NC Division of Water Quality
Planning Section
Modeling and TMDL Unit

MEMORANDUM

To:	Kathy Stecker, Modeling Unit Supervisor
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CC:	Alan Clark, Dianne Reid, Jeff Manning, Peter Caldwell, Cam McNutt, Heather Patt, Sam Whitaker
Date:	October 6, 2009
Subject:	Assessment of Natural Condition for DO and pH in Potecasi Creek, Chowan River Basin, NC

Summary

Potecasi Creek impaired segment (AU# 25-4-8), 42.5 miles, exhibits low velocity and large areas of agricultural and forested lands with swamps and heavy tree canopy. Decomposition of the large inputs of vegetation from areas of forested land with swamps and heavy tree canopy throughout the watershed create lower pH and lower DO as they decay in the creek. There is no discernable anthropogenic impact on the creek. The creek exhibits low nutrient concentrations near or below national background levels from undeveloped areas. There is also not a close correlation between precipitation amounts and field pH at the NC DWQ ambient water quality monitoring station. Based on the information, the water quality standards for Potecasi Creek and its tributaries have not been violated. A Total Maximum Daily Load (TMDL) is not required for DO and pH for the creek.

Introduction

Potecasi Creek was listed as impaired since 1998 on North Carolina's 303(d) Report of Impaired Waters due to violations of the State's water quality standard for DO and pH. As reported in the list, the impaired segment in the creek due to DO and pH is located from the source to the Meherrin River (Figure 1). The assessment unit number for the impaired section of the creek is 25-4-8. The total mileage of impaired section is 42.5 and is designated as Class C NSW. The Division of Water Quality (DWQ) defines Class C as waters protected for secondary recreation, fishing, wildlife, fish, and aquatic life propagation and survival, agriculture and other uses suitable for Class C. The division also defines NSW as supplemental classification intended for waters needing additional nutrient management due to their being subject to excessive growth of microscopic or macroscopic vegetation. This report evaluates the DO and pH impairments by determining if natural conditions are the cause of the apparent impairments, thus obviating the need for a TMDL.

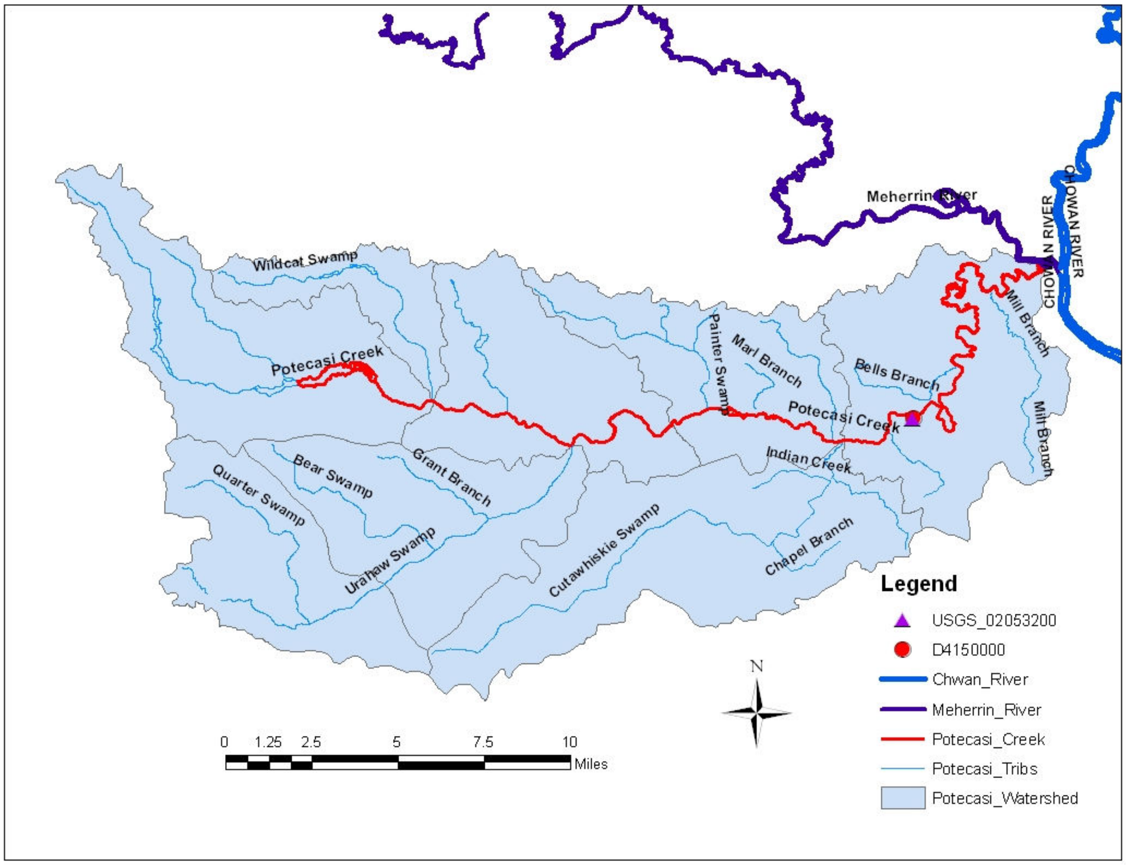

Figure 1. Potecasi Creek watershed

General Description of Watershed

Potecasi Creek, located within both Northampton and Hertford counties in North Carolina, is a tributary to the Meherrin River in the Chowan River Basin. The watershed has an area of approximately 257.48 square miles. There is a USGS flow gauge station (USGS 02053200) and an ambient station (D4150000) at NC11 near Union, with a drainage area of 225 square miles. The USGS gauge station measures flow continuously, whereas the DWQ collects water samples every month to estimate physical and chemical constituents. DO, pH, and flow measured at these stations are utilized for this study.

Geology and Soils

Potecasi Creek is in the Coastal Plain Physiographic area in eastern North Carolina. The Coastal Plain geology consists mostly of marine sedimentary rocks. This rock is overlain by fluvial (waterborne) deposits. These deposits are primarily sand and clay from rivers that have been laid down over many thousands of years (Source: http://www.soil.ncsu.edu/publications/BMPs/physio.html).

Local topographic relief is only 0.8 feet per mile and maximum land surface altitude is about 50 ft above sea level. This low topographic relief is reflected in low hydraulic gradient with less potential to move water to streams. Therefore, the soil characteristics are predominantly hydric soils in the watershed (Figure 2). These soil types are formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions.

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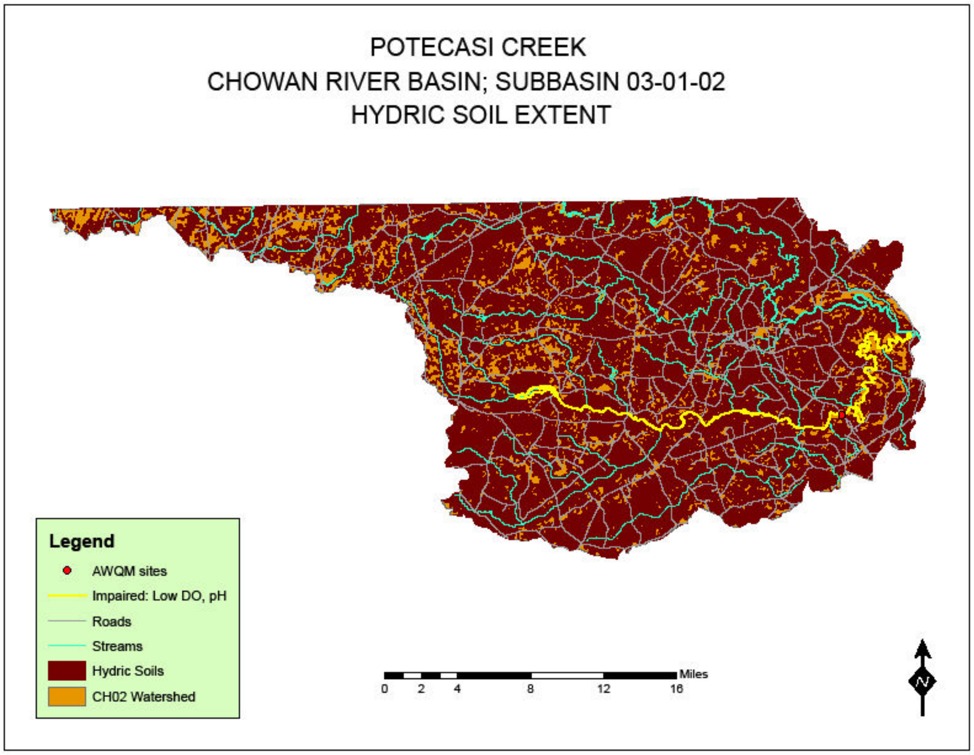

Figure 2. Hydric soil distribution in the Potecasi Creek watershed.

Climate

The climate data is acquired from the State Climate Office of North Carolina (http://www.nc-climate.ncsu.edu) for the study periods, 1998 – 2007. Figure 3 shows monthly averaged temperature and total rainfall distribution at a climate station (#315996) located at Murfreesboro, Hertford County. The average annual maximum and minimum temperature (°F) at the climate station are 69.45 and 47.64, respectively. The average annual precipitation is 46.74 inches. Amount of precipitation gradually increases during summer period in the watershed.

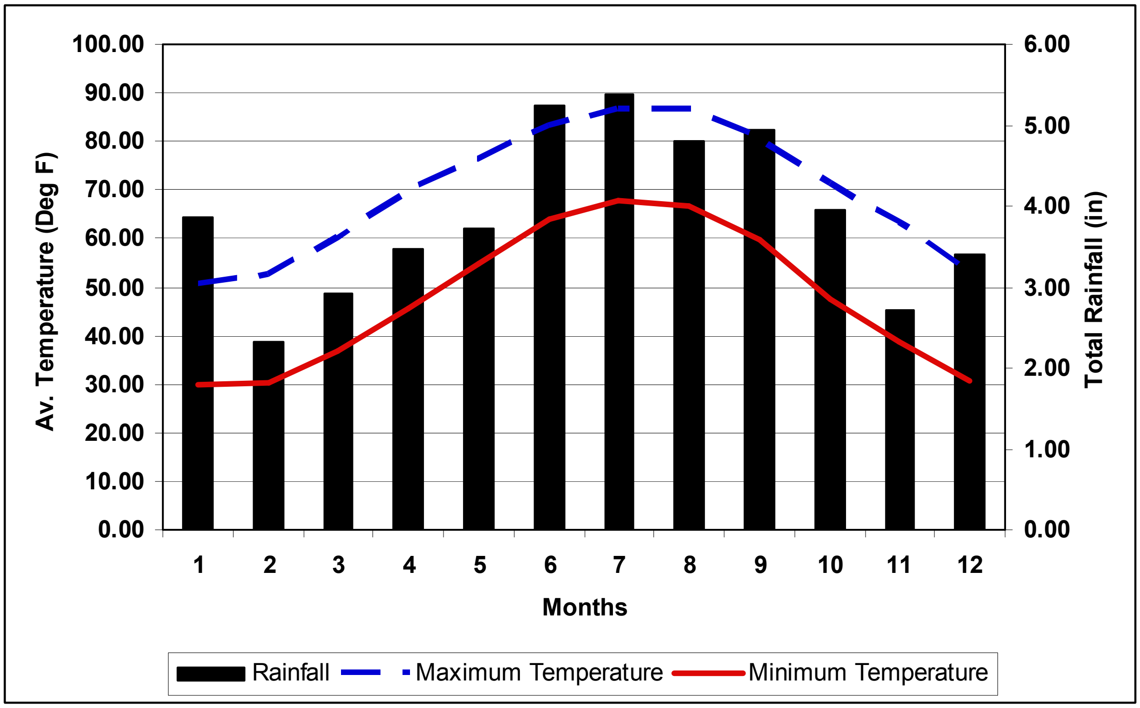

Figure 3. Air temperature and rainfall distribution in the Potecasi Creek watershed, Murfreesboro, NC (Station #315996).

Land Use

The Potecasi Creek watershed is approximately 257.48 square miles in size, and is predominantly forested (46%) and agricultural (38%) (Figure 4). The forested area includes 20% deciduous forest, 25% evergreen forest, and 1% mix forest. The agricultural area includes 26% cultivated crops and 12% pasture/hay lands. Other uses are comprised of 12% woody wetlands, 2% barren lands, and 2% developed open spaces. The woody wetlands are largely concentrated along the creek.

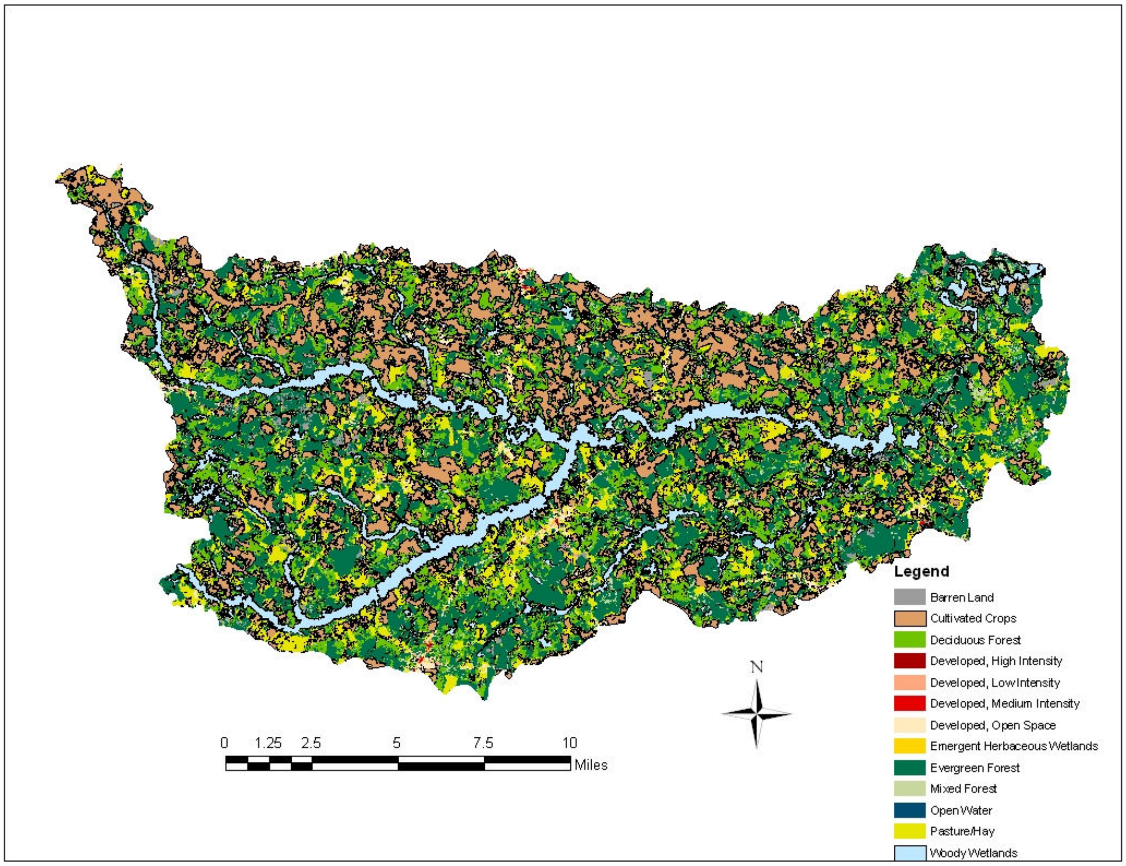

Figure 4: 2001 NLCD of the Potecasi Creek Watershed

Water Quality Standard

According to North Carolina Water Quality Standards for class C waters (15A NCAC 02B.0211), DO concentration shall not be less than 6.0 mg/l for trout waters; for non-trout waters, not less than a daily average of 5.0 mg/l with a minimum instantaneous value of not less than 4.0 mg/l; swamp waters, lake coves or backwaters, and lake bottom waters may have lower values if caused by natural conditions. For pH, it shall be normal for the waters in the area, which generally shall range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions.

Statement of Impairment

The entire length of Potecasi Creek (from source to the Meherrin River) is listed on the 2006 303(d) list of impaired waters for DO and pH. The DWQ recommended that the creek be included in a Swamp Waters Study Plan to determine if the low DO and pH were associated with naturally occurring swamp conditions.

In the Chowan River Basinwide Water Quality Plan (NCDENR, September 2007), it is recommended that the upstream portion of Potecasi Creek [AU# 25-4-8a], from source to Cutawhiskie Creek (21.5 miles), be removed from the 2008 303(d) list of impaired waters due to a moderate swamp benthic bioclassification. This upper portion of the creek exhibits natural channel morphology, intact riparian zones with a mature forest on either side, and a large percentage of the reach are available for benthic colonization.

Lower Potecasi Creek [AU# 25-4-8b], from Cutawhiskie Creek to Meherrin River (21.0 miles), is recommended to remain on the 303(d) list for water quality standards violations for DO and pH, until it can be further determined that these conditions represent natural swamp drainage. Water was sampled 59 times over the course of the five-year assessment period (2002 – 2007) at the ambient site (D4150000). Over 44 percent of the samples were below 5.0 mg/l and over 25 percent were below the 4.0 mg/l standard for dissolved oxygen. The pH was below the standard of 6.0 in 22 percent of the samples.

Natural Condition Assessment

In a water body, oxygen is usually restored through aeration and photosynthesis processes, whereas oxygen is depleted through decomposition and respiration processes. Oxygen-depletion processes dominate oxygen-restoration processes in slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids, thereby reducing pH level. Because swamp waters are characterized by very low velocity, it is common to observe naturally low DO and/or pH level in swamp waters. The situation will be more compounded when excessive nutrients or readily available organic matters are discharged to these waters. Therefore, following five steps are selected to identify natural conditions that result in low DO and/or pH levels and to determine the likelihood of anthropogenic impacts that will exacerbate the natural condition in Potecasi Creek: observation of low velocity, impact from point sources, impact from nonpoint sources, impact from seasonal fluctuation, and field observation.

Observation of Low Flow Velocity

Local topographic relief is only 0.8 feet per mile and maximum land surface altitude is about 50 ft above sea level. Based on the low slope topography, flow velocity in the creek is expected to be low. The low flow 7Q10 values ranges from 0 to 0.019 ft3/s/mi^2, and the median value is 0 (Giese and Manson, 1993). The flow value is expressed by drainage area.

So as to understand the flow velocity in the creek, the daily discharge rates and flow depths measured at the USGS gauge station 02053200 from 1998 through 2007 are obtained from USGS database (Source: http://waterdata.usgs.gov/nc/nwis/rt). The discharge rate ranges from 0.06 ft^3/ sec to 15200 ft^3/ sec, and the median discharge is 69 ft^3/ sec. Since the USGS does not measure velocity at the site, Equation 1 is used to estimate flow velocity.

Velocity (ft/sec) = Discharge (ft^3/ sec)/ Cross Section (ft^2) ----------------------- (1)

Since cross section varies with flow depth, a statistical relationship between cross section and flow depth is estimated using bathymetry data measured at the site (Figure 5). The relationship is quadratic and is given below.

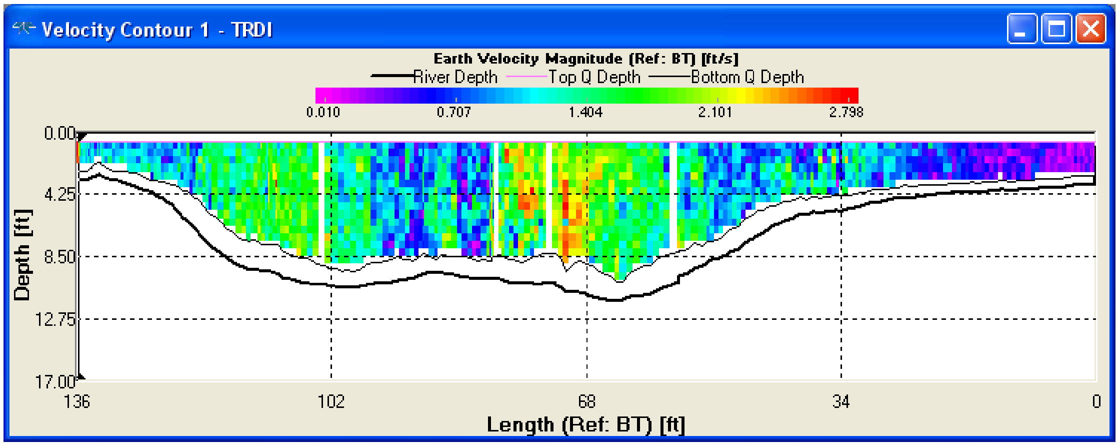

Figure 5. Bathymetry data at USGS 02053200 in Potecasi Creek. (Source: Personal contact with Dr. Loren Wehmeyer, USGS NC Water Science Center 2.)

Cross Section = 5.0186* Depth * Depth + 50.302 * Depth ------ (2)
(R^2= 0.99)

Solving the two equations 1and 2 flow velocities are estimated, which ranges from 0 to 2.78 ft/ sec, and median value is 0.22 ft/ sec. The monthly percentile distribution of the flow velocity from 1998 through 2007 is given in Table 1. It appears that flow velocity in the creek is substantially slow throughout the year. It could be because the watershed location comprises the near upstream and downstream boundaries of the low slope segment. Slow velocity enhances decomposition of vegetation inputs from forested lands with swamps and heavy canopy throughout the watershed, thereby increasing oxygen demand and lowering DO as they decay. Furthermore, the decomposition of vegetation produces organic acid, thereby reducing pH in the creek.

Table1. Monthly percentile distribution of estimated flow velocity (ft/s) at the ambient station (D4150000) at NC11 near Union (1998-2007)

Months	**Minimum**	**10%**	**25%**	**Median**	**75%**	**90%**	**Maximum**
Jan	0.03	0.19	0.25	0.37	0.53	0.73	1.10
Feb	0.11	0.19	0.30	0.44	0.60	0.81	1.31
Mar	0.12	0.18	0.30	0.45	0.60	0.75	1.20
Apr	0.04	0.12	0.20	0.35	0.52	0.72	1.25
May	0.01	0.05	0.07	0.14	0.29	0.50	1.02
Jun	0.01	0.02	0.04	0.10	0.26	0.68	1.41
Jul	0.01	0.02	0.03	0.06	0.25	0.50	0.93
Aug	0.00	0.01	0.02	0.04	0.14	0.51	1.35
Sept	0.00	0.01	0.01	0.04	0.38	0.85	2.78
Oct	0.00	0.01	0.02	0.05	0.20	0.41	1.46
Nov	0.01	0.02	0.05	0.20	0.35	0.54	1.08
Dec	0.01	0.031	0.21	0.29	0.50	0.63	1.14

Impact from Point Sources

There are no point sources in Potecasi Creek watershed.

Impact from Nonpoint Sources

Land Cover

Residential and other developed areas are not significant contributors of the land base composition, an insignificant portion of the watershed. The watershed is predominantly forest (46 %), agricultural (38 %), and wetland (12 %). Forested lands and wetlands are considered background sources. These lands are not indicative of human impact. However, agriculture lands are indicative of human source; therefore, they are considered nonpoint sources.

Excessive nutrient input can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels in the creek where flow is relatively slow and aeration is low. So as to understand the nutrient levels in Potecasi Creek, the ambient monitoring data collected at D4150000 from 1998 through 2007 are obtained from the EPA's Storet database (Source: http://www.epa.gov/storet/). The non-detected values are replaced with half of the practical quantitation limit values specified by the DWQ (Source: http://h2o.enr.state.nc.us/lab/qa/pqlinorg.htm). Monthly averaged nutrient concentrations are given in Table 2.

Table 2. Averaged instream nutrient concentration (mg/L) in Potecasi Creek at the ambient station (D4150000) at NC11 near Union (1998-2007)

Months	**TKN**	**NOx**	**TN**	**TP**
	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Jan	0.64	0.08	0.70	0.09
Feb	0.51	0.13	0.62	0.09
Mar	0.73	0.08	0.79	0.09
Apr	0.75	0.09	0.83	0.12
May	0.80	0.26	1.06	0.14
Jun	0.79	0.23	0.99	0.19
Jul	0.67	0.19	0.81	0.13
Aug	0.65	0.14	0.79	0.15
Sept	0.63	0.10	0.71	0.14
Oct	0.60	0.08	0.65	0.13
Nov	0.62	0.05	0.60	0.10
Dec	0.68	0.10	0.65	0.11
Average	0.67	0.13	0.77	0.12

On average TN concentrations in the creek remained lower than or near to 1.0 mg/L. Except in June, TP concentrations remained below or near to 0.1 mg/L. These averaged nutrient concentrations are near or below the USGS national background averages (Source: http://pubs.usgs.gov/circ/circ1225/index.html). These averages are developed from nutrient concentrations in streams from undeveloped areas with typical concentrations of TN $\leq$ 1.0 mg/L and TP $\leq$ 0.1 mg/L. Overall, TN varies from 0.10 mg/L to 2.6 mg/L and TP varies from <0.01 mg/L to 0.2 mg/L in undeveloped stream basins in the USA (Clark et. al., August 2000). Therefore, the low nutrient concentration levels in Table 2 indicate that Potecasi Creek is not significantly affected by anthropogenic inputs of nitrogen and phosphorus.

Acid Deposition

Acid rains are also indicative of human sources, because the principal causes of acid rain are sulfur, carbon, and nitrogen compounds from human sources, such as electricity generation, factories, and motor vehicles. Coal power plants are one of the most significant contributors. Gases from these plants can travel hundreds of kilometers in the atmosphere, thereby reacting with water molecules in the atmosphere to produce acids. During precipitation the acids are deposited, causing ecological damage. So as to understand its impact in Potecasi Creek, the rainfall pH data are obtained from the nearby National Atmospheric Deposition Program/NTN station in Bertie County, NC (Station Lewiston NC03) (Source: http://nadp.sws.uiuc.edu). Acid deposition occurred in the Bertie dataset, with weekly rainfall pH during the period from 1998-2007 averaging 4.72 SU with a minimum of 3.93 SU and maximum of 6.40 SU. According to an EPA website, (Source: http://www.epa.gov/airmarkets/acidrain/index.html) the natural pH of rain is approximately 5.5 SU.

One method to assess whether acid deposition adversely impacts low pH in the creek is to observe close relationship between rain deposition and the DWQ ambient water quality monitoring field pH data. The relationship was estimated to be weak ($r = 0.37$), suggesting that the extent to which stream pH is decreased by acid deposition in the creek could not be decisively established. Therefore, impact from acid rain is uncertain.

Impact from Seasonal Fluctuation

Figure 6 shows a relationship among averaged monthly DO concentration, water temperature, and flow velocity in Potecasi Creek. As temperature increases DO decreases along with flow velocity. This is indeed a natural phenomenon where flow velocity is lower, because still water is affected by air temperature more rapidly and then facilitates decomposition of plant materials. This process increases oxygen demand and lowers DO as plants decay. Therefore, summer periods seem to be critical for low DO in the creek.

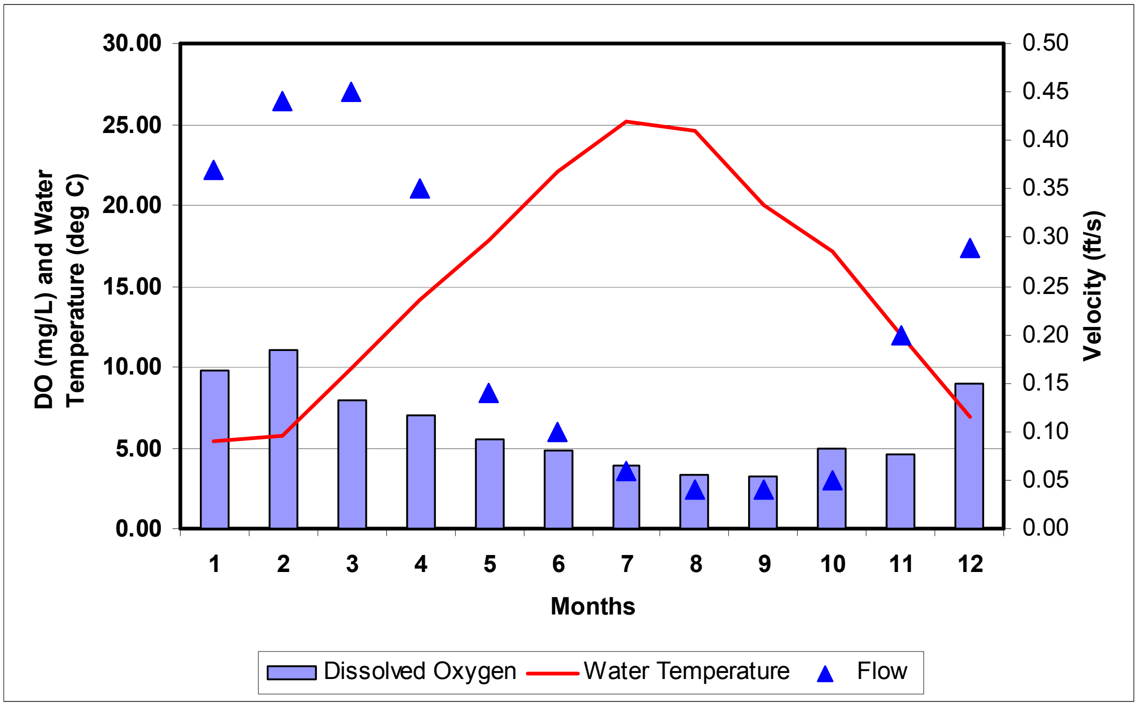

Figure 6. Monthly distribution of median DO, water temperature, and velocity in Potecasi Creek at the ambient station (D4150000) at NC11 near Union (1998-2007)

Field Observation

On May 27, 2009, DWQ staff visited Potecasi Creek to measure DO, water temperature, pH, and conductivity as well as to collect water samples upstream at SR1504, midstream at SR35, and downstream at NC11. The staff also collected water samples from an unnamed tributary in the upper watershed at SR1500 and from Miller Branch in the lower watershed at SR1175. These samples were collected to estimate DO consuming chemical parameters – five-day biochemical oxygen demand (BOD5) and total organic carbon (TOC). TOC was further broken down to labile organic carbon (LOC) and refractory organic carbon (ROC) by using equations 3 and 4. These equations were derived by Hendrickson et al., 2007, considering that LOC and ROC decompose simultaneously, albeit at different rates. Their first-order decay rates were 0.075 day $^{-1}$ and 0.001 day $^{-1}$, respectively. The derivation of the equations is well documented in Hendrickson et al., 2007.

LOC (mg/L) = BOD5*74.906 – TOC)/61.54 --------------------- (3)
ROC (mg/L) = TOC-LOC --- (4)

Equations 3 and 4 represent the St. Johns River, which is one of the largest blackwater rivers of the southeast U.S., draining a 24,765 km^2 area in Atlantic coastal plain river estuary in northeast Florida. The river is slow moving and receives nutrients from adjoining swamp water. Because of its swampy characteristics, it could be assumed that

any information drawn from the river would be applicable to Potecasi Creek as well, although there are some differences in physiological characteristics of the two water body.
Hendrickson et al found lowest level of LOC in urban and forested watershed runoff and highest level of ROC in dairy, row crop, and forested watershed runoff. As per their findings, Potecasi Creek, where forested lands with swamps and heavy tree canopy dominate the landscape, would have relatively more refractory organic carbon.

Table 3 reveals that DO concentration was very low upstream in the creek. Its concentration was only 1.6 mg/L. The concentration gradually improves as it goes down stream. The concentration increased to 2.4 mg/L at the midstream (SR35) and 3.4 mg/L at the downstream (NC11). However, the observed concentrations remained below the standard concentration, 4 mg/L, throughout the creek segment.

Table 3. Water sampling results for Potecasi Creek on May 27, 2009

Sample Site	**Date yy/mm/dd**	**Temp ˚C**	**DO (mg/L)**	**pH**	**Cond.**	**BOD 5day (mg/L)**	**TOC (mg/L)**	**LOC (mg/L**	**ROC (mg/L)**
Potecasi @ SR1504	09/05/27	20.5	1.6	6.1	73	1.76*	24	1.75	22.25
UT @ SR1500	09/05/27	21.9	1.1	6.1	69				
Potecasi @ SR35	09/05/27	21	2.4	6.2	89	1.77*	29	1.68	27.3
Potecasi @ NC11	09/05/27	22.9	3.4	6.3	113	1.08*	16	1.05	14.95
Mill Branch @ SR1175	09/05/27	22.5	3.5	6.1	73	2.10	19	2.25	16.75

* Concentration is below the DWQ's Practical Quantitation Limits (2 mg/L). It is a provisional data

Because ROC concentration was substantially higher than LOC concentration throughout the Potecasi Creek (Table 3), it appears that the low DO concentration was due to the presence of forested lands with swamps and heavy tree canopy. Furthermore, the low DO measurements at the two tributaries, UT (SR1500) and Mill Branch (SR1175) suggest that the watershed is comprised of swamp areas. Visual inspection from locations in the watershed also showed large swamp areas with heavy tree canopy (Figures 7 to 10). There are large inputs of decaying vegetation from areas of forested land with heavy tree canopy throughout the watershed that increase oxygen demand and lower DO as they decay.


Figure 7. Potecasi Creek at SR 1504, May 27, 2009


Figure 8. Wetland feeding upper Potecasi Creek at SR1504, May 27, 2009

Figure 9. Measuring flow velocity at Potecasi Creek at SR35, May 27, 2009. The DWQ staff from left Christopher S. Whitaker and Peter Caldwell.

Figure 10. Potecasi Creek at NC11, May 27, 2009

The DWQ staff also measured flow velocity in the mid stream of Potecasi at SR35 using Marsh McBirney Magnetic Flow Meter (Model #201). The velocity was below its detection limit.

As per the USGS gauge measurement at NC11 near Union, down stream from SR35, average flow was 9.1 cfs and average water depth was 2.71 ft in Potecasi Creek on May 27, 2009. Based on the measurements, velocity was estimated at 0.05 ft/s using equations 3 and 4, which falls on the 10th percentile for May, as reported in Table 1.

Conclusion

Potecasi Creek impaired segment (AU# 25-4-8), 42.5 miles, shows evidence of low velocity and low slope. The watershed comprises predominantly hydric soil and large areas of agricultural and forested lands with swamps and heavy tree canopy. Decomposition of the large inputs of vegetation from areas of forested land with swamps and heavy tree canopy throughout the watershed not only produce organic acids and lower pH but also increase oxygen demand and lower DO as they decay in the creek. Decomposition of vegetation seems more critical during summer period when water temperature reaches 25 degrees C (77 degrees F). These are not considered anthropogenic impacts.

Potecasi Creek exhibits low nutrient concentrations near or below national background levels from undeveloped areas, which is not indicative of human impact. Further more, ROC concentration was substantially higher than LOC concentration, suggesting that low DO concentration in the creek was due to the presence of swamps around the creek.

There is no active permitted NPDES discharger in the Potecasi Creek Watershed.

There is not a close correlation between precipitation amounts and field pH at the NC DWQ ambient water quality monitoring station. The r-value was well below 0.5, which does not indicate a close correlation between the variables. However the extent to which stream pH is decreased by acid deposition cannot be conclusively determined. Swamp waters may have a pH as low as 4.3 if it is the result of natural conditions.

Based on the above information, the water quality in Potecasi Creek and its tributaries is due to natural conditions. For the next 305(b)/303(d) assessment, Potecasi Creek should be assessed as category 2: natural conditions, no TMDL needed.

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