The Importance of Headwater Wetlands and Water Quality in North Carolina

North Carolina Department of Environment and Natural Resources

Division of Water Quality

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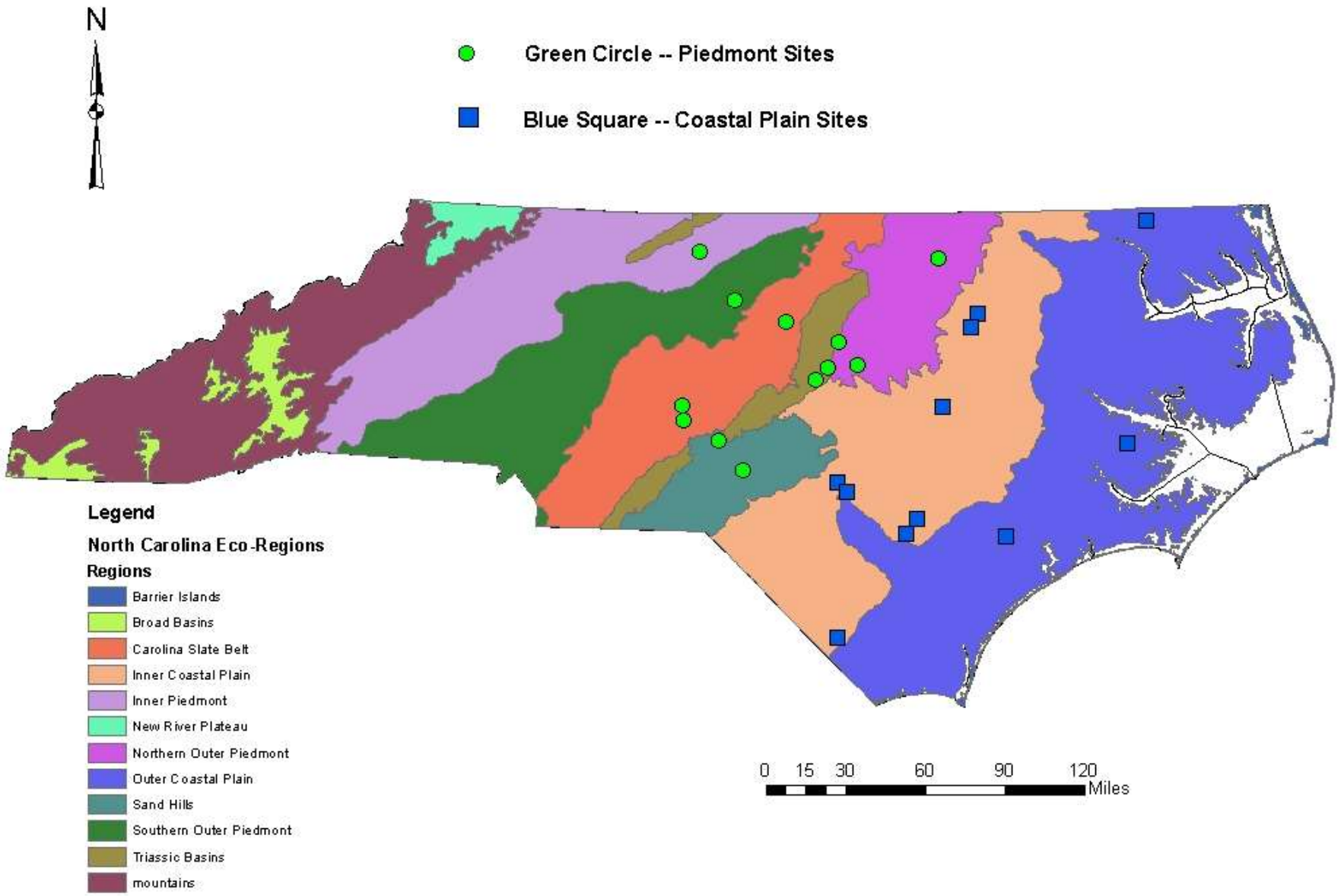
Headwater Wetlands

- Definition – Typically small bowl-shaped wetlands that grade into 1st order streams.
- Location - Upper reaches of watersheds in the Coastal Plain, Piedmont, and Mountain regions of NC.
- Importance – Protects downstream aquatic resources by acting as a natural filtering system for water quality.

Study Objectives

1. To determine whether headwater wetlands with more developed watersheds have lower water quality than wetlands with more natural watersheds.
2. To determine whether headwater wetlands have the capacity to affect pollutant levels by comparing upstream to downstream water quality results.

Headwater Wetland Monitoring Sites



Headwater Wetland Sites

Spring Garden

Kelly Road

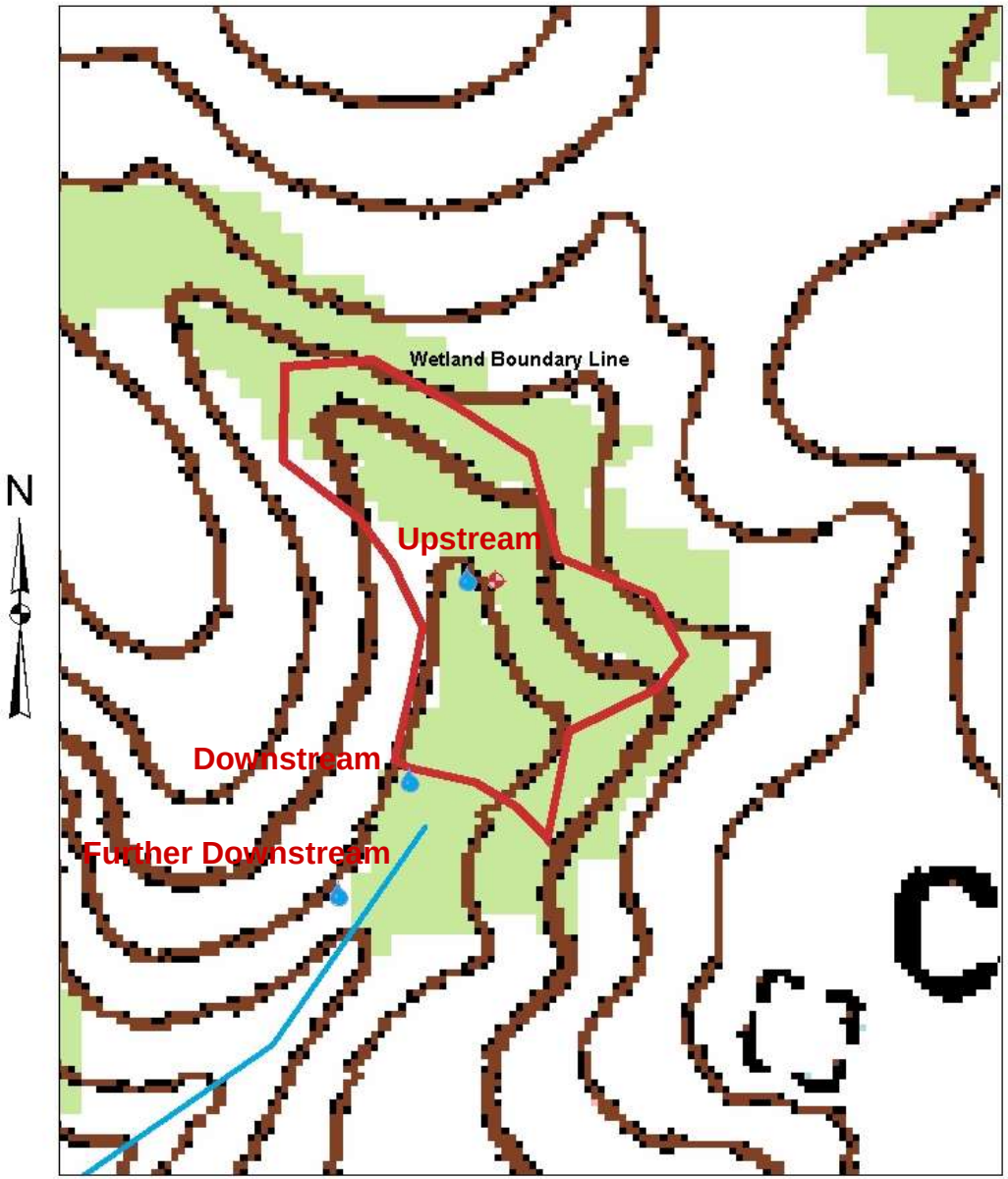
Nahunta

Batchelor

Water Quality Sampling Methods

- Six Quarterly water quality sampling times (2005-2006) at Upstream, Downstream, and Further Downstream stations
- Physical parameters – Temperature, DO, Specific Conductivity, pH, TSS, Turbidity
- Chemical parameters – Nutrients (Nitrate + Nitrite, TKN, Phosphorous, Ammonia), Heavy Metals (Ca, Mg, Zn, Cu, Pb), DOC, TOC, Fecal Coliform
- Samples obtained by direct grab (surface water only) or by digging (soil pore water).
- Separate Analysis for “All data” (surface and soil pore) and “no dug data” (surface water only).

Hog Farm Upper



Legend

- Water Quality Sample Stations
- Well Location

0 65 130 260 390 520 Feet

Quarterly Water Sample Stations at Rough Rider

April 2005

July 2005

October 2005

January 2006

Objective 1-Watershed Affect on Headwater Wetland Water Quality

Analysis Method

- Watershed Condition was determined by calculating the Land-Use Index (LUI, Brown and Vivas, 2003) score for each site's watershed and one-mile buffer.

- Land-Use Index (LUI) - Summarized disturbance score for Land Cover Types in a given area were determined for wetland site watersheds.

- Correlation Analysis was run for each site's LUI score against each site's 19 different water quality parameter results.

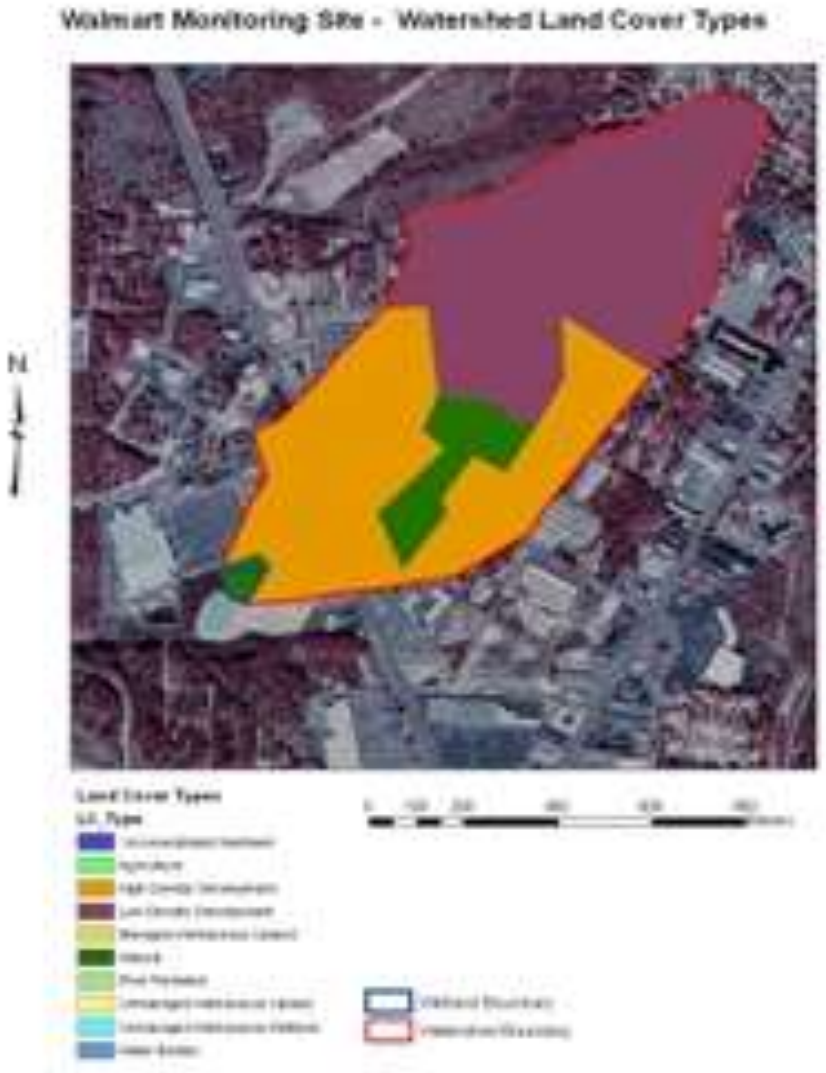
Objective 1-Watershed Affect on Headwater Wetland Water Quality

$$\mathbf{LUI_{Total} = \sum \%Lu\mathit{i} * LUI\mathit{i}}$$

- LUI_{Total} = LUI Ranking for landscape unit ***i***
- $\%Lu_i$= percent of the total area of influence in the land use ***i***
- land use i LUI_I=landscape development intensity coefficient for land use

Headwater Wetland Landcover Type and LUI Coefficient Values

Land Cover Type	*LUI Coefficient (*LUI_I)
Natural Areas	1
Water Bodies	1
Unmanaged Herbaceous Upland	2
Unmanaged Herbaceous Wetland	2
Managed Herbaceous Wetland	2
Cultivated	4
Unconsolidated Sediment	4
Low Intensity Development	5
High Intensity Development	8



Objective 1-To Determine the Watershed affect on Headwater Wetland Water Quality

Results

- Significant correlation between Watershed LUI scores and magnesium, Nitrite + Nitrate, and Fecal Caliform (p-value<0.05) for all water quality samples (surface and pore water) and surface water quality samples.

Conclusion

- There is a direct correlation between the headwater wetland water quality and the condition of the surrounding watershed.

Objective 1 – ORAM

Analysis Method

- Ohio Rapid Assessment Method (ORAM v. 5.0, Ohio EPA 2001) was used to calculate a disturbance score for each site. ORAM assesses a site's size, 50m-buffer condition, hydrology, habitat, and plant community quality and interspersion, and microtopography.
- Correlation Analysis was run for each site's ORAM score against each site's 19 different water quality parameter results.

Results

- Significant correlation ($p<0.05$) between ORAM scores and calcium, magnesium, N+N, Special Conductivity, and Zinc for all water quality samples (surface and pore water and surface only).
- Significant correlation ($p<0.05$) between ORAM scores and ammonia, fecal coliform, and zinc for surface water quality samples only.

Objective 2-
Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

- Water Quality Sampling Stations
  - UP - Upstream
  - DN - Downstream (located 200 feet down stream from Upstream water quality station)
  - FD - Further Downstream - (located another 200 feet down stream from Downstream water quality station, 5 sites in Coastal Plain only, sampled last 2 quarters)
- Water Quality Station Comparisons
  - UP-DN – Upstream compared to Downstream
  - UP-FD – Upstream compared to Further Downstream
  - DN-FD – Downstream compared to Further Downstream

Objective 2-

Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

Methods Analysis

Coastal Plain and Piedmont Regional Station Comparison Analysis of Water Quality Parameters was completed for all data (surface and pore) and surface water data only.

- Overall regional comparisons of UP-DN, UP-FD, and DN-FD water quality parameter station means.
- ANOVA and Rank Sums test for the UP, DN, and FD water quality parameters results was run for each region to determine if there is a significant difference between stations.
- For Significant results in the Coastal Plain, the Tukey Kramer Multiple Comparison test was used to determine which station comparison (UP-DN, UP-FD, DN-FD) were significantly different.

Coastal Plain Station Summary Results - All Water Quality Results

Parameter	Coastal Plain Parameter Means			Coastal Plain Parameter Improvement						
	Upstream (UP)	Downstream (DN)	Further Downstream (FD)	Upstream to Downstream Difference	**Upstream to Downstream Improvement**	Upstream to Further Downstream Difference	**Upstream to Further Downstream Improvement**	Downstream to Further Downstream Difference	**Downstream to Further Downstream Improvement**	**ANOVA / Kruskal Wallis Tests and p-values**
Ammonia mg/L	0.12	0.12	0.04	0.01	No improvement	0.09	improvement	0.08	improvement	UP>DN,FN
Calcium mg/L	9.65	7.54	4.3	2.11	improvement	5.35	improvement	3.24	improvement	
Copper ug/L	15.57	16.25	3.22	-0.68	no improvement	12.35	improvement	13.02	improvement	DN>FD
Dissolved Oxygen (%)	21.74	25.76	36.3	-4.03	improvement	-14.56	improvement	-10.54	improvement	UP<FD
Dissolved Oxygen (mg/L)	2.11	2.68	3.13	-0.57	improvement	-1.02	improvement	-0.44	improvement	UP<DN
DOC mg/L	16.71	13.42	11	3.29	improvement	5.71	improvement	2.42	improvement	
Fecal Coliform cfu/100 ml	1721.41	989.33	15071.5	732.09	improvement	-13350.1	no improvement	-14082.2	no improvement	UP-FD ANOVA Sig No Imp P=0.0380 , RS Sig No Imp P=0.0606
Lead ug/L	44.93	55.29	15.78	-10.36	no improvement	29.15	improvement	39.52	improvement	
Magnesium mg/L	4.53	3.75	2.53	0.78	improvement	2	improvement	1.22	improvement	
NO_2+NO_3 mg/L	2.5	2.79	2.24	-0.29	no improvement	0.26	improvement	0.55	improvement	
Phosphorus mg/L	0.54	0.65	0.24	-0.11	no improvement	0.3	improvement	0.41	improvement	
Specific Conductivity	119.25	121.97	94.74	-2.72	no improvement	24.5	improvement	27.22	improvement	DN>FD
Total Kjeldahl (TKN) mg/L	10.19	4.63	1	5.55	improvement	9.19	improvement	3.63	improvement	UP>FD
TOC mg/L	171.15	126.29	26.64	44.87	improvement	144.51	improvement	99.64	improvement	
TSS mg/L	200.02	202.93	44.93	-2.92	no improvement	155.09	improvement	158.01	improvement	UP>FD
Turbidity NTU	41.91	46.01	.	-4.1	no improvement	.		.		
Water, Temperature C°	17.16	16.53	19.44	0.64	improvement	-2.28	no improvement	-2.92	no improvement	
Zinc mg/L	49.87	60.12	15	-10.25	no improvement	34.87	improvement	45.12	improvement	DN>FD
pH S.U.	4.68	4.84	4.95	-0.16	improvement	-0.26	improvement	-0.11	improvement	

RS=Ranks sums Kruskal-Wallis or Wilcoxon

Water Quality All Data Results Coastal Plain	**UP - DN Mean**	**UP-DN Median**	**UP-FD Mean**	**UP-FD Median**	**DN-FD Mean**	**DN-FD Median**
Improvement	10	8	16	13	16	13
No Improvement	9	11	2	5	2	5

Coastal Plain Station Summary Results - No Dig

	Coastal Plain Parameter Means			Coastal Plain Parameter Improvement						
Parameter	Upstream (UP)	Downstream (DN)	Further Downstream (FD)	Upstream to Downstream Difference	**Upstream to Downstream Improvement**	Upstream to Further Downstream Difference	**Upstream to Further Downstream Improvement**	Downstream to Further Downstream Difference	**Downstream to Further Downstream Improvement**	**ANOVA / Kruskal Wallis Tests and p-values**
Ammonia mg/L	0.07	0.07	0.03	0	no improvement	0.04	improvement	0.04	improvement	UP.FD
Calcium mg/L	6.61	7.45	4.18	-0.84	no improvement	2.44	improvement	3.28	improvement	
Copper ug/L	3.97	5.48	2	-1.51	no improvement	1.97	improvement	3.48	improvement	DN-FD,
Dissolved Oxygen (%)	25.15	28.74	38.41	-3.59	improvement	-13.27	improvement	-9.68	improvement	
Dissolved Oxygen (mg/L)	2.45	3.01	3.31	-0.57	improvement	-0.87	improvement	-0.3	improvement	
DOC mg/L	17.06	12.74	11	4.32	improvement	6. 06	improvement	1.74	improvement	
Fecal Coliform cfu/100 ml	722.1	1010.81	1510.29	-288.71	no improvement	-788.19	no improvement	-499.48	no improvement	UP-FD
Lead ug/L	12.73	19.95	10	-7.22	no improvement	2.73	improvement	9.95	improvement	
Magnesium mg/L	3.92	3.97	2.7	-0.05	no improvement	1.22	improvement	1.28	improvement	
NO_2+NO_3 mg/L	3.05	3.39	2.52	-0.35	no improvement	0.53	improvement	0.88	improvement	
Phosphorus mg/L	0.23	0.41	0.16	-0.18	no improvement	0.07	improvement	0.25	improvement	
Specific Conductivity	120.02	128.69	100.71	-8.67	no improvement	19.31	improvement	27.98	improvement	
Total Kjeldahl (TKN) mg/L	1.52	2.96	0.93	-1.44	no improvement	0.59	improvement	2.03	improvement	DN>FD
TOC mg/L	26.21	42.81	17.98	-16.61	no improvement	8.23	improvement	24.84	improvement	
TSS mg/L	114.6	170.4	37.34	-55.79	no improvement	77.26	improvement	133.05	improvement	DN>FD
Turbidity NTU	41.91	46.01	.	-4.1	no improvement	.		.		
Water, Temperature C°	16.23	16.08	18.88	0.15	no improvement	-2.64	no improvement	-2.8	no improvement	
Zinc mg/L	23.01	29.17	12.63	-6.15	no improvement	10.39	improvement	16.54	improvement	DN>FD
pH S.U.	4.73	4.99	4.91	-0.25	improvement	-0.17	improvement	0.08	no improvement	

RS = Ranks Sum Kruskal Wallis or Wilcoxon

Water Quality All Data Results Coastal Plain	UP - DN Mean	UP-DN Median	UP-FD Mean	UP-FD Median	DN-FD Mean	DN-FD Median
Improvement	4	3	16	13	15	11
No Improvement	15	16	2	5	3	7

Piedmont Summary Results All data and no dig data

	All Data					No Dig Data				
	Piedmont Means		Piedmont Improvement			Piedmont Means		Piedmont Improvement		
Parameter	Upstream (UP)	Downstream (DN)	Upstream to Downstream Difference	**Upstream to Downstream Improvement**	**ANOVA / Wilcoxon**	Upstream (UP)	Downstream (DN)	Upstream to Downstream Difference	**Upstream to Downstream Improvement**	**ANOVA / Wilcoxon**
Ammonia mg/L	0.1	0.08	0.01	improvement		0.06	0.07	-0.01	no improvement	
Calcium mg/L	5.16	6.17	-1.01	no improvement		3.12	3.73	-0.61	improvement	
Copper ug/L	22.11	19.34	2.77	improvement	WC – Sig Imp P = 0.0043	4.43	4.35	0.08	no improvement	
Dissolved Oxygen (%)	33.39	41.51	-8.13	improvement	ANOVA Sig Imp P = 0.0544, WC Sig Imp P = 0.0270	37.59	43.88	-6.29	improvement	
Dissolved Oxygen (mg/L)	3.18	4.09	-0.91	improvement	ANOVA Sig Imp P = 0.0225, WC Sig Imp P=0.0232	3.52	4.32	-0.8	improvement	ANOVA Sig Imp P= 0.0715, WC Sig Imp P=0.0851
DOC mg/L	7.99	7.5	0.49	improvement		7.85	7.59	0.25	no improvement	
Fecal Coliform cfu/100 ml	1705.33	1367.18	338.16	improvement		1028.74	277.07	751.68	improvement	
Lead ug/L	34.67	60.95	-26.27	no improvement	WC Sig No Imp P=0.0242	17.04	17.25	-0.21	no improvement	
Magnesium mg/L	2.66	2.79	-0.13	no improvement		1.29	1.59	-0.3	no improvement	
NO_2+NO_3 mg/L	0.04	0.04	0	no improvement		0.04	0.04	0	no improvement	
Phosphorus mg/L	0.41	0.29	0.11	improvement	WC Sig Imp P = 0.0055	0.15	0.17	-0.01	no improvement	
Specific Conductivity	49.98	56.89	-6.9	no improvement		52.64	57.55	-4.91	no improvement	
Total Kjeldahl (TKN) mg/L	3.1	2.03	1.07	improvement	WC Sig Imp P = 0.0010	1.12	0.75	0.38	improvement	ANOVA Sig Imp P= 0.0824, WC Sig Imp P=0.0361
TOC mg/L	40.77	37.16	3.61	improvement	WC Sig Imp P = 0.0188	18.36	16.2	2.16	improvement	
TSS mg/L	396.3	168.58	227.72	improvement	ANOVA Sig Imp P=0.0918	155.25	170.31	-15.06	no improvement	
Turbidity NTU	114.82	67.85	46.97	improvement	ANOVA – Not, WC Sig Imp P = 0.0962	110.89	72.84	38.05	improvement	ANOVA & WC Sig Imp P=0.0870
Water, Temperature C°	17.58	17.08	0.5	improvement		17.64	16.8	0.84	improvement	
Zinc mg/L	91.39	61.44	29.95	improvement	WC - Sig Imp P = 0.0195	20.72	22.15	-1.43	no improvement	
PH S.U.	5.38	5.48	-0.1	improvement		5.34	5.44	-0.1	improvement	

WC=Wilcoxon

Water Quality All Data Results Piedmont	UP - DN Mean	UP-DN Median		**Water Quality No Dig Data Results Piedmont**	UP – DN Mean	UP-DN Median
Improvement	14	13		**Improvement**	9	9
No Improvement	5	6		**No Improvement**	10	10

Objective 2-
Water Quality Station Comparisons to Determine Headwater Wetland Filtering Capacity

Methods Analysis

Site Station Comparison Analysis of Water Quality Parameters was completed for all data (surface and pore) and surface water data only.

- Site Station comparisons of UP-DN, UP-FD, and DN-FD water quality parameter station means.
- The total number of mean station comparisons (UP-DN, UP-FD, and DN-FD) that showed “improvement” or “no improvement” for each parameter within each site was determined. A Chi-Square test was performed to determine if the number of site comparisons that “improved” was significantly different then the number of site comparisons that had “no improvement”.

Regional Sample Station Location Comparison by Site of Water Quality Parameter Means

All Water Quality Results

Station Comparisons	Piedmont	Coastal Plain			
	UP-DN	UP-DN	UP-FD	DN-FD	Total Stations
Improvement	130	117	73	66	**386**
No Improvement	94	88	17	24	**223**
Total Stations	224	205	90	90	**609**
Chi Square Results	**P=0.016**	**P=0.04**	**P<0.0001**	**P<0.0001**	

Surface Water Quality Results

Station Comparisons	Piedmont	Coastal Plain			
	UP-DN	UP-DN	UP-FD	DN-FD	Total Stations
Improvement	104	104	55	66	**329**
No Improvement	91	101	35	24	**251**
Total Stations	195	205	90	90	**580**
Chi Square Results			**P=0.03**	**P<0.0001**	

Blue - Water Quality **Improved**

Red - Water Quality showed **No Improvement** (stayed the same or became worse)

Parameter Station Comparisons for Individual Sites

Site Name	Parameter	Wilcoxon / Kruskal-Wallis P-Value	Significant Station Comparison
Batchelor	Specific Conductivity	0.009	**UP-DN**
Battle Park	Ammonia	0.0833	**UP-DN**
Battle Park	Dissolved Oxygen (%)	0.0833	**UP-DN**
Battle Park	Dissolved Oxygen (mg/L)	0.0833	**UP-DN**
Black Ankle Powerline	Dissolved Oxygen (%)	0.0495	**UP-DN**
Black Ankle Powerline	Dissolved Oxygen (mg/L)	0.0495	**UP-DN**
Boddie Noell	Dissolved Oxygen (%)	0.0641	**UP-DN**
Boddie Noell	Dissolved Oxygen (mg/L)	0.0641	**UP-DN**
Boddie Noell	Lead	0.0491	**UP-DN**
Boddie Noell	Zinc	0.0603	**UP-DN**
Cox	TKN	0.0642	UP-DN & **DN-FD**
Duke Forest	TKN	0.0833	**UP-DN**
East Fayetteville North	Copper	0.0979	UP-DN & **DN-FD**
East Fayetteville North	pH	0.0995	**UP-DN**
East Fayetteville North	Specific Conductivity	0.0244	**DN-FD**
East Fayetteville South	Magnesium	0.0635	**UP-DN**
East Fayetteville South	pH	0.0861	**UP-DN**
East of Mason	Fecal Coliform	0.0339	UP-DN
Fire Tower	Calcium	0.0731	**UP-DN**
Fire Tower	Copper	0.0021	**UP-DN**
Fire Tower	Dissolved Oxygen (%)	0.0027	**UP-DN**
Fire Tower	Dissolved Oxygen (mg/L)	0.0027	**UP-DN**
Fire Tower	Lead	0.0074	**UP-DN**
Fire Tower	Magnesium	0.0758	**UP-DN**
Fire Tower	pH	0.0026	**UP-DN**
Fire Tower	Phosphorus	0.0037	**UP-DN**
Fire Tower	TKN	0.0065	**UP-DN**
Fire Tower	TOC	0.0039	**UP-DN**
Fire Tower	Total Suspended Residue	0.0603	**UP-DN**
Fire Tower	Zinc	0.0401	**UP-DN**

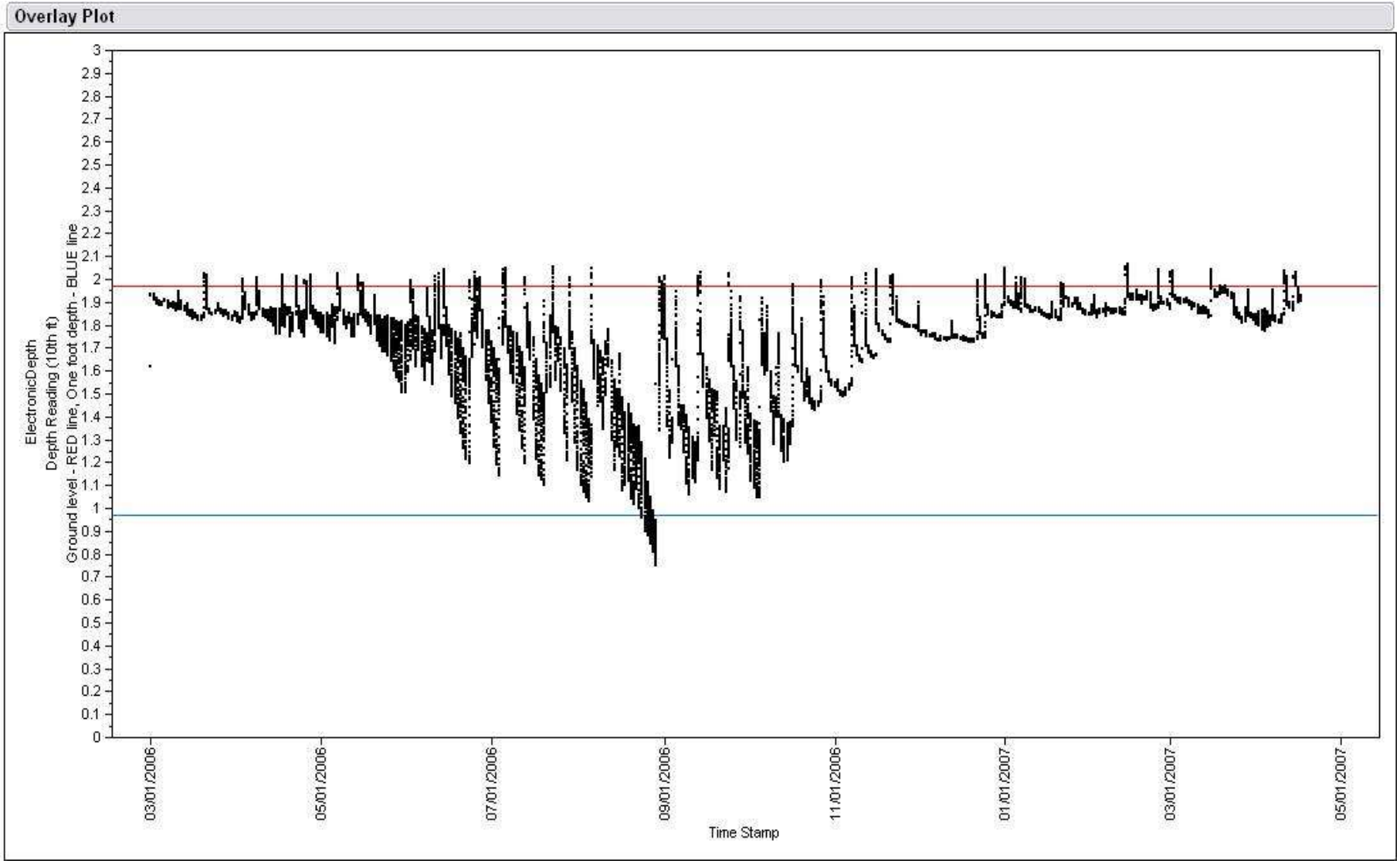
Hog Farm Lower	DOC	0.0641	UP-DN
Hog Farm Lower	Phosphorus	0.0679	UP-DN
Hog Farm Lower	Specific Conductivity	0.0176	UP-DN
Hog Farm Lower	TKN	0.0174	UP-DN
Hog Farm Lower	TOC	0.0176	UP-DN
Hog Farm Upper	Dissolved Oxygen (%)	0.0041	**UP-FD**
Hog Farm Upper	Dissolved Oxygen (mg/L)	0.0099	**UP-FD**
Hog Farm Upper	Magnesium	0.0802	**UP-FD**
Hog Farm Upper	Phosphorus	0.0266	**UP-FD**
Hog Farm Upper	TKN	0.0873	**UP-DN**
Hog Farm Upper	TOC	0.0069	**UP-FD**
Nahunta	Zinc	0.0459	**UP-DN**
PCS	Ammonia	0.0289	**DN-FD**
PCS	Copper	0.0871	**DN-FD**
PCS	Lead	0.0477	**DN-FD**
PCS	TKN	0.0414	**DN-FD**
PCS	TOC	0.049	**DN-FD**
PCS	Zinc	0.0287	**DN-FD**
Pete Harris	Calcium	0.0833	UP-DN
Pete Harris	Magnesium	0.0833	UP-DN
Spring Garden	DOC	0.0833	UP-DN
Umstead	Water, Temperature	0.0209	**UP-DN**
Walmart	Ammonia	0.0086	**UP-DN**
Walmart	Calcium	0.0143	**UP-DN**
Walmart	Copper	0.0027	**UP-DN**
Walmart	Dissolved Oxygen (%)	0.05	**UP-DN**
Walmart	Lead	0.0028	**UP-DN**
Walmart	Magnesium	0.0143	**UP-DN**
Walmart	Phosphorus	0.0082	**UP-DN**
Walmart	Specific Conductivity	0.0176	**UP-DN**
Walmart	TKN	0.0088	**UP-DN**
Walmart	TOC	0.0061	**UP-DN**
Walmart	Zinc	0.0041	**UP-DN**

Bold Blue = Improvement and Red = No Improvement

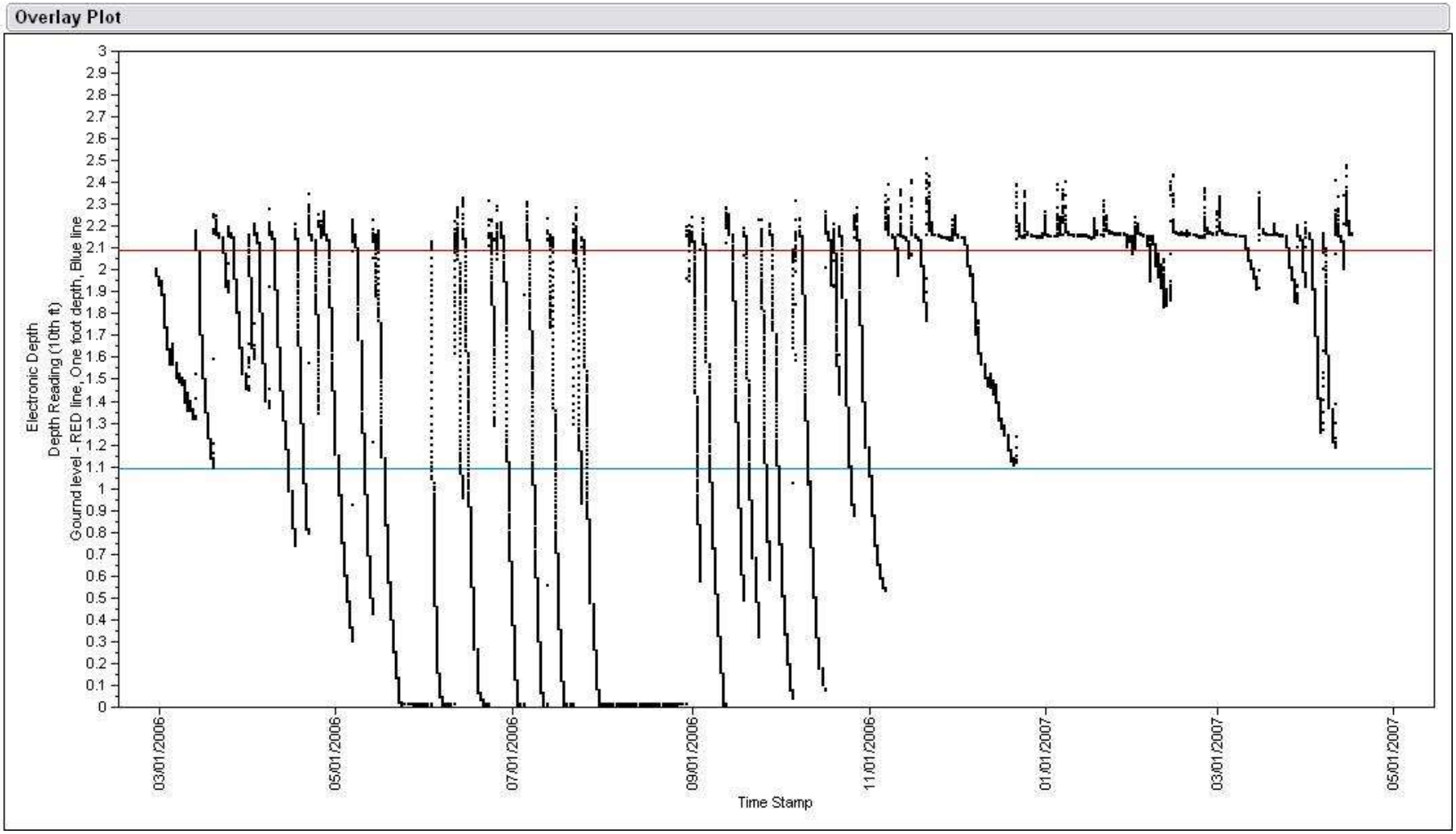
Individual Site Analysis

- 21 of 23 sites showed statistically significant improvement on at least one water quality measure.
- 10 of 23 sites showed statistically significant improvement on at two or more water quality measure.
- Only 2 sites had statistically significant results showing water quality measures degrading

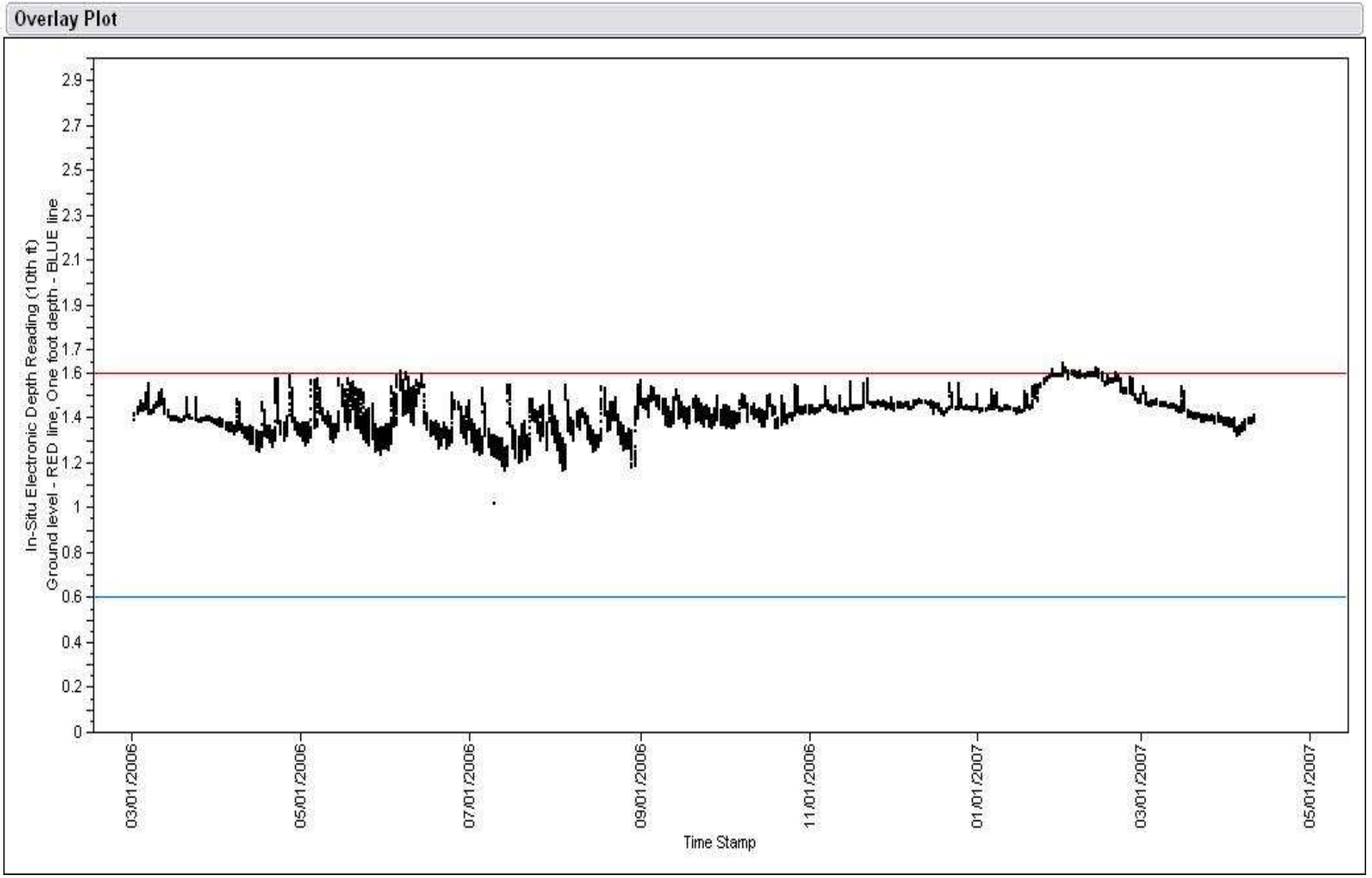
Spring Garden – Piedmont, Natural



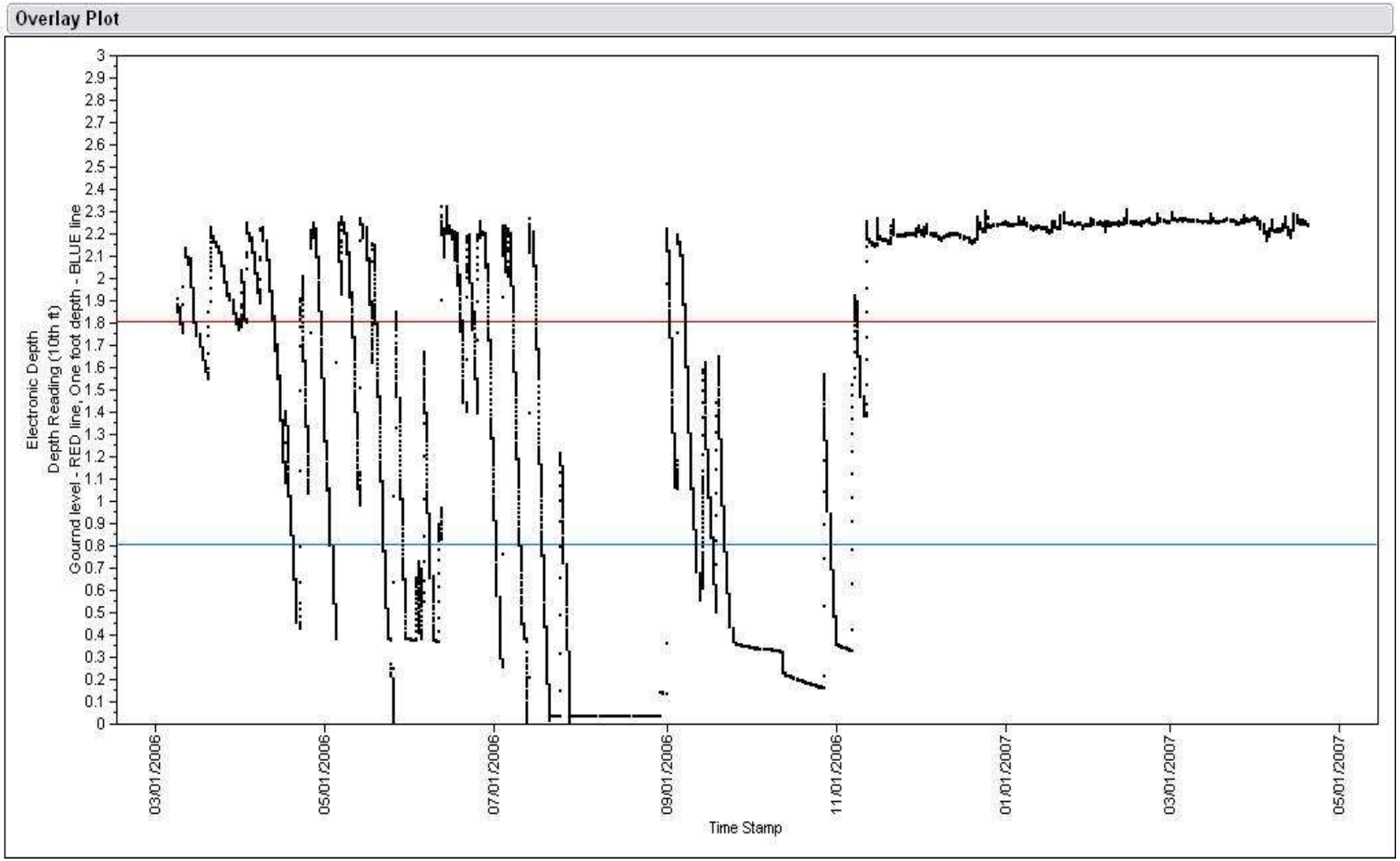
Troxler – Piedmont, Urban



Hog Farm Upper – Coastal Plain, Rural



Boddie Noell – Coastal Plain, Urban



Final Conclusions

- There is a direct correlation between the headwater wetland water quality and the condition of the surrounding watershed.
- Headwater wetlands affectively reduce the amount of pollutants entering downstream waters.
- Headwater wetlands are very individual systems.
- The hydrology of headwater wetlands remains active during the growing season.

Questions?

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