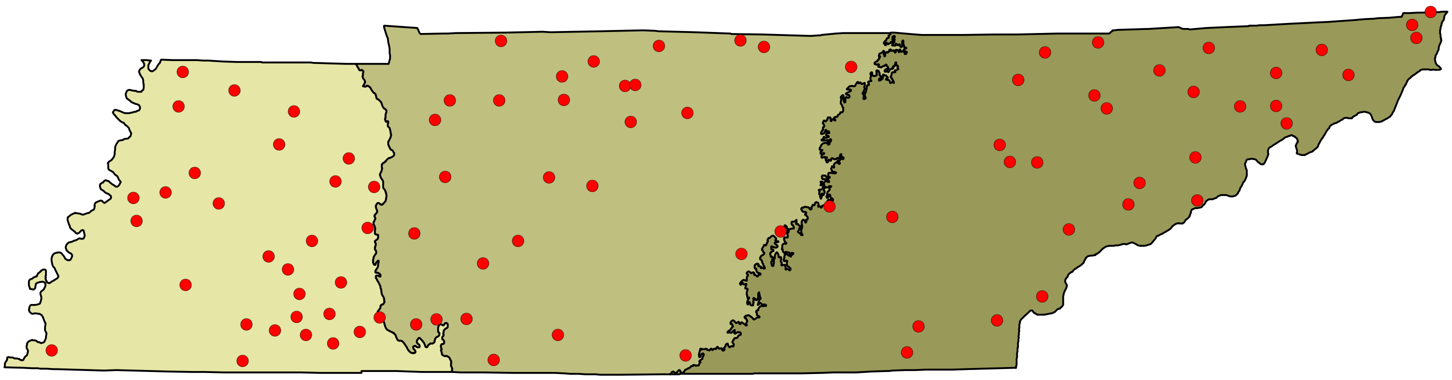
2010 PROBABILISTIC MONITORING OF WADEABLE STREAMS IN TENNESSEE



Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L&C Annex
401 Church Street
Nashville, TN 37243-1534

2010 PROBABILISTIC MONITORING OF WADEABLE STREAMS IN TENNESSEE

By

Deborah H. Arnwine

Michael H. Graf

Amanda L. Whitley

December 2011

Tennessee Department of Environment and Conservation
Division of Water Pollution Control
7th Floor L&C Annex
401 Church Street
Nashville, TN 37243-1534

DEPARTMENT OF ENVIRONMENT & CONSERVATION

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS………………………………………………………	1
EXECUTIVE SUMMARY………………………………………………………	2
1. INTRODUCTION………………………………………………………	3
2. REPRESENTATIVENESS OF PROBABILISTIC SITES…………......	4
a. Stream Order……………..…………………………………………….	4
b. Drainage Area…………………………………………………….....	5
c. Ecoregions……………………………………………………………...	5
d. Watersheds……………………………………………………………..	6
e. Land Use………………………………………………………………	6
f. Flow Conditions………………………………………………………..	6
3. Macroinvertebrate Monitoring..	10
a. 2010 Macroinvertebrate Results……………………………………..	11
b. Comparison of 2007 to 2010 Macroinvertebrate Results……………	13
c. Identification of New Reference Sites...	17
4. Habitat…………………………………………………………………	18
a. Epifaunal Substrate and Available Cover…………………………...	21
b. Sediment Deposition…………………………………………………...	22
c. Riparian Vegetation Width……………………………………………..	23
d. Vegetative Protection…………………………………………………..	24
5. Water Chemistry……………………………………………………....	25
a. Nutrients……………………………………………………………………..	25
b. Field Parameters………………………………………………………..	32
c. Metals…………………………………………………………………..	41
6. SUMMARY………………………………………………………………	48
LITERATURE CITED………………………………………..………………	49

LIST OF TABLES

Table 1	Comparison of sample frequency and parameters between 2007 and 2010 wadeable stream probabilistic studies………..	3
Table 2	Average drainage area of the 2007 and 2010 probabilistic studies...	5
Table 3	Biometrics used for determination of the Tennessee Macroinvertebrate Index……………………………………….	10
Table 4	Habitat assessment parameters………………………………...	18

Table 5	Summary statistics for ammonia concentrations (mg/L) at the probabilistic sites..	28
Table 6	Summary statistics for Total Kjeldahl Nitrogen (mg/L) at the probabilistic sites..	29
Table 7	Summary statistics for total suspended solids (mg/L) at the probabilistic sites..	30
Table 8	Summary statistics for total organic carbon (mg/L) at the probabilistic sites..	31
Table 9	Summary statistics for arsenic (ug/L) at the 2010 probabilistic sites..	41
Table 10	Summary statistics for copper (ug/L) at the 2010 probabilistic sites..	42
Table 11	Summary statistics for chromium (ug/L) at the 2010 probabilistic sites..	43
Table 12	Summary statistics for iron (ug/L) at the 2010 probabilistic sites..	44
Table 13	Summary statistics for lead (ug/L) at the 2010 probabilistic sites..	45
Table 14	Summary statistics for manganese (ug/L) at the 2010 probabilistic sites..	46
Table 15	Summary statistics for zinc (ug/L) at the 2010 probabilistic sites..	47

LIST OF FIGURES

Figure 1	Location of probabilistic monitoring sites in 2007 and 2010….	4
Figure 2	Comparison of stream order distribution between the 2007 and 2010 probabilistic studies.……………………………………..	4
Figure 3	Comparison of statewide land use between the 2007 and 2010 probabilistic studies……………………………………………	6
Figure 4	Palmer Drought Severity Index map for July 2007……………	8
Figure 5	Palmer Drought Severity Index map for July 2010……………	8
Figure 6	NOAA map showing extreme rain event during May of 2010……...	9
Figure 7	The thirteen bioregions of Tennessee………………………….	11
Figure 8	Percent of probabilistic sites meeting regional TMI guidelines in 2010 for each division………………………………………	11
Figure 9	Percent of 2010 probabilistic sites meeting regional guidelines for individual biometrics in each division……………………..	12
Figure 10	Comparison of 2007 and 2010 probabilistic sites scoring at or above 32 for Tennessee Macroinvertebrate Index (TMI)……..	13
Figure 11	Range of Tennessee Macroinvertebrate Scores (TMI) at probabilistic sites in 2007 and 2010..	13
Figure 12	Locations of probabilistic sites meeting regional TMI guidelines in 2007 and 2010…………………………………...	14

Figure 13	Comparison of probabilistic sites meeting regional biometric guidelines between 2007 and 2010 for the west, middle and east divisions in Tennessee…………………………………	16
Figure 14	Comparison of total habitat scores between 2007 and 2010 wadeable stream probabilistic surveys......................................	19
Figure 15	Distribution of probabilistic sites that passed ecoregion habitat guidelines in 2007 and 2010..	19
Figure 16	Percent of probabilistic sites meeting regional guidelines for individual habitat parameters statewide...................................	20
Figure 17	Comparison of epifaunal substrate and available cover between 2007 and 2010 probabilistic surveys...........................	21
Figure 18	Comparison of assessments of sediment deposition between 2007 and 2010 wadeable stream probabilistic surveys..............	22
Figure 19	Distribution of probabilistic sites that passed ecoregion sediment deposition guidelines in 2007 and 2010....................	22
Figure 20	Comparison of riparian zone disturbance between 2007 and 2010 wadeable stream probabilistic surveys.............................	23
Figure 21	Comparison of vegetative protection between 2007 and 2010 wadeable stream probabilistic surveys......................................	24
Figure 22	Percent of probabilistic sites that met regional total phosphorus criteria..	26
Figure 23	Summer total phosphorus ranges by division at the 2007 and 2010 probabilistic sites..	26
Figure 24	Percent of probabilistic sites that met regional nitrate+nitrite criteria...	27
Figure 25	Summer nitrate+nitrite ranges by division at the 2007 and 2010 probabilistic sites...	27
Figure 26	Summer TKN ranges by division at the 2007 and 2010 probabilistic sites...	29
Figure 27	Summer TOC ranges by division at the 2007 and 2010 probabilistic sites..	31
Figure 28	Percent of probabilistic sites that met pH criteria in 2007 and 2010...	32
Figure 29	Summer pH ranges by division at the 2007 and 2010 probabilistic sites...	33
Figure 30	Summer 2010 pH values at the probabilistic monitoring sites by location..	33
Figure 31	Percent of probabilistic sites that met dissolved oxygen criteria in 2007 and 2010...	34
Figure 32	Summer dissolved oxygen ranges by division at the 2007 and 2010 probabilistic sites..	35
Figure 33	2010 dissolved oxygen values at the probabilistic sites by location...	36
Figure 34	Summer temperature ranges by division at the 2007 and 2010 probabilistic sites...	36

Figure 35	Summer flow ranges by division at the 2007 and 2010 probabilistic sites..	37
Figure 36	Percent of probabilistic sites that met regional flow status habitat guidelines in 2007 and 2010...	38
Figure 37	Stream flow at probabilistic sites during the summer of 2007 and 2010 by location...	39
Figure 38	Summer conductivity ranges by division at the 2007 and 2010 probabilistic sites..	40
Figure 39	Summer 2010 copper ranges by division at the probabilistic sites..	42
Figure 40	Summer 2010 total chromium ranges by division at the probabilistic sites..	43
Figure 41	Summer 2010 iron ranges by division at the probabilistic sites.	44
Figure 42	Summer 2010 lead ranges by division at the probabilistic sites.	45
Figure 43	Summer 2010 manganese ranges by division at the probabilistic sites..	46
Figure 44	Summer 2010 zinc ranges by division at the probabilistic sites.	47
APPENDIX A	**2010 MACROINVERTEBRATE DATA**……………………	51
APPENDIX B	**2010 HABITAT ASSESSMENT SCORES**………………….	54
APPENDIX C	**2010 WATER CHEMISTRY DATA**………………………..	58
	C-1 Total Phosphorus and Nitrate+Nitrite Data..................	59
	C-2 Field Measurements and Additional Chemical Quality	61
	C-3 Metals Data……………………………………………	64

ACKNOWLEDGMENTS

This document was prepared by the Planning and Standards Section (PAS), Division of Water Pollution Control, Tennessee Department of Environment and Conservation. Greg Denton is the section manager. Deborah Arnwine was project coordinator for the study. This study was partially funded by a 106 supplemental grant administered by EPA I95446909-0. This document was prepared in partial fulfillment of the requirements of that grant.

Tony Olsen with the USEPA Western Ecology Division in Corvallis, Oregon assisted with the statistical survey design and provided a subsample of randomly selected wadeable streams for each of the three regions. Barbara Rosenbaum, INDUS Corporation, contractor for EPA, assisted with the random selection process.

Aquatic Biology Staff, Tennessee Department of Health Environmental Laboratories conducted the field surveys which included reconnaissance, sample collection, field measurements and habitat assessments. Pat Alicea is the section manager.

Taxonomists with the Aquatic Biology Section, Tennessee Department of Health (TDH) and the Aquatic Resources Center (contractor for TDH) processed the macroinvertebrate samples. The director of the Aquatic Resources Center is Todd Askegaard.

Field activities and site verification were coordinated with the eight Environmental Field Offices of Water Pollution Control, TDEC. The managers of these staff during the study period were:

Chattanooga EFO	Dick Urban	Johnson City EFO	Jeff Horton
Columbia EFO	Ryan Owens	Knoxville EFO	Paul Schmierbach
Cookeville EFO	Rob Howard	Memphis EFO	Terry Templeton
Jackson EFO	Pat Patrick	Nashville EFO	Joe Holland

Cover photos provided by Aquatic Biology, TDH.

Executive Summary

In 2010, the Division of Water Pollution Control completed a statewide probabilistic monitoring study of 90 wadeable streams to supplement the traditional targeted watershed monitoring. This is a follow-up to a study initiated in 2007. Since this is only the second year of monitoring, it is too early to evaluate trends. However, it is possible to compare 2007 data, when most of the state was in a severe drought, to current conditions.

Sample methodology and quality assurance in 2010 followed the same protocols, in accordance with TDEC QSSOPs, as the 2007 study. Due to budget limitations, there was some difference in frequency and the types of parameters collected. The 2010 study only included one site visit per station and was limited to macroinvertebrates, habitat, nutrients and metals, along with associated field parameters.

In 2010 there was a 23% increase in sites meeting macroinvertebrate guidelines in west Tennessee. It is likely the severe drought affected 2007 scores in this part of the state. Passing scores decreased 13 % in middle Tennessee possibly due to effects of record spring floods. There was little change in the eastern division.

Overall habitat scores have fallen statewide in Tennessee. Large scale weather conditions and refinements to the habitat assessment protocol since the last study has probably affected scoring. Future habitat assessments will show if the lowering of scores this year was due to weather conditions, new protocols, or indicate a downward trend.

Statewide, the number of stations that met ecoregional guidelines for narrative criteria in summer for total phosphorus increased, while the number that met nitrate + nitrite criteria guidelines decreased. In 2010, mean and median phosphorus concentrations across the state were a little more than half the 2007 levels.

The 2010 study included the analysis of nine metals which were not in the previous study. Most of the metals, with the exception of chromium, mercury and zinc, were highest in west Tennessee and lowest in the middle division. Cadmium and selenium were not detected at any site. Mercury was only detected at one site, which has a historic source. The toxicity of certain metals on fish and aquatic life can vary based on the total hardness of the water and the level of total suspended solids. All metal exceedances of water quality criteria were in west Tennessee, where low hardness was often a factor.

The information in this document should not be confused with water quality assessments to determine use support. It is important to realize that probabilistic monitoring is a useful tool for trend analysis and for statewide comparisons due to the consistency of methodology at every site. However, the study is not intended to replace the more extensive targeted monitoring program designed for water quality assessments. The probabilistic study reports the percentage of criteria violations for individual parameters based on a single sample event at randomly selected sites. Assessments used for 305(b)/303(d) reporting are based on multiple samples from multiple sites within a single reach as well as evaluations of land-use and field observations.

1. INTRODUCTION

In 2007, the Division of Water Pollution Control initiated statewide probabilistic monitoring of wadeable streams to supplement the traditional targeted watershed monitoring. (Arnwine et al, volumes 2-6, 2009). The 2007 study provided a baseline to which additional effort would be compared, thus providing an opportunity for scientifically valid trend analysis. Since this is only the second year of monitoring it is too early to evaluate trends. However, it is possible to do a comparison between 2007, when most of the state was in a severe drought and current conditions.

It is important to realize that the probabilistic monitoring is a useful tool for trend analysis and for statewide comparisons due to the consistency of methodology at every site. However, the study is not intended to replace the more extensive targeted monitoring program designed for water quality assessments. The probabilistic study reports the percentage of criteria violations for individual parameters based on a single sample event at randomly selected sites. Assessments used for 305(b)/303(d) reporting are based on multiple samples from multiple sites within a single reach as well as evaluations of land-use and field observations.

Sample methodology and quality assurance in 2010 followed the same protocols, in accordance with TDEC QSSOPs, as the 2007 study. Due to budget limitations, there were some difference in frequency and the types of parameters collected (Table 1). Since the 2010 study only included one sample collected in late summer or early fall, comparisons were done to the 2007 sample collected closest to the same time. Metals were added to the 2010 study while pathogens and periphyton were dropped.

Results are reported by division and statewide. Divisions are based on Level IV ecoregions (Arnwine et al, 2000).

East: Ecoregions 66, 67, 68 and 69
Middle: Ecoregion 71
West: Ecoregions 65, 73 and 74

Table 1: Comparison of sample frequency and parameters between 2007 and 2010 wadeable stream probabilistic studies.

Parameter	2007 Study	2010 Study
Macroinvertebrates	summer or fall	summer or fall
Habitat Assessment	summer or fall	summer or fall
Field Parameters	quarterly	summer or fall
Nutrients	quarterly	summer or fall
Metals	not collected	summer or fall
Periphyton	spring, summer or fall	not collected
Pathogens	spring, summer or fall	not collected

2. REPRESENTATIVENESS OF PROBABILISTIC SITES

Overall, the study sites were a good representation of wadeable Tennessee streams. Details are provided in volume 2 of the 2007 study (Arnwine et al, 2009). There were slight changes in the representativeness of the probabilistic sites between the 2007 and 2010 studies. Four sites that were used in the 2007 study were replaced in 2010 due to lack of flow (Figure 1). These sites also had inadequate flow in 2007, but data from the 2004 national study were used. The replacement sites caused slight variations in stream order, drainage area, stream miles, ecoregions, watersheds, and land use. Replacement sites were selected using the same randomization design as the 2007 state survey and the 2004 national survey.

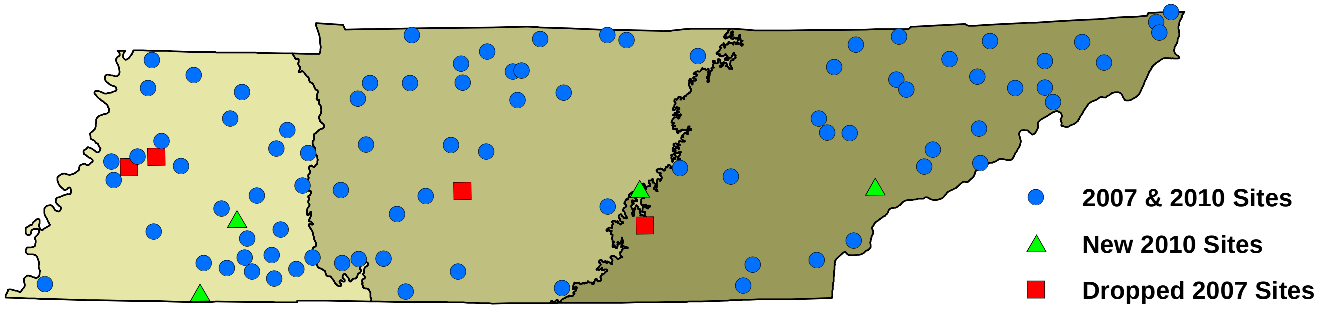


Figure 1: Location of probabilistic monitoring sites in 2007 and 2010.

a. Stream Order

The Strahler stream order at two of the replacement sites was different than the original. A third order stream in West Tennessee was replaced with a second order. A first order was replaced with a third order in the eastern division. Third order streams were the most commonly sampled in both studies (Figure 2).

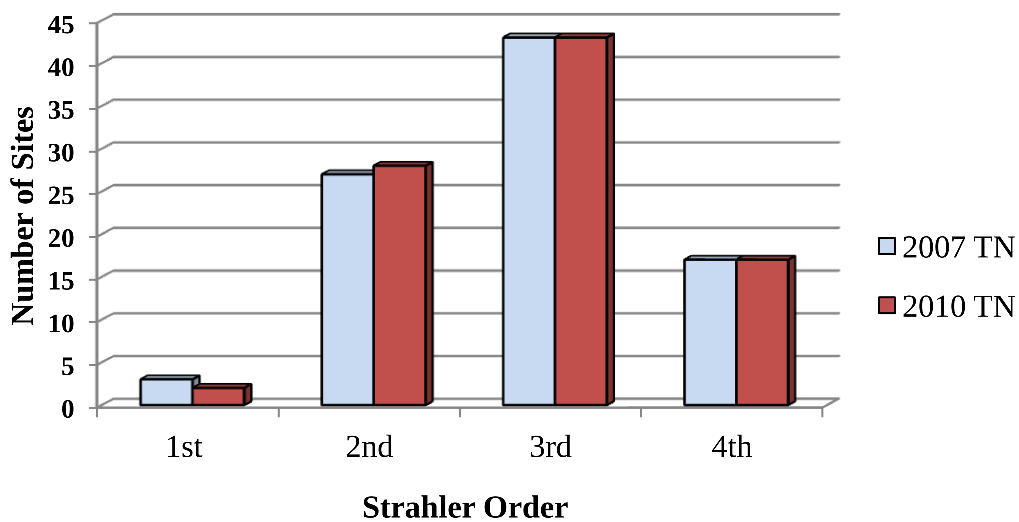


Figure 2: Comparison of stream order distribution between the 2007 and 2010 probabilistic studies.

b. Drainage Area

The overall drainage area represented by the probabilistic sites increased from 1,747 to 1,986 square miles (Table 2). This represents 4.7% of the stream miles in the state. Three of the four replacements sites had larger drainage areas than the originals (Table 3). The greatest difference was in the middle division, where there was a gain of 250 square miles from a single replacement, the Collins River. Although middle Tennessee sites had the highest average drainage area in the study, this is misleading since two of the largest streams, Cane Creek and Collins River, primarily drain the eastern division.

Table 2: Average drainage area of the 2007 and 2010 probabilistic studies.

Division	Avg. Drainage Area (mi^2)
West 2007	14.5
West 2010	**13.9**
Middle 2007	28.0 *
Middle 2010	**36.7 ****
East 2007	16.0
East 2010	**16.2**
TN 2007	19.5
TN 2010	**22.2**

* Cane Creek has 159 square miles drainage, 99 % in east TN.
** Collins River has 323 square mile drainage, 89% in east TN.

The number of stream miles upstream of probabilistic sites also increased as a result of the four replacements. Due primarily to the addition of the Collins River, the total miles represented by the study went from 2,661 to 2,941 (10.5% increase).

c. Ecoregions

All the replacement sites were in a different sub-ecoregion (Level IV) than the original site, three were in a different ecoregion (Level III). One of the new sites, located in the western division, added the Flatwoods/Blackland Prairie Margins (65b) to the study. This is a very small ecoregion comprising only 0.1% of the state's land area. A new site in the eastern division added the Southern Dissected Ridges and Knobs (67i) which is 1.4% of the state. The only site on the Cumberland Plateau (68a) in the 2007 study was dropped due to lack of flow. The Cumberland Plateau is a large ecoregion representing 7.6% of the state and 20% of the eastern division but many of the streams are naturally dry in summer. Some tributaries upstream of both the Collins River and Cane Creek study sites drain the Cumberland Plateau.

d. Watersheds

There were no HUC8 watersheds removed or added in 2010. Two watersheds, the Collins and South Fork Forked Deer, had both a dropped site and a replacement site.

e. Land Use

Land use associated with the probabilistic sites changed very little statewide or in any division as a result of replacing four sites (Figure 3). However, there were some substantial differences in land use between the four replacement sites and the original. The new sites generally represented more forest and less cropland.

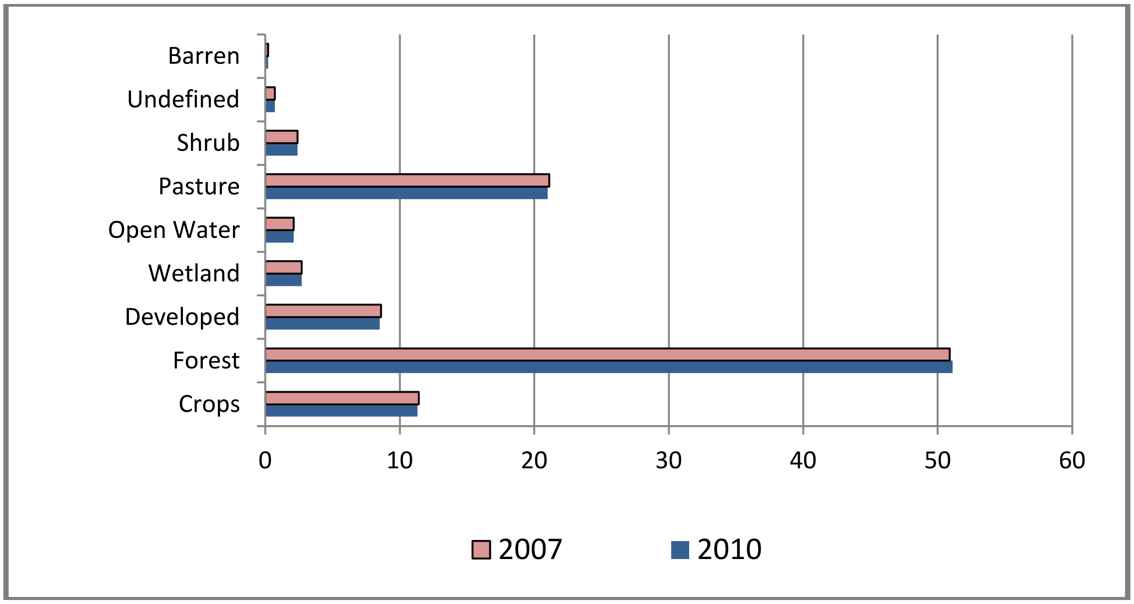


Figure 3: Comparison of statewide land use between the 2007 and 2010 probabilistic studies.

f. Flow Conditions

1) Drought

The effects of drought on stream flow differed greatly between the 2007 and 2010 studies. Different regions of the state were affected with varying degrees. According to the Palmer Hydrological Drought Index for July of 2007, middle Tennessee was classified as being in extreme drought while the other divisions were in severe drought (Figure 4). The index is a long term measurement of precipitation and temperature. These conditions affected both habitat and colonization by benthic macroinvertebrates.

In July 2010, only the eastern division was still in drought conditions, although it was upgraded from severe to moderate (Figure 5). Middle and west Tennessee had normal conditions for the month of July.

Poplar Creek in west Tennessee during summer 2007. Much of the stream habitat such as rooted banks is exposed. Flow was 0.12 cfs.

Photo provided by Jackson Field Office, TDEC.

Poplar Creek site in west Tennessee during summer 2010. More habitats such as submerged roots and snags were available for colonization by aquatic populations. Flow was 29.2 cfs.

Photo provided by Aquatic Biology Section, TDH.

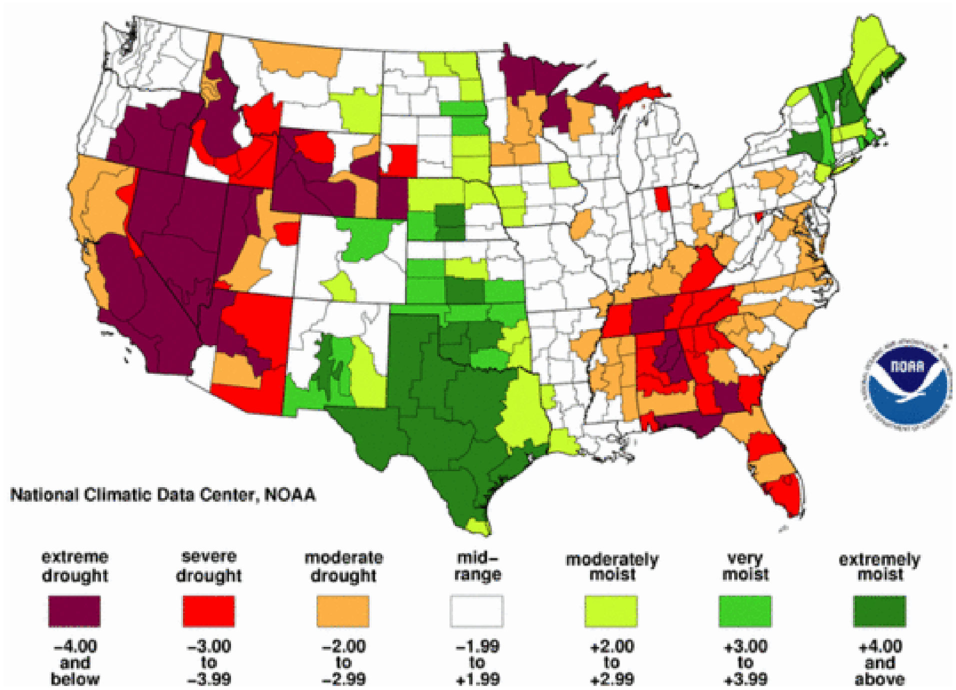


Figure 4: Palmer Drought Severity Index map for July 2007.

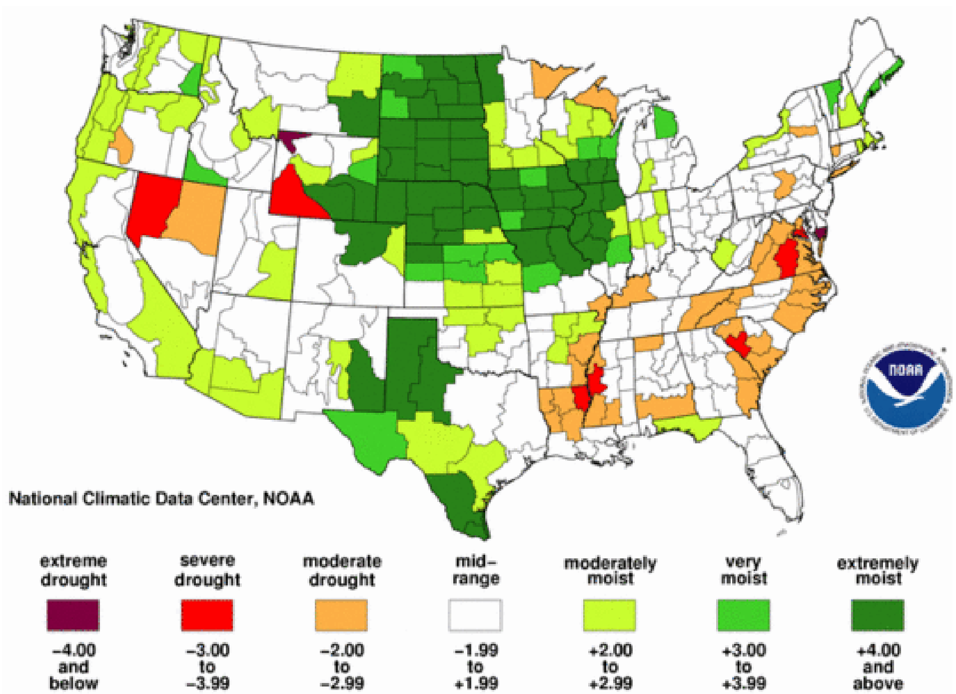


Figure 5: Palmer Drought Severity Index map for July 2010.

2) Flood

On May 1, 2010 a record flood occurred in middle and west Tennessee (Figure 6). Areas received between 10-20 inches of rain within two days (Hayes, 2011). The most intense flooding occurred in the Cumberland River and its tributaries in the middle division. The Cumberland River has a 40 foot flood stage and during the May 2010 event it crested at 51.86 feet (NOAA, 2011). The flooding caused scouring and heavy deposits of sediment within the streams and on the banks. *Photo provided by Jimmy Smith, NEFO, TDEC.*

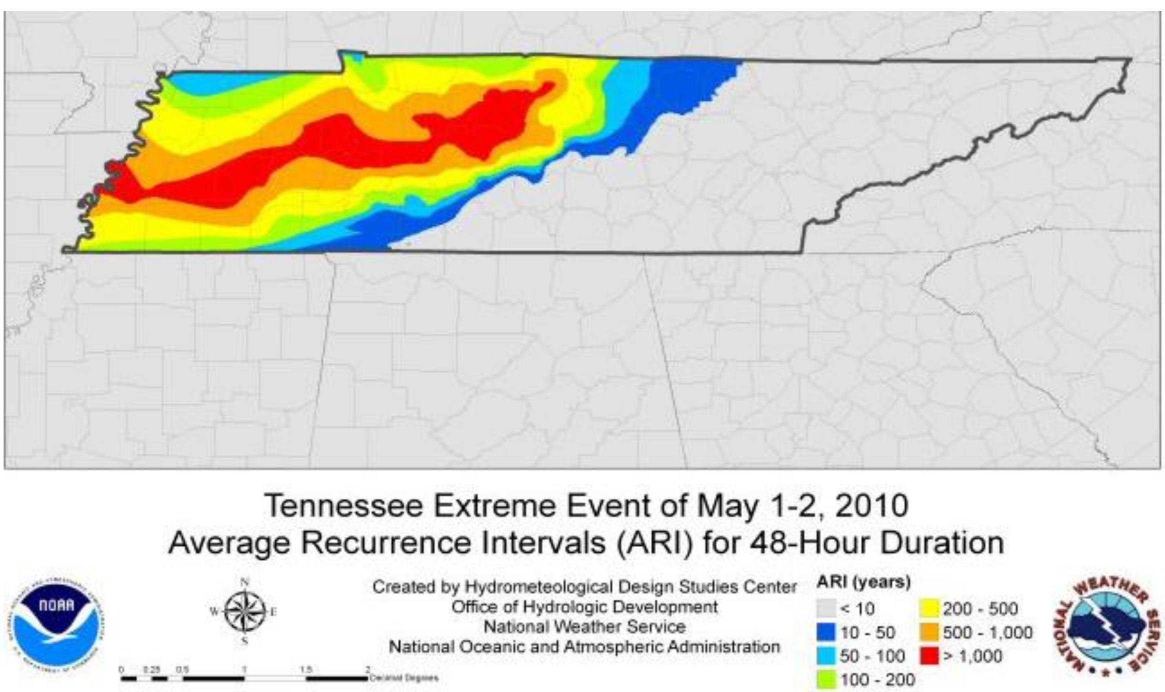


Figure 6: NOAA map showing extreme rain event during May of 2010.

3. MACROINVERTEBRATE MONITORING

Macroinvertebrate sampling, analysis and scoring methods followed the same protocols as the 2007 study (Arnwine et al, volume 3, 2009). Table 3 provides a description of the seven biometrics that comprise the Tennessee Macroinvertebrate Index (TMI). Acceptable metric ranges are calibrated for each bioregion in the state (Figure 7). A TMI score of 32 meets biocriteria and is considered indicative of a healthy stream community.

Table 3: Biometrics used for determination of the Tennessee Macroinvertebrate Index. Adapted from Barbour et al, 1999.

Category	**Metric**	**Definition**	**Predicted response to increase in disturbance**
Richness Metrics	Total Number of Taxa	Measures the overall variety of the macroinvertebrate assemblage.	Decrease
	Number of EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).	Decrease
Composition Metrics	% EPT	Percent of the composite of mayfly, stonefly and caddisfly larvae.	Decrease
	%OC	Percent of the composite of oligochaetes (worms) and chironomids (midges).	Increase
Pollution Tolerance Metrics	NCBI	North Carolina Biotic Index uses tolerance values to weight abundance in an estimate of overall pollution (Lenat, 1993).	Increase
	% NuTol	Percent of the composite of 14 nutrient tolerant taxa (Brumley et al, 2003).	Increase
Habitat Metrics	% Clingers	Percent of the macrobenthos having fixed retreats or adaptations for attachment to surfaces in flowing water.	Decrease

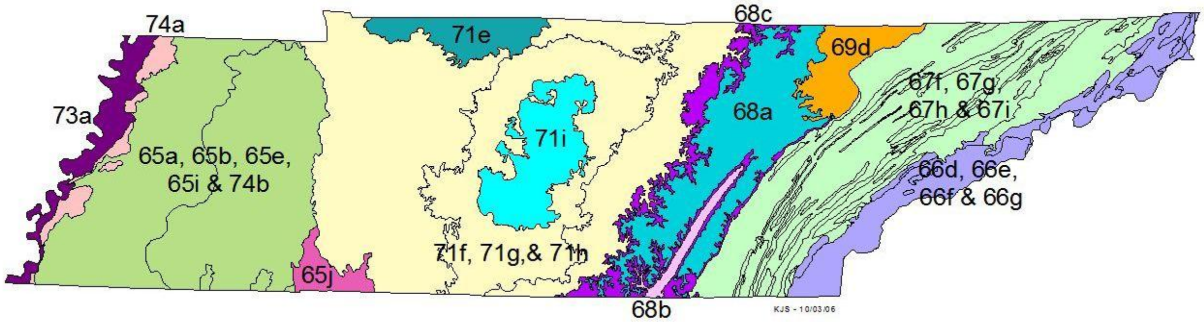


Figure 7: The thirteen bioregions of Tennessee.

a. 2010 Macroinvertebrate Results

Individual biometric and index scores for each site are presented in Appendix A of this document. Statewide, less than half of the sites met biocriteria based on the TMI score. East Tennessee had the highest percentage of sites passing while west Tennessee had the lowest (Figure 8).

All three divisions had a low percentage of sites meeting regional guidelines for Ephemeroptera, Plecoptera, and Trichoptera (EPT) richness and abundance (Figure 9). The western division was most likely to fall below guidelines for EPT abundance (%EPT), oligochaete and chironomid abundance (%OC), and the North Carolina Biotic Index (NCBI). Middle Tennessee had the lowest taxa richness (TR) scores when compared to expected levels for the bioregion. The middle and western divisions were equally likely to score low for EPT richness and abundance of clingers (%Cling). The eastern division was the area of the state most likely to fall below regional guidelines for the abundance of nutrient tolerant organisms (%NUTOL).

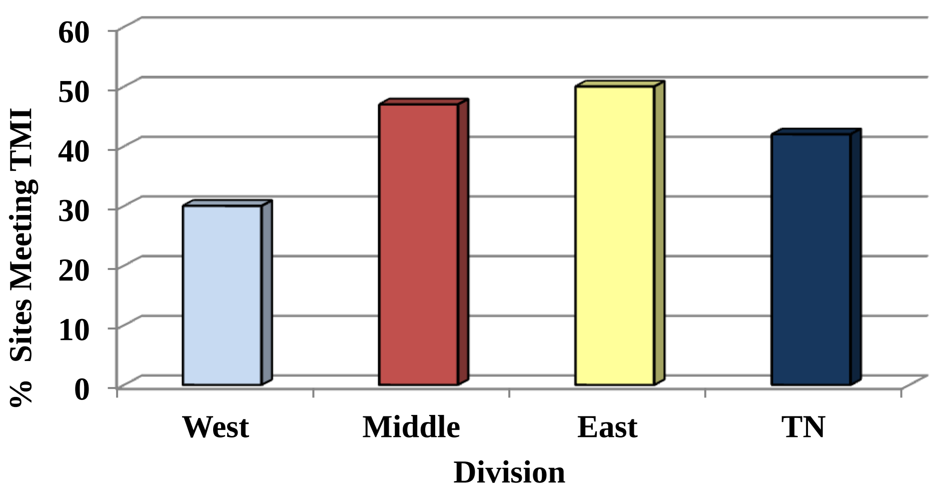


Figure 8: Percent of probabilistic sites meeting regional TMI guidelines in 2010 for each division.

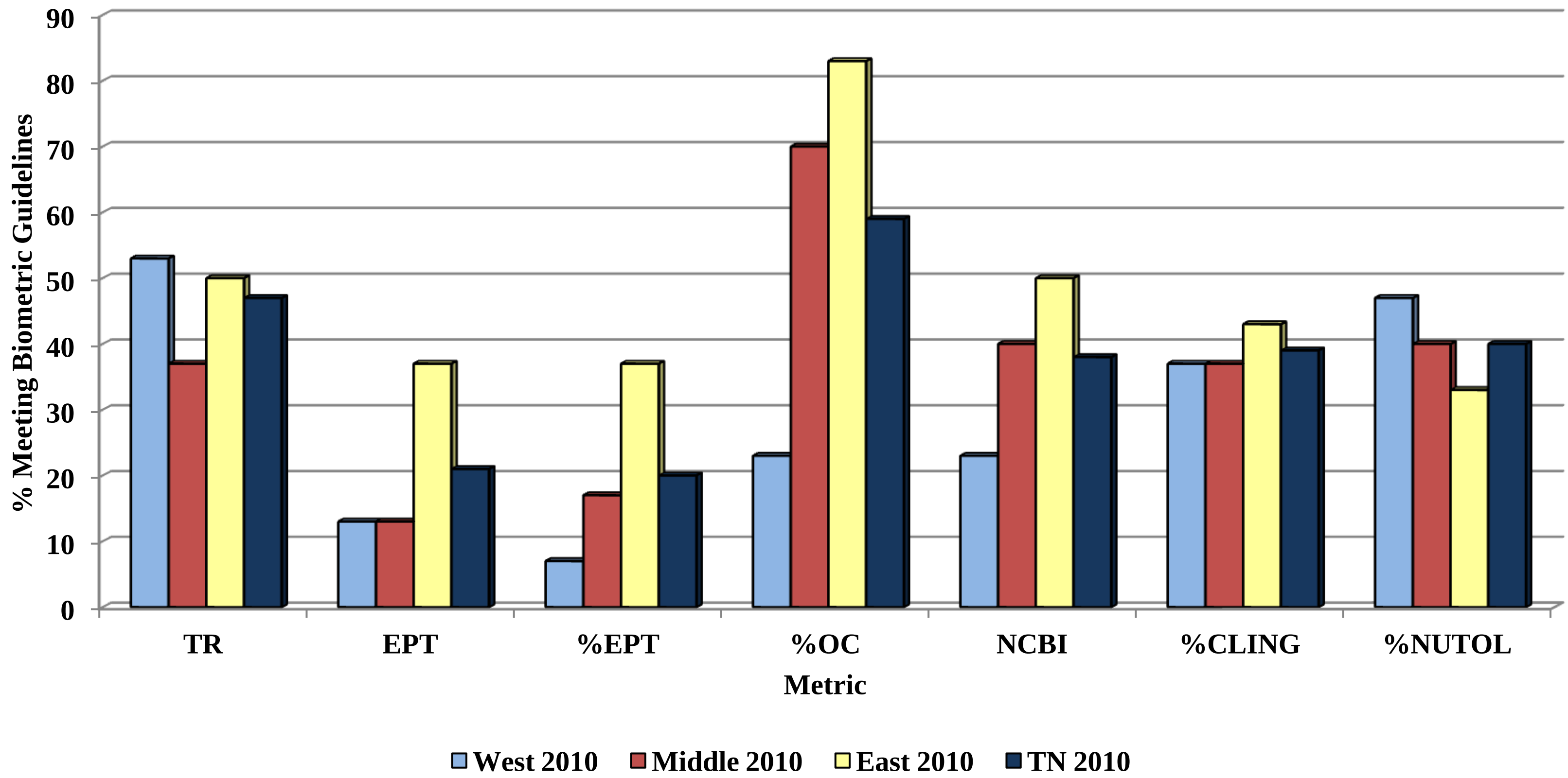


Figure 9: Percent of 2010 probabilistic sites meeting regional guidelines for individual biometrics in each division.

b. Comparison of 2007 to 2010 Macroinvertebrate Results.

Individual biometric and index scores for each site in 2007 are presented in Appendix A of Volume 3 in the 2007 report (Arnwine et al, 2009). Statewide, there was little change in the percent of sites reaching an acceptable TMI score of 32 (Figure 10). However, sites reaching the target score increased by 23% in west Tennessee, possibly due to lessening of drought conditions. The number of sites meeting acceptable scores in the middle division decreased by 13%, most likely due to record floods four months prior to sampling. Several streams were observed to have severe scouring or were dredged to get rid of the gravel/cobble deposited during flooding. There was little change in east Tennessee, which continues to be in a drought.

In 2010, the range of TMI scores dropped in every division (Figure 11). Although more sites passed biocriteria in west Tennessee, they passed by a lower margin while failing scores were generally lower than those in 2007. In the middle and eastern divisions, passing sites were generally very close to the minimum score of 32. The median scores for all three divisions in 2010 were below 32. The location of sites passing TMI scores are presented in figure 12.

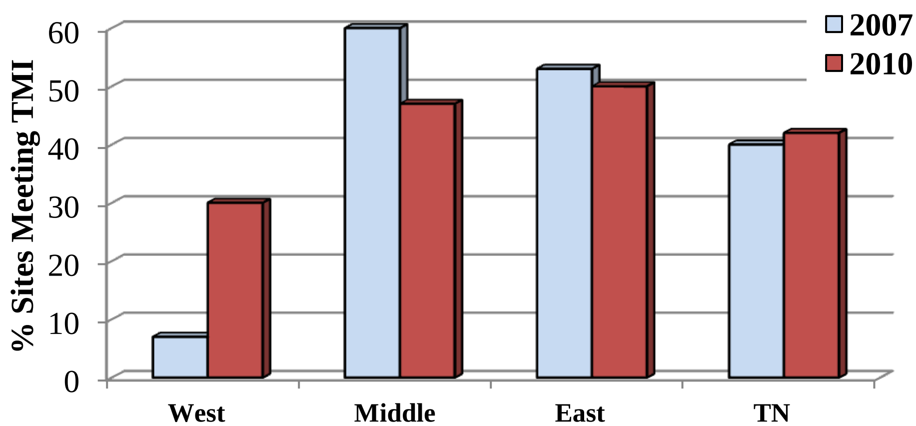


Figure 10: Comparison of 2007 and 2010 probabilistic sites scoring at or above 32 for Tennessee Macroinvertebrate Index (TMI).

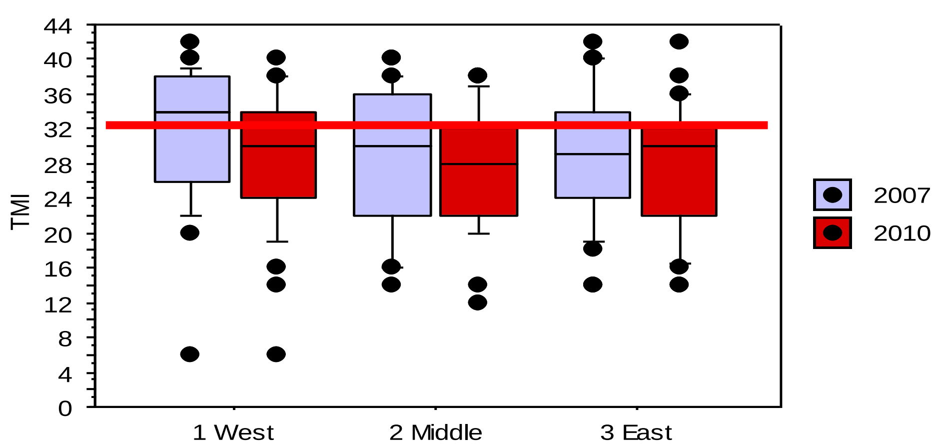


Figure 11: Range of Tennessee Macroinvertebrate Scores (TMI) at probabilistic sites in 2007 and 2010. (Red line denotes passing score of 32).

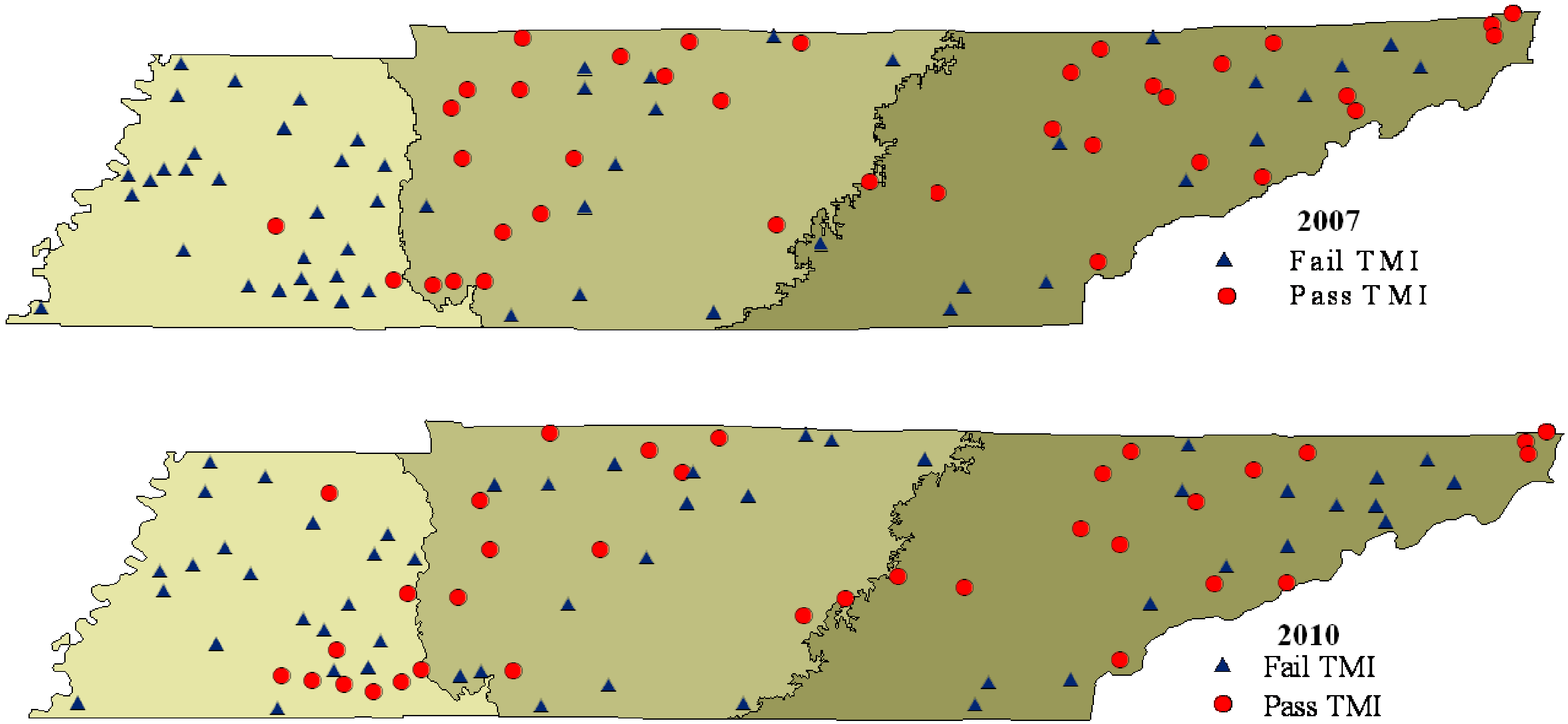


Figure 12: Locations of probabilistic sites meeting regional TMI guidelines in 2007 and 2010.

Individual biometrics also varied between divisions in 2007 and 2010 although they were fairly consistent statewide. West Tennessee showed the greatest improvement in the most biometrics (Figure 13). At least ten percent of the sites met regional expectations for taxa and EPT richness, NCBI and % Clingers. Since there was an increase in flow in west Tennessee streams, more habitats would be available to these organisms. Sites meeting regional guidelines fell in west Tennessee for abundance of %NUTOL and the abundance of oligochaetes and chironomids. The increased flow may have contributed to more nutrient run-off and an associated increase in algal growth which would affect these metrics.

Unlike, the other two divisions, the number of sites meeting regional guidelines for most biometrics in middle Tennessee fell more than 10% in 2010. Sites that passed criteria in 2007 but failed in 2010 were in watersheds that had severe flooding. For example, the TMI score for Trace Creek fell 18 points from 34 to 16. Six sites lost Ephemeroptera (mayfly) taxa that were adapted for clinging. Only taxa richness and percent nutrient tolerant taxa stayed fairly consistent. The decrease in other metrics scores are probably a result of the record May floods that destroyed stable habitat.

East Tennessee demonstrated little change between 2007 and 2010. The only biometrics with substantial changes were EPT richness and the abundance of oligochaetes and chironomids, where 14 and 16 percent more sites met regional guidelines. This division continues to experience drought conditions although to a lesser extent. It is possible scores will continue to improve when normal flow patterns resume.

Trace Creek in July 2007.

Trace Creek in September 2010 after May flooding scoured riffles and deposited large amounts of cobble and gravel.

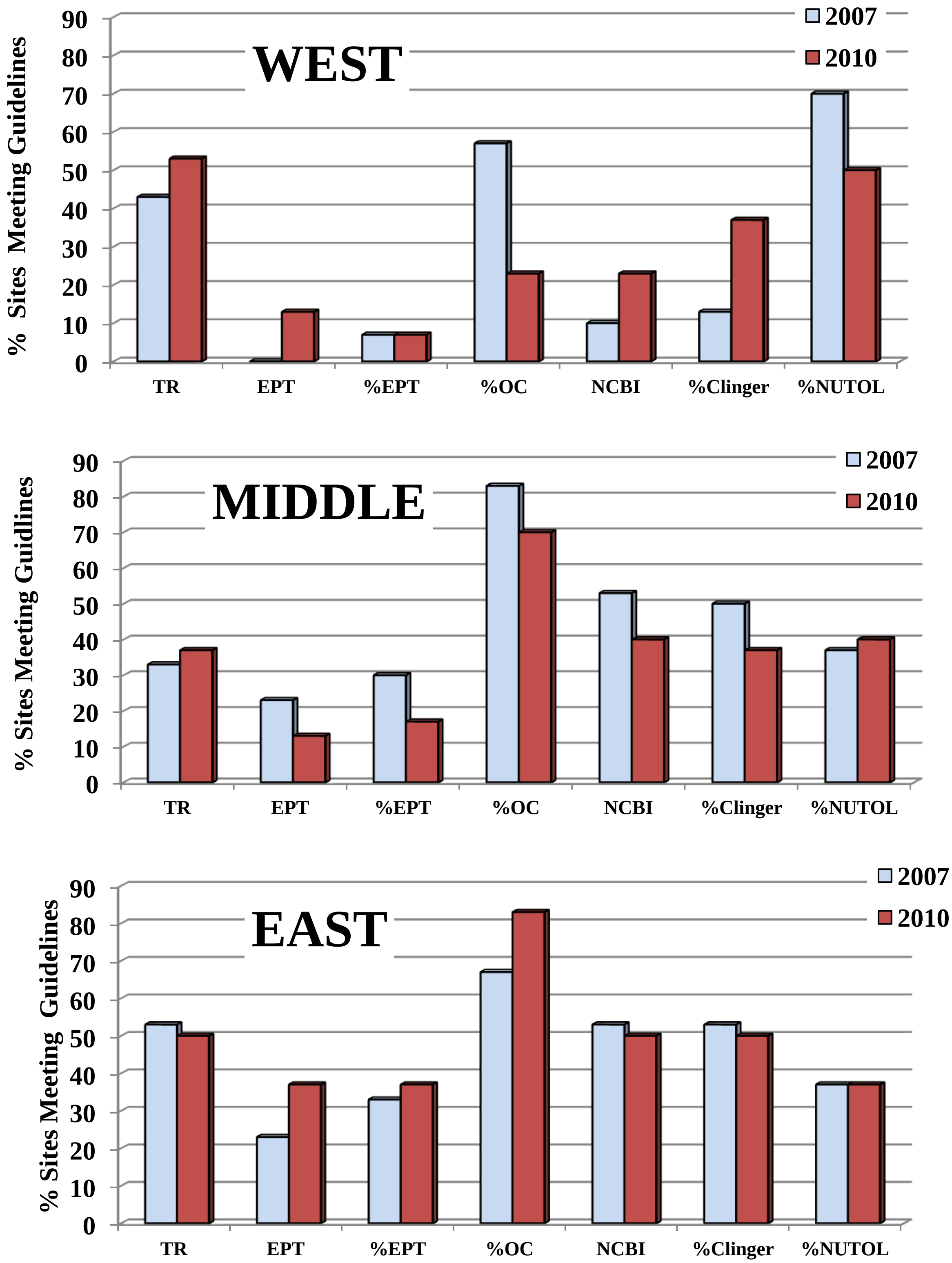


Figure 13: **Comparison of probabilistic sites meeting regional biometric guidelines between 2007 and 2010 for the west, middle and east divisions in Tennessee.**

c. Identification of New Reference Sites

Another goal of the probabilistic study was to identify any potential reference streams or Exceptional Tennessee Water (ETW). The Antidegradation Policy in Tennessee's general water quality criteria (Chapter 1200-4-3-.06) establishes a TMI score of 40 or 42 as representing exceptional biological diversity, one of the characteristics of an ETW. In 2007 six streams were added to the ETW list based on probabilistic survey results. One stream, Indian Creek was identified as a reference stream for the Southern Limestone/Dolomite Valleys and Low Rolling Hills Ecoregion (67f). In 2010, Birch Branch was designated a headwater reference stream for the Southern Sedimentary Ridges (66e) in the Blue Ridge Mountains

Birch Branch was selected as a headwater reference site in the Southern Sedimentary Ridges ecoregion (66e). *Photograph provided by Aquatic Biology Section, TDH.*

4. HABITAT

Clean, diverse and stable habitat is necessary to maintain a healthy stream community. Habitat assessments were conducted concurrent with the macroinvertebrate samples using TDEC protocols (TDEC, 2006) which are a modification of EPA's Rapid Bioassessment technique (Barbour et al, 1999). This method uses qualitative assessments of ten parameters that vary depending on stream gradient (Table 4). High gradient protocols were used in east and middle Tennessee. Low gradient protocols were used in west Tennessee, except for three sites in the Transition Hills (65j) and Bluff Hills (74a). Assessments were conducted by two experienced stream biologists with scores arbitrated in the field. Habitat assessment forms from 2007 were checked at the site to determine whether any scoring difference were due to changes in stream condition. The entire sample reach was evaluated for each parameter.

Table 4: Habitat assessment parameters.

High Gradient Streams	Low Gradient Streams
Epifaunal Substrate/Available Cover	Epifaunal Substrate/Available Cover
Embeddedness	Pool Substrate Characterization
Velocity/Depth Regime	Pool Variability
Sediment Deposition	Sediment Deposition
Channel Flow Status	Channel Flow Status
Channel Alteration	Channel Alteration
Frequency of Riffles or Bends	Channel Sinuosity
Bank Stability	Bank Stability
Vegetative Protective Score	Vegetative Protective Score
Riparian Vegetative Zone Width	Riparian Vegetative Zone Width

Total habitat scores range from 0 to 200 with regional expectations for each parameter as well as the total habitat score calibrated by Level IV ecoregion (TDEC, 2006). These guidelines were used to determine if the seven components of the habitat assessment that were common to all three divisions as well as the total habitat scores were sufficient to support stream biota at each site. Habitat scores for all parameters in 2010 are provided in Appendix B. The 2007 scores are available in Appendix B of the 2007 report (Arnwine et al, volume 3, 2009).

In 2010, fewer sites met regional guidelines for total habitat in all three divisions (Figures 14 and 15). Parameters that dropped by more than 10% include sediment deposition, channel alteration, vegetative protection and riparian zone width (Figure 16). Channel alteration and vegetative protection may be a reflection of refinement of habitat assessment protocols and may not reflect a difference in stream conditions. Differences in other parameters were less than 10% and may be due to the qualitative nature of the assessment which allows for some subjectivity.

In moderate to high gradient streams, velocity/depth regime was the only parameter with a significant increase in habitat scores resulting in 15% more sites passing guidelines. Low gradient streams (west division) had significant increases in pool substrate, pool variability and channel sinuosity. Most of these parameters may have been influenced by an increase in rainfall and stream flow compared to 2007 especially in west Tennessee. Middle Tennessee showed the least change despite record flooding a few months prior to sampling.

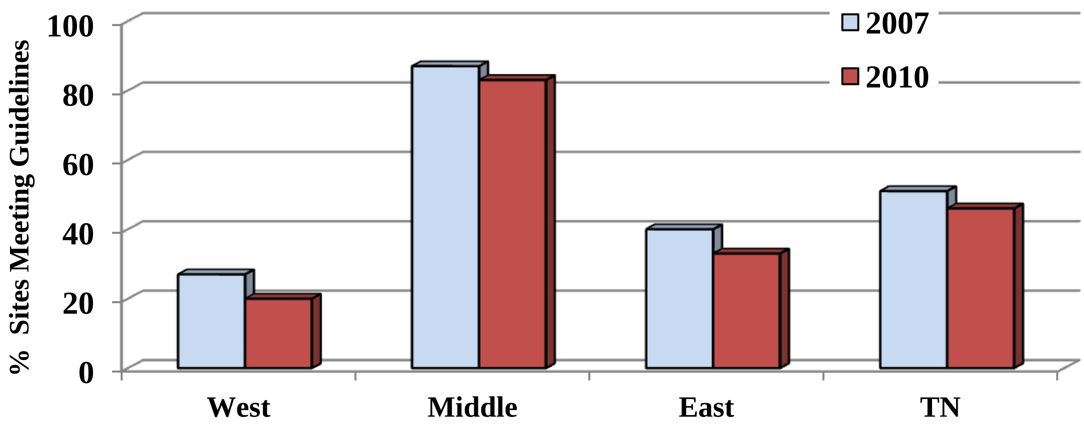
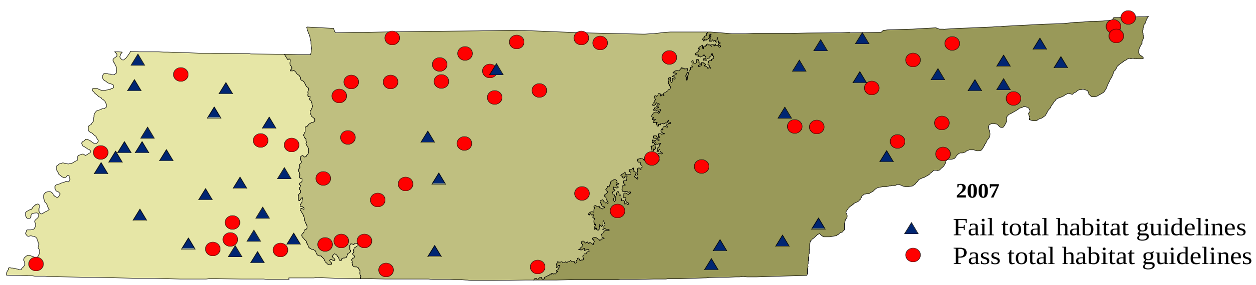


Figure 14: Comparison of total habitat scores between 2007 and 2010 wadeable stream probabilistic surveys.



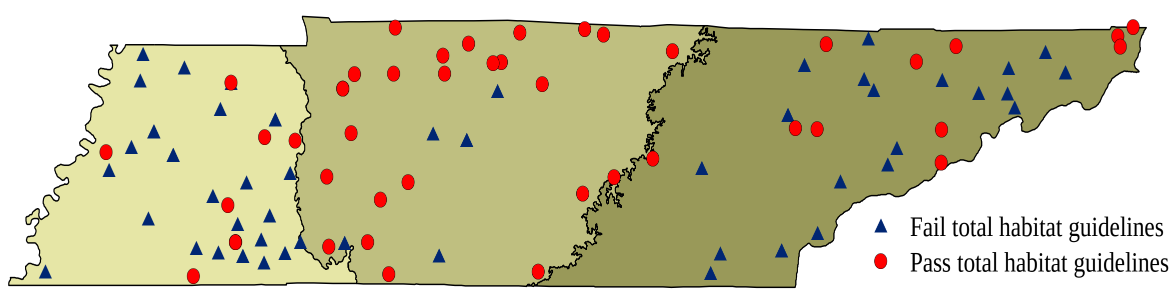


Figure 15: Distribution of probabilistic sites that passed ecoregion habitat guidelines in 2007 and 2010.

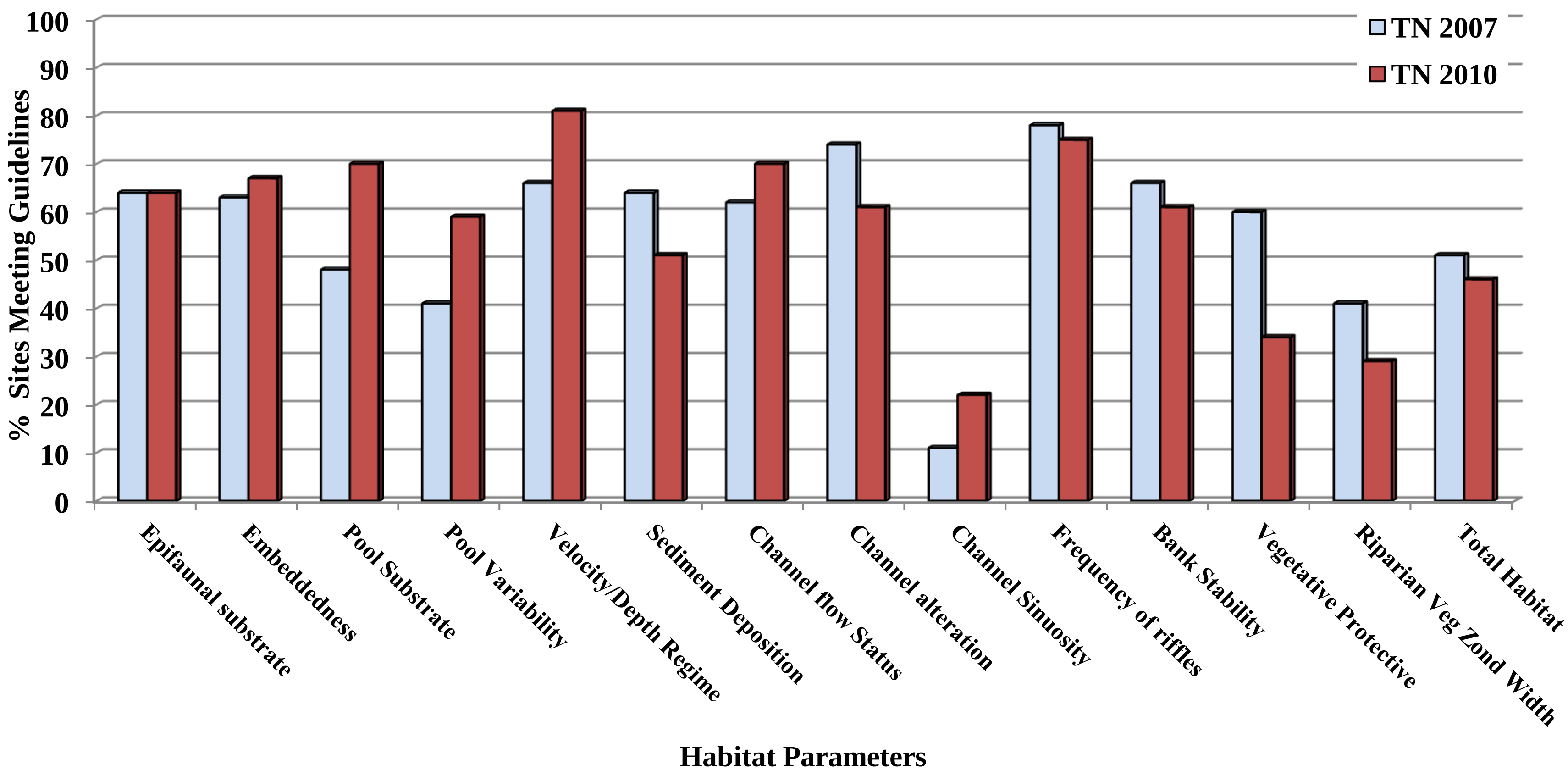


Figure 16: Percent of probabilistic sites meeting regional guidelines for individual habitat parameters statewide. It should be noted that velocity/depth regime, sediment deposition and frequency of riffles in the west division were based on three high gradient sites. No sites in middle or east Tennessee were evaluated for the low gradient parameters of pool substrate, pool variability or channel sinuosity.

a. Epifaunal Substrate and Available Cover

Epifaunal substrate evaluates the quantity and variety of natural structures in the stream such as cobble, riffles, boulders, rock crevices, fallen trees, macrophyte beds and undercut, rooted banks. A wide variety of submerged structures provide stream biota numerous places to hide, feed and reproduce. As the variety of cover is reduced, biotic diversity is compromised and there is less potential for recovery following disturbances.

Despite increased flow statewide and spring flooding in middle Tennessee, there was no change in the percent of sites meeting regional guidelines in 2010 (Figure17). Middle Tennessee streams continue to be most likely to have adequate epifaunal substrate and cover for colonization. It should be noted that this does not mean middle Tennessee streams have more variety of cover than those in other divisions, as the scoring for each parameter is calibrated for typical streams in each ecoregion. For example, mountain streams are expected to have a higher degree of substrate complexity than those in the Interior Plateau. West Tennessee continues to have the lowest percentage of passing scores.

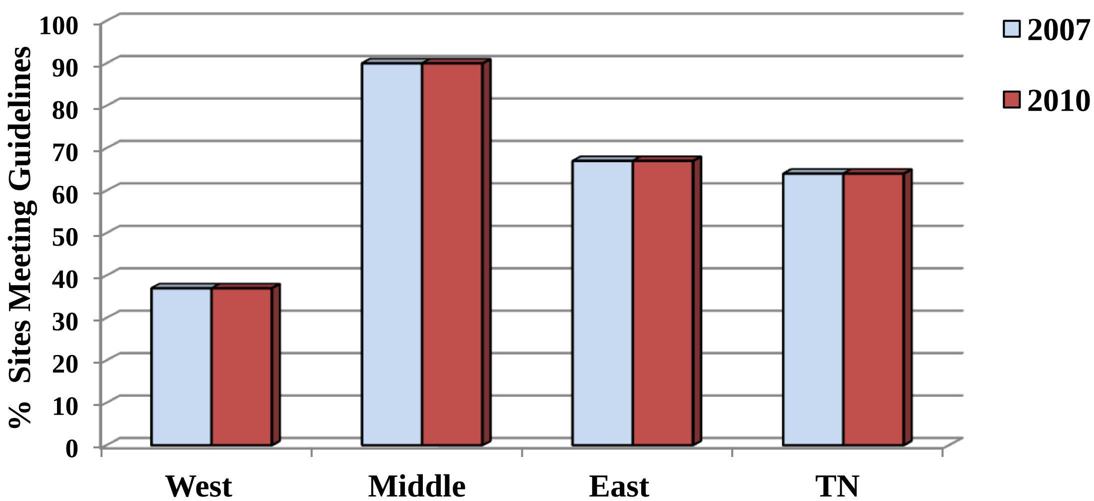


Figure 17: Comparison of epifaunal substrate and available cover between 2007 and 2010 probabilistic surveys.

b. Sediment Deposition

High levels of sediment deposition are characteristic of an unstable stream that does not provide suitable habitat for many organisms. There was only a slight difference in the number of middle Tennessee streams passing guidelines despite the May flooding (Figure 18). Some streams were scoured while others had increased deposition (Figure 19). Substantial differences were observed in west and east Tennessee, which had decreases of 16 and 20 percent respectively for sites meeting guidelines.

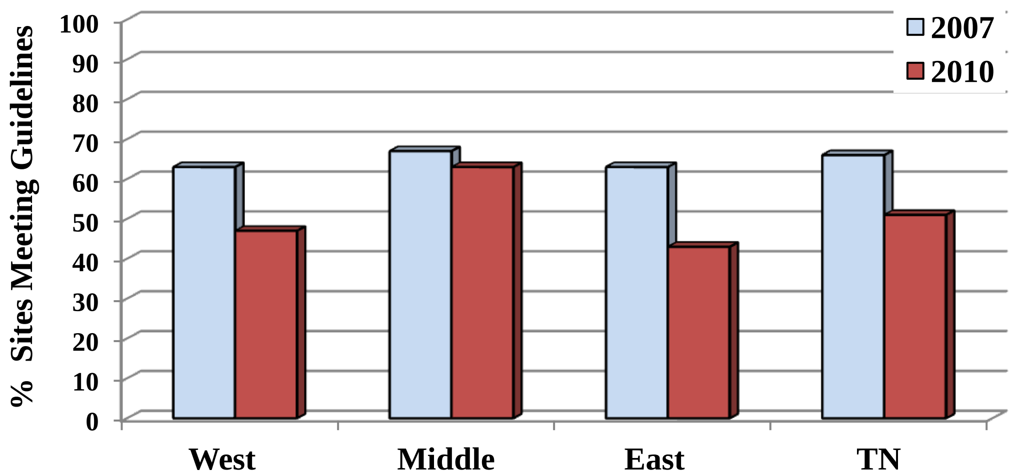


Figure 18: Comparison of assessments of sediment deposition between 2007 and 2010 wadeable stream probabilistic surveys.

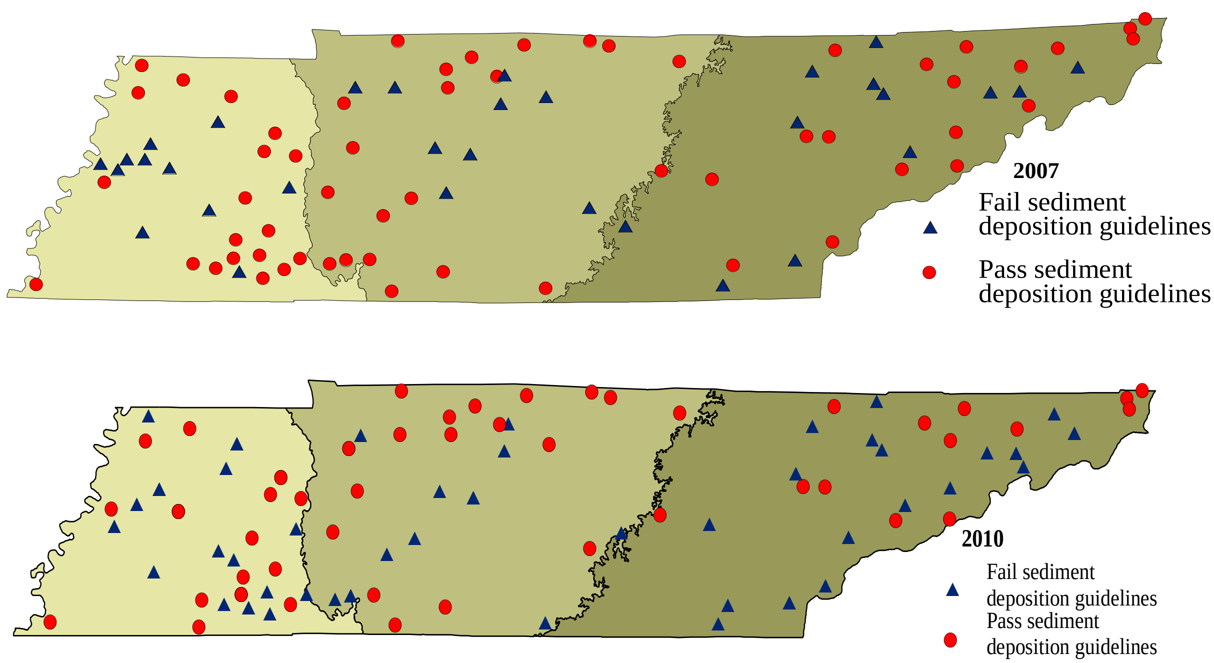


Figure 19: Distribution of probabilistic sites that passed ecoregion sediment deposition guidelines in 2007 and 2010

c. Riparian Vegetation Width

Riparian width determines the proportion of riparian zone vegetation that has been disturbed by human activities. This vegetative zone serves to buffer pollutants entering a stream from runoff and controls erosion. The riparian zone also provides habitat and food to aquatic organisms. Riparian width scores dropped in all three divisions (Figure 20). West Tennessee had the least change and remains the least likely to pass regional guidelines. The number of sites meeting regional guidelines in middle and east Tennessee dropped 16 and 17 percent. Sites in the middle division are still the most likely to have an adequate riparian width for the ecoregion.

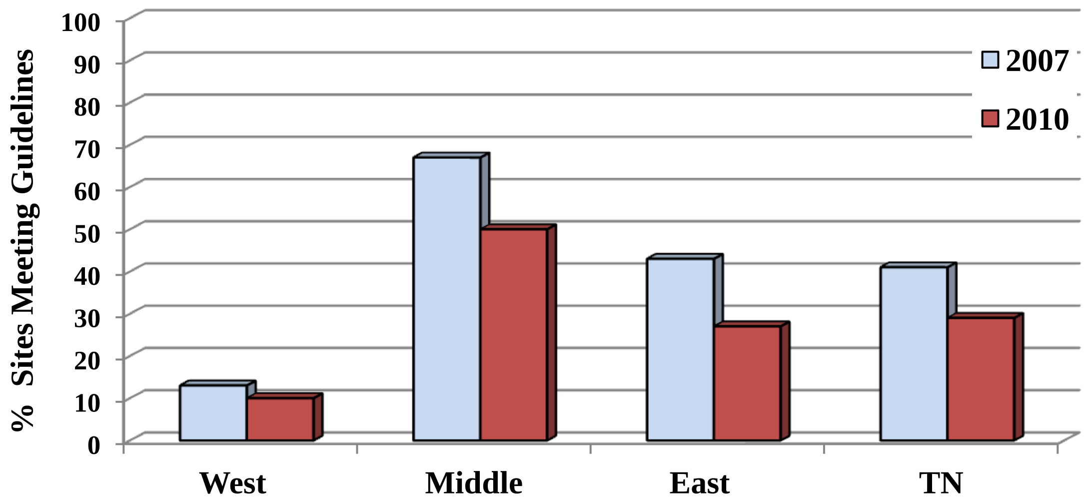


Figure 20: Comparison of riparian zone disturbance between 2007 and 2010 wadeable stream probabilistic surveys.

Riparian zone at Wells Creek in Middle Tennessee in 2007 study. *Photo provided by NEFO, TDEC.*

Riparian zone at Wells Creek in Middle Tennessee in 2010. Saplings growing after riparian removal. *Photo provided by Aquatic Biology Section, TDH.*

d. Vegetative Protection

Vegetative protection determines the degree to which the stream bank is covered by multiple layers of native vegetation. Undisturbed vegetation reduces pollutant runoff, stabilizes banks and reduces water temperatures through shading. Native vegetation provides food and habitat for a variety of aquatic organisms. Ideal cover includes a mixture of large trees, understory and groundcover. The number of sites with adequate streamside vegetation fell 20 to 36% for all divisions since 2007 (Figure 21). Some of the scoring changes may be a result in a refinement of field assessment protocols for this parameter. More emphasis was placed on the presence of non-native vegetation during the 2010 assessment.

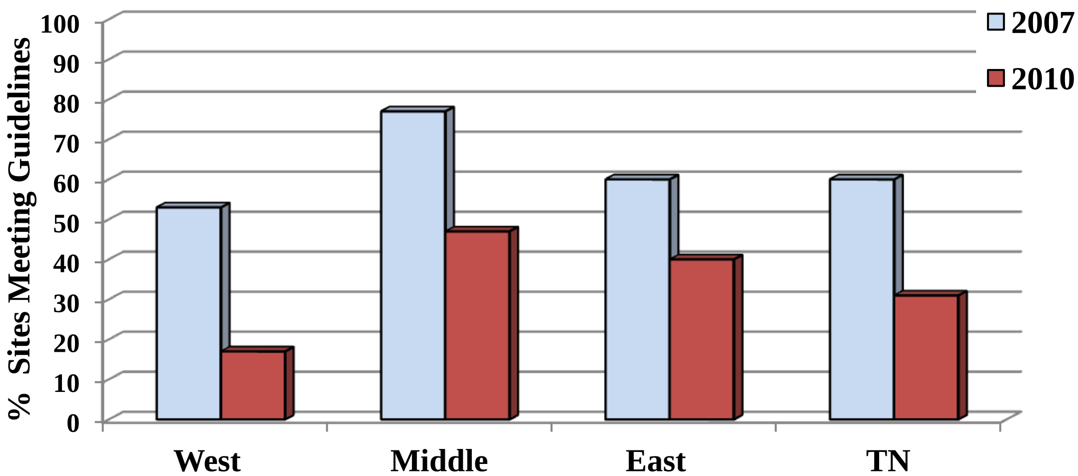


Figure 21: Comparison of vegetative protection between 2007 and 2010 wadeable stream probabilistic surveys. Some 2010 scores may have been lower due to increased emphasis on detecting the presence of non-native vegetation.

Stream side vegetation at the sampling reach on West Fork Hickory Creek was dominated by privet and multiflora rose. These are common invasive species in middle Tennessee. Native aquatic life is not adapted to make full use of non-native plant species for food.

Photo provided by Aquatic Biology Section, TDH.

5. WATER CHEMISTRY

Water quality monitoring consisted of a single summer collection of nutrients and heavy metals as well as instantaneous field measurements of pH, dissolved oxygen, temperature, flow, and conductivity. Data are provided in Appendix C.

Total phosphorus and nitrate + nitrite values were compared to numeric interpretations of narrative criteria for each ecoregion (Denton et al, 2001). The data for pH, temperature, dissolved oxygen, and metals were compared to Tennessee's general water quality criteria (Tennessee Water Quality Control Board, 2007). For comparisons to 2007 probabilistic monitoring, only data from the summer months are used. The 2007 chemical and physical data can be found in Volume 4 of 2007-8 Probabilistic Monitoring of Wadeable Streams in Tennessee (Graf and Arnwine, 2009). Metals and total hardness were not collected in 2007.

a. Nutrients

Nutrients can enter streams from point and nonpoint sources. Point sources include municipal waste water treatment plants, industrial discharges, concentrated livestock operations, urban stormwater, and home waste treatment systems. Non-point sources include soil erosion and runoff from crops, lawns, and pastures. Low nutrient levels limit the growth of algae and aquatic plants. When additional nutrients become available to the system, they can stimulate aquatic plant growth.

Streams with elevated nutrient levels often have floating algal mats and clinging filamentous algae. This condition of nutrient enrichment and high plant productivity can result in low dissolved oxygen levels, which may then lead to a reduction in biological diversity. Increased algal growth can also limit the availability of benthic habitat. Tennessee has narrative nutrient criteria with numeric guidelines for nitrate+nitrite and total phosphorus for each ecoregion (Denton et al, 2001). For the purpose of this report, numeric interpretations of narrative criteria for each ecoregion will be referred to as criteria. This study shows criteria violations, however, sites with elevated nutrient levels are not considered impaired unless there is also a biological response.

Drought can have an effect on the concentration of nutrients. Some studies have shown that nutrients below point sources can increase due to a decrease in stream dilution (Sprague 2005). For some non-point sources such as crop and livestock production, the nutrient levels may decrease during a drought due to reduced runoff. This may help explain the differences in nutrient levels between the 2007 study where the entire state was experiencing record drought and the 2010 study where record floods were recorded in portions of the western and middle divisions.

1) Total Phosphorus

In 2010, the majority of sites (73%) in the middle division met ecoregional criteria for total phosphorus. The word "criteria" for total phosphorus is referring to the numeric interpretations of narrative criteria for each ecoregion (Denton et al, 2001). Half the sites in both the western and eastern divisions met criteria (Figure 22). This was a substantial improvement over 2007 summer samples in both middle and west Tennessee. The greatest difference between the two studies was in middle Tennessee, where the mean and median concentrations in 2010 were less than half of the previous levels and 34% more sites met criteria. There was little change in the number of sites meeting criteria in the eastern division although the median score was lower (Figure 23).

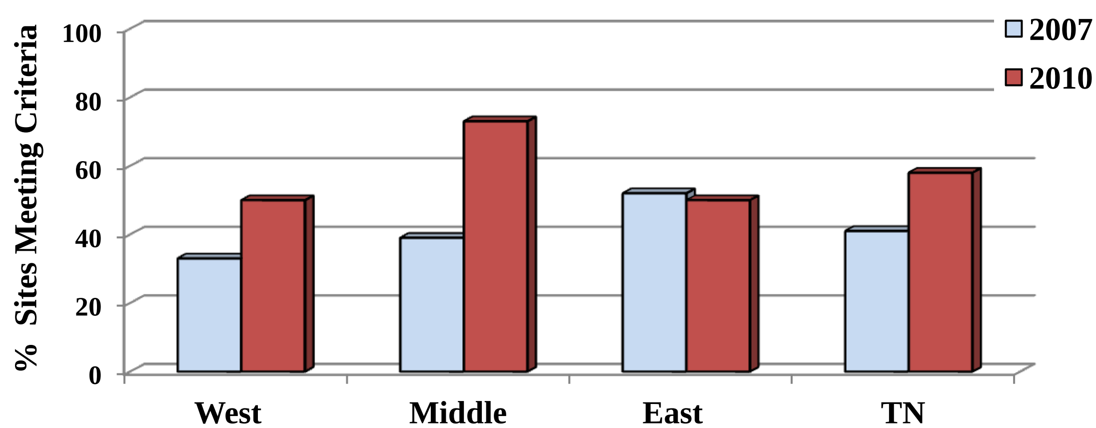


Figure 22: Percent of probabilistic sites that met regional total phosphorus criteria. Data are based on single summer sample each year.

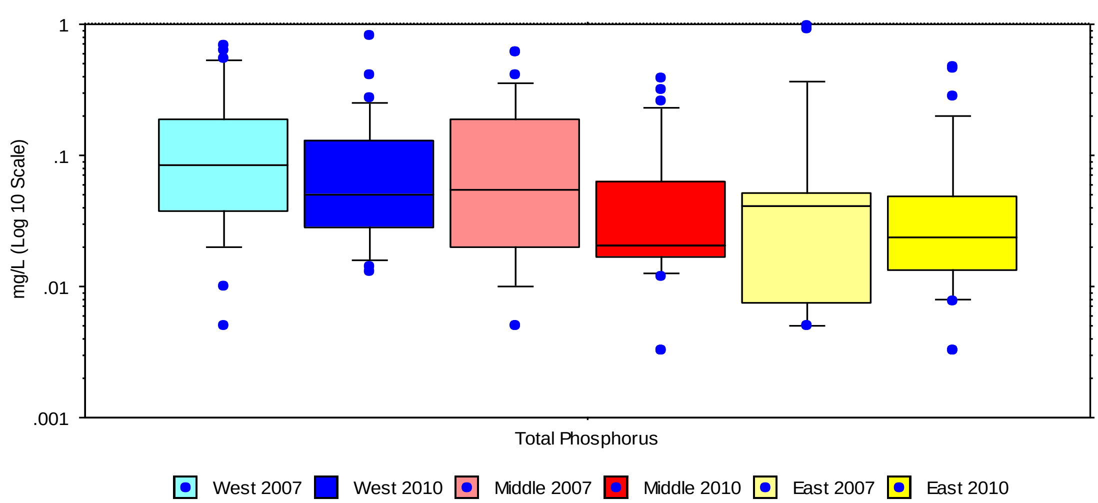


Figure 23: Summer total phosphorus ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

2) Nitrate + Nitrite Results

Middle and west Tennessee had the most sites meeting ecoregional criteria for nitrate+nitrite (Figure 24). There was very little difference between 2007 and 2010 results in these regions. East Tennessee had the lowest percentage of sites that met criteria, with 35% more sites failing to meet criteria compared to summer 2007. The word "criteria" for nitrate+nitrite is referring to the numeric interpretations of narrative criteria for each ecoregion (Denton et al, 2001). Although more sites were above criteria in all three divisions, the median values did not change substantially (Figure 25). The range of scores in west Tennessee streams was closer. The highest concentration of nitrate + nitrite in the state was 4.8 mg/L, which was in east Tennessee at East Fork Poplar Creek in Roan County which is less than one mile downstream of a sewage treatment plant and receives urban runoff. This stream also had the highest concentration during the previous study.

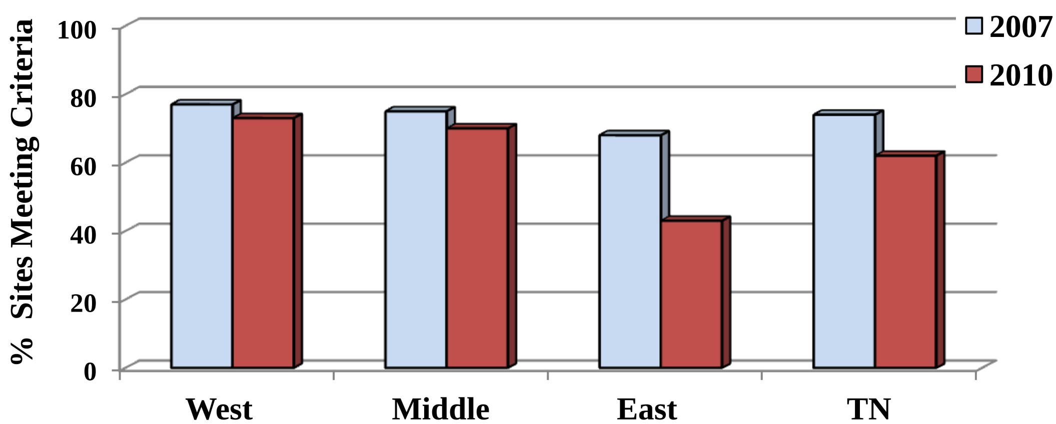


Figure 24: Percent of probabilistic sites that met regional nitrate+nitrite criteria. Data are based on single summer sample each year.

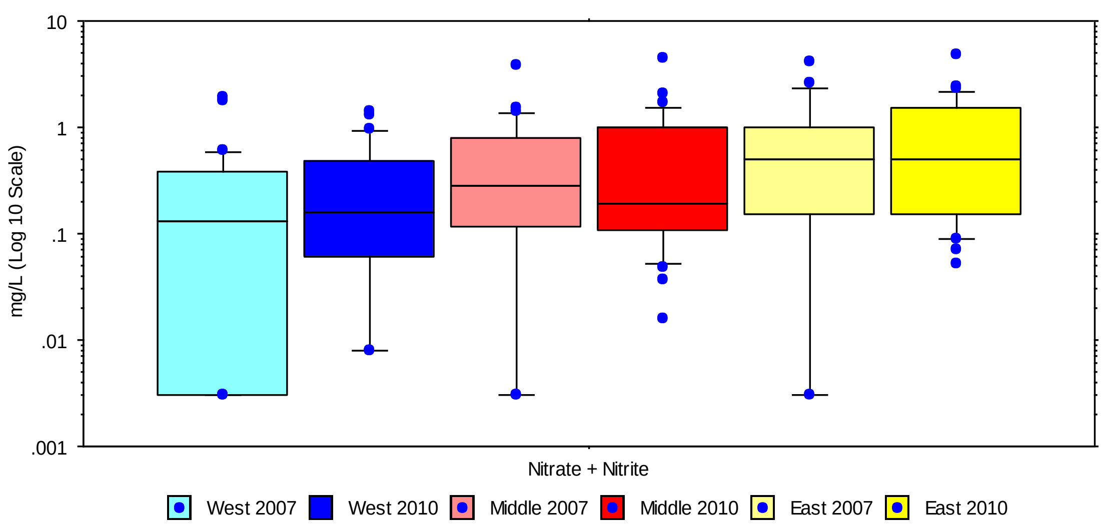


Figure 25: Summer nitrate+nitrite ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

3) Ammonia – N (as Nitrogen)

Ammonia exists in the aquatic environment in two forms. One is an un-ionized form (NH_3) and the other is an ionized form (NH_4^+). The state lab tests for total ammonia nitrogen, which is the sum of both forms. The form of ammonia greatly depends on the pH of the water and to a lesser extent the temperature. More ammonia will become present in the un-ionized form as pH and temperature rise. The un-ionized form is much more toxic to fish and aquatic macroinvertebrates than the ionized form. With the presence of oxygen and specialized forms of bacteria, the ammonia will be converted to nitrites, which are then converted to nitrates.

Ammonia was below detection limits at 74 of the 90 stations. Ammonia levels were highest in west Tennessee where there were 14 sites with detectable levels (Table 5). The mean value in west Tennessee declined from 0.09 mg/L in 2007 to 0.066 mg/l in 2010. Ammonia was not detected at any sites in the middle division and only two sites in the eastern division. Tennessee's fish and aquatic life criterion for ammonia is dependent on the pH of the water and also the temperature if salmonid species are present. No ammonia values in 2007 or 2010 were above the criterion.

Table 5: Summary statistics for ammonia concentrations (mg/L) at the probabilistic sites. Values based on single summer sample per year at each site.

Division	Min	Max	Mean	Median	Stand Dev
West 2007	<0.03	1.20	0.09	<0.03	0.25
West 2010	**<0.028**	**0.54**	**0.066**	**<0.028**	**0.12**
Middle 2007	<0.03	0.03	0.015	<0.03	0.06
Middle 2010	**<0.028**	**<0.028**	**<0.028**	**<0.028**	**NA**
East 2007	<0.03	0.14	0.028	<0.03	0.04
East 2010	**<0.028**	**0.045**	**0.016**	**<0.028**	**0.01**
TN 2007	<0.03	1.20	0.05	<0.03	0.16
TN 2010	**<0.028**	**0.54**	**0.032**	**<0.028**	**0.07**

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

4) Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen (TKN) is a sum of ammonia + organic nitrogen. Tennessee does not have a numeric criterion for TKN. Total Kjeldahl Nitrogen was detected at 52 of the probabilistic sites (24 west, 10 middle, and 18 east). The TKN concentrations were highest in west Tennessee and lowest in middle Tennessee (Table 6). In west Tennessee, the mean TKN concentration in 2010 was less than half the level in 2007. In middle and east Tennessee, the mean concentrations remained about the same. The 2010 concentrations were less variable in west Tennessee but more widely distributed in the rest of the state (Figure 26).

Table 6: Summary statistics for Total Kjeldahl Nitrogen (mg/L) at the probabilistic sites. Values based on single summer sample per year at each site.

Division	Min	Max	Mean	Median	Stand Dev
West 2007	<0.15	4.4	0.85	<0.15	1.22
West 2010	**<0.14**	**1.4**	**0.41**	**0.34**	**0.32**
Middle 2007	<0.15	0.58	0.11	<0.15	0.13
Middle 2010	**<0.14**	**0.27**	**0.11**	**<0.14**	**0.07**
East 2007	<0.15	1.19	0.26	<0.15	0.36
East 2010	**<0.14**	**2.5**	**0.28**	**0.20**	**0.44**
TN 2007	<0.15	4.4	0.37	<0.15	0.76
TN 2010	**<0.14**	**2.5**	**0.27**	**0.18**	**0.33**

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

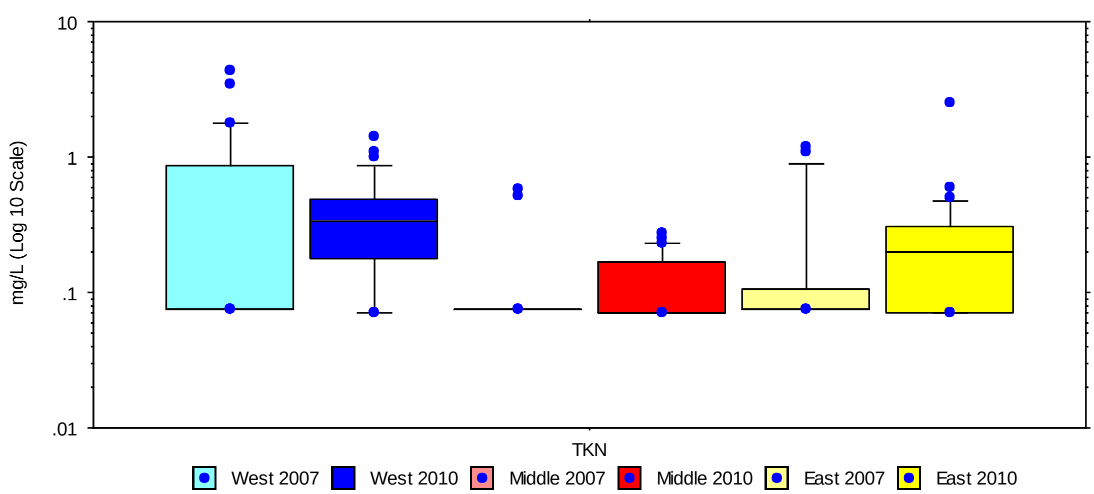


Figure 26: Summer TKN ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

5) Total Suspended Solids (TSS)

Total suspended solids (TSS) measurements include a wide variety of material, such as silt and decaying organic matter. Elevated TSS blocks light from reaching submerged vegetation and reduces photosynthesis and oxygen production. Excessive TSS can also cause an increase in surface water temperatures when suspended particles absorb heat from sunlight. Pollutants such as bacteria, nutrients, pesticides, and metals may attach to sediment particles and be transported to the water where they are released or carried further downstream. A decrease in water clarity caused by TSS can affect the ability of aquatic life to see and catch food. Suspended sediments can clog gills, reduce growth rates, and prevent egg and larval development. When suspended solids settle to the bottom of a stream, they cause a reduction in habitat availability.

Tennessee does not have a numeric criterion for total suspended solids. In 2010, 37% of sites in west Tennessee and 20% of sites in east Tennessee had measurable TSS with the highest values in the western division (Table 7). The mean and maximum levels in both divisions were higher in 2010 than 2007. There were no sites in middle Tennessee with detectable TSS in 2010.

Table 7: Summary statistics for total suspended solids (mg/L) at the probabilistic sites. Values based on single summer sample per year at each site.

Division	Min	Max	Mean	Median	Stand Dev
West 2007	<10	137	24.3	11	3.3
West 2010	**<10**	**640**	**31.6**	**<10**	**115.3**
Middle 2007	<10	35	6.9	5	6.2
Middle 2010	**<10**	**<10**	**<10**	**<10**	**0.0**
East 2007	<10	21	6.13	5	3.9
East 2010	**<10**	**72**	**9.9**	**<10**	**13.5**
TN 2007	<10	137	13.4	5	21.6
TN 2010	**<10**	**640**	**15.49**	**<10**	**69.3**

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

6) Total Organic Carbon (TOC)

Total organic carbon (TOC) measures the amount of carbon bound in organic compounds. TOC can be derived from decaying vegetation, bacterial growth, and metabolic activities of living organisms. Other sources of organic carbon include agricultural chemicals such as herbicides and insecticides, as well as discharges from wastewater treatment plants. Excessive organic content can increase the growth of microorganisms which contribute to the depletion of oxygen.

Tennessee does not have a numeric criterion for total organic carbon. West Tennessee streams had the highest levels of TOC, with the most variability between stations (Table 8). This could be due to the large amount of cropland and agricultural runoff in this part of the state. Middle and east Tennessee were fairly comparable in distribution of TOC levels (Figure 27). Summer 2010 levels are comparable to 2007 in all three divisions.

Table 8: Summary statistics for total organic carbon (mg/L) at the probabilistic sites. Values based on single summer sample per year at each site.

Division	Min	Max	Mean	Median	Stand Dev
West 2007	<0.1	13.0	3.7	2.7	3.6
West 2010	**0.99**	**9.5**	**3.7**	**3.3**	**2.3**
Middle 2007	<0.1	4.0	1.1	0.87	1.0
Middle 2010	**<0.068**	**3.6**	**1.1**	**0.99**	**0.7**
East 2007	<0.1	3.5	1.4	1.4	0.9
East 2010	**0.53**	**3.8**	**1.4**	**1.3**	**0.8**
TN 2007	<0.1	13.0	2.2	1.2	2.6
TN 2010	**<0.068**	**9.5**	**2.1**	**1.3**	**1.9**

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

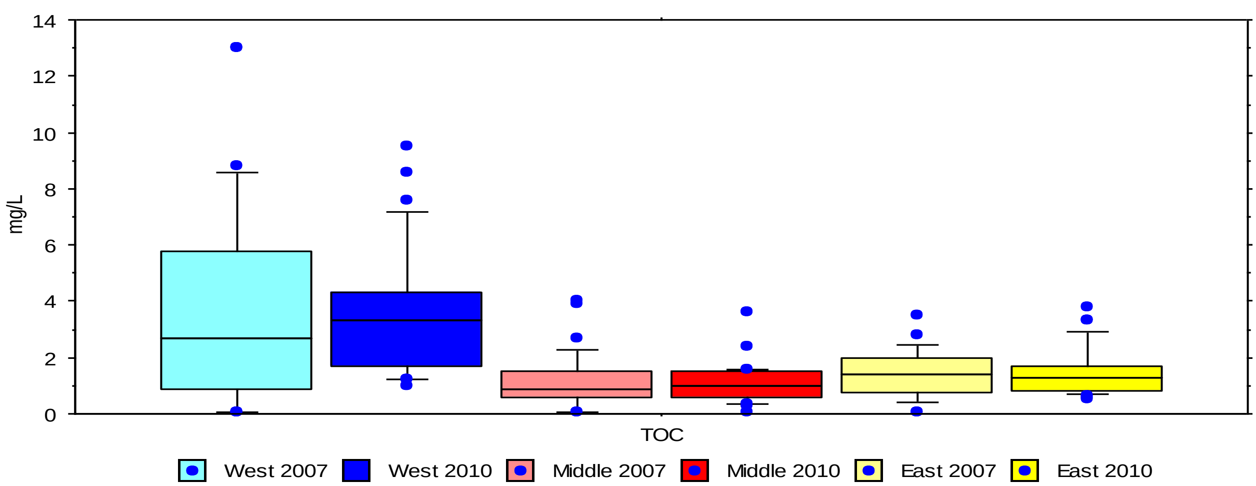


Figure 27: Summer TOC ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

b. FIELD PARAMETERS

Field measurements of pH, dissolved oxygen, temperature, conductivity and flow were taken concurrent with chemical sampling at each site. Data are presented in Appendix C. The 2007 data can be found in volume 4 of the previous study (Graf and Arnwine, 2009).

1) pH

Low pH, elevated alkalinity, or a significant change in the pH or acidity of the water over a relatively short period of time can greatly impact aquatic life. The effects include respiratory or osmoregulatory failure, inability to molt, and alteration of habitat through precipitation of metals. Generally, pH levels below 5.5 increase the toxicity of metals, while pH above 9 increases the toxicity of ammonia.

According to the general water quality criteria, pH values for wadeable streams must be within the range of 6.0 to 9.0 (TWQCB, 2007). In 2010, six sites in the western division had pH values below 6.0 (Figure 28). In the summer of 2007, four sites were below pH criteria; two of which were the same as in 2010. The other two were in the eastern division. Middle Tennessee had the least variation in pH between sites with most sites falling between 7.0 and 8.0 (Figure 29). The western division had the lowest pH levels, with all measurements falling below 8 (Figure 30).

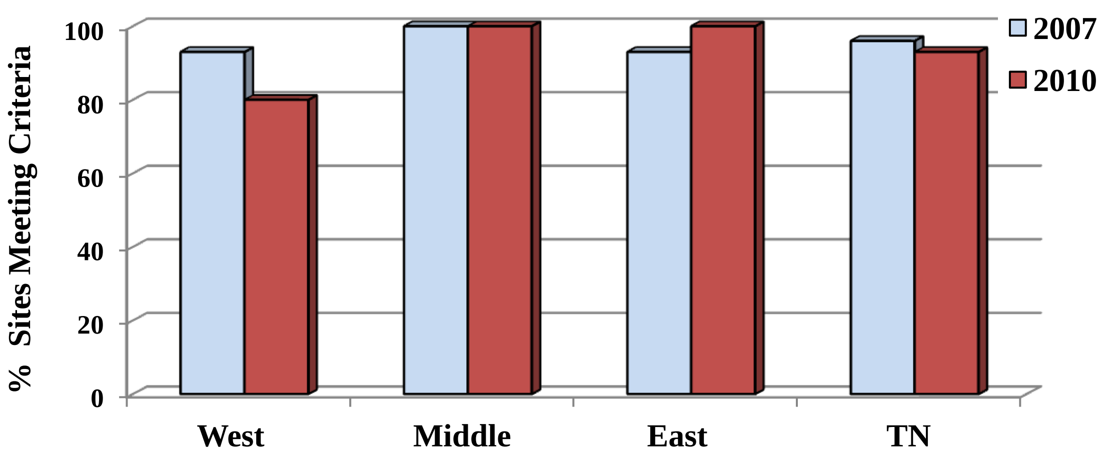


Figure 28: Percent of probabilistic sites that met pH criteria in 2007 and 2010. Data are based on single summer sample each year.

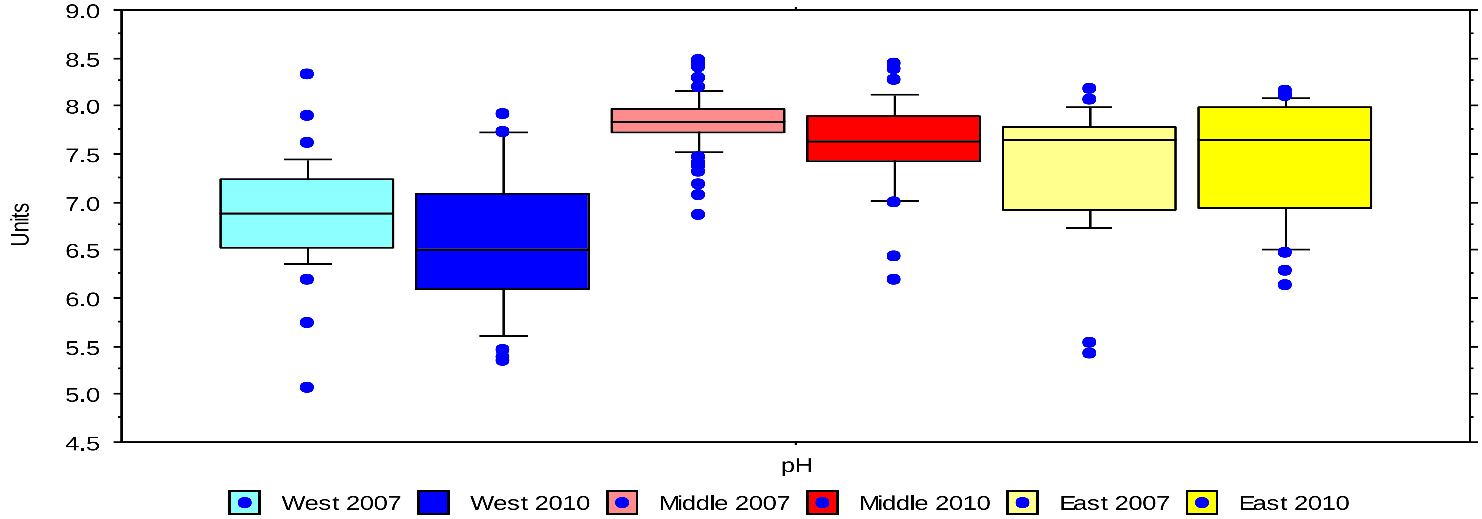


Figure 29: Summer pH ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

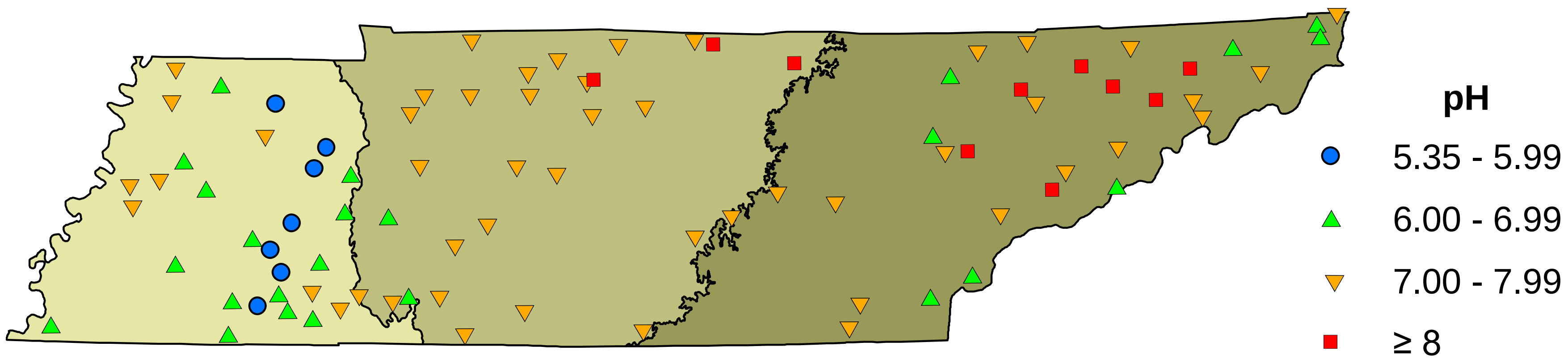


Figure 30: Summer 2010 pH values at the probabilistic monitoring sites by location.

2) Dissolved Oxygen

Adequate dissolved oxygen (DO) in streams is critical for healthy biological populations. Low dissolved oxygen may be caused by decay of organic material, disruption of algal photosynthesis, inflow of substantial amounts of ground water, or reduced stream flow. According to Tennessee's water quality criteria, dissolved oxygen concentrations in most surface waters should be at least 5.0 mg/L to support fish and aquatic life (TWQCB, 2007). The exceptions are trout streams, where the minimum is 6.0 mg/L, streams in the Blue Ridge Mountains (7.0 mg/L), and naturally reproducing trout streams (8.0 mg/L).

Dissolved oxygen criteria were met at 94% of the sites. The percent passing criteria was greater in 2010 than in 2007 in all three divisions (Figure 31). This is especially evident in west Tennessee, where the number of sites meeting criteria doubled. Three naturally reproducing trout streams in the Blue Ridge Mountains of east Tennessee were below 8.0 mg/L.

Minimum DO values in all divisions were higher in 2010 than in 2007. There was also less variability between DO concentrations. In 2010, the median value was slightly lower in East Tennessee, but was higher in the other divisions (Figure 32). DO levels were highest in middle Tennessee, where temperatures were generally cooler and flows were higher than the other two divisions (Figure 33).

Caution should be used when interpreting all dissolved oxygen measurements since only instantaneous daylight readings were taken. This type of monitoring does not reflect any diurnal fluctuations that may be below criteria. Dissolved oxygen was above 11% at two sites in middle Tennessee which is sometimes an indication of excessive algal growth. However, field observations at both sites indicated low to moderate levels of algae.

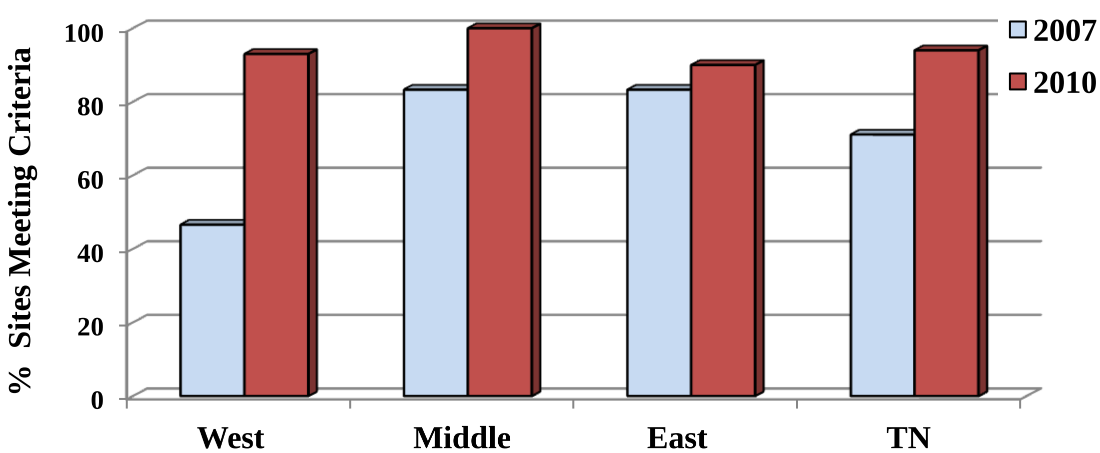


Figure 31: Percent of probabilistic sites that met dissolved oxygen criteria in 2007 and 2010. Data are based on single summer sample each year.

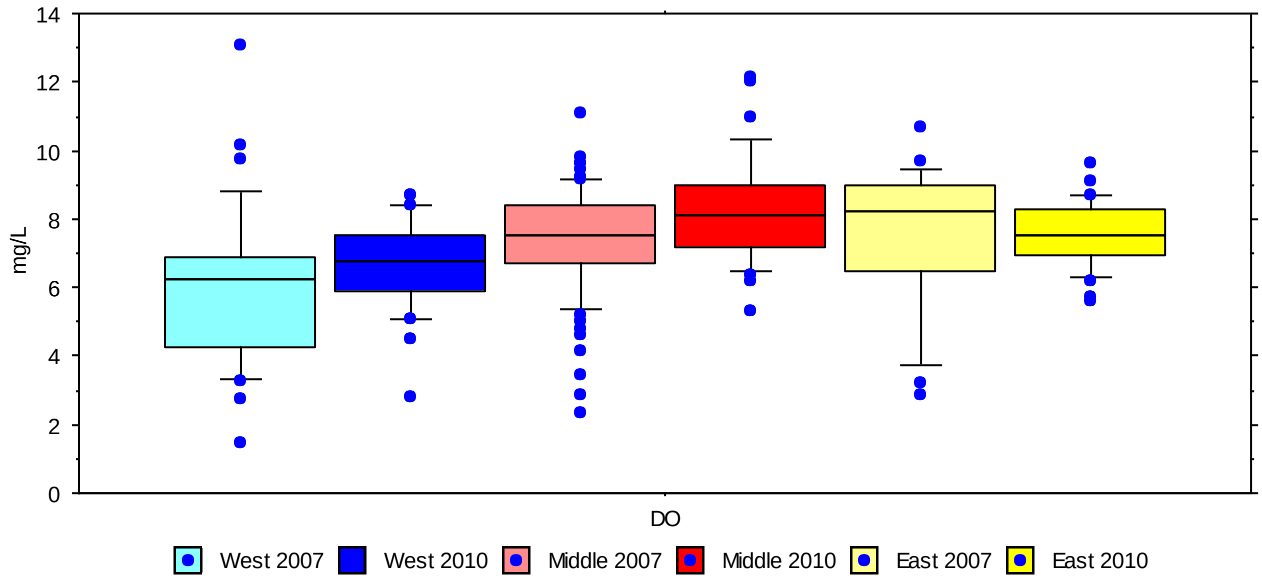


Figure 32: Summer dissolved oxygen ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

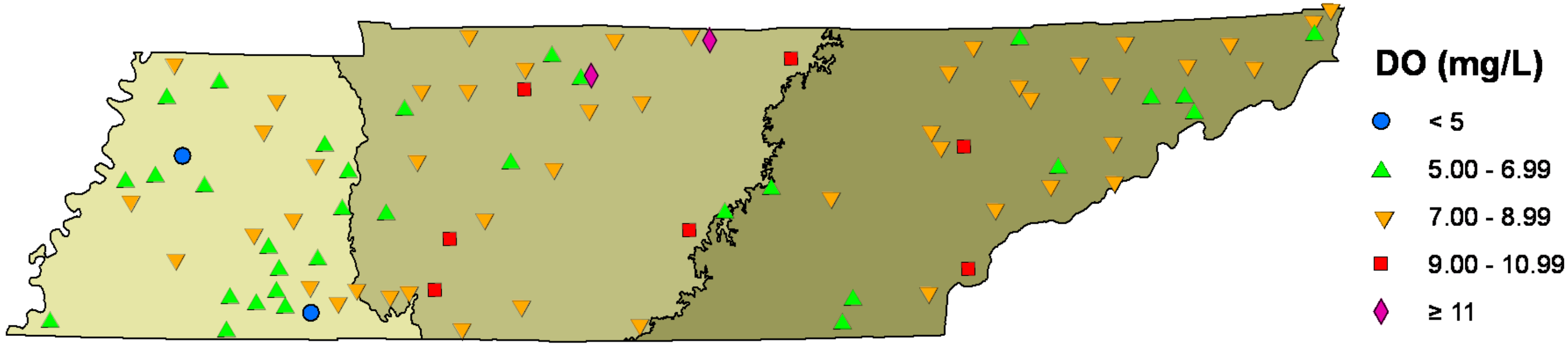


Figure 33: 2010 Dissolved oxygen values at the probabilistic sites by location.

3) Temperature

Water temperature is an important component of the aquatic environment. It is a key factor in determining the distribution, diversity, and abundance of aquatic life. Most species have a preferred temperature range. Metabolism, growth, emergence, and reproduction are directly related to temperature. Water temperature also affects dissolved oxygen levels and the susceptibility of benthic fauna to parasites.

According to Tennessee's water quality criteria for the support of fish and aquatic life in wadeable streams, the temperature shall not exceed 30.5°C (TWQCB, 2007). The maximum temperature in trout streams and tributaries of trout streams should not exceed 20°C. Four percent of sites failed to meet criteria in 2010, compared to 2% in 2007.

In 2010, temperatures in the western division tended to be slightly warmer than in 2007, although 97% of the sites passed criteria both years (Figure 34). Middle Tennessee temperatures were substantially cooler than 2007 and all sites met criteria. Although temperature ranges in the eastern division were relatively consistent, trout streams tended to have higher temperatures in 2010, resulting in three streams failing to meet criteria. No east Tennessee streams in the study failed criteria in 2007.

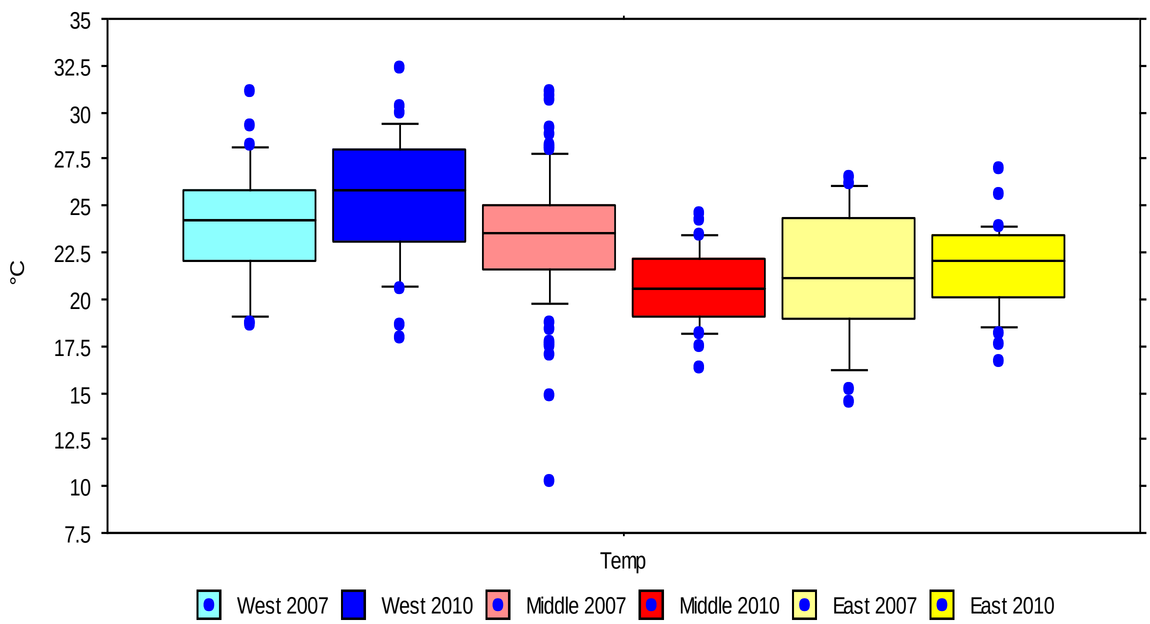


Figure 34: Summer temperature ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

4) Stream Flow

The flow at the probabilistic sites ranged widely due to stream size and rainfall fluctuations (Figure 35). The streams vary in size from a first order with a drainage of 0.1 square mile to a fourth order with a drainage of 250 square miles. In general, flow was higher in 2010 than in 2007, especially in west Tennessee. Middle Tennessee should be viewed with caution since one of the replacement sites had the largest drainage area in the study, which affected the flow ranges. The least change was seen in east Tennessee.

It may be more meaningful to look at the habitat parameter of channel flow status (Figure 36). This is an estimate of the amount of instream habitat that is covered by water and therefore available for colonization. It takes into account stream size and ecoregion. In west Tennessee, almost twice as many sites had adequate channel flow in 2010 although levels were still low compared to the rest of the state. The middle and eastern divsions increased 14 – 16% in the number of sites passing in 2010.

It is also helpful to look at how flow varied at individual sites (Figure 37). This helps differentiate between the number of sites with increased flow versus those with high flow that are new sites.

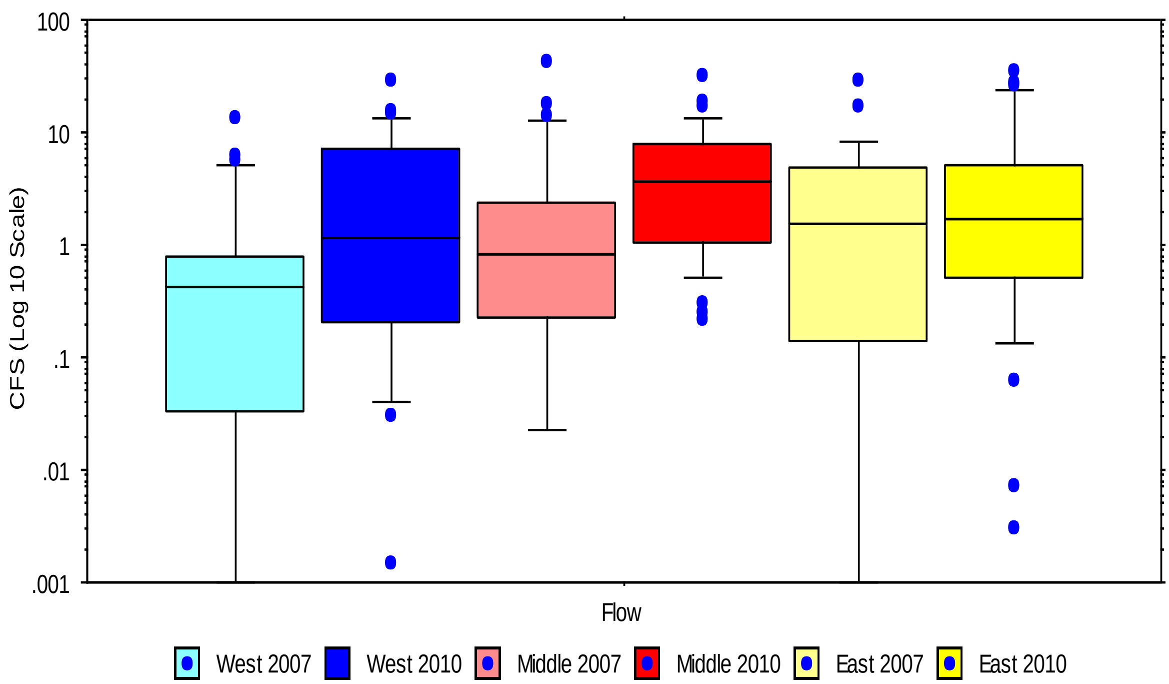


Figure 35: Summer flow ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year

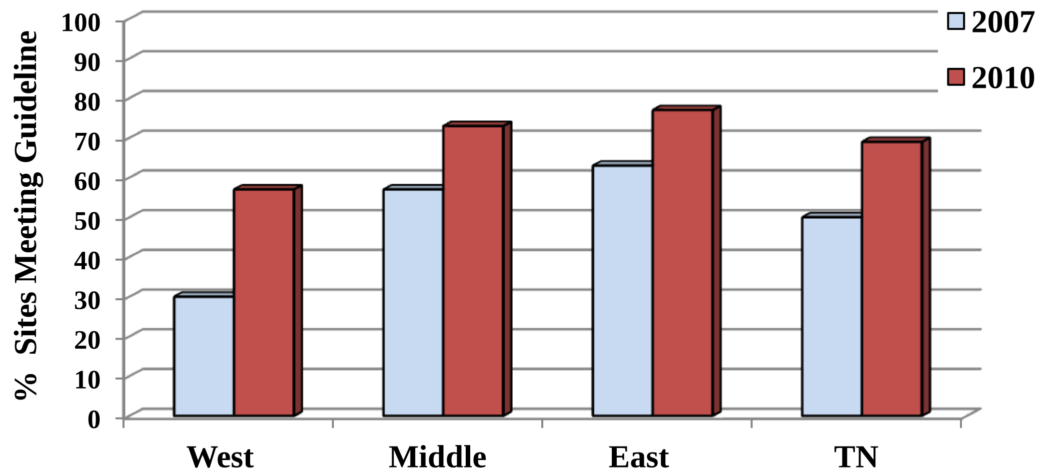


Figure 36: Percent of probabilistic sites that met regional flow status habitat guidelines in 2007 and 2010. Data are based on single summer habitat assessment each year.

In summer 2007, most of the rock habitat in the middle Tennessee stream, Bundrant Branch, was exposed. Few niches were available for macroinvertebrate colonization and the stream was given a channel flow status score of 6. This is below regional expectations in the Western Highland Rim (71f). *Photo provided by Nashville Environmental Field Office, TDEC.*

In 2010, more of the rock habitat was covered by water. Since adequate habitat was available for colonization, the channel flow status score was 13 which is adequate to maintain a healthy biological community in this region. *Photo provided by Aquatic Biology Section, TDH.*

Figure 37: Stream flow at probabilistic sites during the summer of 2007 and 2010 by location.

5) Conductivity

Conductivity is a measurement of water's ability to carry an electric current. Conductivity can reflect the amount of inorganic substances such as total dissolved solids or ions in the water. Substances that raise the conductivity include chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic substances such as oil can lower the conductivity. Conductivity is affected by natural geologic factors such as the types of rocks and soils in the area. However, human disturbance such as municipal or industrial discharges and runoff from urban, agricultural, or mining areas have the potential to cause more fluctuation.

There is no numeric criterion for conductivity. It is difficult to characterize through probabilistic monitoring, since natural conductivity levels vary widely between ecoregions. West Tennsessee had the most similarity in conductivity between the 2007 and 2010 studies (Figure 38). Conductivity in middle Tennessee tended to be slightly lower in 2010. East Tennessee had a wider variability in conductivity in 2010, with a greater number of sites falling below 300 uMHOs.

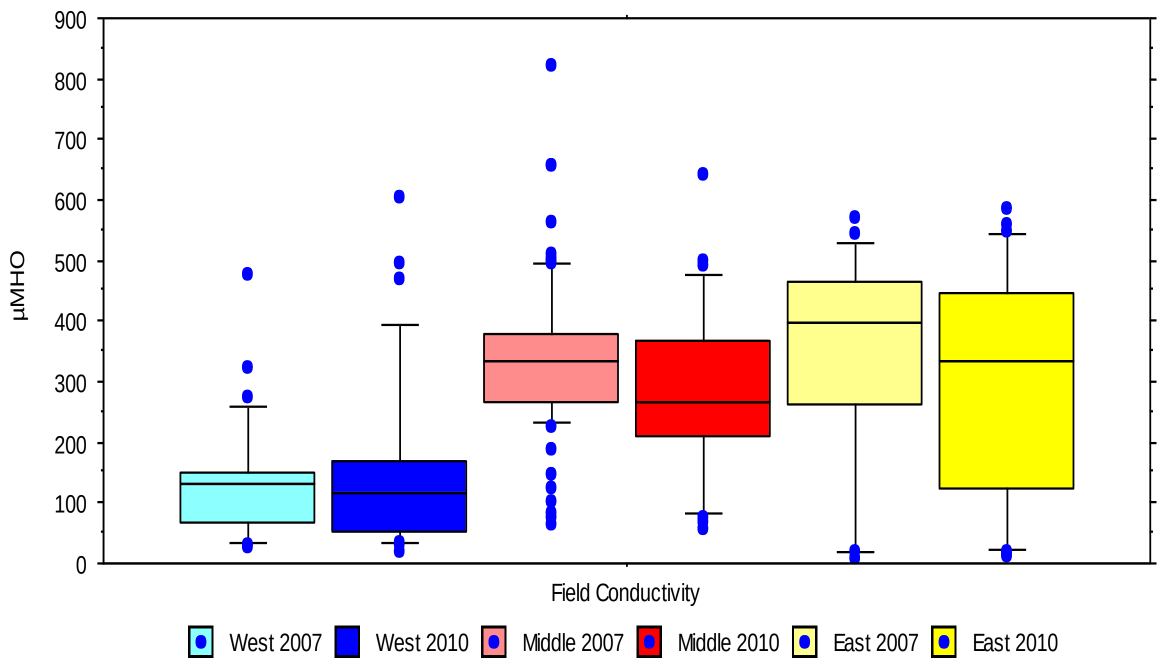


Figure 38: Summer conductivity ranges by division at the 2007 and 2010 probabilistic sites. Data based on single summer sample per site per year.

c. METALS

Nine metals were sampled in 2010 that were not analyzed as part of the 2007 study. Cadmium and selenium were not detected at any site. Mercury was only detected at one station located in east Tennessee. The western division, with the exception of chromium and zinc, generally had the highest metal concentrations. Middle Tennessee had the lowest number of detections and concentrations for all metals. Metal concentrations were compared to Tennessee's water quality criteria, with adjustments for hardness and total suspended solids (TSS) for cadmium, copper, chromium, lead, and zinc. As the hardness of the water increases, the toxicity of these metals to fish and aquatic life decreases. The toxicity of the metals also decreases as TSS increases since metals become bound to suspended solids and are less bioavailable.

1) Arsenic

Arsenic occurs naturally in some rocks, soil and water. It is released into the environment through natural activities such as volcanic action, erosion of rocks, and forest fires. Human activities can also result in arsenic entering surface waters. Approximately 90 percent of industrial arsenic in the U.S. is used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps, and semi-conductors (USEPA, 2011). Arsenic can also come from certain fertilizers and animal feeding operations. Industry practices such as copper smelting, mining and coal burning also contribute to arsenic in the environment. Higher levels of arsenic tend to be found in ground water than in surface water.

Arsenic was detected at 25 of the probabilistic sites, with 67% of the stations in west Tennessee having detectable levels (Table 9). Arsenic was detected at five east Tennessee sites and none in middle Tennessee. Levels were generally well below the water quality criteria for all designated uses although one value in west Tennessee approached the criterion of 10 µg/L for drinking water and recreation.

Table 9: Summary statistics for arsenic (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	20	<0.82	8.2	1.96	1.1	2.1
Middle	0	<0.82	<0.82	<0.82	<0.82	NA
East	5	<0.82	1.9	0.57	1.2	0.4
TN	25	<0.82	8.2	0.98	<0.82	1.4

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

2) Copper

Copper is an abundant naturally occurring trace element. It is a micronutrient at low concentrations and is essential to virtually all plants and animals. At higher concentrations, copper can become toxic to aquatic life. Mining, leather processing, fabricated metal products, and electric equipment are a few of the industries that contribute to discharges of copper into surface waters. Municipal effluents may also contribute additional copper loadings.

Copper was detected at 53 (59%) of the probabilistic sites (Table 10). Most of the sites in west (90%) and east (73%) Tennessee had detectable levels. Copper was only measureable at 13% of the middle Tennessee stations. Copper levels were generally highest in the western division (Figure 39). Five streams in west Tennessee had concentrations above the criterion for fish and aquatic life after adjusting for total hardness and total suspended solids. All five sites had very low hardness, which increased copper toxicity.

Table 10: Summary statistics for copper (μg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	27	<0.34	6.1	1.25	0.60	1.5
Middle	4	<0.34	0.85	0.22	<0.34	0.2
East	22	<0.34	5.2	0.91	0.48	1.2
TN	53	<0.34	6.1	0.79	0.43	1.2

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

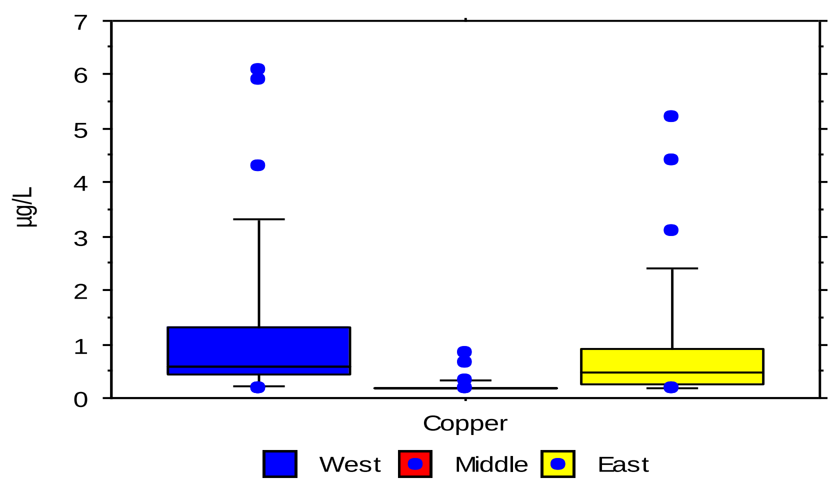


Figure 39: Summer 2010 copper ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

3) Total Chromium

Chromium typically enters the environment in either the Cr(III) or Cr(VI) valence state. Natural sources include leaching from rocks or mineral deposits. Chromium is released through industrial processes associated with stainless steel, furnace bricks, dyes, pigments, leather tanning, wood preserving, and chrome plating. It is also emitted into the atmosphere through the combustion of natural gas, oil and coal.

Chromium was detected at 21 (23%) of the sites, primarily in east and west Tennessee (Table11). Values were generally higher in east Tennessee (Figure 40). None of the values were above the water quality criterion for total chromium.

Table 11: Summary statistics for chromium (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	8	<0.89	2.2	0.76	<0.89	0.5
Middle	1	<0.89	0.9	0.46	<0.89	0.1
East	12	<0.89	4.2	0.99	<0.89	1.0
TN	21	<0.89	4.2	0.73	<0.89	0.7

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

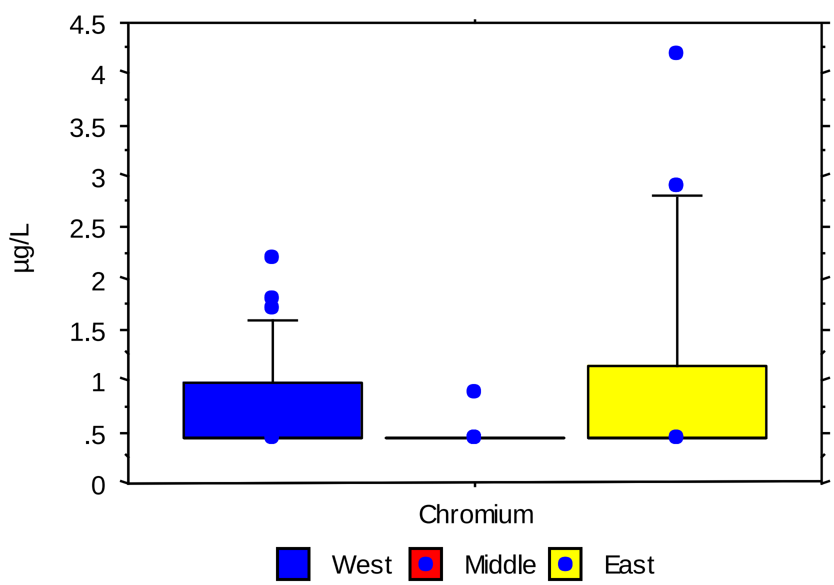


Figure 40: Summer 2010 total chromium ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

4) Iron

Iron is one of the most common elements in the earth's crust. Naturally occurring sources in surface water are from the weathering of rocks. Disturbance of the land through mining activities is the most common human source of iron in Tennessee. In sufficient concentrations, iron will oxidize to produce a floc, which coats habitat and is detrimental to aquatic life.

The concentrations of iron found throughout the state varied greatly by division although iron was detected at all sites. Streams in west Tennessee generally had higher concentrations than the rest of the state with a median value of 797 ug/L (Table 12). The single highest concentration and most variability were in east Tennessee (Figure 41). There is no numeric water quality criterion for iron.

Table 12: Summary statistics for iron (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	30	27	4200	1055.6	797	862.2
Middle	30	5.9	220	44.8	32	42.8
East	30	50	7300	478.6	180	1309.5
TN	90	5.9	7300	526.3	170	987.4

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

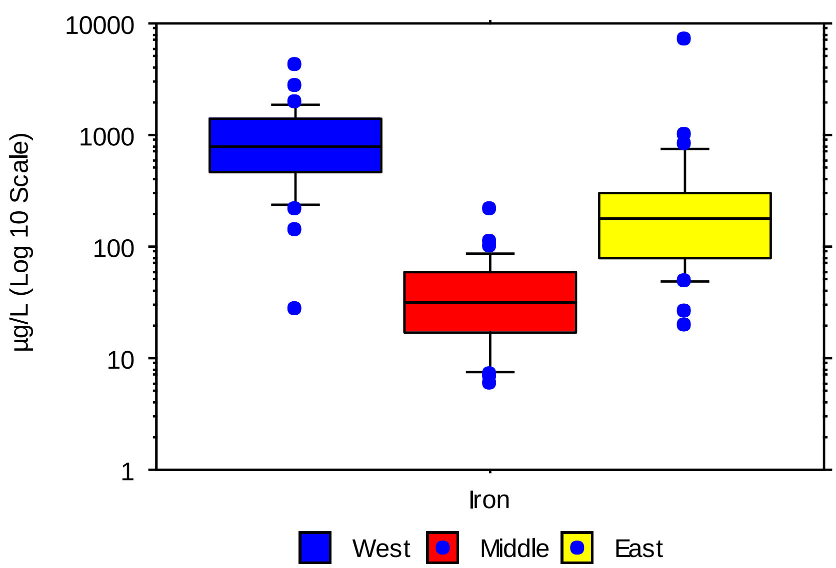


Figure 41: Summer 2010 iron ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

5) Lead

Lead occurs naturally in the environment. However, most of the high levels found in the environment come from human activities. Lead in urban areas may be from from old lead paint and residual air deposition from historic leaded automotive exhaust. Landfill leachate may contain waste from lead ore mining, ammunition manufacturing, or other industrial activities such as battery production.

Some of the chemicals that contain lead are broken down by sunlight, air, and water to other forms of lead. Lead compounds in water may combine with different chemicals depending on the acidity and temperature of the water.

Lead was detected at 15 (17%) of the probabilistic sites, all in the west and east divisions (Table 13). West Tennessee had the highest levels and the most variability between sites (Figure 42). Three streams in west Tennessee had lead concentrations above the fish and aquatic life criterion based on the total hardness and level of total suspended solids.

Table 13: Summary statistics for lead (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	8	<0.51	6.2	0.84	<0.51	1.5
Middle	0	<0.51	<0.51	<0.51	<0.51	NA
East	7	<0.51	4.4	0.49	<0.51	0.8
TN	15	<0.51	6.2	0.53	<0.51	1.0

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

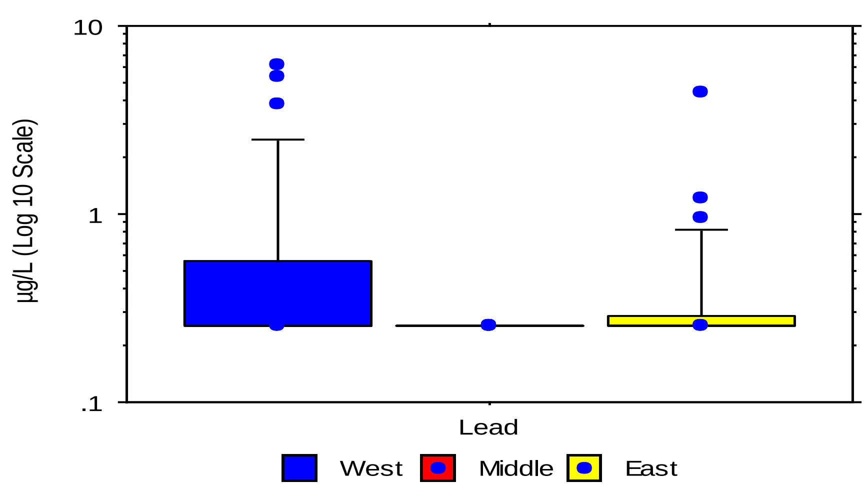


Figure 42: Summer 2010 lead ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

6) Manganese

Manganese occurs naturally in soil, air, and water in low levels. It can be released into waterways through exposure of rocks and soils through mining, impoundments, roadways, and land development. Manganese and manganese compounds are used in smelting, fertilizer, fungicides, livestock feed, and unleaded gasoline as an anti-knock additive.

Manganese was detected at all the probabilistic monitoring sites (Table 14). Concentrations were highest in west Tennessee and lowest in middle (Figure 43). Tennessee does not have a numeric water quality criterion for manganese.

Table 14: Summary statistics for manganese (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	30	21	1200	333.1	210	314
Middle	30	0.74	100	18.4	13.4	20.2
East	30	3.9	300	56.3	31.5	71.7
TN	90	0.74	1200	135.9	38	232.0

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

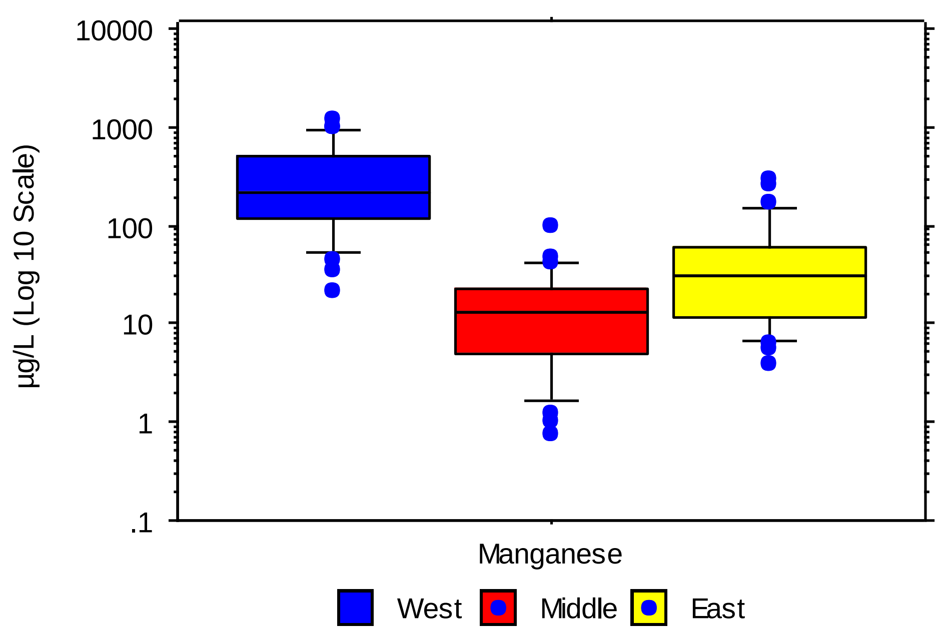


Figure 43: Summer 2010 manganese ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

7) Zinc

Zinc is usually found in nature as a sulfide associated with other metals. It is used in galvanizing iron and steel, as well as to prepare alloys for dye casting. In water, other factors such as pH, hardness, and TSS influence the solubility and toxicity of zinc.

Zinc was detected at 51 (57%) of the sites, mostly in east and west Tennessee (Table 15). East Tennessee had the highest levels (Figure 44). However, they did not violate criteria after adjusting for hardness and TSS. Although zinc levels in west Tennessee were lower than east Tennessee, two stations exceeded the zinc criterion due to the lower hardness and higher TSS levels.

Table 15: Summary statistics for zinc (µg/L) at the 2010 probabilistic sites. Data based on a single summer sample at each site.

Division	Number Detected	Min	Max	Mean	Median	Stand. Dev.
West	20	<1.5	47	6.47	2.3	10.2
Middle	4	<1.5	9.6	1.15	<1.5	1.6
East	27	<1.5	48	8.60	4.1	11.0
TN	51	<1.5	48	5.40	1.95	9.2

< Values are below the detection limit. Half the detection limit was used to calculate the mean and standard deviation.

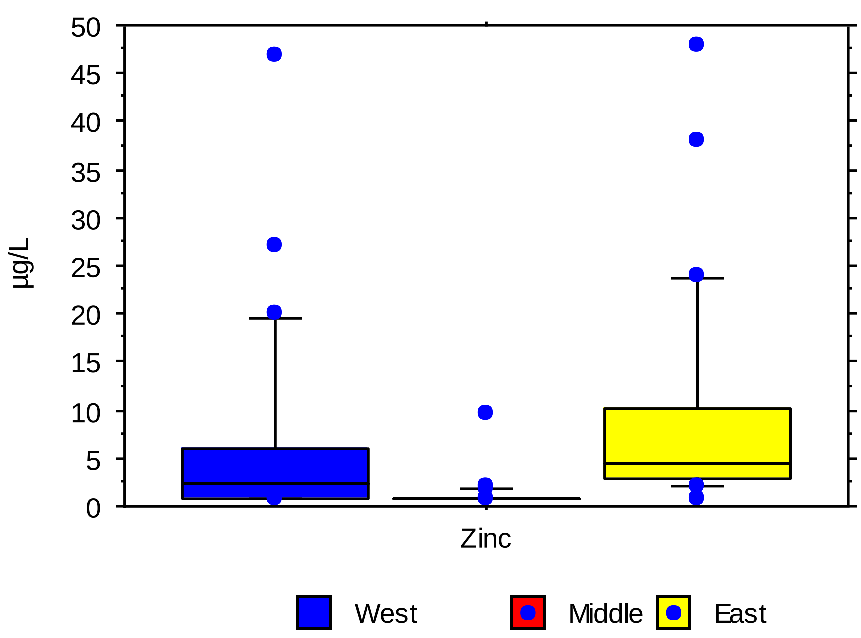


Figure 44: Summer 2010 zinc ranges by division at the probabilistic sites. Data based on a single summer sample at each site.

6. SUMMARY

There were some difference in the study design between 2007 and 2010. Due to stream flow conditions, four sites had to be replaced in 2010. The replacement sites caused some differences in the representativeness of the sites including characteristics such as stream order, drainage area, stream miles, ecoregions, watersheds, and land use. While some differences between an original and replacement site were large, the overall change in representativeness of sites statewide and to each of the three divisions was not substantial.

Forty-two percent of streams statewide met biological guidelines in 2010. There was a 23% increase in sites meeting macroinvertebrate guidelines in west Tennessee. It is likely the severe drought affected 2007 scores in this part of the state. Passing scores decreased 13 % in middle Tennessee possibly due to effects of record spring floods. There was little change in the eastern division.

Overall habitat scores have fallen statewide in Tennessee. Large scale weather conditions and refinements to the habitat assessment protocol since the last study have probably affected scoring. Future sampling will show if the lowering of scores this year was due to weather conditions, new protocols, or indicate a downward trend.

Summer nutrient levels in the 2010 study differed from 2007. Statewide, the number of stations that met ecoregional guidelines for total phosphorus increased, while the number that met nitrate + nitrite guidelines decreased. Mean and median phosphorus concentrations across the state were a little more than half the 2007 levels.

The 2010 study included the analysis of nine metals, which were not in the previous study. Most of the metals, with the exception of chromium, mercury and zinc, were highest in west Tennessee and lowest in the middle division. Cadmium and selenium were not detected at any site and mercury was only detected at one site. The toxicity of certain metals on fish and aquatic life can vary based on the total hardness of the water and level of total suspended solids. With the exception of one mercury sample in east Tennessee, all metal exceedances of water quality criteria were in west Tennessee where low hardness was often a factor.

The information in this document should not be confused with water quality assessments to determine use support. It is important to realize that probabilistic monitoring is a useful tool for trend analysis and for statewide comparisons due to the consistency of methodology at every site. However, the study is not intended to replace the more extensive targeted monitoring program designed for water quality assessments. The probabilistic study reports the percentage of criteria violations for individual parameters based on a single sample event at randomly selected sites. Assessments used for 305(b)/303(d) reporting are based on multiple samples from multiple sites within a single reach as well as evaluations of land-use and field observations.

It must also be emphasized that it is far too early to determine any trends. The first year was during a statewide record drought and this year was after record floods in two thirds of the state. The probabilistic sampling will need to be repeated several more times before trend analyses can be attempted.

LITERATURE CITED

Arnwine, D.H., J.I. Broach, L.K. Cartwright and G.M. Denton. 2000. *Tennessee Ecoregion Project.* Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

Arnwine, D.H. and G.M. Denton. 2001. *Development of Regionally-based Numeric Interpretations of Tennessee's Narrative Biological Integrity Criteria.* Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

Arnwine, D.H., M.H. Graf and G.M. Denton. 2009. *2007-8 Probabilistic Monitoring of Wadeable Streams in Tennessee Volume 2: Study Design and Site Characterization*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

Arnwine, D.H., M.H. Graf, C.J. Brame and G.M. Denton, 2009. *2007-8 Probabilistic Monitoring of Wadeable Streams in Tennessee Volume 3: Macroinvertebrates and Habitat*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

Barbour, M.T., Gerritsen, J., Snyder, B.D. and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers.* EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington D.C.

Denton, G.M., D.H. Arnwine and S.H. Wang. 2001. *Development of Regionally-Based Interpretations of Tennessee's Narrative Nutrient Criterion.* Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Nashville, Tennessee.

Graf, M. H. and D.H. Arnwine. 2009. *2007-8 Probabilistic Monitoring of Wadeable Streams in Tennessee Volume 4: Water Chemistry*. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee.

Hayes, J.L. 2011. *Record Floods of Greater Nashville: Including Flooding in Middle Tennessee and Western Kentucky, May 1-4, 2010.* U.S. Department of Commerce (USDOC); National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, Maryland.

National Oceanic Atmospheric Administration NOAA. 2011. Tennessee Palmer Drought Severity Index (PDSI). http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php?parameter=pdsi&month=8&year=2007&filter=3&state=40&div=0. Retrieved March 15, 2011.

National Oceanic Atmospheric Administration (NOAA), 2011. May 1& 2 2010 Epic Flood Event for Western and Eastern Tennessee. http://www.srh.noaa.gov/ohx/?n=may2010epicfloodevent. Retrieved August 15, 2011.

Palmer, W. C, 1965. Meteorological Drought. Res. Paper No.45, 58pp., Dept. of Commerce, Washington, D.C.

Sprague, L.A. 2005. *Drought Effects on Water Quality in the South Platte River Basin, Colorado.* Journal of the American Water Resources Association 3184: pp. 11-24

Tennessee Department of Environment and Conservation. 2006. *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys.* Division of Water Pollution Control, Nashville, Tennessee.

Tennessee Department of Environment and Conservation. 2009. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water.* Division of Water Pollution Control, Nashville, Tennessee.

Tennessee Water Quality Control Board. 2007. *Rules of the Tennessee Department of Environment and Conservation Division of Water Pollution Control*, Chapter-4-3, General Water Quality Criteria. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

Tennessee Water Quality Control Board. 2007. *Rules of the Tennessee Department of Environment and Conservation Division of Water Pollution Control,* Chapter-4-4, Use Classifications for Surface Waters. Tennessee Department of Environment and Conservation, Nashville, Tennessee.

United States Environmental Protection Agency. 2011. http://water.epa.gov/lawsregs/rulesregs

United States Environmental Protection Agency. 2006. *Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams.* EPA 841-B-06-002. Office of Research and Development, Office of Water, Washington D.C.

APPENDIX A

2010 MACROINVERTEBRATE DATA

Data for the 2007 probabilistic monitoring study can be found in Appendix B of Volume 3: Macroinvertebrates and Habitat (Arnwine et al, 2009).

STATION ID	Division	ECO	DATE	TR	EPT	%EPT	%OC	NCBI	%Cl	%Nutol	TMI
BEAVE008.9KN	East	67F	08-27-2010	25	8	67.7	19.4	5.24	74.7	46.8	34
BFLAT018.0UN	East	67F	08-04-2010	22	9	48.5	3.1	4.05	79.9	54.6	36
BIRCH000.6JO	East	66E	08-03-2010	44	17	59.1	20.7	2.68	69.4	4.7	42
BYRD001.5HS	East	67F	08-02-2010	33	16	59.7	2.5	2.56	52.5	40.3	38
CANDI017.1BR	East	67F	08-31-2010	28	7	32.6	7	5.15	65.6	61.9	30
CANDI033.1BR	East	67G	08-31-2010	28	7	12.2	8.6	4.78	28.4	50.2	24
CLEAR001.3GE	East	67F	08-02-2010	27	7	27.7	21	5.27	71.8	53.8	30
CORN002.5JO	East	66F	08-03-2010	35	14	46.1	5.6	2.46	77	7.3	38
COSBY012.2CO	East	66G	08-10-2010	39	14	64.7	21.4	3.21	63.6	11.2	40
COVE003.8SV	East	66G	08-11-2010	33	15	37	10.3	3.99	49.5	29.9	34
ECO67F27	East	67F	08-03-2010	26	12	50.5	4.3	3.93	67.2	62.4	36
EFPOP007.3RO	East	67F	08/24/2010	25	5	52	10.5	5.07	58.7	64.9	30
FALL001.5UN	East	67F	08-04-2010	25	14	36.9	3	3.82	35.7	67.9	30
FALL003.2HA	East	67F	08-03-2010	30	6	38.2	31.5	5.47	39.9	56.7	28
GAMMO000.7SU	East	67F	08-02-2010	36	5	7.2	43.5	6.07	39.7	21.1	26
GAP000.1CT	East	67F	08-04-2010	32	6	9.8	37.1	5.19	33.0	29.9	24
GRASS005.1GE	East	67F	08-05-2010	16	6	14.7	11.3	4.35	78.9	70.6	24
HICKO008.4CA	East	69E	08-05-2010	33	14	72.6	4	4.02	63.7	10.95	40
HORSE007.0GE	East	66E	08-04-2010	21	6	13.6	6.2	2.71	89.8	77.4	26
LAURE006.3JO	East	66E	08-03-2010	43	17	46.7	11.2	3.1	55.6	36.4	36
MIDDL001.2SV	East	67G	08-11-2010	25	6	39	9.3	4.84	64.4	79.5	26
OTOWN008.9CL	East	69E	08-03-2010	35	4	12.3	44.7	5.76	37.9	27.4	26
POPLA000.1MG	East	69D	08-09-2010	38	14	57.0	11.1	3.55	77.0	32.3	40
RIPLE001.5GE	East	67F	08-05-2010	26	6	23.7	8.1	4.72	65.1	41.9	28
SEQUA101.2BL	East	68B	08-30-2010	22	7	53.5	11.4	4.76	34.6	28.6	40
SINKI003.0CO	East	67G	08-10-2010	24	6	61.9	12.4	5.53	72.2	64.9	30
SIXMI006.6BT	East	67I	09-07-2010	36	6	19.9	55.1	5.23	21.4	36.7	22
TELLI040.5MO	East	66G	09-16-2010	43	16	48.9	27.9	4.11	58.4	43.4	34
TITUS1T0.1CA	East	69E	08-04-2010	44	19	46.4	24.4	3.62	50.6	6	40
TOWEE005.9PO	East	66G	09-06-2010	47	11	31.0	38.7	4.97	43.9	33.8	28
BEAGL008.3OV	Middle	71G	09-09-2010	27	5	27	13	4.25	23	30	28
BUNDR000.6WE	Middle	71F	09-06-2010	24	7	30.2	16.7	4.21	53.5	43.7	30
CANE004.5VA	Middle	71H	08-30-2010	27	6	42.3	22.8	4.59	70.7	33	34
CATHE001.5MY	Middle	71H	09-22-2010	24	6	69.1	8.6	5.54	36	18.9	30
CFORK003.4SR	Middle	71G	09-14-2010	27	8	49.1	11.4	4.9	64	40.6	32
CHISH015.4LW	Middle	71F	09-07-2010	26	10	87.5	4.6	4.32	32.5	15.4	36
COLLI025.8WA	Middle	71G	09-27-2010	23	7	49.1	24.8	4.48	68.8	44.5	34
DIXON000.4LW	Middle	71F	09-07-2010	26	7	51.1	15.4	5.14	28.6	13.2	30
DRAKE011.8SR	Middle	71H	09-23-2010	22	6	64.1	22.8	5.39	42.9	33.7	32
GREEN016.2WE	Middle	71F	09-06-2010	20	6	23.5	72.8	6.02	29.5	26.9	22
LBART006.5DI	Middle	71F	09-21-2010	40	9	15.9	60.2	5.32	27.9	26.9	24
LONG004.9MA	Middle	71G	09-14-2010	29	9	21.3	48.6	4.93	49.5	53.2	28
MILLE007.3RN	Middle	71E	09-22-2010	27	7	10.2	6.1	4.32	26	58.2	28
NFLIC002.0PE	Middle	71F	09-21-2010	24	8	50.3	9.4	4.75	81.3	54.4	32
PRUN000.1GS	Middle	71H	09-07-2010	43	8	20.7	22.3	5.43	46.9	57	28
ROBIN000.6FR	Middle	71H	09-08-2010	31	4	4.8	69.7	5.59	25.5	18.6	22
SCAMP008.3SR	Middle	71H	09-13-2010	23	6	27.3	20.5	5.32	70.2	78	26
SCOTT000.9DA	Middle	71H	09-23-2010	26	4	12.2	66.2	5.81	28.8	60.4	16
SHARP000.1WI	Middle	71F	09-23-2010	28	11	50.7	28.6	5.14	48.8	34.7	32
SPRIN009.0WS	Middle	71I	09-13-2010	25	7	20.5	12.1	4.68	54.4	69.3	30
SULPH036.0RN	Middle	71E	09-16-2010	27	9	48.6	7.6	5.22	32.4	20.5	32

STATION ID	Division	ECO	DATE	TR	EPT	%EPT	%OC	NCBI	%Cl	%Nutol	TMI
TRACE003.5CY	Middle	71G	09-09-2010	24	7	17.7	80.1	5.71	23.2	61.3	16
TUMBL003.8HU	Middle	71F	09-21-2010	25	9	77.9	1	4.55	72.6	33.2	38
WATSO002.3WI	Middle	71H	09-20-2010	28	5	21.4	61	5.55	41.7	54.2	24
WELLS007.6HO	Middle	71F	09-20-2010	17	8	17.8	2.8	3.05	80	36.1	28
WFHIC007.0CE	Middle	71G	09-08-2010	30	9	48	12.2	4.51	57.1	27.6	38
WFRED010.7MT	Middle	71E	09-21-2010	19	7	54.7	1.3	3.71	57.6	11.4	38
WHITE013.5HU	Middle	71F	09-20-2010	25	10	49.2	7.9	3.64	69.9	15.7	38
BEAR002.1WY	West	65E	07-06-2010	29	3	7.8	45.4	7.33	5.9	10.2	20
BIRDS012.3BN	West	65E	07-05-2010	37	10	11.5	76	6.21	34.5	36	30
CANE001.4SH	West	74B	07-12-2010	24	1	0.6	90.2	8.08	1.7	76.3	6
CLOVE6.7T0.5OB	West	74B	07-08-2010	27	1	6.8	67.5	7.71	0.5	19.4	14
COLD006.3LE	West	74A	07-07-2010	19	5	29.9	60.5	5.87	20.9	55.4	22
CROOK005.0MC	West	65E	07-15-2010	40	6	13.6	36.5	6.45	23.5	8.2	32
CYPRE002.1CK	West	74B	07-06-2010	20	1	16.9	79.8	7.24	1.6	37.2	14
CYPRE005.9OB	West	74B	07-07-2010	38	2	1.9	68.4	7.17	28.2	23.8	24
CYPRE023.8MC	West	65E	07-21-2010	23	3	10.2	72.2	8.09	19.1	5.0	18
CYPRE5.5T1.6HR	West	65B	07-22-2010	54	7	20.8	54.6	6.25	27.3	6.6	30
FINGE000.8CS	West	65E	7-20-2010	46	7	12.1	56.8	6.62	17	15.5	28
HALLS001.7LE	West	74B	07-08-2010	27	2	3.4	79.2	7.31	7.7	37.7	14
HAWKI002.1CR	West	65E	07-05-2010	41	3	4.3	67	6.51	28.6	31.4	24
HAYES003.3HR	West	65E	07-15-2010	34	9	40.7	30.2	7	14.6	2.5	32
HROCK002.4CR	West	65E	07-06-2010	44	6	11.6	62.4	6.24	15.5	16.5	24
HURRI007.4HE	West	65E	07-19-2010	38	2	48.3	13.5	7.2	9.6	5.6	30
HYDE002.7LE	West	74B	07-07-2010	29	1	2.3	55.1	7.56	0	32.7	14
KERR000.4HD	West	65J	07-16-2010	30	4	61.5	18.8	5.44	71.2	47.1	34
NFFDE17.9T1.8T0.3HE	West	65E	7-22-2010	38	3	2.1	66.1	7.23	7.8	20.3	20
NREEL000.4OB	West	74B	07-08-2010	32	2	13.8	46.6	7.41	4.2	19.6	20
OWL003.7HD	West	65E	07-16-2010	46	11	22.2	42.6	6.21	31	25.9	38
POPLA014.7HY	West	74B	07-12-2010	48	6	30.6	43.9	7	21.4	34.7	30
ROSE001.3MC	West	65E	07-15-2010	38	11	21.9	59.6	5.92	39.9	30.1	34
SFCUB009.5DE	West	65E	07-05-2010	37	6	22.3	60.6	5.95	34	28.7	32
SFFDE54.1T0.7MN	West	65E	07-20-2010	48	7	11.5	59	6.7	15.3	16.9	26
SFMUD003.8MC	West	65E	07-19-2010	29	1	8.6	28.5	8.06	1.6	36.6	16
SMITH003.5HD	West	65J	07-16-2010	27	10	75.8	3.3	4.02	52.5	30	38
STOKE004.9CK	West	74B	07-06-2010	31	0	0	61.4	7.54	3.2	42.9	14
TAR003.0CS	West	65E	07-21-2010	44	10	14.1	58.7	6.08	34.2	25.5	36
THOMP000.2WY	West	65E	07-07-2010	41	8	33.1	47.4	5.83	46.3	41.1	34

TR = Taxa Richness
EPT = EPT (Ephemeroptera, Plecoptera, Trichoptera) Richness
%EPT = EPT Abundance
%OC = Oligochaeta and Chironomidae abundance
NCBI = North Carolina Biotic Index
%Cl = Clinger abundance
%NutTol = Abundance of nutrient tolerant organisms
TMI = Tennessee Macroinvertebrate Index (Target score = 32)
Shaded Values did not meet guidelines for ecoregion (ECO)

APPENDIX B

2010 HABITAT ASSESSMENT SCORES

Data for the 2007 probabilistic monitoring study can be found in Appendix B of Volume 3: Macroinvertebrates and Habitat (Arnwine et al, 2009).

Table B-1: Habitat assessment results at probabilistic monitoring sites. (Shaded values did not meet habitat guidelines for ecoregion)

Station ID	Division	Date	ECO IV	Epifaunal Substrate	Embeddedness	Velocity/ Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability	Vegetative Protection	Riparian Vegetation	Pool Substrate	Pool Variability	Channel Sinuosity	Habitat Score
BEAVE008.9KN	East	8/12/10	67F	16	14	17	13	16	16	16	17	19	13				157
BFLAT018.0UN	East	8/4/10	67F	13	11	10	9	11	20	10	14	11	19				128
BIRCH000.6JO	East	8/3/10	66E	20	20	15	15	18	20	20	18	20	20				186
BYRD001.5HS	East	8/2/10	67f	15	17	14	18	16	20	19	19	15	13				166
CANDI017.1BR	East	8/31/10	67F	12	8	16	10	12	20	16	5	9	12				112
CANDI033.1BR	East	8/31/10	67G	14	8	16	7	14	17	15	5	5	2				103
CLEAR001.3GE	East	8/2/10	67F	12	10	14	13	19	8	7	17	9	13				122
CORN002.5JO	East	8/3/10	66F	15	18	10	16	16	8	20	15	13	12				143
COSBY012.2CO	East	8/10/10	66G	20	18	17	19	17	18	20	19	16	16				180
COVE003.8SV	East	8/11/10	66G	18	16	19	14	18	17	18	18	17	17				172
ECO67F27	East	8/12/10	67F	19	18	14	15	12	20	20	13	16	13				160
EFPOP007.3RO	East	8/24/10	67F	19	18	17	15	18	18	16	14	10	14				159
FALL001.5UN	East	8/4/10	67F	14	11	10	7	19	17	10	17	9	9				123
FALL003.2HA	East	8/3/10	67F	14	12	14	16	20	17	14	14	4	2				127
GAMMO000.7SU	East	8/2/10	67F	12	6	4	3	19	11	19	3	2	2				81
GAP000.1CT	East	8/4/10	67F	18	8	14	7	20	8	20	16	2	2				116
GRASS005.1GE	East	8/5/10	67F	6	8	14	7	7	8	8	10	12	11				91
HICKO008.4CA	East	8/5/10	69E	19	16	19	14	16	18	10	15	18	19				164
HORSE007.0GE	East	8/4/10	67F	15	7	10	7	9	2	20	14	8	10				102
LAURE006.3JO	East	8/13/10	66E	20	17	19	14	17	9	20	19	16	11				162
MIDDL001.2SV	East	8/11/10	67G	8	2	12	7	19	13	8	13	12	11				105
OTOWN008.9CL	East	8/3/10	69E	6	6	8	3	8	20	4	4	4	8				71
POPLA000.1MG	East	8/9/10	69D	16	8	14	6	6	15	18	9	13	12				116
RIPLE001.5GE	East	8/5/10	67F	6	4	13	3	16	2	4	8	2	2				60
SEQUA101.2BL	East	8/30/10	68B	14	14	18	9	19	19	5	9	6	2				115
SINKI003.0CO	East	8/10/10	67G	14	5	17	10	19	13	13	12	13	13				129
SIXMI006.6BT	East	9/7/10	67I	4	3	7	3	17	19	5	4	4	4				70
TELLI040.5MO	East	9/16/10	66G	17	18	19	12	18	18	18	19	17	12				168
TITUS1T0.1CA	East	8/4/10	69E	10	10	13	8	7	20	14	4	4	20				110
TOWEE005.9PO	East	9/6/10	66G	11	7	12	10	9	18	9	19	18	12				125

Station ID	Division	Date	ECO IV	Epifaunal Substrate	Embeddedness	Velocity/ Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability	Vegetative Protection	Riparian Vegetation	Pool Substrate	Pool Variability	Channel Sinuosity	Habitat Score
TOWEE005.9PO	East	9/6/10	66G	11	7	11	10	9	18	8	19	18	12				123
BEAGL008.3OV	Middle	9/9/10	71G	20	18	15	15	18	20	18	19	20	20				183
BRUSH001.1LS	Middle	9/22/10	71F	10	13	14	9	14	20	17	18	20	20				155
BSPRI003.9CH	Middle	9/22/10	71F	12	18	14	13	10	10	19	14	9	10				129
BUNDR000.6WE	Middle	9/16/10	71F	15	18	14	10	13	18	15	14	17	14				148
CANE004.5VA	Middle	8/30/10	71H	20	18	19	18	15	20	15	14	15	14				168
CATHE001.5MY	Middle	9/22/10	71H	17	8	16	8	18	8	15	9	14	14				127
CFORK003.4SR	Middle	9/14/10	71G	19	18	14	15	12	16	19	9	10	3				135
CHISH015.4LW	Middle	9/17/10	71F	19	18	14	13	18	19	14	15	9	10				159
COLLI025.8WA	Middle	9/27/10	71G	17	15	19	11	18	20	16	14	18	14				162
DIXON000.4LW	Middle	9/17/10	71F	19	18	18	15	12	17	15	13	9	20				156
DRAKE011.8SR	Middle	9/23/10	71H	12	18	13	12	13	11	15	16	12	8				130
GREEN016.2WE	Middle	9/6/10	71F	9	14	14	4	14	3	10	3	1	11				83
LBART006.5DI	Middle	9/21/10	71F	12	17	17	15	9	18	17	8	11	5				129
LONG004.9MA	Middle	9/14/10	71G	19	18	20	15	14	10	18	19	15	11				159
MILLE007.3RN	Middle	9/22/10	71E	17	18	14	15	8	19	18	11	8	19				147
NFLIC002.0PE	Middle	9/21/10	71F	20	18	19	19	10	19	15	8	10	4				137
PRUN000.1GS	Middle	9/17/10	71H	14	18	14	13	13	2	19	6	7	5				111
ROBIN000.6FR	Middle	9/8/10	71H	11	9	18	7	14	19	7	16	10	20				131
SCAMP008.3SR	Middle	9/13/10	71H	12	16	10	10	16	8	17	11	18	6				124
SCOTT000.9DA	Middle	9/23/10	71H	12	14	10	9	9	11	14	12	10	7				108
SHARP000.1WI	Middle	9/23/10	71F	17	13	16	7	14	16	20	6	6	3				118
SPRIN009.0WS	Middle	9/13/10	71I	16	15	10	11	18	17	4	11	14	3				119
SULPH036.0RN	Middle	9/16/10	71E	17	18	17	13	12	20	10	12	10	17				146
TRACE003.5CY	Middle	9/9/10	71G	15	18	14	18	8	15	17	12	12	12				141
TUMBL003.8HU	Middle	9/21/10	71F	19	18	16	14	15	20	11	16	16	18				163
WATSO002.3WI	Middle	9/20/10	71H	7	10	10	6	9	18	17	16	9	8				112
WELLS007.6HO	Middle	9/20/10	71F	17	18	16	8	15	8	15	18	17	4				136
WFHIC007.0CE	Middle	9/8/10	71G	19	18	14	15	15	18	15	15	10	2				141
WFRED010.7MT	Middle	9/21/10	71E	17	14	17	13	12	18	13	10	11	11				136
WHITE013.5HU	Middle	9/20/10	71F	19	18	19	14	12	11	19	13	14	16				157

Station ID	Division	Date	ECO IV	Epifaunal Substrate	Embeddedness	Velocity/ Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles	Bank Stability	Vegetative Protection	Riparian Vegetation	Pool Substrate	Pool Variability	Channel Sinuosity	Habitat Score
BEAR002.1WY	West	7/6/10	65E	3			7	5	13		10	12	4	9	6	5	74
BIRDS012.3BN	West	7/5/10	65E	16			15	17	17		15	17	12	16	14	10	149
CANE001.4SH	West	7/12/10	74B	11			12	16	15		7	8	2	13	7	4	95
CLOVE1T0.5OB	West	7/8/10	74B	8			7	14	13		14	9	2	8	9	9	93
COLD006.3LE	West	7/7/10	74A	12	14	13	8	15	13	10	16	9	5				115
CROOK005.0MC	West	7/15/10	65E	13			8	10	13		3	6	4	9	14	8	86
CYPRE002.1CK	West	7/6/10	74B	8			8	10	13		10	8	6	6	6	8	83
CYPRE005.9OB	West	7/7/10	74B	3			12	11	5		11	12	12	6	8	8	89
CYPRE023.8MC	West	7/21/10	65E	18			14	20	12		18	13	15	13	14	2	149
CYPRE1T1.6HR	West	7/22/10	65B	13			10	6	20		14	18	17	16	7	15	136
FINGE000.8CS	West	7/20/10	65E	10			8	14	17		5	6	20	11	15	9	115
HALLS001.7LE	West	7/8/10	74B	5			6	6	10		4	8	3	7	6	6	61
HAWKI002.1CR	West	7/5/10	65E	16			14	15	17		16	18	18	11	15	10	150
HAYES003.3HR	West	7/15/10	65E	10			12	9	11		7	12	2	9	9	6	87
HROCK002.4CR	West	7/6/10	65E	10			11	14	15		13	6	6	11	7	7	100
HURRI007.4HE	West	7/19/10	65E	6			4	8	5		14	6	2	6	9	5	65
HYDE002.7LE	West	7/7/10	74B	3			4	8	10		10	10	2	7	2	8	64
KERR000.4HD	West	7/16/10	65J	15	8	10	13	13	19	15	15	13	14				145
NFFDE1T1.5HE	West	7/22/10	65E	10			7	19	9		12	11	12	9	9	6	104
NREEL000.4OB	West	7/8/10	74B	2			5	11	5		6	5	8	6	3	4	55
OWL003.7HD	West	7/16/10	65E	13			9	10	13		14	7	2	13	9	2	92
POPLA014.7HY	West	7/12/10	74B	5			3	11	11		6	8	19	6	5	4	78
ROSE001.3MC	West	7/15/10	65E	10			10	15	5		17	9	10	10	14	2	102
SFCUB009.5DE	West	7/5/10	65E	8			6	6	18		8	8	3	9	12	9	87
SFFDE1T0.7MN	West	7/20/10	65E	8			6	8	17		9	9	7	11	9	12	96
SFMUD003.8MC	West	7/19/10	65E	9			9	6	13		7	9	5	12	10	9	89
SMITH003.5HD	West	7/16/10	65J	15	17	19	10	15	10	9	14	12	7				128
STOKE004.9CK	West	7/6/10	74B	5			3	7	11		10	12	5	6	3	5	67
TAR003.0CS	West	7/21/10	65E	18			5	19	8		12	10	16	11	9	2	110
THOMP000.2WY	West	7/7/10	65E	3			2	15	5		6	6	13	9	1	3	63

APPENDIX C

Total Phosphorus and Nitrate+Nitrite Data
Field Measurements and Additional Chemical Data
Metals Data

Data for the 2007 probabilistic monitoring study can be found in Appendix A and B of Volume 4: Water Chemistry (Graf and Arnwine, 2009).

Table C-1: Total Phosphorus and Nitrate + Nitrite Data for the Wadeable Streams Sites.

Station ID	Division	ECO	Sample Date	Total Phos. (mg/L)	Pass/Fail Criteria	Nitrate + Nitrite (mg/L)	Pass/Fail Criteria
BEAVE008.9KN	East	67F	08-12-2010	0.46	Fail	1.7	Fail
BFLAT018.0UN	East	67F	08-04-2010	0.024	Pass	1.5	Fail
BIRCH000.6JO	East	66e	08-02-2010	0.0086	Pass	0.15	Pass
BYRD001.5HS	East	67f	08-02-2010	0.014	Pass	0.48	Pass
CANDI017.1BR	East	67F	08-31-2010	0.06	Fail	0.32	Pass
CANDI033.1BR	East	67G	08-31-2010	0.015	Pass	0.58	Pass
CLEAR001.3GE	East	67F	08-02-2010	0.28	Fail	1.5	Fail
CORN002.5JO	East	66f	08-03-2010	0.012	Fail	0.1	Pass
COSBY012.2CO	East	66G	08-10-2010	0.017	Fail	0.38	Fail
COVE003.8SV	East	66g	08-10-2010	0.029	Fail	0.5	Fail
ECO67F27	East	67F	08-03-2010	0.0078	Pass	0.43	Fail
EFPOP007.3RO	East	67f	08-24-2010	0.47	Fail	4.8	Fail
FALL001.5UN	East	67F	08-04-2010	0.021	Pass	0.91	Pass
FALL003.2HA	East	67f	08-03-2010	0.052	Fail	2	Fail
GAMMO000.7SU	East	67F	08-02-2010	0.043	Fail	1.5	Fail
GAP000.1CT	East	67f	08-04-2010	0.014	Pass	2.4	Fail
GRASS005.1GE	East	67f	08-02-2010	0.077	Fail	2.3	Fail
HICKO008.4CA	East	69E	08-05-2010	0.00325	Pass	0.072	Pass
HORSE007.0GE	East	66F	08-04-2010	0.00325	Pass	0.25	Pass
LAURE006.3JO	East	66E	08-02-2010	0.032	Fail	0.35	Fail
MIDDL001.2SV	East	67G	08-11-2010	0.027	Pass	0.15	Pass
OTOWN008.9CL	East	69E	08-03-2010	0.026	Fail	0.7	Fail
POPLA000.1MG	East	69D	08-09-2010	0.0115	Pass	0.089	Pass
RIPLE001.5GE	East	67F	08-05-2010	0.032	Pass	2	Fail
SEQUA101.2BL	East	68b	08-30-2010	0.059	Fail	0.6	Fail
SINKI003.0CO	East	67G	08-10-2010	0.021	Pass	1.4	Fail
SIXMI006.6BT	East	67I	09-07-2010	0.016	Pass	0.22	Pass
TELLI040.5MO	East	66G	09-06-2010	0.0084	Pass	0.091	Pass
TITUS1T0.1CA	East	69E	08-04-2010	0.047	Fail	0.13	Fail
TOWEE005.9PO	East	66g	09-06-2010	0.021	Fail	0.0525	Pass
BEAGL008.3OV	Middle	71g	09-09-2010	0.02	Pass	1.1	Fail
BRUSH001.1LS	Middle	71f	09-22-2010	0.017	Pass	0.037	Pass
BSPRI003.9CH	Middle	71f	09-22-2010	0.032	Fail	0.87	Fail
BUNDR000.6WE	Middle	71f	09-06-2010	0.014	Pass	0.016	Pass
CANE004.5VA	Middle	71H	08-30-2010	0.00325	Pass	0.12	Pass
CATHE001.5MY	Middle	71h	09-22-2010	0.26	Fail	0.081	Pass
CFORK003.4SR	Middle	71g	09-14-2010	0.018	Pass	0.95	Fail
CHISH015.4LW	Middle	71f	09-07-2010	0.013	Pass	0.14	Pass
COLLI025.8WA	Middle	71G	09-27-2010	0.017	Pass	0.27	Pass
DIXON000.4LW	Middle	71F	09-07-2010	0.029	Pass	1	Fail
DRAKE011.8SR	Middle	71H	09-23-2010	0.021	Pass	0.2	Pass
GREEN016.2WE	Middle	71f	09-06-2010	0.0625	Fail	0.011	Pass
LBART006.5DI	Middle	71f	09-21-2010	0.015	Pass	0.059	Pass
LONG004.9MA	Middle	71g	09-14-2010	0.029	Pass	1.1	Fail
MILLE007.3RN	Middle	71E	09-22-2010	0.018	Pass	2.1	Pass
NFLIC002.0PE	Middle	71f	09-21-2010	0.02	Pass	0.055	Pass
PRUN000.1GS	Middle	71h	09-07-2010	0.2	Fail	1.2	Fail
ROBIN000.6FR	Middle	71H	09-08-2010	0.033	Pass	1.7	Fail
SCAMP008.3SR	Middle	71H	09-13-2010	0.096	Pass	0.16	Pass

Station ID	Division	ECO	Sample Date	Total Phos. (mg/L)	Pass/Fail Criteria	Nitrate + Nitrite (mg/L)	Pass/Fail Criteria
SCOTT000.9DA	Middle	71h	09-23-2010	0.32	Fail	0.62	Pass
SHARP000.1WI	Middle	71f	09-22-2010	0.033	Fail	0.086	Pass
SPRIN009.0WS	Middle	71i	09-13-2010	0.1	Pass	0.049	Pass
SULPH036.0RN	Middle	71E	09-16-2010	0.00325	Pass	0.18	Pass
TRACE003.5CY	Middle	71G	09-09-2010	0.017	Pass	0.73	Pass
TUMBL003.8HU	Middle	71F	09-21-2010	0.017	Pass	0.18	Pass
WATSO002.3WI	Middle	71h	09-20-2010	0.385	Fail	0.6	Pass
WELLS007.6HO	Middle	71F	09-20-2010	0.018	Pass	0.19	Pass
WFHIC007.0CE	Middle	71G	09-08-2010	0.021	Pass	1.4	Fail
WFRED010.7MT	Middle	71e	09-21-2010	0.1	Fail	4.4	Fail
WHITE013.5HU	Middle	71f	09-20-2010	0.012	Pass	0.13	Pass
BEAR002.1WY	West	65e	07-06-2010	0.064	Fail	0.97	Fail
BIRDS012.3BN	West	65e	07-05-2010	0.025	Pass	0.008	Pass
CANE001.4SH	West	74b	07-12-2010	0.41	Fail	0.86	Pass
CLOVE6.7T0.5OB	West	74B	07-08-2010	0.13	Fail	0.1	Pass
COLD006.3LE	West	74a	07-07-2010	0.1	Pass	0.061	Pass
CROOK005.0MC	West	65e	07-15-2010	0.016	Pass	0.026	Pass
CYPRE002.1CK	West	74b	07-06-2010	0.23	Fail	0.008	Pass
CYPRE005.9OB	West	74b	07-07-2010	0.094	Pass	0.26	Pass
CYPRE023.8MC	West	65e	07-21-2010	0.0465	Fail	0.008	Pass
CYPRE5.5T1.6HR	West	65B	07-22-2010	0.05	Fail	0.36	Fail
FINGE000.8CS	West	65E	07-20-2010	0.056	Fail	0.067	Pass
HALLS001.7LE	West	74b	07-08-2010	0.12	Fail	0.008	Pass
HAWKI002.1CR	West	65e	07-05-2010	0.022	Pass	0.23	Pass
HAYES003.3HR	West	65e	07-15-2010	0.05	Fail	0.008	Pass
HROCK002.4CR	West	65E	07-06-2010	0.025	Pass	0.58	Fail
HURRI007.4HE	West	65E	07-19-2010	0.15	Fail	0.16	Pass
HYDE002.7LE	West	74b	07-07-2010	0.15	Fail	0.48	Pass
KERR000.4HD	West	65J	07-16-2010	0.013	Pass	0.26	Fail
NFFDE17.9T1.8T0.3HE	West	65e	07-22-2010	0.04	Pass	0.27	Pass
NREEL000.4OB	West	74b	07-08-2010	0.15	Fail	0.17	Pass
OWL003.7HD	West	65e	07-16-2010	0.032	Pass	0.098	Pass
POPLA014.7HY	West	74b	07-12-2010	0.81	Fail	1.4	Fail
ROSE001.3MC	West	65e	07-15-2010	0.036	Pass	0.065	Pass
SFCUB009.5DE	West	65e	07-05-2010	0.028	Pass	0.008	Pass
SFFDE54.1T0.7MN	West	65e	07-20-2010	0.034	Pass	0.14	Pass
SFMUD003.8MC	West	65E	07-19-2010	0.05	Fail	0.62	Fail
SMITH003.5HD	West	65j	07-16-2010	0.014	Pass	0.1	Pass
STOKE004.9CK	West	74B	07-06-2010	0.27	Fail	1.3	Fail
TAR003.0CS	West	65E	07-21-2010	0.034	Pass	0.16	Pass
THOMP000.2WY	West	65e	07-07-2010	0.016	Pass	0.54	Fail

Table C-2: Field Data and Additional Chemical Data for the Wadeable Streams Sites.

STATION ID	Division	ECO	Sample Date	pH	Cond. (uMHO)	DO (mg/L)	Temp °C	Flow (CFS)	Sus. Res (mg/L)	Tot Hrd (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TOC (mg/L)
BEAVE008.9KN	East	67F	08-12-2010	8.06	410.2	9.1	22.76	35.60	32	310	<0.028	0.2	2.3
BFLAT018.0UN	East	67F	08-04-2010	7.92	365	7.53	23.42	0.48	<10	200	<0.028	<0.14	1.1
BIRCH000.6JO	East	66e	08-02-2010	6.47	12	7.78	17.56	0.80	<10	27	<0.028	0.24	1.3
BYRD001.5HS	East	67f	08-02-2010	7.98	354.3	8.7	19.67	0.57	<10	190	<0.028	0.22	0.59
CANDI017.1BR	East	67F	08-31-2010	7.63	336.6	5.62	23.09	9.80	15	210	<0.028	<0.14	2.1
CANDI033.1BR	East	67G	08-31-2010	7.63	274.4	6.99	21.29	1.74	<10	200	0.045	0.21	1.3
CLEAR001.3GE	East	67F	08-02-2010	8.02	496.7	7.26	22.95	3.26	72	280	0.044	2.5	3.3
CORN002.5JO	East	66f	08-03-2010	6.29	41	6.83	22.05	0.52	<10	46	<0.028	0.25	0.77
COSBY012.2CO	East	66G	08-10-2010	6.14	16	8.16	20.04	2.96	<10	40	<0.028	<0.14	0.7
COVE003.8SV	East	66g	08-10-2010	8.15	264.15	8.26	22.21	6.00	<10	320	<0.028	<0.14	0.68
ECO67F27	East	67F	08-03-2010	8.11	382.6	8.26	23.76	1.93	<10	200	<0.028	<0.14	1.1
EFPOP007.3RO	East	67f	08-24-2010	7.7	428.8	7.74	21.81	19.70	<10	130	<0.028	0.29	1.7
FALL001.5UN	East	67F	08-04-2010	8.01	432.4	8.65	20.14	1.41	<10	240	<0.028	<0.14	1.1
FALL003.2HA	East	67f	08-03-2010	8.1	492.8	8.62	19.33	3.57	20	280	<0.028	0.41	0.67
GAMMO000.7SU	East	67F	08-02-2010	6.83	547	7.53	21.13	1.62	12	300	<0.028	0.6	1.5
GAP000.1CT	East	67f	08-04-2010	7.96	482	8.12	18.16	2.78	<10	250	<0.028	<0.14	0.525
GRASS005.1GE	East	67f	08-02-2010	8.06	542	6.72	23.39	0.23	<10	270	<0.028	0.35	1.4
HICKO008.4CA	East	69E	08-05-2010	7.53	300.1	7.44	25.64	15.27	<10	150	<0.028	<0.14	1.6
HORSE007.0GE	East	66F	08-04-2010	7.28	24	6.74	23.89	1.63	<10	31	<0.028	<0.14	0.84
LAURE006.3JO	East	66E	08-02-2010	7.65	146	7.42	21.39	27.35	<10	130	<0.028	0.17	1.7
MIDDL001.2SV	East	67G	08-11-2010	7.8	586.6	5.7	26.98	0.46	<10	300	<0.028	0.29	1.8
OTOWN008.9CL	East	69E	08-03-2010	7.19	232.4	6.42	23.47	0.01	<10	150	<0.028	0.45	3.8
POPLA000.1MG	East	69D	08-09-2010	6.97	213.5	7.53	23.62	0.06	<10	190	<0.028	<0.14	0.89
RIPLE001.5GE	East	67F	08-05-2010	7.88	560	6.19	21.85	1.65	<10	270	<0.028	0.2	1.3
SEQUA101.2BL	East	68b	08-30-2010	7.51	283.6	7.06	23.35	4.96	<10	170	<0.028	0.5	3.3
SINKI003.0CO	East	67G	08-10-2010	7.8	333.5	8.3	16.64	1.57	<10	170	<0.028	0.14	0.71
SIXMI006.6BT	East	67I	09-07-2010	7.74	233	7.7	18.49	1.96	<10	160	<0.028	<0.14	1.1
TELLI040.5MO	East	66G	09-06-2010	6.82	20.6	9.6	18.96	25.54	<10	50	<0.028	<0.14	0.86
TITUS1T0.1CA	East	69E	08-04-2010	6.58	40.7	7.44	22.01	0.00	26	90	<0.028	0.41	1.6
TOWEE005.9PO	East	66g	09-06-2010	6.76	59.1	7.59	22.63	0.39	<10	93.5	<0.028	0.21	1.3
BEAGL008.3OV	Middle	71g	09-09-2010	8.26	387.1	10.96	17.5	7.55	<10	200	<0.028	0.16	1.5
BRUSH001.1LS	Middle	71f	09-22-2010	7.62	102.8	9.64	19.05	0.30	<10	150	<0.028	<0.14	0.57
BSPRI003.9CH	Middle	71f	09-22-2010	7.94	322	9	21.6	0.84	<10	210	<0.028	<0.14	0.98

STATION ID	Division	ECO	Sample Date	pH	Cond. (uMHO)	DO (mg/L)	Temp °C	Flow (CFS)	Sus. Res (mg/L)	Tot Hrd (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TOC (mg/L)
BUNDR000.6WE	Middle	71f	09-06-2010	7.92	66	8.79	18.26	6.02	<10	71	<0.028	0.18	1.3
CANE004.5VA	Middle	71H	08-30-2010	7.45	188.4	6.8	23.47	3.59	<10	130	<0.028	0.27	1.1
CATHE001.5MY	Middle	71h	09-22-2010	7.48	211.2	7.72	23.16	10.08	<10	160	<0.028	<0.14	0.77
CFORK003.4SR	Middle	71g	09-14-2010	7.44	256.8	8.54	20.01	4.10	<10	140	<0.028	<0.14	1.3
CHISH015.4LW	Middle	71f	09-07-2010	7.22	91	9.08	19.88	5.75	<10	86	<0.028	<0.14	0.7
COLLI025.8WA	Middle	71G	09-27-2010	7.68	347.2	6.35	20.89	16.68	<10	250	<0.028	0.23	1.6
DIXON000.4LW	Middle	71F	09-07-2010	7	159	7.37	18.14	1.83	<10	120	<0.028	<0.14	0.55
DRAKE011.8SR	Middle	71H	09-23-2010	7.74	374	5.32	21.77	1.03	<10	230	<0.028	<0.14	1.5
GREEN016.2WE	Middle	71f	09-06-2010	6.18	75	8.74	20.84	3.09	<10	81.5	<0.028	<0.14	0.034
LBART006.5DI	Middle	71f	09-21-2010	7.95	367	8.48	21.87	0.88	<10	210	<0.028	<0.14	0.83
LONG004.9MA	Middle	71g	09-14-2010	7.62	235.2	7.2	19.04	10.23	<10	140	<0.028	<0.14	1
MILLE007.3RN	Middle	71E	09-22-2010	7.89	498	8.96	16.32	0.25	<10	290	<0.028	<0.14	0.52
NFLIC002.0PE	Middle	71f	09-21-2010	6.43	54.5	6.64	21.36	2.07	<10	45	<0.028	<0.14	0.37
PRUN000.1GS	Middle	71h	09-07-2010	7.62	440	8.06	23.32	0.89	<10	150	<0.028	0.17	1.1
ROBIN000.6FR	Middle	71H	09-08-2010	7.29	256	8.61	19.13	3.78	<10	180	<0.028	0.23	1.1
SCAMP008.3SR	Middle	71H	09-13-2010	8.43	208.5	12.11	24.52	2.94	<10	190	<0.028	0.19	2.4
SCOTT000.9DA	Middle	71h	09-23-2010	7.96	490	8.17	23.32	0.21	<10	320	<0.028	<0.14	1.3
SHARP000.1WI	Middle	71f	09-22-2010	7.39	272.3	6.84	24.27	9.37	<10	270	<0.028	<0.14	0.75
SPRIN009.0WS	Middle	71i	09-13-2010	7.58	306.4	7.29	20.28	2.80	<10	160	<0.028	0.18	3.6
SULPH036.0RN	Middle	71E	09-16-2010	7.63	352.1	6.19	22.21	7.75	<10	190	<0.028	0.25	1.5
TRACE003.5CY	Middle	71G	09-09-2010	8.39	229.6	12.04	20.37	2.32	<10	150	<0.028	0.14	1.5
TUMBL003.8HU	Middle	71F	09-21-2010	7.04	226.3	7.66	20.18	18.90	<10	110	<0.028	<0.14	0.31
WATSO002.3WI	Middle	71h	09-20-2010	7.8	639.4	8.07	19.47	0.70	<10	340	<0.028	<0.14	1.6
WELLS007.6HO	Middle	71F	09-20-2010	7.74	297	8.22	22.97	3.55	<10	170	<0.028	<0.14	0.38
WFHIC007.0CE	Middle	71G	09-08-2010	7.74	368	9.21	18.48	5.73	<10	240	<0.028	<0.14	0.87
WFRED010.7MT	Middle	71e	09-21-2010	7.67	464	7.4	19.86	31.61	<10	270	<0.028	<0.14	0.89
WHITE013.5HU	Middle	71f	09-20-2010	7.42	257	6.93	21.68	9.39	<10	150	<0.028	<0.14	0.45
BEAR002.1WY	West	65e	07-06-2010	7.73	158.8	8.38	28.39	0.25	<10	140	<0.028	0.42	4.7
BIRDS012.3BN	West	65e	07-05-2010	6.93	167.25	5.065	25.54	8.32	<10	200	<0.028	<0.14	3.5
CANE001.4SH	West	74b	07-12-2010	6.86	110.1	6.12	25.9	14.55	26	380	0.077	1.1	8.6
CLOVE6.7T0.5OB	West	74B	07-08-2010	7.73	603.2	6	26	0.05	<10	280	0.036	0.29	3.3
COLD006.3LE	West	74a	07-07-2010	7.72	496	6.39	28.67	1.14	<10	310	<0.028	0.36	2.7
CROOK005.0MC	West	65e	07-15-2010	6.53	116.7	5.92	26.8	1.38	<10	<0.42	0.0395	0.39	2.9
CYPRE002.1CK	West	74b	07-06-2010	6.97	179	6	28.8	0.20	47	47	0.08	0.61	6.1
CYPRE005.9OB	West	74b	07-07-2010	6.21	143.15	6.7	22.55	0.11	<10	99	<0.028	0.22	2
CYPRE023.8MC	West	65e	07-21-2010	6.48	18.2	5.7	29.94	4.84	<10	110	<0.028	0.6	3.8

STATION ID	Division	ECO	Sample Date	pH	Cond. (uMHO)	DO (mg/L)	Temp °C	Flow (CFS)	Sus. Res (mg/L)	Tot Hrd (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TOC (mg/L)
CYPRE5.5T1.6HR	West	65B	07-22-2010	6.24	112.4	6.27	25.9	0.03	13	160	0.035	0.43	3.4
FINGE000.8CS	West	65E	07-20-2010	5.46	51.3	5.76	22.39	0.99	28	<0.42	<0.028	0.18	3.3
HALLS001.7LE	West	74b	07-08-2010	7.92	318	5.09	28.24	0.69	15	<0.42	<0.028	0.34	4.1
HAWKI002.1CR	West	65e	07-05-2010	5.39	35.9	7.23	20.77	1.83	<10	110	<0.028	<0.14	1.2
HAYES003.3HR	West	65e	07-15-2010	6.3	66.6	6.78	27.96	1.14	<10	210	0.084	0.32	4.3
HROCK002.4CR	West	65E	07-06-2010	5.76	45	6.01	18.67	0.54	<10	84	0.023	<0.14	1.25
HURRI007.4HE	West	65E	07-19-2010	6.21	86	5.57	26.85	0.10	23	440	0.055	0.68	6.7
HYDE002.7LE	West	74b	07-07-2010	7.2	268	7.68	24.96	0.22	12	120	0.19	0.48	3.9
KERR000.4HD	West	65J	07-16-2010	7.09	135.4	8.3	20.58	1.28	<10	400	<0.028	0.49	1.6
NFFDE17.9T1.8 T0.3HE	West	65e	07-22-2010	5.35	32.4	7.21	32.4	2.37	<10	<0.42	0.04	0.33	1.3
NREEL000.4OB	West	74b	07-08-2010	7.48	468.3	8.67	25.64	-0.08	<10	280	0.069	0.71	7.6
OWL003.7HD	West	65e	07-16-2010	6.64	116.6	4.52	26.92	8.65	<10	160	<0.028	0.27	2.3
POPLA014.7HY	West	74b	07-12-2010	6.09	51.5	7.52	23.08	29.21	640	350	0.38	1	9.5
ROSE001.3MC	West	65e	07-15-2010	5.97	37.2	6.87	25.74	15.56	<10	140	<0.028	0.27	2.8
SFCUB009.5DE	West	65e	07-05-2010	6.41	78	6.82	22.99	1.84	<10	370	<0.028	<0.14	3.2
SFFDE54.1T0.7MN	West	65e	07-20-2010	6.33	59.6	7.48	24.66	0.13	<10	430	<0.028	<0.14	1.3
SFMUD003.8MC	West	65E	07-19-2010	7.09	288.1	8.7	30.3	0.00	11	36	0.11	0.48	3.8
SMITH003.5HD	West	65j	07-16-2010	7.29	145.9	8.4	24.38	9.54	<10	100	<0.028	0.17	1.2
STOKE004.9CK	West	74B	07-06-2010	6.92	156	2.82	25.04	0.27	23	<0.42	0.54	1.4	6.8
TAR003.0CS	West	65E	07-21-2010	5.96	28.7	6.84	28	7.29	14	360	<0.028	0.2	1.7
THOMP000.2WY	West	65e	07-07-2010	6	38.1	7.99	17.93	12.73	<10	76	<0.028	<0.14	0.99

Table C-3: Metals Data for the Wadeable Streams Sites

Station ID	Division	ECO	Arsenic (µg/L)	Cadmium (µg/L)	Copper (µg/L)	Chromium (µg/L)	Iron (µg/L)	Lead (µg/L)	Manganese (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Zinc (µg/L)
BEAVE008.9KN	East	67f	<0.82	<0.5	1.4	<0.89	450	0.66	84	<0.38	<1.9	9.3
BFLAT018.0UN	East	67f	<0.82	<0.5	1	1.1	150	<0.51	10	<0.38	<1.9	2.2
BIRCH000.6JO	East	66e	<0.82	<0.5	<0.34	2.7	50	<0.51	5.7	<0.38	<1.9	2.8
BYRD001.5HS	East	67f	<0.82	<0.5	<0.34	<0.89	48	<0.51	7.5	<0.38	<1.9	11
CANDI017.1BR	East	67f	<0.82	<0.5	<0.34	<0.89	330	<0.51	110	<0.38	<1.9	3.4
CANDI033.1BR	East	67g	<0.82	<0.5	0.88	<0.89	180	0.61	62	<0.38	<1.9	24
CLEAR001.3GE	East	67f	<0.82	<0.5	1.3	1.3	520	1.2	93	<0.38	<1.9	7.7
CORN002.5JO	East	66f	<0.82	<0.5	0.65	<0.89	85	<0.51	12	<0.38	<1.9	3.4
COSBY012.2CO	East	66g	<0.82	<0.5	<0.34	<0.89	20	<0.51	3.9	<0.38	<1.9	2.1
COVE003.8SV	East	66g	<0.82	<0.5	<0.34	<0.89	180	<0.51	26	<0.38	<1.9	2.3
ECO67F27	East	67f	<0.82	<0.5	0.41	<0.89	68	<0.51	10	<0.38	<1.9	<1.5
EFPOP007.3RO	East	67f	<0.82	<0.5	3.1	<0.89	79	<0.51	22	0.13	<1.9	11
FALL001.5UN	East	67f	<0.82	<0.5	0.47	0.9	130	<0.51	20	<0.38	<1.9	3.9
FALL003.2HA	East	67f	<0.82	<0.5	0.67	1.4	660	0.95	59	<0.38	<1.9	5.8
GAMMO000.7SU	East	67f	1	<0.5	0.6	<0.89	250	0.63	49	<0.38	<1.9	5.5
GAP000.1CT	East	67f	<0.82	<0.5	0.285	1.72	26.5	<0.51	8.95	<0.38	<1.9	2.9
GRASS005.1GE	East	67f	1.9	<0.5	0.49	<0.89	150	<0.51	34	<0.38	<1.9	3.5
HICKO008.4CA	East	69e	<0.82	<0.5	0.59	<0.89	250	<0.51	57	<0.38	<1.9	2.7
HORSE007.0GE	East	66f	<0.82	<0.5	0.45	2.9	160	<0.51	18	<0.38	<1.9	3.7
LAURE006.3JO	East	66e	<0.82	<0.5	0.48	2.9	300	<0.51	30	<0.38	<1.9	5.1
MIDDL001.2SV	East	67g	<0.82	<0.5	5.2	0.45	110	<0.51	41	<0.38	<1.9	9.8
OTOWN008.9CL	East	69e	1.7	<0.5	0.83	<0.89	1000	<0.51	170	<0.38	<1.9	4.3
POPLA000.1MG	East	69d	<0.82	<0.5	1.4	<0.89	270	<0.51	29.5	<0.38	<1.9	6.1
RIPLE001.5GE	East	67f	1.2	<0.5	0.48	<0.89	210	<0.51	33	<0.38	<1.9	48
SEQUA101.2BL	East	68b	<0.82	<0.5	<0.34	<0.89	200	<0.51	57	<0.38	<1.9	<1.5
SINKI003.0CO	East	67g	<0.82	<0.5	0.37	<0.89	72	<0.51	14	<0.38	<1.9	38
SIXMI006.6BT	East	67i	<0.82	<0.5	<0.34	0.89	230	<0.51	51	<0.38	<1.9	<1.5
TELLI040.5MO	East	66g	<0.82	<0.5	<0.34	0.91	59	<0.51	6.4	<0.38	<1.9	11
TITUS1T0.1CA	East	69e	0.97	<0.5	4.4	4.2	7300	4.4	300	<0.38	<1.9	23
TOWEE005.9PO	East	66g	<0.82	<0.5	0.455	0.82	820	0.3825	265	<0.38	<1.9	2.425
BEAGL008.3OV	Middle	71g	<0.82	<0.5	<0.34	<0.89	25	<0.51	4.6	<0.38	<1.9	<1.5
BRUSH001.1LS	Middle	71f	<0.82	<0.5	<0.34	0.9	7.1	<0.51	3.5	<0.38	<1.9	<1.5
BSPRI003.9CH	Middle	71f	<0.82	<0.5	<0.34	<0.89	49	<0.51	11	<0.38	<1.9	<1.5

Station ID	Division	ECO	Arsenic (µg/L)	Cadmium (µg/L)	Copper (µg/L)	Chromium (µg/L)	Iron (µg/L)	Lead (µg/L)	Manganese (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Zinc (µg/L)
BUNDR000.6WE	Middle	71f	<0.82	<0.5	<0.34	<0.89	29	<0.51	1	<0.38	<1.9	<1.5
CANE004.5VA	Middle	71h	<0.82	<0.5	<0.34	<0.89	60	<0.51	42	<0.38	<1.9	1.7
CATHE001.5MY	Middle	71h	<0.82	<0.5	<0.34	<0.89	61	<0.51	23	<0.38	<1.9	<1.5
CFORK003.4SR	Middle	71g	<0.82	<0.5	0.34	<0.89	17	<0.51	4.9	<0.38	<1.9	<1.5
CHISH015.4LW	Middle	71f	<0.82	<0.5	<0.34	<0.89	35	<0.51	10	<0.38	<1.9	<1.5
COLLI025.8WA	Middle	71g	<0.82	<0.5	<0.34	<0.89	63	<0.51	100	<0.38	<1.9	<1.5
DIXON000.4LW	Middle	71f	<0.82	<0.5	<0.34	<0.89	7.6	<0.51	1.2	<0.38	<1.9	<1.5
DRAKE011.8SR	Middle	71h	<0.82	<0.5	<0.34	<0.89	46	<0.51	32	<0.38	<1.9	<1.5
GREEN016.2WE	Middle	71f	<0.82	<0.5	<0.34	<0.89	6.85	<0.51	4.1	<0.38	<1.9	<1.5
LBART006.5DI	Middle	71f	<0.82	<0.5	<0.34	<0.89	51	<0.51	18	<0.38	<1.9	<1.5
LONG004.9MA	Middle	71g	<0.82	<0.5	<0.34	<0.89	9.6	<0.51	5	<0.38	<1.9	<1.5
MILLE007.3RN	Middle	71e	<0.82	<0.5	<0.34	<0.89	28	<0.51	6.9	<0.38	<1.9	9.6
NFLIC002.0PE	Middle	71f	<0.82	<0.5	<0.34	<0.89	8.8	<0.51	0.74	<0.38	<1.9	<1.5
PRUN000.1GS	Middle	71h	<0.82	<0.5	<0.34	<0.89	31	<0.51	11	<0.38	<1.9	<1.5
ROBIN000.6FR	Middle	71h	<0.82	<0.5	<0.34	<0.89	48	<0.51	42	<0.38	<1.9	<1.5
SCAMP008.3SR	Middle	71h	<0.82	<0.5	0.64	<0.89	79	<0.51	17	<0.38	<1.9	<1.5
SCOTT000.9DA	Middle	71h	<0.82	<0.5	<0.34	<0.89	220	<0.51	35	<0.38	<1.9	<1.5
SHARP000.1WI	Middle	71f	<0.82	<0.5	<0.34	<0.89	32	<0.51	18	<0.38	<1.9	<1.5
SPRIN009.0WS	Middle	71i	<0.82	<0.5	0.34	<0.89	70	<0.51	21	<0.38	<1.9	<1.5
SULPH036.0RN	Middle	71e	<0.82	<0.5	<0.34	<0.89	110	<0.51	47	<0.38	<1.9	<1.5
TRACE003.5CY	Middle	71g	<0.82	<0.5	<0.34	<0.89	5.9	<0.51	2	<0.38	<1.9	<1.5
TUMBL003.8HU	Middle	71f	<0.82	<0.5	<0.34	<0.89	21	<0.51	8.6	<0.38	<1.9	2
WATSO002.3WI	Middle	71h	<0.82	<0.5	0.845	<0.89	52	<0.51	24.5	<0.38	<1.9	<1.5
WELLS007.6HO	Middle	71f	<0.82	<0.5	<0.34	<0.89	9.5	<0.51	5.2	<0.38	<1.9	<1.5
WFHIC007.0CE	Middle	71g	<0.82	<0.5	<0.34	<0.89	31	<0.51	18	<0.38	<1.9	<1.5
WFRED010.7MT	Middle	71e	<0.82	<0.5	<0.34	<0.89	98	<0.51	19	<0.38	<1.9	1.8
WHITE013.5HU	Middle	71f	<0.82	<0.5	<0.34	<0.89	32	<0.51	15.7	<0.38	<1.9	<1.5
BEAR002.1WY	West	65e	1.3	<0.5	1.3	<0.89	570	<0.51	130	<0.38	<1.9	3.2
BIRDS012.3BN	West	65e	1.1	<0.5	0.51	<0.89	1700	<0.51	260	<0.38	<1.9	2.5
CANE001.4SH	West	74b	4.8	<0.5	6.1	1.3	2000	5.4	99	<0.38	<1.9	27
CLOVE6.7T0.5OB	West	74b	5.1	<0.5	1.1	<0.89	270	<0.51	350	<0.38	<1.9	14
COLD006.3LE	West	74a	2.7	<0.5	0.76	<0.89	470	<0.51	120	<0.38	<1.9	<1.5
CROOK005.0MC	West	65e	<0.82	<0.5	0.42	<0.89	695	<0.51	980	<0.38	<1.9	<1.5
CYPRE002.1CK	West	74b	4.9	<0.5	1.8	<0.89	2700	1.2	1200	<0.38	<1.9	3.2
CYPRE005.9OB	West	74b	1.1	<0.5	0.92	<0.89	650	<0.51	120	<0.38	<1.9	5.9
CYPRE023.8MC	West	65e	0.64	<0.5	0.26	1.3	765	<0.51	495	<0.38	<1.9	14.4

Station ID	Division	ECO	Arsenic (µg/L)	Cadmium (µg/L)	Copper (µg/L)	Chromium (µg/L)	Iron (µg/L)	Lead (µg/L)	Manganese (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Zinc (µg/L)
CYPRE5.5T1.6HR	West	65b	0.88	<0.5	0.54	<0.89	980	<0.51	260	<0.38	<1.9	<1.5
FINGE000.8CS	West	65e	<0.82	<0.5	0.71	1.7	1600	0.69	560	<0.38	<1.9	2.1
HALLS001.7LE	West	74b	5.1	<0.5	1.8	<0.89	740	0.56	540	<0.38	<1.9	3.6
HAWKI002.1CR	West	65e	<0.82	<0.5	0.55	<0.89	1100	<0.51	160	<0.38	<1.9	20
HAYES003.3HR	West	65e	1.2	<0.5	1.1	<0.89	1300	<0.51	150	<0.38	<1.9	1.5
HROCK002.4CR	West	65e	<0.82	<0.5	0.445	<0.89	830	<0.51	260	<0.38	<1.9	1.9
HURRI007.4HE	West	65e	0.95	<0.5	1.3	0.98	660	0.93	120	<0.38	<1.9	47
HYDE002.7LE	West	74b	5.2	<0.5	1.5	<0.89	1200	0.87	670	<0.38	<1.9	2.9
KERR000.4HD	West	65j	<0.82	<0.5	<0.34	<0.89	250	<0.51	34	<0.38	<1.9	<1.5
NFFDE17.9T1.8T0.3HE	West	65e	0.93	<0.5	0.4	<0.89	1400	<0.51	340	<0.38	<1.9	<1.5
NREEL000.4OB	West	74b	4.5	<0.5	2.3	<0.89	140	<0.51	150	<0.38	<1.9	1.9
OWL003.7HD	West	65e	1.5	<0.5	0.43	<0.89	950	<0.51	150	<0.38	<1.9	<1.5
POPLA014.7HY	West	74b	<0.82	<0.5	5.9	1.4	720	6.2	960	<0.38	<1.9	6.8
ROSE001.3MC	West	65e	1.1	<0.5	0.46	<0.89	1400	<0.51	160	<0.38	<1.9	<1.5
SFCUB009.5DE	West	65e	1.1	<0.5	0.64	<0.89	1700	<0.51	140	<0.38	<1.9	2.5
SFFDE54.1T0.7MN	West	65e	<0.82	<0.5	0.55	1.8	410	<0.51	60	<0.38	<1.9	5.4
SFMUD003.8MC	West	65e	2.4	<0.5	0.48	<0.89	320	<0.51	340	<0.38	<1.9	1.7
SMITH003.5HD	West	65j	<0.82	<0.5	<0.34	<0.89	27	<0.51	21	<0.38	<1.9	<1.5
STOKE004.9CK	West	74b	8.2	<0.5	4.3	2.2	4200	3.8	850	<0.38	<1.9	19
TAR003.0CS	West	65e	<0.82	<0.5	0.44	1.5	1700	<0.51	270	<0.38	<1.9	<1.5
THOMP000.2WY	West	65e	<0.82	<0.5	<0.34	<0.89	220	<0.51	45	<0.38	<1.9	<1.5