four BBS routes in our area.

The BBS provides adequate population data for over half of breeding birds of North America. Two caveats with respect to data interpretation apply. First, most birds are counted along roads. Roads are likely to occur on higher ground and to pass through disturbed habitats, so that not all habitats are sampled equally. Second, the distribution of habitats is continually changing, and the BBS does not have a built-in habitat classification scheme; habitats can, however, be identified after the fact. The BBS has two routes that are in or near the Rivanna River Basin: route #22 is south of Charlottesville from Carter's Bridge to Rt. 619 at the Albemarle County line (count began in 1966), and route #21 in southern Albemarle County from South Garden to Howardsville (count began in 1967).

**Christmas Bird Count**
The Christmas Bird Count is conducted in December of every year. Volunteers walk and ride within a circle, 15 miles in diameter. Volunteers travel in teams (parties) and record the number of individuals by species seen, the number of miles traveled, and the number of hours spent observing. Historic data are standardized over time on a per party, per hour, per mile basis. The US Fish and Wildlife Service is charged with computerizing the counts and making them accessible. Two caveats with respect to data interpretation apply. First, neither the miles covered nor team size is constant, and there is a competitive element in the number of birds recorded; however, numbers recorded per unit effort (total team hours, miles, and number of

observers) can be standardized afterwards to establish population trends. Second, the habitats and routes within each circle can change over time. Nevertheless, the database represents the longest continuous record of non-game wildlife populations in North America. There are six Christmas Bird Counts in our area, three operating continuously for 50 years.

Three CBC areas are surveyed in or near the Rivanna River Basin: a Charlottesville count (centered on Rt. 677 in Ivy between Rt. 676 and Rt. 250, most of the data collection beginning in 1951), a Keene area count (most of the data collection beginning in 1951), and a Big Flat Mountain count (stretching from White Hall to the Greene County line, with most of the data collection beginning in 1955). With the exception of U.S. Geological Survey surface water gauging data from Palmyra, this CBC data is perhaps the region's longest-term environmental data set available.

## Land Cover and Impervious Surface

**Introduction**

The purpose the land cover portion of this project was to create a thematic map of the Rivanna River Watershed showing the spatial variation of impervious surface. Studies of watershed ecology have demonstrated that the percentage of impervious surface within a watershed is a critical measure of man's impact on watershed ecology resulting from non-point-source pollution.

Non-point-source pollution results from nutrients, chemical compounds (such as pesticides and solvents) and bacteria, being washed into streams and lakes by storm water. The key to reducing non-point-source pollution is to reduce storm water runoff. In naturally vegetated areas, storm water tends to get trapped by vegetation and slowly soaks into the ground. In contrast, in areas affected by man (urban, suburban, or agricultural areas) storm water tends to preferentially travel by overland flow, becoming channeled into drains and ditches where it is rapidly discharged into streams and lakes. Channelized runoff and overland flow across impervious surfaces are characterized by high velocities that entrain sediment and pollutants. Resulting increases in flood events in streams and rivers increase erosion and siltation, lower mean water temperatures, increase pollutant levels and have a negative impact on aquatic ecology (especially native fish populations).

Both urban and agricultural areas are renewable resources for:

- sand, silt, and mud from construction areas and plowed fields
- pesticides and nutrients (phosphates and nitrates, in particular) from lawns, gardens, and croplands
- oil, grease, fuel, and toxic chemicals from automobiles and farm machinery
- viruses and bacteria from animal feces and failing septic systems
- heavy metals from automobile tires, from fertilizers and other diffuse sources

For example, bacterial levels measured by DEQ in the Rivanna River show a spatial and temporal correlation with high discharge (storm) events measured by river gauges.

This task was begun as an attempt to map impervious surface utilizing existing land-use/land cover. The aim of the task was to produce a map of the percentage of impervious surface within the Rivanna River drainage basin. This map was to have sufficient resolution and accuracy to compute realistic average value for this parameter at the scale of a third order drainage basin.

**Data Sources**

As initially conceived this project set out to use existing classified LANDSAT imagery to produce a map of impervious surface within the Rivanna River watershed. Such a data set had recently become available through the Virginia Tech Gap Analysis Project. The appropriateness of this data set was evaluated by comparison with panchromatic SPOT imagery, land-use/land cover maps produced by the VIRGIS group at Virginia Tech (as part of the Pesticide Study sponsored by the Thomas Jefferson PDC) and USGS DRG (scanned images of USGS 1:24,000 topographic maps). Some key details of these data sets relevant to their interpretation are:

*Virginia Gap Land-use/Land-Cover Map*

- based on "Best of the US" LANDSAT imagery from 1993
- 30 meter pixels
- supervised classification based on multispectral LANDSAT data and Panchromatic SPOT imagery

*SPOT Imagery*

- panchromatic (gray tone) images with 10 meter pixels
- images rectified to account for topographic and geometric distortions based on 1:24,000 topography and control points.
- based on 1994/1995 images

*Pesticide Land-Use/Land-Cover Map*

- raster image with 33 meter pixels
- based on air-photo interpretation and extensive groundwater studies
- land-use categories based on differing uses of fertilizer; for example, golf courses, park lands, urban and suburban residential areas were aggregated into a category termed "lawns"
- data covers Albemarle and Louisa counties and was completed in 1993

*Digital Raster Graphs (DRG's)*

- raster images of 1:26,000 topographic maps
- based on data last updated by USGS in 1987 for most of watershed
- shows urban areas in generalized manner, shows individual houses in rural areas except in subdivisions
- data based on air-photo interpretation of high altitude photography

*Digital Orthophotography for Albemarle County*

- rectified images with 1 meter pixels
- based on 1997 photography

**Data Source Limitations**

The current study was designed to provide a realistic prediction of the average runoff potential for the watershed at the scale of a third order drainage basin at a time scale of tens of years. Thus, factors such as variations in slope, seasoned variations, variations from wet to dry years, etc., are averaged out. This data should not be used for planning discussions or other analysis on a more detailed level than utilizing the spatial average of percent impervious surface for a whole third order drainage basin.

*GAP Land Use Map*
Based on extensive quantitative and comparison between these image sets it became readily apparent that the Virginia Gap map data was not an appropriate data set to act as the basis for the current study. The Virginia Gap Study was designed to create a land-cover map of Virginia for the specific purpose of studying wildlife habitats. The significance of the aim of the Gap Analysis project in this context can be understood by considering the following observations:

1) Nearly half of the urban area of the City of Charlottesville and adjacent Albemarle County is classified by the Gap Study as “Forest Land”.
2) Over 95 percent of the high-density suburban area with the Lake Monticello subdivision in Fluvanna County is classified as “Forest Land”, the rest of the area as disturbed land.
3) Croplands, cultivated pasture lands and cleared areas are not separated.
4) High and low density housing as well as commercial/industrial areas are not separately classified.

*Spot Imagery*
Examination of SPOT imagery covering the Rivanna watershed revealed the imagery had less than expected resolving power to identify roads and houses in areas with extensive tree cover. The state contracted for “Leaf off” images from SPOT Corporation. Comparison between the Albemarle County orthophotos (which are leaf off) at the same resolution as the SPOT images, demonstrates that the SPOT images have significantly less information on roads and building locations.

*Pesticide Land-Use Maps*
This data set in general holds up well except where more recent housing and/or commercial developments have occurred since creation of this data. Some inconsistencies were noted in this study. For example, only the building area of Fashion Square Mall was included in the “building” category, not the parking lot. However, in the Barracks Road Shopping Center area both buildings and parking lots were included in the “buildings” category. In the context of the current study the Pesticide land-use is too coarse of a classification. For example, all high and low density residential areas, apartments, townhouses, and much commercial areas are included in a single “lawns” category. This is largely because the aim of this analysis was to rate the land-use relative to probability of pesticide usage.

**Estimating Runoff Potential for Land-Cover Categories**
Runoff is defined by the USDA as excess rainfall or that part of rainfall that is not lost due to infiltration, depression storage (ponding) and interception (evaporation from surface, transpiration by vegetation, etc.). The USDA recommends estimating runoff by using a “Runoff Curve Number” model. This model is based on three empirically determined “CN” parameters that are related to soil type:

“A” for sandy soils high infiltration rates
“B” for well drained loams with moderately high infiltration rates

"C" for sandy clay loams with low infiltration rates
"D" clayey soils with very low infiltration rates

The quantitative value of these CN parameters vary with soil group, type of ground cover, treatment (such as tillage, contouring and terracing), hydrologic condition (based on vegetation cover, plant types, surface roughness, etc.) and antecedent runoff conditions (which relates to storm to storm variations in rainfall).

It has been found empirically that runoff is, on the average a linear function of the percentage of impervious surface with urban and suburban watersheds. Numerous studies by the EPA have estimated effective percentage impervious surface for various urban land covers such as 1.0-acre residences, 0.25-acre residence, light commercial industrial, etc. For the purpose of the current study, a compilation of such estimates was made from a variety of sources (including D. Maidment 1992 "Handbook of Hydrology" McGraw-Hill, and more recent EPA studies). In each case, the lowest or most conservative values were chosen, so as not to exaggerate the magnitude of the problem.

In addition, local values for impervious surface were developed by The Kessler Group for the type of development now being constructed in the Charlottesville area. Using an average estimated figure for road width, driveway length width, and house size, 2 acre lots were estimated to have 6.3% impervious surface, 1 acre lots were estimated to have 10.3% impervious surface, R-2 (Forest Lakes South on Rt. 29 North) lots were estimated to have 15%, and R-4) lots were estimated to have 25%.

Based on information in the Albemarle County soils report it was determined that soils within Albemarle County are dominantly mixed of B and C categories with minor amounts of D type soils along the flood plain of the Rivanna. In this study, a simple average of the B and C values was used as a first approximation. These averages of CN values from the Soil Conservation literature were then plotted versus the associated estimates for percent impervious surface and a linear regression was performed. The data displays a good linear fit for the range 10 to 100 percent impervious surface but breaks down at lower values.

A flaw in many studies of percent impervious surface within drainage basins has been an exclusive focus on urban/suburban land-use. Studies of runoff from agricultural lands (plowed fields, grazing lands, croplands, etc.) have shown that agriculture can have similar effects on increasing runoff to urban land-use uses. In the current study, the runoff potential of agricultural land has been modeled by using an estimated equivalent or apparent percent impervious surface.

Values for this parameter have been estimated using the following methodology:

1) Average runoff coefficients from croplands, grazed pasture, ungrazed pasture land, orchards, and golf courses were based on averaging the B and C runoff curve numbers to approximate average Albemarle County soil conditions, as detailed above.
2) These values were used, together with the linear relationship between CN value and percent impervious surface established above, to estimate an Apparent Percentage of Impervious Surface for the various rural/farming land uses.

**Creating the Map**
To create a land-cover map depicting the "Percentage of Impervious Surface" the following methodology was followed:

1) Land-cover categories for use in the classification was based on a set of impervious surface associations culled from the literature:

| Land-Cover | Percentage Impervious Surface |
|---|---|
| Forest | 0 (baseline) |
| Ungrazed grass/shrubland | 2 |
| 5+ acre residences in woodlands | 3 |
| 2-5 acre residences in woodlands | 5 |
| Mowed lawns, moderately grazed pasture, golf courses | 8 |
| 1.0 acre residences | 10 |
| Orchards | 12.5 |
| Grazed pasture lands | 15 |
| Croplands | 25 |
| 0.5 acre residences | 25 |
| 0.33 acre residences | 30 |
| 0.25 acre residences | 35 |
| Townhouses | 50 |
| Apartments | 70 |
| Light Commercial/Industrial Schools, University | 70 |
| Heavy Commercial/Industrial | 90 |
| Pavement, Quarries | 100 |

2) The Pesticide Land-Cover was used as the base map for Albemarle and Louisa counties. The Gap Analysis map was used as the base map for Greene and Fluvanna counties. Appropriate reattribution of these base maps was applied to achieve consistency with the categories listed in (1) above. For example: Forest = Pine Plantation = mixed forest; vegetable fields = croplands, etc.
3) SPOT imagery, DRG images together with photo interpretation techniques were used to identify the classes from (1) above and specific regions for each were systematically added to the base image. Each added region progressively improved the accuracy of classification in the base image.
4) ER Mapper was used to integrate the new regions into the base map to form a coherent new map.

**Map Accuracy**
The aim of this task was to produce a map of the Percentage of Impervious Surface that would be an accurate representation of runoff potential when spatially averaged at the scale of a third order drainage basin. The map produced for this task was designed to be used only as a set of average values, one for each sub-basin. **The map should not be used for local or site specific studies or decision making within a third order sub-basin.**

Given the quality of the image data sets used in this study and the absence of ground truthing misclassifications are inevitable. Studies by NASA suggest that compensating errors typically lead to a greater than expected overall error in studies such as these. At every step in the process a conservative stance has been taken in that:

1) lower values from the literature have been chosen for percentage impervious surface in an effort not to exaggerate the results
2) residential lots larger than two acres have not in general been identified in this study
3) urban areas containing minor park lands and higher density housing have been adjusted in area to give a reasonable percentage in impervious surface for the average of the polygon
4) pasture land has been classified as grazed only if the SPOT imagery suggested bare or near bare areas or evidence of cultivation was present

**Possible Strategies To Improve This Analysis**

To increase the precision and resolution of this map the following strategies are suggested:

1) Use of digital orthophotos with at least three-meter pixels to form the basis for land-cover identification.
2) Computation of spatially variable runoff coefficients by using digital soil maps and digital slope data.
3) Use of soon-to-be-available digital road maps, from the Virginia Department of Transportation to quantify contribution of roads to runoff.
4) Field checking and verification of land-cover map in association with step (1) above.

**Implications of Study for Other Watersheds**

Based on the experiences in the current study several suggestions can be made for future studies of other drainage basins:

1) Land cover maps created by automated or semi-automated classification of multispectral Landsat data are unlikely to provide useful land-cover maps for modeling runoff.
2) Interpretation of high-resolution imagery (at least three meter pixels or better) using air photo interpretation techniques is the best approach to land cover determination for this purpose. This should be combined with field checking and use of local knowledge or corroborating digital data sets. This is a labor-intensive technique and requires relatively skilled staff. Involving university groups through graduate student research projects or well supervised undergraduate project may be a cost effective way to produce similar maps for other river basins in Virginia.
3) The best approach to estimating impervious surfaces is to use a combination of imagery and field inspection. Such mapping could be integrated into the comprehensive planning process at the county level.

## Enfranchising Citizens

Citizens volunteered to conduct field investigations at the Kick-Off day, through newspaper ads, radio spots and the like. One by one they came to the PDC office and chose their river segment, committing to boat, hike, or stop at bridge crossings on Rivanna River Basin Exploration Day. Each volunteer also decided on the best (for him or her) method of documenting the day.

Options included color prints, videos, audiotapes, paintings or drawings, and written documentation in prose or poetry.

Volunteers were asked to estimate the time needed, insure that boat put-in and take-out locations were arranged and that private property owners had been contacted to gain permission to cross their land. With their equipment packed in watertight bags, the volunteer stepped out.
Items citizen volunteers were asked to note included: stream bank and surrounding area conditions, landscape, wildlife, character of the water, the built environment, and any unusual sightings or findings.

All findings were turned into the PDC office. Volunteers received thank you letters and the documentation provided a great deal of information about the Basin. The Basin also became "owned" by the volunteers as they had first hand observations to consider.

# VIII. Data Presentation, Interpretation, and Discussion

## History of the Rivanna River Basin

### Introduction

The Rivanna River has played a critical role in the history of central Virginia. The settlements of the Native Americans in central Virginia were structured around the watershed of the James River, including the Rivanna River. Both the towns and sacred burial grounds were located at important points in the flood plain of the Rivanna. As a sustaining resource for the Native American society, the Rivanna provided drinking water and nourishment. As an artery for trade and transport, the Rivanna linked Native American settlements in the region together.

When colonists began to settle in the region, the Rivanna evolved into a center of industry, commerce, and culture. Like the Native American settlements, the towns and plantations of the colonists fronted the river. For the mills and factories built along its banks, the Rivanna provided a source of power to machine lumber, produce flour, and card wool. Until the middle of the nineteenth century, the Rivanna provided for the primary transport of passengers, tobacco, and other goods. Navigation on the Rivanna and James Rivers linked the communities of Central Virginia to Richmond, the Chesapeake Bay, and beyond.

Perhaps, few residents of Albemarle, Fluvanna, Greene, and Louisa counties realize the contributions of the Rivanna to the history of the area in which they live. Lacking knowledge of this history, citizens of the area may not value the Rivanna for the important role it continues to play both in our regional environment, culture, and urban form. Hopefully, through the following history of settlement and navigation on the Rivanna, the river might figure itself as a stronger presence in the lives of those inhabiting its watershed.

### Native American Settlement in the Rivanna Watershed

The history of human settlement in the Rivanna Watershed begins when the first Native American people settled the region ten thousand years ago[1]. The Monacan confederacy settled a wide region within the piedmont between the fall line and the Blue Ridge Mountains of Virginia. Comprised of two closely related groups, the Monacan confederacy included the Mannahoac, who settled the Rappahannock River watershed, and the Monacan, who settled in the James River watershed.[2]

In contrast to the Powhatan people of the Virginia tidewater, as an interior polity the Monacan confederacy had little interaction with the early colonial settlers. While less is known about the Monocans, several key sources provide an insight into the Monacan confederacy during the early seventeenth century. The 1612 John Smith Map of Virginia with associated text, a description of an expedition to Native American towns on the eastern edge of Monacan territory on the James river, and a description of the Monacan world given by Amoroleck, a captured Mannahoac, to John Smith illustrate how Central Virginia was settled by the Monacan.[3]

In 1608, John Smith, a leader of the early Jamestown colonists, developed a map of Virginia including Native American settlements in Virginia. It is important to note that while John Smith typically explored the tidewater settlements in person, Native American settlement beyond the fall line was mapped "by relation only." Included in this map are indications of Monacan and Mannahoac settlements on the James and Rappahannock Rivers. Rassewek, a Monacan settlement is apparent at the mouth of the Rivanna River as it meets the James. A passage from John Smith's text associated with the map illustrates the hierarchical structure of the Monacan confederacy:

> Upon the head of the Powhatans are the Monacans, whose chiefe habitation is at Rasuweak, unto whom the Mowhemenchughes, the Massinnackacks, the Monohassanughs, the Monasickapanoughs, and other nations pay tributes.[4]

In addition to Rassewek, John Smith located Monasukapanough on the South Fork slightly north of where the Rivanna forks. According to Professor Jeffrey Hantman, Chair of the Department of Anthropology at the University of Virginia, these towns were only two of many Monacan settlements along the James River and its tributaries. In an article published in Powhatan Foreign Relations, Hantman suggests that while the interior of Virginia was probably less densely populated than parts of the tidewater, the total population of the Monacan was probably similar to that of the Powhatan. Hantman continues to dispel another common misconception concerning the Monocans. Documented by John Smith, a famous description of the Monacan World by Amoroleck (a Mannahoac) suggests the Monacans were a nomadic people "living for the most part of wild beests and fruits." To the contrary, Hantman suggests that, "Monacan subsistence was a mix of agriculture, hunting, fishing, and gathering, according to archeological evidence from a number of piedmont sites."[5] Due to the agricultural basis of their society, Monacan settlements shifted only slightly within a fixed region. Furthermore, the location of Monacan settlements within the flood plain of the Rivanna suggest that the River provided an artery for trade that linked the various settlements within the region together.

Only ten days after the initial establishment of Jamestown on May 24, 1607, Captain Christopher Newport led a group of 23 colonists on an exploratory journey into the Virginia piedmont.[6] As they traveled up the James River, they were met by cheering clusters of Native Americans and dinned with Pawatah, a local petty chief, near the fall line of the James. While Pawatah initially promised to guide the expedition beyond the falls and into Monacan territory, he soon changed his mind. A letter, most likely written by Captain Gabriel Archer, a member of the expedition, provides an insight into Pawatah's sudden change of heart:

> He began to tell us of the tedyous travell we should have if wee preceeded any further, that it was a Daye and a halfe Ionrey to Mananacah, and if we went to Quirank [the Blue Ridge mountains], we should get no vittailes and be tyred, and sought by all means to disswade our Captayne from going any further: Also he tolde vs the Manacah was his Enimye, and that he came Downe at the fall of the leafe and invaded his Countrye.[7]

While the Monacan and Powhatan both lived in settled agricultural societies, it appears relations between the two people at the time of contact with the early European colonists were strained. Archeological evidence suggests that a flexible buffer zone slowly developed between the tidewater Powhatan and the interior Monacan. Whether the border between the two polities served as a buffer zone for the maintenance of a sustainable deer population or as a political demilitarized zone, it apparently shifted in location and size as relations between the two polities changed.[8] While the Powhatan and Monacan people often struggled over territory it appears that the Powhatan historically relied on a supply of highly prized copper from Monacan traders.

"Thus the Monacan, who were a potent political and military threat to Powhatan, were at the same time a probable source of that which conveyed symbolic power and authority in his own domain."[9]

Thomas Jefferson's excavation of a Native American burial ground has earned him the title of "The Father of American Archeology."[10] The mound that Jefferson excavated was most likely located several miles up the South Fork of the Rivanna River across from Monasukapanough. As Jefferson indicated in the description of his excavation in Notes on the State of Virginia, a series of similar burial mounds, approximately 15 feet high and 50 feet in diameter, populated the entire territory of the Monacan confederacy:

> many [mounds] are to be found all over this country [though] cleared of their trees and put under cultivation [they] are much reduced in their height, and spread in width, by the plough, and will probably disappear in time.[11]

Indications of these mounds are apparent on the John Smith map of 1612. Typically located in the flood plains, always in view of the river, these burial mounds were the ceremonial centers of the Monacan people. Built before contact with the colonists and possibly continued into the seventeenth century, these mounds were "the emotional heart of the proto-historic and historic Siouan speakers."[12] While Jefferson's account of the Rivanna mound focuses on a formal description of a historical artifact, the following passage from his description indicates the important role these sites played in the life of the Monacans:

> But on whatever occasion they may have been made, they are of considerable notoriety among the Indians: for a party passing, about thirty years ago, through the part of the country where this barrow is, went through the woods directly to it, without any instructions or inquiry, and having staid about it some time, with expressions of sorrow, they returned to the high road, which they had left about half a dozen miles to pay this visit, and pursued their journey.[13]

Rivers played a central role in Monacan society. The drainage of the piedmont, including the Rivanna river watershed, structured the settlement and movement of the Native Americans who inhabited the region. Monacan towns and burial mounds were located in the flood plain of the Rivanna, always in view from those passing in a canoe. The Rivanna served both as an artery for trade and as a link to the Monacan settlements on the James. Finally, by providing water to drink and fish to eat, the Rivanna nourished the Monacans who prospered within its watershed.

**Early European Settlement**

Like the Native Americans, the early settlers depended upon the Rivanna River as a means of transportation and communication. It is no accident that the first land grants were sited along the riverfront. The settlers faced the dilemma of clearing the land and establishing farms and homesteads, while depending upon the Rivanna for receiving the necessary supplies and connecting them back to the already established townships. According to John Hammond Moore, the Rivanna and its streams "were the lifeblood of this growing frontier community and the means by which precious hogsheads of tobacco got to the market" [14].

The early settlers originated from the eastern region of Virginia, particularly around Richmond and the Tidewater area. The movement westward initiated with the plantation settlements along the James, and proceeded up the Rivanna. The first grantees of property along the Rivanna were gentleman farmers and "townsfolk"[15] that were interested in finding new tracts for growing tobacco. Tobacco was the most lucrative cash crops for the colonies and was traded for goods in England and abroad. Tobacco is also a crop that requires extremely rich soils while depleting the soils within a matter of years. As a result, the planters were ever in search of rich soils, which they found in the "dark red alluvial soil" of the "Riveranna," as the Rivanna was originally named [16].

In 1744, Albemarle officially became a county "as the founding fathers organized and nurtured local government [17]. The first land grants were awarded to George Hoomes, Jr., Nicholas Meriwether and George Nicholas. The land grant system was established as a means of honoring those who were loyal to the English crown and required that the tract of land be settled by clearing land and building a home. In most cases, the privileged landowners "dispatched overseers and slaves to clear and cultivate new quarters" before arriving in Albemarle to claim their land [18]. Thus the "settlers" were nominal only, as their slaves endured the bulk of the work.

The next set of patent owners, Thomas Carr, John Carter, Francis Eppes, Allen Howard, and Charles Lewis began settling the area in the 1730's. Peter Jefferson was awarded a 1000 acre tract in 1737 and started construction on his Shadwell home and property shortly thereafter [19]. Although it is no longer extant, Shadwell was built in 1741 and was named after a parish in London were his wife, Jane Rodgers, had spent her childhood. Two years later, Thomas Jefferson was born at Shadwell, where he spent his childhood until the death of his father. In 1770, the Shadwell home burned, including all of Peter Jefferson's early surveys and records and although the foundations have been excavated, no images of the establishment survive.

Peter Jefferson and his fellow land owning citizens held county meetings and "creat[ed] a functioning local government"[20] while surveyors were appointed to lay out the initial road system between the river and the farms. By 1745, the county leaders had plans for building "a courthouse, [and] prison.[21]" These were the initial plans that led to the development of Charlottesville, which was later established in 1762 when a "thousand-acre tract was acquired from Colonel Richard Randolph [22]. However, this did not divert their interests in "seeking better transportation" routes and establishing communications with other towns and Three Notched Road was extended through Albemarle County in 1745. Despite the interest in establishing a road system, river navigation along the Rivanna and the James still remained the most practical means of transporting goods to the eastern markets. As a result, considerable interest was directed toward investing in a canal system that would deem the Rivanna navigable to what was called Pireus, the planned port of Charlottesville located at the site of the Woolen Mills.

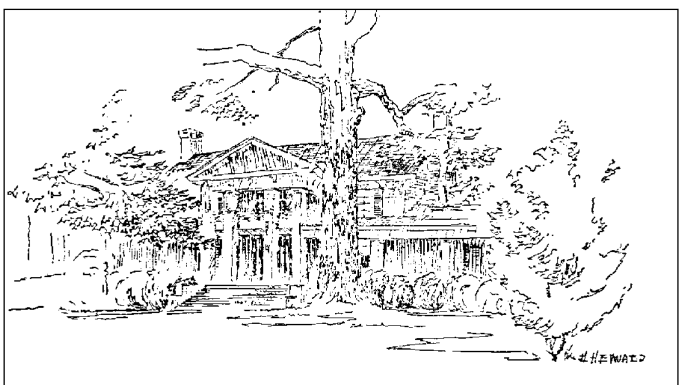
**Agricultural Development along the Rivanna**

Agriculture, most notably the cultivation of tobacco, was the impetus for the settlement of farms along the Rivanna. Although the landowners practiced a variety of other professions in addition to operating their plantations, the value of tobacco made planting the top priority economically for the planters. Early in the settlement of Charlottesville, the planters joined together and formed the Agricultural Society of Albemarle County. This organization was one of the most politically powerful interest groups in the region at the time, and legislation of canal and road building was often advocated by the Society, as investment in the Rivanna and the road systems would ease the transport of tobacco to Richmond.

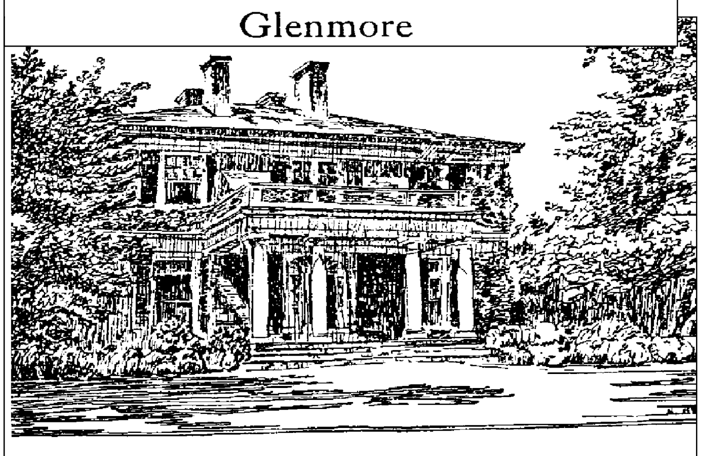
Although tobacco was initially considered the primary crop, the cultivation of tobacco was later reconsidered. First of all, tobacco is an incredibly labor intensive process. From the germination to harvest and curing, constant attention must be given to the crops; thus, necessitating the institution of slavery to provide the basis of the plantation economy. After the curing process, hogsheads of tobacco leaves that weighed up to "1000 pounds when filled" were more efficiently exported by river bateaux than over land, as the road systems were rather crude and rendered impassable when muddy [23]. As the Rivanna was the primary means of river trade, tobacco inspection warehouses developed along the waterfront. In addition, land clearing along the Rivanna was a major activity on these plantations, as tobacco crops can deplete the soil of nitrogen and potassium in a matter of three to four years, the fertile land was rapidly consumed, thus rendering necessary more areas for planting.

Due to the intensity of tobacco farming, planters as early as Jefferson were interested in developing new methods for cultivation. The planters learned the practices of crop rotation and the use of manure for replenishing the soil from the Native Americans. Even such advancements did not slow the waning interest in tobacco as a crop. As early as the Revolutionary war, the planters began to shift to the cultivation of wheat, corn and grains, which were in demand for wartime provisions[24]. These crops were less land intensive, as they did not wreak havoc on the soil. In addition to food crops, hemp and ginseng were grown for export [25].

Although the land owning gentry made up only 5% of the overall population, the small farmers were not able to produce enough crops to compete with the larger plantations[26]. In addition, the planters were also the county leaders and contributed homes that have in some cases been preserved as part of Albemarle's historic legacy. As a result, there is significantly much more information available on the historic plantation homes such as Glenmore, Edgehill, Monticello, and Edgemont (Fig. X, X).



Glenmore



Edgehill

In many cases, these homesteads were preserved by the lineage of land owning families as subsequent generations and wealthy Northerners who arrived in Charlottesville after the Civil War inherited the land. In the case of Pantops and Edgehill, the plantation homes were converted into reputable schools during the $19^{th}$ century. This shift in function from plantation to educational institutions marks the growing interest in the Charlottesville community in education, which has become one of the main "industries" for this area. However, by the twentieth century, many of the plantations were being subdivided into housing developments.

**Mills and Mill Towns**

In addition to agriculture, milling was one of the first important industries along the Rivanna. As the landowners began to shift from tobacco to wheat and corn, mills became a necessary means of processing the grains into flours and meals. The Rivanna River was used as "a source of power for their mills,"[27] thus, valued as a natural resource. Not only were the farmers able to grind their own produce, but the mill owners gained income through charging a fee for the service [28]. Along with mills, flour and tobacco inspection stations were sited along the riverfront at key points for river trade [29]. The flour was inspected "to maintain quality standards"[30] and stored in the warehouses until loaded onto boats for shipment to Richmond.

Shadwell was the first known mill to be sited on the Rivanna River. In 1757, Peter Jefferson built the mill on his estate at Shadwell [31]. The mill was in service until 1771, when a flood destroyed it. Flooding was the greatest liability that the mill owners shared, as all locks dams and mill facilities were at the whim of nature's forces. Streams traveling down from the mountains and feeding into the Rivanna result in rapidly rising water during storms and due to the terrain were frequent occurrences. Mills and river navigation were subject to the availability of water as well. The vulnerability of the mill owners' investments were subject to the unpredictability of the weather.

In 1803, Thomas Jefferson rebuilt the mill buildings of Shadwell and planned on adding another for milling plaster, across the Rivanna [32]. Jefferson leased out his mills to local men who would manage the mills, although he never succeeded in profiting from the venture [33]. Jefferson's mill at Shadwell included two miller's houses, a gristmill and a sawmill, a cotton factory, stores and shops [34]. Although Shadwell Mill was never considered a town, the property served a multitude of uses including "providing the [mill workers] with housing, commerce... and religious facilities[35]. From Shadwell, Jefferson's mill workers processed flour, timber and prepared tobacco for transport to Milton, the primary port for Albemarle County.

Although no longer extant, Milton is perhaps the best example of an established mill town. Almost a mile down river from Shadwell, Milton was located at the head of the waters, or the last river port that could be reached by cargo boat. In 1789, two hundred half acre lots were laid out for the town of Milton, thus establishing the port as "one of the busiest towns in Albemarle"[36] "surpassing Charlottesville in size and wealth"[37]. Although Charlottesville had already become the largest town, Charlottesville's port, Pireus, was located far enough up the Rivanna to make shipping and navigation difficult. During the late 1700's, the Milton became Albemarle's busiest and most profitable port, and wagons brought produce from all over the valley. By the early 1800's, the village had grown considerably and included "a general store, a blacksmith shop, a post office, tobacco and grain warehouses, a jail and a saloon"[38] In 1827, the Rivanna Navigation Company invested in Milton by building a dam and improving the channels for navigation [39].

The demise of Milton did not occur until the arrival of the railroad in the 1830's. With the advent of the railroad came more efficient travel and transport of goods. The second blow to the town occurred with the establishment of Scottsville in 1818 as the local port town directly on the James River [40]. By 1835, Milton was seeing her final days, as river navigation was lost to the railroads. As dependence upon the Rivanna for navigation decreased the traders were no longer victims of the flash floods or low waters. The Great Flood of 1870 provided the final blow to Milton. The entire village was devastated by the flood and any remaining buildings were relocated to properties in Charlottesville as the citizens left the floodplain settlement [41].

**1765- 1806: The Double Canoe, Wing Dams, And Sluices**
In the era of the early colonial settlers, as the passage below indicates, overland transport
The roads were execrable. "You can scarcely conceive the difficulty in finding the proper roads, as they are hardly to be guessed at," wrote Major Anbury of the British army during the Revolution. "When one is bad they make another in a different direction." After a hard rain the roads became almost impassable, and nothing was more common than for travelers to get stuck in the red Albemarle clay.[42]

Given the poor state of the roads, the Rivanna provided a cheaper, quicker, and more effective alternative to convey goods. Thomas Jefferson led the first organized effort to improve navigation along the Rivanna River. In 1765 Jefferson was able to secure two hundred pounds from the colonial government to undertake improvements from the mouth of the Rivanna to the falls at Milton. The improvements made at this time most likely consisted of little else than removing fallen trees in the river and creating channels, known as sluices, by moving stones and gravel.[43] Wing dams, short low dams of loosely piled boulders, were angled in from the bank in order to channel the river into the sluices.[44] Given the simplicity of these early improvements, a maneuverable boat, which could operate well in low water, was critical to the successful transport of goods. During this period Reverend Robert Rose, of St. Anne's Parish, discovered that by lashing two canoes together, goods could be taken down the river safely.

As trade increased along the Rivanna, and the region continued to develop, several government operated tobacco inspection stations were established providing planters a place to warehouse their tobacco in exchange for credit. At the mouth of the Rivanna along the James, one such inspection station was located in 1785. Three years after the construction of the Rivanna Warehouse, the town of Columbia was incorporated. Similarly, both Henderson's warehouse and the town of Milton were established in 1789. Nicholas's warehouse was established on the opposite bank to deal with increasingly heavy traffic on the river. At this time Milton was the head of navigation on the Rivanna and served as a center of shipping for the majority of Albemarle County. Finally, halfway up the Rivanna a fourth tobacco inspection station was located near the town of Bernardsburg, near current day Lake Monticello. [45]

By reducing the cost of transporting goods, river navigation allowed Virginia's inland settlers to make a living. However, navigation along the Rivanna did come with its own inconveniences. Floods, drought, and ice were common impediments to navigation along the river. Countless river craft were wrecked; their cargo lost as floods damaged the river. The following passage from Thomas Jefferson's Farm Book illustrates the havoc the natural processes of the river caused on the operation of the nearby plantations:

> I am entirely in despair, dear Sir, on account of the obstinate state of our river. Such a thing has never been known before since the opening of its navigation 50 years ago, that the drought of the summer, which commenced in June, should meet the ice of the winter, without a single interval for a boat to make a trip. For of the 100 barrels of flour I sent from here October 10, I learn that 60 barrels are still lying in the lower part of the river, and none of the boats which went then have yet got back. I have flour enough ready in the mill, but see no prospect of getting it off unless a plentiful warm rain should come to our aid, fill the river and melt and carry off the ice.[46]

After a particularly devastating storm in 1771, in which many of the double canoe were ruined, Anthony Rucker invented the bateau. Eight feet wide and up to sixty feet long, these flat bottom wooden boats were maneuverable in low water and much more stable than the double canoe.[47]

**1806 -1850: The Bateaux, Crib Dams, And Wooden Locks**

In 1806 the Rivanna Company was incorporated to make more extensive improvements to the river as the region continued to develop and grow. The Rivanna Company was allowed to charge tolls to finance the improvements and to earn a profit for its subscribers.[48] One of the first tasks of this new company was to improve navigation from Milton to Moores ford near Charlottesville. As bateaux reached Charlottesville, a port named "Pireus," developed east of the city were Moores Creek meets the Rivanna. In The Rivanna Scenic River Atlas, W.E. Trout III states that Pireus got its name because Charlottesville called itself "the Athens of the south and named its port Pireus, as ancient Athens had done." Today, the old Woolen Mills still stands were the port once operated.

In 1814, William Wood, owner of Wood's mill near Columbia, supervised improvements south of Milton to the James. In just three short years Wood was straightening and deepening wing dams at 27 falls, shoals, and fords. By 1820, the Rivanna was improved with sluices and wing dams above Charlottesville as far as Hydraulic Mills four miles up the South Fork and as far as Tulloch's mill seven mills up the North Fork.[49] The few milldams that existed on the River during this period were required to provide locks for the bateaux. A survey of 1818 listed seven wooden locks along the river. Three of the seven were located at Shadwell, and the rest were located at Campbell's mills at Buck Island, Union Mills Dam, Palmyra, and Rivanna Mills. In addition, there were short canals at Shadwell, Union Mills and Rivanna mills.[50]

> The 1830s were a time of great progress in Central Virginia. The building boom and the increase in farm production were reflected in the improvement of the Rivanna Navigation system. As trade on the Rivanna increased the sluice system was declared inadequate. One problem with the channels cut through falls and shoals was the consequent draining of the deeper ponds above them.[51]

As the above passage indicates, wing dams and sluices had their limits. Poling the bateaux against the current upstream was a dangerous and arduous task. Even more troubling, however, was the frequent occurrence of low water. Bateaux could travel fully laden only when water was running high during freshets. Moreover, milldams on the Rivanna were beginning to impede navigation. While milldams were required to provide locks for bateaux, there often was simply not enough water in the river for navigation and power.

In accordance with the recommendations of Claudius Crozet, the principal engineer of the State Board of Public Works, a system of locks to improve navigation on the Rivanna was planned. A series of canals, with locks at both ends, would lead bateaux around milldams, from the millpond upstream to navigable water below.[52] The new lock and dam navigation from Charlottesville to the James required 14 dams and 19 locks to overcome the one hundred and eighteen-foot drop over the thirty miles from Moores Ford to Columbia.[53] Five of the dams were old milldams including those at Shadwell, Campbell's, Union, Palmyra, Rivanna and Wood's mill. The rest were newly built and located at Pireus, Milton, Stump Island, Bernardsburg, Broken Island, Stranges, White Rock and Columbia. During this period the South Fork was also improved up to Hydraulic mills with a series of locks and dams.[54] Compared to the simple sluices and wing dams of earlier times, the locks and dams built in the 1830's were elaborate:

> "Most of the dams on the Rivanna were "crib dams" made by building a crib of heart-pine squared timbers, pegged together with huge wooden pegs. Some timbers were bolted with big iron pins to the bedrock. The timbers parallel to the stream slanted downstream and rested on long timbers laid across the stream. The back of the dam looked like a long roofless log cabin; the front was sloping. The hollow cribs were filled with large stones, and the faces and tops of the dams were planked in an effort to make them watertight. This structure, perhaps ten feet high, extended across the river and was stabilized with stone or masonry work- abutments—on each side."[55]

**1850-1908: Canal Boats, Stone Locks, And the Railroad**

As the James River & Kanawha Canal reached Columbia in 1840, larger canal boats were able to transport goods more efficiently up to the mouth of the Rivanna. However, the bateaux locks and dams were much too small to accommodate the larger boats. In addition, canal boats required towpaths along the banks of the river in order for mules to convey them. In a cooperative effort, the James River and Kanawha Company and the Rivanna Navigation Company worked to bring canal boat navigation to the Rivanna River.

In order for canal boats to travel from the James River Canal to the Rivanna, the two navigation companies constructed the "Rivanna Connexion." This new canal branched from the James River Canal in Columbia and connected to the Rivanna at Rivanna Mills. The four and a half mile canal including two locks and two large, walk through culverts not only provided transport for canal boats but also fed water from the Rivanna into the James River Canal system. In addition, the Rivanna Navigation Company built "seven large stone locks, six miles of canals, 20 miles of towpaths and a dam at Carysbrook." to enable canal boats to navigate the Rivanna north of Rivanna Mills. Beautiful stone locks, engineered and constructed under the supervision of John County, were built at Columbia, Rivanna Mills, Carysbrook, Palmyra, Dog Point, Pettit's Island, Bernardsburg, and Union Mills.[56] The lock at Palmyra stands today as a testament to the elegance and durability of the cut stone construction:

> The locks are of carefully shaped granite masonry. The stone facing the lock chamber is "hammer dressed" to a smooth surface to provide both a pleasing appearance and a smooth wall which would not chew up boats rubbing against it...The lock chambers between gates were uniformly 100 by 15 feet, the same as those on the James River."[57]

By the end of the 1850s the Rivanna was navigable by canal boat up to Thrift's Ford at the Albemarle county lines. From their only bateaux could continue. Ironically, while the Virginia

Central Railroad, now the C&O, reached Charlottesville in 1850[58], it would be at least thirty more years before the canal boat navigation would extend to Pireus.

In addition to bateaux and canal boats transporting tobacco, flour, and other goods, pleasure boats often cruised the Rivanna. The following account of an Easter outing in 1895 colorfully illustrates the important role the Rivanna River played in the social lives of those living in reach of its waters:

> After a while we met the boat and the good-natured manager and promoter of the scheme wanted to know if we wished to get on. We replied that we had ridden all over Fluvanna for that purpose alone, whereupon he ran into the bank and we got aboard, and moved smoothly down the pleasant stream regaled by the delightful music of the Fork Union Band whose reputation is already deservedly won...As we glided along, different things of interest to tourists were pointed out to us. First East Point, where Aunt Lavinia sits and follows the apostolic calling so much praised by the Puritans. Then Buzzard's Rock, an immense cliff where so many of the graceful birds whose name it bears rest their wearied pinions. Then the splendid farm of Mr. Marion Wood, where watermelons attain the size of hogsheads, and sweet potato vines reach such a length as to span the river. Then Stillman's where the biggest fish stories of the world originate. Then, lastly, Columbia, nestling quietly on the banks of the majestic James, whose tranquillity is disturbed only by the shriek of the locomotive and the yells of an Easter party.[59]

While the Rivanna Navigation Company survived the Civil War with apparently little difficulty, the great flood of 1870 damaged the public works on the Rivanna severely setting back efforts to further improve navigation along the river. The majority of funds available at the time were spent on repairing existing structures in Fluvanna County rather than extending navigation into Albemarle County. After 1880 goods sent down the Rivanna were transferred to railroad at Columbia. A railroad owned by the Richmond and Allegheny Railroad Company extended to Richmond on the old towpath of the James River and Kanawha canal. As the navigation system along the Rivanna gradually declined for lack of use, the Virginia Air Line Railroad was built in 1908. Unlike the railroad adjacent to the James, this new rail system followed the Rivanna only from Carysbrook to Palmyra. While the river was no longer used for navigation, mills continued to thrive well into the twentieth century.[60]

**The Advent of the Railroad**

Due to increased methods for communication and transportation, Charlottesville experienced greater connections into the outer world. The invention of the telephone and "other modern conveniences lured hundreds from the farm to the city" [61]. At the same time, the railroads were becoming a vital means of transportation. In the 1890's, investments in the Chesapeake and Ohio lines increased accessibility to Charlottesville from smaller towns, while enabling the citizens of Charlottesville to access larger metropolitan areas [62]. Unfortunately, the advent of the railroad was the technology that rendered the use of the Rivanna obsolete for the transportation of goods.

On the more local scale, a streetcar system was the impetus for expansion of neighborhoods within Charlottesville. Neighborhoods such as Rosehill and Belmont were subdivided by the Charlottesville Industrial and Land Improvement Company along what was then considered the perimeter of the city [63]. These developments only foreshadow the large-scale subdivisions, which would develop during the twentieth century on the very properties, which had been the sites of plantations along the Rivanna.

**Twentieth Century Developments**

Up until the 1920's, road building had been eclipsed by the development of river and rail transport. Although not prioritized until the twentieth century, the development of road systems had a profound effect on the awareness of the Rivanna River as a valuable resource within the urban fabric of Charlottesville. As more roads were built and population grew within the city, "real estate developers with an eye on the rapid growth of Roanoke [and other Southern cities], continued efforts to attract industry" to the area [64]. Concurrent with a decline in the rural population, business and employment opportunities such as banks, hotels and light industries began to attract people to the city [65].

After World War II, better road systems enabled developers to speculate on developing properties outside Charlottesville proper. In most cases, the land owning families were no longer reaping the benefits of farming on their properties, and "farmland on the outskirts of Charlottesville was purchased, cut up into house lots, and sold at handsome profits" to the developers of such subdivisions as Key West, Pen Park and Dunlora [66]. As the role of the Rivanna had largely been diminished as a means of transport, the importance of the river remains in the fact that it is the city's source of drinking water. Earlier in this century, growing concerns over the "diminishing water supply" led Charlottesville to develop a municipal waterworks. As water was then pumped and piped into Charlottesville homes, this advancement contributed to the lack of awareness of the Rivanna as a resource. Due to the rapid suburban growth along Route 29, a Reservoir system was proposed in 1968 that was implemented in the 1970's. Today, researchers are trying to revive an awareness of the Rivanna as an important natural resource, historically and environmentally as our lack of awareness have been exacerbated by the nature of the hidden systems that were created during the earlier part of this century.

**Conclusion**

> "Today, as one views the muddy little stream which cuts across Albemarle and Fluvanna and empties into the James, it is hard to realize that for the better part of a century it was for those counties a center of industry and an artery of commerce. The wheels of its mills and factories, save in the case of the woolen mills, have ceased to whirl; one no longer sees the picturesque bateaux loaded with hogsheads or barrels gliding down with the current. But without the river, the development of Albemarle County from the days of its settlement, the days of Peter Jefferson and Joshua Fry, to the advent of the railways, would have been slow indeed." [67]

The above passage from Thomas Jefferson Wertenbaker's history of the Rivanna River summarizes the importance of the river in the development of the region. From the use of the Rivanna for trade by the Monacans, to the simple wing dams and sluices of the early colonial settlers, through the elaborate stone dams and locks of the mid nineteenth century, tracing the history of navigation on the Rivanna reveals the critical contribution the river has made in the cultural and economic development of the region. Whether for drinking water, farming, power, or as a route for transport and trade, the Rivanna occupies has played a crucial role in the history of central Virginia. Today as we continue to drink, fish, and recreate in the Rivanna's waters, we must bear in mind that not only is the Rivanna river an important historical artifact, but it is a critical resource that we share in common. With careful stewardship and prudent use of the river's resources, the Rivanna will continue to be a lively place enhancing the lives of those living within its watershed.

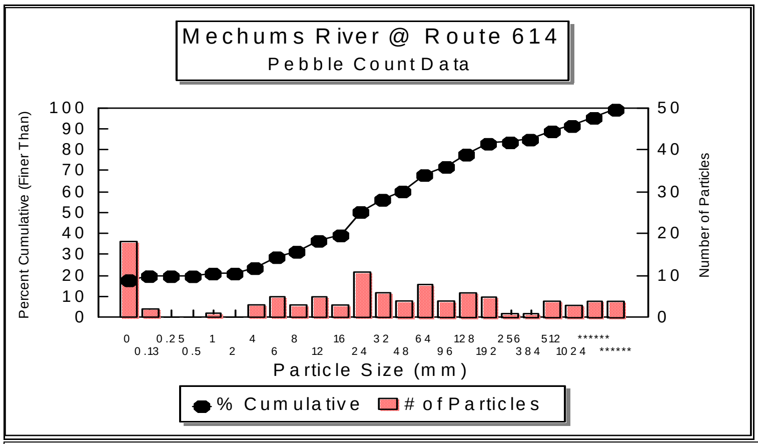
## Morphology

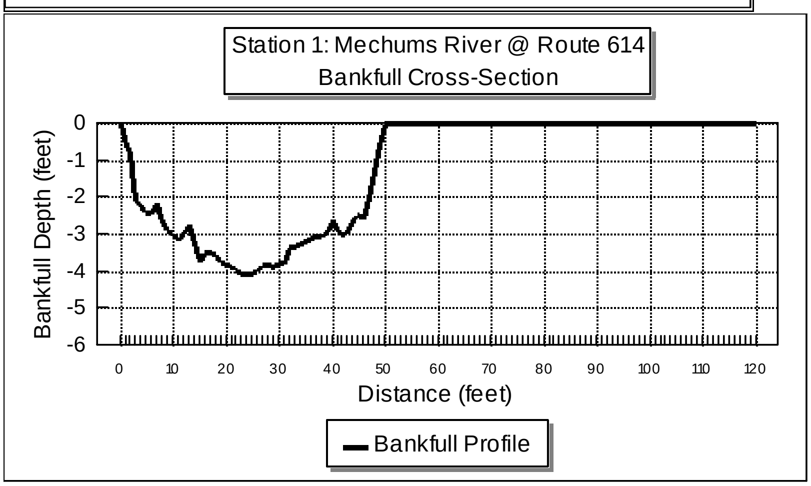
**Findings**
For the purposes of the project, stream morphology measurements were obtained at eight of the stations that were also monitored for chemical and biological factors. These stations, representing the tributary streams to the main stem Rivanna River, were Mechums River, Moormans River, Buck Mountain Creek, North Fork Rivanna at Route 606, North Fork Rivanna at Proffit, Meadow Creek, Mechunk Creek, and Cunningham Creek. The results for each are presented on the following pages.

*Mechums River*

| | |
|---|---|
| Entrenchment Ratio: | 1.5 |
| Width/Depth Ratio: | 18 |
| Sinuosity: | 1.3 |
| d50 Particle Size: | 24 millimeters (gravel) |

Summary: This river segment is moderately entrenched with a moderate width/depth ratio. Particle distribution is bimodal with the highest peak in silt/clay range. The segment classifies as a B4c stream in the Rosgen classification. The chief concern may be the silt/clay bedload, which may be a problem for aquatic habitat. This station has the highest entrenchment ratio (meaning less entrenched) of sampled sites. However, it is only marginally higher than most of the others, only slightly into the “B” stream type category. The channel otherwise exhibits many of the characteristics of an “F”



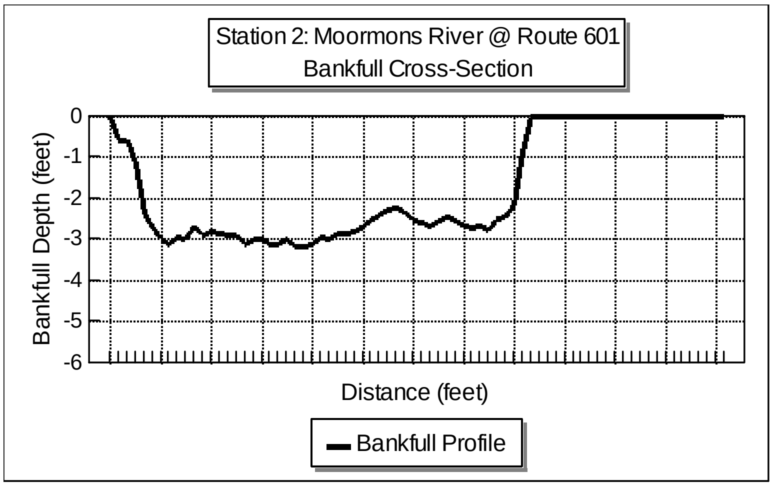

channel.

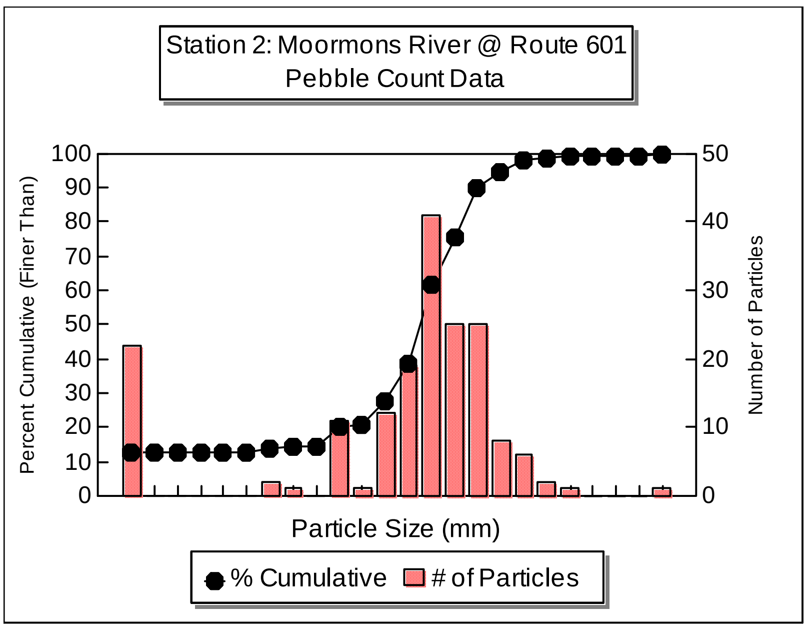
*Moormans River*

| | |
|---|---|
| Entrenchment Ratio: | 1.1 |
| Width/Depth Ratio: | 34 |
| Sinuosity: | 1.4 |
| d50 Particle Size: | 40 millimeters (gravel) |

Summary: This river segment is entrenched with a high width/depth ratio. Particle distribution is bimodal with the highest peak in gravel range. The segment classifies as a F4 stream in the Rosgen classification. Particle distribution is one of the most stable for the sites sampled, with a steep rising cumulative curve in the gravel range and a good distribution within the gravel range. The width/depth ratio is the third highest for the sites sampled, but this does not seem to indicate more instability in relation to the other sites.

Note that the Moormans cross-section may illustrate a "classic" entrenched Piedmont stream, or, alternately, one of our best examples of a "stable F" form.

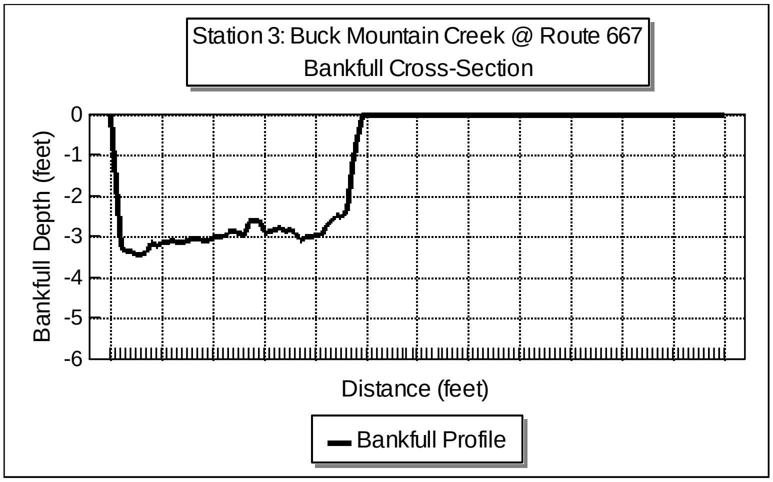


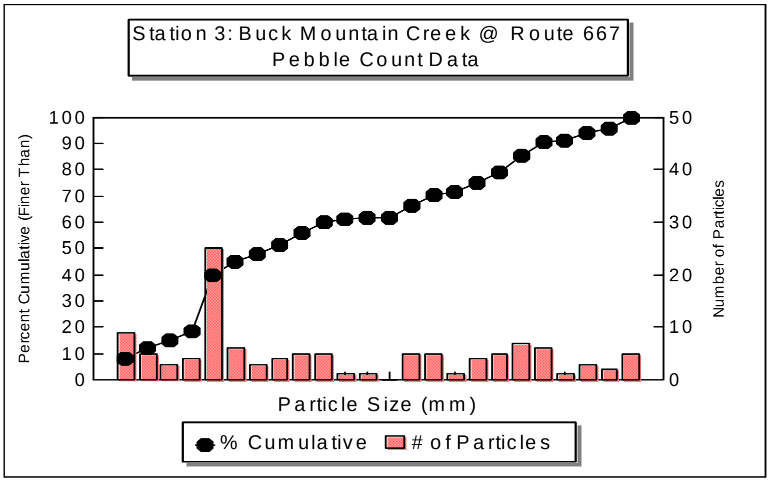



*Buck Mountain Creek*

| | |
|---|---|
| Entrenchment Ratio: | 1.4 |
| Width/Depth Ratio: | 18 |
| Sinuosity: | 1.6 |
| d50 Particle Size: | 5 millimeters (gravel) |

Summary: This river segment is entrenched with a moderate width/depth ratio. Particle distribution is even, with a practically straight cumulative curve. The segment classifies as a F4 stream in the Rosgen classification. The particle distribution is noteworthy for being the most evenly distributed of the sampled sites, exhibiting the presence of silt/clay, sand, gravel, cobble, boulder, and bedrock. This type of distribution may represent an ideal for a Piedmont stream in its lower reaches, and appears to also represent good aquatic habitat. Also, the entrenchment ratio is just barely entrenched, and may be moderately entrenched, which would put this segment more into the "B" category, or a stream that is more stable in relation to the other tributaries. This is due, in part, to the benign assistance of watershed geology (similar to Moormans) and also to land use.

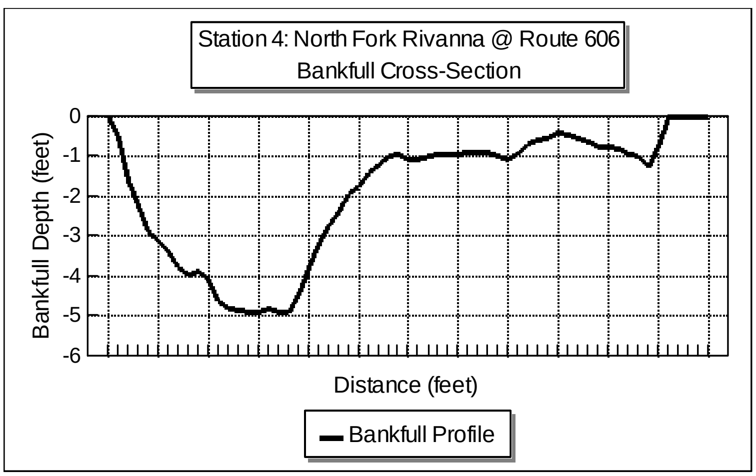


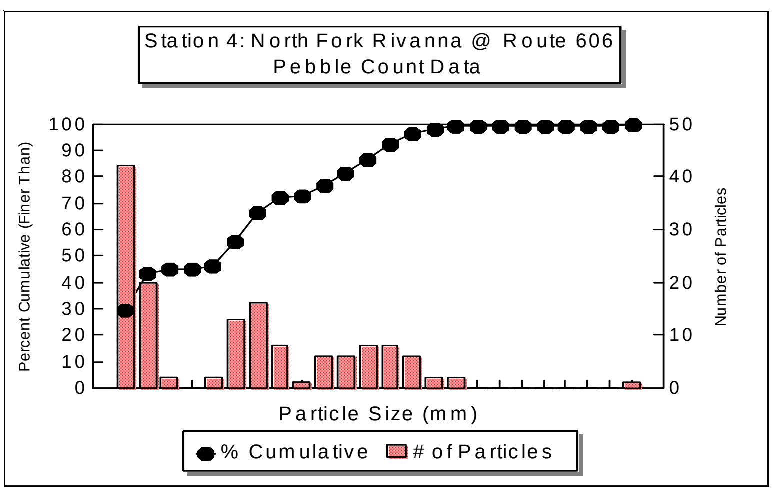



*North Fork Rivanna at Route 606*

Entrenchment Ratio: 1.4
Width/Depth Ratio: 55
Sinuosity: 1.5
d50 Particle Size: 1 millimeter (sand)

Summary: This river segment is entrenched with a very high width/depth ratio (the highest of monitored sites). Particle distribution is skewed towards the silt/clay and sand ranges, with the highest peak in the silt/clay range. The segment classifies as a F5 stream in the Rosgen classification. While the entrenchment ratio as relatively high for an "F" channel, this does not indicate a tendency towards a more stable "B" stream at this site. This is because the channel is severely over-widened, as indicated by the highest width/depth ratio of the sites. A large depositional silt/sand bar is evidenced by the channel cross-section. The stream is having trouble transporting the sediment load that watershed factors are contributing to the system. This is also made evident by the d50 particle in the sand range. Of the RRBP morphology sites, only the two North Fork Rivanna sites have d50 particles in the sand range (with the others being in the gravel range). It is worth noting that the two North Fork sites also have the largest drainage areas of the morphology study sites (108 square miles at Route 606). All of the factors discussed above contribute to compromised aquatic habitat along this segment, and a problem moving bedload.

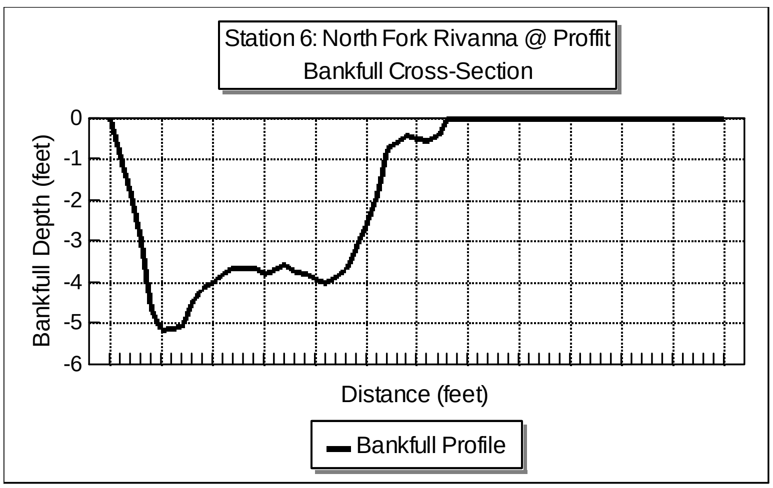


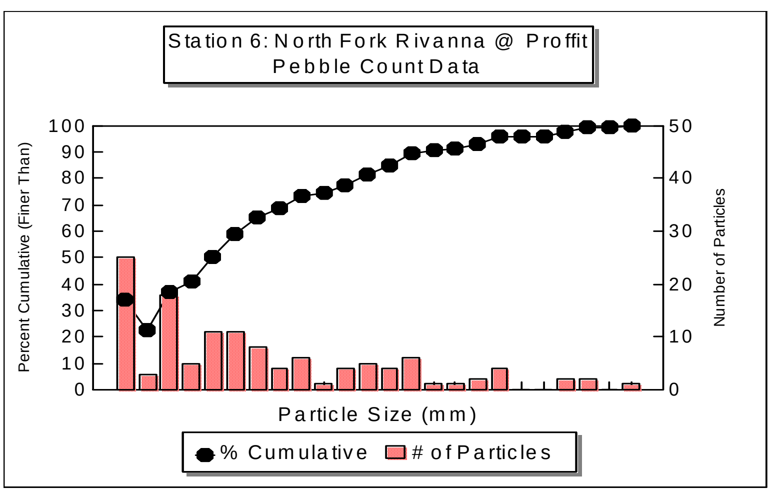



*North Fork Rivanna at Proffit*

| | |
|---|---|
| Entrenchment Ratio: | 1.4 |
| Width/Depth Ratio: | 23 |
| Sinuosity: | 1.4 |
| d50 Particle Size: | 1 millimeter (sand) |

Summary: This river segment is entrenched with a high width/depth ratio. Particle distribution is skewed towards the silt/clay and sand ranges, with the highest peak in the silt/clay range. The segment classifies as a F5 stream in the Rosgen classification. Many of the comments made for the North Fork at Route 606 also apply to this site, although the surveyed channel is not quite as over-widened as the Route 606 site. This station has the largest watershed of all the RRBP morphology sites (176 square miles), and has the deepest channel (over 5 feet deep at the thalweg, or deepest part of the channel). In this regard, this station may approximate morphology for the main stem of the Rivanna as well. The chief issue appears to be the particle distribution with a preponderance of silt/clay and sand, and the implications of this for aquatic habitat.

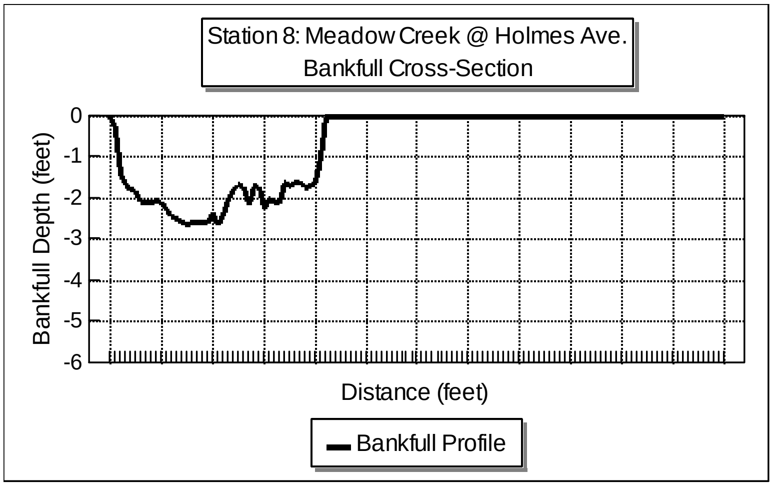


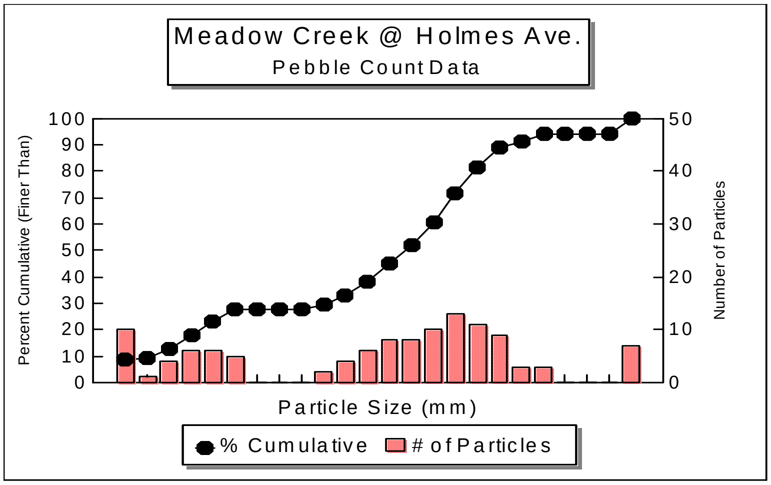



*Meadow Creek*

| | |
|---|---|
| Entrenchment Ratio: | 1.2 |
| Width/Depth Ratio: | 23 |
| Sinuosity: | 1.0 |
| d50 Particle Size: | 40 millimeters (gravel) |

Summary:  This river segment is entrenched with a high width/depth ratio. Particle distribution is bimodal with peaks in the silt/clay, sand, and cobble ranges.  This segment classifies as a Rosgen F4 stream.  Meadow Creek presents an interesting case: the particle distribution is among the healthiest in the basin with good representation of particles in both the gravel and cobble ranges. At a glance, one may assume that aquatic habitat availability is good here.  However, given the highly urbanized nature of the watershed, habitat availability may not be the limiting factor, as evidenced by low SOS scores.  Entrenchment is one of the lowest in the basin, with steep muddy and silty banks, characteristic of urban hydrology.  This urban type hydrology, with quick, steep storm hydrographs, appears to be transporting sediment bedload sufficiently through rapids and runs, based on the particle distribution (this is a kind of urban "flushing"  effect).  A take-home message for Meadow Creek may be that, given a relatively good streambed structure, the creek may be an excellent candidate for restoration if water quality issues can be addressed.

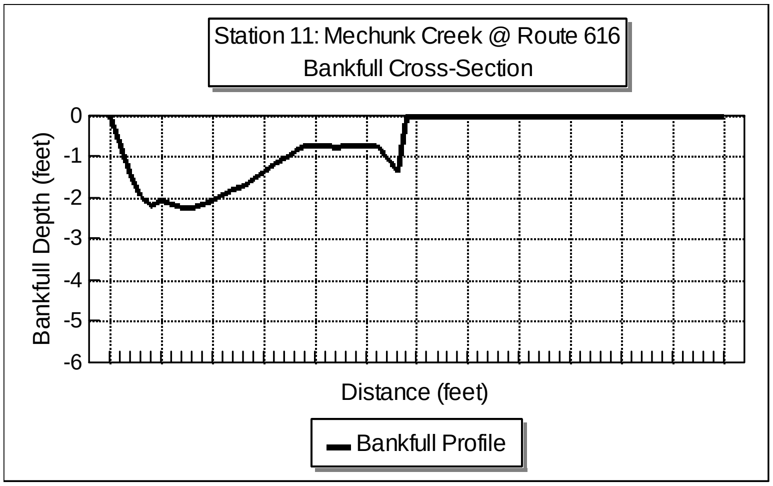


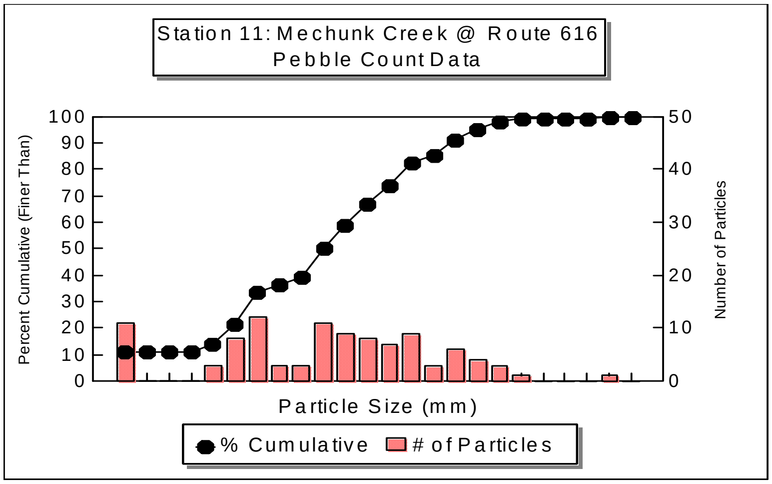



*Mechunk Creek*

| | |
|---|---|
| Entrenchment Ratio: | 1.1 |
| Width/Depth Ratio: | 44 |
| Sinuosity: | 1.6 |
| d50 Particle Size: | 12 millimeters (gravel) |

Summary: This river segment is entrenched with a very high width/depth ratio. Particle distribution is bimodal with peaks in the silt/clay and gravel ranges, with some representation in the cobble range. This segment classifies as a Rosgen F4 stream. Mechunk Creek has a relatively healthy particle distribution (even with a steep rise in the gravel range). The entrenchment ratio is the second highest in the basin, but, like the Moormans River, this does not seem to be the result of a higher level of instability relative to the other sites. Along this segment, the stream runs deep within a steep stream valley, sometimes characterized by rock outcrops along the slopes (similar also to the Moormans). River morphology here is expressing the constraints of topography. Here again, the Mechunk is a good example of a "stable F" within the context of Piedmont streams.

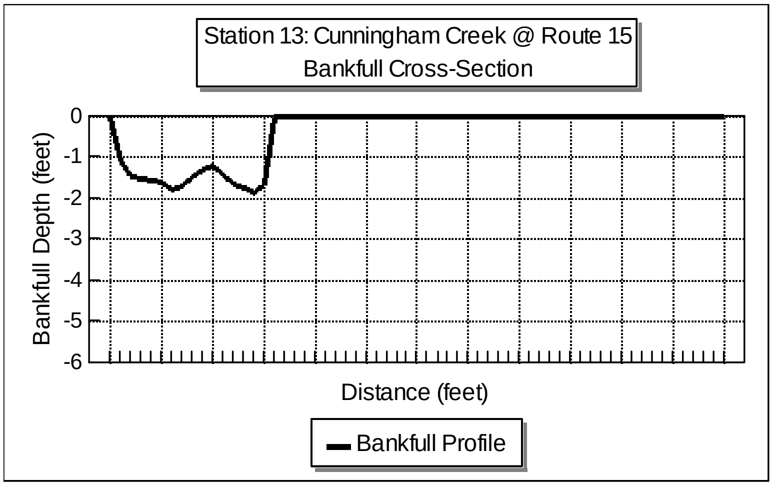


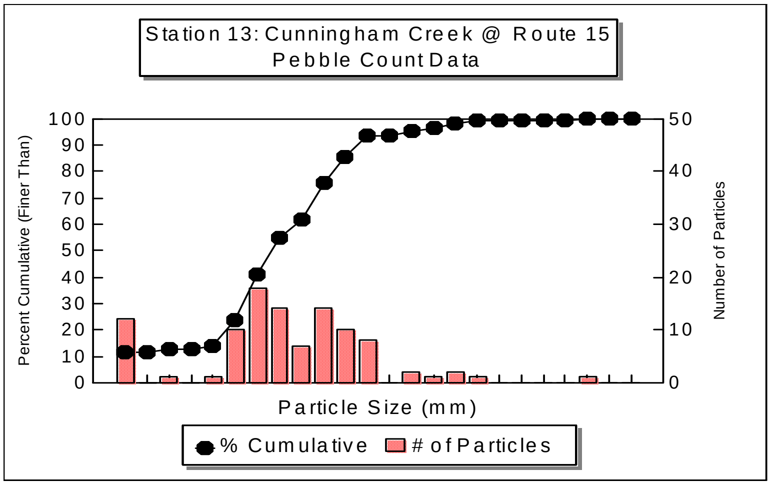



*Cunningham Creek*

| | |
|---|---|
| Entrenchment Ratio: | 1.3 |
| Width/Depth Ratio: | 23 |
| Sinuosity: | 1.4 |
| d50 Particle Size: | 5 millimeters (gravel) |

Summary: This river segment is entrenched with a high width/depth ratio. Particle distribution is bimodal with peaks in the silt/clay and gravel ranges. This segment classifies as a Rosgen F4 stream. The discussion above for Mechunk Creek is largely relevant for Cunningham Creek as well, although Cunningham's width/depth ratio is within the normal range for the RRBP morphology sites, and Cunningham's valley in the vicinity of the sampled stream segment is not as severely sloped as Mechunk's.



**Comparing Morphology Data between Sites**

The bankfull cross-sections have consistency between them. The surveyed streams are primarily entrenched, exhibiting the characteristics of "F" channels in the Rosgen terminology. It appears that "F" channels express a life history of Piedmont watersheds. Several centuries of land clearing for forestry and agriculture have changed watershed hydrology. The streams have adjusted by widening and entrenching within their valleys. In this process, geologic and/or historic active flood plains have been abandoned and a cycle (or cycles) of new flood plain building has begun, as evidenced by the silt, sand, and gravel bar building qualities of these streams. While the tendency of these streams to rebuild their active flood plains can be a destructive process for adjacent streambanks and riparian areas, it is, after all, an attempt to regain some elements of morphologic stability. The Meadow Creek situation is characterized by intensive urbanization, yet has exhibited the same process of widening and entrenchment.

The processes described above help explain the widespread occurrence of a bimodal particle size distribution with one of the peaks being in the silt/clay or sand range. In some of the streams, the silt/clay peak was the largest (e.g., Mechums River, two North Fork Rivanna sites). As streambanks erode and new active flood plains are created, the silty nature (or at least semi-silty nature) of these streambeds will prevail, especially along deposition areas, such as inside bends and pools. A watershed's geology, soils, land uses, and size can either temper or exacerbate this problem.

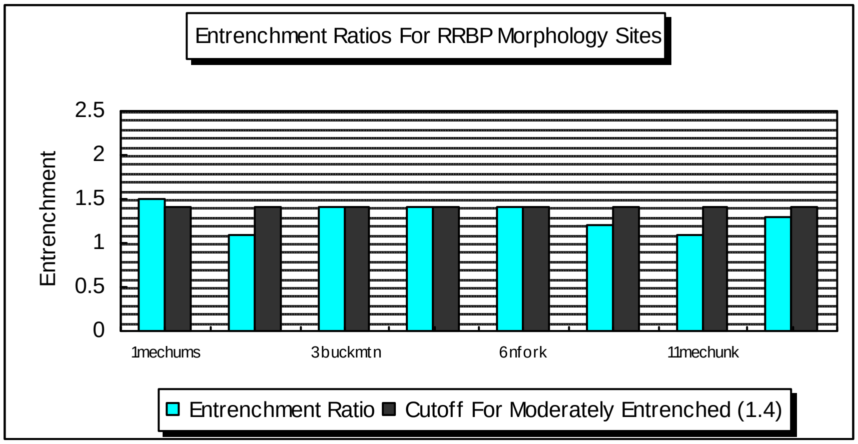
While F channels are known to show several signs of instability—such as problems transporting bedload and/or streambank erosion—several streams in the Rivanna Basin demonstrate what can best be described as a "stable F" form. These streams have forested stream buffers, healthy streambeds composed of a variety of particle sizes, and, from a structural point of view, good opportunities for aquatic habitat. The RRBP morphology sites in this category are Moormans River, Buck Mountain Creek, Meadow Creek, Mechunk Creek, and Cunningham Creek. While these streams still show evidence of instability in the form of steepened streambanks and some bank erosion, they perhaps represent those Piedmont streams that are in the recovery process (given a helping hand from current and future generations). This situation prevails, in some cases, due to the benign assistance of watershed geology. However, land use and riparian corridor management also play an instrumental role.

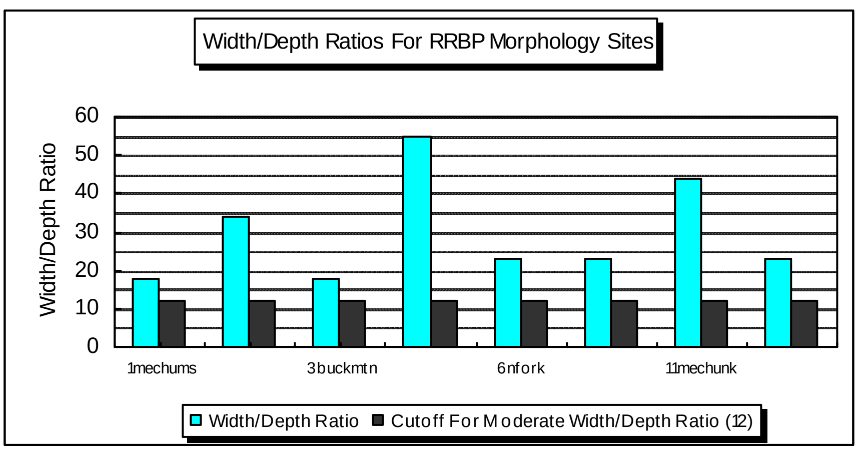
Alternatively, the two North Fork Rivanna River sites stand out as those whose road to recovery may be somewhat longer and more difficult, due in part to watershed characteristics and size. The site at Route 606 in particular demonstrates a case where the stream is unable to transport the load of silt and sediment that the watershed is creating. The stream bed and channel impacts are evident, as are the implications for aquatic habitat.

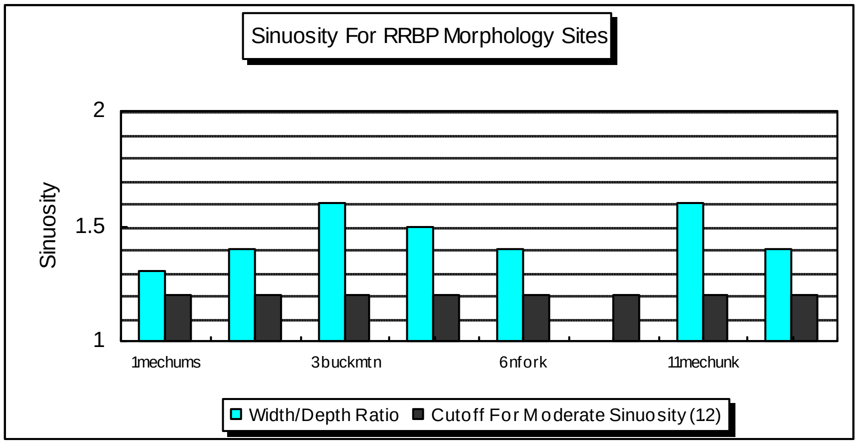
Meadow Creek is the anomaly of the set, with its watershed exclusively in urban land uses. While the stream bed characteristics compare favorably with other sites, at least along this segment (which is well forested), entrenchment, urban hydrology, and urban pollutants bestow on Meadow Creek perhaps the greatest challenge as well as the greatest opportunity.

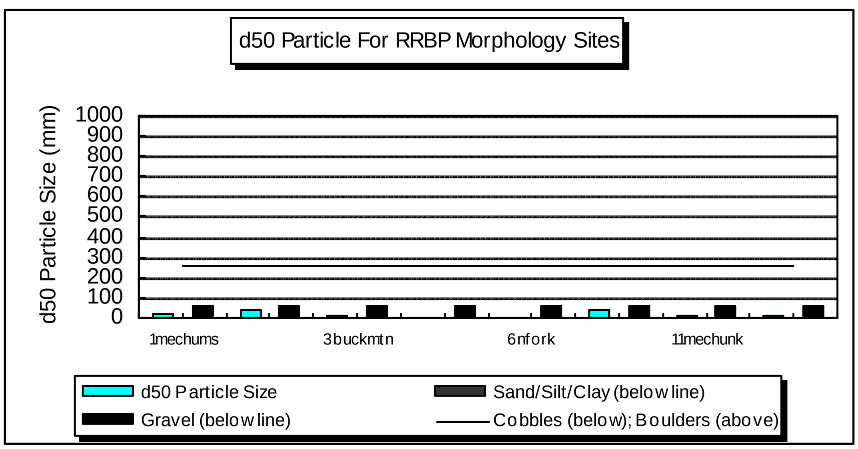
Also of note, these RRBP morphology sites were at the bottoms of their respective drainage areas. It will take further study along the lines of this project to ascertain stream morphology as one moves up into the headwaters. The Rivanna Basin headwaters no doubt exhibit stable streams of the "C,", "B." and "A" varieties. A topic for future study is the extent of the various stream types as well as their vulnerabilities to land use and watershed change.

For comparison purposes, a series of charts follows illustrating entrenchment ratios, width/depth ratios, sinuosity, and d50 particle sizes for each of the RRBP morphology sites.






## Hydrology

The Rivanna River Basin is a 761 square mile (486,900 acre) fan-shaped sub-basin representing approximately 2% of Virginia's total land area (40,000 sq. mi.) and 7.5% of the drainage of the James River watershed (10,102 sq. mi.). The Basin is bordered by the Rapidan River basin to the north, the South Anna River basin to the east, the South Fork Shenandoah River basin to the west, and the Rockfish and Hardware River basins to the south.

The source of the Rivanna River is in the Mechums River drainage basin at an elevation of 1,280 ft. The Rivanna River system is 76.7 miles long, as measured along topographic contours from the source to mouth (elevation 178 ft.). The average rate of all along this path is 38 ft/mi for the Mechums River, 7 ft/mi for the South Fork Rivanna River, and 3 ft/mi for the main stem. The general direction of flow is from northwest to southeast.

The Rivanna River and its tributaries drain major portions of Albemarle and Fluvanna Counties, relatively small portions of Greene and Orange Counties, the City of Charlottesville, the town of Columbia, the village of Palmyra, and a tiny fraction of Nelson County.

**Rainfall**

Essentially all the water in the Basin originates from precipitation, there being no major importation of water to the Basin. Still to be learned are the relationships between topography, precipitation, and stream flow and the effects of weather patterns. This was beyond the scope of this study. Preliminary steps have been taken to develop a basin-wide "water budget", but, while useful, this was also beyond the scope of the project.

**Precipitation (P, or, Precip)**

Essentially all the water in the Basin originates from precipitation, there being no major importation of water to the Basin. Data of the National Weather Service has been collected by the Thomas Jefferson Planning District Commission and is available to the Roundtable. We need, and are searching for isohyetal maps (inches of P distributed over the land) which show how elevation and topography interact to increase precip and, proportionally, to increase streamflow.

Obtaining the precip maps will enable the group to make reasonable estimates of the volume of water yielded by individual sub-basins ($3^{rd}$ and $4^{th}$ order watersheds)--most of which are not equipped with continuous recorders of streamflow. There are only six full-time streamflow stations in the Basin.

The general algebraic relationship used in estimating watershed annual (or longer term) water yield is:

Calculated flow A/ rainfall A = Unknown flow B/ rainfall B.

Evaluating changes in climate, weather patterns, or the potential for weather modification is beyond the scope of this effort.

**Evapotranspiration (ET)**

The fate of precip can be generalized as being threefold: return to the atmosphere, percolation to ground water storage, and the overland and rill movements of water joining to comprise streamflow. The primary way water returns to the atmosphere is through direct evaporation from land and leaf surfaces (called interception) and through transpiration by living plants. For simplicity, we lump these terms into "evapotranspiration (ET)".

There are many methods of estimating ET—some of which are data intensive and time intensive beyond our means. Unit values (called consumptive use) which have been derived for various types of land cover for our climate regime, will be used and, if land cover data becomes available, apply these to estimate ET. It is very important that this exercise be done because ET uses more than half of the precip falling on the Basin, and ET varies considerably by land cover. For example, a riverbottom forest may consumptively use twice as much water as an equivalent area of grassland. Please note: These calculations are only for purposes of accounting for elements of the water balance; we don't mean to discount the high ecologic or stabilizing role of trees. It is desirable to know how changing land use will change ET losses, which, in turn will affect average total annual streamflow.

Plants, of course, use ground water, whether directly through roots drawing on the water table, or by using the pumped water some residents of the Basin apply from domestic wells. Tentatively, we are guessing this use is not large, and the relatively shallow ground water systems of the Basin are generally on a balanced put-and-take basis, i.e., the water extracted is replenished annually, or at least after every prolonged drought. It is important to be able to make this assumption, in order to be able to simplify the task of estimating the effect of changing land use on streamflow.

**Storage (Ground and Surface)**

In a comparative sense, there are no large reservoirs, ground or surface, in the Basin. A review of the available hydrologic information (largely USGS) shows no ground water system (aquifer) capable of sustaining the kind of high capacity wells required for urban or large-scale industrial use. Locally, ground water is an important and, in places, reliable source of water for domestic and farm use. It is our preliminary conclusion that most of the aquifers, which supply wells in the Basin, attain their yield from fractures, joints, or faults in the rock formations. There is little intergranular porosity of the type one sees—e.g., in the Coastal Plain—except in the relatively sparse flood plain alluvium of the Basin, which yields water seasonally, to shallow wells.

The conclusions are based on less than ideal data, and urge support of scientifically designed efforts, e.g., VA Dept. of Mines & Minerals, to increase the practical knowledge of the Basin's ground water resources.

For purposes of storing water for municipal and industrial supply there are two fairly large run-of-the-river reservoirs in the Basin: Sugar Hollow Reservoir, situated high in the Moormans River sub-basin and the South Fork Rivanna River Reservoir located near Charlottesville. Their combined reservoir capacity is about two billion gallons. The primary water utility in the Basin, the Rivanna Water and Sewer Authority diverts about eleven million gallons per day from this system. Thus, the reservoirs must be filled twice per year to provide this volume of water.

The library of the Rivanna Water and Sewer Authority was used to gather information on the existing surface water storage system and on any plans for improvement or expansion of the system. We are compiling a bibliography of what we consider to be the major reports of interest to our mission. These reports span several fields of knowledge and indicate a highly complex system—in terms of hydraulics and limnology.

A quote from just one of these reports (James Z. Sowers, 1982) illustrates the complexity of operating a water supply reservoir in an urban setting: “Excess reservoir water can be discharged over the top of the dam (South Rivanna) or through pipes in the bottom...A substantial difference in water quality exists between water on the surface and on the bottom of the reservoir...the level (elevation) of reservoir discharge will affect the water quality in both the reservoir and the river below the reservoir. Water quality changes in the reservoir will affect the operation of the South Rivanna Water Treatment Plant, which draws water from the reservoir. Also, water quality changes in the Rivanna River below the reservoir may affect the level of wastes that can be discharged into the river by the Moores Creek Sewage Treatment Plant.” (The author, justifiably, could have continued the discussion, introducing additional complexities by bringing in the impacts on biota of reservoir operations—some beneficial, some deleterious.)

The Hydrology Work Group, while it did not pose as experts on surface water storage in the Basin, prepared the Roundtable members for framing the most important issues and raising the pertinent questions necessary to protect this vital water supply and to enhance its operation, compatible with the recreational and environmental uses of the river. The available geologic and hydrologic data indicated that the Rivanna Basin will be dependent on surface water reservoirs. It is important that our reservoirs be planned, constructed, and operated with all users in mind.

**Streamflow (Runoff)**
The runoff flowing past a given point in a stream depends on the P, ET, the net gain/loss to ground water, and diversions occurring above that point in the watershed. The basic water budget equation for the Basin is:

**P - ET + Change in Ground and Surface Storage = Streamflow.**

The USGS reports the mean annual runoff of lands in the Moormans Sub-basin as 19 inches per year, about a third of the water left from P, after ET has taken its big bite. In comparison, the reported mean annual runoff of the whole Rivanna Basin is about 16 inches. This difference is probably due to heavier precip in the Moormans Sub-basin, but, the reason for such differences can not be confirmed until more P and ET data are available.

The Basin can be said to be “water rich”, yielding an average of about 600 gallons/day of streamflow from each acre of land. However, as both our ground water and surface water reservoirs are quite limited in capacity; most of this water cannot be stored, and flows into the James River.

We are not suggesting more dams and reservoirs; free flowing rivers and dry lands are of obvious great benefit. The point is that the basin is not necessarily “water rich” when its natural limitations and the competing demands for water are considered. From a water supply basis, the Basin can likely support a much greater human population and level of industrial activity, but there will have to be tradeoffs with regard to quality of life and sustainability of the water-dependent environment.

We have to look beyond mean streamflow data and examine low flows and high flows in order to understand important differences occurring by place and time.

We can theorize with confidence that on certain days, and during certain weeks (usually Aug-Sept) even the larger streams in the Basin may decline to a trickle or even run dry. Such occurrences are not predictable for a specific year, but the probability of their happening can be stated based on the period of record. The Moormans River is not as reliable a river during drought as the Mechums, the South Rivanna not as reliable as the North Rivanna. We think, that based on geologic information, the Mechums is a better lowflow stream because the watershed seems to have more granular bedrock and greater areas of floodplains, which may contribute to streamflow during dry periods. But, we need to evaluate the role ET plays in these differences before we can be sure.

Low flows of the South Rivanna River, for a reach of about seven miles, are influenced heavily by the operation of the South Rivanna Reservoir. Although the Water Authority stores and diverts streamflow for offstream use, it also releases water immediately downstream of the dam, in order to supplement low flows. The quality of the water depends on which of three vertically staged outlets are opened in the reservoir.

Regarding high flows, specifically peak flood flows, these three types of weather events which generate unusual floods in the Basin: the summer super-cell rain storm, such as struck the Rapidan Basin in June, 1995; a hurricane event; and a winter rain-snowmelt event. Although the maximum recorded peak of the Rivanna is a hurricane caused 86,000 cfs (about equal to the average flow of The Mississippi R. just above St. Louis), it is possible that had the June 1995 storm centered on the Rivanna Basin, much higher peak flows would have resulted. The point is that the Rivanna Basin is subject to very high peak flood flows. With continuing urbanization, and concomitant creation of impervious areas, the flood potential will increase. Many land use and management techniques are available to reduce flood flow frequency, somewhat, and certainly to lower flood damages. Many of these known methods may prove effective in offsetting the increase in imperious areas. In situations in which the ground is saturated or frozen, little can be done to prevent very high peak flows in an upland basin such as the Rivanna, short of dedicating large areas of land to flood control dams (not recommended by the Roundtable).

**Findings**

Low flows of the Mechums River. (adjusting for watershed size) are significantly greater than those of the Moormans R., probably due to comparatively larger ground water inflows to the Mechums. Conversely, the flows of the Moormans tend to be greater in the high flow range.

Streamflows, which can be relied upon ninety percent of the time, are relatively small; instantaneous extreme low flows can approach zero (usually in Aug.-Sept.). This suggests the importance of storage, diversion and release in the hydrologic regime of the Rivanna Basin—i.e., small watersheds with poor ground water storage, in a hilly terrain. And it indicates that the operations of the Rivanna Water and Sewer Authority will become more important as the watershed becomes more urban. **Natural "inadequacies can either be ameliorated or exacerbated by water control facilities and their operation.**

Median-time flows suggest—in the words of a Water and Sewer Authority—that, quantitatively, the Basin is "water rich." For example, assuming that streamflow originating from one square

mile of watershed area equals .6 cfs/day, this is a yield of about 600 gallons/day from each acre of land. The term “water rich,” however, may prove to be an aberration when the water regime is examined in terms of instream needs, water quality, and time and location phenomena.
The measured high flows are what could be expected from considering the geohydrology and stage of development of the Basin. It would be enlightening to extrapolate the intense rainfall of June, 1995 on the Rapidan to the Rivanna and see the resulting peak flows generated—factoring in imperious areas, now and projected. Obviously, very high peak flood flows are a possibility in the Rivanna Basin.

## Water Quality

Unless noted otherwise or qualified as “historic”, all data cited here were obtained by the Field Teams in 1996 and 1997

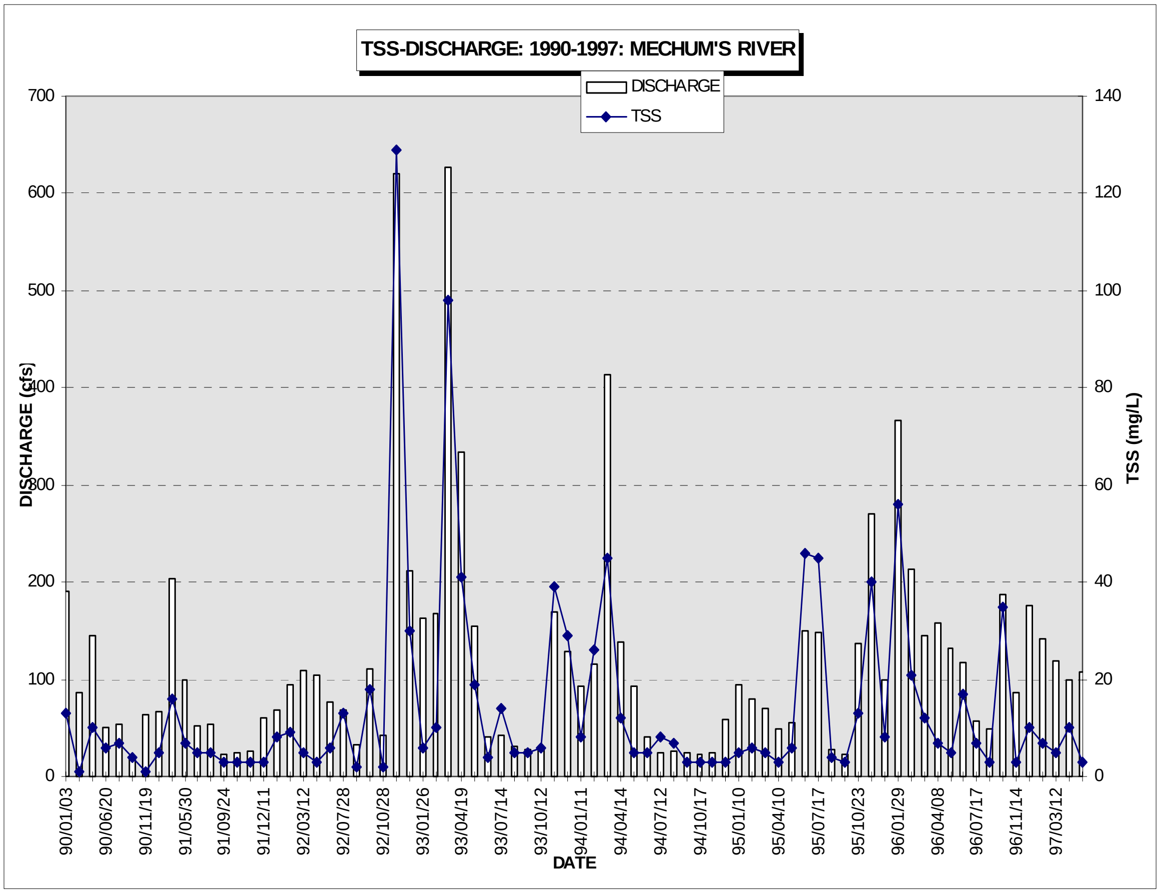
This is a good point to note the rather routine phenomenon of RRBP maximum and mean stormflow concentrations for fecal coliform and TSS being significantly higher than DEQ grab samples, a data set which extends for 4-7 years, depending on the location of the sample site. This gap between RRBP values and DEQ values is probably due to sampling methodology. RRBP samples were specifically taken during baseflow and stormflow periods, while DEQ samples are taken randomly.

Because DEQ sampling protocols are not hydrologically-based, fecal coliform, TSS, and perhaps other discharge-sensitive water quality parameters can be 10-100x higher than the concentrations reported by the agency. Interestingly, in cases such as the South Fork of the Rivanna at Route 29, where the dam may be acting as a filter to remove sediment in most flow conditions, RRBP and DEQ concentrations are nearly identical.

### Physical Indicators

*Mechums River*
*Total Suspended Solids (TSS)*: The mean storm concentration of sediment (282 mg/L) for the Rivanna River Basin Project is dramatically higher than the mean baseflow concentration (approximately 4 mg/L). The Mechums River mean suspended sediment stormflow concentration is the second highest in the basin. High historic DEQ values are in the 200-600 mg/L range and seem to correlate very well with discharge. This correlation shows what many Central Virginians already know: our rivers are muddier during storms. Because these TSS concentrations fall above recommended standards for fish (80-400 mg/L, see Desired Future Conditions for more information on fish water quality standards), TSS is a concern in the Mechums River (Map 2) and could affect the quality and quantity of aquatic life.

*Fecal Coliform:* The mean stormflow fecal coliform concentration for the RRBP samples in the Mechums River is among the highest in the region (17,275 colonies/100 mls). Baseflow values




are approximately 70 colonies/100 mls (approximately in the middle of the pack of the values found in the basin). High historic DEQ values in the Mechums are generally in the 1000-1500 colonies/100 mls range with a relatively flat trend over time. The large disparity between mean stormflow and baseflow coliform concentrations would tend to suggest that fecal coliform enters the river as non-point runoff , rising with increases in runoff.

With mean concentrations above recommended EPA and DEQ limits of 1000 cells/100 mls, fecal coliform is a concern in the Mechums River (Map 3).

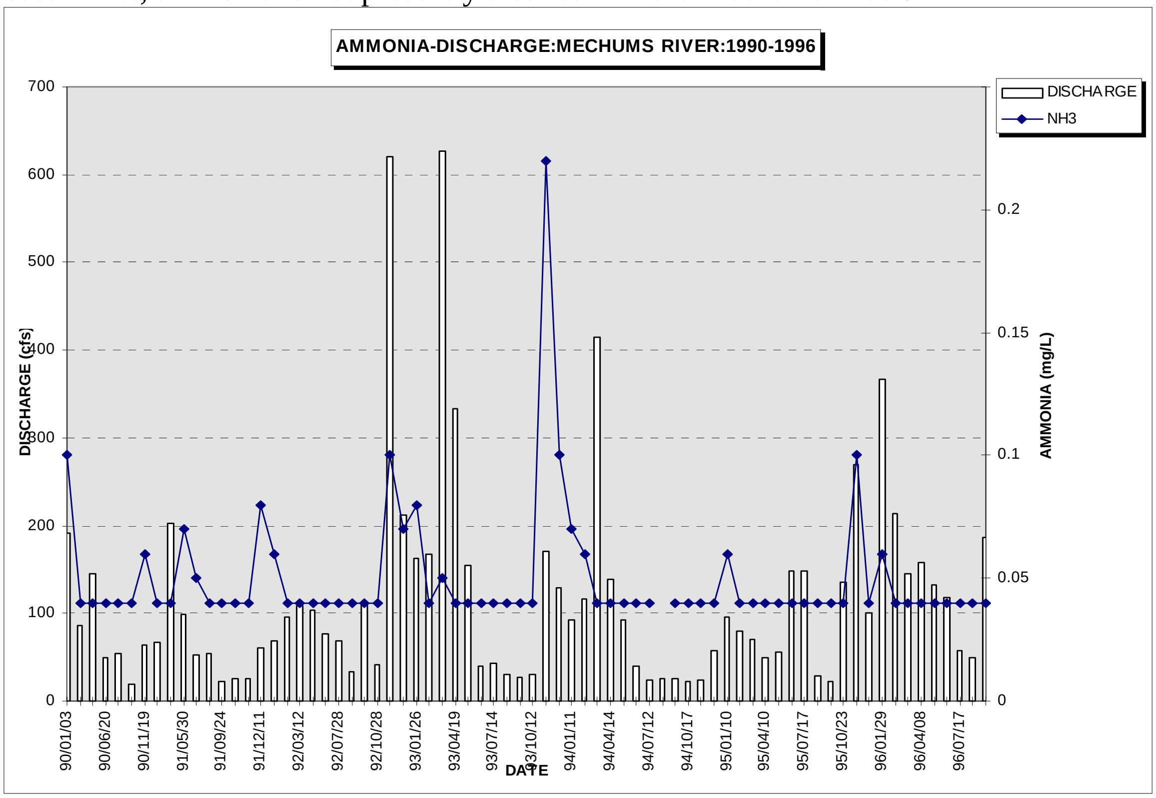
*Total Nitrogen:* The mean stormflow total nitrogen concentration for the RRBP samples is tied for the highest in the basin (1.4 mg/L). Mean baseflow concentrations are on the high end of the values found in the basin, at (0.76 mg/L). DEQ historic high values are in the 1-1.2 mg/L range and as with RRBP results, appear to be fairly well correlated with discharge.

With concentrations well below recommended sunfish and bluegill limits (86-180 mg/L), nitrogen is not presently a concern in the Mechums River.

*Total Phosphorus:* The mean stormflow phosphorus concentration for the RRBP samples is the highest in the basin (approximately 0.4 mg/L). This site also had the highest maximum stormflow concentration in the basin (0.9 mg/L). Historic DEQ records show concentrations generally below detection limits (0.1 mg/L).

With mean and maximum stormflow above the DEQ recommended enrichment trigger, total phosphorus is a concern in the Mechums River (Map 4).

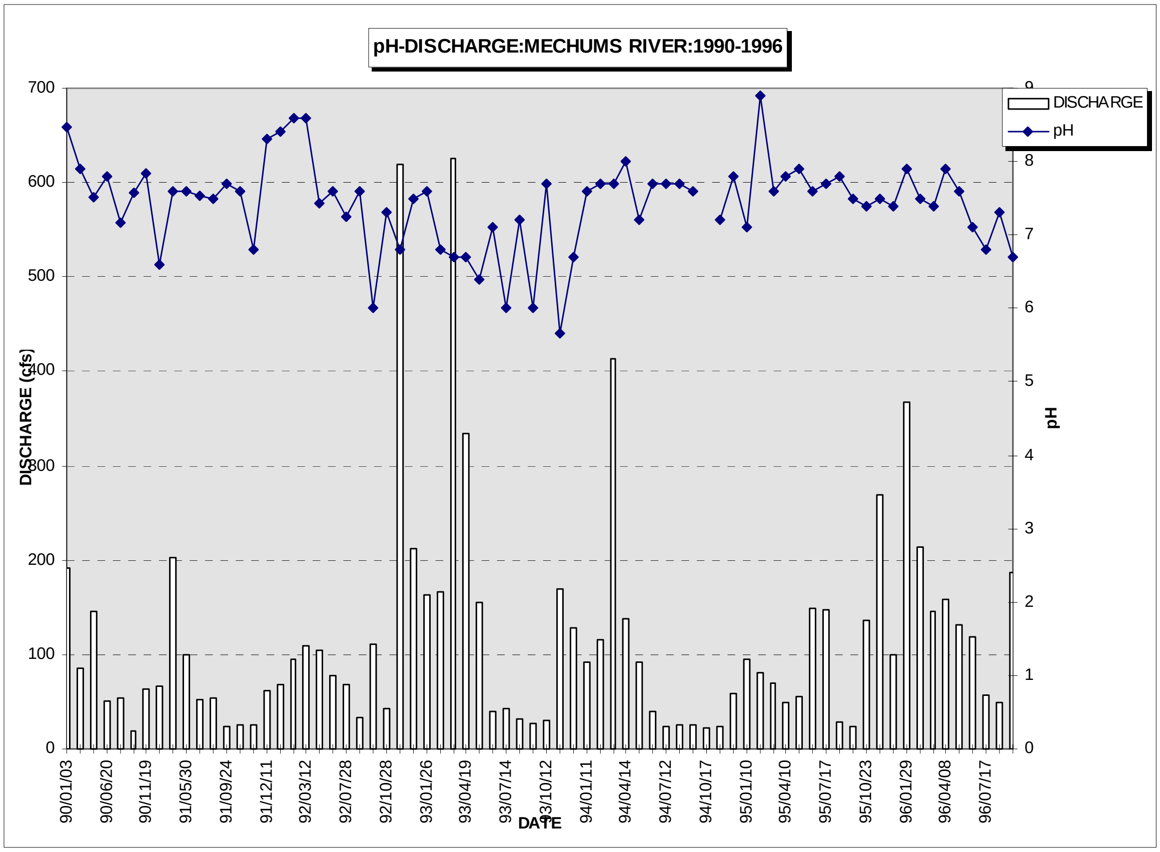
*Ammonia:* The maximum historic concentration was approximately 0.22 mg/L. Many of the concentrations were below the detection limit. Concentrations appear to be poorly correlated to discharge. With a maximum concentration well below the DEQ warmwater fish and smallmouth bass limits, ammonia is not presently a concern in the Mechums River.




*Dissolved Oxygen:* Historic DEQ data regarding dissolved oxygen concentrations range from approximately 8 to 15 mg/L and show a positive correlation to discharge. With lowest concentrations well above recommended minimums for warmwater fish, dissolved oxygen is not presently a concern in the Mechums River.

*pH:* Historic pH values, measuring acidity or alkalinity of water, range from approximately 5.5 to 9. Correlation to discharge is strong and negative. However, RRBP maximum and minimum values are 7.6 and 6.6, respectively. With the lowest historic value below the DEQ recommended lower limit for all aquatic life, pH is a concern in the Mechums River, because the water is too alkaline.

*Temperature:* Temperatures range from 1-3 degrees Celsius. Correlation to discharge is strong and negative.




*Moormans River*
*Total Suspended Solids (TSS)*: TSS levels during storm maximum (115 mg/L) and mean (60 mg/L) concentrations in the Moormans River are among the lowest in the basin. The highest historic concentrations seem to be strongly correlated with discharge. With mean TSS concentrations falling below the 80-400-mg/L fish threshold, TSS is not a concern in the Moormans River.

*Fecal Coliform*: Fecal coliform levels at storm maximum (9,800 cells/100 mls) and storm mean (5,106 cells/100 mls) concentrations are among the lowest in the region. Historic fecal coliform concentrations range from 100 to 200 cells/100 mls with little correlation apparent with discharge. Because storm mean values are above the EPA and DEQ limits of 1000 cells/100 mls, fecal coliform is a concern in the Moormans River.

*Total Nitrogen*: Storm maximum (1.2 mg/L) and mean (1-mg/L) concentrations are also among the lowest in the region. The highest historic concentrations are approximately .65 mg/L with a positive correlation to discharge. Maximum, mean, and historic nitrogen concentrations are above cold water fish recommended limits and well below recommended limits for warm water fish. Assuming that it is unreasonable to have trout in the lower Moormans River, total nitrogen is not presently a concern.

*Total Phosphorus:* The maximum storm concentration is 0.3 mg/L. The mean stormflow concentration is 0.15 mg/L. Historic values are all below the DEQ 0.1 mg/L detection limit.

Because the DEQ enrichment trigger is 0.2 mg/L, above the mean stormflow concentration, phosphorus is not a concern in the Moormans River.

*pH*: Baseflow and stormflow values hover around a pH of 7 and so pH is presently not a concern.

*Buck Mountain Creek*
*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 200 mg/L. The mean stormflow concentration is 78 mg/L. these values are among the lowest in the basin. With the warm water fish limit (assuming that it is unreasonable to have trout in lower Buck Mountain Creek) listed as 80-400 mg/L,  TSS is not a concern in Buck Mountain Creek.

*Fecal Coliform*: The maximum stormflow concentration is 17,364 cells/100 mls. The mean concentration is 5726 cells/100 mls. With the DEQ and EPA limit of 1000 cells/1000 mls, fecal coliform is a concern in Buck Mountain Creek.

*Total Nitrogen*: The maximum total nitrogen stormflow concentration in Buck Mountain Creek is approximately 1.3 mg/L. The mean is approximately 0.9 mg/L. High total nitrogen concentrations for historic DEQ data is 0.8 mg/L. Maximum, mean, and historic nitrogen concentrations are above cold water fish recommended limits and well below recommended limits for warm water fish. Thus, nitrogen is not a concern.

*Total Phosphorus*: The maximum stormflow concentration is 0.27 mg/L. The mean is a little over 0.1 mg/L. Because the mean stormflow concentration is below the DEQ enrichment trigger of 0.2 mg/L, phosphorus is not a concern in Buck Mountain Creek.

*pH:* Baseflow and stormflow pH ranges from 6.8 to 7.2. This is well within the range for fish life, thus, pH is not a concern.

*North Fork Of The Rivanna River (Rt. 606)*
*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 418 mg/L. The mean stormflow concentration is approximately 160 mg/L. Both of these are well above the recommended thresholds for Shad (100 mg/L) and fish (80-400 mg/L), thus, TSS is a concern in the North Fork of the Rivanna at Rt. 606.

*Fecal Coliform*: The maximum stormflow concentration (39,000 cells/100 mls) is among the highest found in the basin, as is the mean stormflow (approximately 15,840 cells/100 mls). These concentrations are well above the DEQ and EPA limits of 1000, thus, fecal coliform is a concern in the North Fork at Rt. 606.

*Total Nitrogen:* The maximum stormflow concentration is approximately 1.4 mg/L. Mean stormflow concentration is just above 1.1 mg/L.  Because these concentrations are well below fish standards, nitrogen is not a concern in the North Fork at Rt. 606.

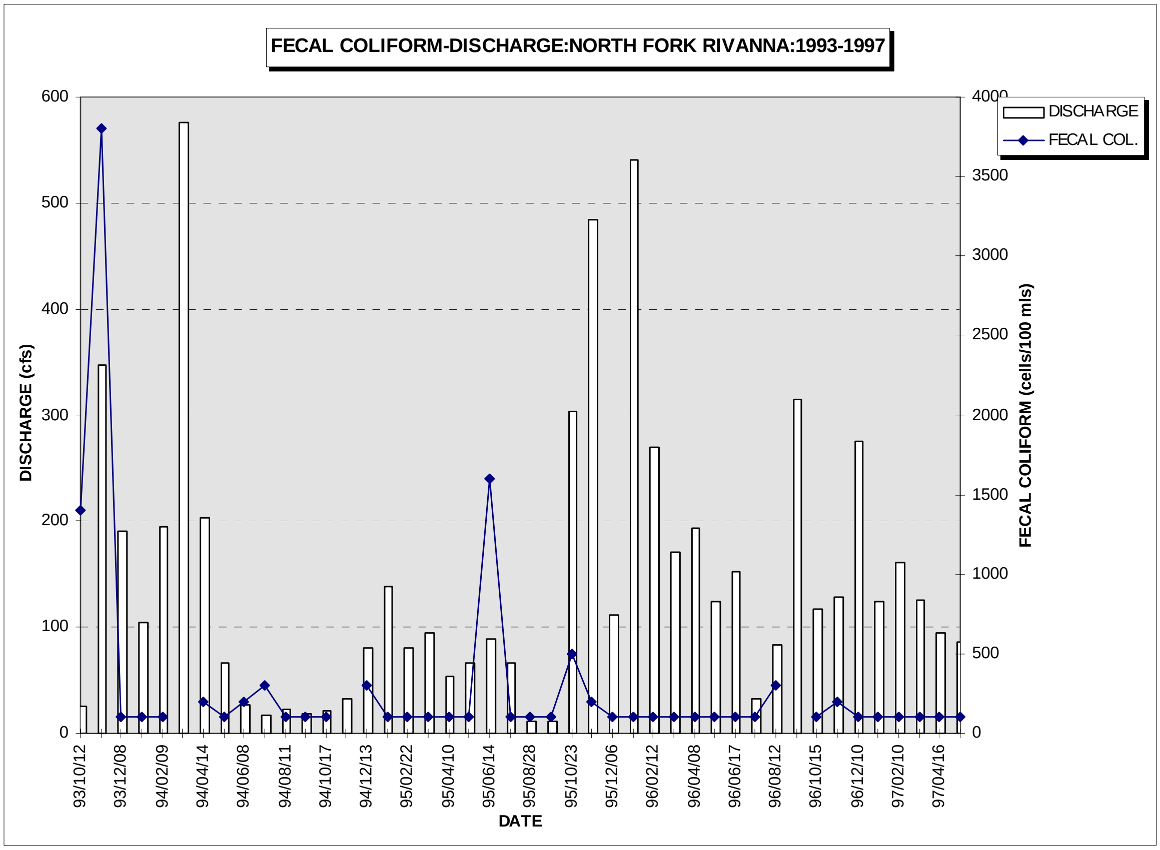
*Total Phosphorus*: The maximum stormflow concentration is 0.4 mg/L. The mean stormflow concentration is 0.2 mg/L. Both of these concentrations exceed or meet the 0.2 mg/L "enrichment trigger" recommended by DEQ. For this reason, phosphorus is a concern in the North Fork of the Rivanna at Rt. 606.

*pH:* The pH measured in the RRBP varied from approximately 7.2 for baseflow concentrations to 6.8 for stormflow concentrations. Both of these values are well within the range of pH recommended for fish habitat, thus, pH is not a concern.

*North Fork Of The Rivanna River At Proffit*

*Total Suspended Solids (TSS)*: The maximum stormflow concentration was the highest in the basin at approximately 654 mg/L. The mean stormflow concentration was also the highest in the basin at 304 mg/L. Historic DEQ data correlate tightly and positively with discharge with high concentrations ranging from 45-75 mg/L. Because TSS levels of 80-400 are recommended for fish, TSS is a concern in the North Fork at Proffit.

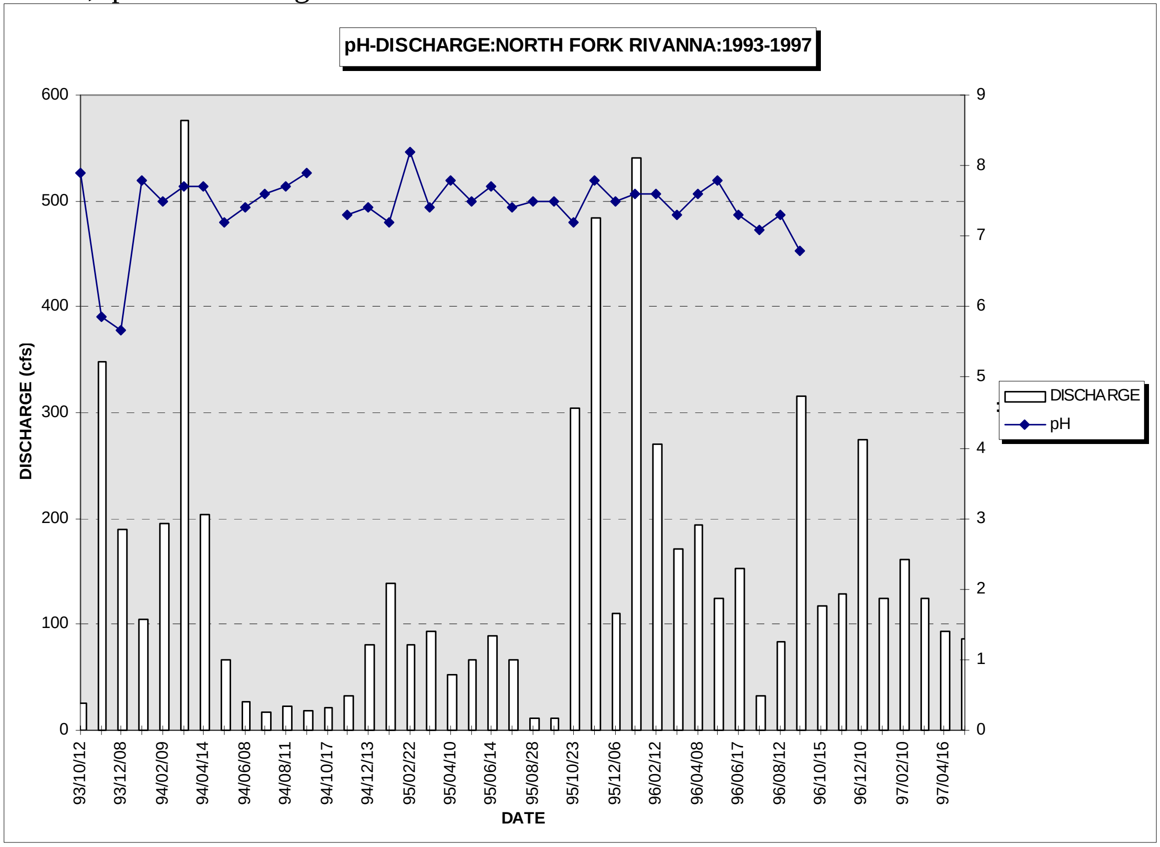
*Fecal Coliform:* The maximum stormflow concentration was approximately 30,000 cells/100 mls. The mean stormflow concentration was approximately 9309 cells/100 mls. The highest historic DEQ concentrations range from 2,000 to 3,800 cells/100 mls. Due to concentrations well above the DEQ and EPA recommended standard of 1,000 cells/100 mls, fecal coliform is a concern in the North Fork Rivanna at Proffit.




*Total Nitrogen:* The maximum stormflow concentration recorded was 1.7 mg/L. The mean stormflow concentration was 1.2 mg/L. Historic DEQ data show a positive correlation with discharge, with most concentrations fluctuating between 0.3-0.8 mg/L. With concentrations well below warm-water fish standards, total nitrogen is not a concern.

*Total Phosphorus*: The maximum stormflow concentration is the second highest in the basin at 0.8 mg/L. The mean stormflow concentration tied for second highest in the basin at 0.4 mg/L. Most of the DEQ historic data concentrations are below detection level of 0.1 mg/L. Highest historic concentrations are 0.2 mg/L, and appear to have no correlation to discharge. Because the RRBP samples are well above the 0.2 mg/L enrichment trigger recommended by DEQ, phosphorus is a concern for the North Fork at Proffit.

*pH:* pH values hover around 7. At this North Fork site, the effect of rainfall on pH is demonstrated with a reduction of pH from baseflow values of approximately 7.2 to stormflow values of 6.8. Interestingly, historic pH values, while generally fluctuating around 7, did fall below 6 to around 5.5, twice in 1993. Because these values have not been detected since in DEQ or RRBP data, this low value is probably a sampling error. Until it is confirmed with future results, pH is not thought to be a concern.




*South Fork Of The Rivanna At Rt. 29*

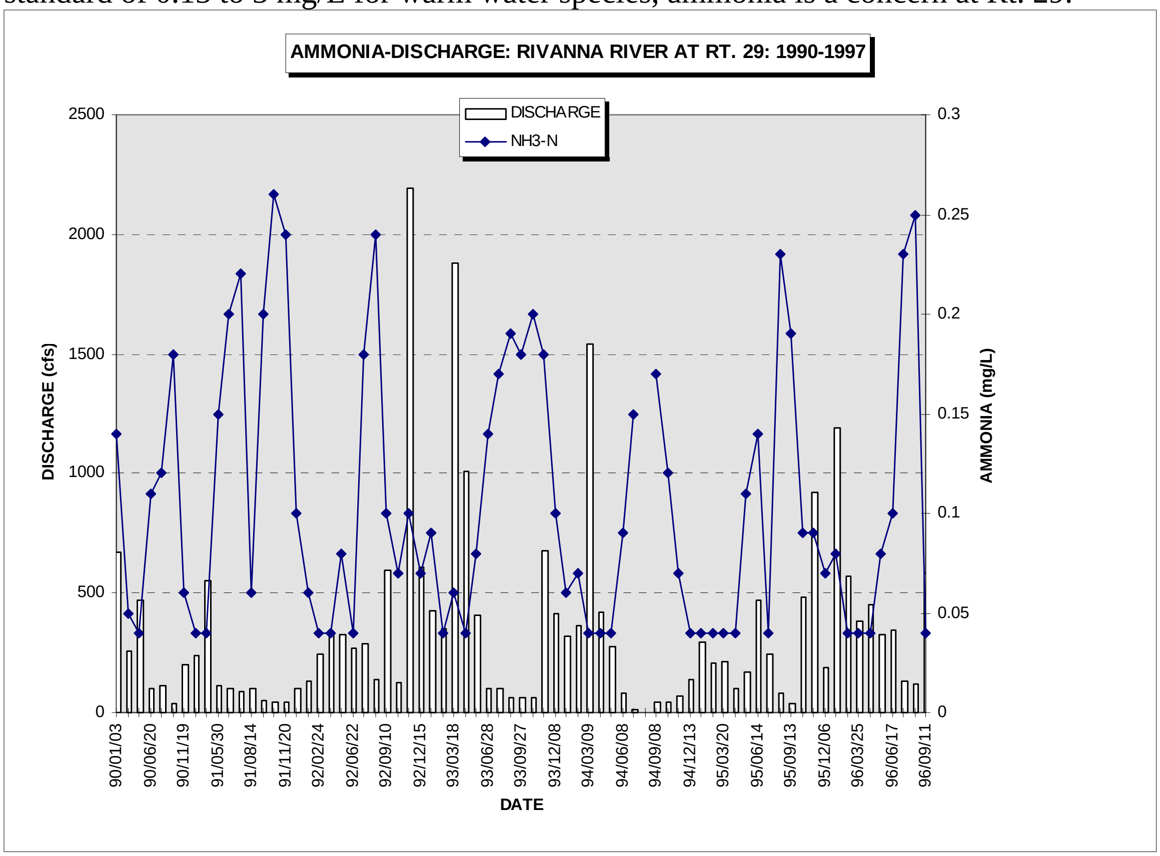
*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 47 mg/L, the lowest in the basin (probably due to the sediment-catching action of the South Fork dam). The mean stormflow is 25 mg/L, the lowest in the basin. Historic DEQ data has high concentrations around 80 mg/L, fairly well correlated with discharge. These values are well below those recommended for fish and shad, thus TSS is not a concern at Rt. 29.

*Fecal Coliform:* The maximum stormflow concentration is 4,000 cells/100 mls, the lowest in the basin. Likewise, the mean stormflow concentration is 1,571 cells/100 mls, the lowest in the basin. Historic DEQ data show concentrations in the area of 4,000 cells/100 mls, with fairly weak associations with discharge. With the EPA and DEQ recommended standard of 1,000 cells/100 mls, fecal coliform is a concern at Rt. 29.

*Total Nitrogen*: The maximum stormflow concentration is 1 mg/L, the lowest in the region. The maximum baseflow value is practically the same concentration. Mean stormflow and baseflow concentrations (0.6-0.7 mg/L) are closer together here than anywhere else in the basin. Historic DEQ data show total nitrate roughly correlating with discharge fluctuating in the range of 0.4-1.4 mg/L. Because this is well below available information about warm water fish nitrogen thresholds, total nitrogen is not a concern.

*Total Phosphorus*: Again, the maximum stormflow concentration (approximately 0.12 mg/L) and mean stormflow concentration (0.07 mg/L) are the lowest values in basin. Considering the 0.2 mg/L enrichment trigger, phosphorus is not a concern at Rt. 29.

*Ammonia*: Historic DEQ data shows ammonia values are inversely related to discharge and generally fluctuate between 0.05 mg/L and 0.25 mg/L. Considering the chronic DEQ ammonia standard of 0.13 to 3 mg/L for warm water species, ammonia is a concern at Rt. 29.




*Dissolved Oxygen*: Historic DEQ dissolved oxygen (D.O.) concentrations generally fluctuate between 4 mg/L and 13-14 mg/L. Considering the minimum DEQ standard of 4 mg/L, and recommended minimum concentration of 5 mg/L for shad, water below the dam failed to meet state standards twice in 1996, and fell below the recommended standard for shad at least 8 times since 1991 (however, according to Albemarle County Water Resources Manager, Dave Hirschman, D.O. levels rise to meet the standard by the Rt. 29 bridge). However, based upon DEQ historic data, D.O. is a concern from the dam to Rt. 29. According to DEQ staff, these low D.O. concentrations are probably due to the release of low oxygen-containing water from the reservoir. Efforts are now underway to correct this problem.

*pH*: pH values are 7 for all hydrologic conditions. Historic DEQ data show pH fluctuating around 7, with a low of approximately 5.3 and a high of 8.8. This value was recorded during a string of 5 low values separately recorded in 1993. Because this value has not been detected since in DEQ or RRBP data, these values are probably a sampling error. Until it is confirmed with future results, pH is not thought to be a concern.

*Rivanna River At Darden Towe Park*

*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 302 mg/L. The mean stormflow concentration is approximately 151 mg/L. Because the recommended threshold for Shad is 100 mg/L, TSS is a concern at Towe Park.

*Fecal Coliform*: The maximum stormflow concentration is 13,818 cells/100 mls. The mean stormflow concentration is approximately 6,605 cells/100 mls. The mean baseflow at Towe is the lowest in the basin at approximately 30 cells/100 mls. Considering the EPA and DEQ recommended standard of 1,000 cells/100 mls, fecal coliform is a concern at Towe Park.

*Total Nitrogen*: The maximum stormflow concentration is one of the lowest in the basin at 1.1 mg/L. The mean baseflow concentration is also one of the lowest, at .5 mg/L.

*Total Phosphorus*: The maximum stormflow concentration is 0.41 mg/L, while the mean stormflow concentration is 0.23 mg/L. Considering the DEQ enrichment trigger of 0.2 mg/L, phosphorus is a concern at Towe Park.

*pH*: The pH fluctuates closely around 7 for both base and storm concentrations and is thus not a concern.

*Meadow Creek*

*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 268 mg/L. The mean stormflow concentration is 82 mg/L. Considering the 100 mg/L threshold for Shad, TSS at Meadow Creek is not a concern.

*Fecal Coliform*: The maximum stormflow concentration is 20,000 cells/100 mls. The mean stormflow concentration is roughly 9,025 cells/100 mls. In addition, the baseflow concentrations are among the highest in the region (approximately 600 mg/L). Based upon an EPA/DEQ recommended threshold of 1,000 cells/100 mls, fecal coliforms at Meadow Creek are a concern.

*Total Nitrogen:* Interestingly, the baseflow maximum (1.4 mg/L) is about the same as the stormflow maximum (1.3 mg/L).

*Total Phosphorus*: The maximum stormflow concentration is 0.4 mg/L. The mean stormflow concentration is 0.17. Based upon a trigger of 0.2, phosphorus is a concern at Meadow Creek.
*pH:* The maximum baseflow pH is nearly 8, the highest pH value for any flow found in the RRBP samples. The mean baseflow (7.5) is also the highest mean pH found in the basin. Based upon a recommended pH for Shad of 6-7.5, pH is a concern at Meadow Creek.

*Monticello*
*Total Suspended Solids (TSS):* The maximum stormflow concentration is 316 mg/L. The mean stormflow is 184 mg/L. Based upon a range of limits for all fish of 80-400 mg/L and a range for Shad of 100 mg/L, TSS is a concern at Monticello.

*Fecal Coliform:* The maximum stormflow concentration is 13,818 cells/100 mls. The mean stormflow concentration is 7,182 cells/100 mls. The maximum baseflow is 930 cells/100 mls. Based upon the DEQ and EPA standard of 1000, fecal coliform is a concern at Monticello.

*Total Nitrogen:* The maximum baseflow concentration is 1.9 mg/L. The mean baseflow concentration is similar to the maximum stormflow concentration of 1.3 - 1.6 mg/L. In addition, Monticello is one of only two sites in the basin where the mean baseflow is a higher concentration than the mean stormflow for nitrogen.

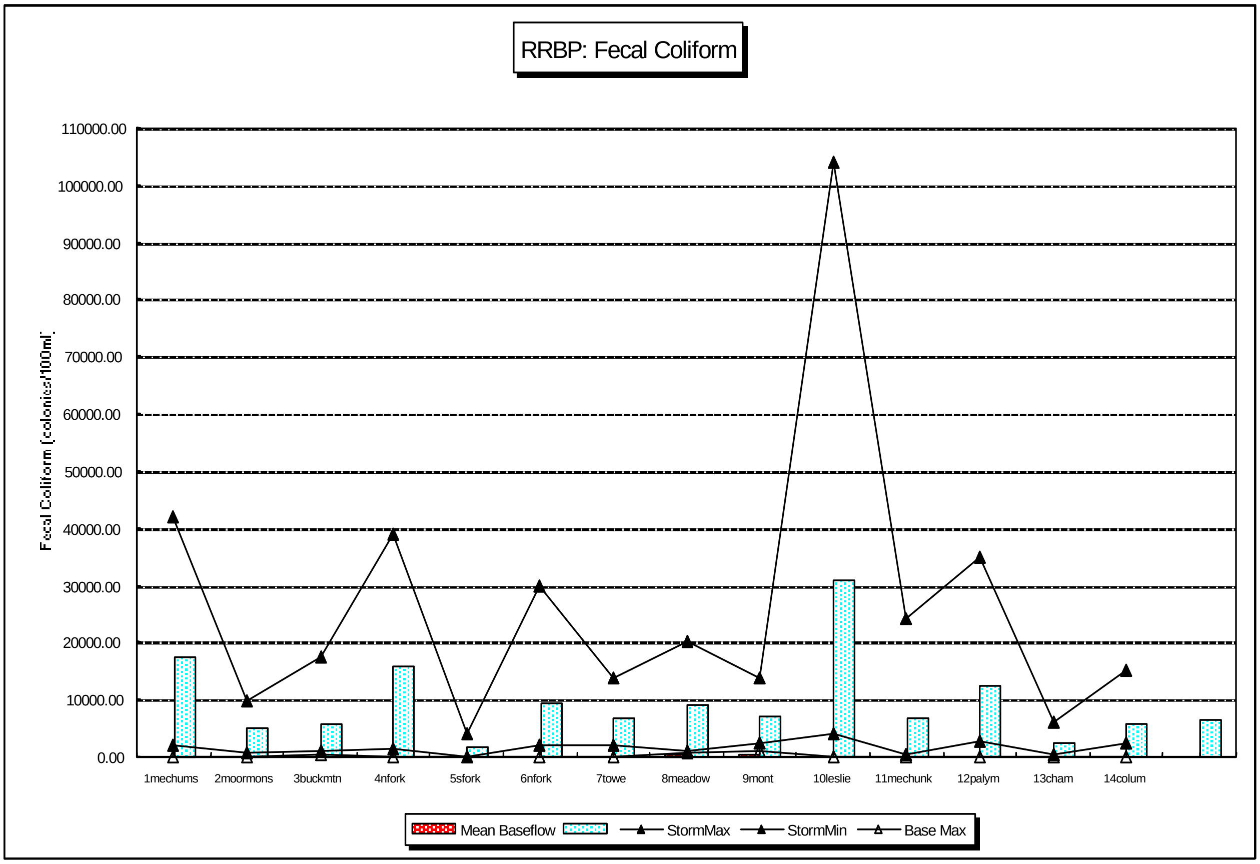
The similarity in baseflow and stormflow concentrations may be due to input from the Moores Creek Sewage Treatment Plant and from urban groundwater from Charlottesville.

*Total Phosphorus:* The maximum stormflow concentration is 0.44 mg/L. The maximum baseflow concentration is 0.27 mg/L, the highest of the sites in the basin. The mean baseflow is also the highest of any of the sites in the basin, at 0.15 mg/L. Considering the DEQ enrichment standard, phosphorus is a concern at Monticello.

*pH:* The pH hovers around 7; pH is not a concern.

*Leslie Site*
*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 415 mg/L. The mean stormflow concentration is 216 mg/L. Considering a recommended minimum standard for Shad of 100 mg/L, TSS is a concern.

*Fecal Coliform*: The maximum stormflow concentration is 104,000 cells/100 mls, the highest recorded fecal coliform concentration in the RRBP samples.  The mean stormflow concentration is 30,832 cells/100 mls, the highest in the basin. Considering the EPA and DEQ limit of 1,000 mls, fecal coliform is a concern at the Leslie site.




*Total Nitrogen:* The maximum stormflow concentration is 0.6 mg/L. The mean stormflow concentration is 0.4 mg/L. The maximum baseflow concentration is also relatively high at 0.15 mg/L.

*Total Phosphorus*: The maximum stormflow concentration is 0.6 mg/L. The mean stormflow concentration is 0.36 mg/L. The maximum baseflow concentration is the second highest of all the RRBP sites, with a concentration of 0.15 mg/L. Considering the enrichment trigger of 0.2 mg/L, phosphorus is a concern at the Leslie site.

*pH*: The pH hovers around 7.

*Mechunk*

*Total Suspended Solids (TSS)*: The maximum stormflow concentration is 117 mg/L, one of the lowest in the basin. Likewise, the mean stormflow concentration is 43 mg/L, also one of the lower values. Considering the all fish standard of 80-400 mg/L, TSS is a probably not a concern.

*Fecal Coliform*: The maximum stormflow concentration is 24,200 cells/100 mls. The mean stormflow concentration is roughly 6,823 cells/100 mls. Considering the EPA and DEQ standard of 1,000 cells/100 mls, fecal coliform is a concern in the Mechunk.

*Total Nitrogen*: The maximum baseflow concentration is 1.4 mg/L, nearly equivalent to the maximum stormflow concentration of 1.3 mg/L.

*Total Phosphorus*: The maximum stormflow concentration of .24 mg/L is the second lowest maximum stormflow in the basin. Likewise, the mean stormflow of .1 mg/L is also the second lowest in basin. Considering the .2 enrichment trigger, phosphorus is not a concern.

*pH*: The pH hovers around 7.

*Palmyra*
*Total Suspended Solids (TSS)*: The maximum stormflow concentration is approximately 545 mg/L. The mean stormflow concentration was approximately 229 mg/L. Both of these values are on the high end of the samples collected during 1996-1997. Historic DEQ data show a high correlation of TSS with discharge. Because these concentrations are higher than those recommended for Shad and fish, TSS is a concern in the Rivanna at Palmyra.

*Fecal Coliform*: The maximum stormflow concentration is approximately 35,000 cells/100 mls. The mean stormflow concentration is 12,352 cells/100 mls. Based on historic DEQ data, fecal coliform is fairly associated with discharge. Highest historic concentrations are in the range of 1,600-5,000 cells/100 mls. Considering the DEQ and EPA standard for coliform of 1,000, fecal coliform is a concern at Palmyra.

*Total Nitrogen*: The maximum stormflow concentration is 2 mg/L of total nitrogen. The baseflow maximum is 1.4 mg/L. The mean stormflow concentration is slightly less: 1.3-mg/L. Historic DEQ concentrations do not seem to track with discharge variability. High values range from 1 to 2.5 mg/L.

*Total Phosphorus:* The maximum stormflow concentration of phosphorus at Palmyra is 0.67 mg/L. The mean stormflow concentration is 0.34 mg/L. High DEQ historic values range from 0.2 to 0.5 mg/L. The relationship with discharge does not appear to be strong. Based upon the DEQ enrichment trigger of 0.2 mg/L, phosphorus is a concern at Palmyra.

*Ammonia:* Ammonia appears to be inversely linked to discharge. High values range from 0.05 to 0.12 mg/L. These appear to be below the recommended thresholds for acute and chronic warm water species. Consequently, ammonia is not a concern at Palmyra

*Dissolved Oxygen*: Dissolved oxygen tends to have a fairly strong and positive relationship to discharge. Concentrations extend no lower than 7 mg/L.

*pH:* pH values are generally around 7.

*Cunningham*
*Total Suspended Solids (TSS):* The maximum stormflow concentration at Cunningham Creek (approximately 110 mg/L) is the second lowest in the basin  Based on the TSS recommended benchmark for Shad and fish, TSS is a concern.

*Fecal Coliform*: The maximum stormflow concentration is 6,000 cells/100 mls. The mean stormflow concentration is 2,385 cells/100 mls. Based upon a DEQ/EPA standard of 1,000 cells/100 mls, fecal coliform is a concern.

*Total Nitrogen*: The maximum baseflow concentration 2.1 mg/L. The maximum stormflow concentration is 1.4 mg/L. This site and Monticello are the only two sites to have mean baseflow concentrations higher than mean stormflow.

*Total Phosphorus:* The maximum stormflow concentration is 0.27 mg/L. The mean stormflow concentration is .1 mg/L. Because the DEQ enrichment trigger is 0.2 mg/L, phosphorus is a concern at Cunningham Creek.

*pH:* The greatest change in pH from mean baseflow to mean stormflow is found in Cunningham Creek. The values, however, hover around 7.

*Columbia*
*Total Suspended Solids (TSS):* The third highest maximum stormflow concentrations (560 mg/L) and one of the three highest mean stormflow concentrations were found at this site (253 mg/L). Based upon Shad and fish standards, TSS is a concern.

*Fecal Coliform*: The maximum stormflow concentration is 15,000 cells/100 mls, well above the mean stormflow concentration of 5,675 cells/100 mls. Based upon the DEQ and EPA standard of 1,000 cells/100 mls, fecal coliform is a concern.

*Total Nitrogen*: The highest maximum stormflow concentration recorded in the RRBP in the basin was 2.5 mg/L at Columbia. In addition, the highest maximum baseflow concentration was recorded (2.2 mg/L). Finally, the second highest mean stormflow concentration in the region was found: 1.4mg/L.

*Total Phosphorus:* The fourth highest maximum stormflow concentration (0.73 mg/L) and third highest mean stormflow concentration (0.4 mg/L) in the basin were found at Columbia. Considering the enrichment trigger, phosphorus is a concern in Columbia.

**SUMMARY OF WATER QUALITY FINDINGS**

(All findings represent withdrawals at high flow; comparable low flow data not available)

| Test>>> | TSS | Fec.Col. | T Nitrgn | T Phos | Ammon | DO | pH | Temp |
|---|---|---|---|---|---|---|---|---|
| Mechums | C | C | X | C | X | X | C | ? |
| Moormans | X | C | X | X | N/A | N/A | X | ? |
| Buck Mt. | X | C | X | X | ? | ? | X | ? |
| N. Fork 606 | C | C | X | C | ? | ? | X | ? |
| N. Fork Profitt | C | C | X | C | ? | ? | X | ? |
| S.Fork 29 | X | C | X | X | C | C | X | ? |
| M-Creek | X | C | ? | C-? | ? | ? | C-? | ? |
| Rivanna – Towe Pk | C | C | X | C | ? | ? | X | ? |
| Monticello | C | C | ? | C | ? | ? | ? | X |
| Leslie | C | C | X | C | ? | ? | X | ? |
| Mechunk | X | C | ? | X | ? | ? | X | ? |
| Palmyra | C | C | ? | C | X | X | X | ? |
| Cunningham | C | C? | ? | C? | ? | ? | X | ? |
| Columbia | C? | C | ? | C | ? | ? | ? | ? |

C = concern ? = no data X = no concern O? or C? = some question about

**Benthic macroinvertebrates**

Of the 14 monitoring sites across the Rivanna Basin, only Meadow Creek has failed to achieve an overall index score in the excellent range (index >22) during at least one of four sampling events throughout the project year.

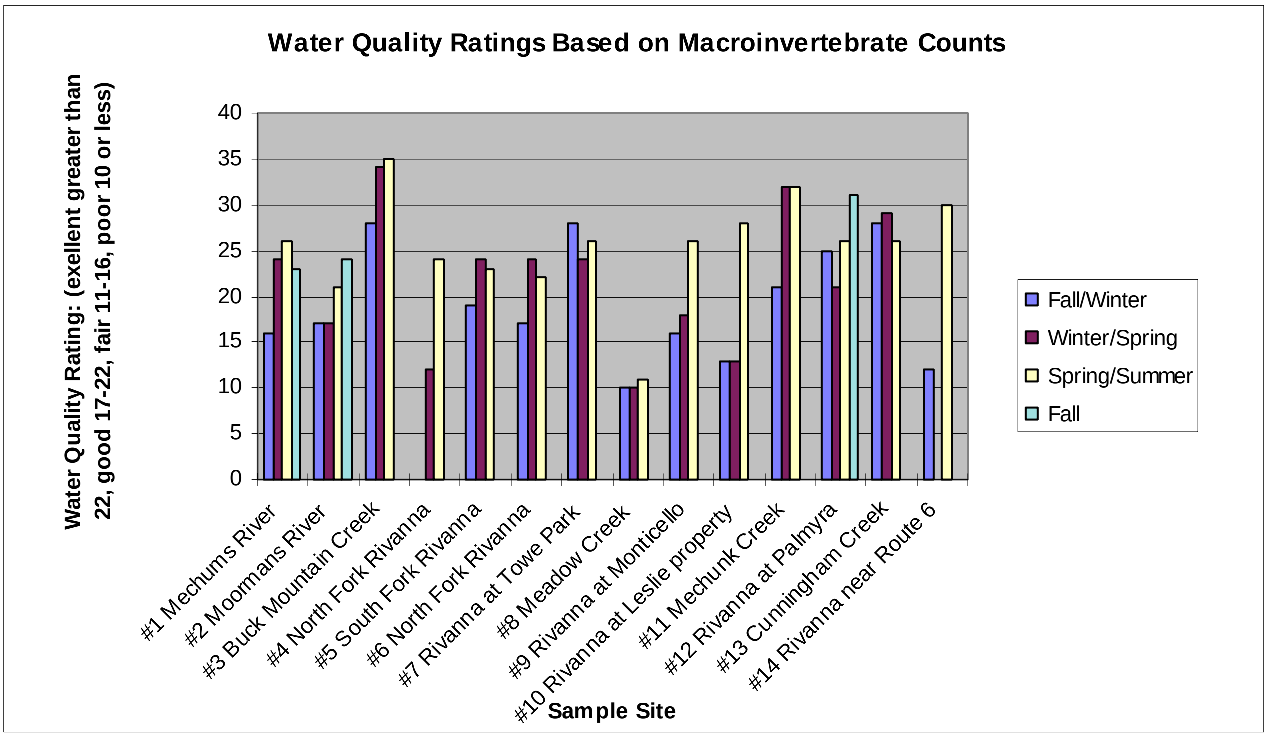
The above results lead to the conclusion that Meadow Creek definitely needs attention. Beyond the fact of the excellent score at each of the other sites, is not clear what the results mean for the remainder of the watershed. It is clear that a baseline data set will be useful in charting trends in future years. It is also necessary to remember that other factors may lead to concern for other segments of the basin.

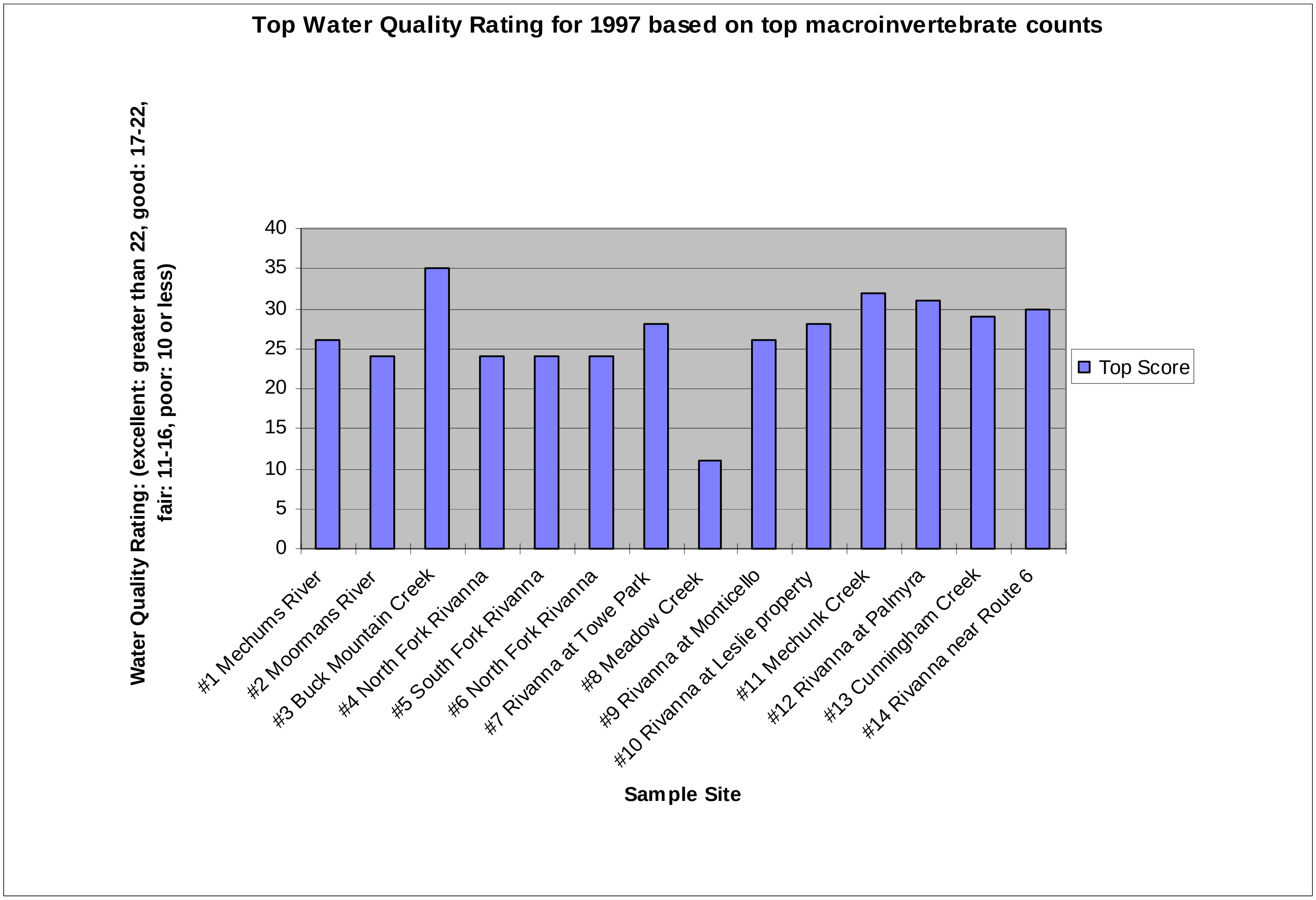
Based on the initial results, there appears to be no reason why any site across the basin should not achieve an excellent SOS score with regularity, based on “natural” conditions. Even with existing human impacts, Meadow Creek remains the only exception. Given that the physical habitat structure is excellent in Meadow Creek, the problem is the quality of the water in the creek. All sites with an excellent score are not the same. Buck Mountain Creek appears to be in a class by itself with a score of 35.

Using top SOS scores for each site, the water upstream of Charlottesville is of varied but generally excellent quality. The water generated within and around Charlottesville is of lesser quality. Major creeks feeding the Rivanna downstream of Charlottesville are of excellent quality, making it likely that some improvement in the river occurs downstream of these sources.

Current annual high SOS scores are consistent with historic data where there is overlap (Buck Mountain Creek/Rivanna River/Moormans River/Meadow Creek) with the exception of Buck Mountain Creek. Although the exact monitoring locations are different, one would expect similar scores over a period of less than ten years unless the watershed had undergone significant changes or a specific impact, such as a factory discharge, affected one monitoring location and not another. The difference in scores for Buck Mountain Creek could be explained by a dramatic improvement in water quality, but that is not likely. This difference in scores over a period of years illustrates the importance of maintaining the monitoring program. If there are trends, they will be recognized only if there is constant observation. Even if what appears as a trend turns out to be explained by monitor error or poor sampling conditions, this will not be verified unless there is ongoing monitoring.

**Top Macroinvertebrate Scores by Site**




Top Water Quality Rating for 1997 based on top macroinvertebrate counts
Water Quality Rating: (excellent: greater than 22, good: 17-22, fair: 11-16, poor: 10 or less)
0
5
10
15
20
25
30
35
40
Top Score
#1 Mechums River
#2 Moormans River
#3 Buck Mountain Creek
#4 North Fork Rivanna
#5 South Fork Rivanna
#6 North Fork Rivanna
#7 Rivanna at Towe Park
#8 Meadow Creek
#9 Rivanna at Monticello
#10 Rivanna at Leslie property
#11 Mechunk Creek
#12 Rivanna at Palmyra
#13 Cunningham Creek
#14 Rivanna near Route 6
Sample Site

**Fish**

VDGIF collections data were mapped by third-order watershed for the three species of Chub, for Redbreast Sunfish, and for Smallmouth Bass (see Map 5, 6, 7). None of the these species was found in the upper portions of the Swift Run watershed in Greene County, in the lower Mechums River Watershed, and in the South Fork Rivanna watershed in the area around Rt. 29 below the confluence with Ivy Creek. In addition, no smallmouth bass were found the upper portion of the Mechums River watershed and in the watershed below the confluence of the Lynch and the Roach Rivers along the Greene-Albemarle County line, and in the watershed immediately above the mouth of Swift Run, also along the Greene-Albemarle County line.

In addition, a map analysis was conducted to explore the relationship between the indicator species (any of the Chub species, Redbreast Sunfish, Fallfish, and Cutlips Minnow) and impervious surface in the third-order watershed in which the sample was collected. The table shows the number of watersheds in which 0-4 species was found, categorized by the Impervious Surface for each watershed. Of the ten watersheds with 3-4 indicator species, 8 had 0-10% (a low percentage) impervious surface values.

This finding is consistent with a study conducted by Schueler and Galli (1992) of the number of fish collected in four small streams in the Maryland Piedmont. As the percentage of imperviousness increased in the watershed, the number of species dropped. Sensitive species, defined as those with a dependence on the substrate for feeding or spawning, declined the most rapidly.

**Number of Piedmont Indicator Fish Species Found at Sampling Stations Classified by Average Impervious Surface of Third-Order Watershed:**

| | **Percent Impervious Surface** | | | |
|---|---|---|---|---|
| **Number of Piedmont Indicator Species** | 0-10% | 10.001-15% | 15.001-25% | 25.001-75% |
| 0 | 2 (67%) | 1 (33%) | | |
| 2 | 1 (100%) | | | |
| 3 | 4 (80%) | 1 (20%) | | |
| 4 | 4 (80%) | 1 (20%) | | |

After inspecting the maps and data prepared for the Roundtable, VDGIF Regional Fisheries Manager John Kaufmann commented that all of these watersheds should have the identified indicator fish species in them. The reasons indicator species were not found in some of the watersheds are unknown, and may include sampling error and/or water quality/habitat problems. Mr. Kaufmann also noted that *it is difficult to comment about the state of the fisheries in the region due to the limited data that is available.*

As a result of the Rivanna River Basin Project, VDGIF has pledged to undertake a systematic fish survey of the Rivanna Basin in 1998, using input from the Roundtable to guide areas where sampling should occur.

## Terrestrial Indicators

### Habitats in Watersheds

Four species-diversity-by-habitat-type maps were created: Forested Streamside Species, Closed Canopy Species, Area Sensitive, Mature Deciduous Species, and Game Bird Species.

The Forested Streamside Indicator Species map shows that 61% of the watersheds in the basin have none of the indicator species associated with this habitat, and 39% having one or more. (see Map 8) The Forested Streamside Indicator Species w/ Forest Cover Map (Map 9), considered below, shows a higher percentage of watersheds with forested streamside species in predominantly forested watersheds (59% compared to 41%).

**Forested Watersheds**

| *Species/Forest Cover Association* | # of watersheds | % of watersheds sharing particular forest cover classification by species classification |
|---|---|---|
| Forested streamside in 60-100% forest | 36 | 59 |
| Forested streamside in 20-60% forest | 31 | 55 |
| Forested streamside in 0-20% forest | 4 | 50 |
| No forested streamside in 60-100% forest | 25 | 41 |
| No forested streamside in 20-60% forest | 43 | 58 |
| No forested streamside in 0-20% forest | 4 | 50 |

The Closed Canopy Indicator Species Map (map 10) and the Closed Canopy Forest Species with Forest Cover (Map 11) considered with data below, show most of the watersheds having no closed canopy species (83%). Of these watersheds, the data suggests that as watersheds lose forest cover, the proportion of watersheds with no indicator species increase.

**Closed Canopy Species / Watershed**

| *Species/Forest Cover Association* | # of watersheds | % of watersheds sharing particular forest cover classification by species classification |
|---|---|---|
| Closed Canopy forest species in 60-100% forest | 17 | 27 |
| Closed Canopy Forest Species in 20-60% forest | 8 | 11 |
| Closed Canopy Forest Species in 0-20% forest | 0 | 0 |
| No Closed Canopy Forest Species in 60-100% forest | 44 | 73 |
| No Closed Canopy Forest Species in 20-60% forest | 66 | 89 |
| No Closed Canopy Forest Species in 0-20% forest | 8 | 100 |

The Area Sensitive, Mature Deciduous Forest Species Map (map 12) and the Area Sensitive, Mature Deciduous Forest Species with Forest Cover (Map 13) considered with the table below, shows a slightly higher proportion of heavily forested (60-100%) watersheds having higher species diversity. Species diversity seems to be unrelated to land cover at lower percentages of forest cover.

**Mature Deciduous Species**

| *Species/Forest Cover Association* | # of watersheds | % of watersheds sharing particular forest cover classification by species classification |
|---|---|---|
| 7-13 Mature Deciduous Species in 60-100% forest | 39 | 64 |
| 7-13 Mature Deciduous Species in 20-60% forest | 38 | 51 |
| 7-13 Mature Deciduous Species in 0-20% forest | 4 | 50 |
| 0-6 Mature Deciduous Species in 60-100% forest | 22 | 36 |
| 0-6 Mature Deciduous Species in 20-60% forest | 36 | 49 |
| 0-6 Mature Deciduous Species in 0-20% forest | 4 | 50 |

Map 14 shows the location of game bird species in the basin. What are particularly striking about this map are the watersheds where Bobwhite and Turkey were found around Charlottesville. This game bird map, as with the other species maps, show reduced diversity in the southern one-half of Charlottesville.

**Summarizing the analyses above:**
For heavily forested (60-100%) watersheds, there seem to be a slightly greater proportion of watersheds having Forested Streamside and Area Sensitive, Mature Deciduous indicator species than having none at all.

The proportion of watersheds with no Closed Canopy indicator species increases as percent forest cover in the watershed decreases.

In watersheds with low proportions of forest cover, there seems to be little relationship between land cover and Forested Streamside and Area Sensitive, Mature Deciduous species diversity.

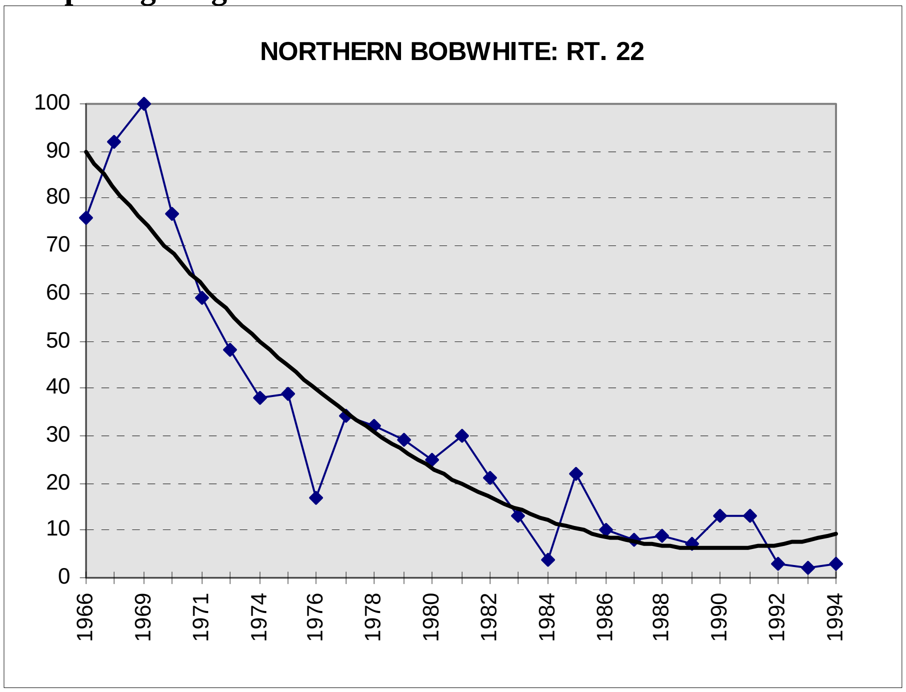
Of the areas sampled, nearly 2/3 of the areas have no Forested Streamside Species and over ¾ have no Closed Canopy species.

Diversity for all species categories is reduced in the basin south of Charlottesville.
The widespread absence of indicators of healthy forests is alarming because healthy forests produce high quality water.

This analysis seems to show that more heavily forested provide adequate habitat for some of the indicator species. The analysis also shows that for other species chosen for the project, less heavily forested watersheds seem to provide less adequate habitat.

**Breeding Bird Survey (BBS) and Christmas Bird Counts (CBC)**
To provide another window on the health of bird indicator species in the basin, the Rivanna River Basin Roundtable analyzed BBS and CBC trend data (see below for sample trend) for each of the indicator species (see Table below). A blank space in the table means for that particular species, a trend had not been plotted due to spotty historic data. Thus, the absence of data may only mean that insufficient data was available to create a plot, not necessarily that in any particularly year, no birds were spotted by BBS or CBC surveyors. A "D" means that the trend appears to be decreasing. An "S" means that the trend appears to be steady, neither increasing nor decreasing over time. An "I" means that the number of birds spotted appears to be increasing over time. A "D" and "I" together indicate that the trend seemed to change. An "NT" means that the variability in the data is sufficient that no trend could be discerned.

**Sample Sighting Trend**



**Bird Sightings**

| *Habitat/Species Type* | BBS: Route # 21 | BBS: Route #22 | CBC: C-ville | CBC: Warren | CBC: Big Flat |
|---|---|---|---|---|---|
| Forested Streamside Species | | | | | |
| • American Woodcock | | | | S | |
| • Acadian Flycatcher | D | D | | | |
| • Louisiana Waterthrush | | | | | |
| Closed Canopy Forest Species | | | | | |
| • Eastern Gray Squirrel | | | | | |
| • Eastern Fox Squirrel | | | | | |
| • Eastern Wood Peewee | D | D | | | |
| • Downy Woodpecker | D | S | S | I | I |
| Area Sensitive, Mature Deciduous Species | | | | | |
| • Cerulean Warbler | | | | | |
| • Black-billed Cuckoo | | | | | |
| • Black-throated Green Warbler | | | | | |
| • Worm-eating Warbler | | | | | |
| • Wood Thrush | D | D | | | |
| • Swainson's Warbler | | | | | |
| • Kentucky Warbler | | | | | |
| • Northern Parula | | | | | |
| • Scarlet Tanager | D, I | D | | | |
| • Summer Tanager | | | | | |
| • Ovenbird | D | I | | | |
| • Yellow-throated Vireo | | | | | |
| • Hooded Warbler | | | | | |
| • Pileated Woodpecker | NT | | I | I | I |
| • Red-bellied Woodpecker | D, I | D, I | I | I | I |
| • Hairy Woodpecker | | | S | S | I |
| Game Species | | | | | |
| • Wild Turkey | | | | S | I |
| • Black Bear | | | | | |
| • Bobwhite Quail | D | D | D | D | D |
| Other | | | | | |
| • Great Blue Heron | | | I | | NT |

What can be gleaned from this data? First, the downward trend in Bobwhite Quail counts are consistent across all five areas in which surveys/counts are conducted. This finding is consistent with bobwhite population trends in other areas of the state, as noted by VDGIF staff, and is widespread due to the transition from agricultural land. The increase in Pileated Woodpeckers and Red-bellied Woodpeckers may be due to regrowth of forests in some areas of the region that, thirty years or more ago, were previously used for agricultural activity (particularly in the mountains).

**Findings**
The presumption behind the inclusion of bird data in a watershed project is that in the long run, healthy habitats lead to stable hydrologic systems, which lead to healthy people and communities. It is a concern that of the areas surveyed in the BBA project, so many were found lacking in Forested Streamside and Closed Canopy bird indicator species. It is also a concern that decreasing percentages of forest cover seem to reduce Closed Canopy species diversity.

These findings should be considered in light of the build-out analysis for Albemarle County and Fluvanna County (Build-out Analysis for the Thomas Jefferson Planning District, 1996).

In Albemarle County in 1990, approximately 71% of the average net residential lot densities in the rural areas ranged from less than or equal to 1 housing unit per 100 acres to 1 housing unit per 21 acres. At build-out, the county's land use ordinances allow for 96% of the average net residential lot densities to range from 1 housing unit per 20.9 acres to 1 housing unit per acre. Explained in other terms, at build-out, nearly 75% of the rural areas of the county has the residential development potential of Barracks Road, as it currently exists, from Georgetown Road to Hunt Country Store.

In Fluvanna County in 1990, approximately 90% of the potential net residential lot densities ranged from less than or equal to 1 housing unit per 100 acres to 1 housing unit per 21 acres. At build-out, approximately 96% of the potential net residential lot densities range from 1 housing unit per 9.9 acres to 1 housing unit per acre. Explained in other terms, at build-out, most of county has the potential to equal or exceed the residential development densities currently seen at Lake Monticello.

Considering the manner in which residential development presently occurs in the basin, these build-out densities will appreciably reduce forest cover by watershed. The build-out study combined with the BBA data points to the need for long-term studies to understand the interplay between habitat and land use for these piedmont-blue ridge bird species. The data presented here and in the Trends for Indicators of Sustainability Report and Appendix are an excellent foundation for future research.

## Land Cover

The Land Cover/Impervious Surface Map (Map 15) shows that most of the region is now covered by the Forest classification (approximately 64%). The second largest land cover classification in the basin is Grazed Pasture Land (approximately 20%). 5+ acre Residences in Woodlands and One-Acre residences are the third largest land cover classifications at approximately 4%. The Mowed Lawns/ Moderately Grazed Pasture/Golf Courses and the Ungrazed Grass/Shrubland each comprise approximately 2% of the land cover in the basin. Other classifications of interest include Croplands at approximately 1% and ½-acre Residences, 1/3- acre Residences, and ¼-acre Residences collectively comprising approximately 2%.

When the Land Cover Map is aggregated to the Third-Order Watershed level (Map 16), a bisected distribution of land uses in the basin is revealed. At both the Western and Eastern ends of the basin, watersheds generally have 80-100% or 60-80% forest cover classifications. A generally decreasing % of forest cover (20-60% around the city, and 0-20% within it) is found moving toward Charlottesville City limits from either end of the basin.

Further aggregating the Land Cover Map to the Hydrologic Unit level (Map 17) shows that most of the sub-basins in the basin are over 60% forest, with three exceptions; Mechums River H.U. and the Charlottesville (Upper Rivanna) H.U. at 50-60% forest, and Ivy Creek with 30-40% forest.

In addition, a Water Quality/Viewshed Buffer Map (Map 18) consisting of land cover within 400 yards of the main stem and each of the major tributaries was created to provide information useful for a future Rivanna River Corridor Analysis. A buffer of this size was chosen for water quality (100' on either side of the stream is a commonly discussed width) and for viewsheds (400 yards is a very rough estimate of the viewshed in the stream valleys of the basin). The map is divided into 19 segments, each of which was analyzed for the percent of the segment found in each land cover/impervious surface category.(See Table next page)

In general, the highest percentage of land cover classification within the buffers of the basin is forest. The highest percentages of forested cover (approximately 75%) are found at Ballinger Creek, Preddy Creek, and Cunningham Creek, while Ivy Creek has the lowest (approximately 25%). The buffer around the Reservoir and Confluence to 64 (from the confluence of the North and South Fork of the Rivanna to Rt. 64) has the highest percent of 1 acre residences within the buffer (a little over 10%), while the lowest percentage is found on the mainstem of the Rivanna from Ballinger Creek to Columbia. The buffer along the Lynch River and the Rivanna River from Milton to the Albemarle County line has the highest percentage of grazed pasture (approximately 35%) while the South Fork Downstream (South Fork of the Rivanna from the reservoir to the confluence) has the lowest (approximately 8%). Percentages of crop activity within the buffer are generally low (0-5%), with one exception: in the South Fork Downstream segment 26% of the buffer has crop activity. Finally, the 0.25 Acre Residences and Pavement/Quarries categories are rarely found within the buffers of the basin. The exceptions are the Confluence to 64, with 11% 0.25 Acre Residence, and the Confluence to 64 and 64 to Milton with approximately 4% Pavement / Quarries.

**Table: Impervious Surface and Land Cover for 400-yard buffer in Rivanna River Basin**

| Impervious % | Category Name | Mechums | Moormans | Lynch | Swift Run | Preddy | Mechunk | Ballinger | Cunningham | Ivy Creek | North Fork |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Forest | 61.23 | 63.95 | 55.88 | 60.00 | 79.18 | 69.23 | 79.26 | 71.18 | 26.25 | 55.94 |
| 2 | Ungrazed grass/shrubland | 0.00 | 0.00 | 4.24 | 4.82 | 1.99 | 1.23 | 5.52 | 10.86 | 0.00 | 0.94 |
| 3 | 5+ acre residences in woodlands | 8.65 | 3.91 | 0.07 | 1.47 | 0.89 | 0.24 | 0.00 | 0.00 | 34.85 | 9.16 |
| 10 | Lawn/mod. Grazed pasture/golf | 0.00 | 0.00 | 0.00 | 14.14 | 0.04 | 9.33 | 0.00 | 0.00 | 1.55 | 0.00 |
| 10 | 1 acre residences | 2.84 | 1.91 | 2.23 | 1.81 | 1.29 | 1.26 | 0.75 | 0.44 | 7.63 | 3.73 |
| 12.5 | Orchards | 0.00 | 0.27 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.00 |
| 15 | Grazed pasture lands | 21.45 | 28.97 | 36.43 | 15.85 | 14.72 | 18.54 | 14.47 | 17.52 | 24.62 | 23.16 |
| 25 | 0.5 acre residences | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | Crops | 5.83 | 0.97 | 0.93 | 1.91 | 1.80 | 0.13 | 0.00 | 0.00 | 3.90 | 6.94 |
| 35 | 0.25 acre residences | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 100 | Pavement/ Quarries | 0.00 | 0.02 | 0.10 | 0.00 | 0.09 | 0.03 | 0.00 | 0.00 | 0.06 | 0.13 |

Table cont'd: Impervious Surface and Land Cover for 400-yard buffer in Rivanna River Basin

| Impervious % | Category Name | South Fork Upstream | Reservoir | South Fork Downstream | Confluence to 64 | 64 to Milton (Camp Branch) | Milton to Alb. Line | Alb. Line to Mechunk | Mechunk to Ballinger | Ballinger to Columbia | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Forest | 70.90 | 57.91 | 42.06 | 34.04 | 61.62 | 48.35 | 67.18 | 71.29 | 65.36 | 61.12 |
| 2 | Ungrazed grass/shrubland | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.97 | 4.15 | 5.99 | 2.21 |
| 3 | 5+ acre residences in woodlands | 3.69 | 14.72 | 13.14 | 9.01 | 6.57 | 3.59 | 2.14 | 0.00 | 0.00 | 5.58 |
| 10 | Lawn/mod. grazed pasture/golf | 0.00 | 0.13 | 0.00 | 9.22 | 0.13 | 3.75 | 12.25 | 0.65 | 0.00 | 2.91 |
| 10 | 1 acre residences | 1.83 | 11.27 | 8.49 | 13.34 | 1.15 | 1.59 | 0.56 | 4.65 | 0.15 | 3.22 |
| 12.5 | Orchards | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.09 |
| 15 | Grazed pasture lands | 16.94 | 15.01 | 8.41 | 10.84 | 26.34 | 36.24 | 14.11 | 18.12 | 28.50 | 21.44 |
| 25 | 0.5 acre residences | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.14 | 0.00 | 0.06 |
| 25 | Crops | 6.63 | 0.88 | 26.08 | 8.29 | 0.00 | 6.33 | 0.79 | 0.00 | 0.00 | 2.73 |
| 35 | 0.25 acre residences | 0.00 | 0.00 | 0.00 | 11.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 |
| 100 | Pavement/ quarries | 0.00 | 0.09 | 1.82 | 4.14 | 4.18 | 0.06 | 0.00 | 0.00 | 0.00 | 0.30 |

## Findings

Impervious Surface within the basin was grouped into four classifications; Healthy (0-10%), At-Risk (11-15%), Degrading (16-25%), and Degraded (26-100%) (Map 19). These classifications are based on recommendations developed by the Metropolitan Washington Council of Governments and the Center for Watershed Protection (Shuler, 1995). Impervious surface of 10% or less has not been found to negatively impact water quality or aquatic biology. Watersheds with impervious surface greater than 10% have been found to correlate well with declining aquatic biology diversity and impaired water quality. "Healthy" means that the amount of impervious surface is below the threshold generally found to impair stream health. "At-risk" means that the amount of impervious surface may be starting to have a negative impact, "Degrading" means that the amount of impervious cover is sufficient to cause a significant decline in stream health, while "Degraded" means that the impervious cover is sufficient to have eliminated much of the natural stream biology (Shuler, 1995).

Approximately 76% of the basin is classified as healthy (0-10% imperviousness). The largest contiguous areas are found in the Blue Ridge Mountains and the Southwestern Mountains. 21% of the basin is classified as At-risk, most of these areas in the rural foothills surrounding the growth areas of Albemarle County, the agricultural area of the Rt. 231 corridor stretching from Shadwell north and in scattered pockets throughout Fluvanna County. Approximately 2% of the basin is classified as Degrading, these areas being confined to Lake Monticello and the growth areas of Albemarle County. 1% of the basin is currently classified as Degraded, with the majority of these areas found in Charlottesville and the Growth Areas of Albemarle County.

All of the impervious cover classifications within each of the third order watersheds were averaged to produce an Impervious Surface Map by Watershed (Map 20). This map shows watershed-wide impervious surface classifications, and reveals a more easily defined pattern of impervious surface. Although most of the watersheds in the basin have an average impervious surface classification of Healthy, watersheds in the Crozet, Ivy, 29 North, of Albemarle County, along with the Lake Monticello watershed, have an impervious surface classification of At-risk. Watersheds with an impervious surface classification of Degrading are also found in the 29 North area of Albemarle County, and in the Free Bridge area east of Charlottesville. All of the watersheds in Charlottesville have an impervious surface classification of Degraded.

## Citizen Involvement

Continued citizen involvement is seen in the participation in the SOS monitoring under the aegis of the Environmental Education Center. It is hope the recent announcement of support by Governor James Gilmore will include funding for this effort. In addition, focus is on the Rivanna River for River Day on May 9$^{th}$. The Roundtable will have an information table with an interactive electric question/answer board as well as a brochure describing the Roundtable work and recommendations. T-shirts with "Putting the Shad Back in Shadwell" with the name of the Rivanna River Roundtable will be given away to spike community interest. The information gathered in this report provided the basis for the discussion of Tributary Strategies in the urbanizing areas of the planning district area. This work was done as part of the overall effort by the Virginia Department of Conservation and Recreation. The Roundtable will be presenting the report to all the local governments, having already done so with the Thomas Jefferson Planning District Commission. The members are developing a strategic plan for moving ahead with the recommendations. The role for citizen involvement is an exciting one in this community of volunteers. This report has laid the groundwork for additional study, volunteer activity, local government planning, and regional cooperation, using the Basin as a common ground.

# IX. Recommendations

Context. High levels of Nitrogen, Phosphorous and Fecal Coliform are found in our waters, throughout the Basin, during storm events. Compared to levels of these pollutants during base flow conditions, storm water run-off emerges as an important non-point source for these pollutants. Vegetated buffers (or "filters") of trees, shrubs and grasses have been shown to slow storm water run-off and encourage percolation, thus reducing the volume of storm flow, while filtering 70 - 80% of water borne pollutants. "Buffer strips create stable stream flow, stabilize stream banks, reduce suspended sediment and turbidity, lower summer water temperatures, and filter chemical and organic pollution. They can also slow topsoil loss from agricultural area, combined with erosion prevention practices on farmland. A healthy riparian zone also benefits terrestrial wildlife." [Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects and Control. American Fisheries Monograph 7.]

1. **Community Design Recommendation**. Determine the appropriate buffer width for the major tributaries and main stem of the Rivanna River, specific to the geological and biological parameters of this region. Studies in other areas have concluded that 100 feet is a useful standard for buffer width.
2. **Community Design Recommendation**. Through BMP and cost share programs, develop vegetated buffers along watercourses throughout the basin.
3. **Community Design Recommendation**. Demonstrate the value of vegetated buffers by creating, on public land, low maintenance vegetative buffers to stabilize stream banks and reduce storm water run-off . Make information on these publicly constructed buffers available for emulation on private land.
4. **Corridor Plan Recommendation**. Ask local governments to institute policies to encourage the development of buffers and to develop priority locations for their implementation. Establish mechanisms to promote the establishment of buffers, in a manner that is fair to riparian landowners.

Context. The levels of Nitrogen and Phosphorus in our waters, although high during storm events, may not typically be sufficient to jeopardize the health of aquatic life within our region. However, these pollutants do accumulate in the streams and rivers, building up in concentration on their way to the James River and the Chesapeake Bay.

5. **Knowledge Base Recommendation**. As part of the James River Tributary Strategy, the DEQ should investigate the effects of the nutrient accumulation in our waters on the eventual nutrient loading of the Chesapeake Bay. Develop target maximum loads based on the ongoing efforts to avoid eutrophication of the James River and the Bay.

Context. Throughout the Basin, Fecal Coliform counts during storm flow conditions frequently exceed the Department of Environmental Quality maximum standard suitable for human contact.

6. **Knowledge Base Recommendation**. The DEQ's Ambient Water Quality Monitoring Program should determine the origin of the Fecal Coliform found in the waters of the basin (humans, cattle, pets, other).

7. **Stewardship Recommendation**. Animal waste should be kept out of the streams and rivers in order to maintain water quality at levels that are safe for human health.
8. **Stewardship Recommendation**. Make available to farmers information about Best Management Practices (BMP) and cost share programs to help them keep their animals out of surface waters.
9. **Knowledge Base Recommendation**. Survey the area around the Leslie monitoring location to understand the very high levels of Fecal Coliform at this point.

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Context. At two sites in the Rivanna River, in May 1997, the DEQ collected single samples with Fecal Coliform at high enough levels for a designation of "contaminated" to be applied. In order for the EPA designation of "contaminated" to be used, however, a minimum of 5 samples must be tested to obtain the mean value.

10. **Knowledge Base Recommendation**. The Department of Environmental Quality should follow through with the multiple sample protocol developed by the EPA when there are indications of excess Fecal Coliform.

Context. Portions of the Rivanna River are identified by the DEQ as not supporting water quality standards and have been listed on the state's (303(d)) list of the most polluted waters, for which the Commonwealth should develop "Total Maximum Daily Loads (TMDLs)". Virginia has not yet enacted TMDL's for point and non-point source pollution.

11. **Resource Organization Recommendation**. The DEQ should develop and implement TMDL's for the designated 303(d) listed streams and rivers in the basin to assure good water quality for people and aquatic life.

Context. Based on the 1996-1997 water quality data collected by the RRBR, selected pollutants related to non-point source run-off (Total Suspended Solids-TSS, Phosphorus, Nitrogen, Fecal Coliform) are consistently higher during storm flows on the Mechums River, the North Fork, Meadow Creek, and portions of the main stem of the Rivanna River.

12. **Knowledge Base Recommendation**. The City of Charlottesville should study Meadow Creek, Albemarle County should study the Mechums River and the North Fork, and Fluvanna County should study the main stem to determine the locations of the non-point source pollution.

Context. Meadow Creek has the worst water quality in the region as determined by the Isaac Walton League Save our Streams methodology. More so than any other stream in the watershed, Meadow Creek has been channelized and placed underground, primarily in its headwaters. Much of the headwaters of Meadow Creek have been placed in pipes under the Grounds of the University of Virginia over the years. Depriving those portions of the creek of sunlight and fresh air has severely impacted the natural biological processes and water cleansing ability of the creek.

13. **Resource Organization Recommendation**. Convene a joint City and University of Virginia task force to develop a plan for the restoration of Meadow Creek, focusing on strategies for bringing the entire length of the creek back to the surface.
14. **Knowledge Base Recommendation**. Identify the nature and source of toxins responsible for the loss of macro-invertebrate species diversity in Meadow Creek.
15. **Knowledge Base Recommendation**. Perform SOS monitoring in the headwaters of Meadow Creek to develop a baseline for assessment of the monitoring downstream.

Context. Several monitoring stations had consistently higher levels of metals in the sediments. The highest levels of metals were found at both of the stations on the North Fork, and at the stations at the South Fork, Monticello, Leslie and Cunningham Creek.

16. **Knowledge Base Recommendation**. Determine the source of the metals found in the sediment, undertake research to identify safe levels, and determine strategies for cleaning the sediments.

Context. The pre-European settlement morphology of our stream and riverbeds has changed due to land use changes. Over the past 300 years, deforestation, row crop agriculture, soil compaction in pastures, road and town building and the construction of impervious surfaces has caused much more water to flow into the streams and rivers during, and immediately after, rain fall events. Less water from rainfall is retained within the ground to replenish the basin's groundwater resources. The resultant storm flow has gouged deeply into the substrata. Our streams and riverbeds are often characterized by unstable channels, which are eroded both by undercutting and run-off. Current scholarship suggests a causal link between the area of impervious surfaces in a watershed and the water quality within that watershed. Within the Rivanna River Basin, there are 25 "third order" (that is, sub-sub-basins) watersheds that have problems: 15 are classified as "At Risk"- having an average imperviousness of 10 - 15%; three are classified as "Degrading" with an imperviousness of 16 - 25%; and seven watersheds (primarily associated with the urban area of the City of Charlottesville) which are classified as "Degraded" having an imperviousness of over 25%. Restoration/mitigation and improved land use and water management is necessary in the 25 watersheds that have already exceeded the 10% threshold.

17. **Corridor Plan Recommendation**. Target imperviousness to no more than 10% per third order watershed throughout the basin in order to maintain or restore water quality in all third order watersheds. The appropriate strategies and Best Management Practices (BMP's) will vary according to the circumstances of each watershed and its land use.
18. **Knowledge Base Recommendation**. Perform further field checking of the Impervious Surface/Land Cover Map (developed for the Rivanna River Basin Roundtable) from which the imperviousness calculations have been made to assure an accurate base line against which to measure progress over time.
19. **Community Design Recommendation**. Institute procedures within each jurisdiction so that increases in the area of impervious surfaces can be systematically recorded throughout the basin. In preparation for its 5 year review and comprehensive land use plan update, each locality should produce an updated land cover map of the region to

record progress toward reducing impervious surfaces, and maintaining and restoring land cover and healthy surface hydrology.

20. **Community Design Recommendation**. Develop and codify a program of practices to mitigate impervious surfaces in new development. These practices could include:

- Using deep rooted native plants to promote infiltration and develop healthy soil
- Reducing the amount of asphalt and other impermeable paving surfaces
- Permitting the use of narrower streets
- Reducing parking requirements
- Promoting the use of permeable materials for pavement
- Using vegetated swales in lieu of concrete gutters, catch basins and underground storm water piping
- Constructing rain gardens to slow and filter storm water at each residential lot
- Using constructed wetlands to trap sediment, slow the progress of run-off and filter pollutants.

21. **Community Design Recommendation**. Review local zoning and planning ordinances and Virginia Department of Transportation regulations for obstacles to achieving reduced imperviousness.

Context. Because sediment is the most serious pollutant in our streams and rivers, efforts should be made to identify current sources of sediment losses and rigorously enforce regulations for sediment control (at construction sites, on roads and highways, and on agricultural lands). Moreover, most, if not all, watersheds outside the headwaters, currently include streams and rivers with highly unstable channels. These channels are characterized by high width-to-depth ratios, broad shallow channels, and high vertical banks of exposed soil that collapse into the channel in high water conditions. We need to reestablish the natural shape and meander patterns to the stream and riverbanks and their flood plains to reduce sediment loading and habitat disruption.

22. **Community Design Recommendation**. Local governments should develop demonstration projects for planting native vegetation on stream and riverbanks on public land. Each jurisdiction should establish an annual target for streambank restoration and improvement in order to move toward greater stability throughout the watershed.
23. **Resource Organization Recommendation**. Local governments and the Soil and Water Conservation districts should form partnerships for buffer and stream bank improvement and restoration efforts.
24. **Resource Organization Recommendation**. Integrate Virginia Department of Forestry tree planting programs into public and private efforts to stabilize stream banks and develop vegetated buffers.
25. **Knowledge Base Recommendation**. Monitor the movement of sandbars and bank erosion rates to track the generation, accumulation and movement of sediment, as a means of identifying sources of new sediment within the waterways.
26. **Resource Organization Recommendation**. Encourage local governments to develop a consistent level of inspection and enforcement of soil and sediment control plans, so that all areas of the watershed may benefit from the same level of protection.

Context. The shape and structure of streams are in a constantly dynamic state which results from the interrelationship of many factors, including: amount of precipitation, soil compaction, infiltration rate, subsurface flow, overland flow, sediment load, elevational fall, bank cutting, water velocity and channel length. Natural or man-made changes in any of these variables will cause corresponding adjustments throughout the system. Current linear models for assessing the relationships between these interrelated elements of the surface hydrologic system have proven inadequate, either for anticipating the effects of changes to the system or for developing coherent public policy.

27. **Knowledge Base Recommendation**. Identify new tools for modeling these critical inter-relationships using a systems dynamics approach. Encourage state and local governments to apply this approach in the development of public policy.

Context. Recent studies have shown that variability in stream flows is an important factor in stream health. Rivanna Water and Sewer Authority (RWSA) has not developed standards for water supply diversions related to minimum in-stream flow. The quantity of water discharged by the RWSA is primarily related to maintaining sufficient quantity within the reservoirs for use by the Authority's customers, and maintaining a minimum flow for the dilution of effluent from the Moores Creek Sewage Treatment Plant. RWSA releases water from the South Fork Reservoir at the base of the dam. This water, due to thermal stratification within the reservoir, can be significantly oxygen deprived, resulting in compromised aquatic habitat below the dam.

28. **Resource Organization Recommendation**. RWSA should establish guidelines and procedures for the operation of the reservoirs based on the attainment of biological/habitat goals downstream. Procedures, such as aeration, should be developed to increase the oxygen content in the discharged water.
29. **Knowledge Base Recommendation**. Local governments should request that the Rivanna Water and Sewer Authority initiate an on-going study of the relationships between in-stream flow, biological conditions and reservoir operations for review by the local governments.
30. **Resource Organization Recommendation**. RWSA should establish a "Flow Committee" to determine minimum in-stream flows and procedures that will support the needs of aquatic plants and animals downstream.
31. **Knowledge Base Recommendation**. Encourage the RWSA to make use of an integrative methodology, such as the "Range of Variability Analysis" method developed by the Nature Conservancy, in the study of in-stream flow requirements.

Context. According to representatives of the Virginia Department of Game and Inland Fisheries (VDGIF), the Piedmont is the least surveyed area of the Commonwealth, with regards to wildlife. Similarly, the waters of the Piedmont have not been studied or protected, at the state level, nearly to the extent of the waters of the Tidewater, presumably due the emphasis on the important on-going efforts toward the restoration of the Chesapeake Bay.

32. **Resource Organization Recommendation**. The State Legislative Delegation, which represents the Rivanna River Basin, should insist on monetary support for research and monitoring of the unique natural resources of our region.
33. **Knowledge Base Recommendation**. The VDGIF should undertake research to determine necessary habitat requirements for Piedmont fish and shellfish, similar to the research incorporated in the publication "Habitat Requirements for Living Resources of the Chesapeake Bay".

Context. The VDGIF fish surveys in the area have not included all 10 hydrologic units, and are too infrequent to determine trends either in species diversity, or in most fish populations; nevertheless, the surveys suggest a local decrease in an ecologically important game fish, smallmouth bass. Also, the sites of fish surveys are not co-located with chemistry, hydrology, habitat, or stream invertebrate surveys.

34. **Knowledge Base Recommendation**. VDGIF should present a plan to initiate regular fish surveys in all of the 10 hydrologic units in the area, at carefully chosen sites, co-located with other kinds of monitoring, so that trends in the fish community may be associated with trends in other important measures of the health of the River. VDGIF should investigate and report on any fish species showing a significant change in occurrence relative to previous surveys.

Context. Current scholarship indicates strong linkages between healthy bird populations and the health of their stream side, forest and grassland habitats. We have available, in the area, high quality annual counts of bird populations going back for 30 years (Breeding Bird Surveys - BBS) and 50 years (Christmas Bird Counts - CBC). This data can be used now and in the future to monitor the condition of desirable elements in our landscape. Unfortunately, there are only a few BBS and CBC sites in the Rivanna Basin.

35. **Knowledge Base Recommendation**. Encourage the US Fish and Wildlife Service and the Audubon Society, which coordinate the surveys and counts, and local volunteer groups, which execute the surveys and counts, to establish new sites in the Rivanna River Basin, especially in the riparian areas.

Context. The Isaac Walton League Save Our Stream (SOS) methodology measures the diversity of animals at the beginning of the aquatic food chain ("benthic macro-invertebrate species"), and is a way to assess the impact of toxic pollutants in surface waters. It is a protocol widely recognized to measure water quality.

36. **Knowledge Base Recommendation**. Continue the network of volunteers using the SOS protocol and monitoring at the 14 sites used in the Rivanna River Basin Roundtable sampling. Continue to test these 14 sites four times a year to develop trend data over time. Assist current teams in becoming self-sufficient so that they can schedule the tests to optimized monitoring conditions. Local governments should help fund the Environmental Education Center to continue its management role of this cost-effective volunteer program.

37. **Knowledge Base Recommendation**. Expand the SOS monitoring effort to include sites at the headwaters of the basin.
38. **Knowledge Base Recommendation**. Expand the SOS monitoring effort to include observations of aquatic plants which are associated with good water and habitat quality. Determine which aquatic plants are "indicator species."

Context. For meeting present and foreseeable water supply needs, the Rivanna River Basin is "water adequate", but not "water rich", as it is sometimes characterized. By "water adequate", we mean that the part of precipitation which becomes stream flow and groundwater, after evapo-transpiration takes its share, is sufficient to meet the needs of users in the basin for many decades, perhaps centuries. Further:

Ground water, while adequate in many places for domestic users, is not a reliable supply for municipal and industrial water use. The Rivanna River and its tributaries are "flashy waters" in which there can be great variability between high and low flows, ranging from conditions of flooding to drought-caused trickles, especially in the headwater areas.
Surface water storage sites, which might allow storage of years of precipitation do not exist, or are not compatible with competing land uses.

39. **Stewardship Recommendation**. Forecasts of future water supply needs should consider aggressive water conservation strategies to postpone or eliminate the need for costly reservoirs.
40. **Stewardship Recommendation**. Plans for increasing the reliability of municipal water supply should include the option of reclaiming both waste water and storm water for reuse.
41. **Community Design Recommendation**. Plans for increasing the reliability of municipal water supply should look at all reasonably possible storage alternatives to the construction of new reservoirs.

Context. Population increases sometime exceed the availability of locally or regionally available water, resulting in the transfer of water from one basin to another. For many years this option has been discussed in the Virginia Beach area. While we believe that the Rivanna River Basin has the resources *and the will* to remain self-sufficient from the perspective of water supply, there has been discussion of transferring water from the Rivanna River Basin to the South Anna/Pamunkey/York River Basin to allow further growth in Zion Crossroads, which straddles the ridge between the two basins.

42. **Resource Organization Recommendation**. Initiate a public dialog on the topic of inter-basin water transfer to assure that the larger context of the subject is considered as part of the decision making. Additional water should not be withdrawn from the Rivanna River until standards for in-stream flow have been developed.

Context. In 1996, the City of Charlottesville, Albemarle County and the University of Virginia commissioned the "Moores Creek Watershed Study". This analysis predicted changes in water run-off patterns as a result of increased urbanization within that watershed. The analysis found that more impervious surfaces speed the run-off on its course, concentrating it in a shorter period of time. The report also predicted a lower infiltration rate, resulting in a larger storm flow volume, greater erosion potential during storms, and lower base flows between storms. The Roundtable's analysis of historic flow data has concluded that, although there have not been significant changes in precipitation, the following trends in flow, associated with urbanization, can be identified throughout the basin:

- Increases in mean daily flows
- Increases in stream flow variability
- Increases in annual high flows
- Decreases in annual low flows

43. **Knowledge Base Recommendation**. Apply the "Moores Creek Watershed Study" methodology to those watersheds within the basin which are most likely to see the greatest rates of increases in development. Determine the need for further on-site reductions to storm water run-off and storm water retention and implement strategies to effect these reductions.
44. **Resource Organization Recommendation**. The City of Charlottesville, Albemarle County and the University of Virginia should implement the recommendations of the Moores Creek Watershed study, such as:

- Develop storm water management practices and policies.
- Develop proactive flood hazard mitigation practices.
- Develop a prioritized remedial plan for watershed improvements.
- Develop a monitoring program.
- Implement a public awareness and education program.

Context. The flow data from Palmyra suggest that the quantity of water in the river during low flow conditions has been decreasing over time, despite no corresponding decrease in precipitation.

45. **Knowledge Base Recommendation**. The DEQ, the local jurisdictions and the University of Virginia should undertake a joint study to examine what appears to be a steady decrease in the low flows in the Rivanna River at Palmyra, and generate proposals to reverse this trend.

Context. Assessment of whether undesirable changes in stream flow are occurring in some tributaries of the Rivanna River could not be accomplished during this project due to the absence of currently active gauging stations on the tributaries of interest. Furthermore, a determination of what is *causing* the undesirable changes in stream flow in the main stem of the Rivanna River, and in those tributaries which *are* currently monitored by stream flow gauges, was hampered by the absence of readily accessible and reliable historical and current information about such things as groundwater levels, evapo-transpiration, runoff rates, etc.

46. **Knowledge Base Recommendation**. The Department of Environmental Quality should develop and implement a reporting plan designed to deliver relevant information concerning the health of the Rivanna River Basin, in a timely manner, to interested local governments and members of the public. We recommend establishment and operation of a centralized data management site, perhaps at an appropriate state-supported college or university, to accomplish these data collection, data analysis, and reporting goals. We envision a regional site performing a data management and research role for the Rivanna River Basin similar to the statewide role currently performed by the State Climatology Office, which is located at the University of Virginia.

Context. The United States Geological Survey (USGS) currently provides some stream flow data (current gauge readings, historical daily mean flows, and historical peak flows) on-line at a World Wide Web site. Because this data is stored and accessible electronically, its availability and utility is greatly enhanced. Other data types which would have been useful for this study, but which were not used because they were not readily available electronically include historical "unit" values, the periodic gauge readings taken once every 15 or 30 minutes which are used for calculating daily mean flows, as well as many data types managed by agencies other than the USGS.

47. **Knowledge Base Recommendation**. The USGS should make historical unit values (flow and stage) available electronically, much as historic daily mean flows and historic peak flows are available now. Similarly, the Department of Environmental Quality and other agencies managing data relevant to the health of the Rivanna River Basin should make their data available to the public electronically.

Context. Historically, towns were sited to take advantage of the commercial potential of the rivers as transportation routes. Many early farms and plantations faced the rivers. Mills and factories were similarly located along the rivers to make use of the energy and transportation potentials of the waterways. However, in recent times, buildings and developments in the region have been oriented away from the rivers and streams.

48. **Corridor Plan Recommendation**. Promote public and private use of existing commercially and industrially zoned riverfront land to better utilize this setting, with uses such as outdoor restaurants and river sports shops. Encourage existing businesses to restore, improve and utilize their river frontage, including flood plains, as a public space. Develop river frontage in ways that allow the free flow of floodwaters and help bring the riverbanks back to a state of natural equilibrium.
49. **Corridor Plan Recommendation**. Support the expansion of any designation of the James River as an American Heritage River to include the Rivanna River and its tributaries.
50. **Corridor Plan Recommendation**. Ask the General Assembly to designate all of the Rivanna River as a State Scenic River.
51. **Corridor Plan Recommendation**. Support designation of the Moormans River and other selected tributaries as Virginia Tier 3 (exceptional waters) by the State Water Control Board.

Context. Although many rivers in the watershed are navigable at least part of the year, the only boat launching facilities are located on the reservoirs and at three locations along the Rivanna River (Palmyra at Route 15, Crofton at Route 600 and Milton at Route 729.)

52. **Corridor Plan Recommendation**. Request that local governments identify and develop new public boat access points on the Rivanna River above and below the Woolen Mills dam and at selected points on the South Fork Reservoir, North Fork, South Fork, Mechums River and Moormans River. Make use of sites with existing public use or ownership and existing parking areas in the development of new access points, for example at Towe, Pen, or Riverview Parks, Ivy Creek Natural Area, or the Fluvanna Heritage Trail. Additional information needs to be gathered as to the riparian rights of certain landowners, which may exclude the public from the waterway.
53. **Corridor Plan Recommendation**. Ask local governments and the Metropolitan Planning Organization to request Virginia Department of Transportation to improve access to rivers and streams at existing publicly-owned crossings (bridges) by steps or trails that minimize impact on the banks.

Context. Although the navigable waters of the basin connect numerous sites of historical, ecological and cultural interest, boaters and travelers along the banks have no readily available information about these sites or events connected to them.

54. **Corridor Plan Recommendation**. Ask a partnership of private individuals, historical organizations and governments to create a series of river identification signs at access points for boaters and walkers that describe significant historic sites, events or physical characteristics of the River and its tributaries. Identify the location of historic sites in general terms only, to protect sites from vandalism and theft.

Context. Very few of the many miles of the Rivanna River and its primary tributaries are served by publicly accessible trails. Of these trails, some are on private property, most under agreements negotiated by the Rivanna Trails Foundation, the City of Charlottesville or Albemarle County. Many of the City's public parks adjoin the Rivanna River or one of its tributaries, and the City has made trails along these tributaries a priority.

55. **Corridor Plan Recommendation**. Encourage a partnership between local governments and citizens groups to develop a plan to link publicly accessible trails for walking, jogging and bicycling along the Rivanna River and its primary tributaries, beginning with any publicly owned lands but extending through privately held property through the acquisition of easements and in some cases, real property.
56. **Corridor Plan Recommendation**. Discuss the possibility of a Rivanna River Corridor Linear Park as a state park under the Virginia Department of Parks and Conservation.

Context. The Rivanna River basin contains many sites of historical importance which deserve special focus and attention. Because there are only a finite number of sites, some of which have already been lost over time and others of which are currently feeling the pressures of the area's growth, there exists a need to preserve and protect historic river resources. This need can be accomplished through developing policies on all government levels and also through the education of the citizens of the basin and the governments which represent them.

57. **Corridor Plan Recommendation**. Modify the various county comprehensive plans to include the historic resources along the Rivanna and its tributaries.
58. **Corridor Plan Recommendation**. Nominate outstanding buildings and sites, including locks, to the Virginia Landmark Register and the National Register of Historic Places.
59. **Corridor Plan Recommendation**. Promote the donation of historic easements to the Department of Historic Resources and conservation easements to the Virginia Outdoors Foundation for the basin's most significant properties.
60. **Corridor Plan Recommendation**. Promote the preservation and rehabilitation of historic structures or other resources associated with the river and its primary tributaries, through State and Federal rehabilitation tax credits, tax incentives (such as real property tax adjustments and reduced federal and state estate taxes) and historic loan pools with low interest rates to provides technical assistance and rehabilitation funds.
61. **Corridor Plan Recommendation**. Encourage local governments and private developers to professionally identify, assess and protect archeological resources within the river corridor prior to development.
62. **Corridor Plan Recommendation**. Incorporate within the proposed Corridor Plan all aspects of an historic district ordinance.

Context. The Rivanna River Basin consists of parts of Greene County, Albemarle County, Orange County, Fluvanna County and the City of Charlottesville. Each of these political jurisdictions has its own unique set of land use plans and ordinances. There is no consistent or coordinated approach to management of the common riparian resources shared by the several jurisdictions.

63. **Corridor Plan Recommendation**. Ask local governments to fund the development of a Rivanna River Corridor Plan incorporating local land use plans; best management practices; historic and archeological sites, recreational areas, uses and access points.
64. **Corridor Plan Recommendation**. Ask local governments to incorporate watershed planning into their zoning/land use plans and to share and coordinate these plans.

Context. It appears that the various federal, state and local agencies that have responsibility for the waters of the basin are not necessarily working in a coordinated manner. Data collection in particular is not organized in a manner allowing the derivation of correlations or the drawing of conclusions. Among these water resource agencies are:

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Local
  City and County Planning Departments
  City and County Engineering Departments

Rivanna Water and Sewer Authority (RWSA)
Albemarle County Service Authority (ACSA)

Regional
Thomas Jefferson Planning District Commission (TJPDC)
Thomas Jefferson Soil & Water Conservation District (TJSWCD)
Culpeper Soil and Water Conservation District

State
Department of Environmental Quality (DEQ)
Virginia Department of Health (VDH)
Division of Mineral Resources (DMR)
Department of Conservation & Recreation - Division of Soil & Water Conservation (DCR-DSWC)
Chesapeake Bay Local Assistance Department (CBLAD)
Virginia Marine Resources Commission (VMRC)
Department of Game and Inland Fisheries (VDGIF)
Virginia Department of Agriculture & Consumer Services (VDACS)
Department of Emergency Services (DES)
Groundwater Protection Steering Committee

Federal
US Army Corps of Engineers (COE)
US Environmental Protection Agency (EPA)
Natural Resources Conservation Service (NRCS)
US Geological Survey (USGS)
Federal Emergency Management Agency (FEMA)

65. **Resource Organization Recommendation**. Pursue funding sources within the community to establish a mechanism or organization that will promote and coordinate data collection, create a data archive, and coordinate studies, planning and implementation of restorative activities.

Context. In general, the 1996-1997 water quality data gathered by Rivanna River Basin Roundtable (RRBR) confirms the historical data collected by DEQ for low flow conditions; however, in many cases the RRBR data collected during storm events shows pollutants at levels significantly higher than any of the DEQ data points. This indicates that the DEQ is collecting water samples primarily at base flow conditions.

66. **Knowledge Base Recommendation**. The DEQ should develop more effective monitoring of water chemistry to improve the reliability of information on the health of the basin. Water chemistry samples should be obtained during flow conditions, which are appropriate for meaningful assessment of the health of the basin. The DEQ should quantify levels of pollutants during the first flush of a storm event to assess the impact of these chemical peaks on aquatic life.
67. **Knowledge Base Recommendation**. The Virginia Department of Environmental Quality should consolidate its water quality and water quantity monitoring so that collection of data for all parameters is done consistently throughout the basin in both high and low flow conditions. The DEQ should maintain all existing gauging stations

in the basin, to assure the continuity of data collection, and add additional stations, especially below Moores Creek, to increase the availability of water quantity data.

68. **Resource Organization Recommendation**. Encourage the co-location of sampling sites and coordination of data so that there is a comprehensive water-monitoring plan

Context. Many of the issues discussed in the of the Rivanna River Basin Roundtable meetings were new to the members, who were chosen for their interest in the continued health and vitality of the region's waters. Although the issues related to the health of the waters of the region are complex and interrelated, they are understandable. There has been a lack of coherent publicly available information, accentuated by the number of agencies at various levels of government that are responsible for parts of the whole.

69. **Stewardship Recommendation**. Ask the Thomas Jefferson Planning District Commission (TJPDC) to reappoint those members of the Rivanna River Roundtable who are willing to continue to serve. Ask the TJPDC to provide continuing support and housing for the Roundtable, as it defines its future mission at the completion of this initial study and report.
70. **Stewardship Recommendation**. Develop a constituency which will support the implementation of the recommendations of this report. Establish mechanisms for public education related to the dynamic interrelation of the many elements that affect the movement and health of water within the region, including:

- Initiate Annual River Festivals to bring public awareness of the ecological, cultural and aesthetic values of our rivers. The first of these festivals is scheduled for May 9, 1998 in Darden Towe Park.
- Continue the annual Explore Day, to encourage groups to explore the rivers while accumulating a contemporary visual and written archive of the state of the basin.
- Print and distribute "I live in the Rivanna River Watershed" bumper stickers.
- Encourage environmental education in the schools of our region to develop an educated constituency for solutions to the problems of our waters.
- Promote river-related historic resources education in schools within the basin using tools such as field trips and contests.
- Initiate competitions to encourage art and writing projects about the Rivanna River Basin, its ecology and its history.
- Ask the American Institute of Architects and the American Society of Landscape Architects to hold river corridor design ideas competitions, perhaps associated with the annual Architecture Week.
- Create an educational video of the Rivanna River for use in schools, churches and civic organizations.
- Publish a book, including many photographs, drawings and maps that tells the history of the Rivanna River and its tributaries.

71. **Stewardship Recommendation**. Create and distribute to the public a summary document outlining the current State of the River, challenges to overcome and a vision of the River's future. Update the State of the River report on a regular basis.

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