# Stressor Analysis for Benthic Macroinvertebrate Impairment for Sandy Bottom Branch and an Unnamed Tributary to Sandy Bottom Branch, Accomack County, Virginia

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## List of Abbreviations

| | |
|---|---|
| CFR | Code of Federal Regulations |
| CPMI | Coastal Plain Macroinvertebrate Index |
| CWA | Clean Water Act |
| DMR | Discharge Monitoring Report |
| NLCD | National Land Cover Data |
| SBB | Sandy Bottom Branch |
| SWCB | State Water Control Board |
| TMDL | Total Maximum Daily Load |
| USEPA | Environmental Protection Agency |
| USS | Un-segmented stream |
| UTSBB | Unnamed Tributary to Sandy Bottom Branch |
| VA DEQ | Virginia Department of Environmental Quality |
| VIMS | Virginia Institute of Marine Science |
| VPDES | Virginia Pollutant Discharge Elimination System |
| WLA | Wasteload Allocation |
| WQS | Water Quality Standard |

## EXECUTIVE SUMMARY

### Background

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies that are exceeding water quality standards (WQSs). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQSs. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish controls based on water quality conditions to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources.

Sandy Bottom Branch (SBB, VAT-C10R_SBB01A00) and Unnamed Tributary to Sandy Bottom Branch (UTSBB, VAT-C10R_XAZ01A00) are located in Accomack County, Virginia. UTSBB discharges to SBB, and the latter discharges to Holdens Creek, which eventually discharges to the Pocomoke Sound of the Chesapeake Bay. These two streams were listed as impaired on Virginia 2006 and 2008 Water Quality Assessment 305(b)/303(d) Integrated Reports (VA DEQ, 2006a; 2008a) due to violations of the State's WQSs for aquatic life use. TMDLs for bacteria for the two streams were completed in 2008 (VA DEQ, 2008b). Based on stressor analysis on current available data and implementation of new permits for effluent, there is no identifiable most probable stressor for the impaired water. Therefore, TMDLs are not needed. This report, upon approval of EPA, provides stressor identification and water quality analysis for SBB and UTSBB.

### Stressor Identification

To identify the most probable causes of the benthic impairment of SBB and UTSBB, a stressor identification process (USEPA, 2000) was conducted. This was based on evaluations of candidate stressors that can potentially impact the impaired segments. The results of stressor identification are listed in Table E-1. Proir to 2005, Dissolved Copper (Cu) is considered the most probable stressor. However, since that time the only permitted point source in the watershed, Tyson Farms, Inc. (VA0004049), has dramatically reduced Cu levels in its effluent. Results from recent observations indicate that the Cu concentrations in SBB and UTSBB are below VA water quality criteria and the condition of benthic macroinvertebrate community has shown improvement. Therefore, no TMDL is required for Cu.

**Table E-1: Summary of Stressors in SBB and UTSBB**

| Category | Candidate |
|---|---|
| Non-Stressors | Low DO, pH, Temperature, Dissolved Heavy Metals in Water Column except Cu, Heavy Metals in Sediment, Organic Contaminants in Sediment |
| Possible Stressors | Nutrients, Chloride |
| Most Probable Stressors | Dissolved Cu in Water Column (prior to 2005) |

Though total phosphorus (TP) is not categorized as the most probable stressor for benthic organisms, its concentration exceeds the Virginia Department of Environmental Quality (VA DEQ) screening level of eutrophication. However, eutrophic conditions in the streams have not been observed based on available field data. Because there is a Virginia Pollutant Discharge Elimination System (VPDES) permit in place to limit the TP discharge and Virginia requires a new wasteload allocation (WLA) starting from 1/1/2011 for TP discharge of Tyson Foods (9 VAC 25-820-70), the point source TP discharge will be significantly reduced and no TMDL for TP is required for SBB and UTSBB.

Given the fact that the condition of benthic macroinvertebrate community has shown improvement, it is recommended that SBB and UTSBB be re-categorized from Category 5A, for which *a Water Quality Standard is not attained. The water is impaired or threatened for one or more designated uses by a pollutant(s) and requires a TMDL (303d list)*, to Category 4B, for which *water is impaired or threatened for one or more designated uses but does not require the development of a TMDL because other pollution control requirements (such as VPDES limits under a compliance schedule) are reasonably expected to result in attainment of the Water Quality Standard by the next reporting period or permit cycle.*

**Public Participation**

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. A first public meeting was held on February 19, 2009 at the Arcadia Middle School in Oak Hall, Accomack County, Virginia. A second public meeting was held on February 3, 2010 at the Accomack-Northampton Planning District Commission in Accomack County, Virginia. Local organizations and individuals, as well as state agency personnel, were invited to attend each meeting.

# 1.0 Introduction

## 1.1 Background

Section 303(d) of the Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for waterbodies which are exceeding water quality standards (WQSs). TMDLs represent the total pollutant loading that a waterbody can receive without violating WQSs. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish controls based on water quality conditions to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources. A TMDL is not needed if water quality analysis has proven that water quality standards are met or other pollution control requirements are reasonably expected to result in the attainment of water quality standards.

## 1.2 Impairment Listing

Sandy Bottom Branch (SBB, VAT-C10R_SBB01A00) and Unnamed Tributary to Sandy Bottom Branch (UTSBB, VAT-C10R_XAZ01A00) were listed as impaired on Virginia's 305(b)/303(d) report in 2006 and 2008 (originally listed in 1996), for violations of the State's WQSs for aquatic life use due to poor condition of the benthic macroinvertebrate community. The SBB was listed as for violations of the State's WQS for Cu in 2002 (VA DEQ, 2002).

## 1.3 Watershed Location and Description

The SBB and UTSBB are located in Accomack County of the Eastern Shore of Virginia (Figure 1.1). The entire watershed (hereafter referred to as the SBB watershed) is about 6.9 $km^2$ in size. It is mainly a forest and agricultural watershed. UTSBB discharges to SBB, and the latter discharges to Holdens Creek, which eventually flows to the Chesapeake Bay. There is an unsegmented stream (USS) that converges with UTSBB about 526 meters upstream of the confluence of SBB and UTSBB. Figure 1.2 displays the delineations of the river segments and the subwatersheds for purposes of this report.

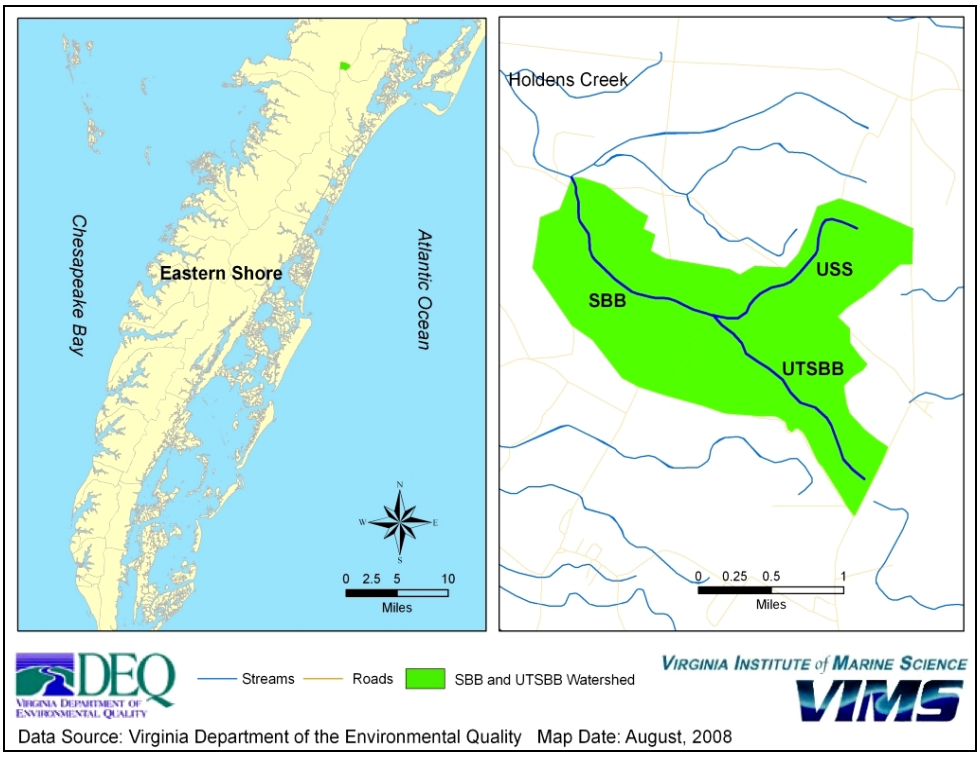


**Figure 1.1: Location Map of SBB and UTSBB**

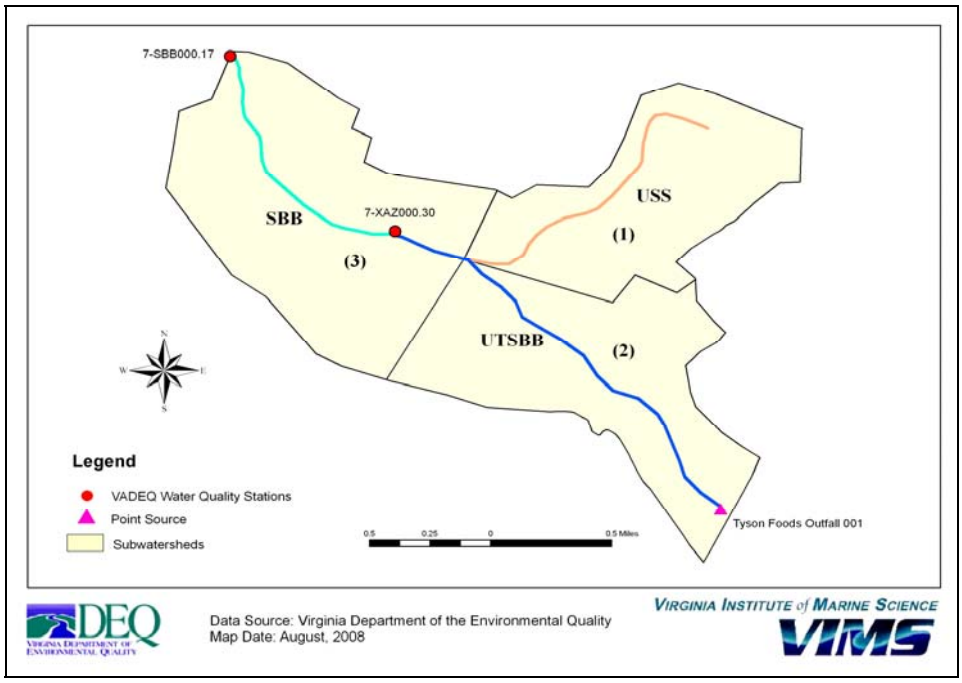


**Figure 1.2: Delineations of the Streams and Sub-Watersheds. The Locations of the Point Source (Tyson Foods, Inc. – VA0004049) and DEQ Water Quality Stations Are Also Shown**

## 1.4 Designated Uses and Applicable Water Quality Criterion

### 1.4.1 Designation of Uses

The identification of the applicable river reaches can be found in the river basin tables at 9 VAC 25-260-520 (State Water Control Board (SWCB), 2010). According to Virginia WQSs (9 VAC 25-260-10),

"*All State waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish*."

Based on the biological assessment surveys conducted by Virginia Department of Environmental Quality (VA DEQ), SBB and UTSBB do not support the aquatic life designated use due to poor health of the benthic macroinvertebrates. The source of the impairment was listed as unknown on the 303(d) list.

### 1.4.2 Water Quality Criterion

The General Standard defined in Virginia Water Quality Standards (9 VAC 25-260-20) provides general, narrative criteria for the protection of designated uses from substances that may interfere with attainment of such uses. It states:

*"All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life."*

The biological assessments conducted at DEQ biological stations 7-SBB000.17 and 7-XAZ000.30 (Figure 1.2) showed impaired macroinvertebrate communities, indicating that some pollutant(s) are interfering with the attainment of the standard. Although biological assessments are indicative of the impacts of pollution, a stressor identification process is needed to identify the most probable stressor.

## 2.0 Watershed Characterization

### 2.1 Topology, Soil, and Climate

Located on the Eastern Shore of Virginia, the SBB watershed is in the Lowland sub-province of the Coastal Plain province. The Virginia Coastal Plain is underlain by a thick wedge of sediments that increases in thickness from a featheredge near the Fall Zone to more than 4,000 meters under the continental shelf. Sand, silt, and clay from the Tertiary and Quaternary periods, which cover much of the Coastal Plain, were deposited during interglacial highstands of the sea under conditions similar to those that exist in the modern Chesapeake Bay and its tidal tributaries. The watershed is flat with poorly drained soils underlain by unconsolidated Coastal Plain sediments. The soils in the watershed range from moderately drained to slow infiltration rate. Elevations of the sub-province range from 0-60 feet.

As part of the Tidewater Climate Region, the watershed experiences average January temperatures of 35-48°F and average July temperatures of 71-85°F (Figure 2.1). The annual precipitation is 41.3 inches. The streams are influenced by stream discharge, groundwater seepage, and surface runoff. The tidal influence is very limited and is not a factor in this assessment.

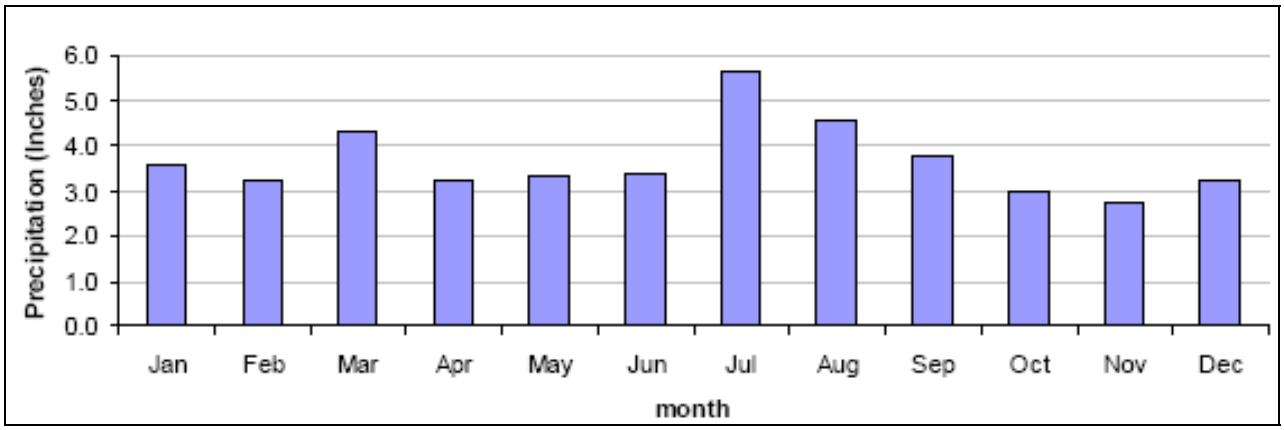


**Figure 2.1: Annual Average Precipitation in the Area of SBB and UTSBB**

### 2.2 Land Use

The land use characterization for the watershed was based on the Virginia National Land Cover Data (NLCD) 2001 Land Use Dataset (Figure 2.2). Dominant land uses in the watershed were found to be forest (61.6%) and agriculture (25.7%), which account for 87.3% of the total area in the watershed. Figure 2.3 and Table 2.1 depict the percentage land uses within the watershed.

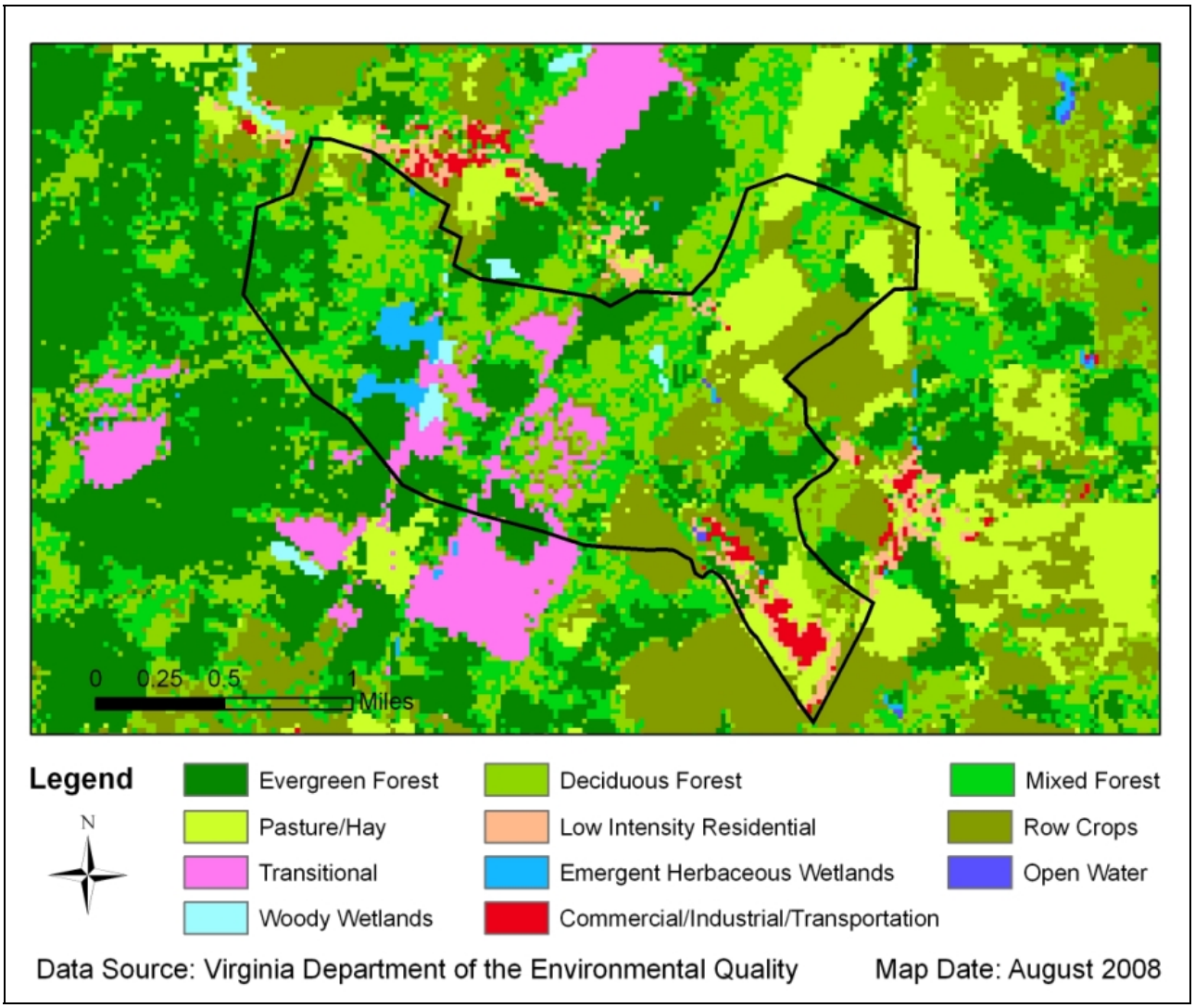


**Figure 2.2: Land Use of the SBB Watershed (NLCD 2001)**

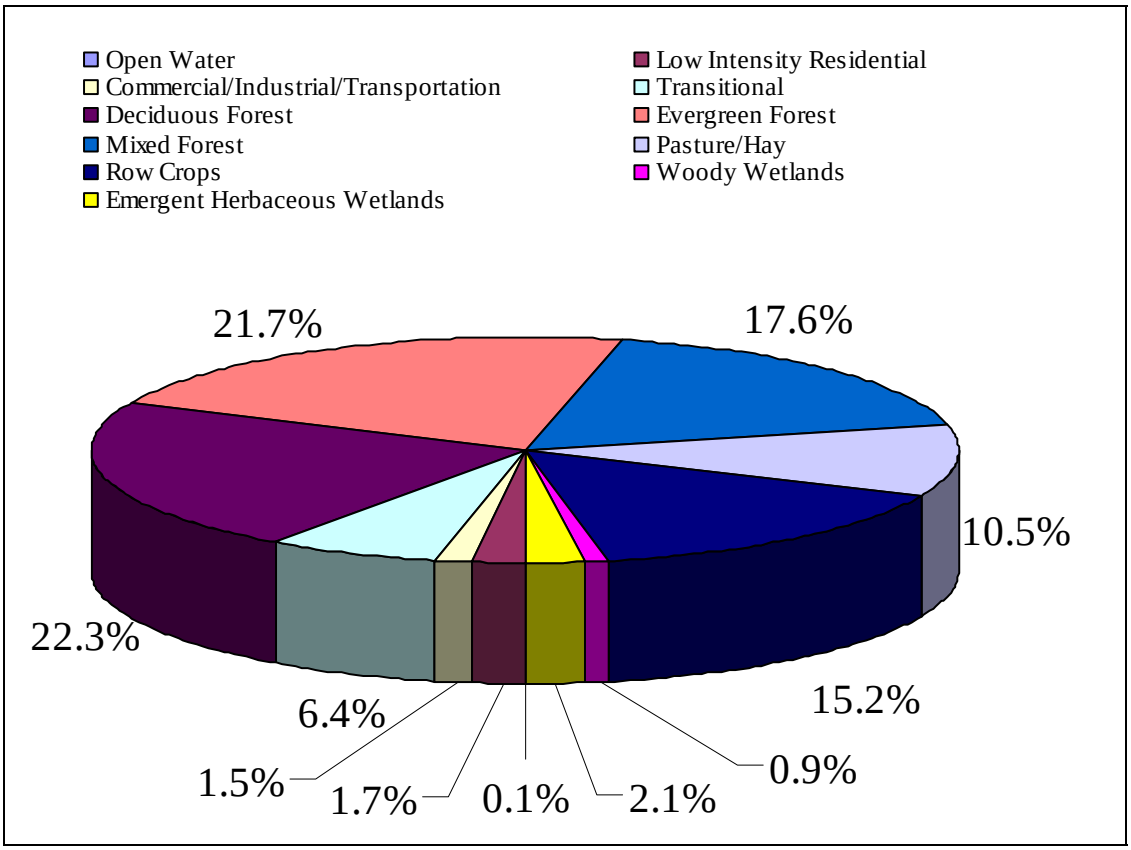


**Figure 2.3: Land Use Percentages of the SBB Watershed**

**Table 2.1: Percentage Land Use of the SBB Watershed**

| Land Use | Area ($km^2$) | Percentage |
|---|---|---|
| Open Water | 0.007 | 0.1% |
| Low Intensity Residential | 0.118 | 1.7% |
| Commercial/Industrial/Transportation | 0.106 | 1.5% |
| Transitional | 0.441 | 6.4% |
| Deciduous Forest | 1.545 | 22.3% |
| Evergreen Forest | 1.501 | 21.7% |
| Mixed Forest | 1.217 | 17.6% |
| Pasture/Hay | 0.725 | 10.5% |
| Row Crops | 1.055 | 15.2% |
| Woody Wetlands | 0.063 | 0.9% |
| Emergent Herbaceous Wetlands | 0.145 | 2.1% |
| **Sum** | **6.92** | **100%** |

# 3.0 Environmental Monitoring

## 3.1 VA DEQ Biological Monitoring Data

From 1994 to 2007, VA DEQ collected biological data every half year at Stations 7-SBB000.17 and 7-XAZ000.30. These data were evaluated using the Coastal Plain Macroinvertebrate Index (CPMI). This index was derived from a collaborative study among six states of the mid-Atlantic coastal plain region (from New Jersey to South Carolina) to develop a consistent approach for collecting, aggregating, and interpreting benthic macroinvertebrate data for low-gradient streams of the coastal plain (Maxted *et al.*, 2000). The calculation of CPMI incorporates 5 metrics. The multiple metrics evaluated together give an overall indication of ecological integrity. The CPMI metrics and their expected response to stream disturbance are presented in Table 3.1.

**Table 3.1: Metrics Used to Calculate the CPMI**

| Metric | Definition | Response to Disturbance |
|---|---|---|
| Total Taxa | Richness measurement of overall variety of invertebrate assemblage | Decrease |
| Hilsenhoff Biotic Index | Uses tolerance values to weight abundance in an estimate of overall pollution | Increase |
| EPT Taxa | Total number of Ephemeroptera, Plecoptera, and Trichoptera taxa | Decrease |
| % Ephemeroptera | Percentage of mayfly nymphs | Decrease |
| % Clinger | Percentage of insects having fixed retreats of adaptations for attachment to surfaces in flowing water | Variable |

The CPMI results for SBB and UTSBB are presented in Table 3.2. At Station 7-XAZ000.30, from 1994 to 2004, 4 out of 22 assessments were listed as “severely impaired”. From 2005 on, the benthic macroinvertebrate condition has improved as all the assessments were listed as “slightly impaired” or “moderately impaired”. There is no severe impairment at Station 7-SBB000.17.

## 3.2 Habitat Assessment Scores

Benthic impairments can be caused either by pollutants or habitat alteration. Habitat can be altered directly or indirectly. The habitat conditions of SBB and UTSBB were visually inspected as part of the biological assessment. The parameters were assigned a score of 0 to 20, with 0 indicating very poor conditions and 20 indicating optimal conditions. The scores were compared with those of the optimal/suboptimal conditions that do not have a signal of biological impairment. The scores of the impacted stream of SBB and UTSBB, and the optimal/suboptimal conditions are listed in Table 3.3. It can be seen that the impaired site experienced reductions in Channel Modification, In-stream Habitat, and Shading scores, while its total score was even higher than that of the optimal/suboptimal conditions, indicating that the habitat quality does not play a significant role in the benthic impairment.

**Table 3.2: CPMI Assessment Results for DEQ Monitoring Stations**

| Date | 7-SBB000.17 | 7-XAZ000.30 |
|---|---|---|
| 10/13/1994 | Moderately Impaired | Moderately Impaired |
| 4/11/1995 | Moderately Impaired | **Severely Impaired** |
| 10/26/1995 | Slightly Impaired | Slightly Impaired |
| 4/10/1996 | Moderately Impaired | Moderately Impaired |
| 10/16/1996 | Slightly Impaired | Moderately Impaired |
| 4/17/1997 | Slightly Impaired | Moderately Impaired |
| 10/21/1997 | Slightly Impaired | Moderately Impaired |
| 4/14/1998 | Moderately Impaired | Moderately Impaired |
| 10/27/1998 | Moderately Impaired | Moderately Impaired |
| 4/14/1999 | Moderately Impaired | Moderately Impaired |
| 10/14/1999 | Moderately Impaired | Moderately Impaired |
| 4/11/2000 | Moderately Impaired | Moderately Impaired |
| 10/11/2000 | Slightly Impaired | Slightly Impaired |
| 4/16/2001 | Slightly Impaired | **Severely Impaired**; Moderately Impaired* |
| 10/3/2001 | Slightly Impaired | **Severely Impaired** |
| 4/3/2002 | Slightly Impaired | **Severely Impaired** |
| 10/2/2002 | Slightly Impaired | Moderately Impaired |
| 5/8/2003 | Slightly Impaired; Moderately Impaired* | Moderately Impaired |
| 10/27/2003 | Slightly Impaired | Moderately Impaired |
| 4/6/2004 | Moderately Impaired | Moderately Impaired |
| 10/27/2004 | Slightly Impaired | Moderately Impaired |
| 4/26/2005 | Moderately Impaired | Moderately Impaired |
| 10/19/2005 | Moderately Impaired | Slightly Impaired |
| 4/27/2006 | Moderately Impaired; Moderately Impaired* | Moderately Impaired; Moderately Impaired* |
| 10/18/2006 | Moderately Impaired; Moderately Impaired* | Moderately Impaired |
| 5/8/2007 | Moderately Impaired; Moderately Impaired* | Moderately Impaired |
| 10/21/2007 | Moderately Impaired | Moderately Impaired |
| 4/29/08 | Slightly Impaired | Moderately Impaired |
| 10/29/08 | Moderately Impaired | Slightly Impaired |

* Indicates two assessments of the same day and same station.

**Table 3.3: Habitat Assessment Scores of the Impacted and Reference Sites**

| Parameter | Definition | Impacted | Optimal Condition |
|---|---|---|---|
| **Channel Modification** | Channelization or dredging conditions | 10 | 15 |
| **In-stream Habitat** | Scored based on the value of in-stream habitat to the fish community | 14 | 16 |
| **Pools** | Variety and complexity of slow or still Water habitat present at a site | 15 | 15 |
| **Bank Stability** | Scored based on the stability of the bank | 12 | 10 |
| **Bank Vegetative Type** | Types of vegetations on banks | 16 | 13 |
| **Shading** | Ratio of stream that is shaded | 15 | 16 |
| **Riparian Zone Width** | Minimum width of vegetated riparian buffer | 18 | 5 |
| **Total** | | 100 | 90 |

## 3.3 VA DEQ Ambient Water Quality Monitoring Data

DEQ has been collecting water quality data periodically at the two stations, 7-SBB000.17 and 7-XAZ000.30 since 1973. The following are summaries of the recent water quality data and their comparisons with the corresponding water quality criteria (9 VAC 25-260).

### 3.3.1 Dissolved Oxygen (DO)

The DO levels ranged from 4.4 to 12.8 mg/L. There were only two occasions, which happened in year 1996, in which the DO concentrations dropped below the daily average criterion of 5 mg/L at station 7-SBB000.17. All the observations were above the minimum criterion of 4 mg/L, indicating adequate levels of DO at both stations (Figure 3.1).

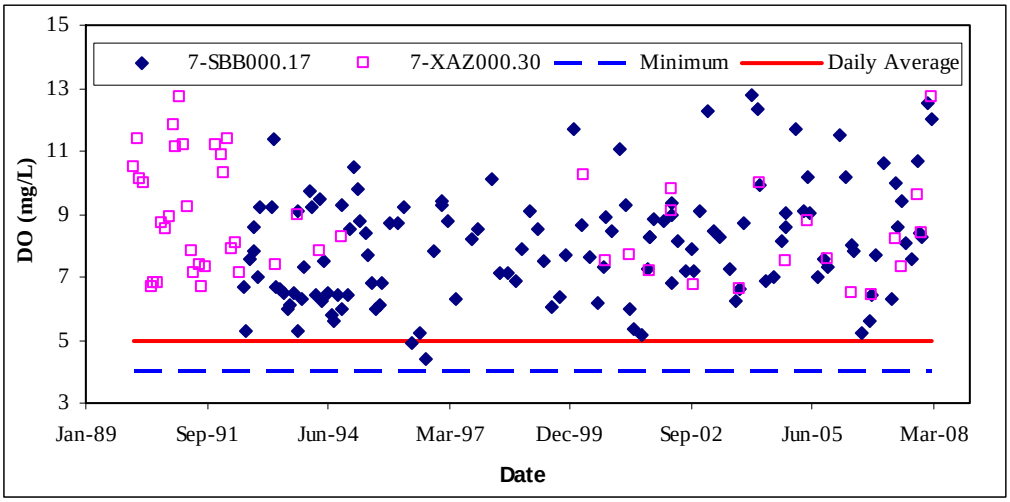


**Figure 3.1: DO Concentrations Observed at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.2 The pH Levels

The pH levels ranged from 5.0 to 8.9. Figure 3.2 indicates that during the evaluation period, all the observations at Station 7-XAZ000.30 were between the minimum (6) and maximum (9) criteria. Only a couple of observations at Station 7-SBB000.17 fell below the minimum criterion.

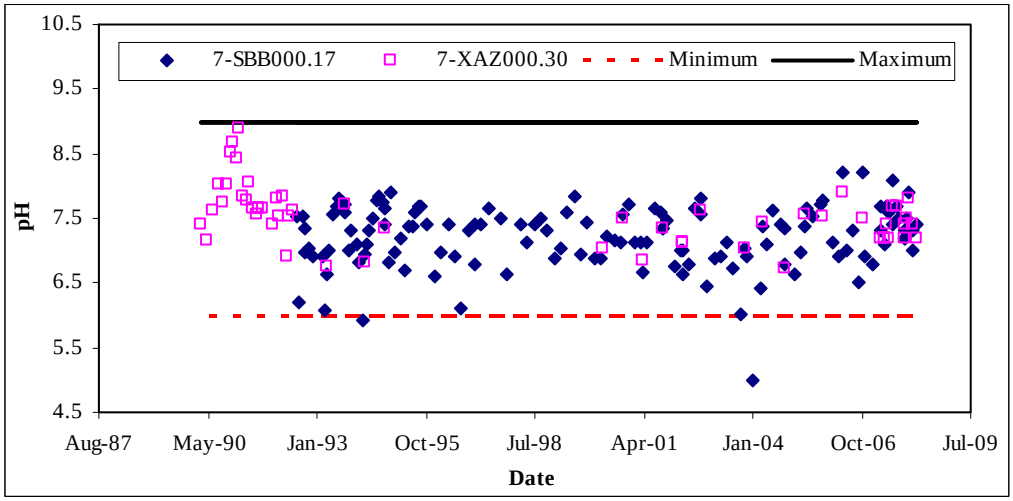


**Figure 3.2: The pH Levels Observed at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.3 Temperature

Figure 3.3 shows that all temperature values (range: 0.9-29.9°C) of both stations were in compliance with the VA DEQ criterion (a maximum of 32°C).

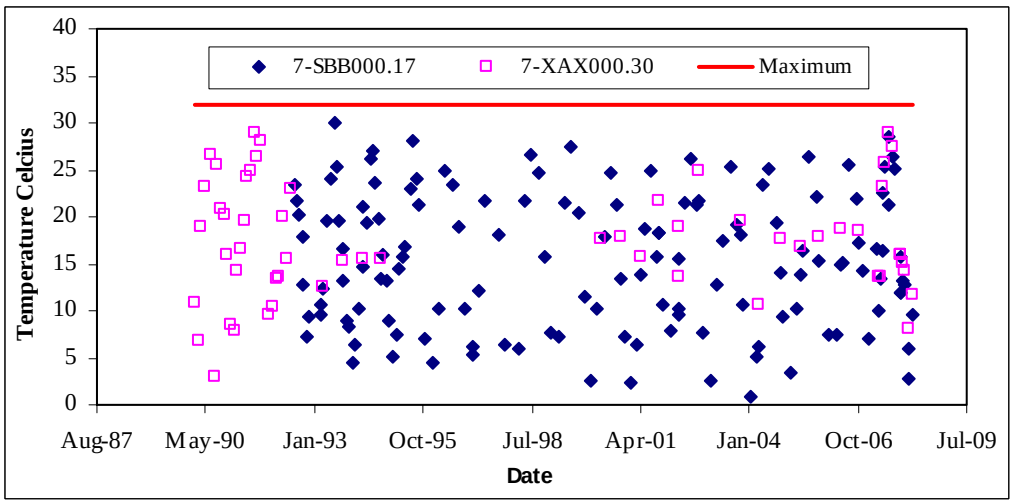


**Figure 3.3: Temperatures Observed at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.4 Biochemical Oxygen Demand (BOD)

The BOD concentrations were generally low (below 6 mg/L) before year 2003. However, starting from 2003, there is an increase of BOD that occurs at both stations. The highest concentration of 60 mg/L was observed in October 2005 (Figure 3.4). There is no screening value or criterion for BOD established by VA DEQ.

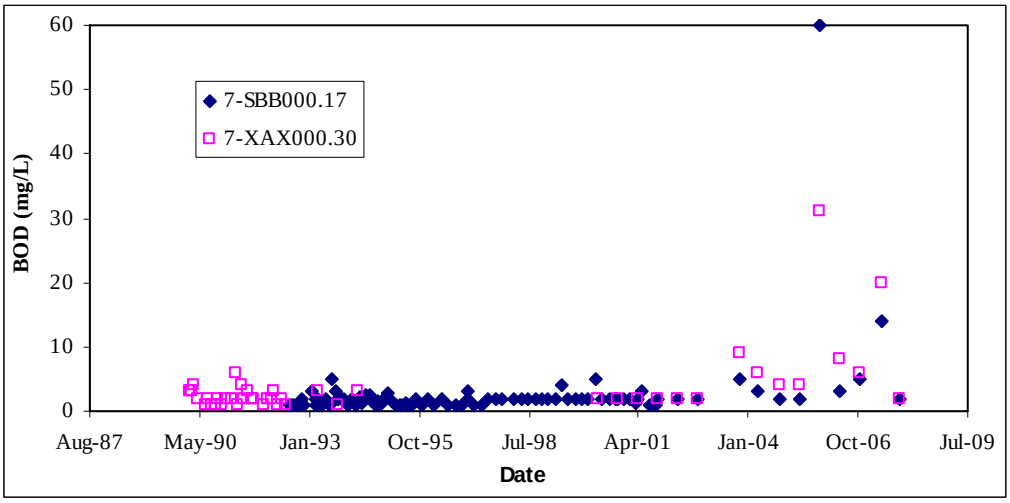


**Figure 3.4: BOD Levels Observed at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.5 Total Suspended Solid (TSS)

The TSS levels ranged from 1 to 26 mg/L. The averaged TSS of Station 7-SBB000.17 (6.8 mg/L) is slightly higher than that of Station 7-XAZ000.30 (5.3 mg/L) (Figure 3.5). There is no VA DEQ screening value or criterion for TSS.

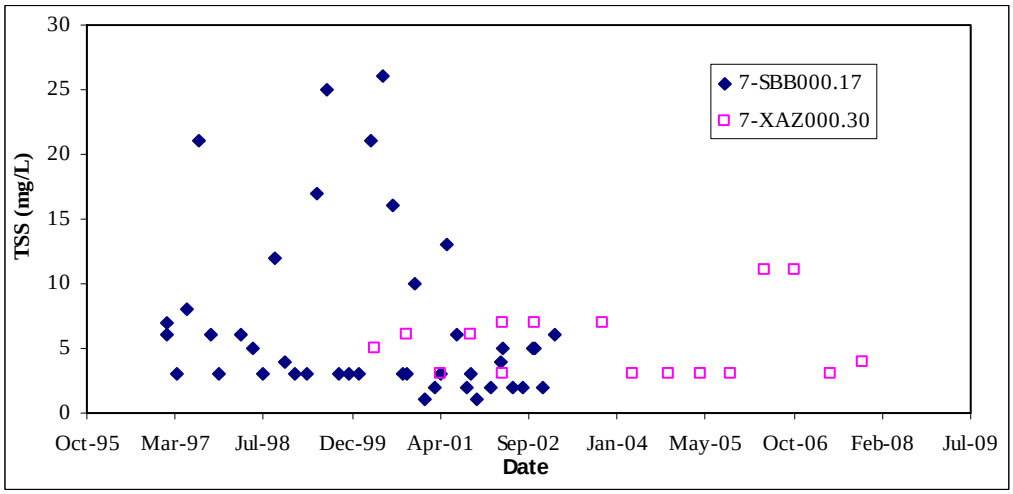


**Figure 3.5: TSS Concentrations at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.6 Total Ammonia-Nitrogen (Ammonia-N)

Figure 3.6 shows the total ammonia-N concentrations at the two stations, together with the corresponding criteria. The criteria vary as they are a function of pH and temperature. In general, the ammonia-N levels were in compliance with the criteria, except in October 2005, when the criteria were exceeded at both stations with unknown cause(s).

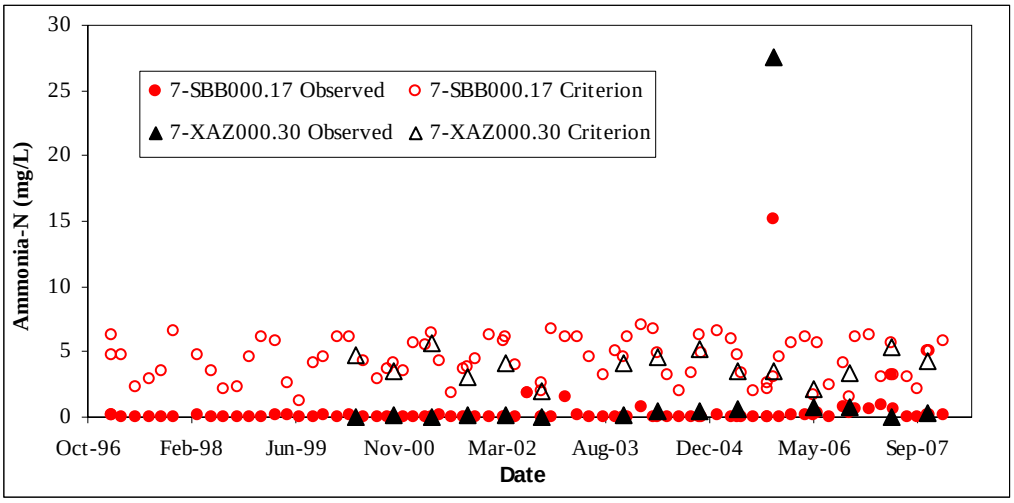


**Figure 3.6: Total Ammonia-N Concentrations at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.7 Nitrate-Nitrogen ($NO_3$-N)

The $NO_3$-N concentrations ranged from less than 1 mg/L to more than 200 mg/L (Figure 3.7), with most of the observations much higher than the VA DEQ reference value of 1.5 mg/L for eutrophication (DEQ, 2006b). In general, there is a tendency of decreasing $NO_3$-N concentration during the period evaluated.

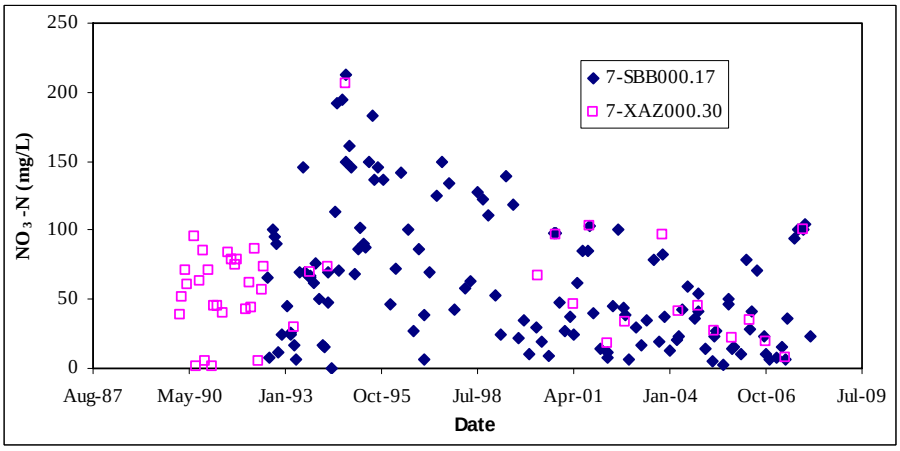


**Figure 3.7: $NO_3$-N Concentrations at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.8 Total Phosphorus (TP)

Figure 3.8 shows the TP concentrations from 1990 to 2008. The concentrations ranged from 0.1 to 28.2 mg/L, with most of the observations much higher than the VA DEQ TP eutrophication screening value of 0.2 mg/L for free flow streams (DEQ, 2006b). Starting from late 2002, the concentrations at both stations decreased by an order of magnitude, due to the adoption of a new TP point source discharge permit.

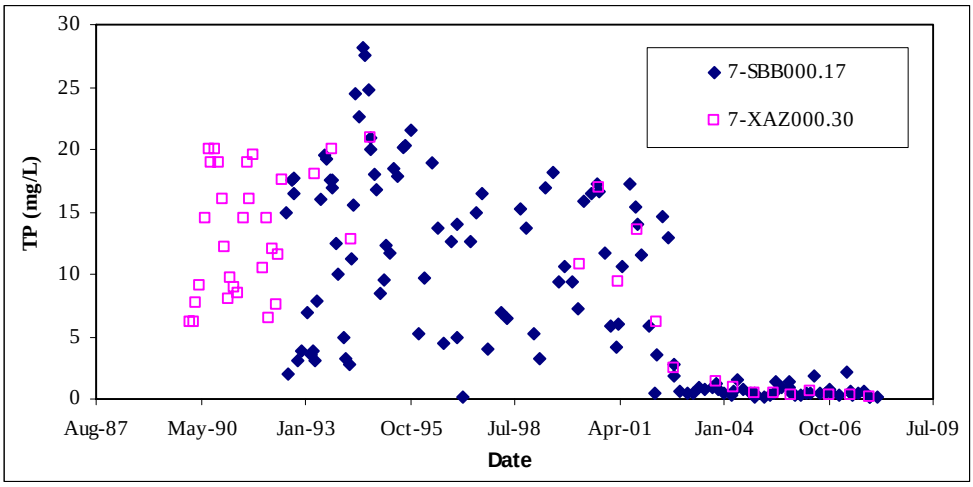


**Figure 3.8: TP Concentrations at Stations 7-SBB000.17 and 7-XAZ000.30**

### 3.3.9 Chlorophyll-*a*

The only Chlorophyll-*a* observations were collected at Station (7-SBB000.17) from 2001 to 2003 (Figure 3.9). The concentrations were below 6 µg/L, much less than the VA DEQ screening level of 50 µg/L.

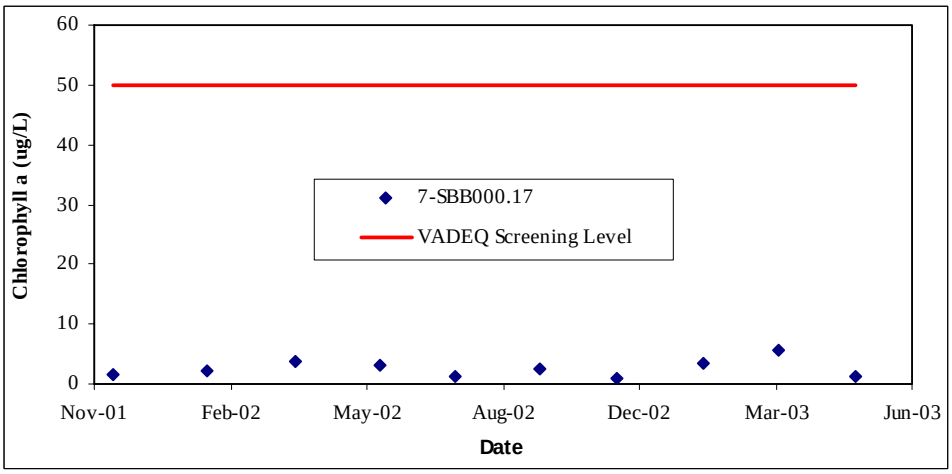


**Figure 3.9: Chlorophyll-*a* Concentrations at Station 7-SBB000.17**

### 3.3.10 Chloride

The chloride concentrations ranged from 0 to 355 mg/L. The VA DEQ criteria for chloride are established at 860 mg/L (acute) and 230 mg/L (chronic). Before 2005, all the observations were lower than the chronic criterion. Since 2005, the chloride concentrations show an increasing tendency (Figure 3.10).

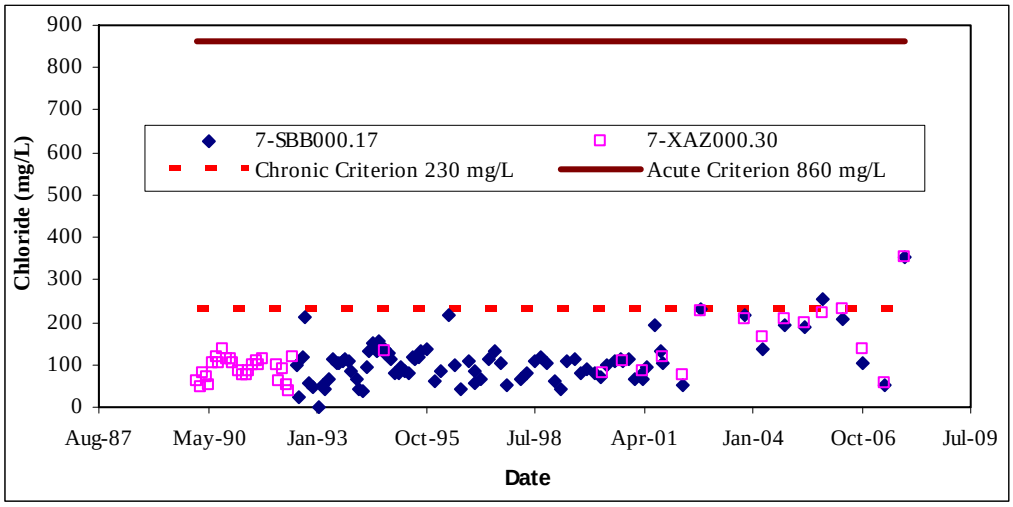


**Figure 3.10: Chloride Concentrations at Station 7-SBB000.17 and 7-XAZ000.30**

### 3.3.11 Conductivity

Figure 3.11 shows the measured conductivity. It averaged 1228 µmhos/cm and ranged from 442 to 2270 µmhos/cm. There is no criterion for conductivity in Virginia.

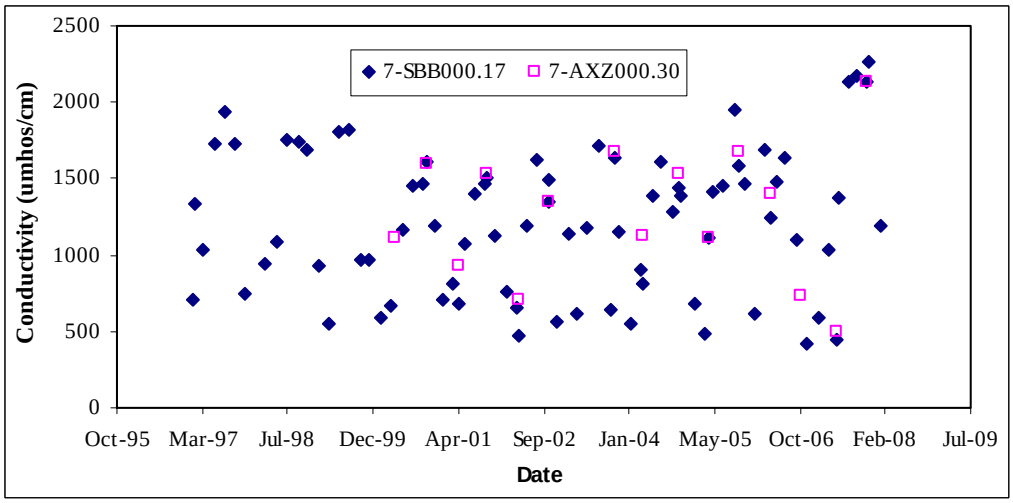


**Figure 3.11: Conductivity at Station 7-SBB000.17 and 7-XAZ000.30**

### 3.3.12 Heavy Metals

The heavy metals measured at the two water quality stations included arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), thallium (TI), and zinc (Zn).

As there's no criteria established for metals in sediment, the Probable Effects Concentrations (PECs, MacDonald *et al.*, 2000) were used to determine aquatic life support. If a PEC is unavailable for a particular contaminant, the VA 99th percentiles were used where available (VA DEQ, 2005). Almost all of the sediment metal levels were below their corresponding standards or the detection limits, or do not have standard available, except that one measurement at Station 7-XAZ000.30 in 1990 had a spiked Cr concentration.

In the water column, the Cu concentrations in both stations exceeded the criteria, which are a function of hardness (Figure 3.12). All other heavy metals were in compliance with VA DEQ water quality criteria or do not have an established standard.

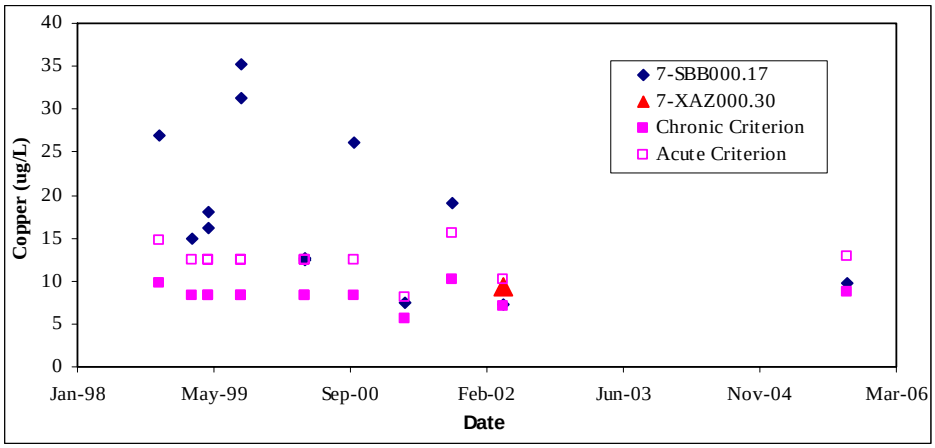


**Figure 3.12: Cu Concentrations at Station 7-SBB000.17 and 7-XAZ000.30**

### 3.3.13 Organic Contaminants

There are no organic contaminant data collected in the water column. From 1993 to 1999, the sediment organics data were available at Station 7-SBB000.17, including aldrin, chlordane, dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), dicofol, dieldrin, endrin, heptachlor epoxide, heptachlor, total polychlorinated biphenyls (PCBs), and toxaphene. As there are no criteria established for organic contaminants in sediment, the PECs (MacDonald *et al.*, 2000) were also used to determine aquatic life support. If a PEC is unavailable for a particular contaminant, the VA 99th percentiles were used where available (DEQ, 2005). All of the organic contaminants were below the detection limits or PECs.

## 3.4 VA DEQ Random Water Quality Data

In order to assess the most recent water quality conditions in SBB and UTSBB, in June 2009, VA DEQ randomly collected water samples in the two streams. The results are listed in Tables 3.4 and

3.5, respectively, for metals and other water quality parameters. All the measurements are below the water quality standards.

**Table 3.4: Metal Concentrations and Hardness in SBB and UTSBB in June 2009**

| Parameters | SBB | | UTSBB | |
|---|---|---|---|---|
| | Dissolved | Total | Dissolved | Total |
| Calcium (mg/L) | 25 | 25 | 25 | 24.9 |
| Magnesium (mg/L) | 10.7 | 10.7 | 10.7 | 10.6 |
| Arsenic (μg/L) | 1.38 | 1.4 | 1.38 | 1.34 |
| Barium (μg/L) | 10 | 10 | 10 | 10 |
| Beryllium (μg/L) | 0.1 | NA | 0.1 | NA |
| Cadmium (μg/L) | 0.1 | 0.1 | 0.1 | 0.1 |
| Chromium (μg/L) | 0.59 | 1.8 | 0.56 | 1.47 |
| Copper (μg/L) | 4.44 | 5.1 | 4.47 | 4.58 |
| Iron (μg/L) | 50 | 176 | 50 | 72 |
| Lead (μg/L) | 0.1 | 0.26 | 0.12 | 0.19 |
| Manganese (μg/L) | 9.72 | 13.6 | 13.4 | 13.8 |
| Thallium (μg/L) | 0.1 | 0.1 | 0.1 | 0.1 |
| Nickel (μg/L) | 3.27 | 3.5 | 3.36 | 3.47 |
| Silver (μg/L) | 0.1 | 0.1 | 0.1 | 0.1 |
| Zinc (μg/L) | 19.1 | 21 | 20.7 | 20.8 |
| Antimony (μg/L) | 0.5 | 0.5 | 0.5 | 0.5 |
| Aluminum (μg/L) | 26.5 | 276 | 21.7 | 103 |
| Selenium (μg/L) | 0.73 | 0.52 | 0.65 | 0.55 |
| Mercury (ng/L) | 1.5 | 1.5 | 1.5 | 1.5 |
| Hardness (mg/L) | 106 | 107 | 107 | 106 |

**Table 3.5: Other Water Quality Parameters in SBB and UTSBB in June 2009**

| Parameters | SBB | UTSBB |
|---|---|---|
| TOC (mg/L as C) | 5.47 | 5.11 |
| TKN (mg/L as N) | 0.1 | 0.1 |
| TP (mg/L as P) | 1 | 1 |
| Total Ammonia N (mg/L as N) | 0.04 | 0.13 |
| Nitrite N (mg/L as N) | 0.08 | 0.09 |
| Nitrate N (mg/L as N) | 121 | 104 |
| Orthophosphate (mg/L as P) | 0.8 | 0.81 |
| Temperature (degrees C) | 24.1 | 23.7 |
| pH | 7.1 | 7.1 |
| DO | 7.7 | 8.2 |
| Specific Conductivity | 1891 | 1944 |
| Salinity | 1 | 0.9 |
| Hardness (mg/L) | 107 | 106 |

## 3.5 VIMS Random Copper Data in the Sediment

In July 2009, sediment samples were collected from SBB and UTSBB to measure for copper levels by Virginia Institute of Marine Science (VIMS). The results are shown in Table 3.6. All of the Cu concentrations were one order of magnitude lower than the 149 mg/kg criterion.

**Table 3.6: Sediment Cu Concentrations in SBB and UTSBB**

| Samples | Concentration (mg/kg) | Average (mg/kg) |
|---|---|---|
| SBB(1): Rep 1 | 3.83 | 3.93 |
| SBB(1): Rep 2 | 4.02 | |
| SBB(2): Rep 1 | 10.97 | 11.90 |
| SBB(2): Rep 2 | 12.84 | |
| UTSBB(1): Rep 1 | 5.92 | 6.38 |
| UTSBB(1): Rep 2 | 6.84 | |
| UTSBB(2): Rep 1 | 10.49 | 15.44 |
| UTSBB(2): Rep 2 | 20.38 | |

## 3.6 Point Source Discharge Monitoring Reports (DMR)

There is only one permitted point source in the SBB watershed. Tyson Foods Inc. (VPDES Permit Number VA0004049 and nutrient trading permit VAN050005) is a chicken processing facility located in Temperanceville, VA. The facility discharges directly to UTSBB. The facility is required to measure water quality parameters from Outfall 001 (Figure 1.2), including BOD, chlorine, bacteria, Cu, DO, flow, nutrients, oil and grease, and TSS. The water quality data of Cu and TP are analyzed below.

### 3.6.1 Cu

Tyson Foods Inc. utilizes Cu as disinfection reagent. The total recoverable Cu concentration in the discharge from Outfall 001 is measured on a weekly basis. The monthly average and maximum total recoverable Cu concentration limits are set as 16 and 22 μg/L, respectively. As the water quality criteria are set for dissolved Cu, a metal translator is needed to convert total recoverable Cu to dissolved Cu. A site-specific Cu translator study was conducted (Tyson Foods, 2005) and it was decided that the metal translator for the Tyson Outfall 001 effluent into UTSBB is 0.76:

$$Cu_{Dissolved} = Cu_{Total\ Recoverable} \times 0.76$$

The total recoverable Cu data (2004-2008) provided by VA DEQ are presented in Figure 5.1. All the monthly average values that reported as less than a certain number was substituted by that number and all the values that reported as less than the detection limit was substituted by the detection limit for presentation purposes. As can be seen from Figure 3.13, since 2005 all the monthly average values were in compliance with the permit limit and only one maximum value exceeded the limit.

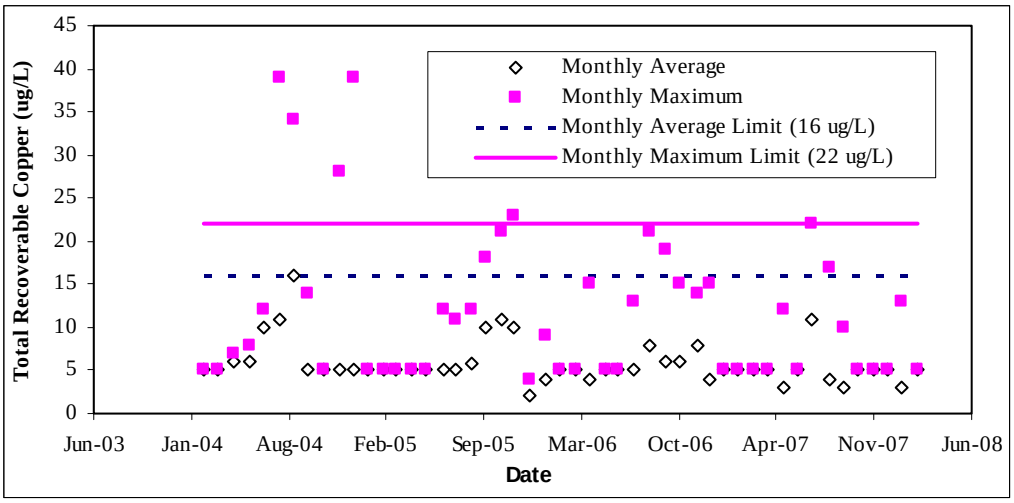


**Figure 3.13: Total Recoverable Cu Concentrations at Tyson Farms Outfall 001**

### 3.6.2 TP

The TP concentration discharged from Tyson Farms is measured on a weekly basis. The monthly average of TP concentration limit is set as 2.0 mg/L (18 lb/day). The monthly average TP data provided by VA DEQ are presented in Figure 3.14. All the monthly average values were in compliance with the permit limit.

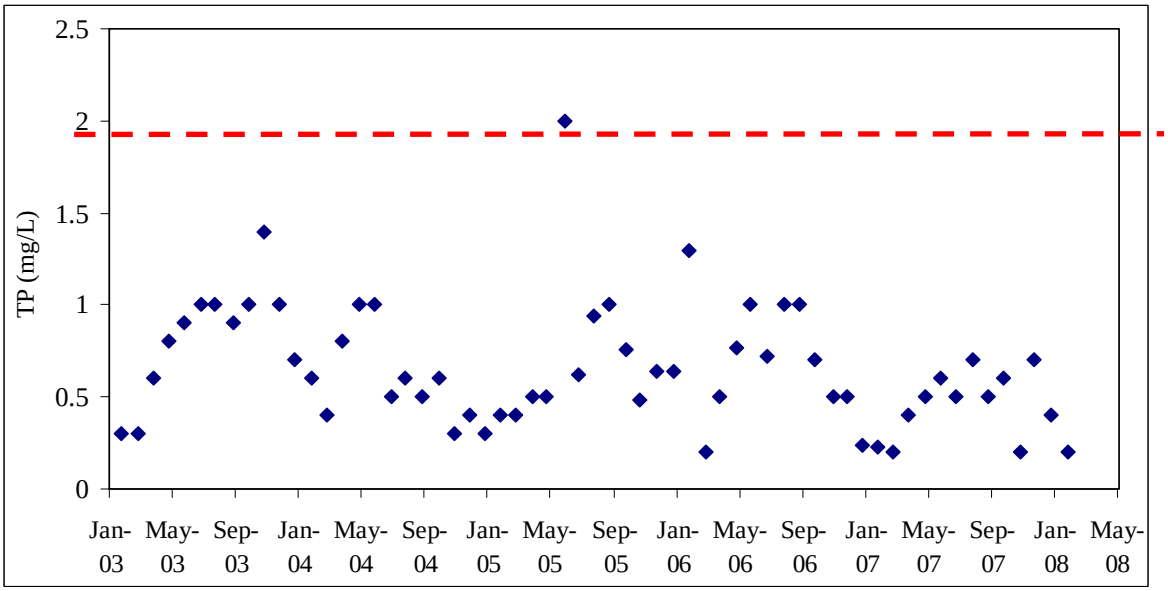


**Figure 3.14: TP Concentrations at Tyson Farms Outfall 001. The Red Line Denotes the 2.0 mg/L Permit Limit**

# 4.0 Stressor Identification

## 4.1 Introduction

TMDL development for the benthic impairment of SBB and UTSBB requires identification of pollutant stressor(s) affecting the benthic macroinvertebrate community (USEPA, 2000). Benthic assessments are good at determining if a particular stream segment is impaired, while they do not provide enough information to determine the causes of the impairment. This was based on evaluations of candidate stressors that can potentially impact the river. Chemical and physical monitoring data and field observations provided evidence to support or eliminate candidate stressors. Each stressor in SBB and UTSBB was then classified as one of the following (Table 4.1):

- Non-stressors: Stressors with data indicating normal conditions, without WQS exceedance, or without any apparent impact.

- Possible stressors: Stressors with data indicating possible links to the benthic impairment, but without conclusive data to show a direct impact on the benthic community.

- Most probable stressors: Stressors with conclusive data linking them to the poor health of the benthic community.

**Table 4.1: Summary of Stressors in SBB and UTSBB.**

| Category | Candidate |
|---|---|
| Non-Stressors | Low DO, pH, Temperature, Dissolved Heavy Metals in Water Column except Cu, Heavy Metals in Sediment, Organic Contaminants in Sediment |
| Possible Stressors | Nutrients, Chloride |
| Most Probable Stressors | Dissolved Cu in Water Column before Year 2005 |

## 4.2 Non-Stressors

### 4.2.1 Low DO

Decreases in water column and sediment DO concentrations can result in oxygen depletion or anoxic sediments, which adversely impact the river's benthic community. Only a couple of DO measurements since 1990 dropped below the daily average criterion, and all of them were higher than the minimum criterion. Therefore, low DO is considered a non-stressor.

### 4.2.2 pH

A suitable range of pH levels are required by benthic organisms to survive and realize optimum growth. Very high or low pH conditions can result in a change of dominant benthic invertebrate populations to pH-tolerant organisms. As shown in Section 3.3.2, since 1990 only a couple of pH observations dropped below the minimum value, which are not low and temporally long enough to impact benthic organisms. Therefore, pH is eliminated from the list of stressors.

### 4.2.3 Temperature

Aquatic organisms need a suitable range of temperature to grow, reproduce, and survive. All the temperature observations since 1990 were lower than the maximum level of DEQ criterion. Therefore, it is considered a non-stressor.

### 4.2.4 Heavy Metals in Water Column except Cu

As analyzed in Section 3.3.12, in the water column, all the heavy metals, except Cu, complied with VA DEQ water quality criteria or do not have any established criterion. They are eliminated from the list of stressors.

### 4.2.5 Heavy Metals in Sediment

According to the metal data provided by VA DEQ, most of the heavy metal concentrations in the sediment were below the PECs or the VA 99th percentiles. Some metal concentrations are either below the detection limit or do not have any standard available. The single observation of the Chromium (Cr) exceedance does not warrant its being listed as a stressor. Therefore, these metals were eliminated from the possible stressor list.

### 4.2.6 Organic Contaminants in Sediment

As the sediment levels of the organic contaminants were all below the PEC or detection limits, they are listed as non-stressors.

### 4.2.7 Sediment

Excessive sedimentation can fill the pores in gravel and cobble substrate, eliminating macroinvertebrate habitat. Potential sources of sediment include agricultural runoff, residential runoff, forestry operations, construction sites, and in-stream disturbances. The habitat assessment scores listed in Table 3.3 show that both Bank Stability and Riparian Zone Width scores of the SBB watershed are higher than those of the reference watershed. The TSS observations are within the reasonable range as well. Both of these indicate that sediment is not a stressor for the benthic biological community.

## 4.3 Possible Stressors

### 4.3.1 Nutrients

Excessive nutrients can stimulate phytoplankton growth and eutrophication, which eventually causes low DO and stresses aquatic organisms. VA DEQ adopts nutrient reference values of 1.5 mg/L $NO_3$-N and 0.2 mg/L TP for eutrophication. From Sections 3.3.7 and 3.3.8, it can be seen that the nutrient levels in SBB and UTSBB measurement stations far exceeded these reference values, indicating a favorable condition for eutrophication. However, the adequate DO (Figure 3.1) and extremely low chlorophyll-*a* levels (Figure 3.9) do not show any evidence of excessive algal growth or eutrophication. Though direct toxicity caused by $NO_3$-N and TP are possible, there's no

conclusive research in the literature indicating a toxicity level. Therefore, the nutrients are classified as possible stressors in this study.

### 4.3.2 Chloride

Chloride is considered to be a toxic substance to benthic organisms. Starting from 2005, the chronic criterion was exceeded three times at both monitoring stations (Figure 3.10). However, when SBB and UTSBB were first listed in 303(d) due to violations of the State's WQSs for aquatic life use (2004 and 1998, respectively), the chloride concentrations complied with the criteria. The benthic CPMI assessment results did not show any degradation tendency from 1994 to 2007 either. Based on these facts, chloride is listed as one of the possible stressors and more monitoring data are needed to draw a conclusion.

## 4.4 Most Probable Stressors

Cu is a kind of heavy metal and excessive amount of Cu can result in decline of the well-balanced, indigenous benthic population. As shown in Section 3.3.12, from 1998 to early 2006, the dissolved Cu concentrations in the water column of the two stations were continuously higher than the hardness-adjusted criteria. However, from Figure 3.12, the dissolved Cu concentration has a trend to decrease. In addition, the random Cu samples collected by VA DEQ in summer 2009 (Table 3.4) shows a very low dissolved Cu concentration of 4.4 μg/L, which was well below the 9.4 μg/L hardness-adjusted criterion. Cu concentrations in the stream have decreased. The average dissolved Cu concentration at Station 7-SBB000.17 from 1998 to 2004 was 19.0 μg/L, in contrast to that of 7.1 μg/L from 2005 to 2009. Therefore, Cu was categorized as the most probable stressor before year 2005. After 2005, following the adoption of the new permit of Tyson Farms, the benthic macroinvertebrate conditions of SBB and UTSBB have improved, as can be seen from Table 3.2. Therefore, Cu is moved from the most probable stressor to the possible stressor list.

## 4.5 Stressor Identification Summary

The data and analysis presented above indicate that pH, DO, temperature, dissolved heavy metals in the water column except Cu, heavy metals in sediment, and organic contaminants in the sediment are adequate to support a balanced invertebrate community, and therefore are non-stressors.

The nutrients and chloride are classified as possible stressors, as analysis of available data could not lead to a definite conclusion. They possibly link to the benthic impairment, but more evidence is needed to show a direct impact on the benthic community. It seems the current nutrient and chloride levels do not have a directly harmful effect on benthic organisms, as the benthic macroinvertebrates condition has shown improvement. The instream TP concentrations dramatically decreased since late 2002 due to the adoption of a new TP permit of the only point source, Tyson Foods, Inc. It is stated in 9 VAC 25-260-330 that

*The Board recognizes that nutrients are contributing to undesirable growths of aquatic plant life in surface waters of the Commonwealth. This standard establishes a designation of "nutrient enriched*

*waters". Designations of surface waters of the Commonwealth as "nutrient enriched waters" are determined by the Board based upon an evaluation of the historical water quality data for one or more of the following indicators of nutrient enrichment: chlorophyll "a" concentrations, dissolved oxygen fluctuations, and concentrations of total phosphorus.*

Therefore, TP, DO, and chlorophyll are three indicators of eutrophication. As can be seen from Section 3.3, neither DO nor chlorophyll exceed the water quality standards, but the current TP level is higher than the VA DEQ eutrophication screening value of 0.2 mg/L for free flow streams (DEQ, 2006b). Therefore TP should be controlled for the “nutrient enriched river”. However, at this point no specific endpoint is indentified and no TMDL for TP is needed for SBB and UTSBB. This is mainly because there is TP permit for the point source in place and the benthic macroinvertebrates condition has shown improvement since the adoption of the current permit. In addition, 9 VAC 25-820-10 et seq. and 9 VAC 25-820-70 require that starting from 1/1/2011 the TP Wasteload Allocation (WLA) for Tyson Foods is limited to 1,142 lbs/year. Upgrades of the plant will allow Tyson Foods to meet this WLA and a technology based limit of 0.3 mg/l TP. This WLA, together with the more stringent TP limit negates the need for a TP TMDL for SBB and UTSBB.

According to VA DEQ, there is no known Cu contaminated site in SBB watershed. Therefore, the only nonpoint source is the background Cu washed off from soils in the watershed, which is insignificant compared with the only point source, Tyson Farms. Dissolved Cu is considered the most probable stressor before year 2005. Since 2005, because of the adoption of a new point source discharge permit, there has been dramatic decrease of the Cu level and both the in-stream water quality (see Tables 3.4 and 3.6) and benthic organism conditions (Table 3.2) have shown significant improvement. In addition, recent monitoring data show that the instream dissolved Cu is lower than the state WQS. Therefore, Cu is moved from the most probable stressor to the possible stressor list and no TMDL is necessary for now.

Based on the aforementioned information, for both dissolved Cu and TP, it is recommended that SBB and UTSBB be re-categorized from Category 5A- *a Water Quality Standard is not attained. The water is impaired or threatened for one or more designated uses by a pollutant(s) and requires a TMDL (303d list),* to Category 4B- *water is impaired or threatened for one or more designated uses but does not require the development of a TMDL because other pollution control requirements (such as VPDES limits under a compliance schedule) are reasonably expected to result in attainment of the Water Quality Standard by the next reporting period or permit cycle.*

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9 VAC 25-820-10. Watershed Permit for Total Nitrogen and Total Phosphorus Discharges and Nutrient Trading in the Chesapeake Bay Watershed