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Quantifying Soil Organic Carbon (SOC) in Wetlands Impacted by Groundwater Withdrawals in West-Central Florida

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Quantifying Soil Organic Carbon (SOC) in Wetlands Impacted by Groundwater Withdrawals in West-Central Florida

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
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Dedication

This research is dedicated to the memory of Eugene David Powell, my friend and husband. A highly respected man by many during his life, his clear, objective thinking and disciplined behavior were an inspiration to me during my study.

Acknowledgments

I would like to thank Scott Emery for inspiring this study. His enthusiasm sparked my interest and kept me going through long, hot, muddy field days. I appreciate all of the hard work from EPC's Gordon Leslie, Dave Watson and Chris Steins, and assistance SWFWMD's John Emery and April Brenton. It's always satisfying to share my interests with my children, so I would like to thank my daughters, Mary and Sarah, for their help building soil corers, collecting samples, and listening to my endless assessments. In addition, I am very grateful to Mark Stewart's son, Matt, for digging so many pits in the hot sun and doing so without complaint. Thanks to Dr. Jack Ma for helping to develop my GIS skills and my final poster. My rewarding experiences here at USF have been chiefly because of support from all of the Geology department office staff, faculty, and students and I would like to thank everyone for their help and companionship. I am grateful to the family members who supported me and especially to my brother, Jerry, for his coaching. Finally, I cannot show my appreciation enough to my entire committee, Jonathan Wynn, Mark Stewart and Mark Rains. Each has been a wonderful mentor and friend, and collectively they have been the greatest graduate committee I could have imagined.

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ABSTRACT

Saturated for most of the year, wetlands accumulate large amounts of biomass in thick organic soil horizons with slow rates of decomposition due to anaerobic conditions. Wetland soils thereby sequester large amounts of organic carbon in relative long-term storage. Municipal water demands in west-central Florida are largely met through extensive groundwater pumping. These withdrawals can impact ecosystems dependent on surface water levels that are ultimately linked to confined aquifers. Soils in a subset of cypress swamps that are monitored by the Southwest Florida Water Management District (SWFWMD) were sampled and analyzed to ascertain the health of the wetlands impacted by groundwater pumping. Soil water content, bulk density, and carbon and nitrogen content were systematically measured on replicate samples from three elevations in transects through the wetlands. “Healthy” wetlands were found to have higher soil water retention and consequently higher soil organic carbon (SOC) content in the top 30 cm of

soil than “harmed” and “significantly harmed” cypress domes. However this trend was only significant at the lowest, central elevation of the wetland, at an elevation of the normal pool level minus 12 inches. These results provide quantitative evidence to support the notion that saturation of soils during most of the year is required to maintain the conditions that are conducive to the accumulation of soil organic matter. Conversely, unsaturated soils appear to be mineralizing large quantities of their stores of organic carbon. Since soil moisture and organic carbon contents are well correlated in the wetlands that were sampled, monitoring of soil water content may prove a convenient proxy for determining the organic carbon stores and thus the relative health of the wetland.

Introduction

Problem Statement

As demand for water continues to rise with population growth, increases in groundwater pumping threatens to disrupt freshwater ecosystems (Postel, 2000). Groundwater pumping in west-central Florida causes declines in the water table that can lead to degradation of sensitive wetlands. In an effort to determine potential damage to wetlands, research targeting the hydrology and ecology of wetlands is ongoing (McPherson et al., 1976; Mitsch and Ewel, 1979; Hull et al., 1989; Bondavalli et al., 2000; Ewing and Vepraskas, 2006; Carr et al., 2006). The Southwest Florida Water Management District (SWFWMD) uses several indicators to establish the "degree of harm" wetlands have sustained from pumping to guide regulatory decision-making (Hull et al., 1989; Berryman and Henigar Inc. 1997; Carr et al., 2006). As part of a larger study assessing vegetation changes within these wetlands, the goal of my research was to determine the relationship between amounts of soil organic carbon (SOC) in these wetlands and the estimated "degree of harm." It is my hypothesis that declining water tables disrupt the processes that lead to organic matter accumulation in wetlands and that measurable stores of SOC are decomposed and CO_2 released to the atmosphere. It was the objective of this thesis to measure differences in SOC content across the spectrum of "healthy," "harmed," and "significantly harmed" cypress domes in order to quantify these changes in relation to hydrologic impact.

Wetlands in west-central Florida

The surficial, or unconfined, aquifer system throughout most of Florida exists in the thin layer of Pleistocene to Holocene deposits of sand, shells, silts and clayey sands overlying older, thick limestone deposits of varying permeability and the confined Floridan aquifer system within (Miller, 1986). The confined and unconfined aquifers come in contact with each other intermittently due to the karstic terrain, and depressions at the surface bring the water table above land surface, inundating these areas for most of the year and forming wetlands.

Wetlands are regions where the local hydrology causes the land to be saturated for long periods of time, developing hydric soils and supporting hydrophytic vegetation (Tiner, 1999). In Florida, wetlands occur as mangrove forests, various saltwater to freshwater swamps and marshes, tidal flats, wet prairies, and riparian areas. They provide valuable functions such as aquifer recharge, water filtration, storm buffering, flood control, recreational uses, and wildlife habitats (McPherson et al., 1976; EPC, 2008).

Cypress domes, or cypress swamps, are one class of wetland found in west-central Florida and were the focus of this study. They are characterized primarily by Pond Cypress trees (*Taxodium ascendens*), occur frequently in poorly drained, depressional areas within pine flatwoods (Riekerk and Kohnak, 2000), and have associated wetland plant species including Lyonia (*Lyonia lucida*), mosses and lichens (epiphytic bryophytes), peelbark St. Johnswort (*Hypericum fasciculatum*), and Saw Palmetto (*Serenoa repens*) (Carr et al., 2006). These wetlands have a small footprint, from 1-10 hectares, and their geometry of larger central trees, possibly due to thick organic soils, tapering outward to smaller trees, give them the characteristic dome appearance (Mitsch and Ewel, 1979; Bondavalli et al., 2000).

Wetlands are an important ecosystem that federal and local governments recognize the need to protect (US EPA, 2002; Dahl, 2006). Sensitive to changes in water table fluctuations, wetlands are of particular interest when permitting groundwater withdrawals as extractions from the aquifer can eventually lead to serious water table declines that can adversely affect wetlands. Tampa Bay Water projects that water demand in its service area will increase from approximately 230 MGD (million gallons per day) in 2003 to about 300 MGD in 2025 (Hazen and Sawyer, 2004). The state of Florida charges the water management districts with monitoring and permitting water within their districts in order to balance water demands with ecosystem needs. The districts must therefore gather, analyze and update information about the interaction between aquifers and ecosystems to make decisions affecting the areas' water resources. Numerical models used to predict how groundwater pumping will affect the surficial aquifer are relied on for regulatory decision making, however they are approximations and have been found to underestimate the effect on the water table when compared to actual measurements once pumping has occurred for a period of time (Stewart and Langevin, 1999).

The Southwest Florida Management District (SWFWMD) has identified rules (Chapter 40D-2.301(c) FAC) meant to prevent negative impacts on wetlands from groundwater withdrawals, and the Florida Department of Environmental Protection (FDEP) as well as the Wetlands Management division of the Environmental Protection Commission of Hillsborough County (EPC) exercise additional regulatory authority within their areas in Florida.

In a 1999 white paper, SWFWMD identified minimum water levels for palustrine cypress wetlands. This paper discussed assessment of ecological parameters within the wetlands, such as vegetation changes and soil loss, which signaled an impact from groundwater withdrawals. Although a rating system was used to analyze several wetlands, the terminology “significant harm” was the focus of the assessments as it related directly to the rules (Chapter 40D-2.301(c) FAC). SWFWMD established minimum water levels for wetlands to avoid “significant harm” based on the rating system and ecological parameters; however the designation “harm” was deemed qualitative in nature and specific parameters were not defined for minimum levels. Currently SWFWMD is working to precisely define the parameters for the designation ”harm” (SWFWMD, 2001, 2002). In an effort to aid in the establishment of quantifiable regulatory parameters for “harm”, the wetlands involved in the study are categorized as “healthy”, “harmed” or “significantly harmed”.

Soil Organic Carbon

Soils are a dynamic interaction of organic matter, minerals, gases, water, and dissolved constituents. The cycle of plant material that decays, accumulates, and is buried in a layer of soil sequesters large amounts of carbon, with a flux of about 60 Pg of C/yr from terrestrial biota and a total SOC pool of approximately 1500 Pg of C worldwide (Trumbore 1997; Houghton, R.A., 2007). As this cycle proceeds, the pools of organic carbon are metabolized by organisms which either release CO_2 or methane (CH_4) into the atmosphere, and also produce increasingly humified organic matter as solid products of decomposition (Schlesinger and Andrews, 2000; Zhang et al., 2002). Residence times for the SOC pool vary depending on climate (Trumbore 1997; Knorr et al., 2005; Davidson and Janssens, 2006) type of vegetation (Schlesinger and Andrews, 2000; Quideau et al., 2001), erosion or disturbance (Smith et al., 2005; Rosenbloom et al., 2006), topography (Yoo et al., 2006), changes in hydrology (Ewing and Vepraskas, 2006), geographic location (Wu et al., 2003; Guo et al., 2006) and land use changes (Zhang et al., 2007).

Hydric soils are defined by the NRCS as “a soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part.” The hydric soils found in wetlands frequently have a large concentration of biomass that accumulates into thick organic soils with slow rates of decomposition. Soils that are saturated long enough to have a predominantly anaerobic, or reducing, environment with slower rates of decomposition will tend to hold their stores of carbon (Ewing and Vepraskas, 2006).

Soils within the wetlands in west-central Florida are poorly drained or very poorly drained and form in hydrophytic plant remains overlying sandy marine sediments in depressional landforms. Most hydric soils in this region belong to the Histosol, Mollisol, Entisol, Alfisol, or Inceptisol soil orders with Aquic moisture regimes for suborders (NRCS, 2008). Given these conditions, these soils represent a potential intermediate-term carbon sink (Richardson and Vepraskas, 2000).

Methods and Materials

Study Area

The Southwest Florida Management District (SWFWMD) is on the west-central portion of the Florida peninsula, encompassing all or portions of 16 counties, including the Tampa metro region. Climate within the area is wet and mild, with mean annual precipitation (MAP) of 55 inches, most occurring during the wet season between June and September, and a mean annual temperature (MAT) of 72 degrees F (NRCS, 2008).

In 2006, Dr. Scott Emery, Visiting Research Professor, USF's Institute for Environmental Studies and President of Environment and Health Integrated (EHI), began a research project for SWFWMD assessing flora for specific indicators of wetland harm. His study area includes over 60 wetland sites (cypress domes, swamps, wet prairies, etc.) within the SWFWMD district boundary. Many sites are monitored by SWFWMD for water table changes and surveyed for biological indicators of hydrology (Carr et al., 2006). This soil carbon study is a complement to Dr. Emery's research project, with the aim of sampling sites utilizing several criteria: 1) sites within Dr. Emery's set of 60+ wetlands, 2) assessed for current status 3) sites that contain monitor wells and 4) sites that are surveyed for hydrologic indicators of seasonal water levels.

Previous research developed a method for determine historic water levels based on vegetation at the perimeter of the wetland and using these indicators for surveying in water level elevations within the wetlands (Carr et al., 2006). The method for surveying specific elevations within each wetland seems to be a reliable indicator of seasonal high water stands (SWFWMD WAP Manual, 2004; Carr et al., 2006). These elevations were defined as normal pool (NP), normal pool -6 inches (NP-6), and normal pool -12 inches (NP-12) (Figure 1).

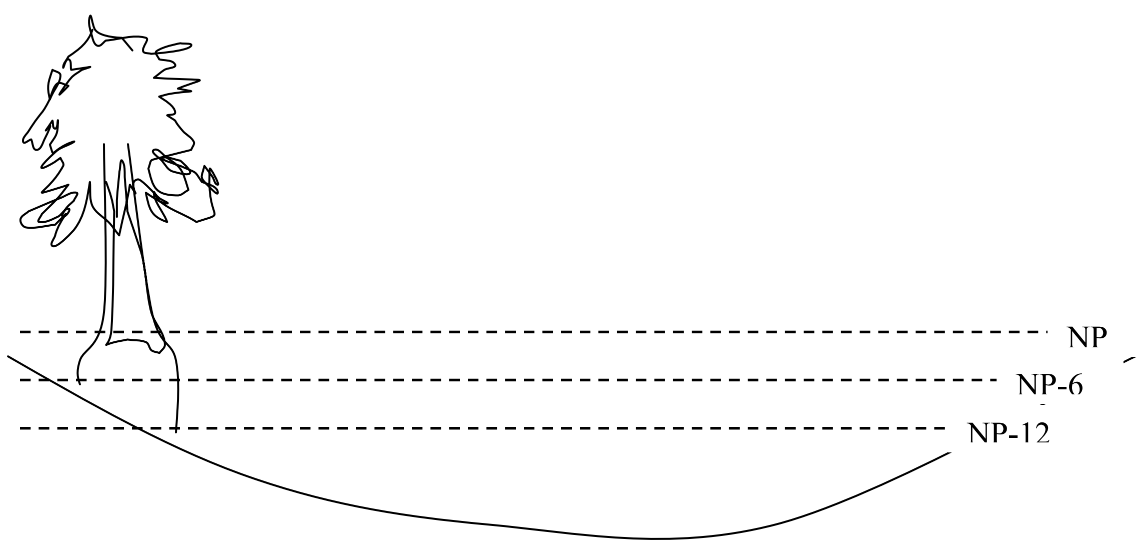


Figure 1. Normal Pool Elevations illustration

As it is one of SWFWMD's objectives to improve the distinction between "harm" and "significant harm" when identifying wetlands impacted by groundwater pumping (SWFWMD 1999), the SWFWMD categories of "healthy", "harmed", and "significantly harmed" were utilized for this soil study. For my study I found it was to further necessary to narrow the selected wetlands not only based on "degree of harm", but also with regard to limiting as many other factors that could contribute to SOC inventories. For this reason, only isolated cypress domes were considered. A small set of such cypress domes within Dr. Emery's study area were selected (Figure 2). Dr. Emery provided the "degree of harm" category for each cypress dome sampled within his study area.

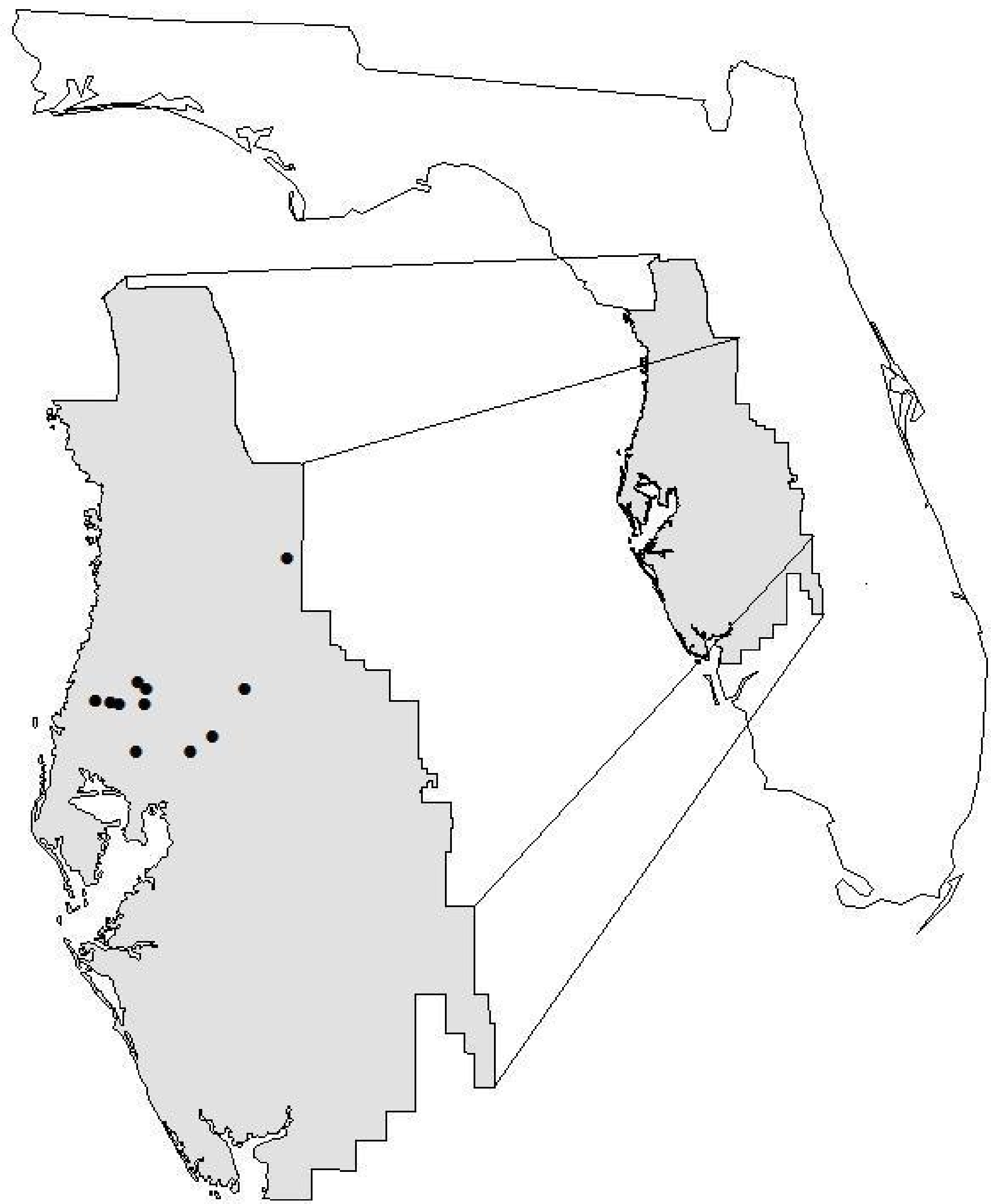


Figure 2. Study area with sampled wetland sites

I selected a minimum of 3 representative cypress domes for each hydrologic impact category of “healthy”, “harmed” and “significantly harmed”. At each of these cypress domes, the three NP elevations were used for sample transects to further differentiate the changes with respect to seasonal water levels.

In total I collected detailed soil samples according to a standardized protocol described below from eleven (11) wetlands between December 2007 and April 2008. A range of sites was chosen that reflected varying levels of impact from “healthy” to “significantly harmed”. Wetlands were given names relating to their location and SWFWMD designations. Locations were recorded on the date of sampling using a handheld GPS and coordinates are in decimal degrees (using WGS84 datum). Table 1 contains a list of wetlands, date of sampling, category, and GPS coordinates.

Table 1. Sampled Wetland Sites, location, and category of harm.

Wetland ID	Date	Category	GPS Coordinates
Starkey D	12/06/07	Sig. Harm	N28.25586, W082.63612
Starkey 1	12/11/07	Healthy	N28.20629, W082.56398
Starkey U	01/23/08	Sig. Harm	N28.25045, W082.62376
Starkey W	01/23/08	Harmed	N28.24616, W082.61278
Section 21	01/29/08	Sig. Harm	N28.12176, W82.509494
Blackwater Creek	02/05/08	Harmed	N28.14588, W082.15249
Green Swamp 7	02/12/08	Healthy	N28.31230, W082.30713
Flatwoods	02/14/08	Harmed	N28.11380, W082.30713
Starkey R	02/26/08	Healthy	N28.24916, W082.55637
Starkey S75	03/04/08	Harmed	N28.25080, W082.56085
New River	04/10/08	Healthy	N28.15189, W82.262444

Soil Collection Protocol

My soil sampling protocol involved replicate extractions of a standardized volume of soil from the upper 30cm of the soil, irrespective, and without knowing a priori of any soil horizon below the sampling location. Custom PVC soil corers were constructed from 1 1/4” diameter PVC pipes and 4-way PVC fittings (Figure 3). An approximately 40cm long section of PVC pipe was glued into one of the openings of the 4-way fitting and an approximately 10cm long section of pipe was glued into another opening of the 4-way fitting at a 90^0 angle from the longer pipe section, creating a handle. A line was drawn around the pipe 30cm from the sampling end of the longer pipe section and the opening was filed to create a beveled edge. The corers were inexpensive and disposable allowing for breakage and damage, the use of multiple, unused corers at each new site to minimize cross-contamination between sampled sites.

After removing surface litter, samples were collected by holding the short PVC pipe section with one hand and pounded into the soil with a mallet until the line was at land surface. Twisting, rotating and pulling up on the handle allowed the soil sample to be extracted and then emptied from the corer into a Legend Tin Top 5" x 9.5" paper sample envelopes to facilitate rapid air-drying of moist samples. The base of the core was inspected for a clean surface representing 30 cm of soil depth without sample loss. Samples with visible soil loss were discarded and another extraction was attempted within close proximity to the discarded core. When roots were encountered and a complete 30 cm soil depth could not be extracted, the sample was discarded and a new extraction attempted as described previously.

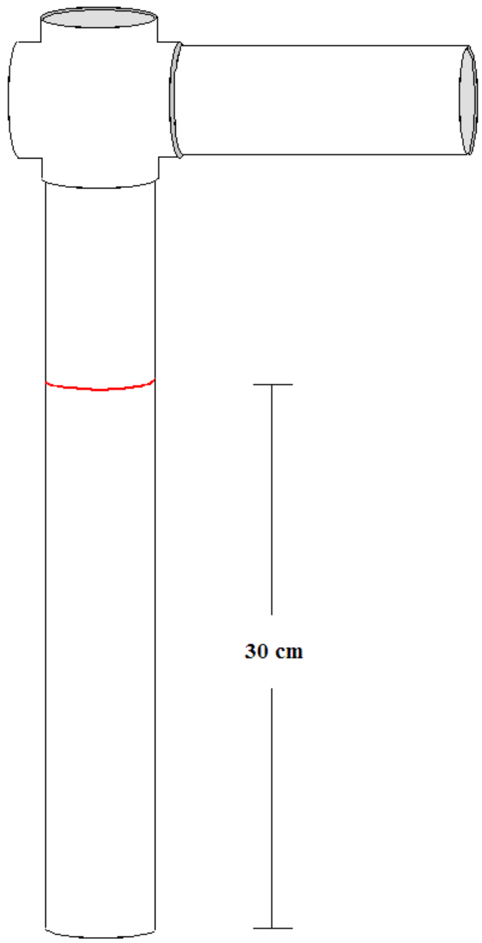


Figure 3. Soil Corer

Fifteen (15) soil cores were taken at each of the three NP elevations within each wetland for a total of 45 soil cores per site. The only exception was the last sampled wetland, New River, which had 15 cores taken solely from the NP-12 elevation as it had been decided to sample one additional site and it was determined that this elevation would provide the most benefit for the resources expended in collecting and processing more samples.

Sample locations were chosen in a non-systematic order at least 1-meter intervals along the NP elevation transect. As they were collected, each sample envelope was labeled with the wetland ID abbreviation, NP elevation, and a number from 1-15. Sampling locations were marked on the ground using flags at elevations surveyed with respect to known elevations at NP stakes or staff gages using a survey rod and Topcon AT-F4 automatic level.

Soil series for each site were referenced using the Natural Resources Conservation Service (NRCS) online Web Soil Survey (WSS) system (Table 2).

Table 2. Soil Series for Sampled Wetland Sites.

Wetland ID	Category	Soil Series
Starkey D	Sig. Harm	Chobee soils
Starkey 1	Healthy	Sellers mucky loamy fine sand
Starkey U	Sig. Harm	Chobee soils
Starkey W	Harmed	Sellers mucky loamy fine sand
Section 21	Sig. Harm	Basinger, Holopaw, Samsula soils, depressional
Blackwater	Harmed	Basinger, Holopaw, Samsula soils, depressional
Green Swamp 7	Healthy	Chobee soils
Flatwoods	Harmed	Basinger, Holopaw, Samsula soils, depressional
Starkey R	Healthy	Sellers mucky loamy fine sand
Starkey S75	Harmed	Sellers mucky loamy fine sand
New River	Healthy	Basinger, Holopaw, Samsula soils, depressional

There were 3 different soil series represented in the 11 sites (NRCS, 2008):

1) Chobee soils**:** Fine-loamy, siliceous, superactive, hyperthermic Typic Argiaquolls very poorly drained, Mollic epipedon, Argillic horizon - 5 to 54 inches.

2) Sellers mucky loamy fine sand: Sandy, siliceous, hyperthermic Cumulic Humaquepts very poorly drained, Umbric epipedon.

3) Basinger, Holopaw, and Samsula soils, depressional
Basinger and similar soils: 35 percent, Holopaw and similar soils: 31 percent, Samsula and similar soils: 18 percent, Minor components: 16 percent

Basinger: Siliceous, hyperthermic Spodic Psammaquents
poorly drained and very poorly drained, Ochric epipedon, Spodic intergrade - the zone from 18 to 36 inches (Bh/E horizon).

Holopaw: Loamy, siliceous, active, hyperthermic Grossarenic Endoaqualfs
poorly and very poorly drained, Ochric epipedon and grossarenic feature, Argillic horizon - 45 to 58 inches (Btg)

Samsula: Sandy or sandy-skeletal, siliceous, dysic, hyperthermic Terric Haplosaprists
very poorly drained, Sapric soil materials

Sample Preparation

Samples were weighed as soon as possible after collection, air dried at room temperature, and weighed again. Samples were grouped into 4 bulk samples for each NP elevation within each site:

Bulk A – samples labeled 1-5

Bulk B – samples labeled 6-10

Bulk C - samples labeled 11-15

Bulk-Bulk – a mixture of 1/3 of each Bulk A, Bulk B and Bulk C.

Dry soil samples were emptied into a soil riffle splitter by bulk grouping, and one quarter (1/4) to one half (1/2) of the bulked sample was retained for further processing. One quarter (1/4) of each of the Bulk A-C samples were set aside during the splitting and bulking process to homogenize and create the Bulk-Bulk sample.

Bulk samples were then sieved to retain particles <2mm. The remaining sieved bulk samples were split as needed to reduce volume. Bulked samples were powdered in a Spex shatterbox and 8” diameter soil mill (Figure 4).

Figure 4. Shatterbox and soil mill

Elemental and Stable Isotopic Analysis

Powered bulked samples were weighed into Costech pressed tin capsules (5 X 9 mm), fed into a Costech Instruments Elemental Combustion System coupled to a Thermo Scientific Delta V Advantage Isotope Ratio Mass Spectrometer (IRMS). Samples were analyzed for % C (carbon), % N (nitrogen), C:N ratio, $\delta^{13}C$ and δ15N values. There were four standards used to assess carbon and nitrogen. The standards used with mean and maximum standard deviation (σ) obtained during all IRMS runs are listed in Table 3. Several replicate measurements of each bulked sample were made between 2/21/2008 and 4/22/2008 and 1-4 results for each bulked sample were averaged.

Table 3. IRMS Standards used to assess (C) carbon and (N) nitrogen content.

Standard	Contains	Measured	Mean	Std Dev (σ)
Fergie CN	Sucrose, KNO_3,	%C	15.01	0.374
	Si, Kaolinite	%N	1.42	0.080
		$\delta^{13}C$	-25.01	0.126
		$\delta^{15}N$	-0.017	0.447
B2151*	High Organic Content	%C	6.70	0.128
		%N	0.50	0.015
		$\delta^{13}C$	-26.29	0.230
		$\delta^{15}N$	4.401	0.393
B2153*	Low Organic Content	%C	1.64	0.030
		%N	0.14	0.010
		$\delta^{13}C$	-27.36	0.070
		$\delta^{15}N$	6.653	0.632
B2155*	Protein	%C	46.27	0.907
		%N	12.33	0.276
		$\delta^{13}C$	-26.94	0.003
		$\delta^{15}N$	7.672	0.482

*Elemental Microanalysis soil/sediment standards

Soil Moisture Meter

Upon review of the preliminary soil water content and %C and %N results from the mass spectrometer, it was surmised that a soil moisture probe could be used to quickly determine relative wetland health. A Ben Meadows portable soil moisture meter, with a moisture scale from 1-10, was utilized at several wetlands on two separate occasions in an attempt to develop a protocol for sampling and interpreting the results. The probe was calibrated in completely saturated conditions to read 10. 5 to 10 readings were taken within a one square meter area, at a probe depth of 30cm. Sampling locations were along a transect from the wetland edge, moving in towards the center at NP elevation stakes NP-6 and NP-12, and at the center of the wetland close to the staff gage.

Wetland Well Data

The monthly records for water levels recorded in the wetland wells were cross referenced with SWFWMD and gathered for six of the eleven sampled sites and hydrographs were created. Review of the data and resulting graphs revealed that water levels at several sites had dropped below the bottom of the well for extended periods of time. Because of this, it was determined the information was of little value to this study, however the graphs are included in Appendix B.

Calculations

The sample volume (V) was calculated by measuring the diameter (D) of the corer, determining the area (A) of the opening, and multiplying the area by the sampled length (30 cm):

$D = 3.70$ cm, $r = 1.85$ cm

$A = \pi r^2 = 10.75 \text{ cm}^2$

$V = 10.75 \text{ cm}^2 * 30 \text{ cm} = 322.56 \text{ cm}^3$

The bulk density (d_b) was calculated for every sample by dividing the dry weight (m) by the volume V (computed above) and reported in units of g/cm^3:

$d_B = m/V$

The arithmetic mean ($\bar{x}$) and standard deviation (σ) of the set of individual soil core values (x_i) for bulk density (d_b) and water content for each elevation (NP, NP-6, NP-12) within each wetland site were computed.

The mean %C, %N, C:N ratio, $\delta^{13}C$ and $\delta^{15}N$ values for the bulked samples for each NP elevation within each site were calculated. The number of values obtained by mass spectrometry for the bulked samples ranged from 4 - 8 for each elevation/site combination, so error was determined using the maximum and minimum values in each set rather than standard deviation.

Statistical comparisons between wetland categories of harm and NP elevations were computed for %C using analysis of variance (ANOVA) with an alpha level (p-value) ≤ 0.05. In addition, regression analysis was performed for soil water content versus %C and %C versus bulk density.

Carbon density was computed by multiplying the mean %C by the mean bulk density ($\overline{d}_b$) for each NP elevation and then dividing by 1000 to convert the units into mg/cm^3.

Isotopes were computed and reported in standard delta (δ) notation, relative differences in isotope ratios between the sample and a standard, in units of ‰ (per mil):

$$\delta^{13}C = 1000 \text{ X } ((^{13}C/^{12}C)_{sample} / (^{13}C/^{12}C)_{standard} - 1)$$

$$\delta^{15}N = 1000 \text{ X } ((^{15}N/^{14}N)_{sample} / (^{15}N/^{14}N)_{standard} - 1)$$

Results

Soil Water Content

Soil water content measured at the time of sampling was examined for replicate measurements taken from individual elevation and “degree of harm” categories. The mean water content ($\overline{w}$) from the sampled cores for each elevation at each wetland site are plotted, with error bars represented by standard deviation (σ) in Figure 5. The range of $\overline{w}$ values for all sampled NP (normal pool) elevations was 5.6% to 22.3%, demonstrating a slight trend of increasing $\overline{w}$ with healthier wetland sites. The transitional elevation of NP-6 was similar to the NP results with values ranging from 5.3% to 23.5% and an analogous trend with “degree of harm”. The most pronounced increase in soil water with “degree of harm” was obtained from the central NP-12 elevation values. The range of $\overline{w}$ for NP-12 was 5.3% to 62.6%, with 3 of the 4 “healthy” sites exhibiting a notable increase in soil water content as compared to either the “harm” or “significantly harmed” wetland sites.

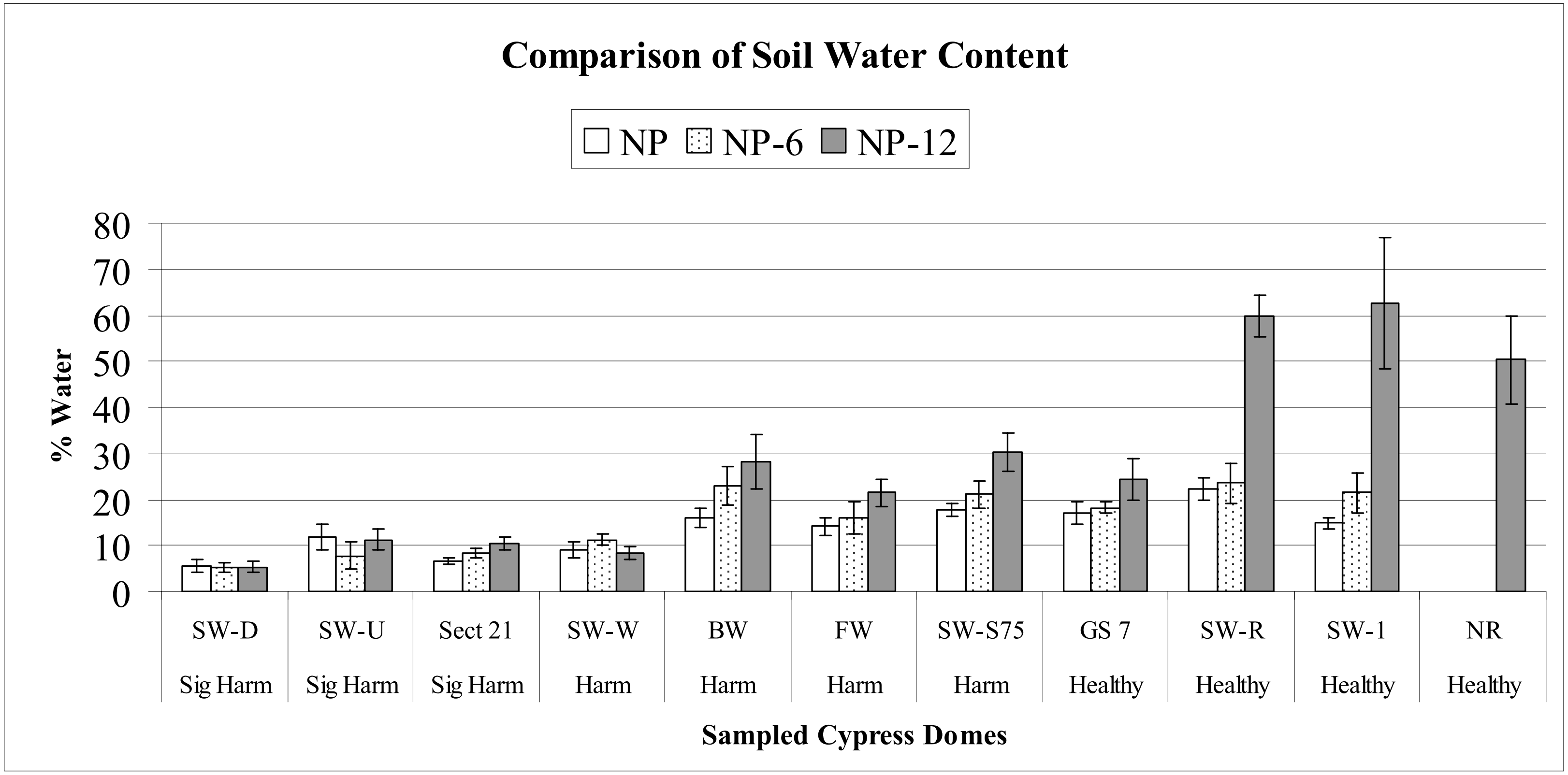


Figure 5. Soil water content comparison by "degree of harm"

Bulk Density

Bulk density (d_b) was calculated for every soil sample, the mean ($\bar{d}_b$) and standard deviation (σ_{d_b}) values for each NP elevation and each wetland site are plotted in Figure 6. $\bar{d}_b$ ranged from as low as 0.2 g/cm^3 in the very organic rich soils, to as high as 1.76 g/cm^3 in exposed surface mineral horizons. There were very few trends, except in the NP-12 elevations where 2 of the 4 “healthy” sites were lower than all other sites.

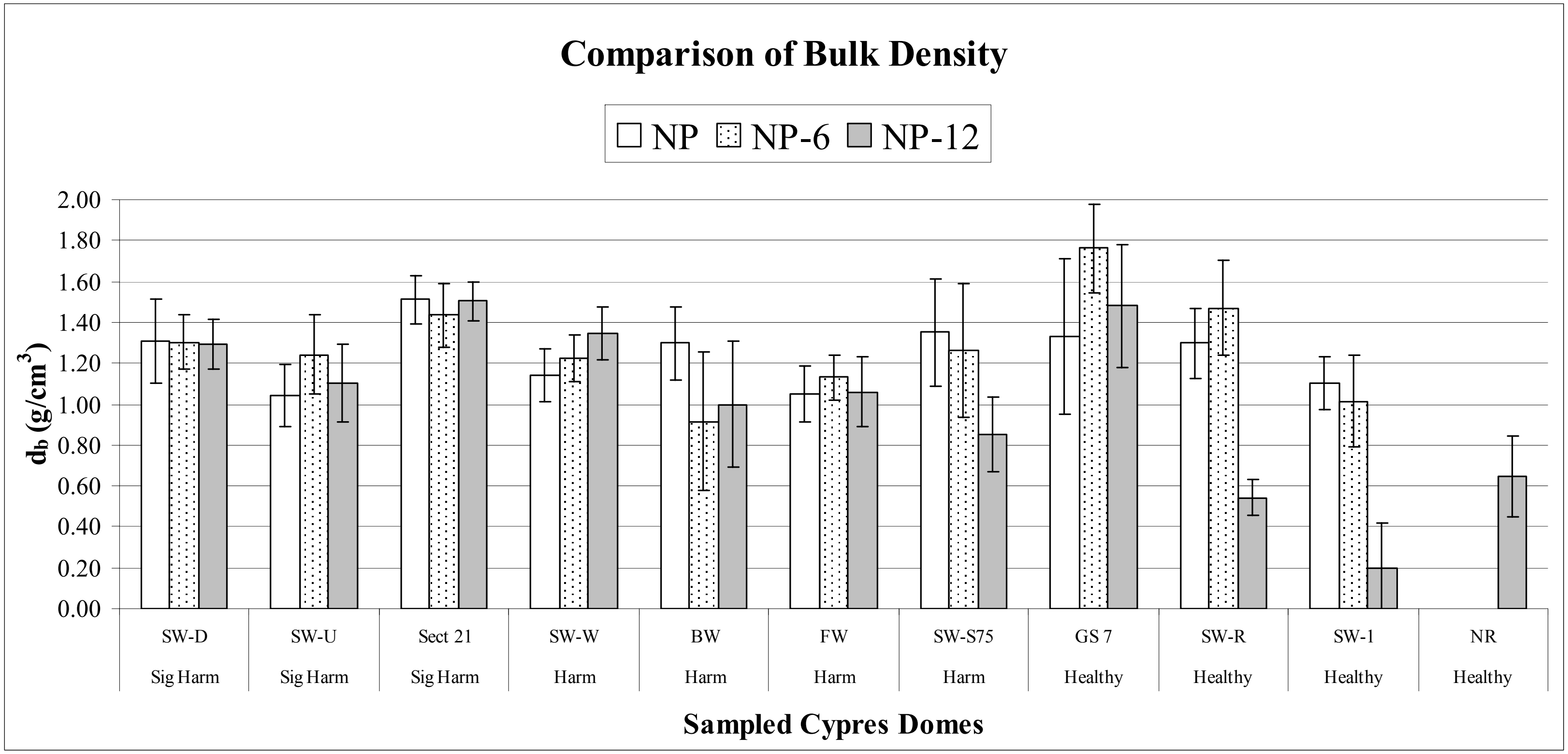


Figure 6. Bulk density comparison by "degree of harm"

Carbon Content

The mean ($\overline{\%C}$) values for bulked samples representing each NP elevation at all wetland sites is plotted in Figure 7. $\overline{\%C}$ in the "healthy", "harm" and "significantly harmed" sites at the NP and NP-6 elevations were relatively low and varied little. The range of $\overline{\%C}$ for the all sampled NP elevations was 1.14% to 3.91%, while at NP-6 $\overline{\%C}$ ranged from 1.05% - 4.8%. Across these categories of "harm", distinctive increases were observed at the NP-12 elevations. The range of $\overline{\%C}$ for this elevation was 1.43% to 23.08%, notably this range being represented within the "healthy" wetland sites, although the overall trend was an increase in %C for 3 of the 4 "healthy" soils.

Carbon density was calculated using the %C and bulk density (d_b) values (Appendix A). The carbon density showed no consistent trends between categories and within the same site across elevations. The Starkey R ("healthy"), Starkey S75 ("harm"), Blackwater ("harm"), and Section 21 ("significant harm") sites increase in carbon density from NP to NP-12 elevations. The Starkey 1 ("healthy"), Flatwoods ("harm"), and Starkey D ("significant harm") sites demonstrated a slight increase from NP to NP-6, then a decrease at the NP-12 elevation. The Green Swamp 7 ("healthy") and Starkey U ("significant harm") sites had a small decrease from NP to NP-6 followed by an increase at NP-12. Starkey W ("harm") showed a general decrease from NP to NP-12.

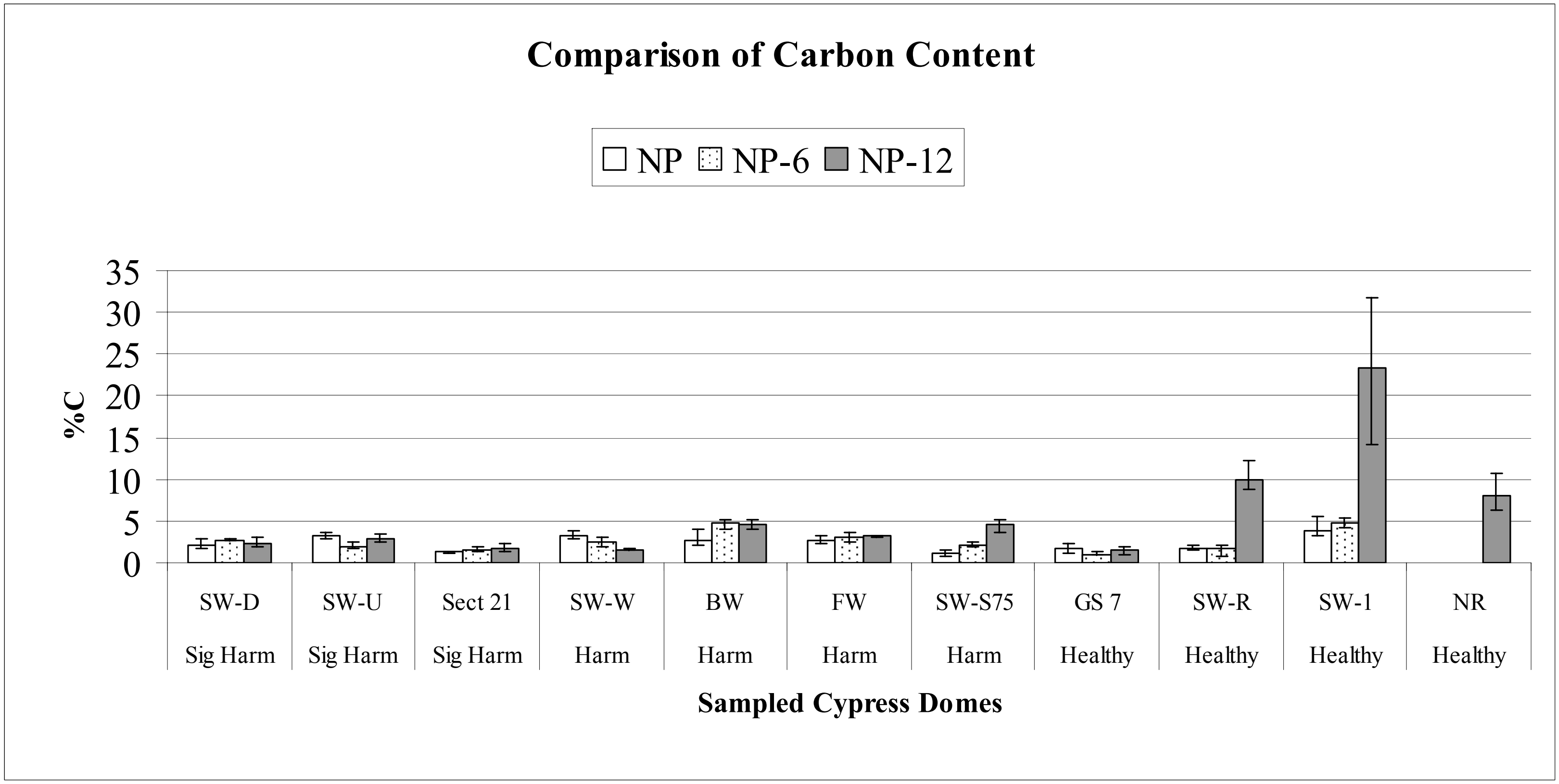


Figure 7. Soil carbon content comparison by “degree of harm”

Water content measurements were coupled with %C for all bulked groups and all wetland sites. Figure 8 shows the results of the analysis and a relationship between these variables, with increasing water content in the soil as %C increases.

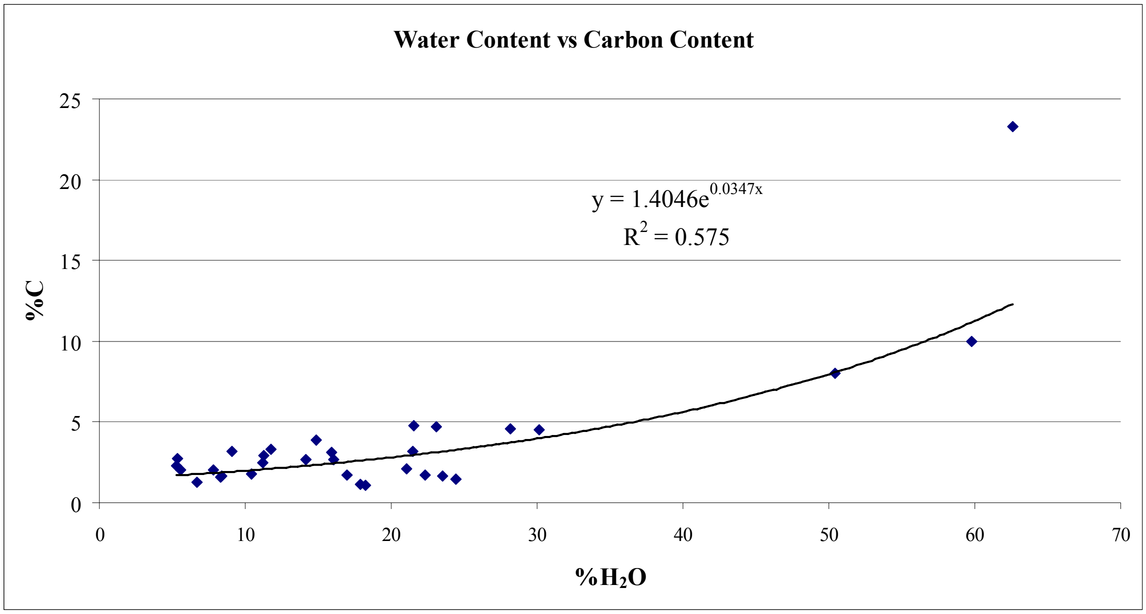
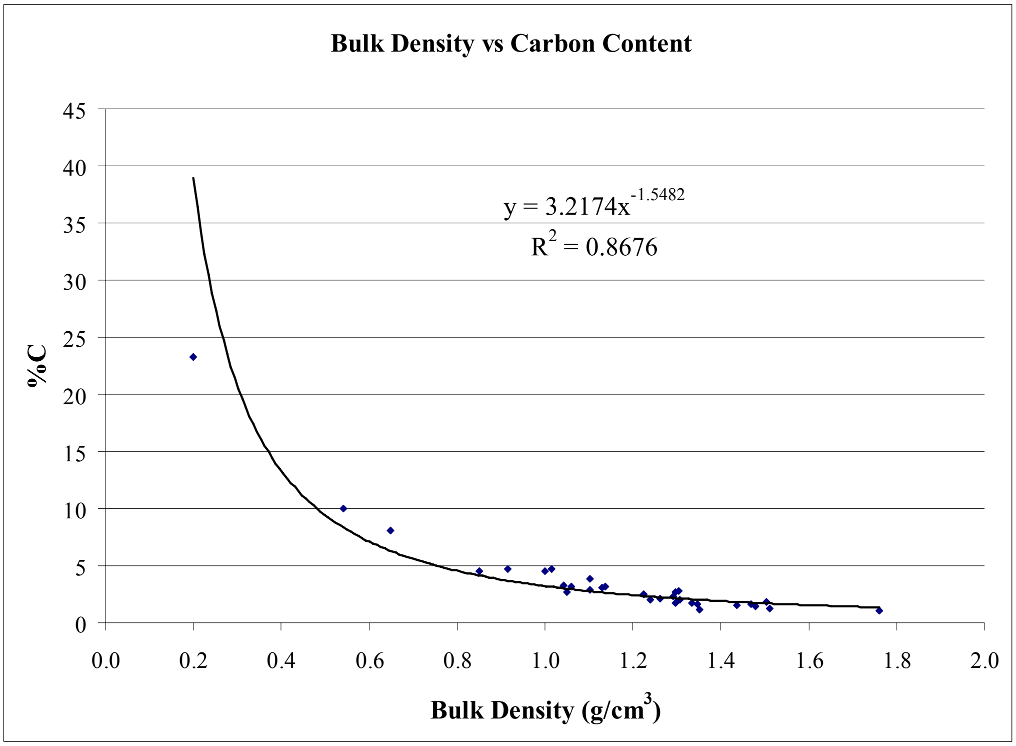
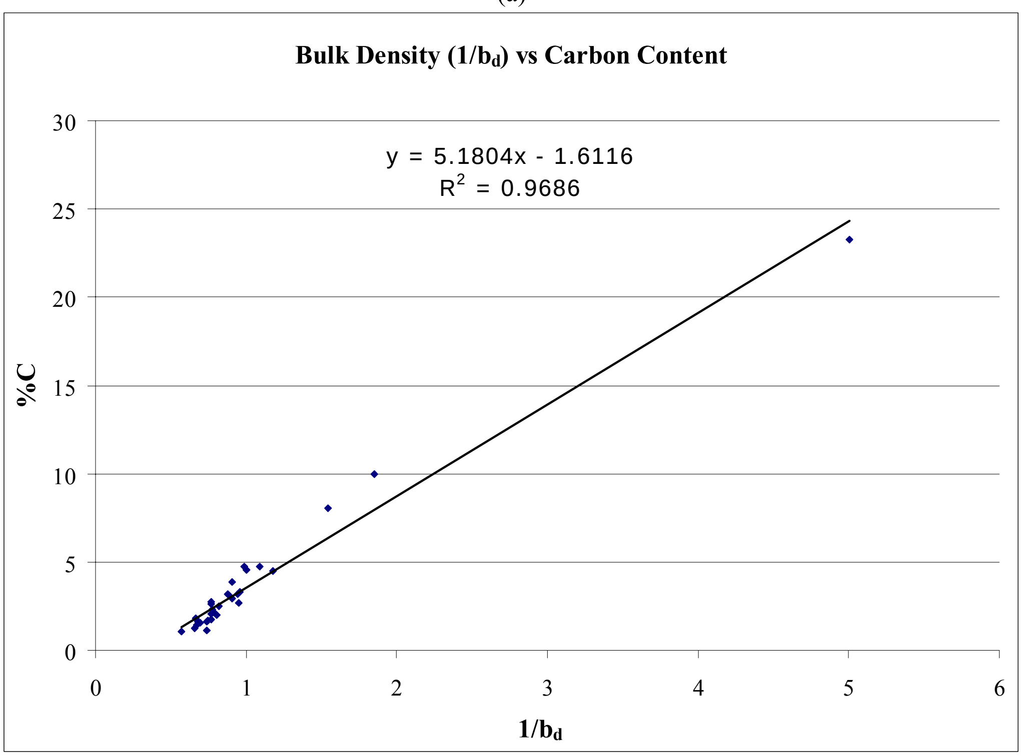


Figure 8. Water content versus %C for all sampled sites

Analysis of changes in bulk density with increasing carbon content were also conducted by bulk group and wetland site and the results were plotted. Figure 9a shows the relationship between bulk density and %C and figure 9b utilizes the inverse of bulk density (d_b) against %C in order to use linear regression for finding the best fit line. In this case, as bulk density increases the %C decreases.



(a)



(b)

Figure 9a. bulk density (d_b) versus %C and 9b. ($1/d_b$) versus %C

Nitrogen Content

The mean ($\overline{\% \text{N}}$) values for bulked samples representing each NP elevation at all wetland sites was calculated and plotted (Figure 10). Values for $\overline{\% \text{N}}$ in the "healthy", "harm" and "significantly harmed" sites at the NP and NP-6 elevations were extremely low. The range of $\overline{\% \text{N}}$ for the all sampled NP elevations was 0.06% – 0.17%, and the NP-6 values ranged from 0.06% - 0.24%. The NP-12 elevation values ranged from 0.09% - 1.19%. Once again, it was this central elevation that demonstrated any trend. There was a prominent increase in $\overline{\% \text{N}}$ for 3 of the 4 "healthy" wetland sites at the NP-12 elevation. It should be noted that these values were of such small quantities that they produced more variance than the values for %C.

C:N Ratio

Mean ($\overline{\text{C}:\text{N}}$) ratios for bulked samples representing each NP elevation at all wetland sites are plotted in Figure 11. There is a decreasing $\overline{\text{C}:\text{N}}$ trend across all categories from NP to NP-12 elevations. %C and %N measurements were only made on replicate samples of "bulk" and "bulk-bulk" samples, so error bars are not determined for these data. However, replicate measurements of %C and %N of standard reference materials are.

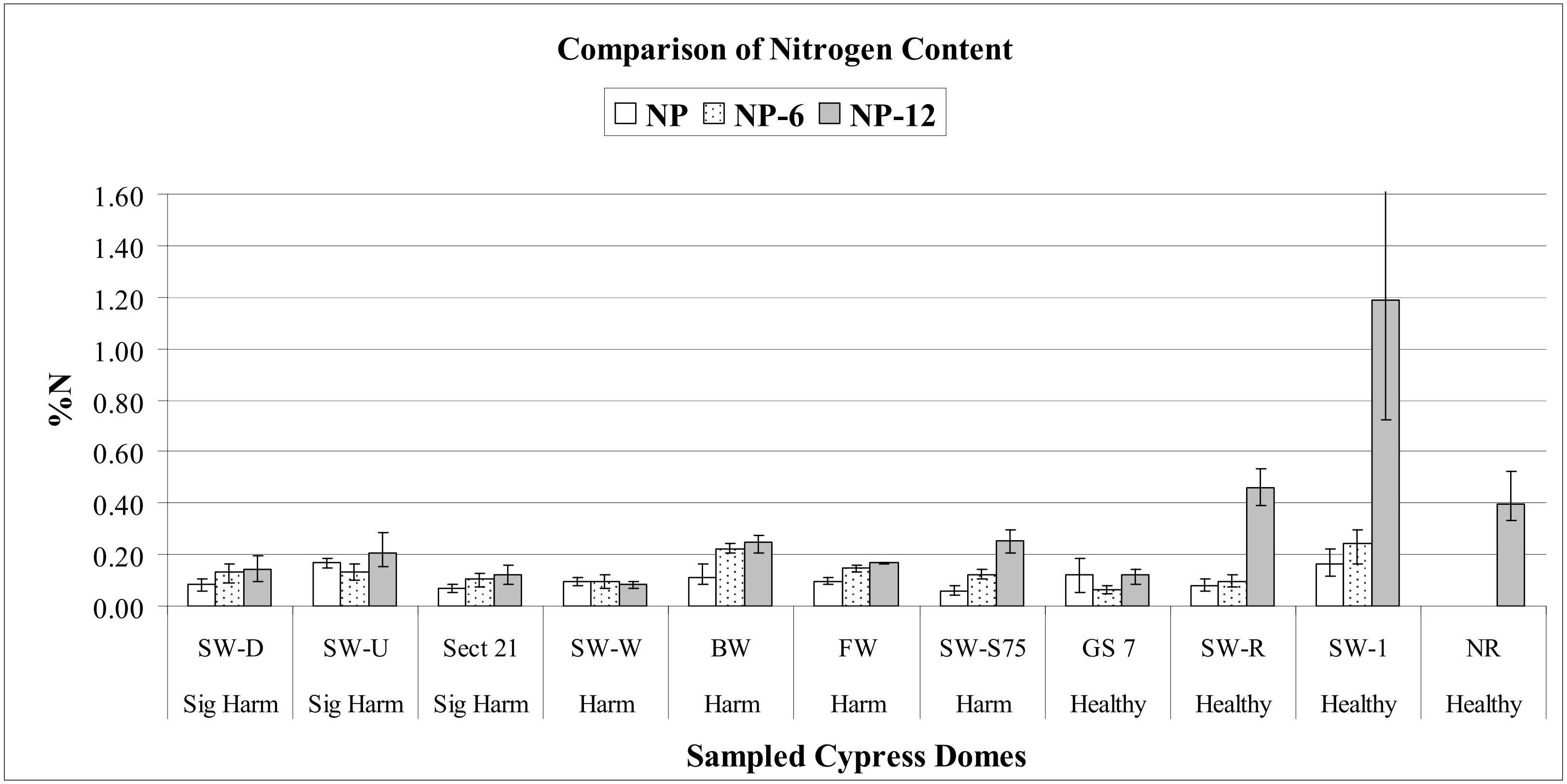


Figure 10. Soil nitrogen content comparison by "degree of harm"

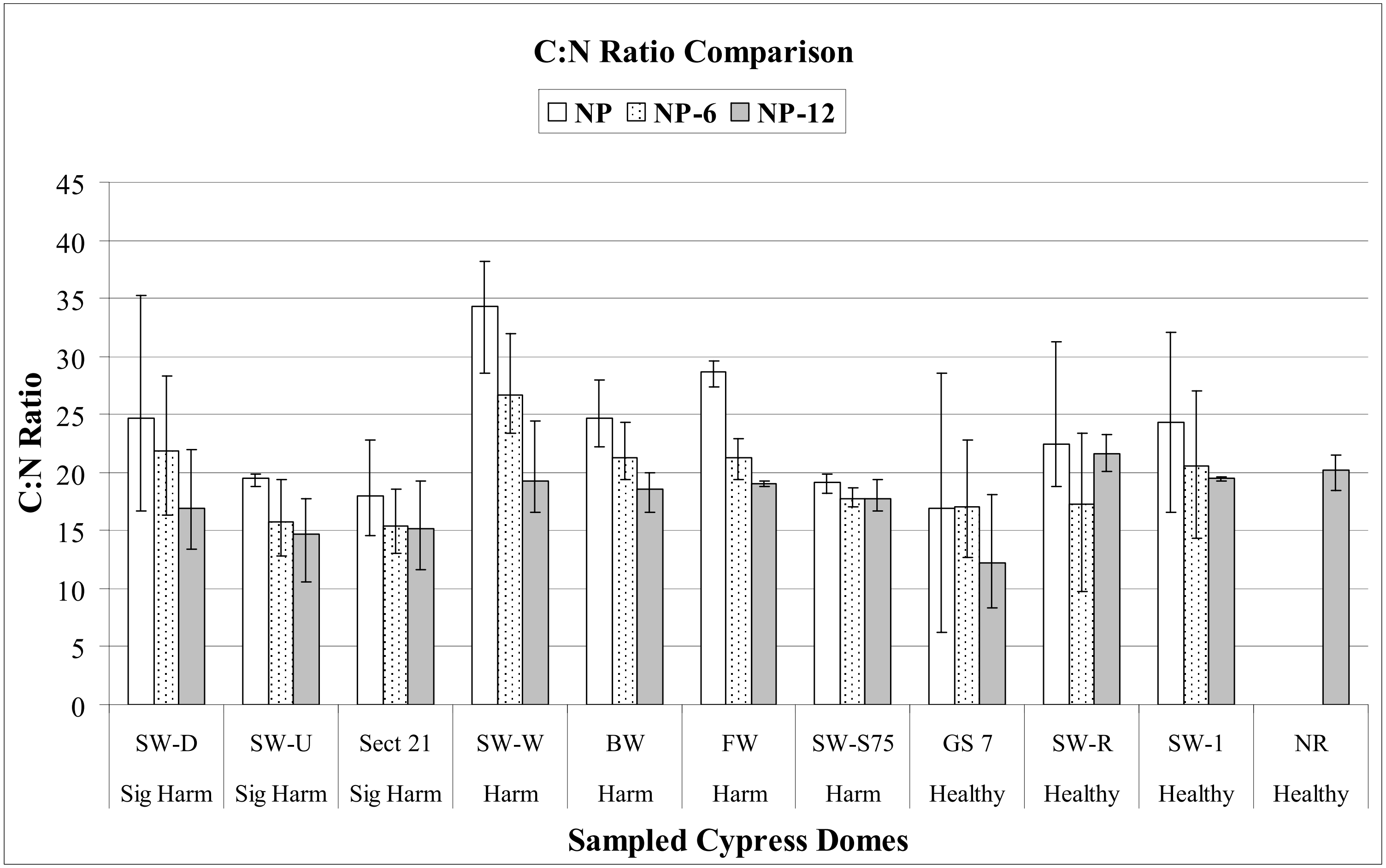
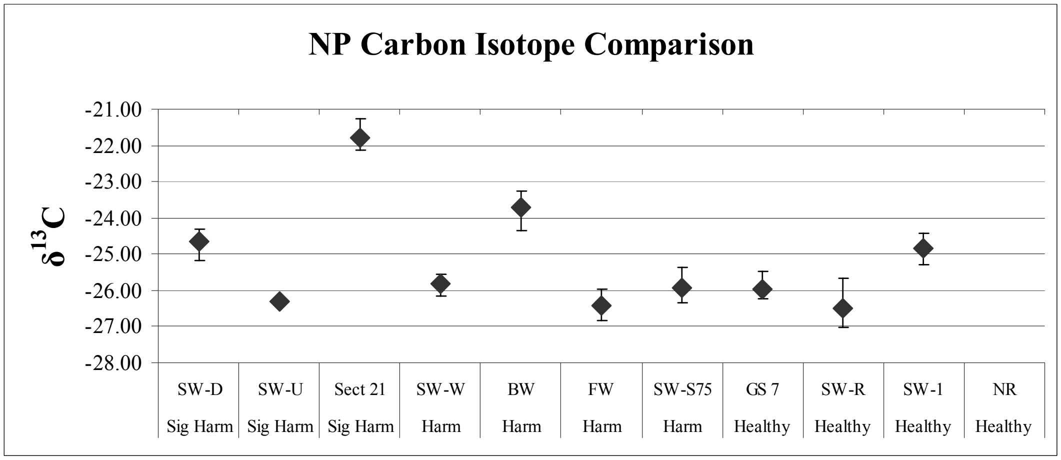


Figure 11. C:N Ratios comparison by "degree of harm"

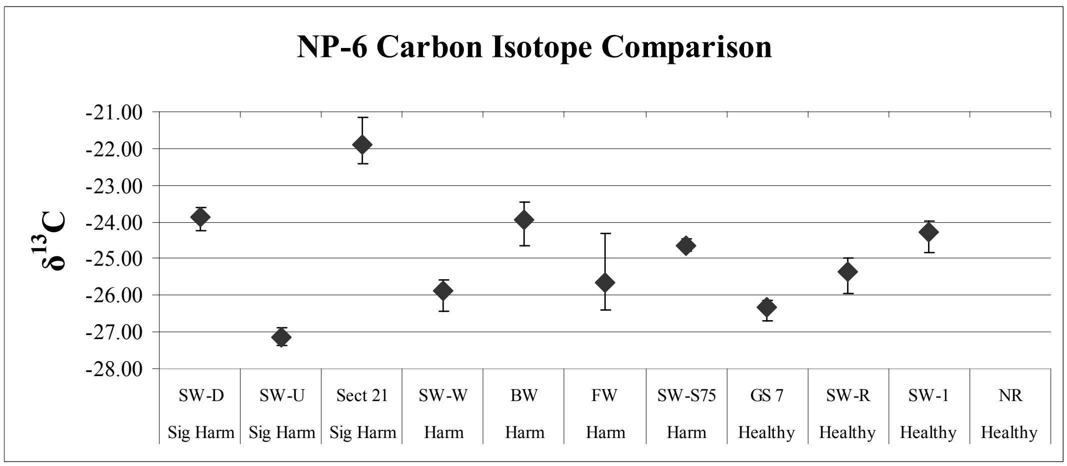
Stable isotopic composition of Soil Organic Matter

Mean values for $\delta^{13}C$ and $\delta^{15}N$ for bulked samples at each site were calculated and plotted by wetland category, against each other, %C and C:N ratio. Differences between isotopic values within each wetland were also examined.

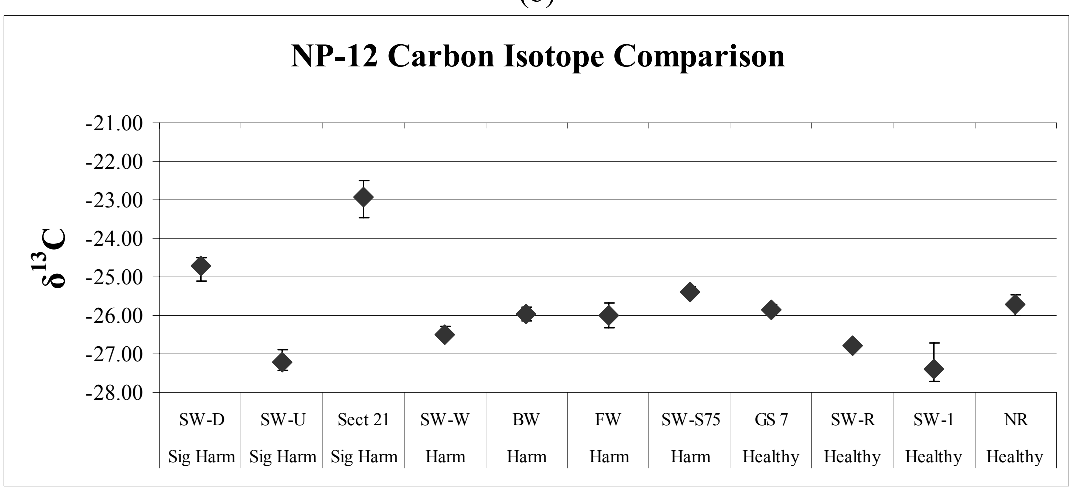
$\delta^{13}C$ for all bulk samples from NP elevations ranged from –27.4 to -21.8‰. This range of $\delta^{13}C$ values is consistent with C3 plants as the primary source of biomass contributing to the soil carbon, and is in agreement with previous studies on the isotopic composition of soils with a moderate to high moisture content and C3 dominant flora (Yonghoon et al., 2001; Bird et al., 2003). The $\delta^{13}C$ values across NP elevations or wetland categories varied (Figure 12), and plots comparing $\delta^{13}C$ with $\delta^{15}N$ values, %C, and C:N ratios showed an increasing variance in $\delta^{13}C$ values with increasing carbon content (Figure 13).



(a)

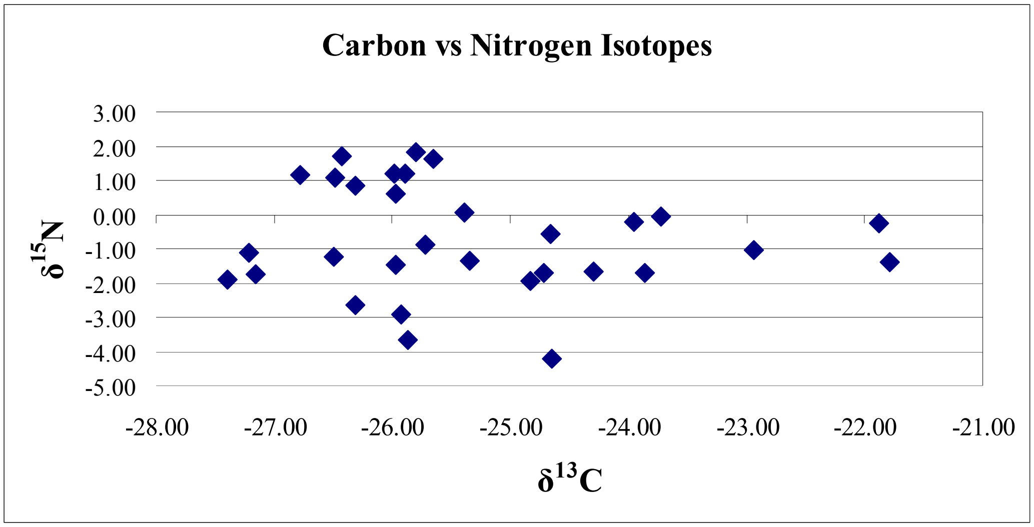


(b)

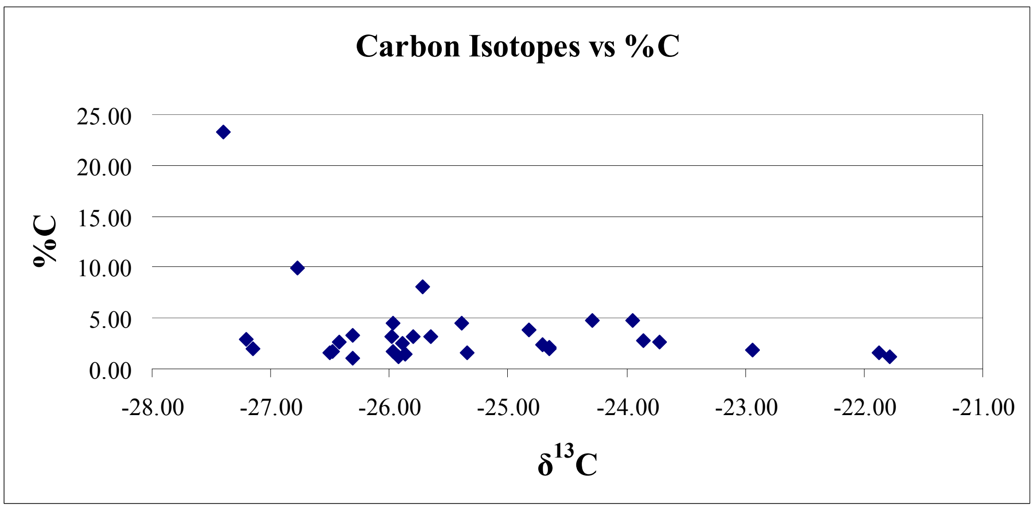


(c)

Figures 12a-c. Carbon Isotope results graphed separately by NP elevations moving from wetland edge (NP) in towards the center (NP-12) top to bottom, and “sig. harm” to “healthy” within each graph, left to right.



(a)



(b)

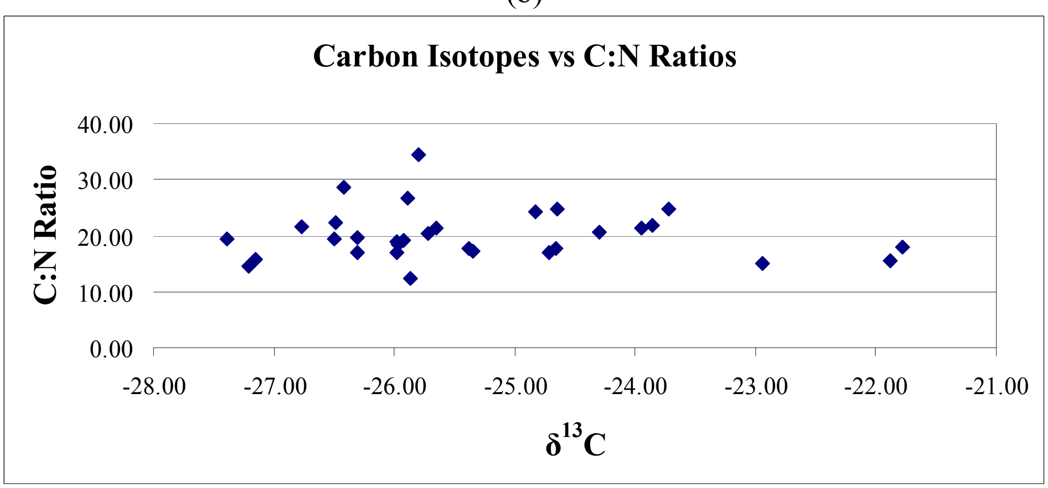


Figure 13a-c. Carbon Isotope results plotted against a. $\delta^{15}N$, b. %C, and c. C:N ratios

There was a trend in the difference in $\delta^{13}C$ values between wetland categories. The mean difference in $\delta^{13}C$ was computed by taking the maximum and minimum $\delta^{13}C$ values for each wetland, finding the difference between these, and calculating the mean of those differences for every wetland category. This mean difference increased with increasing wetland health (Figure 14).

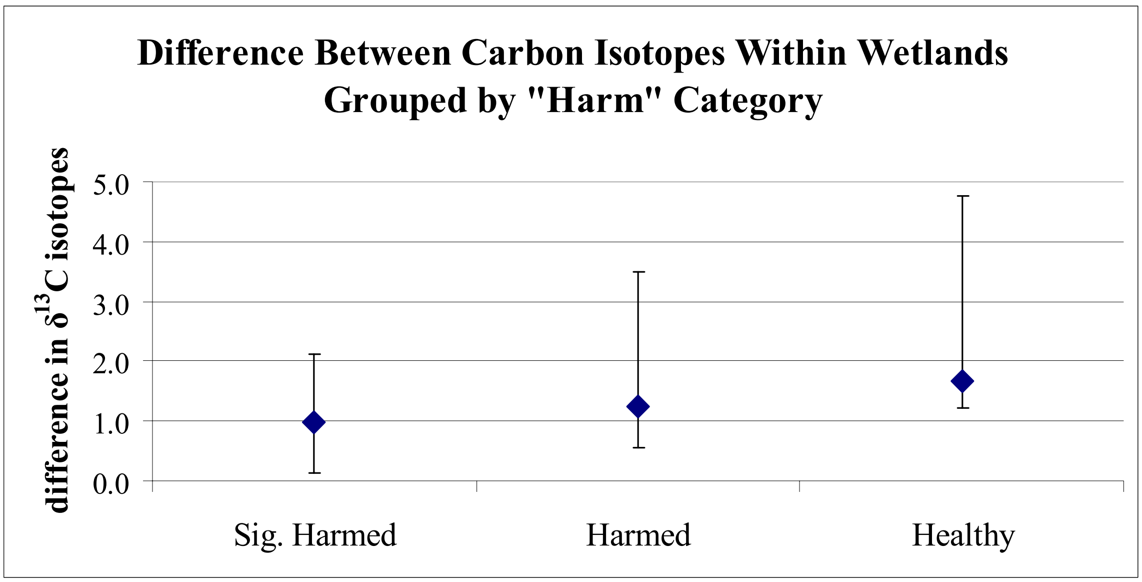
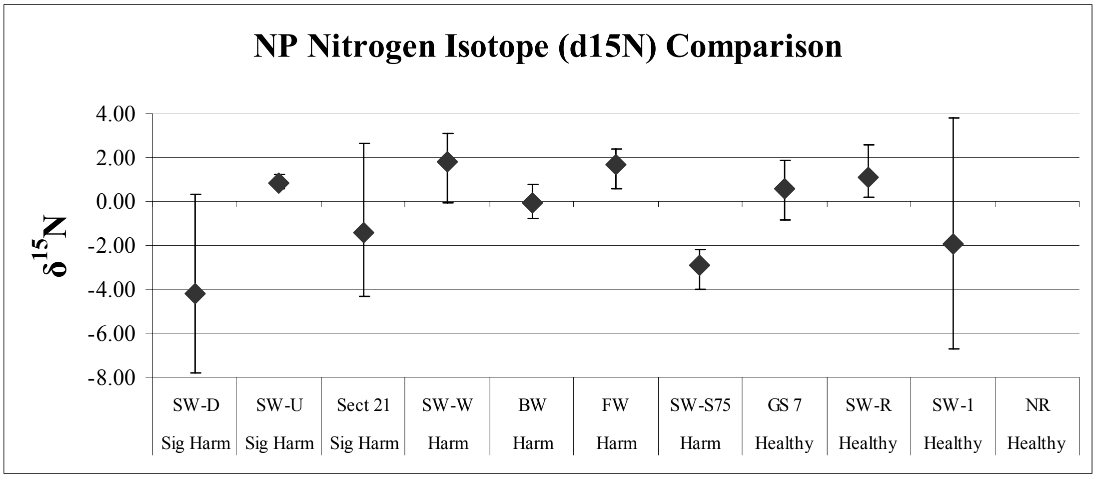
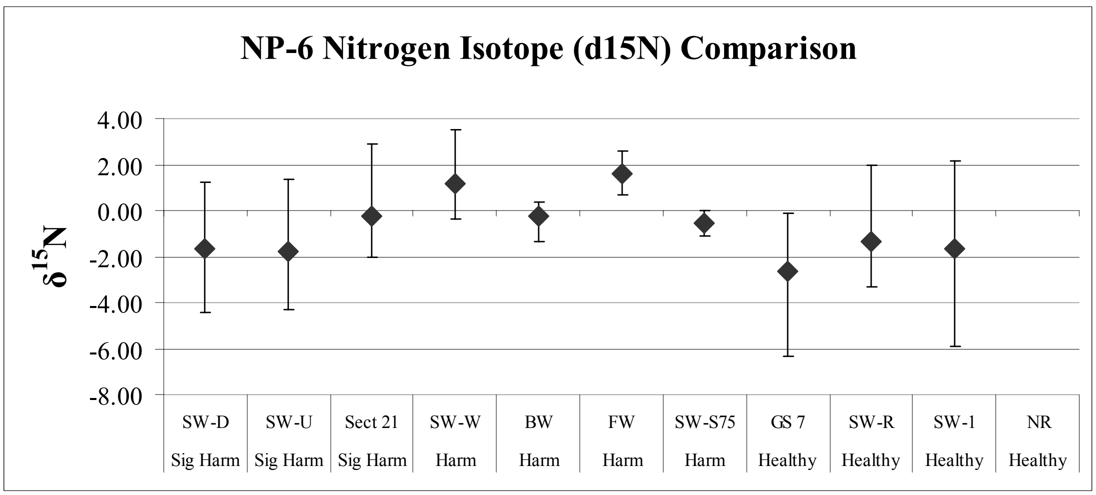


Figure 14. The mean difference in $\delta^{13}C$ values between wetland categories

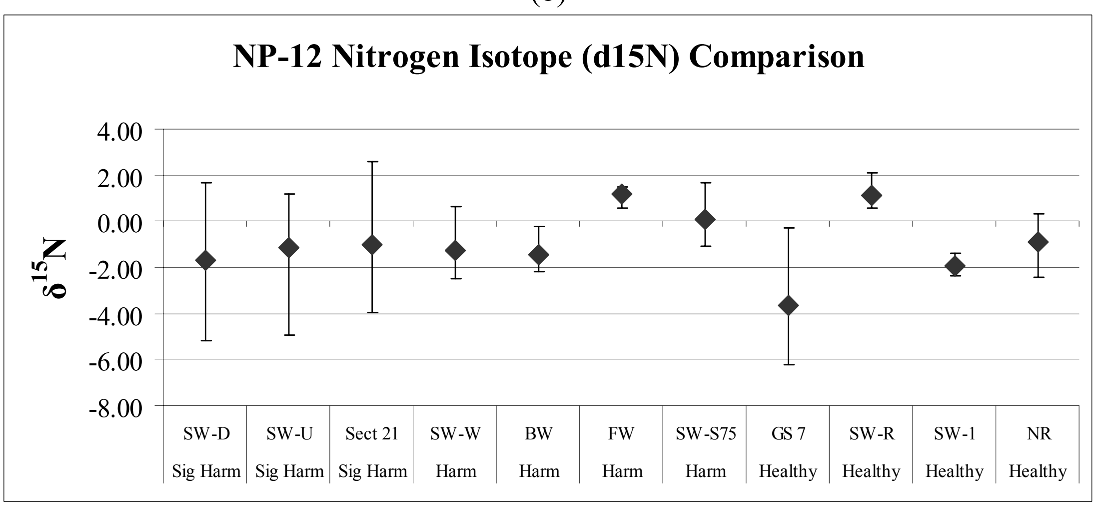
The average $\delta^{15}N$ ranged between –4.2 and 1.8‰ (Figure 15). Results were consistent with the range of values found in soils, which vary greatly, but tend to be slightly positive (Sharp, 2007). The plots with regard to NP elevation and wetland categories were also quite variable within this range.



(a)



(b)



(c)

Figure 15a-c. Nitrogen Isotope results graphed separately by NP elevations

Figure 16 is a plot of the mean difference in $\delta^{15}N$ values, calculated in the same manner as the mean difference in $\delta^{13}C$ values. The mean difference decreased from "significantly harmed" to "harmed", however the "healthy" category had the largest mean difference.

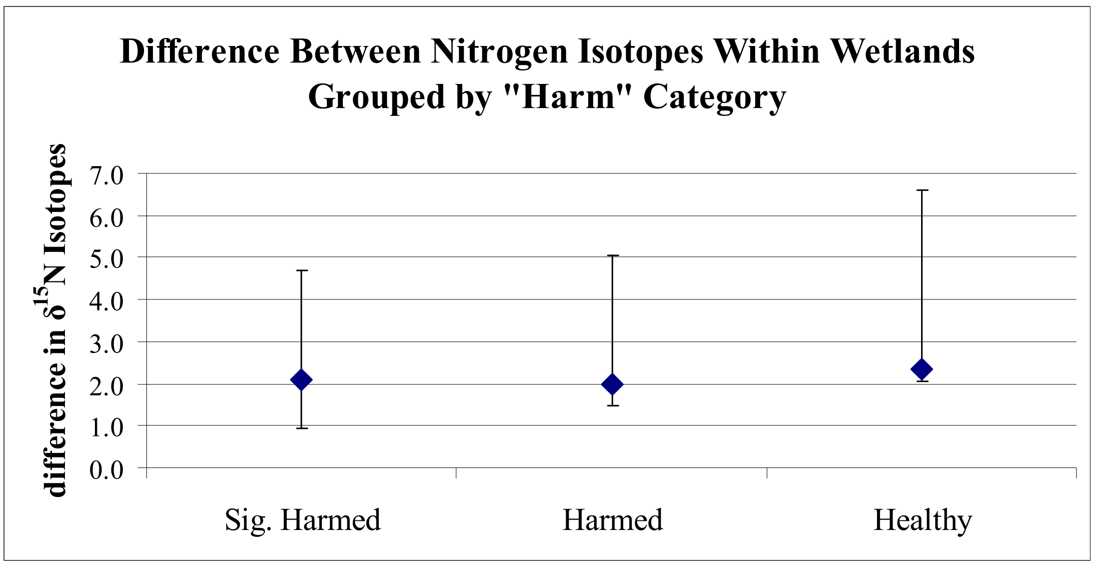


Figure 16. The mean difference in $\delta^{15}N$ values within wetlands of different categories

Soil Moisture Meter

There was a distinct correlation between replicate measurements taken with the soil moisture meter and "degree of harm" in the six wetlands that were measured on a single day under similar meteorological conditions (5/23/2008) at Starkey Wilderness Park (Appendix C). Relative soil moisture increased both along a transect from outer edge to center of the wetland and with increasing wetland health (Figure 17). The 5-10 readings at each location within the wetland (wetland edge, NP-6, NP-12, and staff gage or wetland center) had standard deviations less than 0.5, except for one highly variable spot that had a standard deviation of 2.3. This one sample location was in a "harmed" site and had 10 readings that ranged between 0 and 6 taken in a 1 square meter area at the staff gage (wetland center). It is possible that the soil in the center of this wetland is especially heterogeneous with respect to texture and there are pockets of moist and dry soil in close proximity.

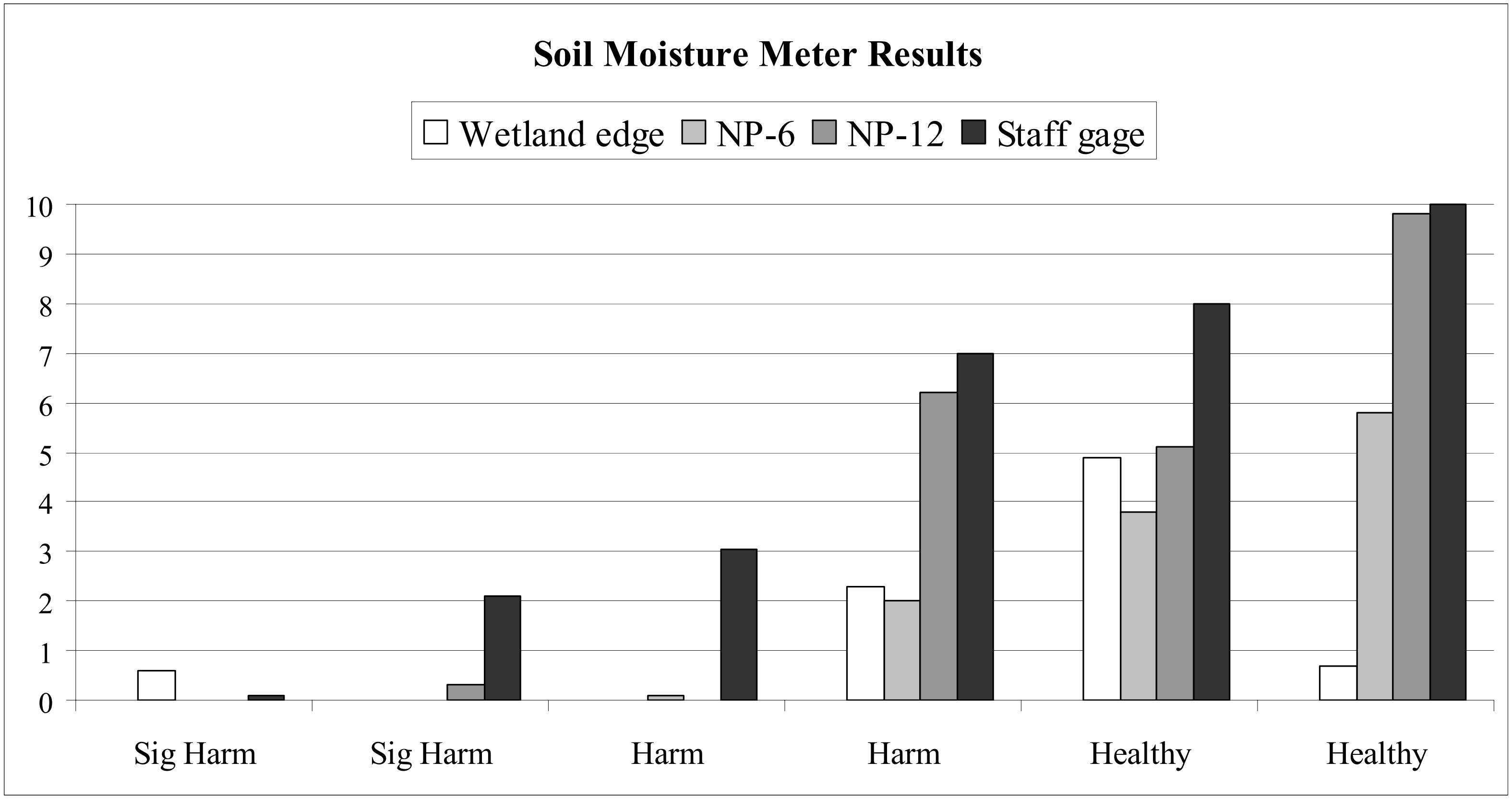


Figure 17. Soil Moisture Meter test results

Discussion

Measurements of $\overline{\%C}$ were statistically significantly different for the “healthy” as compared to the “harmed” and “significant harmed” wetlands. In addition, both mean soil water content ($\overline{w}$) (Figure 5) and $\overline{\%C}$ (Figure 7) showed an increase in “healthy” wetlands over both “harmed” and “significantly harmed” categories, and also demonstrated a trend related to wetland geometry, increasing from the wetland edge towards the center, with a pronounce increase at the NP-12 elevation. Using soil moisture and carbon as an indicator of organic matter content, this is consistent with the thickest development of soil organic matter (SOM) in the center of the wetland dome (Mitsch and Ewel, 1979; Tiner, 1999; Bondavalli et al., 2000).

Graphs of both water and bulk density versus %C further demonstrate the link between organic matter content in soils with soil moisture (Figure 8). As soil water content increases, %C also increases. Coupling the %C with bulk density (Figure 9) showed an increase in organic matter in the soil, as indicated by an increase in carbon content, with a decrease in bulk density. These graphs showed an empirical relationship that could predict values of SOC given the water content or the bulk density of a soil sample.

Values of mean bulk density at the NP-12 elevation correlate well with this trend as 3 of the 4 “healthy” wetlands ranged from 0.2 g/cm^3 to 0.65 g/cm^3, and the measurements at all other wetland sites ranged between 0.85 g/cm^3 and 1.50 g/cm^3. Higher concentrations of organic matter reduce soil bulk density because it contains less dense plant and animal remains as compared to more dense minerals, combined with the effect of processes involved in decomposition, which open up numerous pores within the matrix (Juma, 2004).

The highest measurements of water content and carbon content, and conversely the lowest values for bulk density, would be in the wetlands where conditions exist to develop thick deposits of organic rich soils. These were demonstrated most vividly at the central NP-12 elevation, therefore it follows that the center of the wetland is the most crucial indicator of wetland soil health.

In addition, the soil nitrogen (Figure 10) and C:N ratio (Figure 11) values support the development of SOM at the NP-12 elevations. Plant productivity and decomposition produces larger nitrogen pools in the soil, and decreasing C:N ratios are indications of a high organic content produced in soils that have accumulated over time (Juma, 2004). There is an increase in %N for the NP-12 elevation in the “healthy” wetlands. The C:N ratios between wetlands with different “degrees of harm” was less indicative that the trend within each wetland, where the ratio decreased consistently from the wetland edge towards the center.

The results of this study suggest that water levels during the growing season must be high enough to saturate the center of the wetland for prolonged periods, creating anaerobic conditions that allow for the accumulation of soil organic matter (SOM). It is most likely that this central deposit of organic rich soils retains soil moisture during dry periods and sustains the wetland ecology. Conversely, if a wetland does not achieve high enough pooling in the central elevation during the wet season, unsaturated soils will decompose SOM and lose stores of organic carbon. Loss of SOM means that the wetland will be unable to retain water during dry seasons and the biota will become impacted as water needs cannot be met.

Since soil moisture and organic carbon content are well correlated, tests of soil water content may prove a convenient proxy for determining the organic stores and thus the relative health of the wetland. Wetlands that do not have adequate soil moisture throughout the year in the center may indicate they are "harmed" or impacted in some way. Preliminary tests using a soil moisture meter at six of the wetlands within the same geographic region were encouraging as a simple tool that can be used to quickly measure relative soil water content and therefore soil health (Figure 17). Transects from the wetland edge towards the center showed increases in soil moisture for each site, except for the most "significantly harmed" (Starkey D). This would concur with the wetland center being the key elevation to retain water in the soil during dry periods. In addition, there was an increase in the moisture readings in wetlands of increasing "health", indicating that these wetlands are retaining more water during the same period of time than are the impacted wetlands.

Chaplot et al. (2001) developed a procedure for estimating the soil organic content using an index of soil colors in the upper horizons. This concept could potentially be adapted to conveniently test the wetland soils and correlate soil colors with carbon content.

The Green Swamp 7 site was the only "healthy" wetland of the four that were sampled that diverged from the remainder of the results. Soils at this site were observed to have had a higher sand content, less soil organic matter, and consequently lower soil moisture and higher bulk density as compared to the other "healthy" sites, especially at the NP-12 elevation. However, the biota was healthy and there were no indication of hydrologic impact at the time of sampling. If the wetland is assessed as "healthy" due to vegetation and hydrology, one explanation could be that the water table in that region is not impacted by groundwater pumping and water availability during the year is not yet an issue. Associated with this is the possibility is that the soils may be immature (Quideau et al., 2001; Smith et al., 2004) and the layer of organic matter is increasing but not yet thick enough to be correlated with the other "healthy" sites. Interpreting the carbon and nitrogen isotope measurements may provide more insight into this question (Amundson et al., 2003; Wynn et al., 2005).

An analysis of stable carbon isotope values may indicate the state of decomposition of organic matter due to the magnitude of the differences between the highest and lowest $\delta^{13}C$ values within the same type of soil. Soils in "healthy" wetlands had a higher variance in $\delta^{13}C$ values than "harmed" wetlands, which in turn had a higher variation than the "significantly harmed" wetlands. A study by Wynn et al. (2005) found that finer textured soils had a larger difference in $\delta^{13}C$ values than coarse textured soils of comparable soils forming regimes. They concluded that the processes that dominate decomposition in organic rich soils fractionated the ^{13}C isotopes with increasing depth from the surface. A similar process of 13-Cenrichment during humification may account for the trends observed from NP to NP-12, and for the increase in amplitude of this trend in “healthy” wetlands.

The $\delta^{13}C$ values of SOC can be a quantitative indicator of the dominate plant community that contribute carbon to the soil, and of mixtures of C3 and C4 plants (Yonghoon et al., 2001). As invasive grasses and other plant species begin to take over an impacted wetland, the mean $\delta^{13}C$ values would be less depleted with respect to ^{12}C to reflect increasing biomass contributions from C4 plant communities. This may be the case with the “significantly harmed” Section 21 wetland site, where the mean $\delta^{13}C$ values were the highest (Figure 12) and extensive invasive grasses were observed at all NP elevation on the day of soil sampling.

Organic carbon plays an important role in denitrification in wetland soils (Hill and Cardaci, 2004). Nitrates (NO_3^-) have nitrogen isotopes that are depleted with respect to other pools of nitrogen in the soil and may be a good indicator of the viability of the organic carbon pool (Davidsson and Stahl, 2000). The increasing variance in $\delta^{13}C$ values, along with a similar trend in $\delta^{15}N$ values with increasing health could indicate a more dynamic carbon and nitrogen interaction and SOM accumulation. A thorough isotopic analysis and additional data collection may be needed to fully utilize the $\delta^{13}C$ and $\delta^{15}N$ values from this study.

Continued research may be needed to develop a systematic approach to assessing wetlands for “harm” using soil carbon as the measure. Developing the soil moisture meter and other quick and practical techniques has the potential to provide SWFWMD with improved wetland evaluation procedures that definitively categorize “harmed” wetlands. Results seem to indicate that future research can focus on sampling from the central elevation of NP-12 and determining changes in soil water content and water retention potential in that area.

Conclusion

There is a connection between measurements of the upper soil horizon's water content and wetland health, as related to quantities of soil organic carbon. There appears to be some validity to utilizing a soil moisture meter in the upper 30 centimeters as a proxy for soil carbon stores, which should be higher in the center of a cypress wetland and more pronounced in the healthier sites. A sampling protocol using a soil moisture meter or soil moisture monitoring system should be developed if this will be utilized by entities in the assessment of wetlands.

Further study of the $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotopic composition of decomposing organic matter in the "healthy" wetlands of west-central Florida could be conducted to contrast with the isotopic makeup of impacted wetland soils.

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Appendix A

Individual Wetland Sample Data, Computations of Water Content and Bulk Density, and IRMS Results

Table A-1a. Starkey D (Sig. Harm) Soil Collection Data

Sample Date: 12/4 - 12/6/2007

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	515.4	494.0	21.4	4.15	1.531
NP	2	441.7	405.5	36.2	8.20	1.257
NP	3	521.1	500.5	20.6	3.95	1.552
NP	4	498.5	471.6	26.9	5.40	1.462
NP	5	467.9	448.7	19.2	4.10	1.391
NP	6	456.9	434.4	22.5	4.92	1.347
NP	7	293.1	265.2	27.9	9.52	0.822
NP	8	379.2	355.7	23.5	6.20	1.103
NP	9	433.1	408.2	24.9	5.75	1.265
NP	10	397.8	377.9	19.9	5.00	1.172
NP	11	508.6	484.1	24.5	4.82	1.501
NP	12	370.9	350.0	20.9	5.63	1.085
NP	13	468.8	441.7	27.1	5.78	1.369
NP	14	516.6	493.5	23.1	4.47	1.530
NP	15	421.1	395.7	25.4	6.03	1.227
NP-6	1	351.4	329.8	21.6	6.15	1.022
NP-6	2	487.2	467.8	19.4	3.98	1.450
NP-6	3	432.8	408.6	24.2	5.59	1.267
NP-6	4	478.3	459.3	19.0	3.97	1.424
NP-6	5	434.5	404.4	30.1	6.93	1.254
NP-6	6	397.8	369.9	27.9	7.01	1.147
NP-6	7	451.9	427.7	24.2	5.36	1.326
NP-6	8	502.1	485.0	17.1	3.41	1.504
NP-6	9	426.4	402.5	23.9	5.61	1.248
NP-6	10	406.7	383.4	23.3	5.73	1.189
NP-6	11	442.0	416.4	25.6	5.79	1.291
NP-6	12	424.7	405.0	19.7	4.64	1.256
NP-6	13	446.1	424.0	22.1	4.95	1.314
NP-6	14	479.2	447.9	31.3	6.53	1.389
NP-6	15	496.1	475.3	20.8	4.19	1.474

NP-12	1	482.2	454.8	27.4	5.68	1.410
NP-12	2	500.8	481.0	19.8	3.95	1.491
NP-12	3	421.1	400.8	20.3	4.82	1.243
NP-12	4	414.3	393.9	20.4	4.92	1.221
NP-12	5	504.4	483.3	21.1	4.18	1.498
NP-12	6	411.6	393.4	18.2	4.42	1.220
NP-12	7	477.8	448.2	29.6	6.20	1.389
NP-12	8	477.9	461.0	16.9	3.54	1.429
NP-12	9	390.8	371.1	19.7	5.04	1.150
NP-12	10	381.6	352.8	28.8	7.55	1.094
NP-12	11	415.8	396.0	19.8	4.76	1.228
NP-12	12	435.2	410.1	25.1	5.77	1.271
NP-12	13	420.4	400.2	20.2	4.80	1.241
NP-12	14	443.3	413.1	30.2	6.81	1.281
NP-12	15	417.7	388.8	28.9	6.92	1.205

Table A-1b. Starkey D (Sig. Harm) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	$\delta^{13}C$	$\delta^{15}N$	C:N	MS Date
Bulk A	1.439	0.120	1.65	23.74	mg/cm^3	0.0811	-24.40	-6.69	20.38	2/21/2008
			1.76	25.32	mg/cm^3	0.1050	-24.31	-7.81	16.73	2/21/2008
Bulk B	1.142	0.201	2.83	32.31	mg/cm^3	0.1015	-24.83	-3.18	27.90	2/21/2008
Bulk C	1.342	0.187	1.66	22.28	mg/cm^3	0.0714	-24.50	-5.80	23.19	2/21/2008
Bulk-Bulk	1.308	0.205	2.07	27.07	mg/cm^3	0.0914	-24.64	-4.39	22.61	2/21/2008
			2.05	26.81	mg/cm^3	0.1035	-24.65	-6.31	19.78	2/21/2008
			2.24	29.29	mg/cm^3	0.0718	-25.18	0.19	31.22	3/10/2008
			2.04			0.0578	-24.72	0.33	35.28	4/22/2008
NP-6										
Bulk A	1.283	0.171	2.73	35.04	mg/cm^3	0.1338	-23.76	-2.73	20.44	2/21/2008
Bulk B	1.283	0.141	2.92	37.45	mg/cm^3	0.1412	-23.96	-2.14	20.69	2/21/2008
Bulk C	1.345	0.087	2.77	37.25	mg/cm^3	0.1427	-23.92	-3.49	19.45	2/21/2008
			2.91	39.13	mg/cm^3	0.1168	-24.23	0.61	25.02	3/10/2008
Bulk-Bulk	1.304	0.131	2.77	36.11	mg/cm^3	0.1440	-23.62	-3.56	19.23	2/21/2008
			2.70	35.19	mg/cm^3	0.1652	-23.66	-4.42	16.34	2/21/2008
			2.59	33.76	mg/cm^3	0.1009	-23.86	1.22	25.67	3/10/2008
			2.61			0.0922	-23.88	1.01	28.35	4/22/2008

NP-12	Avg wt	Std Dev	% C	C Density		%N	δ^{13}C	δ^{15}N	C:N	MS Date
Bulk A	1.373	0.133	2.16	29.65	mg/cm^3	0.1435	-24.61	-3.75	15.07	2/21/2008
			2.20	30.20	mg/cm^3	0.1014	-24.51	1.26	21.68	3/10/2008
Bulk B	1.256	0.147	2.62	32.92	mg/cm^3	0.1695	-24.55	-3.81	15.46	2/21/2008
Bulk C	1.245	0.031	3.01	37.48	mg/cm^3	0.1971	-25.09	-2.01	15.25	2/21/2008
Bulk-Bulk	1.291	0.123	1.96	25.31	mg/cm^3	0.1456	-24.54	-5.18	13.44	2/21/2008
			2.21	28.54	mg/cm^3	0.1417	-24.92	1.69	15.58	3/10/2008
			2.08			0.0947	-24.76	-0.16	22.01	4/22/2008

Table A-2a. Starkey 1 (Healthy) Soil Collection Data

Sample Date: 12/11/2007

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	424.4	363.6	60.8	14.33	1.127
NP	2	437.6	375.8	61.8	14.12	1.165
NP	3	426.3	358.4	67.9	15.93	1.111
NP	4	407.8	349.8	58.0	14.22	1.084
NP	5	435.6	377.1	58.5	13.43	1.169
NP	6	417.1	355.7	61.4	14.72	1.103
NP	7	354.0	295.3	58.7	16.58	0.915
NP	8	288.0	237.7	50.3	17.47	0.737
NP	9	408.1	341.2	66.9	16.39	1.058
NP	10	419.6	361.0	58.6	13.97	1.119
NP	11	460.1	395.1	65.0	14.13	1.225
NP	12	465.8	404.3	61.5	13.20	1.253
NP	13	459.3	394.6	64.7	14.09	1.223
NP	14	404.7	342.3	62.4	15.42	1.061
NP	15	442.3	378.4	63.9	14.45	1.173
NP-6	1	528.7	446.2	82.5	15.60	1.383
NP-6	2	488.5	389.8	98.7	20.20	1.208
NP-6	3	486.0	395.5	90.5	18.62	1.226
NP-6	4	294.7	194.2	100.5	34.10	0.602
NP-6	5	391.9	284.6	107.3	27.38	0.882
NP-6	6	395.7	316.1	79.6	20.12	0.980
NP-6	7	293.5	230.2	63.3	21.57	0.714
NP-6	8	369.4	289.3	80.1	21.68	0.897
NP-6	9	376.7	300.1	76.6	20.33	0.930
NP-6	10	477.5	380.1	97.4	20.40	1.178
NP-6	11	422.8	328.0	94.8	22.42	1.017
NP-6	12	314.4	242.1	72.3	23.00	0.751
NP-6	13	446.7	363.6	83.1	18.60	1.127
NP-6	14	423.3	337.0	86.3	20.39	1.045
NP-6	15	504.2	410.8	93.4	18.52	1.274

NP-12	1	120.6	31.8	88.8	73.63	0.099
NP-12	2	72.7	19.8	52.9	72.76	0.061
NP-12	3	161.5	55.6	105.9	65.57	0.172
NP-12	4	140.2	37.5	102.7	73.25	0.116
NP-12	5	98.3	39.2	59.1	60.12	0.122
NP-12	6	124.7	54.8	69.9	56.05	0.170
NP-12	7	270.8	170.7	100.1	36.96	0.529
NP-12	8	138.7	45.3	93.4	67.34	0.140
NP-12	9	378.1	288.0	90.1	23.83	0.893
NP-12	10	105.6	31.3	74.3	70.36	0.097
NP-12	11	107.3	35.9	71.4	66.54	0.111
NP-12	12	108.9	41.7	67.2	61.71	0.129
NP-12	13	151.4	55.4	96.0	63.41	0.172
NP-12	14	133.1	36.0	97.1	72.95	0.112
NP-12	15	93.7	24.2	69.5	74.17	0.075

Table A-2b. Starkey 1 (Healthy) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	$\delta^{13}C$	$\delta^{15}N$	C:N	MS Date
Bulk A	1.131	0.036	5.58	63.18	mg/cm^3	0.2216	-24.57	-2.22	25.19	2/21/2008
Bulk B	0.986	0.161	3.93	38.74	mg/cm^3	0.1829	-25.13	-5.22	21.47	2/21/2008
			4.09	40.34	mg/cm^3	0.1483	-25.28	2.94	27.58	3/10/2008
Bulk C	1.187	0.076	3.41	40.50	mg/cm^3	0.1548	-24.42	-5.34	22.04	2/21/2008
			3.23	38.35	mg/cm^3	0.1162	-24.76	3.82	27.81	3/10/2008
Bulk-Bulk	1.102	0.131	3.45	38.05	mg/cm^3	0.1568	-24.54	-4.21	22.03	2/21/2008
			3.70	40.76	mg/cm^3	0.2238	-25.05	-6.68	16.55	2/21/2008
			3.74			0.1168	-24.87	1.43	32.03	4/22/2008
NP-6										
Bulk A	1.060	0.314	5.28	55.99	mg/cm^3	0.2371	-24.61	-0.99	22.28	3/10/2008
Bulk B	0.940	0.167	5.28	49.67	mg/cm^3	0.2820	-24.01	-4.13	18.74	2/21/2008
Bulk C	1.043	0.191	5.08	52.93	mg/cm^3	0.2968	-24.82	-3.42	17.10	2/21/2008
			4.42	46.08	mg/cm^3	0.1927	-24.45	1.44	22.94	3/10/2008
Bulk-Bulk	1.014	0.223	4.93	50.01	mg/cm^3	0.2870	-24.06	-3.85	17.18	2/21/2008
			4.25	43.11	mg/cm^3	0.2963	-23.98	-5.94	14.36	2/21/2008
			4.35	44.12	mg/cm^3	0.1751	-24.21	1.55	24.85	3/10/2008
			4.46			0.1650	-24.22	2.14	27.04	4/22/2008

NP-12	Avg wt	Std Dev	% C	C Density		%N	$\delta^{13}C$	$\delta^{15}N$	C:N	MS Date
Bulk A	0.114	0.040	31.71	36.16	mg/cm^3	1.6474	-27.57	-1.38	19.25	2/21/2008
			30.44	34.71	mg/cm^3	1.5660	-27.72	-1.58	19.44	2/21/2008
Bulk B	0.366	0.341	14.17	51.84	mg/cm^3	0.7223	-26.71	-2.18	19.62	2/21/2008
Bulk C	0.120	0.035	24.69	29.57	mg/cm^3	1.2641	-27.72	-2.15	19.53	2/21/2008
Bulk-Bulk	0.200	0.221	18.93	37.83	mg/cm^3	0.9639	-27.40	-2.35	19.64	2/21/2008
			18.53	37.04	mg/cm^3	0.9633	-27.25	-1.87	19.23	2/21/2008
			24.40							4/22/2008

Table A-3a. Starkey U (Sig. Harm) Soil Collection Data

Sample Date: 1/23 - *1/29/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density	
NP	1	368.1	316.3	51.8	14.07	0.981	
NP	2	378.8	336.4	42.4	11.19	1.043	*
NP	3	363.1	326.6	36.5	10.05	1.013	*
NP	4	417.5	392.6	24.9	5.96	1.217	*
NP	5	343.6	296.8	46.8	13.62	0.920	
NP	6	325.2	282.2	43.0	13.22	0.875	
NP	7	393.5	348.6	44.9	11.41	1.081	
NP	8	472.2	422.2	50.0	10.59	1.309	
NP	9	374.0	342.9	31.1	8.32	1.063	
NP	10	419.6	368.5	51.1	12.18	1.142	
NP	11	379.0	327.5	51.5	13.59	1.015	
NP	12	255.6	211.8	43.8	17.14	0.657	
NP	13	417.8	380.7	37.1	8.88	1.180	*
NP	14	375.6	328.1	47.5	12.65	1.017	*
NP	15	418.9	360.1	58.8	14.04	1.116	
NP-6	1	412.2	370.3	41.9	10.16	1.148	
NP-6	2	379.7	344.4	35.3	9.30	1.068	
NP-6	3	484.1	439.5	44.6	9.21	1.363	
NP-6	4	363.3	346.8	16.5	4.54	1.075	
NP-6	5	448.7	406.8	41.9	9.34	1.261	
NP-6	6	434.3	412.0	22.3	5.13	1.277	
NP-6	7	476.4	449.7	26.7	5.60	1.394	
NP-6	8	455.5	434.2	21.3	4.68	1.346	
NP-6	9	533.9	509.8	24.1	4.51	1.580	
NP-6	10	283.3	245.1	38.2	13.48	0.760	
NP-6	11	456.0	427.0	29.0	6.36	1.324	*
NP-6	12	416.1	389.7	26.4	6.34	1.208	*
NP-6	13	511.4	467.1	44.3	8.66	1.448	
NP-6	14	416.1	388.3	27.8	6.68	1.204	*
NP-6	15	421.5	367.7	53.8	12.76	1.140	

NP-12	1	473.4	431.3	42.1	8.89	1.337	
NP-12	2	422.2	375.8	46.4	10.99	1.165	
NP-12	3	363.9	317.2	46.7	12.83	0.983	
NP-12	4	435.6	383.5	52.1	11.96	1.189	
NP-12	5	406.7	371.8	34.9	8.58	1.153	
NP-12	6	406.0	363.7	42.3	10.42	1.128	
NP-12	7	531.5	490.3	41.2	7.75	1.520	
NP-12	8	405.2	370.1	35.1	8.66	1.147	
NP-12	9	366.0	315.9	50.1	13.69	0.979	
NP-12	10	319.6	277.5	42.1	13.17	0.860	
NP-12	11	300.9	268.3	32.6	10.83	0.832	
NP-12	12	408.9	371.6	37.3	9.12	1.152	*
NP-12	13	298.1	250.8	47.3	15.87	0.778	
NP-12	14	421.7	366.2	55.5	13.16	1.135	
NP-12	15	438.4	381.1	57.3	13.07	1.181	

* broken items re-sampled on 1/29/08

Table A-3b. Starkey U (Sig. Harm) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	d13C	d15N	C:N	MS Date
Bulk A	1.035	0.112	3.64	37.65	mg/cm^3	0.1842	-26.30	0.76	19.75	2/21/2008
Bulk B	1.094	0.156	2.83	30.93	mg/cm^3	0.1502	-26.28	1.25	18.82	2/21/2008
Bulk C	0.997	0.203	3.48	34.68	mg/cm^3	0.1752	-26.38	0.58	19.85	2/21/2008
Bulk-Bulk	1.042	0.155	3.19	33.21	mg/cm^3	0.1610	-26.27	0.74	19.79	2/21/2008
NP-6										
Bulk A	1.183	0.127	2.39	28.32	mg/cm^3	0.1619	-27.27	-4.31	14.79	2/21/2008
Bulk B	1.272	0.307	1.67	21.28	mg/cm^3	0.1163	-26.93	-3.91	14.39	2/21/2008
			2.05	26.07	mg/cm^3	0.1066	-27.31	1.21	19.22	3/10/2008
Bulk C	1.265	0.122	1.97	24.93	mg/cm^3	0.1545	-27.07	-2.93	12.76	2/21/2008
			2.09	26.43	mg/cm^3	0.1252	-27.36	1.35	16.68	3/10/2008
Bulk-Bulk	1.240	0.194	1.90	23.56	mg/cm^3	0.1476	-26.90	-4.18	12.88	2/21/2008
			1.96			0.1012	-27.24	0.43	19.39	4/22/2008
NP-12										
Bulk A	1.165	0.126	2.99	34.88	mg/cm^3	0.2199	-27.27	-2.34	13.61	2/21/2008
			2.71	31.58	mg/cm^3	0.1739	-27.42	0.97	15.60	3/10/2008
Bulk B	1.127	0.249	2.53	28.53	mg/cm^3	0.1897	-27.22	-0.96	13.35	2/21/2008
Bulk C	1.016	0.194	3.37	34.20	mg/cm^3	0.2413	-27.14	-2.51	13.96	2/21/2008
			3.26	33.11	mg/cm^3	0.1885	-27.18	1.02	17.27	3/10/2008
Bulk-Bulk	1.103	0.193	2.89	31.87	mg/cm^3	0.1900	-27.25	-1.38	15.21	2/21/2008
			3.02	33.30	mg/cm^3	0.2851	-26.88	-4.97	10.58	2/21/2008
			2.67			0.1507	-27.32	1.19	17.73	4/22/2008

Table A-4a. Starkey W (Harm) Soil Collection Data

Sample Date: 1/23 - 1/29/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	381.3	352.7	28.6	7.50	1.093
NP	2	444.4	402.6	41.8	9.41	1.248
NP	3	438.7	400.6	38.1	8.68	1.242
NP	4	416.8	373.7	43.1	10.34	1.159
NP	5	379.7	340.1	39.6	10.43	1.054
NP	6	393.2	356.7	36.5	9.28	1.106
NP	7	394.1	342.4	51.7	13.12	1.061
NP	8	411.1	368.4	42.7	10.39	1.142
NP	9	442.3	401.2	41.1	9.29	1.244
NP	10	497.3	456.6	40.7	8.18	1.416
NP	11	426.9	393.0	33.9	7.94	1.218
NP	12	400.0	370.7	29.3	7.33	1.149
NP	13	313.8	278.8	35.0	11.15	0.864
NP	14	351.9	327.3	24.6	6.99	1.015
NP	15	365.8	342.8	23.0	6.29	1.063
NP-6	1	425.6	379.3	46.3	10.88	1.176
NP-6	2	403.3	361.6	41.7	10.34	1.121
NP-6	3	457.1	406.9	50.2	10.98	1.261
NP-6	4	477.8	437.2	40.6	8.50	1.355
NP-6	5	462.0	405.9	56.1	12.14	1.258
NP-6	6	475.4	420.3	55.1	11.59	1.303
NP-6	7	448.6	397.8	50.8	11.32	1.233
NP-6	8	439.3	390.6	48.7	11.09	1.211
NP-6	9	462.1	404.2	57.9	12.53	1.253
NP-6	10	466.5	414.4	52.1	11.17	1.285
NP-6	11	347.1	298.6	48.5	13.97	0.926
NP-6	12	428.8	378.0	50.8	11.85	1.172
NP-6	13	504.5	457.8	46.7	9.26	1.419
NP-6	14	448.4	398.1	50.3	11.22	1.234
NP-6	15	417.5	369.2	48.3	11.57	1.145

NP-12	1	442.2	385.0	57.2	12.94	1.194
NP-12	2	519.9	473.3	46.6	8.96	1.467
NP-12	3	461.6	426.9	34.7	7.52	1.323
NP-12	4	421.9	391.1	30.8	7.30	1.212
NP-12	5	510.4	470.9	39.5	7.74	1.460
NP-12	6	449.0	411.1	37.9	8.44	1.274
NP-12	7	445.6	405.6	40.0	8.98	1.257
NP-12	8	424.0	388.1	35.9	8.47	1.203
NP-12	9	472.9	434.6	38.3	8.10	1.347
NP-12	10	554.0	511.3	42.7	7.71	1.585
NP-12	11	557.7	516.0	41.7	7.48	1.600
NP-12	12	445.6	406.4	39.2	8.80	1.260
NP-12	13	439.0	413.1	25.9	5.90	1.281
NP-12	14	485.5	444.6	40.9	8.42	1.378
NP-12	15	483.6	441.2	42.4	8.77	1.368

Table A-4b. Starkey W (Harm) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	d13C	d15N	C:N	MS Date
Bulk A	1.159	0.087	2.96	34.30	mg/cm^3	0.0816	-25.55	1.96	36.26	3/20/2008
Bulk B	1.194	0.141	3.14	37.45	mg/cm^3	0.1098	-25.61	-0.09	28.58	3/20/2008
Bulk C	1.062	0.135	3.73	39.62	mg/cm^3	0.0995	-26.14	3.04	37.48	3/20/2008
Bulk-Bulk	1.138	0.128	2.81	31.97	mg/cm^3	0.0899	-25.77	1.11	31.24	3/20/2008
			3.26			0.0855	-25.93	3.10	38.14	4/22/2008
NP-6										
Bulk A	1.234	0.090	1.87	23.14	mg/cm^3	0.0800	-25.57	-0.40	23.42	3/20/2008
Bulk B	1.257	0.037	2.87	36.12	mg/cm^3	0.1200	-25.67	0.57	23.94	3/20/2008
Bulk C	1.179	0.178	3.03	35.70	mg/cm^3	0.1095	-26.45	0.90	27.65	3/20/2008
Bulk-Bulk	1.224	0.113	2.43	29.74	mg/cm^3	0.0919	-25.86	1.32	26.44	3/20/2008
			2.18			0.0681	-25.92	3.52	31.94	4/22/2008
NP-12										
Bulk A	1.331	0.131	1.63	21.69	mg/cm^3	0.0951	-26.47	-2.51	17.13	3/20/2008
Bulk B	1.334	0.150	1.77	23.65	mg/cm^3	0.0910	-26.58	-0.46	19.50	3/20/2008
Bulk C	1.377	0.135	1.56	21.49	mg/cm^3	0.0944	-26.28	-2.37	16.53	3/20/2008
Bulk-Bulk	1.347	0.130	1.52	20.55	mg/cm^3	0.0809	-26.57	-1.50	18.85	3/20/2008
			1.63			0.0666	-26.58	0.65	24.50	4/22/2008

Table A-5a. Section 21 (Sig. Harm) Soil Collection Data

Sample Date: 1/29/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	542.5	504.0	38.5	7.10	1.562
NP	2	503.4	470.9	32.5	6.46	1.460
NP	3	487.1	451.8	35.3	7.25	1.401
NP	4	585.5	552.2	33.3	5.69	1.712
NP	5	497.0	467.4	29.6	5.96	1.449
NP	6	559.3	528.2	31.1	5.56	1.638
NP	7	504.5	471.4	33.1	6.56	1.461
NP	8	530.4	493.7	36.7	6.92	1.531
NP	9	554.5	518.0	36.5	6.58	1.606
NP	10	538.1	499.5	38.6	7.17	1.549
NP	11	523.3	484.1	39.2	7.49	1.501
NP	12	419.0	382.8	36.2	8.64	1.187
NP	13	533.7	500.8	32.9	6.16	1.553
NP	14	533.4	498.9	34.5	6.47	1.547
NP	15	522.9	490.0	32.9	6.29	1.519
NP-6	1	525.3	470.1	55.2	10.51	1.457
NP-6	2	466.6	421.2	45.4	9.73	1.306
NP-6	3	521.6	474.0	47.6	9.13	1.469
NP-6	4	495.4	446.8	48.6	9.81	1.385
NP-6	5	526.6	487.6	39.0	7.41	1.512
NP-6	6	490.9	454.4	36.5	7.44	1.409
NP-6	7	543.8	497.7	46.1	8.48	1.543
NP-6	8	546.7	499.9	46.8	8.56	1.550
NP-6	9	540.4	498.5	41.9	7.75	1.545
NP-6	10	328.5	300.7	27.8	8.46	0.932
NP-6	11	519.6	480.2	39.4	7.58	1.489
NP-6	12	518.7	481.4	37.3	7.19	1.492
NP-6	13	520.8	484.8	36.0	6.91	1.503
NP-6	14	504.0	463.2	40.8	8.10	1.436
NP-6	15	524.1	485.5	38.6	7.37	1.505

NP-12	1	538.3	476.4	61.9	11.50	1.477
NP-12	2	500.9	444.1	56.8	11.34	1.377
NP-12	3	484.8	420.5	64.3	13.26	1.304
NP-12	4	503.9	440.5	63.4	12.58	1.366
NP-12	5	522.4	467.3	55.1	10.55	1.449
NP-12	6	547.1	490.5	56.6	10.35	1.521
NP-12	7	529.1	478.2	50.9	9.62	1.483
NP-12	8	566.9	511.8	55.1	9.72	1.587
NP-12	9	570.6	520.3	50.3	8.82	1.613
NP-12	10	568.5	511.8	56.7	9.97	1.587
NP-12	11	549.8	497.1	52.7	9.59	1.541
NP-12	12	582.6	526.7	55.9	9.59	1.633
NP-12	13	562.1	502.2	59.9	10.66	1.557
NP-12	14	540.3	492.3	48.0	8.88	1.526
NP-12	15	552.4	500.0	52.4	9.49	1.550

Table A-5b. Section 21 (Sig. Harm) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	d13C	d15N	C:N	MS Date
Bulk A	1.517	0.124	1.42	21.52	mg/cm^3	0.0843	-22.11	-2.46	16.82	2/21/2008
			1.40	21.24	mg/cm^3	0.0697	-22.15	0.10	20.04	3/10/2008
Bulk B	1.557	0.069	1.16	18.03	mg/cm^3	0.0738	-21.25	-3.13	15.69	2/21/2008
Bulk C	1.461	0.155	1.18	17.19	mg/cm^3	0.0700	-22.05	-4.32	16.80	2/21/2008
Bulk-Bulk	1.512	0.119	1.25	18.88	mg/cm^3	0.0854	-21.52	-3.29	14.63	2/21/2008
			1.19	17.99	mg/cm^3	0.0630	-21.88	2.66	18.90	3/10/2008
			1.19			0.0520	-21.51	0.71	22.82	4/22/2008
NP-6										
Bulk A	1.426	0.081	1.89	26.94	mg/cm^3	0.1265	-22.41	-1.62	14.94	2/21/2008
			1.84	26.24	mg/cm^3	0.1023	-22.41	1.64	18.01	3/10/2008
Bulk B	1.396	0.266	1.53	21.31	mg/cm^3	0.1156	-21.73	-1.63	13.21	2/21/2008
Bulk C	1.485	0.028	1.39	20.57	mg/cm^3	0.1018	-21.14	-2.00	13.60	2/21/2008
Bulk-Bulk	1.436	0.154	1.53	21.92	mg/cm^3	0.1166	-21.64	-2.03	13.09	2/21/2008
			1.43	20.53	mg/cm^3	0.0858	-22.00	2.90	16.71	3/10/2008
			1.35			0.0730	-21.82	1.08	18.54	4/22/2008

NP-12

Bulk A	1.394	0.069	2.18	30.40	mg/cm^3	0.1589	-23.48	-2.27	13.72	2/21/2008
			2.31	32.21	mg/cm^3	0.1249	-23.43	2.15	18.52	3/10/2008
Bulk B	1.558	0.054	1.53	23.90	mg/cm^3	0.1196	-22.51	-3.35	12.83	2/21/2008
Bulk C	1.561	0.042	1.41	22.08	mg/cm^3	0.1220	-22.51	-3.94	11.59	2/21/2008
Bulk-Bulk	1.505	0.096	1.71	25.74	mg/cm^3	0.1326	-22.82	-3.67	12.90	2/21/2008
			1.69	25.43	mg/cm^3	0.0998	-22.90	2.61	16.94	3/10/2008
			1.67			0.0865	-22.92	1.16	19.27	4/22/2008

Table A-6a. Blackwater Creek (Harm) Soil Collection Data

Sample Date: 2/5/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	598.9	512.8	86.1	14.38	1.590
NP	2	516.0	440.6	75.4	14.61	1.366
NP	3	450.2	380.2	70.0	15.55	1.179
NP	4	472.5	401.9	70.6	14.94	1.246
NP	5	524.3	453.3	71.0	13.54	1.405
NP	6	497.5	417.2	80.3	16.14	1.293
NP	7	363.7	293.2	70.5	19.38	0.909
NP	8	416.1	328.9	87.2	20.96	1.020
NP	9	462.6	383.5	79.1	17.10	1.189
NP	10	507.5	425.1	82.4	16.24	1.318
NP	11	540.5	459.9	80.6	14.91	1.426
NP	12	550.7	470.1	80.6	14.64	1.457
NP	13	545.5	467.8	77.7	14.24	1.450
NP	14	490.3	399.9	90.4	18.44	1.240
NP	15	528.7	444.0	84.7	16.02	1.376
NP-6	1	348.4	276.1	72.3	20.75	0.856
NP-6	2	493.5	395.4	98.1	19.88	1.226
NP-6	3	357.3	276.5	80.8	22.61	0.857
NP-6	4	395.0	307.1	87.9	22.25	0.952
NP-6	5	418.2	324.5	93.7	22.41	1.006
NP-6	6	153.5	102.6	50.9	33.16	0.318
NP-6	7	593.7	488.3	105.4	17.75	1.514
NP-6	8	256.3	188.4	67.9	26.49	0.584
NP-6	9	221.6	158.3	63.3	28.56	0.491
NP-6	10	557.9	457.6	100.3	17.98	1.419
NP-6	11	500.5	398.1	102.4	20.46	1.234
NP-6	12	273.9	200.7	73.2	26.73	0.622
NP-6	13	372.3	283.2	89.1	23.93	0.878
NP-6	14	319.8	243.9	75.9	23.73	0.756
NP-6	15	408.0	327.5	80.5	19.73	1.015

NP-12	1	593.9	477.9	116.0	19.53	1.482
NP-12	2	469.1	341.4	127.7	27.22	1.058
NP-12	3	145.1	80.4	64.7	44.59	0.249
NP-12	4	492.0	360.9	131.1	26.65	1.119
NP-12	5	474.9	348.3	126.6	26.66	1.080
NP-12	6	483.2	349.3	133.9	27.71	1.083
NP-12	7	530.4	396.8	133.6	25.19	1.230
NP-12	8	442.1	311.4	130.7	29.56	0.965
NP-12	9	512.8	386.6	126.2	24.61	1.199
NP-12	10	408.4	273.4	135.0	33.06	0.848
NP-12	11	496.3	371.1	125.2	25.23	1.150
NP-12	12	291.7	192.6	99.1	33.97	0.597
NP-12	13	500.7	379.5	121.2	24.21	1.177
NP-12	14	494.0	369.3	124.7	25.24	1.145
NP-12	15	276.4	196.0	80.4	29.09	0.608

Table A-6b. Blackwater Creek (Harm) IRMS Bulked Sample Results

NP	**Avg wt**	**Std Dev**	**% C**	**C Density**		**%N**	**d13C**	**d15N**	**C:N**	MS Date
Bulk A	1.357	0.159	2.12	28.79	mg/cm^3	0.0860	-23.68	-0.80	24.68	3/20/2008
Bulk B	1.146	0.177	3.93	45.08	mg/cm^3	0.1661	-23.25	-0.08	23.68	3/20/2008
Bulk C	1.390	0.090	2.12	29.50	mg/cm^3	0.0955	-24.33	-0.77	22.22	3/20/2008
Bulk-Bulk	1.298	0.176	2.59	33.61	mg/cm^3	0.1053	-23.74	0.56	24.61	3/20/2008
			2.48			0.0888	-23.62	0.78	27.94	4/22/2008
NP-6										
Bulk A	0.979	0.152	4.89	47.88	mg/cm^3	0.2307	-23.78	0.39	21.19	3/20/2008
Bulk B	0.865	0.558	3.94	34.12	mg/cm^3	0.2038	-24.65	-1.38	19.36	3/20/2008
Bulk C	0.901	0.236	5.13	46.20	mg/cm^3	0.2407	-23.45	0.19	21.30	3/20/2008
Bulk-Bulk	0.915	0.338	4.62	42.27	mg/cm^3	0.2306	-23.87	-0.35	20.03	3/20/2008
			5.05			0.2082	-24.01	0.02	24.26	4/22/2008
NP-12										
Bulk A	0.998	0.453	4.97	49.59	mg/cm^3	0.2698	-25.78	-2.08	18.42	3/20/2008
Bulk B	1.065	0.160	5.08	54.10	mg/cm^3	0.2544	-26.12	-1.58	19.97	3/20/2008
Bulk C	0.935	0.304	4.51	42.18	mg/cm^3	0.2723	-26.13	-2.20	16.56	3/20/2008
Bulk-Bulk	0.999	0.309	4.22	42.13	mg/cm^3	0.2316	-25.93	-1.23	18.20	3/20/2008
			4.02			0.2065	-25.92	-0.23	19.48	4/22/2008

Table A-7a. Green Swamp 7 (Healthy) Soil Collection Data

Sample Date: 2/12/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	597.1	500.7	96.4	16.14	1.552
NP	2	525.0	426.4	98.6	18.78	1.322
NP	3	465.7	374.8	90.9	19.52	1.162
NP	4	234.5	178.4	56.1	23.92	0.553
NP	5	348.1	295.5	52.6	15.11	0.916
NP	6	443.9	379.1	64.8	14.60	1.175
NP	7	325.9	262.3	63.6	19.52	0.813
NP	8	606.5	502.4	104.1	17.16	1.558
NP	9	476.8	398.1	78.7	16.51	1.234
NP	10	594.0	495.4	98.6	16.60	1.536
NP	11	630.8	542.4	88.4	14.01	1.682
NP	12	544.6	459.3	85.3	15.66	1.424
NP	13	526.2	449.0	77.2	14.67	1.392
NP	14	799.6	671.8	127.8	15.98	2.083
NP	15	622.7	518.4	104.3	16.75	1.607
NP-6	1	554.7	448.0	106.7	19.24	1.389
NP-6	2	665.6	554.7	110.9	16.66	1.720
NP-6	3	689.2	582.0	107.2	15.55	1.804
NP-6	4	718.2	587.6	130.6	18.18	1.822
NP-6	5	777.0	636.5	140.5	18.08	1.973
NP-6	6	727.1	585.7	141.4	19.45	1.816
NP-6	7	687.0	560.7	126.3	18.38	1.738
NP-6	8	716.2	589.5	126.7	17.69	1.828
NP-6	9	681.7	557.4	124.3	18.23	1.728
NP-6	10	708.8	584.7	124.1	17.51	1.813
NP-6	11	688.7	572.2	116.5	16.92	1.774
NP-6	12	920.9	740.8	180.1	19.56	2.297
NP-6	13	624.8	498.6	126.2	20.20	1.546
NP-6	14	698.3	574.1	124.2	17.79	1.780
NP-6	15	556.6	447.2	109.4	19.66	1.386

NP-12	1	453.4	293.8	159.6	35.20	0.911
NP-12	2	789.0	584.8	204.2	25.88	1.813
NP-12	1	482.0	338.4	143.6	29.79	1.049
NP-12	2	554.5	423.5	131.0	23.62	1.313
NP-12	2	542.1	377.5	164.6	30.36	1.170
NP-12	6	624.4	491.2	133.2	21.33	1.523
NP-12	7	643.6	499.4	144.2	22.41	1.548
NP-12	8	629.2	474.0	155.2	24.67	1.469
NP-12	9	579.5	431.7	147.8	25.50	1.338
NP-12	10	780.9	610.4	170.5	21.83	1.892
NP-12	11	564.2	430.9	133.3	23.63	1.336
NP-12	12	633.0	505.2	127.8	20.19	1.566
NP-12	13	674.5	526.2	148.3	21.99	1.631
NP-12	14	763.0	615.7	147.3	19.31	1.909
NP-12	15	696.1	554.7	141.4	20.31	1.720

Table A-7b. Green Swamp 7 (Healthy) IRMS Bulked Sample Results

NP	**Avg wt**	**Std Dev**	**% C**	**C Density**		**%N**	**d13C**	**d15N**	**C:N**	MS Date
Bulk A	1.101	0.384	2.37	26.08	mg/cm^3	0.1736	-26.19	1.72	13.64	3/10/2008
			2.27	24.97	mg/cm^3	0.0796	-26.20	-0.84	28.50	3/10/2008
Bulk B	1.263	0.305	1.82	23.01	mg/cm^3	0.1802	-26.25	1.31	10.11	3/10/2008
Bulk C	1.637	0.277	1.16	18.98	mg/cm^3	0.1868	-25.50	0.73	6.20	3/10/2008
Bulk-Bulk	1.334	0.380	1.40	18.62	mg/cm^3	0.1129	-25.96	0.27	12.37	3/10/2008
			1.40	18.64	mg/cm^3	0.0661	-25.89	-0.77	21.13	3/10/2008
			1.39			0.0526	-25.85	1.84	26.41	4/22/2008
NP-6										
Bulk A	1.742	0.217	0.91	15.80	mg/cm^3	0.0594	-26.13	-2.72	15.28	3/10/2008
Bulk B	1.784	0.047	0.90	16.02	mg/cm^3	0.0500	-26.69	-0.93	17.96	3/10/2008
Bulk C	1.756	0.344	1.40	24.51	mg/cm^3	0.0767	-26.20	-2.60	18.20	3/10/2008
Bulk-Bulk	1.761	0.220	1.03	18.22	mg/cm^3	0.0667	-26.29	-3.06	15.52	3/10/2008
			1.01	17.87	mg/cm^3	0.0801	-26.24	-6.34	12.67	3/10/2008
			1.05			0.0460	-26.31	-0.13	22.78	4/22/2008
NP-12										
Bulk A	1.251	0.347	1.83	22.96	mg/cm^3	0.1324	-25.70	-1.74	13.86	3/10/2008
Bulk B	1.554	0.206	1.65	25.71	mg/cm^3	0.1438	-25.94	-4.34	11.50	3/10/2008
Bulk C	1.632	0.210	0.96	15.75	mg/cm^3	0.1158	-25.89	-6.23	8.33	3/10/2008
Bulk-Bulk	1.479	0.297	1.32	19.58	mg/cm^3	0.1175	-25.83	-4.15	11.26	3/10/2008
			1.39	20.62	mg/cm^3	0.1327	-25.83	-5.20	10.51	3/10/2008
			1.49			0.0821	-26.01	-0.29	18.13	4/22/2008

Table A-8a. Flatwoods (Harm) Soil Collection Data

Sample Date: 2/14/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	359.0	313.9	45.1	12.56	0.973
NP	2	410.3	363.2	47.1	11.48	1.126
NP	3	344.2	287.3	56.9	16.53	0.891
NP	4	374.5	330.4	44.1	11.78	1.024
NP	5	445.2	385.9	59.3	13.32	1.196
NP	6	477.6	416.1	61.5	12.88	1.290
NP	7	468.9	407.9	61.0	13.01	1.265
NP	8	393.4	345.4	48.0	12.20	1.071
NP	9	388.4	320.8	67.6	17.40	0.995
NP	10	385.5	325.5	60.0	15.56	1.009
NP	11	379.8	322.8	57.0	15.01	1.001
NP	12	445.4	383.7	61.7	13.85	1.190
NP	13	316.4	271.3	45.1	14.25	0.841
NP	14	344.4	287.5	56.9	16.52	0.891
NP	15	376.8	316.4	60.4	16.03	0.981
NP-6	1	407.1	327.9	79.2	19.45	1.017
NP-6	2	390.2	335.8	54.4	13.94	1.041
NP-6	3	407.0	378.8	28.2	6.93	1.174
NP-6	4	440.8	344.8	96.0	21.78	1.069
NP-6	5	408.2	342.9	65.3	16.00	1.063
NP-6	6	400.8	342.5	58.3	14.55	1.062
NP-6	7	474.9	409.0	65.9	13.88	1.268
NP-6	8	421.4	347.6	73.8	17.51	1.078
NP-6	9	420.6	338.2	82.4	19.59	1.048
NP-6	10	508.6	422.2	86.4	16.99	1.309
NP-6	11	460.5	394.5	66.0	14.33	1.223
NP-6	12	450.4	378.8	71.6	15.90	1.174
NP-6	13	464.8	394.5	70.3	15.12	1.223
NP-6	14	369.6	306.5	63.1	17.07	0.950
NP-6	15	482.7	405.5	77.2	15.99	1.257

NP-12	1	469.2	392.8	76.4	16.28	1.218
NP-12	2	521.1	433.6	87.5	16.79	1.344
NP-12	1	490.9	393.7	97.2	19.80	1.221
NP-12	2	483.4	387.7	95.7	19.80	1.202
NP-12	2	473.2	366.9	106.3	22.46	1.137
NP-12	6	475.8	373.2	102.6	21.56	1.157
NP-12	7	352.1	284.4	67.7	19.23	0.882
NP-12	8	503.8	410.8	93.0	18.46	1.274
NP-12	9	387.1	292.8	94.3	24.36	0.908
NP-12	10	388.2	295.9	92.3	23.78	0.917
NP-12	11	433.3	339.5	93.8	21.65	1.053
NP-12	12	383.8	291.9	91.9	23.94	0.905
NP-12	13	428.4	322.6	105.8	24.70	1.000
NP-12	14	386.7	285.1	101.6	26.27	0.884
NP-12	15	338.7	261.7	77.0	22.73	0.811

Table A-8b. Flatwoods (Harm) IRMS Bulked Sample Results

NP	**Avg wt**	**Std Dev**	**% C**	**C Density**		**%N**	**d13C**	**d15N**	**C:N**	MS Date
Bulk A	1.042	0.121	2.40	25.00	mg/cm^3	0.0820	-26.81	0.56	29.28	3/25/2008
Bulk B	1.126	0.141	2.34	26.38	mg/cm^3	0.0833	-25.95	2.00	28.11	3/25/2008
Bulk C	0.981	0.134	3.24	31.73	mg/cm^3	0.1118	-26.17	2.42	28.95	3/25/2008
Bulk-Bulk	1.050	0.137	2.84	29.84	mg/cm^3	0.0960	-26.72	1.28	29.61	3/25/2008
			2.65			0.0970	-26.45	2.17	27.37	4/22/2008
NP-6										
Bulk A	1.073	0.060	3.13	33.54	mg/cm^3	0.1452	-26.41	1.01	21.54	3/25/2008
Bulk B	1.153	0.125	2.51	28.98	mg/cm^3	0.1295	-25.95	0.66	19.40	3/25/2008
Bulk C	1.166	0.124	3.27	38.16	mg/cm^3	0.1517	-24.32	1.98	21.59	3/25/2008
Bulk-Bulk	1.130	0.108	3.10	35.00	mg/cm^3	0.1485	-25.73	1.93	20.85	3/25/2008
			3.60			0.1577	-25.87	2.56	22.85	4/22/2008
NP-12										
Bulk A	1.224	0.075								
Bulk B	1.027	0.177								
Bulk C	0.931	0.096	3.15	29.35	mg/cm^3	0.1679	-26.31	1.49	18.79	3/25/2008
Bulk-Bulk	1.061	0.171	3.14	33.33	mg/cm^3	0.1663	-25.97	0.54	18.89	3/25/2008
			3.19			0.1654	-25.67	1.51	19.27	4/22/2008

Table A-9a. Starkey R (Healthy) Soil Collection Data

Sample Date: 2/26/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	377.8	0.0	377.8	0.00	0.000
NP	2	423.1	0.0	423.1	0.00	0.000
NP	3	444.6	0.0	444.6	0.00	0.000
NP	4	534.6	0.0	534.6	0.00	0.000
NP	5	646.3	0.0	646.3	0.00	0.000
NP	6	488.7	394.7	94.0	19.23	1.224
NP	7	410.6	295.8	114.8	27.96	0.917
NP	8	573.7	448.4	125.3	21.84	1.390
NP	9	566.9	443.1	123.8	21.84	1.374
NP	10	483.4	366.2	117.2	24.24	1.135
NP	11	599.7	475.7	124.0	20.68	1.475
NP	12	576.8	447.8	129.0	22.36	1.388
NP	13	591.0	460.8	130.2	22.03	1.429
NP	14	589.5	460.6	128.9	21.87	1.428
NP	15	496.5	392.7	103.8	20.91	1.217

*Highlighted cells represent loss of data; soil was processed without being weighed.

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP-6	1	716.6	578.1	138.5	19.33	1.792
NP-6	2	692.1	552.4	139.7	20.18	1.713
NP-6	3	683.1	545.3	137.8	20.17	1.691
NP-6	4	703.9	560.9	143.0	20.32	1.739
NP-6	5	660.0	528.4	131.6	19.94	1.638
NP-6	6	612.4	489.0	123.4	20.15	1.516
NP-6	7	559.6	427.4	132.2	23.62	1.325
NP-6	8	640.8	492.0	148.8	23.22	1.525
NP-6	9	584.2	434.0	150.2	25.71	1.345
NP-6	10	536.9	400.0	136.9	25.50	1.240
NP-6	11	636.7	506.9	129.8	20.39	1.571
NP-6	12	622.2	476.2	146.0	23.47	1.476
NP-6	13	463.2	327.8	135.4	29.23	1.016
NP-6	14	583.2	420.5	162.7	27.90	1.304
NP-6	15	565.0	373.7	191.3	33.86	1.159

NP-12	1	468.8	198.2	270.6	57.72	0.614
NP-12	2	437.8	162.5	275.3	62.88	0.504
NP-12	1	425.8	190.1	235.7	55.35	0.589
NP-12	2	397.1	148.4	248.7	62.63	0.460
NP-12	2	489.0	196.7	292.3	59.78	0.610
NP-12	6	463.1	167.4	295.7	63.85	0.519
NP-12	7	409.5	141.2	268.3	65.52	0.438
NP-12	8	443.4	154.8	288.6	65.09	0.480
NP-12	9	363.3	142.9	220.4	60.67	0.443
NP-12	10	398.1	195.1	203.0	50.99	0.605
NP-12	11	355.6	160.3	195.3	54.92	0.497
NP-12	12	550.5	228.0	322.5	58.58	0.707
NP-12	13	484.1	184.7	299.4	61.85	0.573
NP-12	14	374.6	134.4	240.2	64.12	0.417
NP-12	15	455.8	213.1	242.7	53.25	0.661

Table A-9b. Starkey R (Healthy) IRMS Bulked Sample Results

NP	**Avg wt**	**Std Dev**	**% C**	**C Density**		**%N**	**d13C**	**d15N**	**C:N**	MS Date
Bulk A					mg/cm^3					
Bulk B	1.208	0.194	2.11	25.54	mg/cm^3	0.1056	-27.01	0.21	20.03	3/25/2008
Bulk C	1.387	0.100	1.47	20.43	mg/cm^3	0.0756	-25.67	1.02	19.48	3/25/2008
Bulk-Bulk	0.865	0.648	1.50	13.02	mg/cm^3	0.0801	-26.69	0.56	18.78	3/25/2008
			1.84			0.0590	-26.57	2.55	31.24	4/22/2008
NP-6										
Bulk A	1.714	0.057	0.84	14.36	mg/cm^3	0.0856	-25.96	-3.34	9.79	3/25/2008
Bulk B	1.390	0.125	1.79	24.86	mg/cm^3	0.0765	-25.56	-1.48	23.38	3/25/2008
Bulk C	1.305	0.226	2.02	26.37	mg/cm^3	0.1191	-24.98	-2.11	16.97	3/25/2008
Bulk-Bulk	1.470	0.231	1.75	25.67	mg/cm^3	0.1102	-25.19	-1.70	15.85	3/25/2008
			1.83			0.0892	-25.05	1.95	20.46	4/22/2008
NP-12										
Bulk A	0.555	0.070	8.71	48.37	mg/cm^3	0.3902	-26.75	1.22	22.32	3/25/2008
Bulk B	0.497	0.069	12.33	61.27	mg/cm^3	0.5309	-26.84	0.59	23.23	3/25/2008
Bulk C	0.571	0.118	9.77	55.75	mg/cm^3	0.4853	-26.84	0.59	20.13	3/25/2008
Bulk-Bulk	0.541	0.088	9.04	48.90	mg/cm^3	0.4350	-26.75	1.17	20.78	3/25/2008
			9.95			0.4556	-26.70	2.13	21.84	4/22/2008

Table A-10a. Starkey S75 (Harm) Soil Collection Data

Sample Date: 3/4/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP	1	577.3	473.1	104.2	18.05	1.467
NP	2	508.2	404.4	103.8	20.43	1.254
NP	3	474.9	387.8	87.1	18.34	1.202
NP	4	564.0	459.6	104.4	18.51	1.425
NP	5	470.8	382.3	88.5	18.80	1.185
NP	6	615.7	510.0	105.7	17.17	1.581
NP	7	631.0	520.1	110.9	17.58	1.612
NP	8	422.7	342.9	79.8	18.88	1.063
NP	9	542.7	445.4	97.3	17.93	1.381
NP	10	386.0	310.0	76.0	19.69	0.961
NP	11	686.8	578.2	108.6	15.81	1.793
NP	12	374.0	316.0	58.0	15.51	0.980
NP	13	432.1	360.6	71.5	16.55	1.118
NP	14	631.2	514.7	116.5	18.46	1.596
NP	15	636.1	531.4	104.7	16.46	1.647
NP-6	1	562.8	434.9	127.9	22.73	1.348
NP-6	2	262.2	192.0	70.2	26.77	0.595
NP-6	3	446.4	337.5	108.9	24.40	1.046
NP-6	4	650.4	544.3	106.1	16.31	1.687
NP-6	5	541.1	430.8	110.3	20.38	1.336
NP-6	6	496.4	395.1	101.3	20.41	1.225
NP-6	7	595.8	480.0	115.8	19.44	1.488
NP-6	8	581.3	466.9	114.4	19.68	1.447
NP-6	9	552.2	437.4	114.8	20.79	1.356
NP-6	10	594.6	488.4	106.2	17.86	1.514
NP-6	11	512.6	407.7	104.9	20.46	1.264
NP-6	12	541.9	423.3	118.6	21.89	1.312
NP-6	13	571.5	450.7	120.8	21.14	1.397
NP-6	14	559.8	456.2	103.6	18.51	1.414
NP-6	15	213.3	158.9	54.4	25.50	0.493

NP-12	1	382.6	249.1	133.5	34.89	0.772
NP-12	2	368.9	255.5	113.4	30.74	0.792
NP-12	1	385.3	278.2	107.1	27.80	0.862
NP-12	2	338.3	225.3	113.0	33.40	0.698
NP-12	2	274.1	169.8	104.3	38.05	0.526
NP-12	6	345.6	230.8	114.8	33.22	0.716
NP-12	7	420.2	312.2	108.0	25.70	0.968
NP-12	8	404.9	272.7	132.2	32.65	0.845
NP-12	9	342.1	229.7	112.4	32.86	0.712
NP-12	10	319.8	214.3	105.5	32.99	0.664
NP-12	11	447.5	330.5	117.0	26.15	1.025
NP-12	12	414.3	309.0	105.3	25.42	0.958
NP-12	13	435.0	316.5	118.5	27.24	0.981
NP-12	14	423.1	310.7	112.4	26.57	0.963
NP-12	15	539.6	407.4	132.2	24.50	1.263

Table A-10b. Starkey S75 (Harm) IRMS Bulked Sample Results

NP	Avg wt	Std Dev	% C	C Density		%N	d13C	d15N	C:N	MS Date
Bulk A	1.307	0.130	1.58	20.60	mg/cm^3	0.0809	-25.37	-2.20	19.50	3/20/2008
Bulk B	1.320	0.297	1.12	14.72	mg/cm^3	0.0611	-26.20	-2.31	18.26	3/20/2008
Bulk C	1.427	0.356	0.82	11.65	mg/cm^3	0.0410	-26.34	-3.98	19.91	3/20/2008
Bulk-Bulk	1.351	0.263	1.04	14.00	mg/cm^3	0.0551	-25.78	-3.21	18.80	3/20/2008
NP-6										
Bulk A	1.203	0.408	2.18	26.16	mg/cm^3	0.1243	-24.65	-0.04	17.50	3/20/2008
Bulk B	1.406	0.118	1.91	26.90	mg/cm^3	0.1070	-24.80	-1.12	17.88	3/20/2008
Bulk C	1.176	0.387	2.44	28.69	mg/cm^3	0.1429	-24.71	-1.13	17.08	3/20/2008
Bulk-Bulk	1.262	0.325	1.94	24.48	mg/cm^3	0.1040	-24.46	-0.03	18.66	3/20/2008
NP-12										
Bulk A	0.730	0.128	5.05	36.88	mg/cm^3	0.2908	-25.37	0.47	17.37	3/20/2008
Bulk B	0.781	0.124	5.12	39.96	mg/cm^3	0.2974	-25.48	-0.48	17.20	3/20/2008
Bulk C	1.038	0.128	3.65	37.90	mg/cm^3	0.2044	-25.25	-0.33	17.86	3/20/2008
Bulk-Bulk	0.850	0.182	4.38	37.25	mg/cm^3	0.2618	-25.40	-1.09	16.74	3/20/2008
			4.30			0.2222	-25.42	1.69	19.34	4/22/2008

Table A-11a. New River (Healthy) Soil Collection Data

Sample Date: 4/10/2008

Elev	#	Sample wt	Dry wt	Water wt	%H2O	Bulk Density
NP-12	1	280.0	95.6	184.4	65.86	0.3
NP-12	2	373.3	149.5	223.8	59.95	0.5
NP-12	3	444.7	236.1	208.6	46.91	0.7
NP-12	4	464.5	193.1	271.4	58.43	0.6
NP-12	5	327.2	104.5	222.7	68.06	0.3
NP-12	6	384.0	162.5	221.5	57.68	0.5
NP-12	7	513.2	297.3	215.9	42.07	0.9
NP-12	8	471.6	289.1	182.5	38.70	0.9
NP-12	9	337.9	185.0	152.9	45.25	0.6
NP-12	10	409.9	202.5	207.4	50.60	0.6
NP-12	11	456.7	270.5	186.2	40.77	0.8
NP-12	12	476.0	279.7	196.3	41.24	0.9
NP-12	13	432.2	255.5	176.7	40.88	0.8
NP-12	14	408.1	197.1	211.0	51.70	0.6
NP-12	15	427.5	223.3	204.2	47.77	0.7

NOTE: The only elevation sampled at this site was the NP-12.

Table A-11b. New River (Healthy) IRMS Bulked Sample Results

NP-12	**Avg wt**	**Std Dev**	**% C**	**C Density**		**%N**	**d13C**	**d15N**	**C:N**	MS Date
Bulk A	0.483	0.184	10.64	51.37	mg/cm^3	0.5235	-25.83	0.32	20.32	4/22/2008
Bulk B	0.705	0.192	8.31	58.58	mg/cm^3	0.3866	-26.01	-1.50	21.50	4/22/2008
Bulk C	0.760	0.107	6.32	48.02	mg/cm^3	0.3419	-25.47	-2.43	18.47	4/22/2008
Bulk-Bulk	0.649	0.197	6.86	44.54	mg/cm^3	0.3315	-25.55	0.05	20.70	4/22/2008

Appendix B

Well Hydrographs for Six of the Eleven Cypress Domes Included in this Study

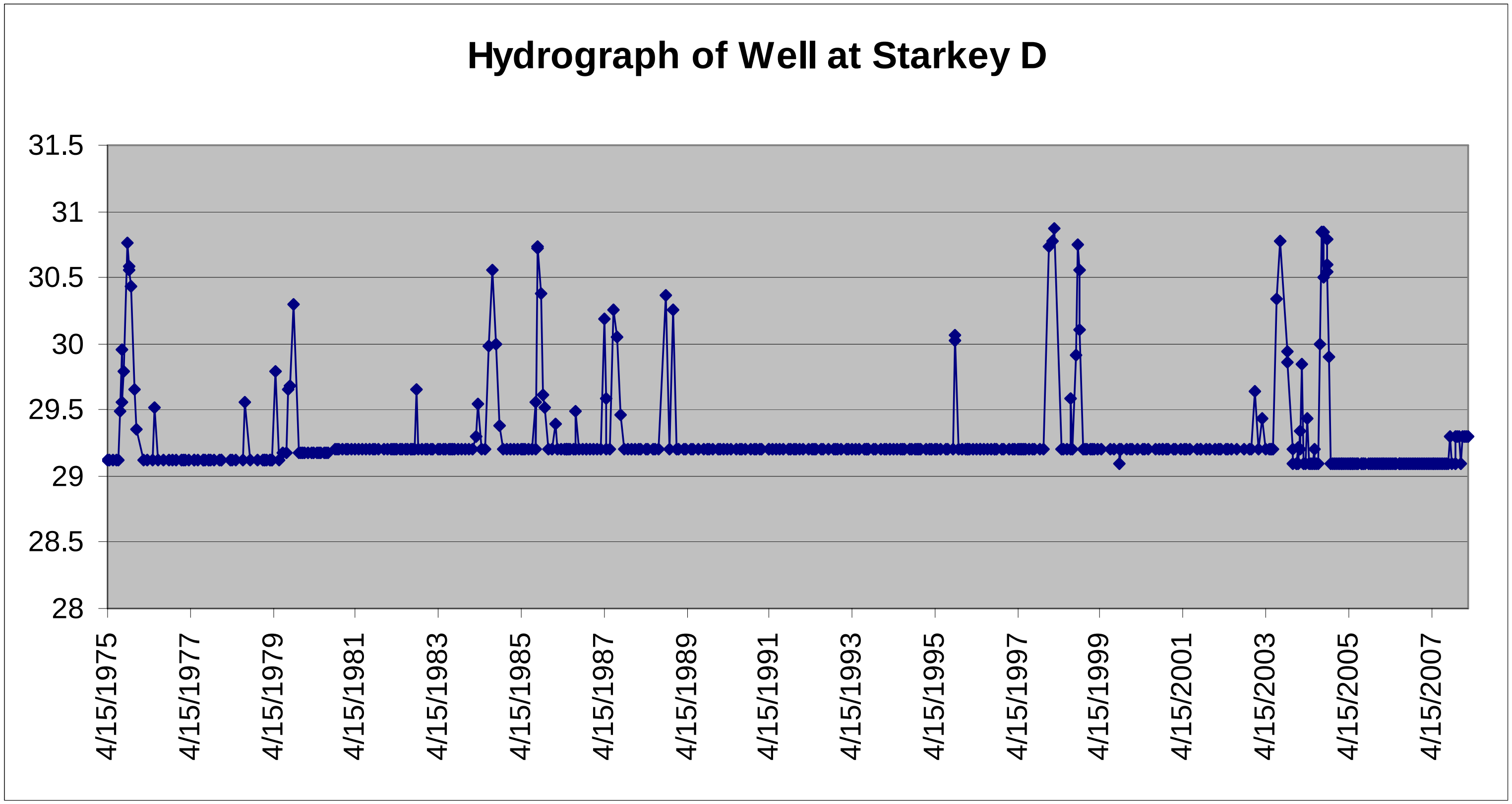

Figure B-1. Hydrograph of well at Starkey D

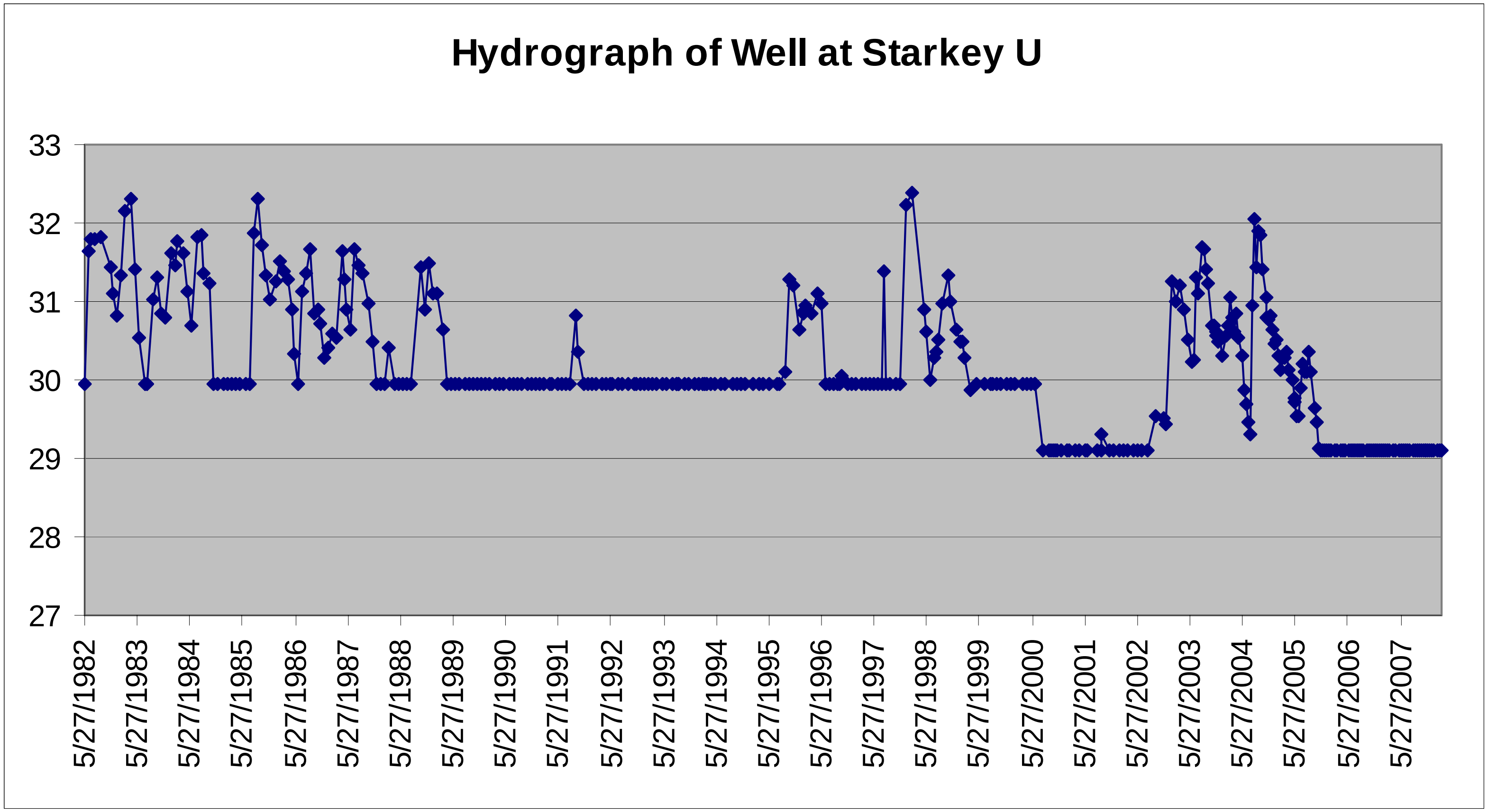

Figure B-2. Hydrograph of well at Starkey U

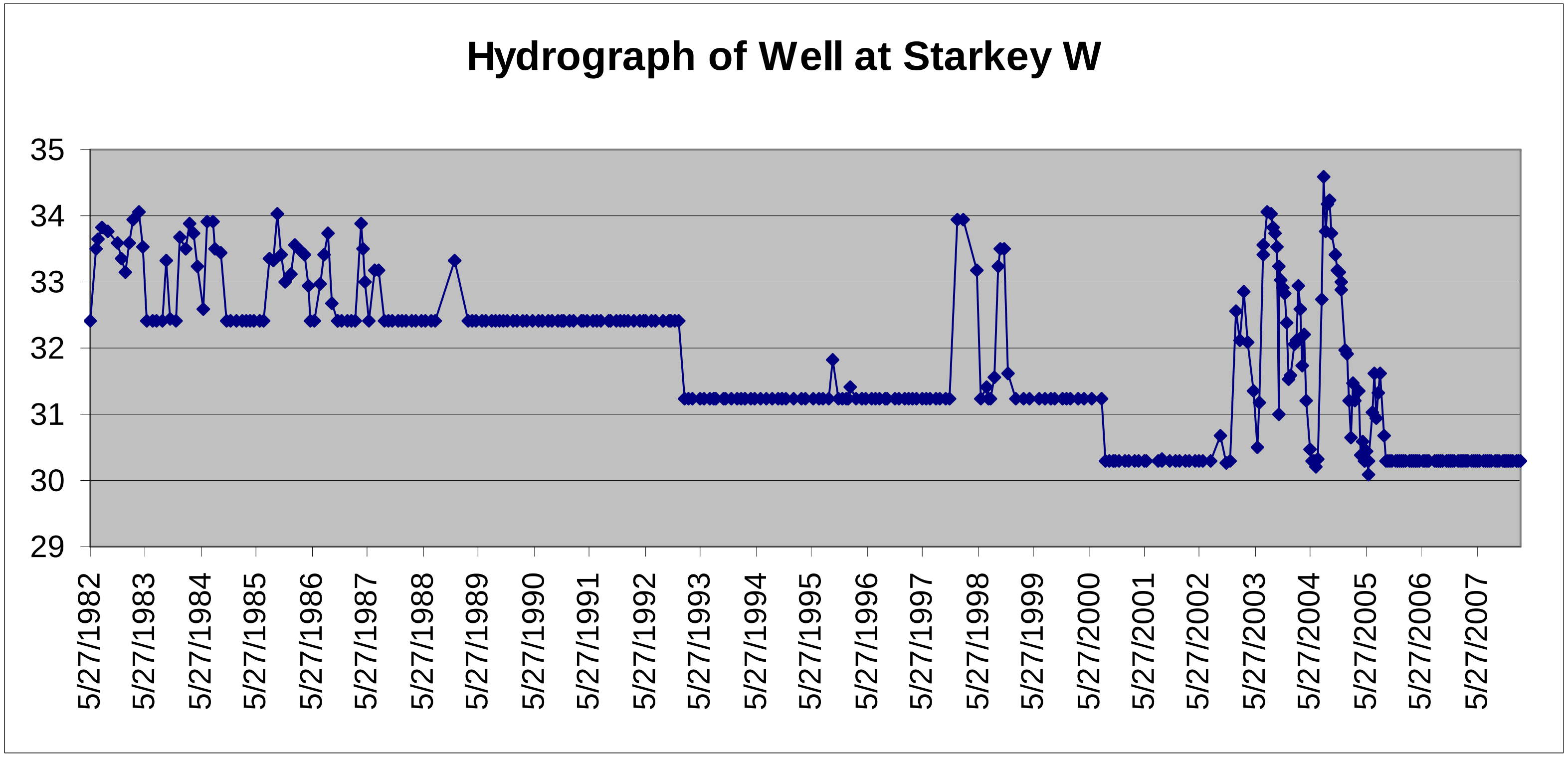

Figure B-3. Hydrograph of well at Starkey W

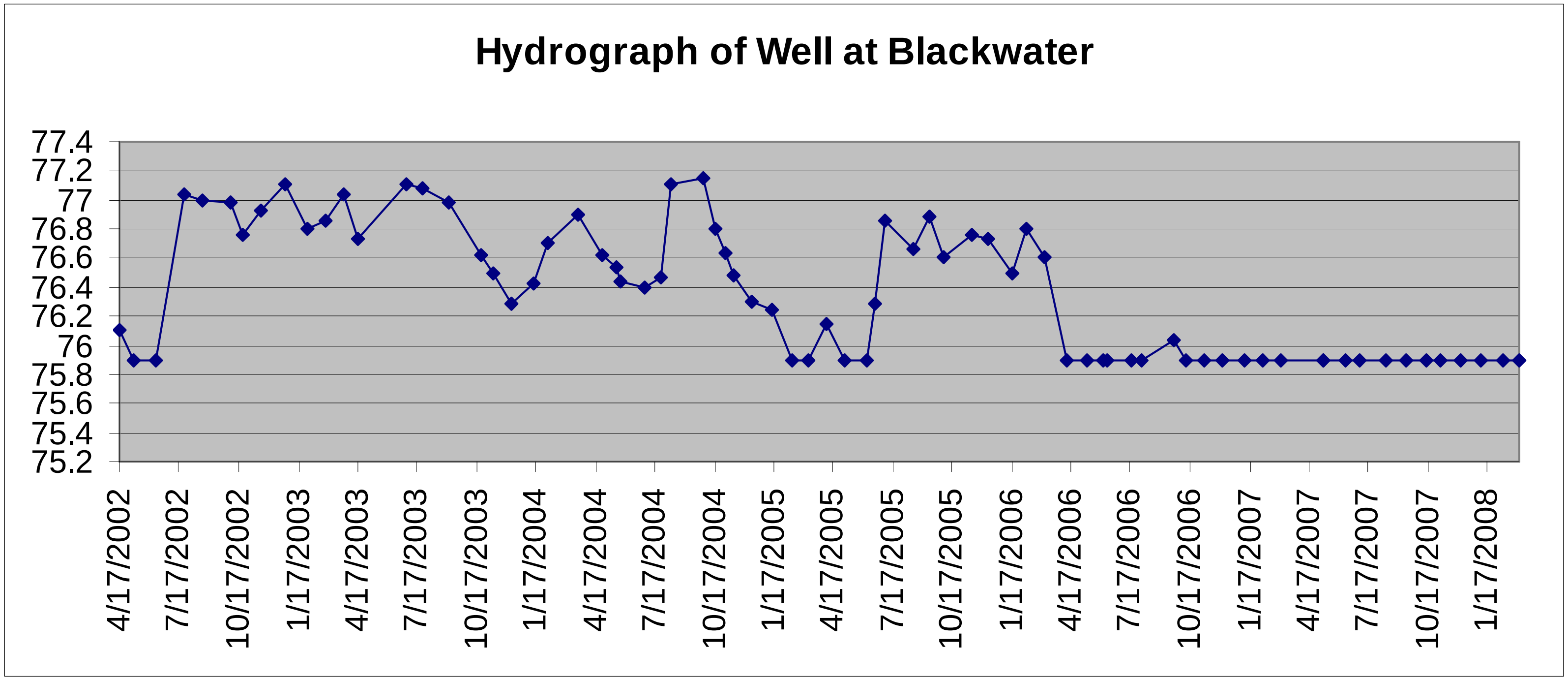

Figure B-4. Hydrograph of well at Blackwater Creek

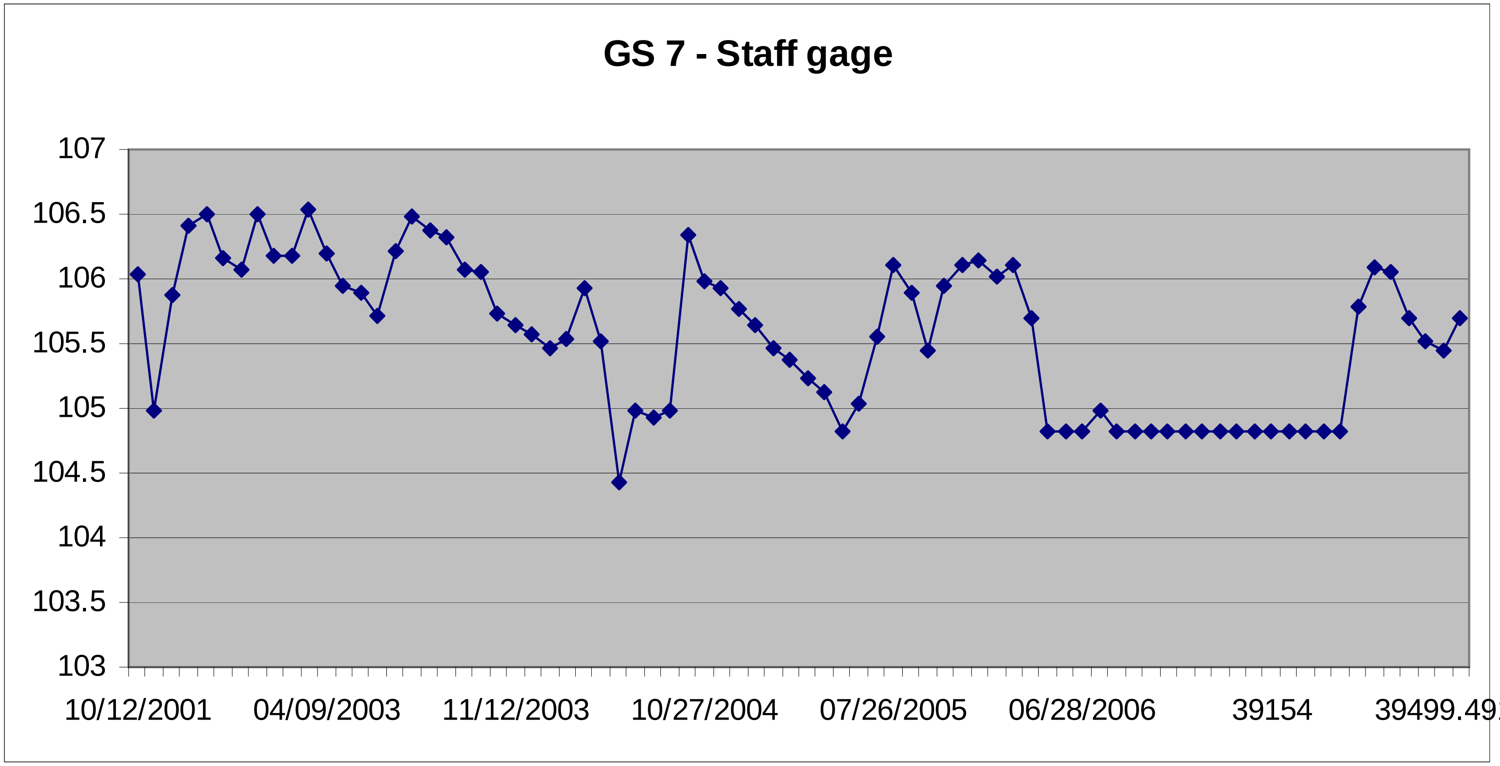

Figure B-5. Hydrograph of well at Green Swamp 7

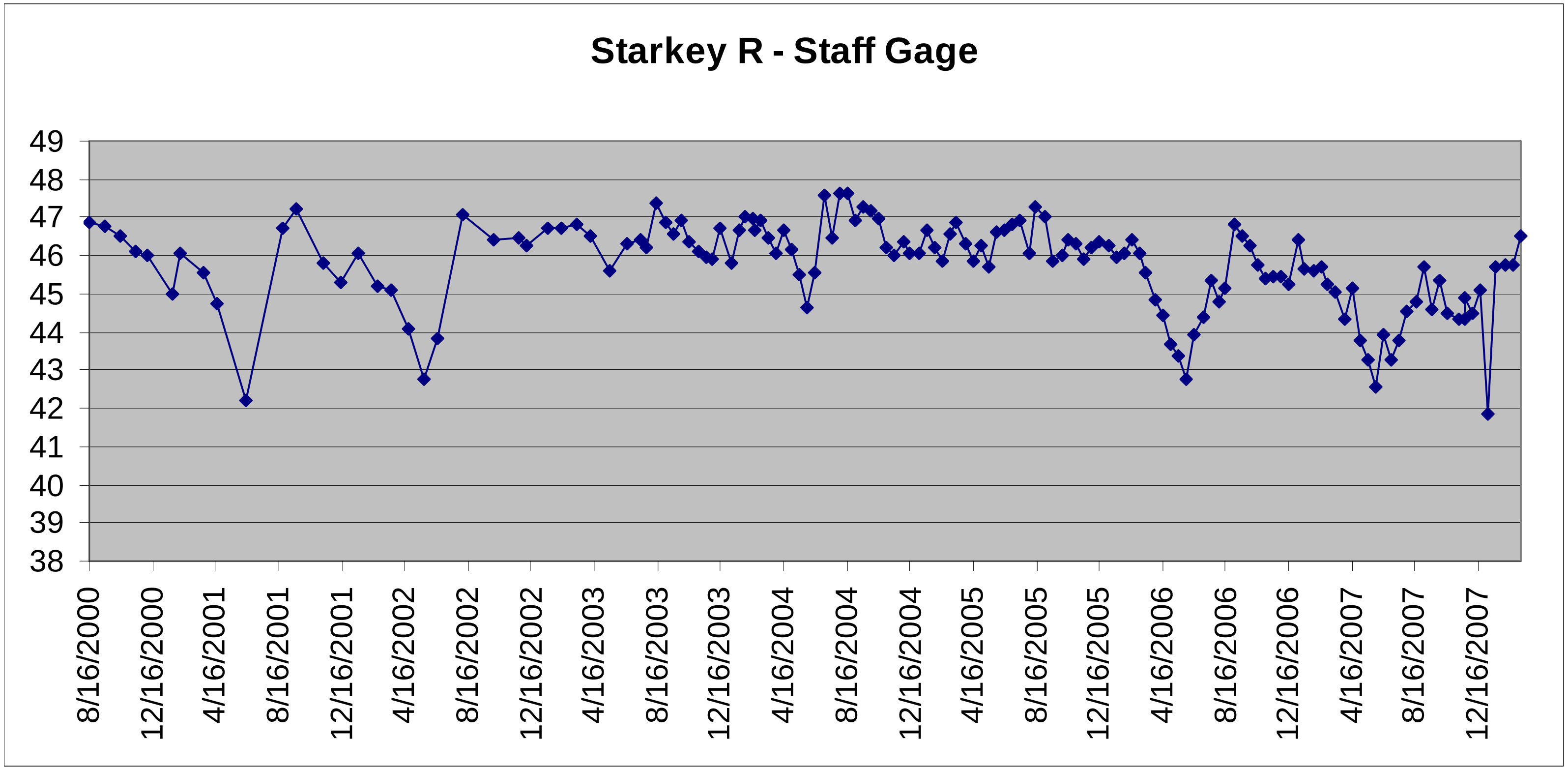

Figure B-6. Hydrograph of well at Starkey R

Appendix C

Soil Moisture Meter Readings Taken for Six of the Eleven Cypress Domes Included in this Study at Starkey Wilderness Park on 5/23/2008

Table C-1 Summary of the mean soil moisture meter readings by wetland

		-------- Location of Sampling in Wetland --------			
Wetland	Category	Edge	NP-6	NP-12	Center
Starkey D	Sig. Harm	0.6	-	-	0.1
Starkey U	Sig. Harm	0.0	0.0	0.3	2.1
Starkey W	Harm	0.0	0.1	-	3.0
Starkey S75	Harm	2.3	2.0	6.2	7.0
Starkey R	Healthy	4.9	3.8	5.1	8.0
Starkey 1	Healthy	0.7	5.8	9.8	10.0

Values are on a scale from 0 – 10, where 10 represents completely saturated.

Table C-2 Starkey D (Sig. Harm) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	1	-	-	0
2	0	-	-	0
3	0	-	-	0
4	1.5	-	-	0.5
5	0.5	-	-	0

Table C-3 Starkey U (Sig. Harm) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	0	0	1.5	1.5
2	0	0	0	4
3	0	0	0	2
4	0	0	0	1
5	0	0	0	2

Table C-4 Starkey W (Harm) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	0	0.5	-	3.5
2	0	0	-	6
3	0	0	-	3.5
4	0	0	-	1.5
5	0	0	-	0
6	-	-	-	1
7	-	-	-	1.5
8	-	-	-	6
9	-	-	-	1.5
10	-	-	-	6

Table C-5 Starkey S75 (Harm) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	3.5	2	7	7.5
2	2	2	6	7
3	2	2	5	7
4	2	2	7	6.5
5	2	2	6	7
6	-	-	-	7

Table C- 6 Starkey R (Healthy) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	4	4	6	8
2	5	4	4	8
3	5	3.5	5	8
4	5.5	4	5.5	8
5	5	3.5	5	8

Table C-7 Starkey 1 (Healthy) Individual Moisture Meter Readings

Sample #	Edge	NP-6	NP-12	Center
1	0.5	5	10	10
2	1	6	9.5	10
3	0.5	6	10	10
4	1	6.5	9.5	10
5	0.5	5.5	10	10