Dan River, NC Watershed Assessment
and
Water Quality Study

Project No. CWMTF 2007-805

Final Report Narrative

Dan River Basin Association
Eden, NC
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Dan River Watershed Assessment
Project No.: CWMTF 2007-805

Dan River Water Quality Study, May 2008 – January 2009

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Part I
NARRATIVE REPORT

A. Narrative Statement – Overview of Study and Key Findings

The Dan River Basin Association initiated The Dan River Watershed Assessment, Water Quality Study in response to reports regarding the health of the Dan River in North Carolina. These studies include the North Carolina Department of Environment and Natural Resources, Division of Water Quality (NC DENR DWQ) listing of portions of the Dan River as impaired due to turbidity and fecal coliform bacteria. According to NC DWQ staff, the process for developing and implementing clean up plans to address impairments could take as long as 13 years. In addition, the Piedmont Land Conservancy Dan River Corridor Study identified riparian buffer protection and restoration as a high priority.

The Dan River Basin Association designed this project to better characterize water quality conditions as related to bacteria and sediment and to identify areas to be targeted for further study to identify sources of pollution. This information is intended to assist watershed stakeholders in prioritizing and targeting management actions to ensure that local waterways meet water quality criteria to support their designated uses, including fish habitat and primary-contact recreation.

This water quality planning initiative provided for the monitoring of fecal coliform bacteria, sediment and other parameters for nine months at 17 sites in the Dan River and tributaries in Rockingham and Stokes counties in North Carolina. This project also included the development and distribution to riparian landowners of educational materials related to the importance of streamside forest buffers in protecting water quality.

Data were analyzed by a state-certified laboratory in Eden, N.C. Data were also analyzed by trained volunteers, one of whom has more than twenty years' experience in laboratory techniques and related analytical work. DRBA wanted to determine whether the test kits used by volunteers would yield data comparable to that of a certified laboratory.

It should be noted that this study resulted in immediate identification and repair of infrastructure to reduce exfiltration-related losses. The study results also point to several geographic areas to be targeted for follow up study.

Dan River initiatives of the Piedmont Triad Council of Governments and the Piedmont Conservation Council's Dan River Coalition will have the benefit of data from this study to support projects underway at the time of this report.

Following is a summary of findings related to the questions to be answered by this study:

<u>Water Quality</u>: DRBA detected relatively low levels of fecal coliform bacteria and turbidity problems in the studied portion of the watershed. Note: It was not the

intention of this study to replicate EPA protocols for the development of Total Maximum Daily Loads (TMDLs) either to list or de-list impaired segments of waterways.

Overall, the geometric mean of all 153 samples collected is 85 cfu/100 ml. This number is below the trigger threshold that NC DENR-DWQ uses to indicate a waterway impairment. Only 11 samples, or about 7%, were above the instantaneous standard of 400 cfu/100ml.

With respect to turbidity, only eight samples exceed the 30 NTU standard, representing only 5.2% of all samples collected.

<u>Targeted Areas for Follow Up Study</u>**: The results reveal a need for further investigation in several areas: Jessups Mill and Town Fork Creek in Stokes County, the area upstream of Route 704 in Madison in Rockingham County, and the Smith River in Eden, also in Rockingham County.** It should be noted that a problem identified while testing the Smith River has been addressed.

<u>Volunteer Testing</u>**: The LaMotte ColiQuant EZ test kits used by volunteers do seem to give an equivalent result.** Analysis of water samples using the LaMotte equipment is less expensive and, importantly, more flexible with respect to timing. The results obtained from this study indicate that there is enough of a correlation between the ColiQuant samples and the samples analyzed by a certified laboratory that both broad patterns in the watershed and high level individual samples are both detected.

B. Narrative Description and Evaluation of Water Quality Improvements - Summary of Study Method and Results

In 2006, the NC DENR issued the state's 305(b) 303(d) integrated water quality report. The report lists segments of waterways in the Roanoke River Basin, including the Dan River watershed, that do not meet water quality criteria for their designated uses.

Local government tourism officials, concerned about news stories regarding the high levels of fecal coliform bacteria in the Dan River, met with the Dan River Basin Association regarding next steps.

DRBA contacted NC DENR and discussed the state's findings and implications. DENR's original data on which the impairments are based are shown in **Exhibit 1**. DENR, DRBA and others felt that the collection of additional data is useful, both to assess the extent of the problem and to help focus on smaller areas for study to better identify sources of bacteria and sediment so that remediation can begin.

DRBA formed a study team to review maps of the Dan River watershed in North Carolina. Using extensive local knowledge, the team identified 17 strategic locations for study. Please see **Exhibit 2** - Maps 1, 2 and 3 – for the locations of sampling sites.

Data Collection
Following the development of a Standard Operating Procedure by a qualified member of the original study team, two teams of volunteers were trained. A preliminary set of data was collected in 2007 in accord with the EPA 5-samples-in-30-days protocol. Following that initial monitoring, DRBA was awarded funding for a full study and a nine-month testing schedule was established. The nine-month period of testing began in May, 2008 and ended in January, 2009. Samples were collected one day per month, rain or shine, so as to capture a range of river conditions.

DRBA teams collected, preserved and delivered water samples to Pace Analytical laboratory in Eden, NC within the six-hour holding time. The teams also maintained chain of custody records.

Volunteers analyzed duplicate samples using LaMotte ColiQuant EZ bacteria test kits. Samples were incubated at the Eden office of the Dan River Basin Association. Analyses by Pace Analytical and by volunteers using the LaMotte equipment were conducted in parallel to assess the degree to which volunteer-generated data and laboratory data yield similar information. The volunteer test kits also offer the advantage of flexibility in timing of the sampling. Please see **Part II, Method for** details.

With support from Southwings, DRBA conducted aerial reconnaissance to assess the condition of a watershed, i.e., the land uses and degree to which waterways are protected by forested riparian buffers. DRBA staff and a volunteer with in depth knowledge of the watershed took a low altitude flight over the length of the Dan River, from the City of Danville to Kibler Valley in Patrick County, Virginia and back down the Smith River corridor. Staff photographed the river corridors, noting impacts such as timbering, ATV tracks, impervious surface and condition of riparian buffers.

Outreach
An important element of this project is public outreach and education. DRBA mailed letters and streamside forest educational brochures to landowners along the Dan River in Stokes and Rockingham counties. Going forward, riparian buffer educational information will be mailed to property owners in areas targeted by this study, particularly along first and second order streams.

DRBA developed web resources and installed educational signs at two well-used and highly visible locations: Moratock Park in Danbury in Stokes County and at the NC Wildlife Commission river access in Eden in Rockingham County. Riparian buffer educational materials were also distributed to the soil and water conservation districts, other organizations and placed at trailheads and locations around the region. Please see **Exhibits 3, 4 and 5**, brochure, signage and web resource.

Stakeholder Assessment of Educational Needs
When monitoring data and preliminary analyses became available, DRBA held a meeting of stakeholders, including soil and water conservation districts and municipal public

utilities officials. As data were reviewed and discussed, a larger picture came into focus with implications for management actions.

Agriculture
The landscape of the area studied is still largely rural, with the vast majority of contributing waterways described as first- and second-order streams. Farming and forestry are well established. Beef cattle farming is evenly spread throughout a large portion of the drainage area, and a large proportion of these farms are overstocked.

Without sufficient vegetation to slow and infiltrate runoff, pollutants, including bacteria, find their way into receiving waterways. While cost share programs are effective, some farmers resist participation in government-sponsored programs. According to local experts, 100% participation in voluntary programs to protect waterways will never be achieved.

In addition, farming infrastructure is often in need of upgrade, and few farmers are willing to make a long-term investment. Many farmers are older and with few heirs to assume the operation of the farm. Not surprisingly, farm owners often wish to keep their options open and not undertake measures that would restrict or limit future land uses.

Timbering
Timbering is another area of impact. Harvests need to be well planned with stream buffers and executed to prevent polluted runoff. In addition, skid trails and log landings compact soil, and vegetation is difficult to reestablish. According to local experts, there may be opportunities to improve on-the-ground management of forestry operations.

Urban Nonpoint Source Pollution
In urban areas (defined as other than agricultural or open space), nonpoint source pollution results from vast areas of impervious surface that were constructed long before stormwater control and best management practices were employed. Stormwater retrofit and application of low impact development techniques, which view stormwater as a resource to be reused and infiltrated into the ground, should be considered.

Next Steps: Community Conversation Needed
Across the Dan River basin, public education targeted to all ages is considered to be perhaps the greatest challenge. Study stakeholders and advisors recommend that a series of community meetings be held to create a platform for education and debate to "foster an atmosphere of open mindedness and objective decision making."

Follow up Study
Following the final analysis, DRBA identified sites needed for follow up action and/or further study. As a result of this study, sewage leakage related to a sanitary sewer blockage has been resolved. Please see **Part III, Results** or findings for a reporting of the data and relationships and **Part IV, Discussion** for analysis of findings.

At locations targeted for follow up, DRBA will continue to collect data and identify localized pollutant sources. DRBA will continue to work with local agencies to determine cost-effective ways to correct problems. Please see **Part V, Recommendations** for complete list of recommendations.

C. Changes made to original scope of project and budget

None

D. Partner participation in the project

DRBA met with local project partners to review initial findings and to solicit observations, comments and recommendations. Observations and recommendations of project partners are included in this report.

DRBA is providing data and analyses developed for this project to a number of organizations for use in developing management actions and to support ongoing and future studies.

DRBA's local and other project partners include the Rockingham County Soil and Water Conservation District, Stokes Soil and Water Conservation District, Piedmont Land Conservancy, public utilities, river-based businesses and water users such as MillerCoors, which supports DRBA's water quality work. Partners such as the City of Eden, the Piedmont Conservation Council, and the Piedmont Triad Council of Governments have also used this project as partial matching funds to support current and future initiatives.

The data generated by this project will be used by the CWMTF-funded "Eden Area Local Watershed Plan" of the Piedmont Triad Council of Governments.

DRBA has provided streamside buffer educational brochures for partners' use in speaking with riparian landowners and decision-makers.

E. Lessons Learned

Please see **Part V, Recommendations**.

F. Documents, reports and other evidence that the work has been completed.

Please see **Exhibits, Tables, and Figures**.

Part II
METHOD

Selection of Sampling Locations

The DRBA team's knowledge of the watershed, land uses and river features helped identify locations on the Dan River and tributaries to be sampled. Study sites included some locations that had been used in previous water sampling studies (2006, Piedmont Land Conservancy and 2007, Dan River Basin Association). Some of these sample sites are used by the NCDWQ.

DRBA also chose sites for water sampling based on ease of access from public property or a highway bridge. DRBA located sampling sites to bracket known waste water treatment plants or other discharge points. The sample sites for this study were slightly modified from previous work to include one sample in the trout waters section of the upper Dan River in western Stokes County and to sample only in North Carolina since funding was restricted to work in the state. Three sample locations were on the upper Dan River, one on Town Fork Creek at the edge of the Triassic basin, ten samples in the lower Dan River Basin (all in the Triassic basin), one at the near the mouth of the Mayo River, and two sampling sites on the Smith River.

Sampling Method

The days selected for sampling had to conform to the schedule of the laboratory. For that reason, no sampling could occur on Fridays, weekends or holidays.

In order to deliver samples to the laboratory within the holding time of six hours, DRBA divided the watershed into two sections and used two teams. One team sampled the upper portion of the river, collecting samples 1-8. This team moved downstream from western Stokes County and into western Rockingham County to the confluence of the Dan and Mayo rivers.

Water samples for the lower portion of the basin were collected by a second team heading upstream from eastern Rockingham County to collect samples 9-17. Both teams met in Madison after about 3.5 hours of work. The samples were combined into one cooler and taken to the Pace Analytical laboratory in Eden, NC well within the holding time limit. The second team also plated out the ColiQuant EZ kit samples, read the plates and entered the in-house, field and laboratory data into spreadsheets.

DRBA collected additional data at each sampling site. Data include water temperature, a turbidity sample, and at least one photograph of the site. Turbidity samples were obtained using a pair of LaMotte 2020e turbidimeters using the 1979 EPA method. The turbidimeter was calibrated the evening before each collection day using a 2 point calibration and a 1 NTU standard.

The Stokes County team also had available a Hanna Combo pH and EC hand held meter to collect data on water temperature, pH, conductivity, and dissolved solids. This meter was also calibrated each evening before a sample day and the results were tabulated by the Stokes County team. Results are shown in **Table 5** as supplementary data and in the spreadsheet data set. Additional field notes were made of the weather at the time of sampling, including any notes of significance about the observable water level, quality and sampling procedure. USGS stream gage data were collected from the Pine Hall gage, at the site of sample 5 in the middle of the basin. Weather data including precipitation within 48 hours of sampling and precipitation for the preceding month was obtained from www.weatherunderground.com. Details relating to the in-house ColiQuant samples and procedure are found in monthly tally sheets in the Excel workbook used to collect and analyze all the data from this study. Individual sheets are included in **Exhibit 6**.

The field sampling protocol required that at least one member of each team have hip waders since the samples were taken in 1-3 feet of water several feet from the bank. The sample collectors were trained to look for the portion of the stream flow that is in the main flow and not influenced by near-bank eddies and slack water. With the exception of November samples, when one member of the Stokes County team was unavailable, all samples were collected by the same team members throughout the study period. At each location the laboratory bottle label was filled out with the site number, time, date, and collector. A smaller bottle for the ColiQuant sample was numbered with a water-proof marker. An additional clean bottle was used to collect the turbidity sample. **Exhibit 7** includes photographs of the sampling and analysis.

Volunteers waded into the water flow and used a thermometer (and/or the Hanna meter) to determine the water temperature and other data. Then, facing upstream, the seal was broken and the top removed from the Pace Analytical laboratory bottle, which was then submerged, top down, a foot under the water surface and then rotated upright to fill. The bottle was then removed from the water and capped. The other two smaller bottles were then filled using the same process and capped. The two samples for fecal coliform analysis were placed in a cooler on ice to preserve the sample. The third sample was used to immediately fill the test vial of the turbidimeter for a river-side determination of turbidity. Two duplicate samples of turbidity were collected and averaged.

Volunteer Analysis

An objective of this study was to see if LaMotte test kits can be used as a less expensive and more flexible screening tool for volunteer water sampling. Thus, in addition to the laboratory analyzed samples, DRBA took duplicate samples for the LaMotte ColiQuant EZ kit fecal coliform sampling procedure.

DRBA volunteers inoculated a sterile pre-prepared mini-plate with the water to be analyzed and then incubated the plate at room temperature 48 hours. After incubation, the bacterial colony growth was counted by eye to give the result.

The ColiQuant kits are significantly less expensive than the laboratory analysis. The kits are easy to use, and they offer an important advantage over laboratory analysis in that samples can be taken on the spot and analyzed any day of the week.

Part III
RESULTS

Weather

The weather and gage data are summarized in **Table 1**. After a wet spring, the summer of 2008 was dry in the northwest and north central piedmont of North Carolina. Notable storm events occurred in early May, in the first week of September, in middle December, and in early January 2009, the month of the most significant storm event. Precipitation generally did not occur on the sampling days with the exception of a brief sleet on January 26 in Stokes County. The 48 hour period before sampling in November and December did register notable rain, but only the December sampling occurred in noticeably higher water. The Pine Hall gage station discharge is plotted on **Figure 1**, and plainly shows the increase in stage in December 2008 and the lower than average levels otherwise.

Bacteria and Turbidity Levels as Related to Weather and Flows

Table 2 compiles nine months in 2008-09 fecal coliform bacteria data from Pace Analytical and 2007 five tests in 30 days from Meritech Labs. The table shows that December 2008 (where water levels were the highest on the sampling day) had the highest mean fecal coliform averages. The geometric mean was 195 colony forming units (cfu) per 100 ml. The arithmetic mean was 257. The highest single record from the lab was 1200 cfu/100ml. **Table 4** also ranks December 2008 as the second highest month for turbidity. Except where noted in the following analysis, no other significant weather-related correlations can be determined from the data sets.

Establishing a Pre-study Baseline: Preliminary analysis of five samples in 30 days

During the summer of 2007 DRBA replicated EPA bacterial Total Maximum Daily Load (TMDL) protocol of taking five tests in 30 days as is done by the NC Department of Environment and Natural Resources – Division of Water Quality (DENR-DWQ). These five samples were analyzed by Meritech Labs in Reidsville, NC.

Unless otherwise noted, all fecal coliform bacteria data shown on charts and tables are derived from samples analyzed by Pace Analytical. Samples analyzed by volunteers are noted as ColiQuant. The five samples in 30 days taken in 2007 were analyzed by Meritech Labs.

Samples at each of 16 stations along the river from Danbury downstream to Berry Hill Bridge (at the NC-VA line) were collected each week from early June to early July (June 5,7,13,28 and July 2, 2007). The resulting sample set includes 80 samples with only 10 samples over the threshold for a total of 12.5 %, versus 20% as the standard. The geometric mean of the entire data set is 152 cfu/100 ml.

For a waterway to be listed as impaired in NC, five consecutive samples at a single site within a thirty day period are analyzed, and the geometric mean of the five samples must be 200 cfu/100 ml or greater. Alternatively, if 20% of the samples exceed the instantaneous standard of 400 cfu/100 ml, a waterway segment can also be identified as impaired.

Field notes of weather for June 2007 indicate that there were at least two weekends of high water, and samples show a pattern of high and low weekly averages alternating across the study period.

Several interesting trends are seen in this data as displayed in **Figure 2**. Samples taken from Town Fork Creek and the Smith River are all above 100 cfu/100 ml. Another trend appears to be that all the samples collected on June 5 appear elevated above the baseline, and all exceed the geometric mean of the entire data set. On the other hand, all the samples collected on June 7 and June 28 appear to be below the set average (excluding the above mentioned Town Fork Creek and Smith River samples). Sixty percent of the samples over 400 cfu/100 ml were collected from the lower basin on June 13. There are also 10 samples over 400 cfu/100 ml and they seem to fall into two groups: upper and lower watershed in the June 5 and July 2 samples and mostly in the middle of the watershed in the June 13 sample. Also of note is that other than the June 5 sampling all the samples taken at Berry Hill and Mayo River are among the lowest in the data set.

The contribution of each site to the overall fecal coliform level of the watershed can be estimated by ranking the geometric means from 1 (lowest) to 16 (highest). The data in **Table 2** and the bar chart in **Figure 3** confirm that Berry Hill, Mayo River and Moratock Park are the three lowest fecal coliform sites, while the two Smith River samples and Settle's Bridge are the highest.

Many results of this study seem to have a multi-modal distribution which is illustrated by some sample distributions showing one, two or more peaks. There are several ways to explain this type of distribution knowing something about the character of this watershed and this will be elaborated on in the **Part IV Discussion** section to follow.

The Dan River Nine Month Water Quality Study

Table 2 displays the results of the nine monthly samples of the 17 locations, the heart of the Dan River Water Quality Study of 2008. (Month-by-month results for temperature, fecal coliform bacteria and sediment testing are shown in **Exhibit 6**.)

A total of 153 samples are reported here with an overall geometric mean of 85 cfu/100 ml. Only 11 samples are above the threshold of 400 cfu/100ml, and that equals 7.1% of the total. The period of May 2008-October 2008 shows a monthly mean consistently around 100 cfu/100 ml. Following is a low in November, a high average in December, and a very low average in January. These fluctuations appear to be at least partially explained by weather patterns (as mentioned above) and may likely indicate less agricultural activity in the watershed in winter months.

All the samples can be seen in **Figures 4 and 5** which represent the upper and lower portions of the basin respectively. The scales of the Y axis have been set to 700 cfu/100 ml. The same scale is used throughout, even though the December 2008 sample from 704 Bridge site tops out at 1200 cfu/100 ml.

Looking at the upper basin samples (**Figure 4**) there does seem to be some correlation with the weather. Spring and early summer of 2008 was wet producing a scattering of sample spikes in the data, followed by a five month dry period, and ending with a wet December which again shows an elevated sample fecal coliform bacteria count. During the middle of the year when the water levels were lowest the two highest samples occur at Town Fork Creek and one at Pine Hall, just down stream from Town Fork Creek. These readings don't appear to be correlated to anything in the data set, but their consistency and sequential nature may imply that something is happening in this area. This is consistent with other data showing Town Fork Creek as atypical. **Table 5**, the Supplementary Data, shows Town Fork Creek to have a low pH during the summer months and an over all consistently higher conductivity in all nine monthly samples. The Pine Hall sample site is immediately down stream and shows some of the same trends.

Data collected for the lower half of the basin area studied (**Figure 5**) reveal less impact of the wet weather pattern than the upper basin area. This variation may reflect the distance from the headwaters and the increasing size of the watershed at this location. There is a little increase in December samples which does correlate to the wettest period during the study.

Elevated levels of fecal coliform bacteria in the Smith River samples throughout the summer months are also apparent. During the same period only one sample (Eden Wildlife) shows a dramatic departure from the basic pattern. Additionally, the samples collected from the Hwy 14 area seem to be at or near the highest of the samples from the Dan River main stem during the summer months.

Figure 6 plots the geometric and arithmetic means of the nine monthly samples at each of the seventeen sample locations. The geometric mean is the most appropriate for this set of data, as the geometric mean reduces the influence of outlier values. The arithmetic mean was generated to compare this set to other non-fecal coliform data. The difference between the geometric and arithmetic means does indicate to some degree the level of sample variability. This variability is demonstrated by the 704 Bridge/Water Street sample which has both the lowest and highest sample fecal coliform values of any location.

Illustrating the trend noted above, the two Smith River samples have the highest mean, followed by Town Fork Creek and Jessups Mill. Surprisingly, Jessups Mill, which is located further up the watershed in the trout waters section of Stokes County, had a high average. However, the Jessups site is located on the downstream end of an agricultural area in northern Stokes and southern Patrick County with known cattle access to the creeks. Further, the site is just downstream from the confluence with the Little Dan River which has an industrial wastewater treatment outfall.

Other trends reveal low levels of fecal coliform bacteria at the Berry Hill Bridge at the eastern end of the watershed area monitored and at Moratock Park and Dodgetown Road Bridge, both in the upper or western portion of the Dan River in North Carolina.

Table 2 lists the compiled geometric means for different parts of the watershed by month. The results are fairly consistent across the monthly means for the early parts of the study period. The data reveal that the Mayo River contributes the lowest totals to the fecal coliform levels in the basin, followed by the upper and lower Dan River basin being somewhat intermediate.

Finally, as seen earlier, Town Fork Creek and the Smith River are consistently contributing higher levels of fecal coliform bacteria to the Dan River. The ranking column on the far right of the table ranks the individual site contributions. These values were used to generate a composite ranking of the watershed sub-segments and tributaries, presented below the main table.

Volunteer Analysis of Data

When compared to the certified laboratory test, the ColiQuant EZ kit data is less expensive (assuming volunteers do the work of making the plates and reading the data) and does seem to give an equivalent result. As shown by the data in **Table 3,** volunteer data is of a wider range than the Pace data (0-7450 cfu/100 ml). Results are expressed in some multiple of 50, which is a multiplier in the formula to convert from colonies on the small plate to cfu/100 ml. This conversion makes the resolution kind of blocky and coarse.

ColiQuant data also reveals a lower limit to detection with many of the samples collected registering zero, when the Pace laboratory duplicate samples never produced a zero. Because of the zeros in the data set a geometric mean can not be calculated. As a result, the ColiQuant means are arithmetic averages. The accumulated averages show the similar trends as in the Pace data set with the Mayo River being the lowest, followed by the Upper Dan, Town Fork Creek, Lower Dan and finally the Smith River highest in fecal coliform concentration.

The ColiQuant sample mean by location composite is shown on the bar chart in **Figure 7**. **Figure 8** adds the mean data from the Pace samples composited for the same locations. The correlation between these data sets looks good at this level of analysis. An alternative way to look at the two data sets is to normalize them into ranking and compare the rankings. **Figure 9** shows the ColiQuant and Pace samples ranked for each location. Again, the Berry Hill Bridge, Mayo River and the Moratock Park and Dodgetown Bridge samples are consistently the lowest and rank 1-4. A familiar trend occurs at the other end of the range with the Smith River samples, Town Fork Creek, Pine Hall and Jessups Mill ranking 13-17.

Turbidity

The turbidity measurements were made at the time of collection of each water sample. This parameter was added to the study since previously published work shows a strong positive correlation between presence of pathogens, including fecal coliform bacteria, and turbidity and suspended sediment in waterways. In addition, some sections of the Dan River and its major tributaries are considered by NCDWQ as impaired for turbidity. The upper reaches of the Dan River in Stokes County are impaired due to the lower turbidity limit in Trout Waters (10 NTU), and the lower reaches of the Dan River are impaired since they exceed the standard limit for Class C waters of 30 NTU. The portion of the river between Francisco, NC and Wentworth, NC is considered not impaired. **Table 4** lists the turbidity data collected at each site for the nine months of the study period. The right-hand columns list the mean for each site and a ranking based on 1 being lowest turbidity and 17 being highest. Averages or means based on watershed location composites, sub watershed segments means, and composite ranks for the entire study period are shown across the bottom of the table.

Figures 10 and **11** graph the individual samples in the upper and lower half of the study area respectively. The Y axis scales have been set to 60 NTU to make the comparison easier even though the highest sample (Pine Hall, June 2008) value of 113 is off scale. A quick scan of each figure will show that turbidity variation also seems to reflect the wet late spring weather at the beginning of the study period and the wet weather just prior to the December sample date. Only eight samples exceed the 30 NTU standard, representing only 5.2% of all samples collected.

Turbidity is generally strongly correlated with land disturbance which would help explain the higher readings seen in the late spring-early summer when the agricultural planting in the watershed is underway, and spring rains fall on freshly turned soil. Previous watershed analysis (Dan River Watershed Plan, 2006) reveal that the Smith River headwaters have a high likelihood of producing non-point source sediment pollution based on slopes, soils, land cover, lack of riparian buffers and residential and urban development. In some cases sediment pollution may be worsened (as in **Figure 11**) by the discharge operations of the impoundments on the river, both in timing in relation to DRBA's sampling and with respect to the volume of water released as higher flows re-suspend sediments from earlier times.

Figure 12 is an attempt to smooth out this variable turbidity data by compiling average values for the various sub watershed portions and tributaries mentioned above. However, turbidity data do not appear to follow the distribution seen in the two fecal coliform data collections. **Figure 13** charts both the basin wide turbidity and the fecal coliform geometric mean on the same chart with two different Y axis scales. *Unfortunately, the software being used does not have an option to use a format suitable for discrete data, like bar graphs, so for the connected line format, the reader should ignore the lines that connect the points on the graph.*

The directional trends in each graph indicate only about a 9 out of 17 (slightly over 50%) coincidence, which is probably no better than chance. This information, taken with the comparative analysis of the turbidity and fecal coliform ranks as shown in **Figure 14,** indicates very low correlation between either of the two bacteria test methods (which do mostly agree with each other) and turbidity ranking of the samples in all North Carolina sites.

In order to examine the direct relationship between fecal coliform numbers and turbidity levels at each sampling period, separate graphs of each month were made using the two axis system as above. **Figures 15-23** are graphs of all individual samples taken each month. For a few of the months there is some positive correlation between the fecal coliform bacteria numbers and the turbidity levels (Fig 16-18, June-August).

June is the most dynamic data set and has the closest positive correlation with the turbidity data. Most of the rest of the months have no apparent pattern in the data. January 2009 (**Figure 23**) has some pattern, which is interesting since January also recorded the lowest levels of both turbidity and fecal coliform counts. For both June 2008 and January 2009, the Jessups Mill data reveal an inverse relationship between turbidity and bacteria levels. If the Jessups Mill site is excluded, a somewhat positive correlation between bacteria and sediment trends is apparent.

Figure 24 displays the ranking of all the turbidity samples based on the average turbidity at each site throughout the study period. A strongly bi-modal distribution is revealed, with Moratock Park, Dodgetown Bridge, Pine Hall and Lindsey Bridge high in the upper watershed and Eden Wildlife, Hwy 14 and the Smith River sites highest in the lower watershed.

The final analysis performed on the data is a Dominants In Common (DIC) comparison of both the fecal coliform tests and the turbidity analysis (**Table 6**). The highest scoring samples in each sample set were tabulated. All the samples over 400 cfu/100ml in the Pace sample set and all the ColiQuant samples above 300 cfu/100 ml were selected along with the top 11 scores in the turbidity ranking. The DIC correlation between the two fecal coliform tests is strong at 5 of 11 (45%) occurring in both samples. The DIC between the bacteria samples and the turbidity set was only 1 of 11 (9%). Interestingly the Jessups Mill month of June sample is found in all lists, indicating how a few high scores in a limited data set can dominate results.

Also of interest is that 45% of all high ranked fecal coliform samples occurred in the first three months of the study. Distribution by season also shows that 100% of all high ranked turbidity samples also occurred in the first three months of the study period.

Part IV
DISCUSSION

The results of this study improve understanding of the dynamics of the watershed in several ways and also inform refinements to DRBA's sampling protocol and future activities. One important consideration that appears evident from this study is the need for closer tracking of weather in the upstream drainage area.

Weather Tracking to Detect Patterns of Precipitation

The Dan River Basin Water Quality Study covered a large area whose diverse headwaters are spread over at least five counties. Localized precipitation patterns are common in this area (especially in the nearby mountains), and storms can drop significant amounts of rain in one location while the rest of the drainage area is missed. These patterns affect a study such as this by making it hard to identify the cause of spikes in fecal coliform bacteria counts or turbidity without a higher resolution of this kind of data. Commercial weather reporting sources do not cover the watershed in sufficient detail to allow sub-watershed analysis of precipitation patterns that might impact a study such as this. In the future, water sampling studies should be designed to include a closer tracking of local precipitation patterns, perhaps using volunteer weather monitors or recording rain gages strategically placed throughout the watershed.

Influence of Impoundments

In addition, sampling, especially for turbidity, might be affected by discharge patterns from the reservoirs at the head of the Dan River and along the Smith River. The management actions of the agencies that control these discharges should be considered. Relatively small increases in discharge or stage might influence turbidity levels.

Overall Low Levels of Bacteria in the Dan River in NC

Based on the number and diversity of sample locations, DRBA detected relatively low levels of fecal coliform and turbidity problems in the watershed as a whole. Of DRBA's 153 samples only 7.1% were greater than 400 cfu/100 ml. The results also point to potential problems in the Smith River and Town Fork Creek sub-watersheds. This is shown both by the mean of all samples collected at these sites and the ranking used to normalize the data. These areas had been identified for further study based on previous watershed assessment work but until now DRBA has not had any data to compare these areas with the rest of the Dan River watershed in North Carolina. Surprisingly, the Jessups Mill samples also ranked relatively high in fecal coliform bacteria, which is an unexpected finding given the rural nature of the area and its designation as a trout stream.

Overall, the geometric mean of all samples collected is 85 cfu/100 ml, which is below the trigger thresholds that NC DENR-DWQ uses to indicate an impairment problem. Some individual samples and sites exceeded the 200 cfu/100 ml threshold used in the state's studies and include both Smith River samples and the 704 Bridge site in Madison. The sites just upstream of Madison are close to the 200 cfu/100 ml mark due to some anomalous high samples. A closer look at the watershed between Walnut Cove (Town Fork Creek) and Madison should be considered. The water quality of the main channel of the Dan River just below Madison may benefit from the contribution of the Mayo River which is uniformly low in fecal coliform bacteria and turbidity.

Feasibility of Volunteer Monitoring

The LaMotte ColiQuant EZ test kits appear to offer an inexpensive way to quickly screen water samples and generate data comparable to the laboratory analysis. The coarse nature of the data and the lower limit of detection make for a data set that is hard to compare to other laboratory-analyzed samples. However, once these characteristics are taken into consideration, ColiQuant kits can be effectively used. The results obtained from this study indicate that there is enough of a correlation between the ColiQuant samples and the Pace Analytical samples that both broad patterns in the watershed and high level individual samples are both detected.

Turbidity Sampling – Main Stem and Tributaries

The turbidity sampling is relatively inexpensive and is able to detect differences in pattern and detail within the study area. Field observations by team members during the sampling period indicate that more might be learned if turbidity samples were taken from the tributaries. In the current study, care was taken to avoid confluences where water quality might be different from the main channel. However, the resulting samples do not accurately depict the range of turbidity seen in the watershed, and some tributaries are more or less turbid than the main channel.

Past Studies of Turbidity

A previous study was conducted in the upper Dan River watershed where suspended sediment was collected from a wide range of tributaries representing a range of land cover and land use. That study was limited in the number of samples collected over the study period due to the drought. However, the study did indicate that significant differences in suspended sediment do occur in tributaries.

The upper Dan River study occurred concurrently with the Dan River Watershed Study by the Piedmont Land Conservancy in 2005-2006. A summary of the results can be found in the appendix of that earlier report. However, a turbidity study to ground truth the watershed study recommendations could be targeted at places now suspected to contribute turbidity problems.

Need for a Reference Stream and future Statistical Analyses

The NC DENR-DWQ impairment listing has motivated more detailed studies of the sources of turbidity in the Dan River watershed. Future studies should be designed with sufficient sample duplication and sampling of reference waters. One such reference stream is the outstanding resource water, Indian Creek, which is entirely within Hanging Rock State Park. Indian Creek could serve as a reference for turbidity and fecal coliform studies.

Discussions with a statistician should occur during the development of any future study to determine in advance of data collection what type of statistical treatments might be appropriate to help analyze this type of data. It was not within the scope of the current pilot study to apply rigorous statistical treatment to this data. However, the power of statistical methods is appreciated and should be especially useful when looking for correlations between different data sets. Additional informational needs include the standard error range for the individual samples and techniques to better recognize trends in the data that relate to natural sample variation.

Quality Assurance and Quality Control

Related to quality assurance of the data is the need for the staff and volunteers involved with water quality projects to be trained and confident in the use of all the techniques necessary to make the study a success. A training session was provided for the team members at the start of the study. The initial formal training did not include all the members who ultimately became involved, and the training was not as comprehensive as it might have been. Repetition of the same tasks each month for nine months certainly helped to hone skills and confidence of study team members.

In addition, while some volunteers were experienced in field science and sterile technique, others may not have had the same background. A disparity in prior knowledge and experience may have affected sample collection consistency.

Although teams followed the manufacturer’s recommended procedures, the equipment used by each team was never cross compared to determine consistency. Finally, better notes from the field on weather and water conditions and other watershed observations might make the interpretation of the data easier, more accurate, and more valid.

Part V
RECOMMENDATIONS

Specific Recommendations from this Water Quality Study data analysis

- Consider additional in depth studies of fecal coliform bacteria contribution of:
  - Town Fork Creek
  - Area above Madison, NC
  - Upper Dan River above Jessups Mill
  - Smith River
- Additional investigation of the area between Walnut Cove and Madison, NC, especially tributaries (most notably East and West Belews Creek) and other creeks that have a noticeable sewage smell during low water periods in summer is needed.
- Tributaries to be studied should include pristine reference sites (Indian Creek) with undisturbed forested conditions in the drainage area.
- Tributaries in watersheds identified as needing further study, by both this study and the Dan River Watershed Assessment (2006) should be included in future studies.
- Additional investigation of the turbidity in the main channel of the upper and lower watersheds is needed. Turbidity does not seem to correlate positively with levels of fecal coliform bacteria at the scale or detection levels used for this study.
- Future studies should model a sampling experiment over a short storm event to sample the same locations before, during and after the peak of the water rise to illuminate the effect of precipitation on fecal coliform bacteria and turbidity from one known storm event in a suspect sub-watershed.
- Next steps should include work with NC DENR-DWQ, VA DEQ and the NC-VA Bi-state Roanoke River Basin Advisory Commission and their Committees to make sure these organizations are aware of this data set and that they incorporate this study and its results into their knowledge of the watershed. Specifically this study should be referenced in the next revision to the Roanoke River Basin Plan.

General Recommendations for Future Watershed Studies from this data analysis

- Add a stronger weather precipitation monitoring component to future turbidity and fecal coliform sampling studies. This could be weather spotters or weather stations located in target sub-watersheds.
- Sample tributaries of the Dan River for turbidity to isolate problem sub-watersheds.
  - Design an experiment to calibrate inexpensive turbidity devises (like secci tubes) using the LaMotte 2020e meters and recruit volunteers to collect turbidity data in targeted areas.
  - Look into the "Muddy Water Watch" program used in other watersheds to allow concerned citizens to report sources of high levels of turbidity.
- Include a statistical experimental design component to future studies to develop a rigorous sample design and analysis strategy before collection starts. This will

mean some kind of duplicate sampling that will allow an estimation of the sample to sample error.

- Expand and enhance training of volunteers and staff.
    - Improve familiarity with the equipment and how to field diagnose problems, calibrate and maintain field equipment.
    - Increase familiarity with the experimental design to promote consistency.
    - Develop more contact and cross-training between different field sampling people to build more bench-depth for consistency and flexibility at all parts of the watershed.
    - Conduct an assessment of the in-house lab space used for ColiQuant sample development with an eye to increasing levels of lab technique (notably sterile technique) and in-house lab suitability and functionality.
    - Create dedicated log book for the entry of volunteer data
- Take additional field photographs and field notes of weather, water conditions and anomalies.
- Work with NC DENR-DWQ and VA DEQ to offer the services of DRBA's team to help state agencies tackle projects in the watershed.

List of Exhibits, Tables and Figures

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