# ASSESSING COASTAL PLAIN RISK INDICES FOR SUBSURFACE PHOSPHORUS LOSS

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Abbreviations: *B*, ditch depth; $D_i$, is the depth of soil layer *i*; DE-PSI, Delaware Phosphorus Site Index; $K_i$, saturated hydraulic conductivity of layer *i*; $K_{\text{sat}}$, saturated hydraulic conductivity; *L*, estimated distance between ditches; MD-PMT, University of Maryland Phosphorus Management Tool version 1; MD-PMT2, Maryland Phosphorous Management Tool version 2; NC-PLAT, North Carolina Phosphorus Loss Assessment Tool; SSURGO, USDA-NRCS Soil Survey Geographic Database; $T_{12}$, transmissivity of the top 12 inches (30 cm); $T_{30}$, transmissivity of the soil profile at a depth of 12 to 30 inches (30 to 76 cm); $T_P$, transmissivity of the entire profile (usually to a depth of 183 cm); $T_{P\text{-}1}$, transmissivity of the soil profile excluding the top 12 inches (30 cm) of soil ; UD, University of Delaware; UMD, University of Maryland College Park; UMES, University of Maryland Eastern Shore; USGS, United States Geological Survey; VA-PI, Virginia Phosphorus Index; WEP, water extractable phosphorus; $WEP_{WT}$, water extractable phosphorus near the water table.

## SITE CHARACTERISTICS, SOIL SAMPLING, AND SOIL ANALYSIS

We selected 26 agricultural fields traditionally planted in grain crops from 18 locations on the Delmarva Peninsula (Fig. 2) to evaluate the subsurface P loss risk assessment methodologies of five Atlantic Coastal Plain P Indices, including the Delaware Phosphorus Site Index (DE-PSI), two iterations of the Maryland Phosphorus Management Tool (MD-PMT and MD-PMT2), the North Carolina Phosphorus Loss Assessment Tool (NC-PLAT), and the Virginia Phosphorus Index (VA-PI). Sampling locations were selected based on the availability of detailed soil characterization data from: 1) a previous leaching study by Kleinman et al. (2015) using intact soil columns collected to a depth of 50 cm from eight agricultural fields sites under no-till corn production (for at least 1 year) with a history of poultry litter application on the Delmarva Peninsula and 2) previous soil coring campaigns conducted by researchers at the University of Delaware (UD), US Geological Survey (USGS), University of Delaware (UD), University of Maryland College Park (UMD), and University of Maryland Eastern Shore (UMES) between 1995 and 2015. Sampled fields represented a wide range of soil, drainage, and management conditions across the Delmarva region, including naturally drained sites with and without irrigation and artificially drained locations of varying drainage intensities.

We used USDA-NRCS Soil Survey Geographic Database (SSURGO) data in ArcGIS 10.4.1 to identify the soil map units within each field and estimate important variables for each of the five P Indices (Supplemental Tables S1 and S2). For samples collected by Kleinman et al. (2015), map units for the Evesboro and Sassafras (USDA-1, -2, -5, and -6) soils were changed to reflect changes in soil classification during remapping of all Delaware soils in 2006. For each identified map unit, we used SSURGO reported texture of the surface horizon, soil drainage class, hydrologic soil group, and depth to seasonal high water table, as is standard practice when calculating P Indices.

A total of 148 composite soil cores were collected from 18 fields using various sampling methods (Supplemental Table S3). In brief, two or three soil core samples were collected from various locations within each field (e.g., along a transect perpendicular to a ditch or within soil management grids) with a Giddings hydraulic probe (10 cm diameter; Giddings Machine Company, Windsor, CO) or bucket auger (10 cm diameter) to a depth of approximately 1 m. Soil cores were divided by horizon or by discrete depth increments and composited for a total of 4 to 16 composite core samples per field. Composited soil samples were air-dried, ground to pass through a 2 mm screen, and bagged until analyzed. Individual core composite samples were analyzed for water extractable P (WEP) or $CaCl_2$-extractable P (Self-Davis et al., 2009) (modified method for UD samples 4 g soil to 40 mL 0.01 M $CaCl_2$) by the molybdate blue method (Murphy and Riley, 1962) and Mehlich 3 extractable P, Al, and Fe (North Eastern Coordinating Commitee, 2011) by inductively coupled plasma optical emission spectroscopy.

## SOIL TRANSMISSIVITY AND DRAINAGE INTENSITY

In order to apply the methods of NC-PLAT (NC PLAT Committee, 2005), we estimated soil transmissivity using Eqn. [S1] and then calculated drainage intensity (m $hr^{-1}$) for each field by the method of (Skaggs et al., 2004). Soil transmissivity defines the rate of water movement through a unit width of saturated soil. As such, it is a key variable in the calculation of $\mathrm{PLAT_{sub}}$ [Eq. S1] for artificially drained soils and in the estimation of drainage intensity by the methods of (Skaggs et al., 2004). In general, transmissivity of a layered soil profile is calculated as:

$$T = \sum K_i D_i \text{ [S1]}$$

where $K_i$ is the saturated hydraulic conductivity of layer $i$ and $D_i$ is the depth of soil layer $i$ (NC PLAT Committee, 2005). It is important to note that the current online version of the NC-PLAT uses soil permeability class instead of saturated hydraulic conductivity in their calculation of soil transmissivity. Given that USDA-NRCS dropped the use of soil permeability class in the National Soil Survey Handbook in favor of saturated hydraulic conductivity in 2003 (USDA-NRCS, 2002), we based our transmissivity calculations for Delmarva soils on this more recent convention.

Four depth-specific transmissivity values were needed to implement NC-PLAT on the Delmarva Peninsula:

- $T_P$ – transmissivity of the entire soil profile (usually to a depth of 183 cm) in $m^2\ hr^{-1}$
- $T_{12}$ – transmissivity of the top 30 cm (12 in.) of soil in $m^2\ hr^{-1}$
- $T_{30}$ – transmissivity of the soil profile from 12 to 30 in (30 to 80 cm) depth in $m^2\ hr^{-1}$
- $T_{P\text{-}1}$ – transmissivity of the soil profile excluding the top 12 in (30 cm) of soil in $m^2\ hr^{-1}$

The first step was to estimate saturated hydraulic conductivity values for each of the specified depth intervals using USDA-NRCS's Soil Data Viewer in ArcGIS 10.4.1. The resultant saturated hydraulic conductivity values were then converted from $\mu m\ s^{-1}$, the raw units reported in SSURGO data, to $m\ hr^{-1}$. All soil transmissivities in $m^2\ hr^{-1}$ were calculated according to Eqn. [S1], with soil transmissivity for the profile excluding the top 12 in (30 cm) of soil ($T_{P\text{-}1}$) inferred by subtracting $T_{12}$ from $T_p$ (Johnson, 2004).

In order to be consistent with NC-PLAT (NC PLAT Committee, 2005), we estimated drainage intensity (m hr$^{-1}$) for each field by the method of (Skaggs et al., 2004):

$$\mathrm{DI} = \frac{[T_{P-1} \times (B-1)]}{(L/100)^2} \quad [\mathrm{S2}]$$

where $T_{P\text{-}1}$ is transmissivity (m$^2$ hr$^{-1}$) of the soil profile from a depth of 30.5 cm to the depth of restrictive layer or 203 cm (whichever was shallower) for the dominant soil map unit in the field; $B$ (m) is ditch depth (average depth observed during field visits); and $L$ (m) is the estimated distance between ditches (calculated in ArcGIS 10.4.1 as the average distance between ditches in the selected field and adjacent fields). Soil transmissivities for different soil depth intervals (top 30.5 cm, entire profile, etc.) were then calculated using Eqn. [S2]. Specifically, weighted averages of saturated hydraulic conductivity ($K_{\mathrm{sat}}$), determined using the USDA-NRCS Soil Data Viewer in ArcGIS 10.4.1, were multiplied by the thickness of each soil depth interval to yield soil transmissivity in m$^2$ hr$^{-1}$.

## PHOSPHORUS INDEX SUBSURFACE COMPONENT SCORE CALCULATION

Phosphorus Index calculations were programmed in an Excel spreadsheet to calculate subsurface P loss risk scores for the DE-PSI (Sims et al., 2016), MD-PMT (McGrath et al., 2013), MD-PMT2 (Fiorellino, unpublished data, 2017), VA-PI (Wolfe et al., 2005), and NC-PLAT (NC PLAT Committee, 2005). In the paper, subsurface P loss risk scores were denoted as DE-PSI$_{\mathrm{sub}}$, MD-PMT$_{\mathrm{sub}}$, MD-PMT2$_{\mathrm{sub}}$, VA-PI$_{\mathrm{sub}}$, and NC-PLAT$_{\mathrm{sub}}$. The accuracy of formulae in the spreadsheet were corroborated by hand calculation of each P Index or, when available, by inputting field variables into online P Index software (e.g., NC-PLAT).

Calculation of subsurface P Index risk scores for the (Kleinman et al., 2015) leaching dataset was completed using soil test data and SSURGO data for each of the sites. At each site, scores were calculated for conditions during a nine-week leachate collection period where no manure was applied and for eight weeks following the application of poultry litter at a total P rate of 52 kg ha$^{-1}$ that was surface applied to the soils. Subsurface P Index scores were also calculated for each of the 18 fields sampled as part of the intensive soil coring campaigns based on characteristics of the dominant soil series and average soil test data. We also calculated subsurface P Index scores for each of the 148 individual soil samples collected from the 18 fields as if they were individual field sites (denoted as sites from here on), thereby allowing us to greatly increase the size and scope of our dataset (from 18 field sites to 148 hypothetical field sites). We assumed no manure or commercial P fertilizers were applied to these sites.

## DISSOLVED PHOSPHORUS LOADS IN DITCH DRAINAGE

We estimated annual dissolved P loads (kg ha$^{-1}$) in ditch drainage to assess subsurface P risk predictions made by the five Coastal Plain P Indices. A survey of published studies on the Delmarva Peninsula revealed four ditch locations where P export in drainage water was estimated for at least one year, including ditch 5 in the study by Kleinman et al. (2007) and the Barclay, Marion, and Westover ditch monitoring locations from Penn et al. (2016). Ditch 5 is located on the University of Maryland Eastern Shore (UMES) Research Farm near Princess Anne, MD, and generally drains the field labeled UMES-2 (Fig. 2). Annual dissolved P export from ditch 5 in 2005 was roughly 2.6 kg ha$^{-1}$ (Kleinman et al., 2007). In the study by Penn et al. (2016), two of the ditch monitoring sites were located near the Maryland towns of Marion and Westover, which lie just to the southwest of Princess Anne, MD (in the vicinity of UMD-5; Fig. 2), while the third location was situated just to the southeast of Barclay, Maryland (near field UMD-3; Fig. 2). Because Penn et al. (2016) reported their dissolved P losses in kg, we needed to estimate the ditch drainage areas in ArcGIS 10.4.1 in order to express them in kg ha$^{-1}$. Based on our drainage area assessment, we found that annual dissolved P losses from the Barclay, Marion, and Westover locations were approximately 0.3, 0.8, and 1.1 kg ha$^{-1}$, respectively, over the four-year monitoring period that extended from 2010 to 2013.

In addition to the published dissolved P load datasets described above, we also identified a third study by Sims et al. (1996) in which dissolved P concentration and discharge measurements (approximately one year of bimonthly monitoring from April 1995 to June 1996) were taken from two ditches (Sites 1 and 2) draining fields used in our broader P Index assessment (UD-2 and UD-3, Fig. 2). In order to estimate annual dissolved P losses from these locations, we first reconstructed daily flow records for both sites by relating their discharge measurements to daily streamflow (e.g., Hirsch, 1979) from the Nanticoke River near Bridgeville, Delaware (USGS Site #01487000) using simple linear regression. The regression equations were significant at $\alpha = 0.1$ (Site 1: $r^2 = 0.50$, $P = 0.1$; Site 2: $r^2 = 0.62$, $P = 0.04$), which we deemed satisfactory for such small datasets ($n = 7$ measurements for Sites 1 and 2). Using the synthetic daily flow records for Sites 1 and 2, we then selected the most appropriate method for estimating dissolved P loads depending on the dissolved P concentration measurements at each site. For Site 1, we simply multiplied the average dissolved P concentration (about 0.02 mg L$^{-1}$) by each daily flow estimate and then summed these values over a two-year period (1995 to 1996) to approximate dissolved P loss in kg yr$^{-1}$ (load interpolation method #1 from Johnes, 2007). At Site 2, we developed a rating curve between dissolved P concentrations and discharge ($r^2 = 0.85$; $P = 0.03$) to predict daily P concentrations (load extrapolation method #7 from Johnes, 2007), which could then be multiplied by daily flows and summed over the same two-year time frame to yield dissolved P flux in kg yr$^{-1}$. Using these methods, we estimated that Sites 1 and 2 exported 0.10 and 0.06 kg ha$^{-1}$ of dissolved P annually.

## SOIL WATER EXTRACTABLE PHOSPHORUS NEAR THE WATER TABLE

Soil water extractable P concentrations near the depth to seasonal high water table ($WEP_{WT}$) were estimated from WEP or $CaCl_2$-extractable P in soil core samples collected from Delmarva agricultural fields during previous intensive soil sampling campaigns. Soil samples were collected to a depth of approximately 1 m and partitioned by horizon or by discrete depth increments (Supplemental Table S3). Depending on the site, soil WEP data were selected from the depth increment or horizon with the mid-point depth closest to the mid-point of the depth to seasonal high water table. The range in depth to seasonal high water table was determined by mapped soil series using SSURGO data for each individual soil core. For example, depth to seasonal high water table ranges from 0 to 25 cm (12.5 cm mid-point) for the Quindocqua soil, which was mapped at the UMES-1 field site. Whenever possible, we selected a single horizon sample with the mid-point closest to the mid-point of the seasonal high water table range. At times, we were required to interpolate between two or more horizons to achieve the desired mid-point soil sample depth. For example, A horizon soils at UMES-1 were often partitioned into two horizons (e.g., Ap1: 0 to 15 cm; Ap2: 16 to 33 cm). Under these circumstances, we calculated a weighted average of WEP from both soil depths to produce one WEP value for a mid-point soil depth of 16.5 cm. When the depth to seasonal high water table was deeper than available soil cores (i.e., greater than 1 m), we selected WEP concentrations for the deepest horizon or depth increment.

## DATA ANALYSIS AND STATISTICS

We compared the subsurface P risk scores of P Indices in this study to 1) dissolved P loads in leachate collected (to a depth of 50 cm) from intact soil cores, 2) dissolved P loads in ditch water at 6 of the 18 field sites where soil core samples were collected, and 3) soil water extractable P at near the depth to seasonal high water table as determined by SSURGO ($WEP_{WT}$), which previous researchers have confirmed as key a factor in P losses by subsurface flow pathways (Flores-Lopez et al., 2013; Obour et al., 2011; Vadas et al., 2007). In addition, we found a significant linear relationship between $WEP_{WT}$ and estimated annual dissolved P load in ditch drainage at six of the sites where core sampling campaigns were conducted (Fig. 8). As such, we suggest that the five subsurface P risk scores evaluated in this study should be related to P concentrations in soil near the seasonal high water table. We employed several tests in SAS version 9.4 (SAS Institute, 2013) to assess P Indices on the Delmarva Peninsula. Spearman rank-order correlation (PROC CORR) was initially used to compare the subsurface P risk scores of the five Atlantic Coastal Plain P Indices, with significant correlations between indices indicating general agreement regarding the direction of subsurface P loss risk. Linear regression (PROC REG) was used to assess subsurface P risk scores of the P Indices against dissolved P loads in drainage water and soil $WEP_{WT}$, with stronger relationships evidencing the ability of a P Index to predict the potential for sites to lose P via subsurface flow pathways (i.e., vertical leaching or subsurface lateral flow). For all statistical tests, we confirmed normality assumptions were met by examining histograms of independent and dependent variables and normality plots of conditional residuals. Correlations and regression models were considered significant at $\alpha = 0.05$.

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Supplemental Table S1. Soil taxonomic information (USDA-NRCS, 2016), hydrologic soil group, and drainage class for soil series mapped at 26 Delmarva (Delaware and Maryland) agricultural field sites sampled by University of Delaware (UD), University of Maryland College Park (UMD), USDA Agricultural Research Service (USDA), University of Maryland Eastern Shore (UMES), USDA Agriculture Research Service (USDA), and US Geological Survey (USGS) that were selected for evaluation of subsurface P loss risk assessment methods used in five Atlantic Coastal Plain P Indices.

| Soil series | Taxonomic information | Depth to seasonal high water table (cm) | Hydrologic soil group | Drainage class† | Field site |
|---|---|---|---|---|---|
| Askecksy | Siliceous, mesic Typic Psammaquents | 0-25 | A/D | P | UD-5, -6 |
| Bojac | Coarse-loamy, mixed, semiactive, thermic Typic Hapludults | 122-183 | A | W | USDA-3, -4 |
| Crosiadore | Fine-silty, mixed, active, mesic Aquic Hapludults | 25-51 | C/D | SP | UMD-2 |
| Downer | Coarse-loamy, siliceous, semiactive, mesic Typic Hapludults | >183 | A | W | USGS-2 |
| Fallsington | Fine-loamy, mixed, active, mesic Typic Endoaquults | 25-51 | C/D | P | UMD-1, -3, -5 |

| | | | | | |
|---|---|---|---|---|---|
| Fort Mott | Loamy, siliceous, semiactive, mesic Arenic Hapludults | >183 | A | W | UMD-1 |
| Hambrook | Fine-loamy, siliceous, semiactive, mesic Typic Hapludults | 102-183 | B | W | UMD-2, USDA-6 |
| Hammonton | Coarse-loamy, siliceous, semiactive, mesic Aquic Hapludults | 46-107 | B | MW | UD-2; USGS-3, -4 |
| Ingleside | Coarse-loamy, siliceous, semiactive, mesic Typic Hapludults | 122-183 | A | W | USGS-1, -2, -3, -4 |
| Keyport | Fine, mixed, semiactive, mesic Aquic Hapludults | 46-107 | D | MW | UD-3 |
| Klej | Mesic, coated Aquic Quartzipsamments | 25-61 | A/D | SP[‡] | UD-1, -2 |
| Manokin | Fine-loamy, mixed, active, mesic Aquic Hapludults | 51-102 | C | MW | UMES-2 |
| Mullica-Berryland | Coarse-loamy, siliceous, semiactive, acid, mesic Typic Humaquepts; Sandy, siliceous, mesic Typic Alaquods | 0-25 | A/D | VP | UD-4, -6 |

| | | | | | |
|---|---|---|---|---|---|
| Othello | Fine-silty, mixed, active, mesic Typic Endoaquults | 0-25 | D | P | UMD-4 |
| Pepperbox | Loamy, mixed, semiactive, mesic Aquic Arenic Paleudults | 51-102 | A | MW | UD-3; USDA-2 |
| Queponco | Fine-loamy, mixed, semiactive, mesic Typic Hapludults | 102-183 | C | W | UMES-3 |
| Quindocqua | Fine-loamy, mixed, active, mesic Typic Endoaquults | 0-25 | C/D | P | USDA-7, -8; UMES-1 |
| Rosedale | Loamy, siliceous, semiactive, mesic Arenic Hapludults | 102-183 | A | W | USDA-1; USGS-2 |
| Sassafrass | Fine-loamy, siliceous, semiactive, mesic Typic Hapludults | >183 | B | W | UMD-2; USDA-5 |
| Woodstown | Fine-loamy, mixed, active, mesic Aquic Hapludults | 46-107 | C | MWD | USDA-6; USGS-1; UMD-1 |

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†W = well drained; MW = moderately well drained; SP = somewhat poorly drained; P = poorly drained; VP = very poorly drained.

Supplemental Table S2. Selected characteristics of 26 agricultural field sites on the Delmarva Peninsula (Delaware and Maryland) sampled by scientists at University of Delaware (UD), University of Maryland College Park (UMD), University of Maryland Eastern Shore (UMES), USDA Agriculture Research Service (USDA), and US Geological Survey (USGS) for evaluation of subsurface P loss risk assessment methods used in five Atlantic Coastal Plain P Indices from Delaware, Maryland, Virginia, and North Carolina.

| Field ID | Drainage | Irrigation | Mapped soil series | Surface soil texture | Drainage intensity† |
|---|---|---|---|---|---|
| | | | | | m hr$^{-1}$ |
| UD-1 | Artificial | Dryland | Klej | loamy sand | 0.49 |
| UD-2 | Artificial | Dryland | Klej | loamy sand | 0.49 |
| | | | Hammonton | loamy sand | 0.92 |
| UD-3 | Artificial | Dryland | Keyport | sandy loam | 0.001 |
| | | | Pepperbox | loamy sand | 0.009 |
| UD-4 | Artificial | Dryland | Mullica-Berryland | sandy loam | 1.12 |
| UD-5 | Artificial | Dryland | Askecksy | loamy sand | 1.26 |
| UD-6 | Artificial | Dryland | Askecksy | loamy sand | 1.26 |
| | | | Mullica-Berryland | sandy loam | 1.12 |
| UMD-1 | Artificial | Dryland | Fort Mott | loamy sand | 0.03 |
| | | | Sassafrass | Loam | 0.02 |
| | | | Fallsington | sandy loam | 0.06 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Woodstown | sandy loam | 0.02 |
| UMD-2 | Artificial | Dryland | Crosiadore | silt loam | 0.04 |
| | | | Fallsington | loam | 0.25 |
| | | | Hambrook-Sassafras | sandy loam | 0.11 |
| UMD-3 | Artificial | Dryland | Fallsington | sandy loam | 1.41 |
| UMD-4 | Artificial | Dryland | Othello | silt loam | 0.31 |
| UMD-5 | Artificial | Dryland | Fallsington | loam | 1.72 |
| UMES-1 | Artificial | Dryland | Quindocqua | silt loam | 0.58 |
| UMES-2 | Artificial | Dryland | Manokin | silt loam | 0.63 |
| UMES-3 | Artificial | Dryland | Queponco | silt loam | 0.08 |
| USDA-1 | Natural | Dryland | Rosedale‡ | sand | --[§] |
| USDA-2 | Natural | Dryland | Pepperbox‡ | sand | -- |
| USDA-3 | Natural | Dryland | Bojac | sandy loam | -- |
| USDA-4 | Natural | Dryland | Bojac | sandy loam | -- |
| USDA-5 | Natural | Irrigated | Sassafras | loamy fine sand | -- |
| USDA-6 | Natural | Irrigated | Hambrook‡ | loamy sand | -- |
| USDA-7 | Artificial | Dryland | Quindocqua | silt loam | 0.58 |
| USDA-8 | Artificial | Dryland | Quindocqua | silt loam | 0.58 |
| USGS-1 | Artificial | Dryland | Woodstown | sandy loam | -- |
| | | | Ingleside | loamy sand | -- |
| USGS-2 | Artificial | Irrigated | Ingleside | loamy sand | -- |

| | | | | | |
|---|---|---|---|---|---|
| | | | Rosedale | loamy sand | -- |
| | | | Downer | loamy sand | -- |
| USGS-3 | Artificial | Irrigated | Hammonton | sandy loam | 0.07 |
| | | | Ingleside | sandy loam | 0.02 |
| USGS-4 | Artificial | Dryland | Ingleside | sandy loam | 0.02 |

†Drainage intensity is calculated for fields with artificial drainage based on the methods of Skaggs et al. (2004).

‡USDA-1 and -2 were originally mapped as Evesboro (EvA), while USDA-6 was originally mapped as Sassafras (SaA) by Kleinman et al. (2015) based on the 1974 print soil survey. The soils series listed here reflects a change in soil classification when Delaware soils were remapped in 2006.

§-- indicates the parameter was not calculated because the site is naturally drained.

Supplemental Table S3. Information about soil core sampling by University of Delaware (UD), University of Maryland College Park (UMD), University of Maryland Eastern Shore (UMES), and US Geological Survey (USGS) at 18 agricultural field sites on the Delmarva Peninsula for evaluation of subsurface P loss risk assessment by Atlantic Coastal Plain P Indices.

| Field ID | County | State | Field size (ha) | Sampling date | Sampling implement | Sampling method | Sample aggregation method | Number of cores per composite | Number of composite samples per field |
|---|---|---|---|---|---|---|---|---|---|
| UD-1 | Sussex | DE | 5.2 | May 1995 | Giddings hydraulic probe | Transect | Horizon | --† | 3 |
| UD-2 | Sussex | DE | 2.3 | May 1995 | Giddings hydraulic probe | Transect | Horizon | -- | 3 |
| UD-3 | Sussex | DE | 9.1 | May 1995 | Giddings hydraulic probe | Transect | Horizon | -- | 6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| UD-4 | Sussex | DE | 6.1 | May 1995 | Giddings hydraulic probe | Transect | Horizon | -- | 3 |
| UD-5 | Sussex | DE | 7.6 | May 1995 | Giddings hydraulic probe | Transect | Horizon | -- | 3 |
| UD-6 | Sussex | DE | 4.8 | May 1995 | Giddings hydraulic probe | Transect | Horizon | -- | 6 |
| UMD-1 | Dorchester | MD | 19.2 | June 2014 | Giddings hydraulic probe | Transect | Horizon | 3 | 12 |
| UMD-2 | Talbot | MD | 13.3 | June 2014 | Giddings hydraulic probe | Transect | Horizon | 3 | 11 |
| UMD-3 | Caroline | MD | 4.86 | Nov. | Giddings | Grid | Depth | 4 | 15 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2012 | hydraulic probe | | | | |
| UMD-4 | Somerset | MD | 3.40 | Oct. 2012 | Giddings hydraulic probe | Grid | Depth | 4 | 15 |
| UMD-5 | Somerset | MD | 3.28 | Nov. 2012 | Giddings hydraulic probe | Grid | Depth | 4 | 15 |
| UMES-1 | Somerset | MD | | Nov. 2015 | Giddings hydraulic probe | Transect | Horizon | 3 | 16 |
| UMES-2 | Somerset | MD | | Nov. 2015 | Giddings hydraulic probe | Transect | Horizon | 3 | 15 |
| UMES-3 | Somerset | MD | | Nov. 2015 | Giddings hydraulic | Transect | Horizon | 3 | 4 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | probe | | | | |
| USGS-1 | Sussex | DE | 3.60 | Mar. 2014 | Bucket auger | Transect | Depth | 2 | 7 |
| USGS-2 | Sussex | DE | 22.4 | Mar. 2014 | Bucket auger | Transect | Depth | 2 | 7 |
| USGS-3 | Queen Anne’s | MD | 37.0 | Mar. 2014 | Bucket auger | Transect | Depth | 2 | 7 |
| USGS-4 | Queen Anne’s | MD | 29.6 | Mar. 2014 | Bucket auger | Transect | Depth | 2 | 7 |

† -- indicates that this information was not reported.