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Vernal Pool Vegetation and Soil Patterns Along Hydrologic Gradients in Western Massachusetts

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VERNAL POOL VEGETATION AND SOIL PATTERNS ALONG HYDROLOGIC GRADIENTS IN WESTERN MASSACHUSETTS

A Thesis Presented

by

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ABSTRACT

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Vernal pools are wetland resources that are known for providing breeding habitat for species adapted to the characteristic wetting and drying conditions. Endemic species are known to vary by geography; for example, on the west coast of the United States vernal pools are known for their endemic plant species, as opposed to the east coast, particularly New England, where vernal pools are recognized for their breeding amphibian populations. In New England, it has been suggested that there may be few plant species, if any, useful in classifying vernal pools separately from other wetlands. However, there are still many aspects of vernal pools that evade scientific understanding from a wetlands perspective, such as hydrology and hydric soil occurrence, which inherently affect the vegetation distribution.

This study looks at relationships along the hydrologic gradient between and within six pools; including the vegetation community, soil characteristics and hydrology. Pool conditions were monitored weekly throughout the 2011 and 2012 growing seasons. Each pool was equipped with permanent platinum-tipped

redox probes to quantify the severity and duration of soil reduction. We described and analyzed 12 soil profiles in each pool, distributed in summit/upland, basin, and rim/transition positions as defined by the high water line. The pools were systematically surveyed for understory vegetation during the 2012 growing season.

Vegetation patterns varied between study areas. No clear pattern of unique vegetation was evident from an ordination of the gradient communities. Time series redox data showed a visual relationship to water table fluxuation, but also a dampening effect from soil organic matter content in the basin positions. Pool basins with substantially less soil organic matter were more susceptible to oxidizing, indicating that the rate of organic matter accumulation was less than organic matter decomposition in the pools.

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CHAPTER 1

VERNAL POOL VEGETATION AND SOIL PATTERNS ALONG HYDROLOGIC GRADIENTS IN WESTERN MASSACHUSETTS

Introduction

Vernal pools are wetland resources that are known for providing breeding habitat for species adapted to the characteristic wetting and drying conditions. While the importance of certain aspects of vernal pools is well recognized, they receive varying degrees of conservation protection throughout the county (Burne and Griffin, 2005; Calhoun et al., 2003; Colburn, 2004; Freeman et al., 2012; Leibowitz, 2003; Zedler, 2003). This is largely due to the lack of comprehensive understanding of vernal pool ecology and significance (Colburn, 2004; Skidds and Golet, 2005). Knowledge of the relationships among biotic and abiotic factors of the vernal pool ecosystem is becoming increasingly important within the scientific community in order to understand the ecological interactions and also manage and predict the consequences of climate change, habitat fragmentation, and wetland resource losses (Brooks, 2009; Colburn, 2004; Freeman et al., 2012; Leibowitz, 2003; Palik et al., 2007; Palik and Kastendick, 2010; Williams, 2005).

Vernal pools are generally defined as shallow depressions that become inundated in the winter through early spring and dry either partially or completely in the late spring or summer. They are inherently complex due to the seasonal wetting and drying, allowing for the evolution of endemic species by the exclusion of others. The type of endemic species is known to vary by geography; for example, on the west coast of the United States vernal pools are known for their endemic plant species, as opposed to the east coast, particularly New England, where vernal pools are recognized for their endemic breeding amphibian populations (Brooks, 2009; Colburn, 2004; Leibowitz, 2003). In New England it has been suggested that there may be few plant species, if any, useful in classifying vernal pools separately from other wetlands (Colburn, 2004; Cutko, 1997; Cutko and Rawinski, 2008). For this reason, there are limited numbers of studies on the plant populations in New England, but the underlying importance of an understanding of vernal pool ecology remains significant (Colburn, 2004; Palik and Kastendick, 2010).

Changes in vegetation are known to be linked to both soil type and hydrologic stress factors, but the strength and magnitude of the interactions are still topics to research (Battaglia and Collins, 2006; Kirkman et al., 1998). As land development increases, there is a need for an understanding of the distribution of microenvironments (Kirkman et al., 1998). Seasonality of vernal pool hydrology creates physical ambiguity in the field, including whether saturation remains long enough to develop hydric soils- a main component in the standard “three parameter approach” for wetland determination and delineation (U.S. Army Corps of Engineers, 2012). To be defined as a hydric soil, the physical description needs to be positive for the established Field Indicators of Hydric Soil. It is not uncommon for vernal pools to fail in meeting hydric soil criteria (U.S. Army Corps of Engineers, 2012; Yu and Ehrenfeld, 2010). In concert with hydric soil, wetland hydrology and hydrophitic vegetation are needed in most situations to declare an area wetland. By nature, vernal pools can be problematic, as any one of the three parameters may or may not be present, depending on the season. A positive wetland determination can mean the difference between affording vernal pools wetland protection or not.

The main objectives of this study are to: (1) determine the presence and properties of hydric soils within the basin and in rim portions of the pools, (2) examine the commonalities in soil properties between adjacent vernal pools, (3) investigate the relationship among gradients in the plant community, soil, and hydrologic properties from upland to wetland conditions in adjacent pools. Hypotheses that were explored:

(1) Vernal pools meet federal indicators for hydric soils in the basin and rim portions of the pools, (2) Soil properties i.e. particle size distribution, soil profiles, and redoximorphic potential will be similar across pools of the same parent material and similar geomorphic area, and (3) The vegetation community composition, environmental, and soil properties in adjacent vernal pools are repeated along similar hydrologic gradients. In this study, we investigate the relationship of vernal pool substrates to the plant communities in western Massachusetts, including pool and landscape factors.

Palik and Kastendick (2010) showed that there is a relationship between herbaceous community structure of vernal pools and a surrounding upland forest. However, most studies of vernal pool herbaceous vegetation are contained within the high water line of the pool. Thus, the purpose of this study is to investigate the sequential changes of the vegetative communities with the soil properties in order to shed more light on the complex interactions within vernal pools. This study could help to determine environmental factors significant in community establishment, which could have implications for conservation and in design of constructed vernal pools for mitigation.

This thesis is organized into three parts: analysis of soil profiles, soil redox, and the vegetative communities. Each part will describe differences within and among the study areas in Amherst and Deerfield. We present the overall message, indicating where this research will fit in the larger picture of vernal pool ecological studies, as well as make suggestions for future studies.

Literature Review

Maximum depth and volume in a vernal pool usually occurs in the early spring, and are distinguished from other wetlands by fluctuating hydrologic conditions and the seasonal presence of standing water resulting from groundwater, surface water, or precipitation inputs (Colburn, 2004; Cutko and Rawinski, 2008). They are also referred to as seasonal forest pools, ephemeral pools, and autumnal pools. For consistency, we will solely employ the term “vernal pools”.

Vernal pool research has been increasing in recent years, though a large majority of studies have occurred along the Pacific Coast and the information is not universally applicable (Zedler, 2003). Zedler (2003) found using an abstract search for the term “vernal pool”, 73% of the resulting research papers represented the Pacific Coast, while only 10% were about pools in the northeastern United States. Although there are general similarities between west coast and east coast pools, differences exist (Gamble and Mitsch, 2009) due to the differing geologic history, climate, and landscape development; all factors which affect soil formation and species distribution (Cutko and Rawinski, 2008). Many studies of vernal pools in New England have focused on the fauna (Cutko and Rawinski, 2008). However, the limited number of studies that exist outside the realm of vernal pool wildlife have established baselines for further studies in abiotic and floral components. These studies include vernal pool hydrology (Brooks and Hyashi 2002; Brooks 2004; Skidds and Golet 2005; Skidds et al. 2007), morphology (Brooks and Hayashi 2002), and vegetation (Cutko 1997; VT DEC 2003; Skidds et al. 2007; Cutko and Rawinski 2008; Ciccotelli et al. 2011).

In New England, knowledge gaps still exist and research is driven toward establishing reference ecological data, predicting and assessing valuable wildlife habitat for breeding amphibians reliant on the vernal pools, and warranting protection on a local, state, or federal level (Calhoun and DeMaynadier, 2008; Colburn, 2004; Cutko, 1997; Skidds et al., 2007). Vernal pools are unique in that they often provide both upland and hydric soil conditions in close proximity, while the cyclic dry and wet periods can allow for both upland plants and hydrophytes to thrive. However, documentation of hydric soils in vernal pools in not always consistent according to federal standards, as not all vernal pools have been found to meet the criteria for hydric soil (Clausnitzer et al., 2003; O'Geen et al., 2008). Natural Resource Conservation Service (NRCS) soil maps are too coarse in resolution (1:24,000) for inclusions of small vernal pools (Soil Survey Staff).

Further description of the underlying substrate is needed for accurate characterization of vernal pool ecosystems.

In Massachusetts, where statutes have been adopted in the protection of wetlands, understanding the presence and boundaries of wetlands are becoming increasingly important. Defining wetlands has been an ongoing discussion as parameters are debated and refined. A currently accepted federal standard is the “three parameter approach” based on vegetation, hydrology, and soil, set forth by the United States Army Corps of Engineers (U.S. Army Corps of Engineers, 2012) . Although this methodology can be used in Massachusetts, the state only requires a “two parameter” approach documenting wetland hydrology and hydrophitic vegetation. Hydric soil is used in this method, but as an indicator of hydrology.

A defining characteristic of wetlands is soil that displays evidence of long term hydrology—often in the form of redoximorphic features. Redox features form in the presence of fluctuating water tables or standing water and indicate the presence or absence of oxygen in a soil. Soil redox potential (Eh) has known implications for plant functioning and adaptation to life in anaerobic conditions. Redox state can be assessed visually using the presence of redoximorphic features or as a reading of Eh, the quantity of free electrons in the soil. Redox levels are a direct measure of soil processes that result from hydrologic moisture regimes (Faulkner et al., 1989). Redox reactions influence the ionic species of elements in the soil, such as iron and manganese, which have a direct impact on wetland plant functioning (Pezeshki, 2001). A reduced state can be stressful to plants as it represents a lack of oxygen in the soil, but also a concentration of materials in the soil that could be harmful in the soil, like soluble iron. The state of redox is known to affect physiological changes in plant functioning (Pezeshki, 2001). Certain plants have the ability to excrete oxygen into their immediate root zone in a soil to prevent iron, in its reduced form, from diffusing into the plant itself (Mitsch and Gosselink, 2007). By pumping oxygen from the root to the environment, the immediate iron is oxidized and therefore immobilized. Evidence has suggested that endemic wildlife species of vernal pools (invertebrates and amphibians) are not directly dependent on the plant species composition (Palik and Kastendick, 2010; Semlitsch and Skelly, 2008; Skidds et al., 2007). However, as unique wetland ecosystems isolated in uplands that support obligate species, there remains a need for understanding the underlying relationships that are important in the maintenance of vernal pool environments. Vernal pools in the northeast are known to support hundreds of plant species, in addition to rare species closely associated with isolated wetlands. Seemingly because of the lack of signature flora, vegetation in the northeast has been overlooked (Cutko and Rawinski, 2008).

Vernal Pool Research in the United States

Vernal pools on the west coast occur in a Mediterranean climate and are often underlain by a duripan that creates a perched water table with high clay content (Keeley and Zedler, 1998; O'Geen et al., 2008; Rains et al., 2006). In the northeast, vernal pools are formed from glacial parent material in a mild, continental climate (Rheinhardt et al., 2007). West coast vernal pools tend to completely desiccate and produce high soil temperatures during the summer dry period (Keeley and Zedler, 1998; O'Geen et al., 2008), while pools in the northeast may not even dry down completely every year (Calhoun and DeMaynadier, 2008; Colburn, 2004). In California there are approximately 43 plant species that are vernal pool specialists and are only found within these disappearing resources; however, this is not the case in New England (Ciccotelli et al., 2011; Cutko, 1997; Cutko and Rawinski, 2008; Schlising and Sanders, 1982). Limited studies in New England have determined that most plant species are wetland generalists that have differing tolerances to root inundation (Ciccotelli et al., 2011; Cutko, 1997; Cutko and Rawinski, 2008). There are 20 species that are listed as at-risk and are commonly associated with vernal pools in New England (Cutko and Rawinski, 2008).

Vernal Pools in New England

Hydrology has proven essential for breeding amphibians and aquatic invertebrates of vernal pool system (Skidds and Golet, 2005; Skidds et al., 2007). Amphibians are particularly sensitive to vernal pool hydrology, especially hydroperiod (Colburn, 2004; Semlitsch and Skelly, 2008). Some species found in New England are characteristic of short hydroperiod pools (*Scaphiopus holbrooki* -eastern spadefoot, *Anaxyrus americanus* -American toad, *A.woodhousei*- Fowler's toads, *Hyla versicolor*- gray treefrog, *Lithobates sylvatica*- wood frog), while others require longer hydroperiods (*L. catesbeiana*-bullfrog, *L.clamitans*- green frog, *L.palustris*-pickerel frog, *Notophthalmus viridescens*- red-spotted newt). Some require intermediate hydroperiods (*Ambystoma maculatum*- spotted salamander, *A.laterale* blue-spotted salamander, *A. jeffersonianum*- Jefferson salamander and *A. opacum*- marbled salamander) and at least one species is considered a hydroperiod generalist (*Pseudacris crucifer*- spring peeper). *Eubranchipus spp.* (fairy shrimp) requires a particular type of vernal pool hydrology. The eggs of fairy shrimp are deposited on the pool bottom and must both dry and freeze, then be inundated in water before they will hatch (Colburn, 2004).

Skidds et al. (2007) studied the reproductive efforts of well-known vernal pool obligate amphibians- spotted salamander and wood frog- in 65 vernal pools of Rhode Island. Using within-pond and landscape-scale habitat characteristics, the study attempted to better define and predict the variation in reproductive effort, as significant variables could prove useful for local governments in prioritizing vernal pool and amphibian conservation efforts. As part of the within-pond variables, Skidds et al. (2007) conducted line-intercept transects within the high water boundary and recorded the interception of persistent non-woody plants and shrubs. Canopy cover was measured along each transect and converted to a total percentage representative of the whole pool. Four soil parent materials were also included as within-pond variables: alluvium, dense till, glacial fluvial and loose till. Results showed that spotted salamander egg mass counts had no association with percent tree canopy cover, shrub cover, persistent non woody plant cover, loose till, dense till, or glacial fluvial till. Similarly, wood frog egg mass counts showed no association with shrub cover or loose till. Both spotted salamander and wood frog egg mass counts showed a negative association with alluvial till. In contrast to spotted salamander, wood frog egg mass counts were positively associated with glacial fluvial material and persistent non-woody plant cover, but showed a negative association with canopy cover and dense till, which the authors reported was consistent with the findings of previous studies. The authors also noted that within-pond characteristics explained more variation in egg counts for wood frog than for spotted salamanders.

Although Skidds et al. (2007) is a more comprehensive analysis of vernal pool habitat than most studies, there remains a need for fine scale assessment that may elucidate inter-pool differences based on more specific qualities of the vegetation, such as gradient and community make-up. It has been suggested that vernal pool fauna may have specific correlations to vegetative species (Colburn, 2004; Cutko and Rawinski, 2008). Most results of vernal pool studies for management recommendations insist that more information about vernal pool ecology is needed (Calhoun and DeMaynadier, 2008; Colburn, 2004; Cutko, 1997; Cutko and Rawinski, 2008). Of the few studies on flora that have been conducted in New England, most aim at building inventory of the plant communities (Ciccotelli et al., 2011; Cutko, 1997; VT DEC, 2003). In a review of vernal pool flora in the glaciated northeast United States, Cutko and Rawinski (2008) identify 422 associated plant species as observed in previous studies.

Cutko (1997) sampled 33 vernal pools in two separate areas of Maine and developed an inventory of vegetative communities associated with New England vernal pools. This study was the first to suggest that there was no divergent plant community strictly associated with vernal pools in New England, as the 132 plant species encountered were also found in other wetland types. However, ordination results showed large difference in species composition between the two study regions, which were separated by 200 miles. The author concluded that the vegetation was reflective of biophysical characteristics of region. With a further regionally separated cluster analysis of the vegetation associations, Cutko proposed that there were different types of vernal pools, suggesting a division of small, upland isolated pools with sparse vegetation, “pocket” swamps dominated by shrubs and trees, and forested swamps. However, he concluded that these types elucidated from the 33 vernal pools were not distinctly different from other wetland types and that further, more expansive research is needed.

Comparably, Ciccotelli et al. (2011) conducted a vegetative inventory within Acadia National Park, ME. These authors also cited the need for systematic survey of the flora of vernal pools in the northeastern United States, as current characterizations rely on few surveys. Building from the Cutko (1997) data, Ciccotelli et al. conducted radial interrupted belt transects solely focused on the in-pool vegetation in six vernal pools. The survey resulted in 65 species, 13 of which had not been previously reported as associated with New England vernal pools. However, because of the sheer number of vernal pools in New England, the distinction between vernal pools and general wetland populations remains ambiguous. The results of this study are descriptive only, and are therefore useful as an addition to the vernal pool community roster for future comparisons. The authors provided no comparison to any biotic or abiotic factors.

The Vermont Department of Environmental Conservation (VT DEC, 2003) also conducted a general assessment of 28 vernal pools throughout the state and noted a lack of knowledge as an impediment to resource definition and standardization against which to measure future changes. Similarly to Ciccotelli et al. (2011), the VT DEC vegetation survey was conducted within the high water line. Although the authors had anticipated seeing vegetation zonation patterns within and surrounding the pool, as is often observed in both west and east coast pools (Crowe et al., 1994; Cutko and Rawinski, 2008; Schlising and Sanders, 1982), none were observed in the 28 Vermont vernal pools. The surrounding buffer communities were also assessed, noting any differences in topography or landscape. In agreement with Cutko (1997), VT DEC found “extreme variability” in vegetation among pool areas, in both abundance and composition.

The VT DEC inventory resulted in 99 species, including rare and uncommon species, found within the high water line and indicating adaptability to periods of inundation. In tandem with their collected fauna, VT DEC ran a cluster and ordination analysis to look for grouping patterns among pools that might indicate a logical vernal pool classification system. They determined that variation in aquatic macroinvetebrate and plant species composition are related to environmental gradients in percent canopy cover, depth of organic soil, and several water chemistry variables. Similar to the inferences of Cutko (1997), VT DEC concluded that the fauna may be more indicative of ecological vernal pool types than the vegetation, but stated the results were neither clear nor strong. Currently, there are no known vegetation studies of vernal pools in western Massachusetts.

Vernal Pool Vegetation and Soil Correlations

Studies on the west coast have reflected the presence of vegetation zonation and have attempted to explain this phenomenon with the substrate characteristics. Crowe et al. (1994) explored two theories to explain the zones surrounding vernal pools. The first theory attributes the zonation patterns to the hydrology and the seasonal duration of standing water. The second theory, and the theory tested in Crowe's study, attributes the pattern to soil properties, specifically moisture content, organic carbon, particle size, electrical conductivity, pH, and sodium adsorption ratio. Using one vernal pool in eastern Washington, the authors demarcated and sampled both soil and vegetation within each of six defined zones in order to quantify the differences between the vegetative communities based on the soil. The authors concluded that there were zonal differences in vegetation, but the soil differences were insignificant. However, the authors did note a general trend in decreasing particle size from outside to the inside of the basins. The study did not measure soil moisture, but they concluded that soil moisture potential might have a large explanatory effect on the plant zones observed, particularly because they measured all the other soil properties included in the original theory. Although this study is promising in helping to define the zonation pattern, there was no conclusive explanatory power to this study in regards to the soil characteristics observed. This could be due to the fact that their sample size was small and no direct correlation was made between the vegetation and soil variables.

Stallings and Warren (1996) took a soil series approach to assessing differences among vernal pool communities, specifically citing the effect that soils have on the vegetation community in California. The authors tested three different soil series under 27 pools. Using an ordination and a cluster analysis, they found moderately strong differences between soil type and their corresponding vegetation. They note that there was overlap, according to the ordination results, and infer that the differences may be due to soil series' hydrologic characteristics.

Notably lacking in these studies were correlations of accumulated soil organic matter, hydrology and vegetation. Crowe (1994) suggested at the connection of vegetation to soil moisture, but soil evaluations of vernal pools in New England are absent. Using soil conditions in connection with hydrology, we will look for a correlation to the change in plant communities. This correlation information is historically lacking (Yu and Ehrenfeld, 2010). One of the goals of this study is to document the duration and seasonality of reduced, anaerobic soil conditions. Soil organic matter accumulation has been suggested to be an important indicator of inundation patterns (Gosselink and Turner, 1978). Overlap of species and substrate in these areas may carry indications as to which species may be more able to adapt to climate change and increasingly variable weather patterns (Stohlgren, 2007). The underlying soil conditions and their interaction with hydrology over time will also provide information about the conditions within the substrate that enable these unique ecosystems to persevere.

Study Area

Six vernal pools were selected for this study: three in Amherst, MA (SA1, SA2, SA3) and three in Deerfield, MA (SD1, SD2, SD3). These two areas were chosen for their density of vernal pools in close proximity that occur in the same topographic position and soil parent material, relatively recently undisturbed upland/wetland transition areas. At both study areas, the normal rising phase of hydrologic flows occurs in the fall through late spring. The water level typically declines in mid-to-late summer and may not dry completely.

The study area in Amherst is located approximately 3.5 km southeast of Amherst proper in Hampshire County, MA on town-owned North Plum Brook Conservation Area (

Figure 1). The three pools are within a 200 m radius at the elevation of 51 m. The major soil series is Amostown[1] fine sandy loam (coarse-loamy, mixed, mesic Typic Dystrochrepts) underlain by friable sandy glaciofluvial deposits over silty glaciolacustrine deposits (Soil Survey Staff). The typical Amostown soil profile consists of fine sandy loam over stratified very fine sand to silt loam.

Vernal pools in Deerfield are located in Franklin County, MA on the University of Massachusetts Amherst Agronomy Farm (Figure 2). The three pools are located within a 400 m radius at the elevation of 43 m, at the intersection of the alluvial soils beside the Connecticut River and a kame terrace

[1] In Soil Taxonomy, there are six levels of classification: (1) order (most general level); (2) suborder; (3) great group; (4) subgroup; (5) family; and (6) soil series (most specific level).

deposit on the eastern shoulder of North Sugarloaf Mountain. The major soil series is Merrimac fine sandy loam (sandy, mixed, mesic Typic Dystrochrepts). Parent material is loamy over sandy and gravelly glaciofluvial deposits. The typical Merrimac profile consists of fine sandy loam, gravelly sandy loam or sand over very gravelly sand.

Methods

Soil Sampling

Each pool was equipped with permanently installed redox probes at three stations along microtoposequences: summit, rim and basin (Clausnitzer et al., 2003; Flinn et al., 2008; O'Geen et al., 2008). Redox probes were constructed and installed following the method proposed by Vepraskas and Bouma (1976) by soldering a 1.25 cm platinum wire (20 gauge) to copper wire (12 gauge) (Figure 3). The copper wire was sealed inside a 0.67 cm PVC pipe using epoxy. The probes were installed at depths of 15, 30 and 45 cm in triplicate, within 25 cm of a salt bridge. The depths of the probes were chosen to correspond with rooting zones and the regulations and guidelines for hydric soils relevant to the northeast United States (Faulkner et al., 1989; U.S. Army Corps of Engineers, 2012). The salt bridge was made from 1.25 cm PVC pipe, filled with saturated KCl in 3% agar (Veneman and Pickering, 1983) . Holes were drilled in the salt bridges at 15, 30 and 45 cm. Redox potential (Eh) readings were taken weekly with a calomel electrode (Fisher Scientific, Pittsburg, PA) connected to a digital multi-meter (Radio Shack, Fort Worth, TX) and corrected to a standard hydrogen electrode at pH 7 by adding +244 mV to each reading (Bates, 1973; Faulkner et al., 1989). Before installation, electrodes were tested for accuracy using a poised ferric/ferrous ion solution (Bates, 1973).

Soil profile descriptions were completed along a transect at the summit, rim and basin locations according to the Soil Survey Manual (Soil Survey Staff). This was repeated three additional times around the pool by dividing the pool area into four quadrants, with a transect within each quadrant. Each profile was assessed using the Hydric Soil Indicators for the Northeast Region (U.S. Army Corps of Engineers, 2012). Samples were collected along genetic horizons and analyzed in the laboratory for soil organic matter content by loss on ignition (Nelson and Sommers, 1996), particle size distribution by pipette method (Gee and Bauder, 1986), and pH.

Vegetation Sampling

The plant community assessment was conducted in July 2012 after herbaceous vegetation had already established, following the timing procedures suggested for assessing vernal pool vegetation in the dry season (U.S. Army Corps of Engineers, 2012). Growing season was defined as soil temperature at 50 cm reaching $5^{o}C$ (biological zero) (Veneman and Pickering, 1983). Each pool was assessed using a systematic sampling design of parallel interrupted belt transects of 1 m^2 plots placed every 2 m and aligned from summit-rim-basin-rim-summit across the short axis of each pool (Flinn et al., 2008; Kirkman et al., 1998; Laliberte et al., 2007; Schlising and Sanders, 1982; Stohlgren, 2007). Directionality was determined using the short axis of the pool in order to maximize the intersection of the gradient. The plots were identified in situ as summit, rim, or basin location. Transects were spaced 6 m apart and run the length of the pool until the opposite end was reached. Species percent cover was recorded to the nearest percent by visual estimation for all species in herbaceous, shrub, or woody vine strata rooted within a plot. Any unknown species were collected and pressed for later identification at the University of Massachusetts Herbarium. Species were recorded in the form of standardized USDA NRCS PLANTS database codes (USDA, 2013). Species were categorized by the National Wetland Inventory indicator status for the Northcentral and Northeast region (Lichvar, 2012) and used to calculate prevalence index for each plot (Table 1) (U.S. Army Corps of Engineers, 2012).

Environmental Data

Relative elevation (elev) at each vegetation plot and soil sampling location was measured using a transit level (Laliberte et al., 2007). Depth to free water was determined with wells installed at each summit, rim, and basin station to approximately 40 cm (Faulkner et al., 1989). Using two piezometers per pool at depths of 50 cm and 100 cm, water movement was monitored to document water table directionality (Faulkner et al., 1989). Stations were monitored weekly or biweekly starting at the first thaw after the winter until the first frost in the following winter season corresponding to an approximation of the growing season, with monthly measurements during the winter. Approximate start and end dates of the growing season were determined by soil temperature at 50 cm reaching biological zero, measured with sensors installed at 25 and 50 cm

(Clausnitzer and Huddleston, 2002; Clausnitzer et al., 2003; Fiedler and Sommer, 2004; Megonigal et al., 1993).

Analysis

Soil

Profile data were documented and assessed for hydric status. Within-pool soil data were compared in R software (R Core Development Team, 2013) using statistical package "aqp" (Beaudette et al., 2012). This package was chosen for its specific design for numerical/statistical comparison of soil profiles for measures of dissimilarity and aggregation for a representative profile (Beaudette et al., 2013). At each position within pool, the four transect profiles were aggregated to create a mean soil profile. Mean soil profiles were compared using the Gower's generalized dissimilarity metric (Gower, 1971) by fixed depth segments every 2 cm (Beaudette et al., 2013). Gower's generalized dissimilarity metric is a nonmetric distance measure useful for mixed data types with limited occurrences of missing values (Romesburg, 1984). Profiles were both aggregated and compared based on physical properties: percentages of sand, silt, and clay, organic matter, and pH. Values of each variable were normalized according to the number of contributing profiles to account for differing total depth. Resulting mean profiles were added to the corresponding pool and position vegetation data.

For use in vegetation analysis, summary measures of the time series soil and hydrology data in the upper 30 cm root zone were used (Table 2) (Dimick et al., 2010; Josselyn et al., 1990; Palik et al., 2007). We calculated a weighted average of percent soil organic matter weighted by the depth of the horizon (WeightOM). Redox potential readings were summarized to measures of intensity (percent of total time (RedPerct), fluxuation (interquartile range-Red IQR), and maximum consecutive duration (RedMax) of reducing conditions, defined as ≤300 mV, in the upper 30 cm during the growing season (Fiedler and Sommer, 2004; Megonigal et al., 1993). Water table variables were summarized in the same manner with percent of total time when the water table was within 30 cm of the soil surface (WTPerct), fluxuation (WTIQR), and maximum consecutive duration of saturation(WTMax) (Dimick et al., 2010; Fiedler and Sommer, 2004; Palik et al., 2007; Yu and Ehrenfeld, 2010).

Vegetation

Vegetation data, including elevation and prevalence index, were aggregated and relativized to position within pool for analysis. An unconstrained ordination using nonmetric multidimensional scaling (NMDS) in PC-ORD version 6 (McCune and Medford, 2011) was chosen to extract gradients of maximum variation without imposing linear assumptions on the data. Plots that did not include any vegetation (100% bare ground) and rare or overly abundant species defined as ± 2 standard deviations were removed from the analysis. NMDS was run with Sorensen distance measure and a random number generator for the starting point (Flinn et al., 2008; Laliberte et al., 2007). Sorensen distance measure is a semi metric proportion coefficient measured in city-block space that is less sensitive to outliers and heterogeneous datasets (McCune and Grace, 2002). After dimensionality was assessed by the lowest number of axes giving the highest stress reduction, we used 200 runs with real data. Environmental variables were superimposed on the ordination with a biplot for correlation among variables and with axes (McCune and Grace, 2002). Stability of ordination stress was assessed by a plot of stress vs. iteration, instability <0.0001. Any sample unit ties with unequal ordination distance were not penalized. The resulting axes were rotated to achieve statistical independence from other axes and to create an order of decreasing importance. Stress was assessed for significance with a Monte Carlo randomization test using 200 runs, determining the probability that a similar final stress reduction could be achieved by chance (McCune and Grace, 2002). Pearson's product moment correlations were used to determine effect size of the environmental variables along the ordination axes (McCune and Grace, 2002). Environmental summary variables were subsequently tested for significance within and among pools with ANOVA. Relationship between variables was estimated using bivariate linear or log regression ($y=ax+b$; $y=a*ln(x)+b$).

Results and Discussion

Soil Profiles

A total of 12 soil profile descriptions were completed for each pool (n=72) (Appendix). Soil profiles were described to the maximum depth possible, though attention is given to the top 30 cm for comparison of vegetation and wetland delineation information. Hydric soil indicators in Amherst pools were met at all basin positions and most rim positions (75%). Hydric soils were more variable in Deerfield pools, with 92% of basin profiles being hydric, and fewer rim stations meeting hydric soil indicators (58%), similar to previous findings in vernal pools in Oregon and California (Clausnitzer et al., 2003; O'Geen et al., 2008). California pools have horizons with high clay content near to the soil surface creating a shallow, perched water table. Because of the shallow water table, soil reduction persists. They display comparatively little to no soil organic matter accumulation, rarely reporting O horizons (Hobson and Dahlgren, 1998; O'Geen et al., 2008). O'Geen et al. (2008) suggested that more specific hydric soil indicators should be created for vernal pool scenarios.

Amherst Pools

SA2 displayed variability in silt percentage, however not enough to significantly change the texture class designation, reflecting a small shift from loam to sandy loam. Both pools SA2 and SA3 show an increase in clay percentage around 80 cm, indicating the depth of glaciolacustrine parent material and aquatard. Rim profiles display higher spatial variability in texture (Figure 5). The upper layers show mean similarity through the rooting zone, but intercept the silty/clayey aquatard at different depths, both within and among pools, indicated by the large standard deviation. Apparent "thresholds" in the data represent the transition between genetic horizons with depth. SA2 basin had the highest percentage and depth of organic matter within the profiles (Figure 6), not surprisingly, since the basin positions met either indicator A1 (Histisol) or A2 (Histic Epipedon[2]). Both Histisols and Histic Epipedons are organic soils at least 20 cm thick saturated for at least 30 days; the significance being that the organic

[2] "Epipedon" refers to the uppermost soil horizon (Buol et al., 2011).

matter accumulation is due to wetness. Although not all wetland soils are Histisols, nearly all Histisols occur in wetlands (Buol et al., 2011). A hydrologic regime where free water is maintained at or near the surface facilitates an environment where rate of organic matter production exceeds microbial organic matter decomposition (Buol et al., 2011).

All pools in the basin position display textural variation attributed to the glaciolacustrine parent material and stratified layers of fine particles. Glaciolacustrine parent materials are commonly stratified as a result of sediment settling patterns that would occur in glacial lakes during seasonal weather. Without ice cover, lake waters receive sediment input from associated streams or ice melt. The relative decrease in energy allows coarser particles like finer sands and silts to settle. Glacial lake waters are more still during winter months when covered in ice for very fine particles of clay to settle. This layering/stratification is commonly known as “varved” deposit. Amherst basin substratum textures are on a continuum that is reflective of composites of the soil samples taken, ranging from fine sandy loam to silty clay.

Cumulative measures of dissimilarity with depth (Figure 7) show 1:1 comparisons among pools. Trends in Amherst soil profiles along the gradient include an increase in overall measured variability both within and among pools from summit to basin. SA1 and SA3 appear to accumulate a steady level of dissimilarity in both the summit and rim positions. At the basin position, however, the slope of the accumulation line drops sharply through the rooting zone, indicating low levels of dissimilarity in the upper part. Comparisons of SA2 and

SA3 are the most similar in the rim and summit positions, while SA1 and SA2 are the least similar overall. The slice-wise distance figures (Figure 7) show where dissimilarities originate: in the rim position, SA1 and SA2 are most similar from about 10 to 30 cm, and then accumulate higher measures of dissimilarity to achieve maximum total profile dissimilarity. SA2 and SA3 display the opposite trend, with less dissimilarity deeper in the soil profile. These cumulative and dissimilarity measures can be considered a consolidated assessment of the soils among pools. On that assumption, we would expect to see comparable associations of similarity reflected in the vegetation ordination.

Overall, Amherst pools show relatively low measures of dissimilarity throughout the mean profiles and, specifically, the rooting zone. However, the spread around the mean within and among pools are good indications that we will see differences in hydrology, due to the variation in depth of the aquatard and the depth of organic matter.

Although the Soil Survey mapping units were used as a guide, the scale in Natural Resource and Conservation Service (NRCS) maps does not lend itself to definite exactness at such a large scale, as expected. Soil series' are mapped at 1:24,000, which is too coarse a scale for assumed accuracy at the 1:1 level of this study (Soil Survey Staff). Based on NRCS map unit characteristics, we conclude that all 3 Amherst summit positions are, in fact, Amostown series, while the soils in the depression of the pool are Raynham, a typical inclusion of the Amostown mapping unit. Raynham series (coarse-silty, mixed, active, nonacid, mesic, Aeric Epiaquepts) is very deep, poorly drained soil in silty estuarine or glaciolacustrine deposits in depressions and drainageways. Unit inclusions represent likely soil series' associated with the mapping unit, but encountered at a lower frequency or in relatively small areas in a catena.

Deerfield Pools

Summit profiles in all Deerfield pools show a consistent mean and standard deviation with depth, but widely different means a pools (Figure 8). Around 40 cm, SD2 and SD3 summit profile textures shift into alignment, while SD1 has consistent mean and spread indicating spatial textural variability. Overall, all three pools in the summit position show more dissimilarity and spread within pools than seen in Amherst summit profiles.

Deerfield rim positions are variable the rooting depth, but SD1 shows a major change in texture at approximately 45 cm, and almost identical means across all three pools (Figure 9). Additionally, SD2 and SD3 display the same mean texture through the entire profile depth, which was not seen in the summit positions. This same confluence of textures is displayed in the basin profiles, with SD1, again, showing the major texture change (Figure 10).

The Deerfield pools lie in the oldest portion historic floodplain of the Connecticut River and display a common flood event around 40 cm, texturally consistent with silty alluvial deposits. Lack of similarity in the upper part of the summit stations are most likely due to disturbances, particularly agricultural. Although these areas have not been disturbed in recent years, the eastern sides of both SD1 and SD2 summit profiles had plow pans and are adjacent to farmland, while SD3 has a small hydrologic barrier. It is likely that SD3 summit positions are displaying characteristics of undisturbed soil, as it is in a physically less accessible area. Disturbance in SD1 and SD2 could have resulted in fill or removal in the upper part of the soil, contributing to the textural differences. Depth-wise dissimilarities support this idea, in that SD3 is similar to both SD1 and SD2, but SD1 and SD2 are much more dissimilar (Figure 11).

The Deerfield pools exhibit variability from the mapped soil series determinations, matching a Winooski Series (Coarse-silty, mixed, superactive, mesic Fluvaquentic Dystrudepts) and drainage sequence to the Limerick series. The Winooski series is widespread adjacent to the pools in the farmland with silty alluvium parent material and is very deep and moderately well drained. Limerick series (Coarse-silty, mixed, superactive, nonacid, mesic Fluvaquentic Endoaquepts) are very deep, poorly drained soils on floodplains. Parent material is loamy alluvium.

Organic Matter and pH

In general, wetlands are known to accumulate organic matter as a result of extensive periods of saturation and anaerobic conditions (Mitsch and Gosselink, 2007). Soil organic matter was highly variable across both study areas. Most notably, SA2 basin showed an accumulation of organic matter well below 60 cm from the surface, also maintaining a more acidic depth profile, while SD1 and SD2 had very little soil organic matter accumulation in the upper part. Soil organic matter content and pH have an inverse relationship, seen in the mean depth profiles where there are decreases in acidity as organic matter decreases. Carbon dioxide from decomposing organic matter and root respiration dissolving in soil water form a weak organic acid, while formation of strong organic and inorganic acids, such as nitric and sulfuric acid from decaying organic matter are likely causing the strongly acidic conditions in the more organic pools. Even at the depth of the buried A horizon of SD1 basins, acidity increases slightly in concert with a slight increase in soil organic matter.

Hydrology

Water table was detected in most monitoring wells within 30 cm of the soil surface at some time during the study period. The 2011 growing season saw heavy precipitation events late in the summer as a result of two hurricane events in late August/early September (Figure 12), resulting in sharp increases in water table and basin depth. Minimal precipitation in the winter of 2011-2012 allowed the pools to dry sooner than was observed in 2011. Piezometric head varied considerably over the monitoring period (Figure 13). Although they are monitored in situ at each pool, piezometer data are indicative of groundwater conditions at the landscape scale. All six pools are dominated by a positive piezometric head during the monitoring period, but SA3 is the only pool to show incidences of negative head, indicating periods of net downward movement of water and direct response to precipitation. The lack of fluxuation between upwelling and recharge indicates that water is primarily removed from the pools by evaporation and transpiration, as opposed to infiltration. These data are in partial contrast to the findings of Brooks (2004), where vernal pools in a Massachusetts study were primarily driven by the effects of precipitation and evapotranspiration. The piezometric data from this study period indicates a greater connectedness of some vernal pools to groundwater systems. Vernal pool inundation from precipitation plays a larger role in our vernal pools in its influence on groundwater at the landscape scale. Although the vernal pools from Brooks' study are geographically close to the Amherst and Deerfield pools, it could be that the dense glacial till parent material was the factor limiting in pool inundation from groundwater.

Redox Potential

Soil redox potential (Eh) showed seasonal fluctuations responding to precipitation, temperature, and water table. SA1 summit stations remain regularly oxidized, due to the lack of high water table (Figure 14). Rim stations mirror the patterns of the corresponding summit station, but show a more pronounced depth separation of oxidation levels, explained by a lag time in water table recession due to a shallower aquatard (Figure 15). Amherst basin profiles show consistent state of reduction and exemplify the effect of soil organic matter on Eh (Figure 16).

Eh generally followed the depth profile of oxidation to reduction when assessed using overall average/summary measures for the 2011-2012 growing seasons. However, the time series data shows temporal flips in Eh with depth. At SA1 rim stations, inversions occurred in both 2011 and 2012 with significant differences where 45 cm probes being less reduced than the 30 cm probes. Only with a complete and extended absence of water table in 2012 did the 30 cm probes become less reduced for the first time during the two seasons, but still below the level of the 45 cm probes. The mean depth profile analysis shows a change in texture to a higher clay percentage below the 30 cm probes, indicating that the 45 cm probes intercepted smaller micropores. In fact, in all pools where there is a flip in redox with depth, there is an increase in percentage of silt and/or clay at the level of the higher oxidized probes. This is a similar result to Megonigal (1993), although they concluded that texture did not affect their redox readings. Megonigal's study area was comprised of sandy soils, so it is likely that limited the occurrences of small soil pores or micropores in the study area. Our data suggests that genetic horizon texture distribution does affect redox readings. Our findings are supported by the effect of textural stratification and organic matter on the efficacy of water movement, especially in stratified layers (Gardner, 1986).

The SA2 basin profile showed a similar scenario—at times when the water table was below the 15 cm probes, the 30 cm probes were oxidized while probes at 15 cm remained reduced. This instance could be attributed to high percentages of organic matter in addition to the upwelling seen in the piezometric data. This finding is in support of previous studies in bottomland hardwood forests (Faulkner and Patrick, 1992), but is in contrast to studies in a freshwater tidal wetland (Seybold et al., 2002). Organic soils are known to hold water longer, often exceeding gravitational pull, maintaining anaerobic conditions even with absent water table (Clausnitzer et al., 2003; Gardner, 1986; O'Geen et al., 2008). Piezometer data shows the pools receiving water from upwelling. When the hydraulic head is gone, the only source of water is precipitation. Some precipitation will infiltrate downward, but will also be removed by evapotranspiration. This creates a scenario where there may be water at 15 cm and 45 cm, but absent at 30 cm.

Deerfield pool summit positions displayed the most instances of disagreement with increased reduction with depth (Figure 17). SD1 and SD2 summit profiles actually display periods of reduction, particularly during the wet season of 2011, which has been shown in other upland situations without the development of hydric soil indicators, especially early in the season (Faulkner and Patrick, 1992). Deerfield rim redox showed the most similarity to rim stations in Amherst in response to water table movements (Figure 18). SD1 and SD2 pool basins have a higher incidence of oxidation in the upper part than was seen in Amherst (Figure 19). Both SD1 and SD2 had the lowest soil organic matter, which could allow higher rates of oxygen diffusion into the soil pore space.

SD3 had little water table fluxuation in all positions and piezometric stability through both growing seasons, creating a static redox environment. Although the pool dried, the water table barely dropped below the levels of the probes, except at the summit position. SD3 summit was perpetually dry and remained oxidized in the upper part throughout the study.

Duration of reducing conditions, when present, appear to be dependent on many variables: seasonal influences of the water table and soil temperature, soil organic matter, and whether "leaf out" has occurred. Cooler temperatures earlier in the growing season coincide with more gradual transitions in measurements, as opposed to after leaf out, when probe averages could spike within a single week although this finding has not proven consistent in all cases

(Faulkner and Patrick, 1992; Seybold et al., 2002). After full leaf-out during both growing seasons (around mid-June) there is a sharp drive toward oxidation and decline in water table depth.

Growing Season

Similar to previous findings, our data suggests that using 5^{o}C as an approximation resulted in a growing season that is almost year-round (Megonigal et al., 1993; Seybold et al., 2002). Application of biological zero criteria indicates that 3 of the 6 summit monitoring stations exceeded 5% of the growing season with saturation within the root zone with long term-monitoring, without displaying physical evidence of hydric soil. This brings into question the usefulness of defining growing season for ecological studies. "Non-growing season", as it is defined for plant purposes can be "bud break" or a certain number of frost free days. From the 2011 to the 2012 growing season, the soil temperature at 50 cm did not reach biological zero in Amherst pools for more than one monitored occurrence. The redox readings from this study clearly show microbial activity almost year-round, evidenced by the continuing minor fluxuation in Eh in the profile.

Environmental Data

A positive linear relationship between the summarized measures of water table (WTPerct) and redox (RedPerct) was highly significant, although not as strong as anticipated (r^2=0.43, p<0.001) (Figure 20). The additional soil environmental factors affecting redox, including microbial communities, textural pore space and organic matter content explain this variability and emphasize the complexity of the soil redox. To test this, we fit a log regression to RedPerct against WeightOM. The relationship was not strong (r^2= 0.33, $p<0.05$), but supports our assumptions of the significance of soil organic matter on the redox readings (Figure 21). Weighted organic matter and water table were not significantly related. Although this is surprising given that wetlands generally accumulate organic matter, the hydrologic variability of vernal pool does not support significant organic matter accumulation. A previous study in southern Rhode Island reported similar correlations of organic matter thickness to mean hydroperiod in vernal pools (Skidds and Golet, 2005).

The only variable displaying differences between all six pools was soil organic matter ($p<0.05$). As expected, elevations were significantly different by position ($p<0.05$) (Table 3). Greatest fluxuation in water tables (WTIQR) were seen at the basin wells and were significantly different from the rim and summit station readings ($p<0.01$). Again it was expected that redox IQR would exhibit the same pattern and was found to be significant when the p-value was relaxed at $p<0.10$.

When within-area (Deerfield or Amherst) variables were compared, environmental variables again showed significance of differences between positions, not pools. All redox variables in Amherst were significantly different between position ($p<0.05$), indicating similar gradients for all three pools. In contrast, redox variables overall showed a lack of significance both among pool and position in Deerfield. However, water table variables were significantly different by position. Although there was a delay in instrumentation of all pool basins, the lack of statistical significance is more likely due to the lesser amount of soil organic matter in Deerfield pools. By comparison, all basins in Amherst remain reduced for 100% of the growing season in portions, if not the entirety of the upper 30 cm, while Deerfield pools SD1 and SD2 oxidized in the upper parts during the 2012 growing season when the water table receded.

The oxidation in SD1 and SD2 basins has important implications regarding carbon storage in wetlands. Carbon storage in wetlands is a result of the slow diffusion rate of oxygen in water vs. air, leading to anaerobic conditions as the facultative and obligate microorganisms use up the residual oxygen in soil pores. This facilitates slow decomposition rates of carbon inputs. The oxidative states in the basins of SD1 and SD2 imply that the ability to store carbon is lower than in the other pools in this study due to the long periods of soil oxidation. This shows that periodic flooding of vernal pools is not sufficient enough in all cases to provide the anaerobic conditions that keep the rate of organic matter accumulation above the rate of decomposition.

Interestingly, however, the summarized measures of hydrology were not significantly different between pools in Deerfield. In other words, they display similar hydrologic gradient conditions. This would suggest that all three pools would show similar rates of organic matter accumulation. The lack of uniformity brings to the forefront the effect of more recent past anthropogenic disturbance/alteration in SD1 and SD2 being the cause of the low soil organic matter content. More information would be needed on the history of the disturbance and how the pools were altered in order to address that question.

Vegetation

A total of 83 species were sampled in the six pools, with 38 and 66 occurring in Amherst and Deerfield, respectively (Table 4). Of the total species, 20% were OBL, 29% were FACW, 22% were FAC, and 29% were FACU (Lichvar, 2012). We did not encounter any rare or endangered species and all species had been previously identified within northeast vernal pools. Species richness decreased from upland to wetland, with higher covariance of species in Amherst than Deerfield (Table 5). After relativization, three species were removed following an outlier analysis: *Lemna minor* (duckweed), *Quercus palustris* (pin oak), and *Viburnum nudum var. cassinoides* (withe-rod). NMDS ordination with two axes represented 73% of the variance species composition with both axes 1 and 2 showing similar levels of importance, 37% and 36%, respectively (Figure 22). Final stress of NMDS was at 10.43 achieved after 186 iterations indicating a good ordination fit ($p<0.05$) (McCune and Grace, 2002). Overlay of environmental variables showed the water table variables were correlated to Axis 2 while redox percent and physical soil characteristics were correlated with Axis 1. Correlations with $r^2 > 0.20$ were determined to be indicative of the gradient reflected in the axes (Table 6) (McCune and Grace, 2002). The environmental overlay was not a factor in the ordination scores, so inferences are limited to that of suggestion and not causality.

Obvious similarities in ordination space are pronounced in the Amherst pools, particularly in SA2 and SA3 rim and summits, which are clustered tightly together. SA1 shows more definition along the axis correlated to the soil variables. These three pools show a dichotomous separation along axis 2 reflecting the hydrologic gradient.

Deerfield pools show the opposite results with higher dissimilarity among pools. SD2 and SD3 are seen to ordinate more similarly along soil axes. Deerfield pool communities are also driven by hydrology; however, it is the hydrologic similarity, or lack of dissimilarity, that has likely allowed a similar community make-up to persist within pools. The visual spread of the Deerfield vegetation between pools would have led us to infer that the environmental variables are significantly different among pools. This is not the case, but the pools maintain statistically significant differences along the hydrologic gradient, which is also surprising based on the ordination.

The correlation coefficients show that the combination of the water table characteristics and soil organic matter (WeightOM) represent the strongest potential explanatory variables (Table 6). The visual connectivity of time series graphs of Eh to water table led us to hypothesize that Eh and water table variables would be correlated along the same axes, but given that redox percent is correlated along the same axis with organic matter, it reinforces the idea that soil organic matter is maintaining saturation in the upper part, exceeding the presence of the free water.

The comparison of means of aggregate soil profile characteristics mirrors the dissimilarities seen in the ordination. Although Deerfield soils are similar below the rooting zone it appears that a lack of organic matter underlay SD1 and SD2 separation in vegetation ordination space. This idea is supported by the proximity of SD3 to the Amherst pools along both axes, having a high soil organic matter content.

Our results support other studies of wetlands with similar hydrologic regimes, including the distinct ordination of hydrologic characteristics and soil properties on differing axes in NMDS (Laliberte et al., 2007). Also in line with the findings of the previous vernal pool research in the northeast, our results point to a lack of vegetation consistency across geographic range in vernal pools (Cutko, 1997; VT DEC, 2003). While pools in Deerfield were nearby in geography and topographic position, variability in soil, vegetation assemblages and hydrology were reflected in the inability to produce replicate redox conditions. Based on the vegetation ordination and temporal redox data, we would have expected significant differences in environmental data among pools in Deerfield, but this was not the case. Lack of statistical significance could be addressed with a different study design, specifically, attention to variables at the 1:1 scale. The inherent difficulty of such a large ecological study, the constraints of time and resources, is often the case in field ecology.

Conclusion

What is clear from this study is the role of soil organic matter on both the plant composition and the substrate in vernal pools. Wetland hydrology and the accumulation of soil organic matter, once established, perpetuate anaerobic conditions. Saturated organic matter in the upper layers of soil serves an insulating-like function in response to short term climactic changes in maintaining reduction. Only in the basin soils that lack substantial percentages of soil organic matter did the upper layers become oxidized during dry conditions. The significance of the positive relationship between temporal measures of reduction to the weighted percentage of organic matter is influential on the future of vernal pool research in the northeast. We suggest using the weighted organic matter metric for future studies as it gives an accurate, quantitative measure of the soil organic matter state as opposed to a single measure of organic matter depth. It provides a better indication of the pore spaces in the organic layers, since sapric soil organic matter has smaller pores, and is known to have high water retention as opposed to more fibric material (Boelter, 1964). Therefore, this weighted metric used as a measure of both organic matter quality and redox when used in future studies can provide a more concise assessment of the hydrologic and substrate conditions.

Vernal pools that have been disturbed through macrophyte removal, peat harvesting, or physical factors increasing aeration of the organic matter may not have the ability to revert naturally to accumulating organic matter. In matters of wetland restoration, we imply that better success may be had with the addition of hemic/sapric organic matter in order to restore the anaerobiosis and may act as an assurance against aeration with water table fluxuation. Our suggestion on the past disturbance being the cause of the soil conditions in SD1 and SD2 needs further research. Depending on the pool history, this could stimulate information on the necessity for the proper restoration of substrate in tandem with hydrology for the success of vernal pools as wetlands to not only maintain anaerobiosis, but the potential to provide carbon sequestration. There is yet to be a consensus on the role of wetlands in carbon sequestration (Kayranli et al., 2010), let alone, ephemeral wetlands such as vernal pools. The results of our study highlight the importance of establishment of soil organic matter in the attempts restoration and replication of vernal pools. Additional research investigating the facultative microbial populations may also provide a better indication of the components in the pool soils leading to the successful hydric soil development.

The results of this study are largely in agreement with previous studies the effect of organic matter on redox potential and, separately, on vernal pool vegetation patterns in the northeast. As a follow up to this study, a multiple regression analysis could be used to better determine the strength of the combined influence of multiple variables. Additional information would also be gained from a nutrient analysis of the substrate, hydrology and vegetation among the pools. Also in support of previous findings, one hydrologic model does not fit all vernal pools, showing the ephemeral nature of inundation differs in the microtoposequence as well as at a landscape scale (Brooks, 2004; Gamble and Mitsch, 2009). A long term study would be needed to track the lasting effects on the vernal pool vegetation distributions and redox.

Previous studies have suggested that hydrology is the most important factor for many aspects of vernal pool ecology, including the breeding wildlife (Brooks, 2004; Skidds and Golet, 2005). This study suggests that the maintenance of soil organic matter may be just as influential in connection with the hydrology. While the least organic pools in Deerfield continue to display vernal pool hydrology and ecology, the absence of soil organic matter in the upper part is a defining characteristic separating the current vegetation communities and substrate reduction differences. This is reinforced by the similarity of SD3 in ordination space to the more organic Amherst pools.

The data collected during this study adds to the growing information on the currently ambiguous relationships of substrate variables and pool hydrology and indicates where additional data is needed. As has been suggested, changing weather patterns are likely to have an effect on the hydroperiod and the substrate content within vernal pools, including the breeding success of the ephemeral fauna (Brooks, 2009). The ongoing discussion of not only vernal pools, but the role of wetlands in carbon sequestration or greenhouse gas contribution will be an essential topic as the scientific community progresses in making management decisions around wetlands and their ecological services.

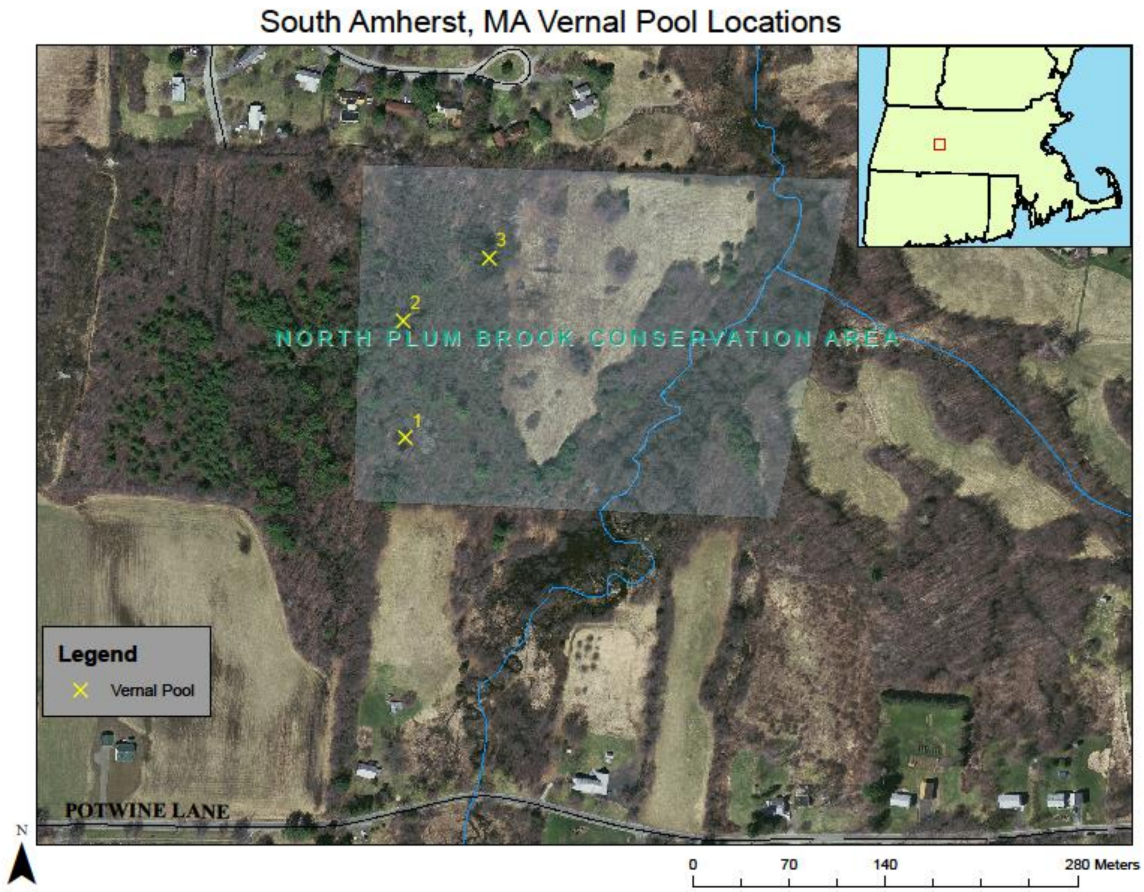

Figure 1- Location of vernal pools in Amherst, MA (SA1, SA2, SA3)

South Deerfield, MA Vernal Pool Locations

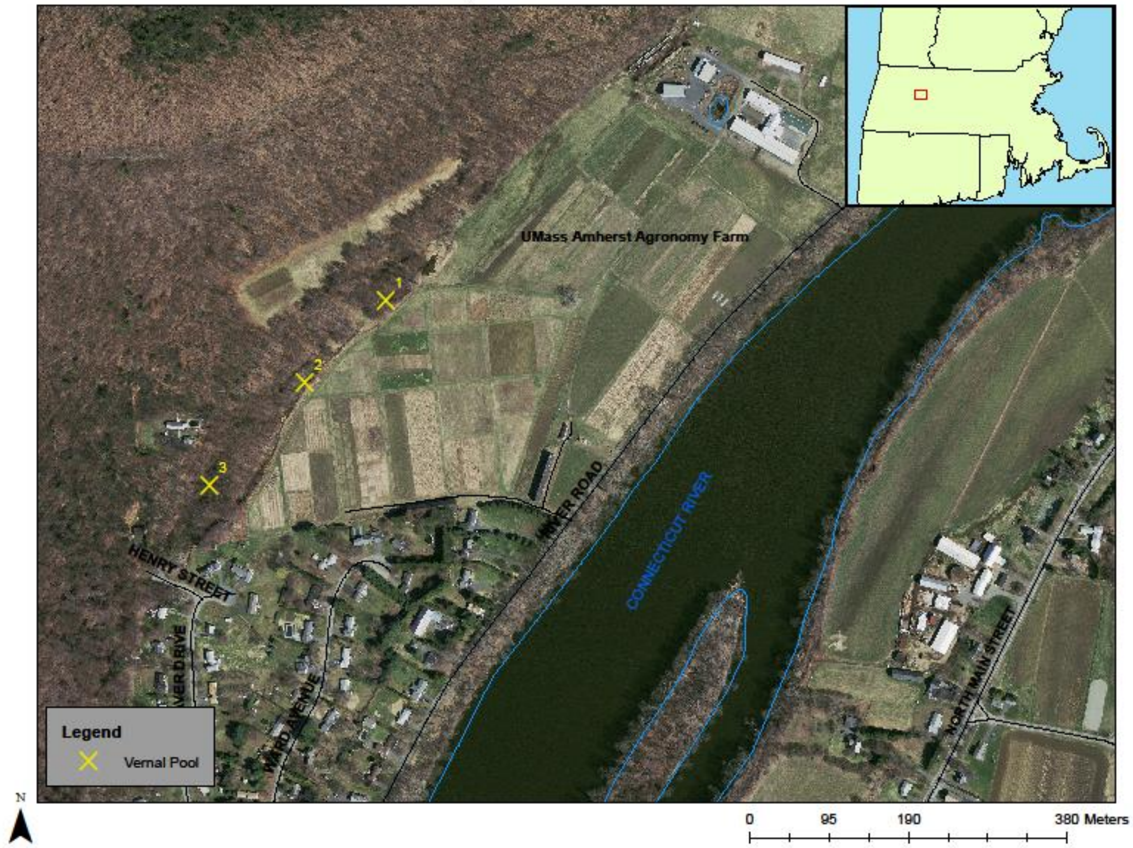

Figure 2- Locations of vernal pools in Deerfield, MA (SD1, SD2, SD3)

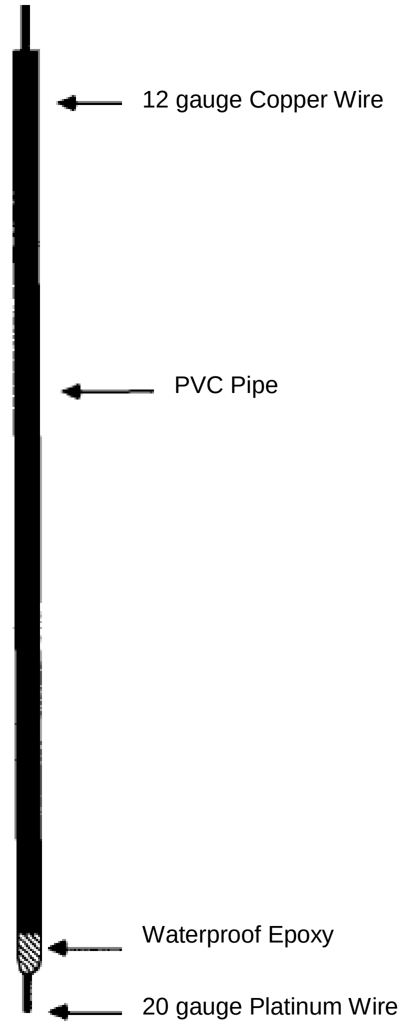

Figure 3- Example of redox probe construction, adapted from (Faulkner et al., 1989)

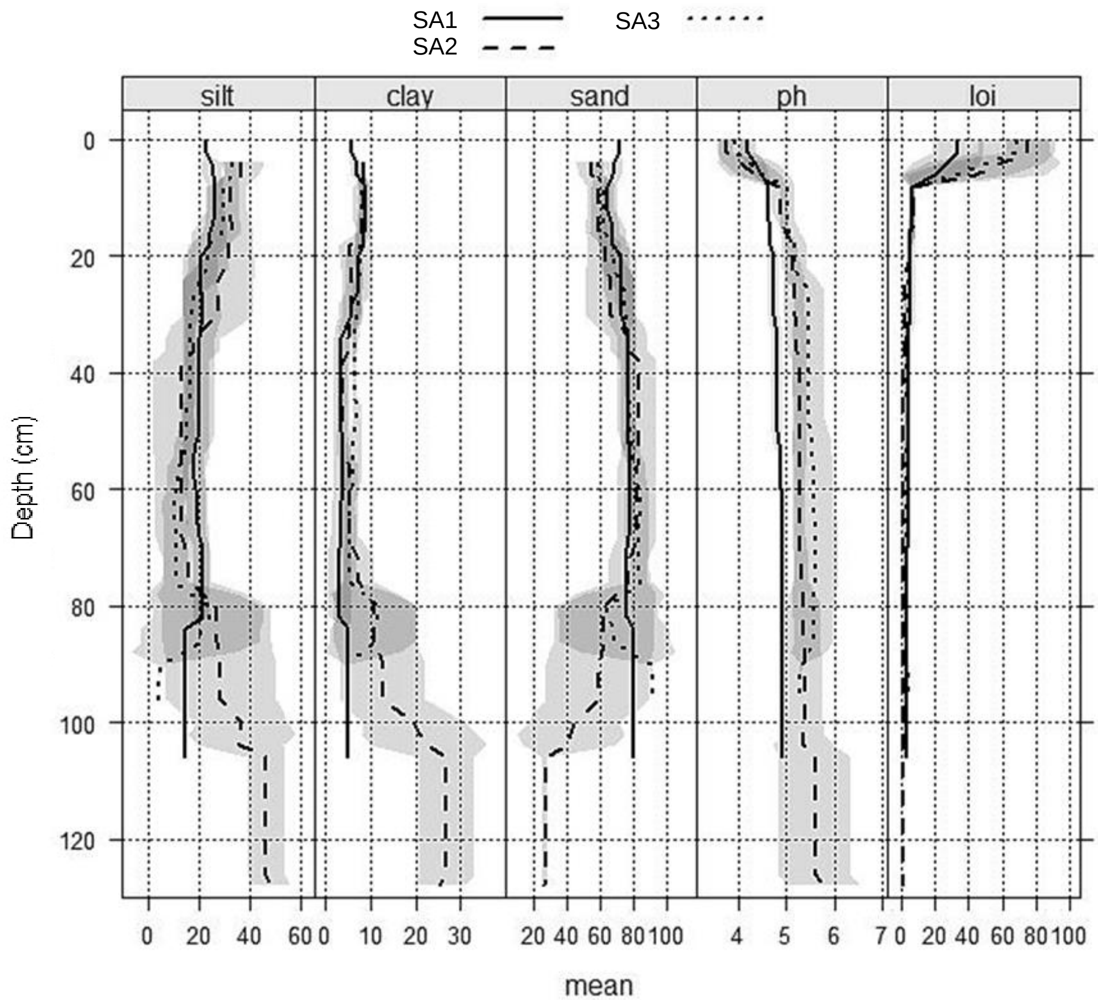

Figure 4- Mean soil profiles ± 1 standard deviation for Amherst pools in summit positions.

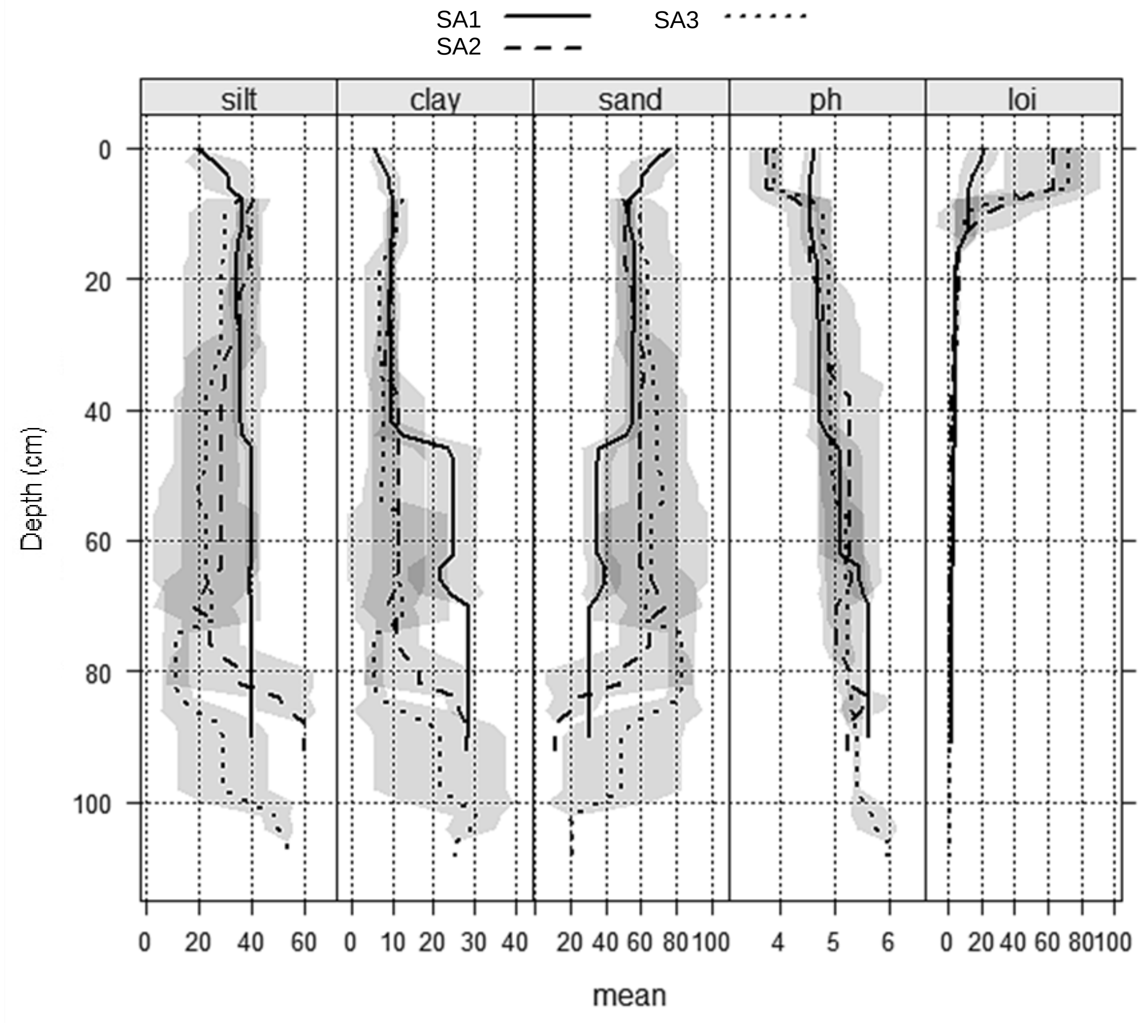

Figure 5- Mean soil profiles ± 1 standard deviation for Amherst pools in rim positions.

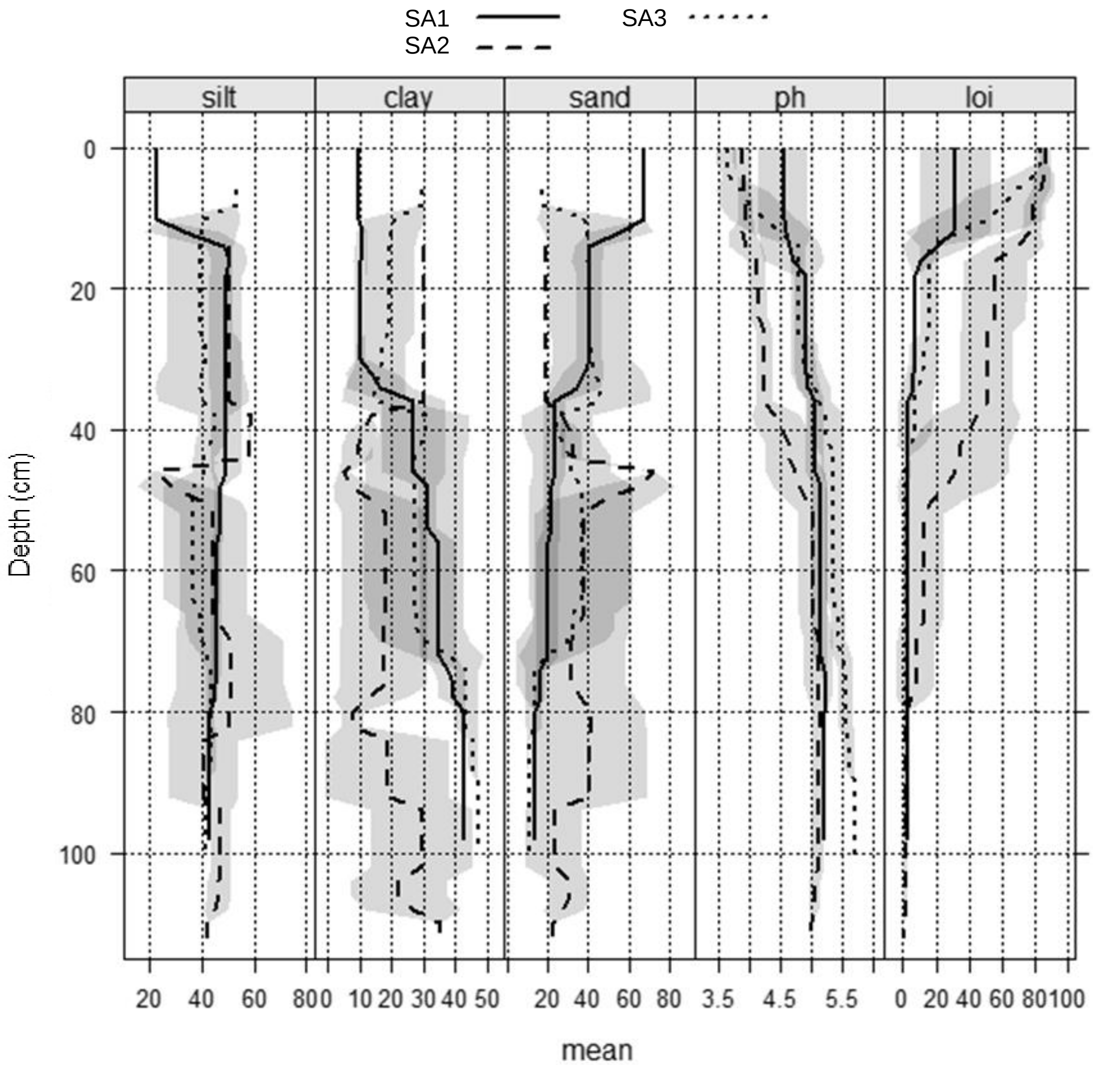

Figure 6- Mean soil profiles ± 1 standard deviation for Amherst pools in basin positions.

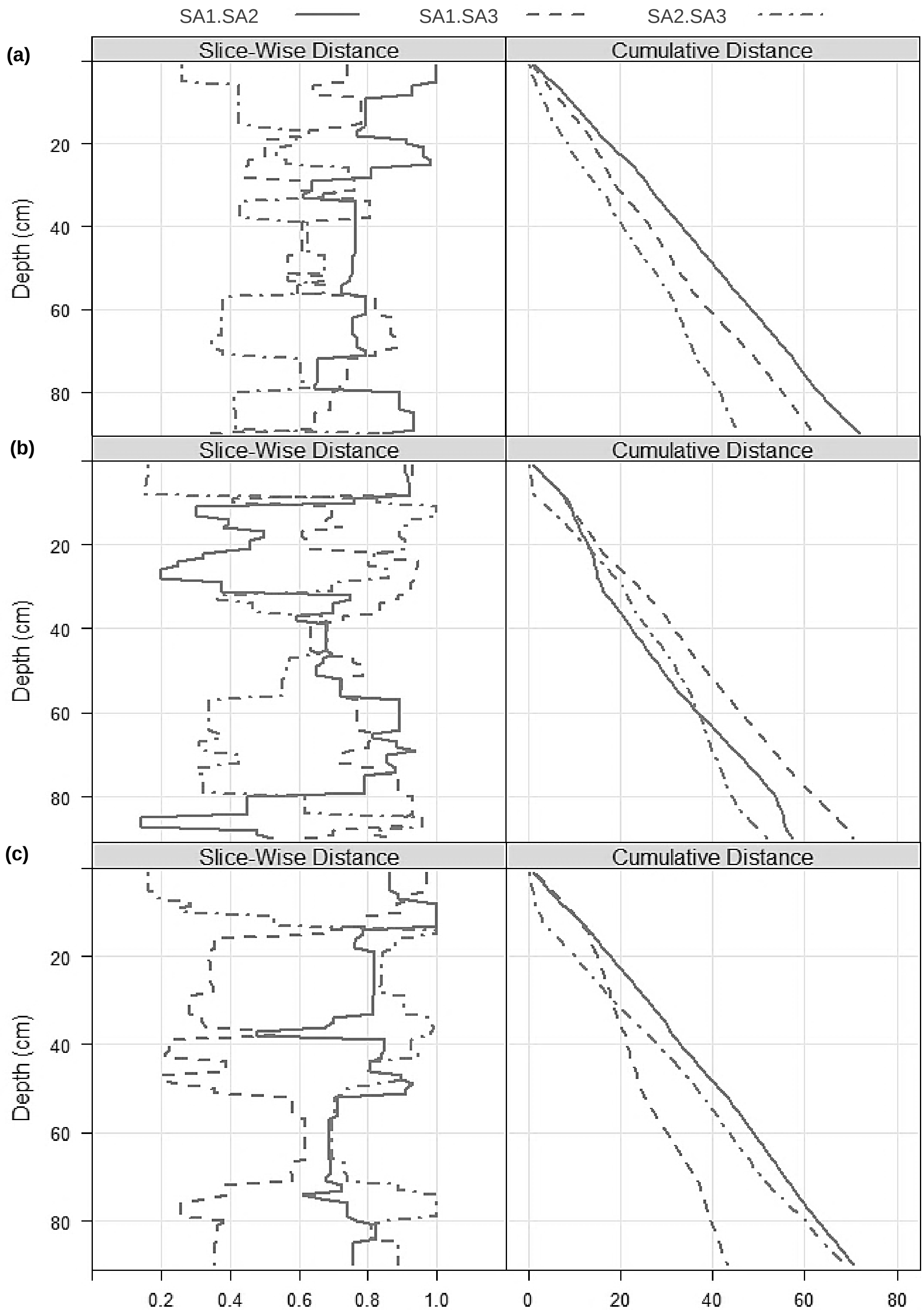

Figure 7- Depth profile distance comparisons for Amherst pools in (a) summit, (b) rim, and (c) basin positions.

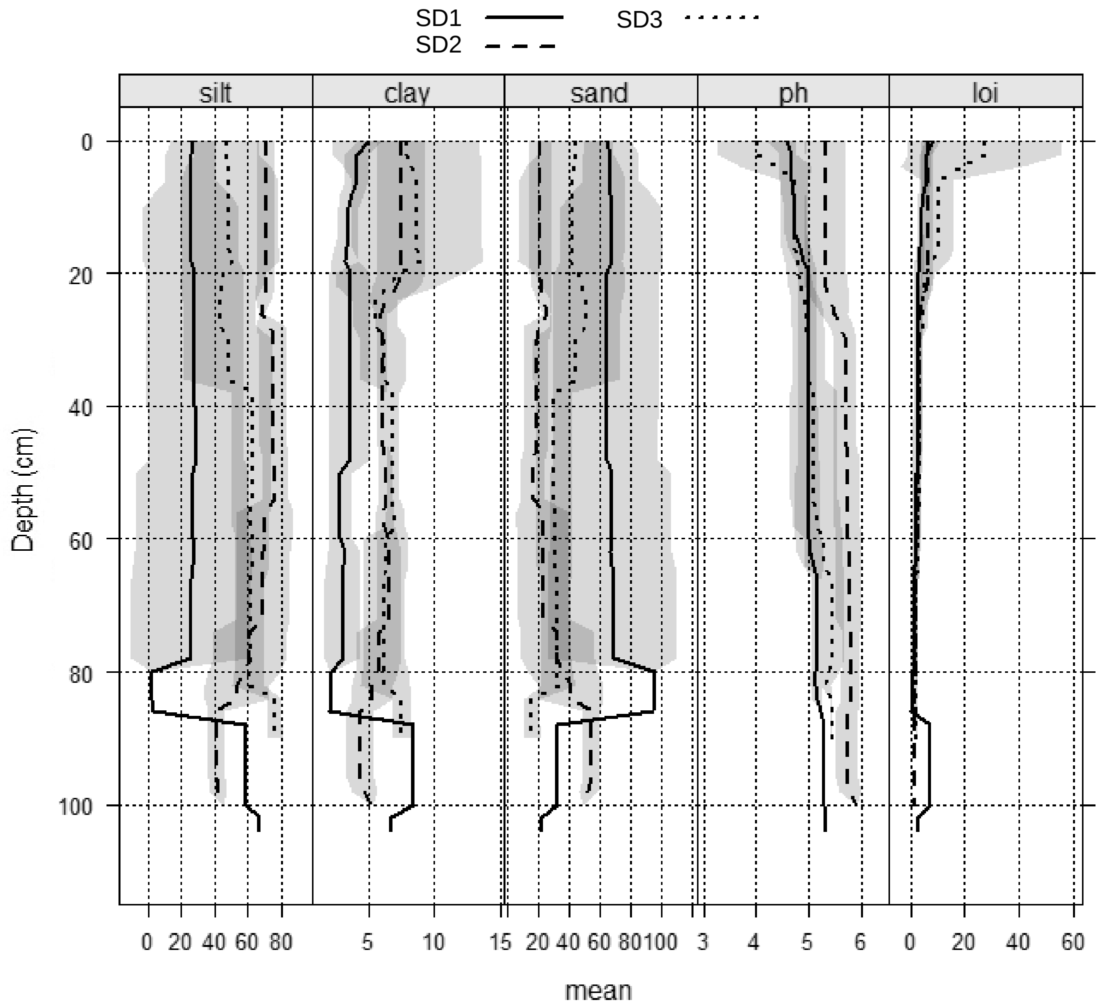

Figure 8- Mean soil profiles ± 1 standard deviation for Deerfield pools in summit positions.

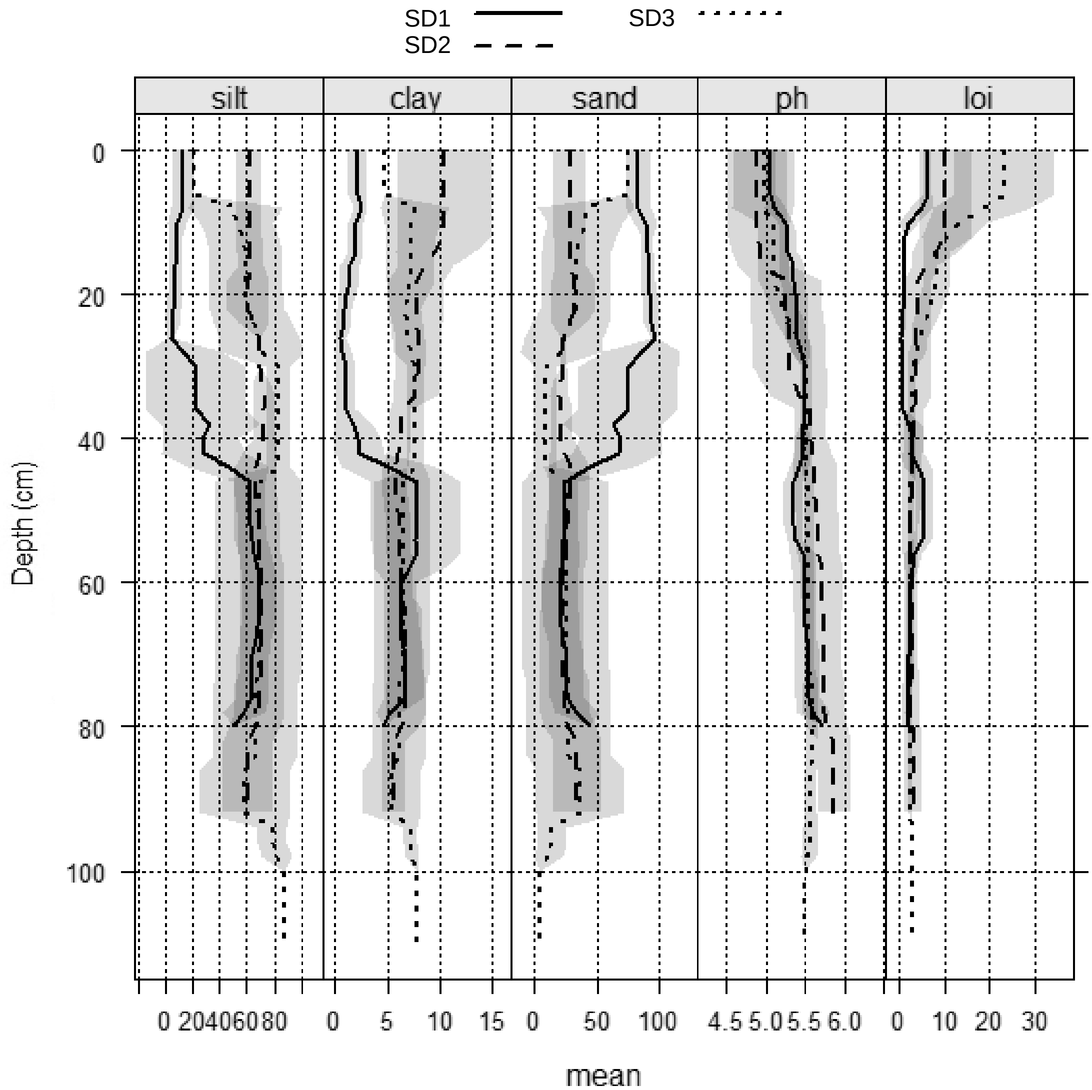

Figure 9- Mean soil profiles ± 1 standard deviation for Deerfield pools in rim positions.

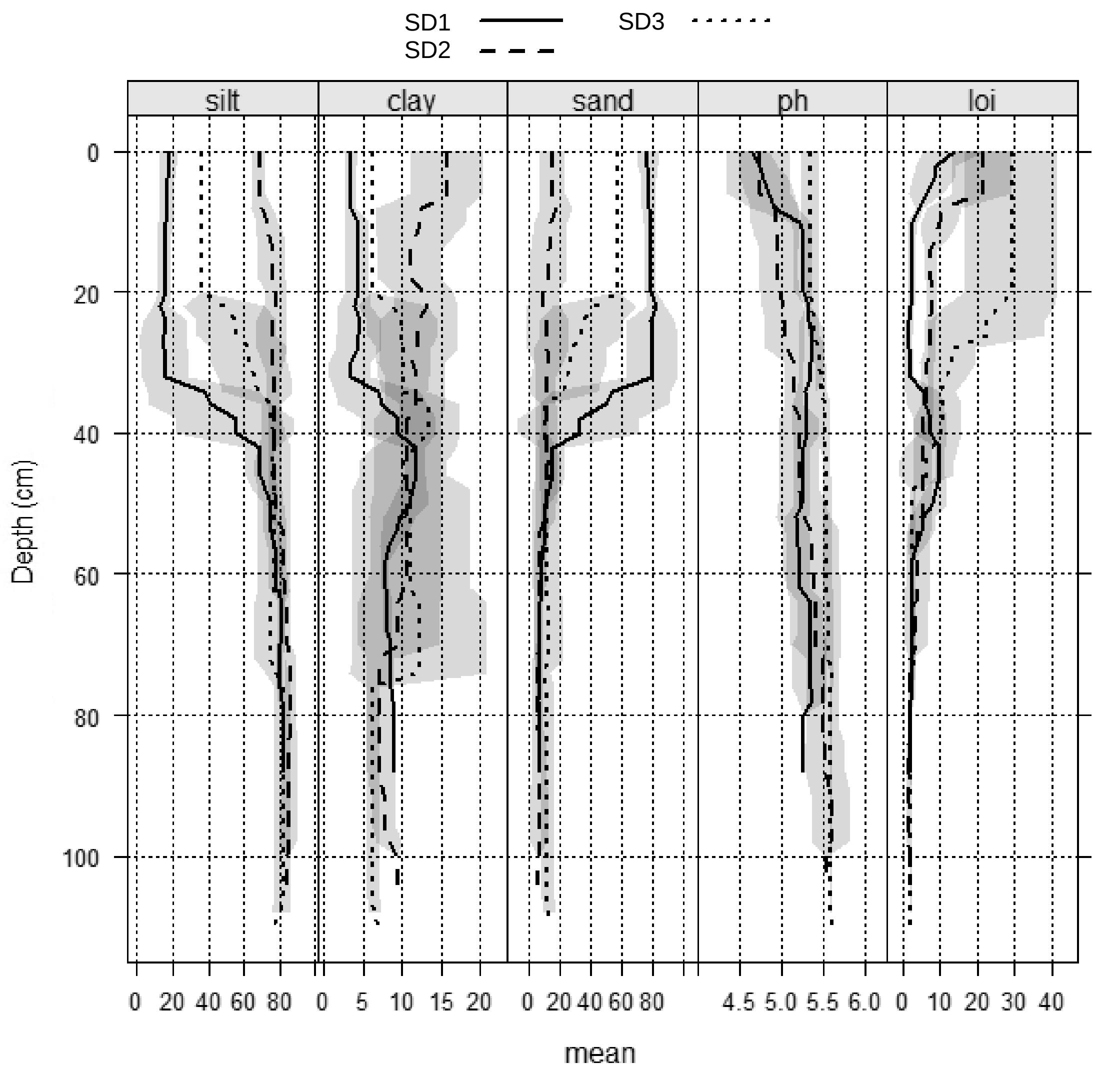

Figure 10- Mean soil profiles ± 1 standard deviation for Deerfield pools in basin positions.

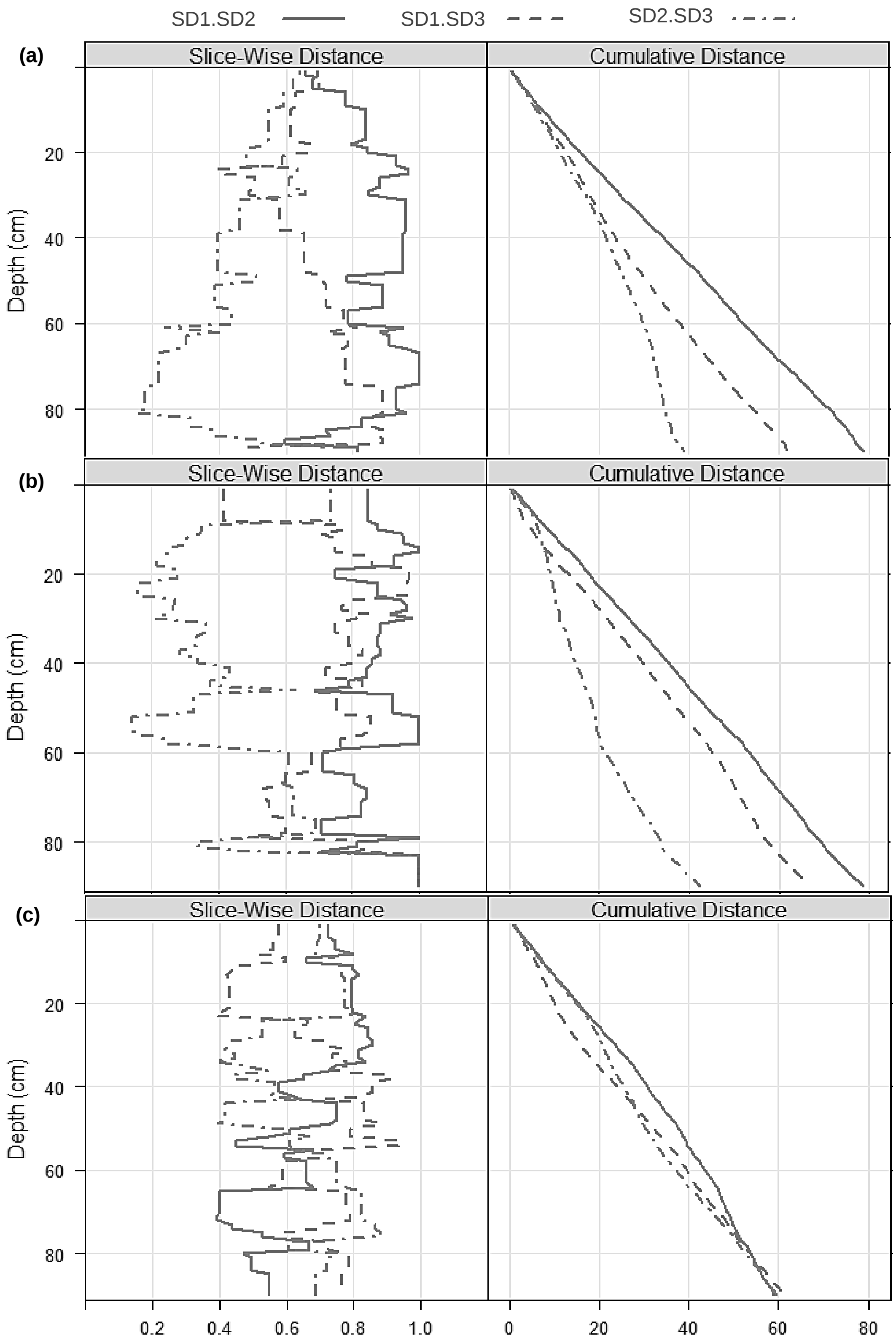

Figure 11 - Depth profile distance comparisons for Deerfield pools in (a) summit, (b) rim, and (c) basin positions.

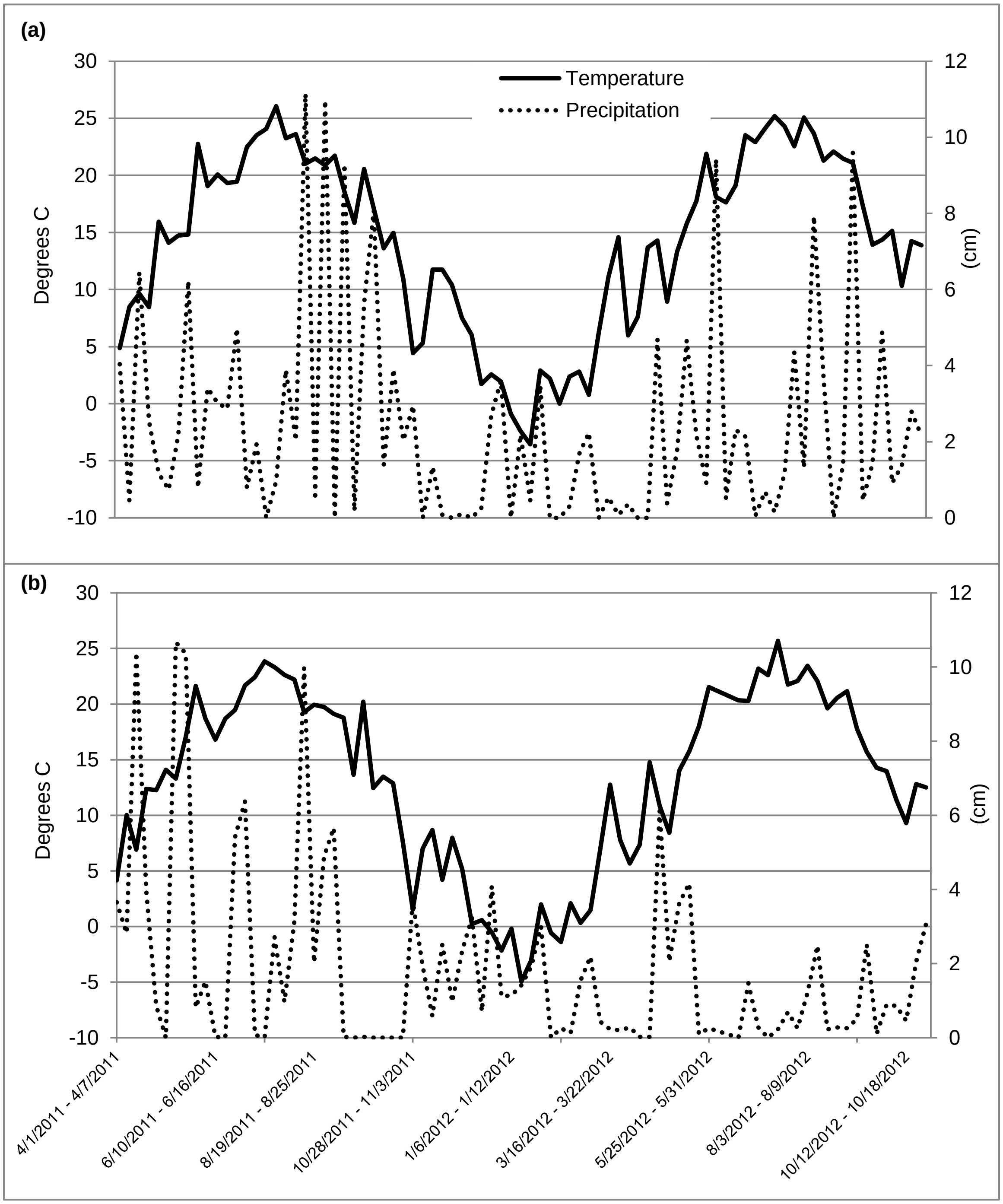

Figure 12- Weekly Precipitation Totals and Ambient Temperature Averages in (a) Amherst and (b) Deerfield, MA for 2011-2012 monitoring period.

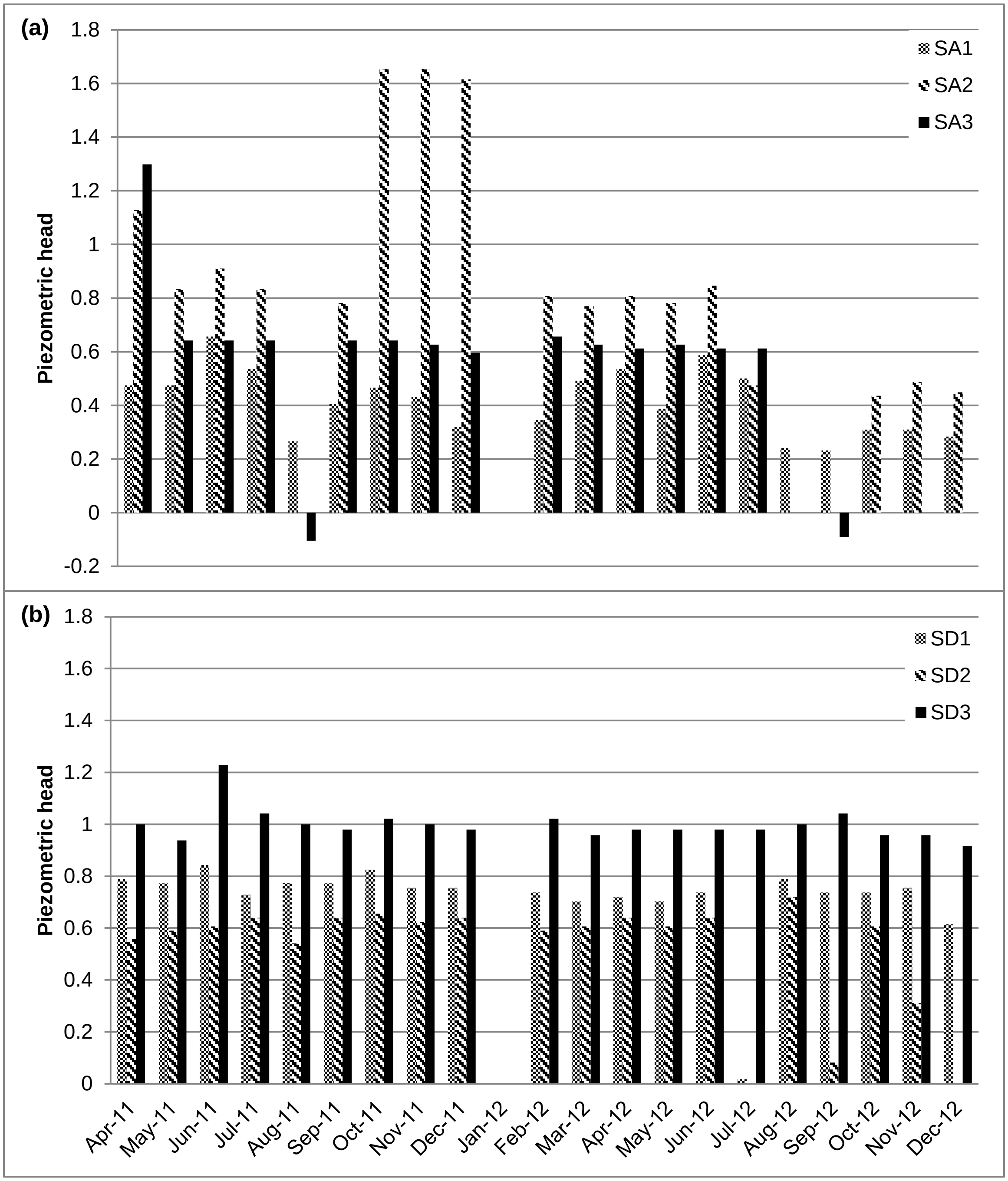

Figure 13- Piezometric head for (a) Amherst pools and (b) Deerfield pools over the 2011-2012 monitoring period.

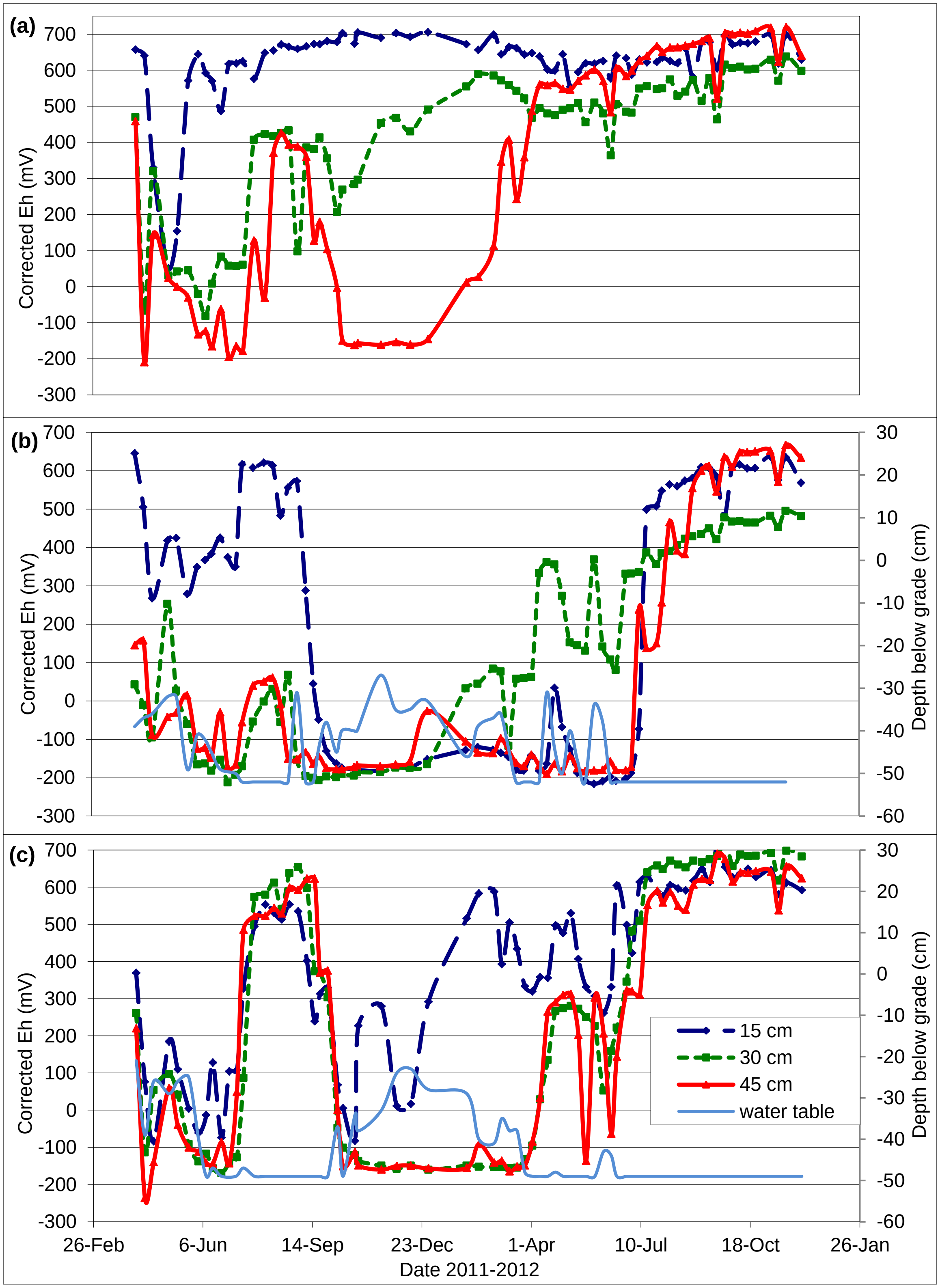

Figure 14- Average redox depth profiles and water table levels for Amherst pools (a) SA1, (b) SA2, (c) SA3 in summit positions. NOTE: SA1 water table was never within well- range.

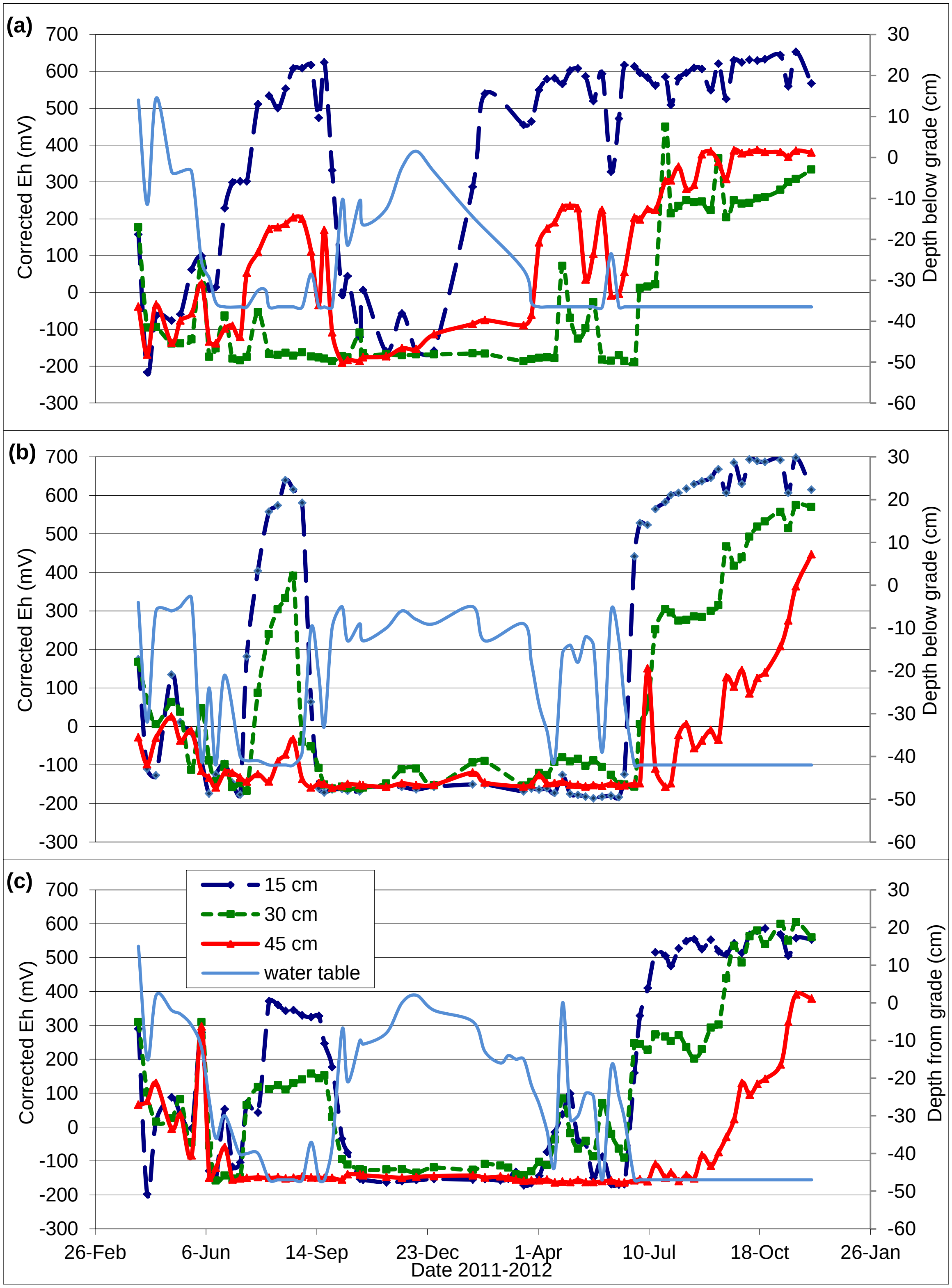

Figure 15- Average redox depth profiles and water table levels for Amherst pools (a) SA1, (b) SA2, (c) SA3 in rim positions.

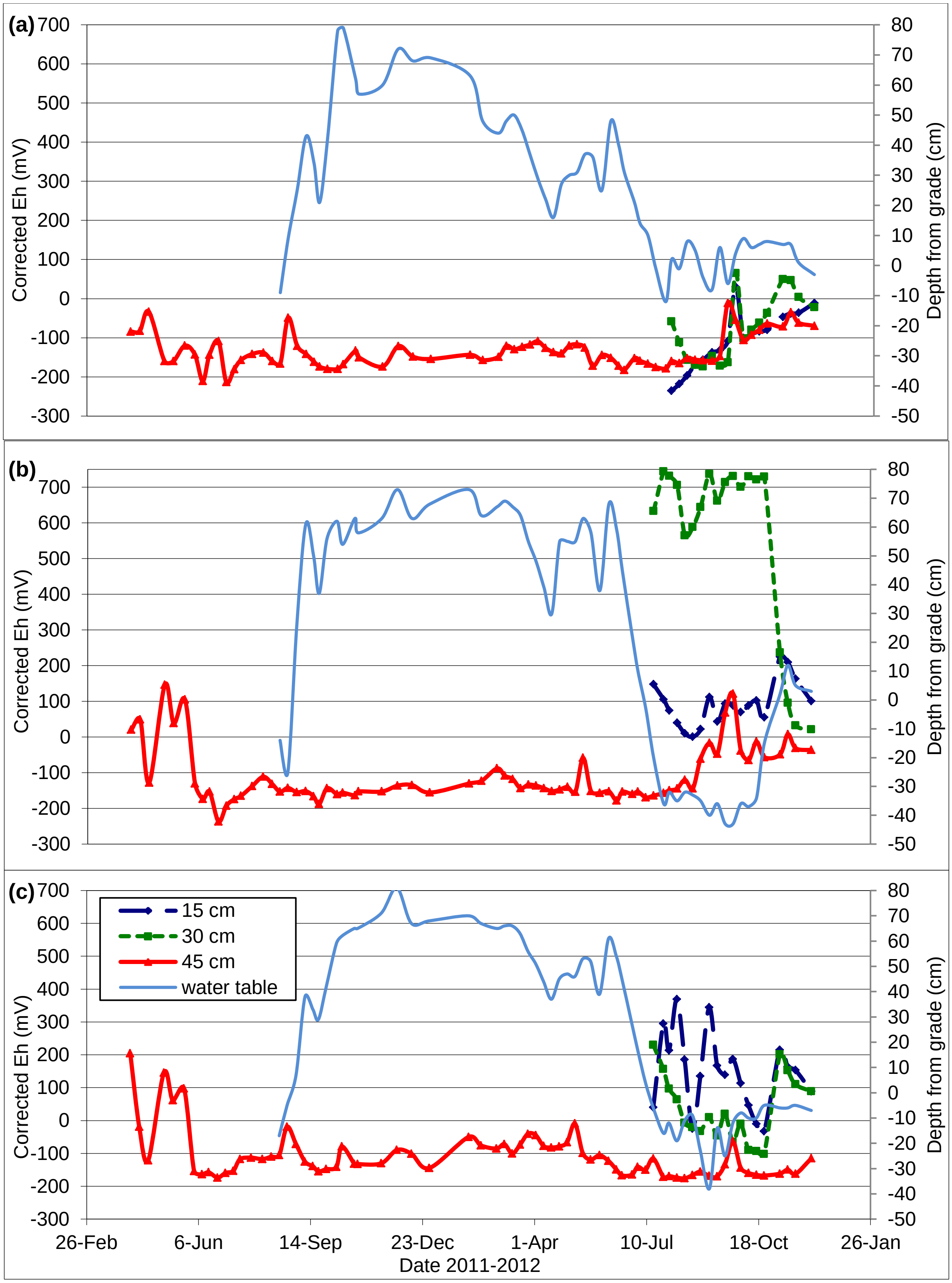

Figure 16- - Average redox depth profiles and water table levels for Amherst pools (a) SA1, (b) SA2, (c) SA3 in basin positions. Note: Change in water table scale and delayed instrumentation of 15 and 30 cm probes.

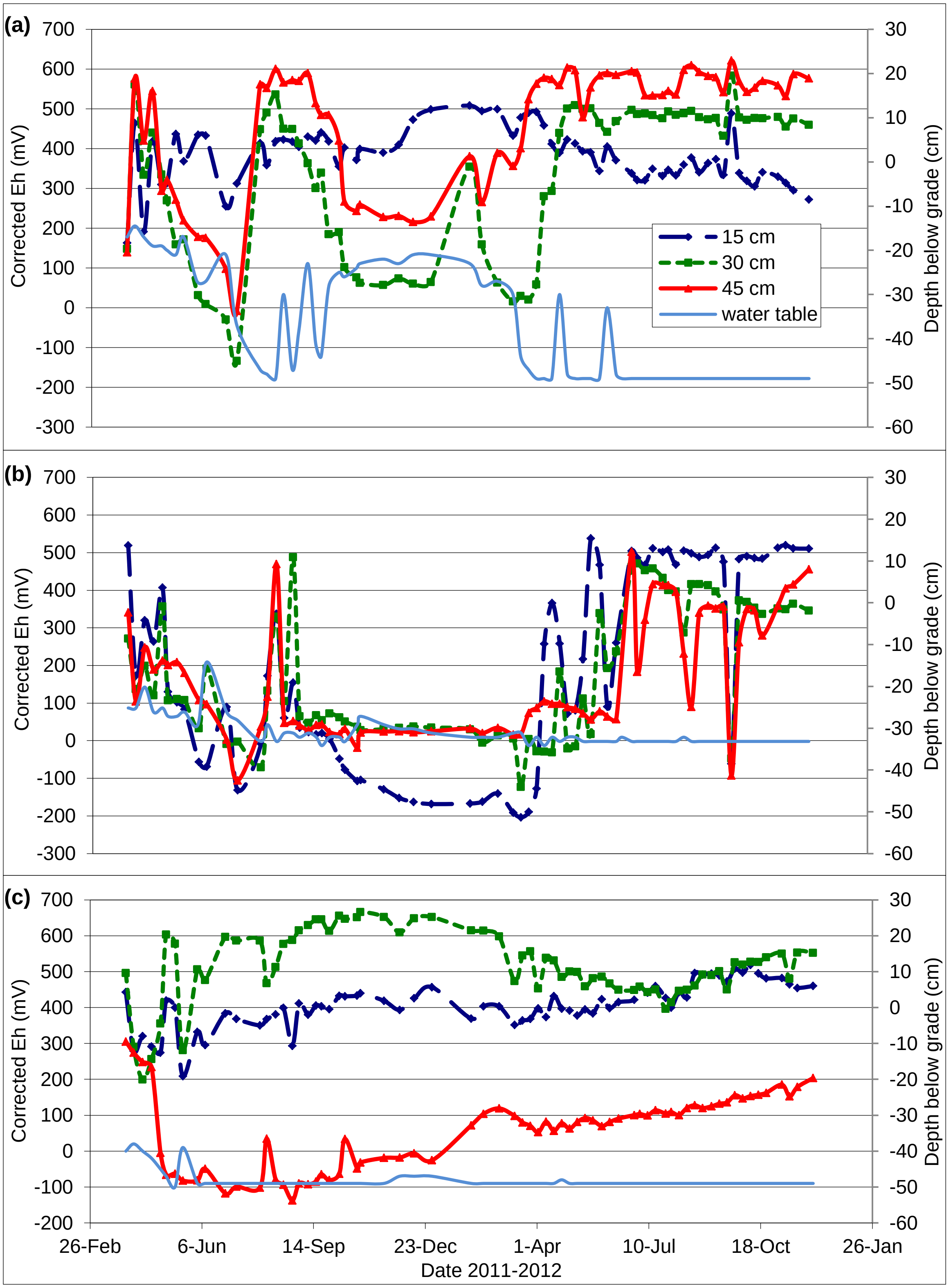

Figure 17- Average redox depth profiles and water table levels for Deerfield pools (a) SD1, (b) SD2, (c) SD3 in summit positions.

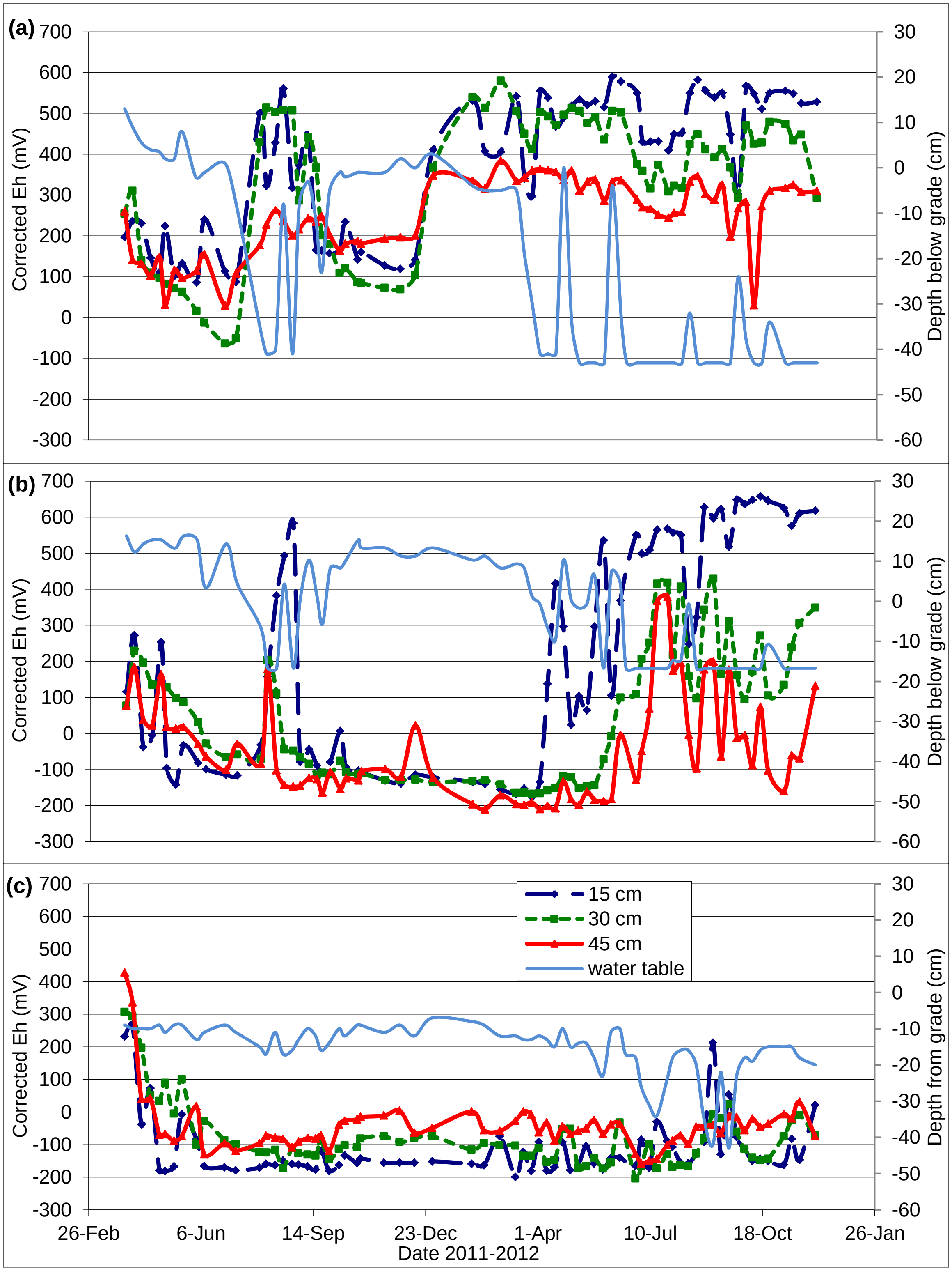

Figure 18- Average redox depth profiles and water table levels for Deerfield pools (a) SD1, (b) SD2, (c) SD3 in rim positions.

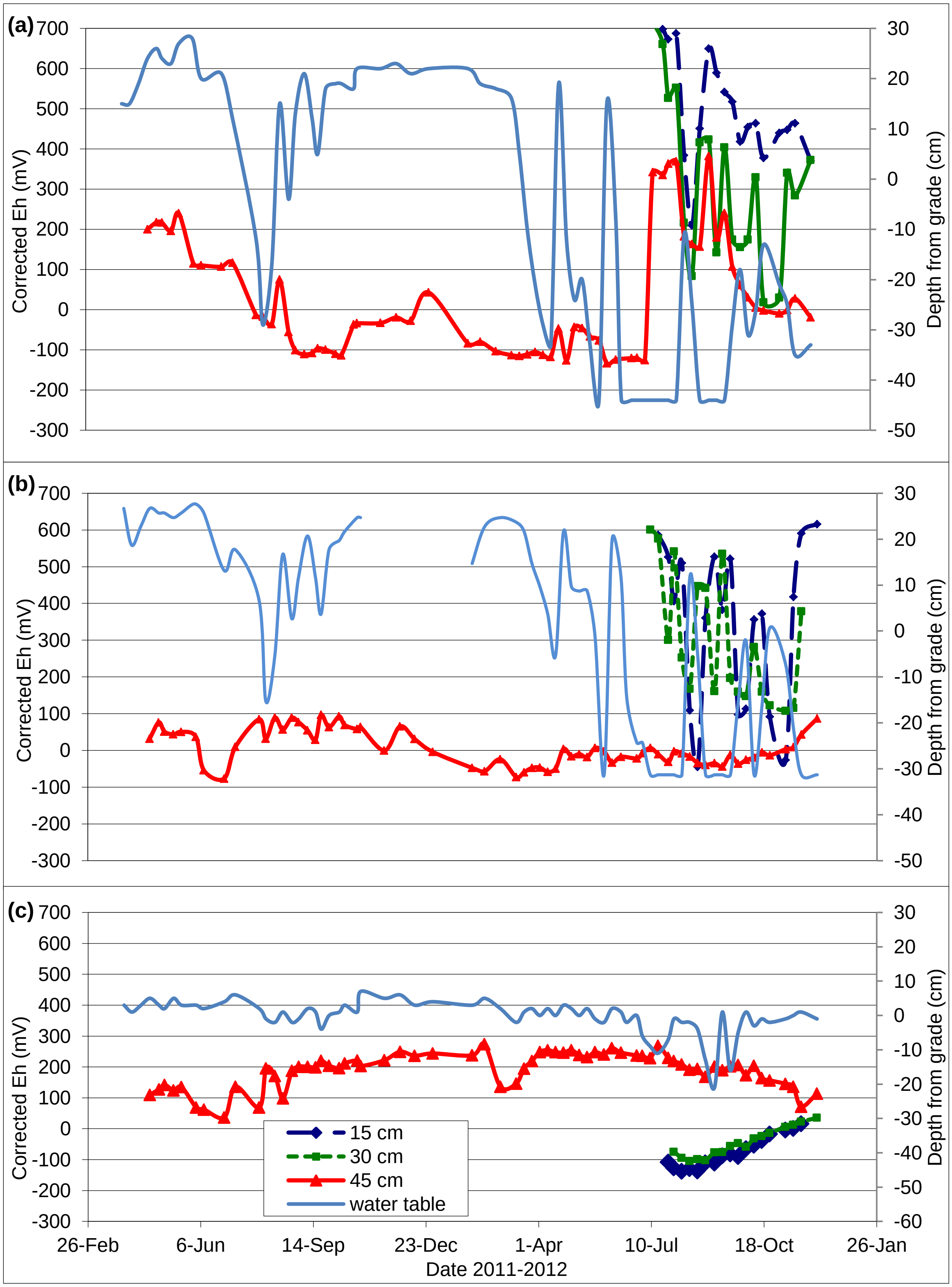

Figure 19- Average redox depth profiles and water table levels for Deerfield pools (a) SD1, (b) SD2, (c) SD3 in basin positions. Note: missing data in SD2 water table due to well damage and delayed instrumentation of 15 and 30 cm probes.

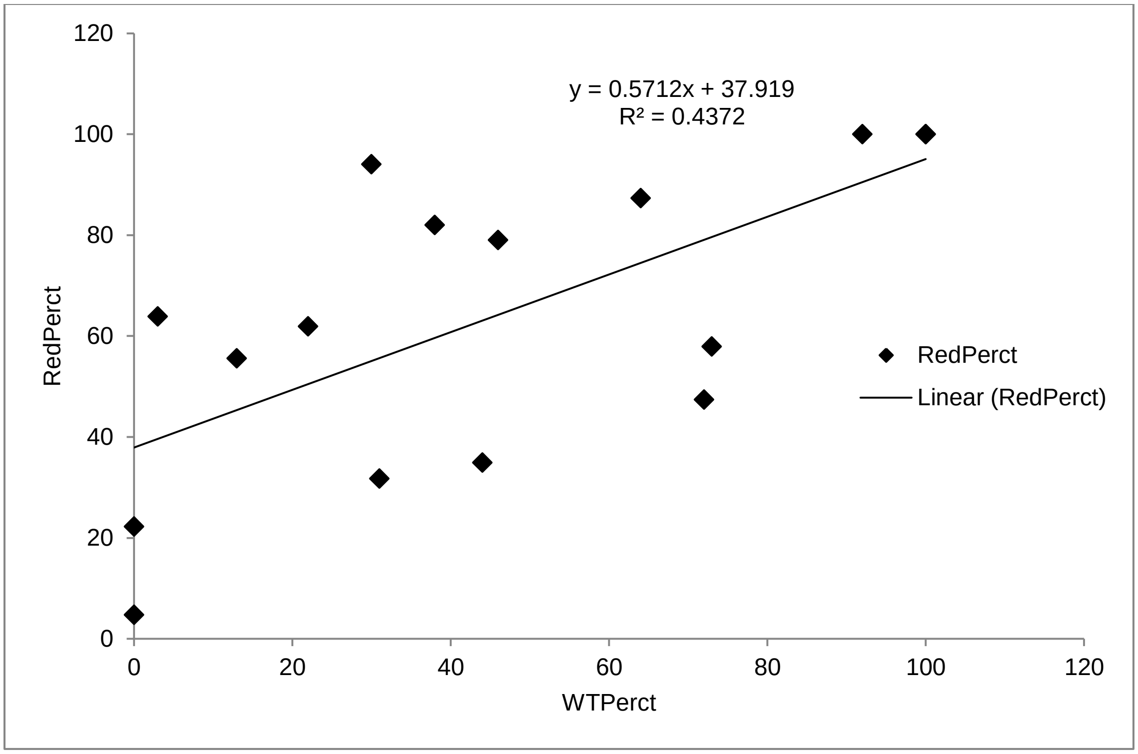

Figure 20- Linear regression of the percentage of the growing season reduced conditions in the upper 30 cm of the soil surface (RedPerct) against percentage of the growing season with water table within 30 cm (WTPerct) ($p<0.001$)

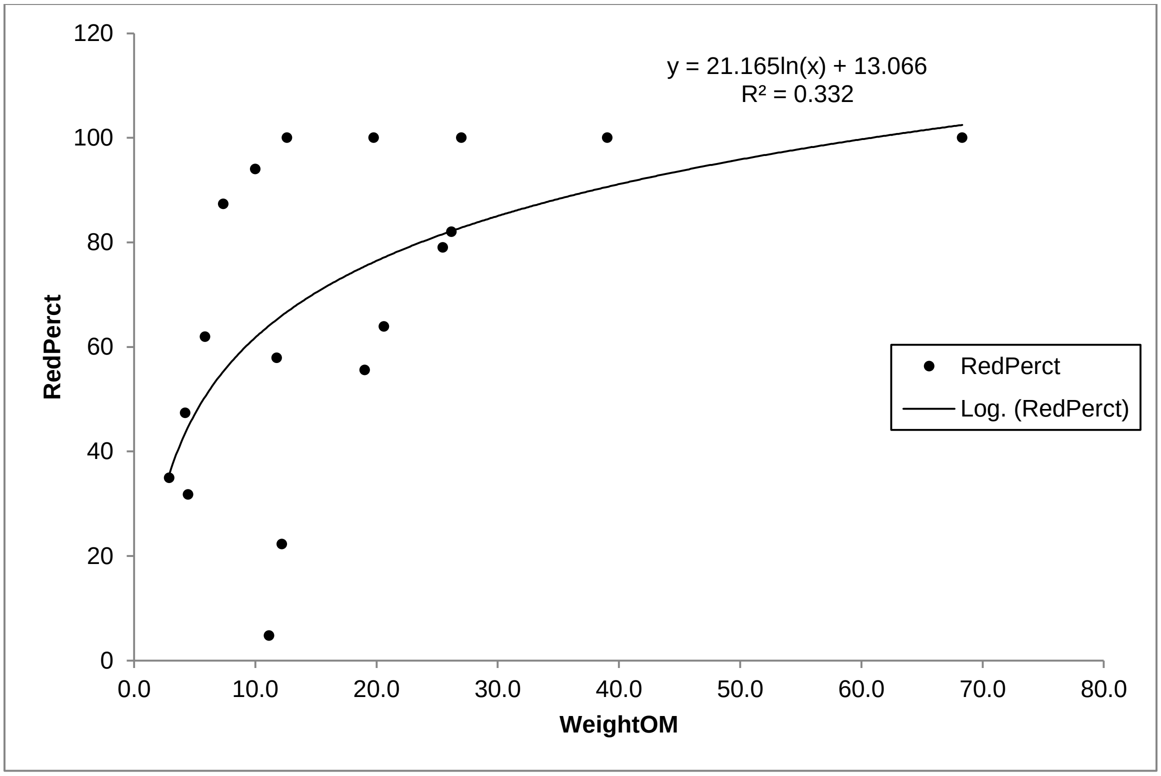

Figure 21- Log regression of the percentage of the growing season with reduced conditions in the upper 30 cm of the soil surface (RedPerct) against weighted soil organic matter in the upper 30 cm (WeightOM) ($p<0.05$).

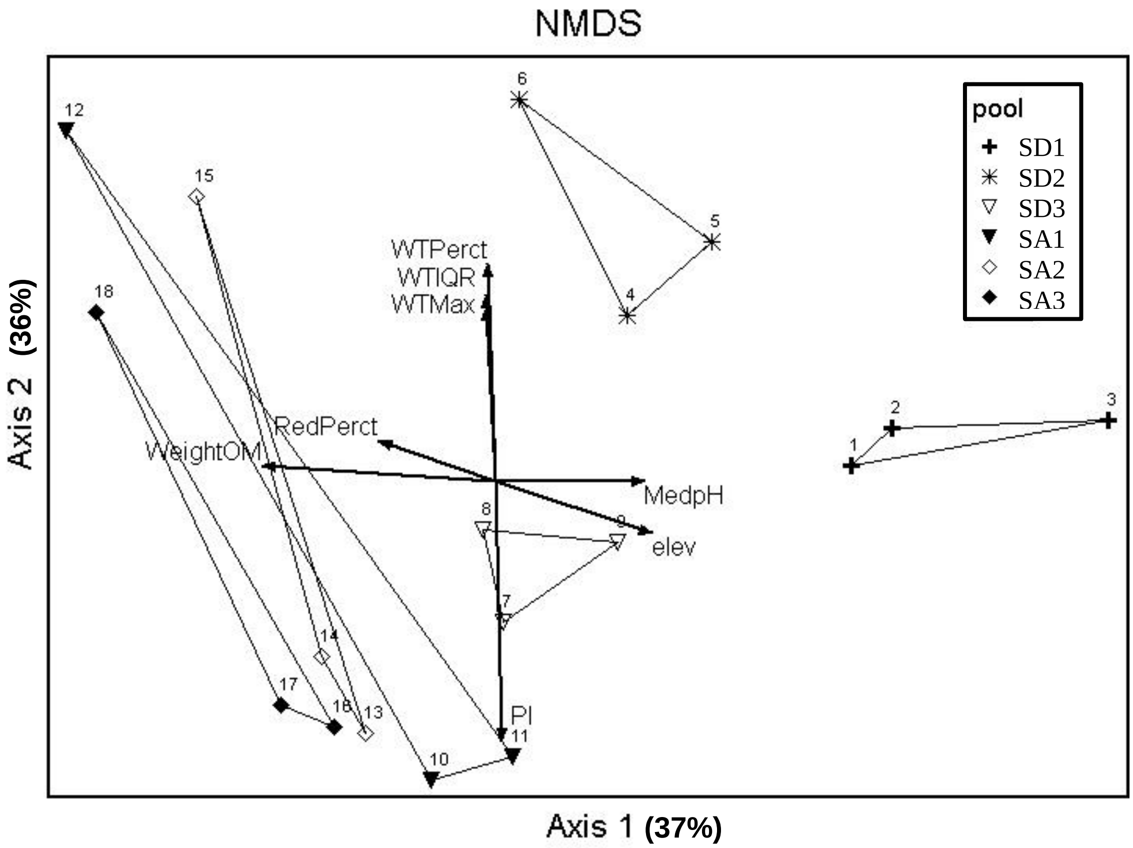

Figure 22- Results of NMDS ordination grouped by pool, with percent variance explained by each axis. Environmental matrix is overlaid, showing associations with each axis. Numbers 1-18 represent plot locations in each pool for summit (1,4,7,10,13,16), rim (2,5,8,11,14,17) and basin (3,6, 9,12,15,18).

Table 1- Indicator categories used to assign indicator status of wetland plants. Indicator codes are also used to assign weighted values in calculating Prevalence Index (PI). Adapted from (USDA, 2013).

Code	Indicator Status	PI	Comment
OBL	Obligate Wetland	1	Almost always is a hydrophyte, rarely in uplands
FACW	Facultative Wetland	2	Usually is a hydrophyte but occasionally found in uplands
FAC	Facultative	3	Commonly occurs as either a hydrophyte or non-hydrophyte
FACU	Facultative Upland	4	Occasionally is a hydrophyte but usually occurs in uplands
UPL	Obligate Upland	5	Rarely is a hydrophyte, almost always in uplands

Table 2- Description of variables used in analysis

Variable	Description
pool	1=SD1,2= SD2, 3=SD3, 4=SA1, 5=SA2, 6=SA3
position	0=summit, 1=rim; 2=basin
elev	Relative elevation to lowest point in pool basin
PI	Prevalence index
WTPerct	% of time during the growing season (g.s.) that water table (wt) was within 30 cm of the soil surface
WTMax	Maximum # of consecutive measurements of wt within 30 cm
WTIQR	WT interquartile range over g.s.
RedPerct	% of time during the g.s. that soil was reduced (<300mV) within 30 cm of the soil surface
RedMax	Maximum # of consecutive measurements of soil reduced within 30 cm
RedIQR	Redox potential interquartile range over g.s.
MedpH	Median pH from aggregated soil profile descriptions
WeightOM	% organic matter (OM) in the upper 30 cm weighted by horizon thickness

Table 3- Summary statistics for environmental variables grouped by position. Significance of ANOVA results between positions are denoted in the summit means.

	Variable	Mean	Stand.Dev.	Minimum	Maximum	Skewness	Kurtosis
Summit							
	elev	1.168 [a,b]	0.2	0.82	1.37	-1.058	1.349
	PI	2.888 [a,b]	0.276	2.57	3.22	0.036	-2.667
	WTPerct	11.5 [a,b]	12.88	0	31	0.691	-1.241
	WTMax	4.167 [a,b]	4.75	0	10	0.617	-2.1
	WTIQR	7.333 [a,b]	8.981	0	23	1.245	0.991
	RedPerct	40.167 [a]	24.203	5	64	-0.468	-1.649
	RedMax	18 [a]	14.029	2	39	0.466	-1.121
	RedIQR	431.667 [a]	269.953	132	750	0.267	-2.202
	MedpH	4.925	0.285	4.64	5.39	0.848	-0.097
	WeightOM	12.25 [a,b]	6.605	4.5	20.6	0.188	-1.727
Rim							
	elev	0.862	0.315	0.44	1.21	-0.208	-2.222
	PI	2.172	0.334	1.75	2.54	-0.662	-1.7
	WTPerct	52.333	22.465	30	92	1.299	1.423
	WTMax	19.667	12.691	10	44	1.891	3.558
	WTIQR	24.333	13.201	7	41	-0.385	-1.326
	RedPerct	79.5	23.124	35	100	-1.845	3.9
	RedMax	43.5	18.865	10	63	-1.264	1.661
	RedIQR	474.167	255.36	77	769	-0.561	-0.599
	MedpH	4.878	0.31	4.51	5.27	0.279	-1.798
	WeightOM	14.1	9.652	2.9	26.2	0.492	-1.703
Basin							
	elev	0.538	0.282	0.28	0.96	0.564	-1.463
	PI	0.967	0.601	0.14	1.66	0.049	-1.268
	WTPerct	86.333	14.292	72	100	-0.008	-3.254
	WTMax	43	12.586	32	64	1.115	0.065
	WTIQR	46	26.766	4	83	-0.323	0.663
	RedPerct	84.167	24.774	47	100	-1.053	-1.366
	RedMax	13.833	6.706	3	19	-1.125	-0.518
	RedIQR	195.167	121.817	73	413	1.374	1.734
	MedpH	4.838	0.495	4	5.41	-0.846	1.085
	WeightOM	28.35	22.985	4.2	68.3	1.13	1.226

[a] indicates significant ($p<0.05$) differences between summit, rim and basin positions in Amherst
[b] indicates significant ($p<0.05$) differences between summit, rim and basin positions in Deerfield

Table 4- Species list of recorded and identified vegetation from six vernal pools in western Massachusetts. Plant ID codes are from USDA PLANTS database (USDA, 2013). Wetland indicator status' were obtained from the National Wetlands Inventory (Lichvar, 2012).

Common Name	Genus	Species	Code	Status
Red Maple	*Acer*	*rubrum*	ACRU	FAC
Shadbush	*Amelanchier*	*canadensis*	AMCA4	FAC
Wild Sarsaparilla	*Aralia*	*nudicaulis*	ARNU2	FACU
Jack In The Pulpit	*Arisaema*	*triphyllum*	ARTR	FAC
Lady Fern	*Athyrium*	*filix-femina*	ATFI	FAC
Japanese Barberry	*Berberis*	*thunbergii*	BETH	FACU
Black Birch	*Betula*	*lenta*	BELE	FACU
Grey Birch	*Betula*	*populifolia*	BEPO	FAC
Beggars Ticks	*Bidens*	*connata*	BICO5	FACW
False Nettle	*Boehmeria*	*cylindrica*	BOCY	OBL
Bluejoint	*Calamagrostis*	*canadensis*	CACA4	OBL
Blue Beech/Ironwood	*Carpinus*	*caroliniana*	CACA18	FAC
Bladder Sedge	*Carex*	*intumescens*	CAIN12	FACW
Brome-Like Sedge	*Carex*	*bromoides*	CABR14	FAC
Fringed Sedge	*Carex*	*crinata*	CACR6	OBL
Shallow Sedge	*Carex*	*lurida*	CALU5	OBL
Bristlebract Sedge	*Carex*	*tribuloidies*	CATR7	FACW
Beaked Sedge	*Carex*	*utriculata*	CAUT	OBL
Buttonbush	*Cephalanthus*	*occidentalis*	CEOC2	OBL
Sweet Wood Reed	*Cinna*	*arundinacea*	CIAR2	FACW
Enchanter's Nightshade	*Circaea*	*lutetiana*	CILUC	FACU
Silky Dogwood	*Cornus*	*amomum*	COAM2	FACW
Redosier Dogwood	*Cornus*	*stolonifera*	COST4	FACW
Intermediate Wood Fern	*Dryopteris*	*intermedia*	DRIN5	FAC
Purpleleaf Willowherb	*Epilobium*	*coloratum*	EPCO	OBL
Eastern Daisy Fleabane	*Erigeron*	*annuus*	ERAN	FACU
Glossy Buckthorn	*Frangula*	*alnus*	FRAL4	FAC
Green Ash	*Fraxinus*	*pennsylvanica*	FRPE	FACW
Wintergreen	*Gaultheria*	*procumbens*	GAPR2	FACU
Melic Manna Grass	*Glyceria*	*melicaria*	GLME2	OBL
Manna Grass	*Glyceria*	*striata*	GLST	OBL
Witch Hazel	*Hamamelis*	*virginiana*	HAVI4	FACU
Winterberry	*Ilex*	*verticillata*	ILVE	FACW
Jewelweed	*Impatiens*	*capensis*	IMCA	FACW
Blueflag	*Iris*	*versicolor*	IRVE2	OBL

Continued on next page

Table 3 continued

Common Name	Genus	Species	Code	Status
Sheep Laurel	*Kalmia*	*angustifolia*	KAAN	FAC
Duckweed	*Lemna*	*minor*	LEMI3	OBL
Spicebush	*Lindera*	*benzoin*	LIBE3	FACW
Princess Pine	*Lycopodium*	*obscurum*	LYOB	FACU
Whorrled Loostrife	*Lysimachia*	*quadrifolia*	LYQU2	FACU
Canada Mayflower	*Maianthemum*	*canadense*	MACA4	FACU
False Solomon's Seal	*Maianthemum*	*racemosum*	MARA7	FACU
Allegheny Monkeyflower	*Mimulus*	*ringens*	MIRI	OBL
Partridge Berry	*Mitchella*	*repens*	MIRE	FACU
Sensitive Fern	*Onoclea*	*sensibilis*	ONSE	FACW
Cinnamon Fern	*Osmunda*	*cinnamomea*	ONCI	FACW
Interrupted Fern	*Osmunda*	*claytoniana*	OSCL2	FAC
Royal Fern	*Osmunda*	*regalis*	OSRE	OBL
Virginia Creeper	*Parthenocissus*	*quinquefolia*	PAQU2	FACU
Reed Canary Grass	*Phalaris*	*arundinacea*	PHAR3	FACW
Purple Chokeberry	*Photinia*	*floribunda*	PFGL9	FACW
White Pine	*Pinus*	*strobus*	PIST	FACU
Arrow Leaved Tear Thumb	*Polygonum*	*sagittatum*	POSA5	OBL
Black Cherry	*Prunus*	*serotina*	PRSE2	FACU
Choke Cherry	*Prunus*	*virginiana*	PRVI	FACU
Pin Oak	*Quercus*	*palustris*	QUPA2	FACW
White Oak	*Quercus*	*alba*	QUAL	FACU
Multiflora Rose	*Rosa*	*multiflora*	ROMU	FACU
Dwarf Red Raspberry	*Rubus*	*pubescens*	RUPU	FACW
Red Raspberry	*Rubus*	*ideaus*	RUID	FACU
Swamp Dewberry	*Rubus*	*hispidus*	RUHI	FACW
Pussy Willow	*Salix*	*discolor*	SADI	FACW
Silky Willow	*Salix*	*sericea*	SASE	OBL
Elderberry	*Sambucus*	*nigra*	SANI4	FACW
Sassafras	*Sassafras*	*albidum*	SAAL5	FACU
Mad Dog Scullcap	*Scutellaria*	*lateriflora*	SCLA2	OBL
Nightshade	*Solanum*	*dulcamara*	SODU	FAC
Canada Goldenrod	*Solidago*	*canadensis*	SOCA6	FACU
American Mountain Ash	*Sorbus*	*americana*	SOAM3	FAC
White Meadow Sweet	*Spiraea*	*alba*	SPAL2	FACW
Skunk Cabbage	*Symplocarpus*	*foetidus*	SYFO	OBL
New York Fern	*Thelypteris*	*noveboracensis*	THNO	FAC
Marsh Fern	*Thelypteris*	*palustris*	THPA	FACW

Continued on next page

Table 3 continued

Common Name	**Genus**	**Species**	**Code**	**Status**
Poison Ivy	*Toxicodendron*	*radicans*	TORA2	FAC
Starflower	*Trientalis*	*borealis*	TRBO2	FAC
Eastern Hemlock	*Tsuga*	*canadensis*	TSCA	FACU
Highbush Blueberry	*Vaccinium*	*corymbosum*	VACO	FACW
Lowbush Blueberry	*Vaccinium*	*angustifolium*	VAAN	FAC
Southern Arrowwood	*Viburnum*	*recognitum*	VIDE	FAC
Withe-Rod/Wild Raisin	*Viburnum*	*cassinoides*	VINUC	FACU
Grape	*Vitis*	*lambrusca*	VILA8	FACU

Table 5- Summary statistics for average plot values (n=290), grouped by position.

	S	E	H	D`	Variance	CV
Amherst						
Summit	4.10	0.73	1.04	0.55	1624.8	59.2%
Rim	3.40	0.67	0.83	0.45	1843.1	77.8%
Basin	1.30	0.19	0.13	0.08	1092.2	84.3%
Deerfield						
Summit	3.70	0.65	0.86	0.47	1252.9	52.2%
Rim	3.80	0.71	0.94	0.51	1317.0	45.7%
Basin	3.00	0.58	0.70	0.39	1444.8	59.6%

S = Richness

E = Evenness

H = Shannon's diversity index

D' = Simpson`s diversity index

Table 6- Pearson correlations with NMDS Ordination Axes (n=18). $r^2 > 0.2$ are bolded and considered indicative of the underlying gradient in the vegetation ordination.

Axis	1		2	
Variable	r	r^2	r	r^2
elev	0.55	**0.302**	-0.315	0.1
PI	0.103	0.01	-0.707	0.5
WTPerct	-0.124	0.015	0.648	**0.419**
WTMax	-0.132	0.017	0.579	**0.336**
WTIQR	-0.139	0.019	0.599	**0.359**
RedPerct	-0.475	**0.226**	0.281	0.079
RedMax	-0.274	0.075	-0.326	0.106
RedIQR	-0.029	0.001	-0.305	0.093
MedpH	0.534	**0.285**	-0.027	0.001
WeightOM	-0.669	**0.448**	0.17	0.029

APPENDIX: SOIL PROFILES

Table 7- Amherst pool 1 summit soil profiles, transects A-D.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	8-0									53.59	0.21	4.39
A	0-25	10YR 3/2	13	7.5 YR 4/6	5	Fine Sandy Loam		granular	firm	8.89	0.80	4.60
Bw	25-76	10YR 5/6				Fine Sandy Loam		single grain	friable	4.27		4.89
C	76-99+	10YR 4/4	76	7.5 YR 5/8	5	Loamy Sand		single grain	v. friable	3.51		4.91
Transect B												
Oa	5-0									36.05	0.28	4.08
A	0-15	10YR 3/2				Fine Sandy Loam		granular	friable	7.35	0.74	4.66
Bw	15-54+	10YR 5/6	51	7.5YR 5/8	10	Loamy Sand		single grain	v. friable	7.01		4.9
Transect C												
Oa	5-0									31.71	0.18	4.02
A	0-10	10YR 3/3				Sandy Loam		granular	friable	6.47	0.81	4.52
Bw	10-76+	10YR 4/6				Loamy Sand		single grain	v. friable	2.60		4.75
Transect D												
A	0-8	10YR 2/1				Sandy Loam				13.97	0.38	4.29
A2	8-28	10YR 3/3				Fine Sandy Loam		granular	friable	5.07	0.75	4.67
Bw	28-53	10YR 5/6				Fine Sandy Loam		massive	v. friable	3.18		4.69
C	53-84+	2.5Y 4/4	53	5YR 4/6	3	Sandy Loam		massive	v. friable	2.88		4.94

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 8- Amherst pool 1 rim soil profiles, transects A-D. Hydric soil indicators F3, F3, A11, and A11, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	15-0									23.19	0.38	4.48
C	0-10	10YR 4/1	0	7.5YR 4/6	5	Fine Sandy Loam		massive	firm	3.87	0.93	4.60
Ab	10-30	10YR 2/2	10	7.5 YR 3/6	10	Fine Sandy Loam		massive	firm	5.16		4.63
2Cg	30-81+	5B 5/1	30	10YR 5/8	40	Clay Loam		massive	v. firm	2.08		5.64
Transect B												
Oa	3-0									30.08	0.23	4.49
Mucky A	0-15	10YR 2/1				Loam		granular	friable	9.27	0.48	4.37
C	15-43	10YR 4/1	15	10YR 5/8	10	Loam		massive	friable	4.44		4.64
Cg	43-61+	10GB 5/1	43	7.5YR 5/8	15	Loam		massive	firm	3.33		4.67
Transect C												
Oa	5-0									26.80	0.26	4.6
Mucky A	0-10	10YR 2/1	0	7.5 YR 5/8 10YR 5/1	10 15	Loam		granular	friable	12.58	0.57	4.51
C	10-46	10YR 4/2	15	10YR 5/8 10YR 5/2	20 15	Loam		massive	friable	5.78		4.63
Cg	46-61+	10GB 5/1	46	10YR 6/8	25	Clay Loam		massive	firm	3.67		4.89
Transect D												
A	0-8	2.5Y 2.5/1				Sandy Loam				7.61	0.53	4.85
A2	8-28	10YR 2/1	0	7.5YR 4/6	10	Fine Sandy Loam		granular	friable	4.65	0.75	4.84
C	28-48	10YR 3/1	28	7.5YR 4/6	15	Sandy Loam		massive	friable	3.55		5.04
Cg	48-69+	5PB 5/1	48	7.5YR 5/6	15	Loam		massive	firm	3.52		5.24

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 9-Amherst pool 1 basin soil profiles- transects A-D. All profiles meet hydric soil indicator A4

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	18-0									23.83	0.42	3.94
Mucky A	0-18	10YR 3/1				Loam		granular	friable	8.65	0.76	4.68
Cg	18-61+	5PB 5/1	58	10YR 4/6	25	Silty Clay Loam		massive	firm	1.72		5.27
Transect B												
Oi	15-0									66.16	0.17	4.7
Mucky A	0-17	10YR 3/1				Loam		granular	friable	8.31	0.59	4.93
Cg	17-59+	10B 4/1				Silty Clay Loam		massive	firm	2.48		5.11
Transect C												
Oa	15-0									23.13	0.39	4.7
A	0-33	2.5Y 3/1				Silt Loam		granular	friable	6.11	0.91	4.9
Cg	33-41	5B 4/1	33	7.5YR 5/8	20	Clay Loam		massive	firm	3.07		5.25
Cg2	41-84+	10B 5/1	41	7.5YR 5/8	45	Silty Clay		massive	firm	3.03		5.2
Transect D												
Mucky A	0-13	2.5Y 2.5/1				Fine Sandy Loam				14.37	0.50	4.88
A2	13-36	10YR 2/1				Loam		granular	friable	5.87	0.70	5.09
Cg	36-74+	5PB 5/1	36	7.5YR 5/8	40	Clay Loam		massive	firm	2.27		5.0

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 10- Amherst pool 2 summit soil profiles, transects A-D

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
O	5-0									54.55	0.16	3.64
Ap	0-10	10YR 3/1	0	2.5Y 5/3 7.5YR 5/8	15 10	Loam		granular	friable	7.44	0.51	4.62
E	10-28	2.5Y 5/3				Loam		massive	friable	2.47		5.09
Bs	28-66	10YR 5/8				Sand		single grain	loose	0.85		5.21
C	66-74	2.5Y 5/1				Sandy Loam		massive	v. friable	0.87		5.43
Cg	74-109+	10Y 5/1	74	7.5YR 4/6 5YR 3/4	20 10	Silt Loam		massive	v. firm	1.87		5.9
Transect B												
Oi	8-0									77.30	0.11	3.97
Ap	0-15	10YR 2/2				Fine Sandy Loam		granular	friable	6.56	0.88	4.95
Bw	15-71	10YR 5/8	15	7.5YR 5/8	20	Loamy Coarse Sand		single grain	loose	0.48		5.49
C	71-97	2.5Y 5/4	71	7.5YR 4/6	5	Loamy Sand		single grain	loose	1.90		5.26
2Cg	97-122+	10Y 4/1	97	5YR 3/4 7.5YR 4/6	5 20	Silt Loam		massive	very firm	1.48		6.24
Transect C												
Oi	5-0									81.82	0.10	3.65
Ap	0-13	10YR 2/1	5	10YR 5/8	5	Fine Sandy Loam		granular	friable	5.85	0.82	5.01
Bw	13-51	2.5Y 5/3	13	7.5Y 5/8	5	Fine Sandy Loam		massive	v. friable	4.23		5.24
C	51-84	2.5Y 5/4	51	10YR 5/8	10	Fine Sandy Loam		massive	v. friable	1.64		5.23
Cg2	84-97+	N 6/_	84	10YR 5/8 5YR 3/3	30 10	Loam		massive	v. firm	1.36		5.44

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

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Table 8 continued- Amherst pool 2 summit soil profiles, transects A-D

Transect D			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	8-0									86.49	0.13	3.78
Ap	0-10	10YR 2/2	0	7.5YR 4/6	3	Fine Sandy Loam		granular	friable	8.85	0.72	4.92
Bw	10-15	10YR 4/6	10	5YR 4/6	15	Fine Sandy Loam		massive	friable	7.07		5.2
E	15-30	10YR 5/1				Fine Sandy Loam		massive	friable	2.78		4.93
Bs	30-71	10YR 5/8				Coarse Sand		single grain	loose	2.21		5.15
C	71-91	2.5Y 5/4				Loamy Coarse Sand		single grain	loose	1.48		5.03
2Cg	91-121+	N 6/_	91	7.5YR 5/8	15	Clay Loam		massive	v. firm	1.63		4.95

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 11-Amherst pool 2 rim soil profiles, transects A-D. Hydric soil indicators A11, A11, not hydric, and A12, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	8-0									84.89	0.10	3.51
A	0-15	10YR 2/2	10	10YR 5/8	5	Loam		granular	friable	6.53	0.49	4.95
Cg1	15-28	10Y 7/1	15	10YR 6/6	20	Loam		massive	friable	1.63		5.43
Cg2	28-61+	10Y 6/1	28	10YR 5/8	30	Loam	2	massive	firm	1.80		6.15
Transect B												
Oi	10-0									74.89	0.11	4.08
Ap	0-18	10YR 2/1				Sandy Loam		granular	friable	7.62	0.86	4.7
BC	18-56	2.5Y 6/1	18	10YR 4/6	10	Fine Sandy Loam		massive	v. friable	3.04		5.10
C	56-74	2.5Y 5/3				Loamy Sand		single grain	loose	1.97		5.28
Cg	74-77+	10B 5/1	74	10YR 4/6	20	Loam		massive	v. firm	1.90		5.97
Transect C												
Oa	8-0									17.30	0.37	3.99
Mucky A	0-13	10YR 2/1	8	10YR 5/2	2	Loam		granular	friable	8.83	0.69	4.63
E	13-23	2.5Y 4/2	13	10YR 4/6	10	Fine Sandy Loam		massive	friable	4.72		5.06
Bs	23-64	10YR 4/6				Sand		single grain	loose	1.63		5.08
C	64-71	2.5Y 5/2	64	10YR 4/6	5	V. Fine Sandy Loam		massive	v. friable	1.16		5.14
2C	71-86+	10Y 5/1	71	7.5YR 4/8	20	Silty Clay Loam		massive	v. firm	2.52		5.26
Transect D												
Oi	13-3									76.08	0.14	3.45
Oe	3-0									69.01	0.14	3.90
Ap	0-25	10YR 2/1				Loam		granular	friable	6.75	1.01	3.97
Cg	25-66+	N 5/_	28	10YR 4/6	20	Loam		massive	firm	1.87		4.72

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 12- Amherst pool 2 basin soil profiles transects A-D. Hydric soil indicators A2, A1, A1, and A1 respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	38-25									86.11	0.10	3.94
Oe	25-23									67.40	0.19	3.46
Oa	23-0	10YR 2/1				Silt Loam		granular	friable	27.82	0.33	4.34
C	0-8	2.5Y 4/1				Silt Loam		massive	friable	3.95		5.04
Cg	8-13	10Y 5/1				Fine Sandy Loam		massive	v. friable	0.70		5.29
Cg2	18-46+	5B 4/1	18	10YR 3/6	15	Silty Clay Loam		massive	v. firm	1.66		5.38
Transect B												
Oi	51-36									81.26	0.12	3.97
Oe	36-25									72.65	0.12	3.98
Oe2	25-0	10YR 2/1						granular	friable	54.56	0.23	4.38
Mucky A	0-18	10YR 3/2	0	10YR 5/6	20	Silt Loam		massive	v. friable	20.68		4.87
Cg	18-33	5BG 5/1	18	10YR 5/6	5	Silt Loam		massive	v. friable	2.01		5.24
Cg2	33-53+	10BG 5/1	33	10YR 6/6	15	Silty Clay		massive	v. firm	1.73		5.21
Transect C												
Oi	79-71									89.04	0.11	3.99
Oe	71-58									72.61	0.13	4.10
Oe2	58-30	10YR 2/1						granular	friable	68.84	0.22	4.22
Oa	30-0	10YR 2/2	28	10YR 5/1	5	Silt Loam		massive	friable	27.24		4.80
Cg	0-30+	10G 5/1	0	10YR 4/6	5	Silt Loam		massive	v friable	2.97		5.13

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

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Table 10 continued- Amherst pool 2 basin soil profiles transects A-D

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi1	41-36									89.76	0.11	3.67
Oi2	36-25									76.50	0.16	3.79
Oe	25-0	10YR 2/1						granular	friable	51.86	0.24	4.08
Mucky A	0-5	10YR 3/3				Silt Loam		granular	friable	10.13		4.99
Cg	5-53	10B 6/1	5	10YR 6/8	10	Fine Sandy Loam		massive	v. friable	0.89		5.03
2Cg	53-74+	5B 5/1	53	10YR 4/6	15	Clay Loam		massive	v. frim	0.99		4.99

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 13-Amherst pool 3 summit soil profiles, transects A-D

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	5-0									88.11	0.12	3.63
A	0-20	10YR 3/2	5	5YR 5/8	10	Sandy Loam		granular	firm	6.51	0.72	4.77
Bw	20-46	2.5Y5/4	20	7.5YR 5/8	5	Loamy Sand		single grain	loose	2.36		5.97
Csm	46-74	10YR 5/4	46	7.5YR 4/6	45	Sand		single grain	loose	1.05		6.21
2C	74-84+	2.5Y 5/1	74	2.5YR 2.5/2 10YR 5/6	10 35	Silt Loam		massive	v. firm	2.85		6.10
Transect B												
Oi	5-0									73.45	0.17	3.85
Ap	0-13	10YR 3/4				Fine Sandy Loam		granular	friable	7.61	0.96	5.14
Bw	13-51	10YR 5/8	28	5YR 4/6	2	Sandy Loam		single grain	loose	4.61		5.35
Csm	51-61+	10YR 5/6	51	5YR 5/8	25	Loamy Sand		massive	firm	4.45		5.47
Transect C												
Oa	8-0									33.19	0.31	4.46
A	0-10	10YR 3/3	3	7.5YR 4/6	10	Fine Sandy Loam		granular	friable	9.30	0.76	5.07
Bw	10-23	10YR 4/6	10	7.5YR 5/8	20	Sandy Loam		massive	friable	5.97		5.26
C	23-38	2.5Y 6/1	23	7.5YR 4/6	15	Sandy Loam		massive	friable	2.02		5.19
Ab	38-53	10YR 3/3	38	7.5YR 4/6	10	Sandy Loam		massive	friable	6.02		5.28
Bw2	53-69	10YR 4/6				Loamy Sand		single grain	loose	4.96		5.34
Csm	69-89+	5YR 4/6				Sand		single grain	loose	4.90		5.27
Transect D												
Oi	8-0									81.17	0.17	3.75
A	0-8	10YR 2/2	0	7.5YR 4/6	2	Sandy Loam		granular	friable	6.06	0.82	5.09
Bw	8-76	2.5Y 5/4	8	7.5YR 5/6	15	Sandy Loam		massive	friable	3.87		5.31
C	76-84+	2.5Y 5/3	76	10YR 5/8	10	Sand		single grain	loose	1.93		5.34

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 14-Amherst pool 3 rim soil profiles, transects A-D. Hydric soil indicators for B-C F2, A11. A and D not hydric.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
O	8-0									78.60	0.15	3.79
A	0-25	10YR 3/1	8	7.5YR 4/6	2	Loam		granular	friable	8.01	0.55	4.92
C	25-48	2.5YR 6/1	25	10YR 5/8	25	Loam		massive	friable	2.31		5.15
2Cg	48-66+	10BG 5/1	48	7.5YR 5/8	30	Silty Clay Loam		massive	v. firm	2.84		5.53
Transect B												
Oi	8-0									76.43	0.16	3.82
Mucky A	0-8	10YR 2/2				Loam		granular	friable	20.55	0.44	4.63
Bg	8-28	N 4/_	18	10YR 4/6	2	Sandy Loam		massive	friable	4.44		4.72
Ab	28-66	10YR 3/3				Fine Sandy Loam		massive	friable	5.82		4.64
BC	66-76	2.5Y 5/3				Loamy Sand		single grain	loose	3.09		4.89
C	76-81+	2.5Y 6/1	76	7.5YR 5/8		Sandy Loam		massive	friable	1.07		5.11
Transect C												
Oe	8-0									59.42	0.19	4.07
Mucky A	0-10	10YR 2/1				Sandy Loam		granular	friable	9.11	0.80	4.75
Bg	10-30	N 4/_				Loamy Sand		single grain	loose	5.82		5.03
Bg2	30-48	N 4/_				Coarse Sand		single grain	loose	1.55		4.96
C	48-79	2.5Y 5/1				Sand		single grain	loose	0.87		5.32
2Cg	79-97+	5B 5/1	79	10YR 5/8	15	Clay Loam		massive	firm	1.29		5.37
Transect D												
Oi	10-0									75.80	0.14	3.84
A	0-41	10YR 2/2				Loamy Sand		granular	friable	5.37	0.82	4.91
BC	41-58	2.5Y 5/4	41	10YR 5/6	5	Sand		single grain	loose	1.90		5.3
Cg	58-91	10Y 6/1	58	10YR 5/6	20	Loamy Sand		single grain	loose	1.35		5.49
2Cg	91-99+	N 6/_	91	7.5YR 5/8	35	Silt Loam		massive	firm	0.93		5.98

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 15- Amherst pool 3 basin soil profiles, transects A-D. Hydric soil indictors A1, F2, A12, and F2, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	43-36									85.90	0.13	3.73
Oa	36-0	10YR 2/1				Silt Loam		granular	friable	24.42	0.35	4.83
Cg	0-30	5B 5/1	0	10YR 5/8	2	Loam	1	massive	friable	1.97		5.25
Cg2	30-58+	10BG 5/1	30	10YR 4/6	25	Silty Clay		massive	firm	2.06		5.69
Transect B												
Oi	13-0									86.49	0.12	3.69
Mucky A	0-15	10YR 2/1				Loam		granular	friable	16.63	0.62	4.83
Cg	15-25	10BG 5/1	15	10YR 5/8	2	Silt Loam		massive	firm	2.41		5.19
Cg2	25-76+	10BG 4/1	25	10YR 5/6	35	Silty Clay		massive	v.firm	2.69		5.54
Transect C												
Oi	10-5									79.61	0.14	3.4
Oe	5-0									48.12	0.30	3.76
Mucky A	0-25	10YR 2/1				Fine Sandy Loam		granular	friable	11.65	0.55	4.62
Bg	25-38	10Y 4/1				Loam		massive	friable	1.71		5.14
Cg	38-56	5B 5/1				Sandy Loam		massive	friable	0.79		5.22
Cg2	56-61+	5B 5/1	56	10YR 5/6	1	Fine Sandy Loam	2	massive	v.firm	1.51		5.49
Transect D												
Oi	13-0									81.11	0.13	3.77
Mucky A	0-20	10YR 2/1				Fine Sandy Loam		granular	friable	12.82	0.54	4.9
C	20-25	2.5Y 4/1				Loamy Sand		single grain	loose	2.01		5.33
2Cg	25-64+	5B 4/1	28	7.5YR 4/6	15	Silty Clay Loam	2	massive	firm	1.37		5.44

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 16-Deerfield pool 1 summit soil profiles, transects A-D

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	2-0									12.06	0.71	4.09
Ap	0-15	10YR 2/2				Loamy Sand		granular	friable	2.74	1.24	4.48
Bw	15-40	2.5Y 5/4	33	7.5Y 5/8	10	Sand	2	single grain	loose	0.51	0.38	5.11
C	40-86	2.5Y 6/3	40	7.5Y 5/8	10	Coarse Sand	5	single grain	loose	0.28	1.08	5.21
2Ab	86-100	10YR 2/1				Silt		massive	friable	7.07		5.28
2C	100-104+	10YR 5/1	100	10YR 5/8	30	Silt Loam		massive	firm	2.98		5.32
Transect B												
A	0-9	10YR 3/2				Silt Loam		granular	friable	8.11		4.46
A/B	9-65	10YR 3/3	37	5YR 3/4	15	Loamy Sand	2	single grain	loose	2.74		4.70
C	65-85+	2.5Y 6/4	65	7.5Y 5/8	10	Sand		single grain	loose	1.05		5.05
Transect C												
Ap	0-9	10YR 3/4	0	7.5 YR 5/8	10	Sandy Loam	10	granular	friable	6.97		5.01
Bw	9-62	2.5Y 5/4	48	7.5 YR 4.6	10	Silt Loam		massive	firm	3.98		5.02
C	62-80+	5Y 5/3	62	7.5 YR 4/6	30	Silt Loam		massive	firm	3.12		5.17
Transect D												
A	0-20	10YR 3/3				Sandy Loam	15	granular	friable	5.28	0.84	4.77
C	20-50+	7.5YR 2.5/3	20	5YR 3/4	5	Sandy Loam	15	massive	friable	4.28	0.86	5.08

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 17-Deerfield pool 1 rim soil profiles transects A-D; C and D hydric soil indicators F8 and S5, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
A	0-8	10YR 2/2				Sandy Loam	1	granular	friable	5.60	1.17	5.07
A/B	8-16	2.5Y 4/2				Loamy Sand	1	single grain	loose	1.34	1.38	5.29
Bw	16-40	2.5Y4/6	39	2.5YR 3/6	10	Coarse Sand		single grain	loose	0.63	1.19	5.53
C	40-45	5Y 5/1				Sand		single grain	loose	0.53		5.61
2Ab	45-59	10YR 2/1				Silt		massive	firm	6.39		5.34
2Cg	59-67	5GY 4/1				Silt		massive	firm	3.21		5.46
2C	67-78+	10R 5/4	67	2.5Y 5/1 7.5YR 6/8	10 20	Silt		massive	firm	2.75		5.51
Transect B												
A	0-10	10YR 3/2				Loamy Sand		granular	friable	6.01	0.74	5.03
BC	10-29	2.5Y 4/2				Loamy Sand		single grain	v. friable	1.15	1.31	5.17
C	29-45	2.5Y 5/3	40	10YR 4/6	15	Sand		single grain	loose	0.78	1.22	5.47
2Ab	45-55	10YR 2/1				Silt		massive	friable	7.54		5.16
2C	55-79+	10YR 4/1	55	10YR 3/6	20	Silt Loam		massive	firm	2.75		5.37
Transect C												
A	0-10	5YR 3/1				Sandy Loam		granular	friable	6.69	0.91	4.98
A/C	10-21	7.5YR 3/2	10	5YR3/4	15	Loamy Sand		single grain	loose	1.71	1.02	5.23
C	21-29	2.5Y 5/3	21	7.5YR 4/6	20	Coarse Sand		single grain	loose	0.50		5.42
2C	29-40	5Y 4/2	29	10 YR 3/6	40	Loamy Fine Sand		massive	firm	1.42		5.47
2Ab	40-43	10YR 3/1				Silt		massive	friable	4.34		5.34
3C	43-70+	10YR 4/2	43	10YR 4/6	15	Silt		massive	firm	2.63		5.45

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

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Table 15 continued- Deerfield pool 1 rim soil profiles transects A-D

Transect D			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	2-0							granular	friable	23.98	0.36	4.68
A	0-8	10YR 2/2				Loamy Sand		granular	friable	5.16	0.89	4.97
A/C	8-28	10YR 3/2				Loamy Coarse Sand		single grain	v. friable	1.19	1.21	5.37
C	28-36	10YR 4/4	28	7.5YR 4/6	10	Loamy Sand		single grain	loose	2.54	1.55	5.31
2Ab	36-55	10YR 2/1				Silt Loam		massive	friable	8.97	0.64	5.32
2Bg	55-68+	10Y 3/1	55	10YR 2/1	10	Silt		massive	firm	3.02		5.36

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 18-Deerfield pool 1 basin soil profiles, transects A-D. Hydric soil indicators S5, F1, F6, and not hydric, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
A	0-10	10YR 2/2				Loamy Sand		granular	friable	5.84	0.53	4.48
A/B	10-25	5Y 3/2	12	10YR 4/6	15	Loamy Sand		single grain	loose	1.84	1.37	5.31
C	25-34	2.5Y 4/3				Sand		single grain	loose	0.38	1.37	5.58
2Ab	34-52	10YR 2/1				Silt		granular	friable	11.61	0.72	5.27
2A/C	52-64	10YR 3/1	55	10YR 4/6	10	Silt		granular	friable	2.85		5.00
2C	64-80+	2.5YR 4/4 5Y 4/2	64	10YR 4/6	10	Silt		granular	friable	2.08		5.52
Transect B												
Mucky A	0-7	2.5Y 2.5/1				Loamy Sand		granular	friable	17.52	0.49	4.57
A	7-22	10YR 3/2				Loamy Sand		granular	friable	3.26	0.96	5.08
C	22-35	2.5Y 3/3	22	10YR 4/6	30	Coarse Sand		single grain	loose	1.20	1.37	5.33
2Ab	35-55	10YR 2/1				Silt Loam		massive	friable	8.83	0.63	5.10
2A/C	55-70	5Y 3/1				Silt		massive	firm	3.30		5.17
2C	70-90+	2.5Y 4/1	70	10YR 5/8	20	Silt Loam		massive	firm	2.00		5.27
Transect C												
Mucky A	0-4	2.5Y 2.5/1				Sandy Loam		granular	friable	6.93	0.96	4.93
A	4-12	10YR 2/2				Sandy Loam		granular	friable	4.37	1.01	5.15
A/C	12-24	10YR 3/1	12	5YR 4/6	20	Sandy Loam		massive	friable	3.46	1.06	5.29
C	24-35	10YR 3/2				Sandy Loam		massive	v. friable	3.53	1.03	5.21
C2	35-42	2.5Y 4/2				Sand		single grain	loose	0.56	1.53	5.53
2Ab	42-49	10YR 2/1	42	2.5YR 3/6	30	Silt Loam		massive	friable	10.59	0.70	5.34
2Bg	49-64+	10Y 2.5/1				Silt		massive	firm	1.95		5.31

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Continued on next page

Table 16 continued-Deerfield Pool 1 Basin profiles, transects A-D

Transect D			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	2-0							granular	friable	23.98	0.36	4.68
A	0-8	10YR 2/2				Loamy Sand		granular	friable	5.16	0.89	4.97
A/C	8-28	10YR 3/2				Loamy Coarse Sand		single grain	v. friable	1.19	1.21	5.37
C	28-36	10YR 4/4	28	7.5YR 4/6	10	Loamy Sand		single grain	loose	2.54	1.55	5.31
2Ab	36-55	10YR 2/1				Silt Loam		massive	friable	8.97	0.64	5.32
2Bg	55-68+	10Y 3/1	55	10YR 2/1	10	Silt		massive	firm	3.02		5.36

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 19-Deerfield pool 2 summit soil profiles, transects A-D.

Transect A			Redox									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Ap	0-28	10YR 3/2	8	10YR 3/8	2	Silt Loam	1	granular	friable	4.72	0.60	5.26
Bw	28-61	10YR 5/3	28	7.5YR 5/8	15	Silt		massive	friable	3.61		5.73
C	61-81+	2.5Y 4/2	61	7.5YR 5/8	15	Silt		massive	friable	2.99		5.85
Transect B												
A	0-25	10YR 3/3	0	7.5YR 4/6	5	Silt Loam		granular	friable	9.34	0.60	4.78
Bw	25-74	2.5Y 5/3	25	10YR 5/8	20	Silt Loam		massive	friable	2.25		5.37
C	74-99+	2.5Y 5/1	74	10YR 5/8	10	V. Fine Sandy Loam		massive	friable	1.36		5.54
Transect C												
Ap	0-30	10YR 3/3	13	2.5Y 5/4 7.5YR 4/6	10 20	Silt Loam	10	massive	firm	4.19	1.04	5.42
Bw	30-48	2.5Y 4/4	30			Silt Loam		massive	friable	4.68		5.80
Cg	48-86+	10Y 5/1	48			Silt Loam		massive	friable	2.45		5.92
Transect D												
Ap	0-23	10YR 3/3	8	7.5YR 4/6	3	Silt Loam		granular	friable	7.53	0.66	5.80
Bw	23-56	2.5Y 4/4	23	10YR 5/8	20	Silt Loam		massive	friable	3.07		5.90
C	56-102+	2.5Y 5/3	56	10YR 5/8	20	Sandy Loam		single grain	v. friable	1.36		5.91

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 20-Deerfield pool 2 rim soil profiles, transects A-D. Hydric soil indicators only for B and D, both A11.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Ap	0-36	10YR 3/1				Silt Loam		granular	friable	8.80	0.88	4.9
A2	36-51	10YR 3/2	36	10YR 5/2 10YR 4/6	15 5	Silt Loam		granular	friable	6.52		5.50
C	51-94+	2.5Y 5/2	51	10YR 5/8	20	Silt Loam		massive	friable	5.08		5.69
Transect B												
A	0-15	10YR 2/2				Silt Loam		granular	friable	19.37	0.43	4.53
A/C	15-33	2.5Y 4/1	15	2.5Y 6/2 7.5YR 4/6	2 5	Silt Loam		massive	friable	1.68		4.83
C	33-64	2.5Y 5/3	33	2.5Y 6/8	25	Silt		massive	friable	1.92		5.34
Cg	64-81+	N 6/_	64	10YR 5/8	30	Silt		massive	friable	1.57		5.45
Transect C												
Ap	0-18	10YR 3/3	0	10YR 3/6	3	Silt Loam	10	granular	friable	5.69	0.85	4.65
C	18-25	5YR 3/3 2.5Y 5/6	23	5YR 4/6	5	Fine Sandy Loam	30	massive	friable	2.81		5.45
2Ab	25-58	10YR 2/1	25	10YR 5/1 5YR 4/6	10 15	Silt Loam		massive	friable	2.01	1.01	5.59
Cg	58-74+	10Y 5/1	58	10YR 5/8	10	Silt Loam		massive	friable	3.19		5.78
Transect D												
A	0-18	10YR 3/2	8	7.5YR 4/6 2.5Y 5/2	15 20	Silt Loam		granular	friable	7.27	0.82	5.47
BC	18-43	2.5Y 5/2	18	7.5YR 4/6	15	Silt Loam		massive	friable	3.43		5.85
C	43-94+	2.5Y 5/1	43	7.5YR 4/6	20	Silt Loam		massive	friable	1.57		6.05

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 21-Deerfield pool 2 basin soil profiles, transects A-D. Hydric soil indicators, A12 F6, F3, and F6, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Mucky A	0-10	10YR 2/1				Silt Loam		granular	friable	11.73	0.63	5.32
A2	10-38	10YR 3/2	25	10YR 5/1 10YR 5/6	5 2	Silt Loam		granular	friable	7.18	0.92	5.31
Bg	38-51	10Y 4/1	38	10YR 4/6	2	Silt Loam		massive	friable	2.83		5.59
Cg	51-84	10Y 5/1	51	10YR 4/6	2	Silt		massive	friable	1.43		5.79
Cg2	84-99+	N 3/_	84	10YR 4/6	5	Silt		massive	firm	1.08		5.89
Transect B												
Mucky A	0-13	2.5Y 2.5/1				Silt Loam		granular	friable	17.67	0.36	4.56
A2	13-30	10YR 2/2	13	10YR 3/6	3	Silt Loam		granular	friable	8.21	0.77	4.71
Bg	30-63	10Y 3/1	30	7.5YR 5/8	2	Silt Loam		massive	friable	4.68		5.09
Cg	63-91+	10Y 6/1	63	10YR 6/8	40	Silt		massive	friable	2.75		5.29
Transect C												
Oe	8-0									31.60	0.16	4.37
C	0-13	2.5Y 4/2	0	10YR 3/6	10	Silt Loam	2	massive	friable	5.39	0.95	5.00
2Ab	13-64	10YR 3/1	13	10YR 3/6	10	Silt Loam	1	granular	friable	9.09	0.58	5.03
2Cg	64-91+	5GY 5/1	64	2.5Y 6/8	5	Silt		massive	friable	1.62		5.39
Transect D												
Oa	8-0									25.00	0.38	4.70
Mucky A	0-15	10YR 2/2				Silt Loam		granular	friable	9.56	0.60	4.86
C	15-23	2.5Y 5/2	15	10YR 4/6	2	Silt Loam		massive	friable	5.29		5.16
2Ab	23-46	10YR 3/1	23	10YR 4/6	15	Silt Loam		massive	friable	5.70		5.16
2Cg	46-97	10Y 5/1	46	10YR 6/8	25	Silt		massive	friable	2.07		5.54

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 22-Deerfield pool 3 summit soil profiles, transects A-D

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oi	5-0									73.58	0.15	2.85
Ap	0-15	10YR 3/1				Silt Loam		granular	friable	16.28	0.50	4.68
Bw	15-25	10YR 4/6	15	7.5YR 4/6	3	Silt Loam		massive	friable	7.59		4.71
C	25-61	10YR 5/3	25	10YR 5/8	30	Silt Loam		massive	friable	3.48		4.84
C2	61-86+	2.5YR 5/1	61	7.5YR 4/6	10	Silt Loam		massive	friable	2.43		5.45
Transect B												
A	0-5	10YR 2/1				Sandy Loam		granular	friable	14.07	0.19	4.05
Bw	5-25	10YR 3/4	18	5YR 4/6	5	Sand		single grain	very friable	1.64	1.51	5.15
C	25-38	10YR 3/3	25	5YR 4/6	5	Loamy Coarse Sand		single grain	loose	2.78		5.43
2Cg	38-81+	10Y 5/1	38	10YR 5/6	15	Silt Loam		massive	firm	1.56		5.78
Transect C												
A	0-18	10YR 2/2				Sandy Loam		granular	friable	13.47	0.85	4.53
Bw	18-60	10YR 4/4				Silt Loam		massive	friable	4.25		4.7
C	60-84+	10YR 5/4	74	10YR 5/8	15	Silt Loam		massive	friable	2.08		5.23
Transect D												
A	0-23	5YR 3/3				Silt Loam		granular	friable	9.38	0.58	4.6
BC	23-56	5YR 4/4	23	5YR 5/2 5YR 5/8	5 5	Silt Loam		massive	friable	3.56		5.06
C	56-84	5YR 4/3	56	5YR 5/2 5YR 5/8	10 10	Silt Loam		massive	friable	2.65		5.28
2C	84-91+	2.5YR 6/2	84	7.5YR 5/8	20	Silt Loam		massive	firm	2.25		5.42

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 23-Deerfield pool 3 rim soil profiles, transects A-D. Hydric Soil Indicators F3, A11, F3 and not hydric, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oa	13-0									23.10	0.31	5.28
A	0-15	10YR 3/1				Silt		granular	friable	5.08	0.89	5.27
C	15-89+	10YR 5/2	15	7.5YR 4/6	25	Silt		massive	firm	2.92		5.49
Transect B												
A	0-30	10YR 2/2				Coarse Sandy Loam		granular	friable	6.86	0.69	5.28
C	30-46	2.5Y 4/1	30	2.5Y 6/1	15	Loamy Coarse Sand		single grain	v. friable	2.23		5.52
2Cg	46-94+	10Y 4/1				Silt Loam		massive	firm	2.11		5.58
Transect C												
Oa	10-0									32.32	0.38	4.39
Mucky A	0-15	10YR 3/2	5	7.5YR 4/6 10YR 4/2	5 15	Silt Loam		granular	friable	10.87	0.80	4.96
C	15-76+	10YR 5/2	15	7.5YR 5/8	15	Silt		massive	friable	2.61		5.63
Transect D												
Oa	8-0									30.52	0.53	4.96
Mucky A	0-13	10YR 2/1				Silt		granular	friable	11.18	0.66	4.9
C	13-38	10YR 4/2				Silt		massive	friable	4.21		5.42
2C	38-66	5YR 4/2	38	7.5YR 4/6	2	Silt Loam		massive	friable	3.71		5.52
3Cg	66-91+	10Y 5/1	66	7.5YR 4/6	5	Silt Loam		massive	firm	2.95		5.66

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

Table 24-Deerfield pool 3 basin profiles, transects A-D. Hydric Soil Indicators A2, A2, A12, and A2, respectively.

Transect A			**Redox**									
Horizon	**cm**	**Color**	**Depth**	**Color**	**%**	**Texture**	**CF***	**Structure**	**Consistence**	**LOI***	**BD***	**pH**
Oe	28-0									45.98	0.35	5.28
A	0-13	10YR 2/1				Silt Loam		granular	friable	9.00	0.91	5.57
Cg	13-51+	10Y 4/1	5	10YR 3/6	10	Silt		massive	firm	1.84		5.49
Transect B												
Oa	33-0									21.10	0.43	5.45
Mucky A	0-10	10YR 3/1				Silt		granular	friable	10.38		5.52
Cg	10-76+	10Y 5/1				Silt		massive	firm	2.39		5.59
Transect C												
Mucky A	0-36	2.5YR 2.5/1				Sandy Loam				16.25	0.52	5.43
Mucky A2	36-48	10YR 2/1				Silt Loam		massive	friable	18.30		5.59
Cg	48-76+	10B 5/1	48	10YR 5/8	5	Silt Loam		massive	firm	3.81		5.63
Transect D												
Oa	23-0									33.45	0.35	5.23
A	0-20	10YR 4/1				Silt Loam		massive	firm	6.64		5.41
C	20-51	5YR 4/3	20	5YR 5/1 5YR 5/8	20 10	Silt Loam		massive	friable	3.07		5.51
2C	51-79+	10Y 4/1	51	10YR 5/6	2	Silt Loam		massive	firm	2.26		5.6

*CF= % Coarse fragments ; LOI= % organic matter by loss on ignition; BD= bulk density

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