DUKE SWAMP WETLAND AND STREAM RESTORATION PROJECT

ANNUAL MONITORING REPORT FOR 2011 (YEAR 4)

Contract Number D06065-A

Submitted to: NCDENR - Ecosystem Enhancement Program
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Ecosystem Enhancement PROGRAM

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1.0 EXECUTIVE SUMMARY

This Annual Monitoring Report details the monitoring activities during the 2011 growing season (Monitoring Year 4) on the Duke Swamp Wetland and Stream Restoration Site ("Site"). As per the approved Restoration Plan for the Site, this Annual Monitoring Report presents data on stream geometry, wetland monitoring data, stem count data from vegetation monitoring stations, and discusses any observed tendencies relating to stream stability and vegetation survival success.

Historically, land use on the Site consisted of agricultural production. The UT1a area was used for seasonally rotated crop production. Mowing and crop production had curtailed any efforts for native woody vegetation to establish along the stream banks which resulted in an inadequate riparian buffer throughout reach UT1a. The historic flow pattern and flooding regime of UT2 had been altered significantly. Backwater effects had been the result of an existing spoil pile that ran along the right bank of UT1b in the forested wetland area. Flows were being diverted along this spoil pile and blocking the natural connection between UT1 and UT2. Prior to restoration, Duke Swamp was channelized and lacked bedform diversity. After construction, it was determined that 5,441 linear feet (LF) of stream were restored.

A total of 12 vegetation monitoring plots were used to predict survivability of the woody vegetation planted on-site. The Year 4 vegetation monitoring indicated an average survivability of 347 stems per acre. During Year 4 monitoring, vegetation plots 5, 10, 11, and 12 were found to have low stems counts. Tree densities within plots 5, 10, 11 and 12 ranged from 40 to 160 stems per acre. It appears that stem mortality within vegetation plots 5, 10, 11 and 12 is high due to heavy competition with a thick herbaceous layer and/or wet soil conditions.

Based on the Year 4 vegetation monitoring data, 3 plots on the downstream portion of UT1a will not meet the final vegetative success criteria of 260 stems per acre after Year 5 monitoring. Baker will work with the North Carolina Ecosystem Enhancement Program (NCEEP) during 2012 in order to reach a solution for resolving the concerned vegetative problems areas on the Site. These areas will be assessed with NCEEP during Year 5 to determine an appropriate course of action.

Cross-section and longitudinal profile data for stream stability were collected during Year 4 monitoring. The seven permanent cross-sections along the restored channel were re-surveyed to document stream dimension at the end of monitoring Year 4. All cross-sections indicate that there has been very little adjustment to stream dimension since construction. During Year 4 monitoring, approximately 3,375 LF of stream channel was re-surveyed to document longitudinal profile morphology. The results of the Year 4 longitudinal profile show that the riffles and pools have remained relatively stable since construction. Dimension and profile as well as the in-stream structures remained stable during Year 4.

The on-site crest gauge documented the occurrence of at least three bankfull flow events during Year 4 of the post-construction monitoring period. Inspection of conditions during site visits revealed visual evidence of out-of-bank flow, confirming the highest crest gauge reading of 2.90 feet (34.80 inches) above the bankfull stage.

The crest gauge on the Site has documented at least one bankfull event per year since as-built conditions. Four bankfull events have been recorded in separate years, which meets the success criteria as stated in the site Restoration Plan. The crest gauge readings will continue to be recorded through Year 5 of the project in order to observe bankfull events that may occur on the Site.

As first noted during Year 1 monitoring, the area between stations 38+00 and 40+00 has undergone subsidence on the right floodplain. Prior to restoration activities, this area was the connection between the remnant channel and farm pond 3 that was filled in during construction. The settling has allowed below bankfull flows to permanently flood the right floodplain as shown on cross-section 7. The floodplain elevation of cross-section 7 has decreased since as-built conditions, but it has remained stable since Year 2 data collection. This subsided area has also remained stable and no significant changes have been noted since Year 1. However, according to the yearly survey data, this area has been steadily increasing in elevation which is likely due to deposition of sediments and organic matter onto the floodplain. It appears the natural morphological processes are slowly building up the subsided area from the Year 2 elevation. Prior to close out of the project it is probable that the subsided area within the cross-section 7 floodplain will have decreased in size and depth, therefore, lessening the need for any potential repairs.

Other than the subsided area between stations 38+00 and 40+00, the Site is on track to meet the stream success criteria specified in the Site's Restoration Plan.

Weather station data from the Buckland Elementary Weather Station (Buckland, BUCK - ECONET) in Gates, North Carolina, in conjunction with a manual rain gauge located on the Site were used to document precipitation amounts. Total observed rainfall at the Buckland station for the period of January 2011 through November 2011 was 34.17 inches. According to the Buckland gauge, total rainfall during the Year 4 monitoring period from January 2011 through November 2011 was 12.07 inches below the historic approximated average.

A total of five automated groundwater-monitoring stations were installed across the project area to document wetland hydrologic conditions of the restored site. The success of the on-site wells during Year 4 is attributed to the higher local water table as a result of the Site's restoration and periodic backwater conditions from Duke Swamp.

A total of five automated water level gauges documented the occurrence of numerous flooding events within the UT1b area during Year 4 of post-construction monitoring.

The Site is on track to meet the hydrologic success criteria specified in the Site's Restoration Plan.

2.0 PROJECT BACKGROUND

The project involved the proposed restoration of 5,422 LF of stream and 15.8 riparian wetland SMU's. Table 1 summarizes the restoration areas on the Site. Selected site photographs are shown in Appendix A, B and C. Based on the as-built survey, a total of 12.0 acres of riverine wetlands and 5,441 LF of stream were restored on the Site. The project also enhanced 7.6 acres of riverine wetlands on the Site. A conservation easement totaling 25.4 acres has been recorded that protects the streams, wetlands, and riparian buffers in perpetuity.

2.1 Project Objectives

The specific goals for the Duke Swamp Wetland and Stream Restoration Project were as follows:

- Restore functional stream channels
- Restore riparian wetlands
- Enhance existing riparian wetlands
- Improve water quality within the Duke Swamp watershed by reducing sediment and nutrient inputs
- Improve aquatic and riparian habitat functions by creating deeper pools with in-stream structures
- Establish native stream bank and floodplain vegetation within the agricultural field areas.

2.2 Project Structure, Restoration Type and Approach

After examining the assessment data collected and exploring the Site's potential for restoration, an approach to the Site was developed that addressed restoration of both stream and wetland functions within the agricultural field areas. The approach also needed to take into account the existing swamp system at the downstream end of the Site, which had been impacted in the past by channelization. Topography and soils on the Site indicated that the project area most likely functioned in the past as a tributary stream system with associated wetlands, feeding into the larger Duke Swamp system.

Therefore, a design approach was formulated to restore this type of system. First, appropriate stream types for the valley types, slopes, and desired wetland functions were selected and designed to tie in at the upstream road culvert. Then a grading plan was developed to restore the adjacent wetland areas to a "Coastal Plain small stream swamp" as identified by Schafale and Weakley (1990), which had been previously converted to farmland. Finally, a design approach was developed for the downstream swamp area, to remove the past effects of channelization and restore historic flow patterns within the swamp. Special consideration was given to minimizing disturbance to existing wetland and wooded areas.

For analysis and design purposes, Michael Baker Engineering, Inc. (Baker) divided the Duke Swamp tributaries into three reaches labeled UT1a, UT1b and UT2 to Duke Swamp. UT1a begins on the upstream side of the project at a culvert under SR 1320. From the culvert, UT1a flows west and ends inside the forested wetland boundary. Downstream of the wood line, the channel is labeled UT1b. UT1b then continues through the forested area and eventually connects to the Duke Swamp system. UT2 begins at the outlet of a small cypress pond on the northwestern corner of the Site. UT2 flows south from the cypress pond and connects with UT1b within the forested wetland area.

UT1a Channel Restoration

A stable cross-section was achieved by restoring a single thread, meandering channel across the abandoned floodplain, increasing the width/depth ratio and raising the streambed to restore a channel that was appropriately sized for its drainage area. Due to the upstream road culvert and the need to avoid increased flooding of the road, floodplain grading was performed to allow for increased capacity during large storm events. Grading activities were aimed at restoring historic flow patterns and adjacent wetland hydrology by removing past channel spoil and other agricultural land manipulations. The channel was restored to a C-type stream (Rosgen 1994) and the sinuosity was increased by adding meanders to lengthen the channel and restore bed-form diversity. Minimal grade control was required for the project, due to the low channel slope and low potential for channel incision. In-stream wooden structures, such as log vanes, rootwads, and cover logs were included in the channel design to provide improved aquatic habitat.

UT1b Channel Restoration

As discussed in the approved restoration plan, UT1b was channelized through an existing wetland swamp system. The channelization and piling of spoil along the right bank had disrupted the historic flow and flooding patterns of the site, and disconnected the natural confluence of UT1 and UT2. However, historic channel remnants existed within the area adjacent to the existing canal. Restoration of this reach sought to restore historic flow and flooding processes, while avoiding and minimizing disturbance to the existing wetland vegetation. The restoration of UT1a through the farm fields ended at the edge of the jurisdictional wetland system. At this location, the constructed UT1a channel connects with a historic channel remnant which forms the beginning to UT1b. Construction equipment entered the existing wetland area along UT1b by traversing the existing spoil pile, thereby avoiding disturbance to wetland vegetation. The excavator placed the spoil material back into the channel and restored the natural topography in the area of the spoil pile. Flows through UT1b are now allowed to follow historic flow patterns and the stream functions as a DA-type stream system as it spreads out through numerous channel remnants, in the same way the system once functioned. The historic connection between UT1 and UT2 was restored.

UT2 Channel Restoration

As discussed in the preceding section, restoration in the area of UT1b and UT2 involved removing the existing spoil pile which was affecting the flow of UT2. The UT2 channel was experiencing backwater ponding and damming effects as a result of the spoil pile. By removing the spoil pile and restoring the surrounding topography, the historic flow pattern and flooding regime of UT2 was restored as a transition from a single to multi-thread channel. Rather than ponding and flowing along the spoil pile, flows greater than bankfull on the restored UT2 are now able to spread across the UT2 floodplain and mix with overbank flows from UT1.

Wetland Restoration Area #1

Wetland functions on the Site had been severely impaired as a result of agricultural conversion. The main stream (UT1) flowing through the Site was channelized years ago to reduce flooding and provide drainage for adjacent farm fields. As a result, most of the wetland functions were lost within these agricultural field areas.

Wetland restoration of the prior-converted farm fields on the Site involved grading areas of the farm fields to resemble natural floodplain topography and raising the local water table to restore a natural flooding regime. Reach UT1a was restored to a stable dimension, pattern, and profile, such that riparian wetland functions were restored to the adjacent hydric soil areas. Drainage ditches and Pond 3 were filled to decrease surface and subsurface drainage and raise the local water table. Native wetland vegetation was planted throughout the riparian buffer areas.

Wetland Enhancement Area #2

As mentioned above, wetland functions on the Site had been severely impaired as a result of agricultural conversion. Wetland enhancement of the existing jurisdictional wetland pockets involved grading areas of the farm fields to resemble natural floodplain topography and raising the local water table to enhance natural flooding regime and hydrology. Drainage ditches and Pond 3 were filled to decrease surface and subsurface drainage and raise the local water table. Additionally, the water level of Pond 1 was lowered to function as a wetland. Native wetland vegetation was planted throughout the riparian buffer areas as shown on the as-built plans.

Wetland Enhancement Area #3

Wetland enhancement of the existing jurisdictional wetlands within the downstream wooded area involved the removal of an existing spoil pile by placing the spoil material back into the channel thereby re-establishing the natural topography in the area. The historic hydrologic connection between UT1 and UT2 was restored. Native vegetation was planted along the spoil pile that was removed as shown on the as-built plan sheets.

Table 1. Project Restoration Components

Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A								
Project Segment or Reach ID	**Existing Feet/Acres**	**Mitigation Type ***	**Approach****	**Linear Footage or Acreage**	**Mitigation Ratio**	**Mitigation Units**	**Stationing**	**Comment**
UT1a	2,860	R	P1, P2	4,026	1:1	4,026	10+00 - 50+26	Restoration - Priority I and II
UT1b	880	R	-	900	1:1	900	10+00 - 19+00	Restoration of historic flows throughout remnant channels, flooding functions and hydrologic connectivity
UT2	880	R	-	515	1:1	515	10+00 - 15+15	
Wetland area #1	0	R	-	12	1:1	12	See plan sheets	Riverine wetland restoration
Wetland areas #2 and #3	7.5	E	-	7.6	2:1	3.8	See plan sheets	Riverine wetland enhancement

Mitigation Unit Summations

Stream (LF)	Riparian Wetland (AC)	Non-riparian Wetland (AC)	Total Wetland (AC)	Buffer (AC)	Comment
5,441	19.6	0	19.6	25.4	

*R=Restoration
E =Enhancement

**P1=Priority I
P2 = Priority II

2.3 Location and Setting

The Site is located in Gates County, NC (Figure 1), approximately nine miles northeast of the town of Gatesville. The Site lies in the Chowan River Basin within North Carolina Division of Water Quality sub-basin 03-01-01 and NCEEP targeted local watershed 03010203040010.

2.4 Project History and Background

Historically, land use on the Site consisted of agricultural production. The UT1a area was used for seasonally rotated crop production. Mowing and crop production had curtailed any efforts for native woody vegetation to establish along the stream banks which resulted in an inadequate riparian buffer throughout reach UT1a. The historic flow pattern and flooding regime of UT2 had been altered significantly. Backwater effects had been the result of an existing spoil pile that ran along the right bank of UT1b in the forested wetland area. Flows were being diverted along this spoil pile and blocking the natural connection between UT1 and UT2.

The chronology of the Duke Swamp Wetland and Stream Restoration Project is presented in Table 2. The contact information for all designers, contractors, and relevant suppliers is presented in Table 3. Relevant project background information is presented in Table 4.

2.5 Project Plan

Plans depicting the as-built conditions of the major project elements, locations of permanent monitoring cross-sections, and locations of permanent vegetation monitoring plots are presented in Figures 2A, 2B, 2C, 2D, 2E and 2F of this report.

Table 2. Project Activity and Reporting History

Duke Swamp Wetland and Steam Restoration Site: Project No. D06065-A			
Activity or Report	**Scheduled Completion**	**Data Collection Complete**	**Actual Completion or Delivery**
Restoration Plan Prepared	N/A	N/A	Apr-07
Restoration Plan Amended	N/A	N/A	N/A
Restoration Plan Approved	May-07	N/A	Apr-07
Final Design – (at least 90% complete)	N/A	N/A	Jun-07
Construction Begins	Jul-07	N/A	Jul-07
Temporary S&E mix applied to entire project area	Dec-07	N/A	Dec-07
Permanent seed mix applied to entire project area	Dec-07	N/A	Dec-07
Planting of live stakes	Dec-07	N/A	Dec-07
Planting of bare root trees	Dec-07	N/A	Dec-07
End of construction	Oct-07	N/A	Sep-07
Survey of As-built conditions (Year 0 Monitoring-baseline)	Oct-07	Oct-07	Oct-07
Year 1 Monitoring	Dec-08	Oct-08	Dec-08
Year 2 Monitoring	Dec-09	Oct-09	Dec-09
Year 3 Monitoring	Dec-10	Oct-10	Dec-10
Year 4 Monitoring	Dec-11	Nov-11	Dec-11
Year 5 Monitoring	Scheduled Dec-12	Scheduled Oct-12	Scheduled Dec-12

Table 3. Project Contact Table

Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A	
Designer	
Michael Baker Engineering, Inc.	8000 Regency Parkway, Suite 200 Cary, NC 27518 Contact: Kevin Tweedy, Tel. 919-463-5488
Construction Contractor	
River Works, Inc.	8000 Regency Parkway, Suite 200 Cary, NC 27518 Contact: Will Pedersen, Tel. 919-459-9001
Planting Contractor	
River Works, Inc.	8000 Regency Parkway, Suite 200 Cary, NC 27518 Contact: Will Pedersen, Tel. 919-459-9001
Seeding Contractor	
River Works, Inc.	8000 Regency Parkway, Suite 200 Cary, NC 27518 Contact: Will Pedersen, Tel. 919-459-9001
Seed Mix Sources	Mellow Marsh Farm, 919-742-1200
Nursery Stock Suppliers	International Paper, 1-888-888-7159
Monitoring Performers	
Michael Baker Engineering, Inc.	8000 Regency Parkway, Suite 200 Cary, NC 27518
Stream Monitoring Point of Contact:	Dwayne Huneycutt, Tel. 919-463-5488
Vegetation Monitoring Point of Contact:	Dwayne Huneycutt, Tel. 919-463-5488

Table 4. Project Background Table

Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A	
Project County:	Gates County, NC
Drainage Area:	
Reach:	
UT1a and UT1b	2.9 mi²
UT2	0.03 mi²
Estimated Drainage % Impervious Cover:	
M1	<5%
M2	<5%
Stream Order:	
UT1a and UT1b	2
UT2	1
Physiographic Region	Coastal Plain
Ecoregion	Mid-Atlantic Flatwoods
Rosgen Classification of As-Built:	
UT1a	C
UT1b	DA
UT2	DA
Cowardin Classification:	
UT1a, UT1b and UT2	Palustrine, Forested Wetland
Dominant Soil Types:	
UT1a	NaA, NoA,
UT1b	NaA
UT2	NaA, PaA
Reference site ID	Beaverdam Branch, Jones County
USGS HUC for Project and Reference sites	3010203
NCDWQ Sub-basin for Project and Reference	03-01-01
NCDWQ classification for Project and Reference:	
Reference	C
UT1a	C
UT1b	DA
UT2	DA
Any portion of any project segment 303d listed?	No
Any portion of any project segment upstream of a 303d listed segment?	No
Reasons for 303d listing or stressor?	N/A
% of project easement fenced	0%

3.0 PROJECT CONDITION AND MONITORING RESULTS

3.1 Vegetation Assessment

3.1.1 Description of Vegetative Monitoring

As a final stage of construction, the stream margins and riparian area of the Site were planted with bare-root trees, live stakes, and a seed mixture of temporary and permanent ground cover of herbaceous vegetation. The woody vegetation was planted randomly six to eight feet apart from the top of the stream banks to the outer edge of the project's re-vegetation limits. In general, bare-root vegetation was planted at a target density of 680 stems per acre, in an 8-foot by 8-foot grid pattern. The tree species planted at the Site are shown in Table 5. The permanent seed mix of herbaceous species applied to the project's riparian area included Virginia wild rye (*Elms virginicus),* switchgrass (*Panicum virgatum),* fox sedge (*Carex vulpinoidea*), smartweed (*Polygonum pennsylvanicum),* soft rush (*Juncus effusus),* and hop sedge (C*arex lupulina*). This seed mixture was broadcast on the Site at a rate of 15 pounds per acre. All planting was completed in December 2007.

At the time of planting, 12 vegetation plots – labeled 1 through 12 - were delineated on-site to monitor survival of the planted woody vegetation. Each vegetation plot is 0.025 acre in size, or 10 meters x 10 meters. All of the planted stems inside the plot were flagged to distinguish them from any colonizing individuals and to facilitate locating them in the future. The trees also were marked with aluminum metal tags to ensure that the correct identification is made during future monitoring of the vegetation plots.

On a designated corner within each of the 12 vegetation plots, an herbaceous plot was also delineated. The herbaceous plots measure 1 meter by 1 meter in size. These plots are photographed at the end of each growing season. The locations of the 12 vegetation plots are presented in Figures 2A through 2F.

3.1.2 Vegetative Success Criteria

To characterize vegetation success criteria objectively, specific goals for woody vegetation density were defined. Data from vegetation monitoring plots should display a surviving tree density of at least 320 trees per acre at the end of the third year of monitoring. The final vegetative success criterion is a surviving tree density of at least 260 five-year-old trees per acre at the end of the five-year monitoring period.

Table 5. Vegetation Species Planted Across the Restoration Site – As-built

Scientific Name	Common Name	Percent Planted by Species	Total Number of Stems
Bare Root Tree Species			
Betula nigra	river birch	15%	1,800
Celtis laevigata	sugarberry	5%	600
Fraxinus pennsylvanica	green ash	7%	900
Nyssa sylvatica	swamp tupelo	14%	1,600

Table 5. Vegetation Species Planted Across the Restoration Site – As-built			
Scientific Name	**Common Name**	**Percent Planted by Species**	**Total Number of Stems**
Platanus occidentalis	sycamore	19%	2,300
Quercus lyrata	overcup oak	10%	1,200
Quercus michauxii	swamp chestnut oak	10%	1,200
Quercus phellos	willow oak	8%	900
Taxodium distichum	bald cypress	12%	1,400
Total			**11,900**
Native Herbaceous Species			
Elymus virginicus	Virginia wildrye	15%	NA
Panicum virgatum	switch grass	15%	NA
Carex vulpinoidea	fox sedge	15%	NA
Polygonum pennsylvanicum	smartweed	15%	NA
Juncus effusus	soft rush	25%	NA
Carex lupulina	hop sedge	15%	NA
Woody Vegetation for Live Stakes			
Cephalanthus occidentalis	button bush	10%	1,038
Salix nigra	black willow	10%	1,039
Salix sericia	silky willow	40%	1,040
Sambucus canadensis	elderberry	40%	520

3.1.3 Vegetative Observations and Results

Most of the species that were part of the permanent ground cover seed mixture broadcast on the Site after construction were present during Year 4 monitoring of the Site.

Tables A.1 through A.6 in Appendix A present vegetation metadata, vegetation vigor, vegetation damage and stem count data of the monitoring stations at the end of the Year 4 monitoring period. Data from the Year 4 monitoring event of the 12 vegetation plots showed a range of 40 to 720 stems per acre. The Year 4 data showed that the Site had an average of 347 stems per acre. Vegetation plot 10 displayed an average density of 40 stems/acre following Year 4, due to one stem that had been previously overlooked. Data on the vegetation plots and problem areas that experienced low stem counts during Year 4 are detailed in Section 3.1.4.

Trees within each monitoring plot are flagged regularly to prevent planted trees from losing their identifying marks due to flag degradation. It is important for trees within the monitoring plots to remain marked to ensure they are accounted for during the annual stem counts and calculation of tree survivability. Permanent aluminum tags are used on surviving stems to aid in relocation and identification during future counts. Flags and PVC posts are also used to mark trees because they do not interfere with the growth of the tree.

Black willow (*Salix nigra*) shrubs were noted in or adjacent to some of the monitored vegetation plots. Currently, the *Salix nigra* plants are assisting in shading out some the problem herbaceous species within some of these plots. The vegetation plots will continue to be assessed during Year 5 monitoring for volunteer species.

3.1.4 Vegetative Problem Areas

The Site has experienced issues with woody vegetation performance in certain areas within the conservation easement after three years of post-construction monitoring. The following sections provide details concerning the issues and re-planting events regarding the problem vegetative areas.

3.1.4.1 Year 1 and 2 Vegetative Issues

Based on the Year 1 (2008) vegetation monitoring results, it was determined that the Site would not meet the interim success criteria of 320 stems per acre at the end of monitoring Year 3. A large number of tree fatalities occurred within the floodplain on the downstream portion of UT1a during the Year 1 growing season. Many of the planted trees were lost soon after initial planting when a large storm event caused straw mulch that had been placed over the Site for erosion control to wash and wrap around the newly planted stems, uprooting many trees. Also during 2008, high water levels within the floodplain during periods of the Year 1 growing season caused many of the smaller saplings to drown.

Therefore, to re-establish the stems within the floodplain, the Site was re-planted on February 27, 2009. The re-planting was limited to the floodplain area below the terrace of UT1a. The re-planting started at station 49+75 and terminated near the SR 1520 culvert, approximately at station 11+00. A total of 2,400 supplementary stems were planted in the affected area. The supplementary stems planted were limited to two water tolerant species, Bald Cypress (*Taxodium distichum*) and Black Gum (*Nyssa sylvatica*). Subsequent to re-planting, the newly established trees within the vegetation plots were flagged, marked with stakes and identified. The established herbaceous vegetation on-site was expected to protect the newly planted stems from damage due to high flows and wrack lines.

Following the Year 2 (2009) monitoring event, the 12 vegetation plots showed a range of 0 to 640 stems per acre. The Year 2 vegetation data revealed that the Site demonstrated an average of 403 stems per acre.

3.1.4.2 Year 3 and 4 Vegetative Issues

The Year 3 (2010) vegetation monitoring data revealed that the Site demonstrated an average of 350 stems per acre. Vegetation plots 5, 10, 11 and 12 were experiencing low stems counts following Year 3. The stems counts of these plots were 120, 0, 200 and 80, respectively (see Table A.6).

According to the Year 3 monitoring data, vegetation plots 5, 10, 11 and 12 would not meet the final vegetative success criteria of 260 stems per acre after Year 5 monitoring. Therefore, Baker worked with NCEEP during 2011 in order to reach a solution for resolving the concerned vegetative problems areas on the Site.

To determine the appropriate course of action prior to project closeout of the Site, Baker first collected soil samples from vegetation plots 5, 10, 11 and 12 and three on-site reference samples from the UT1b area. Results of the soil samples and further details describing on-site conditions in the problem vegetative areas, as well as the hydrological conditions, were described in a Technical Memorandum submitted by Baker to NCEEP and the United States Army Corps of Engineers (USACE), dated October 7, 2011.

As described in the Technical Memorandum, Baker recommended re-planting approximately 200 containerized trees in a 0.6 acre area around vegetation plot 5 (Figure 3). Applying fertilizer in the area during fall/winter 2011 was also recommended. The memorandum states that the soils are less saturated in the Vegetation Plot 5 area and re-planting in this area has a higher likelihood of survival than the saturated lower portion of the Site.

As stated above, vegetation plot 5 and the immediate vicinity were re-planted on November 3, 2011. This re-planting event was comprised of 200, 3-gallon containerized plants. The trees were approximately 4 years in age and were limited to three species, bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*) and green ash (*Fraxinus pennsylvanica*). These species were selected due to their tolerance to saturated conditions and in keeping with species documented in site Restoration Plan. The area replanted during this event was approximately 0.6 acres and is presented in Figure 3.

One additional planted stem was also located during Year 4 (2011) monitoring in Vegetation Plot 5 which provided and increased density to 160 stems per acre versus 120 stems per acre following Year 3. Based on the Year 4 vegetation monitoring data, plots 10, 11 and 12 will likely not met the final vegetative success criteria of 260 stems per acre after Year 5 monitoring.

These problem vegetation plots (10, 11 and 12) are located on the downstream portion of the Site where conditions are wet for most of the year. The downstream portion of the Site ties into the existing Duke Swamp system and has characteristics of a Non-Tidal Freshwater Marsh during wet periods. Vegetation plot 10 demonstrated a density of 40 stems per acre following Year 4 and continues to be wet for most years. Plot 10 is in an area on top of the remnant channel and the remnant pond 3 where fill soils have subsided since construction. Due to the subsidence of the soils in Vegetation Plot 10, overbank flooding of at least 6 inches has remained present in this area year round and has proved detrimental to sapling survival. Plot 11 displayed a density of 160 stems per acre during Year 4 and is also experiencing heavy competition with a very thick herbaceous vegetative layer and saturated soils. Plot 12 displayed a density of 120 stems per acre during Year 4 and is the most downstream vegetation plot. This plot is experiencing saturated soils for most of the year at the UT1a/UT1b tie-in. The saplings in vegetation plot 12 are experiencing difficulties in surviving the extremely wet conditions.

These downstream problem areas will be observed closely during Year 5 monitoring, but it is likely that these monitored locations will not support the typical woody stem density of drier locations. This difficulty in sapling establishment is also observed in mature swamp systems, where extended saturation periods can lead to clear areas where it is hard for volunteer recruitment to occur. Under natural conditions, swamp systems exhibit slow establishment of young trees, with sapling establishment typically occurring in dry years because the samplings cannot withstand prolonged submergence unless they are planted on hummocks (mounds) or microtopographic features that enable the tree roots to obtain oxygen from the soil.

3.1.4.3 Vegetative Problem Species

A combination of weedy vegetative species have been observed on the Site. The species present on the Site and within many vegetation plots is identified as arrowleaf tearthumb (*Polygonum sagittatum*). This vine is growing in dense layers that are on top of the planted herbaceous and planted stems. The grass species *Panicum spp.* has been identified in the vegetation plot 5 area and is causing substantial problems for the remaining stems within the immediate vicinity. After replanting plot 5 with larger trees in 2011, it is anticipated that the *Pancium spp*. will begin to die off due to shading from the newly planted stems. Broad-leaf cattail (*Typha latifolia*) has also been identified on the downstream and wetter portions of the Site in the un-shaded wetter areas.

As the Site matures and becomes more shaded it is expected that the arrowleaf tearthumb, *Panicum spp*. and cattail species will become less prevalent as has been noted at other similar restoration sites. The other weedy species occurring are mostly annuals which are not anticipated to threaten vegetation survivability on the Site.

3.1.5 Vegetation Photographs

Photographs are used to visually document vegetation plot success. A total of 12 reference stations were established to document tree conditions at each vegetation plot across the Site. Additional photo stations were also established at each of the 12 vegetation plots for herbaceous vegetation monitoring. Reference photos of the vegetation plots and herbaceous conditions are taken at least once per year. Photos of the tree plots and herbaceous plots showing the on-site vegetation are included in Appendix A of this report.

3.2 Stream Assessment – Reach UT1a

3.2.1 Description of Stream Monitoring

Cross-sections: Two permanent cross-sections were installed per 1,000 LF of stream restoration work, with one of the locations being a riffle cross-section and one location being a pool cross-section. A total of seven permanent cross-sections were established across the Site. Each cross-section was marked on both banks with permanent pins to establish the exact transect used. The permanent cross-section pins are surveyed and located relative to a common benchmark to facilitate easy comparison of year-to-year data. The annual cross-section surveys include points measured at all breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg.

Longitudinal Profiles: A complete longitudinal profile was surveyed following construction completion to record as-built conditions and to establish a baseline profile. A longitudinal profile will be completed during each year of the five-year monitoring period. The profiles will be conducted for the entire length of the restored channel (UT1a). Measurements will include thalweg, water surface, inner berm, bankfull and top of low bank. Each of these measurements will be taken at the head of each feature (e.g., riffle, pool, and glide). In addition, maximum pool depth will be recorded. All surveys will be tied to a single, permanent benchmark.

3.2.2 Morphometric Success Criteria

To document the stated stream success criteria in the approved Restoration Plan, the following monitoring program was instituted following construction completion on the Site:

There should be little change in as-built cross-sections. If changes do take place, they will be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting or erosion) or a movement toward increased stability (e.g., settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sections will be classified using the Rosgen Stream Classification System (1994), and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

The longitudinal profiles should show that the bedform features are remaining stable; (i.e., they are not aggrading or degrading). The pools should remain deep, with flat water surface slopes, and the riffles should remain steeper and shallower than the pools. Bedforms observed should be consistent with those observed for channels of the designed stream type.

3.2.3 Morphometric Monitoring Results

Year 4 cross-section monitoring data for stream stability were collected during November 2011. The seven permanent cross-sections along the restored channel (four located across riffles and three located across pools) were re-surveyed to document stream dimension at the end of monitoring Year 4. Data from each of these cross-sections are summarized in Appendix B in Table B.3. All cross-sections, except cross-section 7, show that there has been very little adjustment to stream dimension since construction.

Cross-sections 1, 3, 5, and 7 are located across riffles, which are found between meander bends. Based on the Year 4 survey data, all riffle cross-sections exhibited a relatively similar streambed elevation compared to baseline conditions. The elevations of the riffle cross-sections have remained stable since Year 1 cross-section monitoring. All riffle cross-sections are currently stable and do not show signs of channel instability.

However, according to the Year 4 survey data, channel dimension within riffle cross-section 3 has demonstrated a decrease in bankfull cross-sectional area. The thalweg elevation has remained stable since as-built conditions and it has been determined that a thick layer of aquatic vegetation has filled the left channel in cross-section 3. Therefore, the survey data displays a shift in the thalweg to the right portion of the channel following Year 4 monitoring. This area does not demonstrate signs of instability and appears to be very stable.

Cross-sections 2, 4 and 6 are located across pools which are found at the apex of meander bends. The Year 4 data show that the pool cross-sections exhibit a relatively similar streambed elevation compared to baseline conditions. Based on the Year 4 pool cross-section data and visual observations, the pools have not shown strong development of point bar features on the inside bank of the meander bends. It is concluded that point bar features have continued to show little development due to low sediment delivery from the watershed or low hydrologic energy within the channel.

It also is significant to note that the Year 4 cross-sectional data continues to demonstrate that the floodplain areas throughout the Site between the top of banks and the permanent cross-section pins have experienced various degrees of settling. This settling of the floodplain on the Site is most evident on the right bank of cross-section 7. This area was first noted to have subsided during Year 1 monitoring. The settling allowed below bankfull flows to permanently flood the right bank and floodplain. The right bank floodplain elevation of cross-section 7 decreased after as-built conditions. According to the survey data, the average elevation of the right bank was lowest following Year 2. Following Year 4 monitoring, the survey data currently show that the average elevation of the subsided right bank area has increased approximately 0.3 feet, since Year 2. According to the yearly survey data, this area has slowly increased in elevation, which is likely due to deposition of sediments and organics onto the floodplain. It appears that the natural morphological processes are slowly building up the subsided area from the Year 2 elevation. Prior to close out of the Project, it is probable that the subsided area with the cross-section 7 floodplain will have decreased in size and depth, therefore, lessening the need for any potential repairs.

The longitudinal profile for Year 4 was surveyed in November 2011 and was compared to data collected during the as-built condition, Year 1, Year 2 and Year 3 surveys. The longitudinal profiles are presented in Appendix B. The results of longitudinal profile during Year 4 show that the pools in UT1a have maintained elevations and depths similar to those documented during the as-built survey. However, some pools in UT1a have filled in slightly since as-built conditions. These pools will be observed during Year 5 monitoring for stability and functionality. The water surface slopes across the pools remained flat during Year 4 monitoring.

The longitudinal profile shows that some of the riffles, most of which are located in the middle portion of the Site, have fluctuated in elevation slightly since as-built conditions. The results of the 4 longitudinal profile in the middle portion of the Site show that the riffle elevations have stayed relatively stable since Year 1.

A minimal number of in-stream structures were installed within the restored stream channel. These structures include constructed riffles, log vanes, and root wads. Visual observations of these structures throughout the Year 4 monitoring season have indicated that all structures are functioning as designed and holding their elevation grade. Log vanes placed in meander pool areas have provided bank protection and scour to keep pools deep and provide aquatic habitat. The two constructed riffles have maintained bed elevations and have provided some downstream scour, providing habitat. Rootwads placed on the outside of meander bends have provided bank stability and in-stream cover for fish and other aquatic organisms.

3.2.4 Hydrologic Success Criteria

One manual crest gauge was installed on the Site to document bankfull events. The gauge is checked regularly and records the highest out-of-bank flow between site visits. The gauge is located on the downstream portion of reach UT1a at station 45+50, which is presented in Figure 2D.

The approved Restoration Plan requires the following criteria be met to achieve stream restoration success: Two bankfull flow events must be documented within the five-year monitoring period. These two bankfull events must occur in separate years, otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years.

3.2.5 Hydrologic Monitoring Results

Table 6. Verification of Bankfull Events			
Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A			
Date of Data Collection	Estimated Date of Occurrence of Bankfull Event	Method of Data Collection	Measurement Feet (Inches)
3/24/2011	2/6/2011	Crest Gage on UT1a	0.92 (11.04)
8/30/2011	8/28/2011	Crest Gage on UT1a	2.90 (34.80)
10/19/2011	9/28/2011	Crest Gage on UT1a	2.34 (28.08)

The on-site crest gauge documented the occurrence of at least three bankfull flow events during Year 4 of the post-construction monitoring period, as shown in Table 6. Inspection of conditions during site visits revealed visual evidence of out-of-bank flows, confirming the crest gauge readings. The largest on-site stream flow documented by the crest gauge during Year 4 of monitoring occurred in August 2011 during Hurricane Irene. The gauge reading following this event was approximately 2.90 feet (34.80 inches) above the bankfull stage and was the result of overbank flooding of UT1a.

The crest gauge on the Site has documented at least one bankfull event per year since as-built conditions. Four bankfull events have been recorded in separate years, which meet the success criteria as stated the site Restoration Plan. The crest gauge readings will continue to be recorded through Year 5 of the project in order to observe flood event depths that may occur on the Site.

3.2.6 Stream Problem Areas

During 2008, the Site experienced a bank/floodplain stability issue on the lower portion of UT1a between stations 46+00 and 49+00. The left bank and floodplain in this section of the Site had subsided and were underwater during normal flow periods. The area affected extended from the left stream channel to the left toe of terrace, where the old stream channel had been filled. Conditions were very wet during construction of the Site, and the fill material that was placed into the old channel subsequently experienced settling. Repairs to this portion of the Site were completed in November 2008. The area was backfilled with on-site soil to raise the elevation of the floodplain to appropriate elevations. This area was backfilled from the toe of terrace to within 20 feet of the stream channel. The remaining 20 feet of the affected area were too unstable to be accessed by heavy equipment; therefore, no work was done adjacent to the channel. In Year 2 and Year 3 this area was observed closely during site visits. Year 3 and 4 monitoring revealed that the repaired area is stable and did not exhibit any restoration-related problems.

As mentioned in Section 3.2.3, the area between stations 38+00 and 40+00 near cross-section 7, has undergone subsidence on the right floodplain. This area was first noted to have subsided during Year 1 monitoring. The settling has allowed below bankfull flows to permanently flood the right floodplain of cross-section 7. The floodplain elevation of cross-section 7 decreased following as-built conditions, but has remained stable since Year 2. It is noted that according to Year 4 cross-section data, this subsided area has experienced an increase in average elevation from its lowest point following Year 2 monitoring. It is likely this area has slowly been filling in with the deposition of sediments and organics. It appears the natural morphological processes are slowly building up the subsided area from the Year 2 elevation. This area will continue to be observed closely during Year 5 and prior to project close out and any significant changes will be reported.

For the period of Year 4 monitoring, UT1a did not experience any other restoration-related problems.

3.2.7 Stream Photographs

Site photographs are used to visually document restoration success. A total of 10 reference stations were installed and photographed after construction. Photographs from these reference stations will be continued for at least five years following construction. Reference photos will be taken at least twice per year, and will be taken in enough locations to document the condition of the restored system. Permanent markers were established to ensure that the same locations (and view directions) on the Site are documented in each monitoring period.

The restored stream will be photographed longitudinally beginning at the downstream portion of the restoration reach and moving upstream to the beginning of the reach. Photographs will be taken looking upstream at delineated locations. Reference photo locations will be marked and described for future reference. Points will be sufficiently close to provide an overall view of the reach. The angle of the shot will depend on what angle provides the best view, which will be noted and continued in future shots. When modifications to photo position must be made due to obstructions or other reasons, the location will be noted along with any landmarks.

Additional photographs will be taken to document any observed evidence of flooding patterns such as debris, wrack lines, water marks, channel features, etc.

Both stream banks are photographed at all permanent cross-section photo stations. For each stream bank photo, the photo view line follows a survey tape placed across the channel, perpendicular to flow (representing the cross-section line). The photograph is framed so that the survey tape is centered in the photo (appears as a vertical line at the center of the photograph), keeping the channel water surface line horizontal and near the lower edge of the frame.

A photo log of the restored channel is presented in Appendix B of this report. Photographs of the restored channel were taken at the end of the monitoring season to document the evolution of the stream geometry. Herbaceous vegetation was dense along the edges of the restored stream, making the photography difficult in some areas of the stream channel.

3.2.8 Stream Stability Assessment

Table B.1. in Appendix B provides a summary of the results obtained from the visual inspection of in-stream structures performed during each year of post-construction monitoring. The percentages noted are a general, overall field evaluation of the how the features were performing at the time of the photo point survey. According to the visual stability assessment for Year 4, all features on the Site, with the exception of the area described in Section 3.2.6, are performing as designed.

3.2.9 Quantitative Measures Summary Tables

The quantitative pre-construction, reference reach, and design data used to determine restoration approach, as well as the as-built baseline data used during the project's post-construction monitoring period are summarized in Table B.2. (located in Appendix B).

3.3 Stream Assessment – UT1b and UT2

3.3.1 Description of Stream Monitoring

Geomorphic monitoring of reaches UT1b and UT2 will be conducted for five years to evaluate the effectiveness of the restoration practices. Since restoration of these reaches involved the restoration of historic flow patterns and flooding functions to remnant channel segments in a multi-threaded swamp system, monitoring efforts will focus on visual documentation of stability and the use of water level monitoring gages to document saturation and flooding functions.

The occurrence of bankfull events and flooding functions within the monitoring period will be documented by the use of automated water level monitoring gauges, photographs and videos. Five automatic monitoring gauges were installed within the restored system to document shallow groundwater and flooding levels. The data loggers are programmed to collect data every six hours, which records the highs and lows of flooding with greater accuracy.

3.3.2 Hydrologic Criteria

Two bankfull flow events must be documented within the five-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years. The water level monitoring gauges should document the occurrence of periodic inundation and varying groundwater levels across the restored site. The gauges should also document the connectivity of flooding between the restored UT1b and UT2 reaches.

3.3.3 Hydrologic Monitoring Results

According to the water level gauge data graph, presented in Appendix B, the on-site automated gauges documented the occurrence of numerous flooding events during Year 4 of the post-construction monitoring period. Flood gauges 1, 4 and 5 are located in the UT1b wetland area and flood gauges 2 and 3 are located in the UT2 wetland area.

As indicated by the data, the area around flood gauge 1 was consistently inundated by water throughout most Year 4. The data show that flood gauges 2, 3 and 5 were relatively similar and consistent in water level measurements. Flood gauge 4 was the least inundated of the gauges during the growing season and showed varying water levels throughout 2011.

Inspection of conditions during site visits revealed visual evidence of diffuse swamp flows, confirming the flood gauge readings. According to the data, the largest on-site flood event documented by all the flood gauges during Year 4 of monitoring took place on August 27 and 28, 2011. All five flood gauges recorded their highest levels of 2011 during this time due to a tropical system (Hurricane Irene) that passed over the Site. According to the gauge data, all five flood gauges recorded high readings during the same day, as demonstrated in

Appendix B. This event and other smaller ones, documents the occurrence of numerous bankfull events and flooding within UT1b and UT2 during Year 4 of monitoring.

3.3.4 Stream Problem Areas

During Year 2 monitoring, UT1b and UT2 did not experience any restoration-related problems.

3.3.5 Stream Photographs and Videos

Photographs and video footage are used to document restoration success visually. A total of three reference photograph stations were established after construction and will be continued for at least five years. Reference photos are taken at least twice per year at each station to document the condition of the restored system and to document the connectivity between reaches UT1b and UT2. Permanent markers were established to ensure that the photo and video points are documented in the same location and view direction during each monitoring period.

As required by the Site Restoration Plan, reference videos are also recorded at photo stations 11 and 13 to determine connectivity between the restored reaches. Videos are taken at least twice a year or whenever a site visit determines that UT1b and UT2 are flowing across the restored backfilled ditch that separated the two reaches prior to restoration.

Photographs and videos were taken looking upstream at the established locations. The angle of the shots depended on what position provided the best view and was noted for future shots. Additional photographs were taken to document any observed evidence of flooding patterns such as debris, wrack lines, water marks, channel features, etc.

A photo log of the UT1b and UT2 reference stations and photographs of each water level monitoring gauge are presented in Appendix B and C. Videos depicting the connectivity between reaches UT1b and UT2 are presented in the CD attached with this report.

It is noted that the videos points in the attached CD depict low to moderate flows across video point 1 (photo point 11) in the south to north direction (UT1b towards UT2). During site visits, video point 1 is normally observed flowing north from UT1b across the remnant ditch fill area towards UT2.

However, during site visits immediately following large storm events in March 2009, May 2010 and August 2011 (Hurricane Irene) it has been noted that both video points (1 and 2) flow from north to south (UT2 towards UT1b). These videos depicted flow in the north to south direction, presumably due to the time of the site visit corresponding to rising flood waters within the main Duke Swamp system. Therefore, it has been confirmed during multiple site visits, that during large storm events and high flows, the flood waters in the main Duke Swamp system flow from north to south (UT2 towards UT1b) across the remnant ditch fill area. Once the flood water depths fall, the water resumes a south to north flow direction (UT1b towards UT2) back across the remnant ditch fill, then the water flows along UT2 and flows around the fill area into the main swamp, thus into the Chowan River watershed. This direction returns the water to its normal low to moderate flow path around the downstream portion of the remnant ditch fill area.

3.4 Wetland Assessment

3.4.1 Description of Wetland Monitoring

Groundwater-monitoring stations were installed across the project area to document hydrologic conditions of the restored site. Five groundwater monitoring stations were installed, with all five stations being automated groundwater gauges. Groundwater monitoring stations follow the United States Army Corps of Engineers (USACE) standard methods found in Stream Mitigation Guidelines (USACE 2003).

In order to determine if the rainfall is normal for the given year, rainfall amounts are tallied using data obtained from the Gates County WETS Station and an on-site rain gage.

3.4.2 Wetland Criteria

The primary objective of groundwater monitoring is to demonstrate that the Site is saturated within 12 inches of the soil surface for at least 8 percent of the growing season and that the Site exhibits an increased frequency of flooding. The restored site's hydrology was compared to pre-restoration conditions both in terms of groundwater and frequency of overbank events.

3.4.3 Wetland Monitoring Results

The average growing season (defined as the period in which temperatures are maintained above 28 degrees Fahrenheit under average conditions) for Gates County is 232 days, beginning on March 25 and ending November 11. Gates County has an average annual rainfall of 50.39 inches (USDA 1992).

Weather station data from the Buckland Elementary Weather Station (Buckland, BUCK - ECONET) in Gates, NC, are used in conjunction with a manual rain gauge located on the Site to document precipitation amounts. The Buckland station is located approximately 7.0 miles from the Site. Therefore, data from this station is the primary source of rainfall information. The manual rainfall gauge was initially installed in February 2008 and is used to validate data observations at the Buckland station. Rainfall data from the Great Dismal Swamp National Wildlife Refuge (VGDR) automated weather station (RAWS) are also used when data from the Buckland station or data from the on-site gauge are missing or exhibit errors.

Total observed rainfall at the Buckland station for the period of January 2011 through November 2011 was 34.17 inches, as compared to the VDGR gauge of 42.37 inches for the same period. According to the Buckland gauge, total rainfall during the Year 4 monitoring period from January 2011 through November 2011 was 12.07 inches below the historic approximated average for Gates County.

Monthly rainfall totals during the 2011 growing season were at or below normal amounts and occurred in the summer and fall months. The months of January through June and October were relatively dry. The months of July, August and September were average to wet.

However, in late August 2011 a tropical system (Hurricane Irene) moved over the region and supplied a large amount of rain to the project area. Prior to this event, the Site had been relatively dry. According to the Buckland gauge, the storm event deposited approximately 8.88 inches of rain from August 26 to August 28 (see Table 7 and Figure 4).

The Duke Swamp Restoration Plan specified that five automated monitoring wells would be established across the restored site. A total of five automated wells were installed in October 2007 to document water table hydrology in all required monitoring locations. All wells are located in the restored wetland areas adjacent to UT1a, and the locations of monitoring wells are shown on the as-built plans. Hydrologic monitoring results are shown in Table 8. Well hydrographs and a photograph log of the wetland well monitoring stations are included in Appendix C of this report.

During Year 4, five wells recorded consecutive hydroperiods of at least 11 percent during the growing season. The recorded amounts for Year 4 are significantly greater than the 8 percent recommended for wetlands in the Site Restoration Plan. During Year 4, recorded hydroperiods ranged from 11 percent to 100 percent for the growing season. Due to below average rainfall conditions during the 2011 growing season, the success of the on-site wells is attributed to the higher local water table as a result of the Site’s restoration and periodic backwater conditions from Duke Swamp. The hydrology of the restored system appears to be similar to the downstream wooded swamp area in responding to rainfall events, which exhibits prolonged saturated conditions.

However, during the past three years of monitoring, it has been observed that the restored channel (UT1a) retains a large portion of water that flows onto the Site. This backwater condition is attributed to a lower thalweg elevation of the restored channel at the tie-in point with UT1b. Hydrographs for all five wetland monitoring stations are presented in Appendix C.

Table 7. Comparison of Historic Average Rainfall to Observed Rainfall (Inches)					
Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A					
Month	**Average**	**30%**	**70%**	**Observed 2011 Precipitation**	**Difference from Average**
January	4.49	2.63	6.13	2.35	-2.14
February	4.26	2.23	6.04	2.05	-2.21
March	4.71	2.93	6.31	3.66	-1.05
April	3.52	1.19	5.42	1.23	-2.29
May	4.56	2.41	6.44	0.85	-3.71
June	3.95	2.19	5.5	1.44	-2.51
July	4.52	1.58	6.94	3.9	-0.62
August	4.85	2.11	7.18	9.93	5.08
September	4.45	1.56	6.82	5.2	0.75
October	3.65	1.18	5.66	2.13	-1.52
November	3.28	1.31	4.93	1.43	-1.85
December	4.15	1.89	6.08	--	--
Totals:	**50.39**	**41.54**	**59.63**	**34.17**	**-12.07**

Figure 4. Historic Average vs. Buckland Observed Rainfall

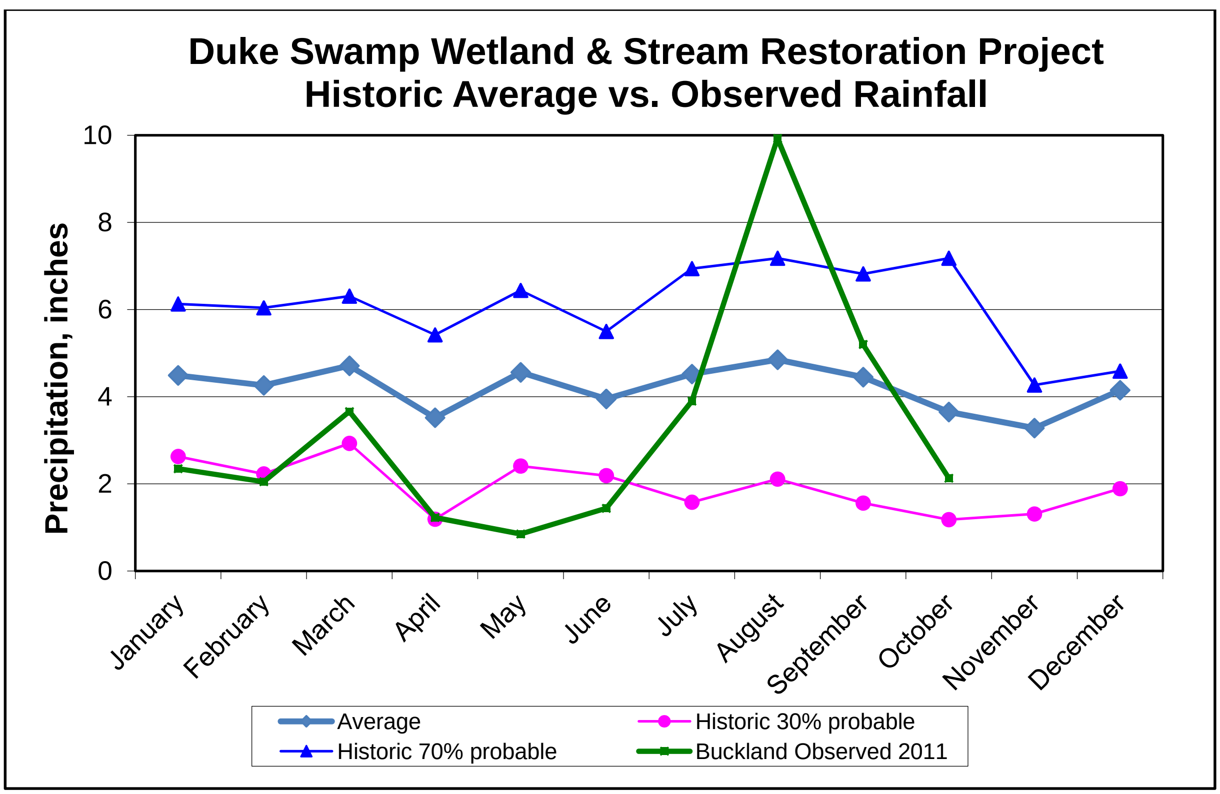

Table 8. Hydrologic Monitoring Results

Duke Swamp Wetland and Stream Restoration Site: Project No. D06065-A			
Well ID	**Most Consecutive Days Hydrology has been Met[1]**	**Cumulative Days Meeting Criteria[2]**	**Number of Instances Meeting Criteria[3]**
AW1	110 (47%)	225 (97%)	4
AW2	77 (33%)	152 (66%)	7
AW3	232 (100%)	232 (100%)	1
AW4	232 (100%)	232 (100%)	1
AW5	26 (11%)	105 (45%)	11

[1] Indicates the most consecutive number of days within the monitored growing season with a water table less than 12 inches from the soil surface.
[2] Indicates the cumulative number of days within the monitored growing season with a water table less than 12 inches from the soil surface.
[3] Indicates the number of instances within the monitored growing season when the water table rose to less than 12 inches from the soil surface.

3.4.4 Wetland Problem Areas

During Year 4 of monitoring, the Site did not experience any significant wetland restoration-related problems.

However, as mentioned in Section 3.2.6, the area on UT1a at stream stations 46+00 through 49+00 experienced a bank/floodplain stability issue during 2008. The left bank and floodplain in this section of the Site had subsided and were underwater during normal flow periods. The lowered ground surface elevation in the area around AW5 caused very wet conditions to occur in Year 1. In November 2008, AW5 was removed and the area was backfilled with on-site soil to raise the floodplain to an appropriate elevation. After repairs had been completed, AW5 was reinstalled in the new fill material.

In Year 4 this area was observed closely during site visits. Monitoring has revealed that the repaired AW5 floodplain is currently stable. AW5 data from Year 2 through Year 4, demonstrates that drier conditions are being experienced following repair work. These drier conditions are attributed to the new higher elevation within the repaired floodplain area. AW5 exhibited a 17.7 percent hydroperiod during the 2009 growing season, an 8 percent hydroperiod during the 2010 growing season and an 11 percent hydroperiod during the 2011 growing season.

3.4.5 Wetland Photographs

A photo log of the wetland groundwater monitoring stations is presented in Appendix C.

4.0 OVERALL CONCLUSIONS AND RECOMMENDATIONS

Vegetation Monitoring - A total of 12 monitoring plots were used to predict survivability of the woody vegetation planted on-site. Due to a low stem count during Year 1 monitoring, the Site was re-planted in February 2009. The re-planting was limited to the floodplain area below the terrace of UT1a. A total of 2,400 supplementary bare root trees were planted and limited to two water tolerant species, Bald Cypress (*Taxodium distichum)* and Black Gum (*Nyssa sylvatica*).

The Year 4 vegetation monitoring indicated an average survivability of 347 stems per acre. During Year 4 monitoring, vegetation plots 5, 10, 11, and 12 were found to have low stem counts. The tree densities within plots 5, 10, 11 and 12 ranged from 40 to 160 stems per acre. Planted stems within vegetation plots 5, 10, 11 and 12 are experiencing problems due to heavy competition with a thick herbaceous layer and/or wet soil conditions.

According to the Year 4 vegetation monitoring data, 3 plots on the downstream portion of UT1a will not meet the final vegetative success criteria of 260 stems per acre after Year 5 monitoring. Baker will be working with NCEEP in order to reach a solution for resolving the concerned vegetative problems areas on the Site. These areas will be assessed with NCEEP early in Year 5 to determine an appropriate course of action.

Stream Monitoring - The total length of stream channel restored on the Site was 5,441 LF. This entire length was inspected during Year 4 of the monitoring period to assess stream performance. Based on the data collected, all riffles, pools, and other constructed features within the restored channel are stable and functioning as designed.

During Year 1 monitoring, one stream/wetland related repair was completed. The Site experienced bank and floodplain settling on the lower portion of UT1a between stations 46+00 and 49+00. The area was backfilled with on-site soil to raise the elevation of the floodplain to post-construction conditions. This repaired area was found to be stable and functioning properly during Year 4 monitoring.

On reach UT1a, the on-site crest gauge documented the occurrence of at least three bankfull flow events during Year 4 of the post-construction monitoring period. The crest gauge on the Site has documented at least one bankfull event per year since as-built conditions. Four bankfull events have been recorded in separate years, which meet the success criteria as stated in the Site Restoration Plan. The crest gauge readings will continue to be recorded through Year 5 of the project in order to observe flood events that may occur on the Site.

On reaches UT1 b and UT2 within the wetland enhancement area, all five of the automated water level gauges documented the occurrence of numerous flooding events during Year 4 of the post-construction monitoring period. Photographs and videos recorded the connectivity between reaches UT1b and UT2.

The area between station 38+00 and 40+00 has undergone subsidence on the right floodplain. The settling has allowed below bankfull flows to permanently flood the right floodplain near AW4, vegetation plot 10 and cross-section 7. The floodplain elevation of cross-section 7 has decreased since as-built conditions, but it has remained stable since Year 1 data collection. The subsided area between stations 38+00 and 40+00 has also remained stable and no significant changes have been noted. This area will continue to be closely observed during Year 5 and prior to project closeout and any significant changes will be reported.

Other than the subsided area between stations 38+00 and 40+00, the Site is on track to meet the stream success criteria specified in the Site's Restoration Plan.

Wetland Monitoring - During 2011, all five monitoring wells recorded hydroperiods greater than 8 percent during the growing season. The success is accredited to the higher local water table as a result of the Site's restoration and periodic backwater conditions from Duke Swamp. A total of five automated water level gauges documented the occurrence of numerous flooding events within the UT1b area during Year 4 of post-construction monitoring.

Total observed rainfall at the Buckland station for the period of January 2011 through November 2011 was 34.17 inches. According to the Buckland gauge, total rainfall during the Year 4 monitoring period from January 2011 through November 2011 was -12.07 inches below the historic approximated average.

5.0 WILDLIFE OBSERVATIONS

Observations of white-tailed deer and deer tracks are common on the Site. Wild turkey tracks have also been observed during site visits. During the Year 4 monitoring season, herons, egrets, ducks, snakes, turtles, frogs and crawfish were periodically observed. The Site has shown excellent diversity in the types of water birds observed on the Site throughout the monitoring years.

A visual confirmation of a Northern River otter was observed in UT1b during November 2010. During Year 4 monitoring, no direct observations or activities of beaver, nutria or otter were documented within the project area.

6.0 REFERENCES

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FIGURES

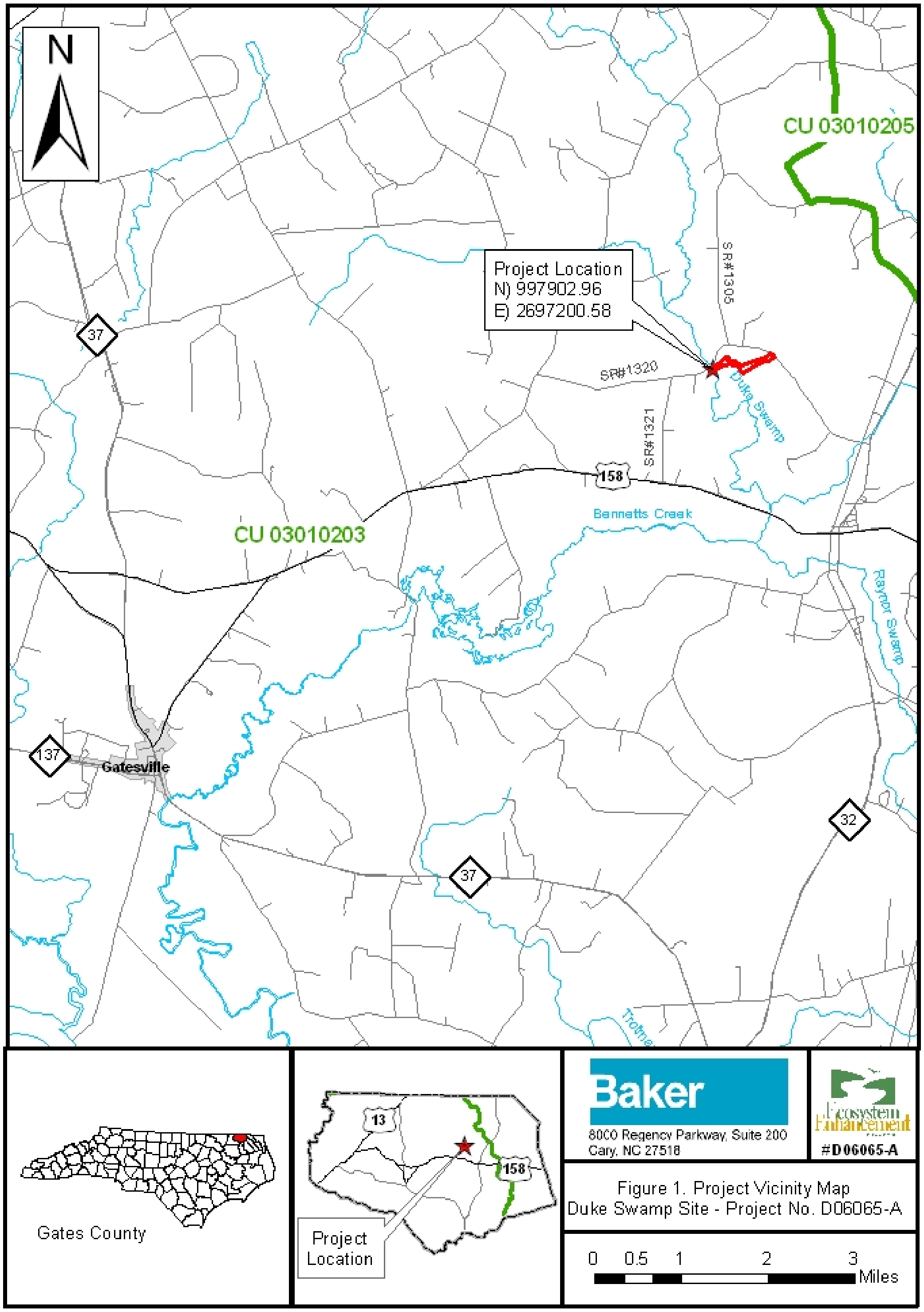


Figure 1. Location of Duke Swamp Wetland and Stream Restoration Site.

PROJECT: 109351 DUKE SWAMP

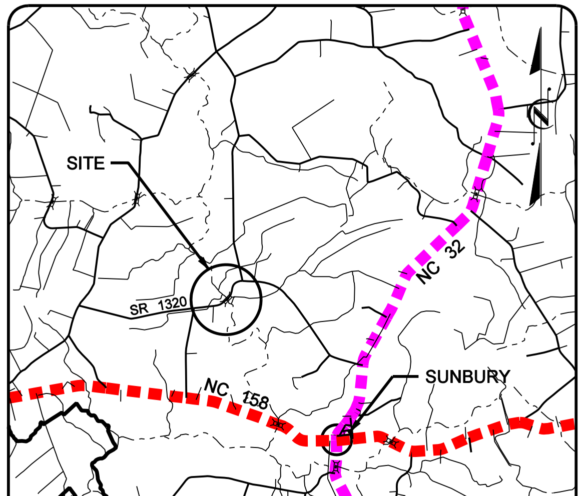
STATE	BAKER PROJECT REFERENCE NO.	SHEET NO.	TOTAL SHEETS
NC	109351	1	11
REVISIONS			
PER EEP COMMENTS DATED 3/4/08			

DUKE SWAMP WETLAND AND STREAM RESTORATION PROJECT
NC ECOSYSTEM ENHANCEMENT PROGRAM
PROJECT # D06065-A

GATES COUNTY

LOCATION: NINE MILES NORTHEAST OF GATESVILLE OFF SR 1320

TYPE OF WORK: AS-BUILT DRAWINGS FOR MITIGATION REPORT



VICINITY MAP

INDEX OF SHEETS

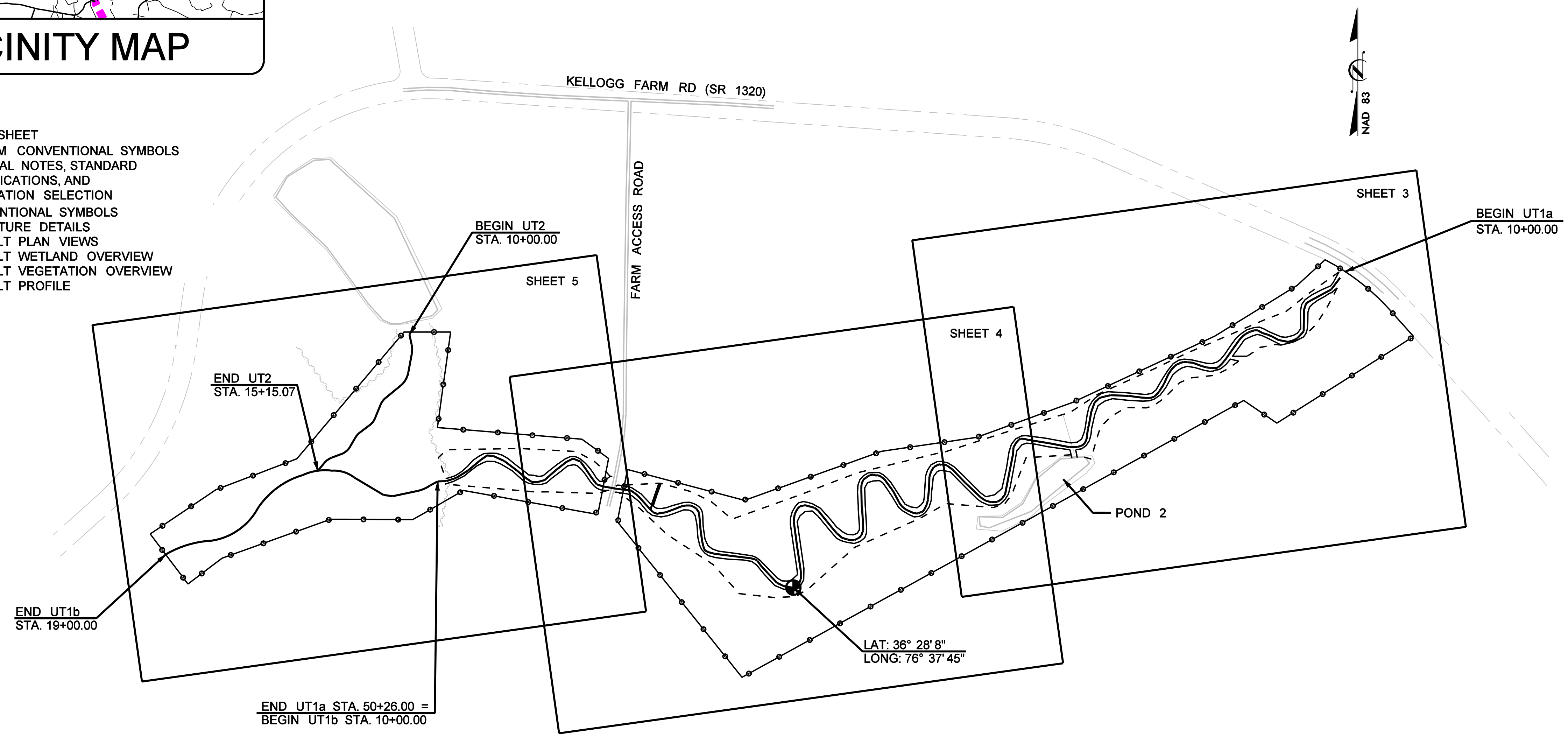


FIGURE 2A

GRAPHIC SCALES

100 25 0 50 100
PLANS

50 25 0 50 100
PROFILE (HORIZONTAL)

5 2.5 0 5 10
PROFILE (VERTICAL)

AS-BUILT SUMMARY (YEAR 0 - BASELINE DATA)

AS-BUILT UT1A DESIGN STREAM RESTORATION LENGTH (TOTAL)	=	4,026 FEET
AS-BUILT UT1B DESIGN STREAM RESTORATION LENGTH	=	900 FEET
AS-BUILT UT2 DESIGN STREAM RESTORATION LENGTH	=	515 FEET
AS-BUILT RIVERINE WETLAND ENHANCEMENT ACREAGE (AREAS #2 AND #3)	=	7.6 ACRES
AS-BUILT RIVERINE WETLAND RESTORATION ACREAGE (AREA #1)	=	12.0 ACRES

PREPARED FOR THE OFFICE OF:

Ecosystem Enhancement

NCDENR - ECOSYSTEM ENHANCEMENT PROGRAM
2728 CAPITAL BLVD, SUITE 1H 103
RALEIGH, NC 27604

NCEEP CONTACT: GUY PEARCE
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PROJECT ENGINEER

KAYNE VAN STELL
PROJECT MANAGER

DECEMBER 2007
COMPLETION DATE

PROJECT ENGINEER

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027337
MARCH 24, 2008

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P.E.

SIGNATURE:

BAKER PROJECT REFERENCE NO.	SHEET NO.
109351	3

PROJECT ENGINEER

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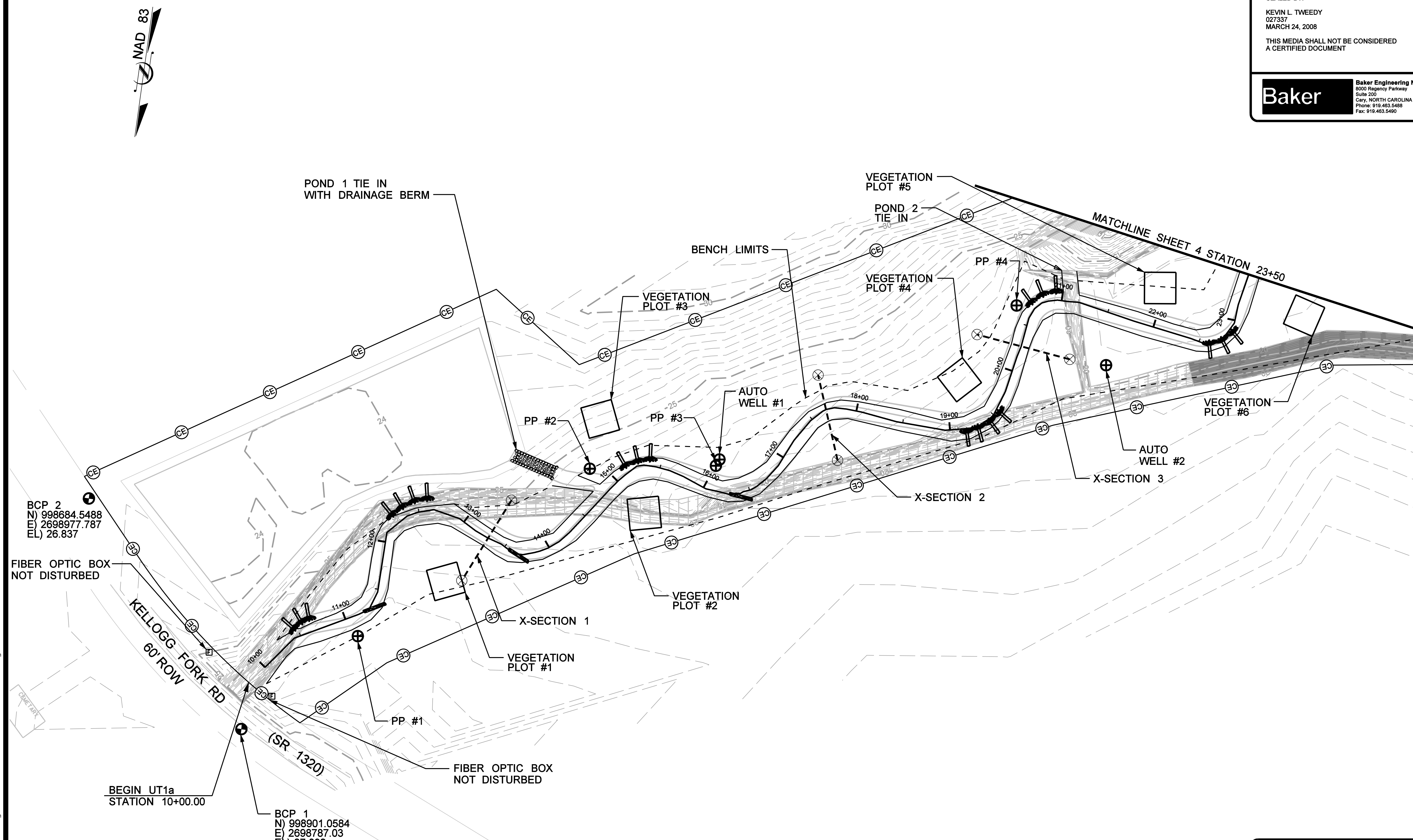

FILLED CHANNEL

DITCH PLUG

NOTE: CONTOURS SHOWN DEPICT PRE-CONSTRUCTION CONDITIONS.

FIGURE 2B

DUKE SWAMP AS-BUILT PLAN VIEW

50 25 0 50 100
SCALE (FT)

2/26/03

12/8/2008
r:\109351-Duke Swamp\Design\as-built\109351_BUCK_asb_PSH_03.dgn

BAKER PROJECT REFERENCE NO.	SHEET NO.
109351	4

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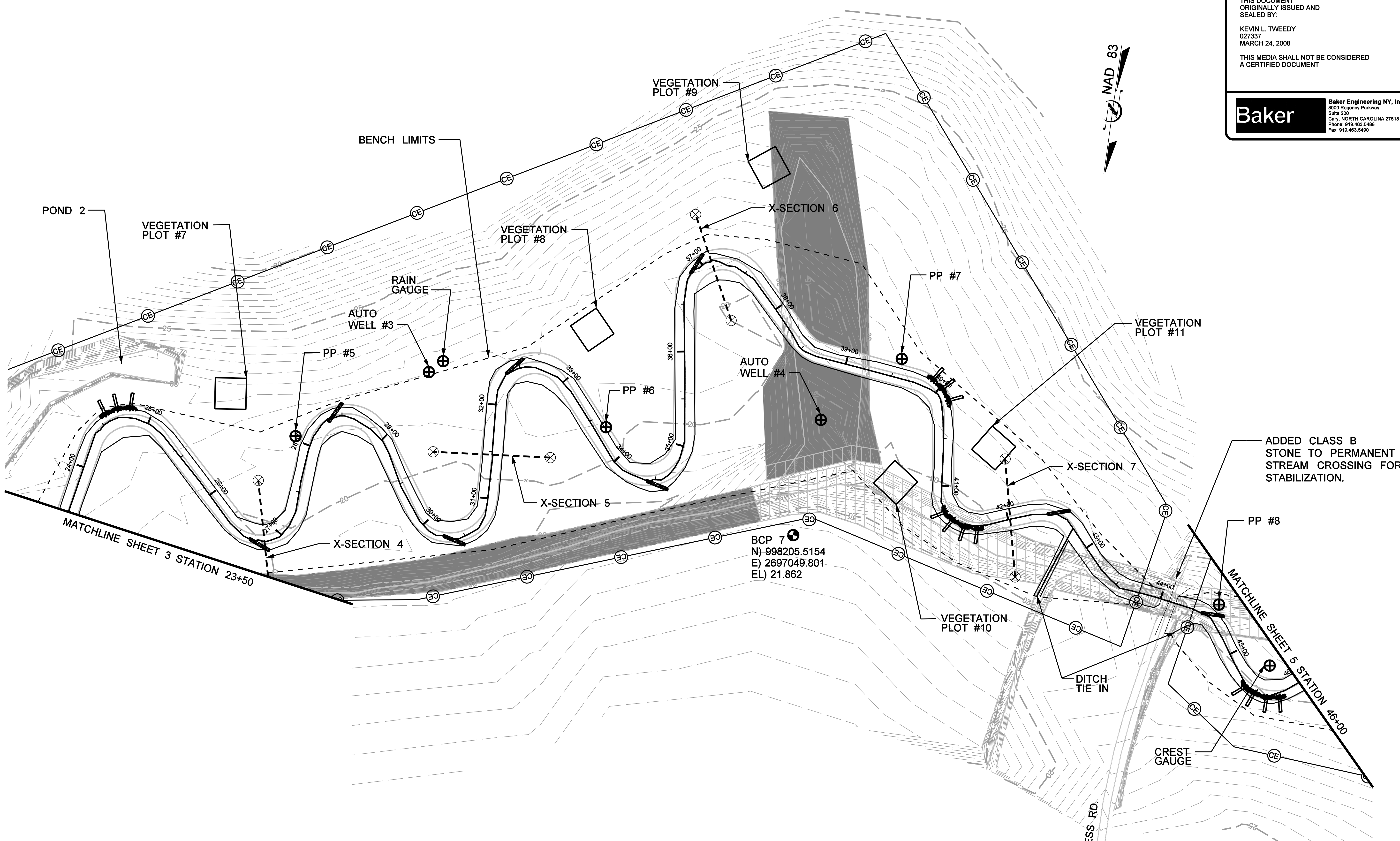

FILLED CHANNEL / POND

DITCH PLUG

FIGURE 2C

NOTE: CONTOURS SHOWN DEPICT PRE-CONSTRUCTION CONDITIONS.

DUKE SWAMP AS-BUILT PLAN VIEW

50 25 0 50 100
SCALE (FT)

2/26/03

12/8/2008
r:\109351-Duke Swamp\Design\as-built\109351_BUCK_asb_PSH_04.dgn

BAKER PROJECT REFERENCE NO.	SHEET NO.
109351	5

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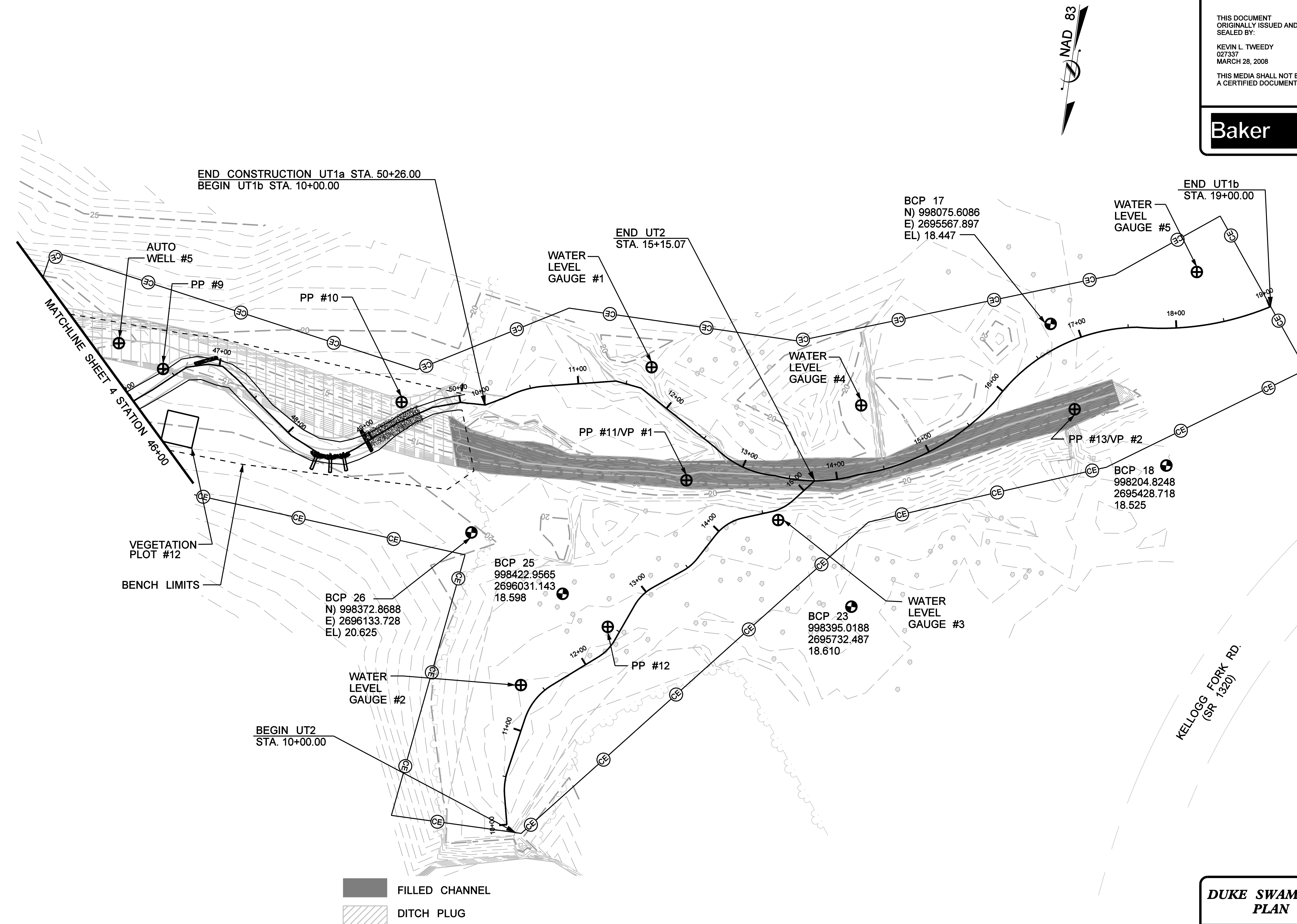

FIGURE 2D

NOTE: CONTOURS SHOWN DEPICT PRE-CONSTRUCTION CONDITIONS.

DUKE SWAMP AS–BUILT PLAN VIEW

50 25 0 50 100
SCALE (FT)

2/26/03
12/8/2008
r:\109351-Duke Swamp\Design\as-built\109351_BUCK_asb_PSH_05.dgn

BAKER PROJECT REFERENCE NO.	SHEET NO.
109351	6

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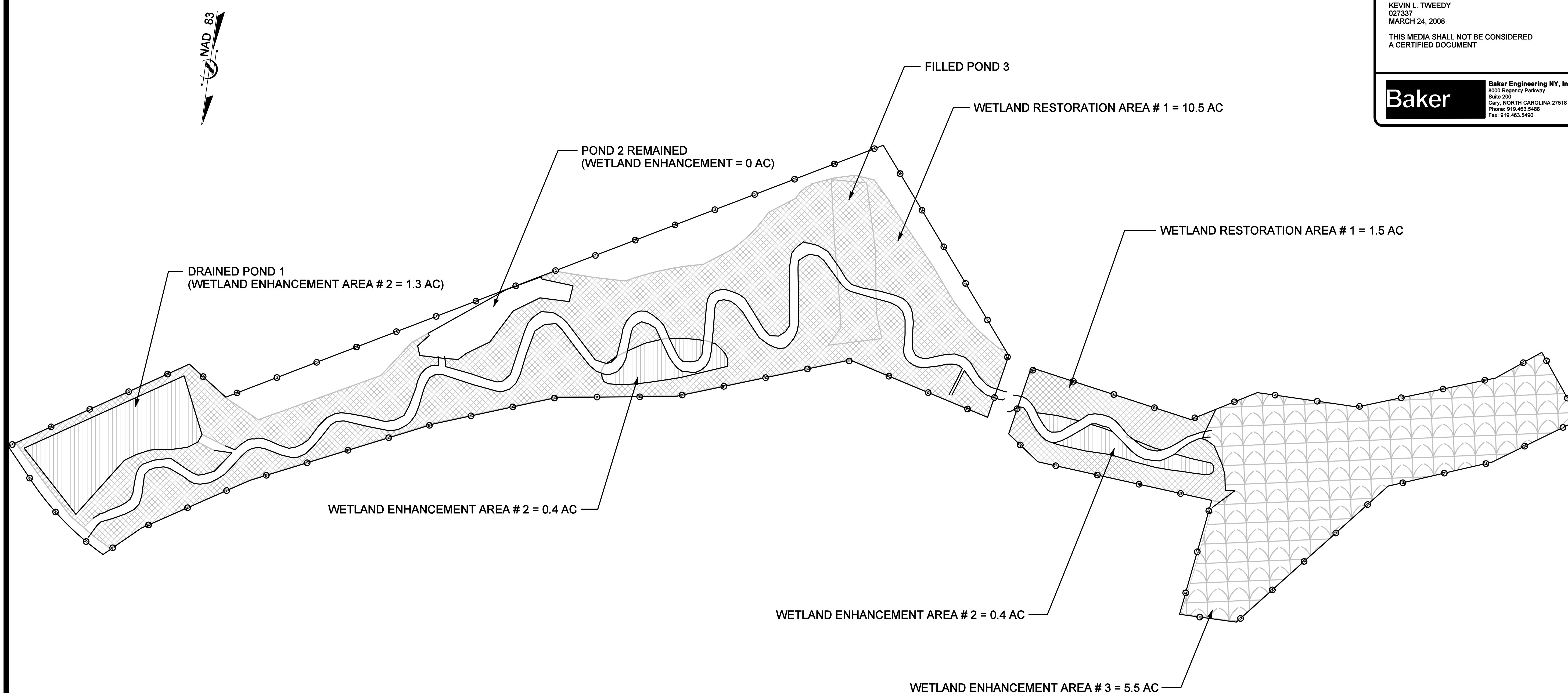

AS–BUILT WETLAND SUMMARY

AS–BUILT RIVERINE WETLAND RESTORATION ACREAGE (AREA #1)	= 12.0 ACRES
AS–BUILT RIVERINE WETLAND ENHANCEMENT ACREAGE (AREA #2)	= 2.1 ACRES
AS–BUILT RIVERINE WETLAND ENHANCEMENT ACREAGE (AREA #3)	= 5.5 ACRES

FIGURE 2E

DUKE SWAMP AS–BUILT WETLAND OVERVIEW

125 0 125 250
SCALE (FT)

BAKER PROJECT REFERENCE NO.	SHEET NO.
109351	7

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NOTES:

1. TOTAL PLANTING AREA = 17.2 AC.
2. TOTAL CONSERVATION EASEMENT AREA = 25.4 AC.
3. SEE VEGETATION SELECTION TABLES ON SHEET 1A.

NAD 83

CONSERVATION EASEMENT PLANTING

MATURE ENHANCEMENT AREA (AREA NOT PLANTED)

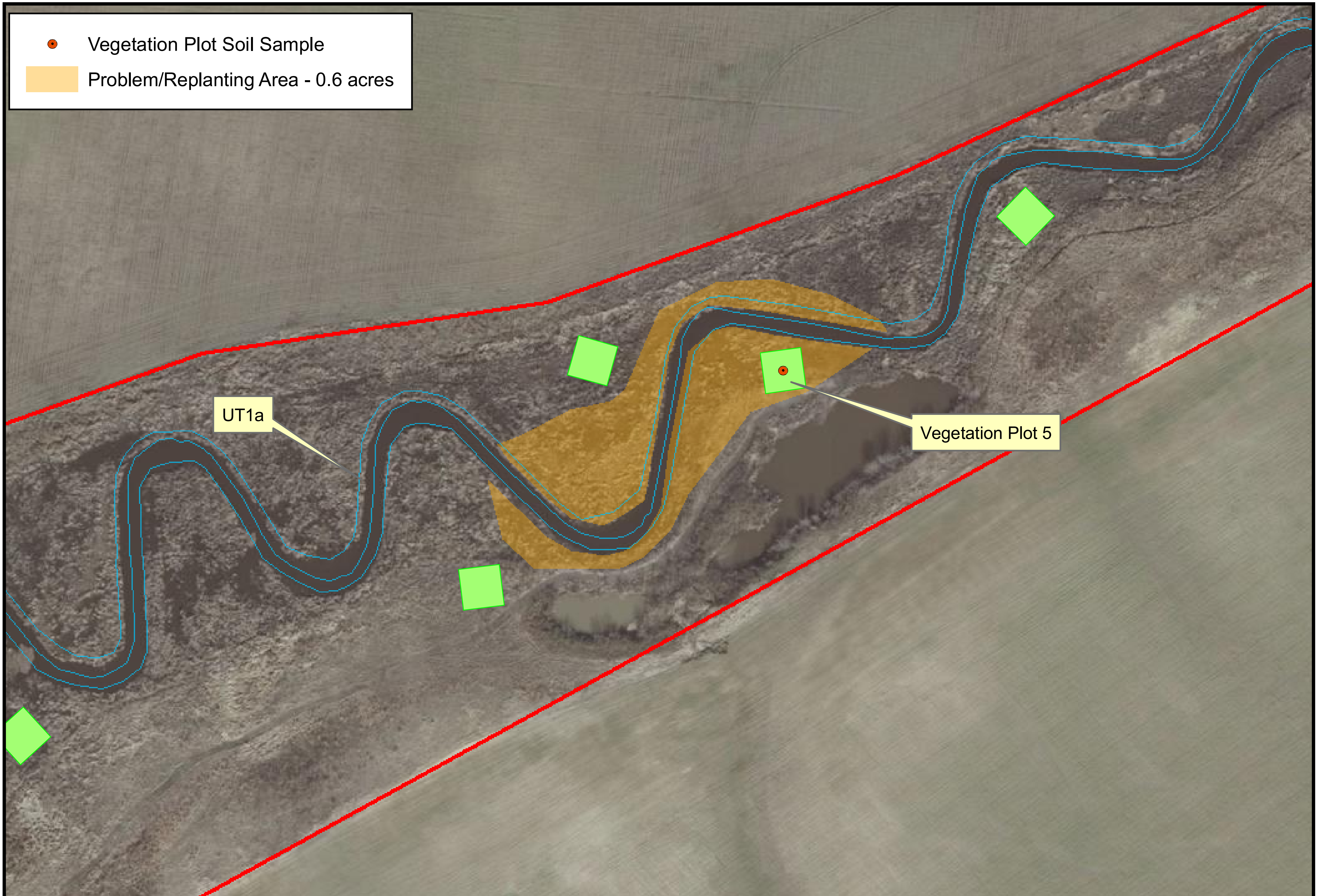
FIGURE 2F

DUKE SWAMP
AS-BUILT
VEGETATION OVERVIEW

125 0 125 250
SCALE (FT)

2/26/03

12/8/2008
r:\109351-Duke Swamp\Design\as-built\109351_BUCK_asb_PSH_07.dgn



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Ecosystem Enhancement Program

D06065-A

0 100 200 Feet

N

Figure 3.
Vegetation Plot 5 Map
Duke Swamp Site
Gates County, NC

APPENDIX A

VEGETATION DATA

VEGETATION

TABLES

Table A.1. Vegetation Metadata

Duke Swamp Restoration Site: Project No. D06065-A	
Report Prepared By	Dwayne Huneycutt
Date Prepared	12/6/2011 13:12
database name	Baker-2010-B-PinchGut_DukeSwamp.mdb
database location	L:\Monitoring\Veg Plot Info\CVS Data Tool\2010
computer name	CARYWDHUNEYCU2
file size	38309888
DESCRIPTION OF WORKSHEETS IN THIS DOCUMENT------------	
Metadata	Description of database file, the report worksheets, and a summary of project(s) and project data.
Proj, planted	Each project is listed with its PLANTED stems per acre, for each year. This excludes live stakes.
Proj, total stems	Each project is listed with its TOTAL stems per acre, for each year. This includes live stakes, all planted stems, and all natural/volunteer stems.
Plots	List of plots surveyed with location and summary data (live stems, dead stems, missing, etc.).
Vigor	Frequency distribution of vigor classes for stems for all plots.
Vigor by Spp	Frequency distribution of vigor classes listed by species.
Damage	List of most frequent damage classes with number of occurrences and percent of total stems impacted by each.
Damage by Spp	Damage values tallied by type for each species.
Damage by Plot	Damage values tallied by type for each plot.
Planted Stems by Plot and Spp	A matrix of the count of PLANTED living stems of each species for each plot; dead and missing stems are excluded.
PROJECT SUMMARY-------------------------------------	
Project Code	DS
project Name	Duke Swamp
Description	The Duke Swamp Stream and Wetland Restoration Site was restored through a full delivery contract with the North Carolina Ecosystem Enhancement Program (NCEEP).
River Basin	Chowan
length(ft)	5441
stream-to-edge width (ft)	45
area (sq m)	45489.08
Required Plots (calculated)	12
Sampled Plots	0

Table A.2. Vegetation Vigor by Species

Duke Swamp Restoration Site: Project No. D06065-A								
	Species	**4**	**3**	**2**	**1**	**0**	**Missing**	**Unknown**
	Betula nigra	10	1					
	Celtis laevigata		1					
	Fraxinus pennsylvanica		2					
	Nyssa sylvatica	4	7	8		11		
	Quercus lyrata	8	5	2		2		
	Quercus michauxii	1	2					
	Quercus phellos	5	4	1				
	Taxodium distichum	11	20	1		1		
	Platanus occidentalis	10	1			2		
	Unknown					4		
TOTAL	**10**	**49**	**43**	**12**		**20**		

Table A.3. Vegetation Damage by Species

Duke Swamp Restoration Site: Project No. D06065-A						
	Species	**Count of Damage Categories**	**(No Damage)**	**Deer**	**Unknown**	**Vine Strangulation**
	Betula nigra	0	11			
	Celtis laevigata	0	1			
	Fraxinus pennsylvanica	0	2			
	Nyssa sylvatica	15	15	3	1	11
	Platanus occidentalis	1	12			1
	Quercus lyrata	3	14			3
	Quercus michauxii	0	3			
	Quercus phellos	0	10			
	Taxodium distichum	2	31			2
	Unknown	2	2			2
TOTAL	**10**	**23**	**101**	**3**	**1**	**19**

Table A.4. Vegetation Damage by Plot

Duke Swamp Restoration Site: Project No. D06065-A						
	Plot	Count of Damage Categories	No Damage	Deer	Unknown	Vine Strangulation
	DS-B-0001-year:4	0	18			
	DS-B-0002-year:4	1	11		1	
	DS-B-0003-year:4	0	13			
	DS-B-0004-year:4	6	4	1		5
	DS-B-0005-year:4	9	4			9
	DS-B-0006-year:4	3	12	1		2
	DS-B-0007-year:4	0	12			
	DS-B-0008-year:4	1	10			1
	DS-B-0009-year:4	0	9			
	DS-B-0010-year:4	0	1			
	DS-B-0011-year:4	2	3			2
	DS-B-0012-year:4	1	4	1		
TOTAL	**12**	**23**	**101**	**3**	**1**	**19**

Table A.5. Planted Stems by Plot and Species

Duke Swamp Restoration Site: Project No. D06043-A																		
	Comment	Species	Common Name	Total Planted Stems	Number of Plots	Average number of Stems	plot DS-B-0001-year:4	plot DS-B-0002-year:4	plot DS-B-0003-year:4	plot DS-B-0004-year:4	plot DS-B-0005-year:4	plot DS-B-0006-year:4	plot DS-B-0007-year:4	plot DS-B-0008-year:4	plot DS-B-0009-year:4	plot DS-B-0010-year:4	plot DS-B-0011-year:4	plot DS-B-0012-year:4
		Betula nigra	river birch	11	4	2.75	1		3				6	1				
		Celtis laevigata	sugarberry	1	1	1			1									
		Fraxinus pennsylvanica	green ash	2	1	2			2									
		Nyssa sylvatica	blackgum	19	6	3.17		3		3		7		1			4	1
		Platanus occidentalis	American sycamore	11	4	2.75	4		4		1		2					
		Quercus lyrata	overcup oak	15	7	2.14		3		3	2	3		1	2	1		
		Quercus michauxii	swamp chestnut oak	3	2	1.5			1						2			
		Quercus phellos	willow oak	10	3	3.33			2				4		4			
		Taxodium distichum	bald cypress	32	8	4	13	3		3	1	3		6	1			2
	n/a: no stems			0	1													
TOTAL	**0**	**9**	**9**	**104**	**9**		**18**	**9**	**13**	**9**	**4**	**13**	**12**	**9**	**9**	**1**	**4**	**3**

Table A.6. Stem Count for Each Species Arranged by Plot
Duke Swamp Restoration Site: Project No. D06065-A

Tree Species	Plots 1	2	3	4	5	6	7	8	9	10	11	12	Year 4 Totals	Average Stems/acre
Betula nigra	1		3				6	1					11	
Celtis laevigata			1										1	
Fraxinus pennsylvanica			2										2	
Nyssa sylvatica		3		3		7		1			4	1	19	
Platanus occidentalis	4		4		1		2						11	
Quercus lyrata		3		3	2	3		1	2	1			15	
Quercus michauxii			1						2				3	
Quercus phellos			2				4		4				10	
Taxodium distichum	13	3		3	1	3		6	1			2	32	
Stems/plot	18	9	13	9	4	13	12	9	9	1	4	3		
Stems/acre Year 4	720	360	520	360	160	520	480	360	360	40	160	120		347
Stems/acre Year 3	720	360	520	360	120	600	440	440	360	0	200	80		350
Stems/acre Year 2	640	320	520	640	360	600	560	520	360	0	200	120		403
Stems/acre Year 1	680	120	600	400	80	200	520	480	360	0	360	40		320
Stems/acre Initial	688	607	648	688	769	729	688	850	1012	769	607	607		722

VEGETATION PHOTOGRAPHS

Vegetation Plot 1-Herbaceous

Vegetation Plot 1

Vegetation Plot 2-Herbaceous

Vegetation Plot 2

Vegetation Plot 3-Herbaceous

Vegetation Plot 3

Vegetation Plot 4-Herbaceous

Vegetation Plot 4

Vegetation Plot 5- Herbaceous

Vegetation Plot 5

Vegetation Plot 6- Herbaceous

Vegetation Plot 6

Vegetation Plot 7- Herbaceous

Vegetation Plot 7

Vegetation Plot 8-Herbaceous

Vegetation Plot 8

Vegetation Plot 9-Herbaceous

Vegetation Plot 9

Vegetation Plot 10-Herbacious

Vegetation Plot 10

Vegetation Plot 11-Herbaceous

Vegetation Plot 11

Vegetation Plot 12-Herbaceous

Vegetation Plot 12

APPENDIX B

GEOMORPHIC
DATA

STREAM TABLES

Table B.1. Categorical Stream Feature Visual Stability Assessment

Duke Swamp Restoration Site: Project No. D06065-A						
	Performance Percentage					
Feature	**Initial**	**MY-01**	**MY-02**	**MY-03**	**MY-04**	**MY-05**
A. Riffles	100%	100%	100%	100%	100%	
B. Pools	100%	100%	100%	100%	100%	
C. Thalweg	100%	100%	100%	100%	100%	
D. Meanders	100%	100%	100%	100%	100%	
E. Bed General	100%	100%	100%	100%	100%	
F. Bank Condition	100%	90%	95%	95%	95%	
G. Wads	100%	100%	100%	100%	100%	

Table B.2. Baseline Stream Summary

Duke Swamp Wetland and Stream Restoration Project, EEP Project D06065-A

Duke Swamp - Reach UT1a

Parameter	USGS Gauge		Regional Curve Interval			Pre-Existing Condition			Reference Reach(es) Data			Design			As-built		
Dimension - Riffle	-----	-----	LL	UL	Eq.	Min	Mean	Max	Min	Mean	Max	Min	Med	Max	Min	Mean	Max
BF Width (ft)	-----	-----	-----	-----	-----	17.9	18.8	19.6	16.8	18.7	20.5		19.4		17.7	20.5	23.4
Floodprone Width (ft)	-----	-----	-----	-----	-----	151.0	166.0	181.0	174.0	195.0	216.0	50.0	75.0	100.0	85.0	104.9	124.9
BF Mean Depth (ft)	-----	-----	-----	-----	-----	2.3	3.0	3.8	1.2	1.4	1.5	-----	1.4	-----	1.2	1.6	1.9
BF Max Depth (ft)	-----	-----	-----	-----	-----	4.0	4.7	5.4	2.1	2.3	2.4	1.8	2.2	2.5	2.1	2.2	2.3
BF Cross-sectional Area (ft^2)	-----	-----	-----	-----	-----	40.0	57.0	74.0	24.8	25.3	25.7	-----	27.0	-----	25.4	29.0	32.7
Width/Depth Ratio	-----	-----	-----	-----	-----	5.2	6.6	8.0	11.0	14.0	17.0	-----	14.0	-----	12.6	14.7	16.8
Entrenchment Ratio	-----	-----	-----	-----	-----	7.7	8.9	10.1	10.4	10.5	10.6	8.0	10.0	12.0	5.3	5.9	6.4
Bank Height Ratio	-----	-----	-----	-----	-----	1.2	1.3	1.3	1.2	1.3	1.3	-----	1.0	-----	1.0	1.0	1.0
BF Velocity (fps)	-----	-----	-----	-----	-----	-----	-----	-----				-----	1.0	-----	-----	-----	-----
Pattern																	
Channel Beltwidth (ft)	-----	-----	-----	-----	-----	-----	-----	-----	49	77	105	49	77	105	-----	-----	-----
Radius of Curvature (ft)	-----	-----	-----	-----	-----	-----	-----	-----	30	35	40	30	45	60	-----	-----	-----
Meander Wavelength (ft)	-----	-----	-----	-----	-----	-----	-----	-----	92	109	125	92	109	125	-----	-----	-----
Meander Width Ratio	-----	-----	-----	-----	-----	-----	-----	-----	3	5	6	5	7	8	-----	-----	-----
Profile																	
Riffle Length (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Riffle Slope (ft/ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.0003	-----	-----	-----	-----
Pool Length (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Pool Spacing (ft)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	55	77.5	100	-----	-----	-----
Substrate and Transport Parameters																	
d16 / d35 / d50 / d84 / d95	-----	-----	-----	-----	-----		.06/.08/.10/.18/.23			.3/.4/.5/.9/1.2			.06/.08/.10/.18/.23		-----	-----	-----
Reach Shear Stress (competency) lb/f²	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Stream Power (transport capacity) W/m²	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Additional Reach Parameters																	
Channel length (ft)	-----	-----	-----	-----	-----	-----	2,860	-----	-----	-----	-----	-----	3,983	-----	-----	4,026	-----
Drainage Area (SM)	-----	-----	-----	-----	-----	-----	2.9	-----	-----	3.2	-----	-----	2.9	-----	-----	2.9	-----
Rosgen Classification	-----	-----	-----	-----	-----	-----	E5	-----	-----	E5/C5	-----	-----	C5	-----	-----	C5	-----
BF Discharge (cfs)	-----	-----	-----	-----	-----	-----	-----	-----	-----	25.8	-----	-----	25.6	-----	-----	25.6	-----
Sinuosity	-----	-----	-----	-----	-----	-----	1.05	-----	-----	1.66	-----	-----	1.6	-----	-----	1.6	-----
BF slope (ft/ft)	-----	-----	-----	-----	-----	-----	0.0003	-----	-----	0.0004	-----	-----	0.0003	-----	-----	0.0003	-----

Table B.3. Morphology and Hydraulic Monitoring Summary

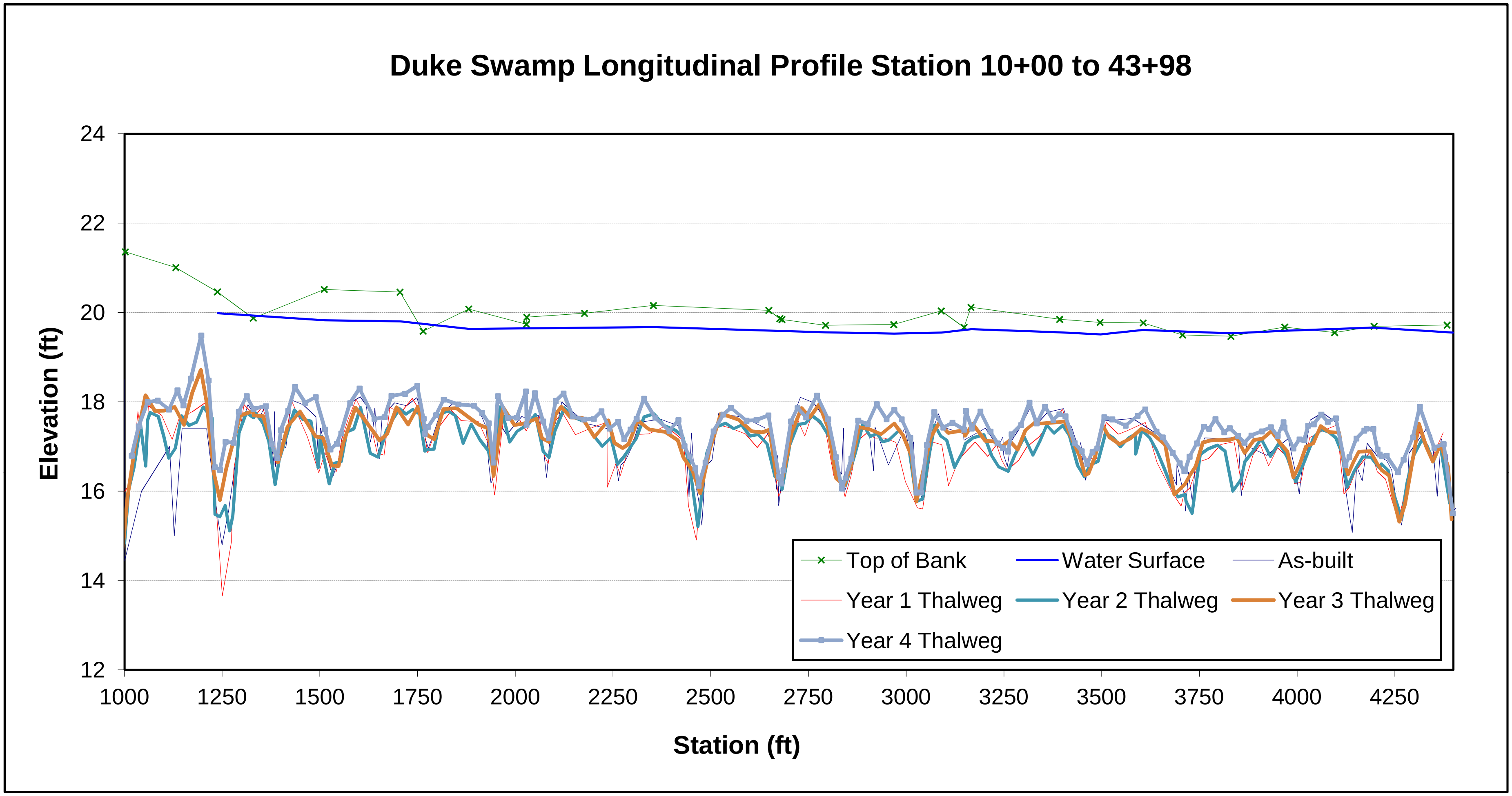
Duke Swamp Wetland and Stream Restoration Project, EEP Project No. D06065-A

Reach: UT1a (4026 Feet)

Parameter	Cross-section 1 Riffle					Cross-section 2 Pool					Cross-section 3 Riffle					Cross-section 4 Pool				
	MY1	MY2	MY3	MY4	MY5	MY1	MY2	MY3	MY4	MY5	MY1	MY2	MY3	MY4	MY5	MY1	MY2	MY3	MY4	MY5
Dimension																				
BF Width (ft)	17.01	19.81	17.38	15.21		16.79	20.59	12.70	14.90		18.07	18.96	18.53	17.35		25.10	30.84	24.48	23.20	
BF Mean Depth (ft)	1.44	1.23	1.34	1.44		1.41	1.12	1.48	1.27		1.69	1.44	1.51	1.20		1.91	1.64	1.80	2.02	
Width/Depth Ratio	11.8	16.1	13.0	10.6		11.9	18.4	8.6	11.7		10.7	13.15	12.26	14.51		13.12	18.86	13.6	11.51	
BF Cross-sectional Area (ft^2)	24.5	24.4	23.3	21.9		23.6	23.1	18.8	18.9		30.5	27.3	28.0	20.7		48.0	50.4	44.1	46.8	
BF Max Depth (ft)	2.27	2.21	2.06	1.96		2.64	2.66	2.21	2.26		2.57	2.24	2.29	2.17		3.61	3.51	3.4	3.43	
Width of Floodprone Area (ft)	98.43	98.44	98.49	98.57		91.28	91.29	91.24	91.37		108.22	108.55	108.21	108.28		111.31	111.28	111.37	111.38	
Entrenchment Ratio	5.8	5.0	5.7	6.5		5.0	4.1	6.5	5.5		5.5	5.3	5.4	5.8		4.4	3.6	4.5	4.8	
Bank Height Ratio	1.0	1.0	1.0	1.1		1.0	0.9	1.0	1.1		1.0	1.0	0.9	1.1		1.0	1.0	1.0	1.1	
Wetted Perimeter (ft)	19.89	22.27	20.06	18.09		19.61	22.83	15.66	17.44		21.45	21.84	21.55	19.75		28.92	34.12	28.08	27.24	
Hydraulic Radius (ft)	1.2318	1.0956	1.1615	1.2106		1.2035	1.012	1.2005	1.0837		1.4219	1.25	1.2993	1.0481		1.66	1.477	1.5705	1.7181	
Substrate																				
d50 (mm)																				
d84 (mm)																				

Parameter	Cross-section 5 Riffle					Cross-section 6 Pool					Cross-section 7 Riffle									
	MY1	MY2	MY3	MY4	MY5	MY1	MY2	MY3	MY4	MY5	MY1	MY2	MY3	MY4	MY5					
Dimension																				
BF Width (ft)	19.62	19.47	18.47	18.76		29.30	37.17	30.77	30.67		26.95	25.26	24.49	27.17						
BF Mean Depth (ft)	1.67	1.53	1.53	1.40		1.39	1.15	1.27	1.14		1.38	1.52	1.47	1.24						
Width/Depth Ratio	11.7	12.7	12.1	13.5		21.0	32.3	24.3	26.8		19.6	16.67	16.61	21.87						
BF Cross-sectional Area (ft^2)	32.8	29.9	28.3	26.2		40.9	42.7	39.0	35.1		37.1	38.3	36.1	33.8						
BF Max Depth (ft)	2.60	1.53	2.02	2.00		2.78	2.82	2.58	2.36		2.66	2.56	2.47	2.16						
Width of Floodprone Area (ft)	118.59	123.64	123.76	123.66		139.89	139.82	139.85	139.96		124.88	124.89	124.86	124.86						
Entrenchment Ratio	6.0	6.3	6.7	6.6		4.0	3.2	3.8	3.8		4.6	4.9	5.1	4.6						
Bank Height Ratio	1.0	1.0	1.0	1.1		1.2	1.0	1.1	1.1		1.0	1.0	1.0	1.1						
Wetted Perimeter (ft)	22.96	22.53	21.53	21.56		32.08	39.47	33.31	32.95		29.71	28.3	27.43	29.65						
Hydraulic Radius (ft)	1.4286	1.3271	1.3144	1.2152		1.2749	1.082	1.1708	1.0653		1.2487	1.3534	1.3161	1.1400						
Substrate																				
d50 (mm)																				
d84 (mm)																				

STREAM DATA
AND PHOTOGRAPHS

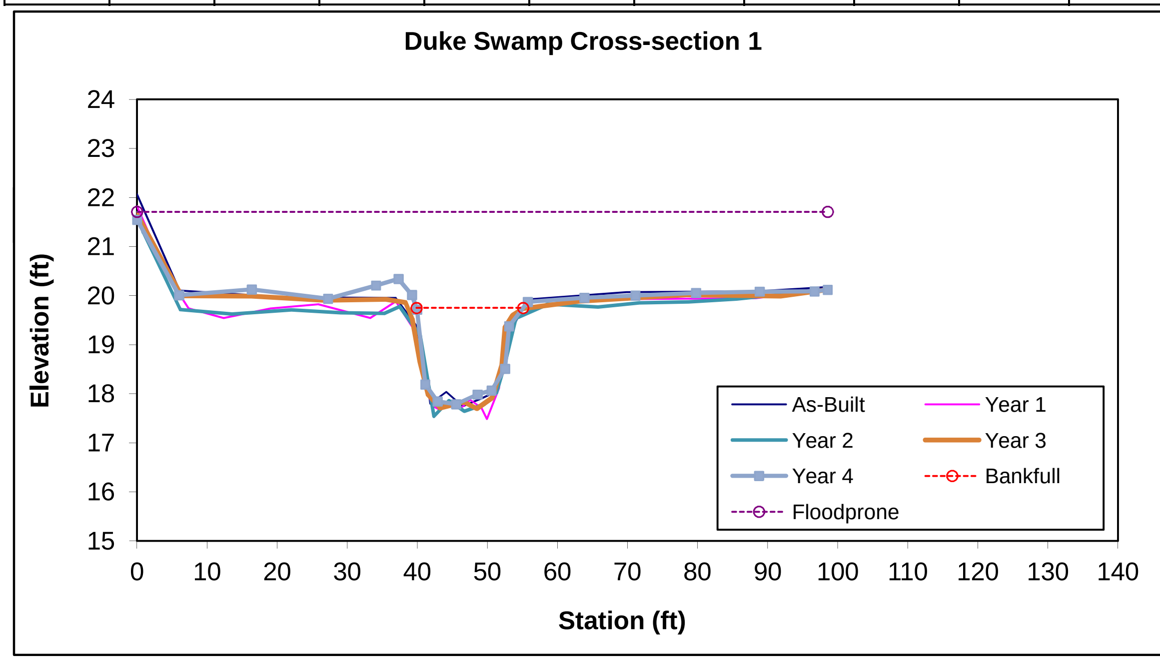

Duke Swamp Longitudinal Profile Station 10+00 to 43+98
Elevation (ft)
Station (ft)
24
22
20
18
16
14
12
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
4250
Top of Bank
Water Surface
As-built
Year 1 Thalweg
Year 2 Thalweg
Year 3 Thalweg
Year 4 Thalweg

Permanent Cross-section 1, Station 13+30
(Year 4 Data - Collected November 2011)

Looking at the Left Bank

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	E	21.9	15.21	1.44	1.96	10.56	1.1	6.5	19.75	19.87



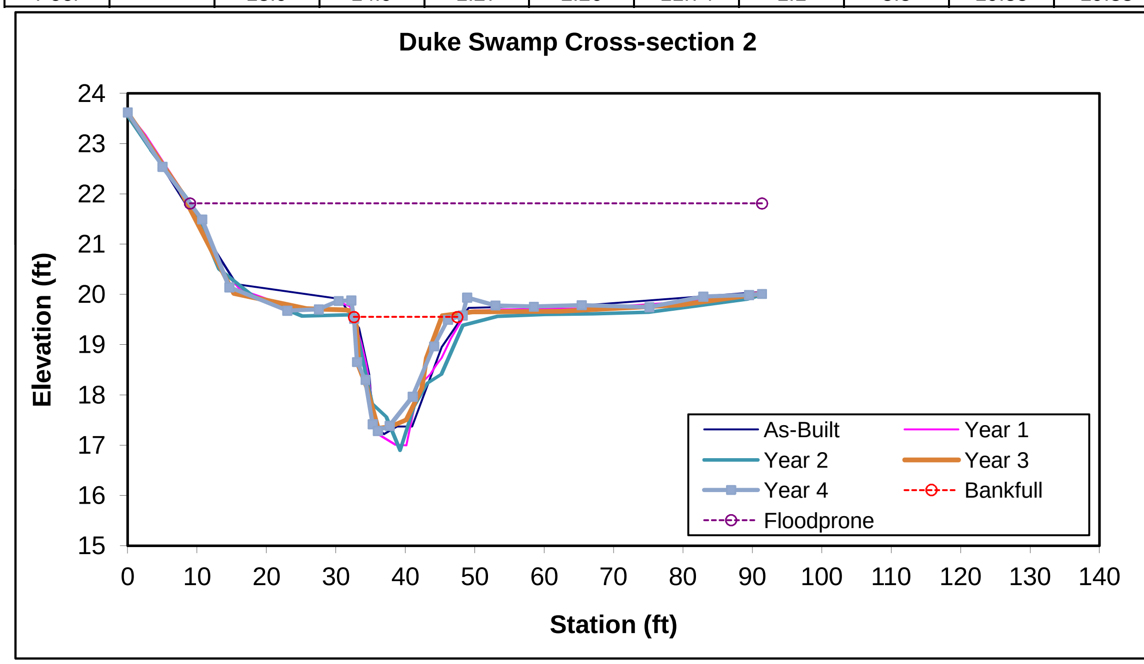
Permanent Cross-section 2, Station 17+69

(Year 4 Data - Collected November 2011)

Looking at the Left Bank

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		18.9	14.9	1.27	2.26	11.74	1.1	5.5	19.55	19.88



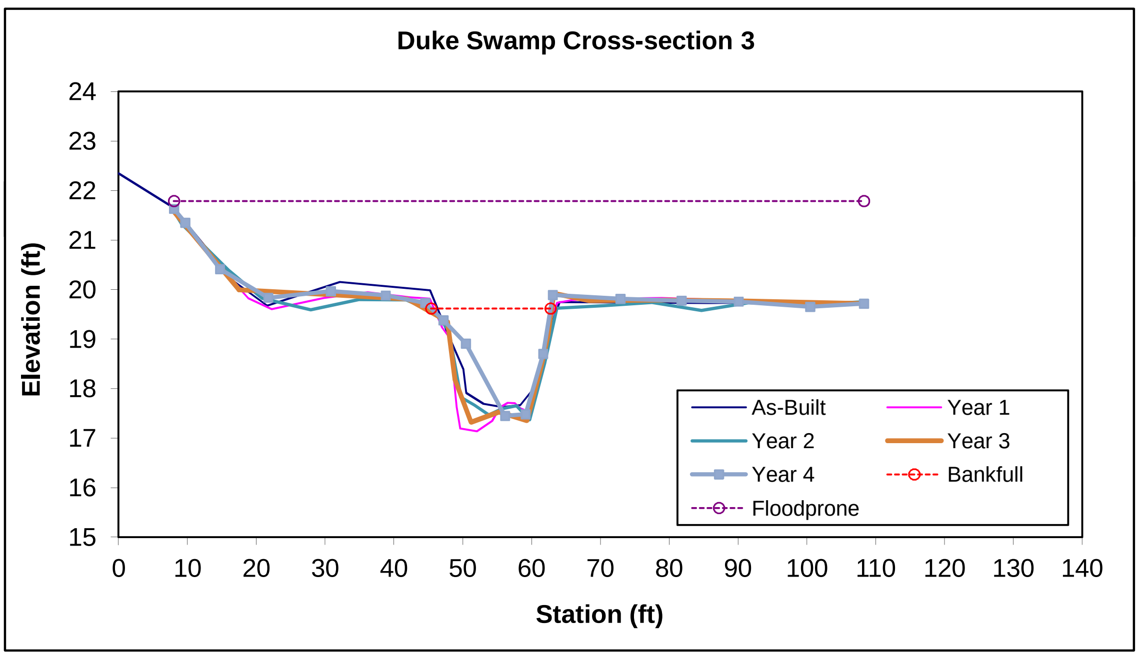
Permanent Cross-section 3, Station 20+27

(Year 4 Data - Collected November 2011)

Looking at the Left Bank

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	Cc	20.7	17.35	1.2	2.17	14.51	1.1	5.8	19.62	19.73

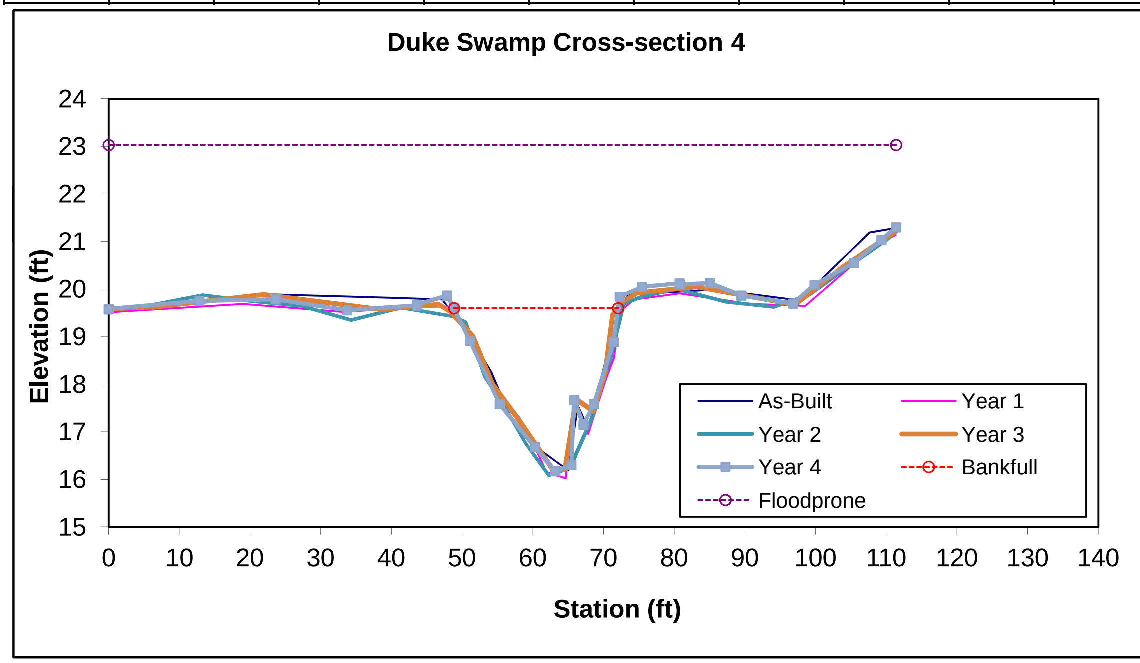


Permanent Cross-section 4, Station 26+81
(Year 4 Data - Collected November 2011)


Looking at the Left Bank

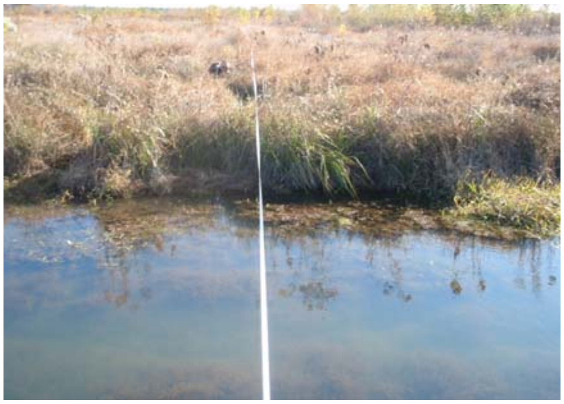

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		46.8	23.2	2.02	3.43	11.51	1.1	4.8	19.6	19.84



Permanent Cross-section 5, Station 31+47

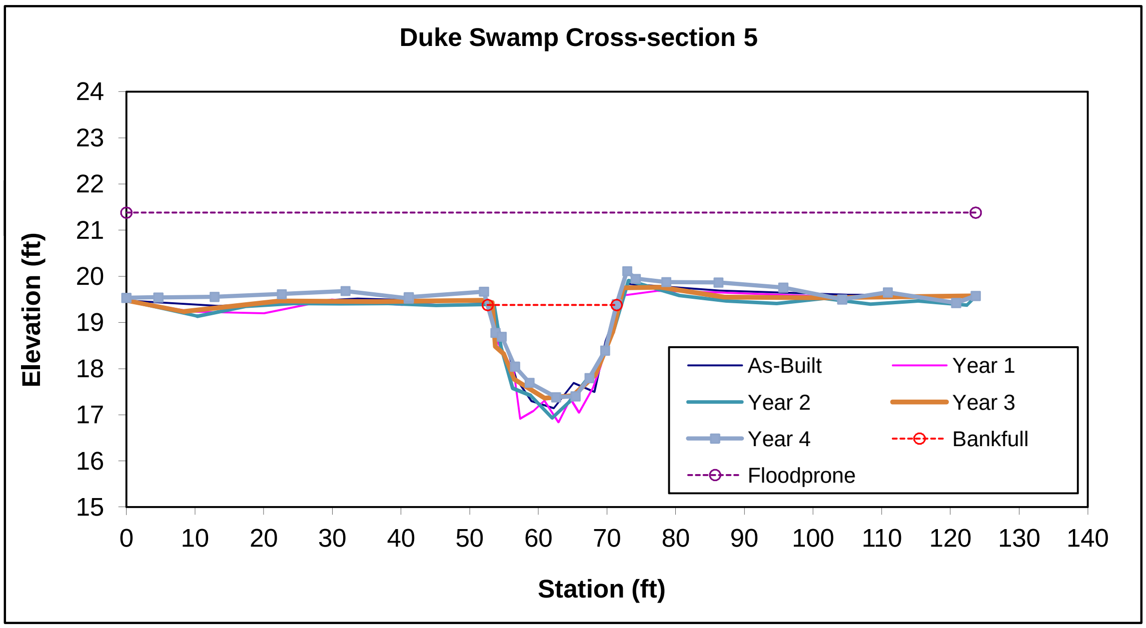
(Year 4 Data - Collected November 2011)



Looking at the Left Bank

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	Cc	26.2	18.76	1.4	2	13.45	1.1	6.6	19.38	19.67

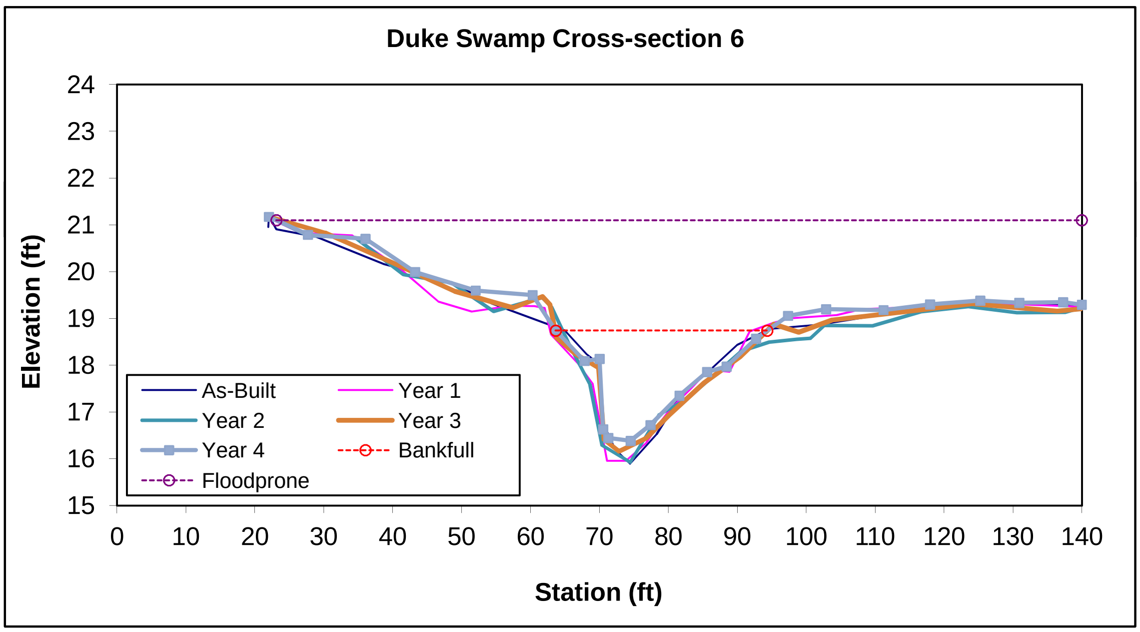


Permanent Cross-section 6, Station 37+13
(Year 4 Data - Collected November 2011)

Looking at the Left Bank

Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		35.1	30.67	1.14	2.36	26.81	1.1	3.8	18.74	19.06



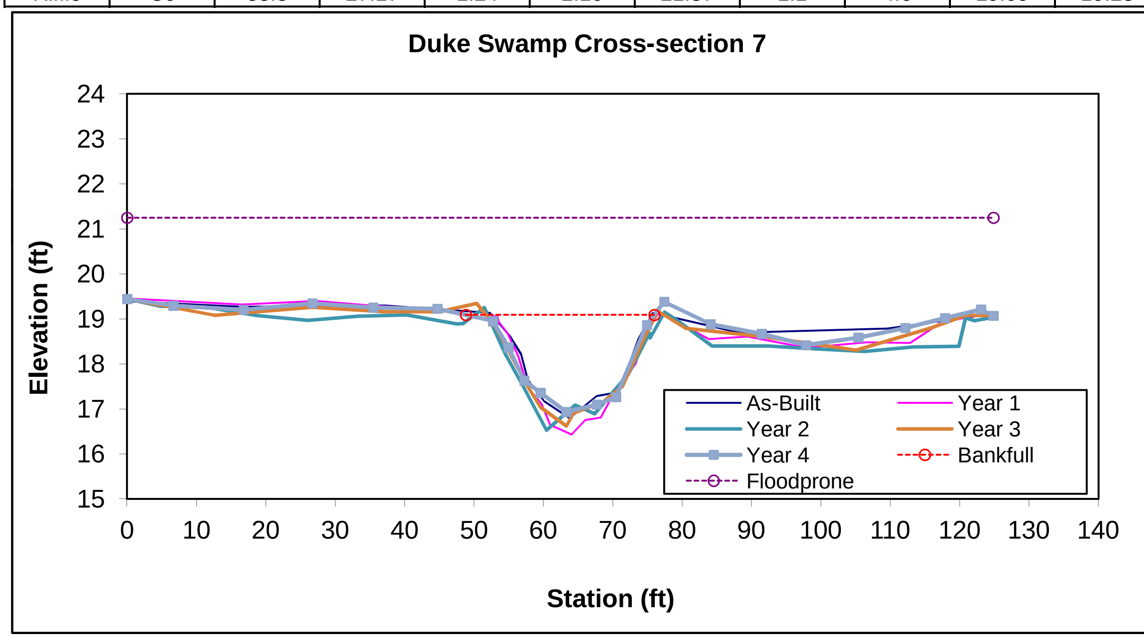
Permanent Cross-section 7, Station 42+05

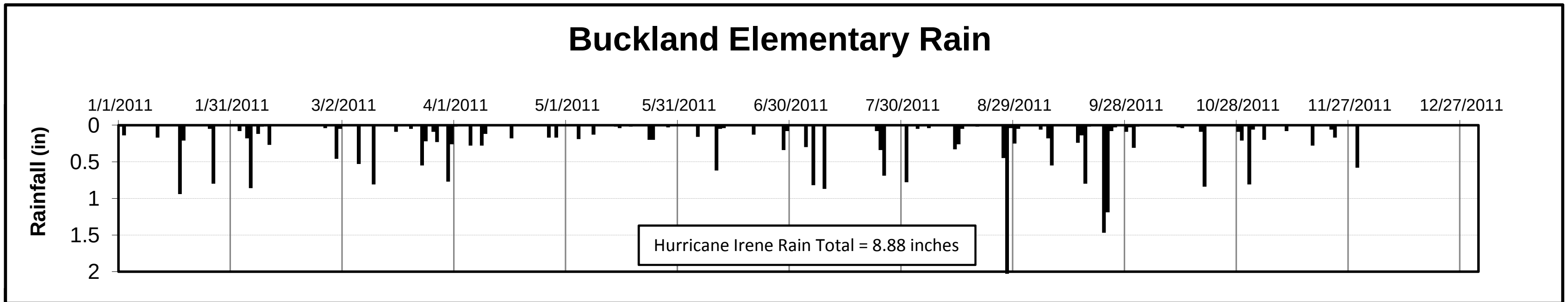
(Year 4 Data - Collected November 2011)

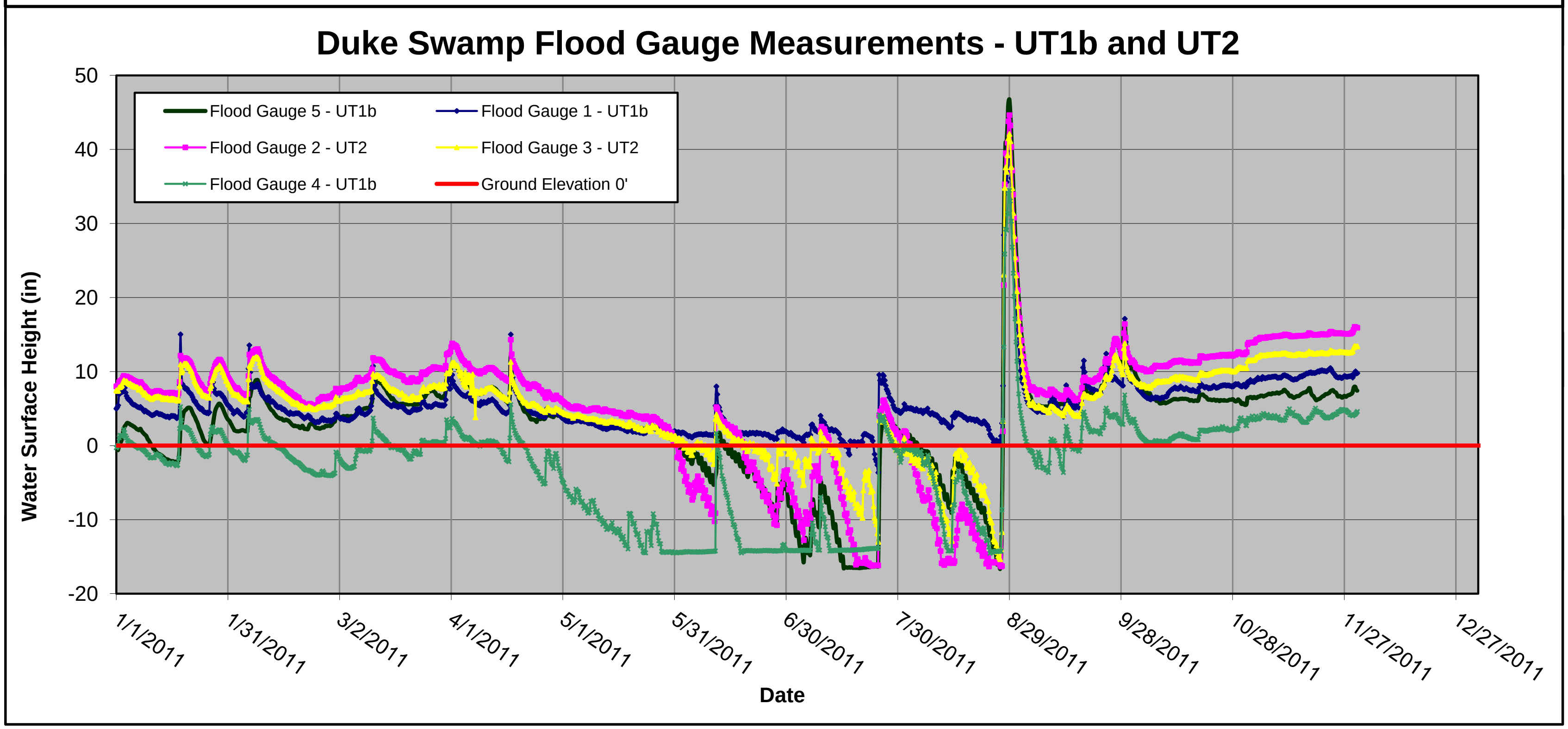
Looking at the Left Bank

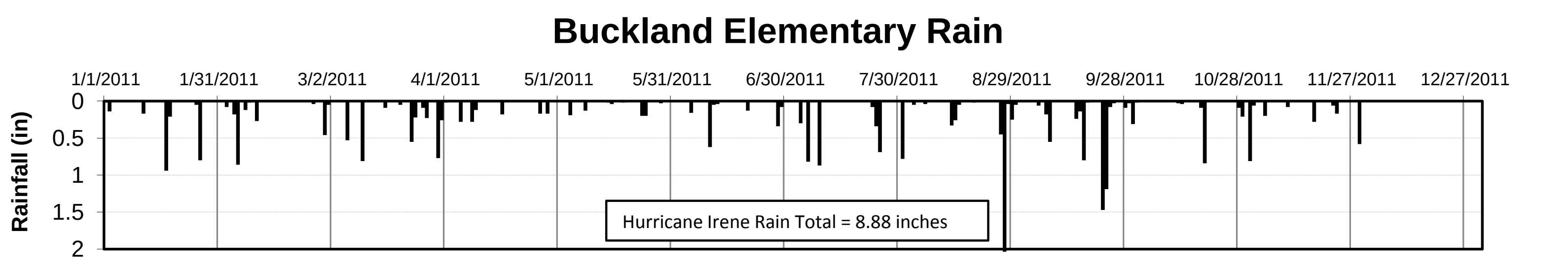
Looking at the Right Bank

Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	Cc	33.8	27.17	1.24	2.16	21.87	1.1	4.6	19.09	19.23

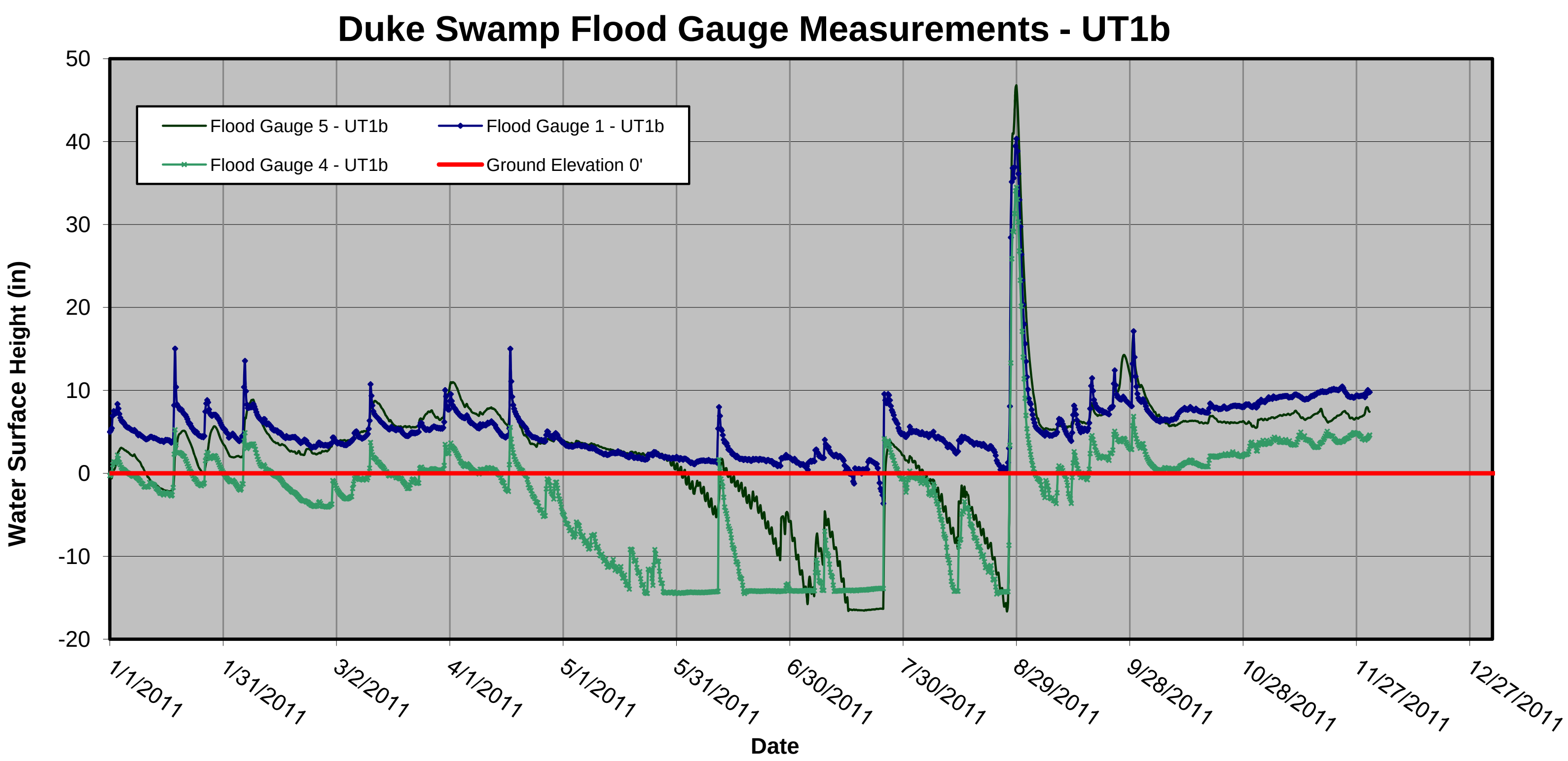



Buckland Elementary Rain
Rainfall (in)
0
0.5
1
1.5
2
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
Hurricane Irene Rain Total = 8.88 inches

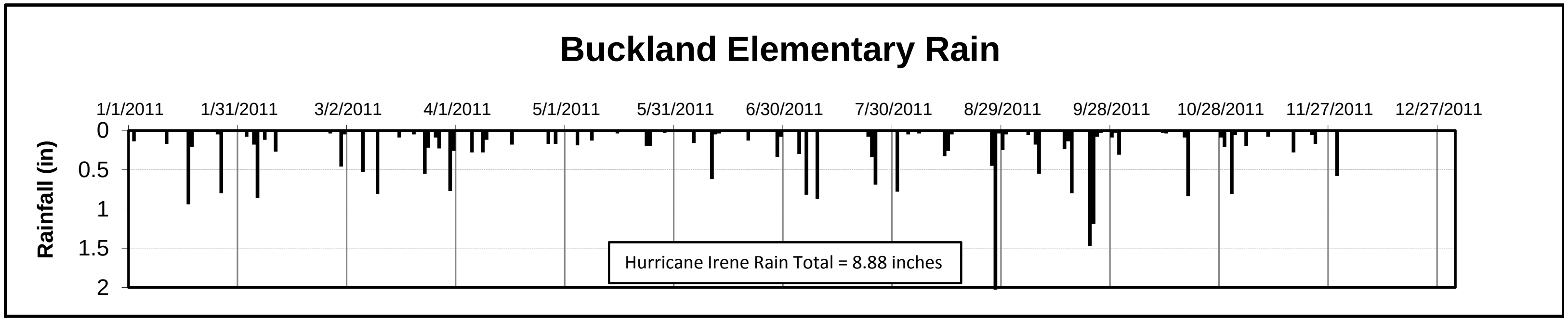

Duke Swamp Flood Gauge Measurements - UT1b and UT2
Water Surface Height (in)
50
40
30
20
10
0
-10
-20
Flood Gauge 5 - UT1b
Flood Gauge 1 - UT1b
Flood Gauge 2 - UT2
Flood Gauge 3 - UT2
Flood Gauge 4 - UT1b
Ground Elevation 0'
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
Date



Buckland Elementary Rain
Rainfall (in)
0
0.5
1
1.5
2
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
Hurricane Irene Rain Total = 8.88 inches



Duke Swamp Flood Gauge Measurements - UT1b
Water Surface Height (in)
50
40
30
20
10
0
-10
-20
Flood Gauge 5 - UT1b
Flood Gauge 1 - UT1b
Flood Gauge 4 - UT1b
Ground Elevation 0'
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
Date


Buckland Elementary Rain
Rainfall (in)
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
0
0.5
1
1.5
2
Hurricane Irene Rain Total = 8.88 inches

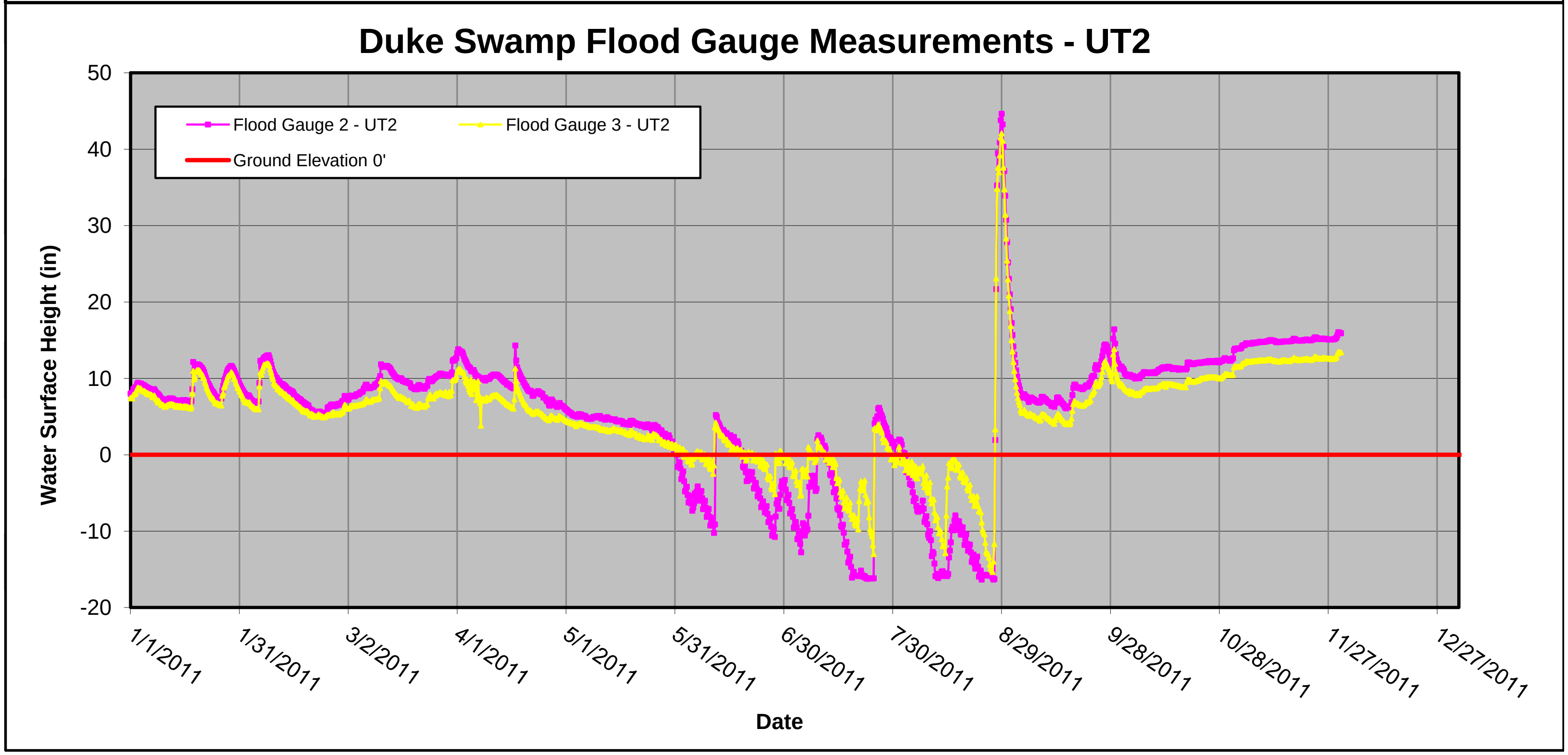

Duke Swamp Flood Gauge Measurements - UT2
Flood Gauge 2 - UT2
Flood Gauge 3 - UT2
Ground Elevation 0'
Water Surface Height (in)
50
40
30
20
10
0
-10
-20
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
12/27/2011
Date

Photo Point 1

Photo Point 2

Photo Point 3

Photo Point 4

Photo Point 5

Photo Point 6

Photo Point 7

Photo Point 8

Photo Point 9

Photo Point 10

Photo Point 11

Photo Point 12

Photo Point 13

Hurricane Irene flood waters at crest gauge
(Storm event occurred on August 27, 2011)

Crest Gauge – 2.90 feet, following Hurricane Irene
(Storm event occurred on August 27, 2011)

Strong upstream bankfull evidence at station 22+50
(Storm event occurred in August 27, 2011)

UT2 flowing south across fill area to UT1b
(Storm event occurred in August 27, 2011)

Flood gauge 1 with wrack from Hurricane Irene
(Storm event occurred in August 27, 2011)

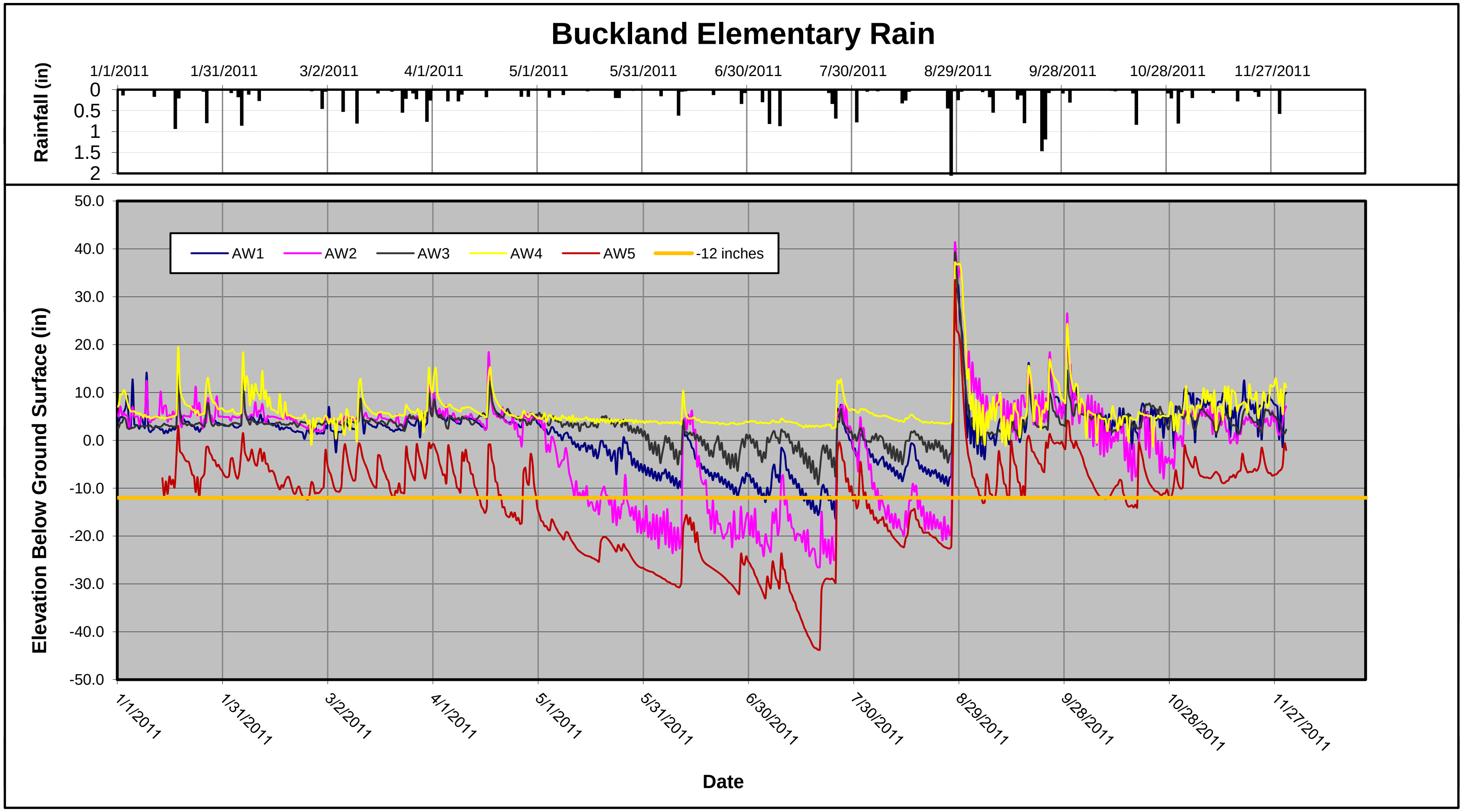
APPENDIX C

WETLAND

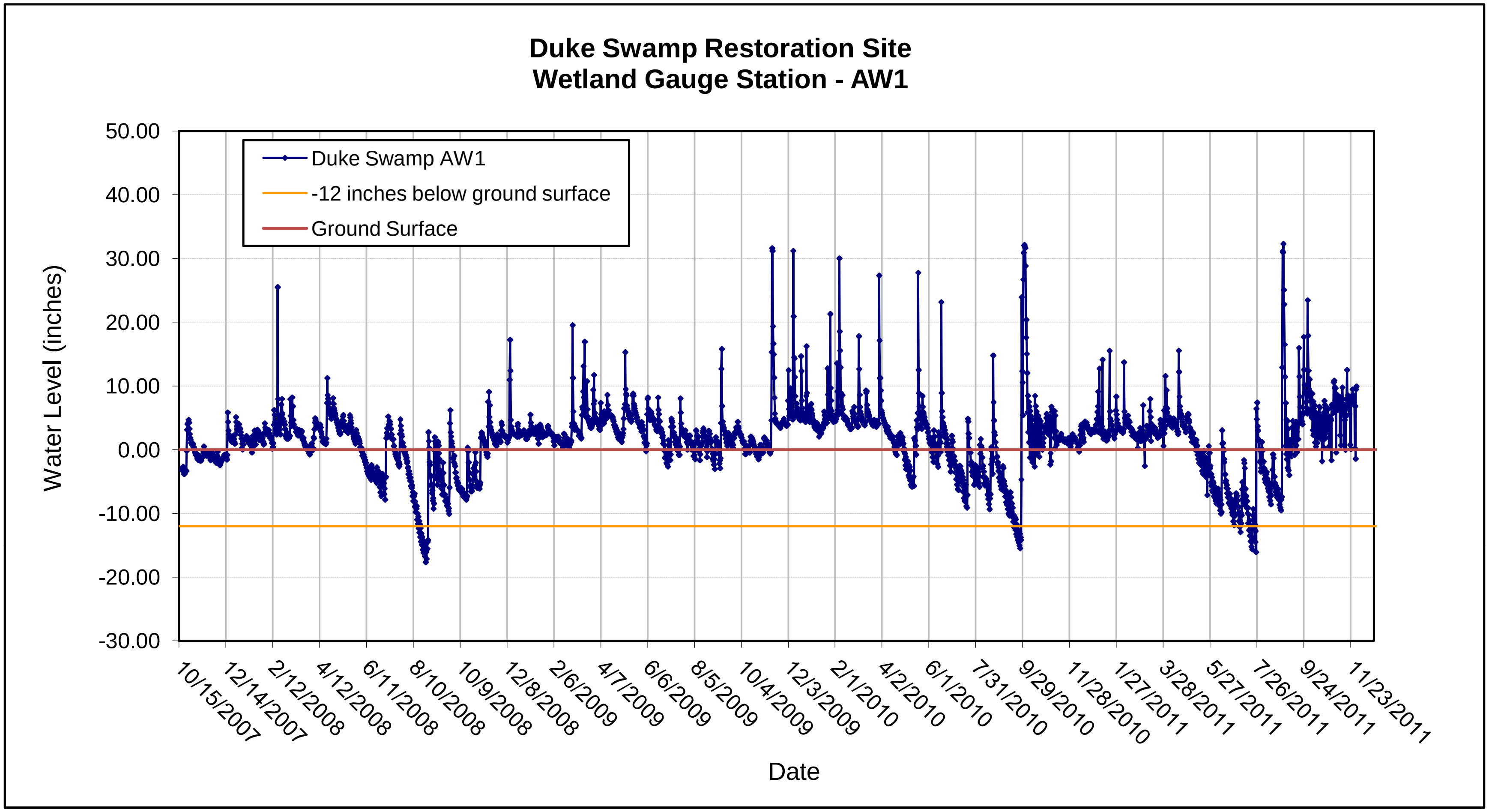
DATA

WETLAND

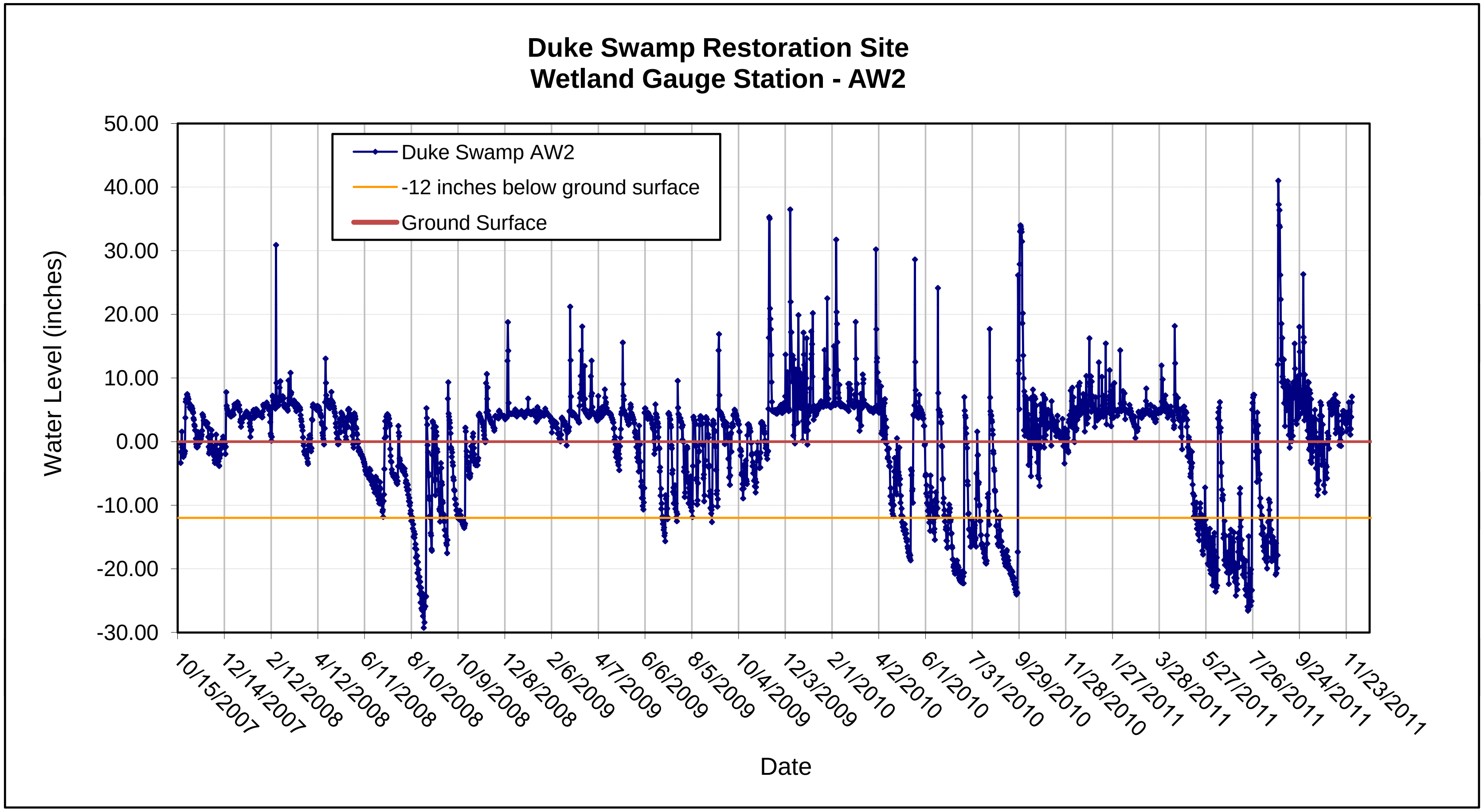
WELL DATA



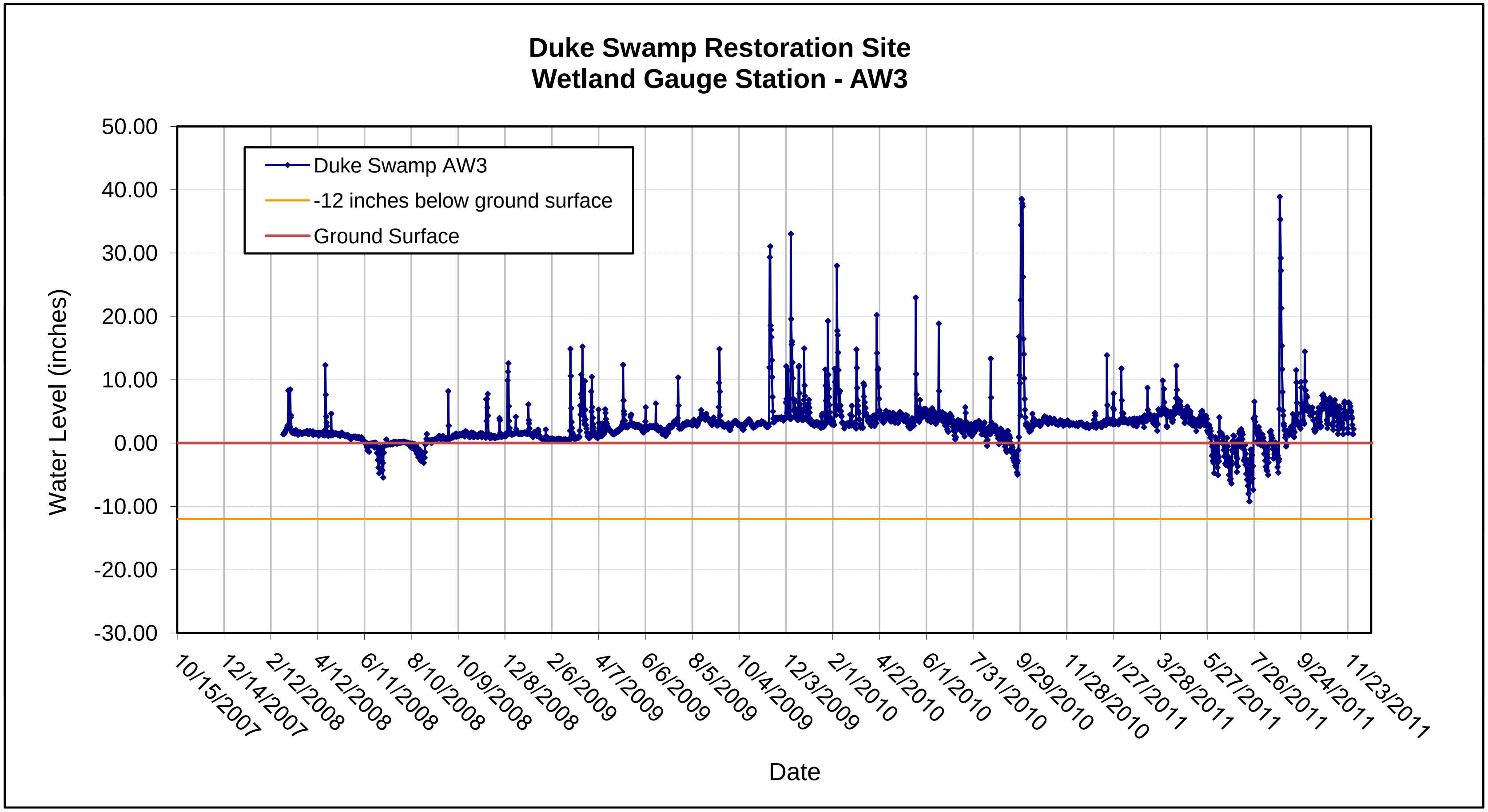
Buckland Elementary Rain
Rainfall (in)
0
0.5
1
1.5
2
1/1/2011
1/31/2011
3/2/2011
4/1/2011
5/1/2011
5/31/2011
6/30/2011
7/30/2011
8/29/2011
9/28/2011
10/28/2011
11/27/2011
Elevation Below Ground Surface (in)
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
AW1
AW2
AW3
AW4
AW5
-12 inches
Date



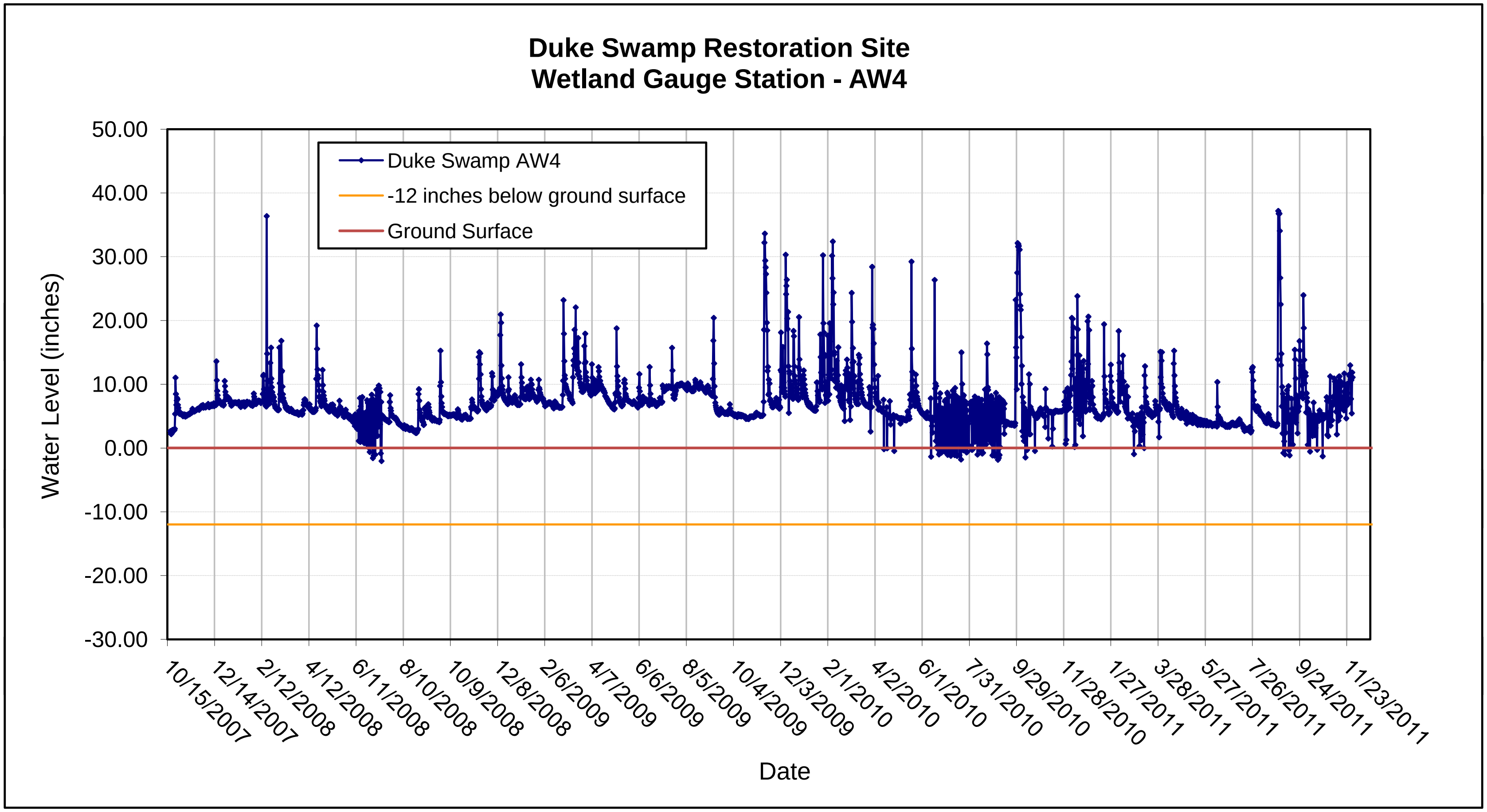
Duke Swamp Restoration Site
Wetland Gauge Station - AW1
Duke Swamp AW1
-12 inches below ground surface
Ground Surface
Water Level (inches)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
10/15/2007
12/14/2007
2/12/2008
4/12/2008
6/11/2008
8/10/2008
10/9/2008
12/8/2008
2/6/2009
4/7/2009
6/6/2009
8/5/2009
10/4/2009
12/3/2009
2/1/2010
4/2/2010
6/1/2010
7/31/2010
9/29/2010
11/28/2010
1/27/2011
3/28/2011
5/27/2011
7/26/2011
9/24/2011
11/23/2011
Date



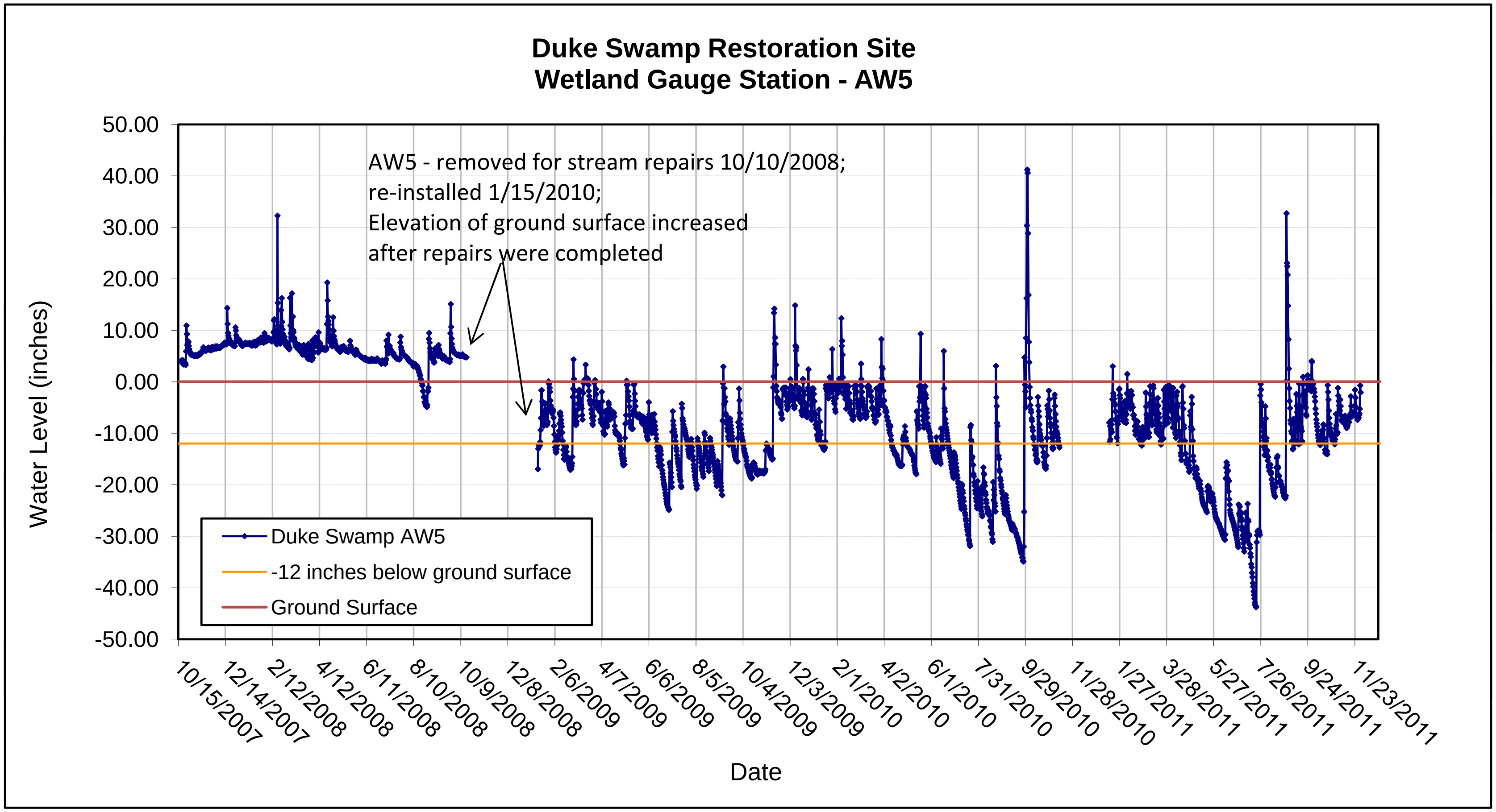
Duke Swamp Restoration Site
Wetland Gauge Station - AW2
Duke Swamp AW2
-12 inches below ground surface
Ground Surface
Water Level (inches)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
10/15/2007
12/14/2007
2/12/2008
4/12/2008
6/11/2008
8/10/2008
10/9/2008
12/8/2008
2/6/2009
4/7/2009
6/6/2009
8/5/2009
10/4/2009
12/3/2009
2/1/2010
4/2/2010
6/1/2010
7/31/2010
9/29/2010
11/28/2010
1/27/2011
3/28/2011
5/27/2011
7/26/2011
9/24/2011
11/23/2011
Date



Duke Swamp Restoration Site
Wetland Gauge Station - AW3
Duke Swamp AW3
-12 inches below ground surface
Ground Surface
Water Level (inches)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
10/15/2007
12/14/2007
2/12/2008
4/12/2008
6/11/2008
8/10/2008
10/9/2008
12/8/2008
2/6/2009
4/7/2009
6/6/2009
8/5/2009
10/4/2009
12/3/2009
2/1/2010
4/2/2010
6/1/2010
7/31/2010
9/29/2010
11/28/2010
1/27/2011
3/28/2011
5/27/2011
7/26/2011
9/24/2011
11/23/2011
Date



Duke Swamp Restoration Site
Wetland Gauge Station - AW4
Duke Swamp AW4
-12 inches below ground surface
Ground Surface
Water Level (inches)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
10/15/2007
12/14/2007
2/12/2008
4/12/2008
6/11/2008
8/10/2008
10/9/2008
12/8/2008
2/6/2009
4/7/2009
6/6/2009
8/5/2009
10/4/2009
12/3/2009
2/1/2010
4/2/2010
6/1/2010
7/31/2010
9/29/2010
11/28/2010
1/27/2011
3/28/2011
5/27/2011
7/26/2011
9/24/2011
11/23/2011
Date


Duke Swamp Restoration Site
Wetland Gauge Station - AW5
AW5 - removed for stream repairs 10/10/2008;
re-installed 1/15/2010;
Elevation of ground surface increased
after repairs were completed
Water Level (inches)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Duke Swamp AW5
-12 inches below ground surface
Ground Surface
10/15/2007
12/14/2007
2/12/2008
4/12/2008
6/11/2008
8/10/2008
10/9/2008
12/8/2008
2/6/2009
4/7/2009
6/6/2009
8/5/2009
10/4/2009
12/3/2009
2/1/2010
4/2/2010
6/1/2010
7/31/2010
9/29/2010
11/28/2010
1/27/2011
3/28/2011
5/27/2011
7/26/2011
9/24/2011
11/23/2011
Date

WETLAND WELL
AND FLOOD GAUGE
PHOTOGRAPHS

Auto Well 1 – North, August 2011

Auto Well 1 – East, August 2011

Auto Well 1 – South, August 2011

Auto Well 1 – West, August 2011

Auto Well 2 – North, August 2011

Auto Well 2 – East, August 2011


Auto Well 2 – South, August 2011


Auto Well 2 – West, August 2011


Auto Well 3 – North, August 2011


Auto Well 3 – East, August 2011


Auto Well 3 – South, August 2011


Auto Well 3 – West, August 2011

Auto Well 4 – North, August 2011

Auto Well 4 – East, August 2011

Auto Well 4 – South, August 2011

Auto Well 4 – West, August 2011

Auto Well 5 – North, August 2011

Auto Well 5 – East, August 2011

Auto Well 5 – South, August 2011

Auto Well 5 – West, August 2011

Flood Gauge 1 – West, July 2011

Flood Gauge 1 – West, November 2011

Flood Gauge 2 – South, July 2011

Flood Gauge 2 – South, November 2011

Flood Gauge 3 – West, July 2011

Flood Gauge 3 – West, November 2011

Flood Gauge 4 – West, July 2011

Flood Gauge 4 – West, November 2011

Flood Gauge 5 – East, July 2011

Flood Gauge 5 – East, July 2011