Data Evaluation Report No. 3:
“Contaminant History as Recorded in the Sediments”

LOWER EIGHT MILES OF THE LOWER PASSAIC RIVER
DATA EVALUATION REPORT NO. 3: CONTAMINANT HISTORY AS RECORDED IN THE SEDIMENTS

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1 INTRODUCTION

This document is part of a series of data evaluation reports, which were prepared to support the Remedial Investigation (RI) and Focused Feasibility Study (FFS). Reports in this series describe different aspects of the Lower Passaic River. Where necessary, data evaluation reports are cross-referenced to direct the reader to another report that contains further explanation. Topics discussed in this series include boundary conditions for the river, historical sediment contamination, surface sediment contamination, contaminant inventory calculations, and biota analysis. The following data evaluation report examines the historical concentrations of contaminants of potential concern (COPCs) and contaminants of potential ecological concern (COPECs) on suspended solids in the river as recorded in the sediments and their implications for the history of contaminant discharges to the river.

1.1 Overview of the FFS Study Area

The FFS Study Area is located within the Lower Passaic River Study Area (LPRSA), which is the 17-mile, tidal portion of the Passaic River from Dundee Dam [located at River Mile (RM[1]) 17.4] to the confluence with Newark Bay at RM0 and the watershed of this river portion, including the Saddle River (RM15.6), Third River (RM11.3) and Second River (RM8.1) [Figure 1-1]. During a comprehensive study of the Lower Passaic River, the sediments of the lower eight miles were found to be a major source of contamination to the rest of the river and Newark Bay. Therefore, the United States Environmental Protection Agency (USEPA) completed the FFS to evaluate alternatives to address those sediments in the lower eight-mile stretch from RM0 to RM8.3, near the border between the City of Newark and Belleville Township. The entire 17-mile Lower Passaic River is the subject of another Remedial Investigation/Feasibility Study (RI/FS)

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[1] The FFS uses the "River Mile" (RM) system developed by the United States Army Corps of Engineers (USACE), which follows the navigation channel of the Lower Passaic River. The Data Evaluation Reports (Appendix A), Empirical Mass Balance (Appendix C) and Lower Passaic River-Newark Bay model (Appendix B) were initially developed at the beginning of the 17-mile Remedial Investigation and Feasibility Study (RI/FS), and thus follow a RM system developed for that RI/FS, which follows the geographic centerline of the River. RM0 is defined by an imaginary line between two marker lighthouses at the confluence of the Lower Passaic River and Newark Bay: one in Essex County just offshore of Newark and the other in Hudson County just offshore of Kearny Point. River miles then continue upriver to the Dundee Dam (RM17.4). The two RM systems are about 0.2 miles apart.

being implemented by the Cooperating Parties Group (CPG; a group of approximately 70 potentially responsible parties who signed an agreement with USEPA in 2007), under USEPA oversight. The Upper Passaic River watershed (the portion of the Passaic River located above the Dundee Dam) contributes solids, water, and contaminants that cross over the head-of-tide, which is represented by the Dundee Dam[2], into the Lower Passaic River.

1.2 Overview of the Contaminant History

This document examines contaminants in dated sediment cores as an indication of historical water quality changes and sediment contamination in the Lower Passaic River. A common approach for evaluating trends is to apply statistical tests to historical water quality data. However, determining water-quality trends using historical data is often subject to several limitations, such as lack of sufficient data, changing sampling techniques through time, and variations in analytical methods and detection levels. These limitations can be crucial when dealing with trace elements and hydrophobic organic compounds, which normally occur at very small concentrations in the water column. Detecting trends for some minor elements and compounds often is further complicated by large variability in aqueous concentrations over short time intervals.

An alternative approach for evaluating water-quality trends for some constituents is paleolimnology, the use of age-dated sediment cores to reconstruct water-quality histories (Van Metre, *et al.*, 2004; Callender and Van Metre, 1997; Davis, 1980; Eisenreich *et al.*, 1989; Hites *et al.*, 1981; Van Metre, *et al.*, 1997). Historical water-quality records can be partly reconstructed using dated sediment cores collected from receiving water bodies, such as reservoirs, lakes, and estuaries. Water quality trends that reflect urbanization and industrial discharges can be established from contaminant concentrations on particles that were originally suspended in the water column, deposited on the sediment bed and subsequently captured in the dated sediment cores.

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[2] The Dundee Dam represents a hydraulic boundary. The head-of-tide actual location is downstream of the dam because even though the tides can influence the water level near the dam, the upper-most extent of saltwater (*i.e.*, the salt front) typically stops several miles below the Dundee Dam (refer to Lower Passaic River System Understanding of Sediment Transport [HQI and Sea Engineering Inc, 2011] for further details on the salt front migration).

The Lower Passaic River is a dynamic environment, experiencing both periods of net erosion and net deposition, with daily tidal exchanges and periodic high flow events. Solids that enter the Lower Passaic River at Dundee Dam, tributary confluences, and local discharge points are blended and re-worked through tidal mixing and erosional/depositional events. Eventually, some of these solids are transported downstream and deposited in Newark Bay. Solids also enter the river via tidal exchange from Newark Bay, only to be reworked and blended with the solids from the other sources and either deposited in the river or exchanged back to Newark Bay. These processes are further described in Appendix B of the FFS.

As solids are deposited on the river bottom, they largely retain their burden of particle-reactive and persistent contaminants, reflecting the suspended solid water quality conditions at the time of deposition. In some sheltered locations, the deposition is steady and undisturbed enough to create a nearly continuous record of settling solids and associated contaminants through time. Cores obtained from these areas provide a means to construct these records.

By examining the levels of well-documented radionuclides in the core, the approximate year of deposition can be established for various depths within the core. In turn, the contaminant levels in these dated layers are then considered reflective of the mean concentrations of contaminants associated with suspended solids present in the river during the deposition period. In this manner, a dated sediment core can be considered a record of historical water column conditions at the collection site and the surrounding area, in the same way that a fossilized fish embedded in sedimentary rock provides data regarding its prior life in the water column. For the purposes of the FFS, deposition over the last 50 to 100 years is of greatest interest. The core intervals reflecting this period of deposition were established based on the depth distribution of radioactive Cesium-137 (Cs-137), which is discussed in Section 2.

By obtaining cores from locations distributed along the river, the spatial and temporal distribution of solids-borne contaminants can be discerned. A dated sediment core at RM1.4 can provide a record of suspended solids contamination in the saline waters near the mouth of the Lower Passaic River; whereas a core at RM12.6 provides a record of suspended solids associated contamination in the largely fresh waters of this area of the river. Cores obtained between these locations can be used to document changes along the main axis of the river.

This data evaluation report examines downcore profiles collected in the Lower Passaic River by both the USEPA and Tierra Solutions, Inc. (TSI) [under USEPA oversight]. The analysis is focused on the chronologies obtained from five dated sediment cores collected in 2005 by the USEPA, which provide the greatest detail concerning the long-term trends of contamination in the Lower Passaic River. In 2007, the USEPA reoccupied the locations of the 2005 high resolution cores and obtained a 0 to 2 centimeter (cm) sample using a shallow box core. The 2007 surface sediment concentrations will be presented and discussed to extend the contaminant trends obtained from the dated cores. In addition, a comparison to 1995 TSI cores, specifically the longest 1995 sediment cores with interpretable Cs-137 profiles, is also presented. Figure 1-2 shows the location of the 1995 and 2005 cores examined in this data evaluation report.

This data evaluation report is composed of the following sections in addition to the introduction:

- *Section 2.0, Conceptual Model of Sediment Core Dating and the FFS Coring Program:* presents the theoretical and practical considerations for collection and dating of sediment cores as well as a description of the USEPA's dated sediment core collection efforts.
- *Section 3.0, Examining the Sediment Record of Historical Contamination:* characterizes the historically-deposited sediments in the river and presents a geochronology of contaminant loading.
- *Section 4.0, Acronyms*: defines the acronyms used in this report.
- *Section 5.0, References*: lists the references used in this report.

2 CONCEPTUAL MODEL OF SEDIMENT CORE DATING AND THE FFS CORING PROGRAM

Before discussing the high resolution sediment core results, it is useful to outline the basic concepts on which core collection and analysis are based. The first assumption is that sediments that accumulate at a given location reflect the water column conditions at the time of deposition at that location (*i.e.*, the sediments are effectively a time-integrated sample of the water column suspended matter). Sediments best retain the concentrations and patterns of particle-reactive contaminants, such as polychlorinated dibenzodioxins/ furans (dioxins), polychlorinated biphenyls (PCBs), heavier polycyclic aromatic hydrocarbons (PAHs), and heavy metals. Highly soluble compounds such as volatile organics are not well conserved in the sediments and usually cannot be examined by this approach.

High resolution cores must be collected from areas that exhibit specific attributes in order to yield a core with an interpretable chronology and associated contaminant history (Olsen, 1979, Olsen *et al.*, 1981, and Bopp *et al.*, 2006). Sediment accumulation at the core location must occur continuously or almost continuously over time. Cores collected from rivers and estuaries where hydrodynamic energies are relatively high and surface sediments are frequently scoured and redeposited do not yield profiles that reflect steady annual deposition and obtaining datable cores is unlikely. The techniques used to verify continuous or almost continuous sediment accumulation are discussed below.

To translate the layers of deposited sediments into a geochronology of contaminant loading, several additional criteria must be satisfied. Several key criteria follow.

- Sediment accumulation is relatively constant on an annual basis although varying seasonally with flow. Long term variations in annual deposition rate can be addressed when multiple radionuclide indicators are available.
- Little resuspension occurs subsequent to sediment deposition (*i.e.*, few or no erosional events).

- Biological stirring (bioturbation) of the sediments occurs only minimally, typically mixing only a few years of deposition.
- The effects of human activities on sediment accumulation are minimal or can be documented (*e.g.,* a known dredging event).

When these criteria are satisfied then the factors governing contaminant concentrations on water column suspended matter will also be reflected in sediment concentrations (*e.g.,* contaminant concentrations in the sediment will decrease downstream of a major tributary relatively free of contamination, mimicking the contaminant water column concentrations upstream and downstream of the tributary).

2.1 Establishing Sediment Core Chronologies: Radionuclide Dating Principles

Radionuclides serve either as event markers or as "clocks" in establishing core chronologies. A radionuclide used as an event marker has a well-defined input history, such that minimum or maximum concentrations in the core sediments can be ascribed to known events. A radionuclide clock is a radionuclide whose rate of input to the sediments is approximately constant over long periods of time. Input to the sediment by other processes after deposition must be minimal and/or measurable. The decline in the concentration of the radionuclide with depth due to radioactive decay can then be ascribed to the approximate age of the sediments, similar to a clock counting the elapsed time since deposition. In order to understand how radionuclides serve these purposes, it is first necessary to define radionuclides, their properties and their origins.

A radionuclide is an atom with an unstable nucleus that will eventually decay to a more stable state, releasing radiation in the process. Each radionuclide has its own atomic form and amount of radioactivity released over a time period. Radionuclides can be detected at extremely low concentrations. For example, the detection limit for Cs-137 is about one part in 10^{15} by weight (1 femtogram/gram), which is 0.06 picocuries per gram (pCi/g) or about 6 disintegrations per minute in a 50-g sample. Radionuclides decay exponentially over time. The rate of decay is characterized in terms of a half-life ($t_{1/2}$), which is defined as the time for a radionuclide concentration to decay to half of its original concentration.

In general, it is difficult to detect environmental levels of a radionuclide after about five half-lives have passed (*i.e.*, when only about 3 percent of the initial concentration remains). In this report, measurements of radioactivity for individual radionuclides are reported in pCi/g.

Radionuclides are produced by many different processes. Some are generated naturally, such as beryllium-7 (Be-7) and carbon-14 (C-14), which are produced by solar radiation in the upper atmosphere. Some radionuclides are man-made, such as Cs-137, which is produced during detonation of a nuclear weapon or as a by-product in a nuclear reactor. Most of the Cs-137 present on the earth's surface was produced as a result of the atmospheric nuclear weapons testing that took place between 1954 and 1963.

For a radioisotope to be useful in sediment core dating, it must be strongly sorbed to fine particles, so it remains with the sediment after deposition. It must also have a half-life that is appropriate for the period to be examined. Cs-137 and lead-210 (Pb-210) have half-lives of 30.2 and 22.3 years, respectively, making them useful for sediment dating over the last 50 to 100 years. Be-7 has a half-life of 53.4 days, making it a useful indicator of very recent sediment deposition (6 to 12 months or less). In contrast, C-14 has a half-life of about 5,700 years, too long for use in this FFS. All three isotopes, Cs-137, Pb-210, and Be-7 associate strongly to particles and have been successfully used to date sediments in estuarine environments.

2.1.1 Interpretation of Cs-137 in the Sediments

Because of its well-known input history and its residual levels in soils and sediments across the planet, Cs-137 is used as an event marker rather than a sedimentological "clock." Most of the historical release of Cs-137 to the environment has been the result of atmospheric weapons testing, which occurred almost exclusively between 1954 and 1963. The historical input of Cs-137 to the New York area has been summarized by Bopp *et al*. (1982) and Olsen (1979). Cs-137 provides two known time horizons, as indicated by:

(1) The appearance of Cs-137 in 1954 as a consequence of the onset of atmospheric atomic weapons testing; and

(2) A Cs-137 release maximum in 1963 corresponding to an extensive amount of atmospheric weapons testing just prior to the implementation of the Partial Test Ban Treaty (PTBT) in October 1963 (CIA, 2009).

These two horizons are detectable around the planet, with a somewhat stronger signal in the northern hemisphere. However, there are also local Cs-137 inputs that can serve as local time horizon markers. Much of Europe has a second Cs-137 maximum in the sediments, corresponding to the 1986 Chernobyl nuclear power accident. In the Hudson, there is a second Cs-137 maximum in the sediments, corresponding to releases from the nuclear reactor site at Indian Point, Buchanan, New York in 1971 (Bopp *et al*, 1982). Only the 1954 and 1963 Cs-137 horizons have been noted in Passaic River sediments (Bopp *et al.*, 1991 and Chaky, 2003).

In addition to the two horizons in the Cs-137 record, Cs-137 provides a third line of evidence related to sediment age. Since essentially no environmental levels of Cs-137 existed prior to 1954, fine-grained sediment lacking Cs-137 is considered deposited pre-1954. As a result of the atmospheric atomic weapons testing, a residual Cs-137 burden remains in soils throughout planet and in particular, in the northern hemisphere. Ongoing erosion of soils into receiving waters such as the Lower Passaic River continues to deliver suspended solids that contain measureable levels of Cs-137 to the present day. Thus, essentially all post-1954 fine-grained deposition contains measureable levels of Cs-137.

In establishing the age of sediments in this FFS, the 1963 Cs-137 maximum and the 1954 appearance of Cs-137 are the primary marker horizons. The sediment depth corresponding to the bottom of the first core segment with detectable levels of Cs-137 is assigned the year 1954. The mid-point of the core segment with the maximum Cs-137 value in the core is assigned the year 1963. The deepest Cs-137-bearing layer in a sediment core can be ascribed to about 1954 as long as deeper sediments are shown to be free of Cs-137 and the dredging history of the area is known.

To establish the approximate year of deposition for any depth within the core, the year is estimated by interpolating between the 1954 and 1963 horizons or by interpolating between the 1963 horizon and the top of the core, which is assigned the year of core collection. In the best of conditions, the number of centimeters of sediment accumulation per year is a constant for the two intervals but this is not essential to interpret a core chronology. More sophisticated means of core interpolation can be applied, which consider solids mass deposited per year rather than centimeters per year (cm/yr). However, for the purpose of this FFS, the approach described above provides sufficient accuracy for the needs of the project.

2.1.2 Interpretation of Be-7 in the Sediments

In contrast to Cs-137, Be-7 is serves as a sedimentological clock to identify very recently-deposited sediments. Be-7 is continuously produced in the upper atmosphere by cosmic radiation and as a result, has a fairly constant fallout rate at any given location (Lal *et al.*, 1958). As Be-7 settles to the earth's surface, either as particles or in rainfall, it enters receiving water bodies such as the Lower Passaic River. This occurs directly at the air-water surface and by surface runoff delivered from the tributaries. Once in the water column of the Lower Passaic River, Be-7 quickly associates with the suspended matter. Thus, settling solids will contain measurable amounts of this isotope. Because of its short half-life, (53.4 days), Be-7 will be limited to sediments deposited within the last 6 to 12 months.

While it is theoretically possible to use this radionuclide to examine very short term variations in deposition rates (less than 6 months), its use in this manner is limited by the physical conditions of the river. Specifically, annual sediment deposition rates, the expected thickness of biological mixing and the minimum thickness of a measurable sediment layer are all on the order of 1 cm or more. Thus, the uppermost layer in a core in a depositional setting will typically represent 1 to 2 years of deposition, will be relatively well mixed and contain Be-7. The next layer down will be 2 to 4 years old and free of Be-7. Based on this, the presence of Be-7 in the top layer of a core is taken to indicate very recent deposition (sediments deposited within the last 6 to 12 months).

Deeper layers are generally free of Be-7 except in areas of very high deposition rates. Because of its limited presence in deeper sediments, Be-7 concentrations were not determined for samples deeper than eight centimeters.

2.1.3 Consideration of Pb-210

Samples were also analyzed for Pb-210 as part of the USEPA coring investigation of the Lower Passaic River. However, these data were subject to analytical issues such as method blank contamination and did not meet the data quality objectives. As a result, these results were not used in the interpretation of the cores. Since these results were not used in this report, no further discussion of the Pb-210 dating process is warranted.

2.1.4 Definition of a High Resolution Sediment Core

The term *high-resolution* sediment coring refers to the method by which sediment cores are collected and sliced for analysis. High-resolution sediment cores are collected from the river bottom, preferably from a relatively undisturbed region of fine-grained sediments. The sediment from the core is carefully extruded from the end of the coring tube and sliced into relatively thin segments, typically 2 to 4 cm intervals. Each slice is then sub-sampled for COPC and COPEC analysis and radionuclide analysis, among other parameters. These intervals, which generally represent only a few years of deposition, reflect the characteristics of suspended matter in the river at the time that they were deposited. Typical deposition rates of 0.5 to 2 cm/yr permit the analysis of one to four years of sediment accumulation per slice. This technique produces a *highly resolved* sediment deposition chronology, hence the name.

2.2 Core Suitability for Dating

Beginning with the data quality objectives (DQOs) developed for the Lower Passaic Restoration Project Quality Assurance Project Plan (QAPP) (Malcolm Pirnie, Inc., 2005b) several criteria were developed to select suitable cores for dating purposes. These criteria are listed below. If a core met these criteria, then the approximate year of deposition was estimated for the appropriate depths based on the various time horizons recorded in the core. The core selection criteria for dating are presented below:

Criterion No. 1:	Enough Cs-137 (*e.g.,* 0.2 pCi/g at the surface and a maximum of at least 1 pCi/g at depth) must be present in core sediments for a core chronology to be established.
Criterion No. 2:	A clear Cs-137 peak (*i.e.,* highest Cs-137 concentration) must be present relating to the 1963 or 1971 event.
Criterion No. 3:	Be-7 must be present in the surface layer.

As noted previously, the objective of the sediment dating program was to examine water-borne contaminant transport as recorded in the sediments of the river. The sediments of the river record this transport when they are derived from the suspended matter carried by the river. The sediments suitable for dating must be fine-grained since the radionuclides (used in this FFS), as well as several contaminants have a greater affinity for these materials than for coarse-grained sediments such as sand and gravel. Fine-grained sediments are also carried and deposited on a more continuous basis, thus increasing the potential for a continuous, steady record of the river's suspended-matter conditions.

In light of the above, enough Cs-137 must be present in core sediments for a core chronology to be established (Criterion No. 1). In general, the higher the Cs-137 levels in a given core, the greater the fine-grained sediment content and the higher the sediment deposition rate relative to cores with lower levels of Cs-137. In addition to the presence of Cs-137, a clear Cs-137 peak defining 1963 is imperative for using Cs-137 as an event-marker (Criterion No. 2). If there is no clear maximum, the core is considered not dateable, since this implies either lack of steady deposition, extensive biological mixing or a man-made disturbance such as dredging.

The presence of Be-7 in the surface layer (Criterion No. 3) confirms the presence of sediment that has been deposited within a year from the time of collection. In a core lacking Be-7, the age of the surficial sediments cannot be determined with accuracy. The location may have been disturbed by scour processes or it may simply represent a currently non-depositional environment.

The ability to assign ages to various sediment layers in a core based on radionuclides is affected by factors like sediment deposition rate variation, sediment scour, biological activity, and anthropogenic activities. These factors alter the amount of sediment present in a core for a given interval or mix sediments across intervals and so affect the certainty of the assigned dates of deposition. The uncertainty of the assigned dates is also not constant over the length of the core, but rather is a function of the distance from "known" time points (*e.g.*, the top layer is 2005 or the Cs-137 maximum at 1963).

2.3 Application of Be-7 in the Lower Passaic River

For the purposes of the FFS, an activity of Be-7 greater than 0.5 pCi/g was used as the minimum value in classifying sediments as “recently depositional.” Detection limits for Be-7 were on the order of 0.3 pCi/g. In several instances Be-7 activity was much higher, indicating that the samples were very recently-deposited and/or contained a higher fraction Be-7 bearing, recently-deposited particles (Figure 2-1). The highest Be-7 levels were obtained from tributary suspended sediment trap samples. The Third River suspended matter had Be-7 activity as high as 30 pCi/g (Figure 2-1). These high values identify the tributaries and the Upper Passaic River as a major means of delivery of Be-7 to the Lower Passaic River. Analysis of Be-7 in both surface sediments and suspended sediment traps confirmed that Be-7 bearing surficial sediments obtained by various coring techniques were similar to suspended matter captured in suspended sediment traps. Thus Be-7 in surface sediments indicates the presence of recently-deposited material, as noted previously. This close link between Be-7 bearing surface sediments and suspended matter was further demonstrated near the head of tide. Recently-deposited Be-7 bearing sediment samples collected from above Dundee Dam were found to contain similar Be-7 activity and contaminant concentrations as those found in sediments from sediment traps deployed just below the Dundee Dam (at RM17.1).

Besides its use in sediment core dating and its identification of the link between suspended matter and recently-deposited sediments, Be-7 was also used to identify possible candidate sites for high resolution core collection. Specifically, since a criterion for a datable core is the presence of Be-7 at the surface, then a coring site must have detectable Be-7. A survey of site locations to identify recently-deposited surface samples with Be-7 activity was conducted by USEPA prior to core collection (Malcolm Pirnie, Inc., 2005a).

In further support of the results from the high resolution cores collected in 2005, Be-7 bearing sediments and sediment traps were used to characterize the current properties of suspended matter carried by the tributaries, the Upper Passaic River, and main stem of the Lower Passaic River. Targeted fine-grained surface sediment sampling by Malcolm Pirnie, Inc. in 2007-2008 yielded surface sediment Be-7 concentrations of up to 10 pCi/g. Figure 2-1 presents the Be-7 levels for surface sediment of the Lower Passaic as well as Newark Bay, the Upper Passaic River and the tributaries. Notably the Be-7 levels of the main stem of the Lower Passaic River are comparable to those observed in the tributaries and higher than observations in Newark Bay and the Upper Passaic River. The results indicate the occurrence of many recently depositional sites, whose properties can be used to characterize mean water column suspended matter properties over the 2005 to 2007 period. Further discussion on the application of Be-7 to identify recently-deposited sediment contamination can be found in Data Evaluation Report No. 4.

2.4 FFS High Resolution Coring Program

2.4.1 2005 High Resolution Sediment Coring Program for the Lower Passaic River

High resolution sediment cores were collected by Malcolm Pirnie, Inc. for USEPA from 14 candidate locations in the Lower Passaic River and Upper Passaic River in September and October 2005 to assess historical contaminant loading to the river and current surface sediment concentrations. These candidate locations were identified by the Be-7 surface sediment collection survey described above. The details of the coring locations selection and samples selection are described in Data Evaluation Report No. 1.

Radiological data indicated that five cores (located at RM1.4, RM2.2, RM7.8, RM11.0, and RM12.6) had acceptable Cs-137 profiles. These cores also provided a spatially well-distributed set of coring sites. Samples from the selected cores were analyzed for a suite of inorganic and organic parameters. Samples from every interval of the cores were analyzed for Target Analyte List (TAL) metals, including mercury, through USEPA's Contract Laboratory Program (CLP) by Sentinel, Inc. (Huntsville, Alabama). For organic compounds (analyses conducted by Axys Analytical Services Ltd. in British Columbia, Canada), sediment samples were defrosted[3] and manually combined (every two intervals, consecutively, to yield approximately 20 samples per core) prior to submittal to the laboratory. The organic compound classes included dioxin congeners, PCB congeners, PAHs, and pesticides.

For the cores at RM1.4, RM2.2, and RM11, organic analyses for dioxins, PCBs and pesticides were conducted in the same manner, also yielding about 20 samples per core. For the locations at RM7.8 and RM12.6, only a subset of the organic samples for dioxins, PCBs, and pesticides were analyzed due to the budget limitations, with samples primarily analyzed near the top of the core and at the 1963 Cs-137 maximum. A few additional samples were analyzed along the length of the core at RM12.6. The latter two cores at RM7.8 and RM12.6 were analyzed in this fashion to support the information obtained from the well-resolved core record recovered at RM11.

With approximately 20 samples per core, this segmentation process resulted in the first four segments in each core representing approximately two-year time intervals (with the top interval representing the 2005-2003 time horizon), and the remainder of the segments (approximately 16 segments) each representing approximately a four-year time interval (or approximately 64 years total). The total time period represented in each core was approximately 1940 to 2005, or about 65 years. Given the use of Cs-137 as the primary dating basis, the temporal assignments of the various core layers is considered most accurate from about 1954 to 2005. For more information on the high resolution sediment

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[3] See Data Evaluation Report No. 1 for more details on sample archiving prior to analysis of organic compounds.

sampling program, refer to the *Field Sampling Plan, Volume 1* (Malcolm Pirnie, Inc., 2006).

Before analyzing the results of the high resolution coring program, the qualifiers assigned to the results by the laboratory and data validator were reviewed. Due to the additional analytical cleanup methods employed in the Lower Passaic River sampling programs, method detection limits were relatively low, which resulted in few samples being reported as not detected (qualifiers containing a “U”). No rejected data were reported in this dataset.

The 2005 high resolution sediment core dataset can be summarized as follows:

- The analysis of bathymetric surveys, side-scan sonar surveys, and historical coring work helped to identify potential sites for high resolution core collection. A subsequent field reconnaissance survey using Be-7 further reduced the candidate sites to 14 locations. Cores were obtained at all 14 locations. Of these, 5 sites were selected for chemical analysis based on the quality of the radionuclide profile and the location in the river, providing information on contaminant levels over the last 50 to 60 years at locations from RM1.4 to RM12.6, encompassing nearly two-thirds of the Lower Passaic River.
- Radionuclide levels were readily quantified and provide a sound basis for establishing contaminant chronologies at each of the 5 coring locations.
- Chemical analyses were obtained from each of the dated sediment cores to provide well resolved contaminant histories at each location. The interpretation of these analyses is the subject of Section 3 of this data evaluation report.

2.4.2 2005 and 2007 Upper Passaic Coring Program

A description of the 2005 and 2007 Upper Passaic Coring Programs and a summary of the resulting datasets are described in the subsequent subsections.

2.4.2.1 2007 Dundee Lake Coring Program

Additional sediment cores were collected by USEPA from nine locations in the Upper Passaic River, between the Dundee Dam and the Interstate Route 80 Bridge, for dating and analysis. These cores were intended to assess historical and current contaminant loading to the Lower Passaic River from the Upper Passaic River. Locations were identified based on bathymetric data, historical satellite photographs showing shoreline development, literature references, and field reconnaissance conducted on December 14, 2006. These data resources were used to select coring locations with potentially undisturbed silt deposits in net depositional areas.

Dated sediment samples from above the head of tide, along with estimates of the suspended solid load, were used to determine the load of particle-borne contaminants contributed from the Upper Passaic River to the Lower Passaic River at the time corresponding to the dated core interval. To confirm that this approach was appropriate, filtered suspended matter samples and sediment trap samples obtained just below Dundee Dam (RM17.1, representing Upper Passaic River water that had not been mixed with Lower Passaic River water) were compared and were found to contain similar contaminant concentrations to the Be-7 bearing sediment core locations occupied above Dundee Dam (north of RM17.4). Refer to Data Evaluation Report No. 2 for further discussion of the Upper Passaic River loads.

At each location, a geological boring and co-located high resolution sediment core were collected. The geological boring was split horizontally to examine geologic sequences and determine if the core was collected from a silt deposit location. Four locations were classified as potentially depositional, and the corresponding co-located high resolution sediment cores were divided vertically into 2 cm and 4 cm intervals, yielding approximately 20 samples per core. Samples were shipped to a laboratory immediately for analysis for the following parameters: dioxin congeners, PCB congeners, PAH compounds, pesticides, metals including mercury and titanium, total organic carbon (TOC), particle size distribution, Cs-137, and Be-7 (core top sample only).

Based on an analysis of the resulting radiological data, two cores were eliminated from further consideration because the core top segment was not Be-7 bearing, indicating that the location did not contain recently-deposited sediments. As such, it was unlikely that the cores contained a continuous depositional history that could be accurately dated using radiological data from each interval of the core. As a result, the corresponding chemical analyses for these cores were halted. Chemical analyses were completed on the two remaining cores that possessed a Be-7 bearing core top. However, further evaluation of the Cs-137 data indicated that the radiological profile was discontinuous, suggesting that the sediments had been disturbed and that the core was not representative of a continuous depositional location. As a result, the 2007 Dundee Lake sediment core dataset addressed only a subset of its original goals and can be summarized as follows:

- Be-7 bearing surface sediments from two locations represent recent suspended matter concentrations on solids entering the Lower Passaic River from the Upper Passaic River in 2006.
- The dataset provides evidence of the scale of historical contaminant concentrations on suspended matter, based on the presence of Cs-137 in the deeper layers of one core. The Cs-137 levels were too low to establish a core chronology.

2.4.2.2 2005 Dundee Lake Coring Program

In addition to the cores obtained by USEPA in 2007, several cores were obtained by scientists from Rensselaer Polytechnic Institute (RPI) and Lamont-Doherty Earth Observatory (L-DEO) in September 2005. These cores were initially segmented and dried to permit long term storage while awaiting subsequent analysis. Two of the cores were shown to contain Be-7 and were subsequently successfully radiologically dated using Cs-137. Given that the 2007 Upper Passaic River program only partially achieved its goals, segments from the 2005 cores obtained by RPI and L-DEO were then analyzed for the USEPA Lower Passaic River investigation in 2007 and 2008, following the same protocols used for the USEPA high resolution sediment cores. In addition, a separate analysis was conducted to demonstrate the viability of the sample collection and processing procedures used by the RPI and L-DEO scientists. This was done on a series of separate sediment sample splits that were handled by both USEPA processing procedures as well as the drying procedures used by RPI and L-DEO. The samples were chemically analyzed following the standard Lower Passaic River procedures, thereby creating sample pairs differing only by the processing procedure. Note that all processing procedures described in this paragraph were performed in accordance with the USEPA-approved QAPP (Malcolm Pirnie, Inc., 2005b).

The 2005 Dundee Lake dated sediment cores provide the following information, satisfying the major goals for the Upper Passaic River coring.

- Be-7 bearing surface sediments were obtained from two locations to represent contaminant concentrations on suspended matter delivered to the Lower Passaic River at the Dundee Dam in 2005.
- The dataset provides a radionuclide-dated sediment core profile documenting historical contaminant concentrations on suspended matter entering the Lower Passaic River. In particular, the profile provides a basis to estimate the historical loads of all major contaminants to the Lower Passaic River going back to the 1960s.

3 EXAMINING THE SEDIMENT RECORD OF HISTORICAL CONTAMINATION

As described above, radionuclide chronologies for the sediment cores of the Lower Passaic River were established based on Cs-137 and Be-7. The following discussion describes the interpolation process to assign an approximate year of deposition to each depth in the core as well as the interpretation of the sediment record for several major contaminants of the Lower Passaic River.

3.1 Radiological Profiles for the 2005 High Resolution Cores from the Lower Passaic River

The sedimentation rate and a core chronology were established for five sediment cores from the Lower Passaic River collected in 2005, located at RM1.4, RM2.2, RM7.8, RM11, and RM12.6. As described previously, Cs-137 profiles were used to determine the depositional nature of the sediment cores and to place chronological tie-points between cores, the historical timeline and contamination events. Figure 3-1 illustrates the Cs-137 profile for the core located at RM11. This core represents the best Cs-137 profile among the five cores and has the highest Cs-137 peak (approximately 6 pCi/g), indicating it contains a large fraction of fine grained sediment and represents a consistently depositional area. The peak Cs-137 concentration is found at the depth of approximately 100 cm in the core. This point in the core was assigned a date of 1963, following the dating procedures described above. Be-7 was not measured in the surface layer of the core. However, since the core was collected from a Be-7 bearing location based on the 2005 reconnaissance survey conducted just 2 weeks prior, the upper-most core section was considered to be recently-deposited and the core surface was assigned a date of 2005 (the year of the core collection).

The sediment thickness between the core surface and the depth of the Cs-137 maximum was divided by the time between the two intervals (42 years) to determine a sedimentation rate (cm/yr), assuming a constant rate of sediment accumulation during this period. For the core located at RM11, the sedimentation rate between 1963 and 2005 is approximately 2.3 cm/yr. Sediment sample intervals between these horizons were assigned an approximate year of deposition based upon this rate. A second deposition rate was determined for the deeper segments in the core, using the 1954 and 1963 horizons (the difference in the sedimentation rates between the upper and lower portions of the core will be discussed later in this section). Specifically the distance between the mid-point of the interval containing the Cs-137 maximum (1963) and the bottom of the first segment with detectable levels of Cs-137 (1954) represented the total amount of deposition that occurred over this time period, approximately 70 cm. The elapsed time between the intervals is 9 years. These values yield a deposition rate of about 8 cm/yr or about 4 times greater than the post-1963 period in this core. Applying these deposition rates to the appropriate core segments provides an approximate year of deposition for all depths in the core. Plotting the Cs-137 profile as a function of approximate year of deposition rather than depth yields the profile shown on the right side of Figure 3-1.

The purpose of this figure is to show how the use of the multiple Cs-137 event horizons adjusts the core chronology to account for variable deposition rates. These adjustments provide a more accurate interpolation of the conditions captured by the core with respect to time. When done across multiple cores, these adjustments help to ensure that cross-core comparisons are made for relatively well defined periods of time, *i.e.*, that a cross-core comparison of 1970s-age sediments is in reality a comparison of sediments of this period. Given the variation of sedimentation rates both within and among cores, these horizons provide an accurate basis for consistent comparisons across the core chronologies.

The other four cores were dated in a similar fashion to the RM11 core. The 1963 time horizon can be identified in all five cores (dashed black line in Figure 3-2). In each core, the Cs-137 maximum is found relatively deep within the core, with a gradual decrease in the Cs-137 concentration in the overlying layers moving to the top of the core. Note the absolute difference in the depth of this horizon across the cores; the range is from about 90 to 420 cm. Yet because of the consistent presence of the Cs-137 maximum in each core, the profiles can be accurately normalized to a consistent timeframe, as will be evident in later discussions.

The 1954 time horizon can be identified in only three out of the five cores (dotted gray line in Figure 3-2). Cores at RM7.8 and RM12.6 did not capture pre-1954 material. In the case of the core at RM12.6, the sediment record suggests that little or no pre-1963 material was present at the location given that the peak Cs-137 concentration of approximately 3 pCi/g lies directly above coarse-grained, non-Cs-137 bearing material. It is presumed that this underlying sediment is quite old given the absence of Cs-137.

Also notable among the cores containing the 1954 horizon is the change in the sediment deposition rate from the period 1954 to 1963 versus the period 1963 to present day (the core top). In each instance, the 1954 to 1963 deposition rate is 3 to 4 times greater than the post-1963 period. While the reason for this change is not known, it is likely the reduction in sedimentation rate reflects the rapid changes in the Lower Passaic River channel geometry following the effective cessation of maintenance dredging around 1950. Specifically, during the first decade or so after dredging ceased, sediments deposited rapidly throughout the river due to the slow water velocities that would have existed with the deep navigation channel. As the channel filled in during later years, the shallower channel would have caused water velocities to increase and deposition rates would have slowed in response. The well-known input history of Cs-137 to the river system provides a high degree of accuracy in dating sediment layers during this period and lends a high degree of confidence to the adjustment in deposition rates.

All five locations were shown to have Be-7-bearing material present at the coring site based on the field reconnaissance survey conducted just a few weeks prior to core collection. Based on this survey, all five cores were thought to contain recently-deposited sediments (*i.e.,* circa 2004-2005) at the core top. However, for the core at RM12.6, the age assignment of the top segment of the core was adjusted to align more closely with the upper portion of the 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) concentration profiles of the cores at RM11 and RM7.8. The two latter cores both exhibit a multi-fold increase in the 2,3,7,8-TCDD concentration on the second segment from the top of the core, corresponding to an apparent circa 2000 2,3,7,8-TCDD release event. A similar increase in the 2,3,7,8-TCDD concentration occurs in the uppermost layer of the core at RM12.6.

Since the uppermost layer of the RM12.6 core and the second interval from the RM7.8 and RM11 cores all displayed the 2,3,7,8-TCDD concentration change as well as a corresponding change in the mixture of dioxin congeners[4], it was inferred that the very top layer of the core at RM12.6 was either very thin or missing, so that the uppermost layer found in the RM12.6 core can be assumed to correspond in age to the second interval of the RM7.8 and RM11 cores. The surface of the RM12.6 core was assigned an age of 2002, thereby placing the large 2,3,7,8,-TCDD event at circa 2000 in all three cores. Figure 3-3 shows a detailed plot of 2,3,7,8-TCDD concentrations for the last 25 years of deposition at each coring site based on the Cs-137 dating described above. The plot trace for RM12.6 has been adjusted as described above. The three- to four-fold increase in 2,3,7,8-TCDD concentrations relative to the 1995 interval is evident in all three cores above RM7. This change in concentration and the change in the relative distribution of the dioxin congeners are the basis for the adjustment in the year assignment for the core at RM12.6. Also of note in the plot is the essentially complete recovery to 1995 concentrations for Be-7 bearing sediments collected at these coring sites in 2007 (described further below). This is considered direct evidence for the cessation of the release. It can be observed that no other contaminants show an increase in concentration at the circa 2000 horizon (as can be seen in Figures 3-7 through 3-13).

A detailed discussion of the spike of 2,3,7,8-TCDD concentration at RM7.8, RM11, and RM12.6 in circa 2000 is outside the scope of this report. Its inclusion here is solely for the purpose of improving the dating agreement across cores.

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[4] Described in Section 3.2.1.2 and shown in the right-hand panel in Figure 3-6.

3.2 Downcore Profiles and Contaminant History

As described in the preceding section, the five cores obtained by the USEPA each have an interpretable radionuclide chronology that permits the assignment of the approximate year of deposition to each segment in the core. The cores also have sufficient vertical resolution to provide a detailed chronology of contaminant concentrations on settling solids, which in turn can be used to infer historical loads borne by the river. This section discusses the contaminant chronologies of the 2005 high resolution cores along with some more recently collected samples and some of the results of the 1995 Tierra Solutions, Inc. (TSI) coring survey.

The period of interest captured by the five cores, between 2005 and approximately 1940, has been augmented by a subsequent 2007 sampling event. In 2007, a survey of recently-deposited sediments over the entire Lower Passaic River was conducted by obtaining Be-7 bearing sediments (0 to 2 cm) at locations throughout the 17-mile stretch of the Lower Passaic River as well as from above Dundee Dam. As part of this survey, Be-7-bearing samples were collected at or close to the five high resolution coring sites, effectively providing an additional sediment layer above the 2005 horizon in each core.

In addition to the interpretation of the five cores described above, USEPA also evaluated a subset of the cores obtained by TSI in 1995. The survey conducted by TSI was limited to RM1 to RM7. USEPA identified 14 cores (see Table 3-1) with Cs-137 profiles that partially satisfied the criteria described in Section 2.2. While the TSI cores yielded Cs-137 profiles that were considered indicative of steady sediment accumulation, the core segmentation for chemical analysis was much coarser and so can only provide limited resolution of contaminant histories at the coring locations. Nonetheless, the cores provide supporting evidence that can be interpreted in the context of the more detailed 2005 cores. This discussion will use the five longest cores of the 14 TSI core locations, extending from RM2.7 to RM6.3 in a comparison with the 2005 observations. These cores provide information on the entire post-1954 period as documented by their Cs-137 profiles, as well as some time prior to 1954. The locations of the five TSI cores used in the comparison are shown on Figure 1-2.

As noted previously, this data evaluation report is focused on the history of contamination as recorded in the sediments, and so only examines a limited number of cores where conditions preserved the history in a “readable” form. However, extensive sediment core data from the 1991, 1993, and 1995 sampling programs are available to characterize the general level of sediment contamination throughout much of the region between RM1 and RM7. As part of the preparation of this report, the chemical profiles of each historical core were plotted to evaluate the depositional environment at the core locations. Cadmium, copper, lead, mercury, total petroleum hydrocarbons (TPH), low molecular weight (LMW) PAHs, high molecular weight (HMW) PAHs, dieldrin, Total PCBs, 2,3,7,8-TCDD, Total DDx [the sum of 4,4’- dichlorodiphenyltrichloroethane (4,4’-DDT) and its metabolites 4,4’-dichlorodiphenyldichloroethane (4,4’-DDD), and 4,4’-dichlorodiphenyldichloroethylene (4,4’-DDE)], and Cs-137 were plotted for 120 historical cores. These plots can be found in Attachment A.

In the following discussion, example compounds from four major contaminant groups are examined, including dioxins (2,3,7,8-TCDD), PCBs, pesticides, and heavy metals. In each discussion, the 2005 results are provided first, followed by the additional results for the 2007 program. For one compound in each contaminant group, an additional comparison is made between the 2005 core results and the five TSI locations mentioned above.

3.2.1 Tetrachlorodibenzo-p-dioxin (TCDD) Profiles

The results for 2,3,7,8-TCDD for the five dated sediment cores collected in 2005 are presented as downcore profiles versus approximate year of deposition in Figure 3-4. The year assignments for these and all subsequent representations of these cores were derived as described in Section 3.1. The downcore profile for the core at RM11, which provides the most well-resolved core chronology, is shown on the left-most panel of Figure 3-4. The middle panel of the figure shows the results from all the five 2005 high resolution cores superimposed on the same chart. While there are some differences among the profiles, the most important observation is that they all show similar trends and magnitude of contaminant concentration despite the distances that separate the cores. This observation, that contaminant concentrations and trends through time, particularly post-1975, are consistent from RM1.4 to RM12.6, forms the foundation for the geochemical understanding of the Lower Passaic River and is further discussed below.

In all five cores, the highest 2,3,7,8-TCDD concentration occurs between the mid-1950s and the mid-1960s. The maximum value is between 6 and 20 micrograms per kilograms of sediment (µg/kg) across all five cores, despite their distances from each other and the known sources[5] of 2,3,7,8-TCDD contamination to the river. The occurrence of the maximum concentrations during this period is consistent with Bopp *et al.* (1991) who showed that the highest TCDD concentration occurs in sediment dating to the 1950s and 1960s, based on the geochronology of a sediment core from Newark Bay. This peak concentration was attributed by Bopp *et al.* (1991) to coincide with the peak production and discharge of TCDD into the Passaic River in the 1950s and 1960s. The two downstream-most cores (RM1.4 and RM2.2) show 2,3,7,8-TCDD maxima that occur earlier and are less broad than those indicated by the three more upstream locations. Some of these differences may reflect differences in short term deposition rates.

While all five cores document the period of greatest 2,3,7,8-TCDD discharge, the recent conditions are more pertinent to the FFS since current trends form the basis for estimating future conditions. Notably for all five cores, the concentration of 2,3,7,8-TCDD is slowly declining from 1980s to the present. The rate of decline, as suggested by the roughly parallel trends on these log-scale plots, is approximately the same at all five locations, indicating that the recovery rate throughout the river is closely linked. During this period, the 2,3,7,8-TCDD concentrations tracked quite closely (approximately a factor of two variation[6] among the 5 cores) for the last 20 years. The rate of decline during this period

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[5] Although the 80 Lister Avenue site represents a well-documented discharge of 2,3,7,8-TCDD to the river, historically another herbicide manufacturer, Montrose Chemical, was located immediately adjacent to the Diamond Alkali Company.

[6] The concept of a factor of two variation is used extensively throughout this discussion as measure of the agreement across cores. The term “a factor of two” refers to the ratio of the maximum value over the minimum value in a set of values. If only two values were involved (as in a split sample duplicate pair), this would be equivalent to a relative percent difference of 66 percent. However, when

(exclusive of the circa 2000 event) is quite slow. As can be seen in the right hand panel of Figure 3-4 (or in Figure 3-3), concentrations in 2007 [150 to 500 nanograms per kilograms of sediment, (ng/kg)] are roughly half of what was observed in 1980 (400 to 800 ng/kg), suggesting a “half time” for the decline of 2,3,7,8-TCDD concentrations on the order of 30 years.[7]

A closer look at the core profiles shows that the concentrations for the cores at RM1.4 and RM12.6 are consistently lower than that of the other cores, especially post-1990 (right-most panel of Figure 3-4). These two cores represent the downstream-most (near Newark Bay) and upstream-most locations. As such, they are the first locations to be affected by solids entering the Lower Passaic River from Newark Bay and from the Upper Passaic River, respectively. The three sediment cores located between these two locations show still greater similarity among concentrations and trends than the entire group of five cores.

This observation was further supported by the Be-7 bearing surface sediment concentrations obtained in 2007, some of which are plotted in the right hand panel of Figure 3-4. The locations at RM1.4 and RM12.6 are in areas where steep concentration gradients occur as solids from the main part of the Lower Passaic River are mixed with Newark Bay solids (RM1.4) and Upper Passaic River solids (RM12.6) (see Data Evaluation Report No. 4). Between these locations, the 2,3,7,8-TCDD concentrations for the other three cores, which are located at RM2.2, RM7.8, and RM11, have been in very close agreement since 1980, excluding the event circa 2000 previously discussed. Similarly close agreement is

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this degree of variability is observed across multiple cores, a much higher level of agreement can be inferred. Specifically when used in the context of this analysis, all values (typically five) fall within this factor of two range, meaning that most value pairs differ by much less and agree more closely than the two extreme values. Typical coefficients of variance (defined as the standard deviation over the mean) are the order of 25 percent or less. For example, the Total PAH values for the year 2000 differ by slightly less than a factor of two (maximum/minimum = 1.7, see Figure 3-9a, right panel) with a coefficient of variance of 21 percent. Given that the comparison is among samples from cores located miles apart and from variable depths assigned only by radionuclide dating, this is constitutes a very high degree of agreement and bears out the robustness of the radionuclide-based core dating technique. Note that the typical acceptable level of agreement among split sample duplicates (*i.e.*, two allotments from the same mixing bowl) as suggested by USEPA guidance is an RPD of 40 percent, equivalent to a factor of 1.5.

[7] The use of the term “half time” in this sense is not to imply decay or destruction of 2,3,7,8-TCDD over time, akin to the decay of a radionuclide. Rather, the term here is used to simply express a rate for the decline of 2,3,7,8-TCDD concentrations in the solids accumulating at each coring location. Specifically, “half time” is the time necessary for the 2,3,7,8-TCDD concentration to decline to half of its current value. The processes that affect the decline are multifold, including many of the fluxes and processes that occur in an urban estuary. The “half time” expression is just a means to encompass these processes and note their net effect on concentration through time.

observed for all of the other contaminants examined in this FFS, as discussed below. This indicates that tidal energies have been and continue to be sufficient to minimize concentration gradients and maintain a narrow range in concentration for settling suspended solids at these three locations over the 27-year period ending in 2007. The analysis of Be-7-bearing sediments presented in Data Evaluation Report No. 4 indicates that this area extends from RM2 to RM12.

3.2.1.1 Other Lines of Evidence Regarding 2,3,7,8-TCDD

The observations based on the five 2005 cores are supported by other lines of evidence: 1) 2007 Be-7-bearing surface sediment data (see Data Evaluation Report No. 4); and 2) the historical data collected by TSI from RM1 to RM7 in 1995, discussed below.

As part of the 1995 investigation conducted by TSI under USEPA oversight, TSI obtained cores from about 95 sites. Of these, 14 cores had detectable levels of Be-7, direct evidence for the presence of recently-deposited sediments at these locations. The cores from these sites were reviewed for their Cs-137 profiles as potentially dateable cores. Of these, five were selected based on the quality of their Cs-137 profile (satisfying the criteria in Section 2.2) and having a declining 2,3,7,8-TCDD profile near the core bottom, indicating that the core had captured pre-1940 conditions. These five cores are located at RM2.7, RM3.1, RM4.0, RM4.5, and RM6.3.

Figure 3-5 compares the results from the 2005 coring effort with the profiles from these five cores. While the 2005 cores were sufficiently well resolved to permit useful approximate year of deposition assignments to individual core segments, the 1995 TSI cores had thicker core segments and so approximate year of deposition assignments were not made. This reflects the coarser resolution of the chemical analyses relative to the radionuclide analyses within these cores, as described above. Nonetheless, the 1995 TSI cores are consistent with the observations made from the 2005 cores.

In all five cases, the 2,3,7,8-TCDD maximum occurs with or before the Cs-137 maximum. This is similar to the 2005 cores, in particular to the closest of the 2005 cores at RM1.4 and RM2.2, which both showed pre-1963 2,3,7,8-TCDD maxima. (Note that the 2005 core at RM7.8 was not fully analyzed for this period.) Additionally, four of the five 1995 core maximum values were in the range of 5 to 20 µg/kg, similar to that of the 2005 cores (6 to 20 µg/kg). Only the core at RM2.7 fell outside this range. Its maximum value of nearly 100 µg/kg is not surprising given its proximity to the known discharge from the 80 Lister Avenue facility,

Like the 2005 USEPA cores, the 1995 TSI cores also show a decline from the maximum to the surface. While the 1995 TSI cores do not provide sufficient resolution to permit an accurate assessment of the post-1980 period for comparison against the 2005 cores (the 1995 cores typically only have four samples from the circa 1960 maximum to the surface), three of the 5 show a slowing rate of recovery, similar to the 2005 cores.

Lastly, all five TSI cores show a surface concentration of 0.15 to 0.3 µg/kg 2,3,7,8-TCDD, well within the range of the 2007 Be-7-bearing surface sediments collected at or near the 2005 coring sites. This is also within the range of circa 1995 values obtained from the 2005 core profiles (0.1 to 0.3 µg/kg). The observation that Be-7-bearing surface sediments in 1995 are essentially the same as those obtained in 2007 indicates a very slow rate of recovery for 2,3,7,8-TCDD concentrations. This is entirely consistent with the estimated rate of decline derived from the dated 2005 cores alone.

3.2.1.2 Ratio of 2,3,7,8-TCDD to Total Tetrachlorodibenzo-p-dioxin (Total TCDD)

The dated sediment cores also provide information on 2,3,7,8-TCDD in addition to the trend of concentration with time. A study by Chaky (2003) showed the usefulness of examining the ratio of 2,3,7,8-TCDD to Total TCDD in tracing the impact of Passaic River dioxins throughout metropolitan New York City harbor. Following this lead, downcore profiles of the ratio of 2,3,7,8-TCDD/Total TCDD were generated for each of the USEPA 2005 cores. The results are shown in Figure 3-6. Note that the layout is the same as that of Figure 3-4. This layout will be used for the presentation of the 2005 core results throughout this data evaluation report.

The left hand panel shows that the ratio of 2,3,7,8-TCDD/Total TCDD has been around 0.7 for three of the five post-1990 core intervals, with the exceptions associated with the core segments closest to the year 2000. As noted previously, the discussion of the circa 2000 event is outside the scope of this FFS. The value of 0.7 indicates that for the dated sediment core at RM11.6, 2,3,7,8-TCDD represents 70 percent of the Total TCDD concentration in most of the post-1990 deposition. The second panel in the figure shows the ratio for the other dated cores in addition to the core at RM11.6. The profiles show that throughout the Lower Passaic River, the ratio has remained within the range of 0.58 to 0.82 since 1980. The profiles also show that a high ratio of 2,3,7,8-TCDD/Total TCDD (greater than 0.58) has persisted throughout the Lower Passaic River since the 1950s, as recorded by these cores. These high values should be contrasted against the Chaky (2003) observations for urban runoff, sewage discharges, and atmospheric deposition, all of which yield ratios of 0.04 to 0.06 (more than an order of magnitude lower)[8]. The observations of low 2,3,7,8-TCDD/Total TCDD ratios by Chaky (2003) in potential external loads to the Lower Passaic River were borne out by the USEPA 2007-2008 field program which sampled tributaries, combined sewer overflows (CSOs) and stormwater outfalls (SWOs) throughout the Lower Passaic River area and obtained ratios typically less than 0.1 (discussed in Data Evaluation Report No. 2).

The consistency and uniqueness of this ratio through time as documented by the 2005 cores shows that Lower Passaic River 2,3,7,8,-TCDD contamination has been dominated by industrial sources for the last 50 years. It is evident in the pre-1950 deposition in these cores (see the middle panel of Figure 3-6) that the 2,3,7,8-TCDD/Total TCDD ratio prior to 1950 was at or close to the range of 0.04 to 0.06, commensurate with 2,3,7,8-TCDD concentrations on the order of 0.01 µg/kg (see Figure 3-4). These values are characteristic of conditions prior to the onset of major discharges of 2,3,7,8-TCDD, and can be

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[8] Note that a 2,3,7,8-TCDD/Total TCDD ratio of 0.04 indicates that 2,3,7,8-TCDD comprises just 4 percent of the Total TCDD concentration in a sample.

attributed to sources like atmospheric deposition and urban runoff, based on Chaky (2003). The observation that the ratio has been so consistent since about 1980 is indicative of the extensive tidal mixing of suspended solids prior to deposition. The close agreement among the cores with respect to concentration during this period, as discussed above, supports this indication as well.

3.2.2 Integration of Observations Concerning 2,3,7,8-TCDD

The observations of 2,3,7,8-TCDD concentrations and the 2,3,7,8-TCDD/Total TCDD ratio in the 2005 dated sediment cores are supported by the 2007-2008 USEPA surveys and the 1995 TSI coring results. The 2005 coring results provide both the spatial and temporal variation of 2,3,7,8-TCDD concentrations, which in turn lead to several very significant observations concerning the Lower Passaic River. As mentioned previously, the observation that surface contaminant concentrations and trends through time are consistent from RM1.4 to RM12.6 forms the foundation for the geochemical understanding of the Lower Passaic River. Specifically, these observations can only be explained by a very hydrodynamically active river, where suspended solids are mixed over long distances prior to permanent deposition. This can be accomplished by either extensive mixing within the water column prior to deposition or by extensive settling and redeposition combined with water column mixing, repeatedly reworking settled solids. In either case, concentration gradients are largely eradicated over relatively short periods of time. The close agreement of Be-7 bearing sediments over long distances suggests this process may work as rapidly as a few Be-7 half-lives (6 months to a year).

An upper bound on the mixing timeframe is suggested by the older, less resolved core segments. In this instance, the core records from the late 1960s show substantive differences in 2,3,7,8-TCDD concentrations between the upstream and downstream cores. However, by 1975, or less than 10 years later, concentrations at all coring locations are in close agreement, indicating an eradication of the concentration gradient from RM1.4 to RM12.6 within that time (see Figure 3-4, middle panel). Thus the observation that recently-deposited surface sediments exhibit similar levels of contamination between

RM2 and RM12 is attributed to mixing within the RM2 to RM12 interval, with gradients due to local discharges dissipated in roughly 10 years or less.

The history of contamination recorded by the dated sediment cores was also used to estimate the rate of decline of the concentration of 2,3,7,8-TCDD since about 1980, when industrial loads to the Lower Passaic River are thought to have subsided. All five cores yield consistent chronologies that suggest a “half time” on the order of 30 years for 2,3,7,8-TCDD concentrations on recently-deposited sediments, indicative of very slow recovery.

3.2.3 PAH Profiles

Downcore profiles for Total PAHs are presented in Figure 3-9a for the 2005 high resolution cores. Total PAHs were present in nearly all sediment samples at nearly all depths. In all five cores, Total PAH concentrations increase slightly with depth. However, maximum core concentrations are achieved at the core bottom, with no decline for the deepest sediments, unlike 2,3,7,8-TCDD and Total PCBs. Also unlike 2,3,7,8-TCDD and Total PCBs, the Total PAH concentration from 1980s to the present does not decline measurably. Within-year Total PAH concentrations typically vary by a factor of two from 1980 to 2005 (Figure 3-9a) but with no particular trend with time, suggesting that the Total PAH contaminant load to the Lower Passaic River has not changed significantly over this period.

Higher Total PAH concentrations are observed in the 1960s with typical concentrations near 90,000 µg/kg, roughly two times greater than those observed post-1980, with a median concentration near 40,000 µg/kg (Figure 3-9a). HMW PAHs account for approximately 80 percent of the Total PAH concentration. Upon closer inspection of the HMW PAH profiles and the LMW PAH profiles (Figures 3-9b and 3-9c), it is apparent that the relative relationships among cores have remained constant since about 1970, and all five cores show little trend in their absolute concentrations (right hand panel of Figures 3-9b and 3-9c). The lack of trend within the cores and consistent relationship among the cores can be attributed to the extent of tidal mixing and the observation that

PAH concentrations in solids delivered by Upper Passaic River and Newark Bay are similar to those found in the Lower Passaic River. Thus, unlike 2,3,7,8-TCDD, there is no large source of low PAH solids to the Lower Passaic River that might serve to lower PAH concentrations over time. This is confirmed by the results from the Be-7-bearing sediments collected in 2007 from the entire length of the Lower Passaic River, which show little difference between Lower Passaic and Upper Passaic River samples, and only minor differences between Newark Bay and the Lower Passaic River (see Data Evaluation Report No. 4). Without differences among these solids sources, there is no basis to create concentration gradients like those observed for 2,3,7,8-TCDD and to a lesser extent, Total PCBs. The latter two contaminants both have measureable gradients along the Lower Passaic River, higher concentration in the surface sediments of the Lower Passaic River relative to the external sources, and declining concentrations with time in the high resolution cores.

Select individual PAH compounds are presented, one from the LMW PAH group (Phenanthrene) and two from the HMW PAH group (Benzo[a]pyrene and Fluoranthene), in Figures 3-9d to 3-9f. The individual PAH compounds show similar trends to the Total PAH profile. These profiles further reinforce the similarity of PAH concentrations and PAH patterns among the five coring sites since both the trend of the individual concentrations and the relationships among the cores are consistent across PAH compounds.

The five 2005 high resolution cores were plotted adjacent to the five deep 1995 TSI cores for comparison in Figure 3-10. An important aspect of the sediment history is captured by the deeper TSI cores, which extend fairly far below the 1954 horizon and are generally deeper than the 2005 USEPA cores. The observation of the PAH maximum at the bottom of several of the 2005 USEPA cores is consistent with that observed in four of the five TSI cores. The exceptions in the 2005 USEPA cores occur in both of the upstream locations (RM11 and RM12.6). While the reason for the exception at RM11 is not known, the sedimentological evidence at RM12.6 indicates that the lowest layer in this core is physically very different from the overlying sediments and probably very old. The age of the underlying layer based on its physical properties suggests it may be glacial in age, so low levels of PAHs would be expected in this layer. In all of the other USEPA and TSI cores, which are located below RM8, the bottom core maxima suggest that maximum PAH discharges to the Lower Passaic River took place prior to 1950. This suggestion is supported by the core at RM4.5 which shows a clear PAH maximum about 3 feet below the Cs-137 maximum, followed by a decline to nominal concentrations below 13 ft, more than twice the depth of the Cs-137 maximum in the core. The TSI cores also confirm the other important observation from the 2005 USEPA cores concerning post-1970 deposition. In four of the five TSI cores, there has been little decline in the PAH concentration since the 1963 Cs-137 maximum.

Overall, the profiles of Total PAH concentrations in the cores are consistent with the inferences drawn from the 2,3,7,8-TCDD and PCB profiles regarding sources and tidal mixing within the Lower Passaic River. However, PAH concentration differences among solids sources are so small that little concentration differences among areas or over the last 35 years are observed. However, this has one other implication, specifically that the sources of PAH contamination to the Lower Passaic River are not abating.

3.2.4 Pesticide Profiles

The evaluation of the 2005 high resolution core pesticide data focuses on the following pesticide compounds: DDE, dieldrin, and trans-chlordane, which have been identified as COPECs. Dated sediment core profiles for these compounds are provided in Figures 3-11a through 3-11c.

DDE is examined in detail here as a surrogate for the sum of DDT and its metabolites. Analytical interferences often affect quantitation of these pesticide forms and DDE was the least impacted by analytical issues based on the data quality review and its consistent behavior in the profiles. DDE concentrations are shown in Figure 3-11a. The distribution of the core maxima are similar to those of Total PCBs and 2,3,7,8-TCDD. Notably the maximum values extend over a greater period than those for Total PCBs and 2,3,7,8-TCDD, with high values as late as 1970.DDE concentrations have slowly declined over the past 25 years. Since 1990, the range of concentrations within a given year have generally varied by about a factor of two, similar to the observations for Total PCBs and 2,3,7,8-TCDD during this period. The slowly declining concentration trend is confirmed by the 2007 surface sediment concentrations, where concentrations are only slightly lower than 2005.

The dated core results for dieldrin (shown in the left and center panels of Figure 3-11b) show peak concentrations in the 1960s with concentrations at RM11 and RM12.6 about 5 times greater than those observed downstream. This difference is large enough and sustained enough to indicate the existence of a significant upriver source of dieldrin during this period. While dieldrin concentrations decline from their 1960s maxima, this trend does not continue after 1985, and concentration begin to increase in the upper portions of all five cores, increasing about five-fold from 1985 to 2005. This increasing trend is continued by the 2007 Be-7 bearing samples, as shown in the third panel of Figure 3-11b. Dieldrin is the only contaminant with a consistent increase in concentration across all five cores in the post-1980 period. As discussed in Data Evaluation Report No. 2, the 2007 sampling results for the Third River (at RM11) and the Saddle River (at RM15.4) both show elevated concentrations of dieldrin in suspended solids and Be-7-bearing sediments. Dieldrin concentrations in Upper Passaic River Be-7 bearing sediments are comparable to those observed in Lower Passaic River Be-7 bearing sediments. The dated sediment core results taken together with the Be-7 bearing sediment results, indicate that the Upper Passaic River, the Saddle River and the Third River are likely substantive external sources of dieldrin to the Lower Passaic River. Of these, it is likely that the Upper Passaic River is the most important source, simply because of the size of the flow from this tributary. This indication is quantitatively evaluated in Appendix C.

The observations that dated sediment core concentrations of dieldrin have trended roughly parallel since 1985 despite the presence of ongoing sources is further indication of the extent and rapidity of mixing within the river. The river has further reduced the variability from 1995, when the variation among cores was an order of magnitude variation to the most recent samples, which vary about a factor of three. This decline in variability has occurred even as the overall mean concentration has roughly doubled since 1995.

Trans (or gamma) Chlordane concentrations follow a trend that falls between the behaviors of DDE and Total PAHs (see Figure 3-11c). Trans Chlordane has a broad maximum between 1960 and 1975 with approximately a factor of three variations across all five cores, followed by a slow rate of decline such that changes from 1985 to the present are barely detectable. Variation among cores is reduced during the post 1975 period, with a typical range of a factor of two and often less. Like dieldrin, the concentrations in the Upper Passaic cores are comparable to those of the Lower Passaic River (see Data Evaluation Report No. 2).

Figure 3-12 presents a comparison of dieldrin for the 1995 TSI and 2005 high resolution cores. The dieldrin profiles for 1995 have notably poor resolution (fewer data points with depth than other contaminants, particularly in top few feet) and so provide little information for the most recent deposition. Additionally, since the most recent rise takes place since 1985, the TSI cores were collected too close to the change in slope to exhibit the increase given their resolution. Nonetheless, the 1995 cores do provide support for several features seen in the 2005 cores. The surface concentrations for all the cores from these two datasets are comparable, in the range of 5 to 20 µg/kg. The range in peak concentrations in the 1995 cores (50 to 250 µg/kg) is essentially the same as the range observed in the 2005 cores (40 to 240 µg/kg). Finally, the maximum in the TSI cores occur around the Cs-137 maximum, consistent with the 1960s maxima seen in the 2005 cores.

In summary, the variation of these pesticides over time, although clearly not the same as that for the other organic compounds, still identify the 1960s as the period of maximum release. Unlike the other chlorinated organic compounds 2,3,7,8,-TCDD and Total PCBs, the trends for the pesticides do not decline appreciably over time. The pesticide temporal trends are closer to that of the PAHs. One pesticide, dieldrin, clearly shows an increasing trend with time, indicating an increase in external loads during the post-1985 period. The pesticide results also support the supposition of extensive tidal mixing throughout the Lower Passaic River. The historical sources of these pesticides, especially dieldrin and Chlordane, are unlikely to be the same as those for 2,3,7,8-TCDD or Total PCBs or PAHs and yet difference among the core profiles for post-1980 deposition remain minor in comparison to their historical maxima. This observation is further evidence for the importance of tidal mixing in the control of depositing solids throughout the Lower Passaic River.

3.2.5 Metals Profiles

For the 2005 high resolution cores, metals analyses were performed on every core segment in the five dated sediment cores, typically 40 samples per core. In order to provide similar temporal resolution to the organic analytes (at nominally 20 samples per core), reported metal concentrations were averaged in pairs to create the same sediment intervals as the organic analyses. Dated sediment core profiles for cadmium, chromium, copper, lead, and mercury are presented in (Figures 3-13a to 3-13e). In general, metals concentrations varied approximately one order of magnitude or less over time with maximum concentrations occurring in the 1950s and 1960s, depending on metal and location. Note that the concentration axis is linear on Figures 3-13a to 3-13e, unlike the concentration axes for the organic compounds. For all the metals examined except for lead, the maximum concentration for the two upper river cores (RM11 and RM12.6) is higher than those in the lower portion of the river (RM1.4 to RM7.8). For lead, the highest peak concentration was found at RM7.8 followed by the cores at RM11 and RM12.6. Additionally, the maximum concentration consistently occurred earlier downstream relative to upstream, with maximum concentrations occurring in the mid-1950s at RM1.4 and RM2.2 followed by RM7.8 and RM11 and ending at RM12.6 in the mid-1960s. As described previously, all of the dated sediment cores with 1954 and 1963 Cs-137 horizons show a decline in deposition rate after 1963.

While this observation is of some interest relating to historical loads, of far greater importance is the convergence of the metals concentrations across all five cores during the post-1980 period. This is the same convergence observed for all of the organic compound classes, and again is considered indicative the effectiveness of tidal mixing and the absence of major external sources. Also similar is the very gradual decline in concentrations since 1980 for all five metals examined. This trend also parallels the trend observed for most organics and suggests a similar causative mechanism for contamination observed in depositing solids for all the compounds and metals examined here (*i.e.*, resuspension of contaminated Lower Passaic River sediments).

Like all of the organic interpretations presented here, the metals observations from the 2005 USEPA cores are supported by the 1995 TSI cores. Figure 3-14 shows a comparison between the 1995 TSI and 2005 high resolution cores for mercury. Similar to the observation on the other contaminants, the mercury surface concentration of the 1995 TSI cores is comparable to that of the 2005 high resolution cores, approximately 1.5 to 3.5 milligrams per kilograms of sediment (mg/kg) for the 1995 cores *vs.* about 1 to 2 for the 2007 Be-7-bearing sediments. The 1995 TSI cores are poorly resolved and are subject to somewhat greater analytical uncertainty than the 2005 USEPA cores (see the sample duplicate pair at RM6.3, depth of 9.5 ft). These results are too poorly resolved to confirm the trends in the mercury maximum with river mile and time seen in the USEPA cores.

3.2.6 PCB Profiles

In this and each of the remaining subsections under Section 3.2, the data presentations are provided in a parallel fashion to that shown for 2,3,7,8-TCDD. Downcore profiles for Total PCB are presented in Figure 3-7a for the 2005 high resolution cores. The left hand panel of Figure 3-7a shows the downcore profile of Total PCBs for the best dated core (RM11). All five cores are shown in the middle panel, and an expanded view of the top portion of the cores, along with the 2007 results are shown in the right hand panel. Similar to 2,3,7,8-TCDD, Total PCB profiles show peak concentrations in the late 1950s and early 1960s. The peak concentrations range from about 10,000 to 30,000 µg/kg. Also similar to 2,3,7,8-TCDD, the Total PCB concentration declines slowly in all cores from 1980 to the present. In any given time period within the dated cores, the variation among the cores is less than that observed for 2,3,7,8-TCDD, *i.e.*, approximately a factor of two.

The most recent Be-7 bearing samples (2007) exhibit somewhat greater variability. The Total PCB concentrations post-1980 have declined by about a factor of three but there has been almost no change between 1995 and 2007 (see the right hand panel of Figure 3-15a). Like 2,3,7,8-TCDD, there is a similar spatial pattern of the Total PCB, with lower concentrations at the upstream-most and downstream-most high resolution core locations after about 1990. However, the difference between the extremes and the middle river mile locations is less pronounced than that observed for 2,3,7,8-TCDD. The minimal scatter in the Total PCB concentrations among the profiles over different year suggests that the solids delivered by the Upper Passaic River and Newark Bay are fairly comparable in PCB concentration to the resuspended solids of the Lower Passaic River, resulting in smaller gradients across the entire Lower Passaic River. As is shown in Data Evaluation Report No. 4, the Be-7-bearing sediments show concentration gradients outside the RM2 to RM12 interval similar in direction to those suggested by the 2005 high resolution cores, but the gradients are only about a factor of two, not the orders of magnitude observed for 2,3,7,8-TCDD. Like 2,3,7,8-TCDD, the observations for Total PCBs support the conclusions about tidal mixing and the absence of major point source discharges in the Lower Passaic River.

Four PCB congeners are presented to examine the individual congeners. Two low molecular weight congeners (Ballschmiter and Zell [BZ] 52 and BZ61) and two high molecular weight PCBs (BZ110 and BZ180) were plotted in Figures 3-7b through 3-7e.[9] The individual PCB congeners followed similar trends to the Total PCB profile, indicating that the mixture of PCBs has remained fairly constant over time. From this it can be inferred that the congener mixtures in the sources of PCBs to the river have remained fairly consistent through time as well. Taken together with the concentration differences noted among the cores and the distribution of PCBs in Be-7-bearing sediments, these results suggest that the sediments of the main stem of the Lower Passaic River are more contaminated with PCBs relative to external sources over at least the last

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[10] This analysis compared the sum of detected PCB congeners with the sum of detected Aroclors for 10 low resolution core samples collected in 2006 from various locations in the Lower Passaic River. This analysis indicated the likelihood of a relatively small difference between the two methods for Lower Passaic River PCBs. The Aroclor method was on the order of 25 percent lower relative to the sum of PCB congeners. This difference was significant at about a 93 percent level of confidence. The summary statistics for this analysis are presented in Attachment B.

10 to 15 years, with solids containing lower PCB concentrations contributed by the Upper Passaic River and Newark Bay. Like the observations for 2,3,7,8-TCDD, the observations of PCBs in the tops of the 2005 cores indicate the absence of concentration gradients between RM2 and RM12, supporting the inference of rapid tidal mixing (see Data Evaluation Report No. 4).

A comparison between the five 1995 TSI cores identified previously and the 2005 high resolution cores is shown in Figure 3-8. The comparison was made for Total PCB only since the 1995 TSI cores were analyzed for PCB Aroclors and only a limited number of PCB congeners. Although the sum of Aroclors from the 1995 cores and the sum of PCB congeners from the 2005 cores are not exactly the same measurement, the sum of Aroclors can still be examined as a surrogate for the sum of PCB congeners. This premise was borne out by analysis of a subset of USEPA’s low resolution sediment cores wherein samples were analyzed for both PCB congeners and Aroclors.[10] A similar sum cannot be constructed from the 1995 congener data since too few congeners were reported to represent a true sum of all PCB congeners present. As was the case for the 2,3,7,8-TCDD comparison, the 1995 cores have relatively poor temporal resolution for PCBs but still allow for some useful comparisons.

Consistent with the 2005 cores, the 1995 cores also show PCB maxima occurring in the early 1960s. The magnitude of the peak is between 3,500 and 10,000 µg/kg, lower than the observations for the 2005 cores (10,000 to 30,000 µg/kg) but the variation in the values are similar (about a factor of three from minimum to maximum). The difference in the absolute magnitude of the core maximum can only partially be explained by differences in the analytical procedures (see footnote 9). More importantly, however, just like the 2005 high resolution cores, all 1995 TSI cores show a decline in concentration from the peak concentration to the top of the cores. The surface concentration of the 1995 cores is comparable to that of the 2005 high resolution cores, approximately 1,000 to

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[10] This analysis compared the sum of detected PCB congeners with the sum of detected Aroclors for 10 low resolution core samples collected in 2006 from various locations in the Lower Passaic River. This analysis indicated the likelihood of a relatively small difference between the two methods for Lower Passaic River PCBs. The Aroclor method was on the order of 25 percent lower relative to the sum of PCB congeners. This difference was significant at about a 93 percent level of confidence. The summary statistics for this analysis are presented in Attachment B.

2,000 µg/kg. Just as for 2,3,7,8-TCDD, the observations from the 1995 TSI cores directly support the observations from the more detailed 2005 cores.

3.3 Summary of the Contaminant History as Recorded in the Sediments and its Implications

The analysis of contaminant histories for the five compound classes examined above provides the following significant observations.

- Dated sediment cores provide a means to compare temporal variations in contamination over the entire length of the Lower Passaic River. The procedure to establish core chronologies is well established in the literature. Dated sediment cores were obtained by both USEPA and TSI (under USEPA oversight).
- The cores provided a means to examine a broad range of contaminants and their histories, including 2,3,7,8-TCDD, PCBs, PAHs, pesticides, and heavy metals.
- The results obtained from the USEPA 2005 high resolution cores are well supported by the 1995 TSI cores. Although the 1995 TSI cores lack temporal resolution, they still confirm the occurrence and magnitude of historical contaminant concentrations and the gradual decline in sediment concentrations since the peak periods.
- The results obtained from the USEPA 2005 high resolution cores are well supported by the 2007 Be-7-bearing sediment survey, which served to confirm the similarity of concentrations across from RM2 to RM12 in recently-deposited sediment indicated by the 2005 dated sediment cores. The 2007 results also confirmed the anticipated concentration trend for most contaminants in recently-deposited sediments predicted from the 2005 core profiles.
- The core profiles showed that all of the contaminants examined converge to a relatively narrow range of concentrations after about 1980. Typical intra-annual concentrations for a given analyte varied about a factor of two or less across dated sediment cores separated by as much as 11 miles, spanning about two-thirds of the entire length of the Lower Passaic River and a 25-year time span. This high level of agreement should be contrasted with the range of historical concentration

measurements of these contaminants, which often vary by orders of magnitude over short distances.

  - The observed narrow range in concentration across many contaminant types and across nearly two-thirds of the river is considered direct evidence of the extent and intensity of tidal mixing of solids prior to permanent deposition, and the absence of major external sources comprised of highly concentrated discharges (*i.e.*, no point sources).
  - This dynamic mixing condition has existed since at least since 1980, given the narrow range of concentrations in depositing sediments (*i.e.*, the narrow range in the dated sediment cores) that have existed since that time. Infilling of the channel by depositing sediments may be a factor, serving to increase water velocities that would then cause more thorough mixing of suspended solids in more recent times.

- The ratio of 2,3,7,8-TCDD to Total TCDD showed the sediment burden of 2,3,7,8-TCDD to be almost exclusively industrial in nature since the early 1950s. The core analysis combined with other USEPA sampling work showed that this signature ratio value does not occur in any of the external sources to the Lower Passaic River. See Data Evaluation Report No. 2 and in Data Evaluation Report No. 4.
- Most contaminant concentrations declined over time, but only slowly, with “half times” for the decline in sediment concentration on the order of 30 years for post-1980 deposition.
  - The parallel decline among many different compounds with many different sources over time implies that concentrations of these compounds in recently-deposited sediments are no longer governed by multiple sources but rather by a single causative process that governs organic and inorganic substances alike.
  - Based on a number of lines of evidence (as discussed throughout these data evaluation reports), including existing sediment contaminant concentrations, solids transport, and variations among bathymetric survey elevations, the single causative process sustaining these concentrations at

    the river's surface and in the depositing sediments captured by the high resolution cores is the resuspension of contaminated sediments of the Lower Passaic River.

- The strongest geochemical evidence for both resuspension and the intensity and extent of tidal mixing of solids is provided by 2,3,7,8-TCDD, which has the largest absolute differences between Lower Passaic River sediments and external solids sources and yet still follows the trends seen in the other, less varied contaminants. In particular, the dated sediment cores show close agreement in concentration from RM1.4 to RM12.6 for 2,3,7,8-TCDD since 1980 (excluding the circa 2000 event) paralleling the more detailed trend in 2,3,7,8-TCDD concentrations documented by the Be-7 bearing sediments collected in 2007 (see Data Evaluation Report No. 4).
- A few contaminants did not decline at all with time although they still exhibited a narrow range of concentration. These contaminants indicate the presence of important external sources but also show them to be sufficiently low in concentration that tidal mixing is able to distribute these loads across the Lower Passaic River, resulting in the characteristic lack of concentration gradients from RM2 to RM12. As will be shown in Appendix C, resuspension of contaminated Lower Passaic River sediments still comprises major sources for these contaminants but their concentrations in external sources largely prevents any notable decline in their concentrations with time.
    - PAHs contamination showed no decline with time since about 1970 and appears to be controlled by external loads originating in the Upper Passaic River.
    - Dieldrin concentrations have been rising since reaching a minimum in the mid-1980s. Much of the dieldrin likely originates with tributaries to the Lower Passaic River, including the Upper Passaic River.
    - These observations are further discussed in Data Evaluation Report No. 2 and in Data Evaluation Report No. 4.
- Although a relatively narrow range of concentrations was observed among the dated sediment cores, the core locations at the upstream and downstream-most

locations were typically lower than those from RM2.2 to RM11 for 2,3,7,8-TCDD and Total PCBs.

  - Lower concentrations at RM1.4 and RM12.6 for these compounds are likely due to the introduction of relatively clean solids from the main external sources of solids.
  - Despite the substantive differences between the concentrations on these external solids and those found within the river, extensive tidal mixing serves to eliminate much of the concentration gradient across the central 10 miles of the Lower Passaic River.

4 ACRONYMS

2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin (also referred to as “dioxin”)
Be-7	Beryllium-7
BZ	Ballschmiter and Zell
C-14	Carbon-14
CLP	Contract Laboratory Program
cm	centimeters
cm/yr	centimeters per year
COPC	Contaminants of Potential Concern
COPEC	Contaminants of Potential Ecological Concern
CPG	Cooperating Parties Group
Cs-137	Cesium-137
CSO	Combined Sewer Overflow
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
dioxins	Polychlorinated Dibenzodioxins/furans
DQO	Data Quality Objective
FFS	Focused Feasibility Study of the Lower Eight Miles of the Lower Passaic River
g	gram
HMW	High Molecular Weight
L-DEO	Lamont-Doherty Earth Observatory
LMW	Low Molecular Weight
LPRSA	Lower Passaic River Study Area
mg/kg	milligrams per kilograms of sediment
ng/kg	nanograms per kilograms of sediment
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PCB	Polychlorinated Biphenyl

pCi/g	picocuries per gram of sediment
PTBT	Partial Test Ban Treaty
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
RM	River Mile
RPI	Rensselaer Polytechnic Institute
SWO	Stormwater Outfall
$t_{1/2}$	half-life
TAL	Target Analyte List
TOC	Total Organic Carbon
Total TCDD	Total Tetrachlorodibenzo-p-dioxin
TCDD	Tetrachlorodibenzo-p-dioxin
TPH	Total Petroleum Hydrocarbons
TSI	Tierra Solutions, Inc.
µg/kg	micrograms per kilograms of sediment
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

5 REFERENCES

Bopp, R.F., S.N. Chillrud, E.L. Shuster, and H.J. Simpson, 2006. "Contaminant Chronologies from Hudson River Sedimentary Records." In: The Hudson River Estuary, J. Levinton and J. Waldman eds., Cambridge University Press, January 2006, Chapter 26: 383-397.

Bopp, R.F., M.L. Gross, H. Tong, H.J. Simpson, S.J. Monson, B.L. Deck, and F.C. Moster, 1991. "Sediment sampling and radionuclide and chlorinated hydrocarbon analysis in Newark Bay and the Hackensack and Passaic Rivers." Report to New Jersey Department of Environmental Protection, Division of Science and Research Contract P24096. March 31, 1991.

Bopp, R.F., H.J. Simpson, C.R. Olsen, R.M. Trier, and N. Kostyk, 1982. "Chlorinated hydrocarbons and radionuclide chronologies in sediments of the Hudson River and Estuary, New York." Environmental Science Technology. 16(10): 666-676.

Callender, E., and P.C. Van Metre, 1997. "Reservoir sediment cores show U.S. lead declines." Environmental Science and Technology, 31(9):424A-428A.

Chaky, D.A., 2003. "Polychlorinated Biphenyls, Polychlorinated Dibenzo-p-Dioxins and Furans in the New York Metropolitan Area; Interpreting Atmospheric Deposition and Sediment Chronologies." PhD Thesis, Rensselaer Polytechnic Institute, Troy, NY.431 pp.

Central Intelligence Agency (CIA), 2009. "The World Factbook 2009." Available at: https://www.cia.gov/library/publications/the-world-factbook/index.html. Retrieved August 10, 2011.

Davis, R.B., 1980. "The scope of Quaternary paleolimnology", in Davis, R.B., ed., Paleolimnology and the reconstruction of ancient environments: Boston, Kluwer Academic, p. 1–24.

Eisenreich, S.J., P.D. Capel, J.A. Robbins, and R.A. Boubonniere, 1989. “Accumulation and diagenesis of chlorinated hydrocarbons in lacustrine sediments.” Environmental Science and Technology, 23(9):1116-1126.

HDR|HydroQual, Inc. (HQI) and Sea Engineering, Inc. 2011. “Lower Passaic River System Understanding of Sediment Transport.” Prepared by HDR|HydroQual, Inc. and Sea Engineering, Inc. for USEPA.

Hites, R.A., R.E. LaFlamme, J.G Windsor, J.W. Jr., Farrington, and W.G. Deuser, 1981, “Polycyclic aromatic hydrocarbons in an anoxic sediment core from the Pettaquamscutt River (Rhode Island, U.S.A.).” Geochimica et Cosmochimica Acta, v. 44, p. 873–878.

Lal, D., P. K. Malhotra, and B. Peters, 1958. “On the Production of Radioisotopes in the Atmosphere by Cosmic Radiation and Their Application to Meteorology”. Journal of Atmospheric and Terrestrial Physics, v. 12, iss. 4, p. 306-328.

Malcolm Pirnie, Inc., 2006. “Field Sampling Plan, Volume 1.” Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. January 2006.

Malcolm Pirnie, Inc., 2005a. “Work Plan.” Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. August 2005.

Malcolm Pirnie, Inc., 2005b. “Quality Assurance Project Plan.” Lower Passaic River Restoration Project. Prepared in conjunction with Battelle and HydroQual, Inc. August 2005.

Olsen, C.R., H.J. Simpson, T.S. Peng, R.F. Bopp, and R.M. Trier, 1981. “Sediment Mixing and Accumulation Rate Effects on Radionuclide Depth Profiles in Hudson Estuary Sediments.” Journal of Geophysical Research. 86(C11):11020-11028.

Olsen, C.R., 1979. “Radionuclides, Sedimentation, and the Accumulation of Pollutants in the Hudson Estuary.” Ph.D. Dissertation, Columbia University, New York, New York. 343 pp.

Van Metre, P.C., J.T. Wilson, C.C. Fuller, E. Callender, and B.J. Mahler, 2004. “Collection, analysis, and age-dating of sediment cores from 56 U.S. lakes and reservoirs sampled by the U.S. Geological Survey, 1992-2001.” U.S. Geological Survey Scientific Investigations Report SIR-2004-5184. 180 pp.

Van Metre, P.C., E. Callender, and C.C. Fuller, C.C., 1997. “Historical trends in organochlorine compounds in river basins identified using sediment cores from reservoirs.” Environmental Science and Technology, 31(8), pp 2339-2344.

TABLES

Table 3-1: Locations of 1995 TSI Cores with Complete Cesium-137 Profiles

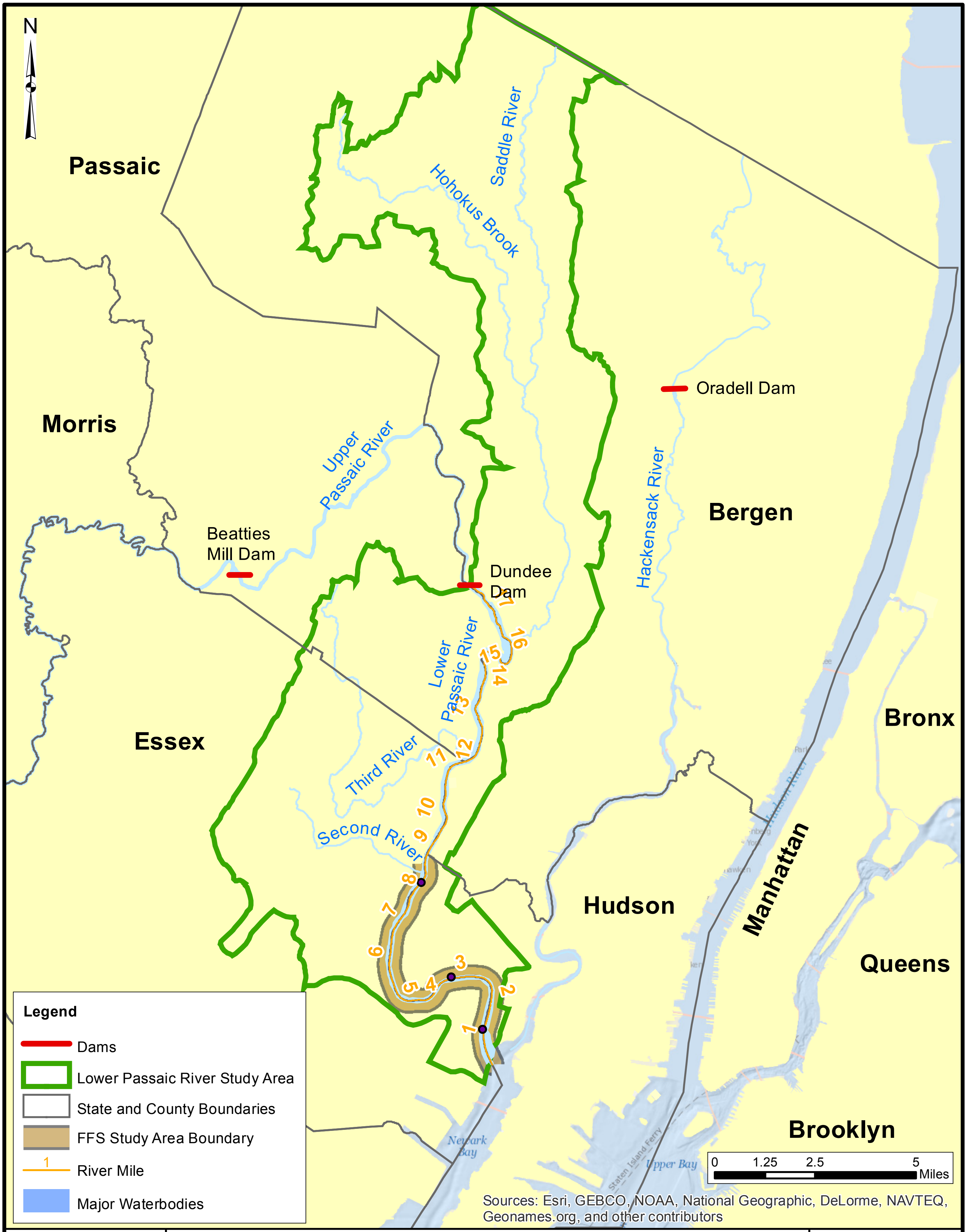
Tierra Solutions, Inc. Location	X-Coordinate	Y-Coordinate	River Mile	Depth of Sediment Sampled (feet)[a]
TSI 209	598198	691320	1.46	5.5
TSI 222[b]	595563	695459	2.65	13.6
TSI 228[b]	593188	695244	3.10	11
TSI 230	593149	695455	3.10	7.2
TSI 286	593249	695021	3.10	5.6
TSI 232	592028	694972	3.33	6
TSI 235	591151	694213	3.55	7.2
TSI 241[b]	589595	692519	4.01	11.9
TSI 248[b]	587218	692459	4.47	14.8
TSI 251	586182	693013	4.70	8.5
TSI 253	585542	693974	4.92	5.5
TSI 272[b]	585243	701014	6.27	10.5
TSI 296	585527	701638	6.40	5.6
TSI 275	585643	702116	6.49	7

Notes:

a: Depth represents bottom of last core segment sampled for either radiological or analytical samples. This depth does not necessarily represent the total coring depth since segmentation of the core extended only to the 1940 time horizon [Field Sampling Plan (Tierra Solutions, Inc., 1995a)].

b: These cores were selected for comparison with 2005 EPA cores.

FIGURES



Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors

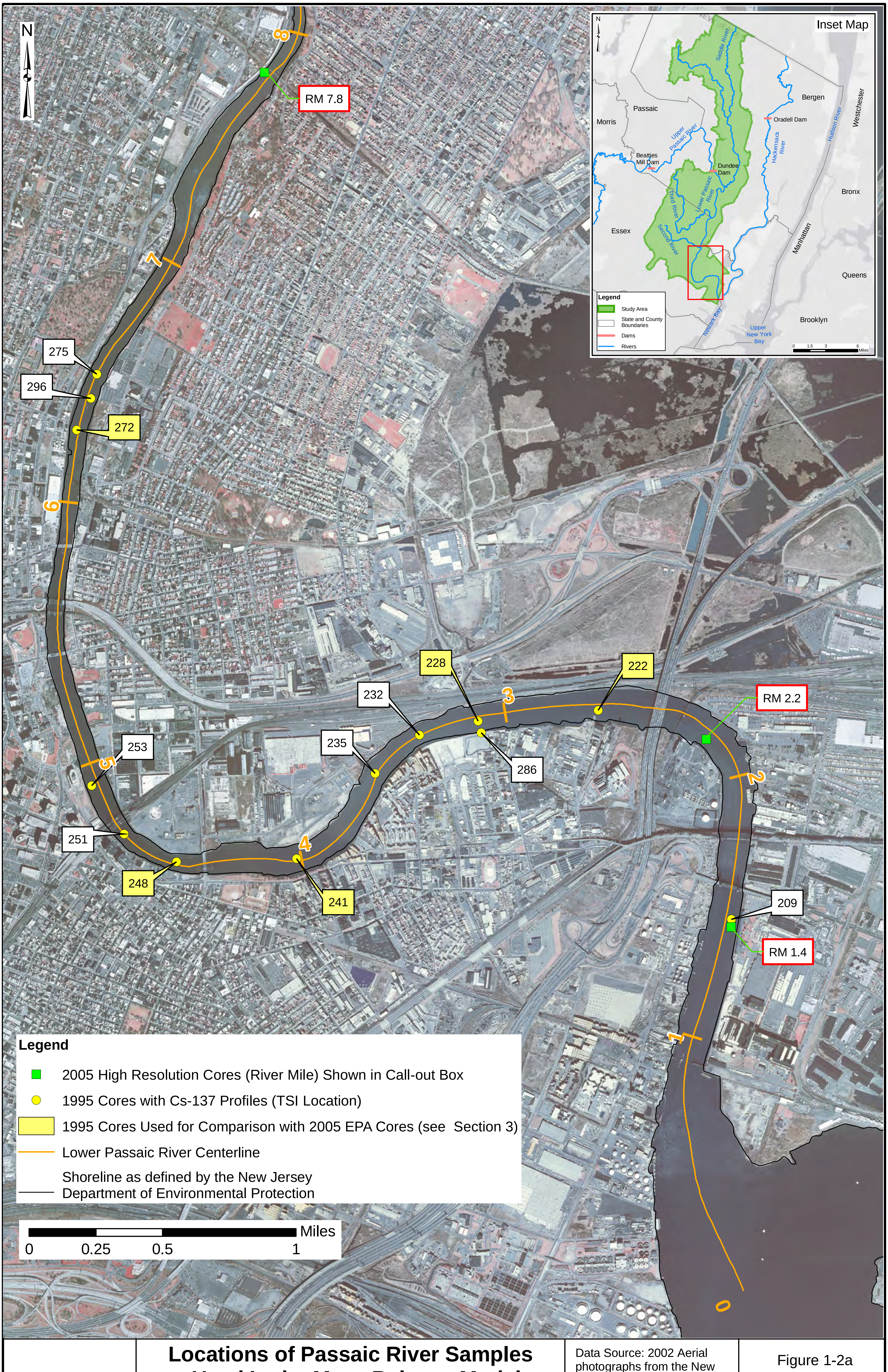
FFS Study Area Location Map

Lower Eight Miles of the Lower Passaic River

Figure 1-1

2014

Path: P:\02855924\Mapping\CSM_MassBalance\sitelocation_CSM_no_logos.mxd



Locations of Passaic River Samples Used In the Mass Balance Model

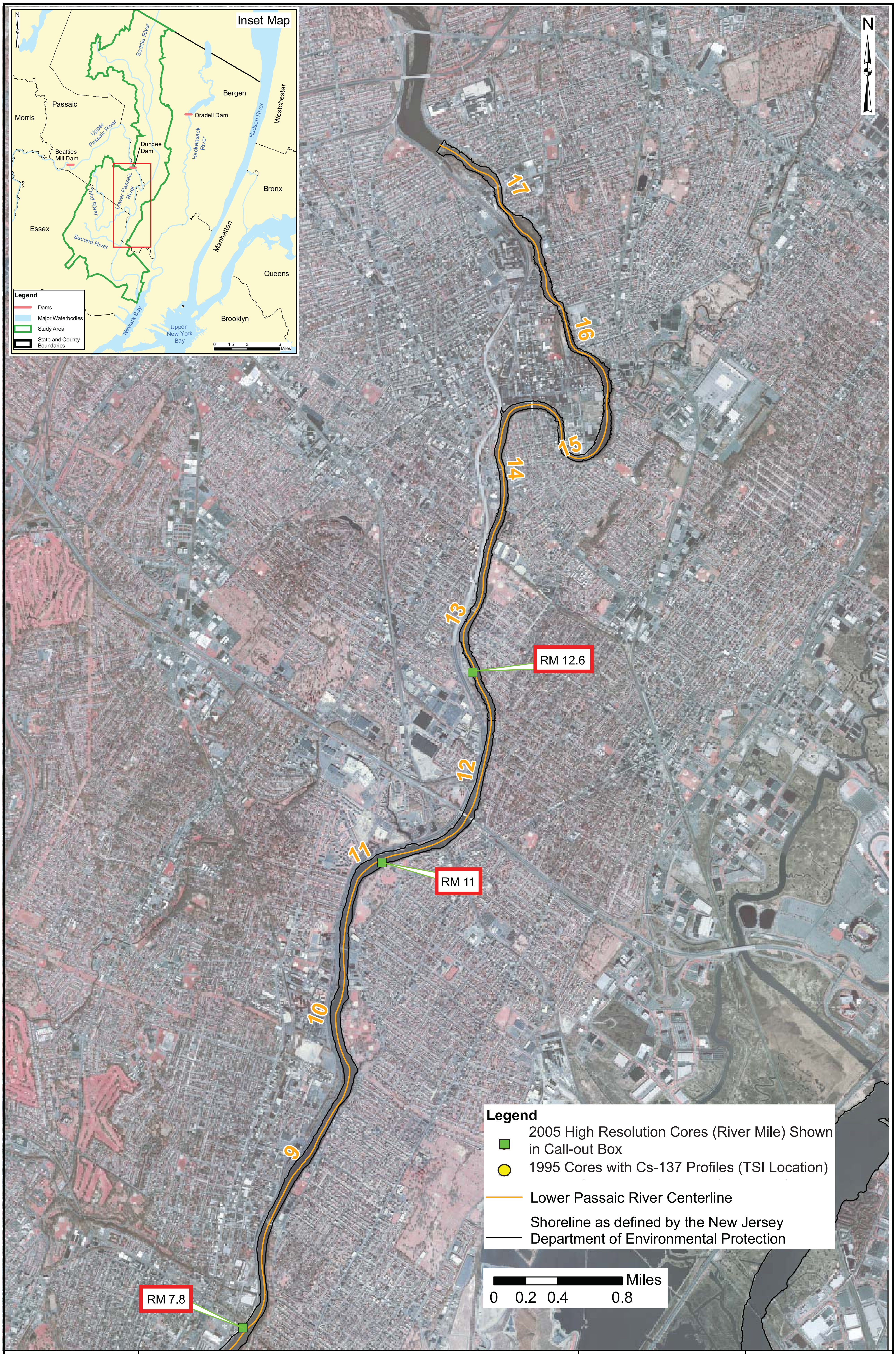
Lower Eight Miles of the Lower Passaic River

Data Source: 2002 Aerial photographs from the New Jersey State data clearing house (http://njgin.state.nj.us).

Figure 1-2a

2014

s:\projects\PASSAIC\MapDocuments\4553001-CERCLA\Figure4-1a_MassBalance - 4/3/2012



Locations of Lower Passaic River Sediment Cores Used to Examine Contaminant History

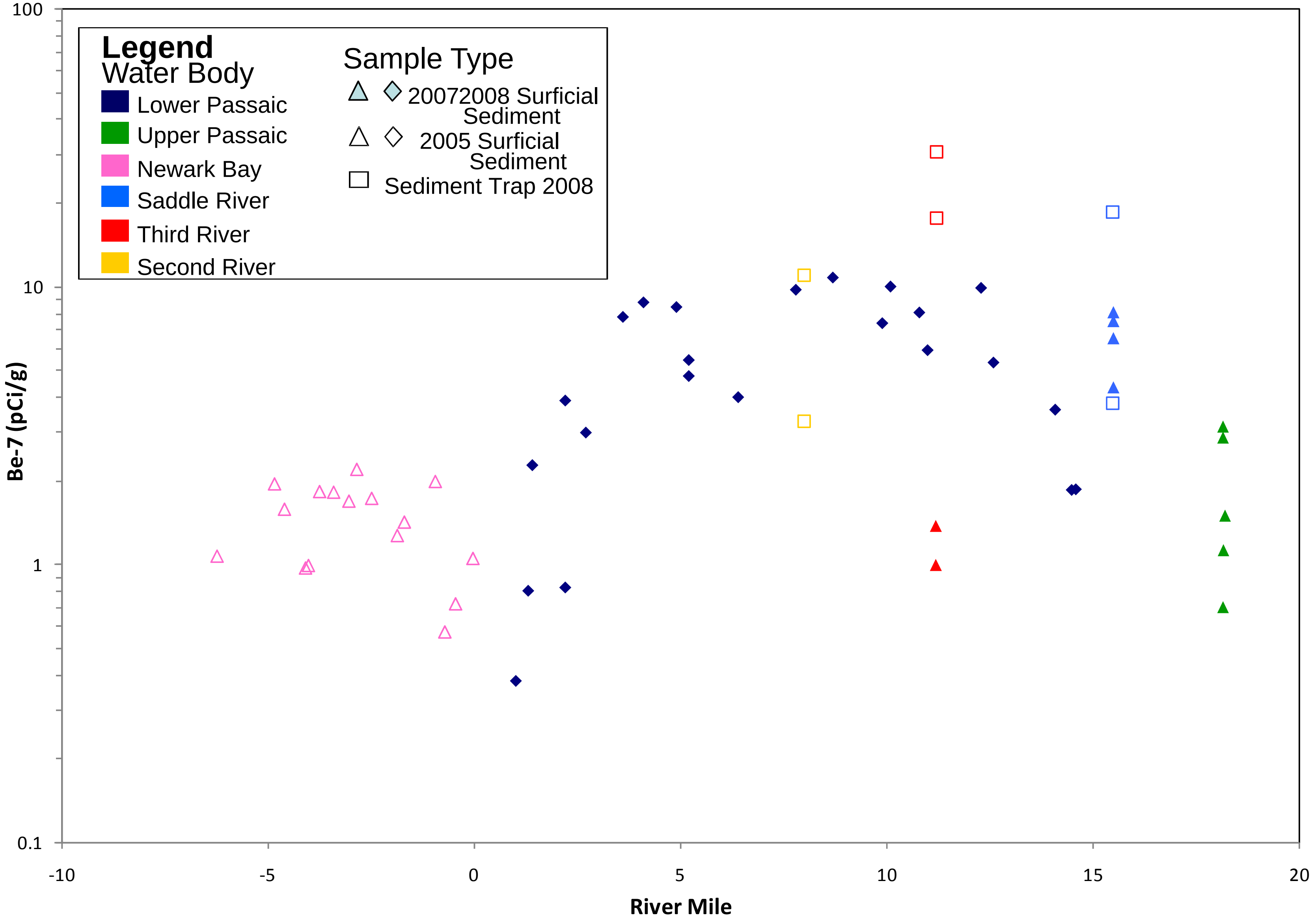
Lower Eight Miles of the Lower Passaic River

Data Source: 2002 Aerial photographs from the New Jersey State data clearing house (http://njgin.state.nj.us).

Figure 1-2b

2014

S:\Projects\PASSAIC\MapDocuments\4553001-CERCLA\Figure4-1b_MassBalance.mxd - 5/30/2008 @ 3:55:11 PM

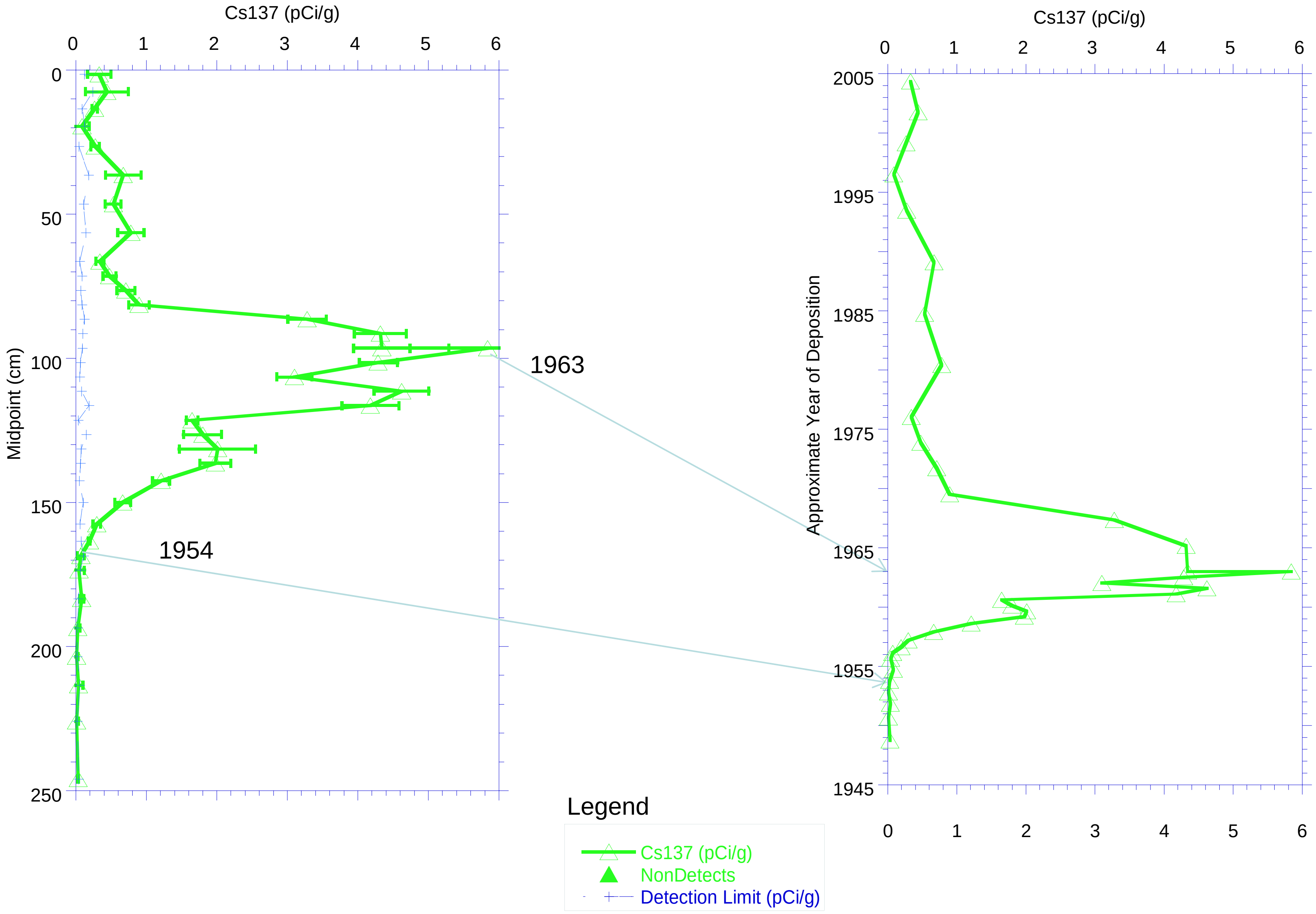


Beryllium-7 Activity vs. River Mile

Lower Eight Miles of the Lower Passaic River

Figure 2-1

2014

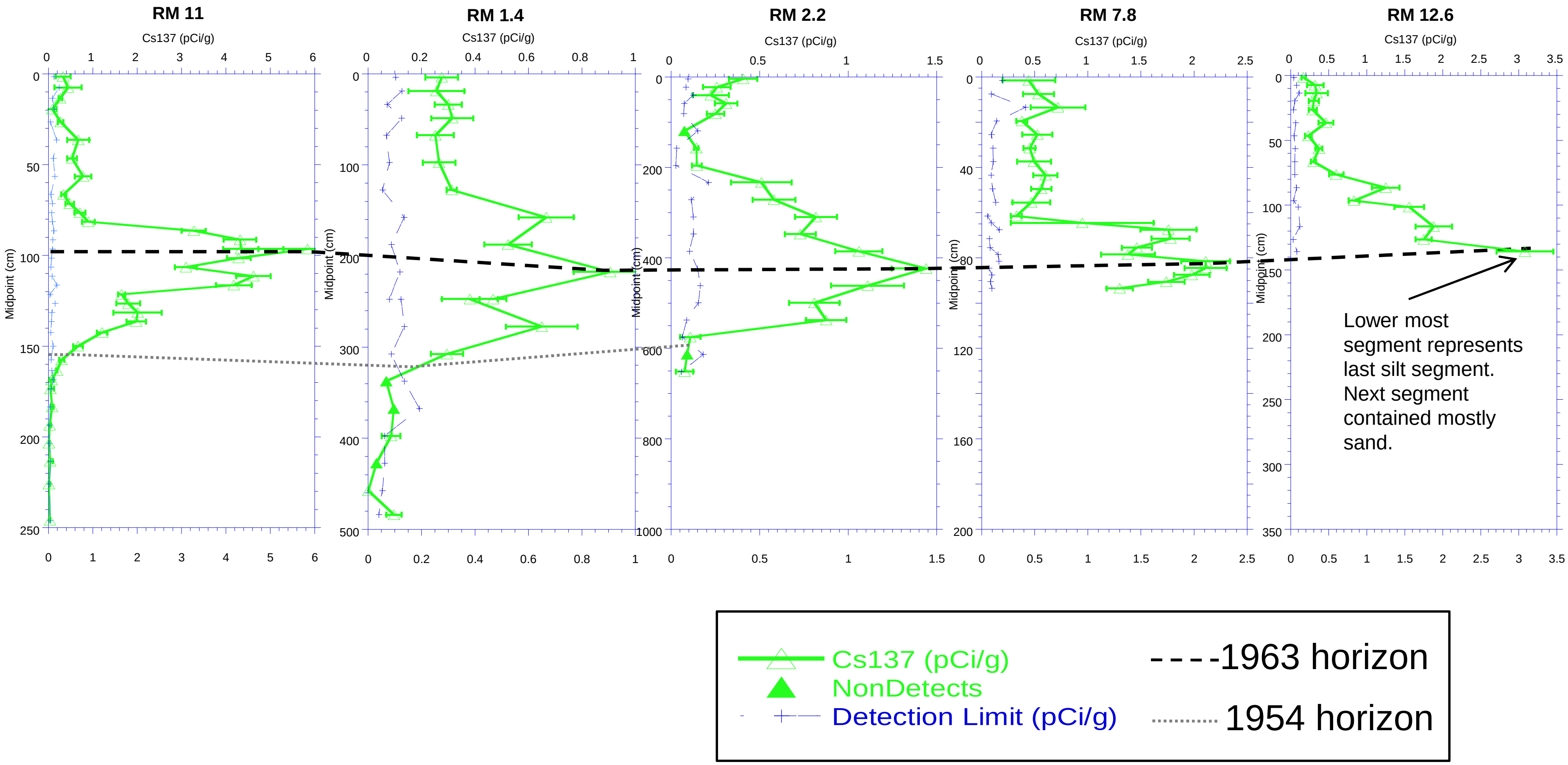


Assignment of the Approximate Year of Deposition based on the Cs-137 Profile for the Core at RM11

Lower Eight Miles of the Lower Passaic River

Figure 3-1

2014



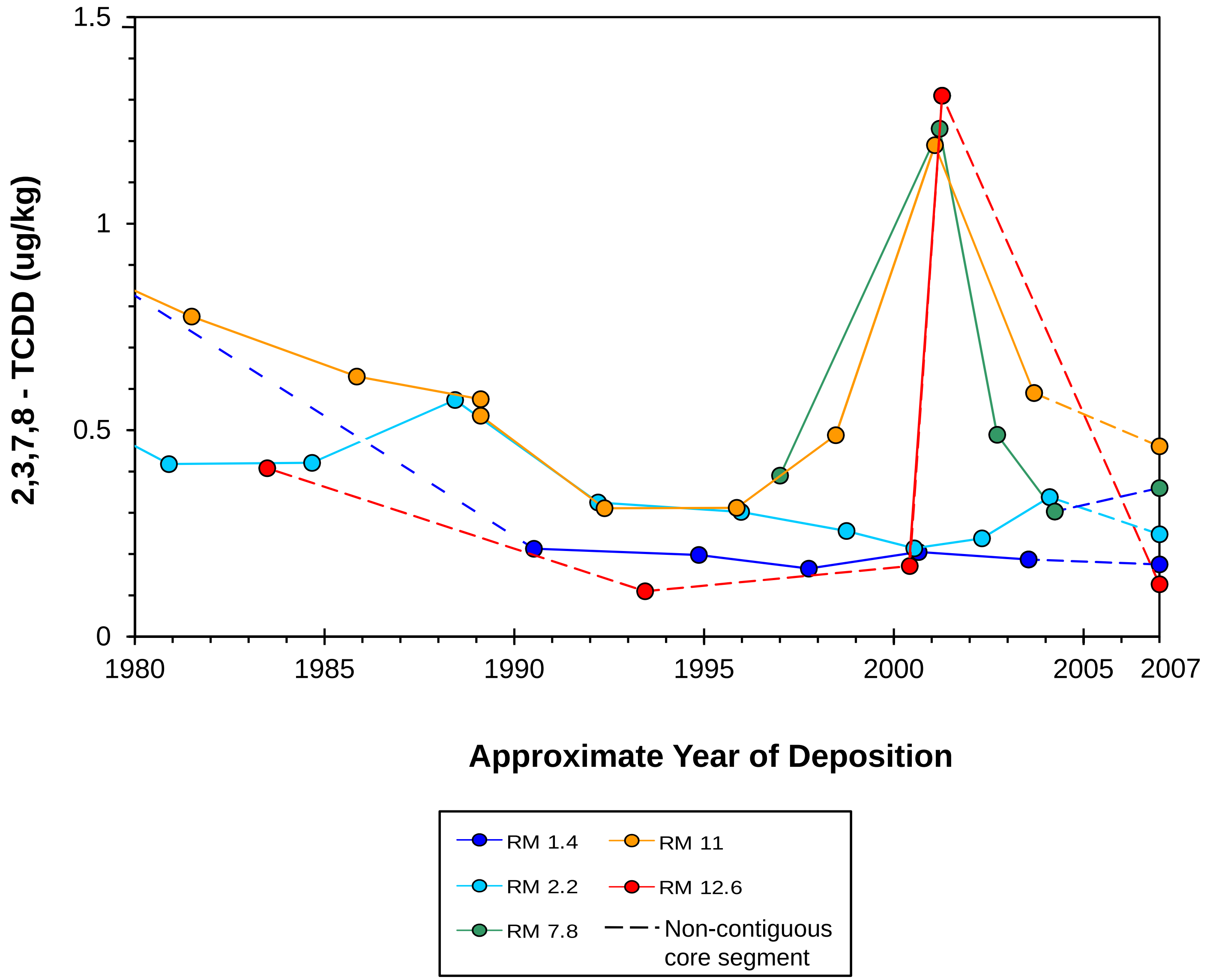
Lower most segment represents last silt segment. Next segment contained mostly sand.

Cs-137 Downcore Profiles for 2005 High Resolution Cores

Lower Eight Miles of the Lower Passaic River

Figure 3-2

2014

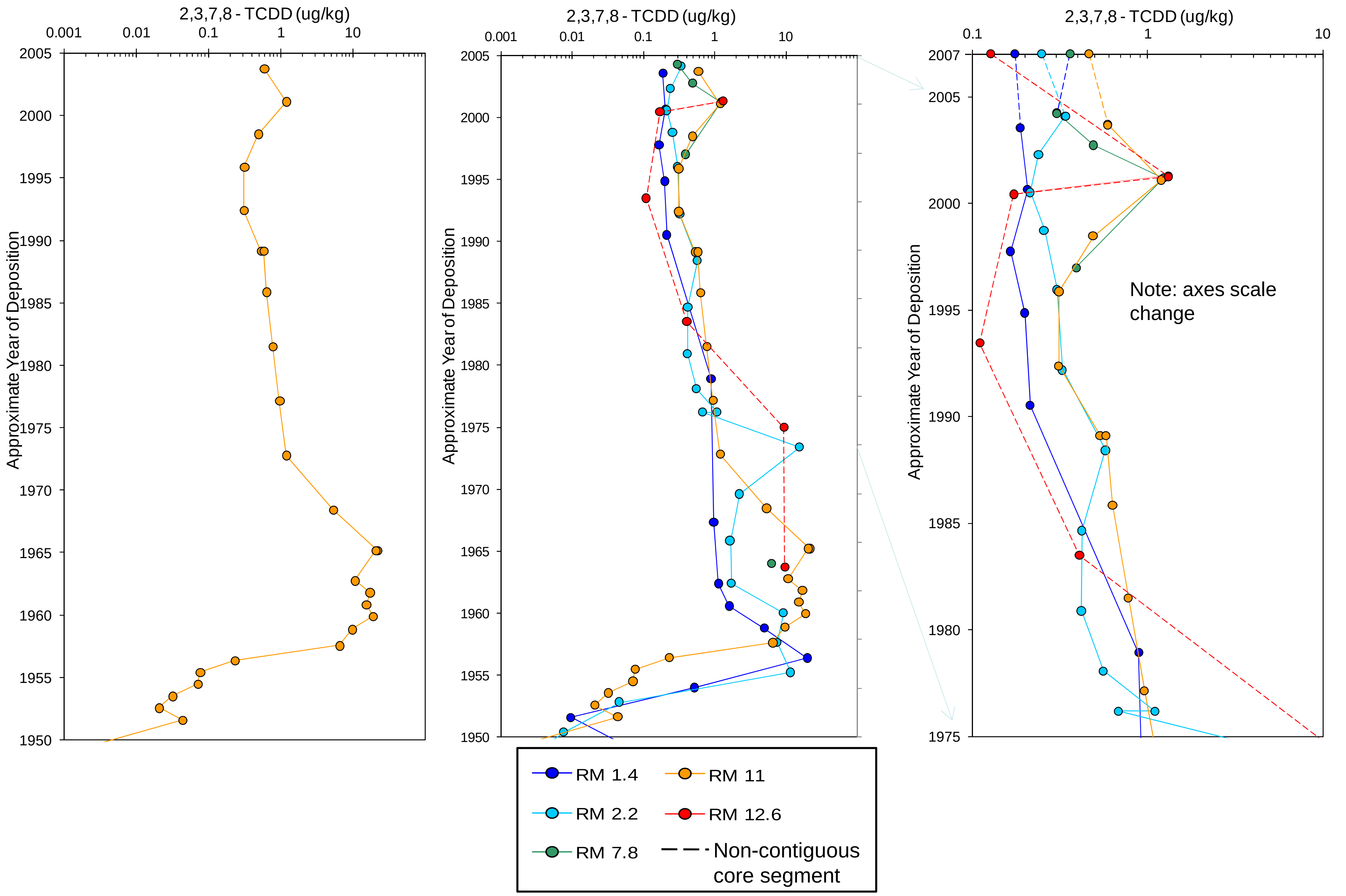


Dated Sediment Core Profiles for 2,3,7,8-TCDD:
Post 1980 Deposition - Linear Scale

Lower Eight Miles of the Lower Passaic River

Figure 3-3

2014

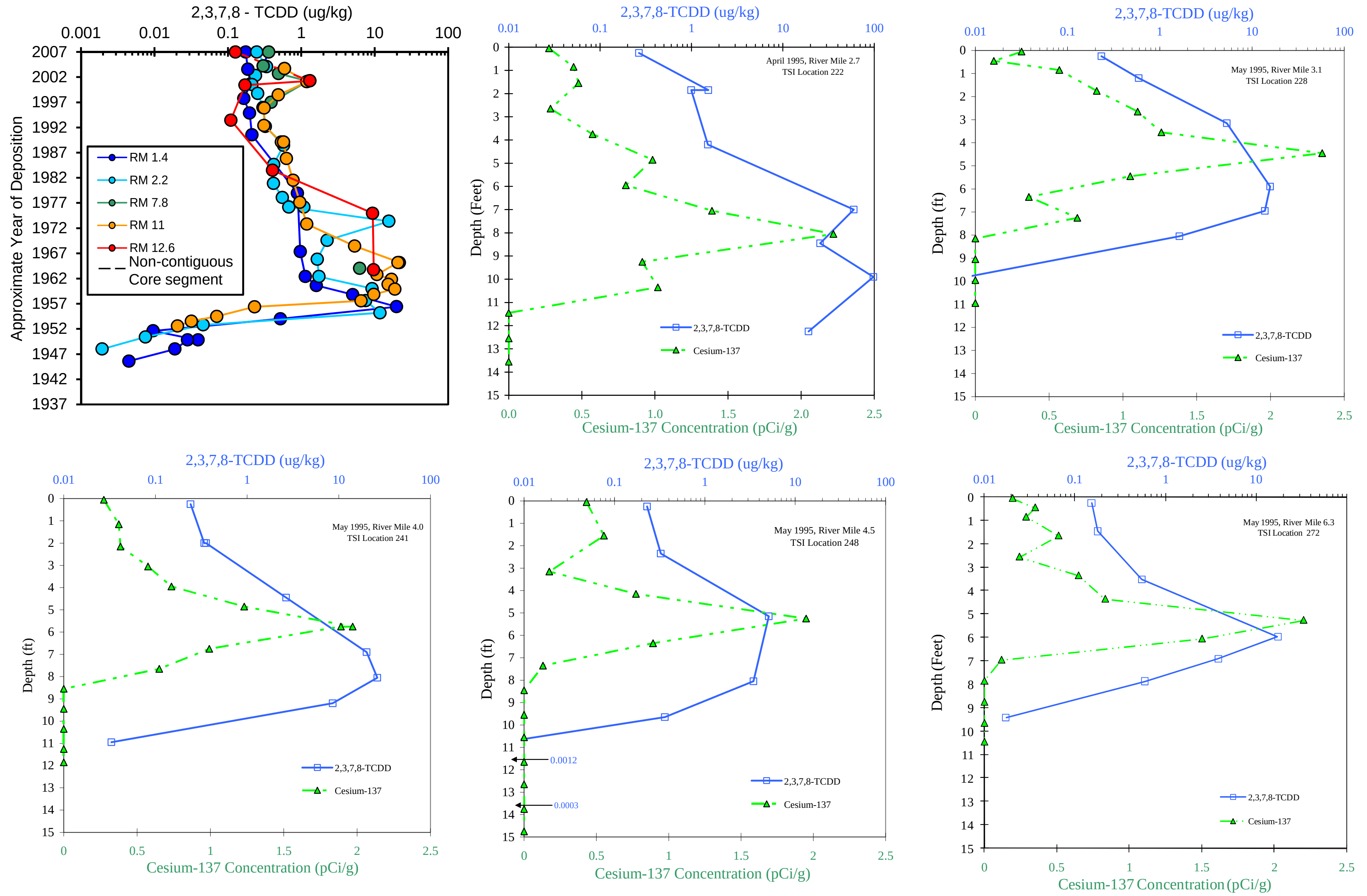


Dated Sediment Core Profiles for 2,3,7,8-TCDD:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-4

2014

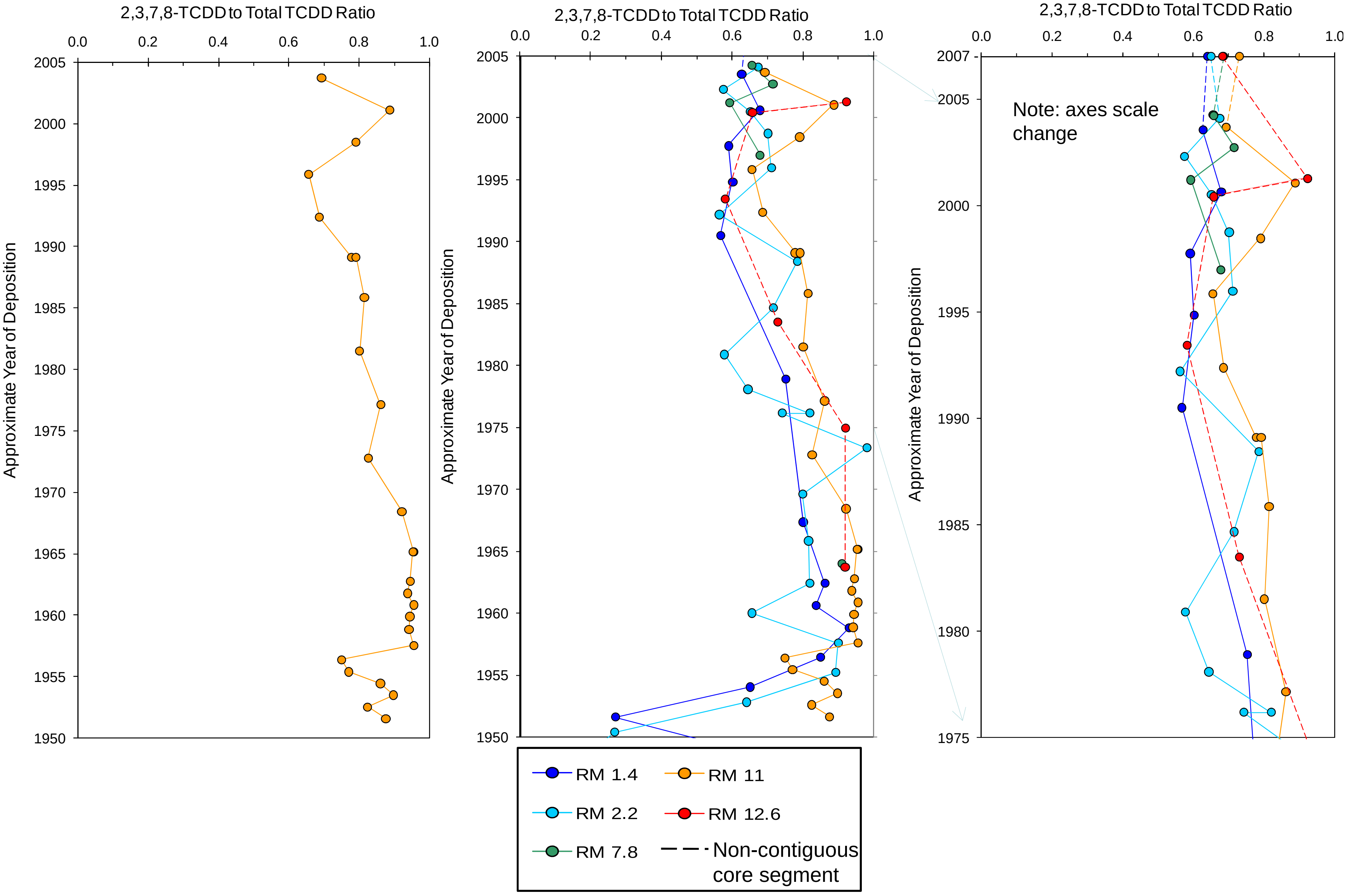


Comparison of EPA 2005 and TSI 1995 Downcore Profiles: 2,3,7,8-TCDD

Lower Eight Miles of the Lower Passaic River

Figure 3-5

2014

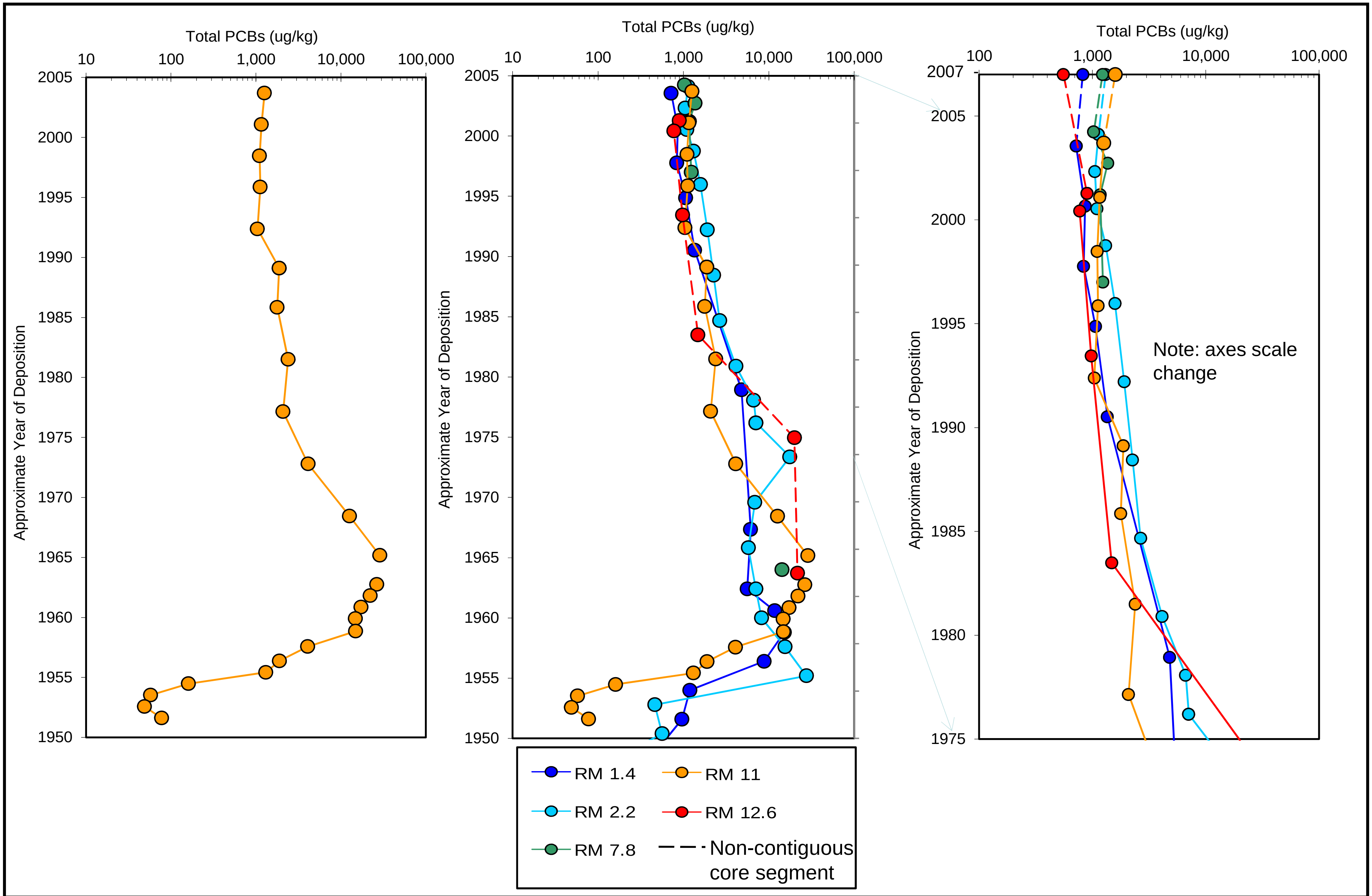


Dated Sediment Core Profile for 2,3,7,8-TCDD to Total TCDD Ratio: 2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-6

2014

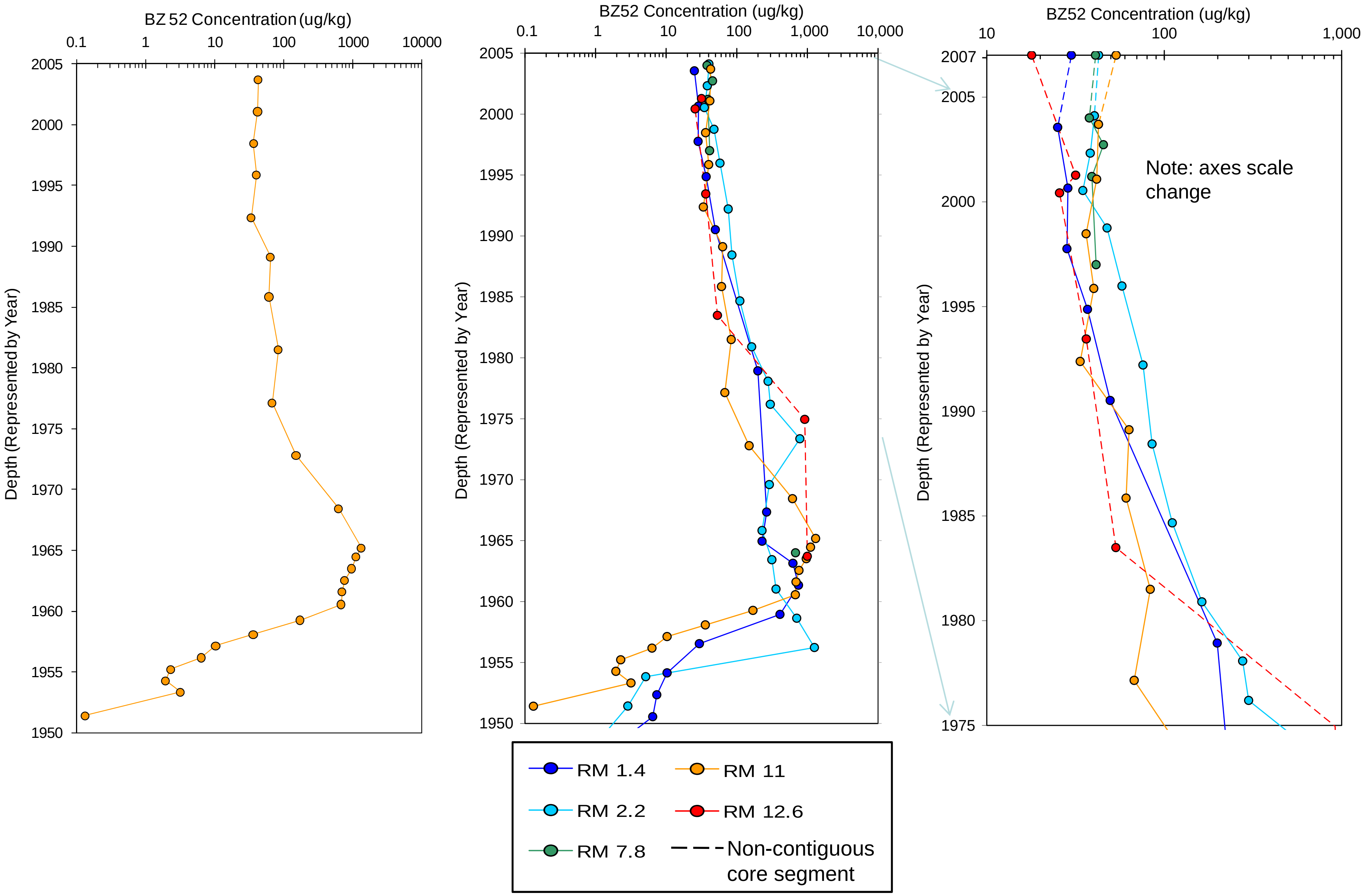


Dated Sediment Core Profile for Total PCBs:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-7a

2014

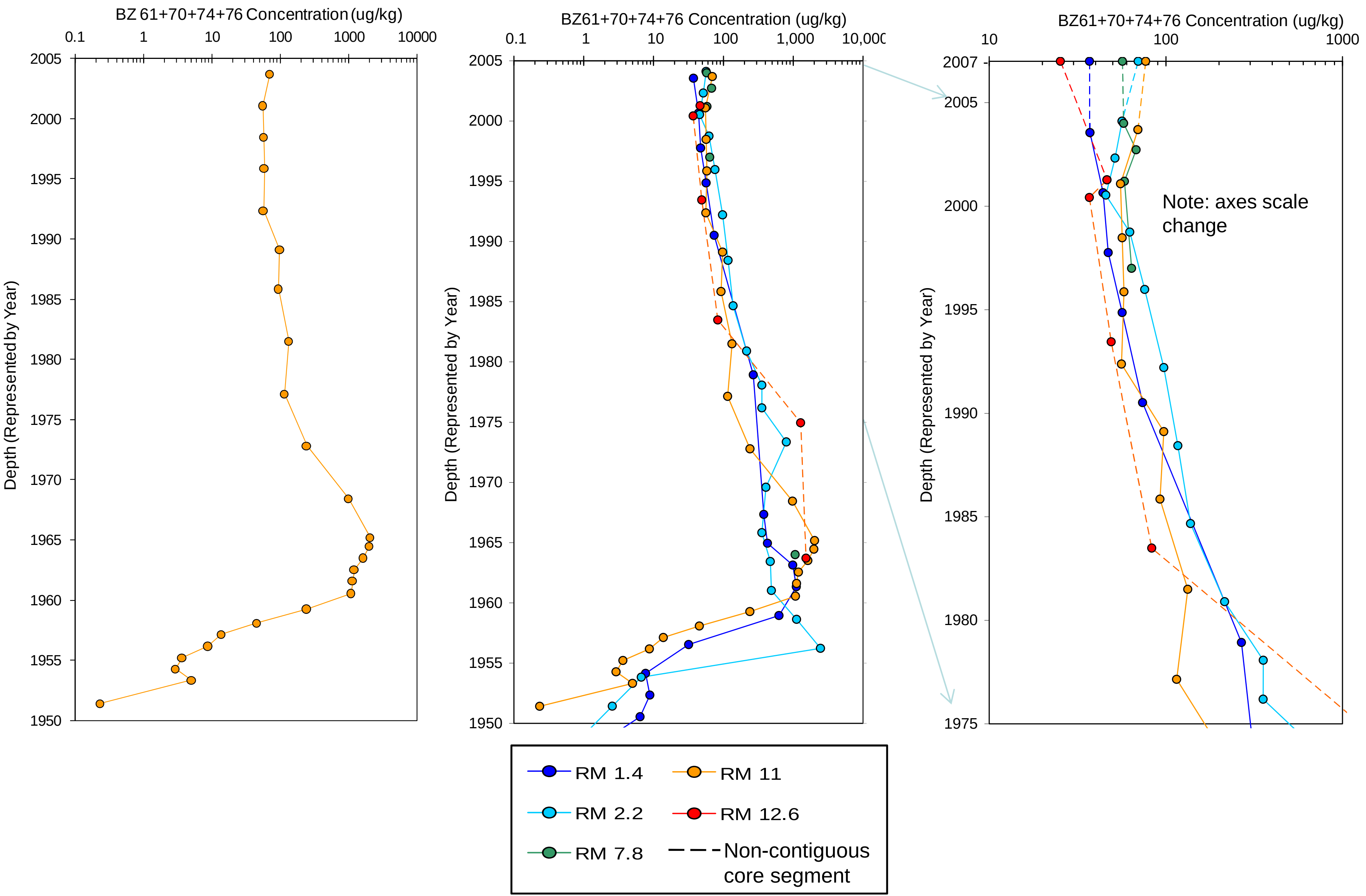


Dated Sediment Core Profile for BZ52:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-7b

2014

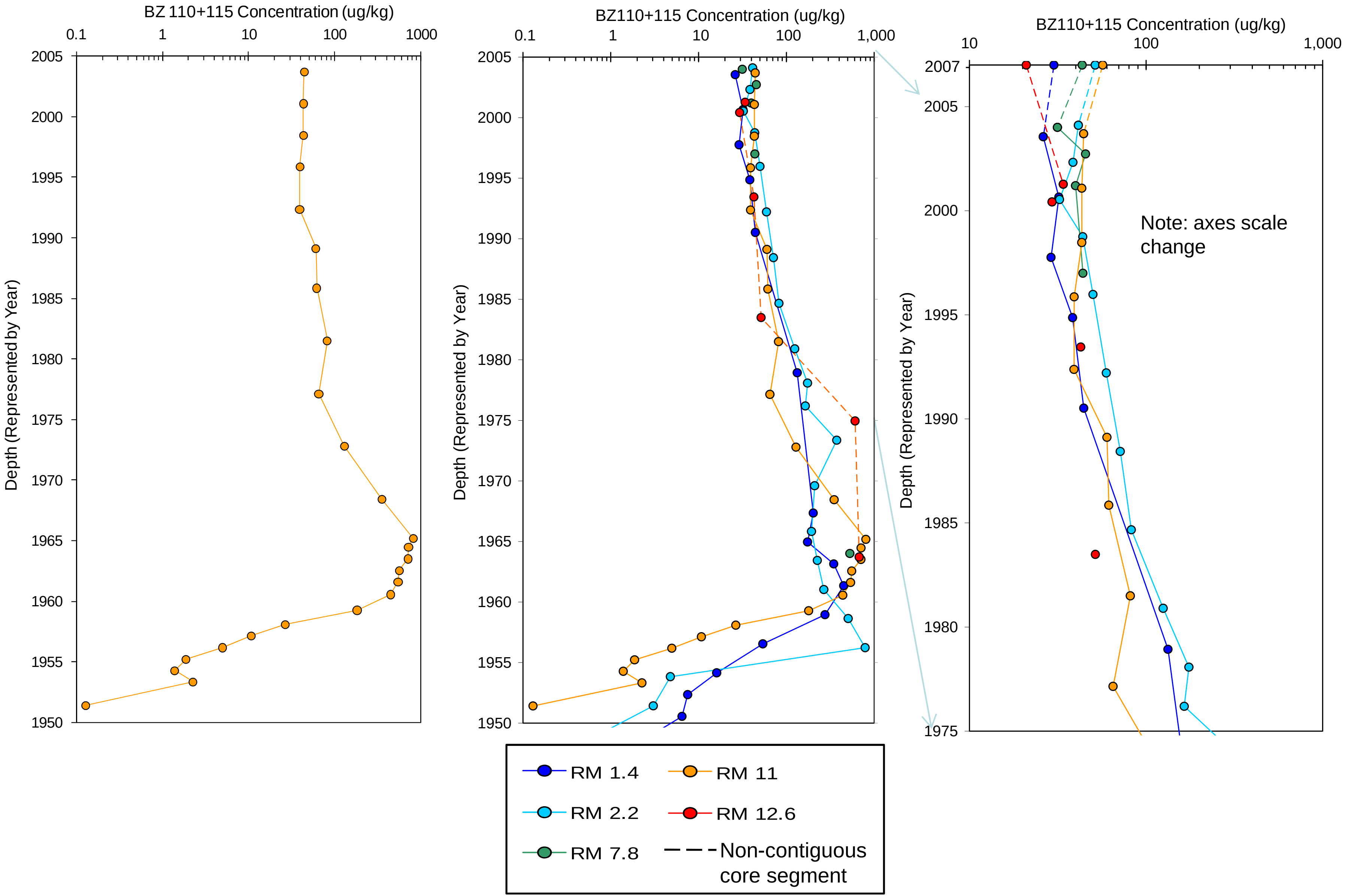


Dated Sediment Core Profile for BZ61+70+74+76:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-7c

2014

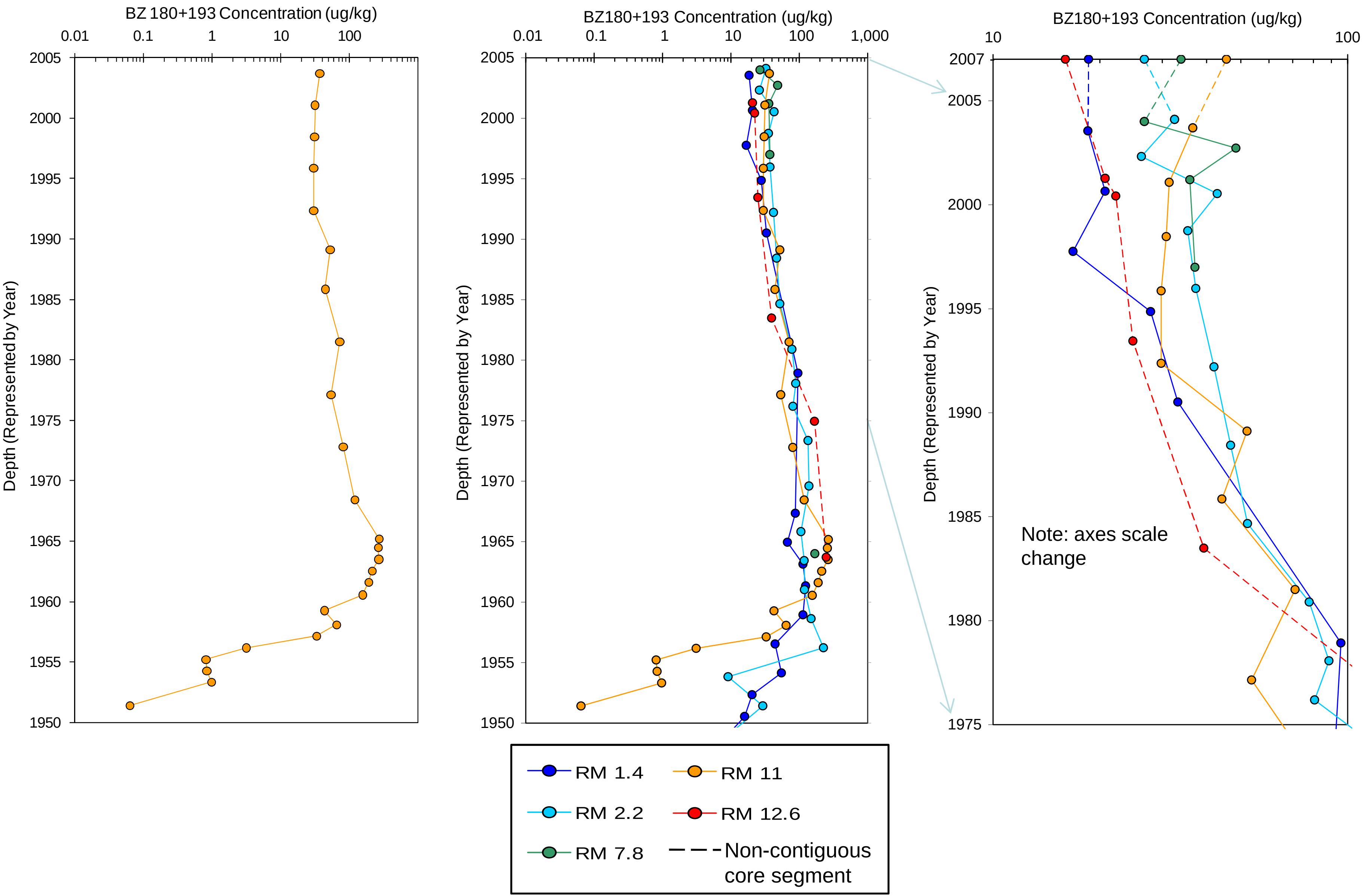


Dated Sediment Core Profile for BZ110+115:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-7d

2014

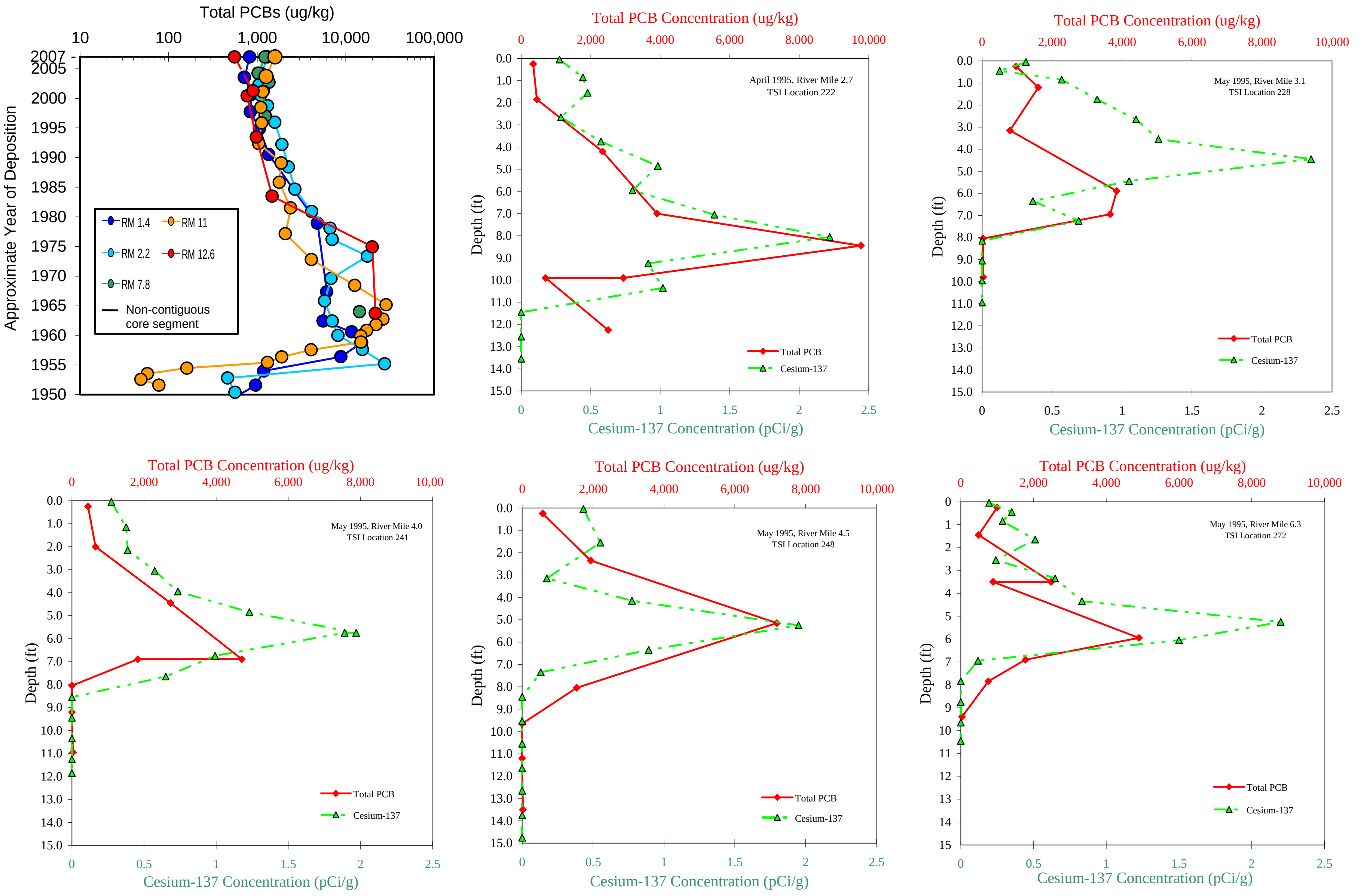


Dated Sediment Core Profile for BZ180+193:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-7e

2014

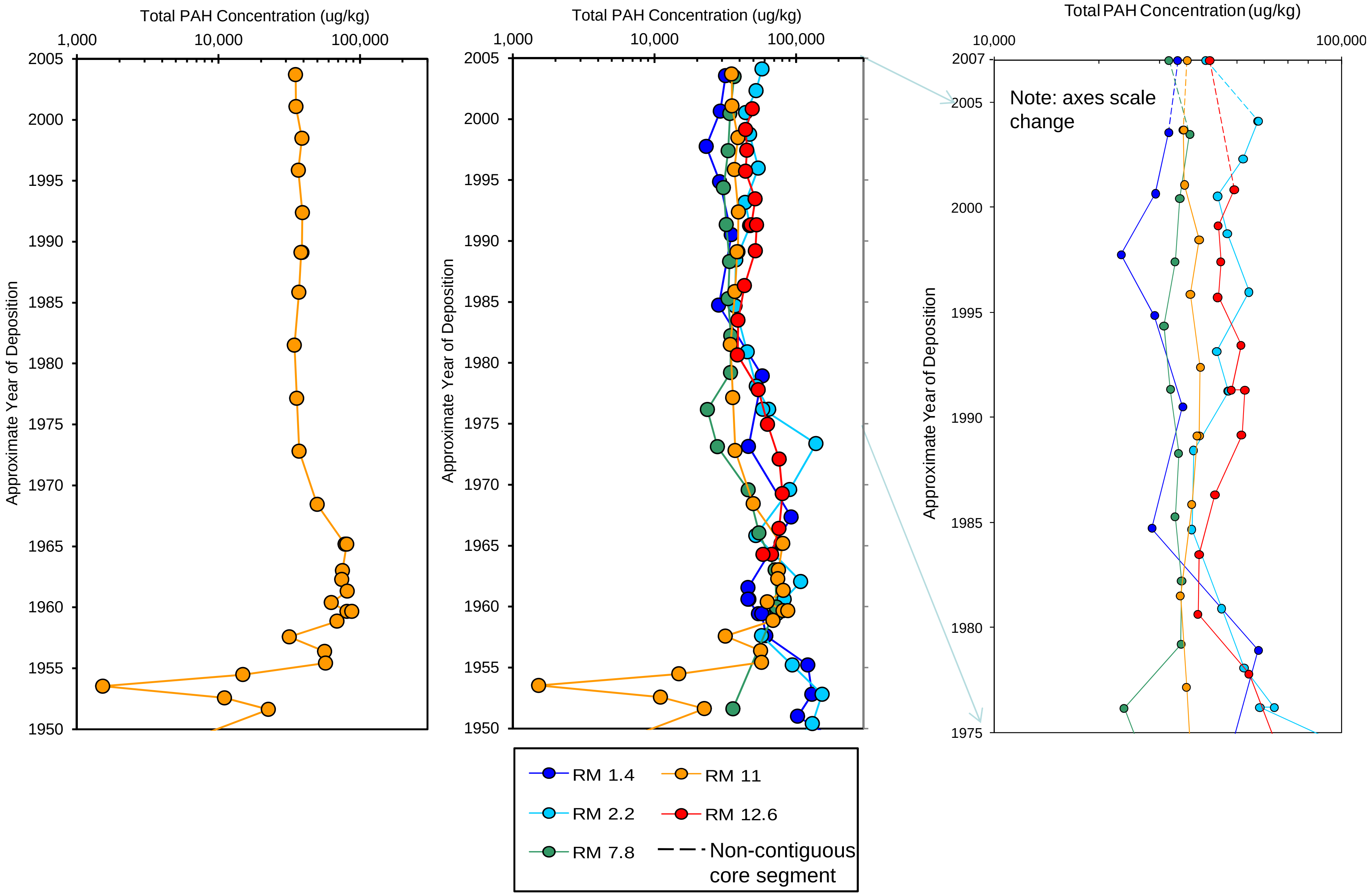


Comparison of EPA 2005 and TSI 1995 Downcore Profiles: Total PCBs

Lower Eight Miles of the Lower Passaic River

Figure 3-8

2014

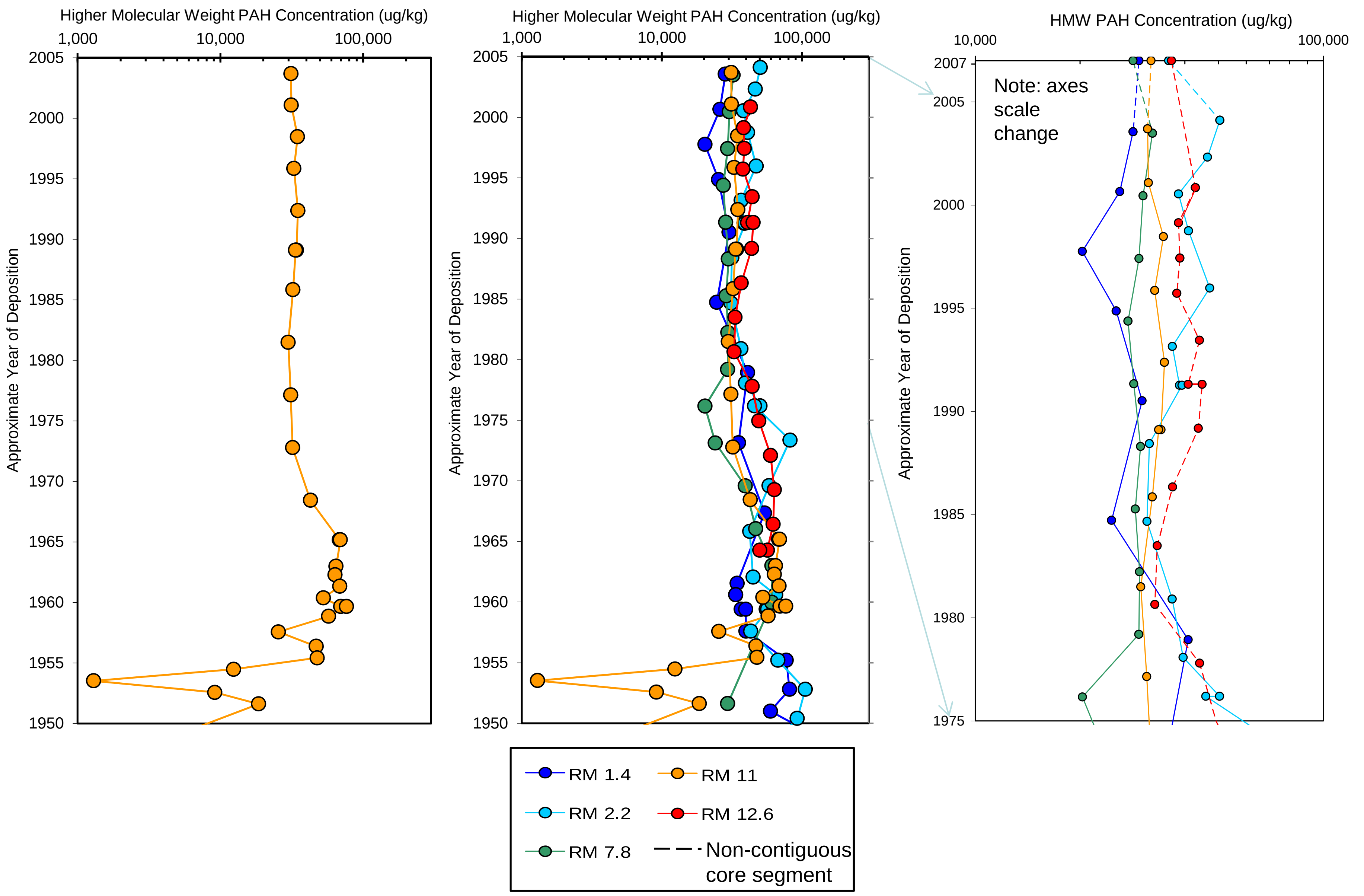


Dated Sediment Core Profile for Total PAHs:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9a

2014

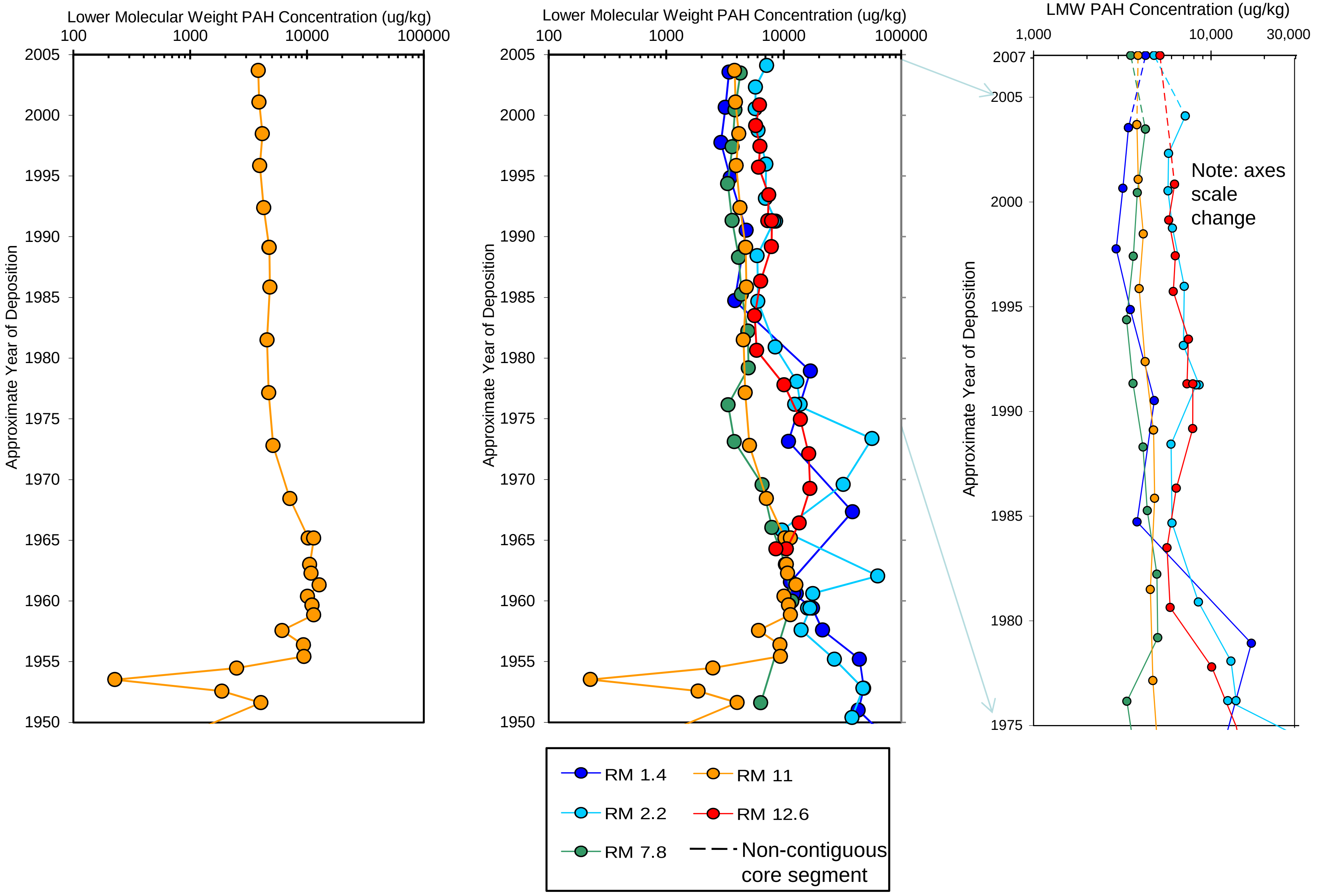


Dated Sediment Core Profile for High Molecular Weight PAHs:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9b

2014

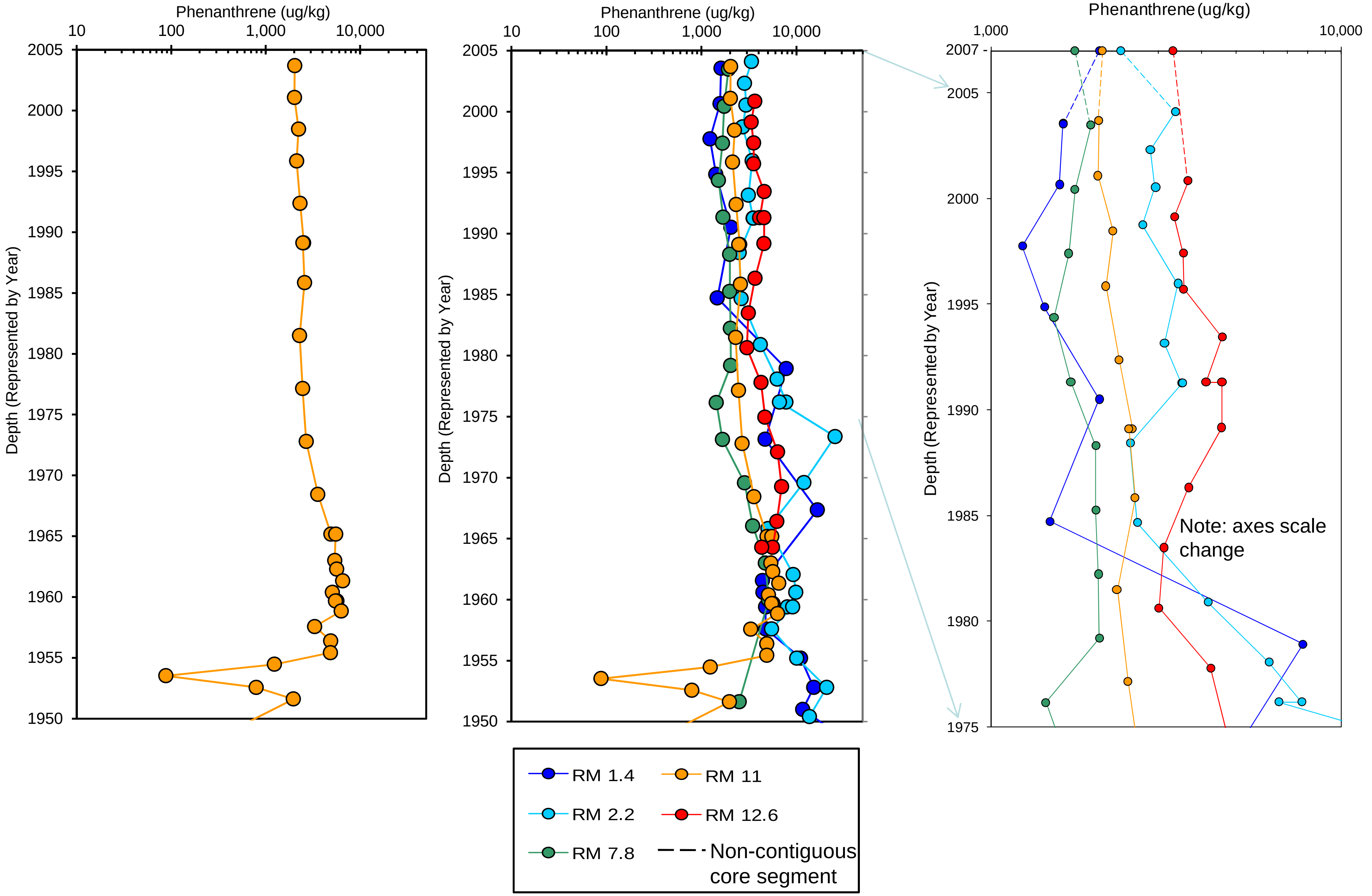


Dated Sediment Core Profile for Low Molecular Weight PAHs: 2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9c

2014

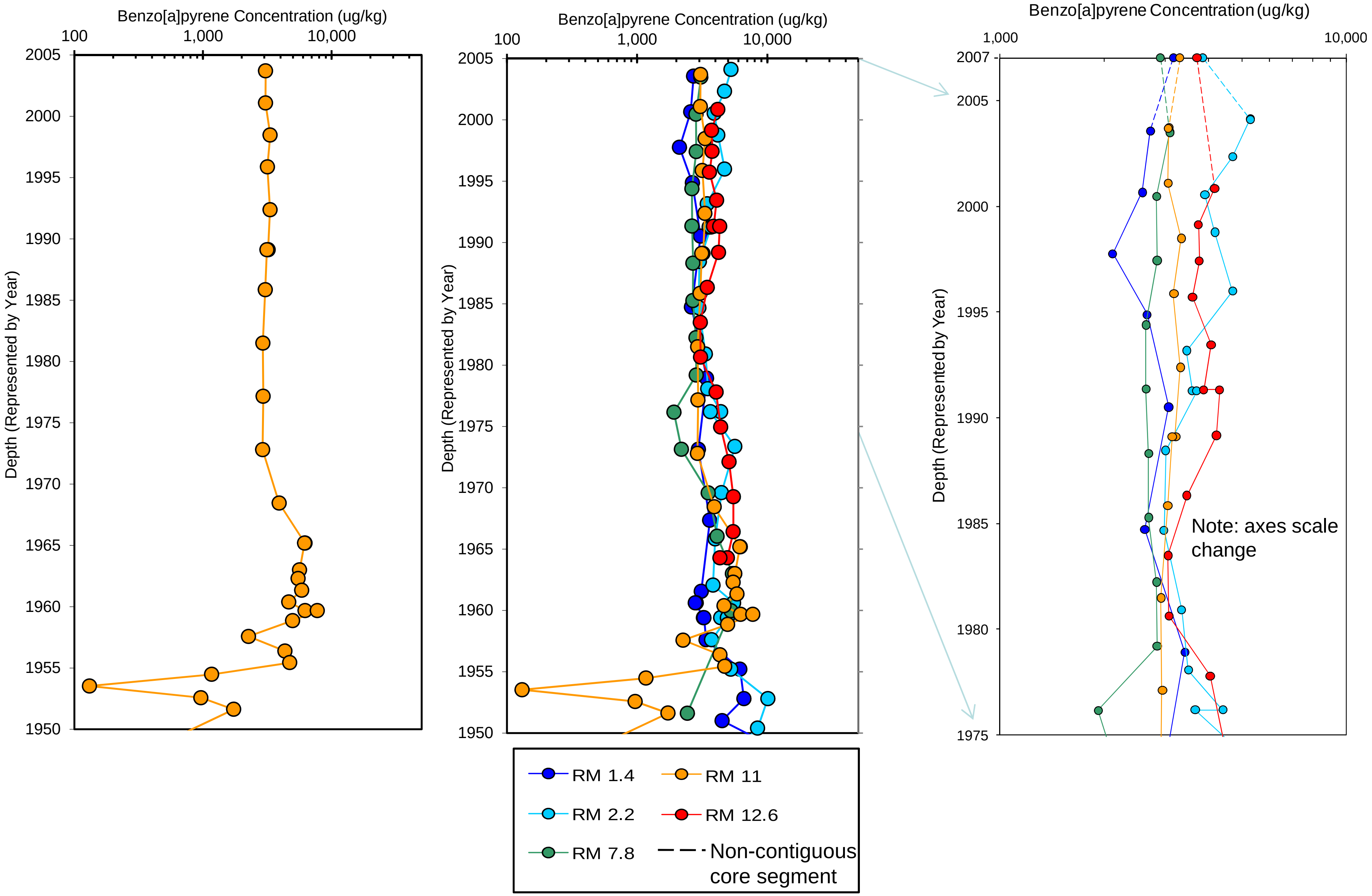


Dated Sediment Core Profile for Phenanthrene: 2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9d

2014

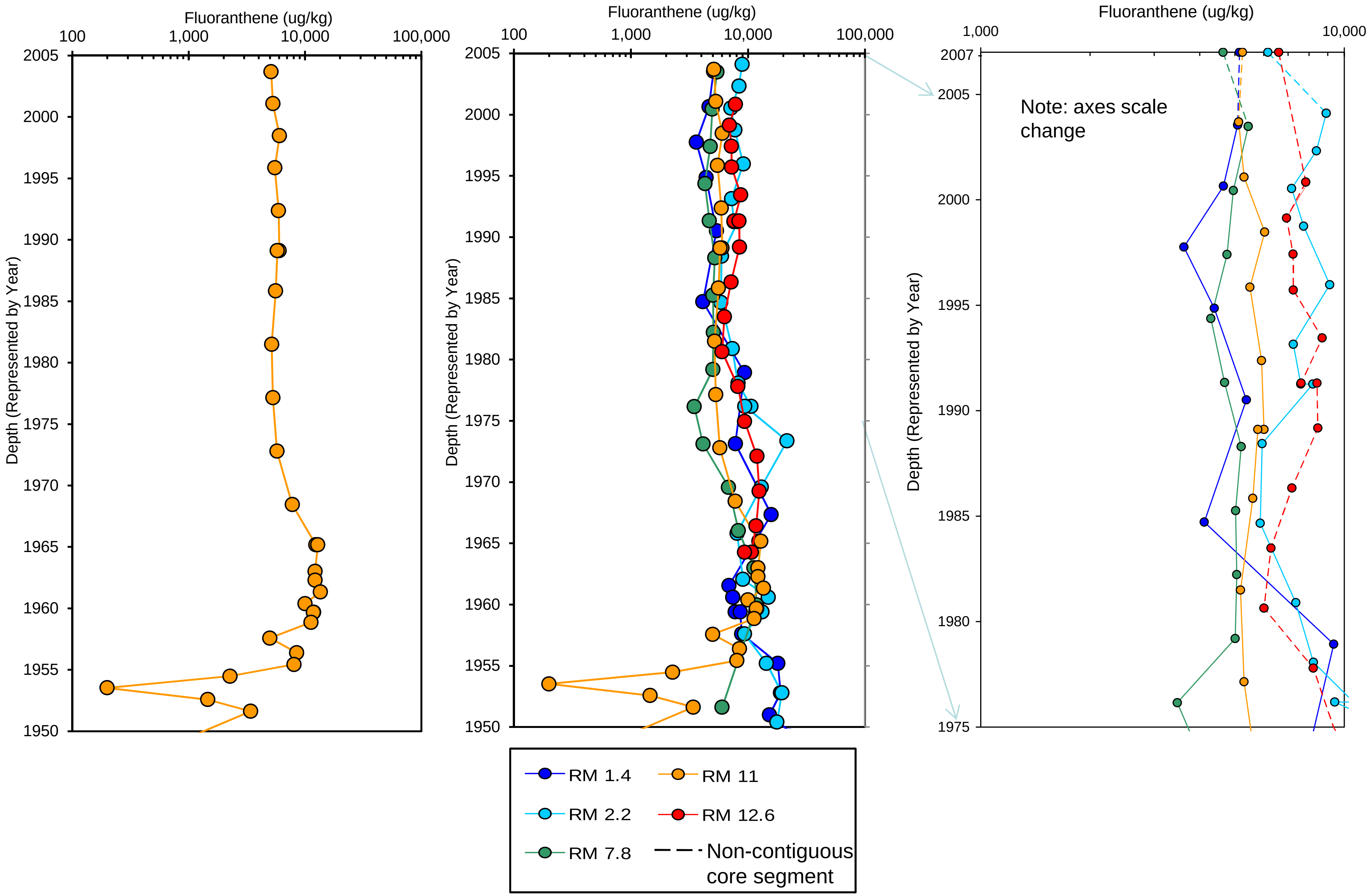


Dated Sediment Core Profile for Benzo[a]pyrene:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9e

2014

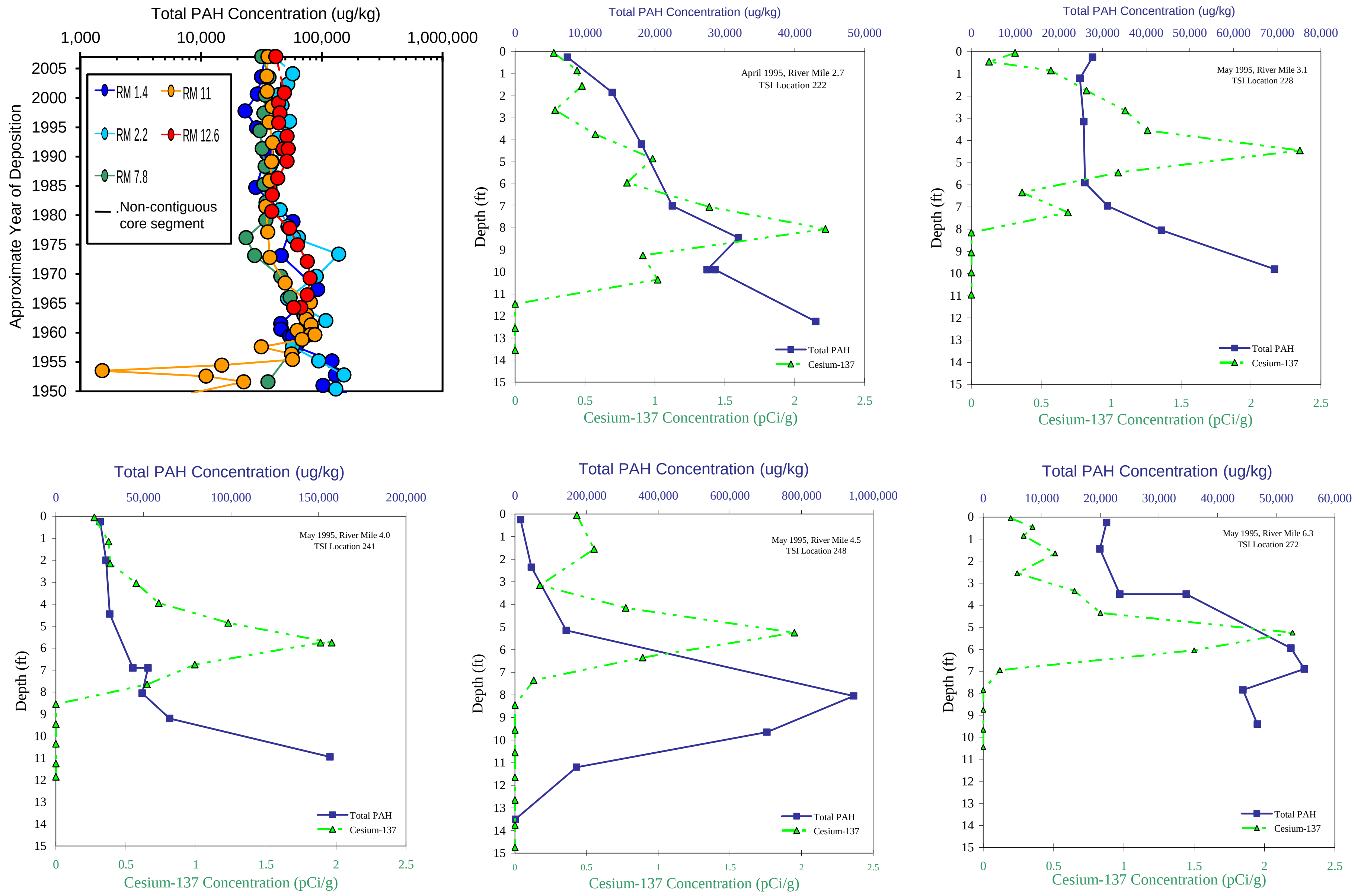


Dated Sediment Core Profile for Fluoranthene:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-9f

2014

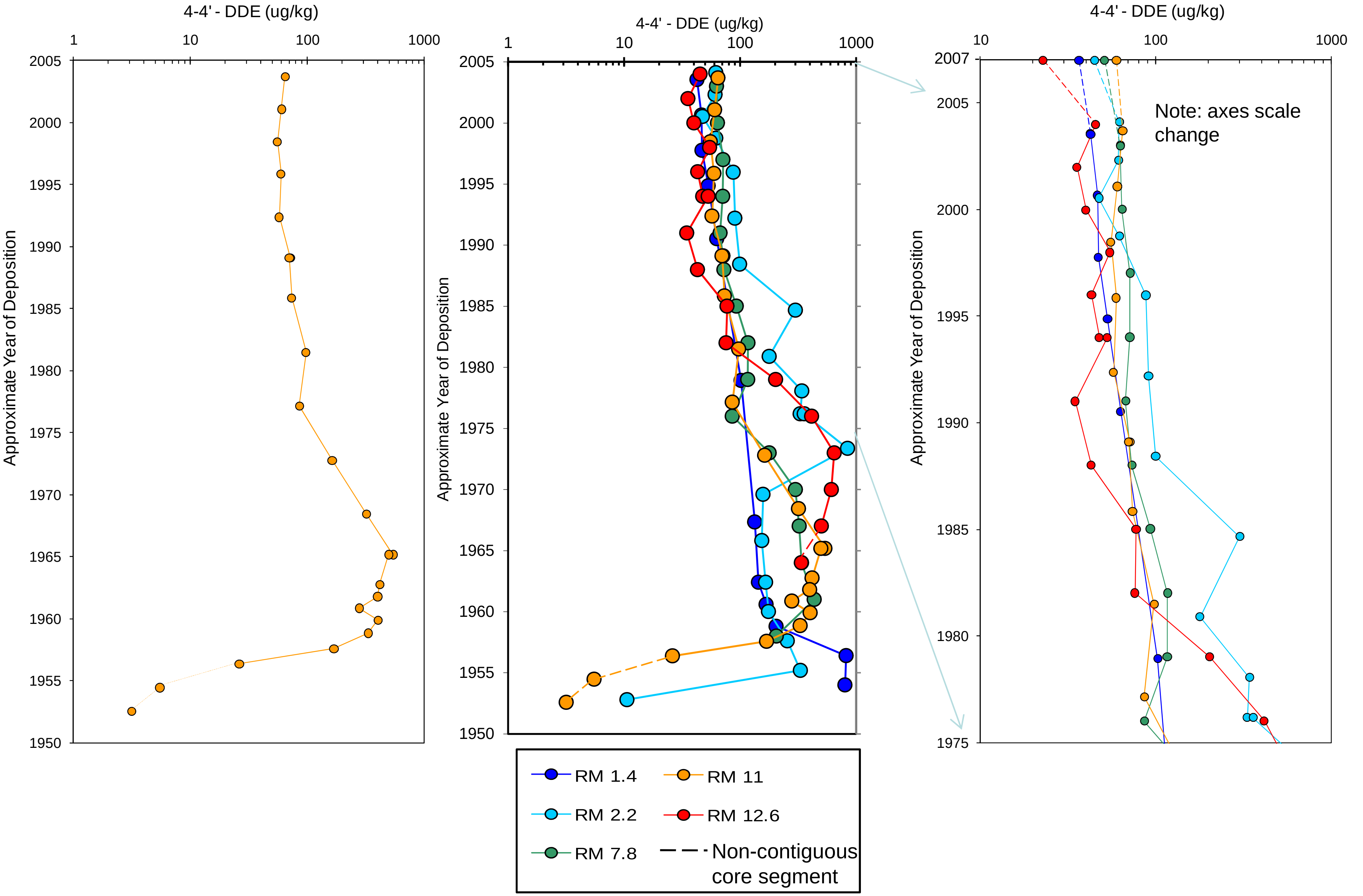


Comparison of EPA 2005 and TSI 1995 Downcore Profiles:
Total PAHs

Lower Eight Miles of the Lower Passaic River

Figure 3-10

2014

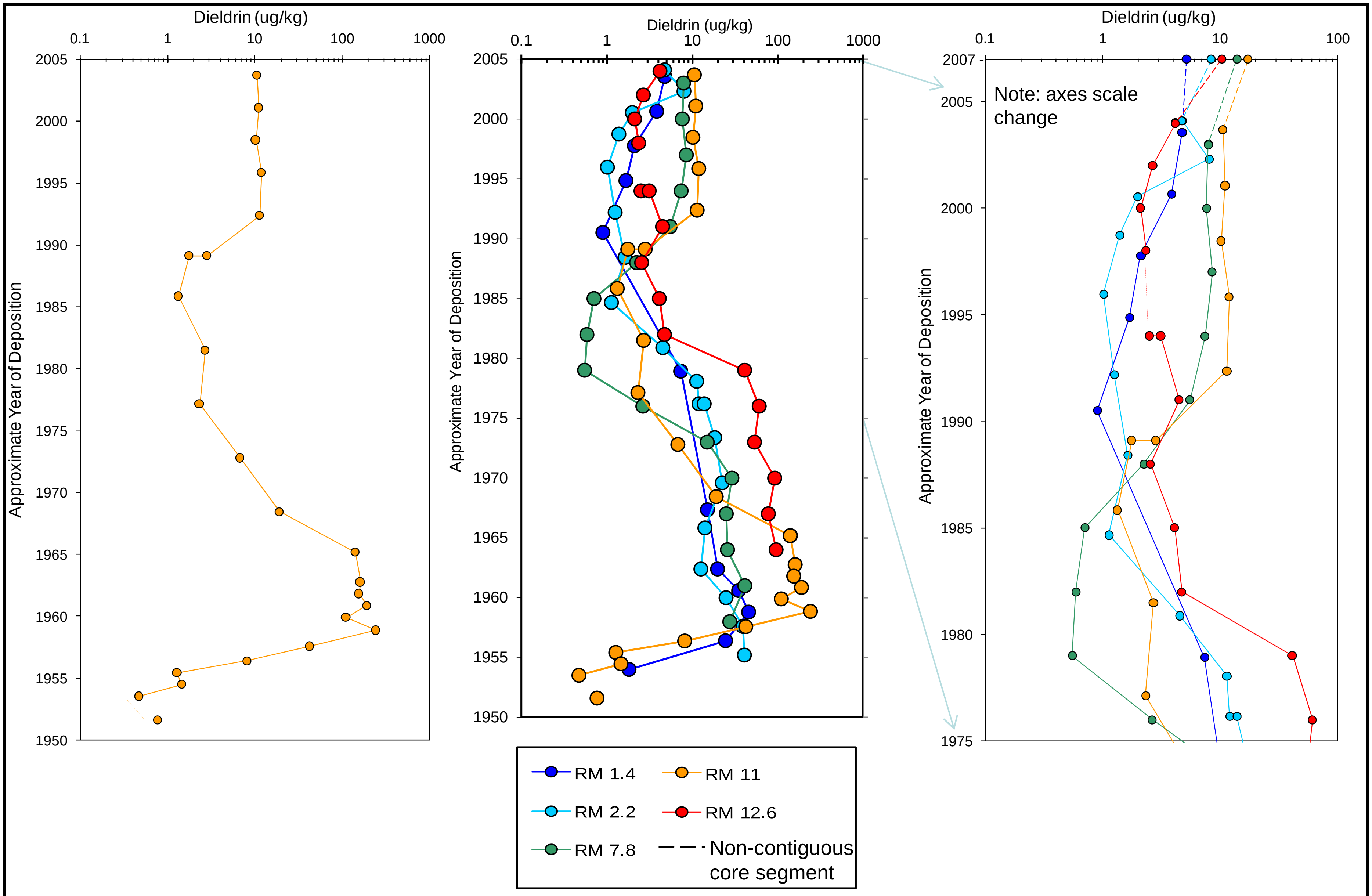


Dated Sediment Core Profile for 4,4’-DDE:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-11a

2014

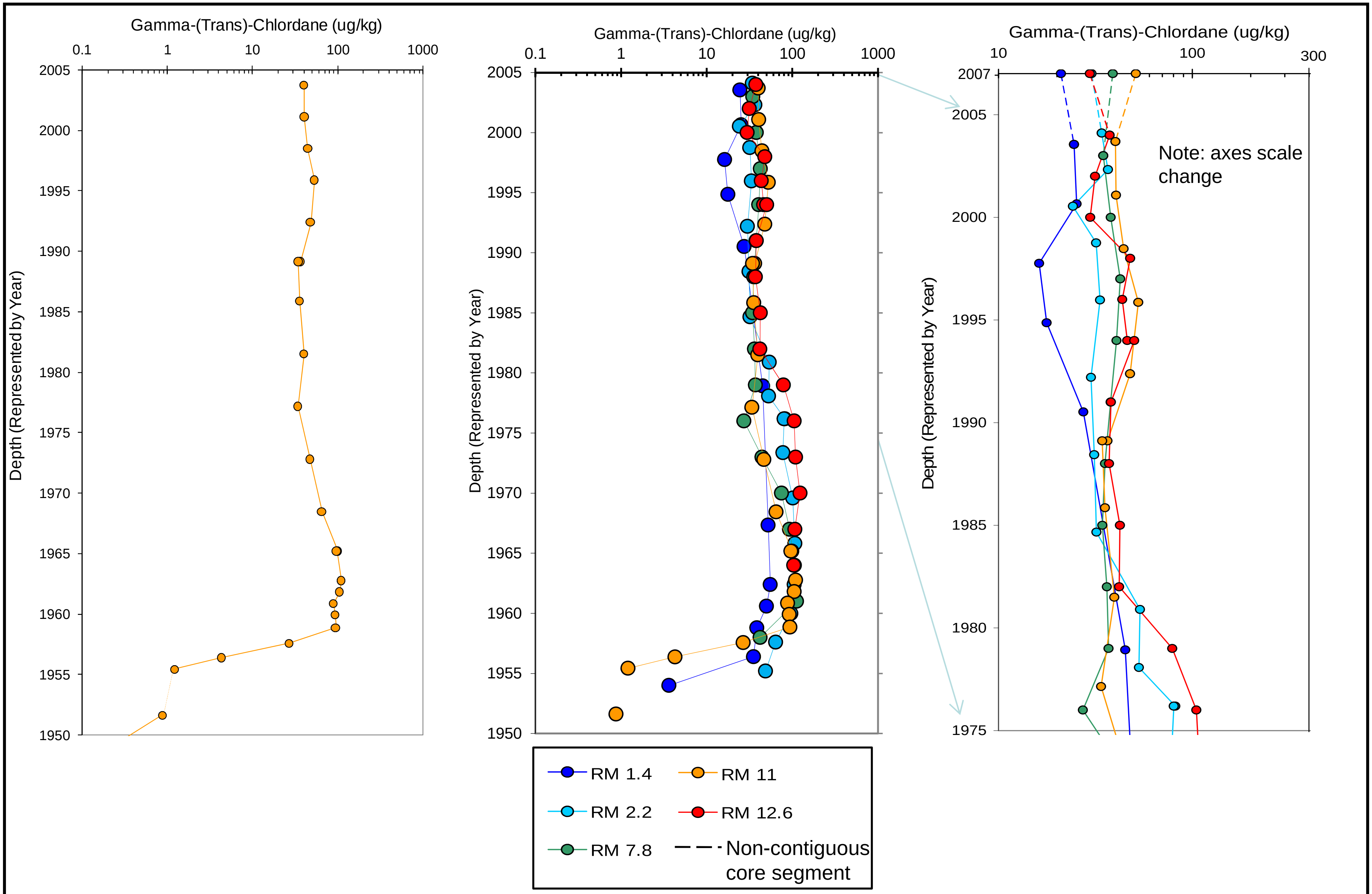


Dated Sediment Core Profile for Dieldrin:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-11b

2014

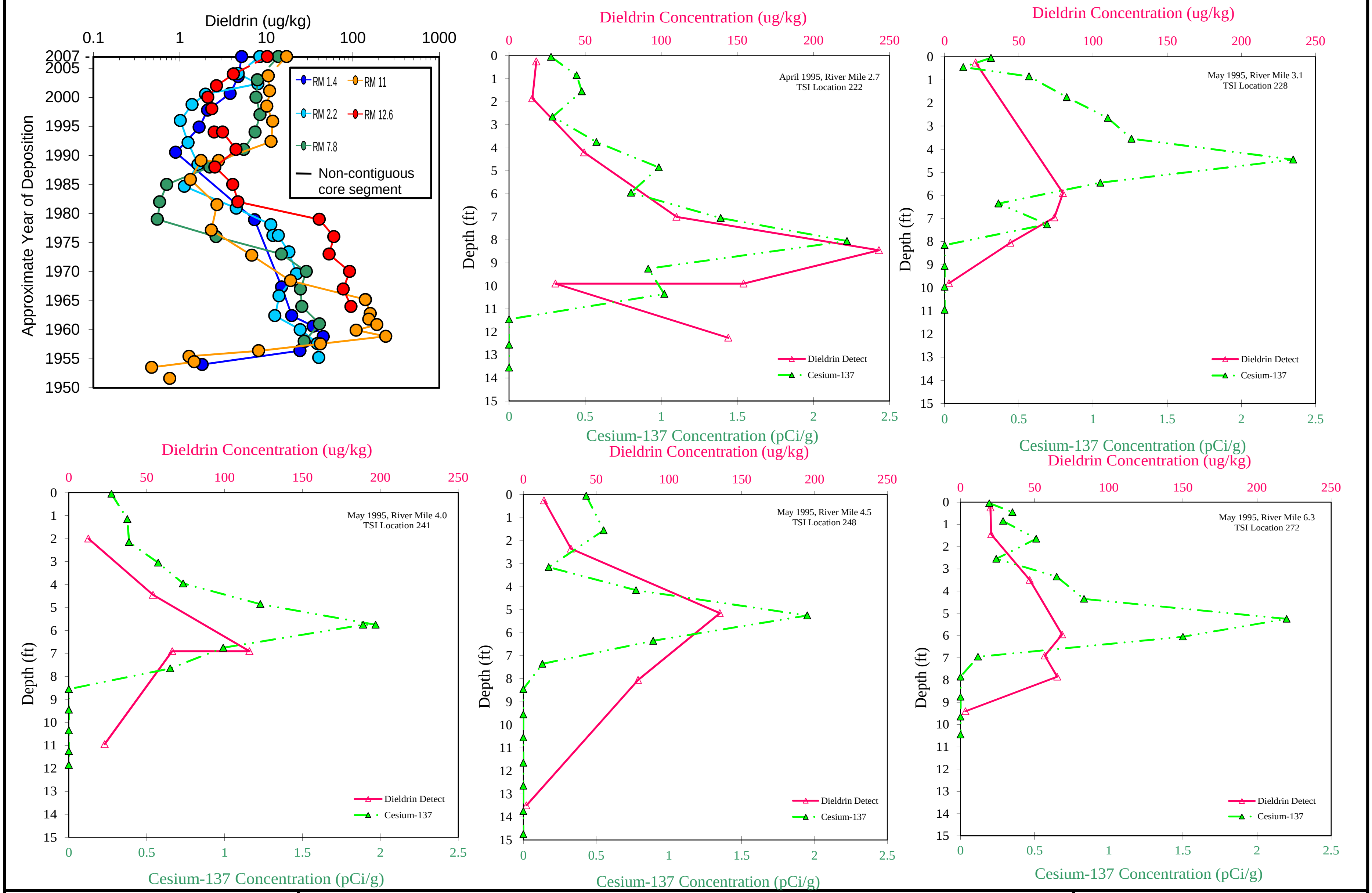


Dated Sediment Core Profile for Chlordane (gamma, trans): 2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-11c

2014

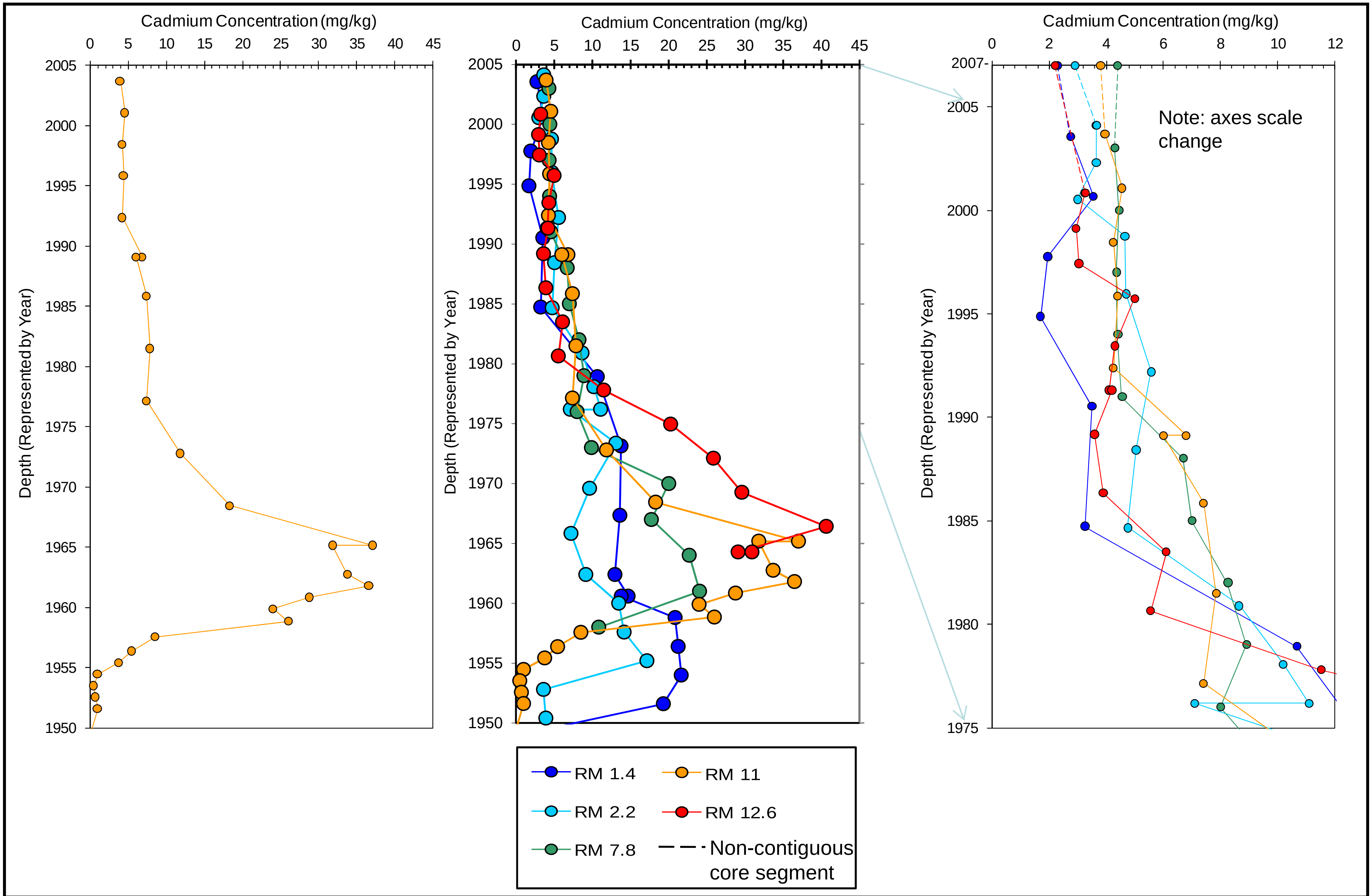


Comparison of EPA 2005 and TSI 1995 Downcore Profiles: Dieldrin

Lower Eight Miles of the Lower Passaic River

Figure 3-12

2014

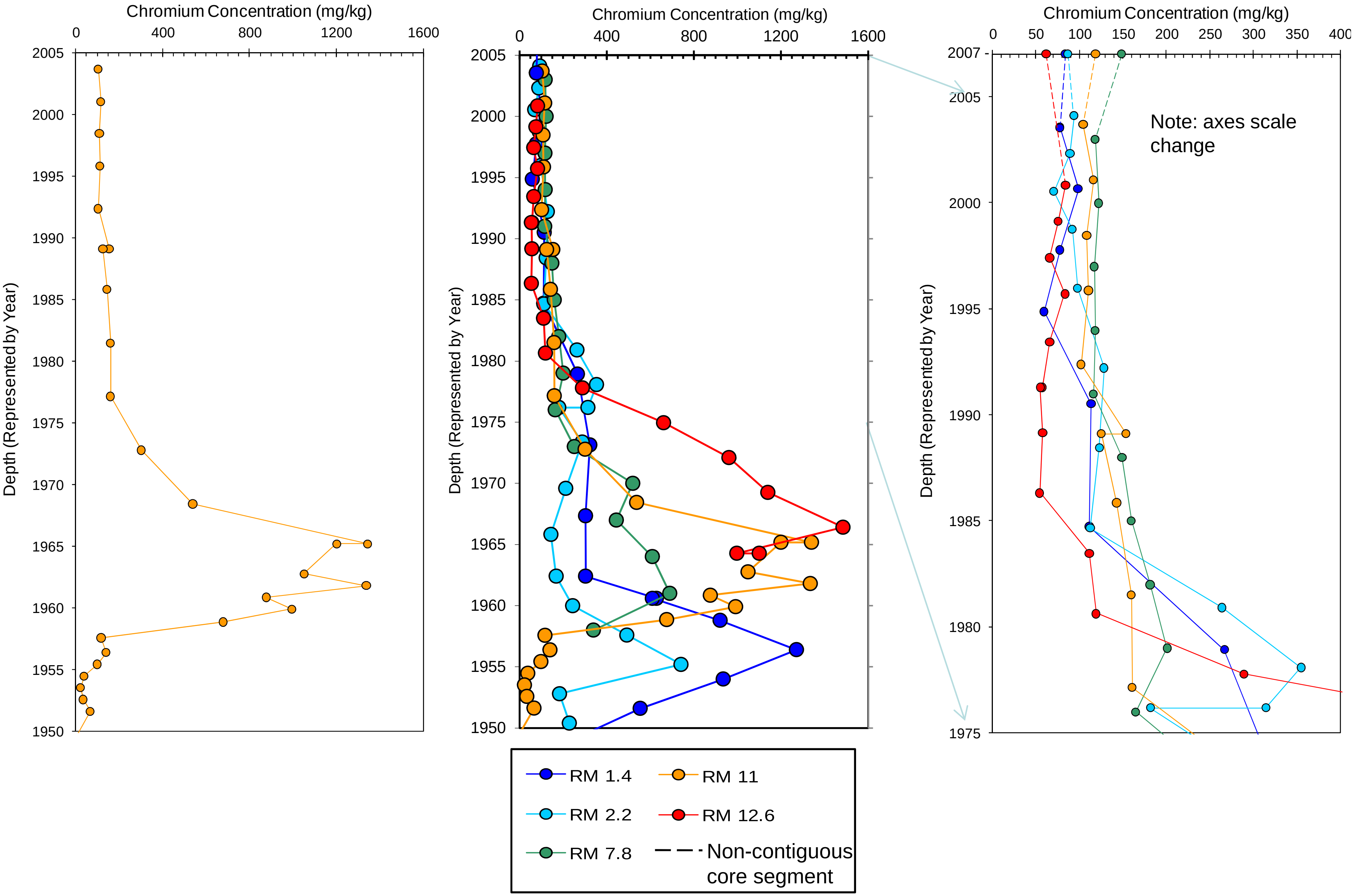


Dated Sediment Core Profile for Cadmium:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-13a

2014

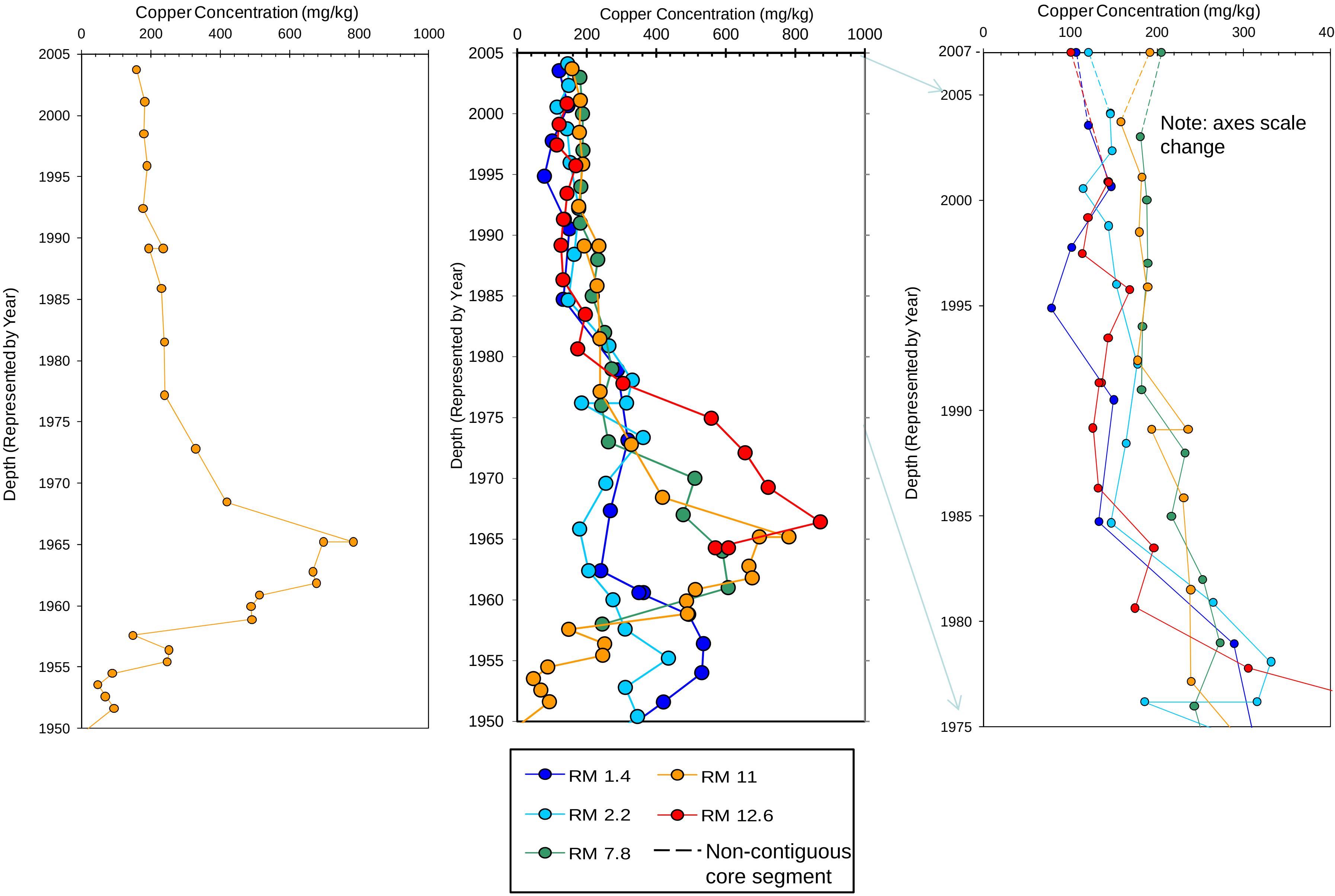


Dated Sediment Core Profile for Chromium:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-13b

2014

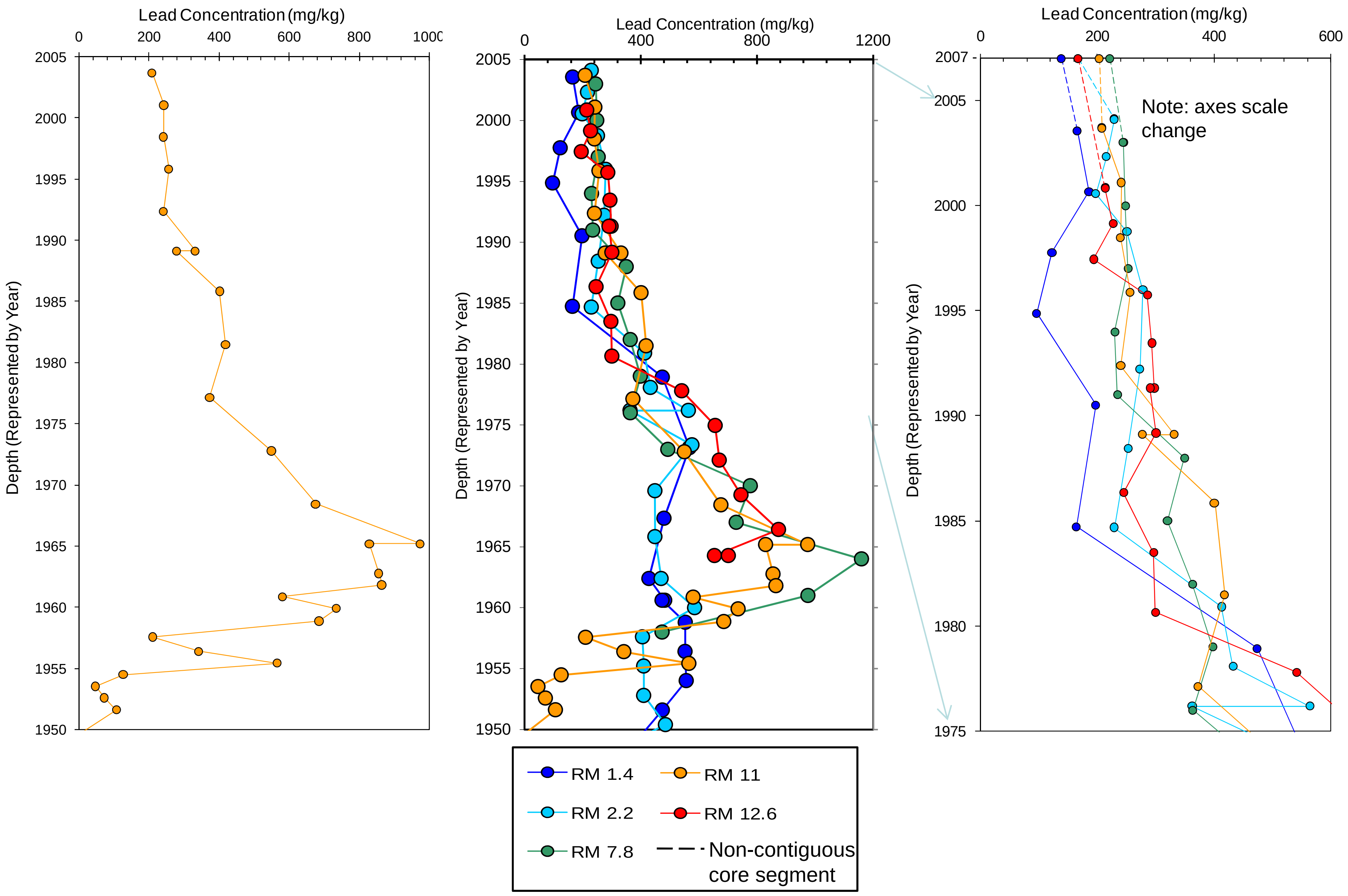


Dated Sediment Core Profile for Copper:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-13c

2014

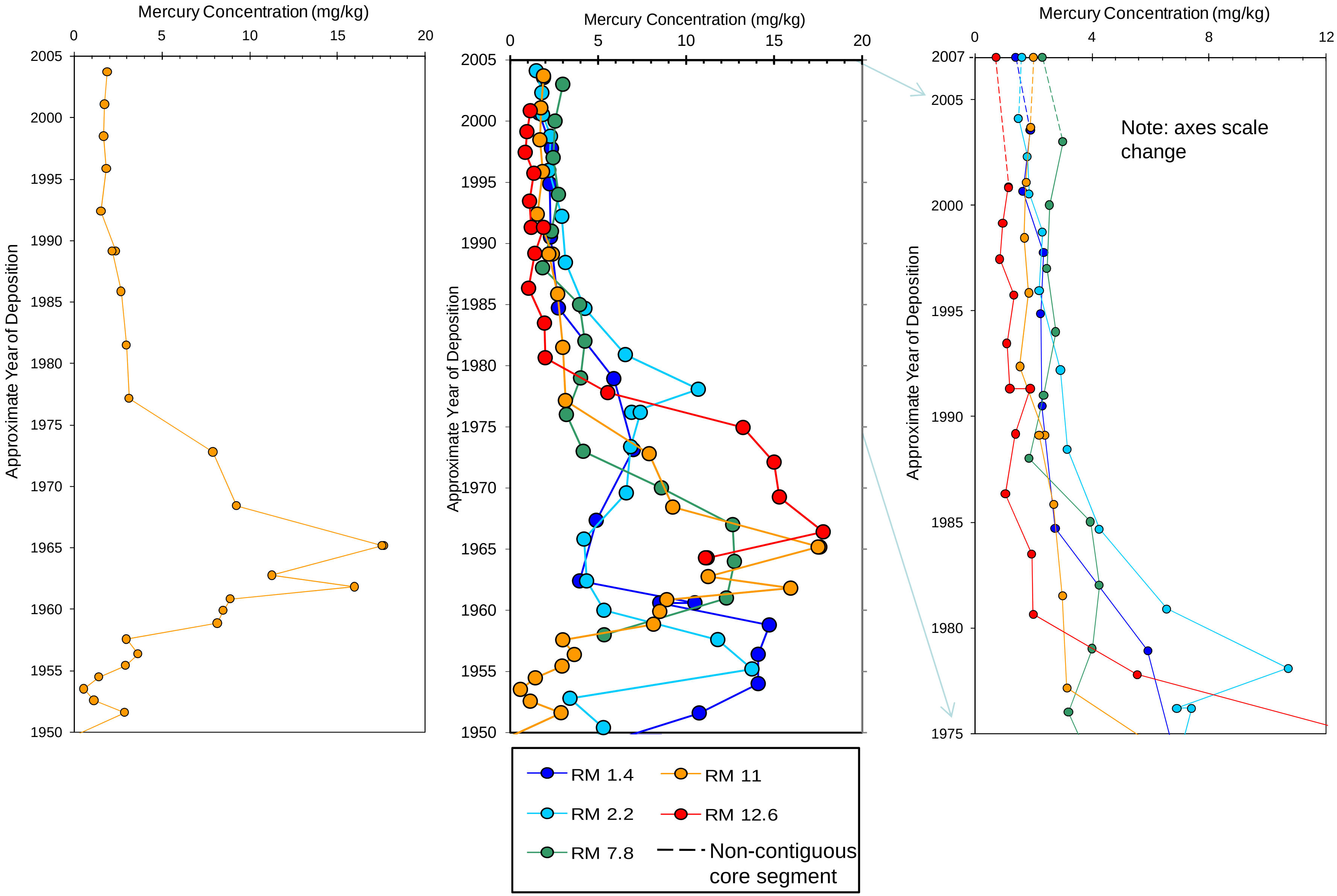


Dated Sediment Core Profile for Lead: 2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-13d

2014

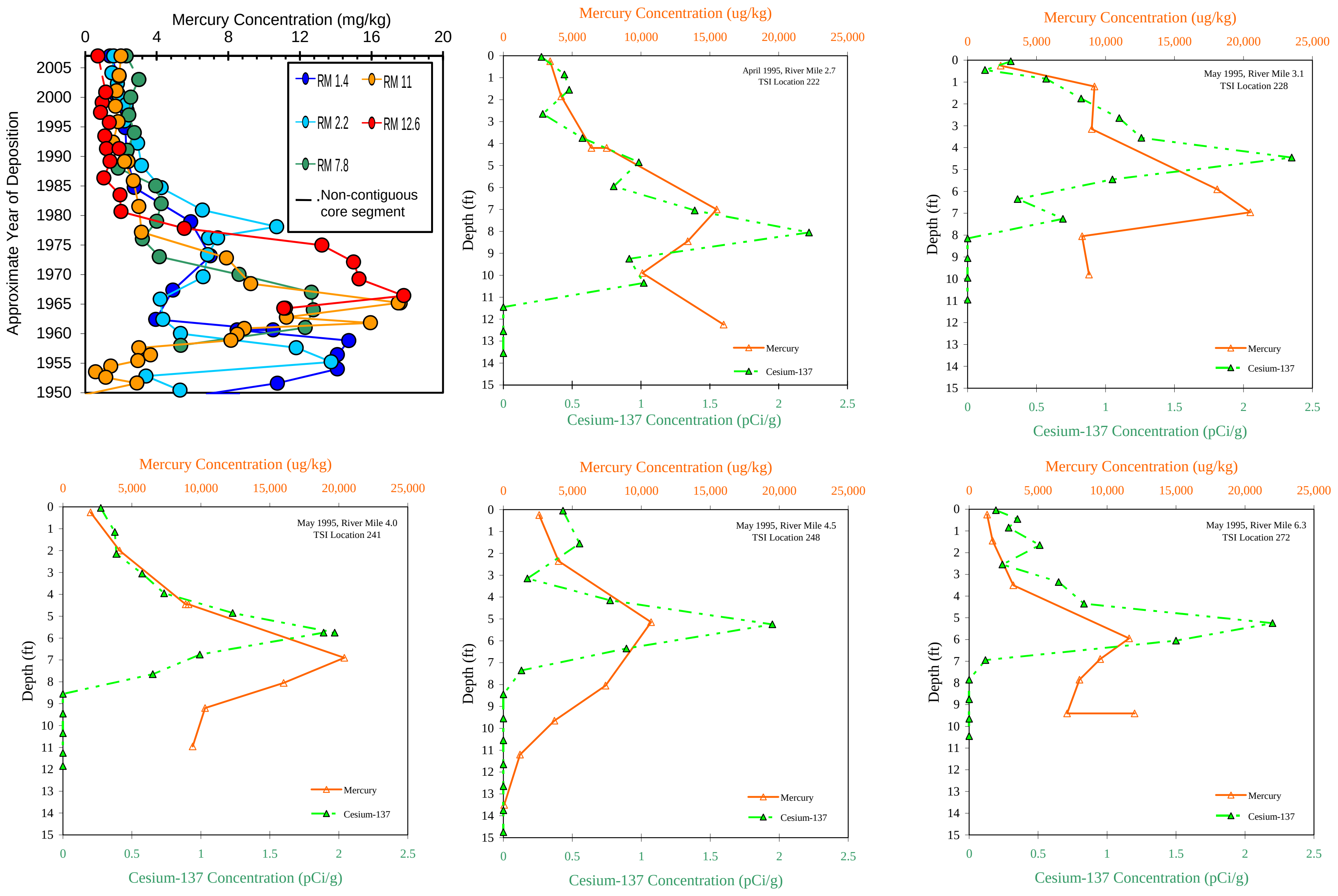


Dated Sediment Core Profile for Mercury:
2005 High Resolution Cores and 2007 Surface Samples

Lower Eight Miles of the Lower Passaic River

Figure 3-13e

2014



Comparison of EPA 2005 and TSI 1995 Downcore Profiles:
Mercury

Lower Eight Miles of the Lower Passaic River

Figure 3-14

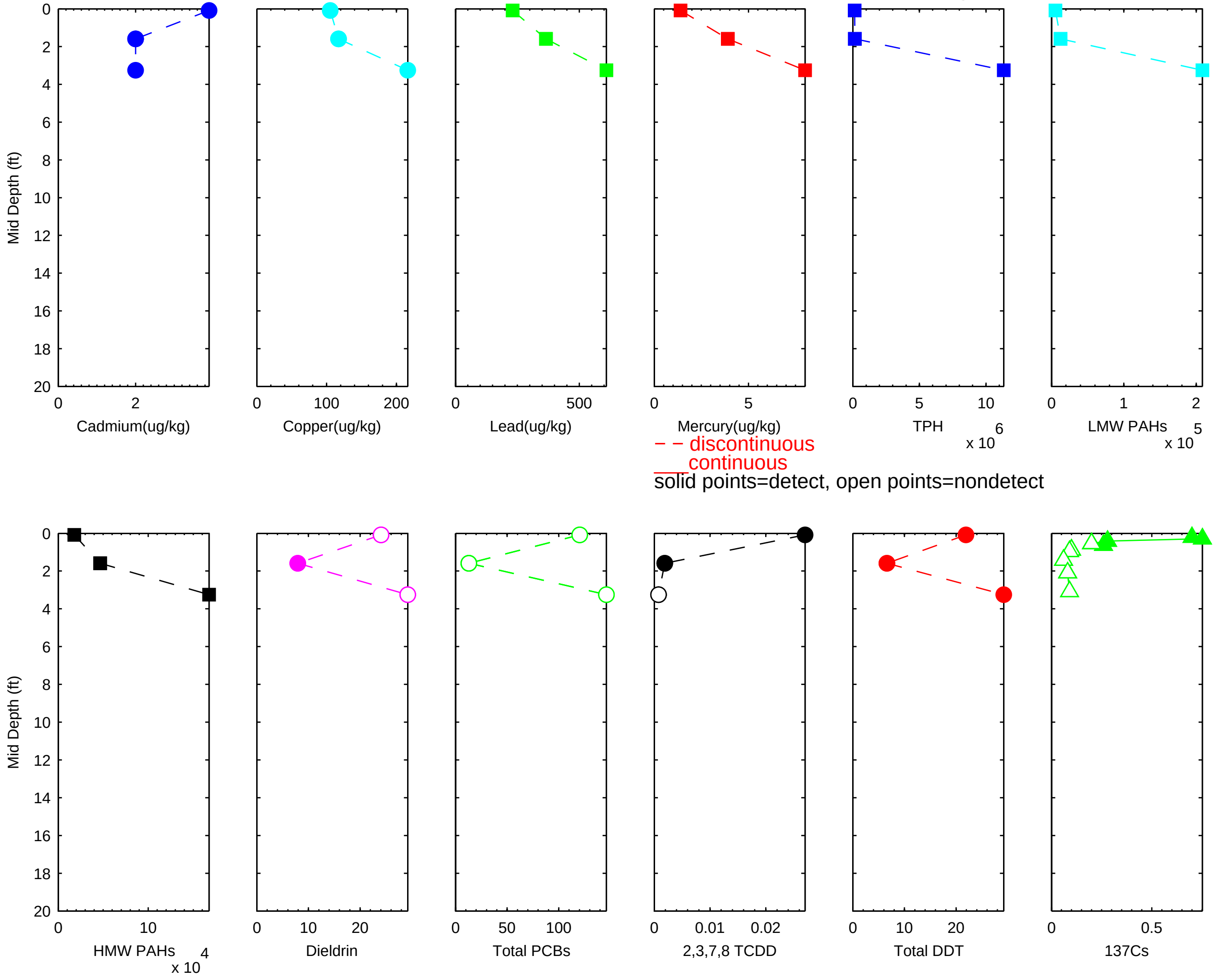
2014

ATTACHMENTS

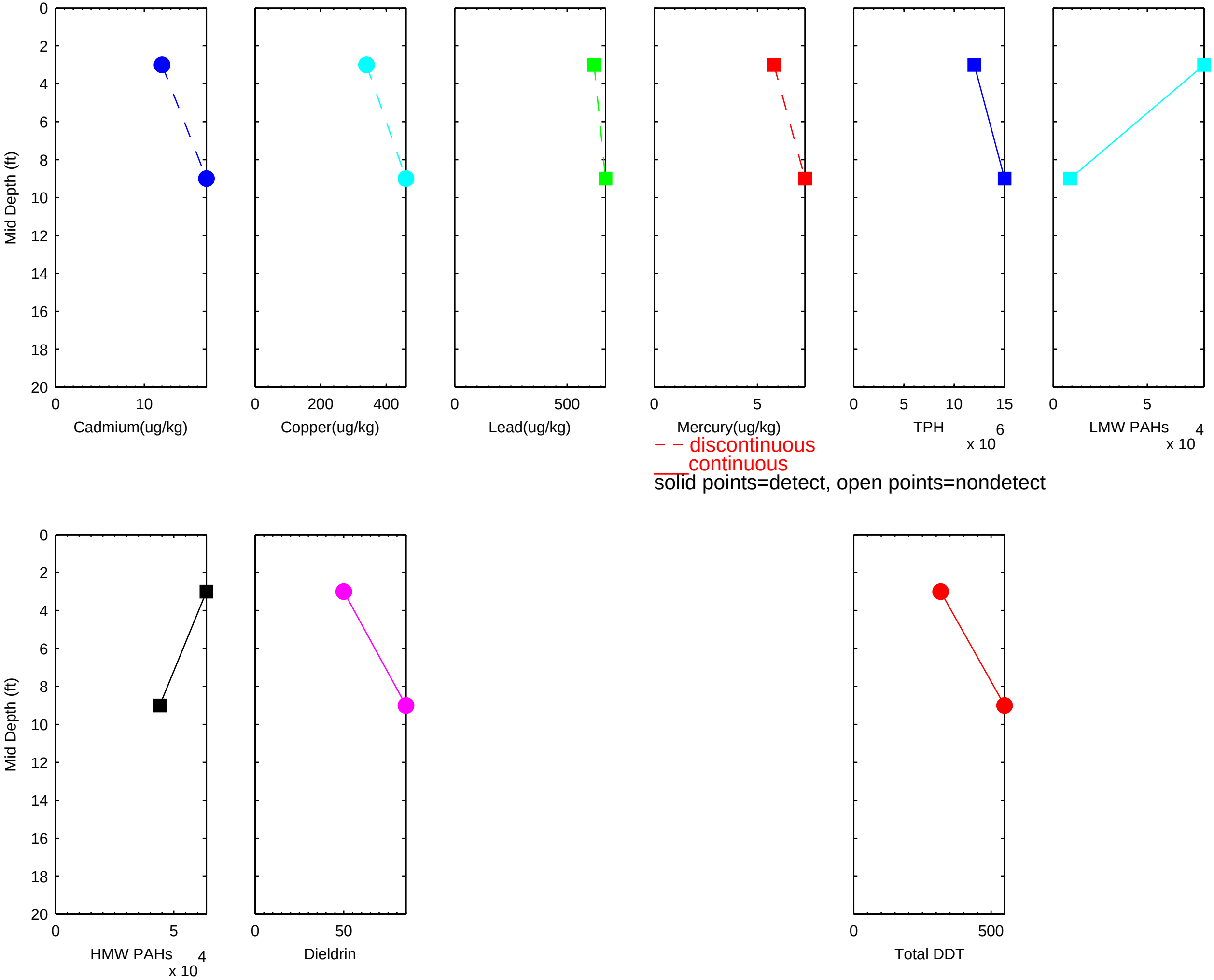
Attachment A

Downcore Profiles of Historical Cores (1991 to 1995)

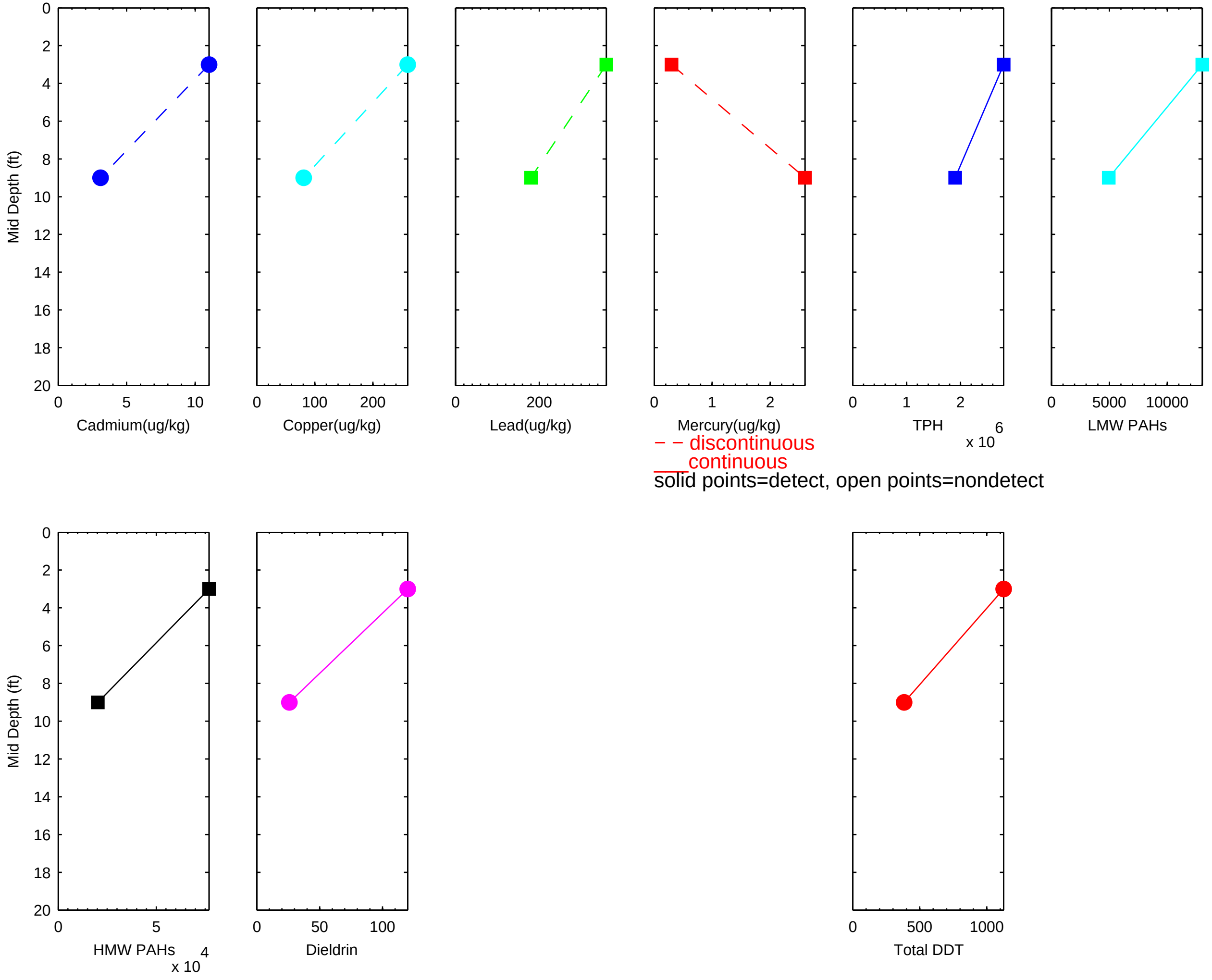
Sample ID: 01A River Mile 17.43 PASSAIC 1991 Core Sediment Investigation



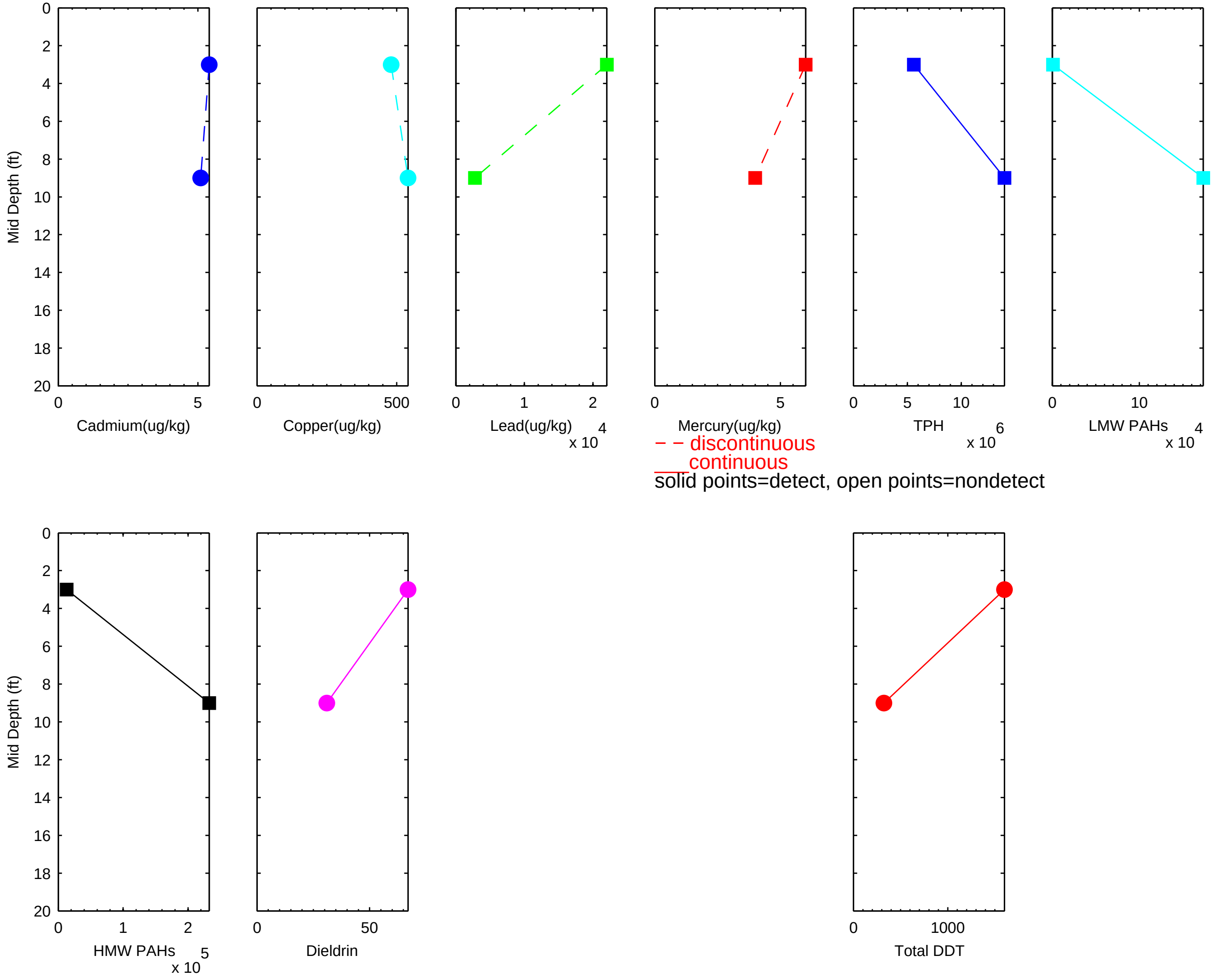
Sample ID: WTH−6 River Mile 4.98 PASSAIC 1995 USACE Minish Park Investigation



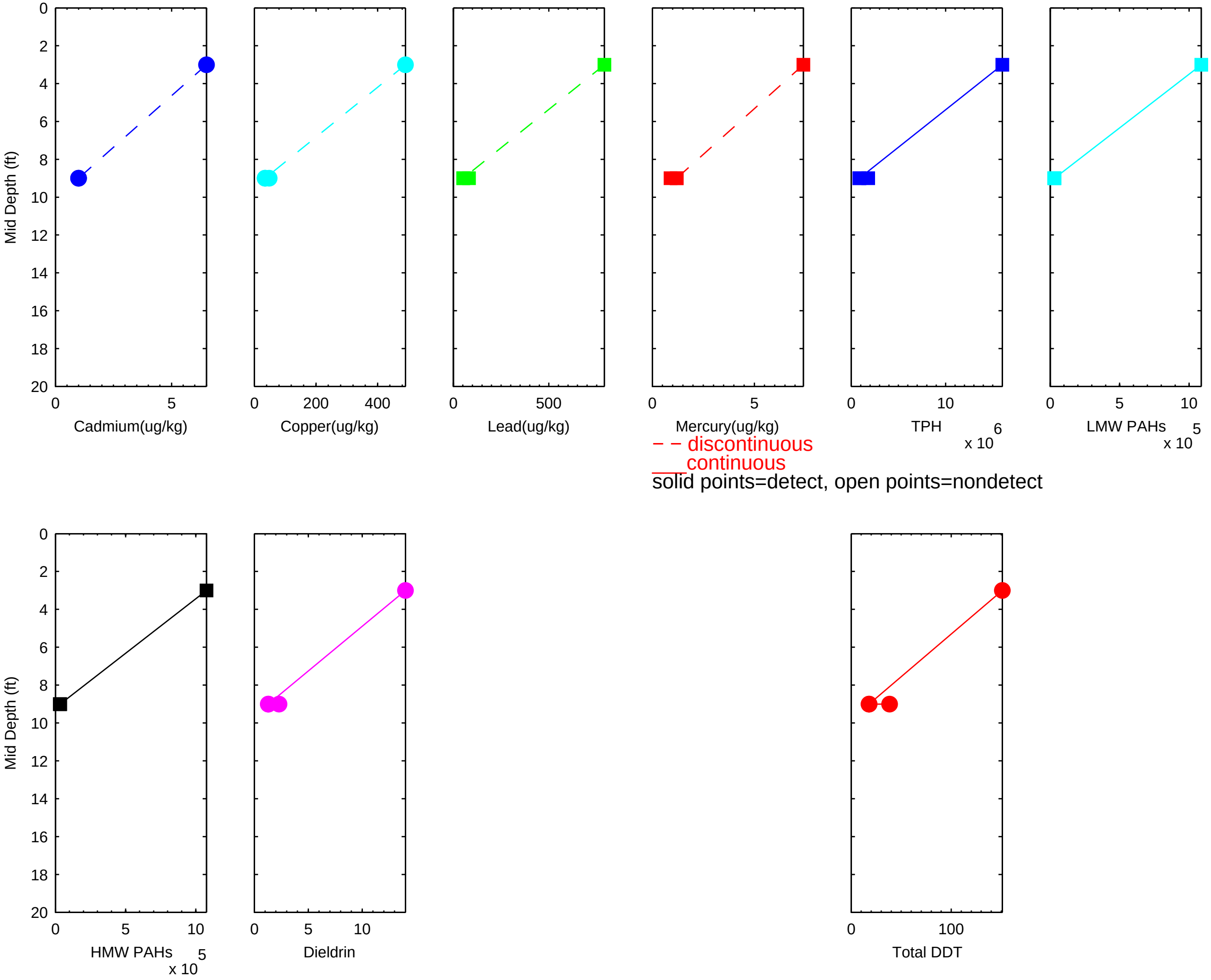
Sample ID: WTH−5 River Mile 4.74 PASSAIC 1995 USACE Minish Park Investigation



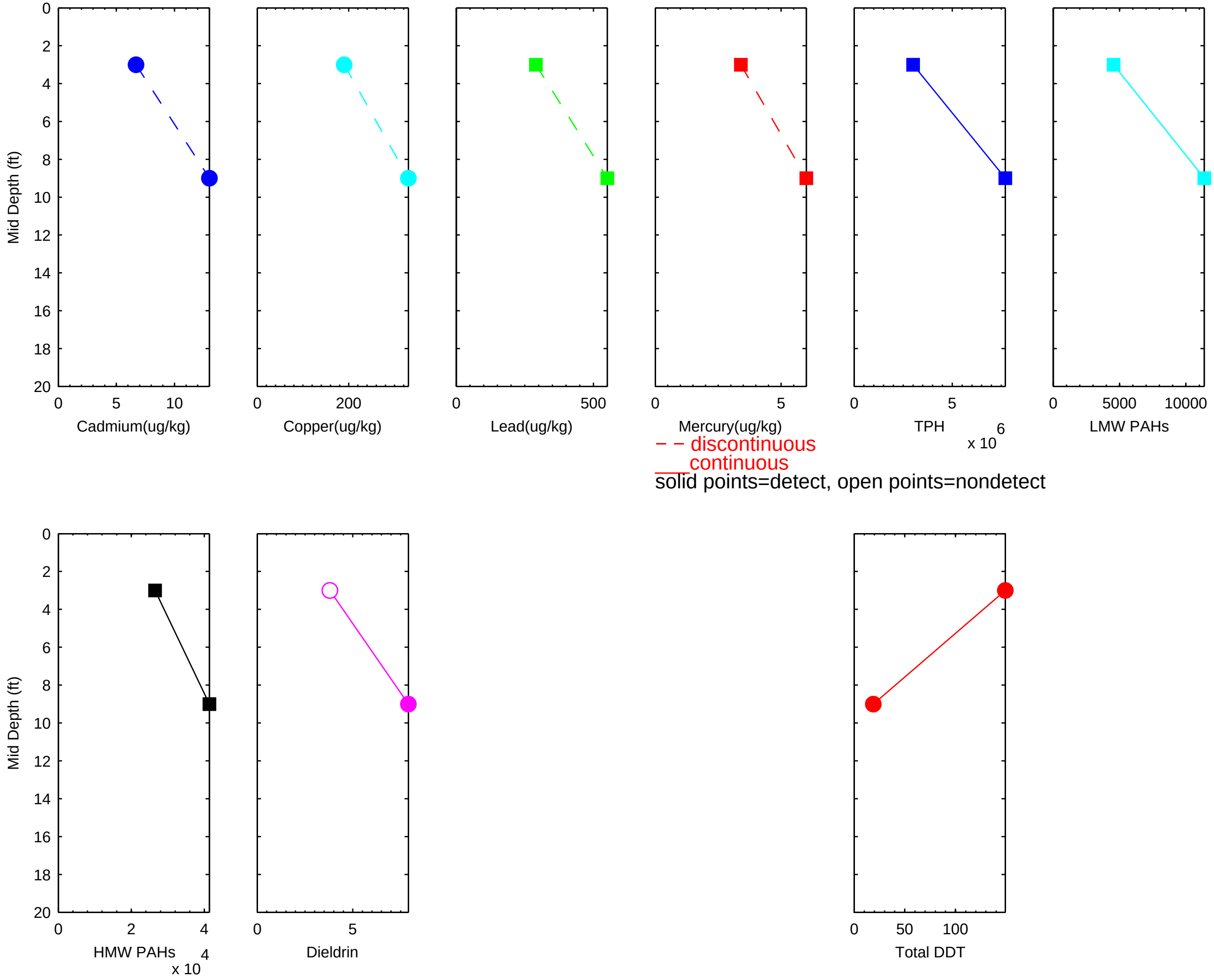
Sample ID: WTH−3 River Mile 4.36   PASSAIC 1995 RI Sampling Program



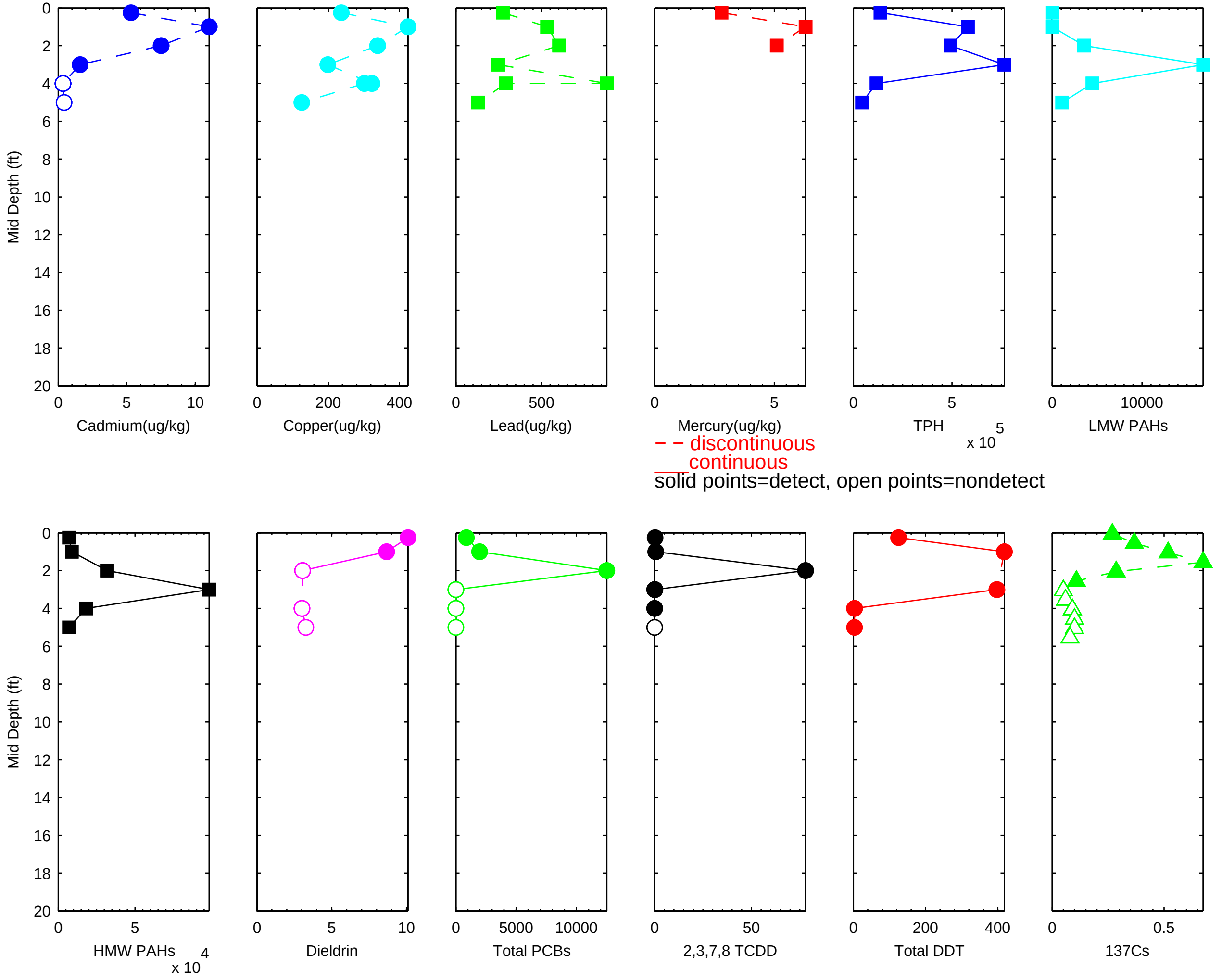
Sample ID: WTH−2 River Mile 4.04 PASSAIC 1995 USACE Minish Park Investigation



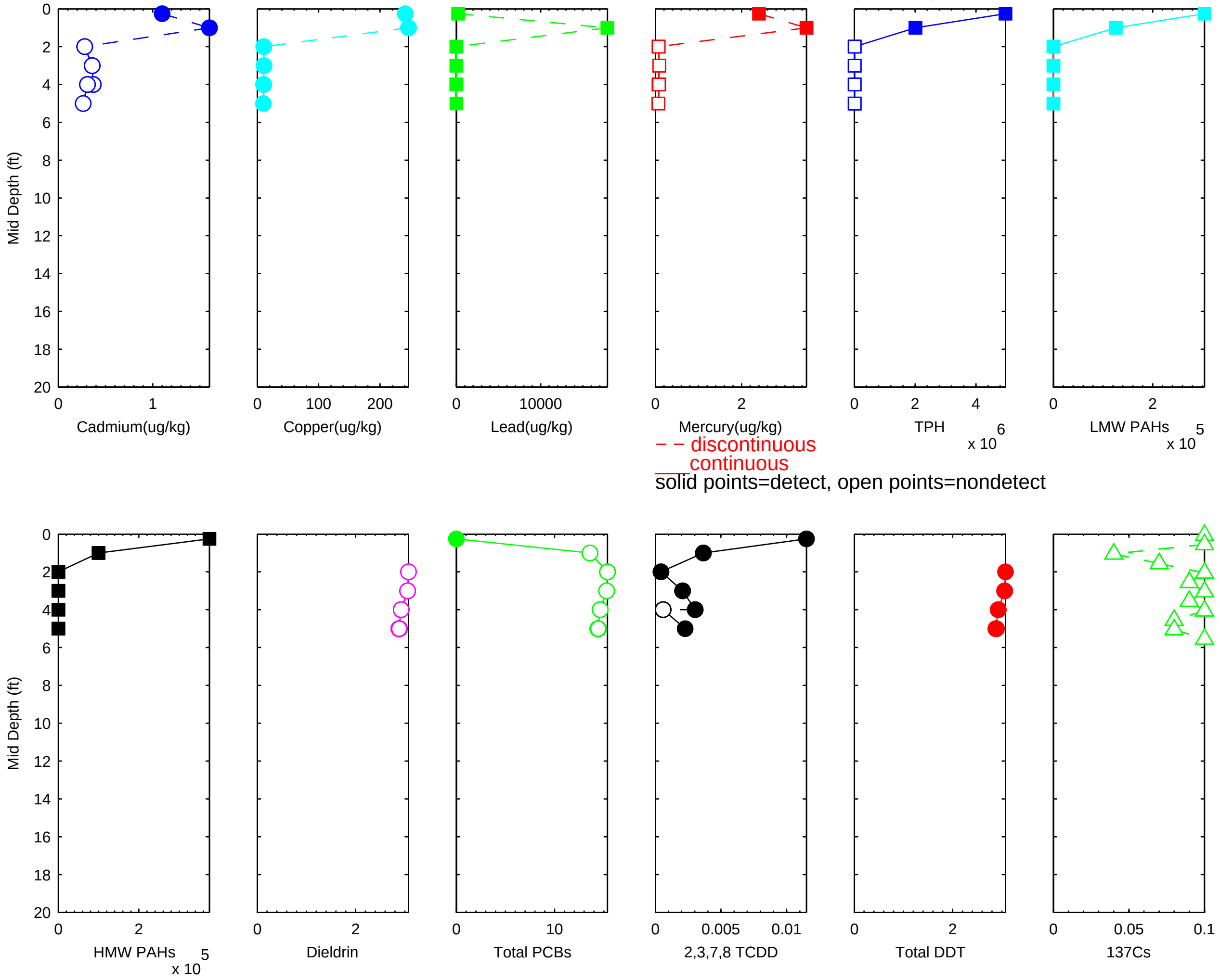
Sample ID: WTH−1 River Mile 5.39 PASSAIC 1995 USACE Minish Park Investigation



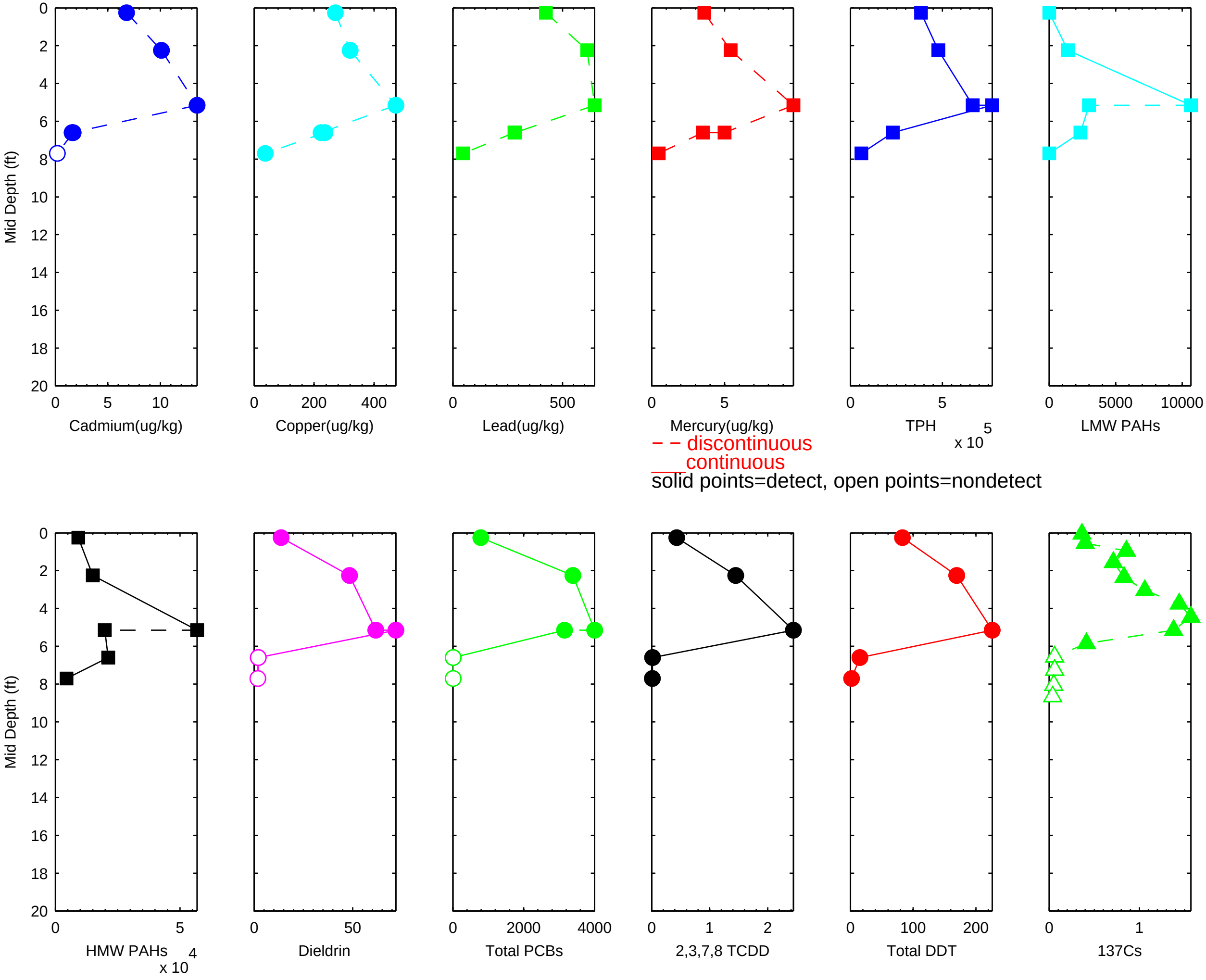
Sample ID: D03 River Mile 2.65 PASSAIC 1995 RI Sampling Program



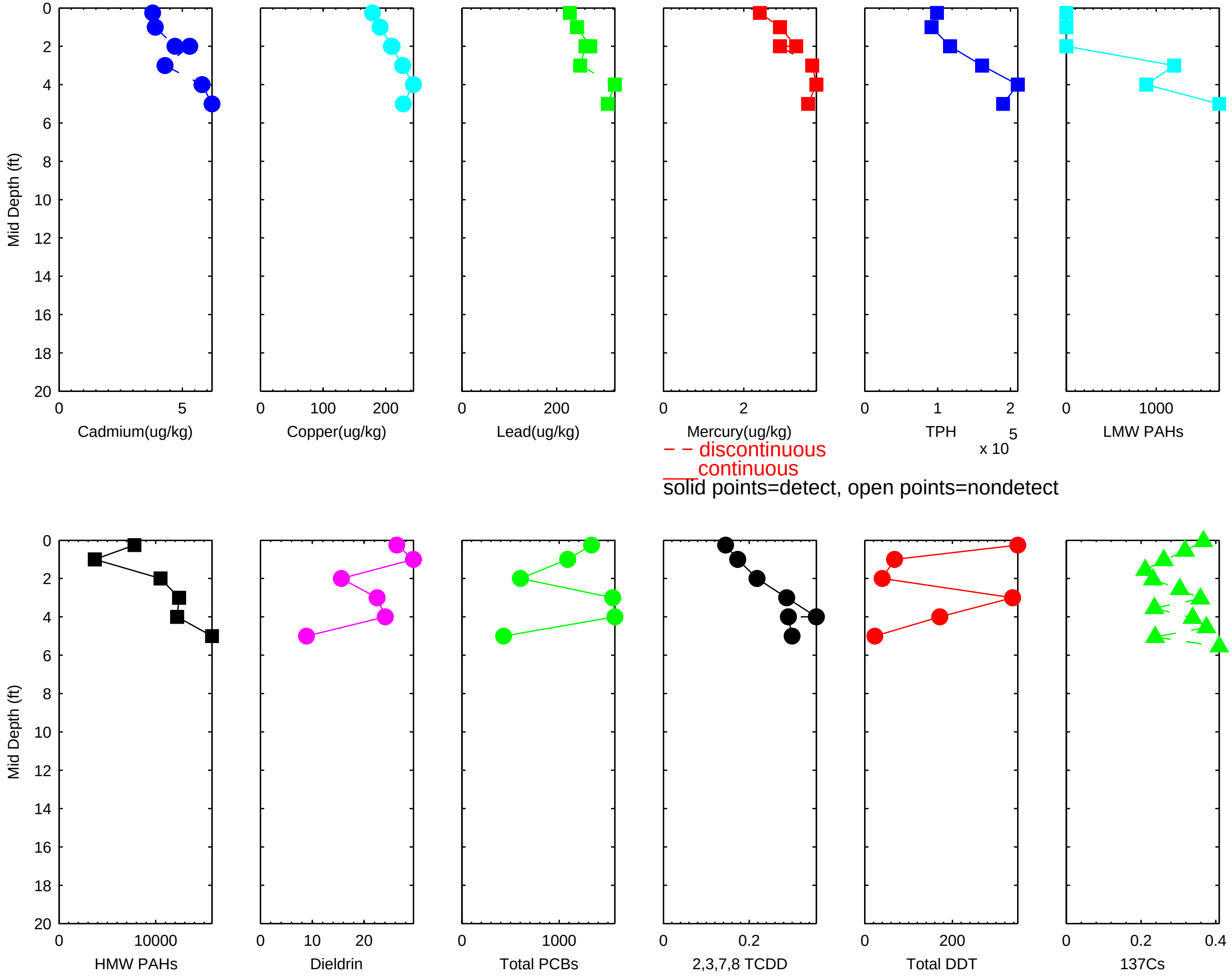
Sample ID: D02 River Mile 3.64   PASSAIC 1995 RI Sampling Program



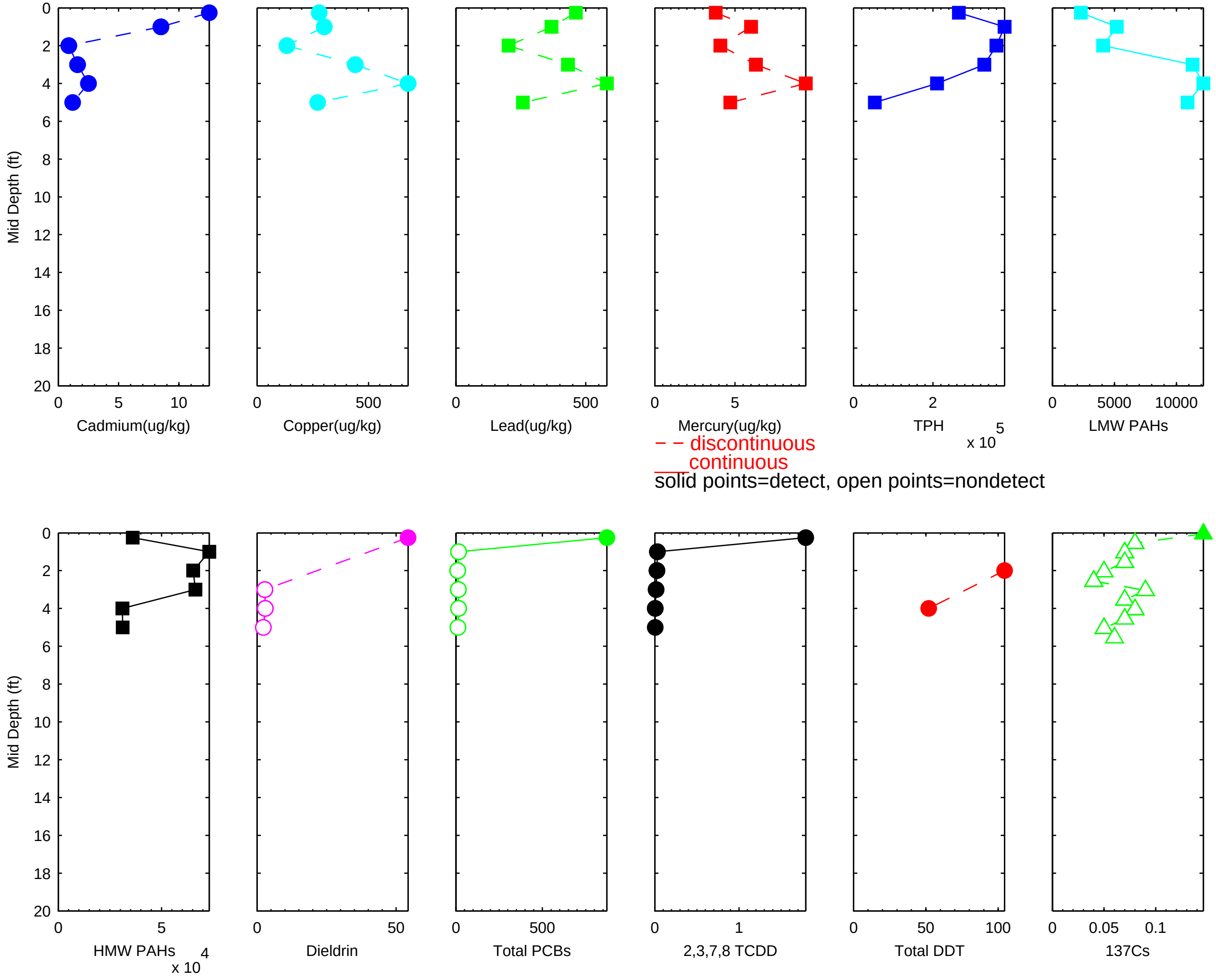
Sample ID: D01 River Mile 5.16   PASSAIC 1995 RI Sampling Program



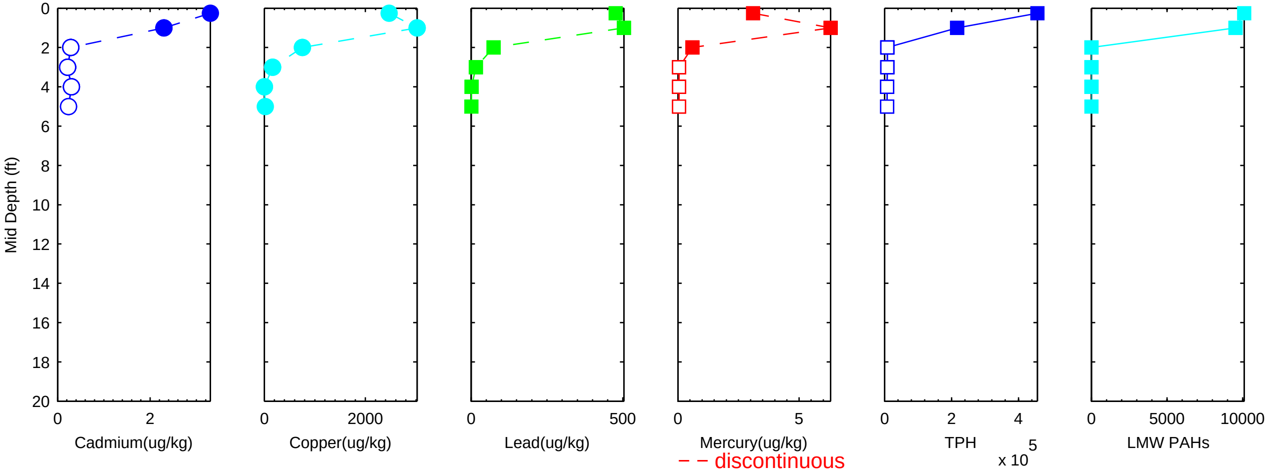
Sample ID: 295 River Mile 2.01   PASSAIC 1995 RI Sampling Program



Sample ID: 294 River Mile 3.13   PASSAIC 1995 RI Sampling Program



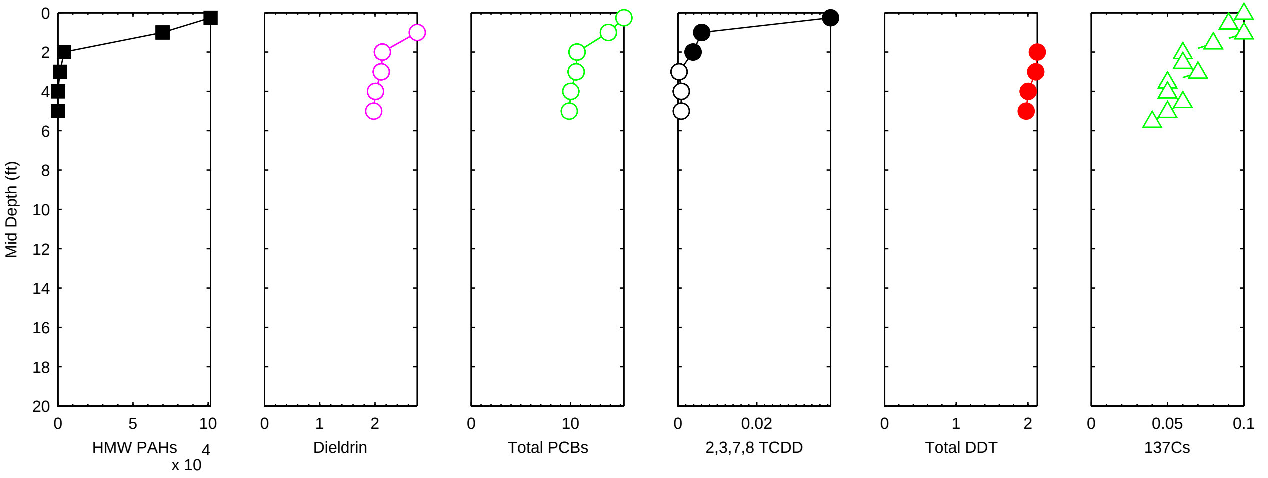
Sample ID: 293 River Mile 5.08 PASSAIC 1995 RI Sampling Program



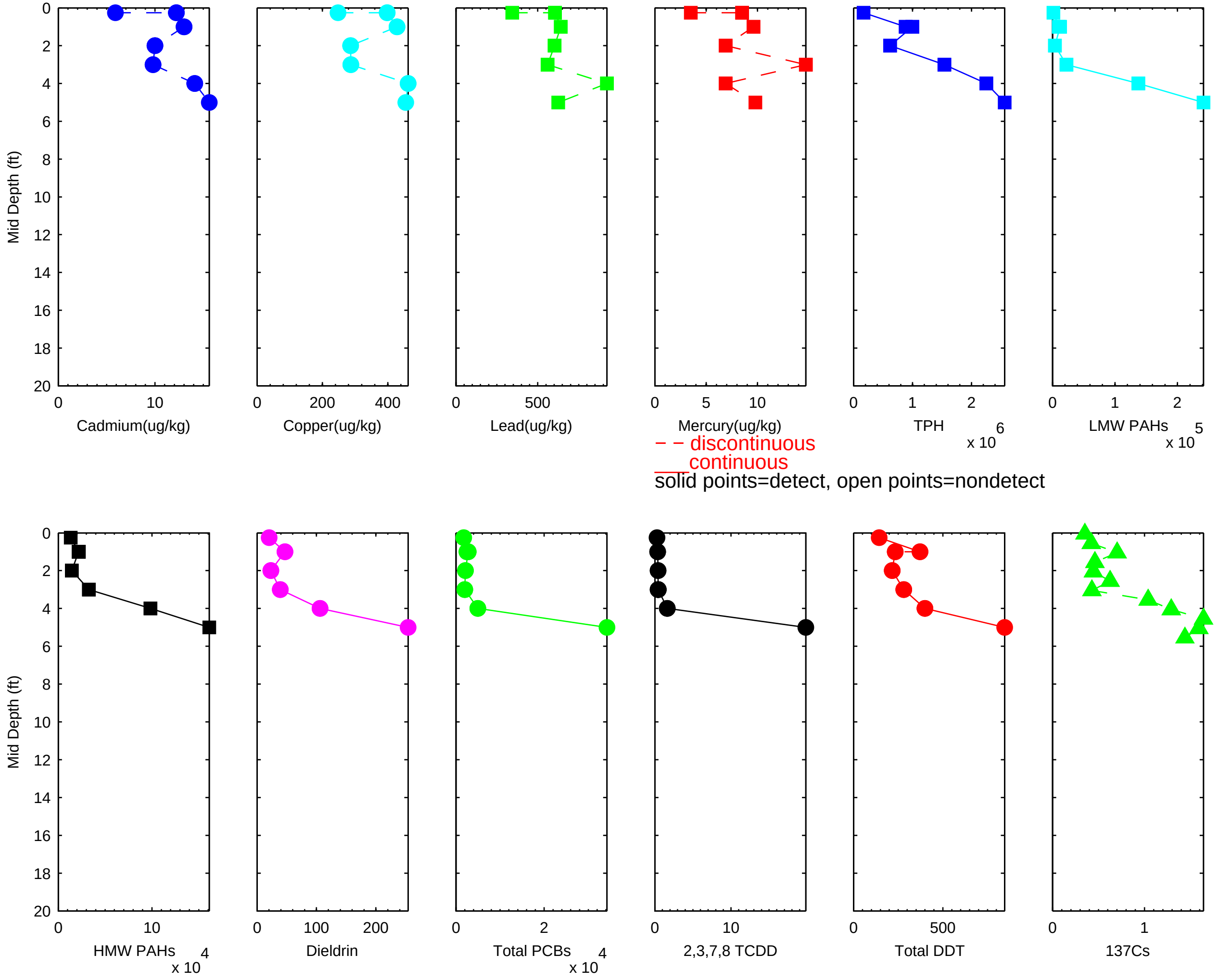
— — discontinuous

___ continuous

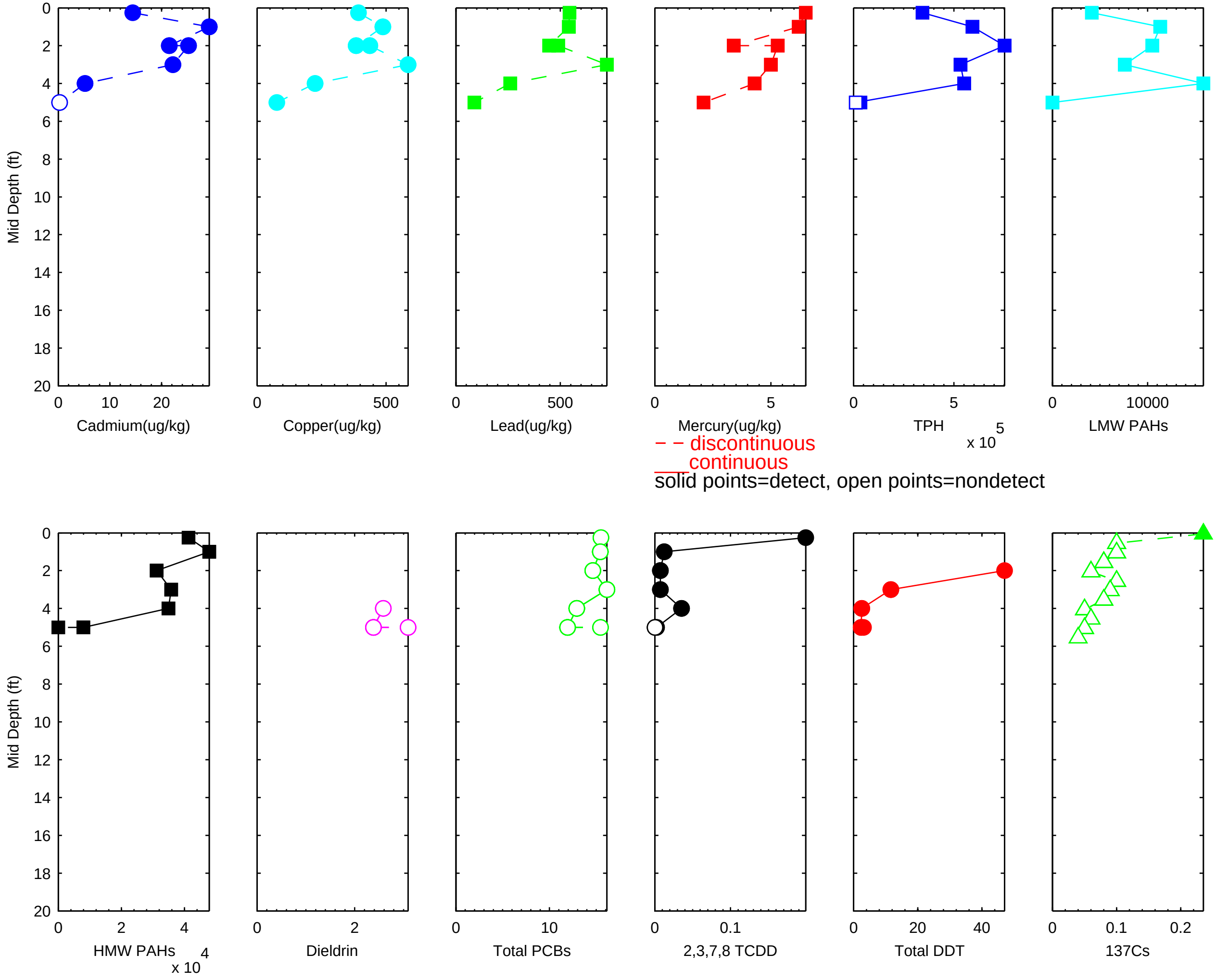
solid points=detect, open points=nondetect



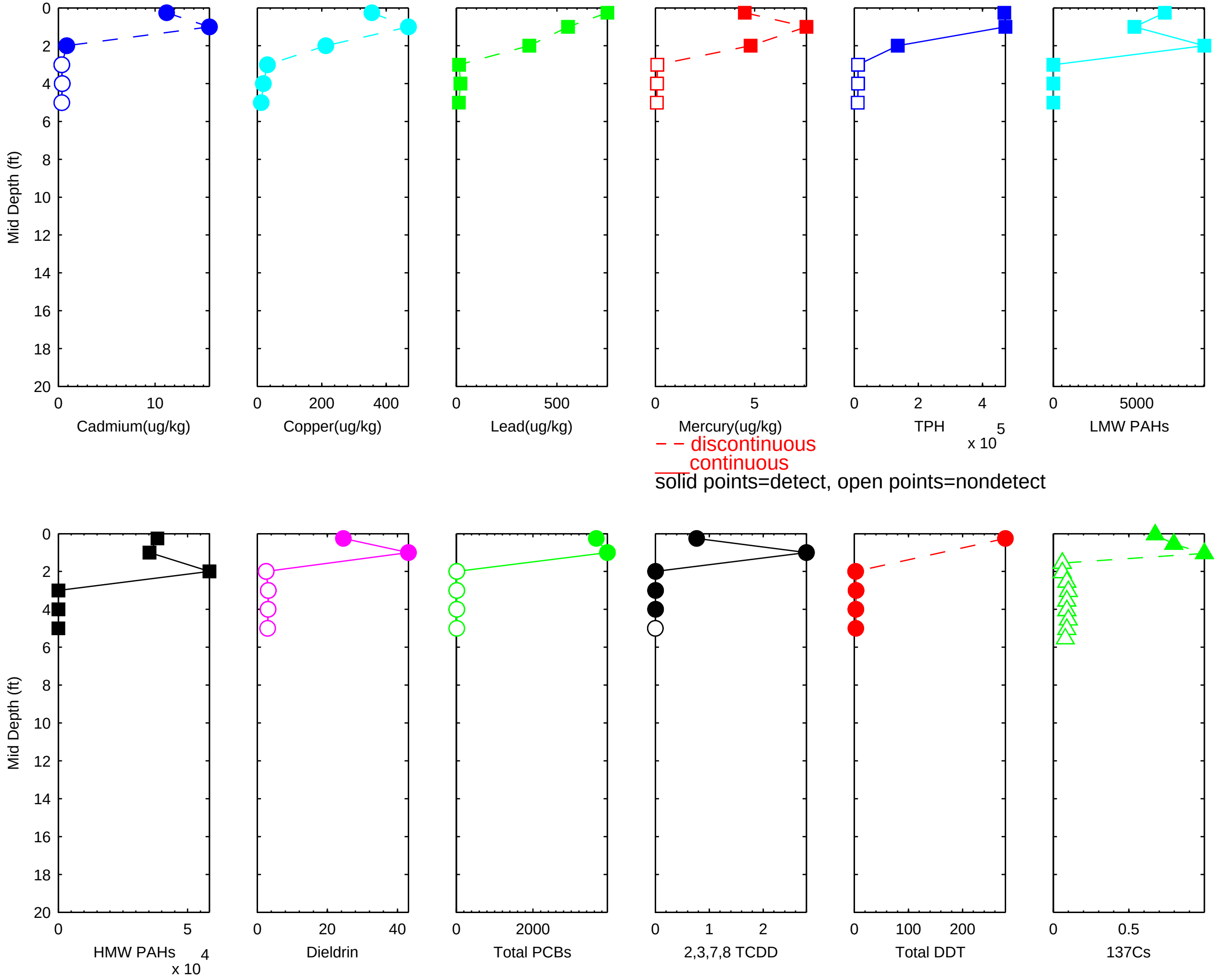
Sample ID: 292 River Mile 4.37   PASSAIC 1995 RI Sampling Program



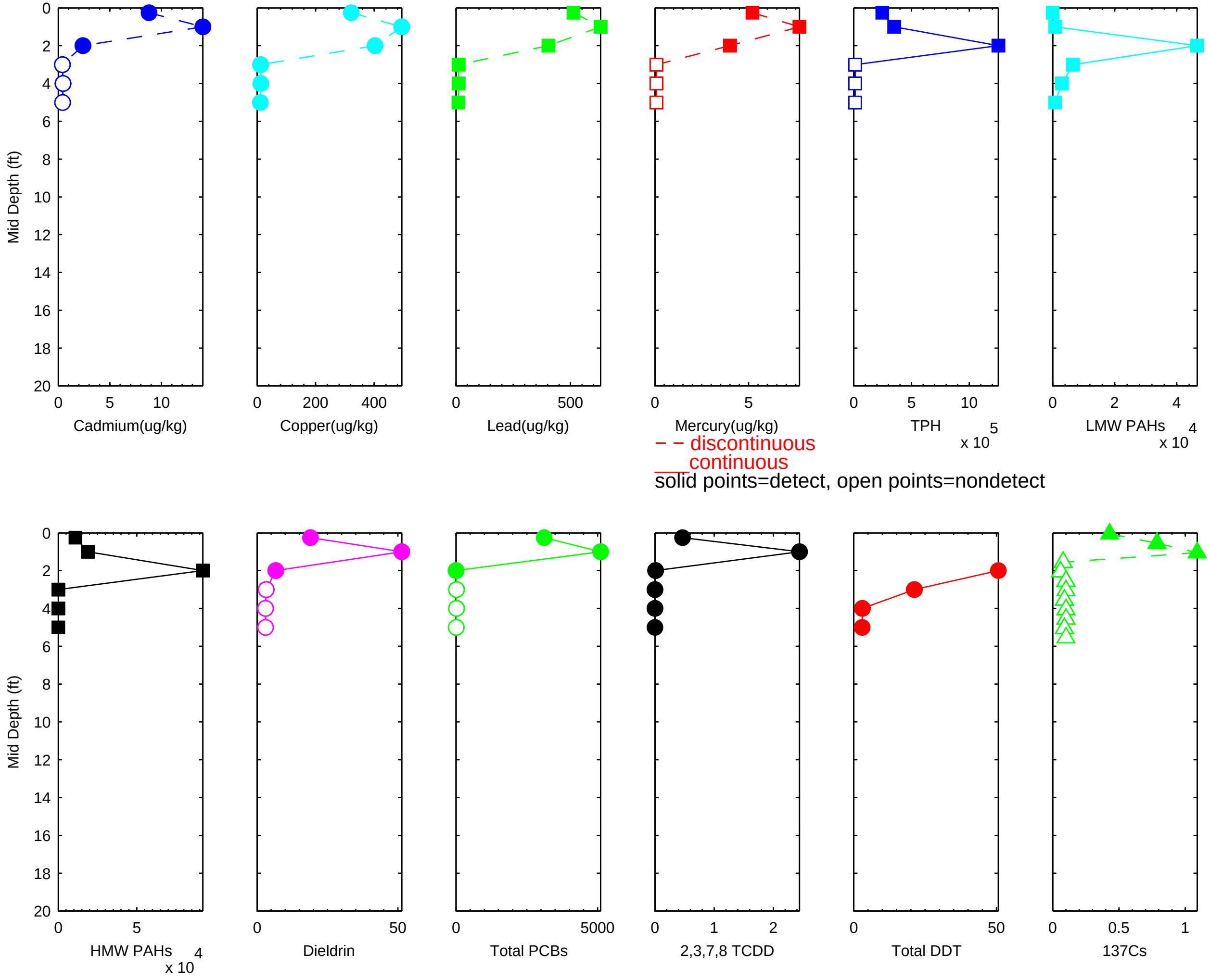
Sample ID: 291 River Mile 4.3   PASSAIC 1995 RI Sampling Program



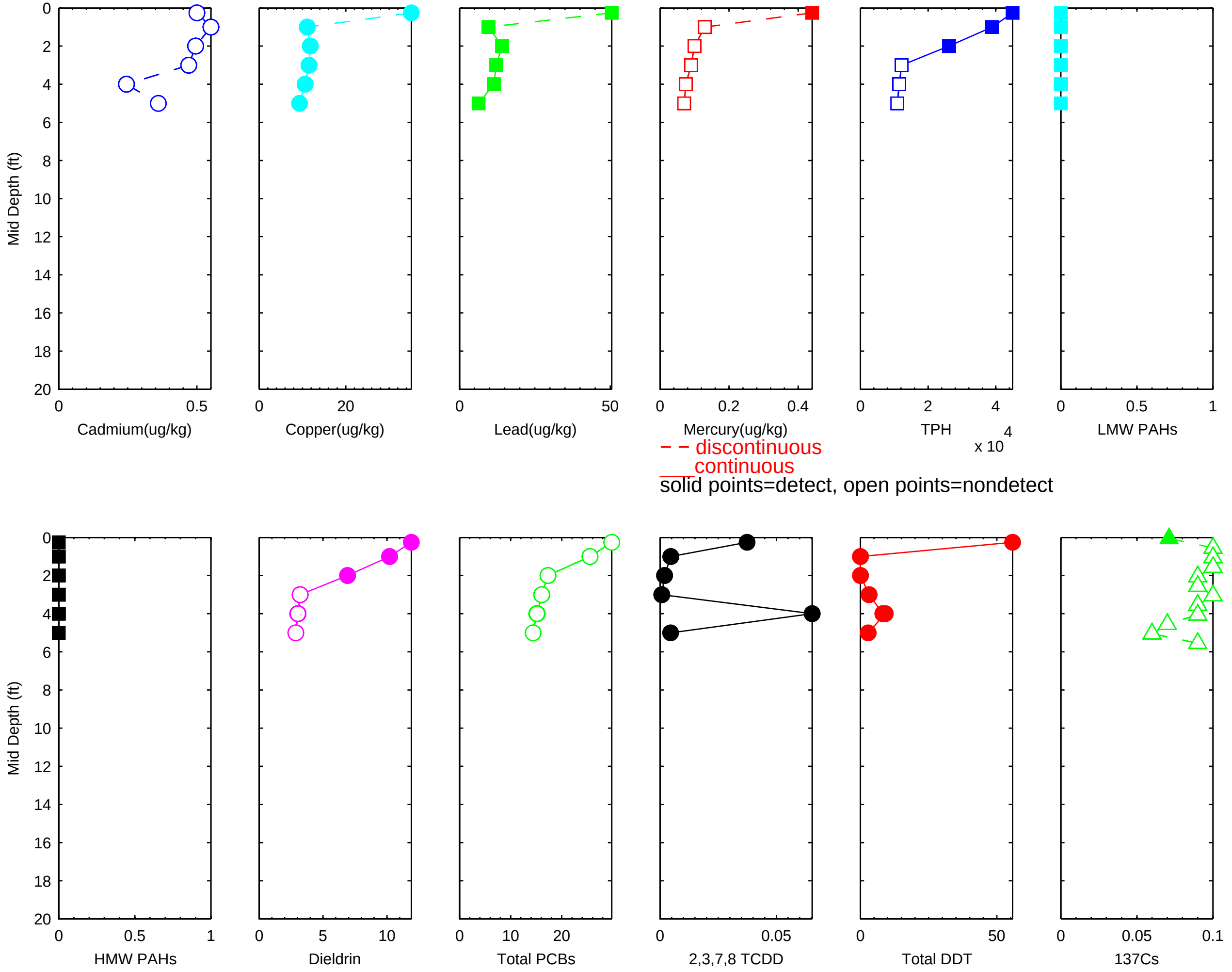
Sample ID: 290 River Mile 4.24 PASSAIC 1995 RI Sampling Program



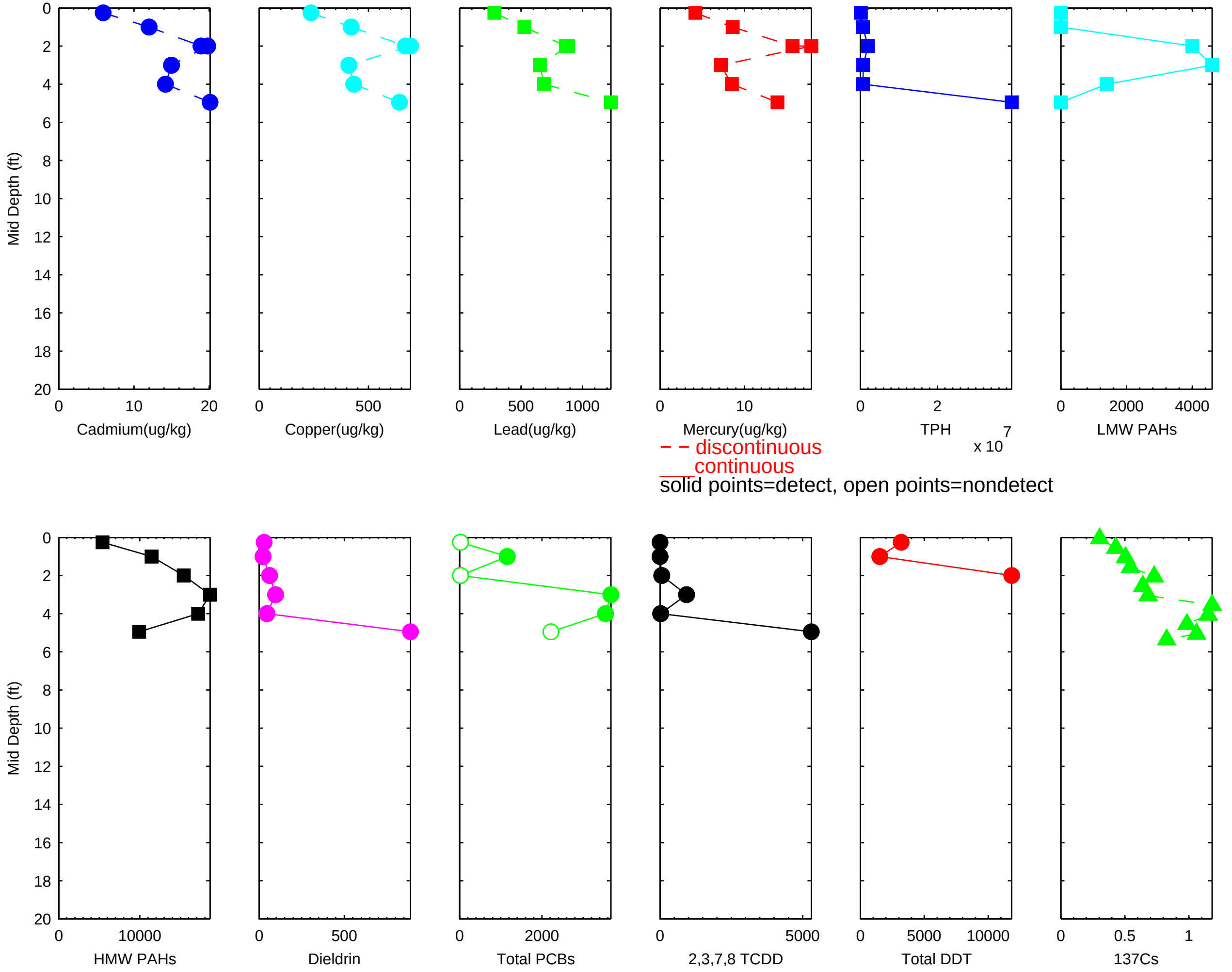
Sample ID: 289 River Mile 4.17 PASSAIC 1995 RI Sampling Program



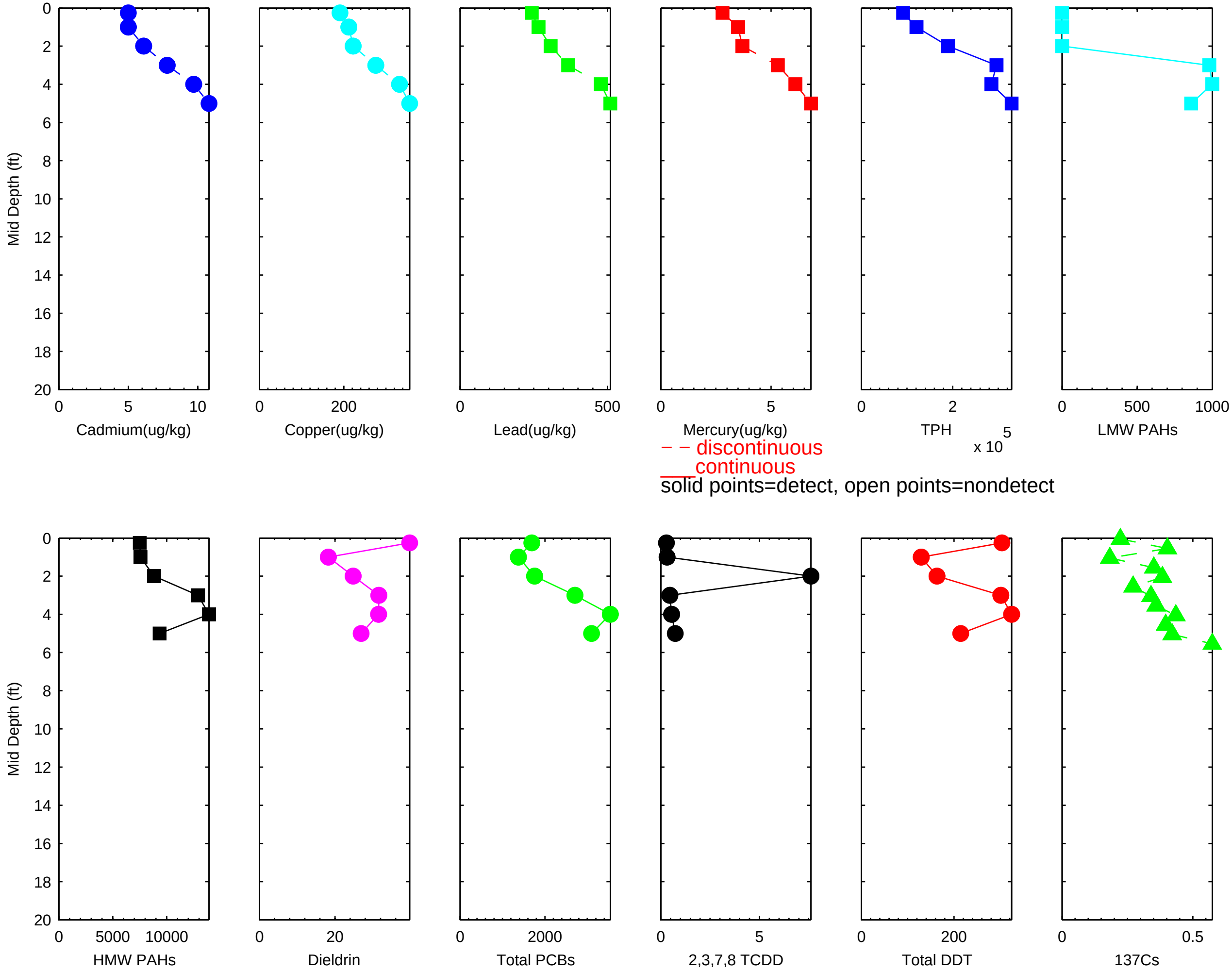
Sample ID: 287 River Mile 3.58   PASSAIC 1995 RI Sampling Program



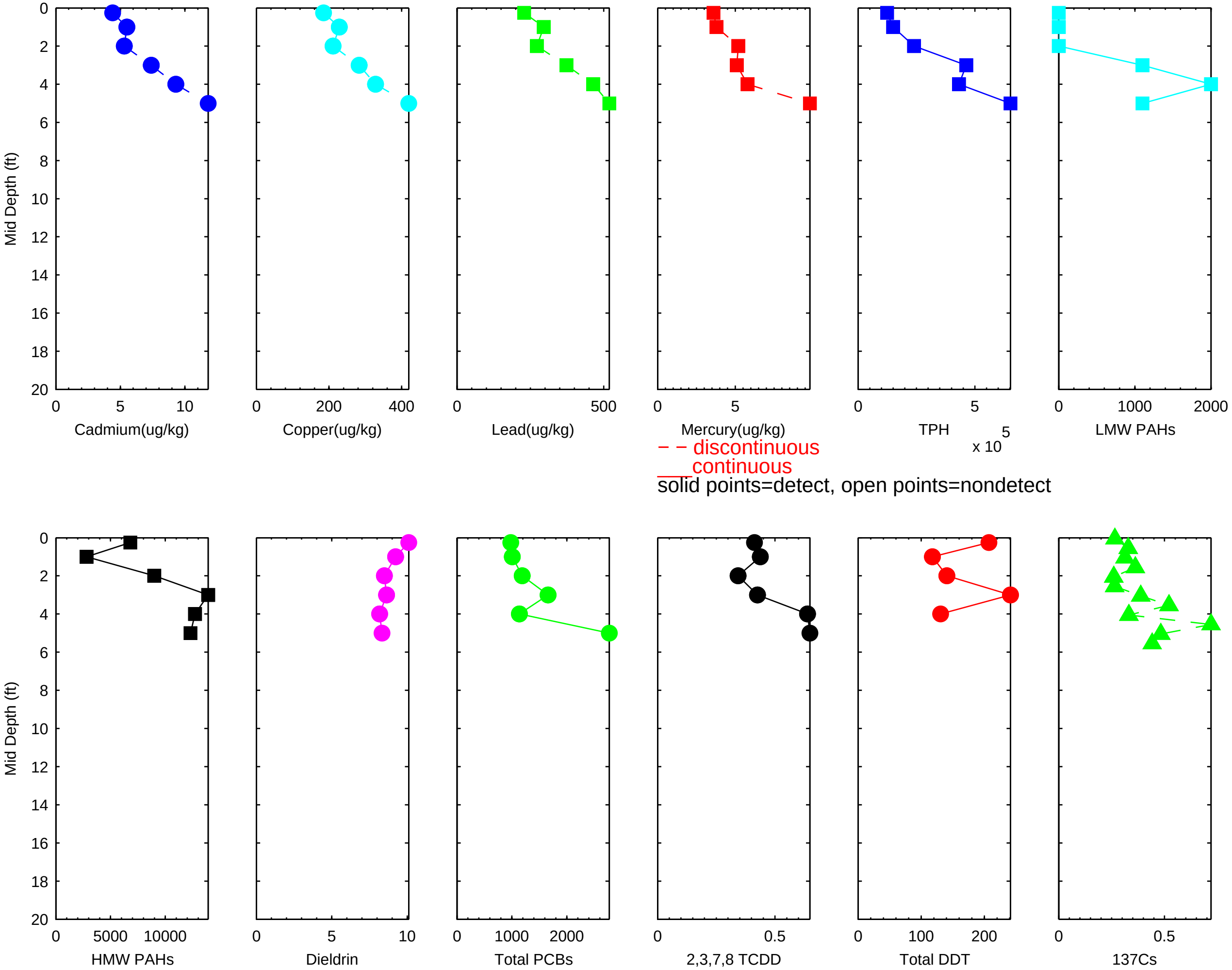
Sample ID: 285 River Mile 3.14   PASSAIC 1995 RI Sampling Program



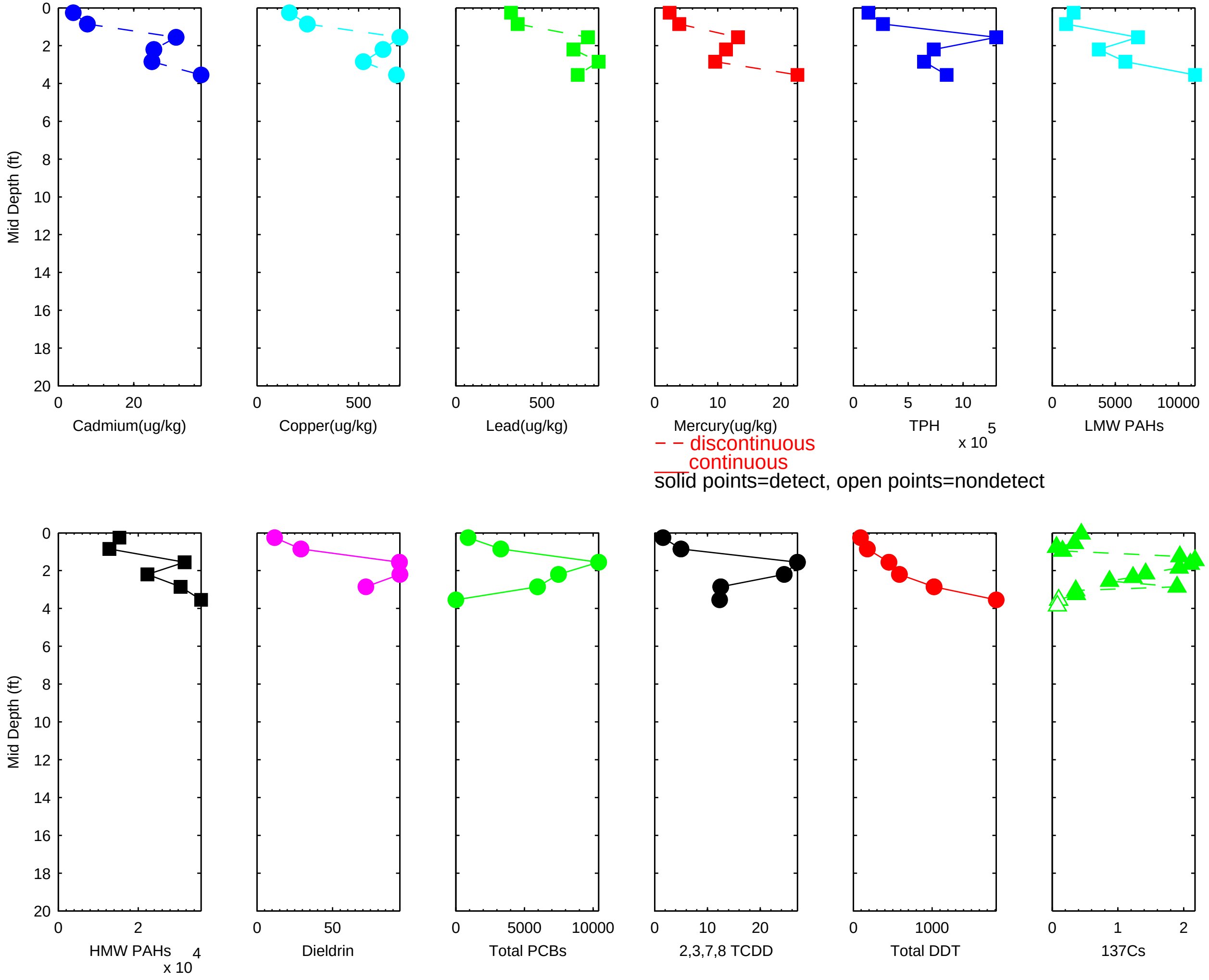
Sample ID: 283 River Mile 2.24 PASSAIC 1995 RI Sampling Program



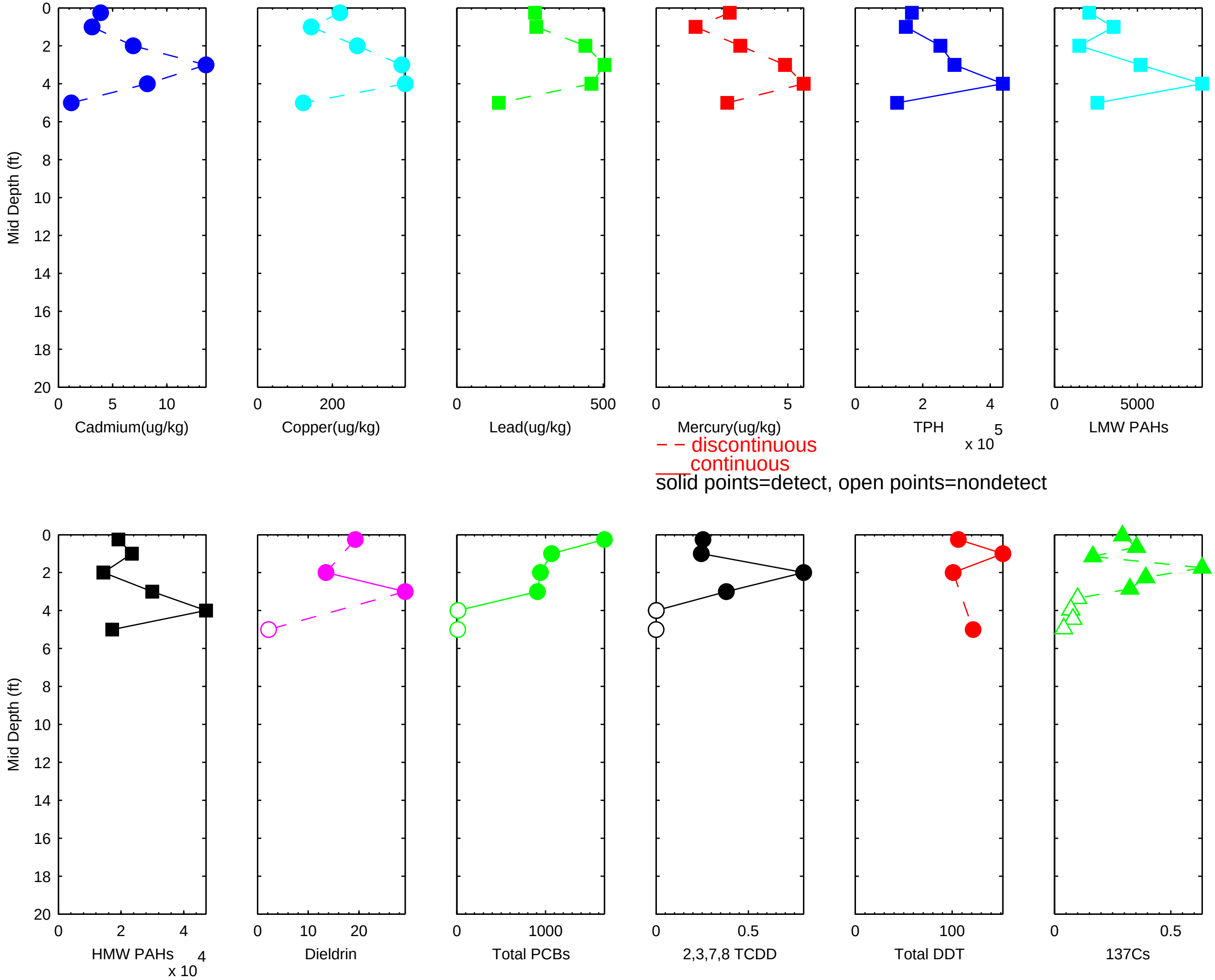
Sample ID: 282 River Mile 2.17   PASSAIC 1995 RI Sampling Program



Sample ID: 278 River Mile 6.74   PASSAIC 1995 RI Sampling Program



Sample ID: 277 River Mile 6.74 PASSAIC 1995 RI Sampling Program



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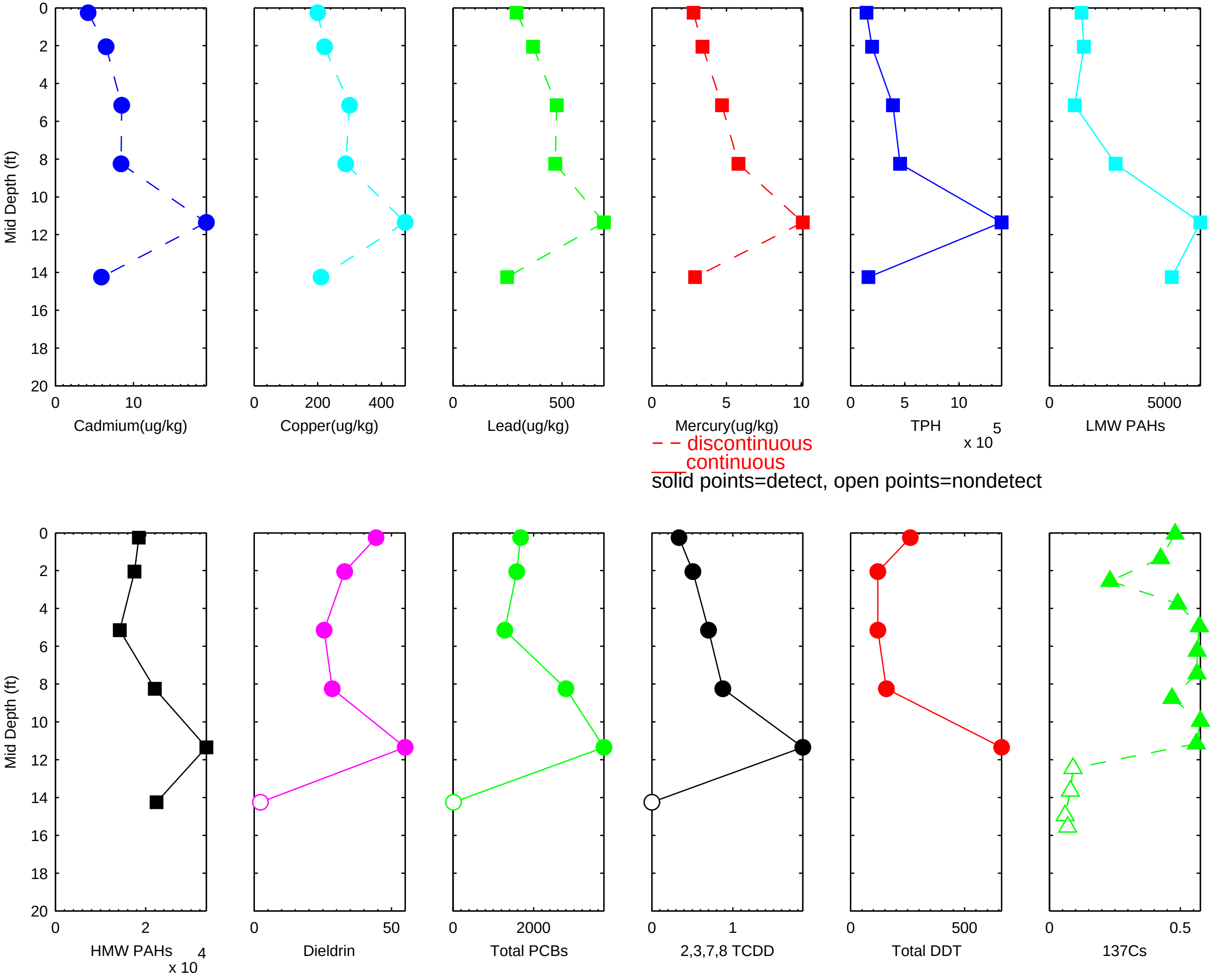
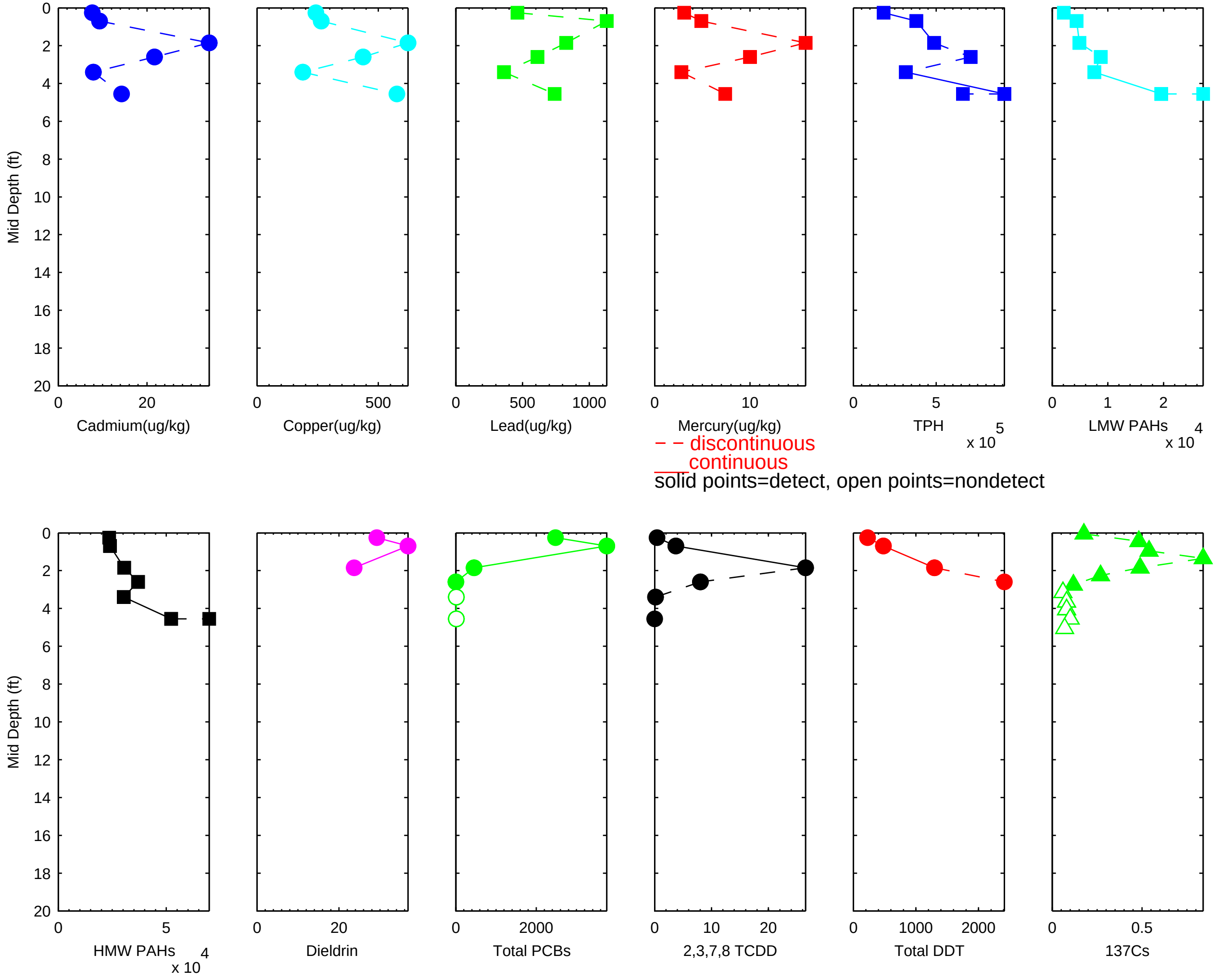


– – discontinuous

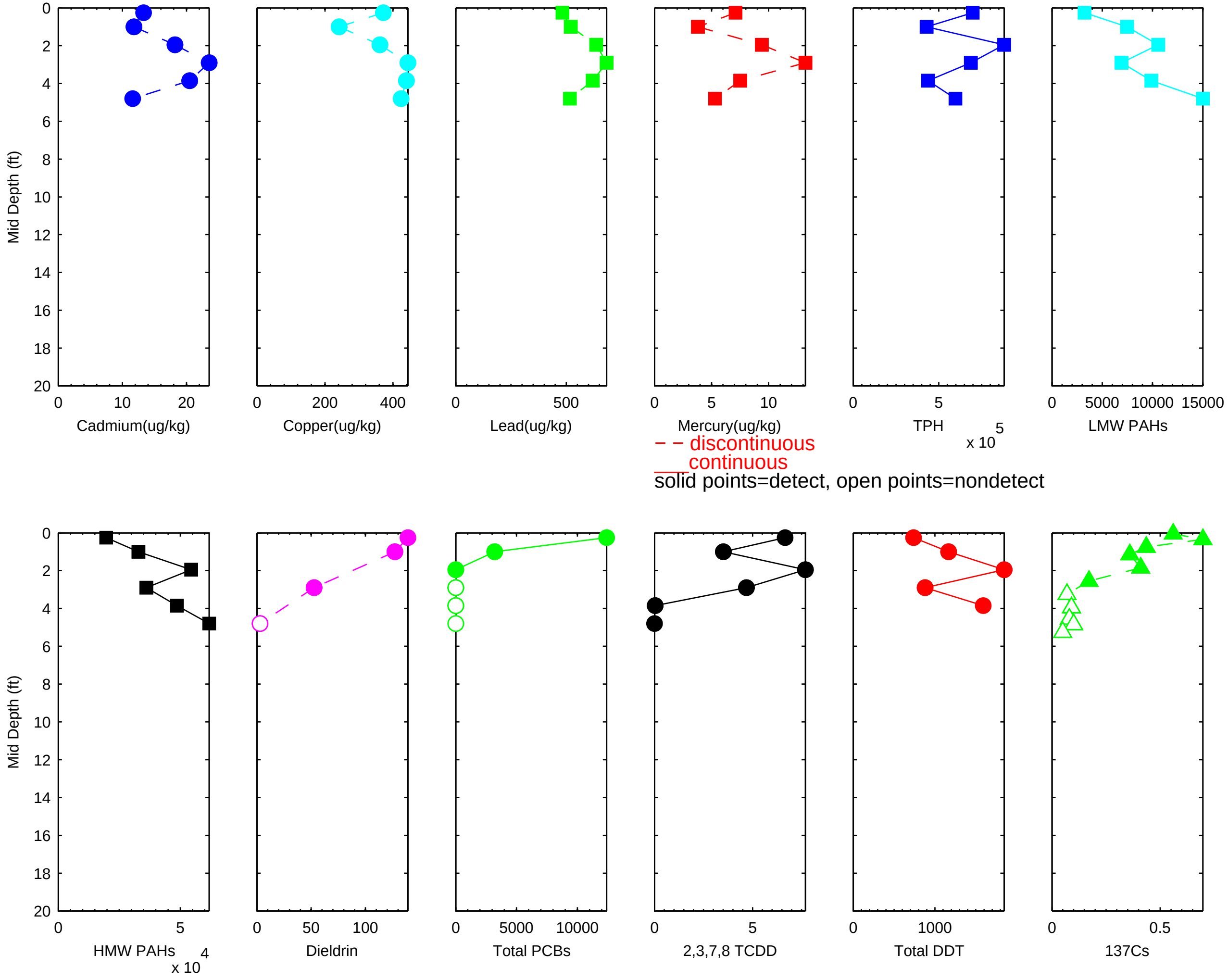
___ continuous

solid points=detect, open points=nondetect

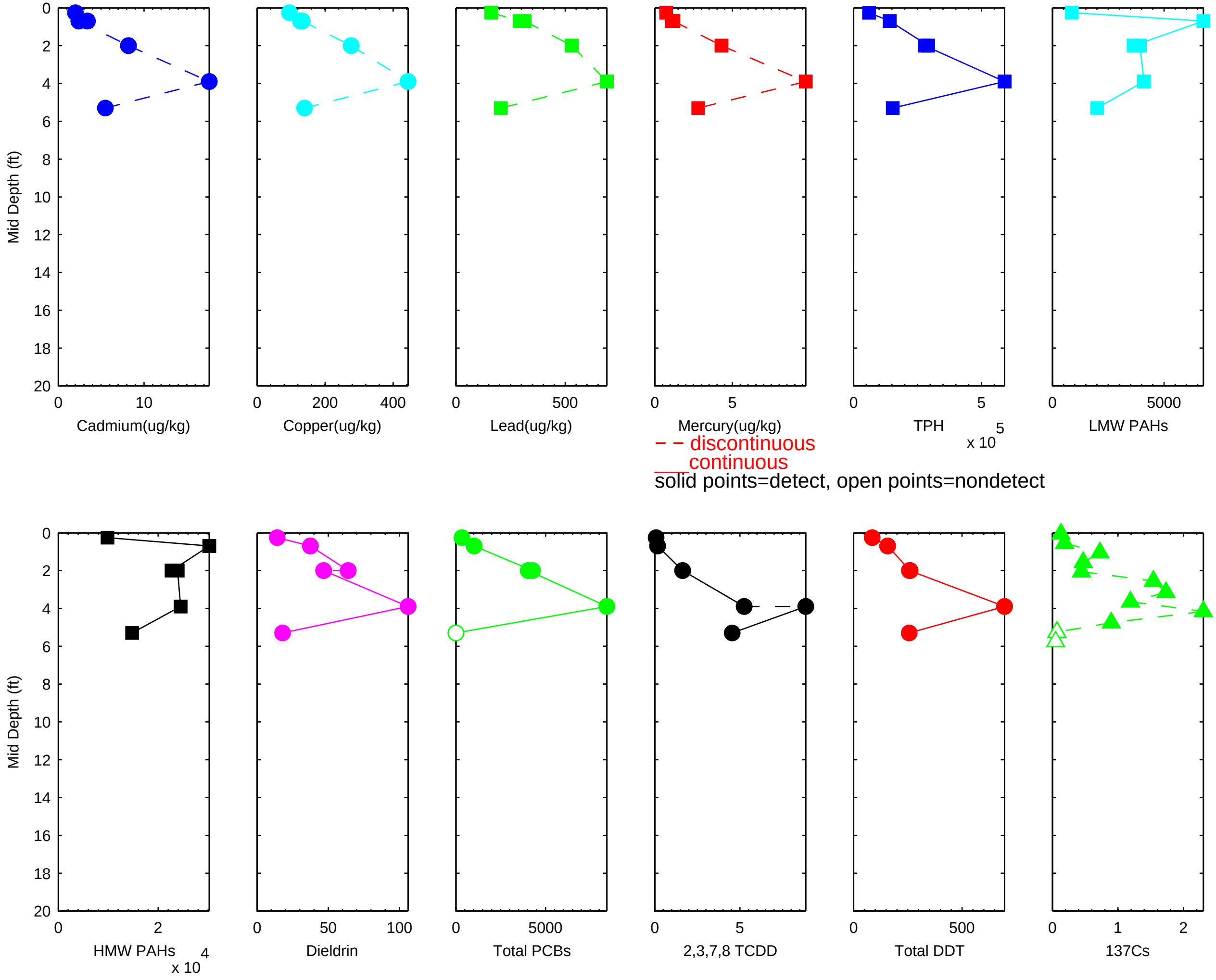
Sample ID: 274 River Mile 6.51   PASSAIC 1995 RI Sampling Program



Sample ID: 273 River Mile 6.51   PASSAIC 1995 RI Sampling Program



Sample ID: 271 River Mile 6.28   PASSAIC 1995 RI Sampling Program



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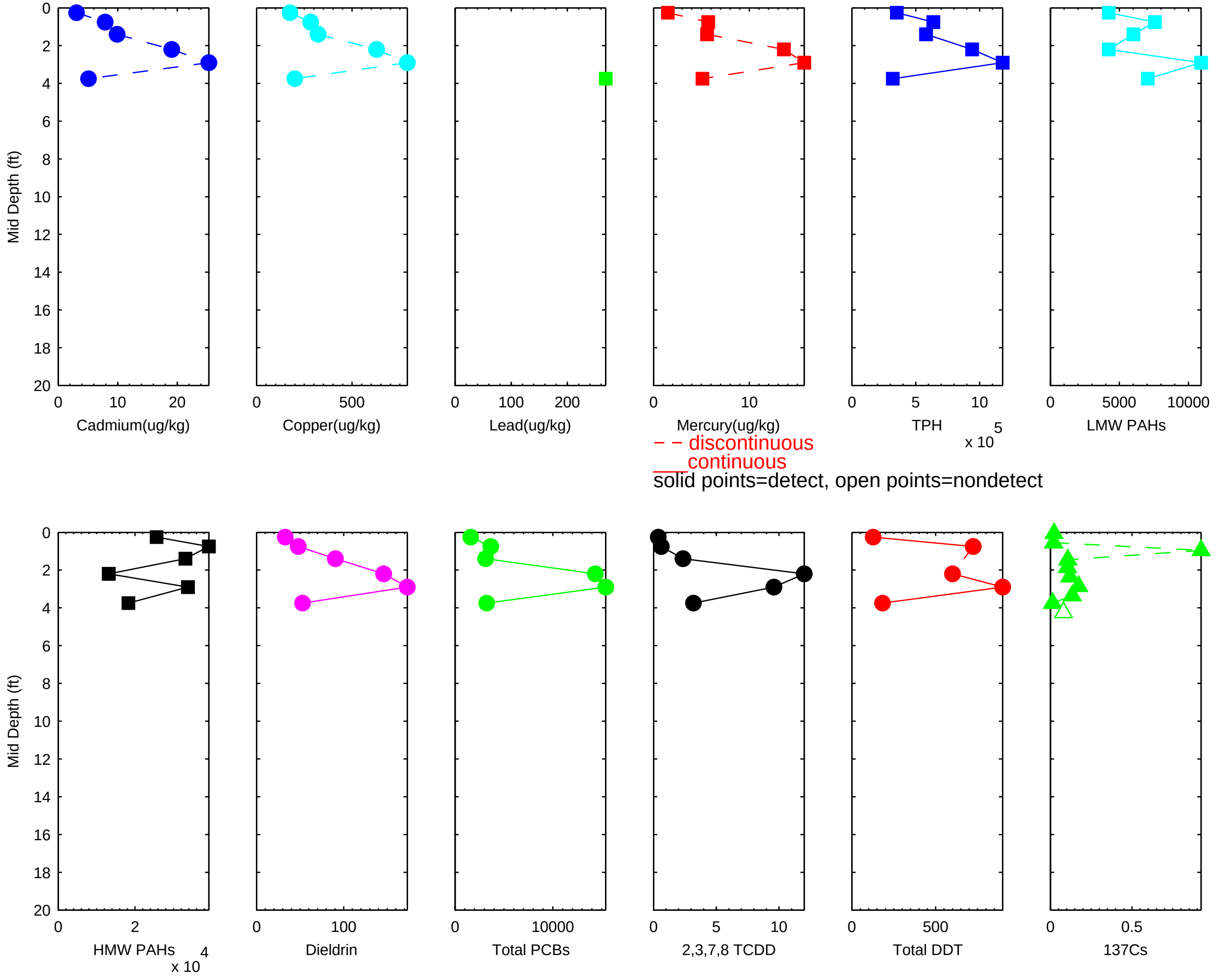

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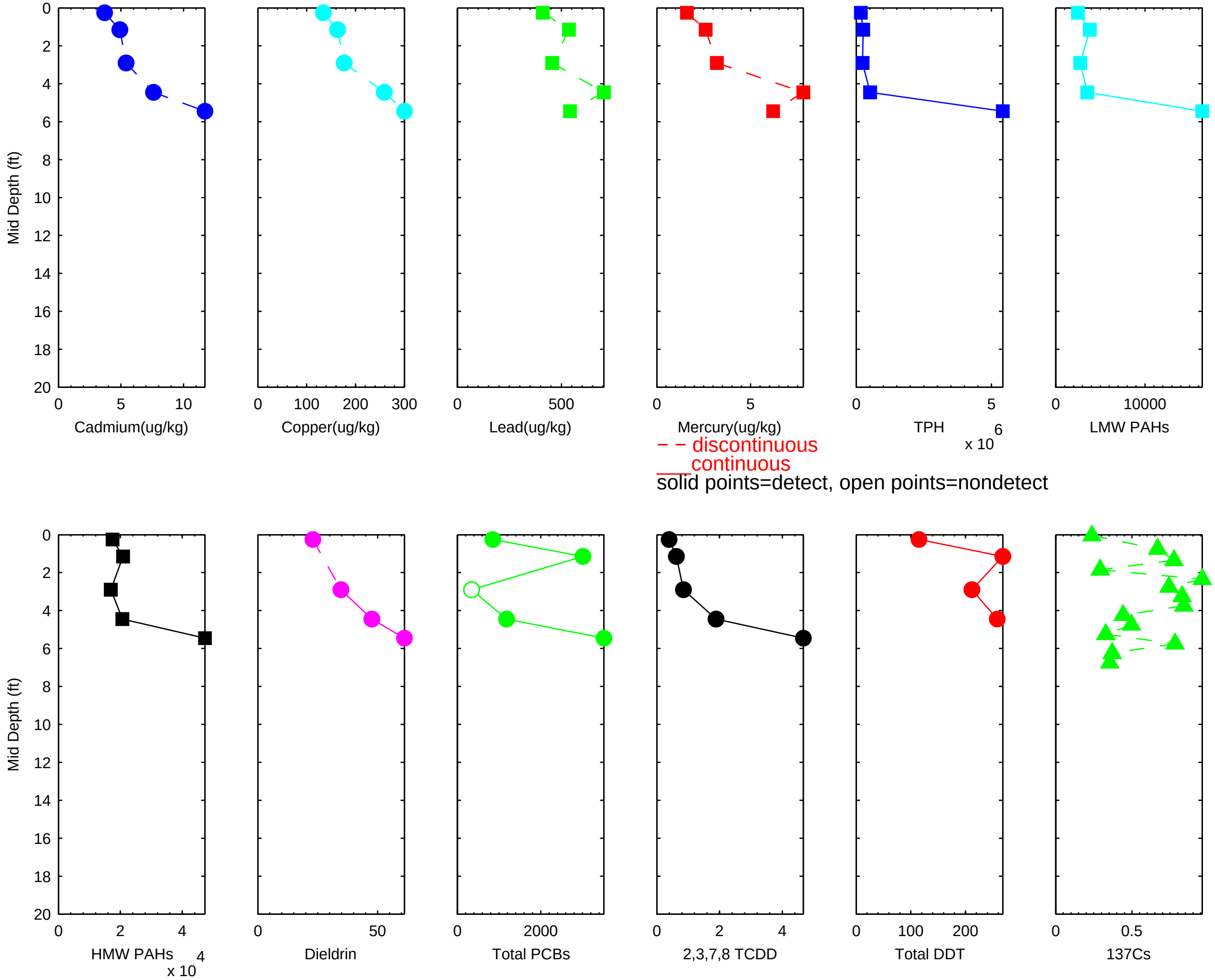

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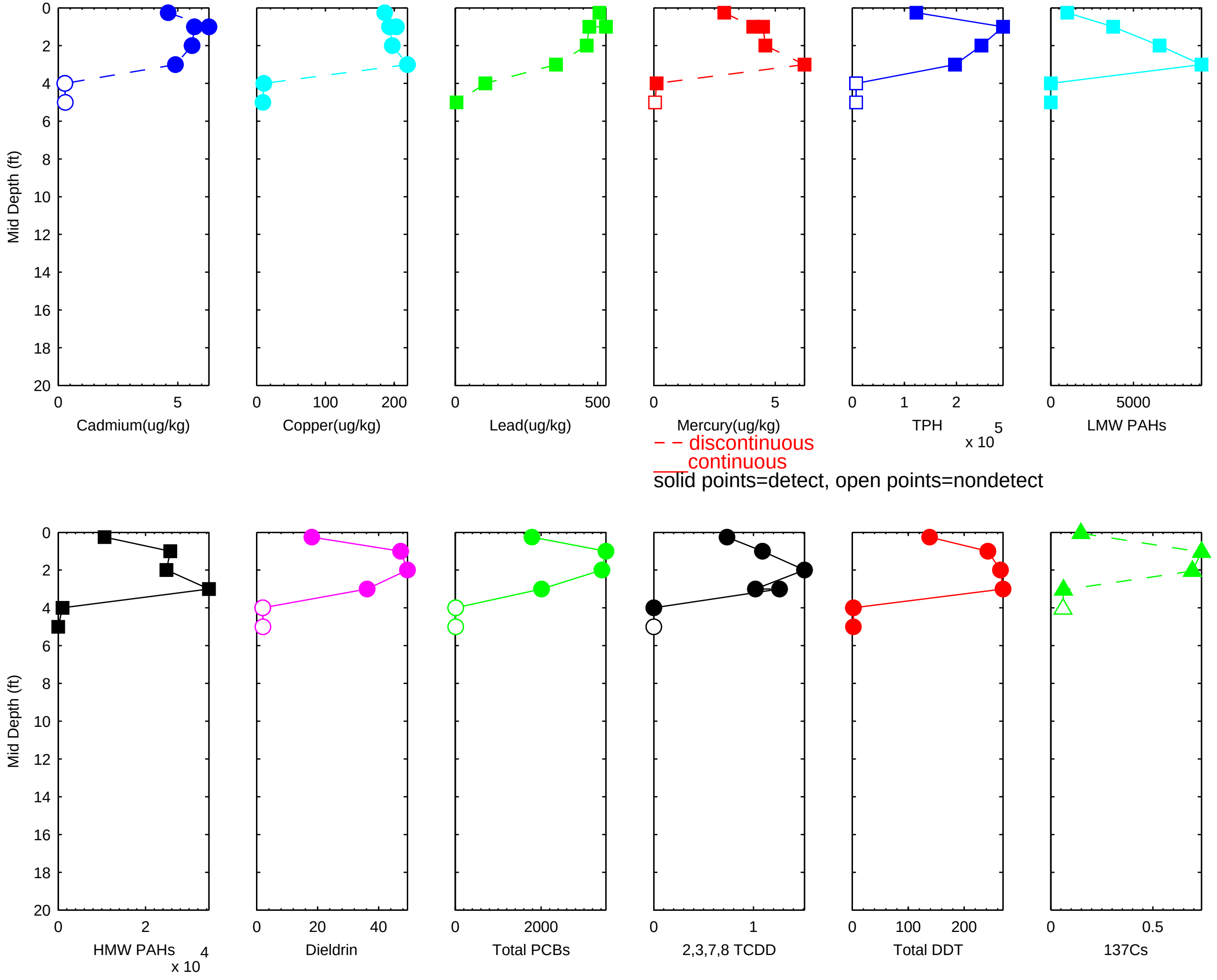

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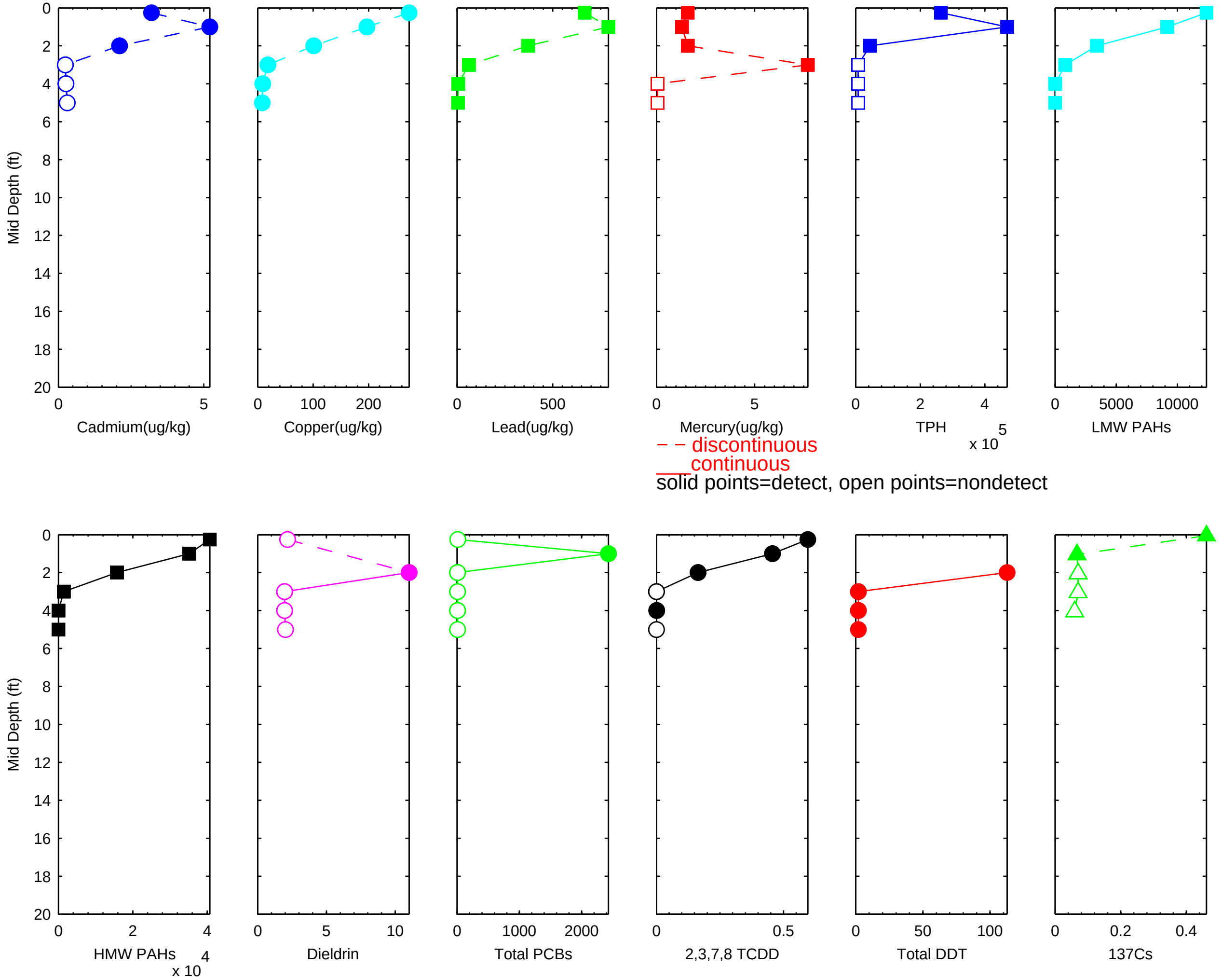

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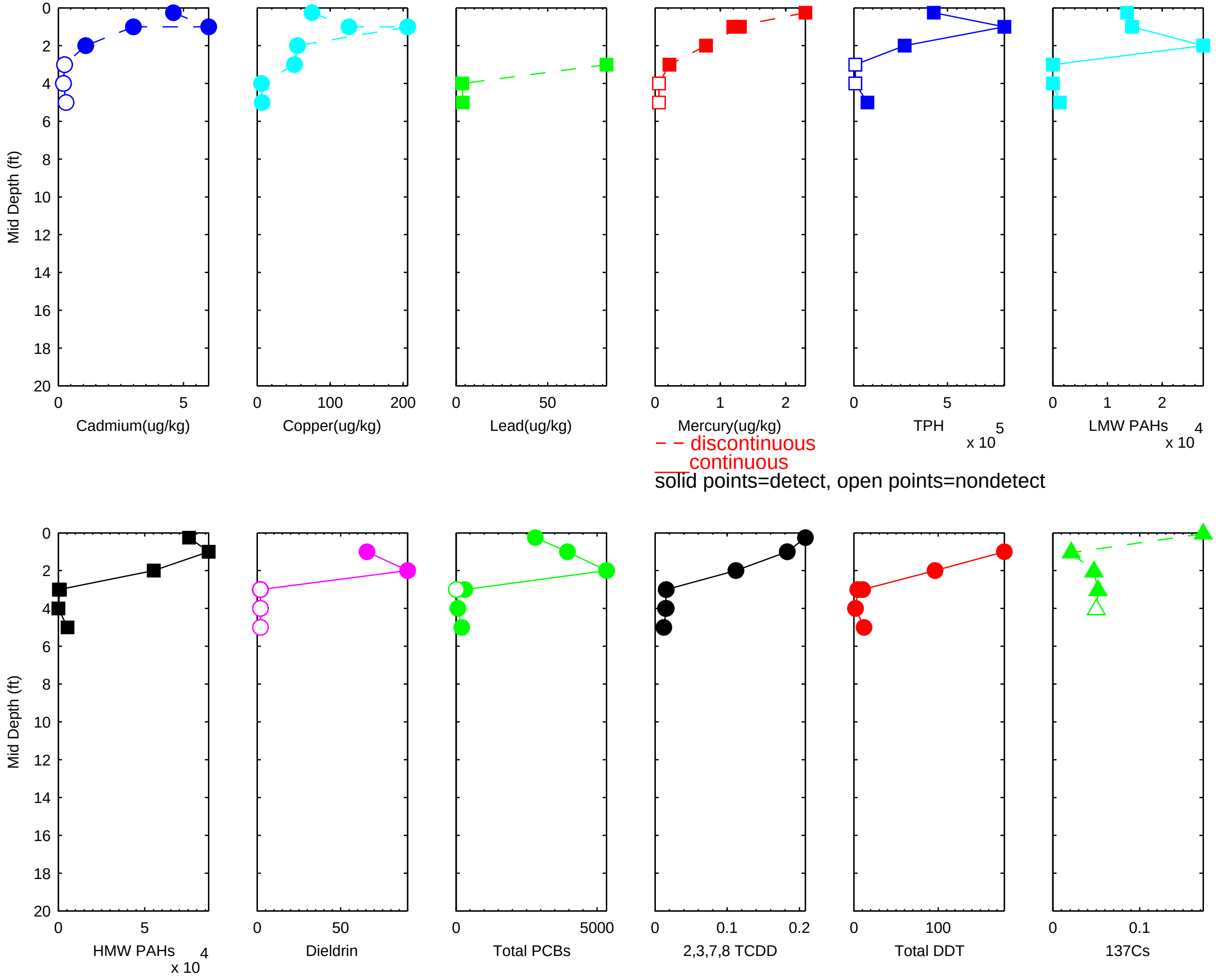

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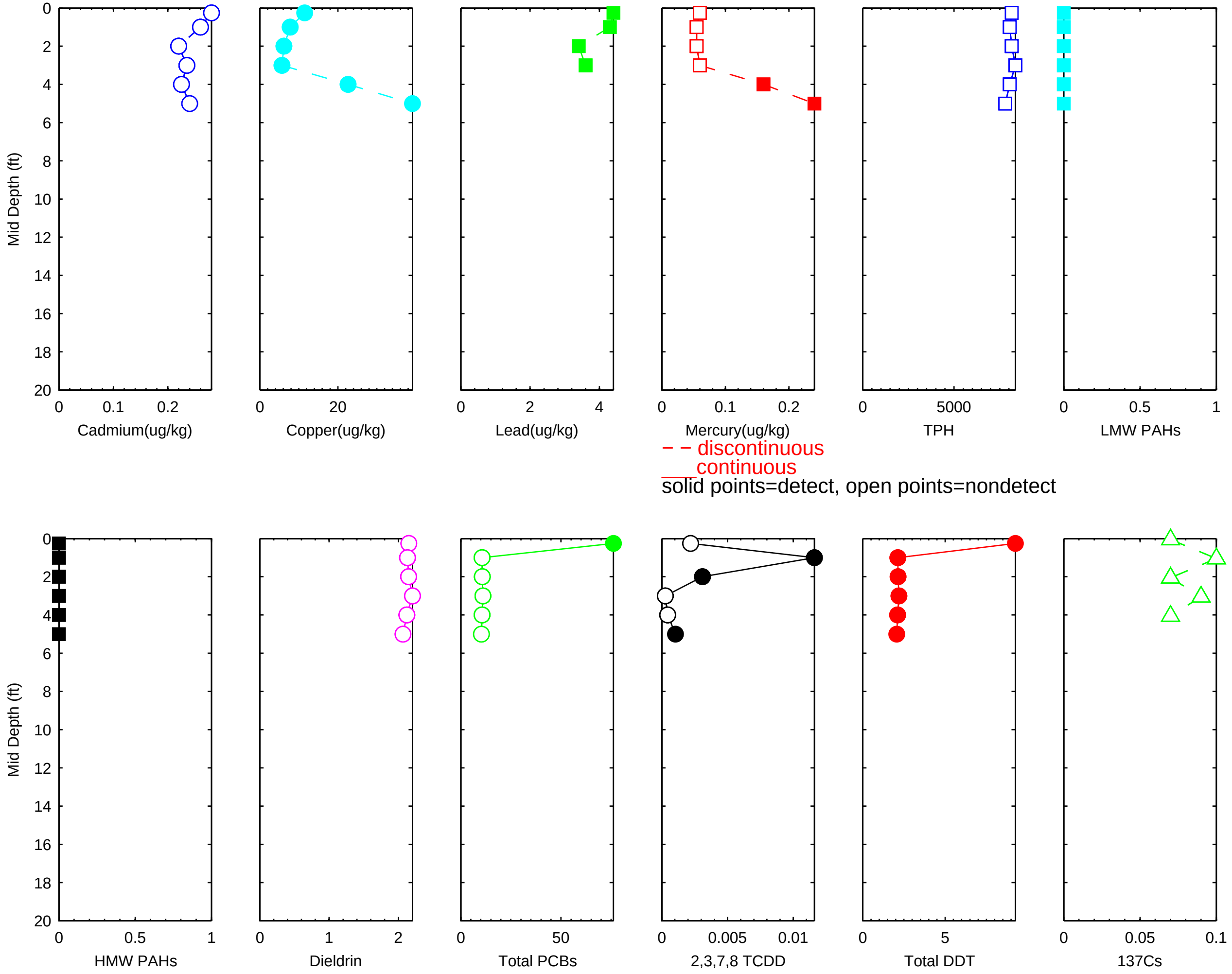

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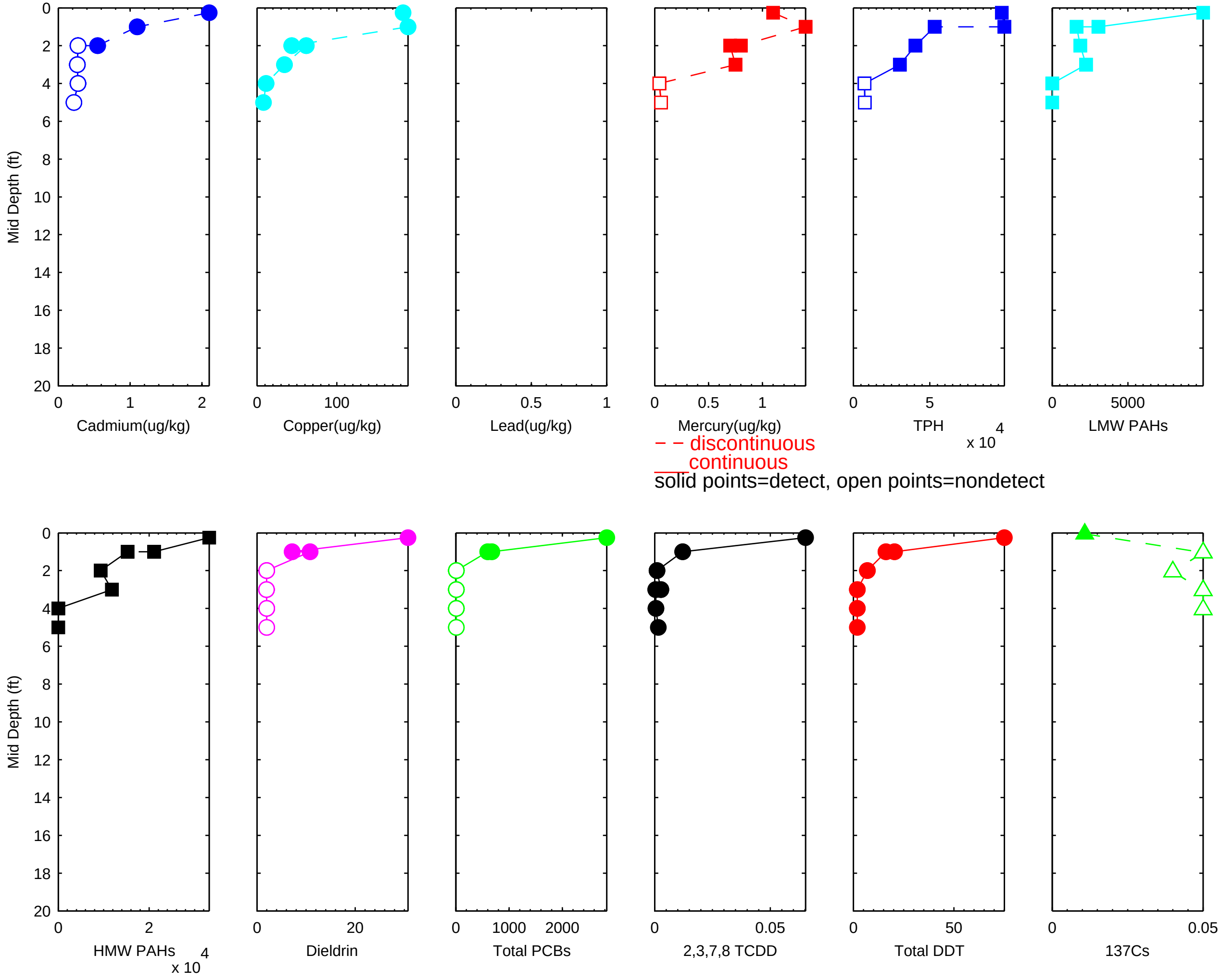

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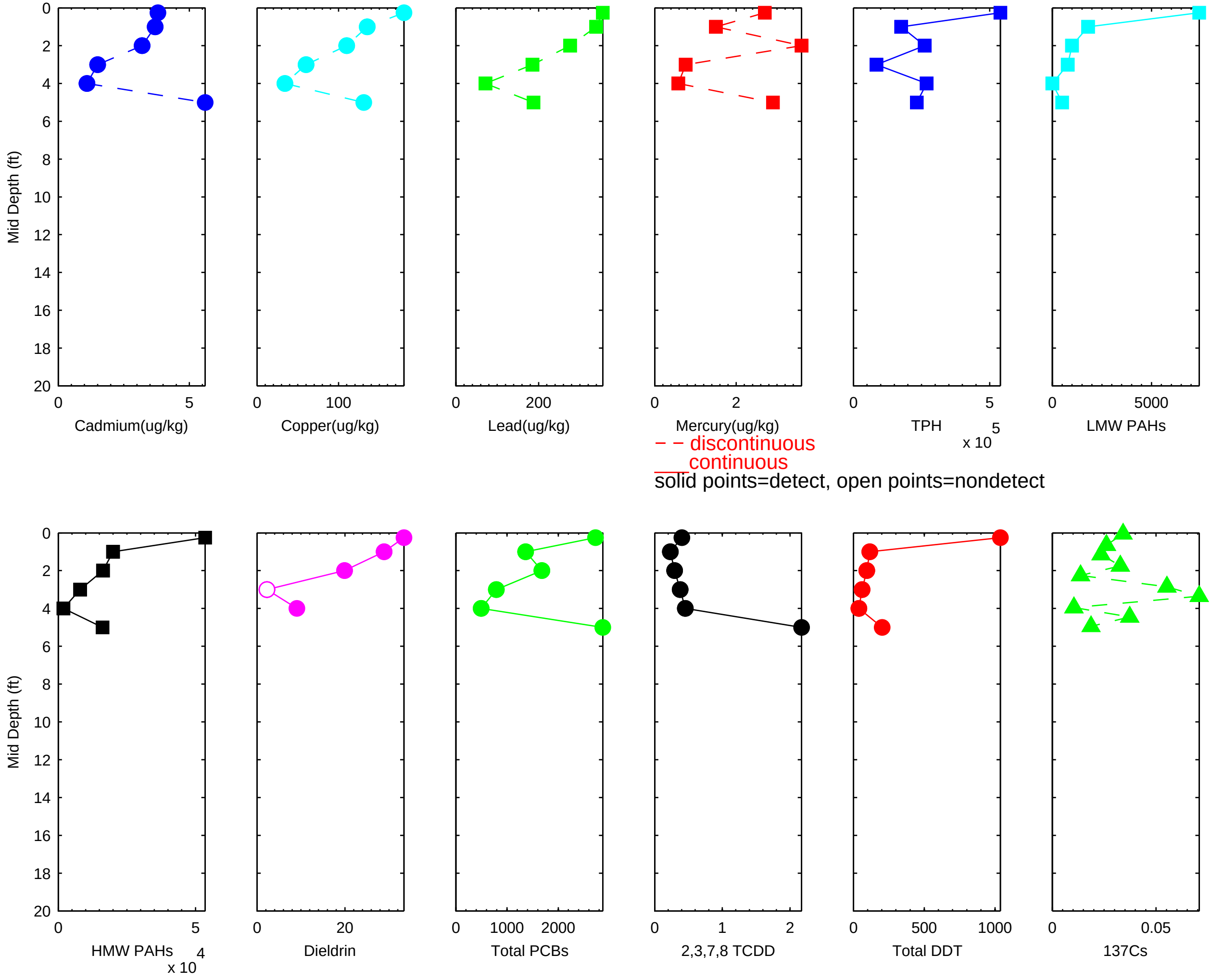

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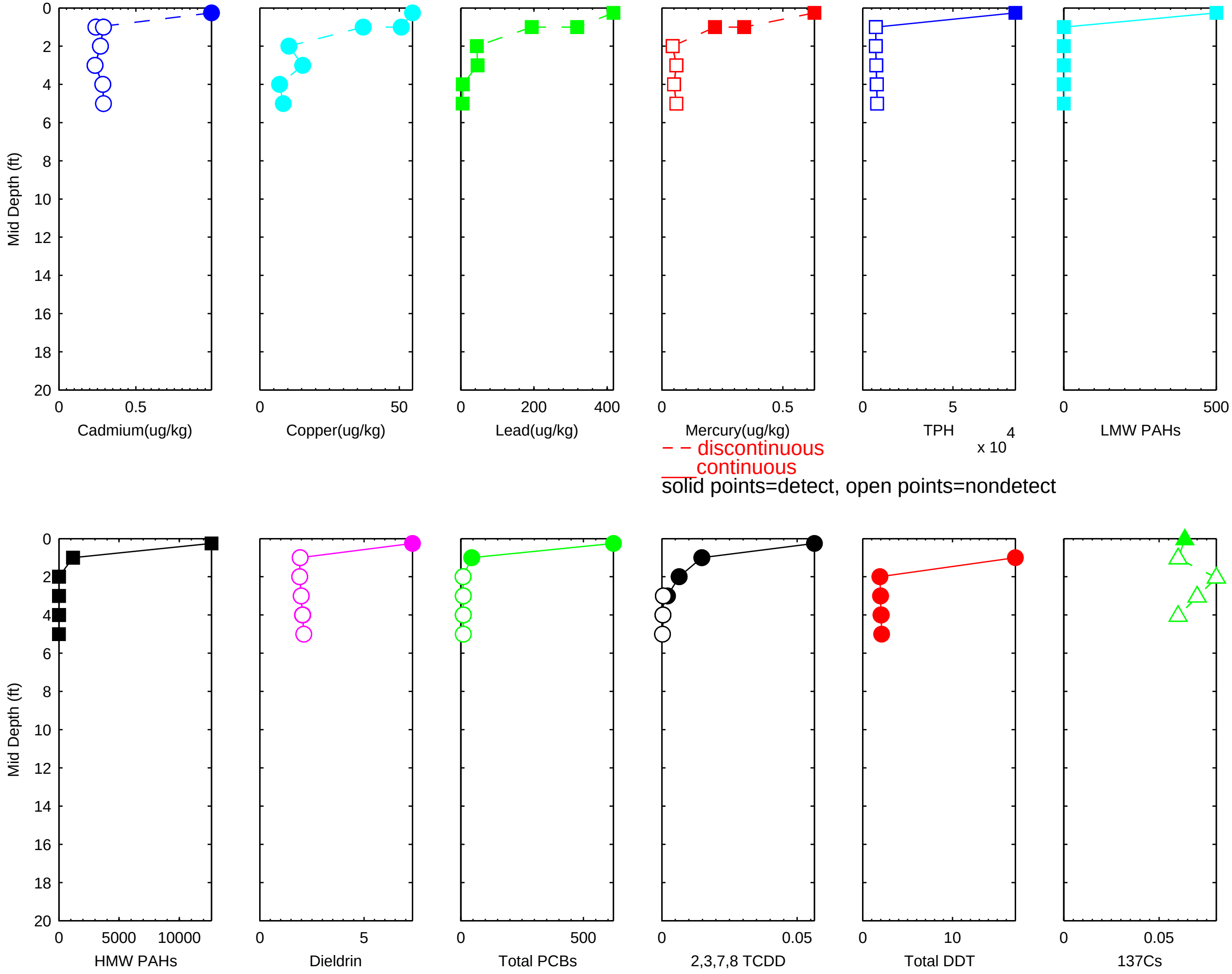

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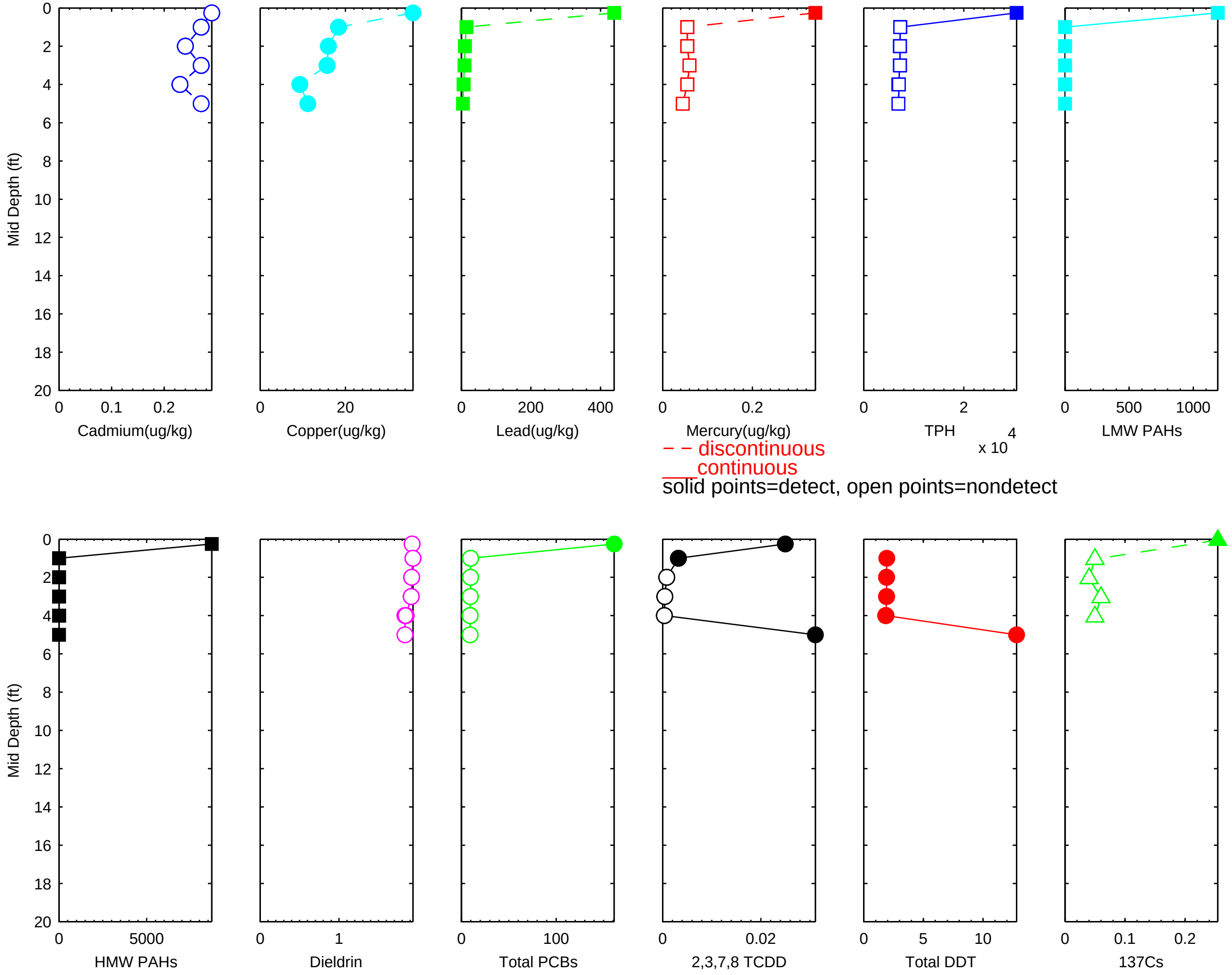

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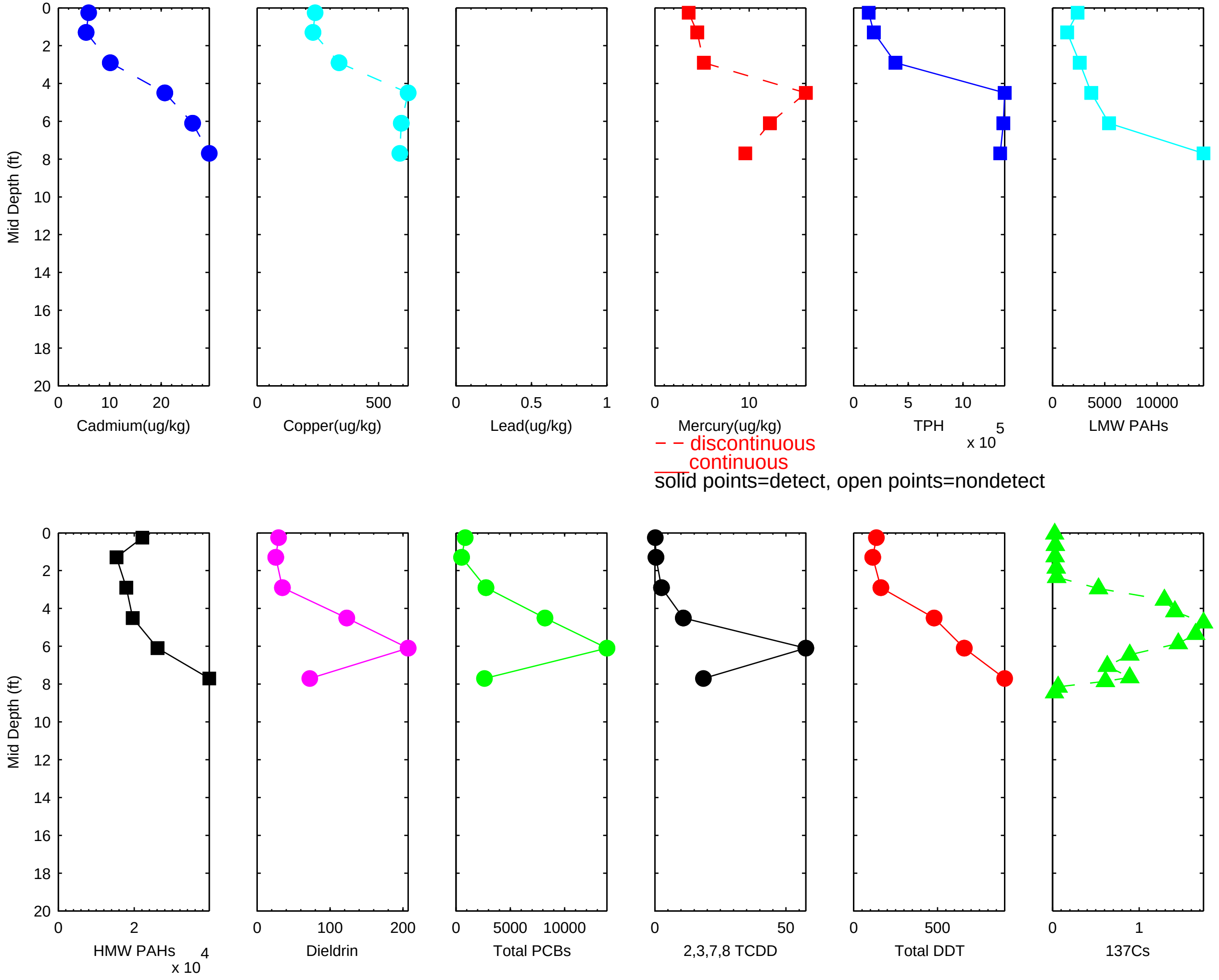

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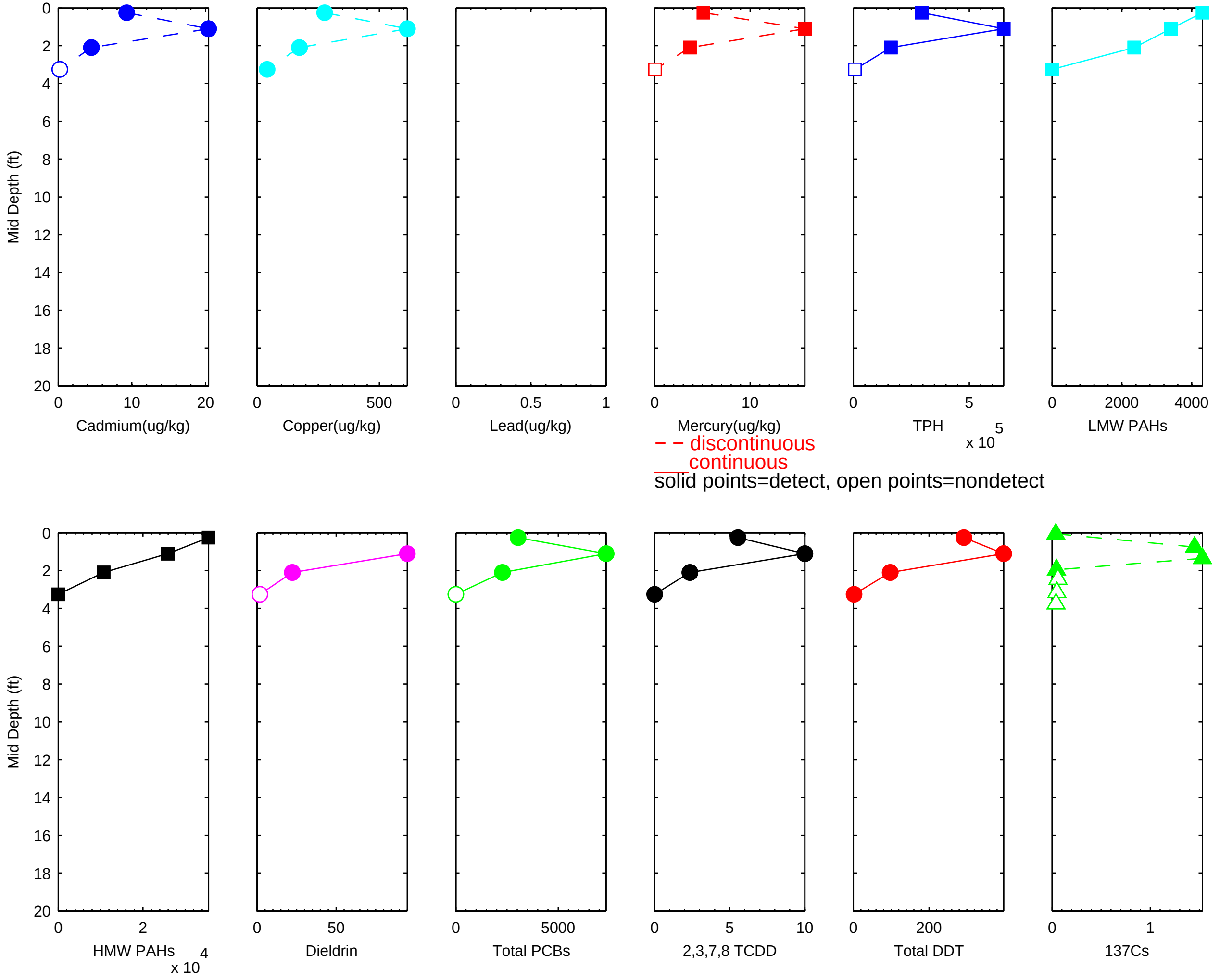

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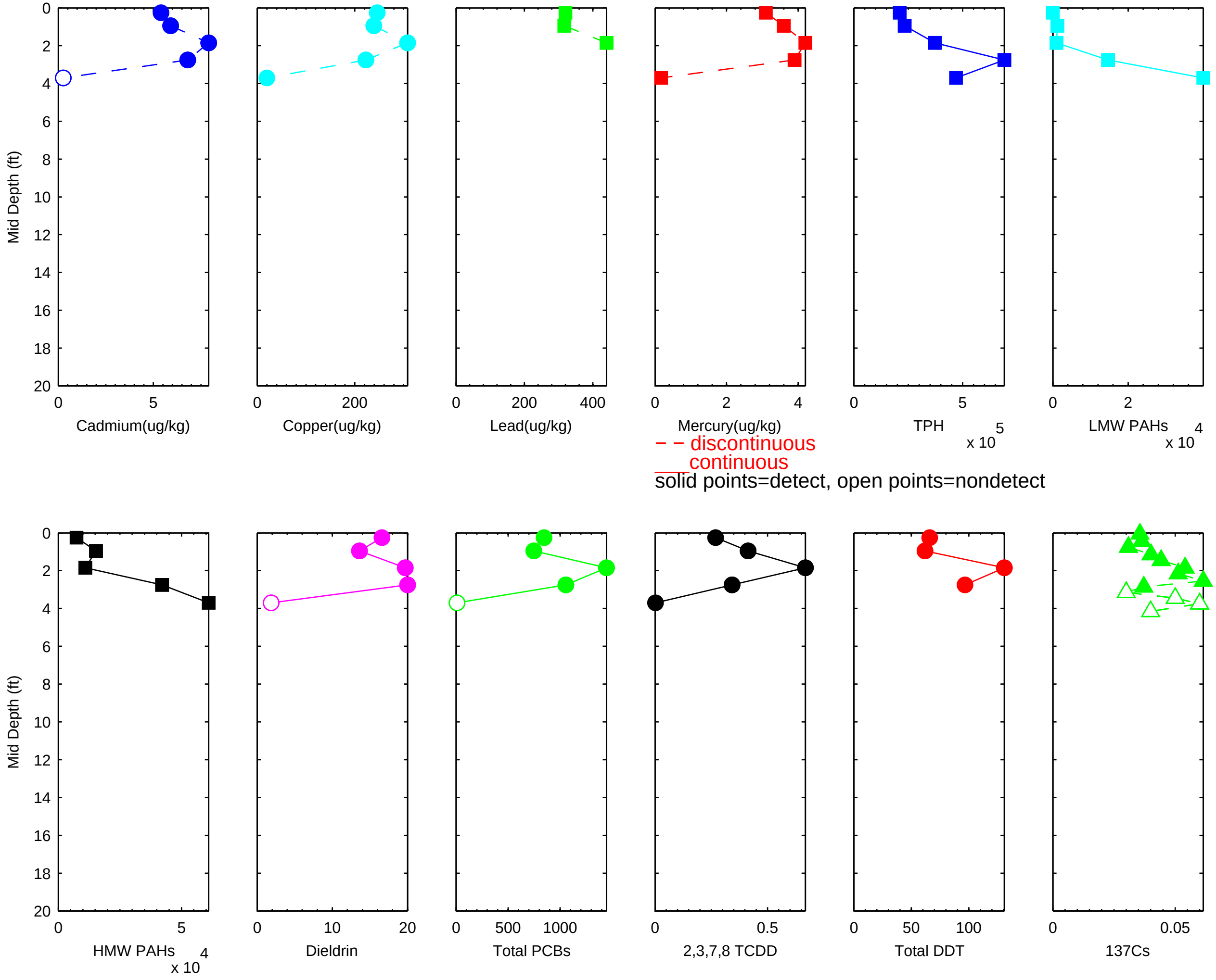

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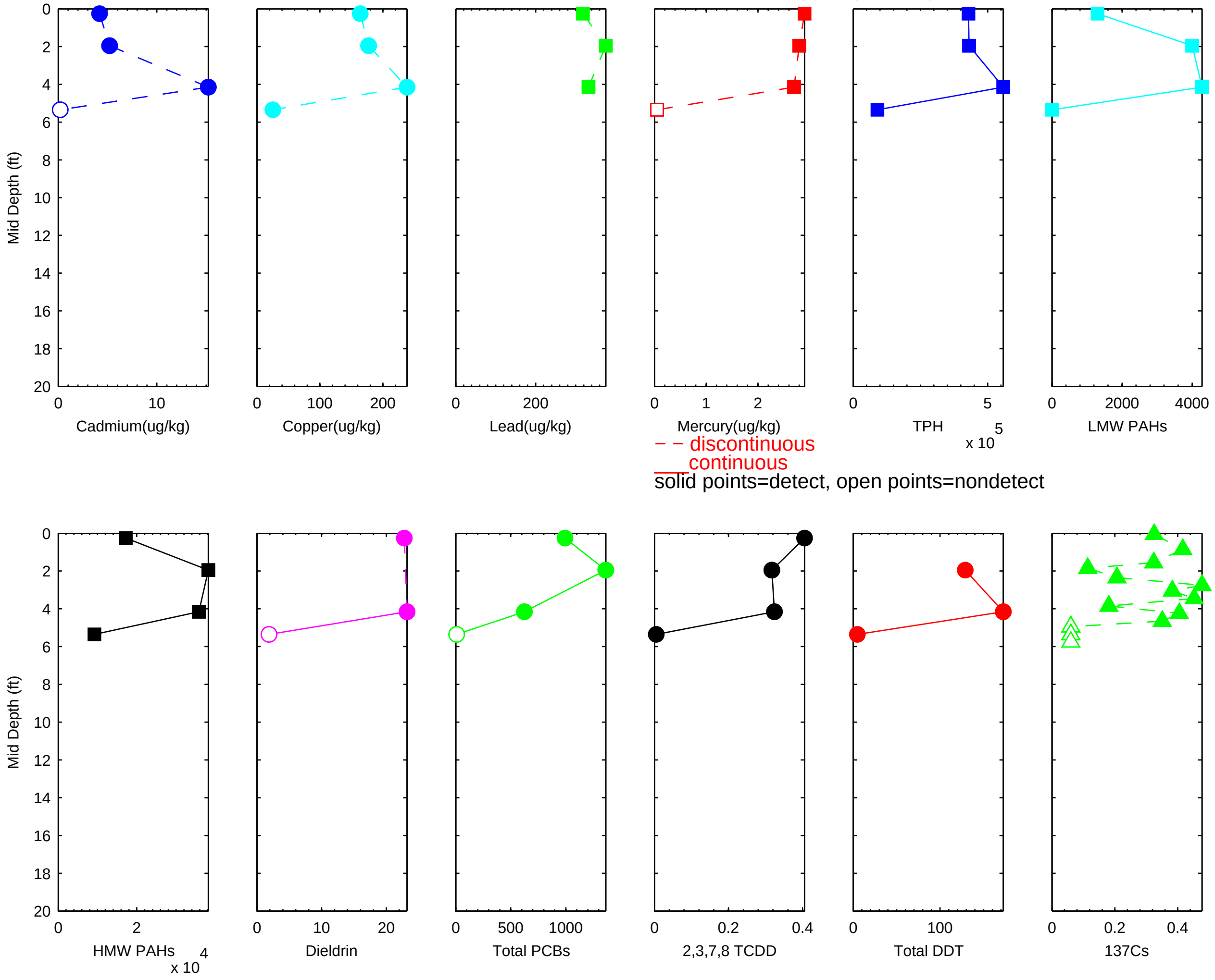

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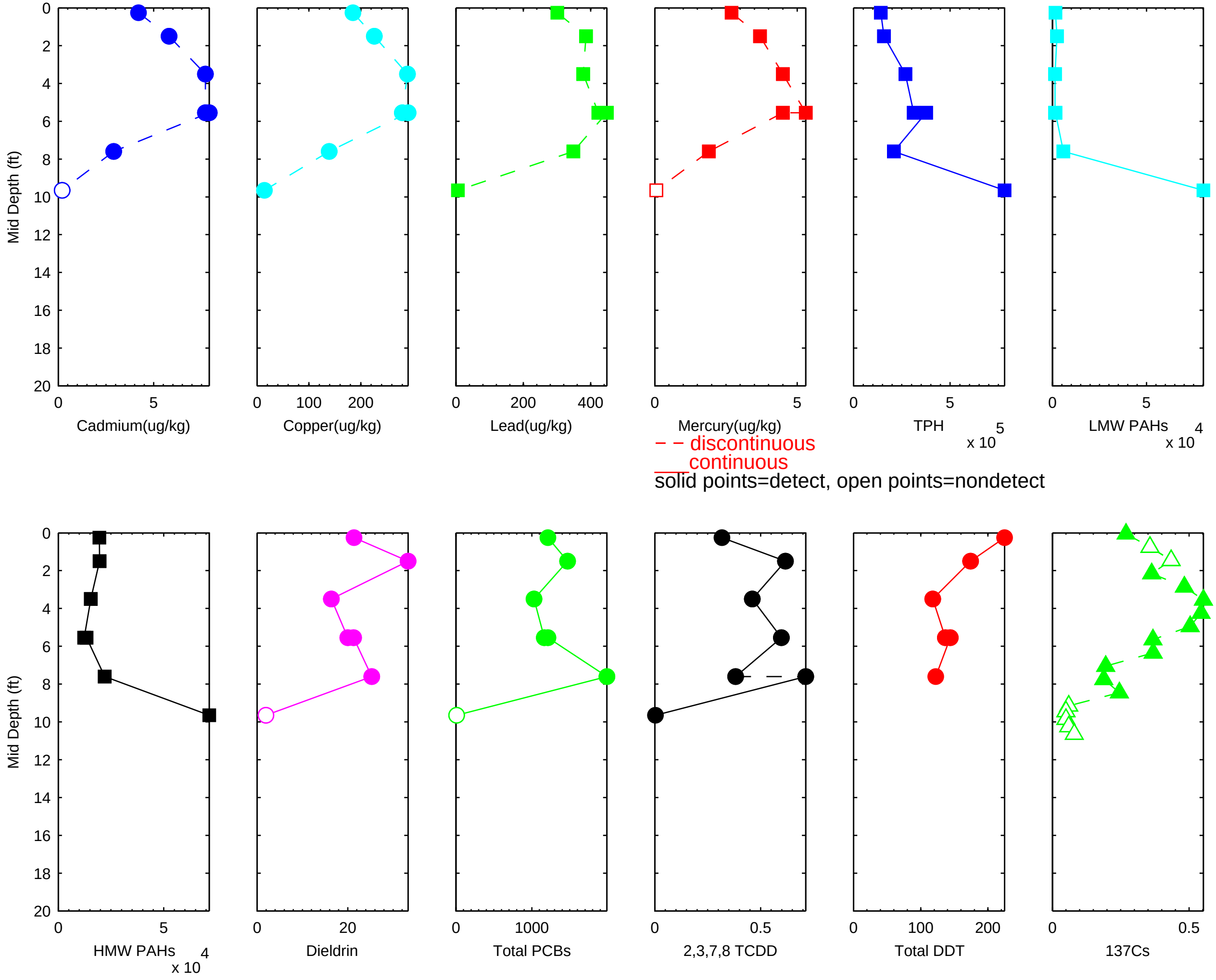

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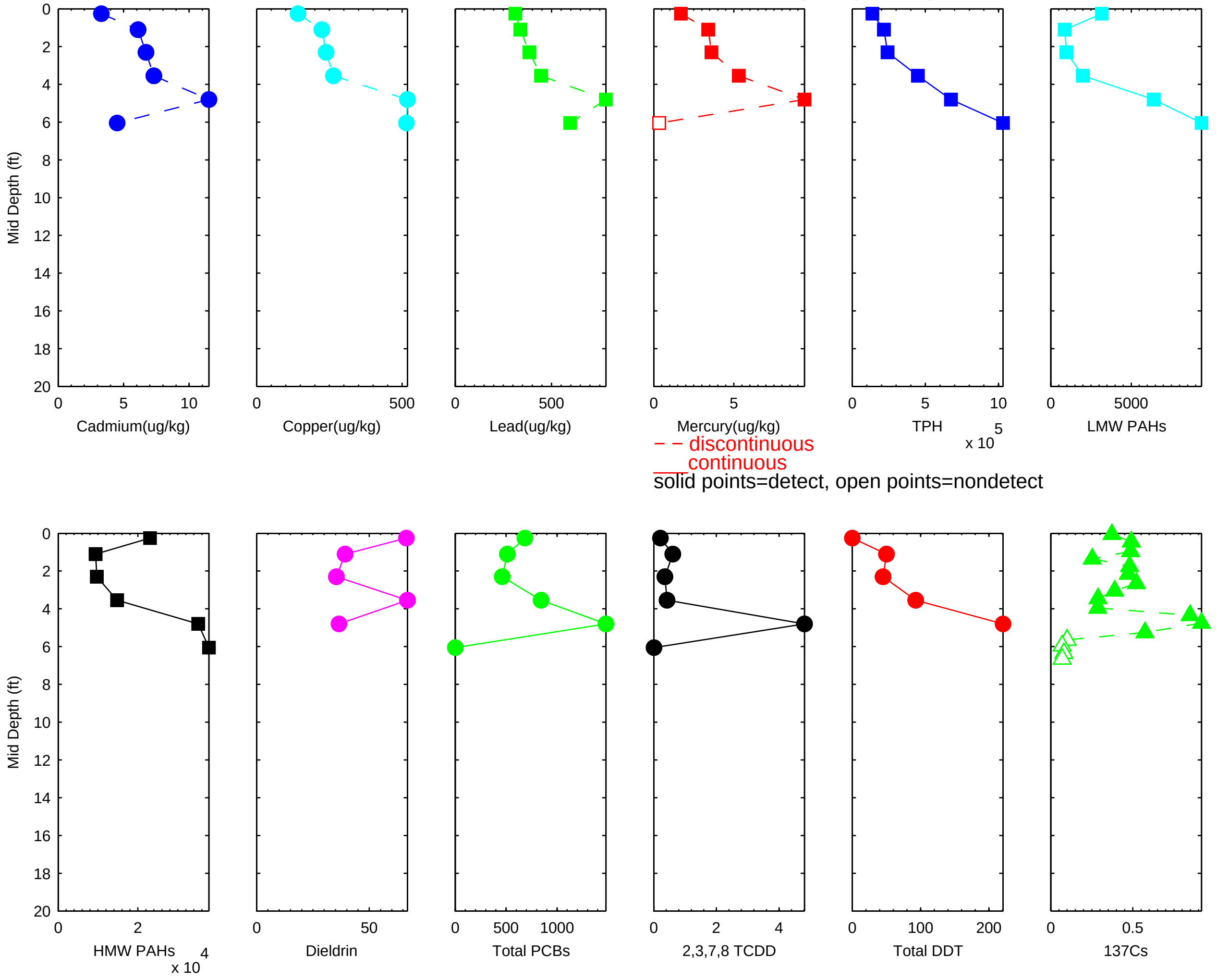

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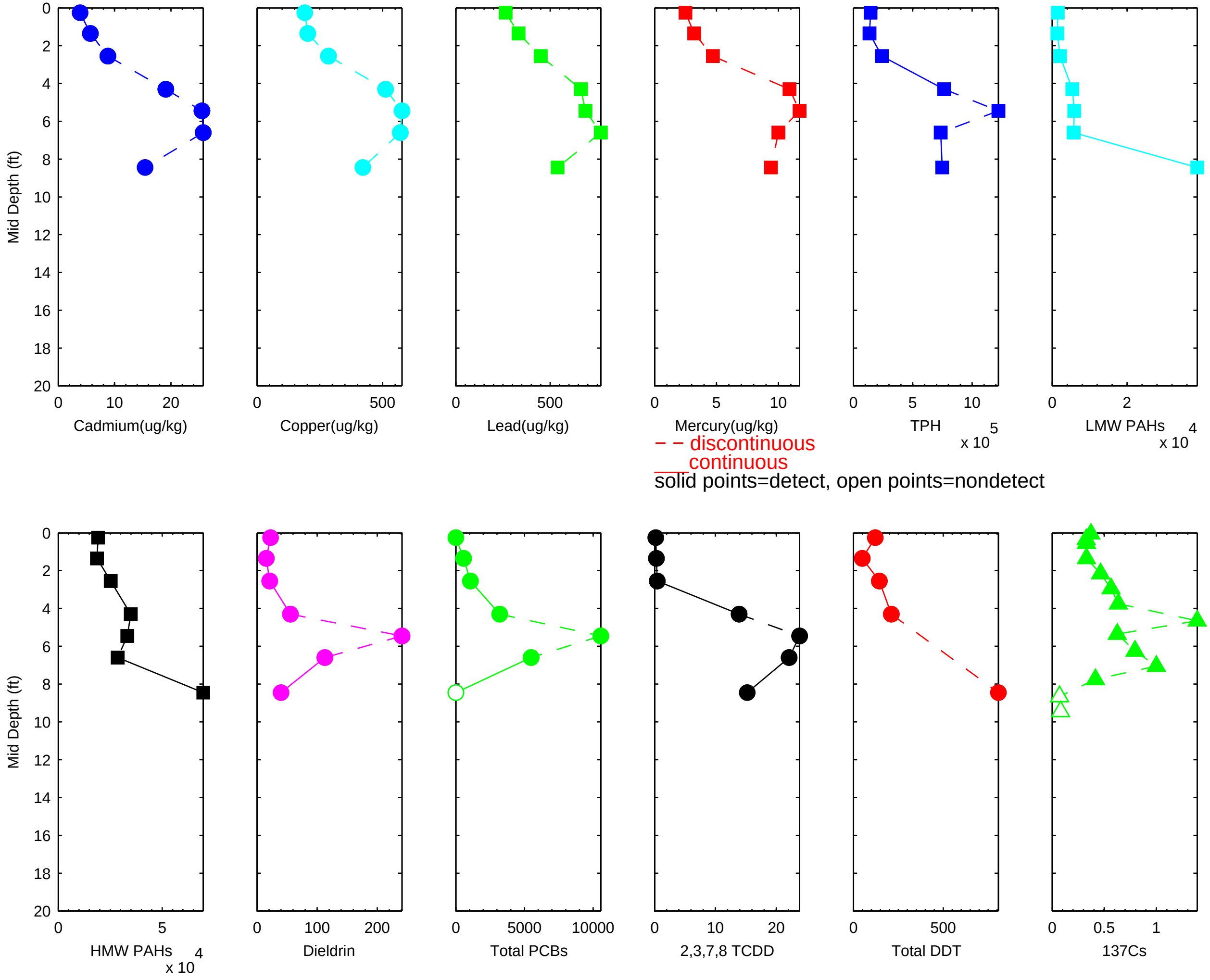

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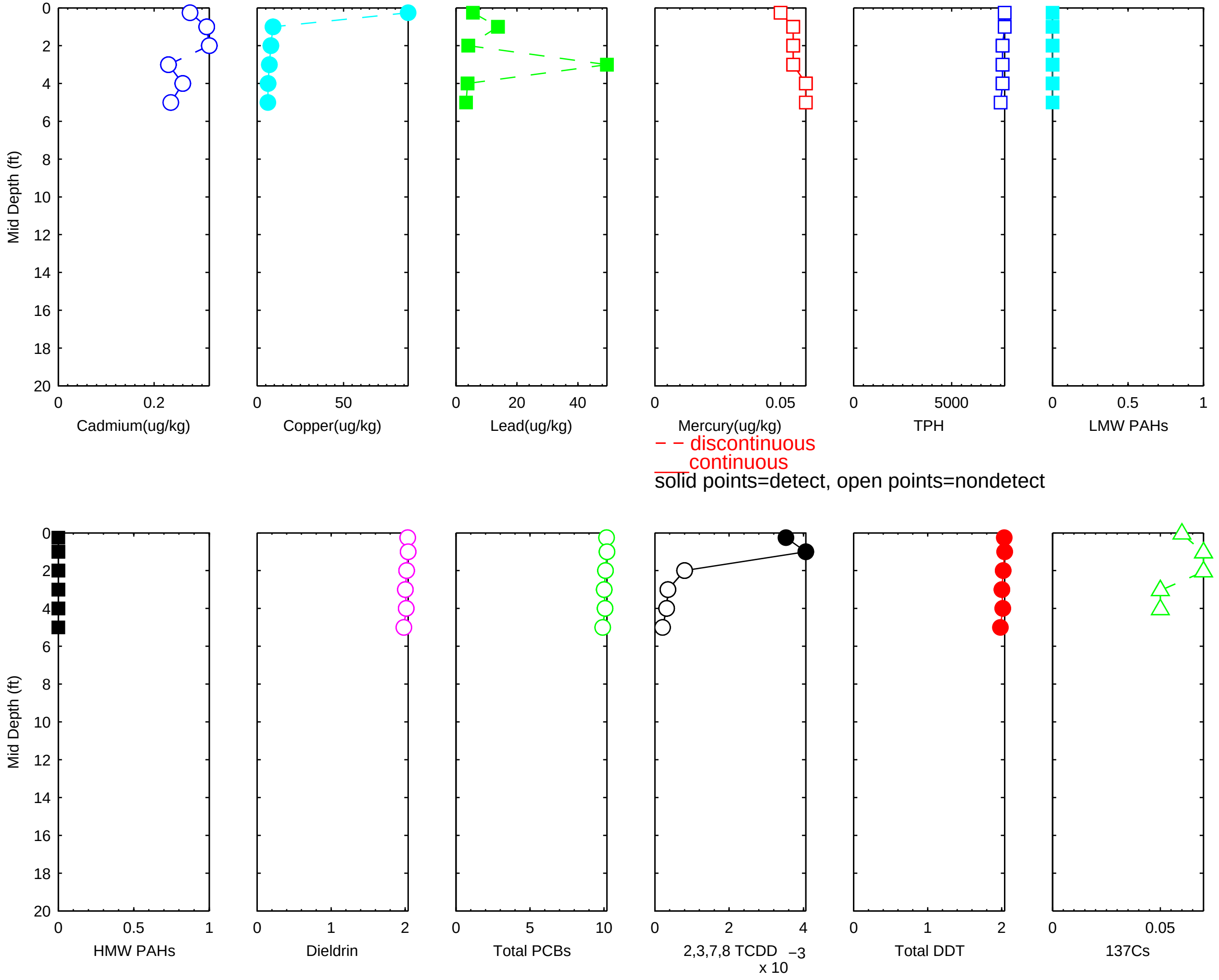

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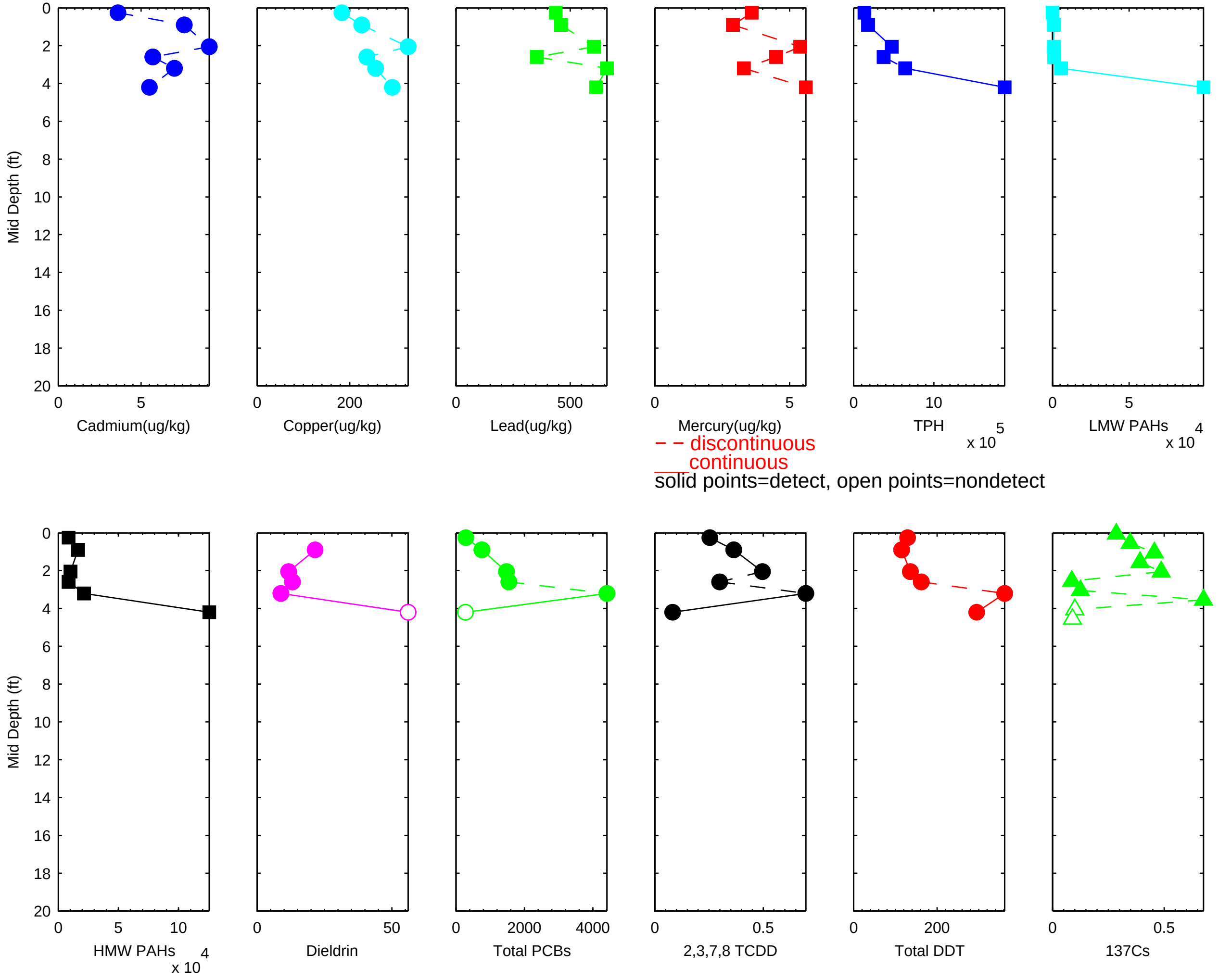

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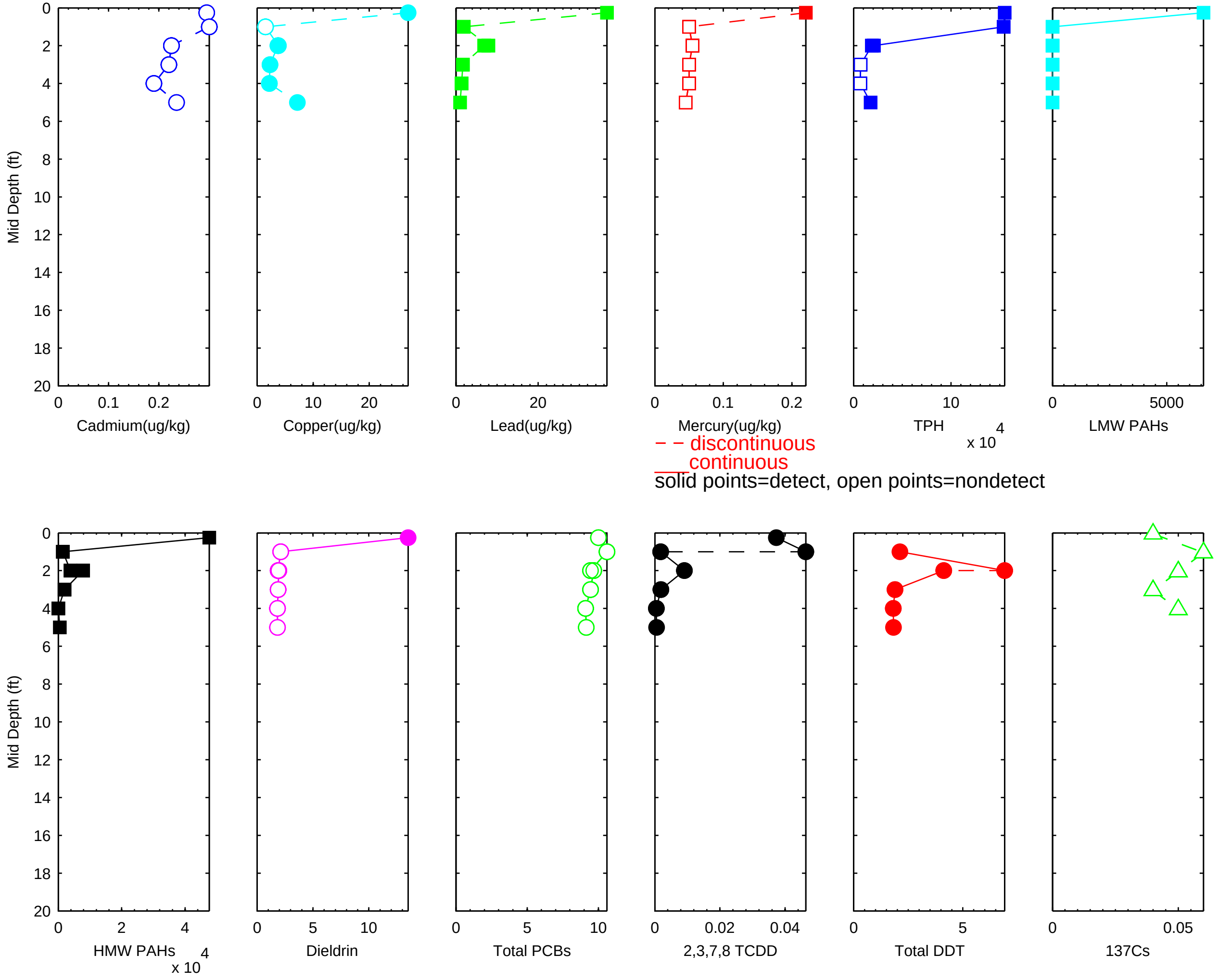

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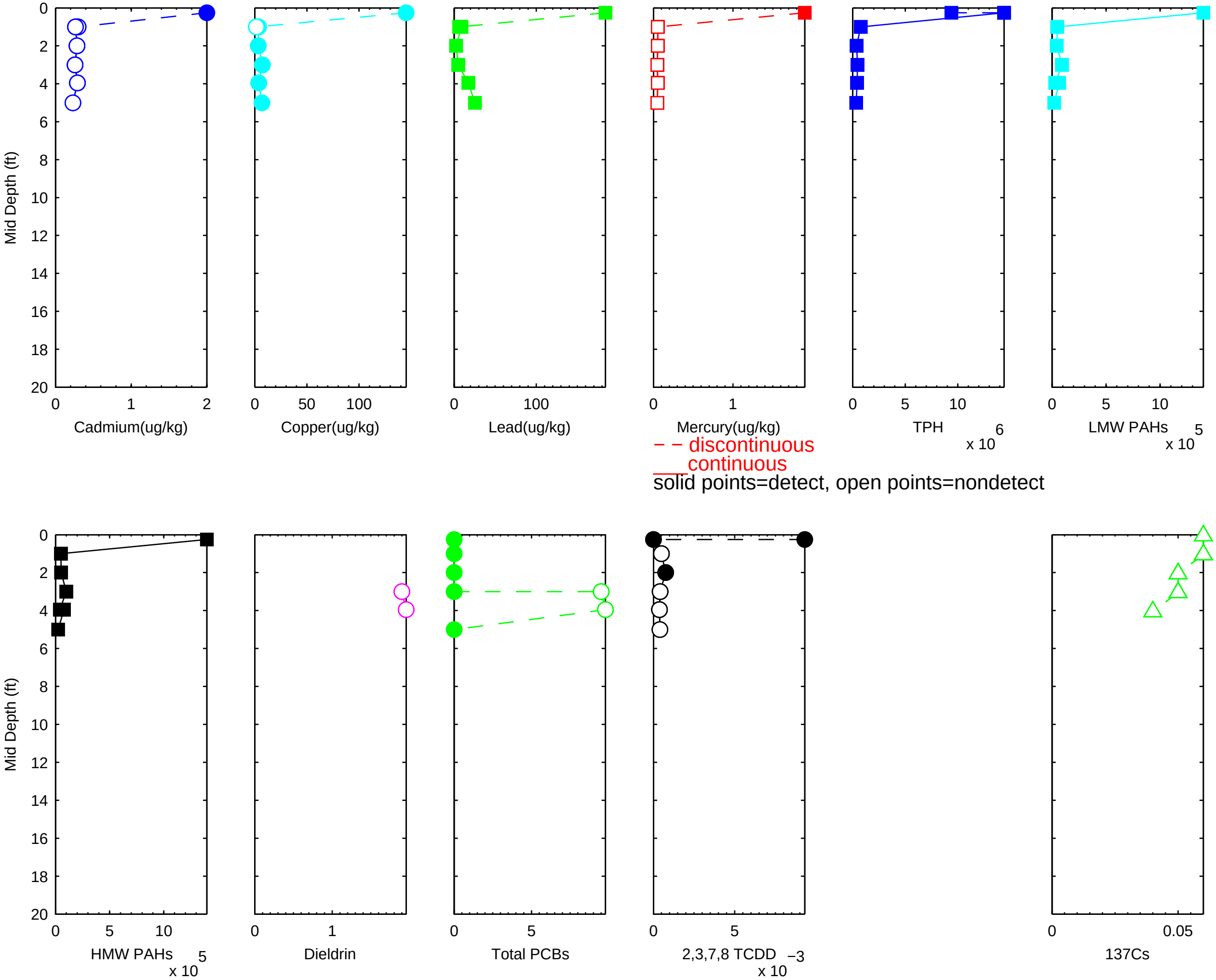

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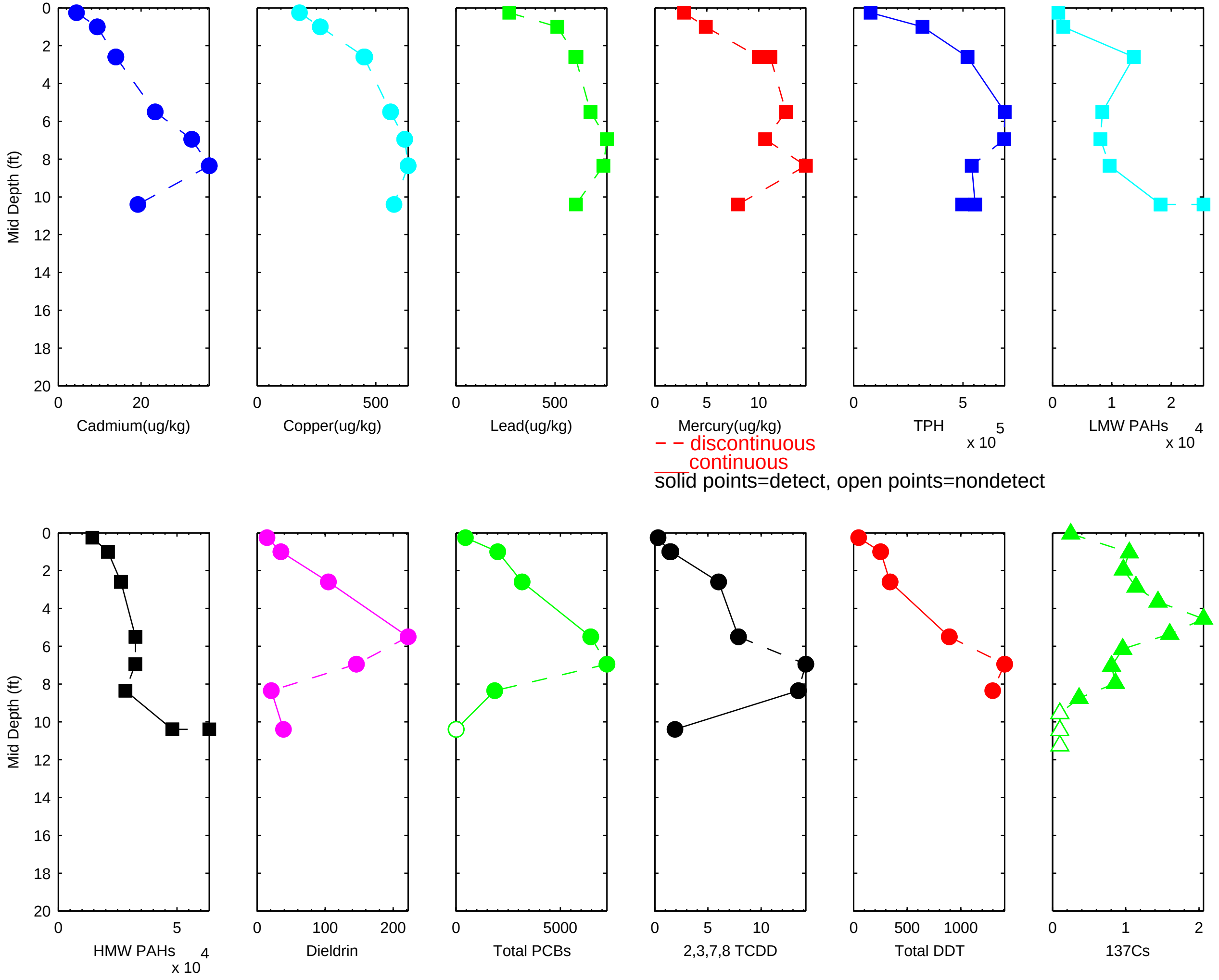

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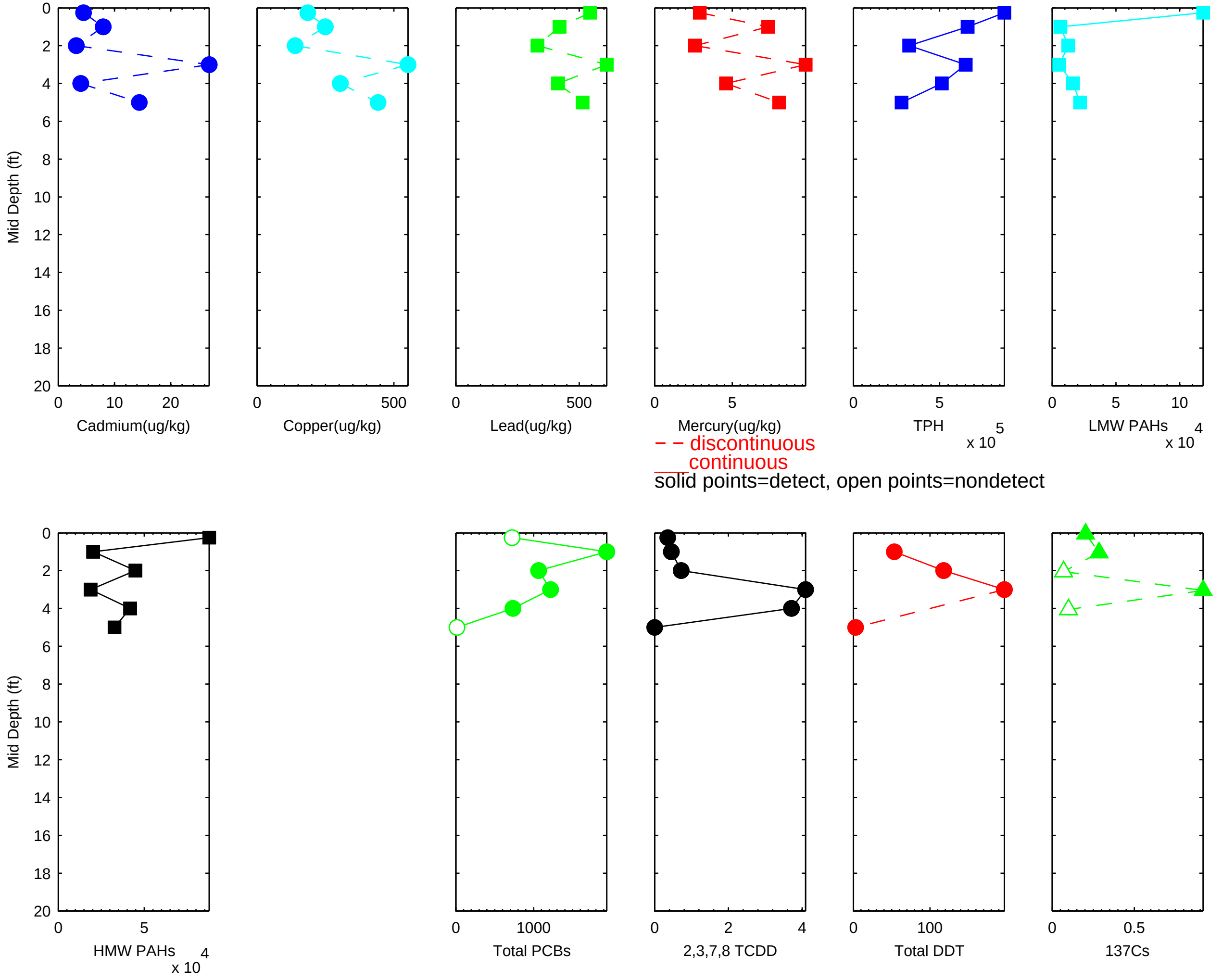

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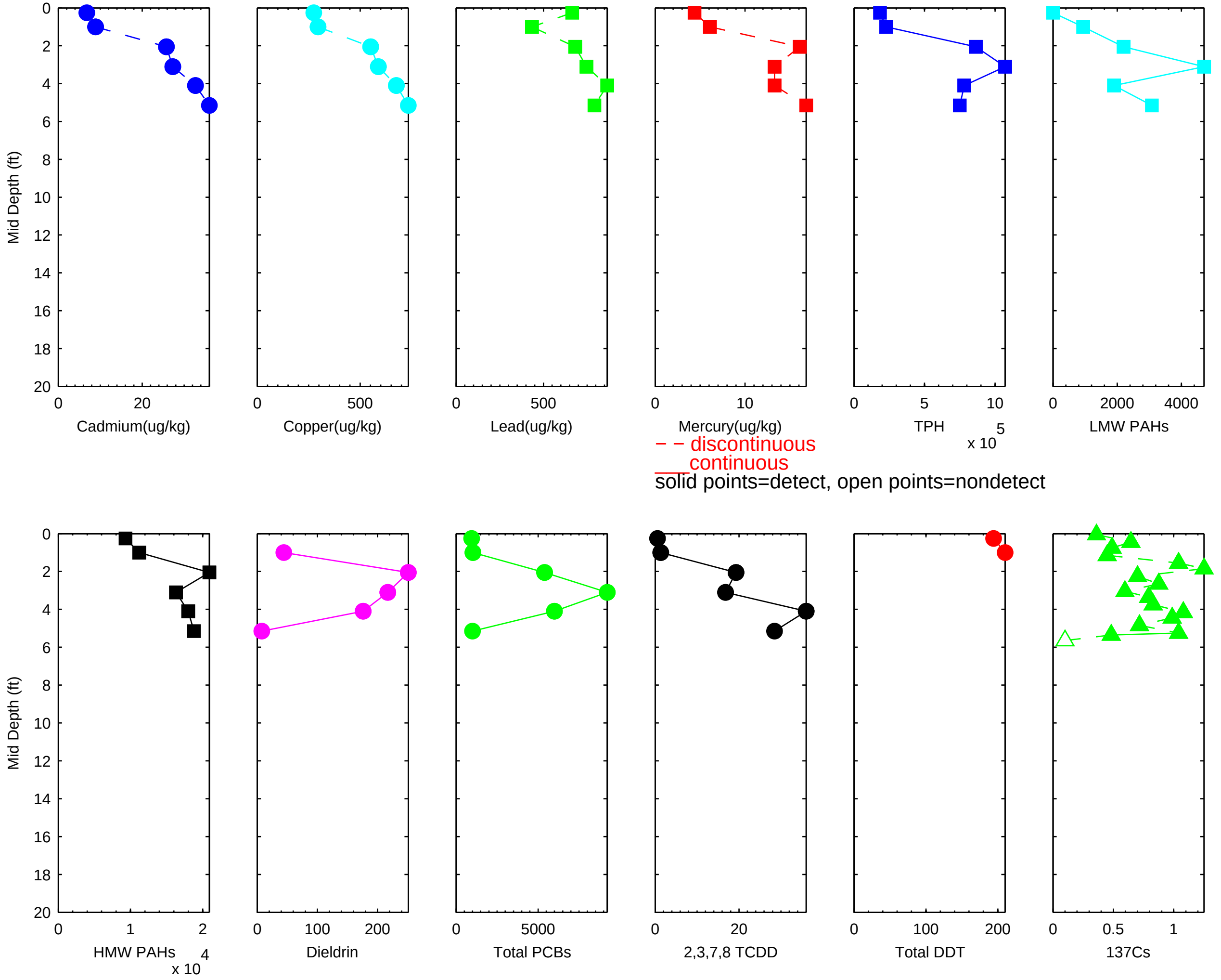

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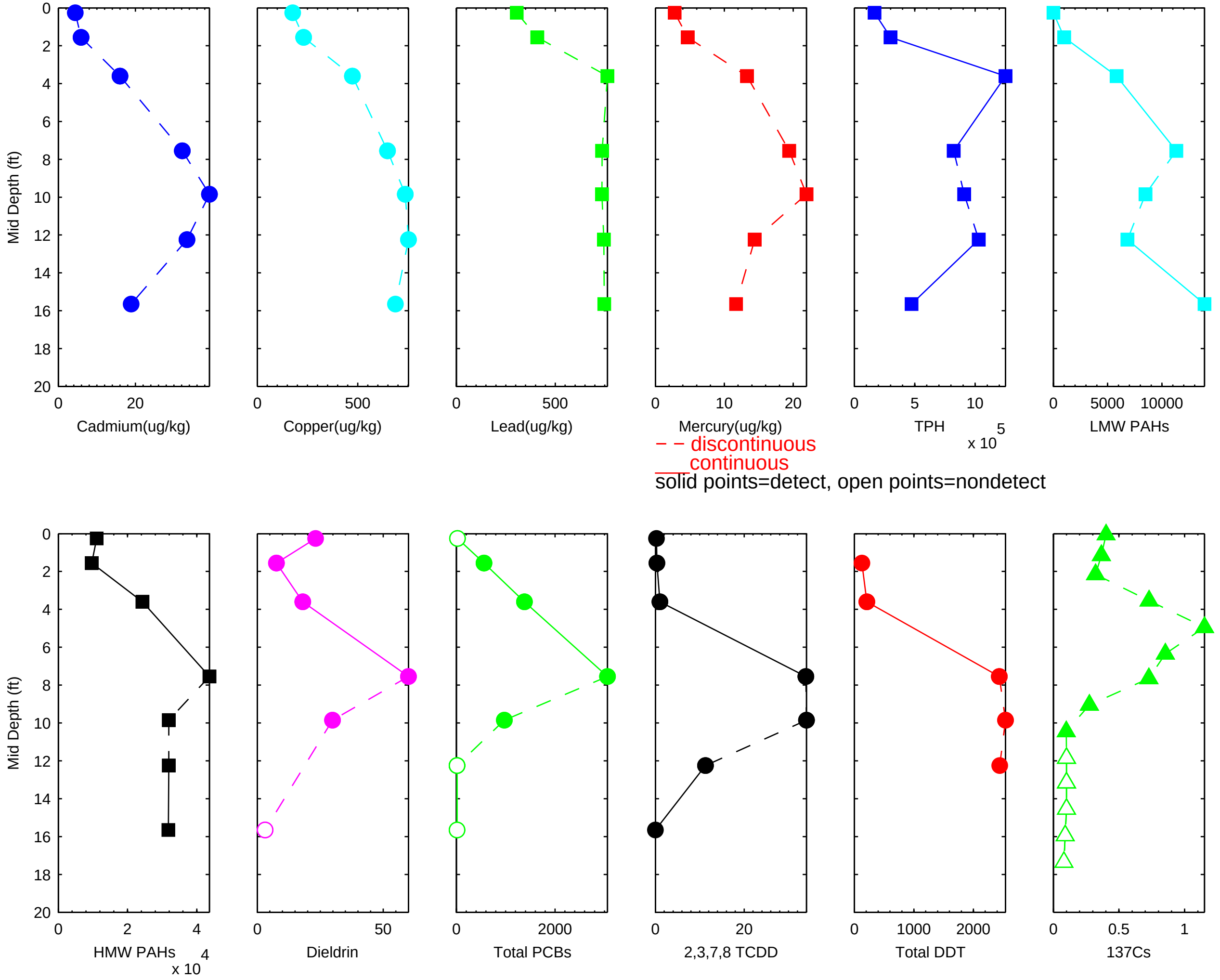

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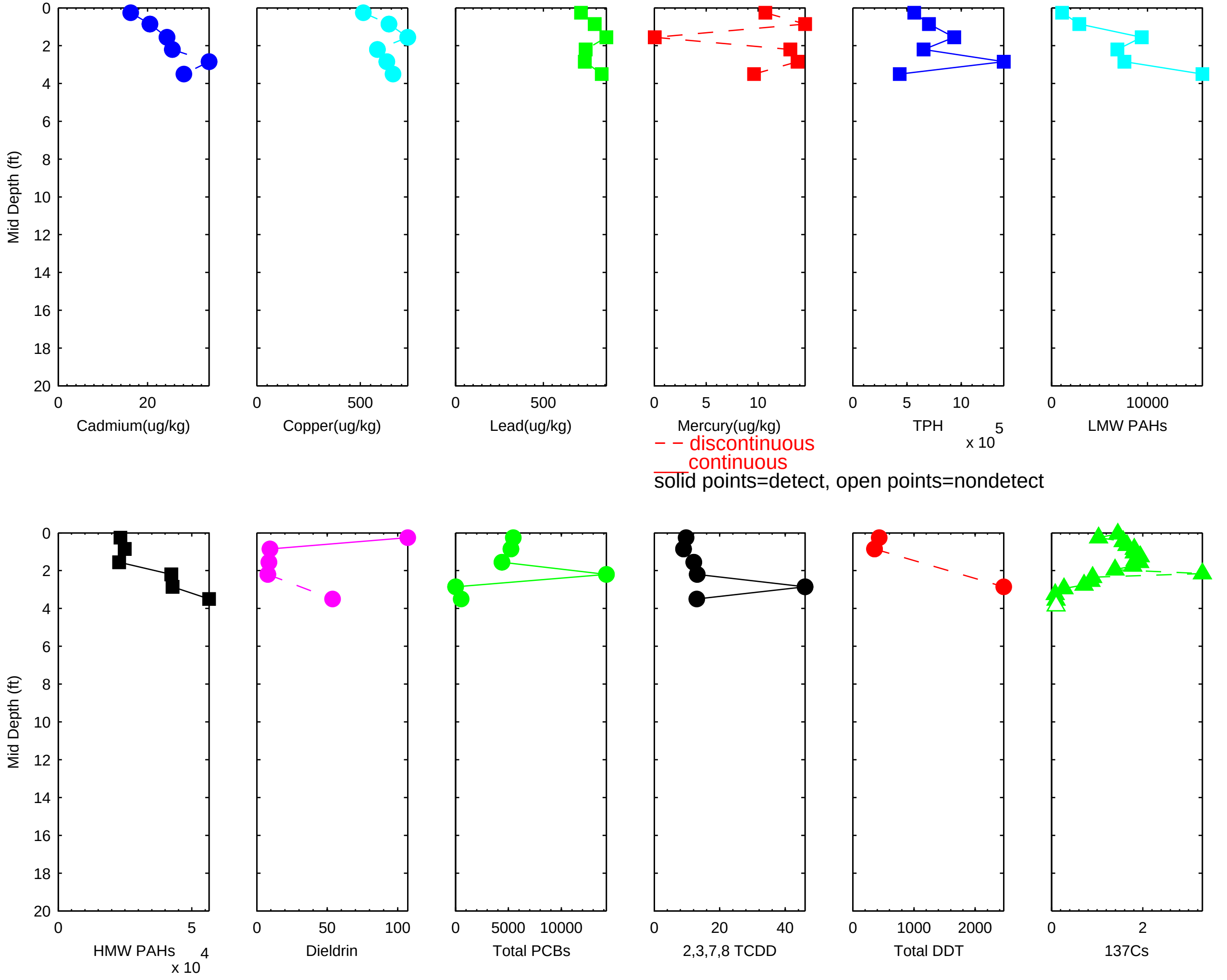

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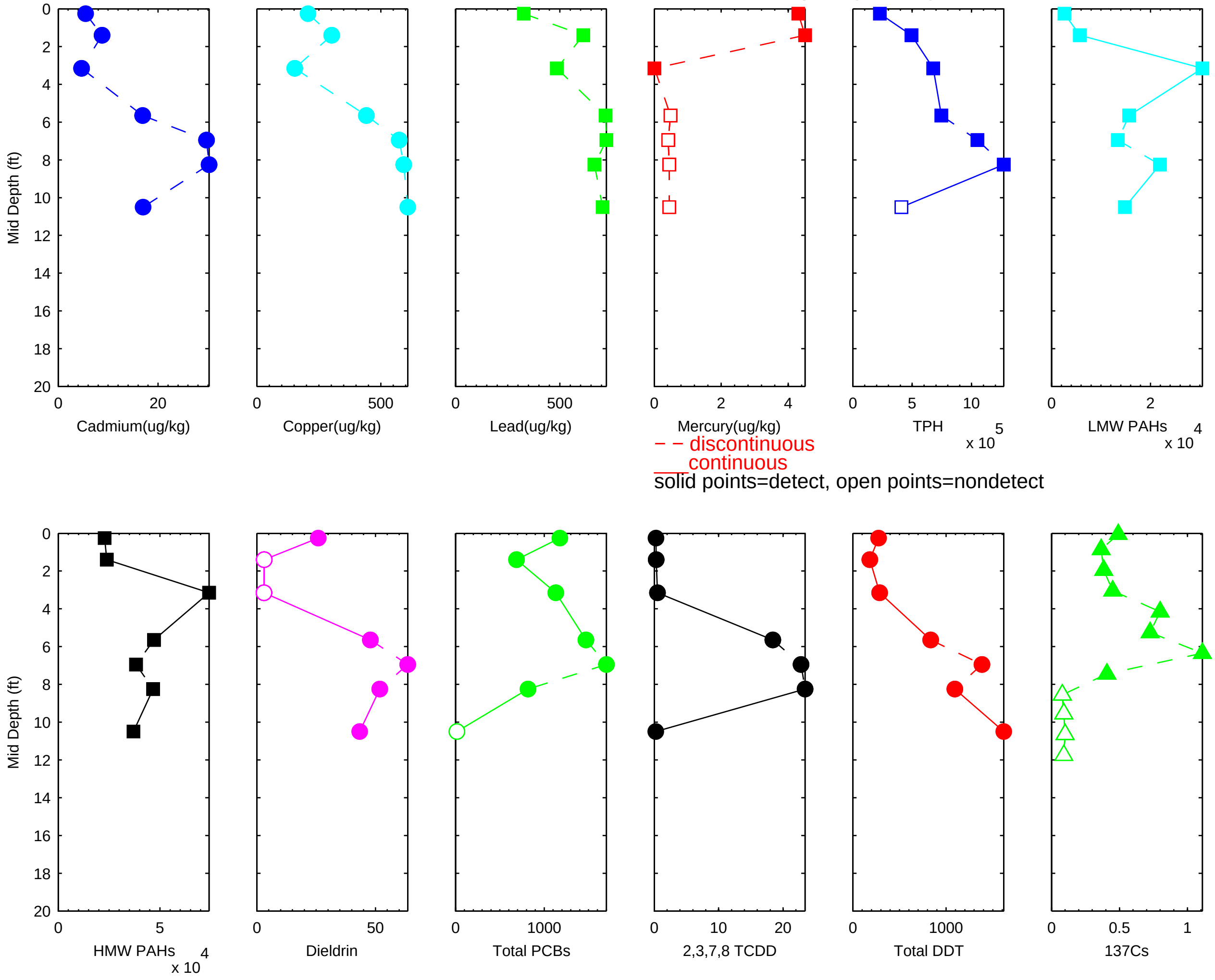

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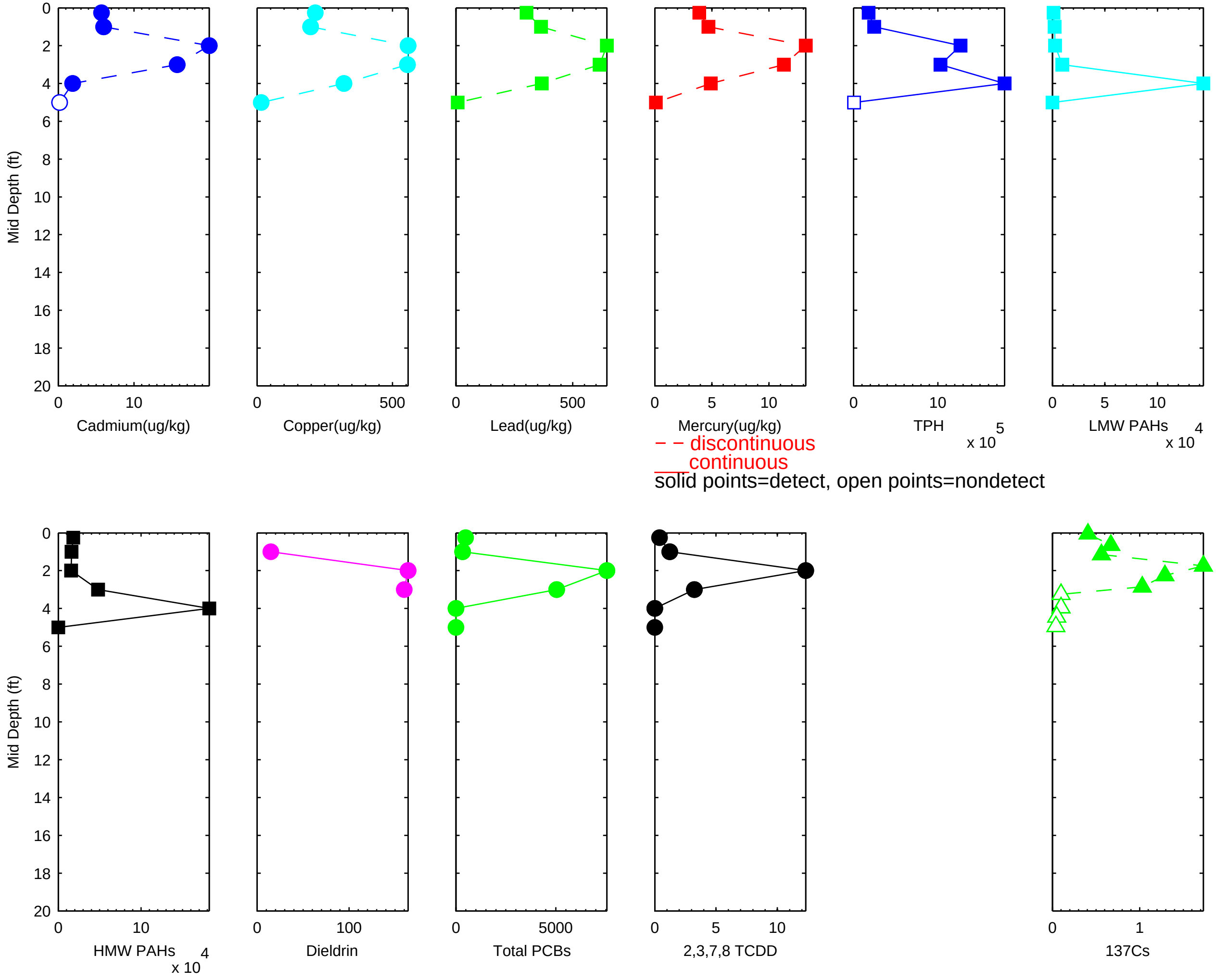

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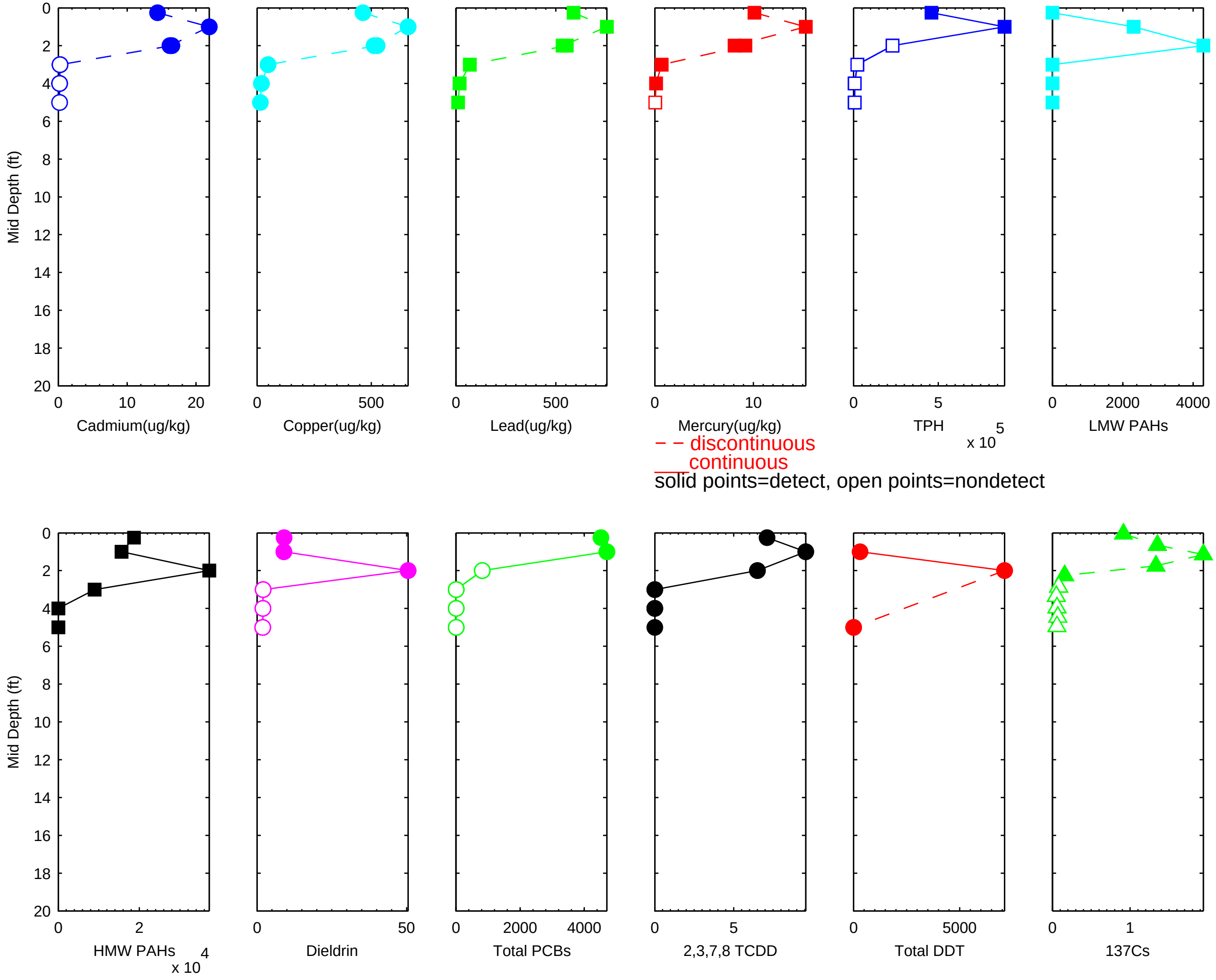

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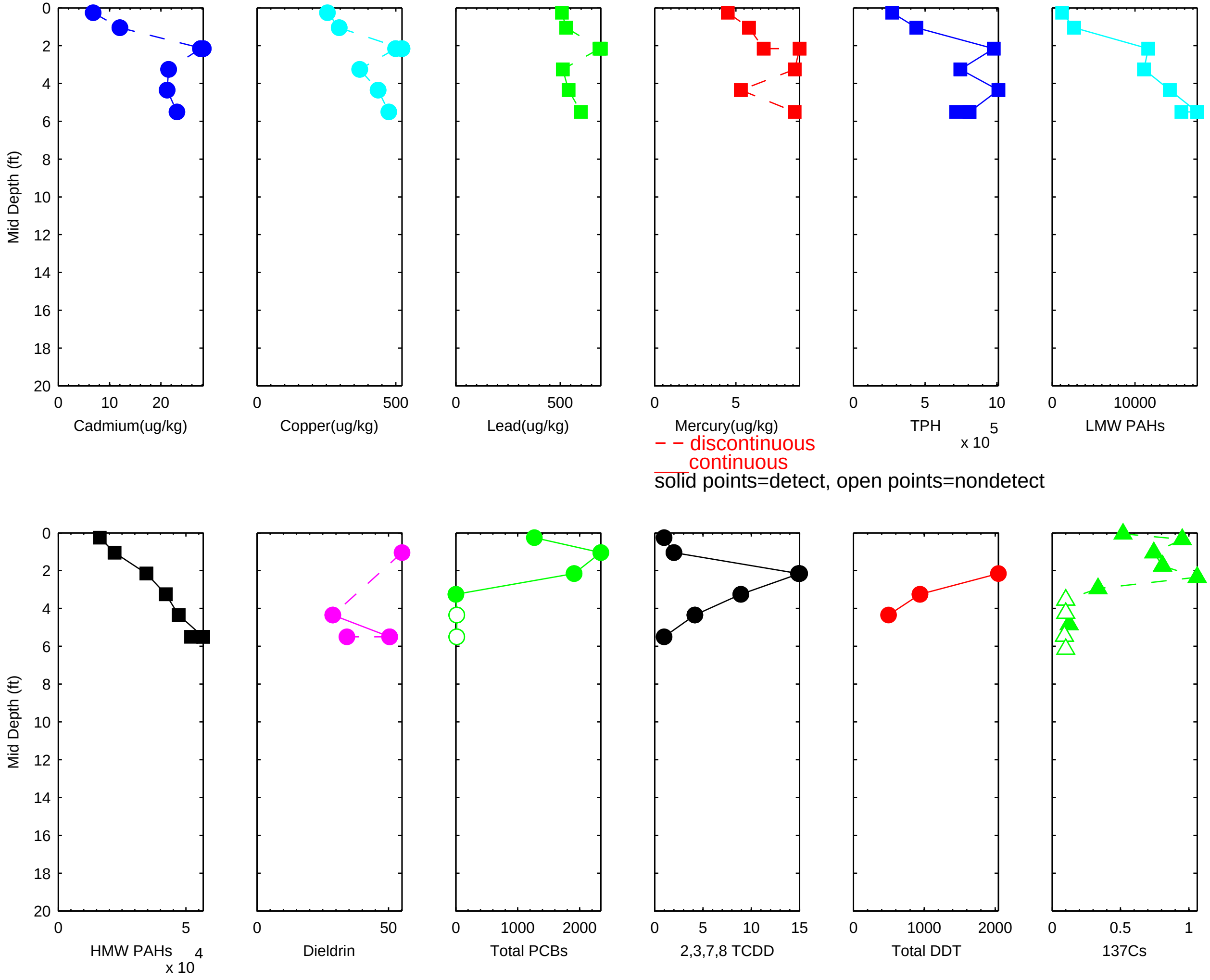

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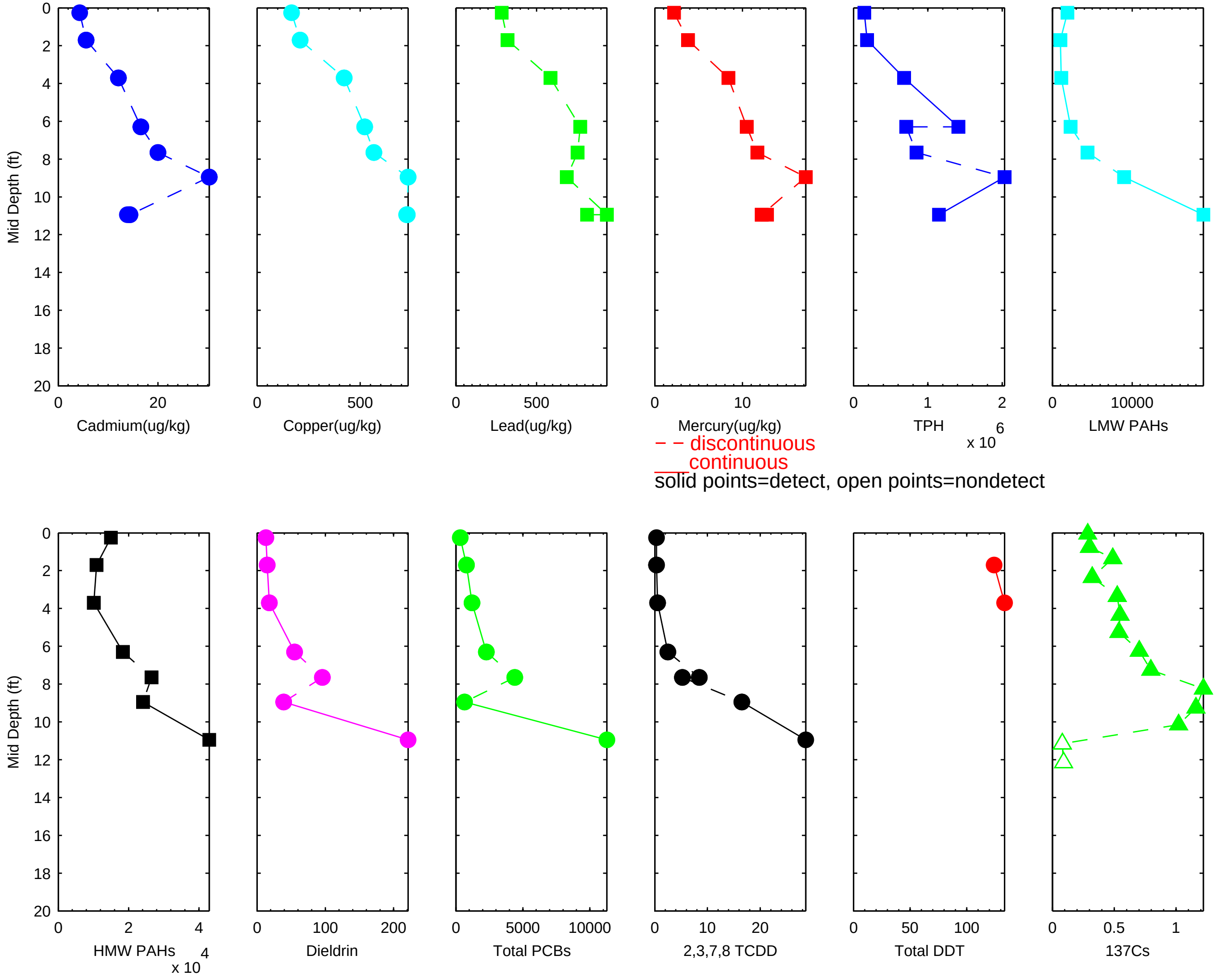

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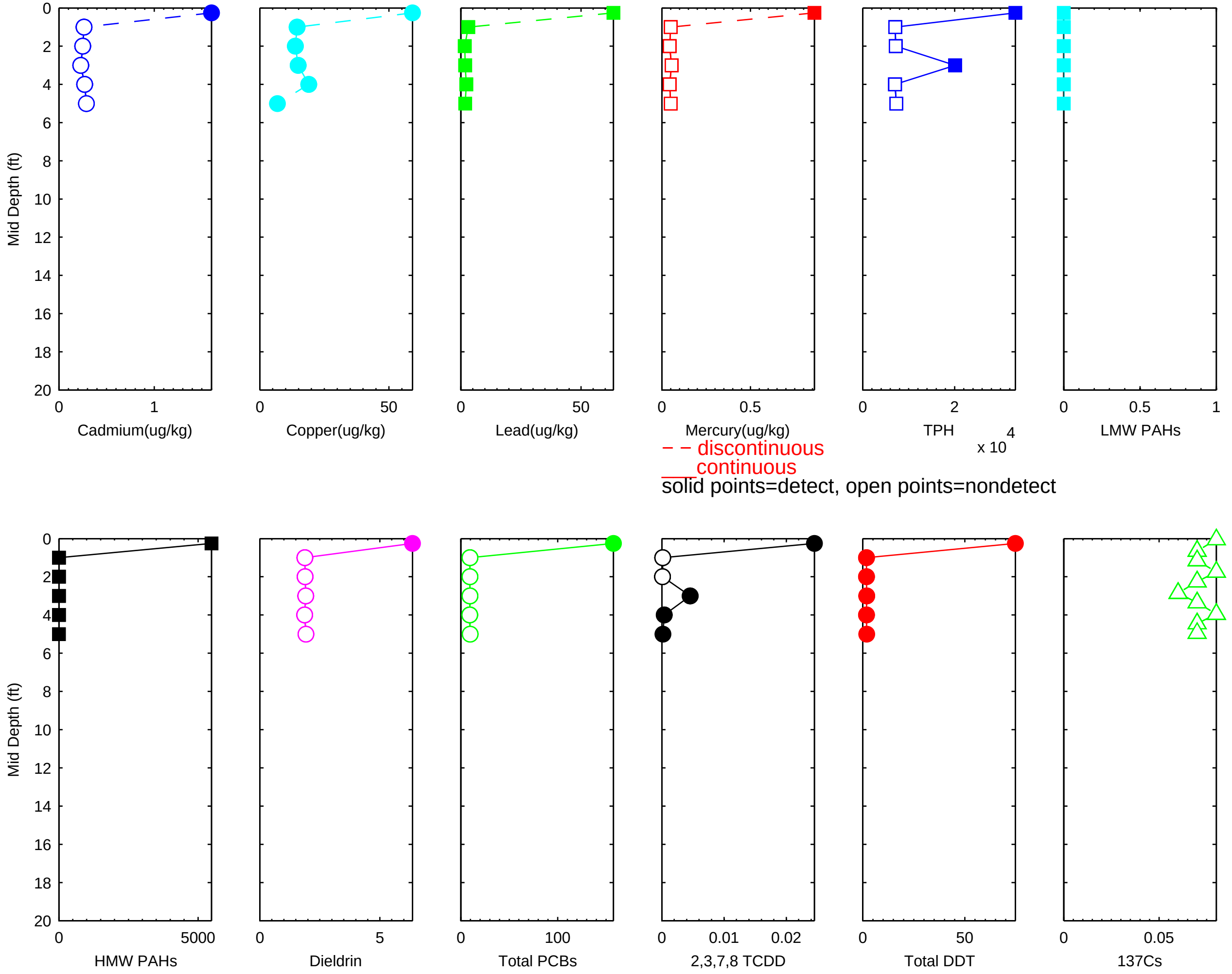

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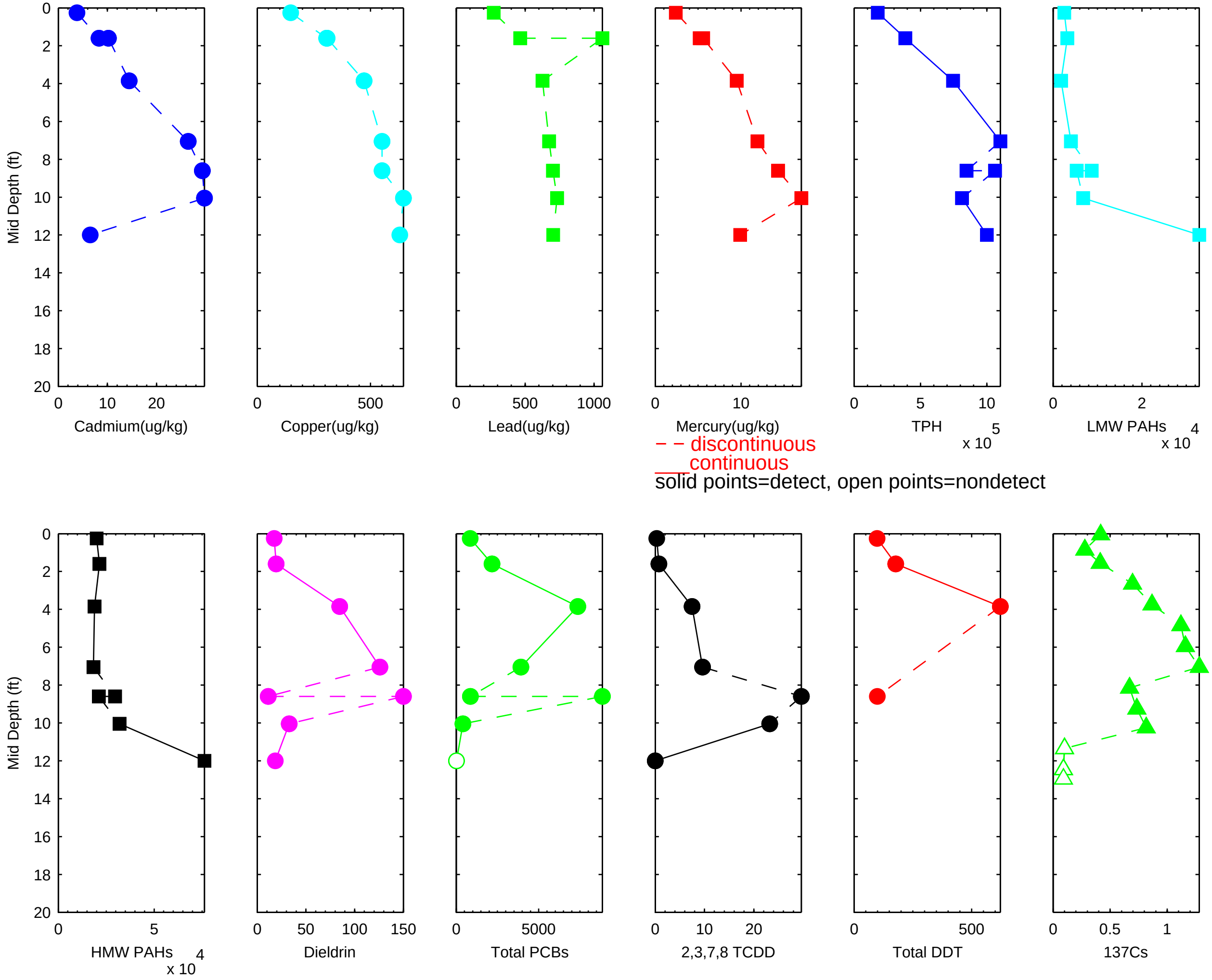

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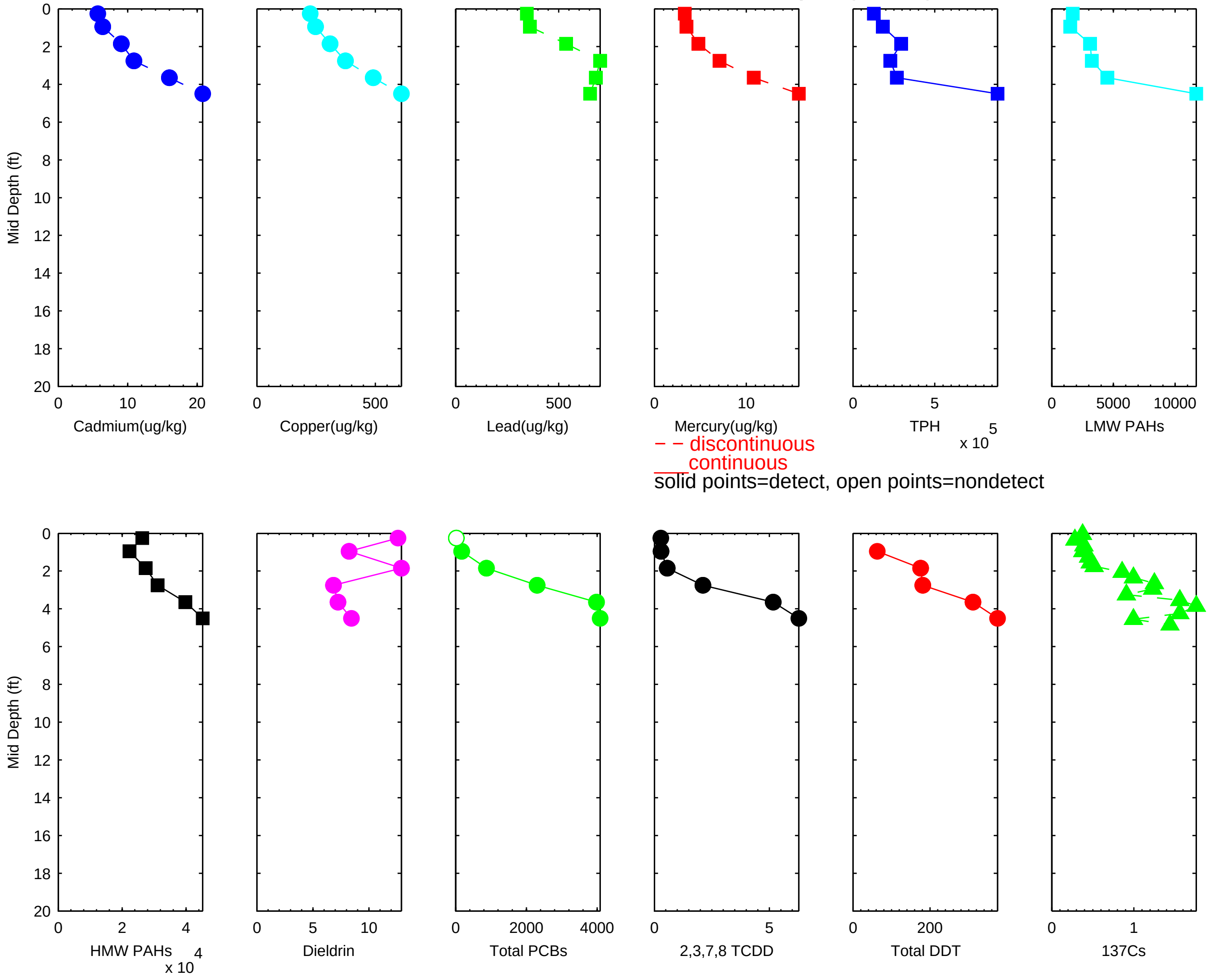
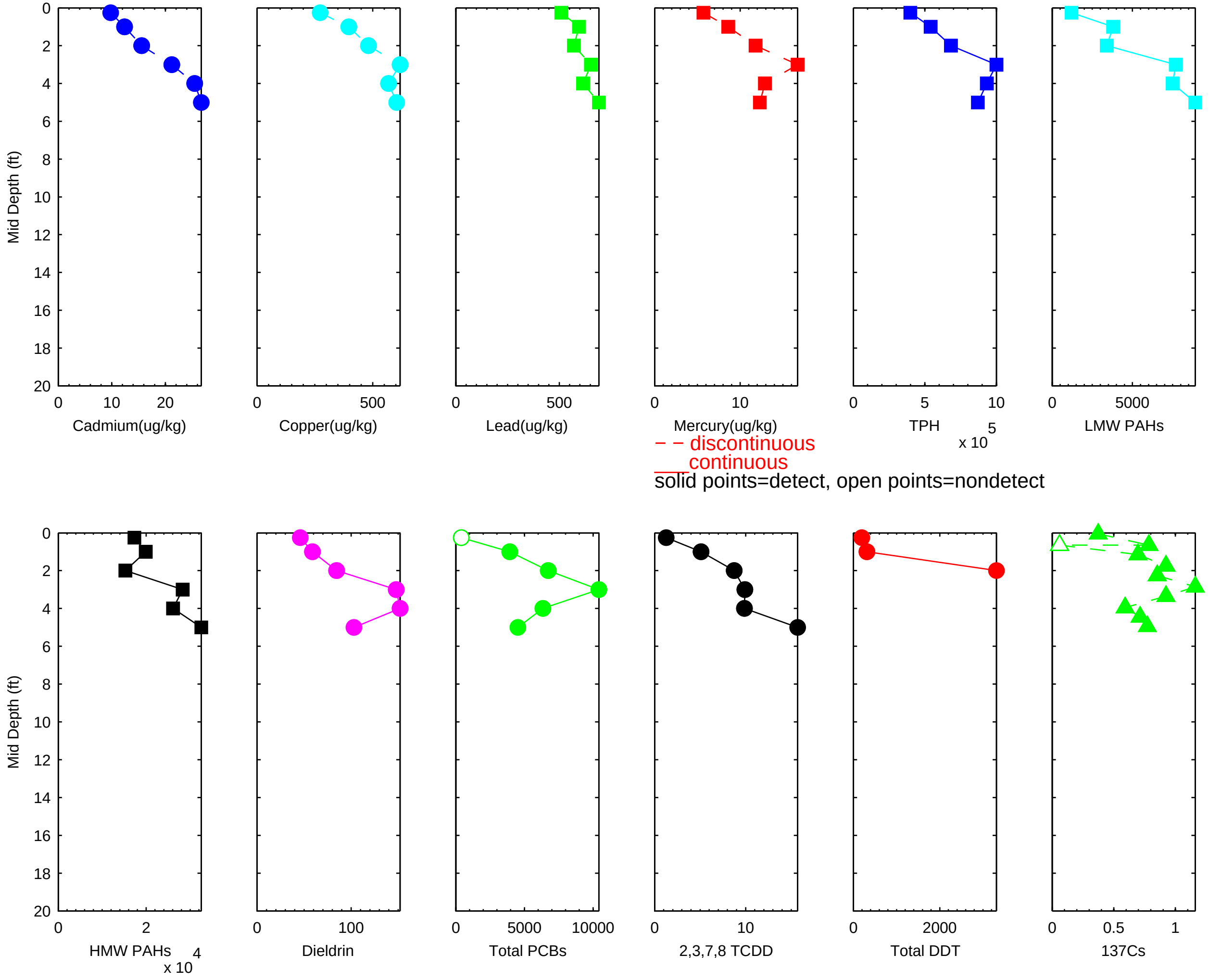


Sample ID: 227 River Mile 2.86 PASSAIC 1995 RI Sampling Program



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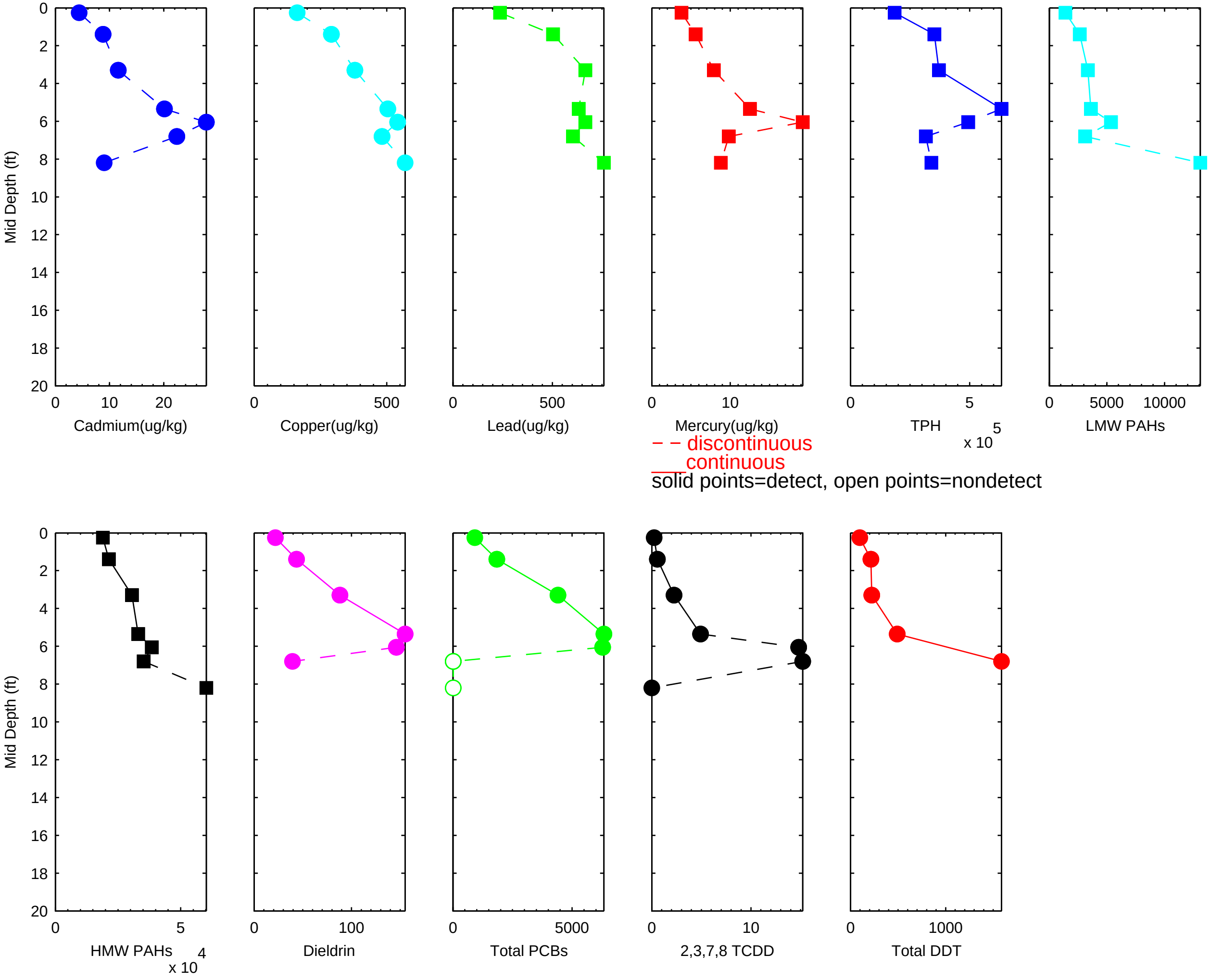

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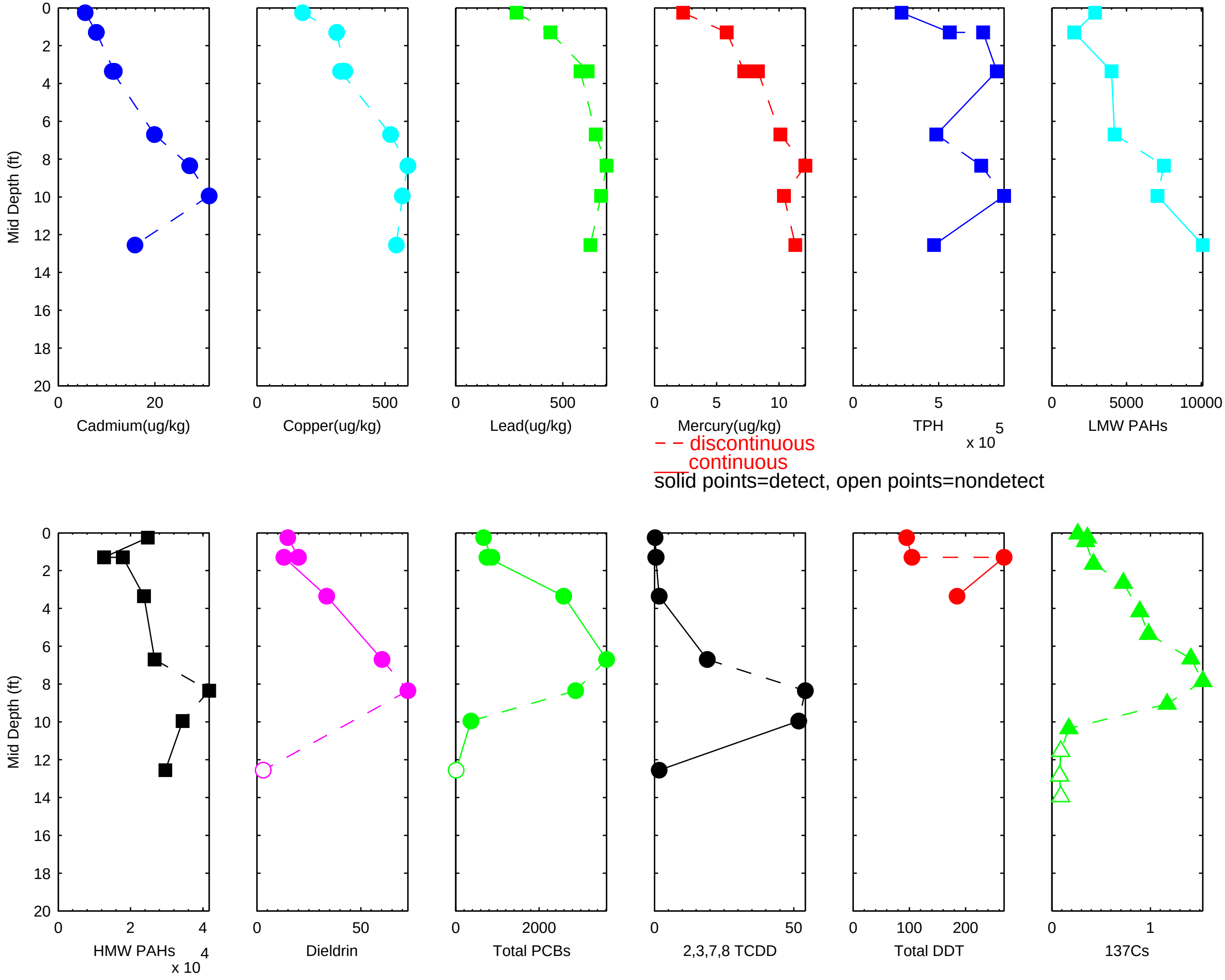

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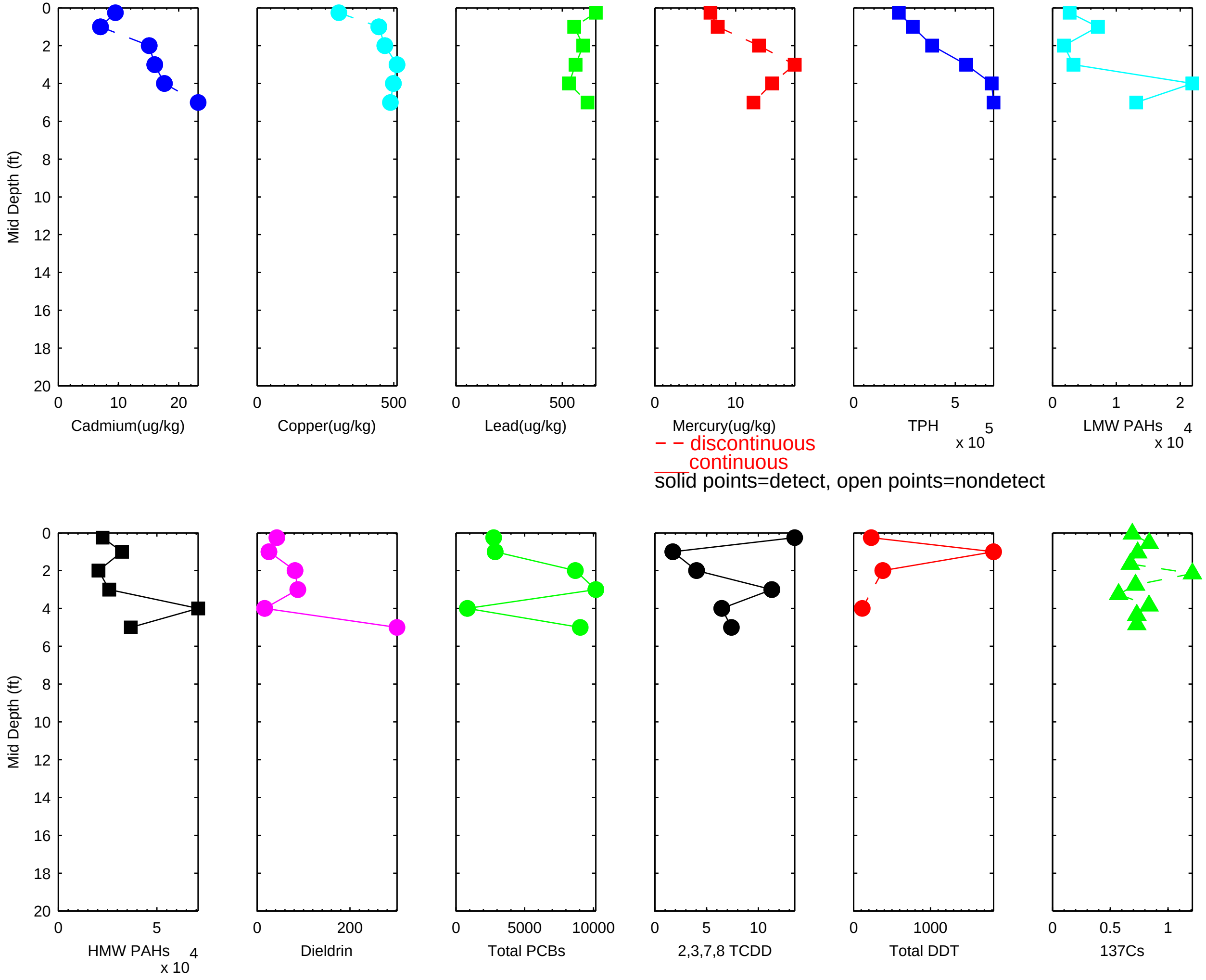

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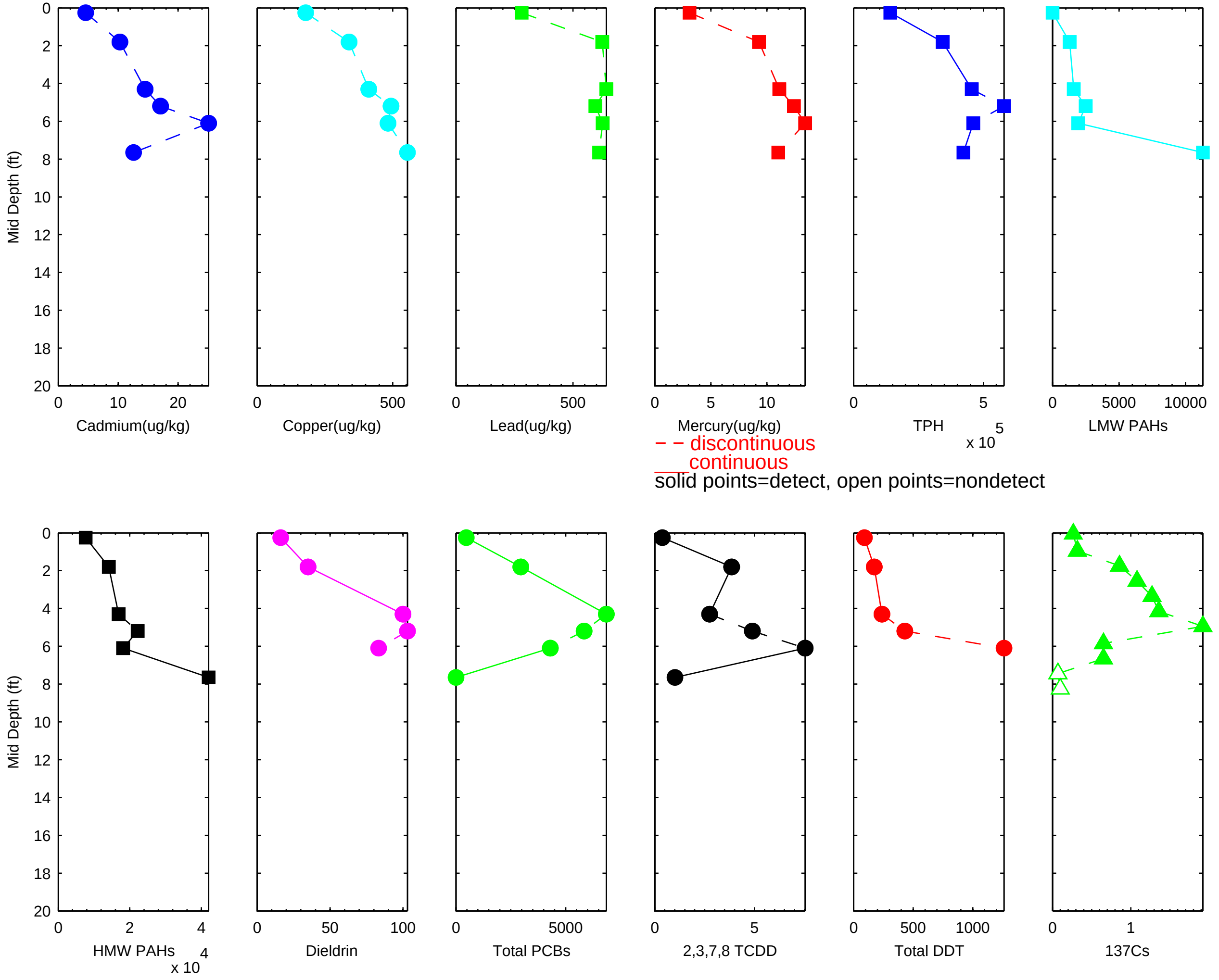

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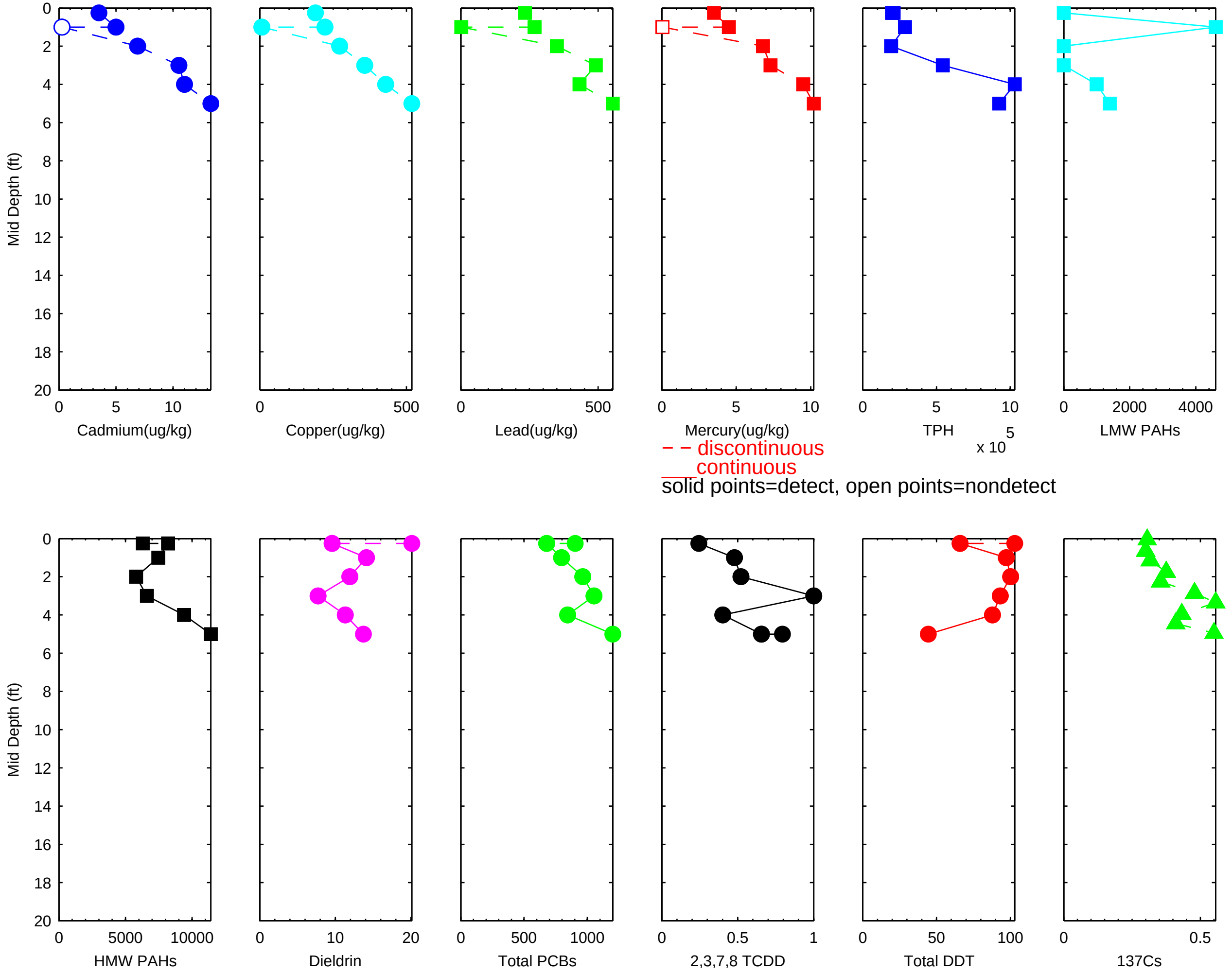

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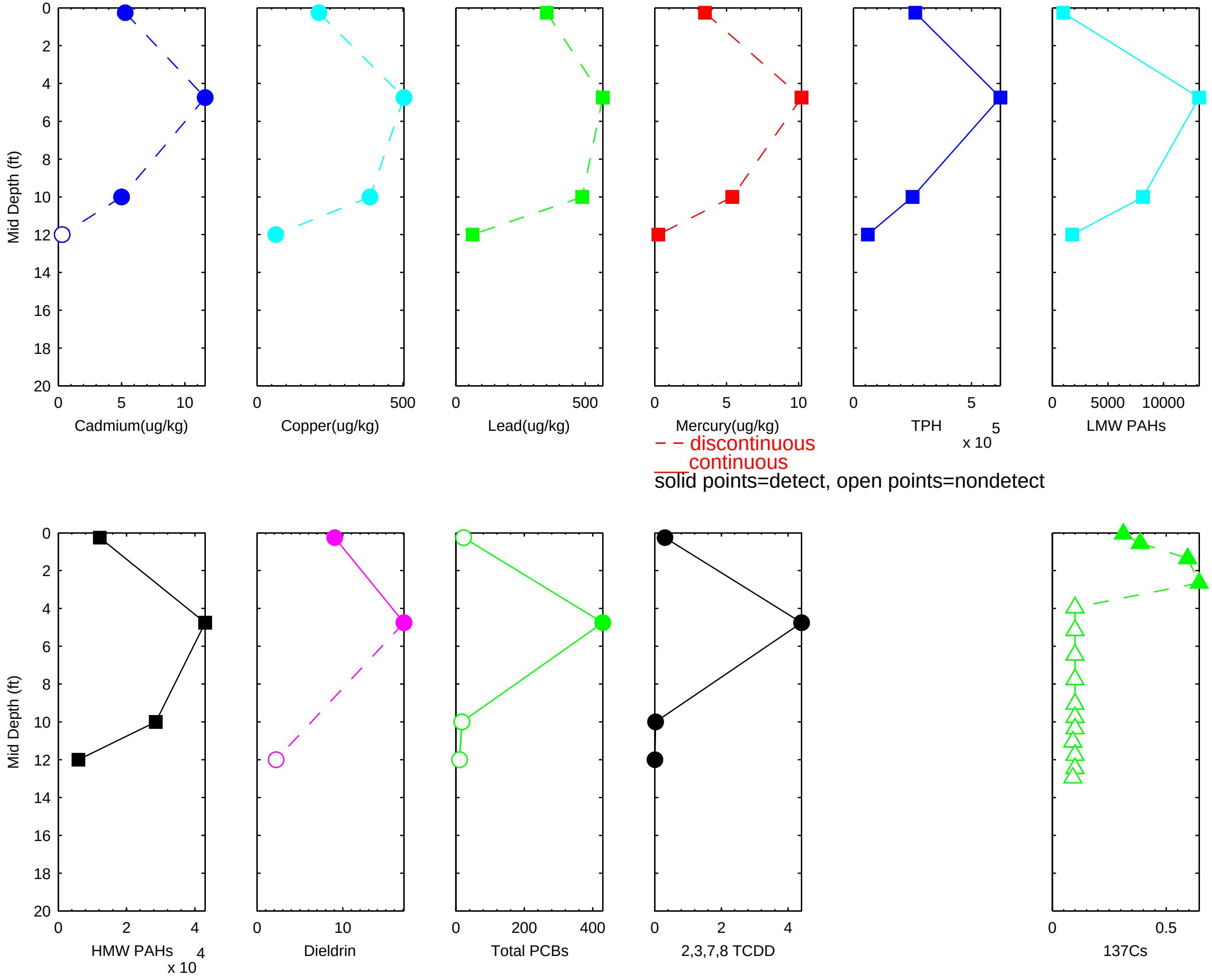

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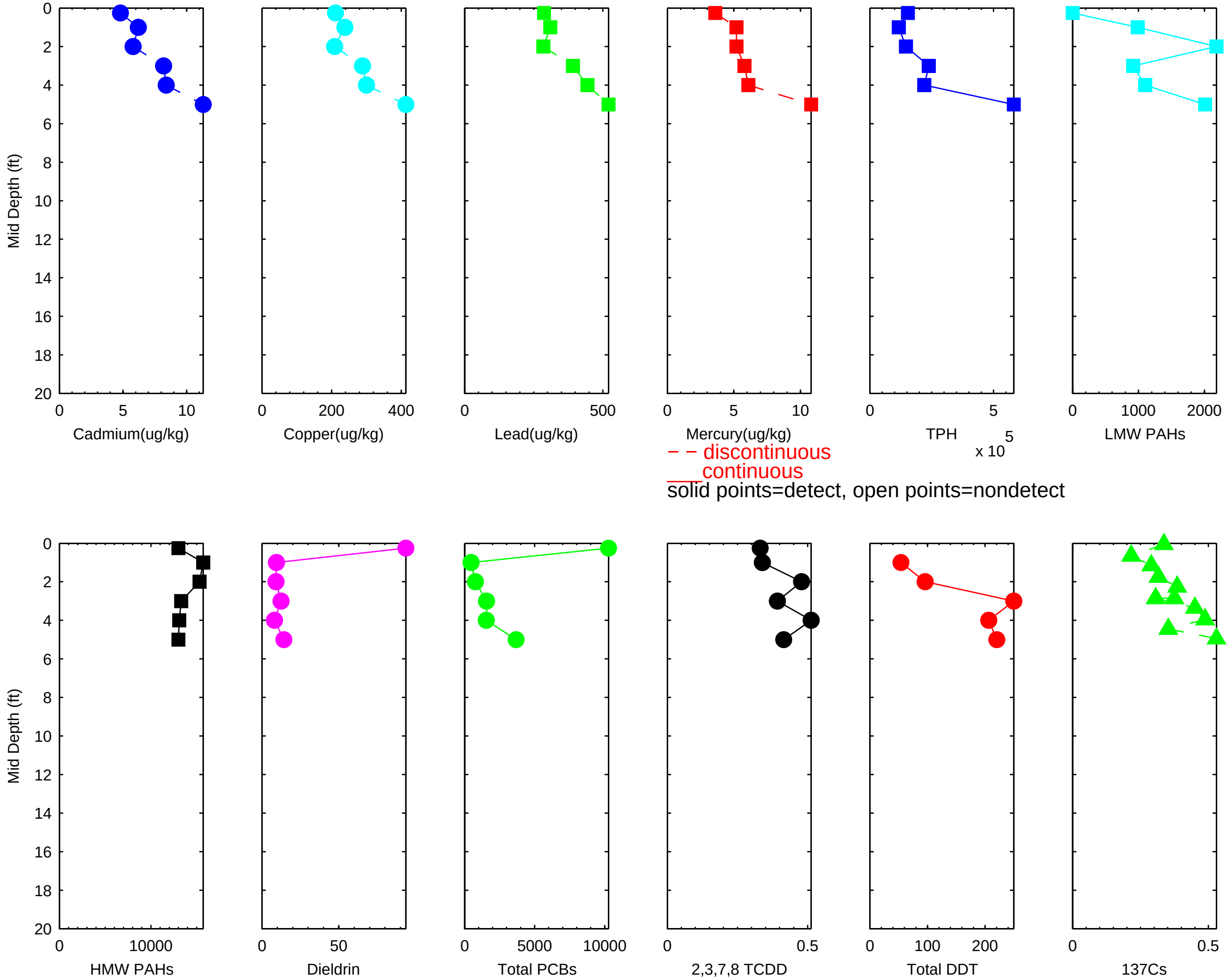

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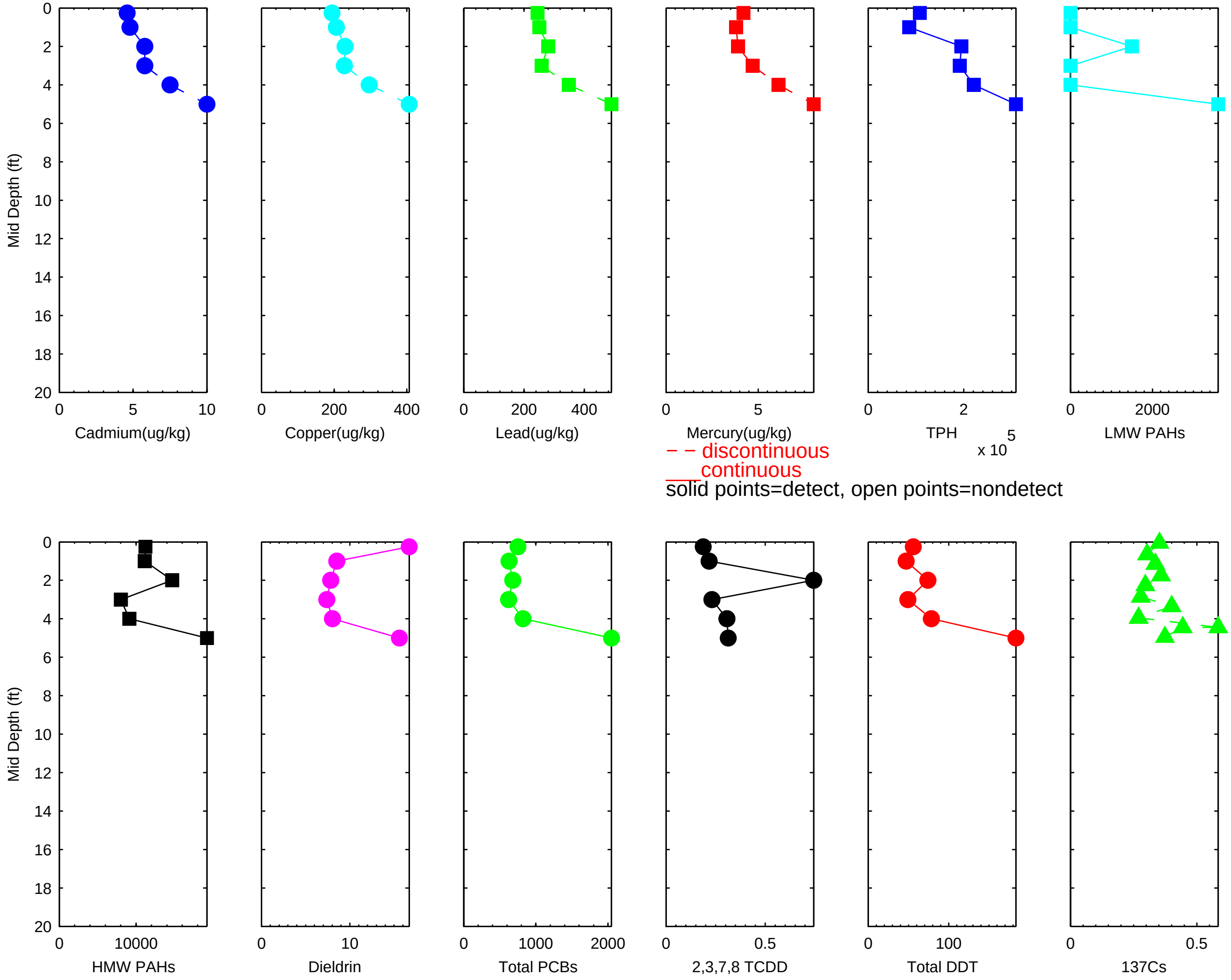

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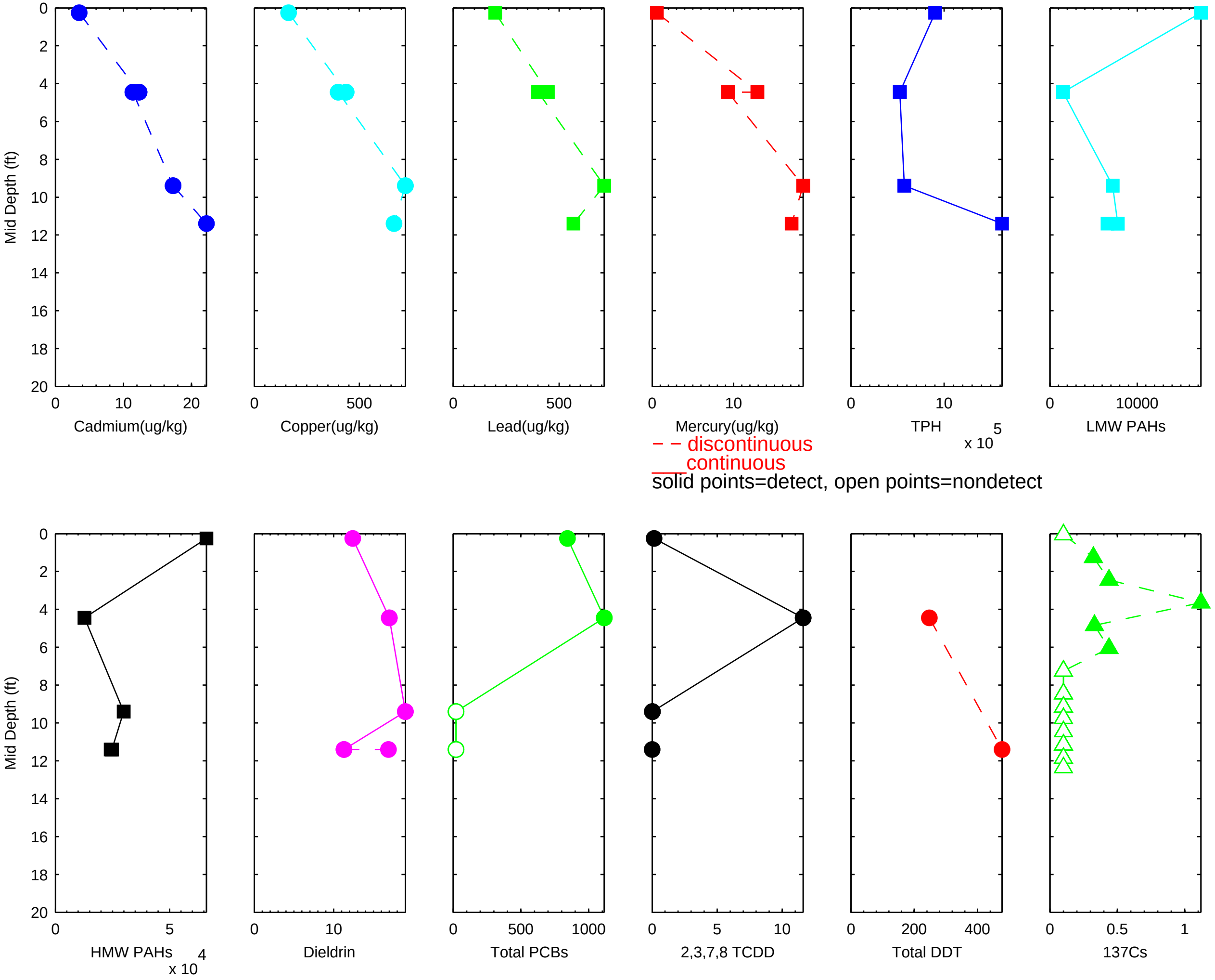

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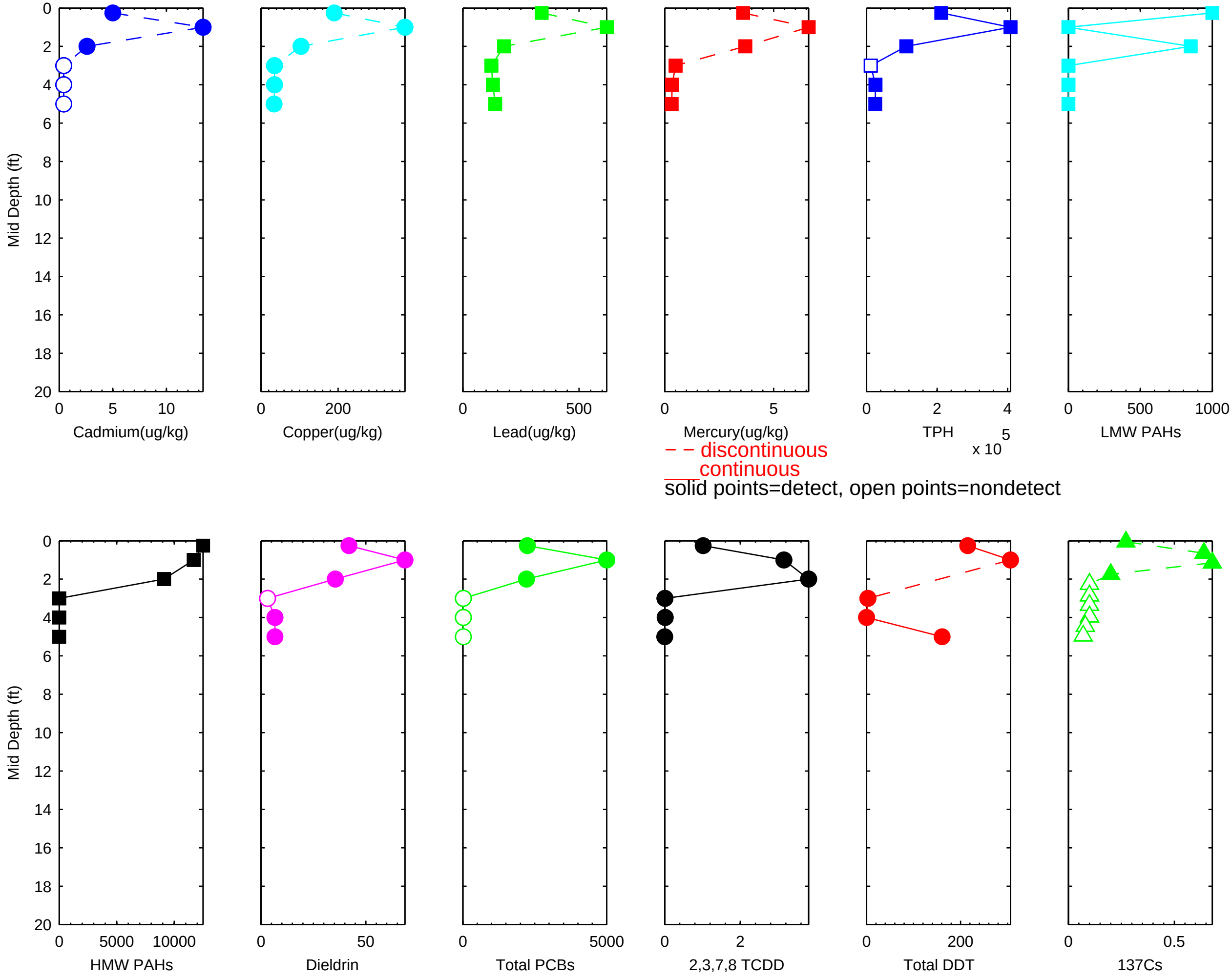

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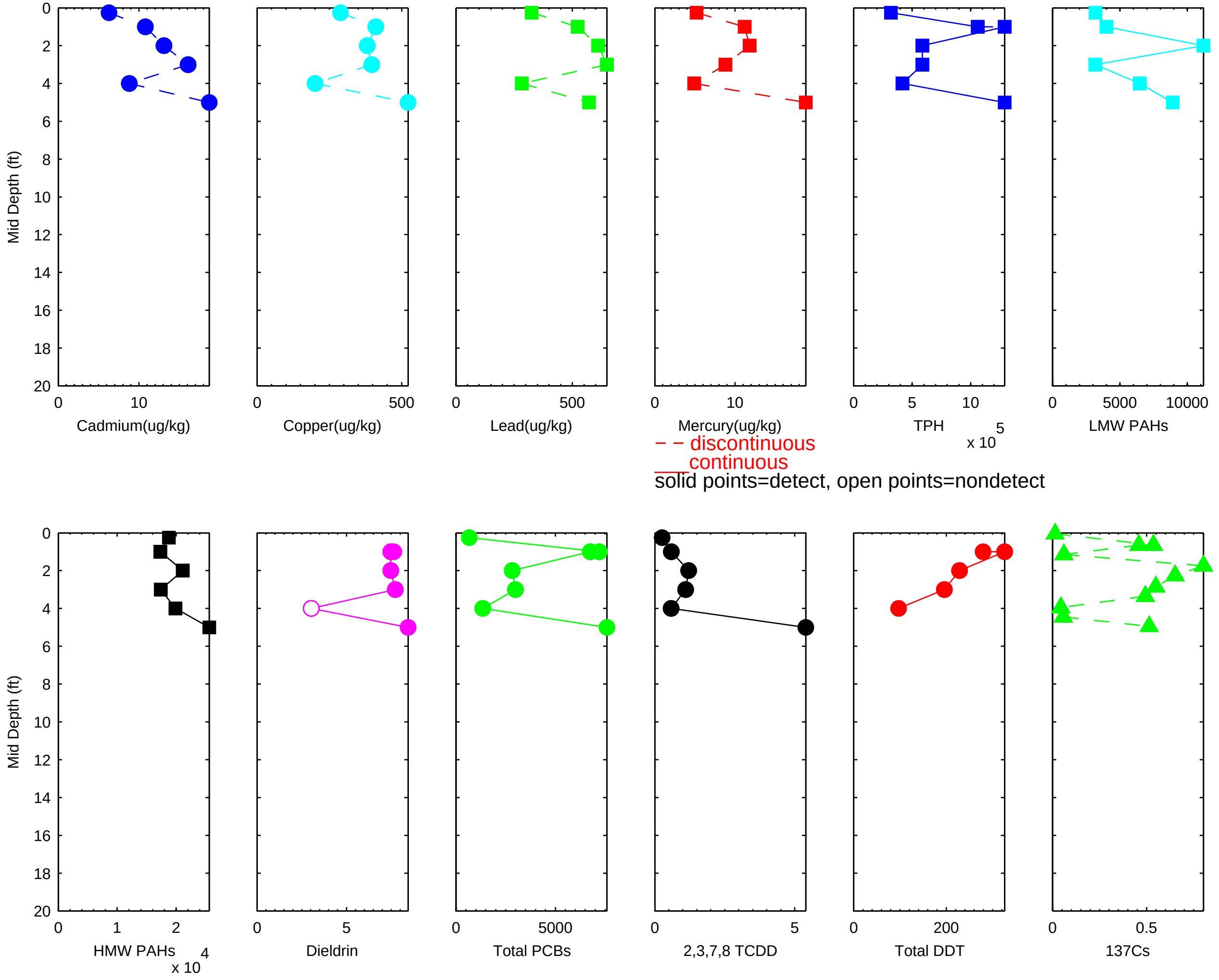

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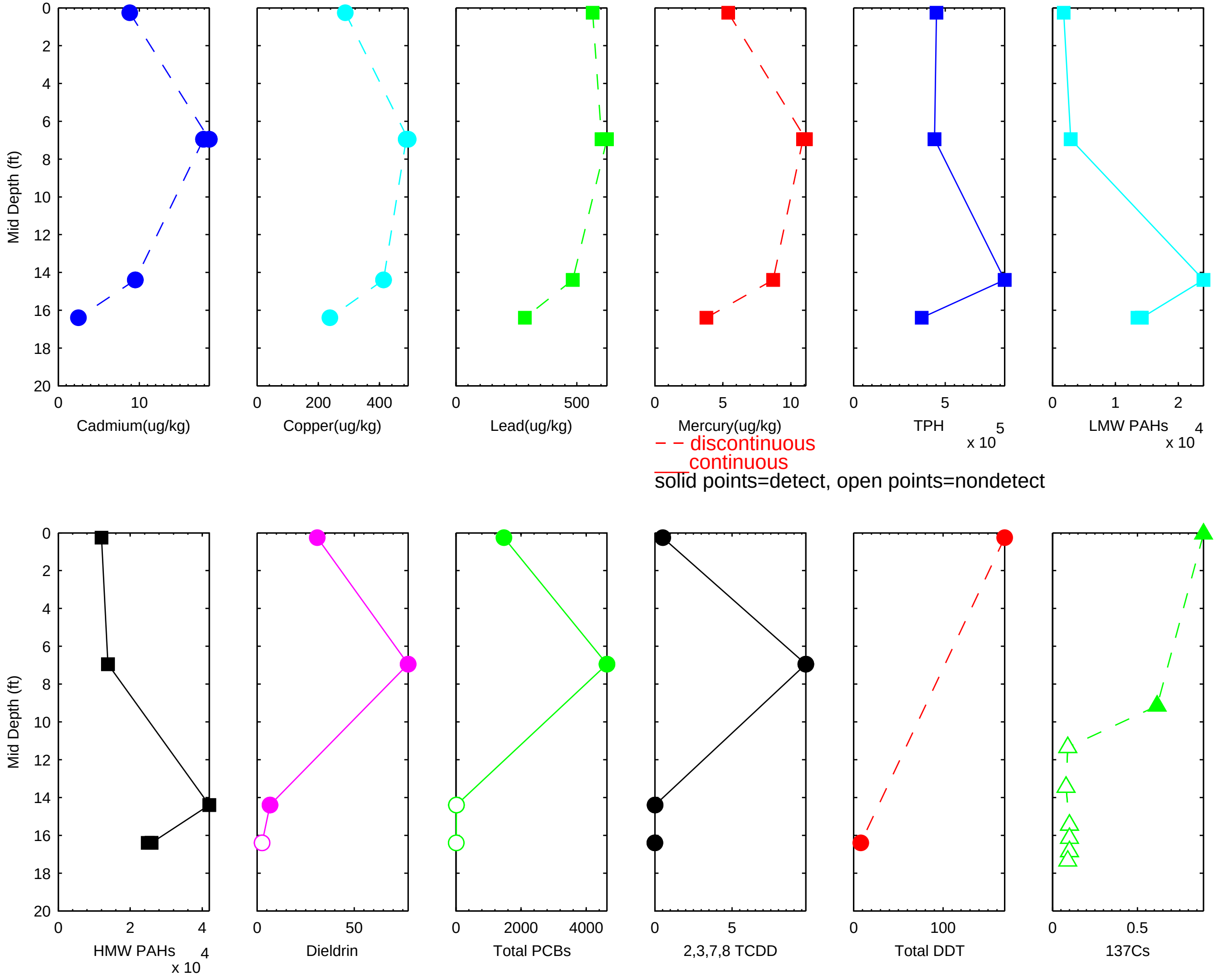

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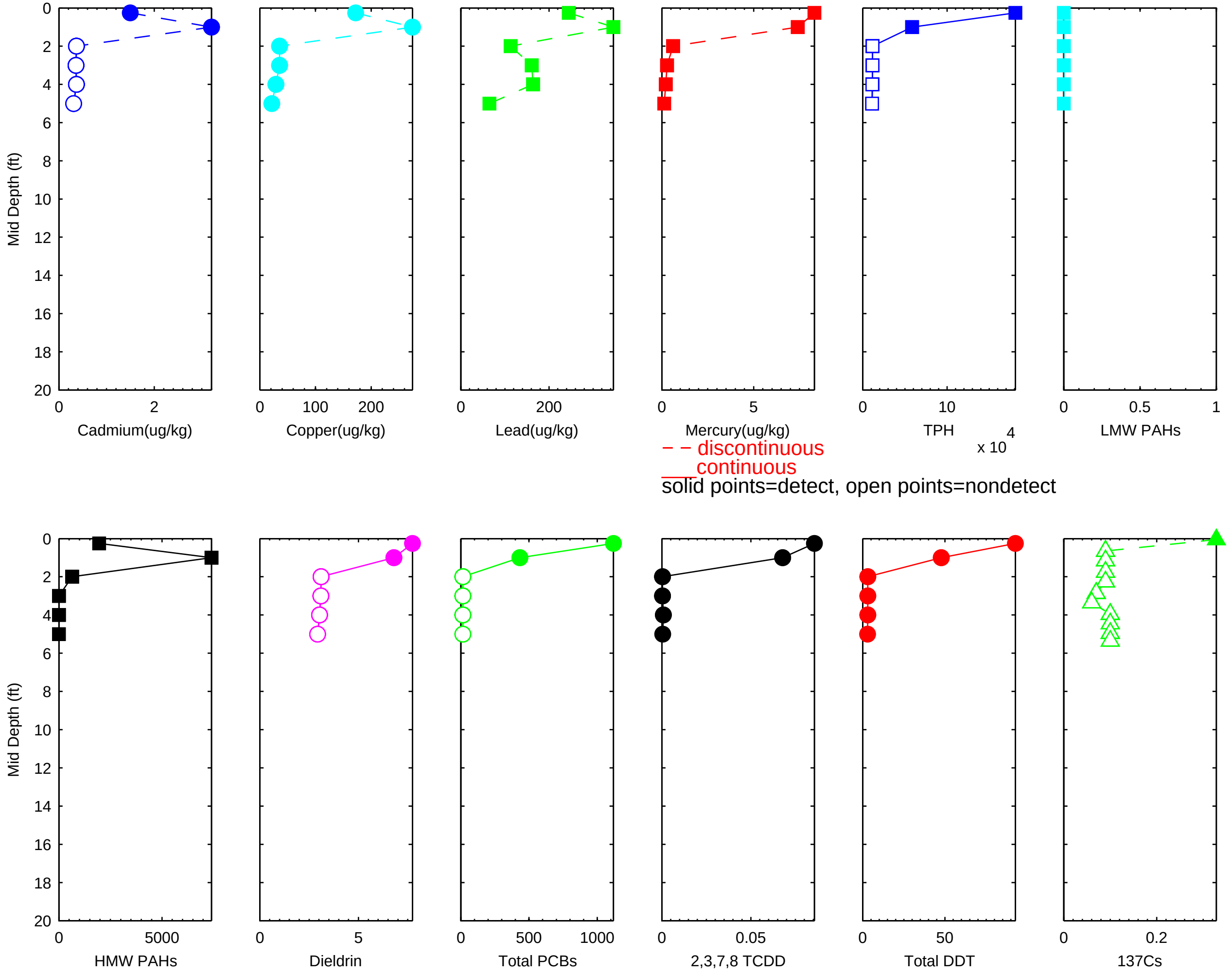

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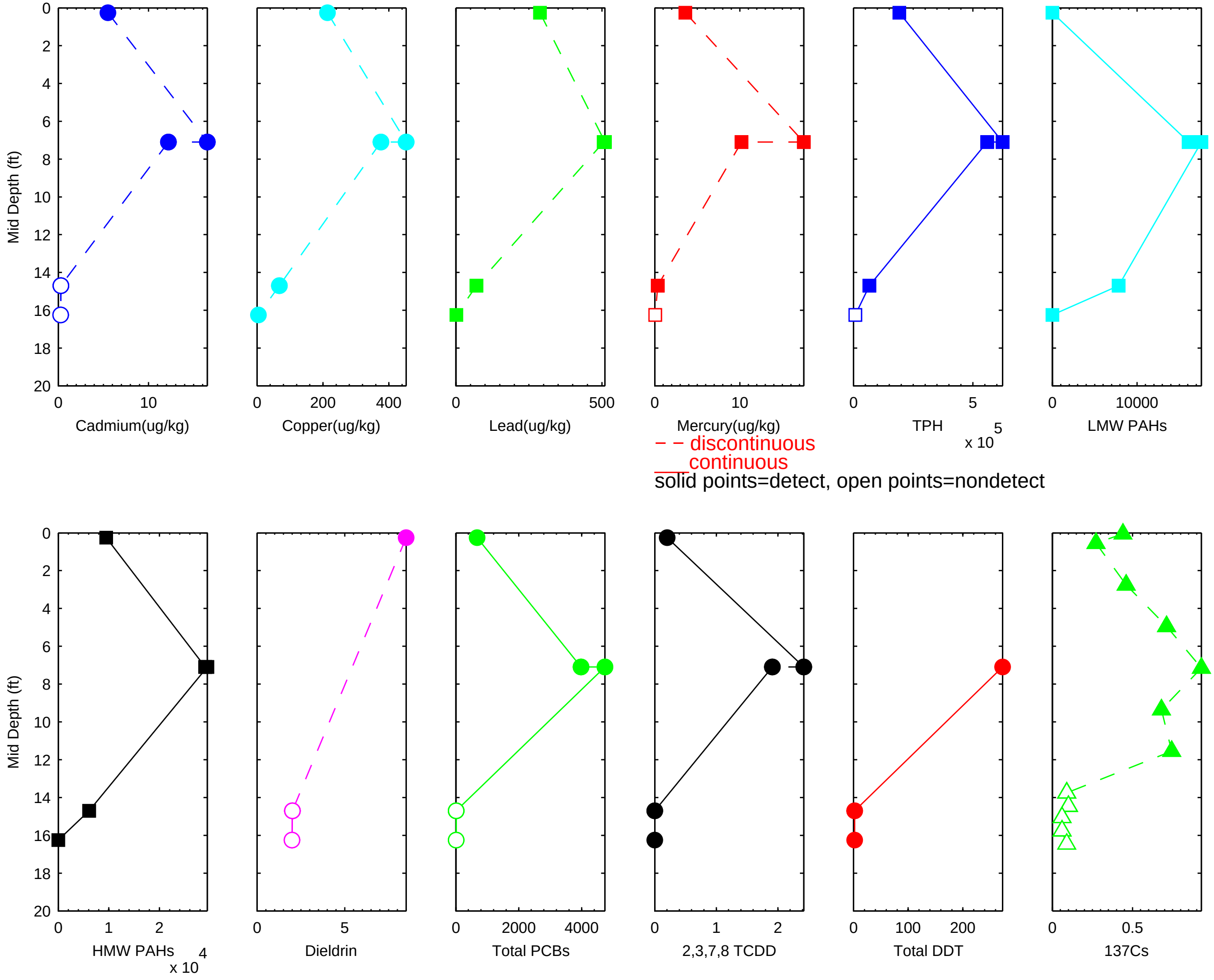

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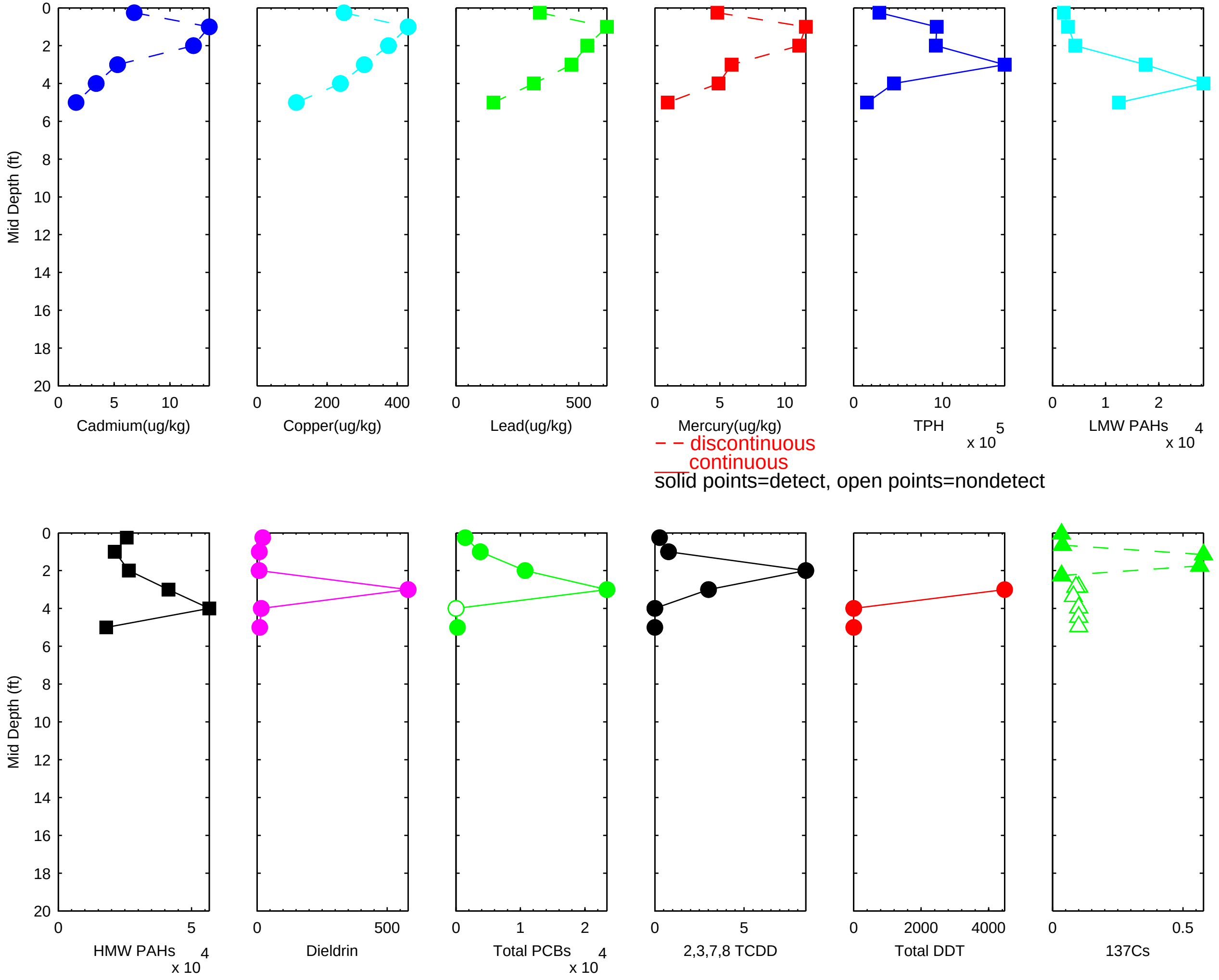

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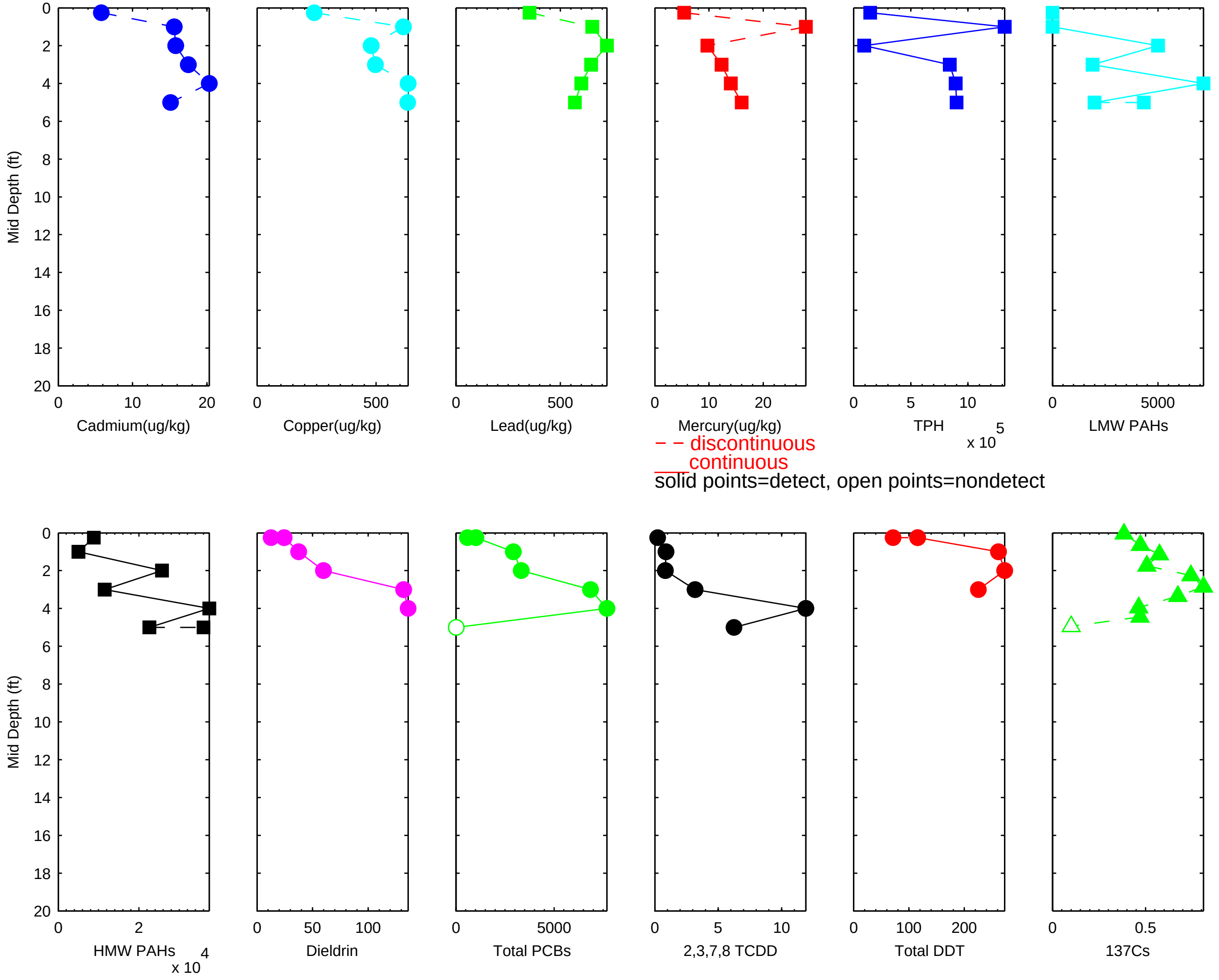

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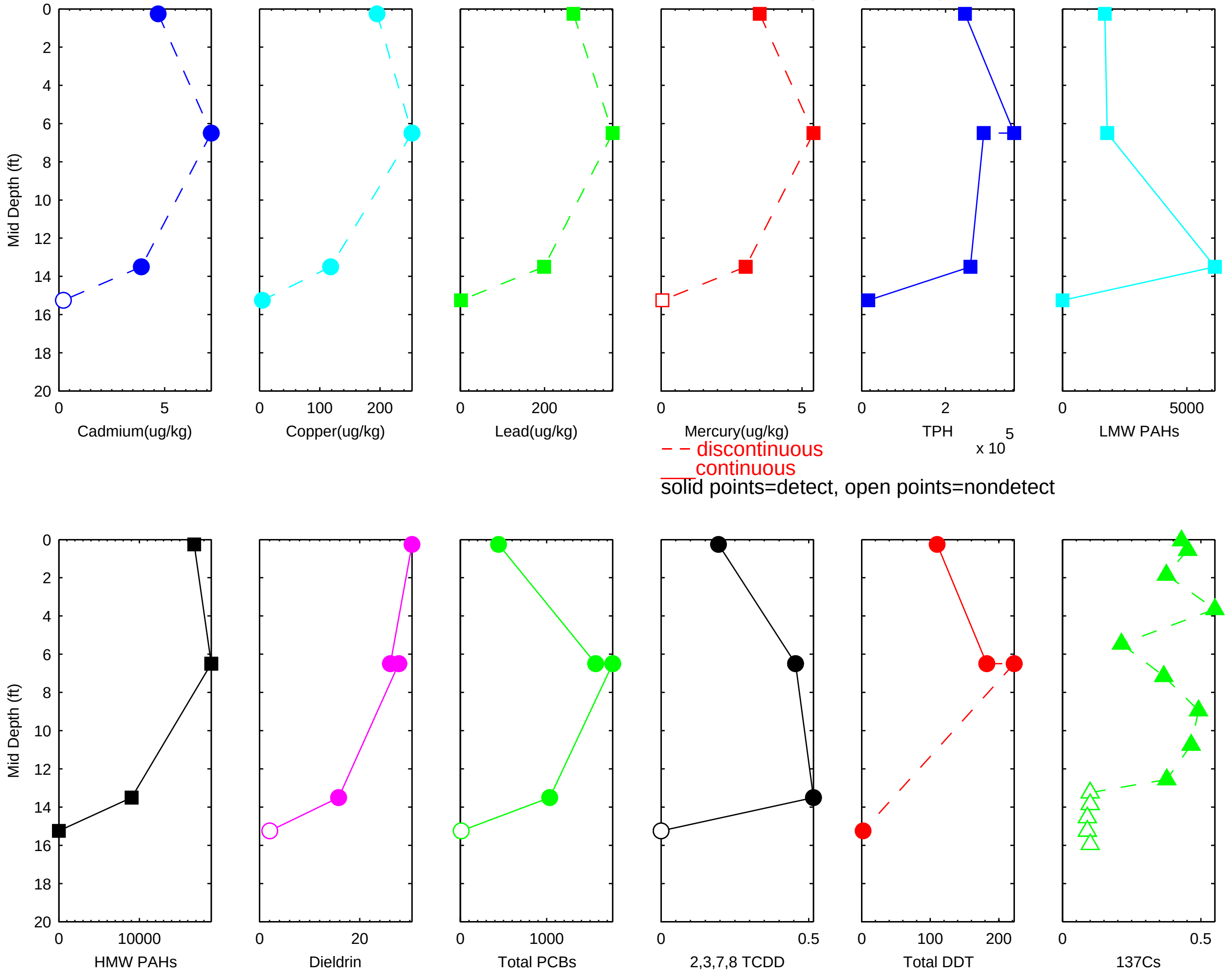

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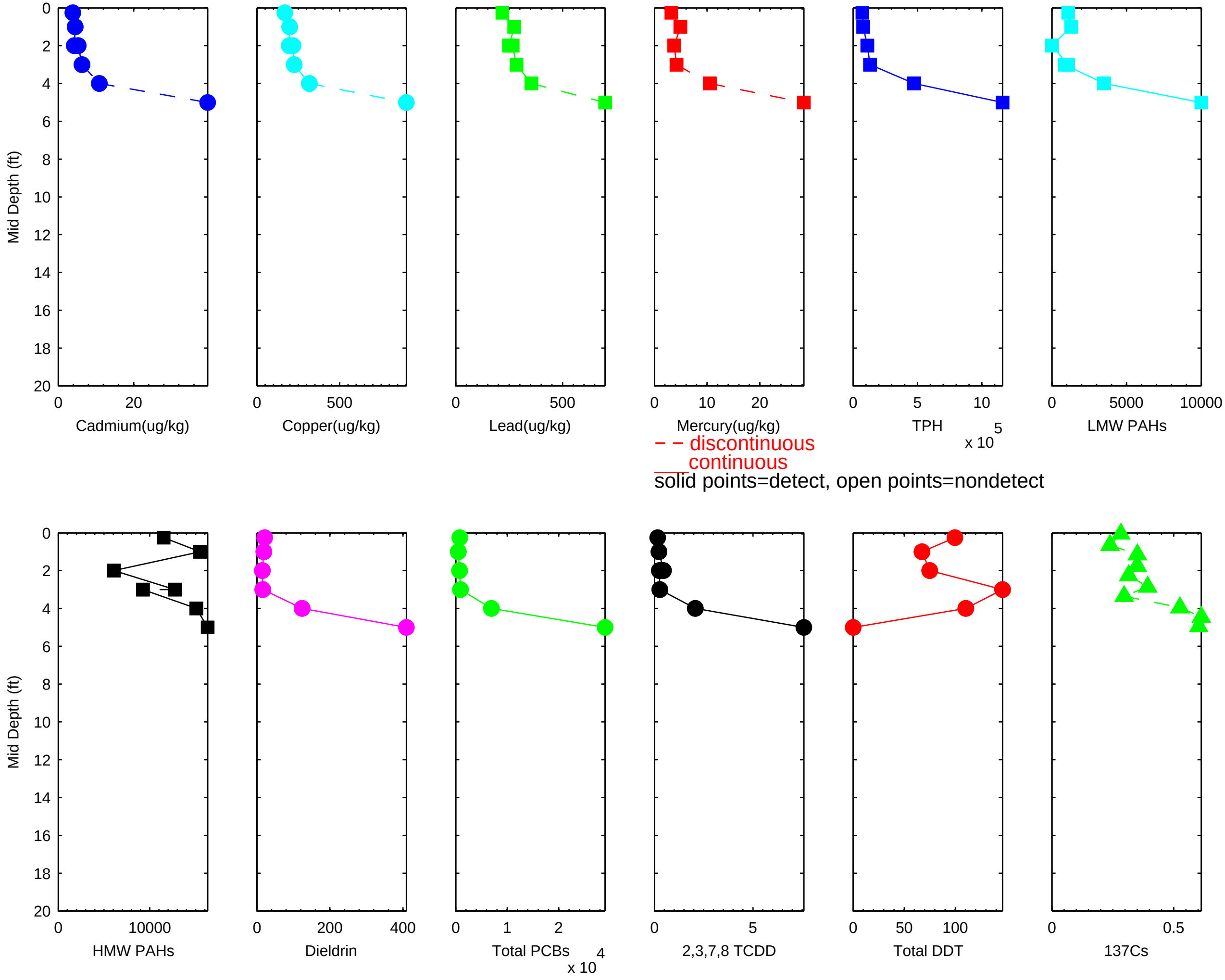

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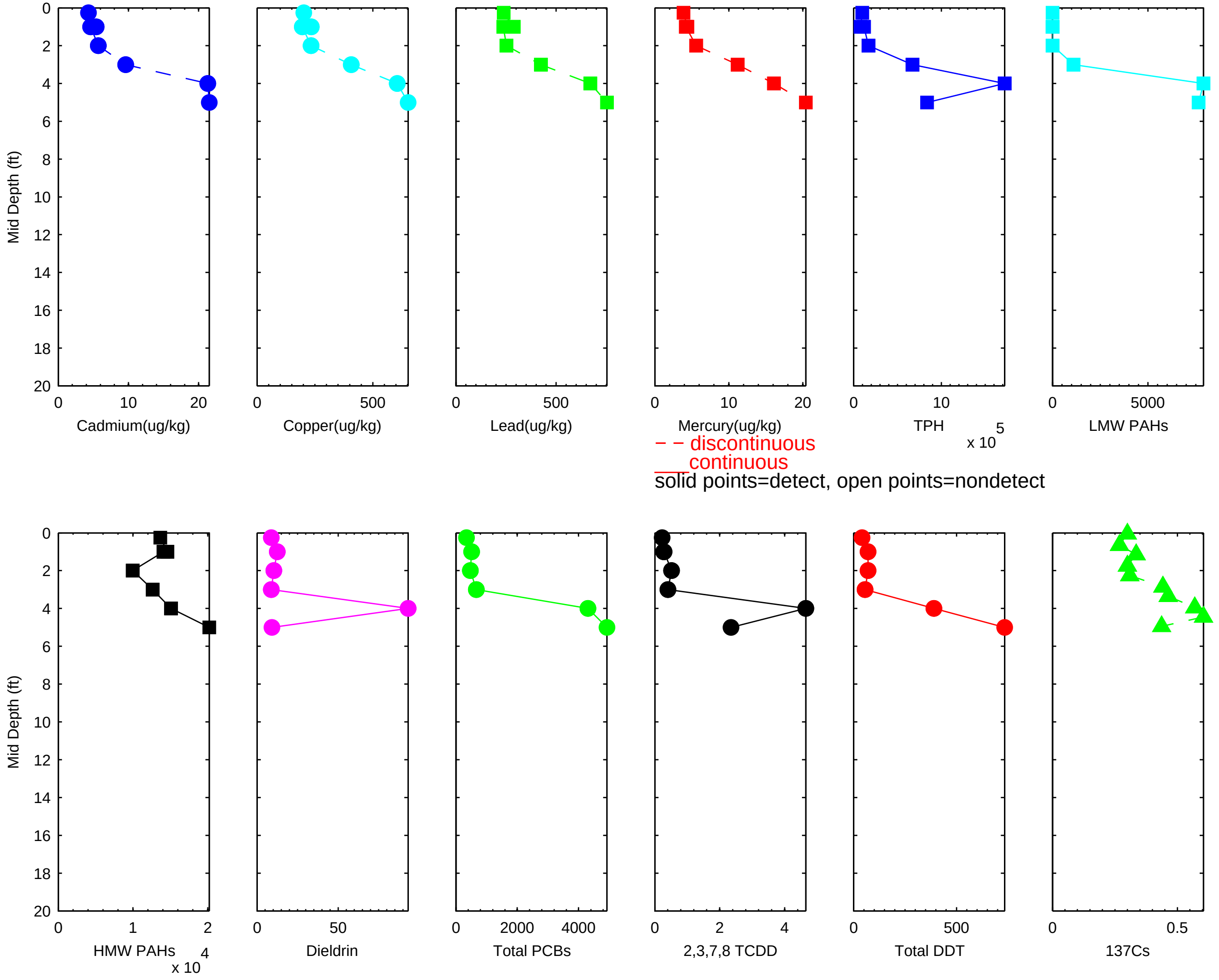

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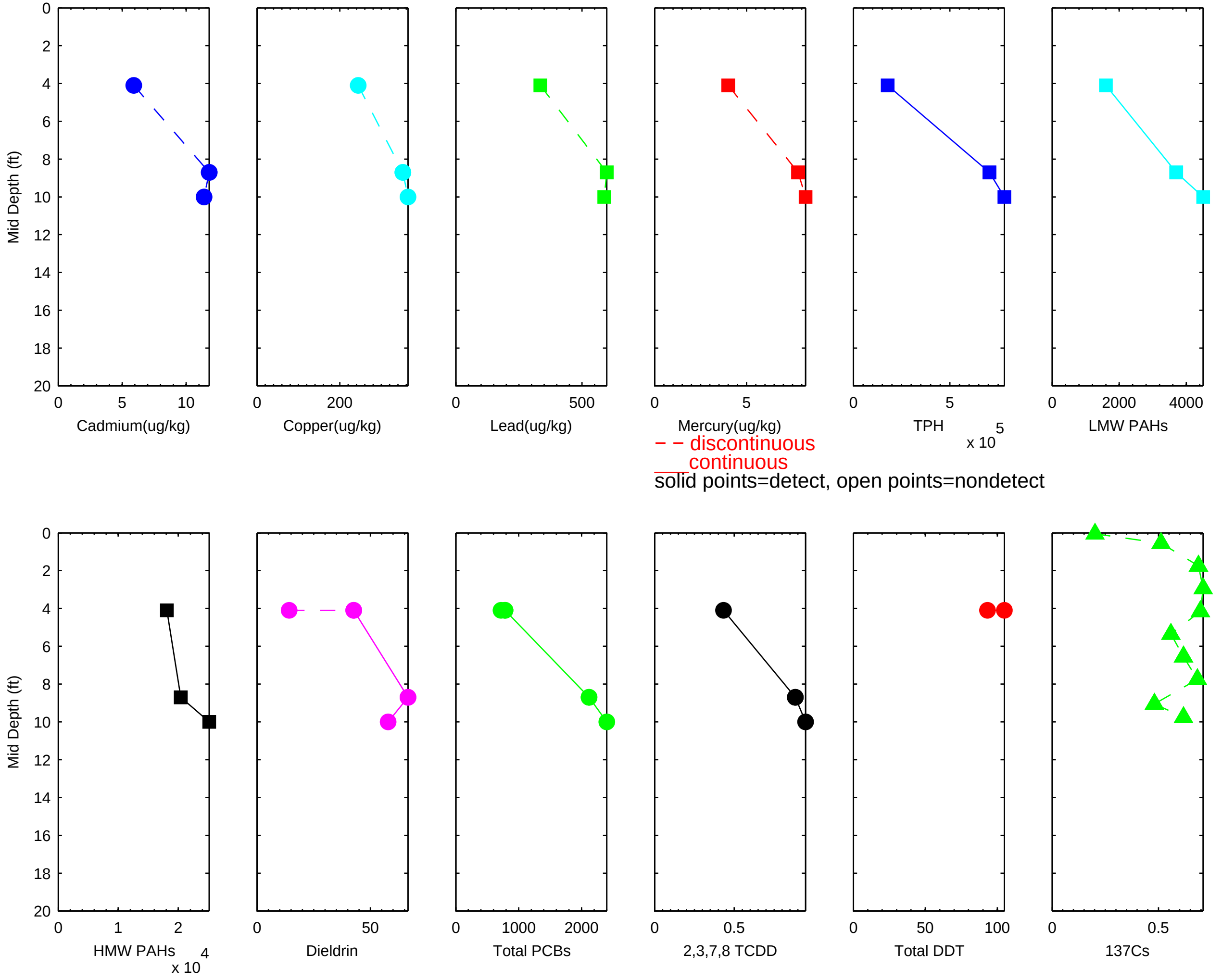

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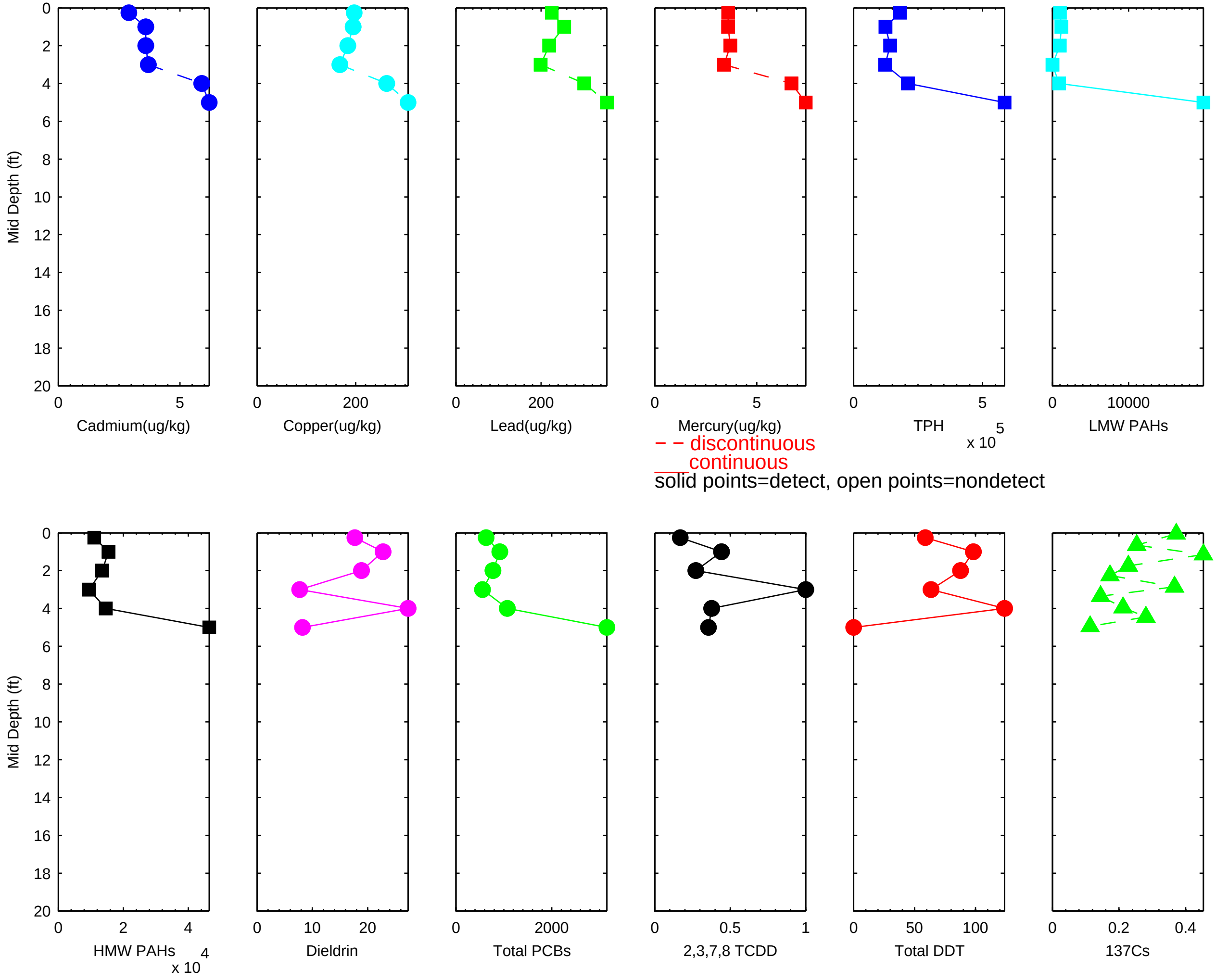
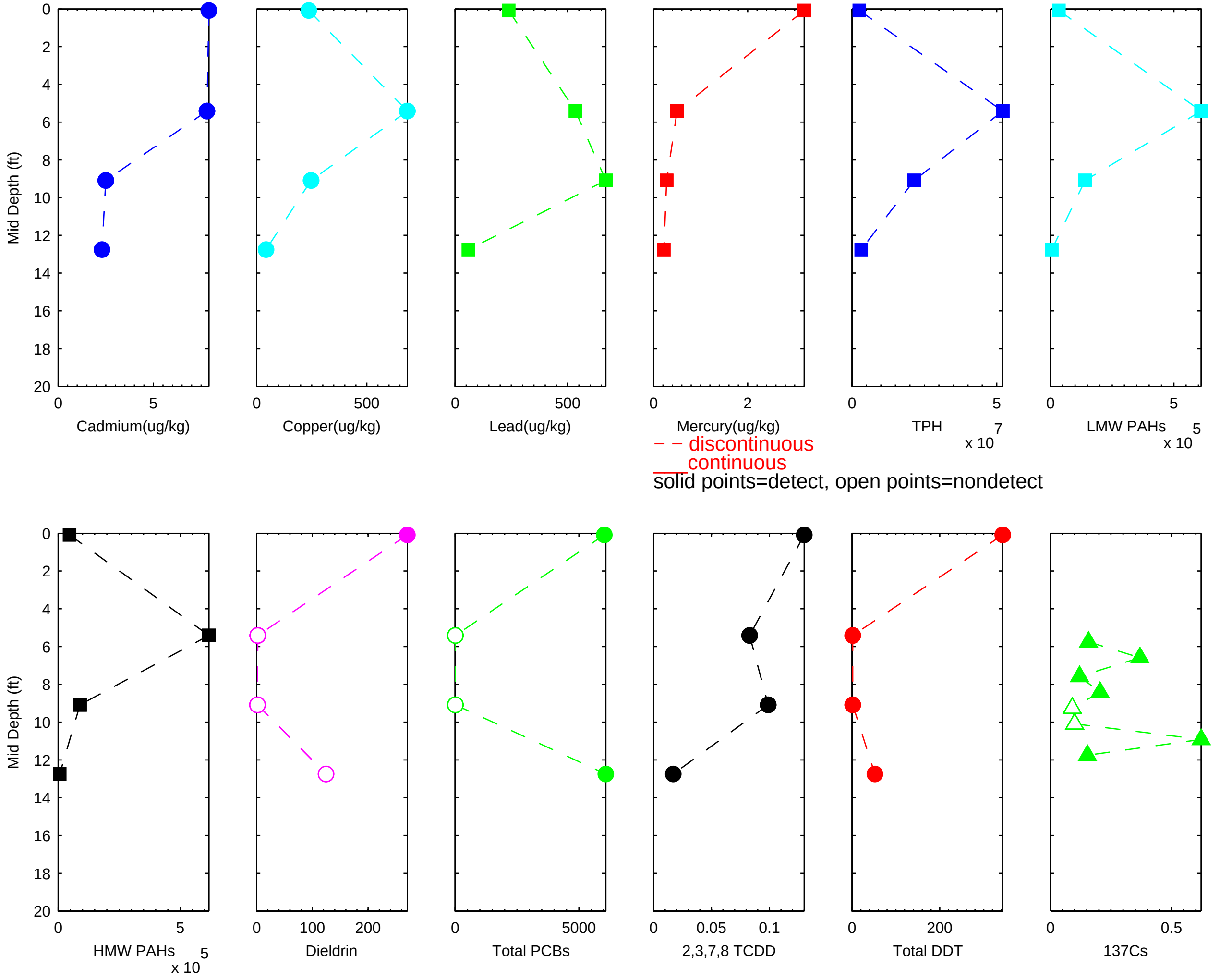
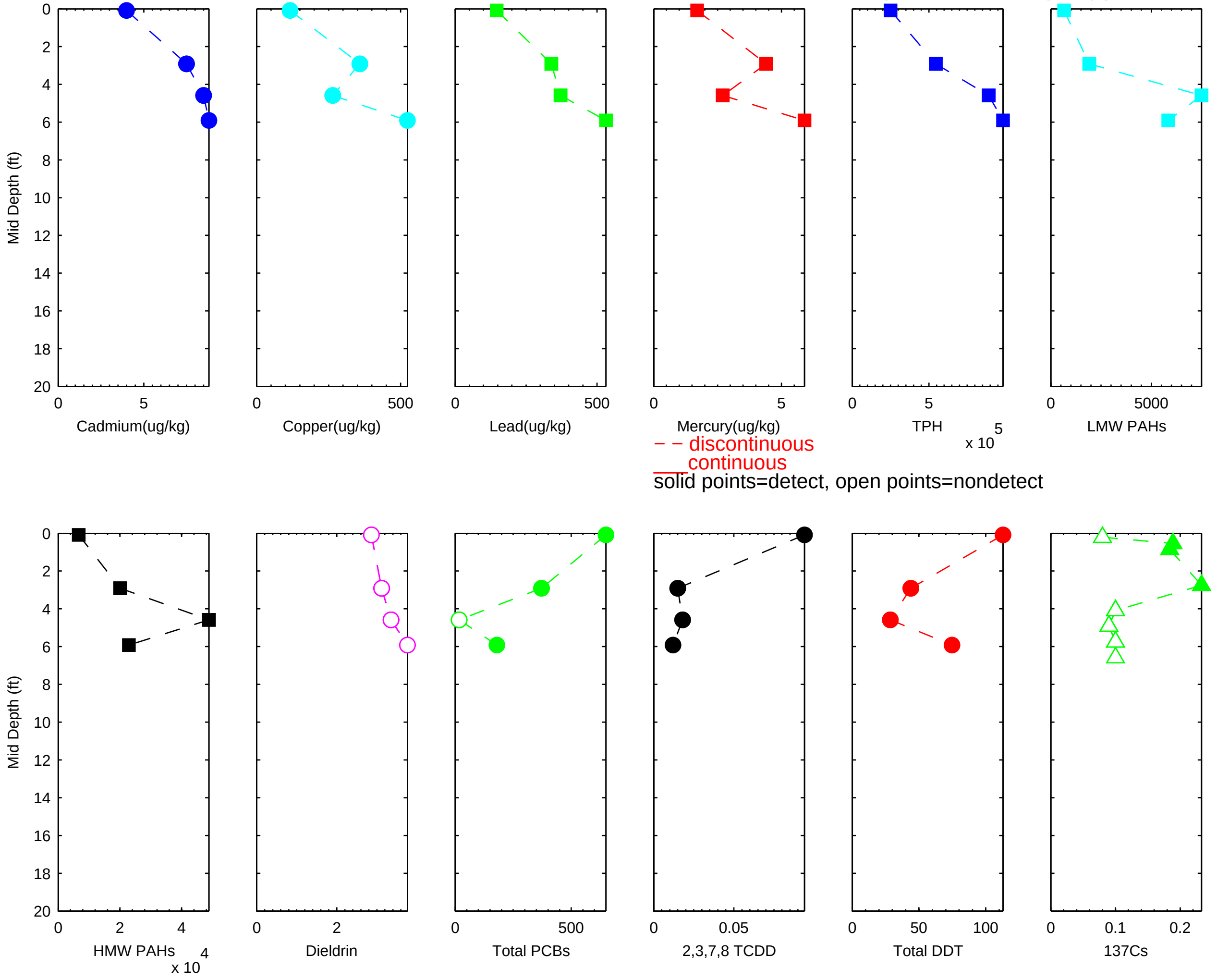


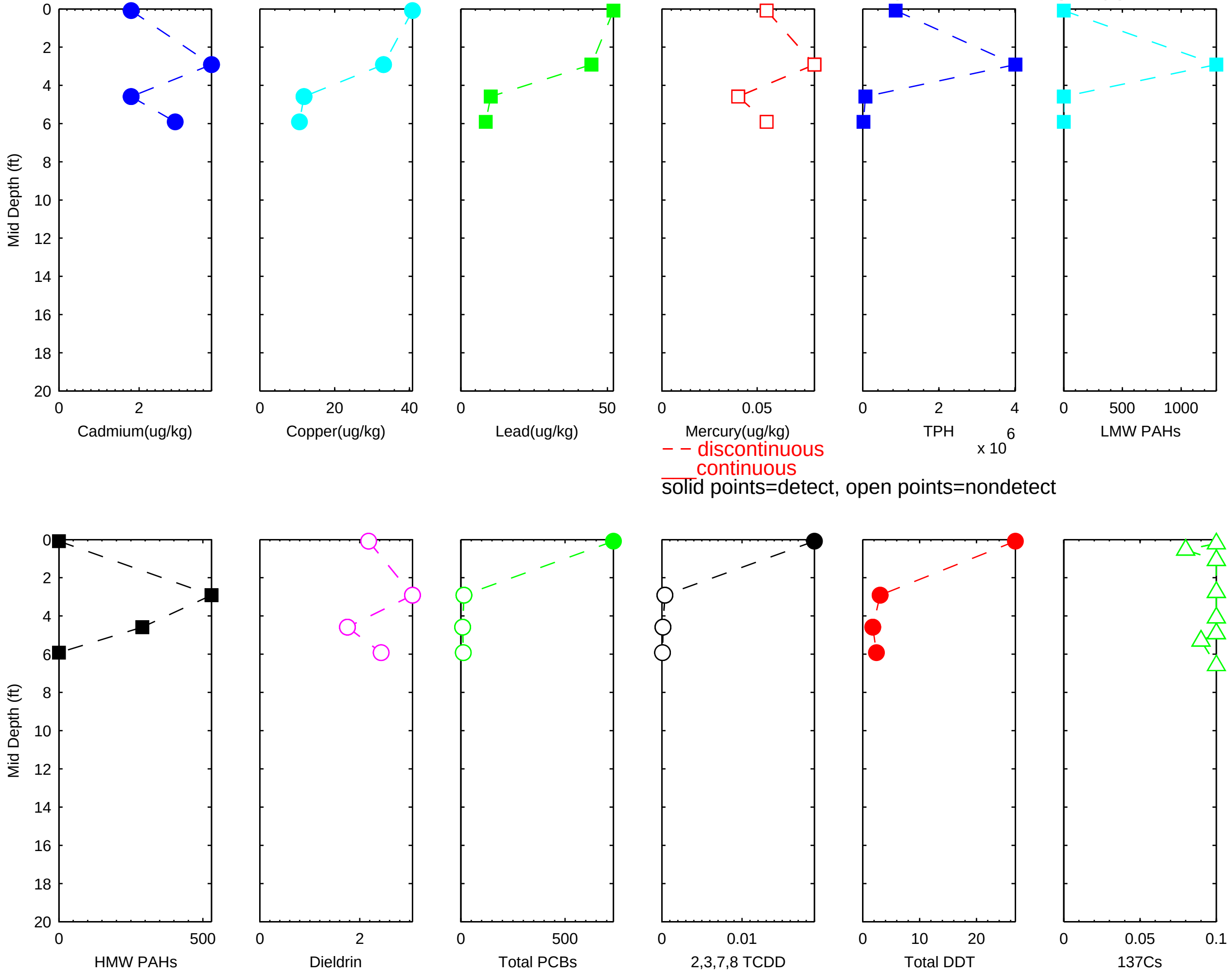
Sample ID: 100 River Mile 1.13PASSAIC 1993 Core Sediment Investigation − 02 (July)



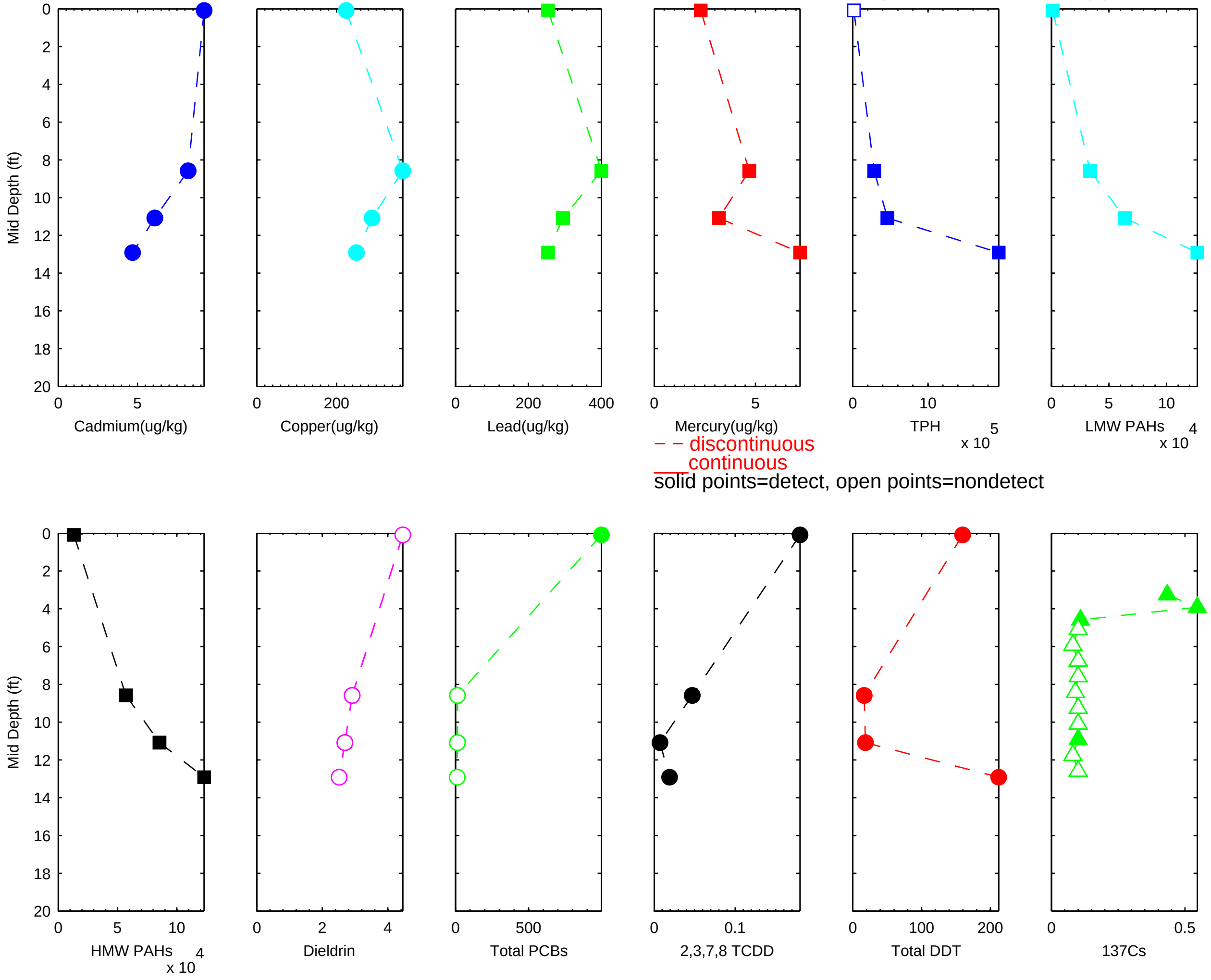
Sample ID: 99A River Mile 0.64PASSAIC 1993 Core Sediment Investigation − 02 (July)



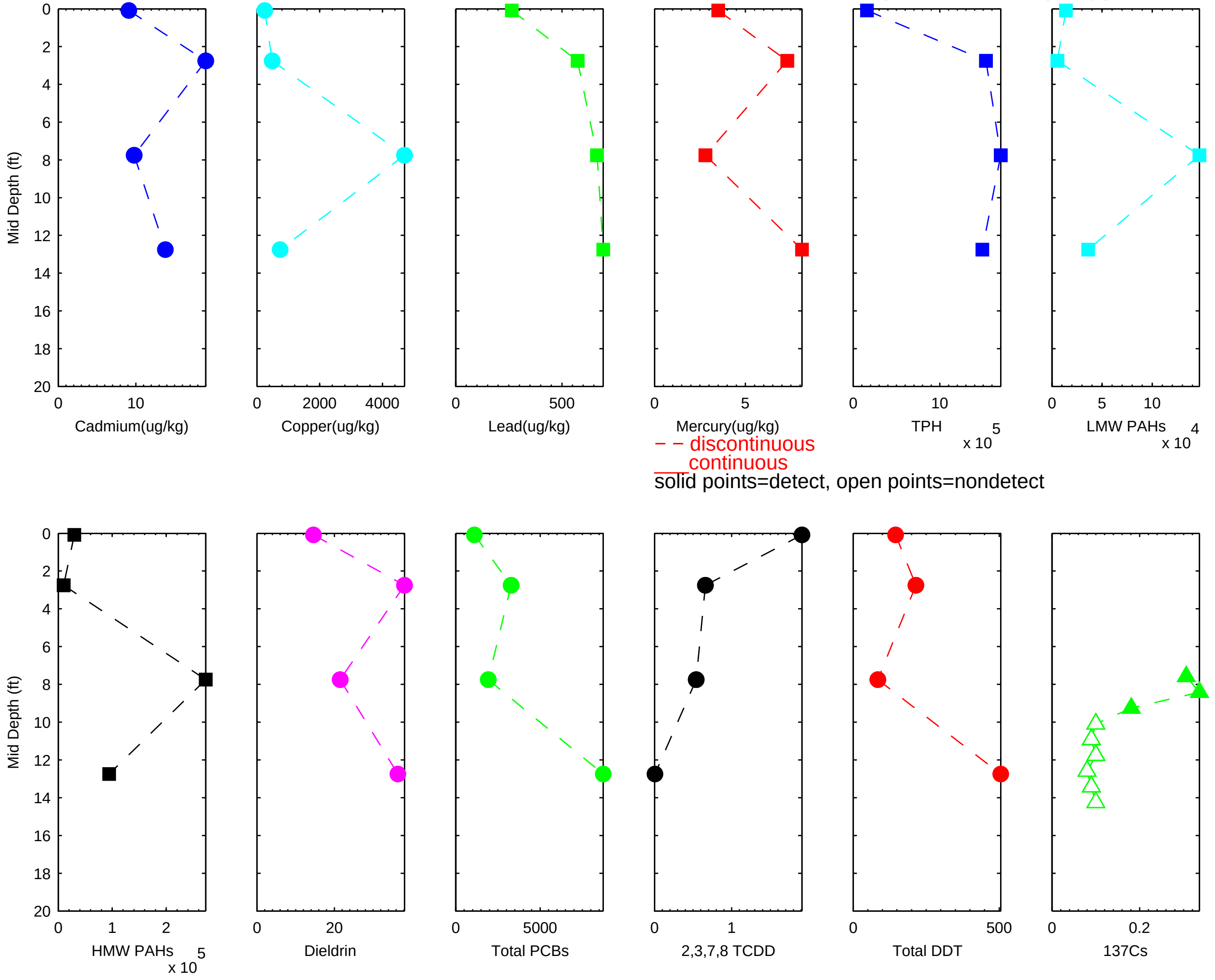
Sample ID: 98A River Mile 0.54PASSAIC 1993 Core Sediment Investigation − 02 (July)



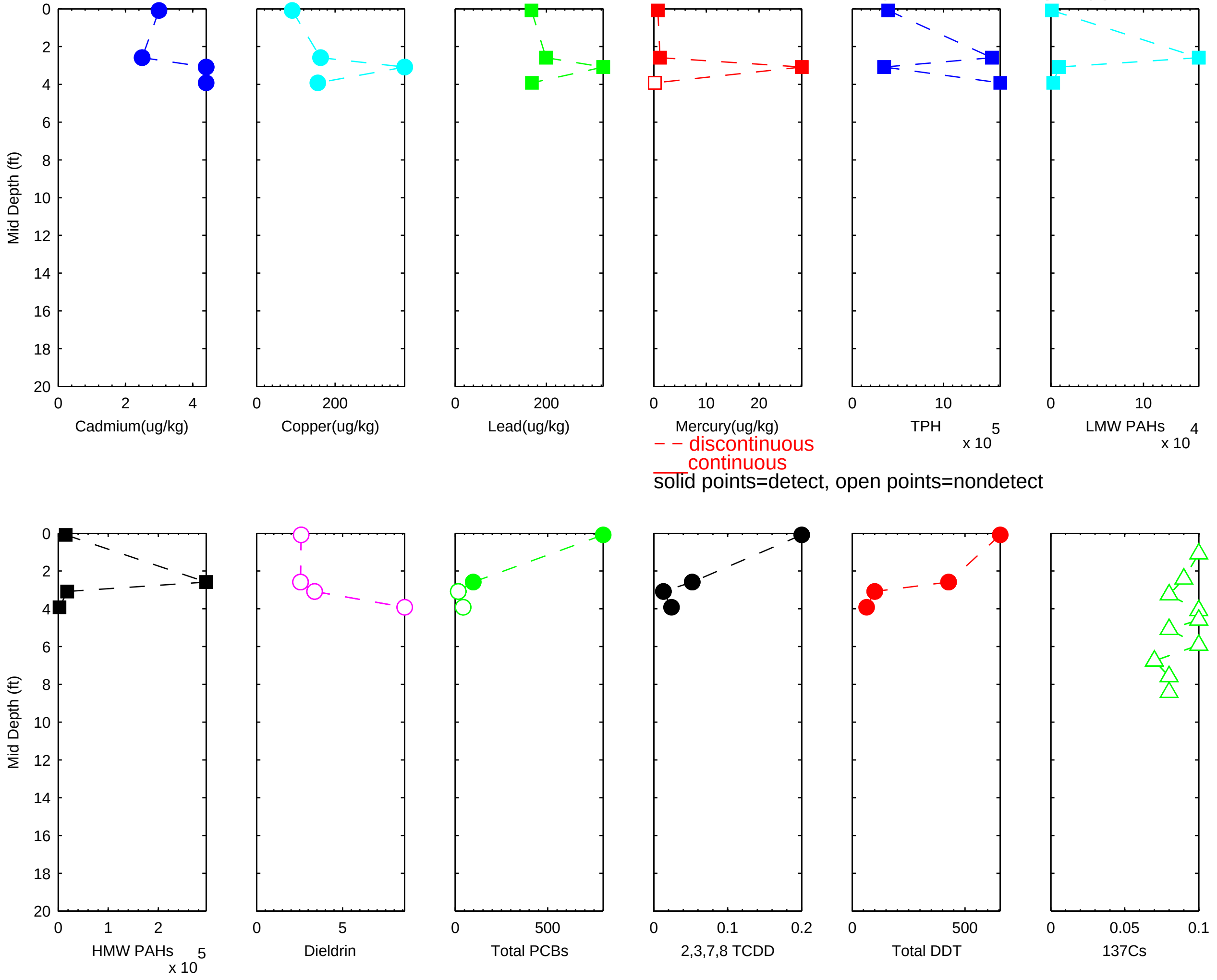
Sample ID: 97B River Mile 1.51PASSAIC 1993 Core Sediment Investigation − 02 (July)



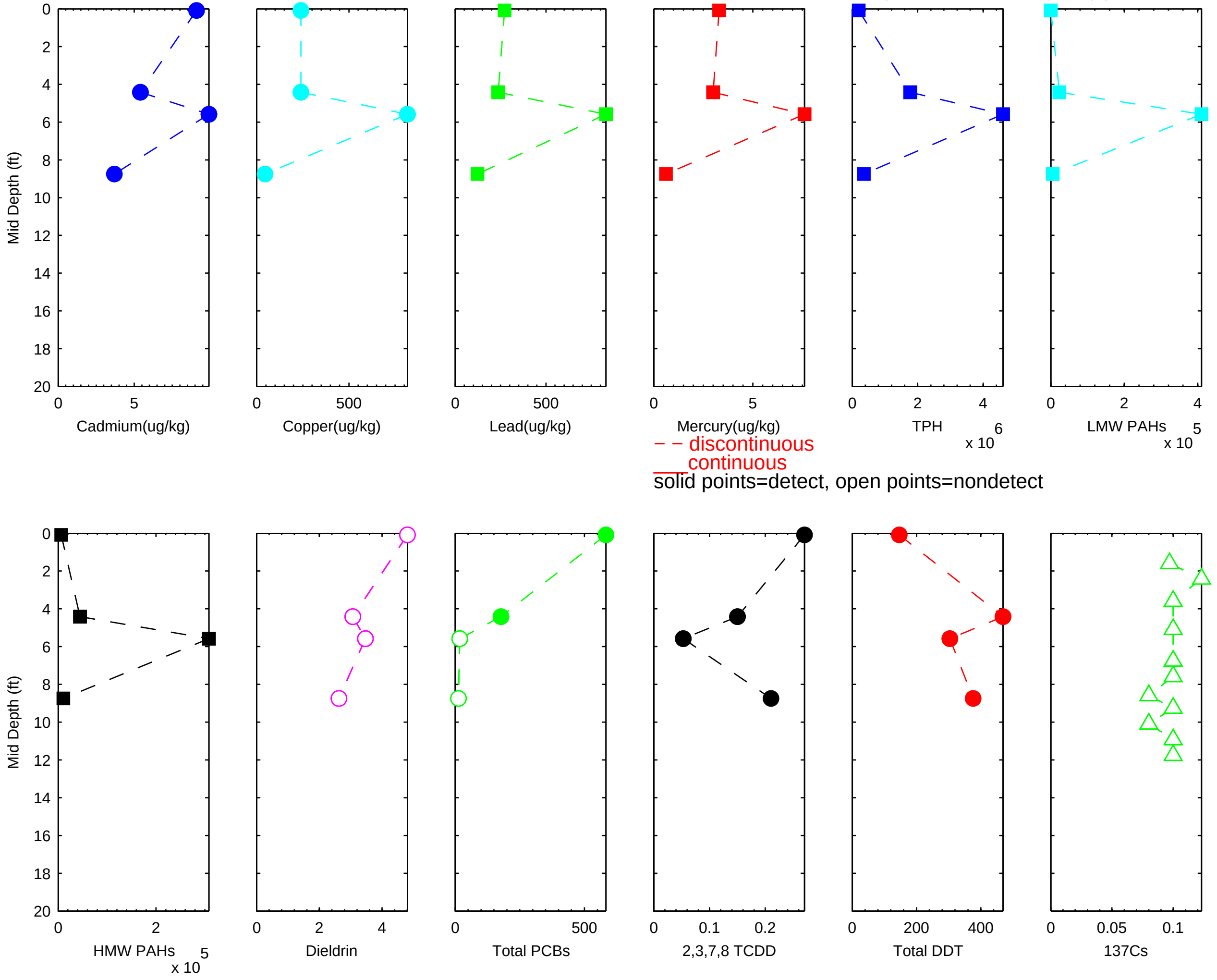
Sample ID: 96A River Mile 1.1 PASSAIC 1993 Core Sediment Investigation − 02 (July)



Sample ID: 95A River Mile 2.3 PASSAIC 1993 Core Sediment Investigation − 02 (July)



Sample ID: 94A River Mile 2.91PASSAIC 1993 Core Sediment Investigation − 02 (July)



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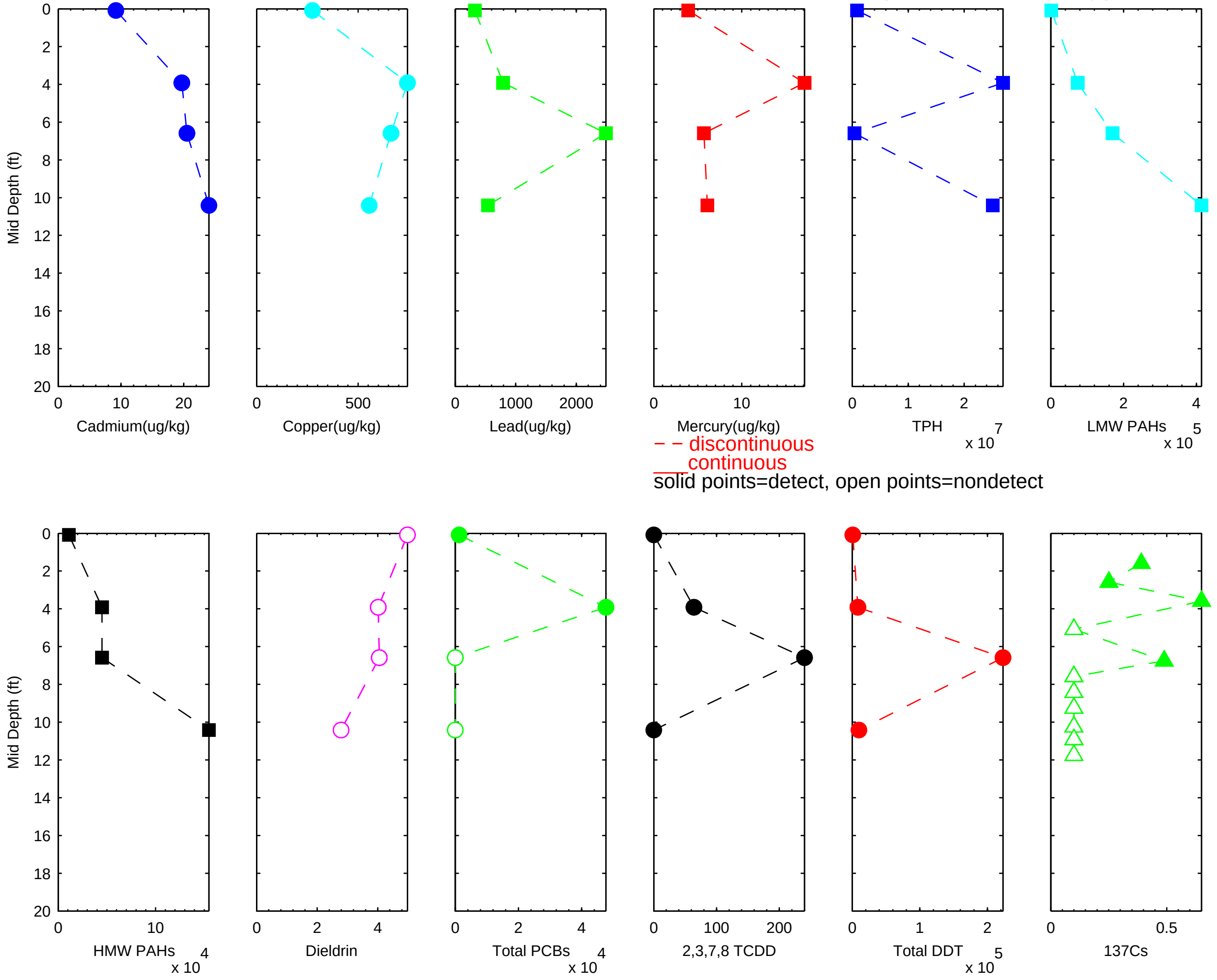
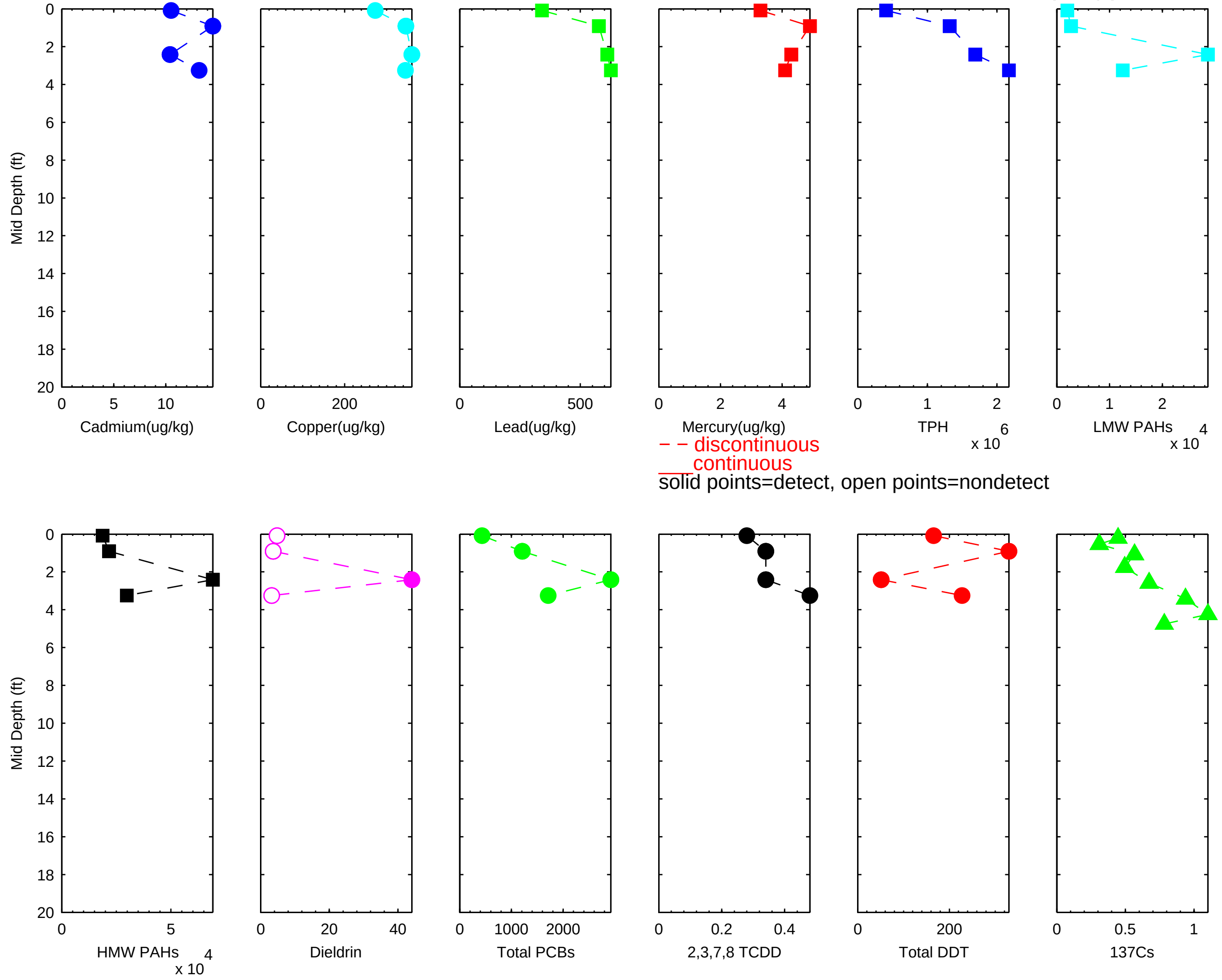


Sample ID: 92A River Mile 1.66PASSAIC 1993 Core Sediment Investigation − 02 (July)



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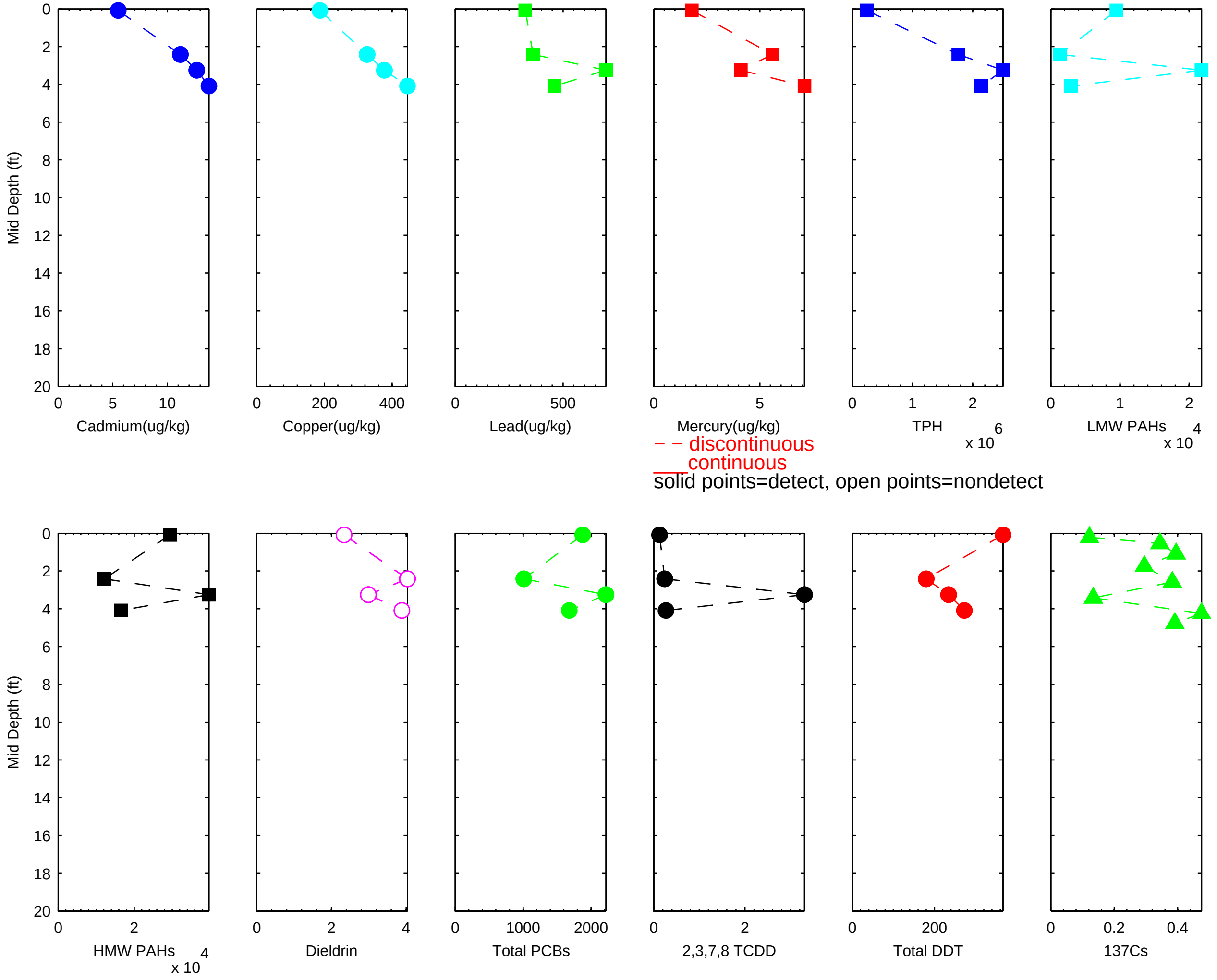

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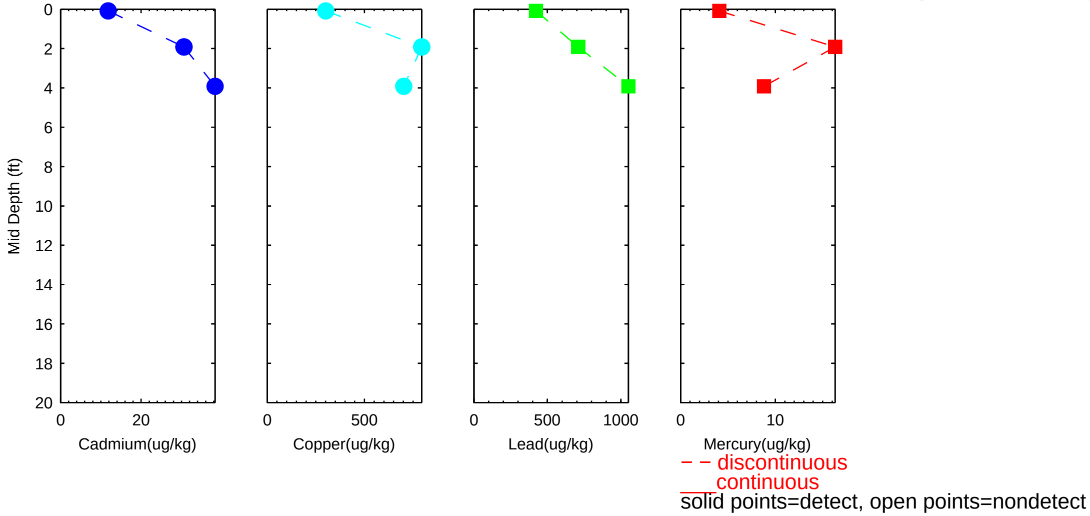
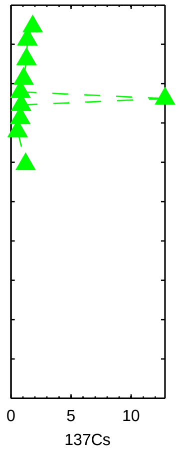
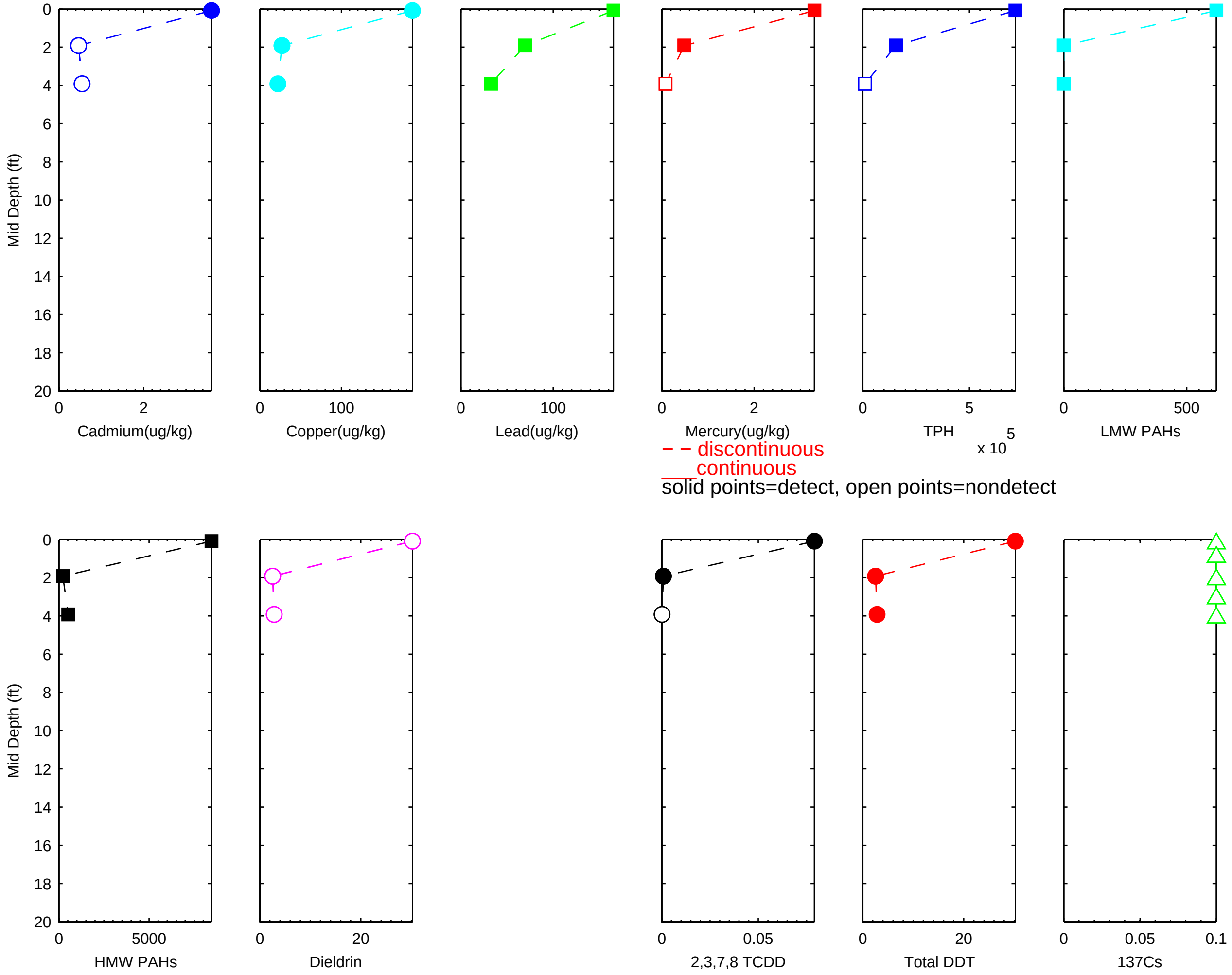
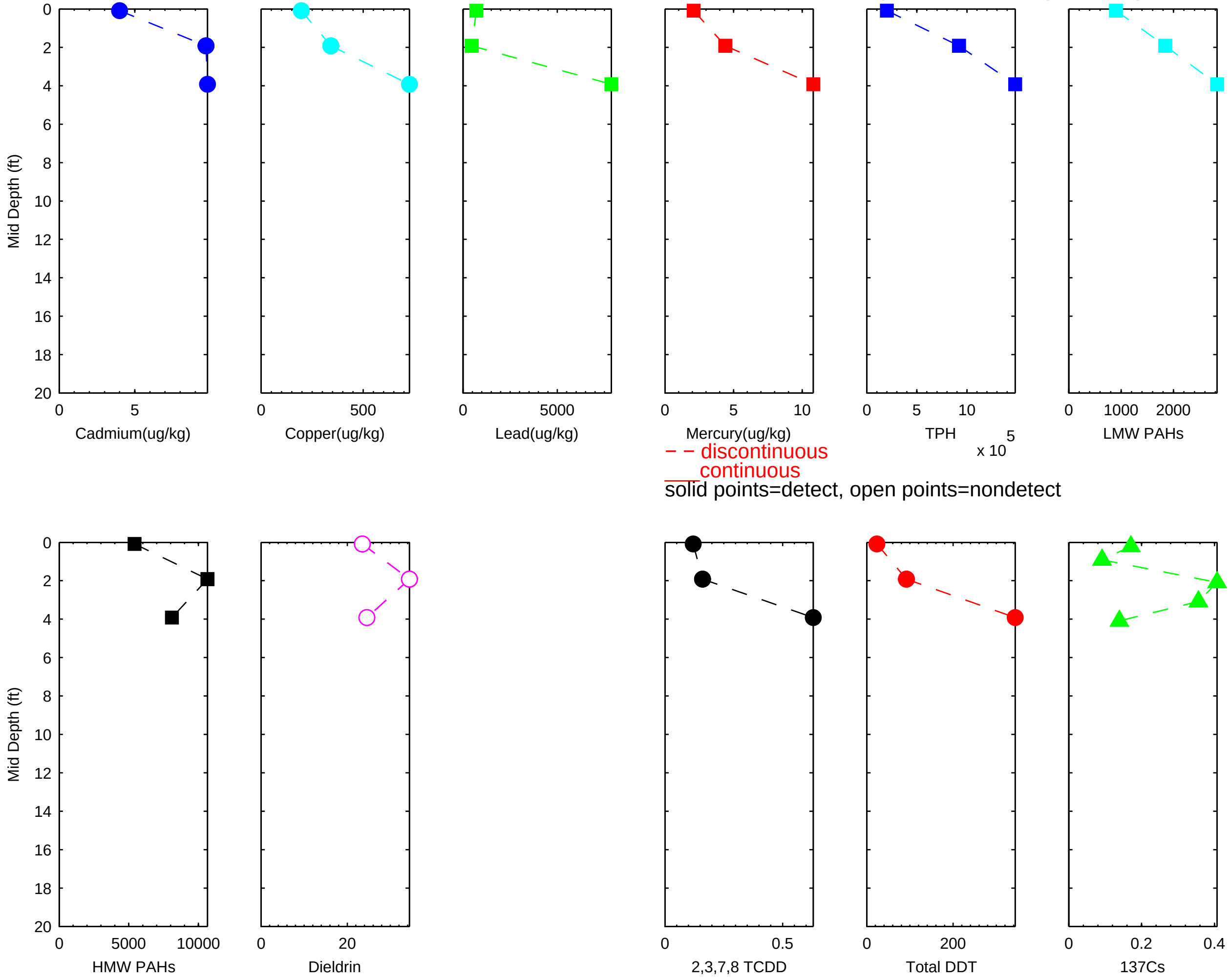




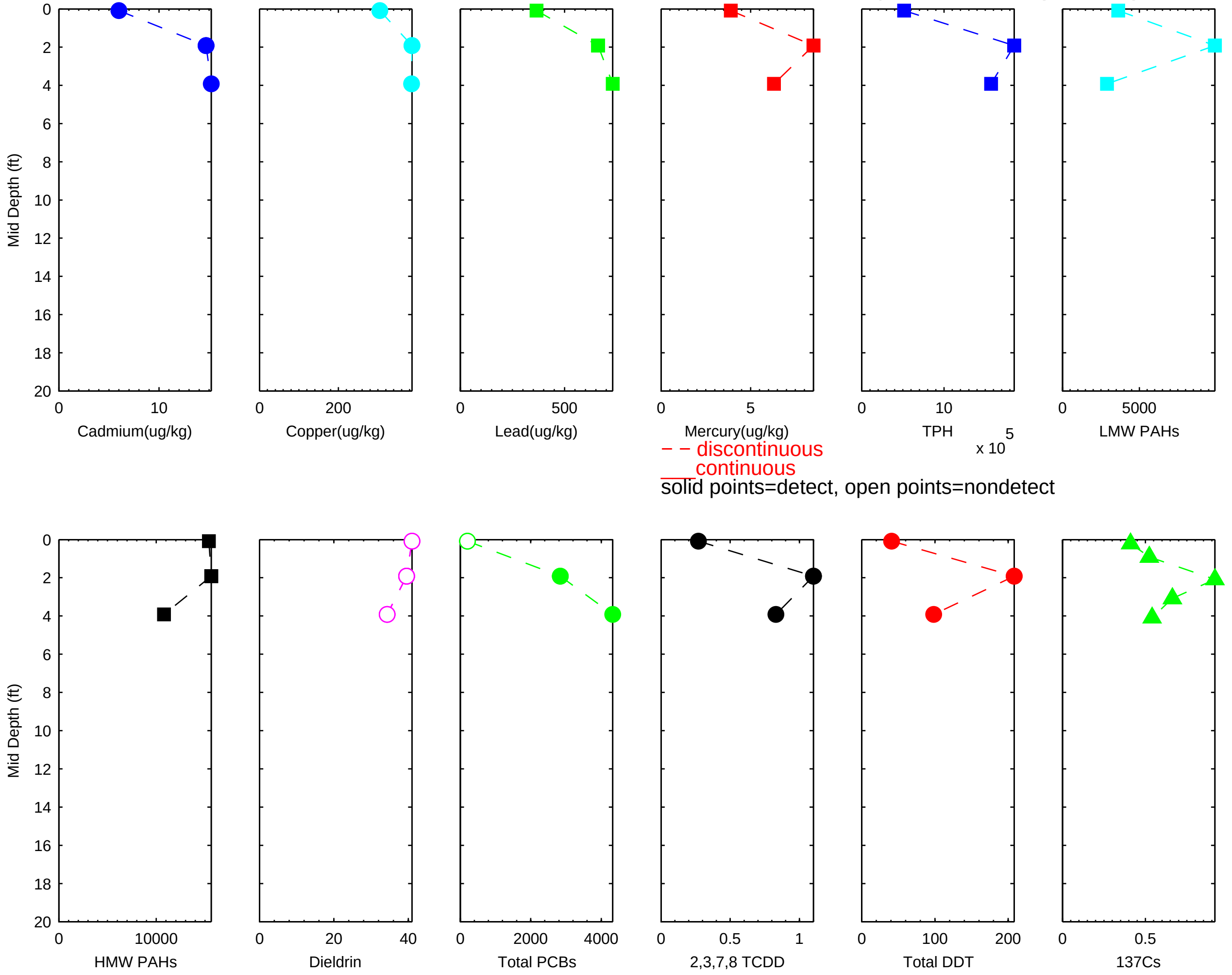
Sample ID: 82A River Mile 0.34 PASSAIC 1993 Core Sediment Investigation − 01 (March)



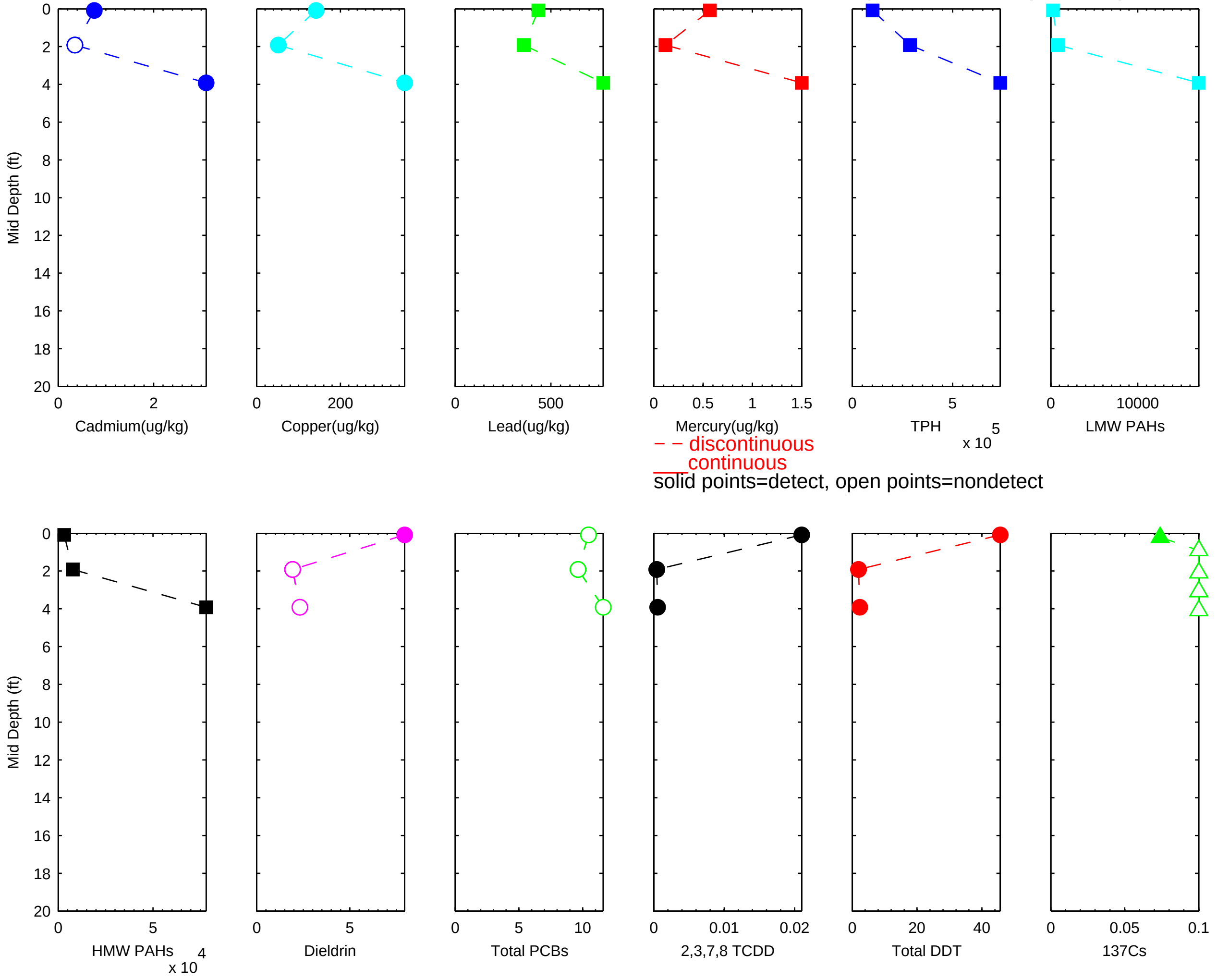
Sample ID: 81A River Mile 0.31 PASSAIC 1993 Core Sediment Investigation − 01 (March)



Sample ID: 77A River Mile 2.14 PASSAIC 1993 Core Sediment Investigation − 01 (March)



Sample ID: 76A River Mile 6.92 PASSAIC 1993 Core Sediment Investigation − 01 (March)



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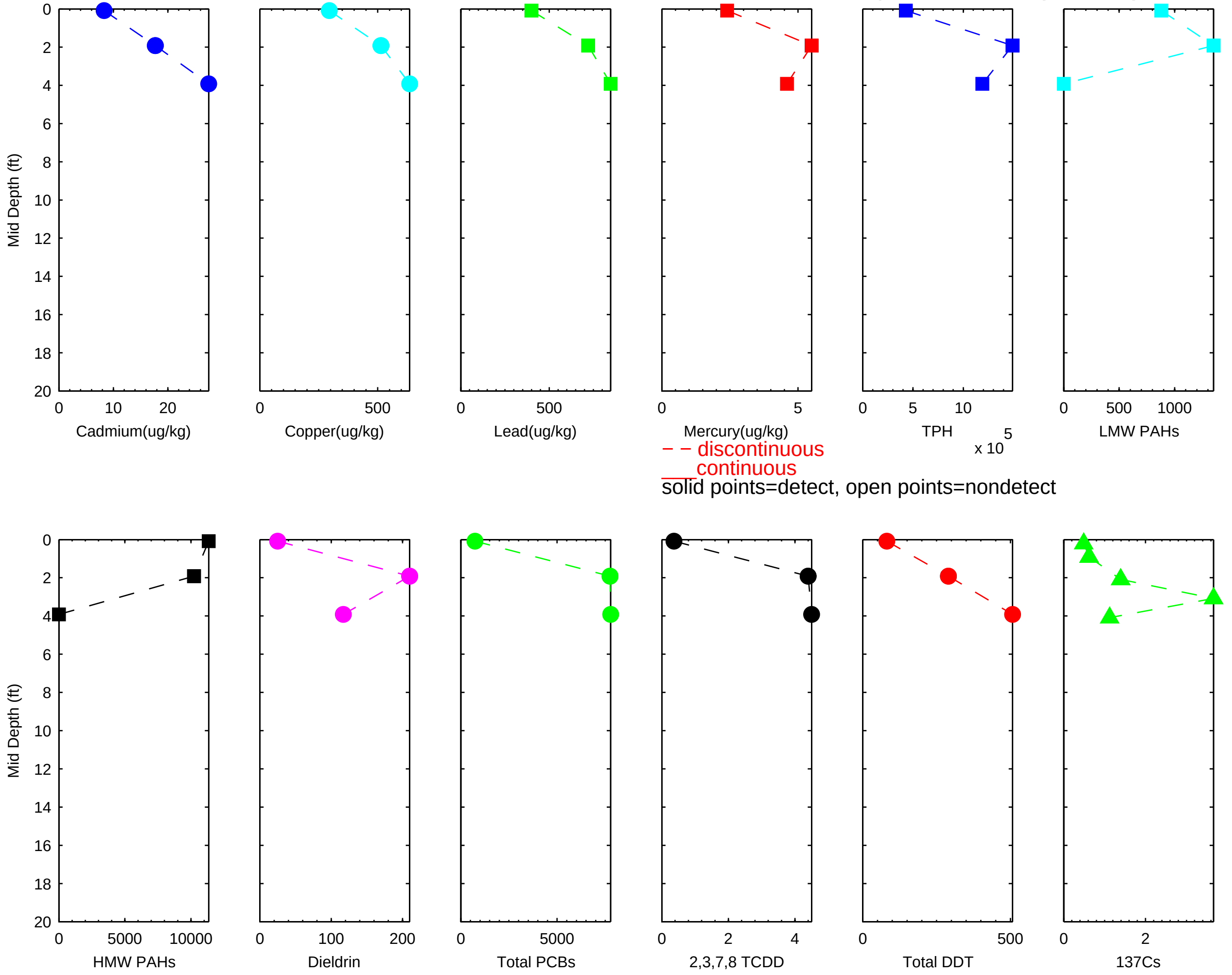
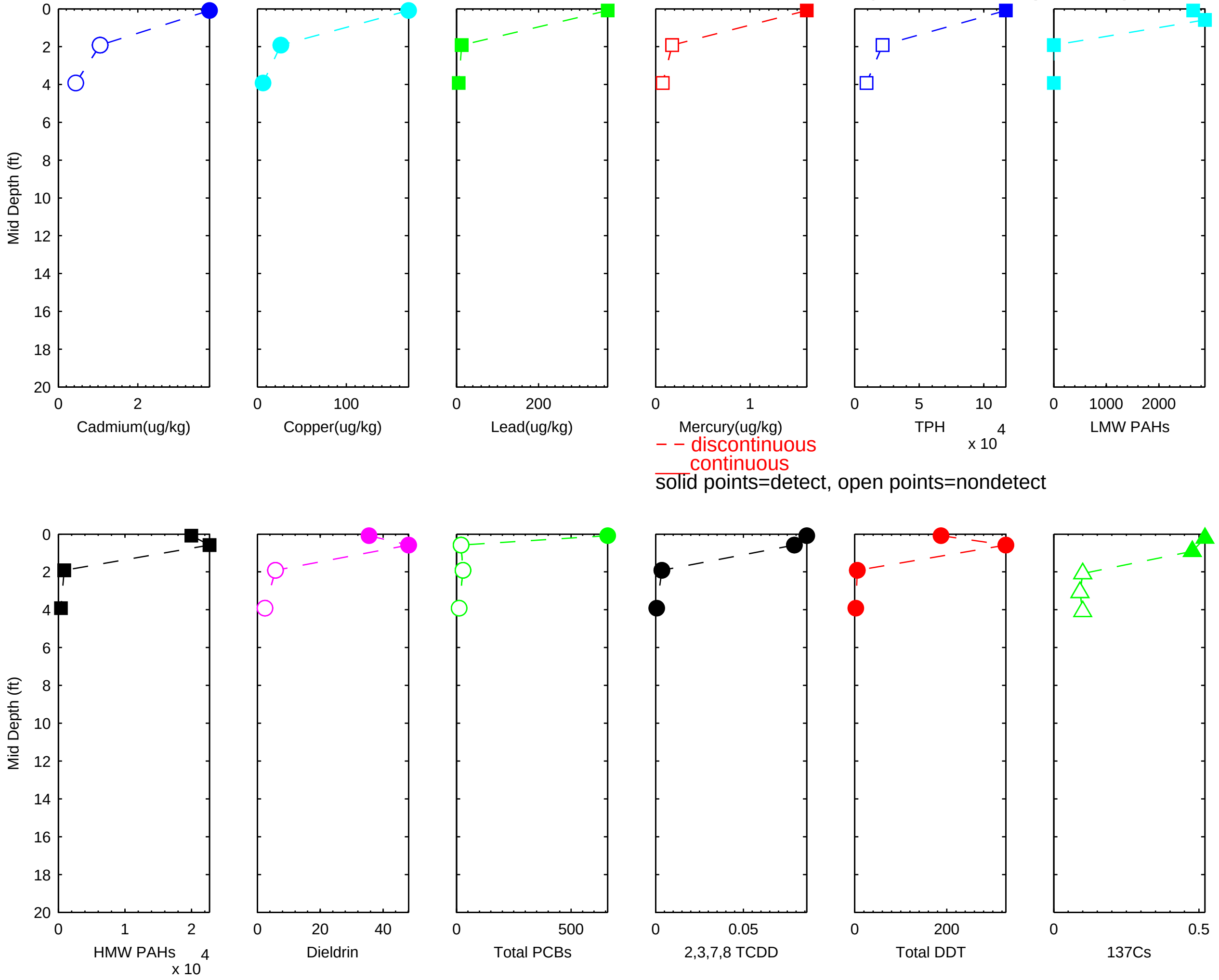
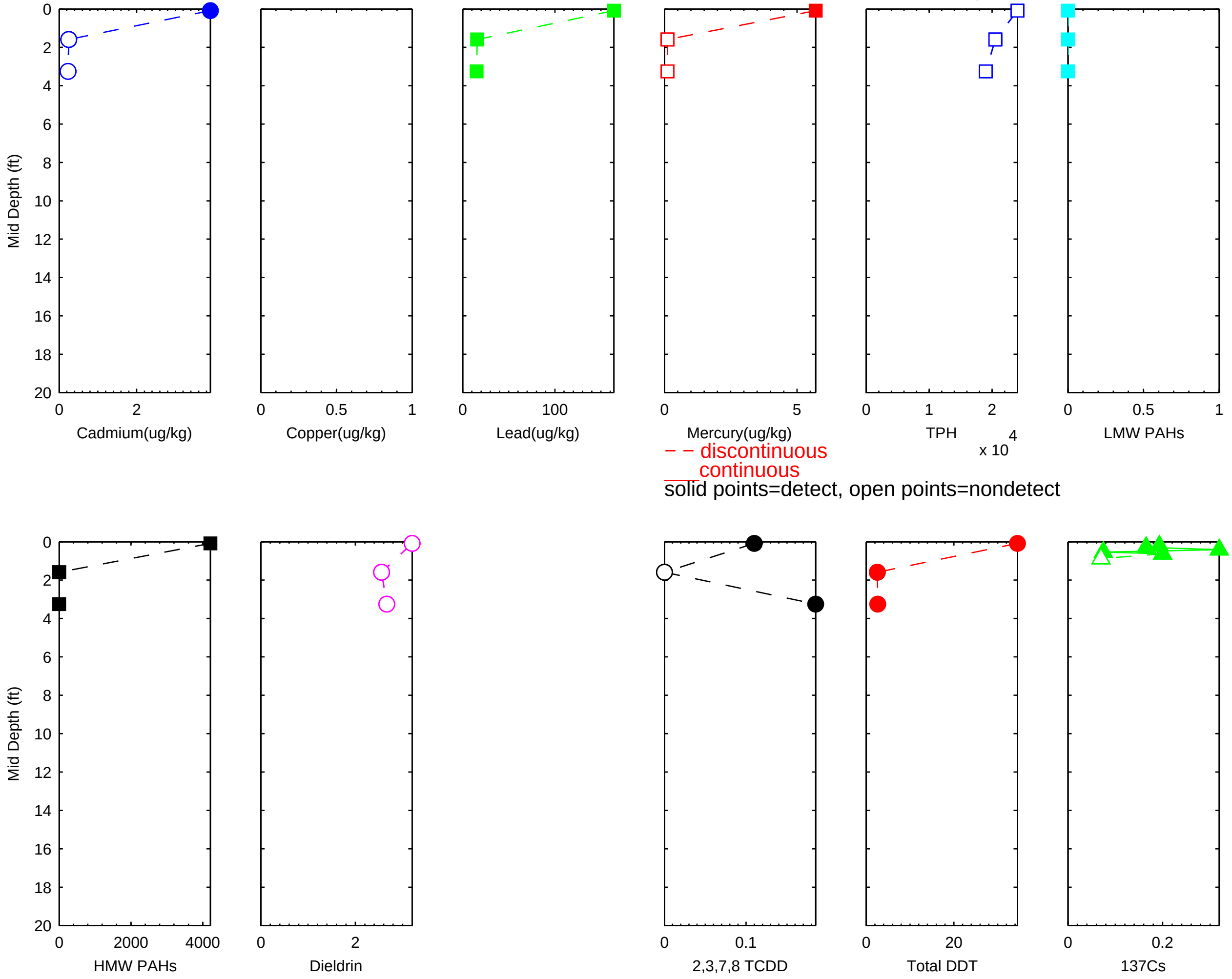


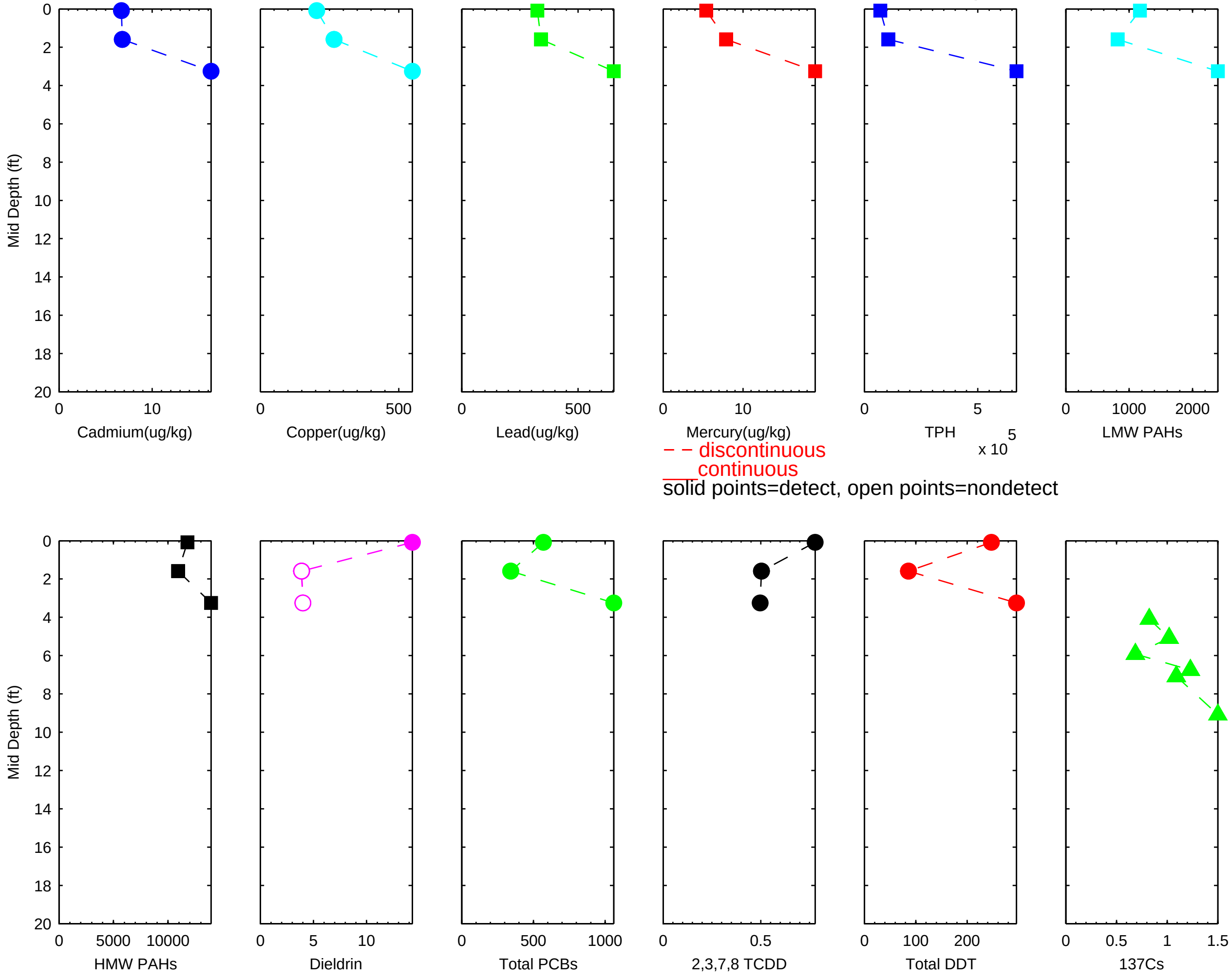
Sample ID: 74A River Mile 11.16 PASSAIC 1993 Core Sediment Investigation − 01 (March)



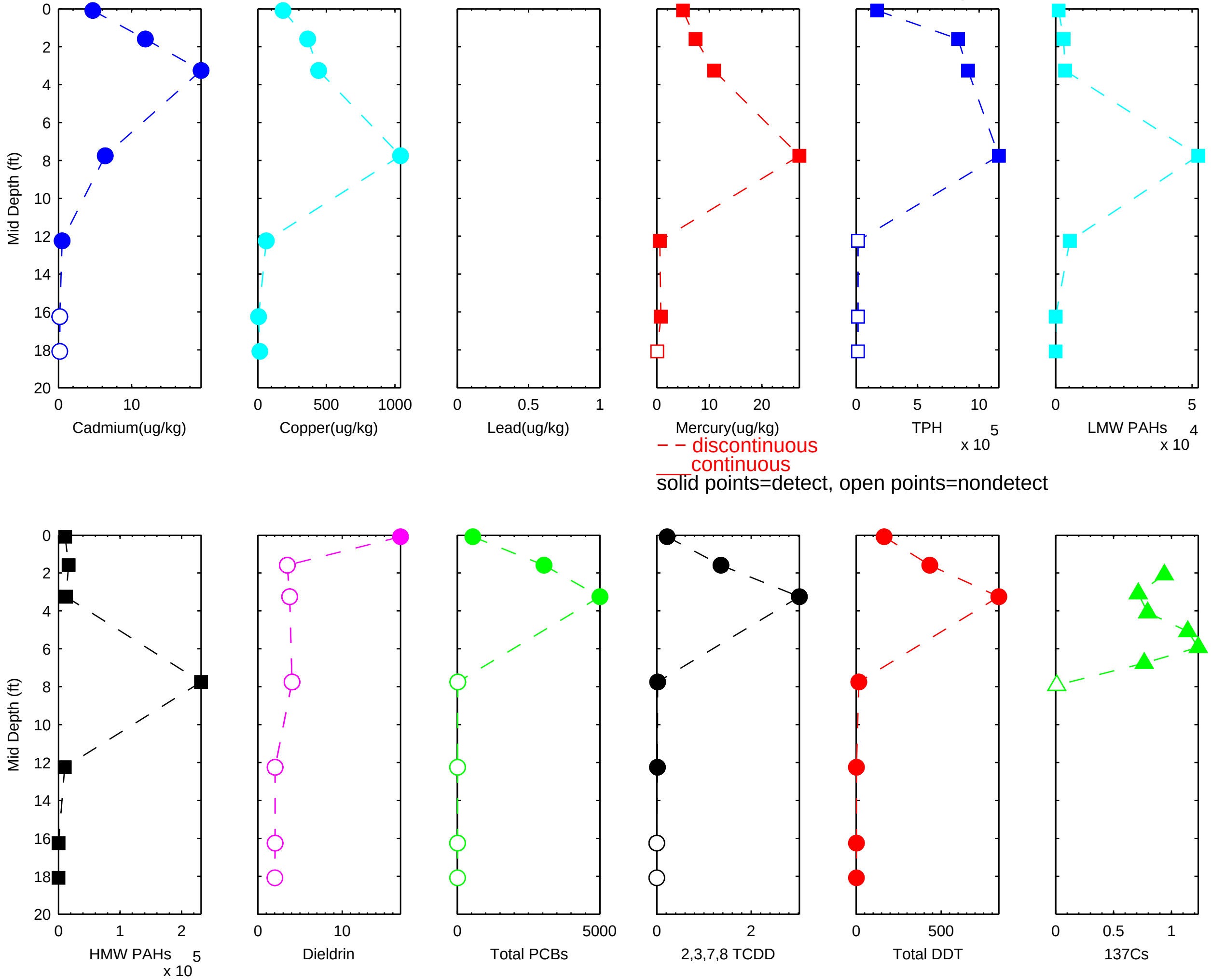
Sample ID: 26A River Mile 0.21 PASSAIC 1991 Core Sediment Investigation



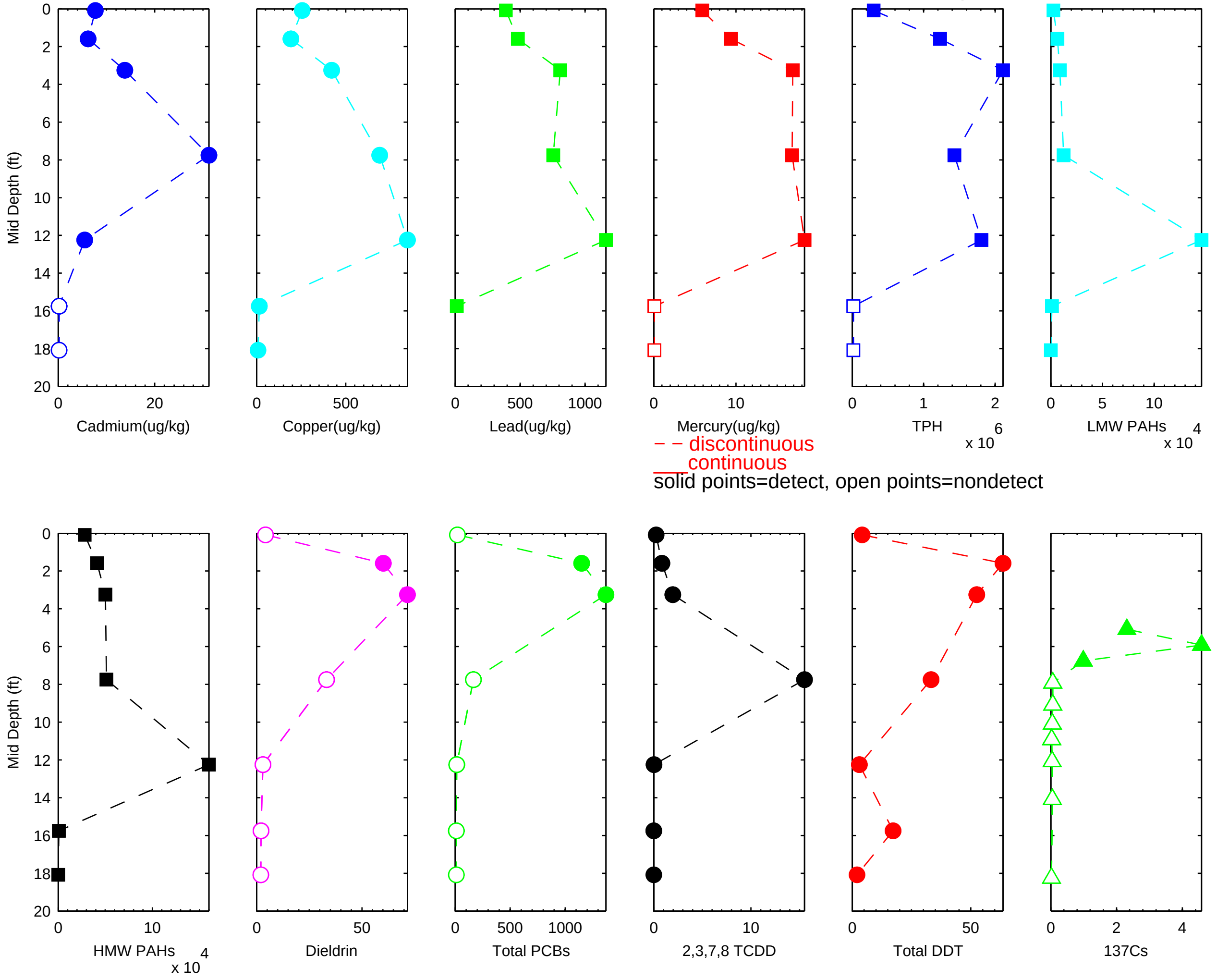
Sample ID: 23A River Mile 2.02   PASSAIC 1991 Core Sediment Investigation



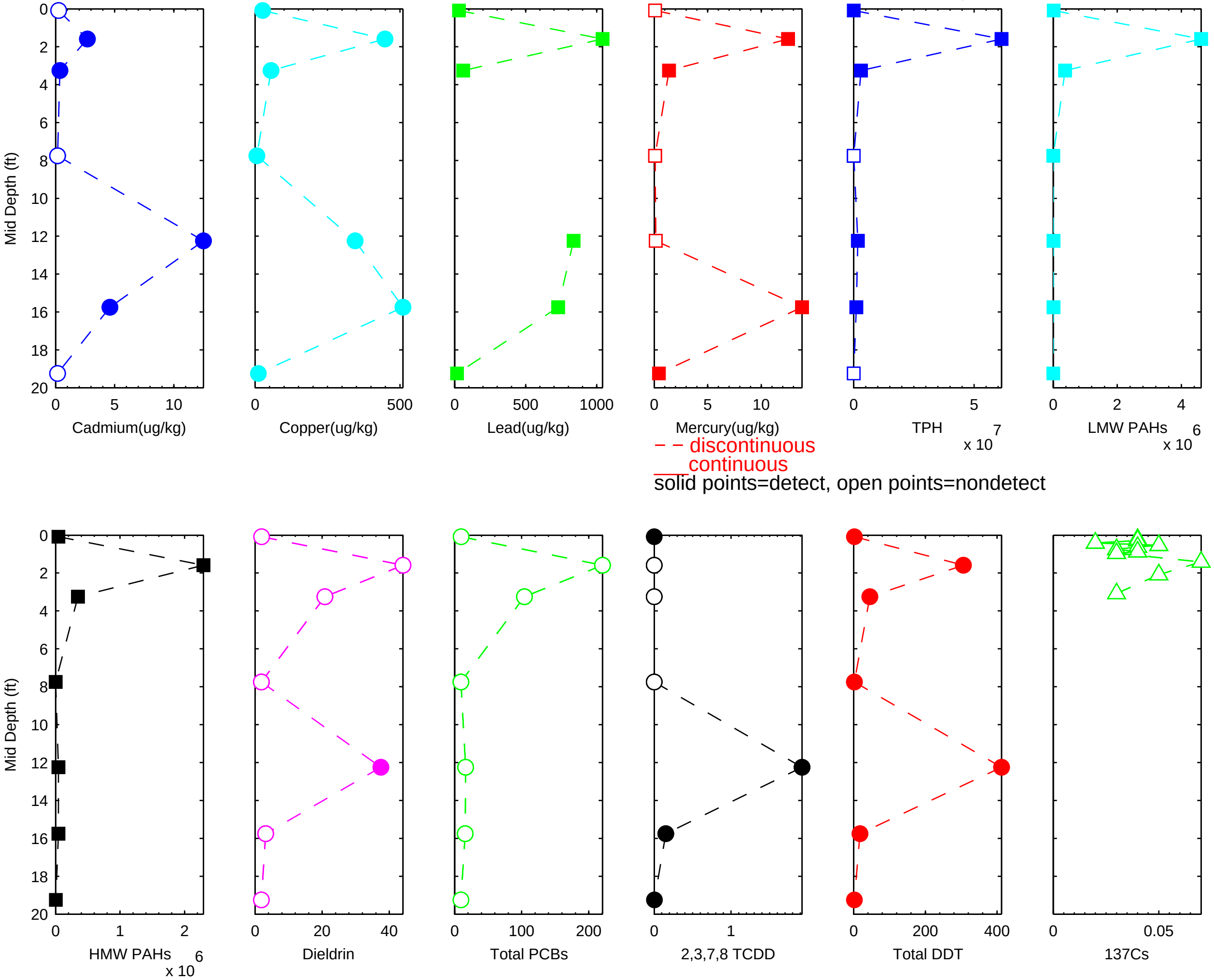
Sample ID: 22A River Mile 2.39 PASSAIC 1991 Core Sediment Investigation



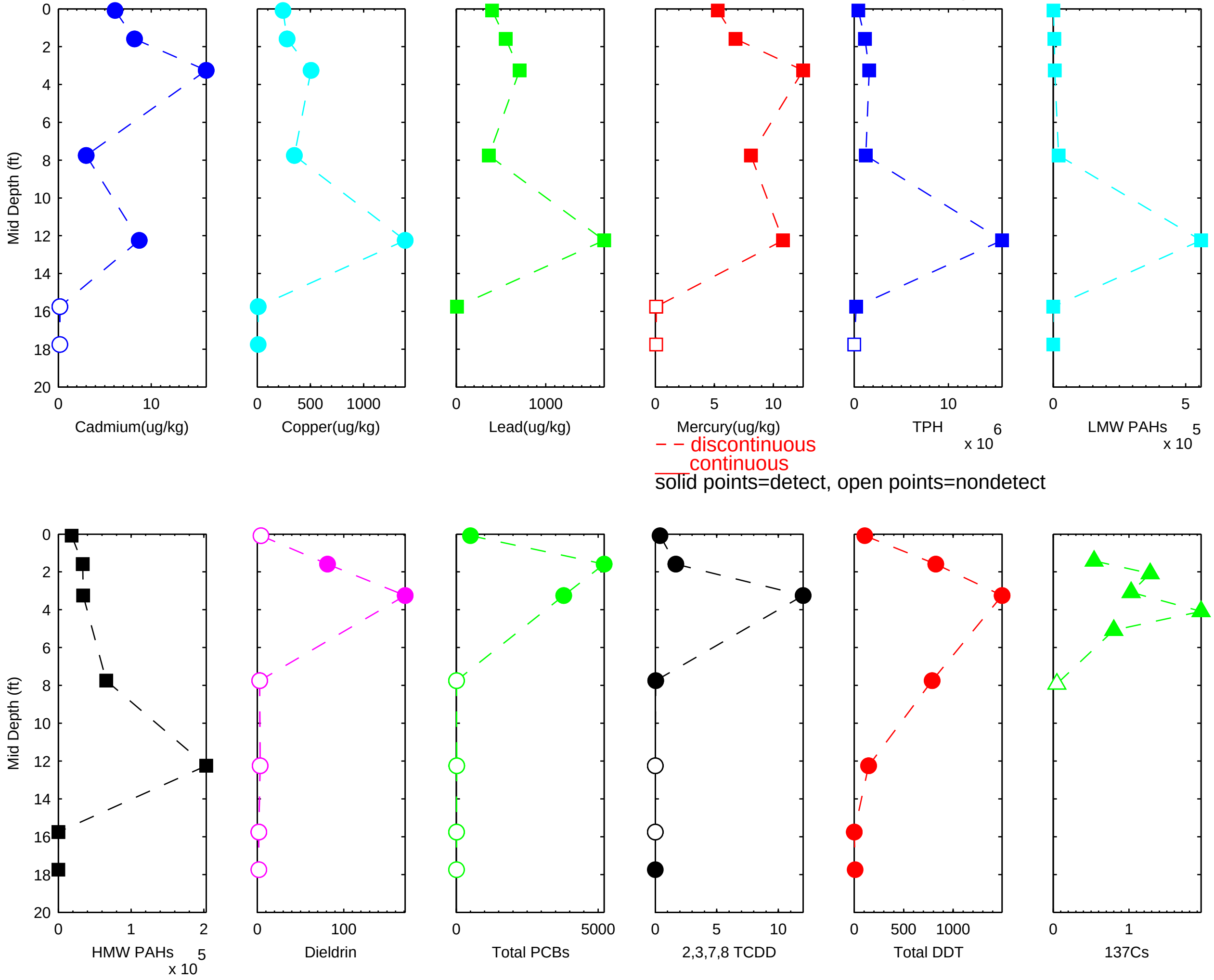
Sample ID: 21A River Mile 3.01 PASSAIC 1991 Core Sediment Investigation



Sample ID: 20A River Mile 3.05 PASSAIC 1991 Core Sediment Investigation



Sample ID: 19A River Mile 3.09 PASSAIC 1991 Core Sediment Investigation



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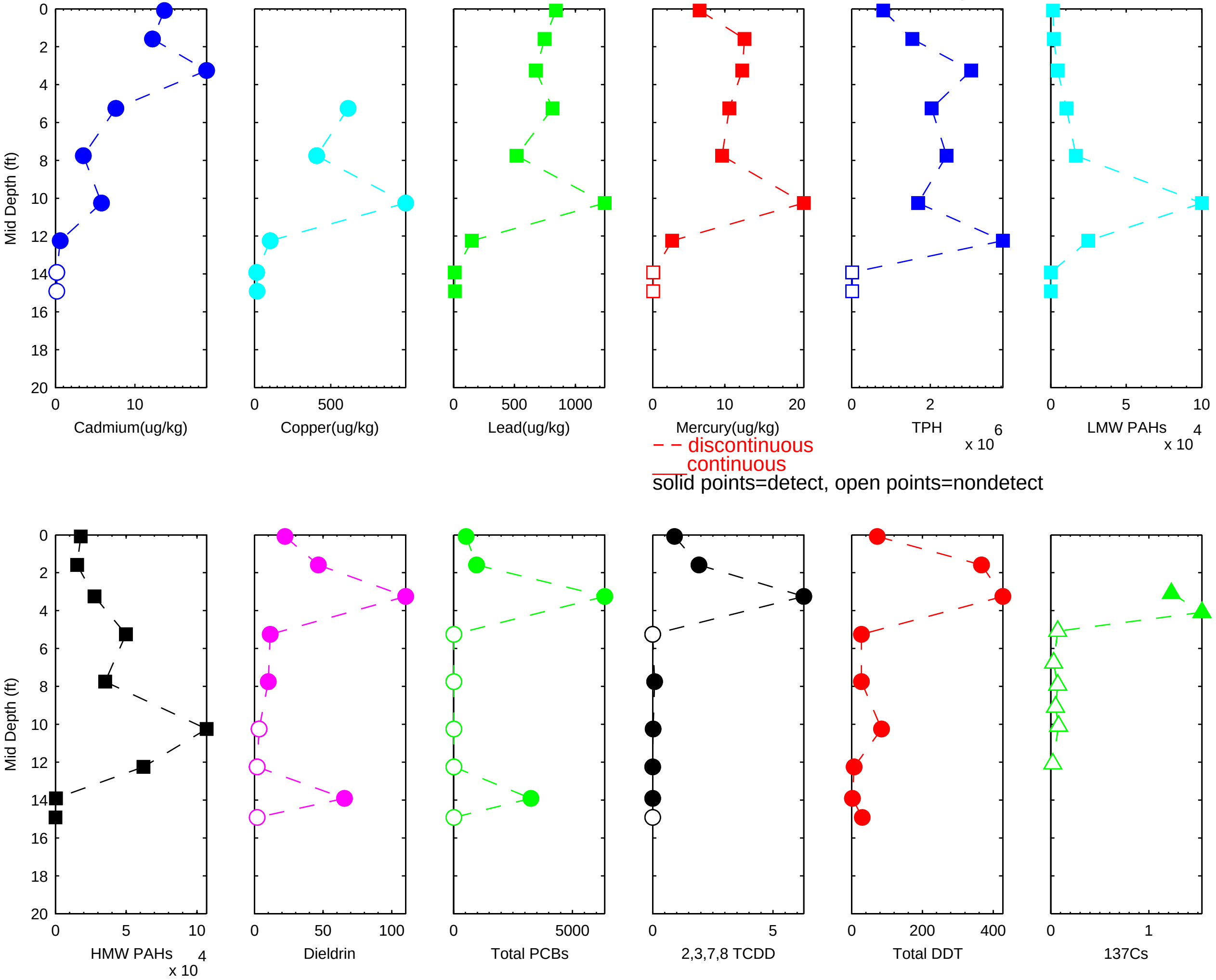
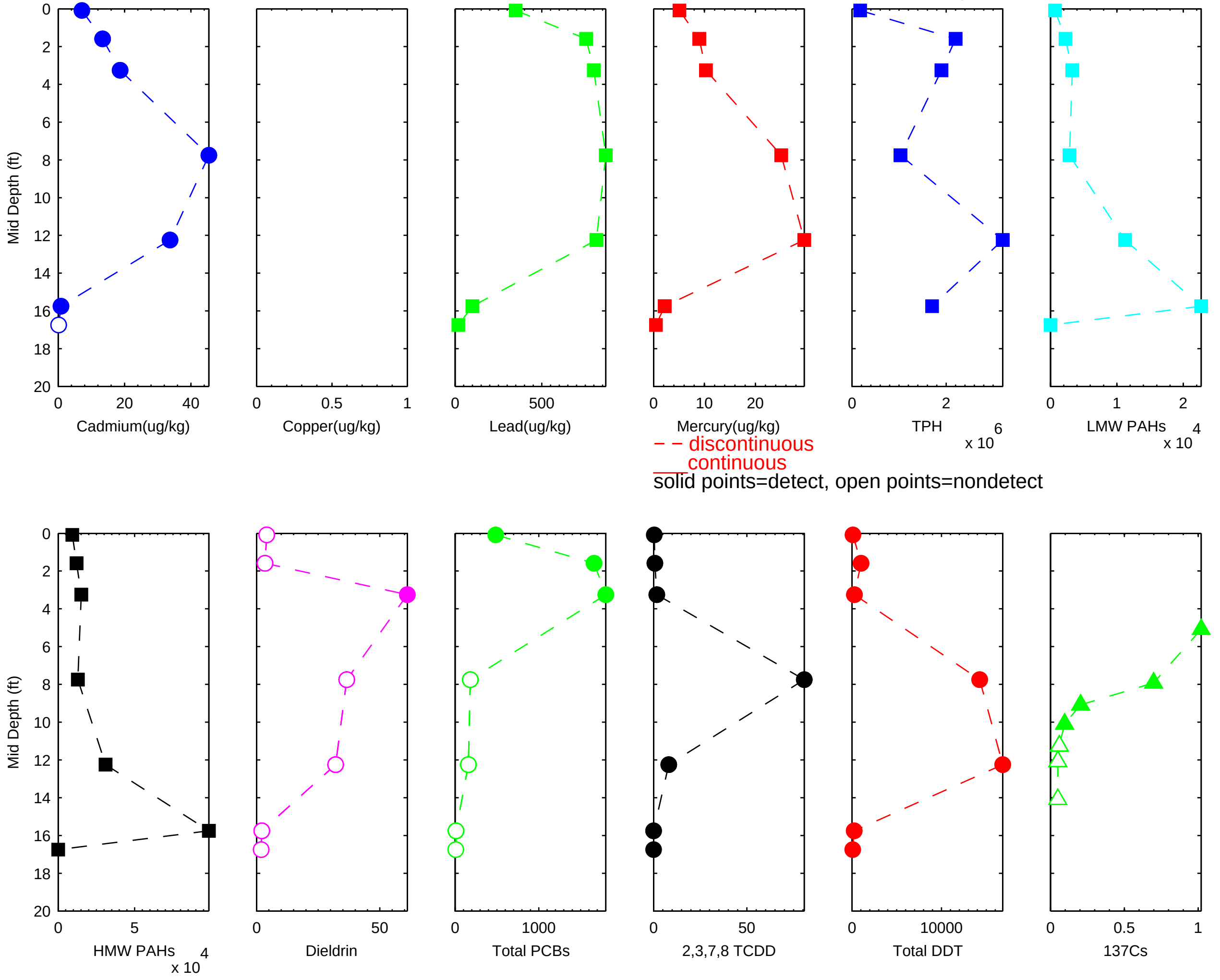


Sample ID: 17A River Mile 3.25   PASSAIC 1991 Core Sediment Investigation



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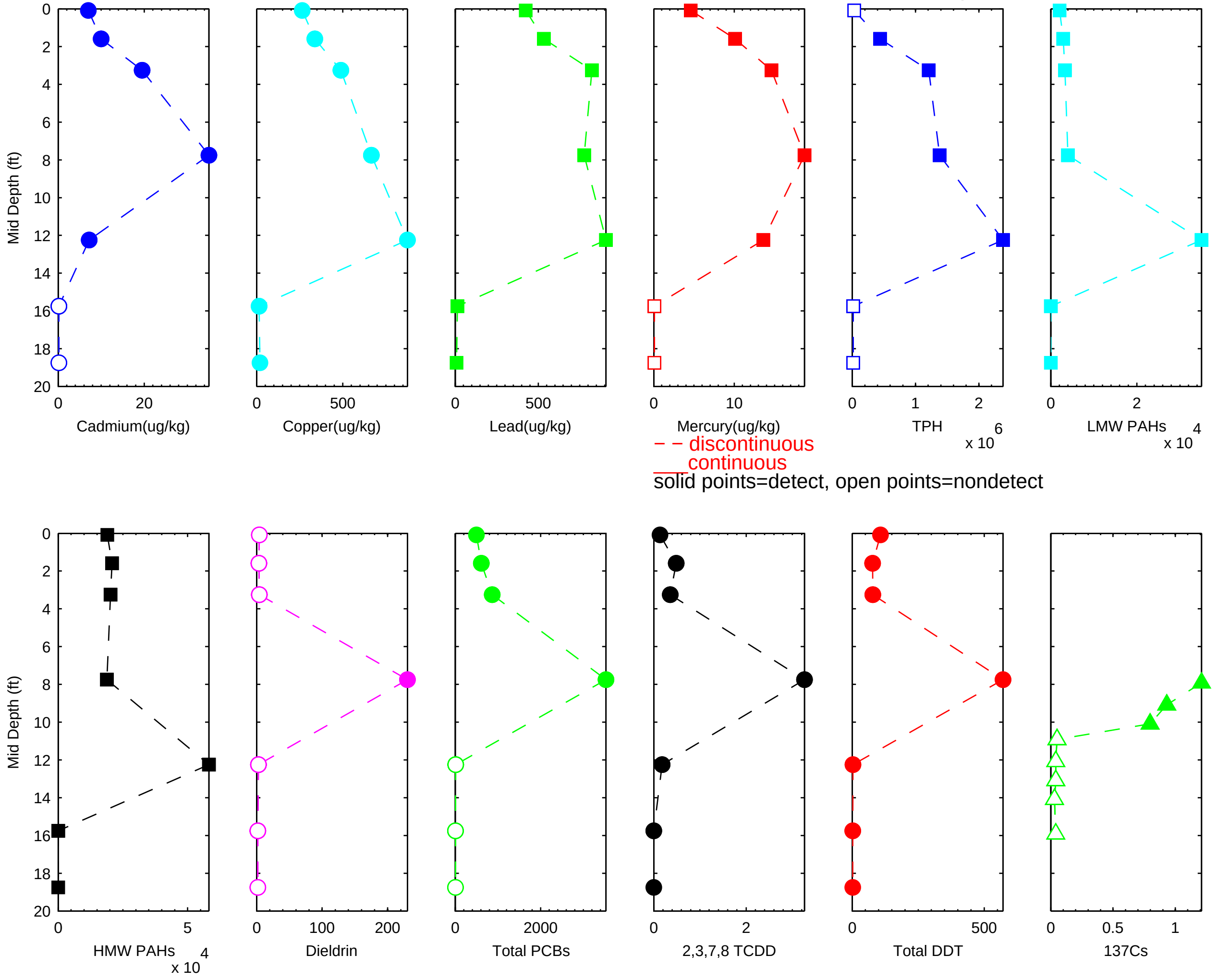
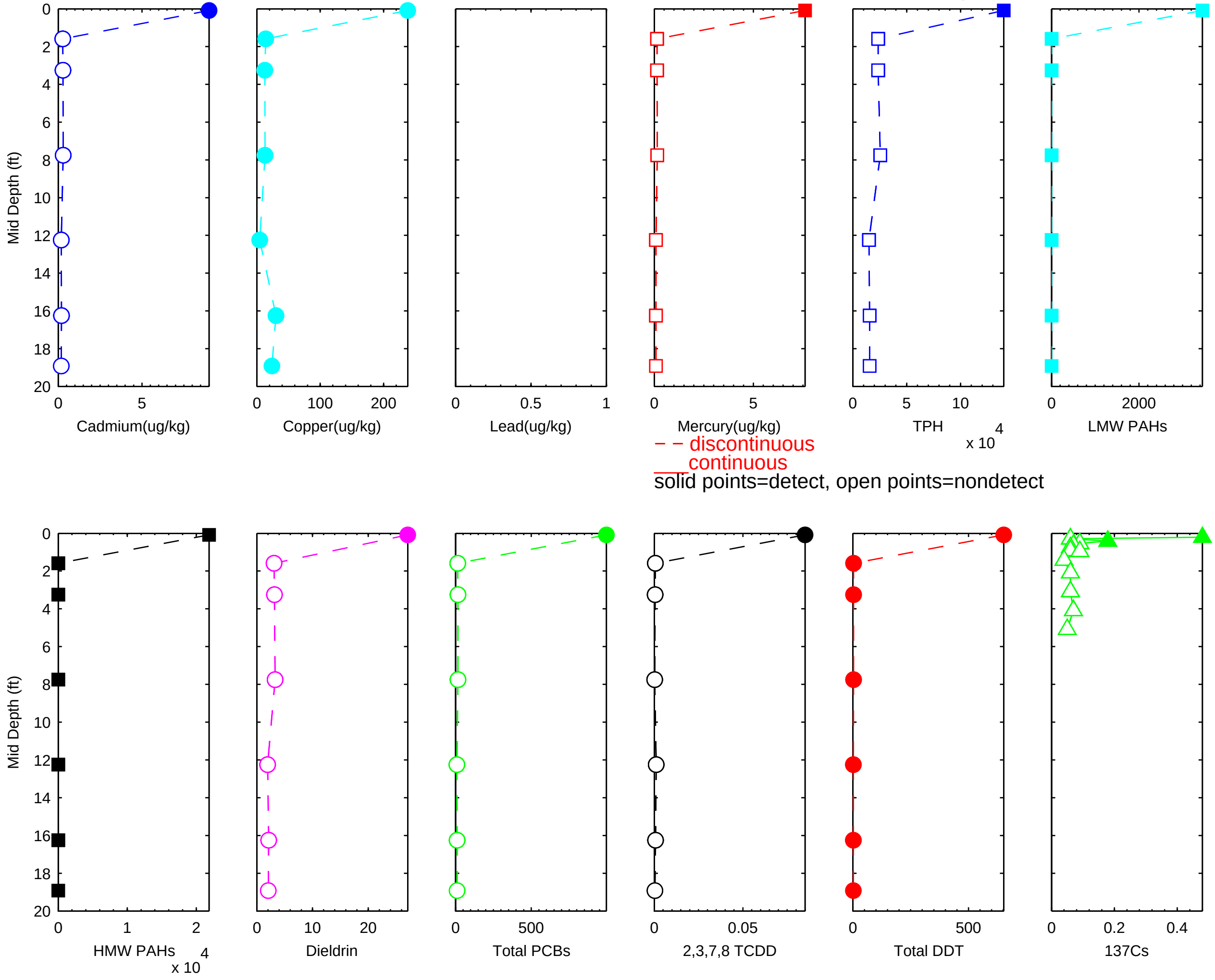
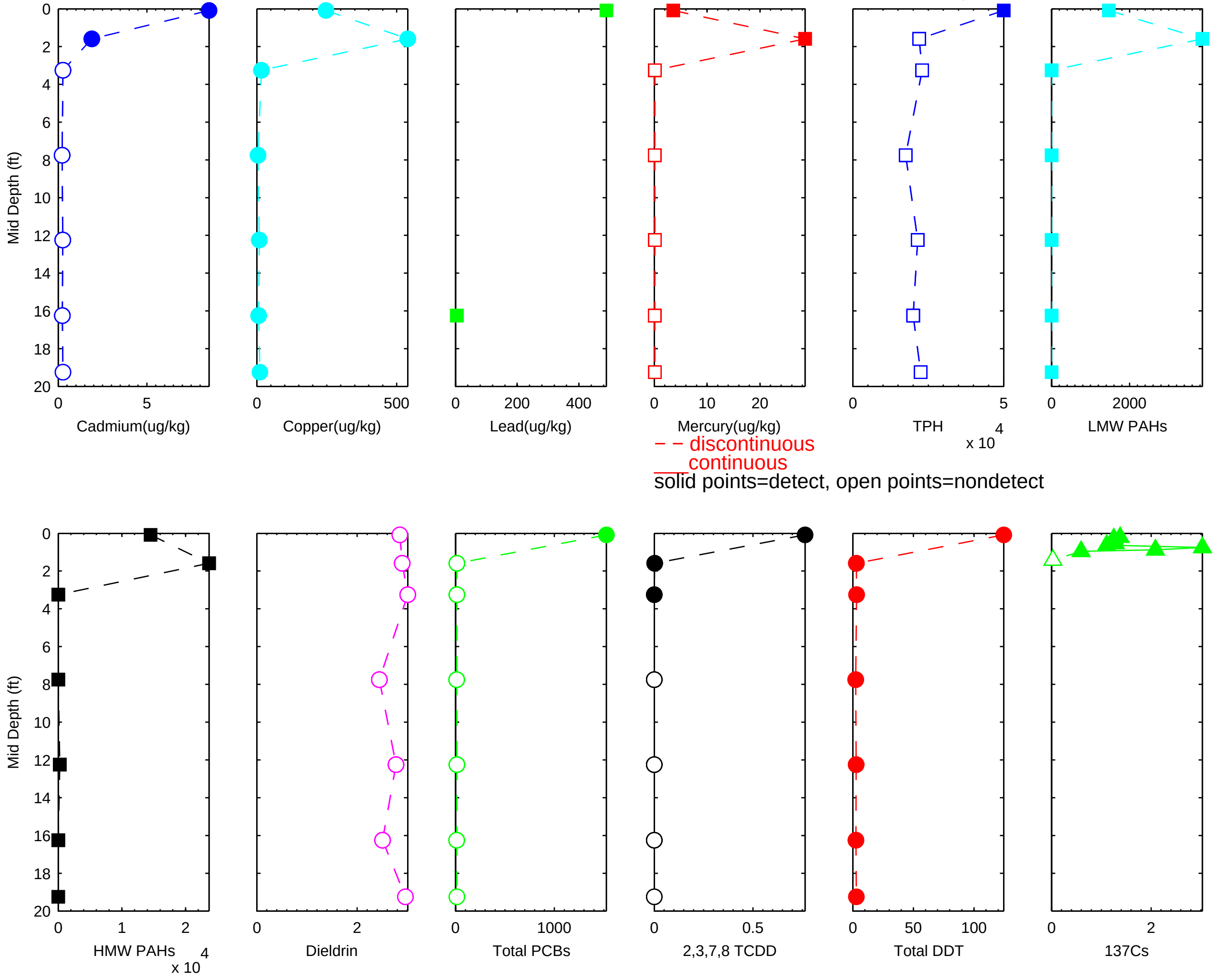


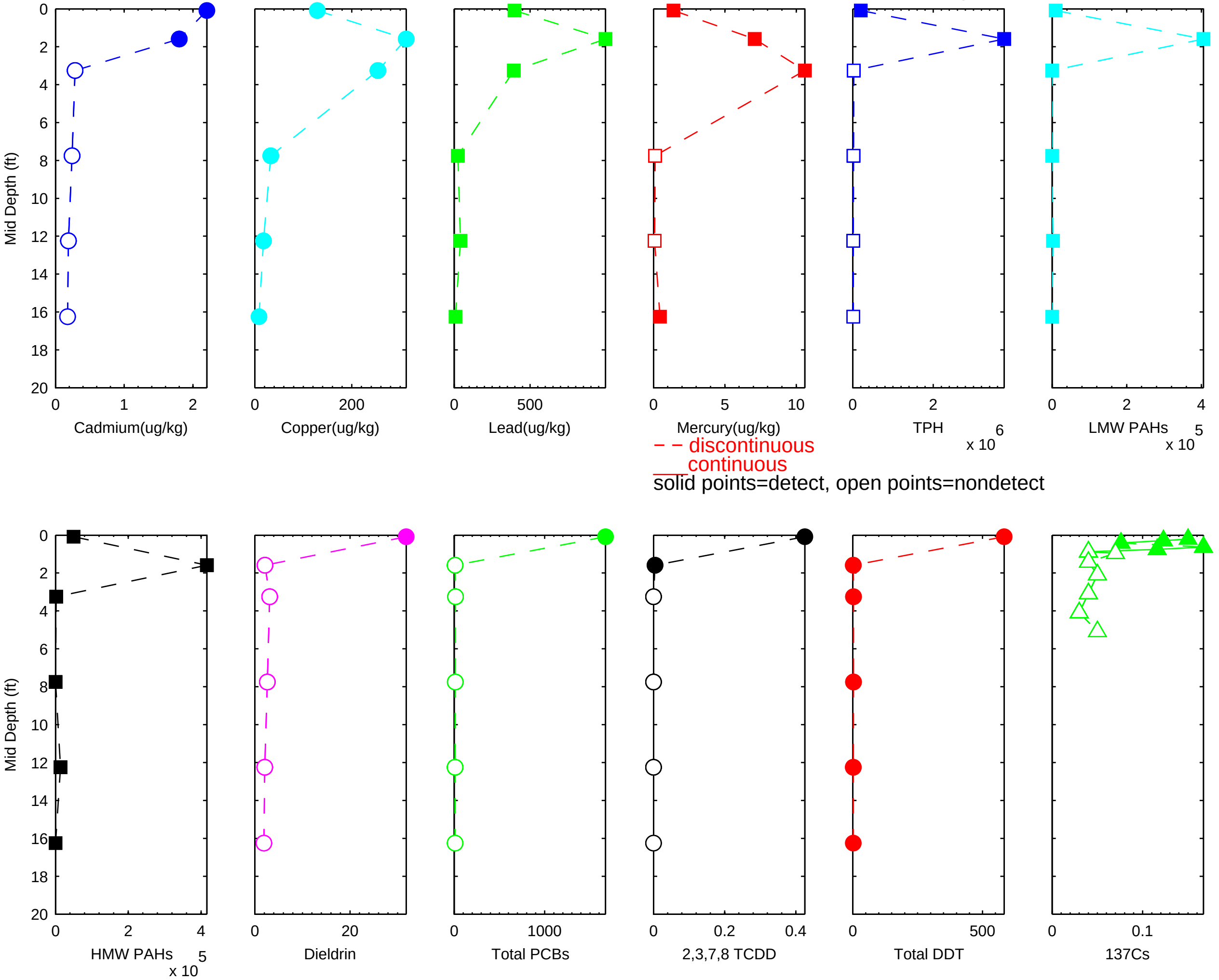
Sample ID: 15A River Mile 3.55 PASSAIC 1991 Core Sediment Investigation



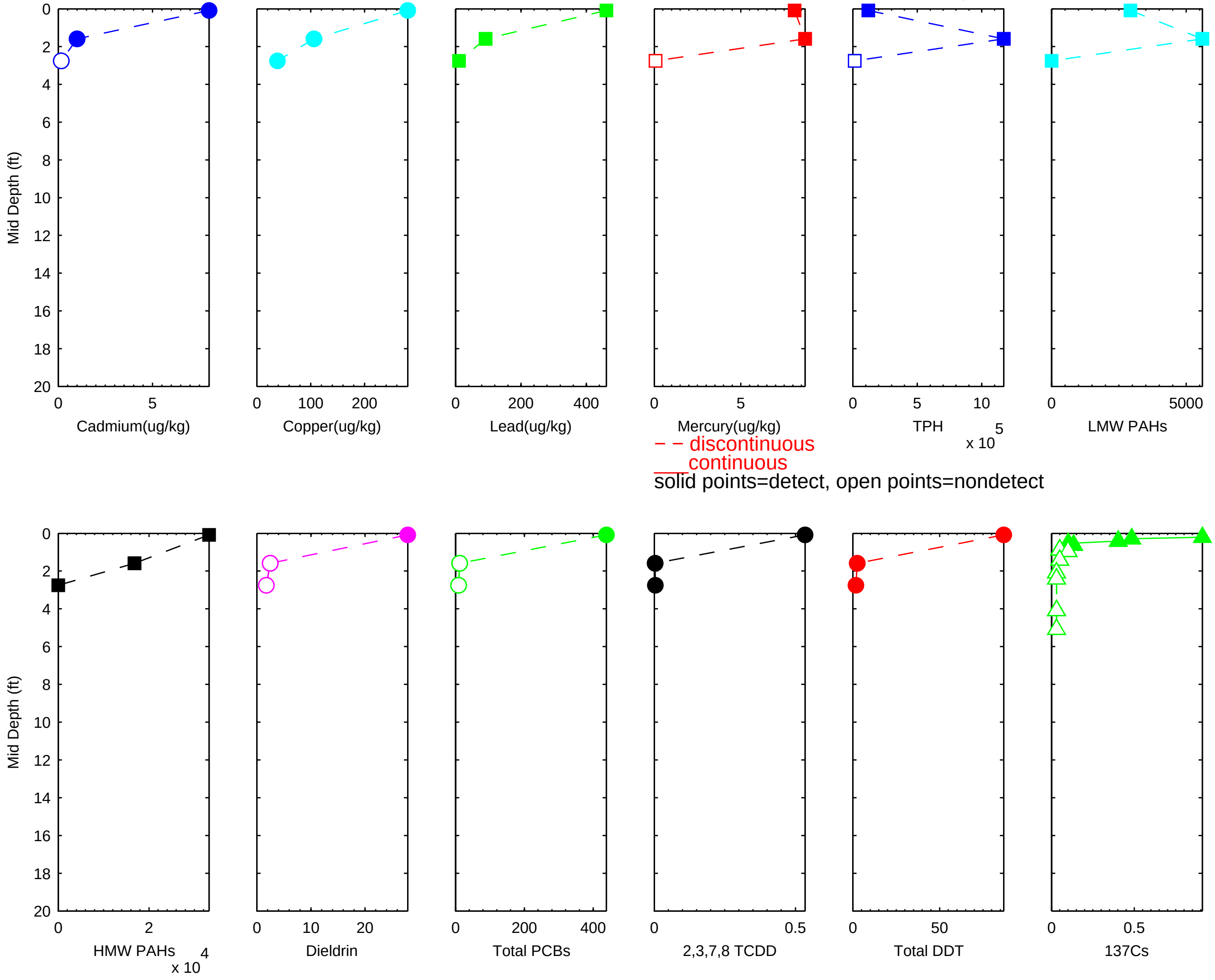
Sample ID: 14A River Mile 4.2   PASSAIC 1991 Core Sediment Investigation



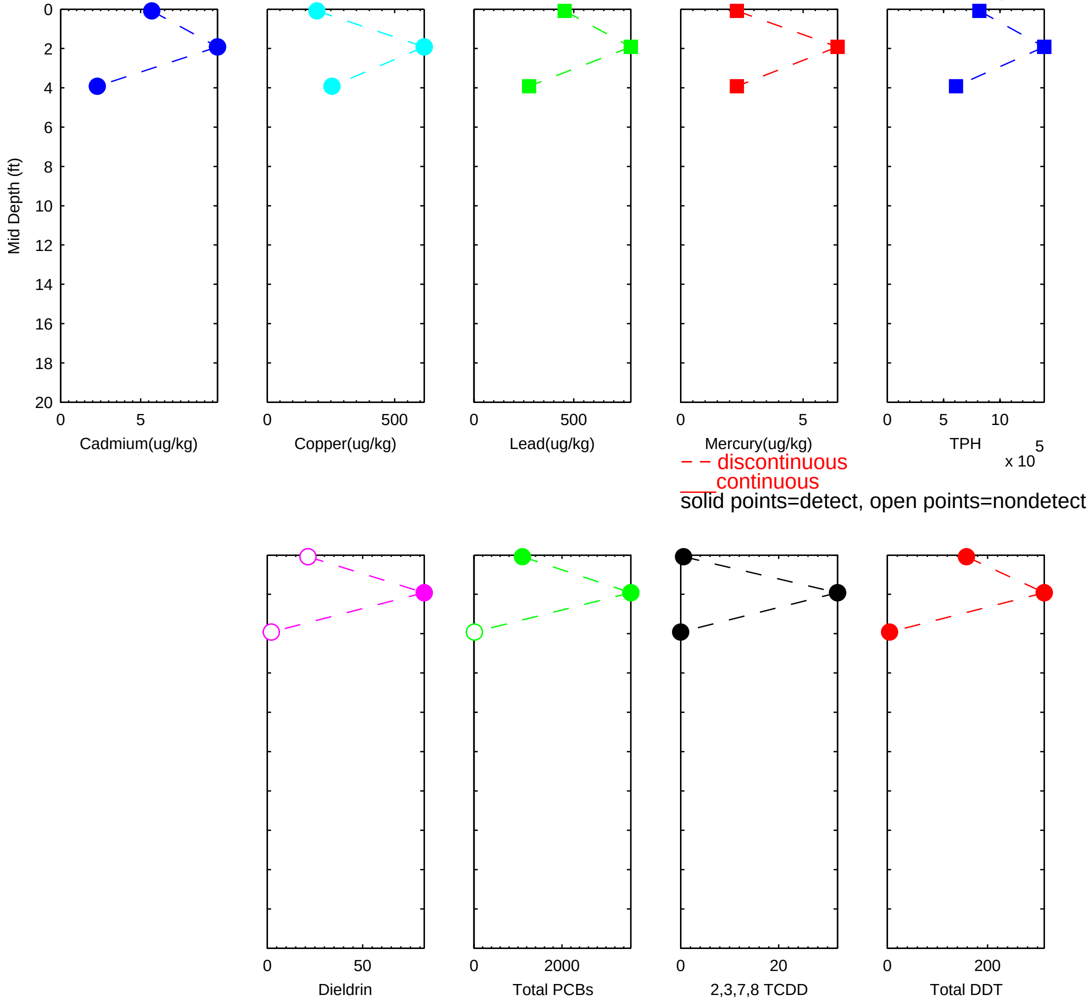
Sample ID: 13A River Mile 3.97 PASSAIC 1991 Core Sediment Investigation



Sample ID: 12A River Mile 4.87 PASSAIC 1991 Core Sediment Investigation



Sample ID: 10A River Mile 6.91 PASSAIC 1991 Core Sediment Investigation



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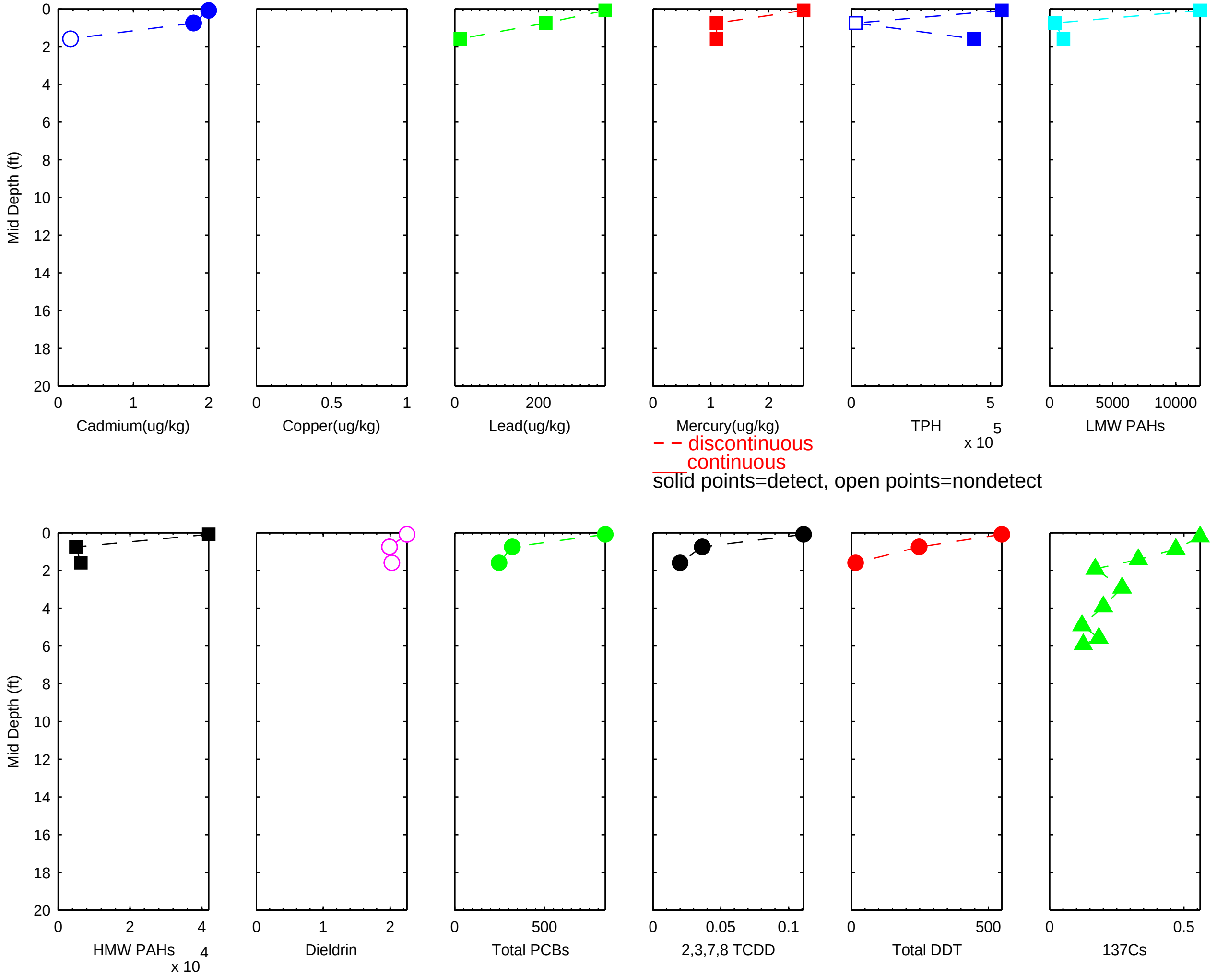

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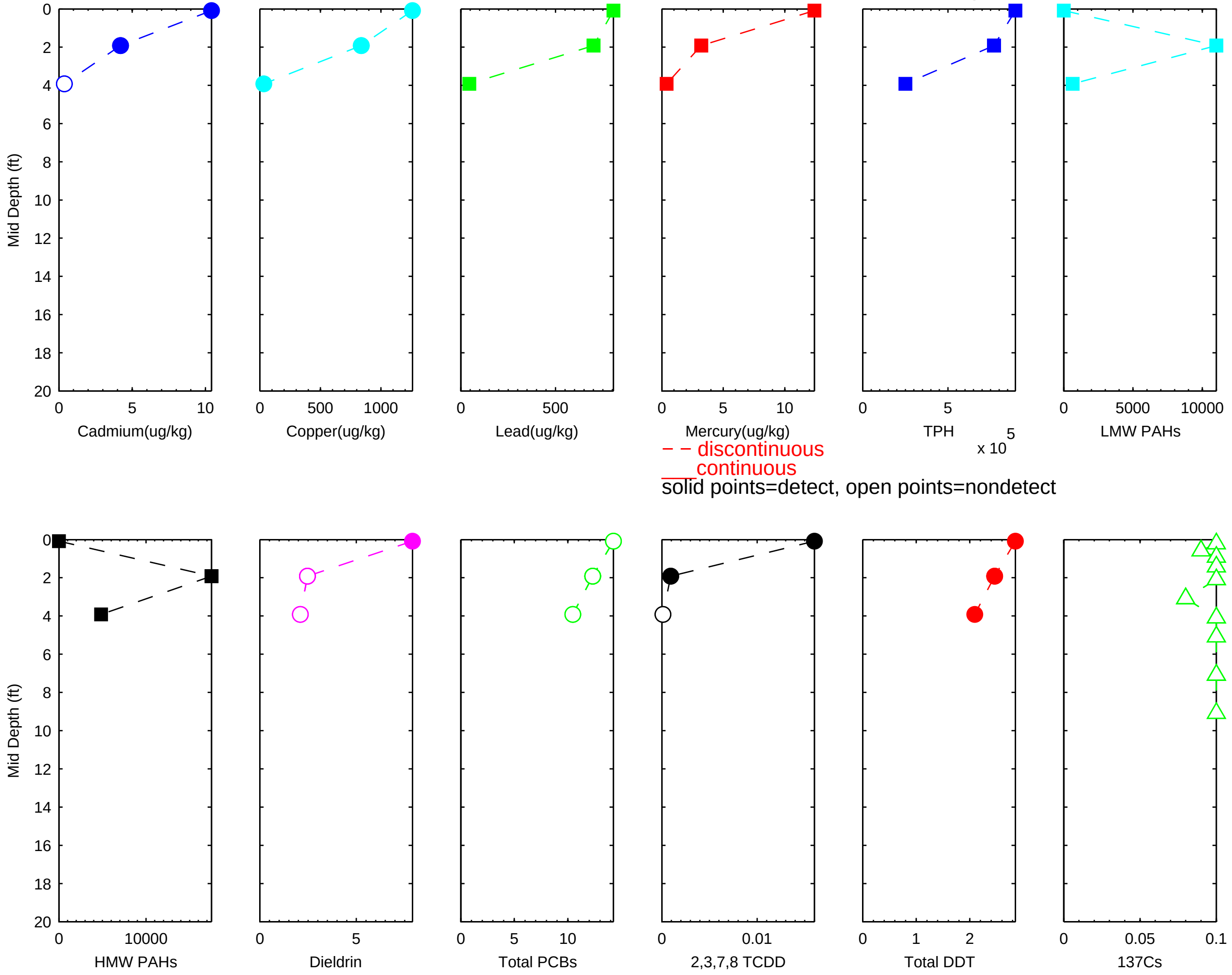
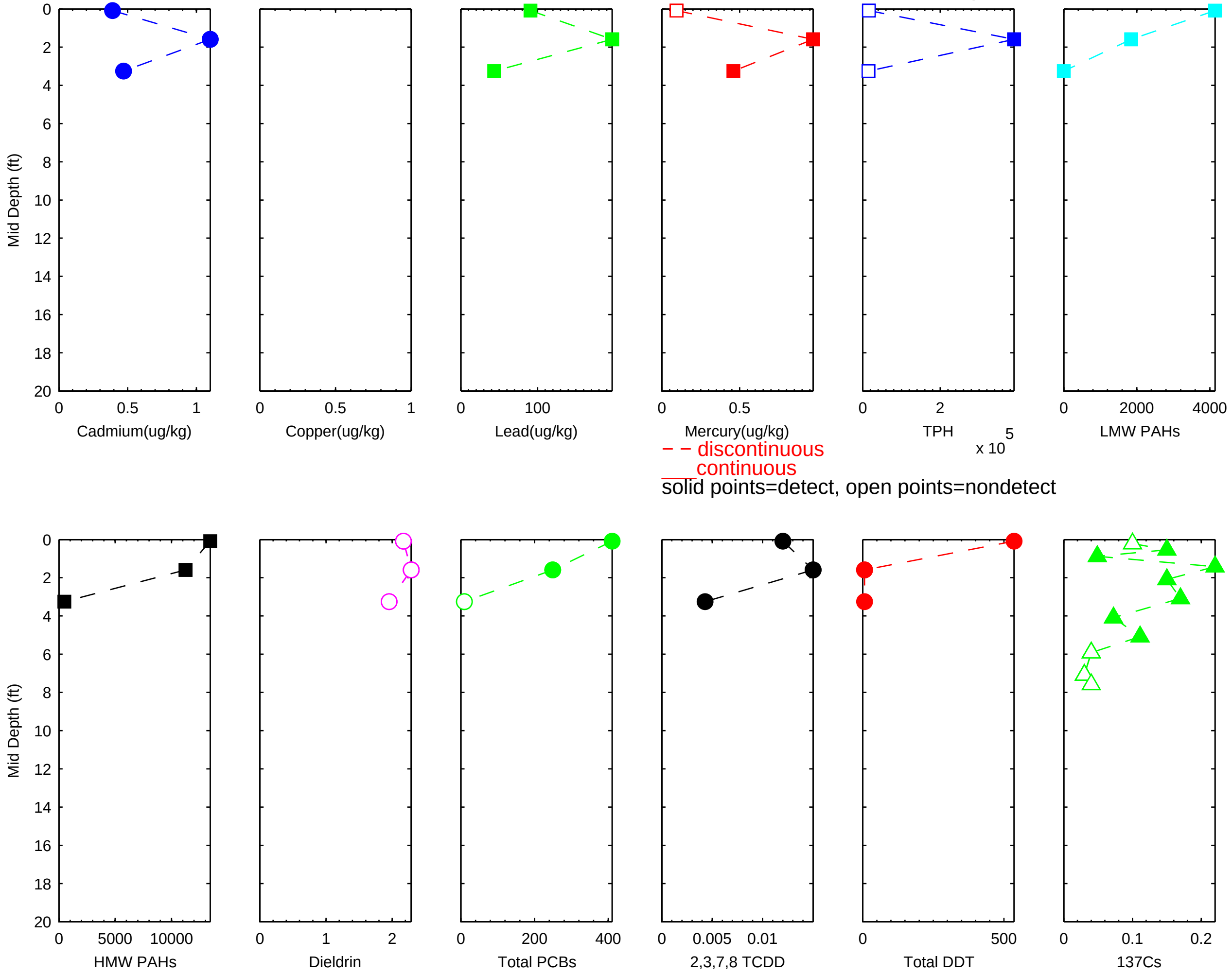
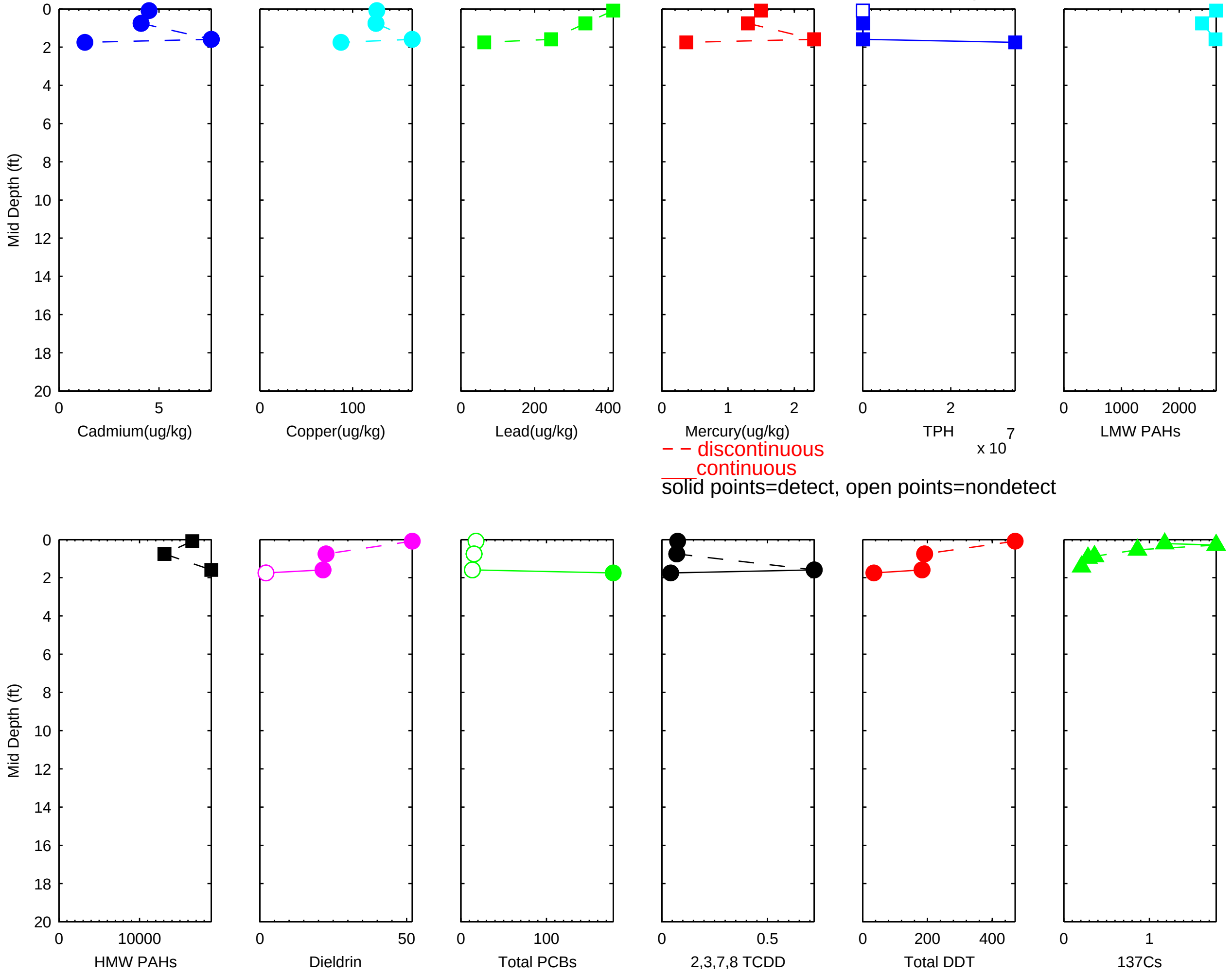


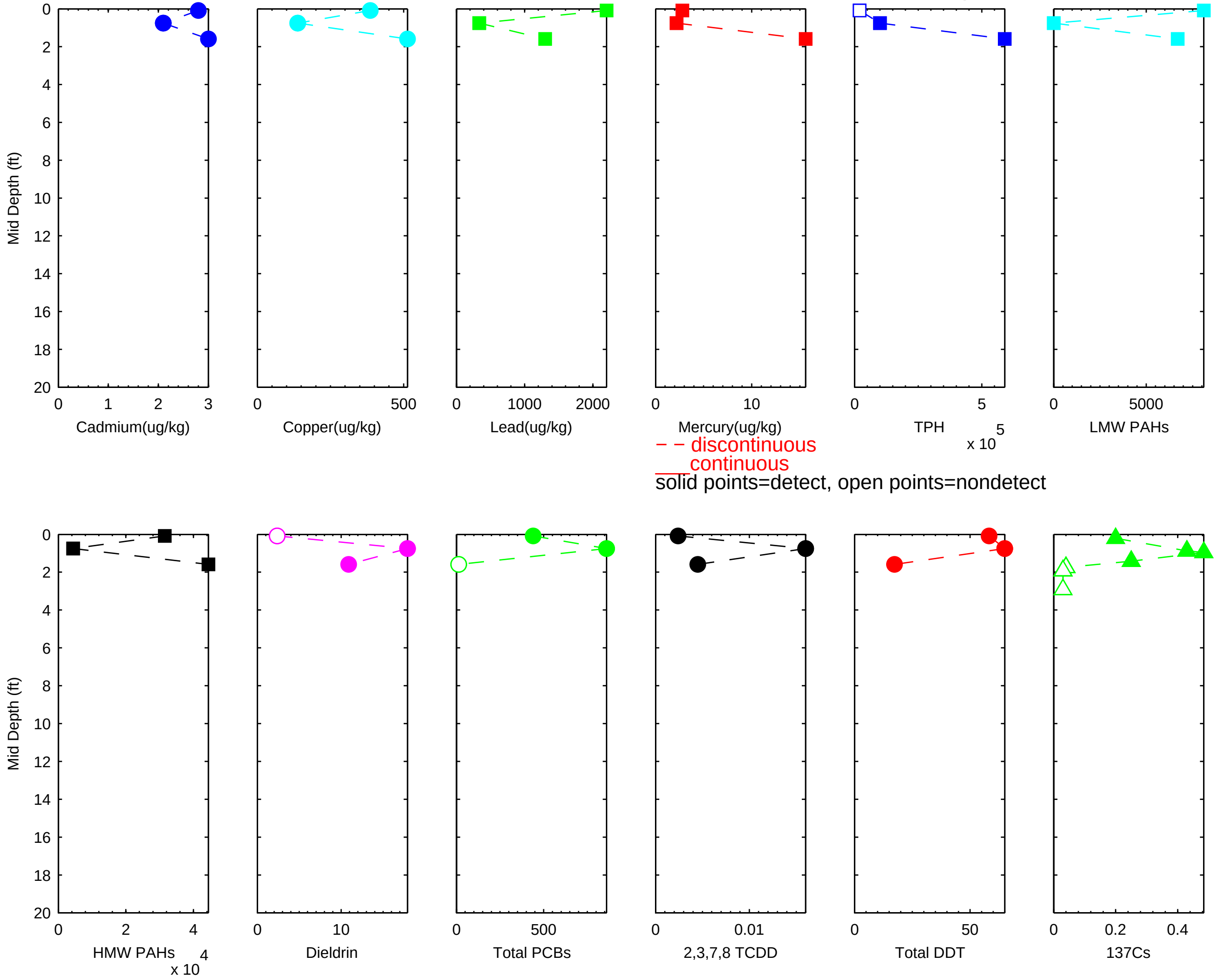
Sample ID: 06A River Mile 11.21 PASSAIC 1991 Core Sediment Investigation



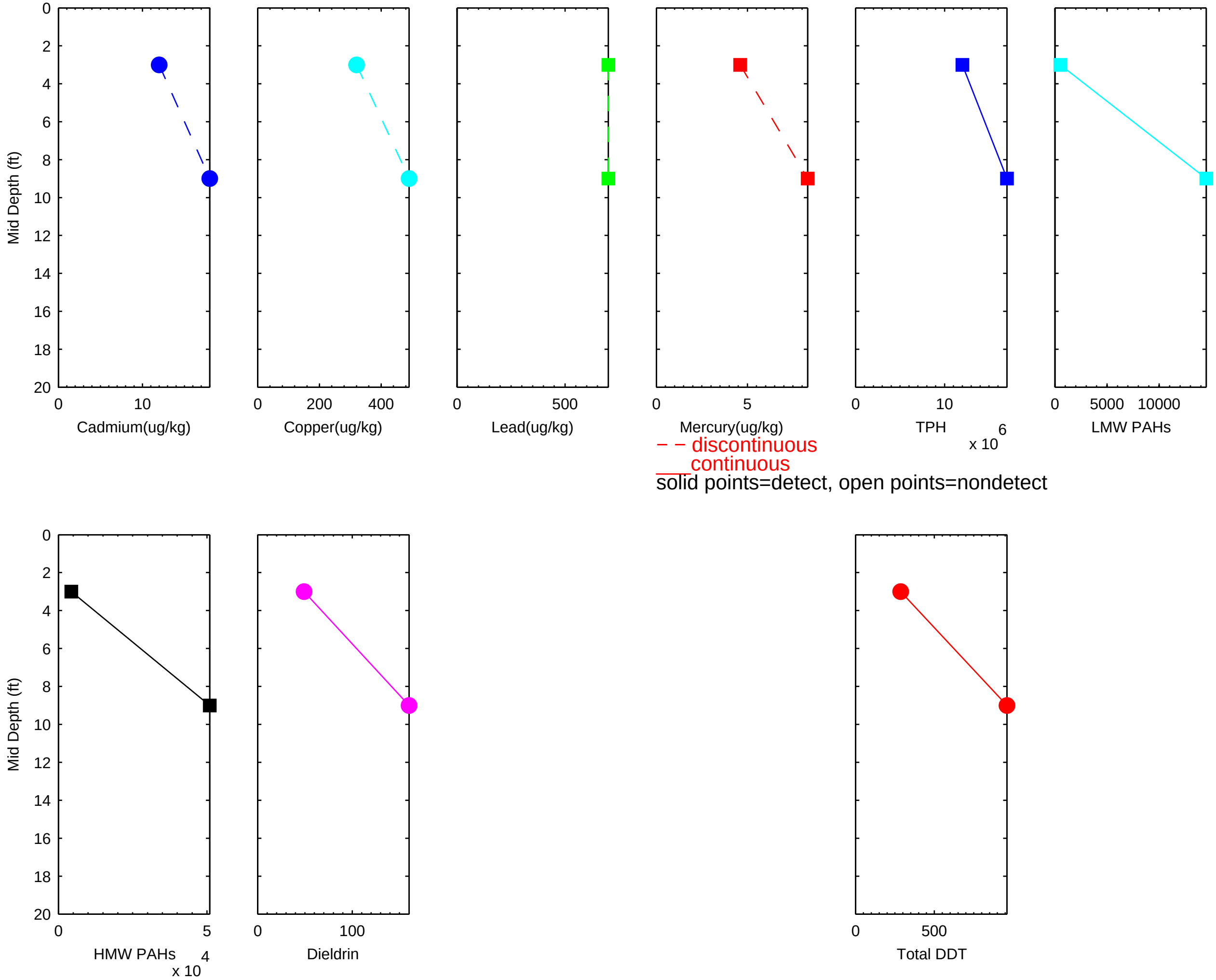
Sample ID: 05B River Mile 11.19 PASSAIC 1991 Core Sediment Investigation



Sample ID: 02A River Mile 16.95 PASSAIC 1991 Core Sediment Investigation

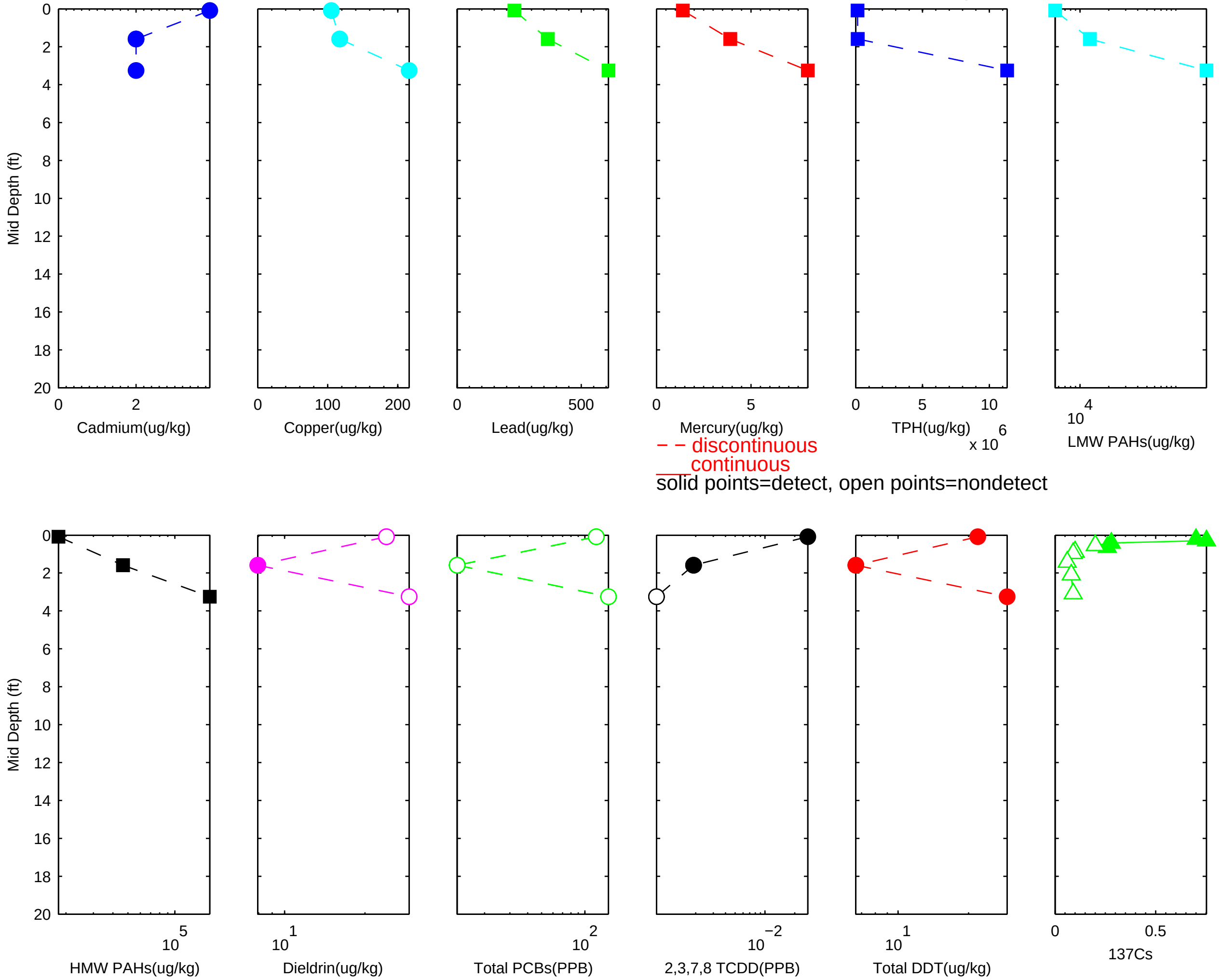


Sample ID: WTH−7 River Mile 5.02 PASSAIC 1995 USACE Minish Park Investigation



Historical Analyte Plots,
Plotted on a Logarithmic Scale

Sample ID: 01A River Mile 17.43   PASSAIC 1991 Core Sediment Investigation



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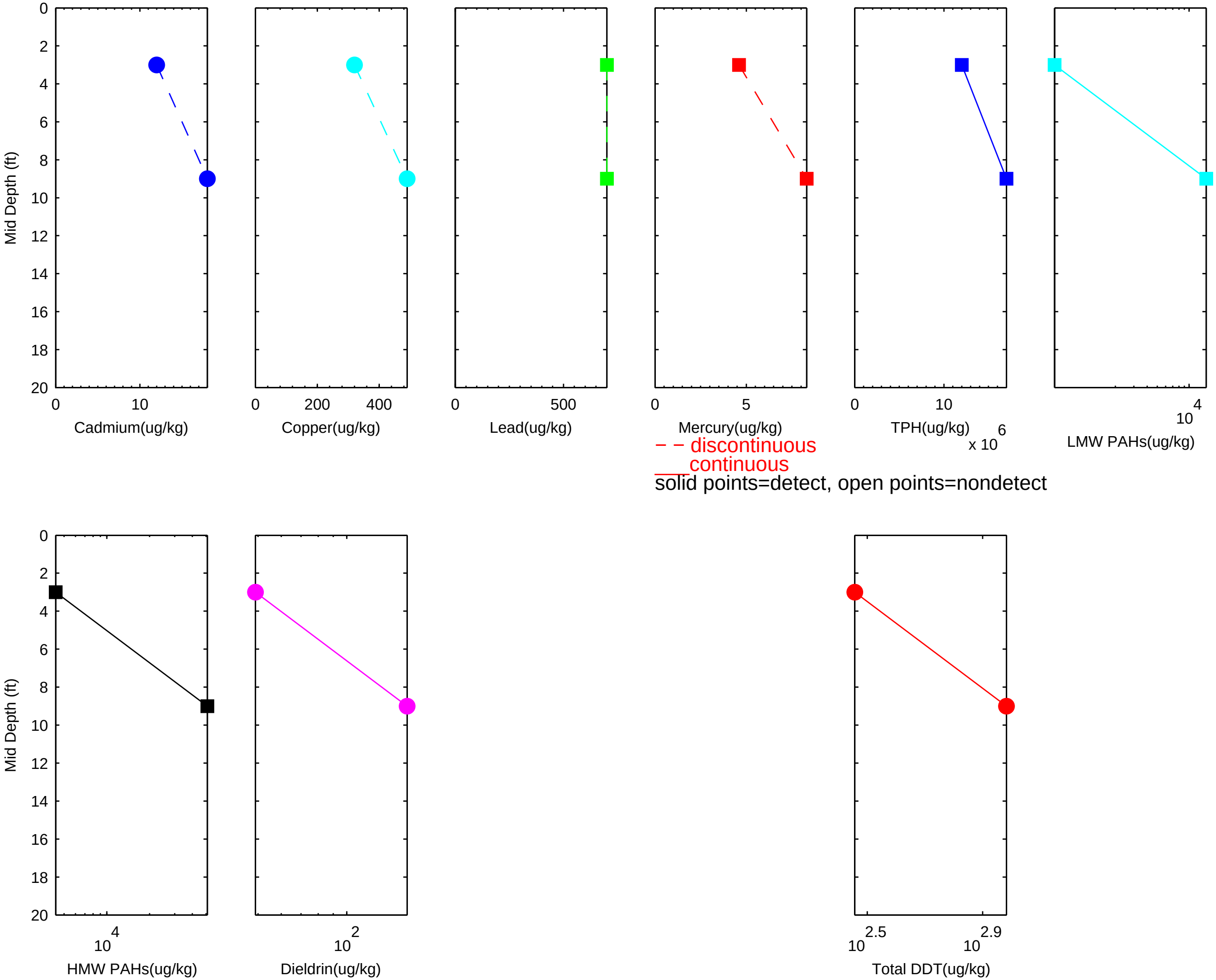
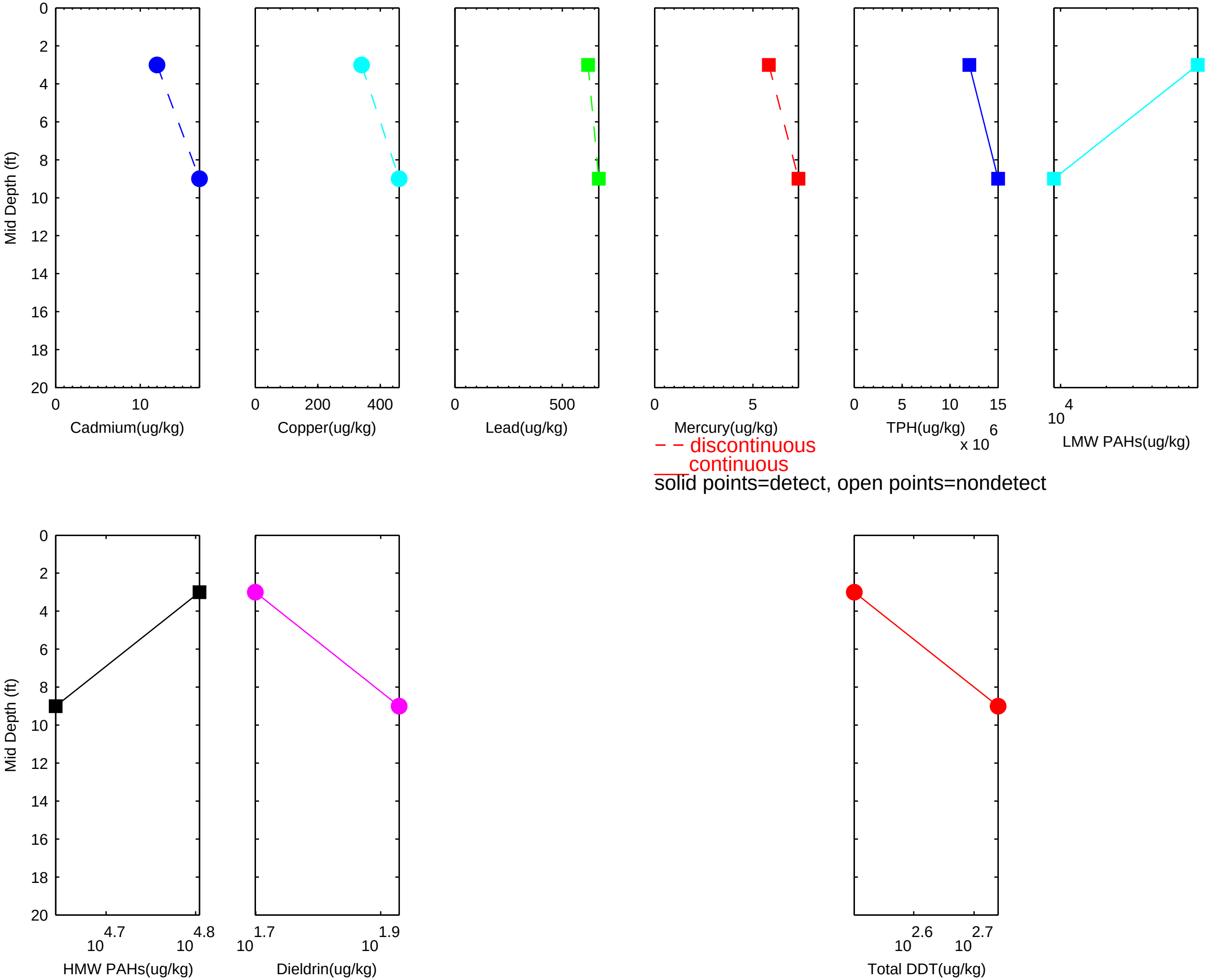
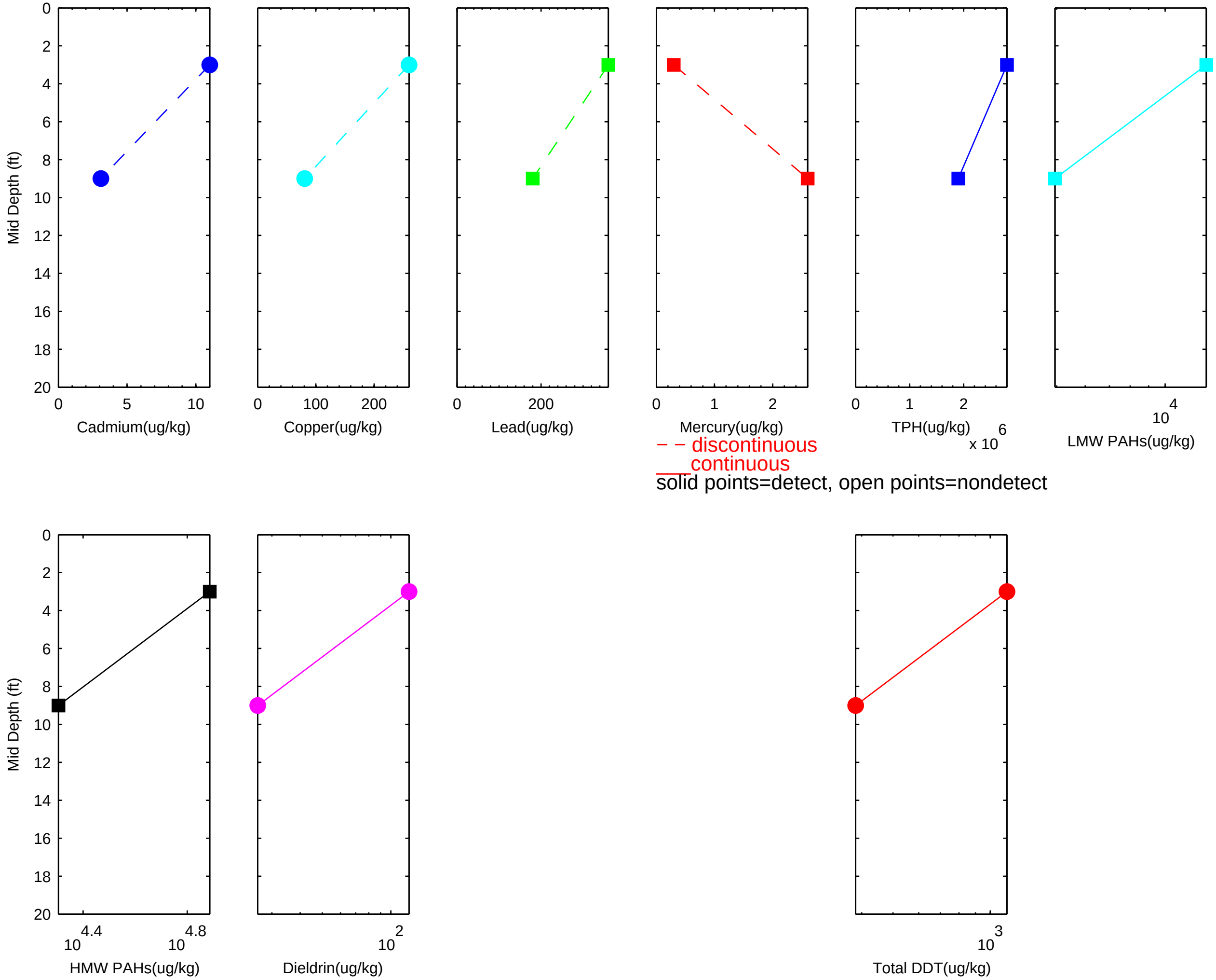


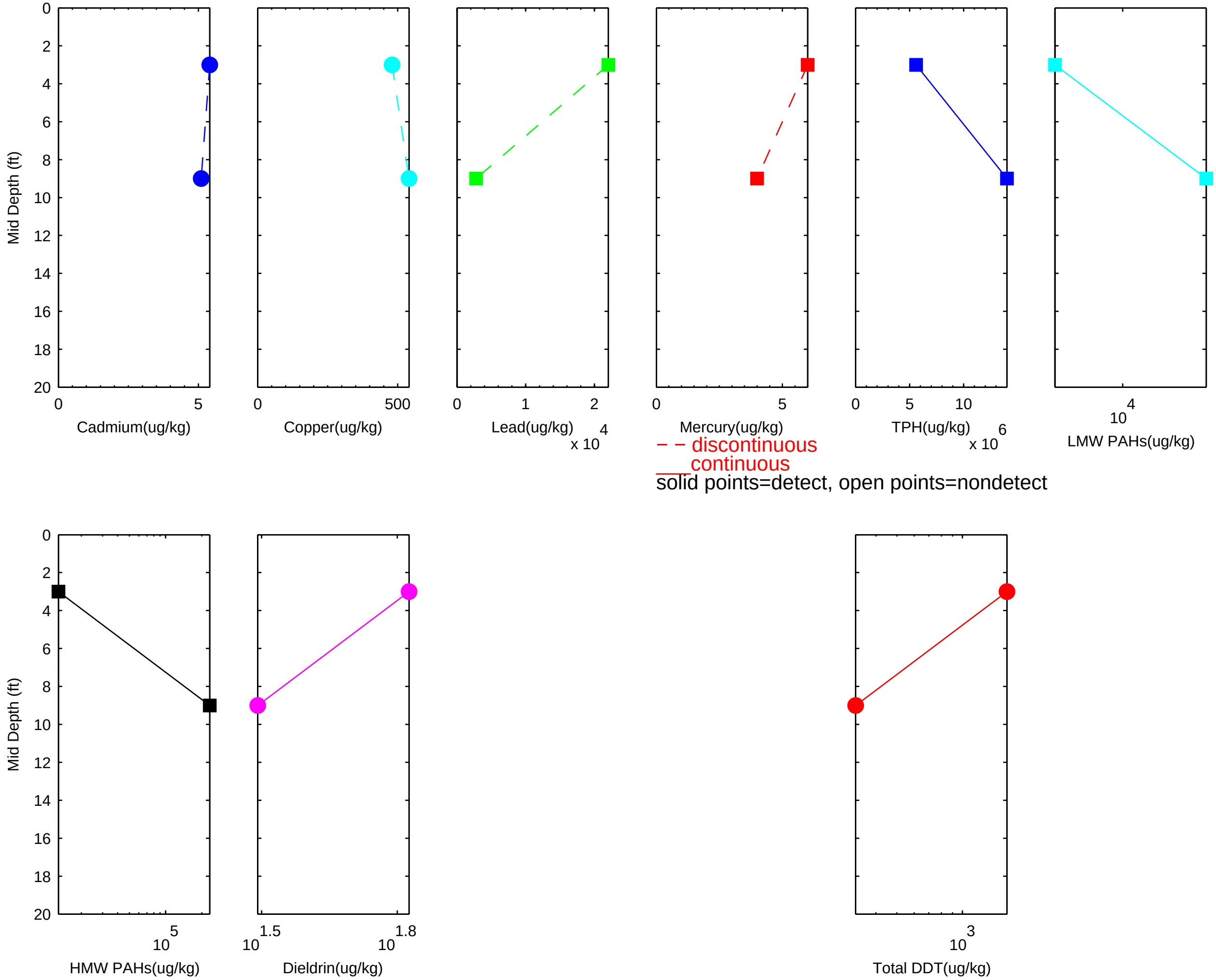
Sample ID: WTH−6 River Mile 4.98 PASSAIC 1995 USACE Minish Park Investigation



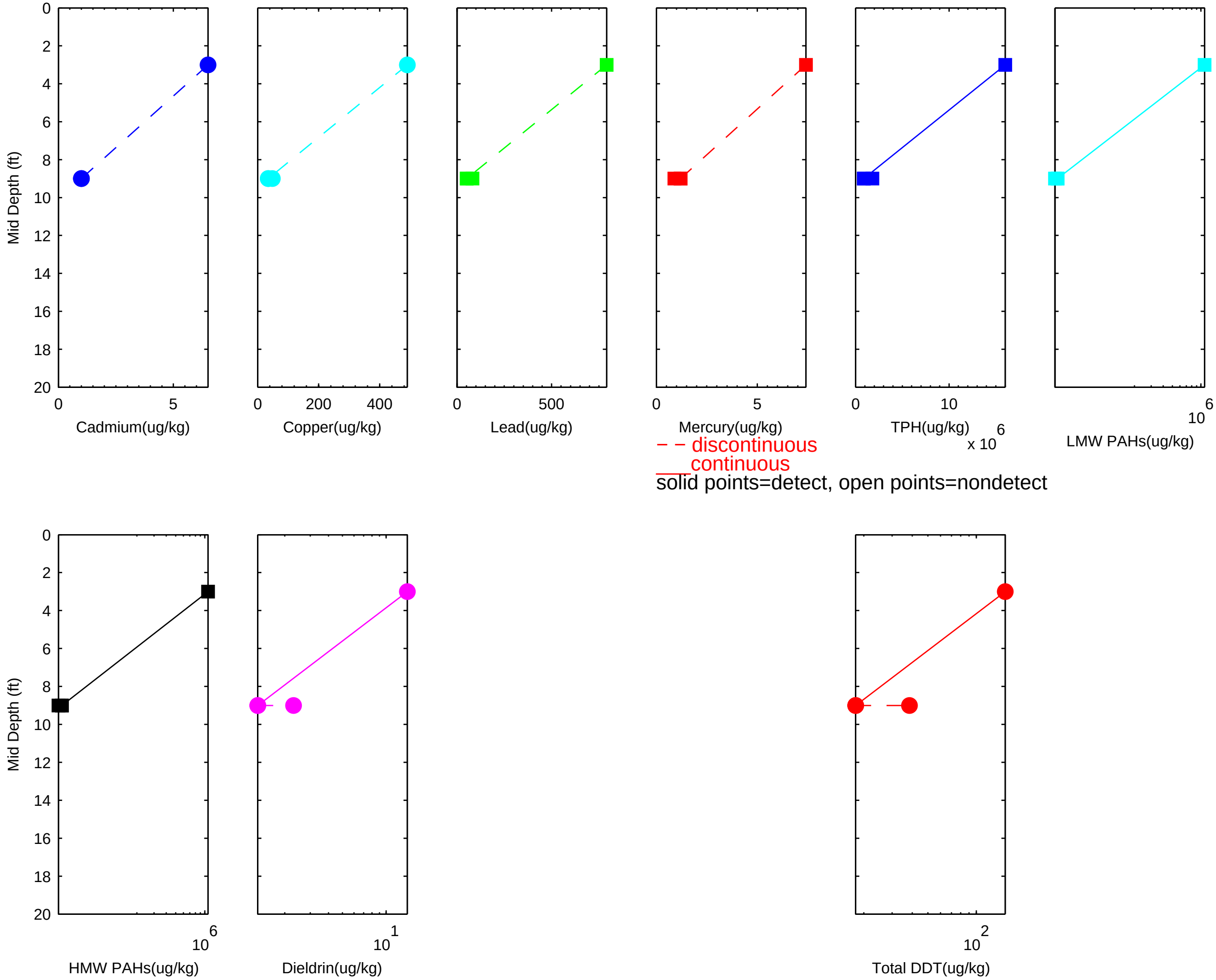
Sample ID: WTH−5 River Mile 4.74 PASSAIC 1995 USACE Minish Park Investigation



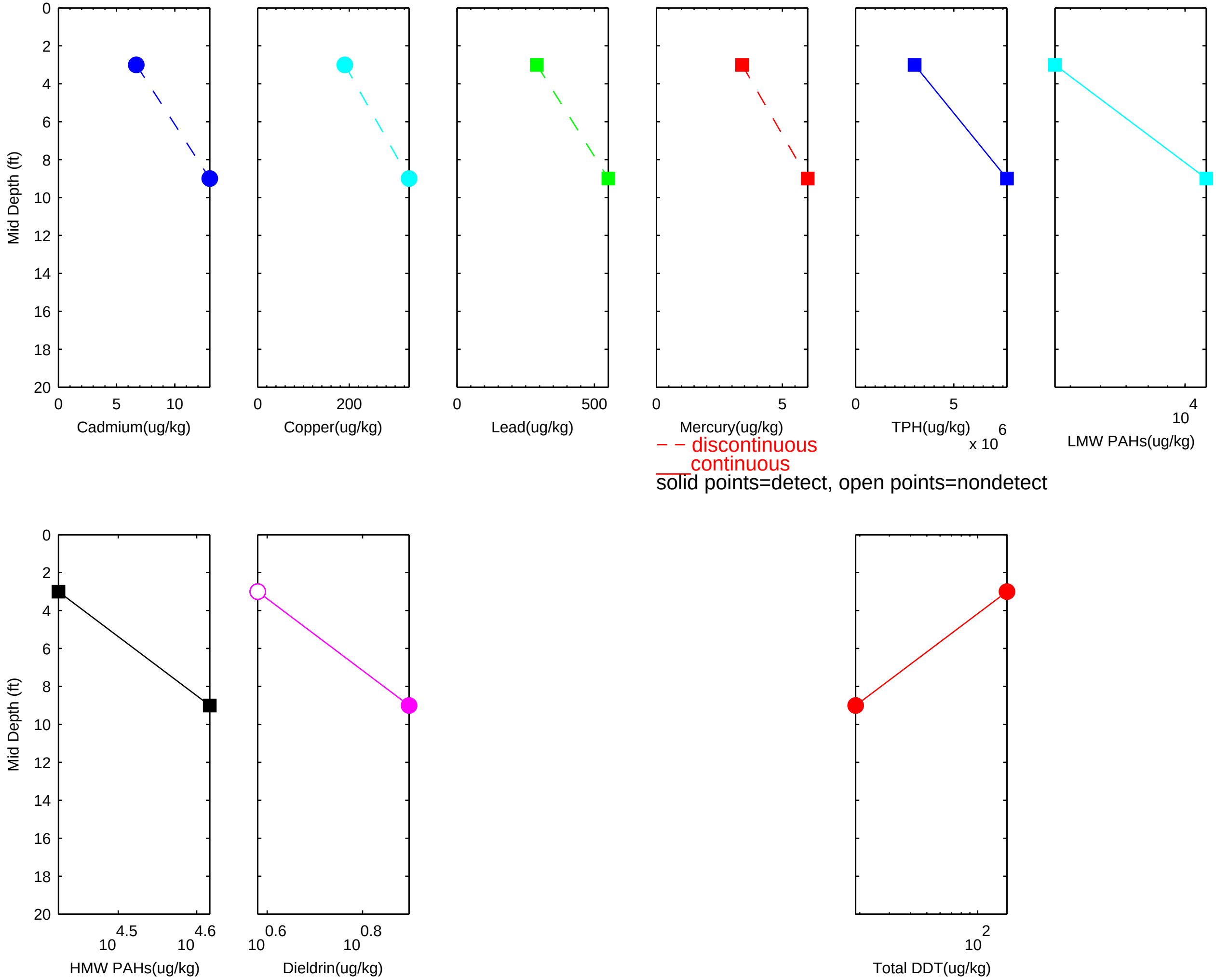
Sample ID: WTH−3 River Mile 4.36 PASSAIC 1995 RI Sampling Program



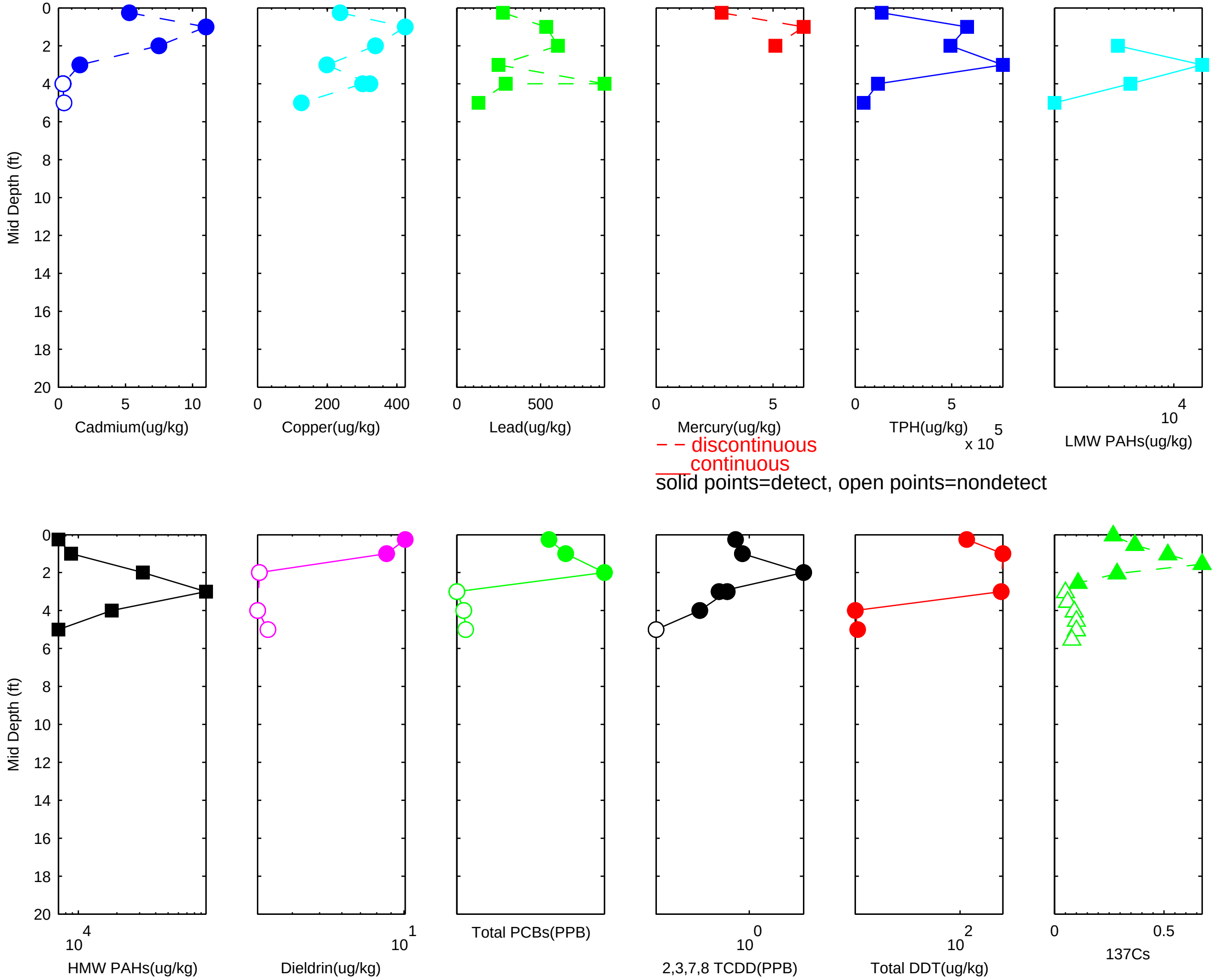
Sample ID: WTH−2 River Mile 4.04 PASSAIC 1995 USACE Minish Park Investigation



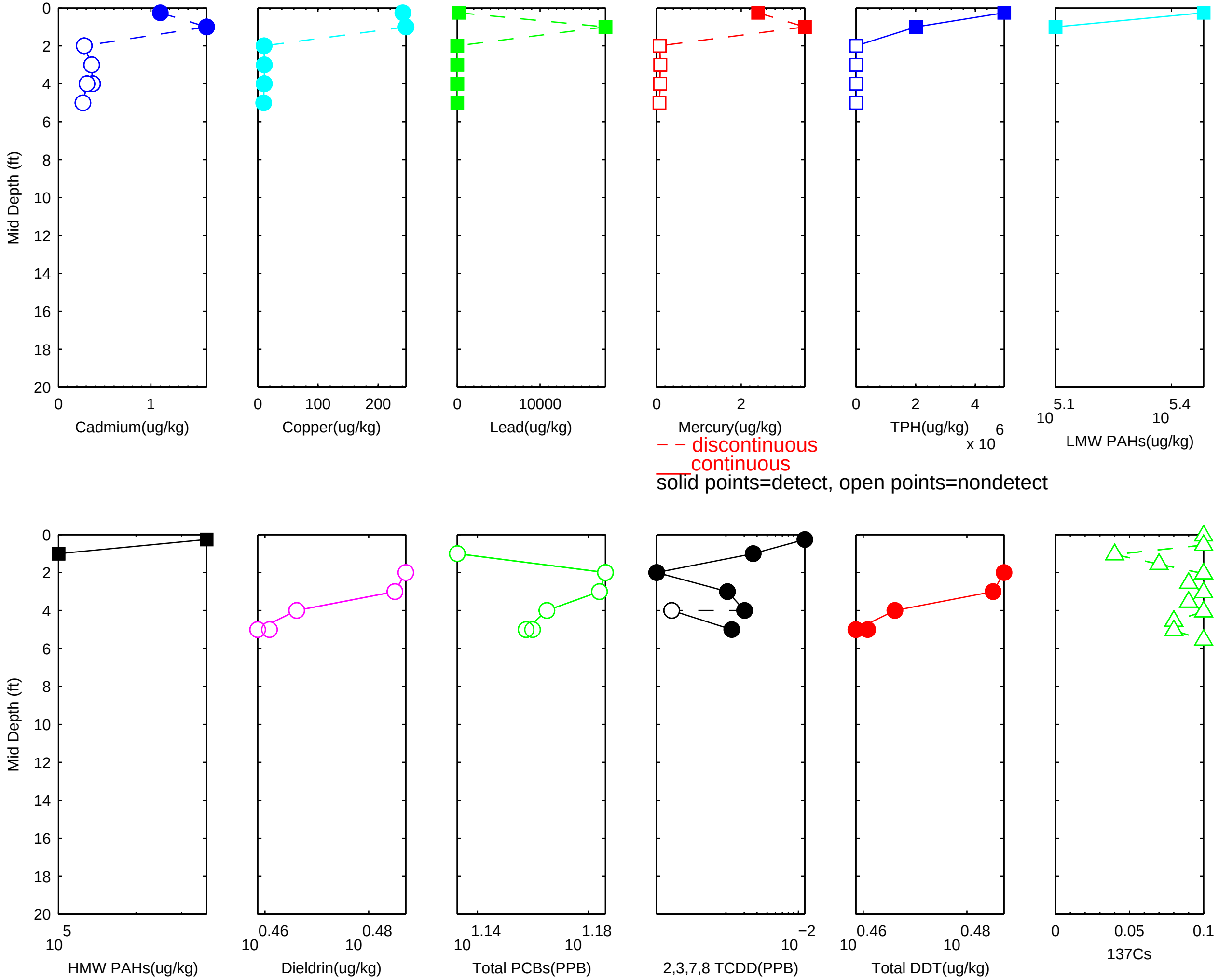
Sample ID: WTH−1 River Mile 5.39 PASSAIC 1995 USACE Minish Park Investigation



Sample ID: D03 River Mile 2.65   PASSAIC 1995 RI Sampling Program



Sample ID: D02 River Mile 3.64 PASSAIC 1995 RI Sampling Program



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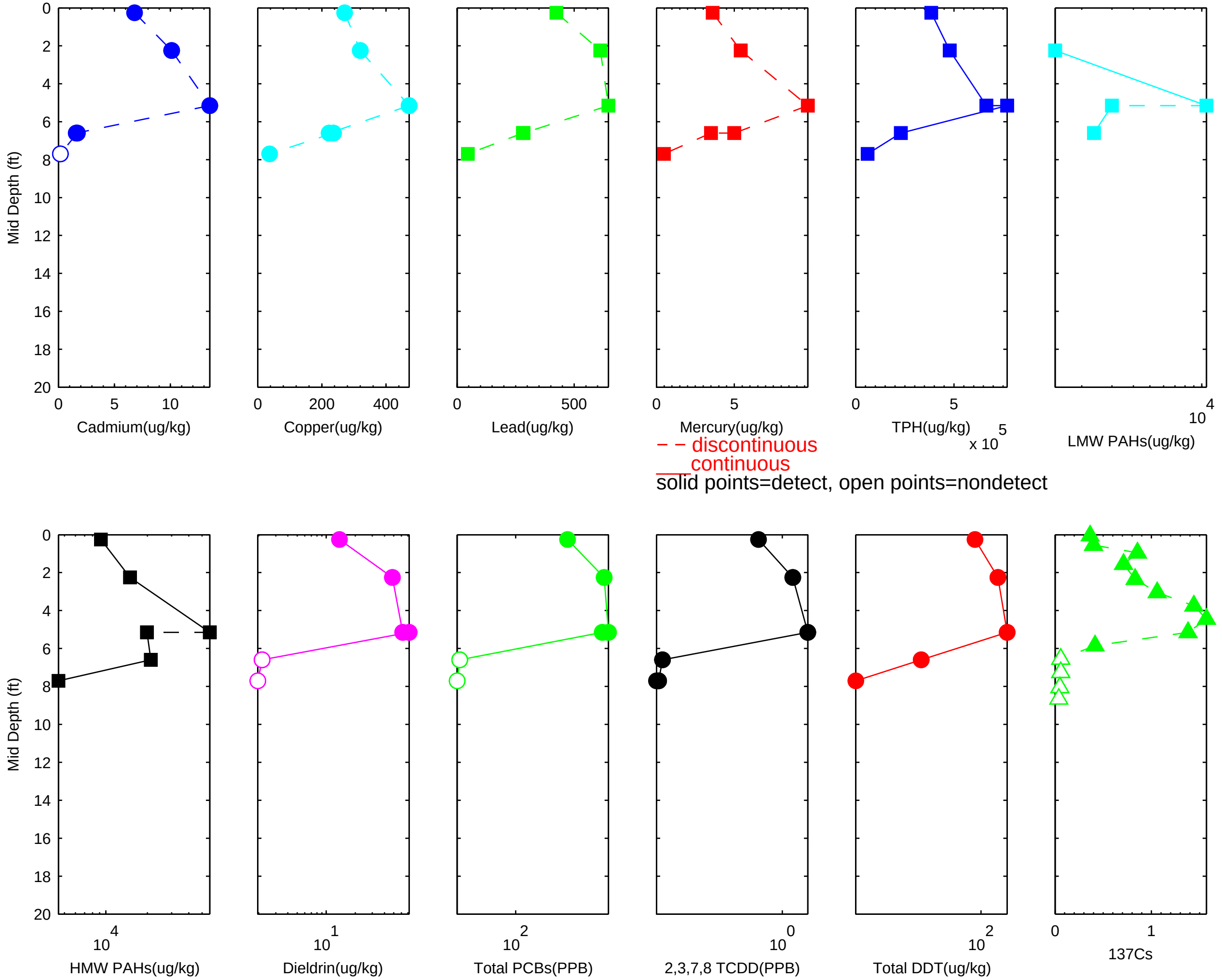

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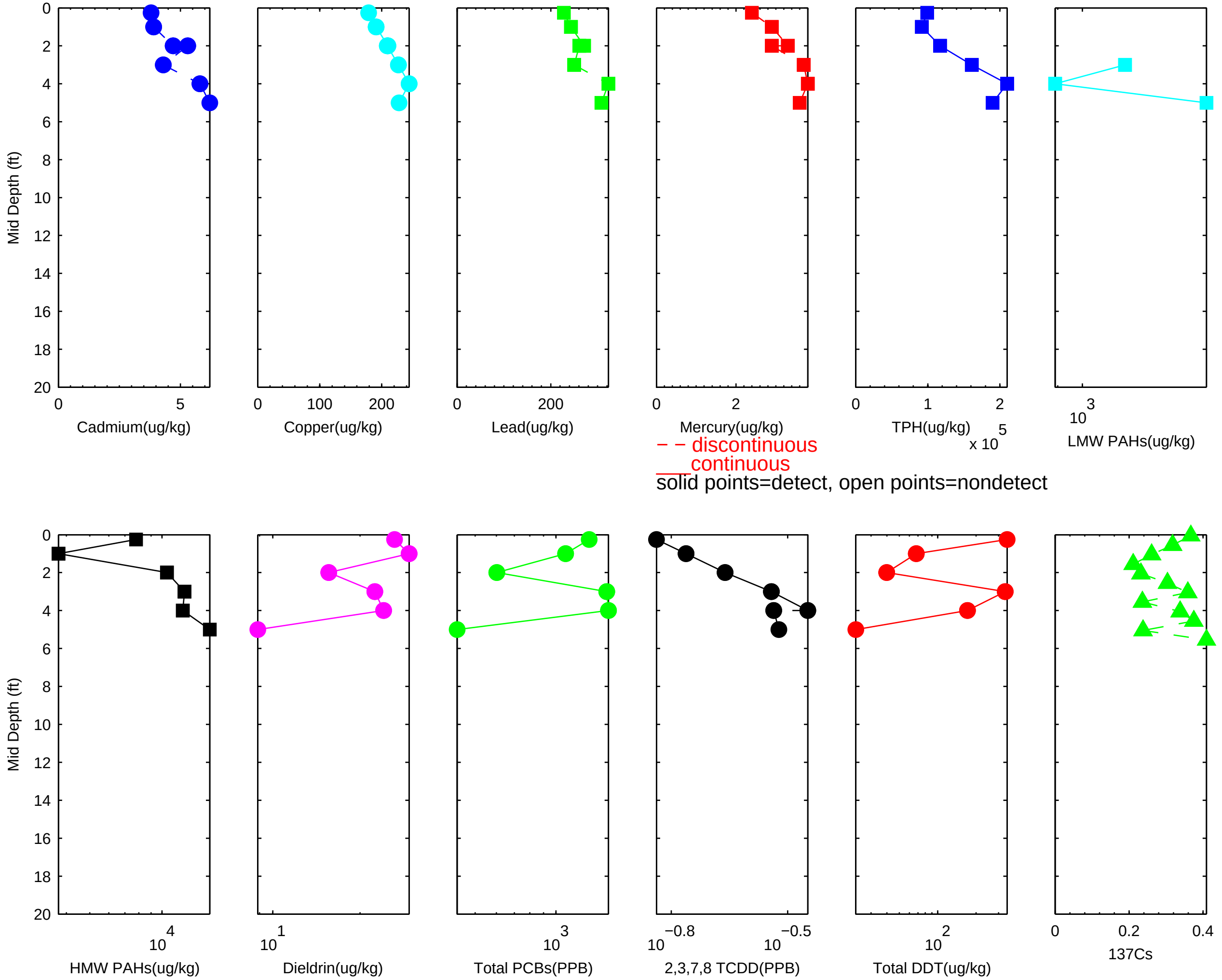
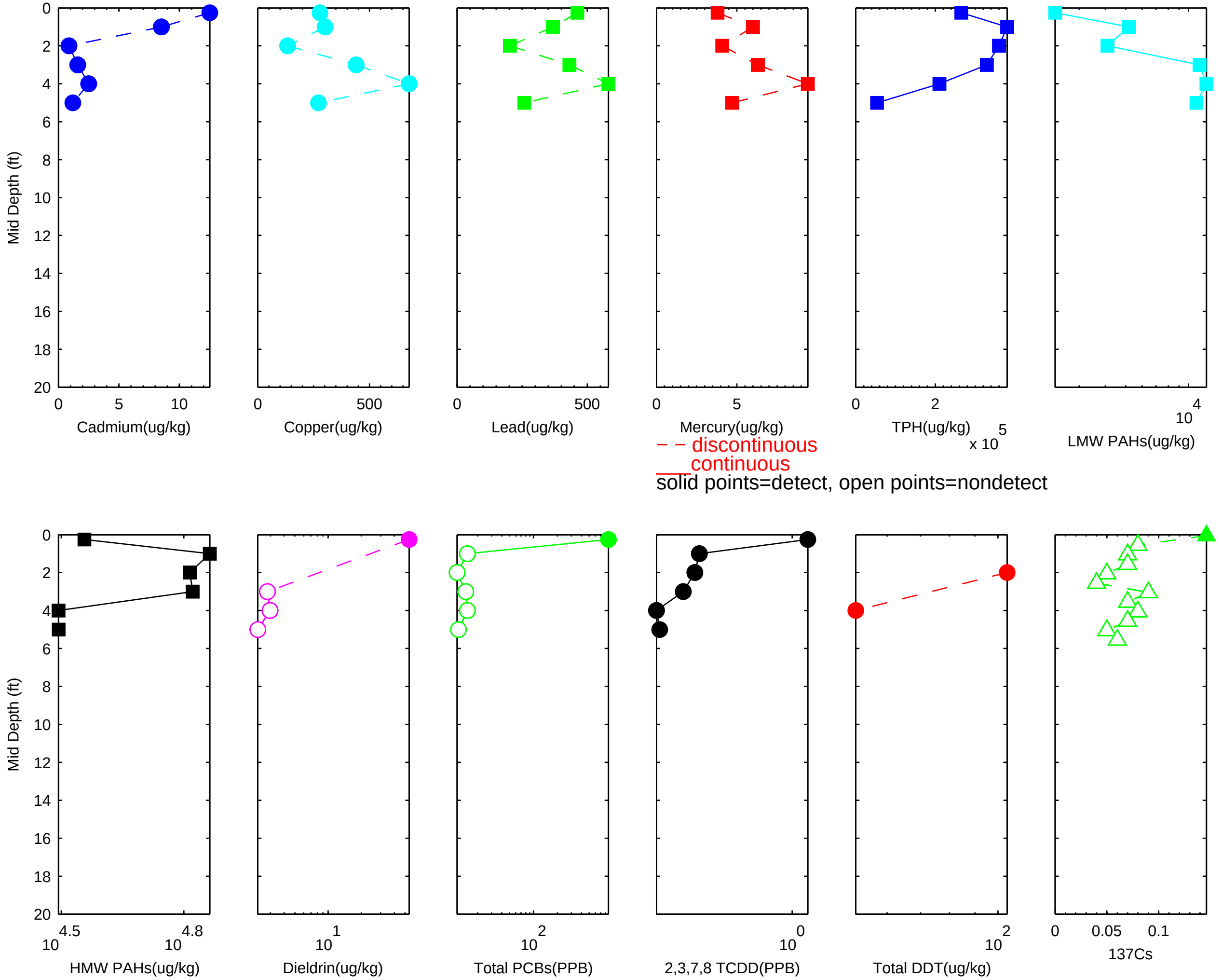


Sample ID: 294 River Mile 3.13   PASSAIC 1995 RI Sampling Program



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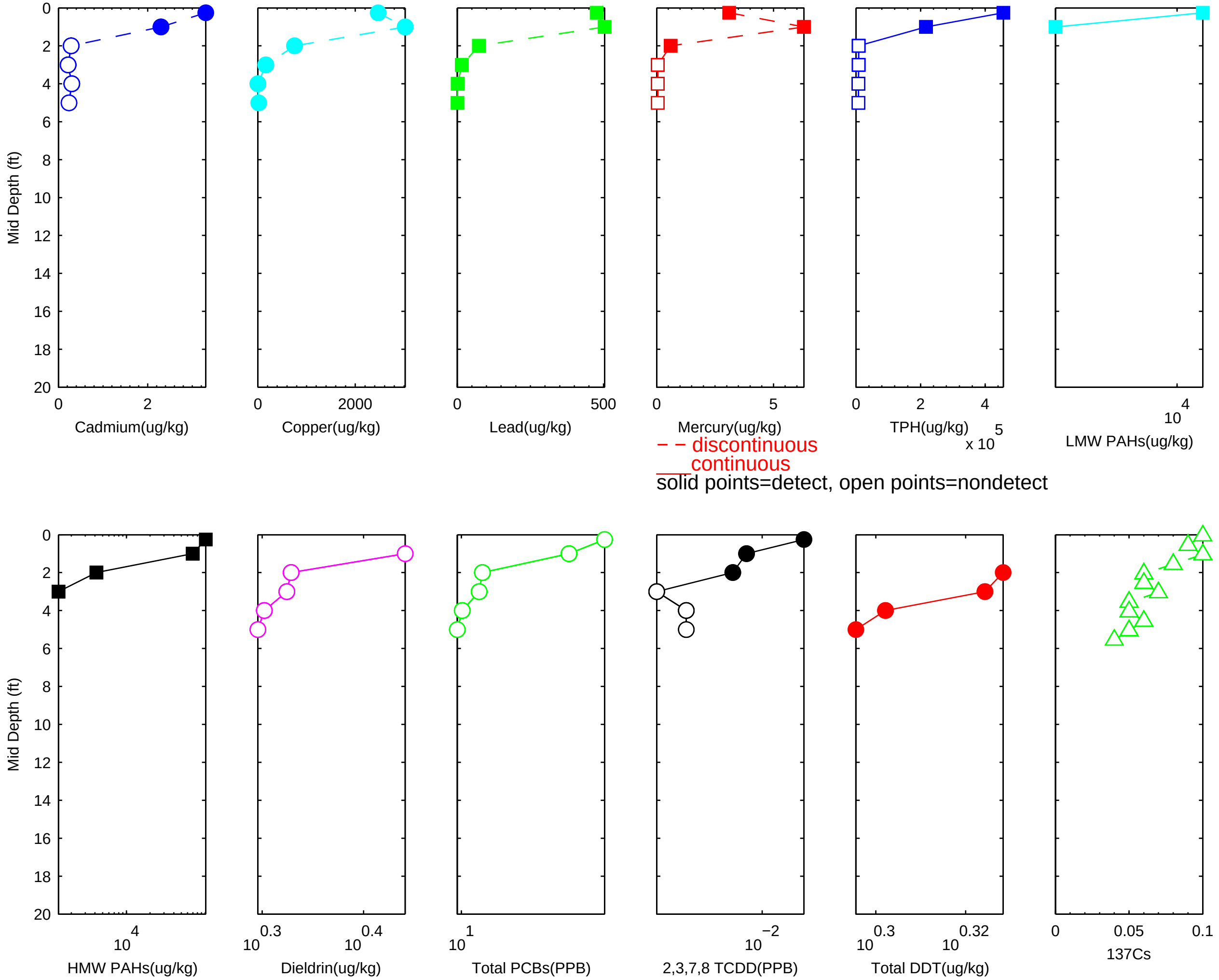

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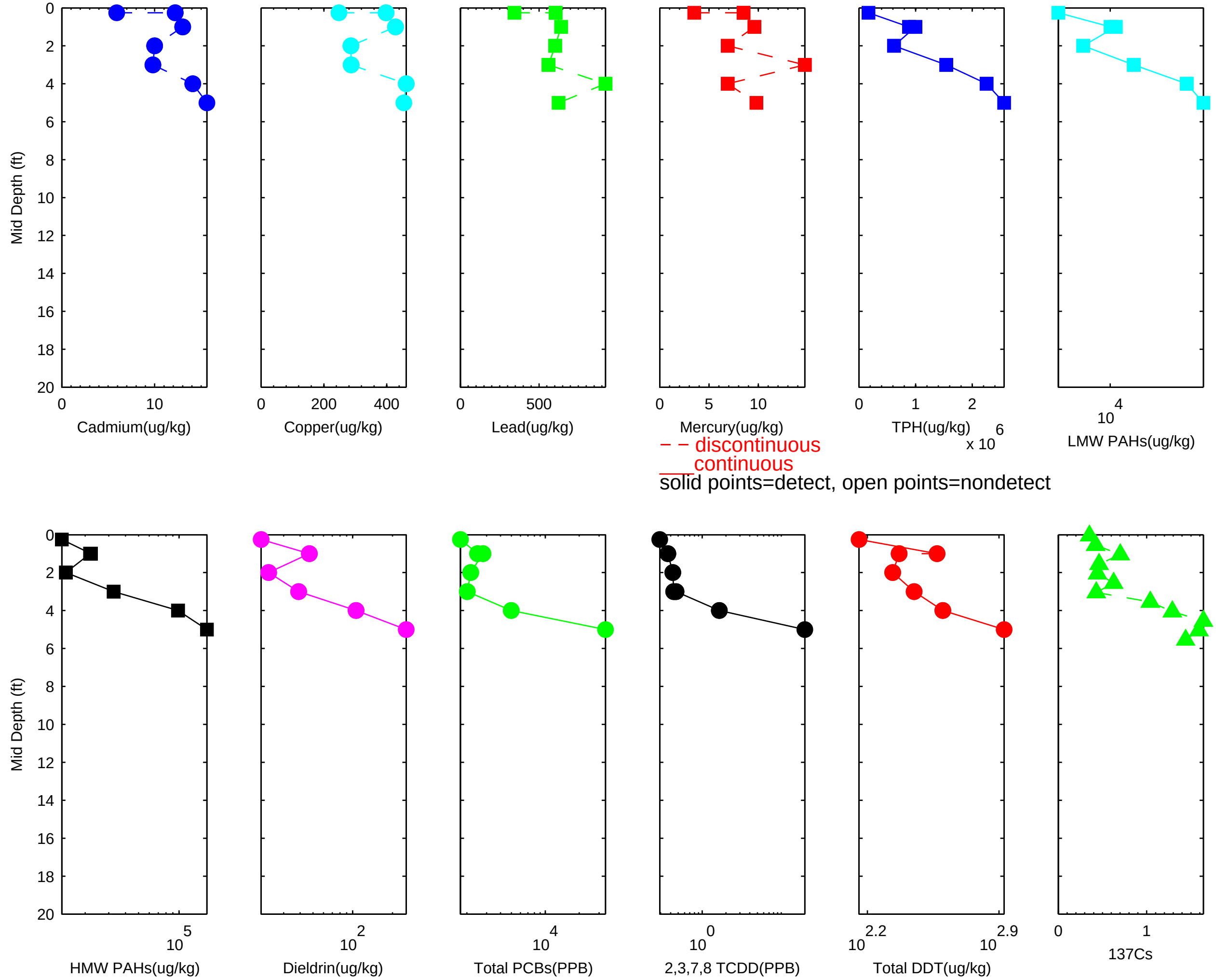
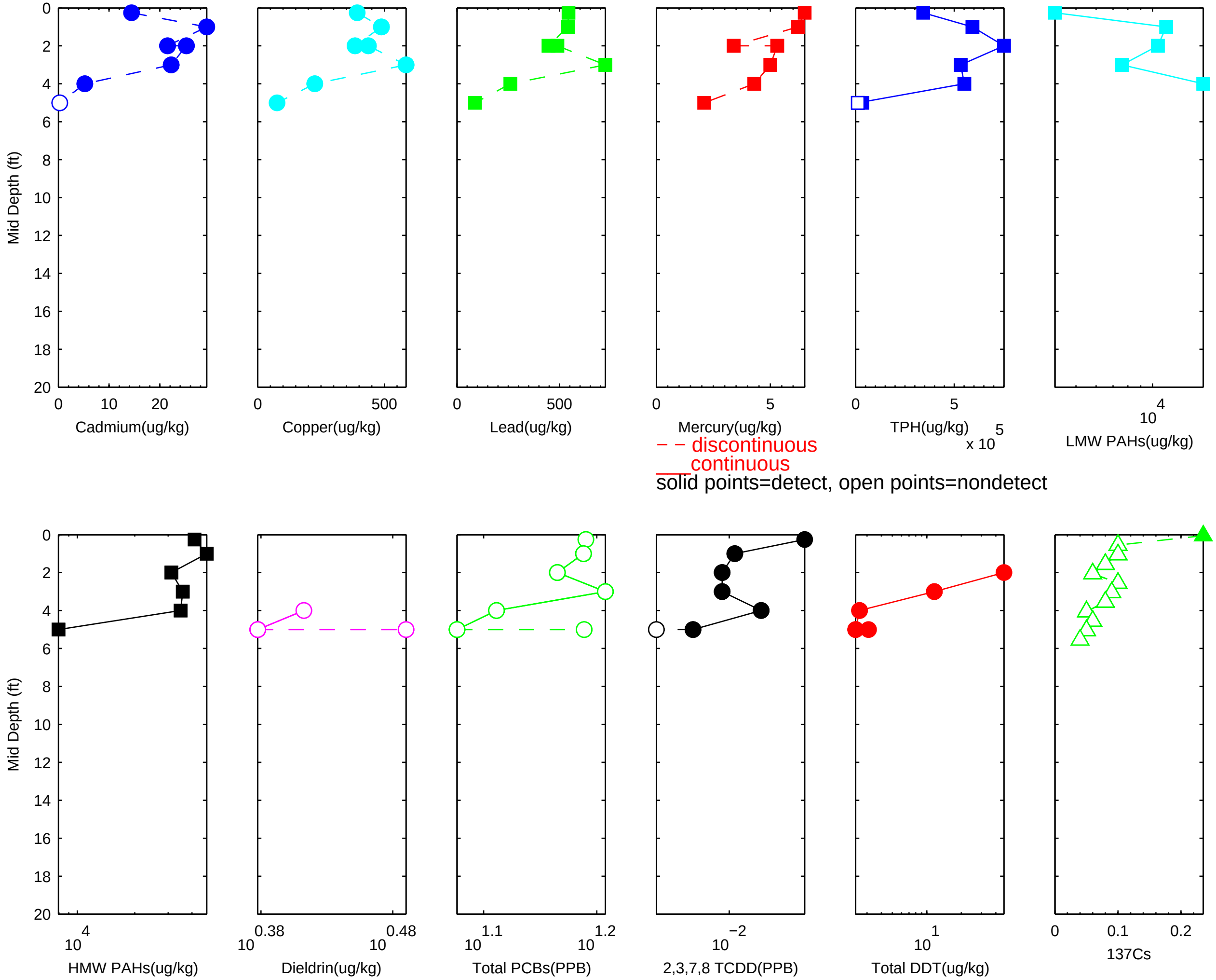
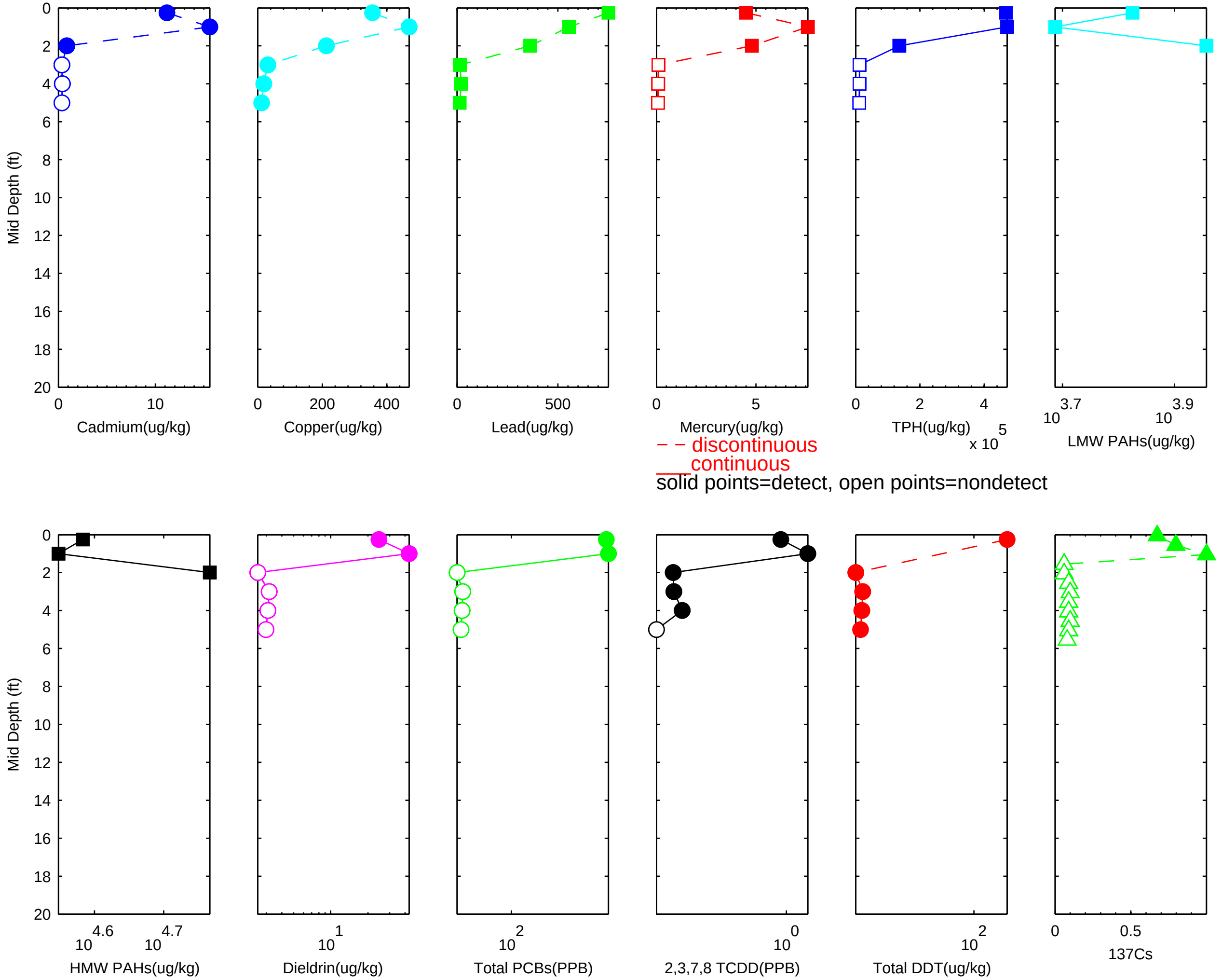


Sample ID: 291 River Mile 4.3 PASSAIC 1995 RI Sampling Program



Sample ID: 290 River Mile 4.24   PASSAIC 1995 RI Sampling Program



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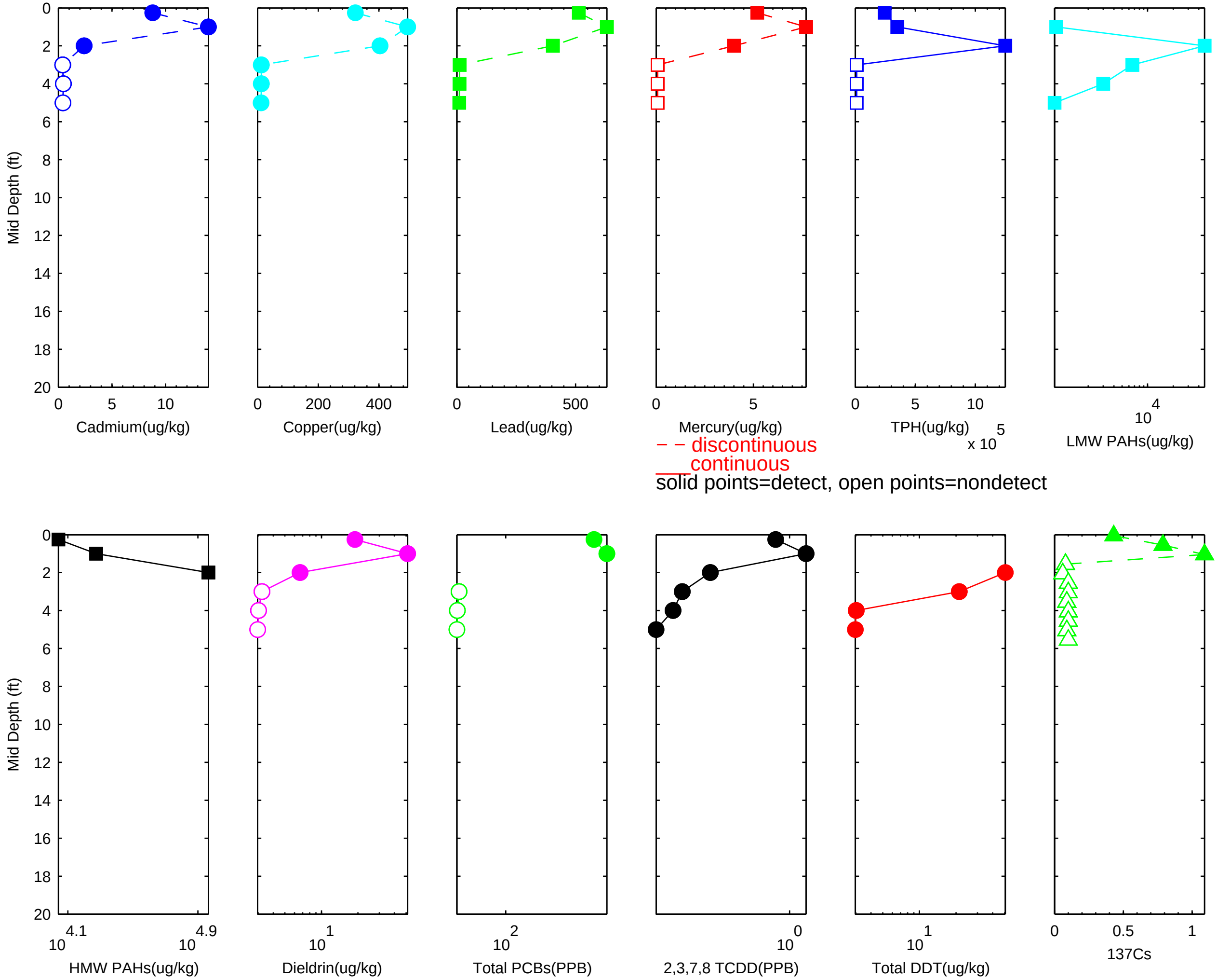
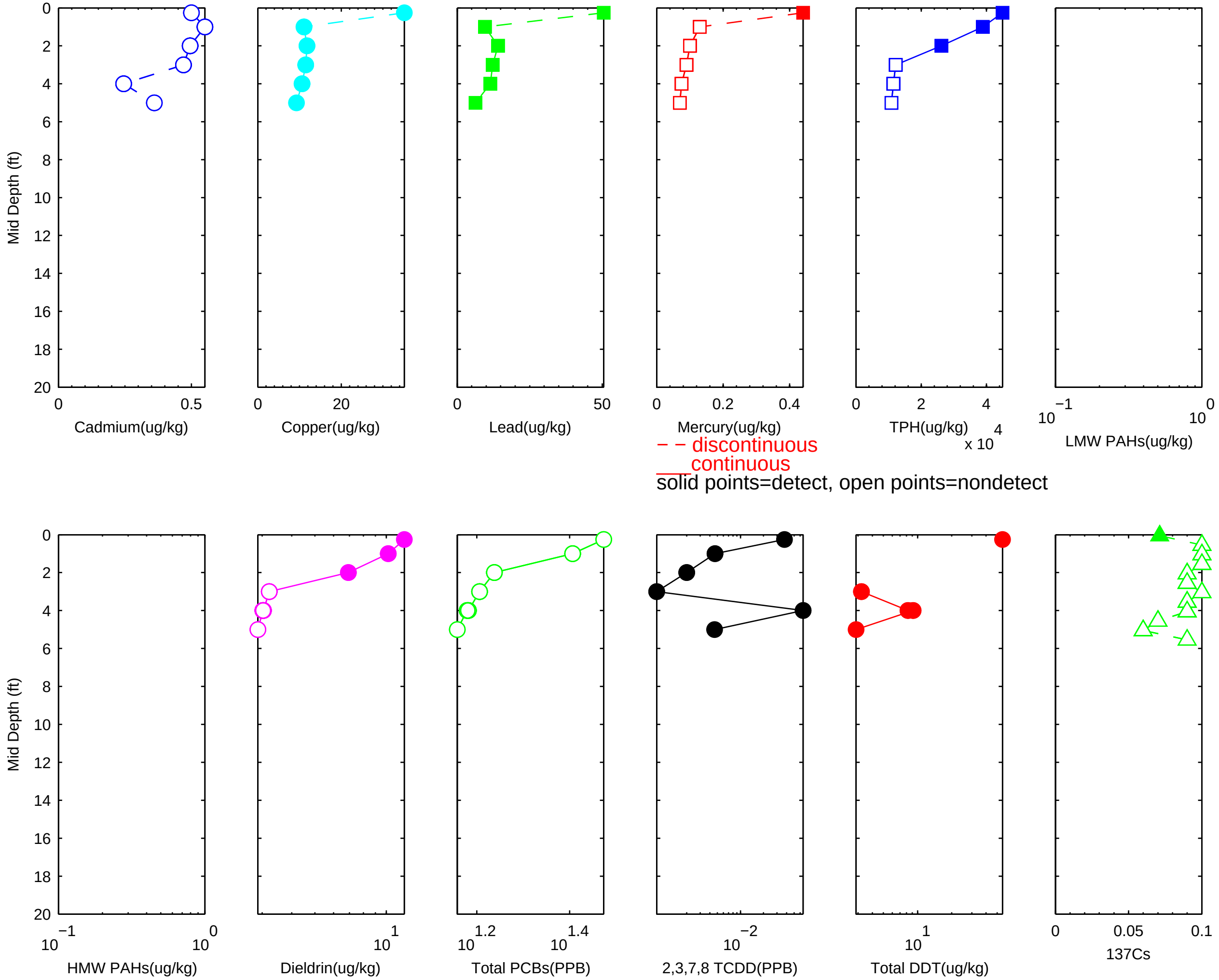
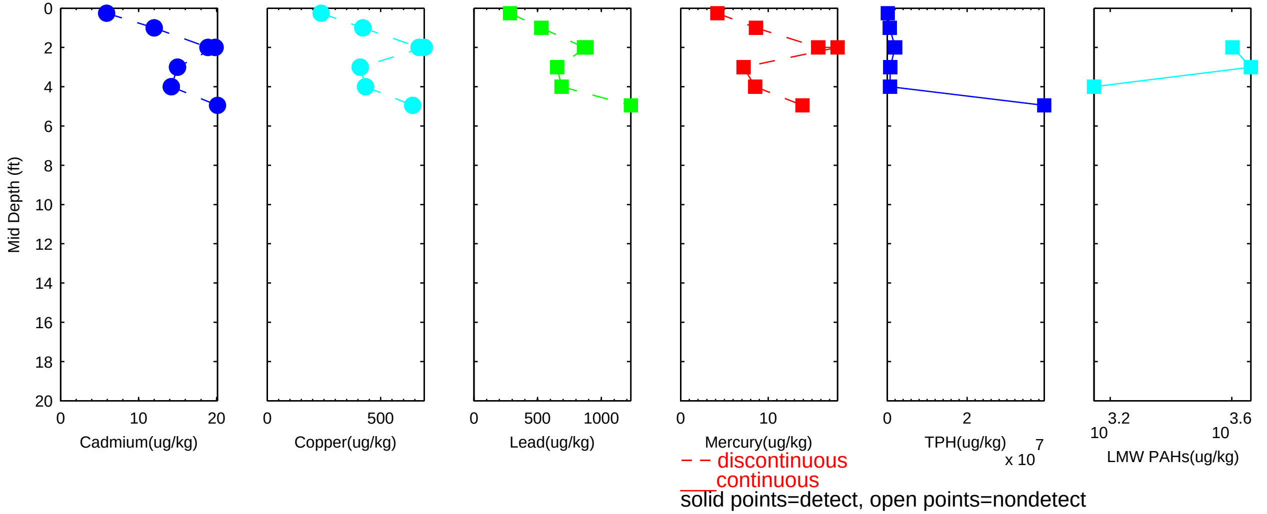
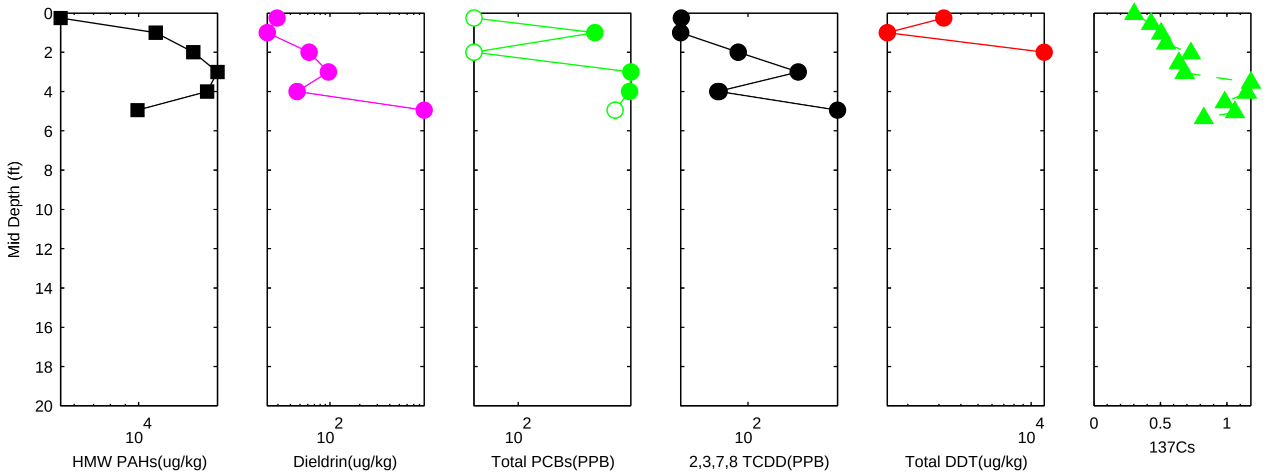


Sample ID: 287 River Mile 3.58 PASSAIC 1995 RI Sampling Program



Sample ID: 285 River Mile 3.14   PASSAIC 1995 RI Sampling Program





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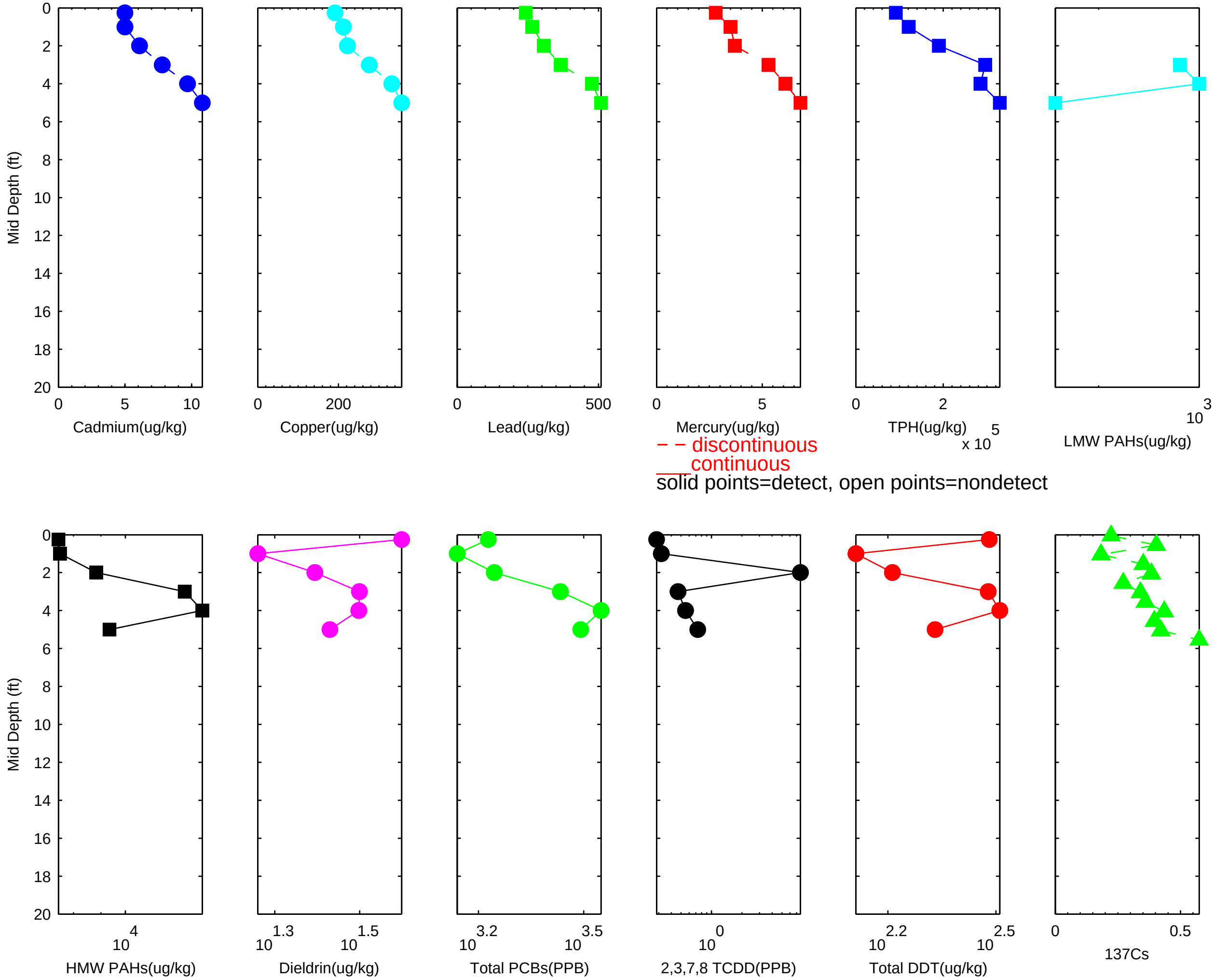
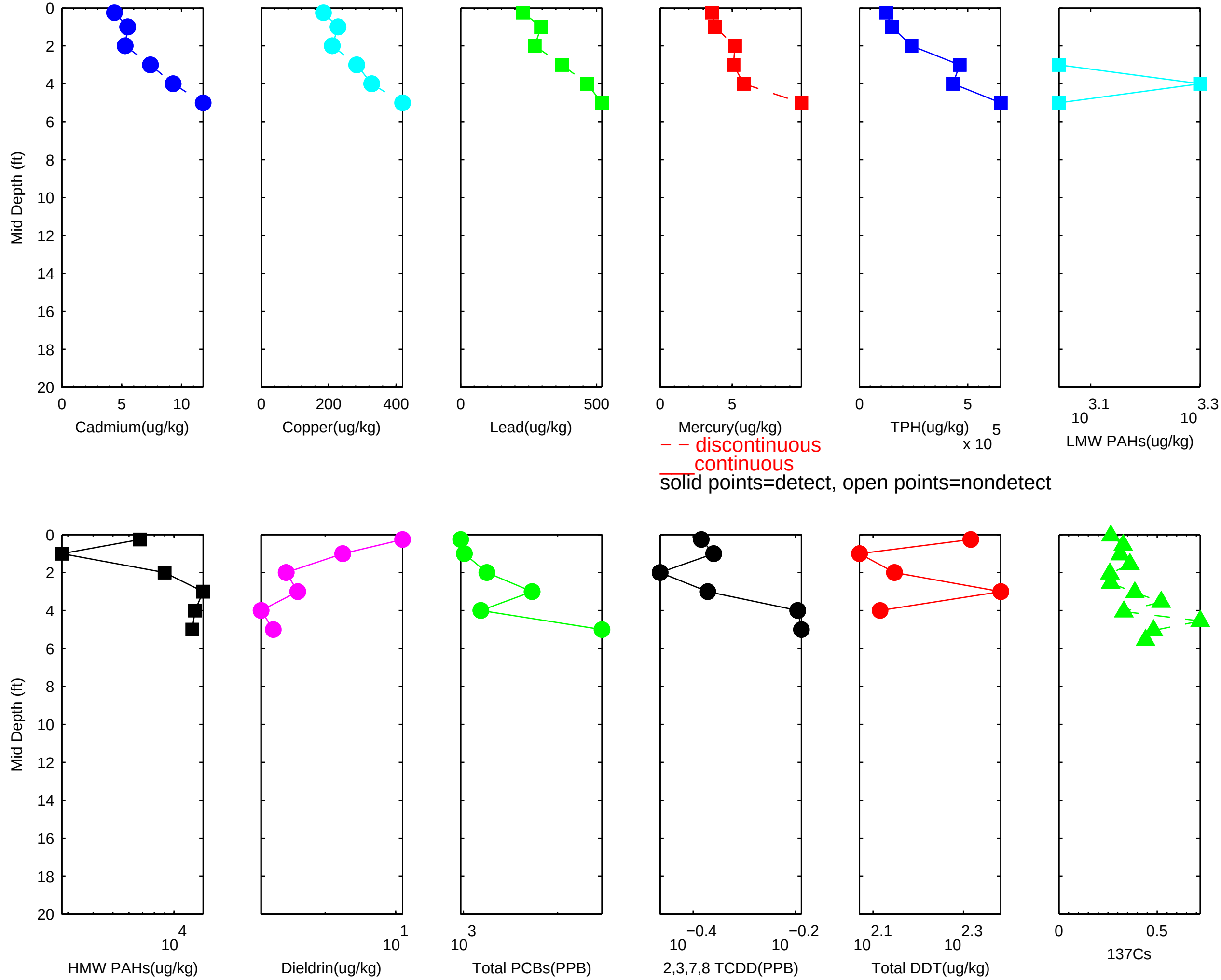
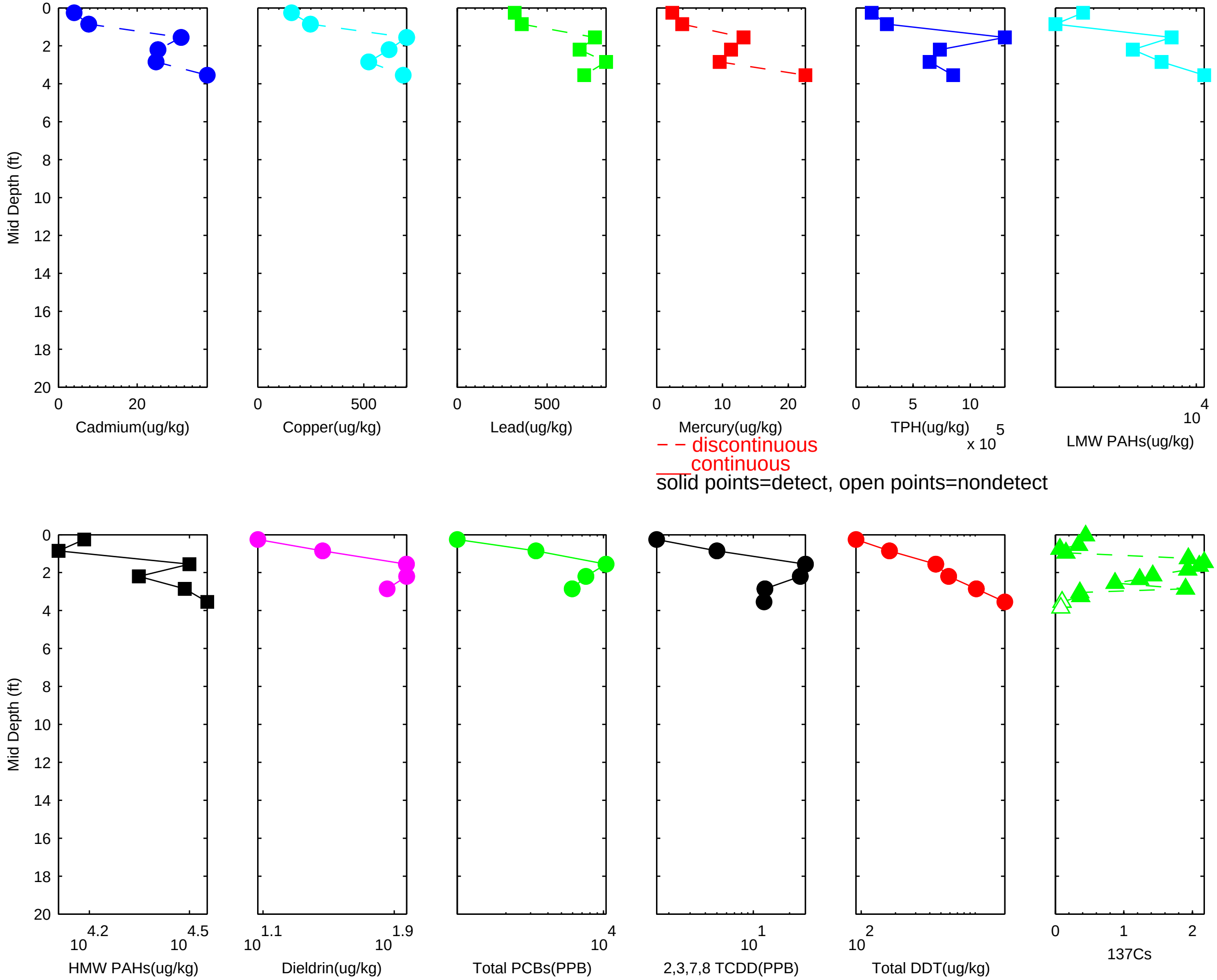


Sample ID: 282 River Mile 2.17 PASSAIC 1995 RI Sampling Program



Sample ID: 278 River Mile 6.74 PASSAIC 1995 RI Sampling Program



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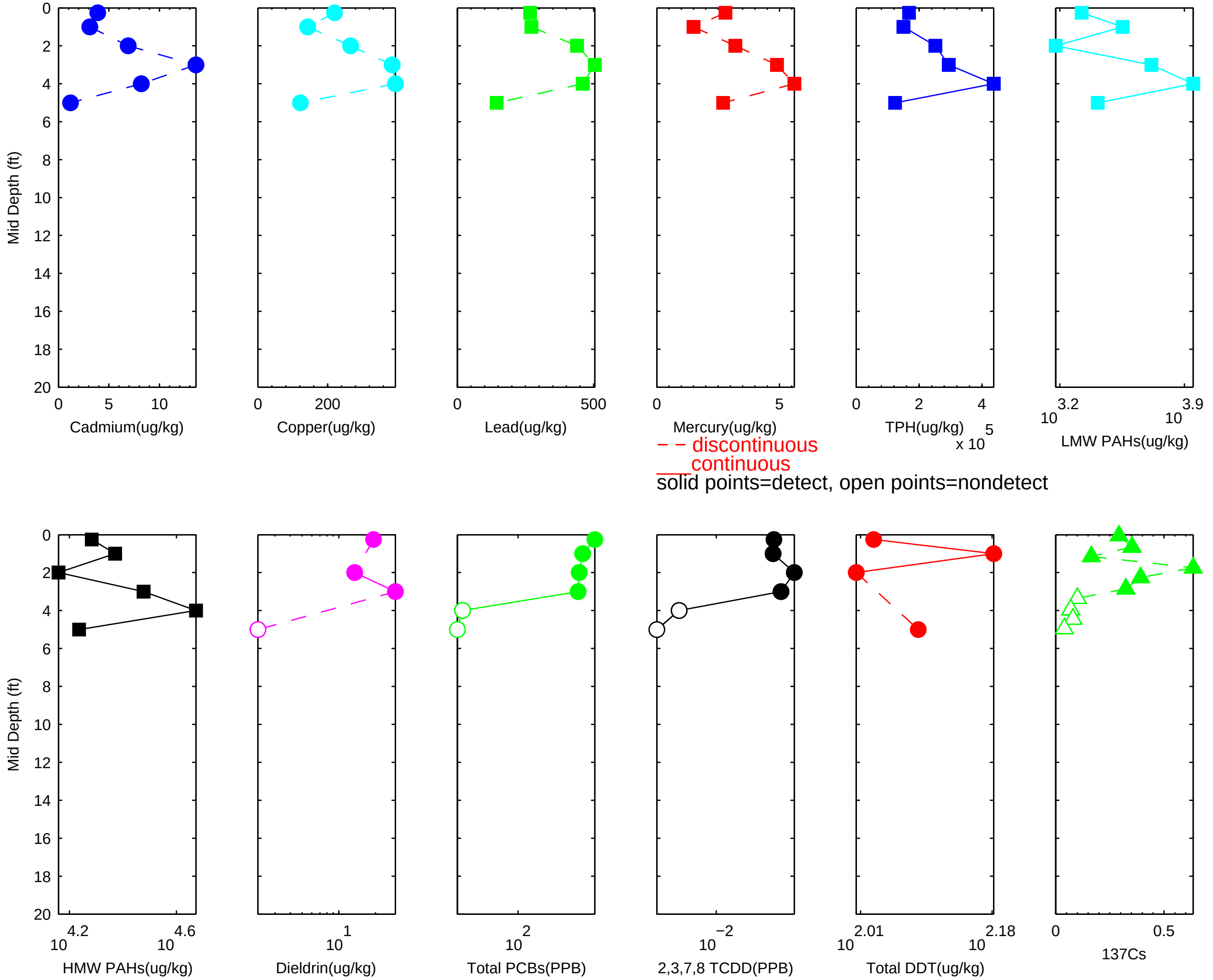

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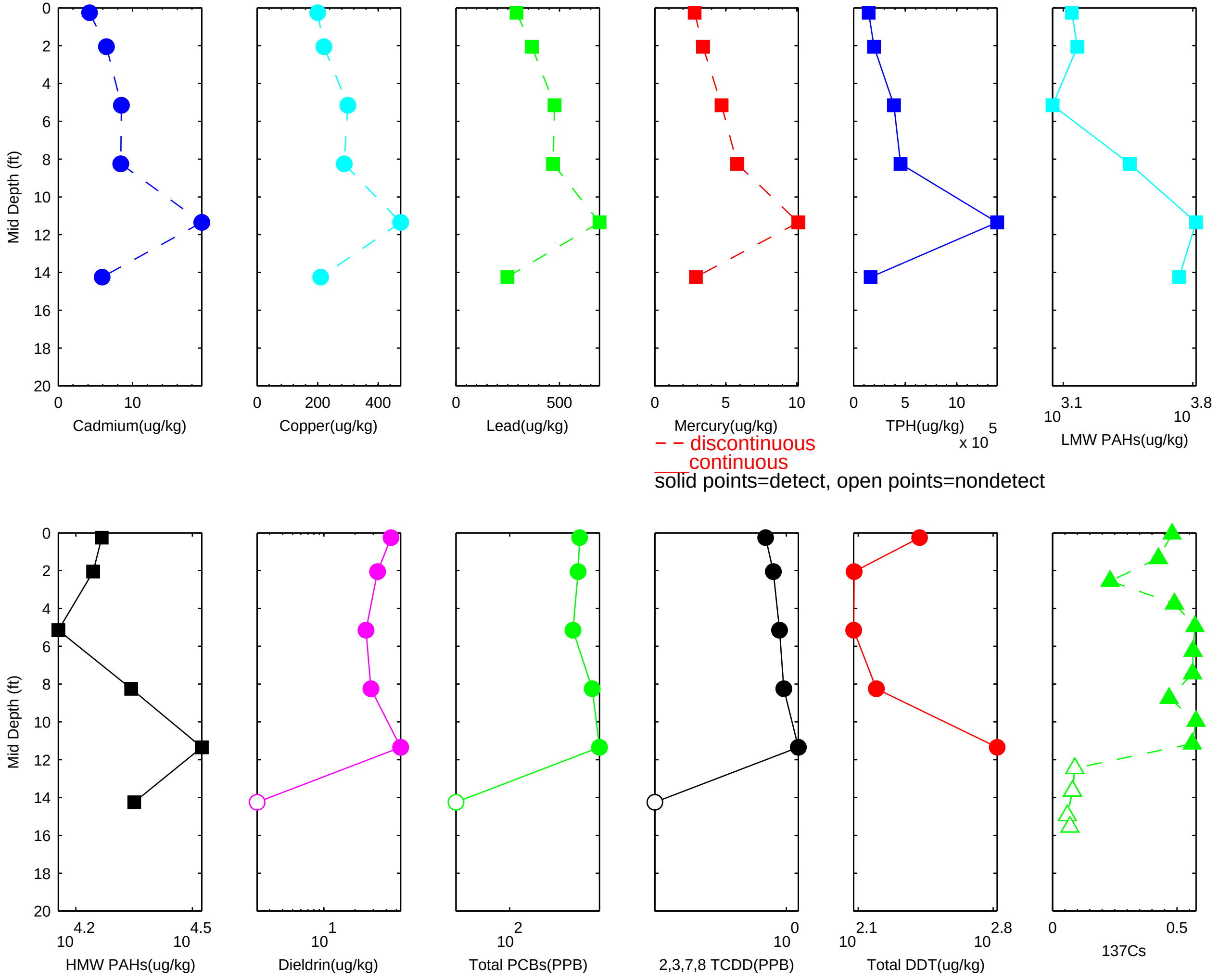

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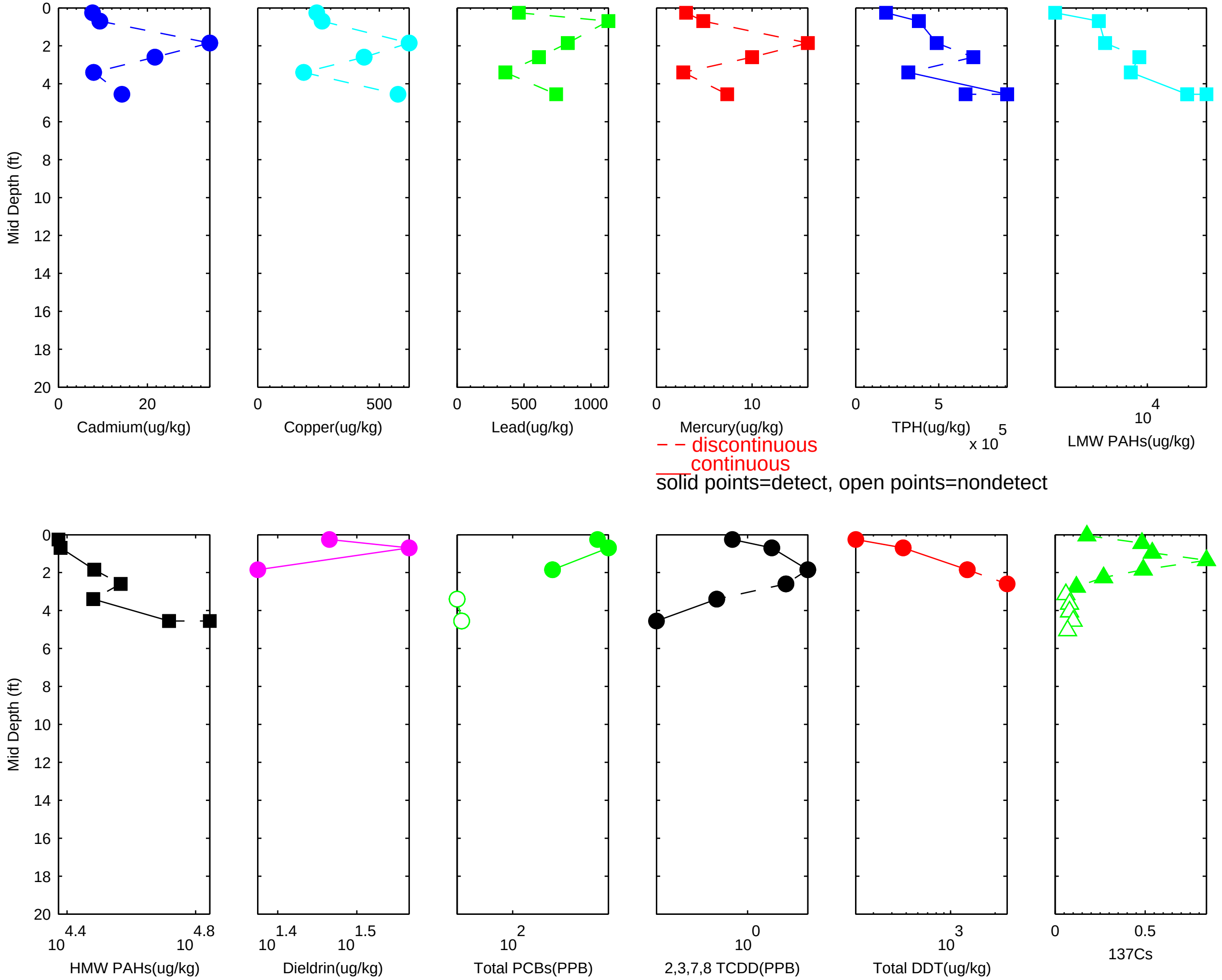

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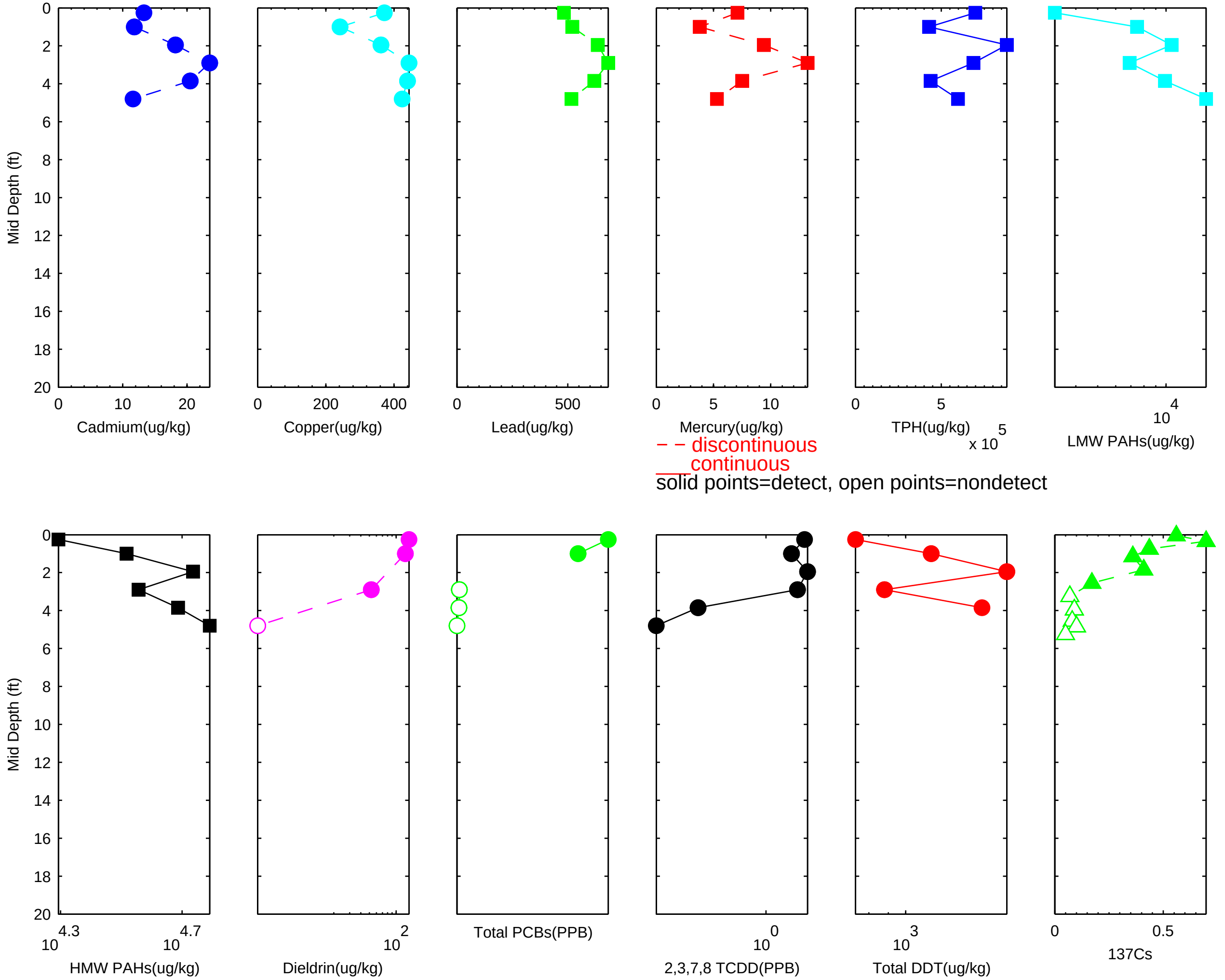
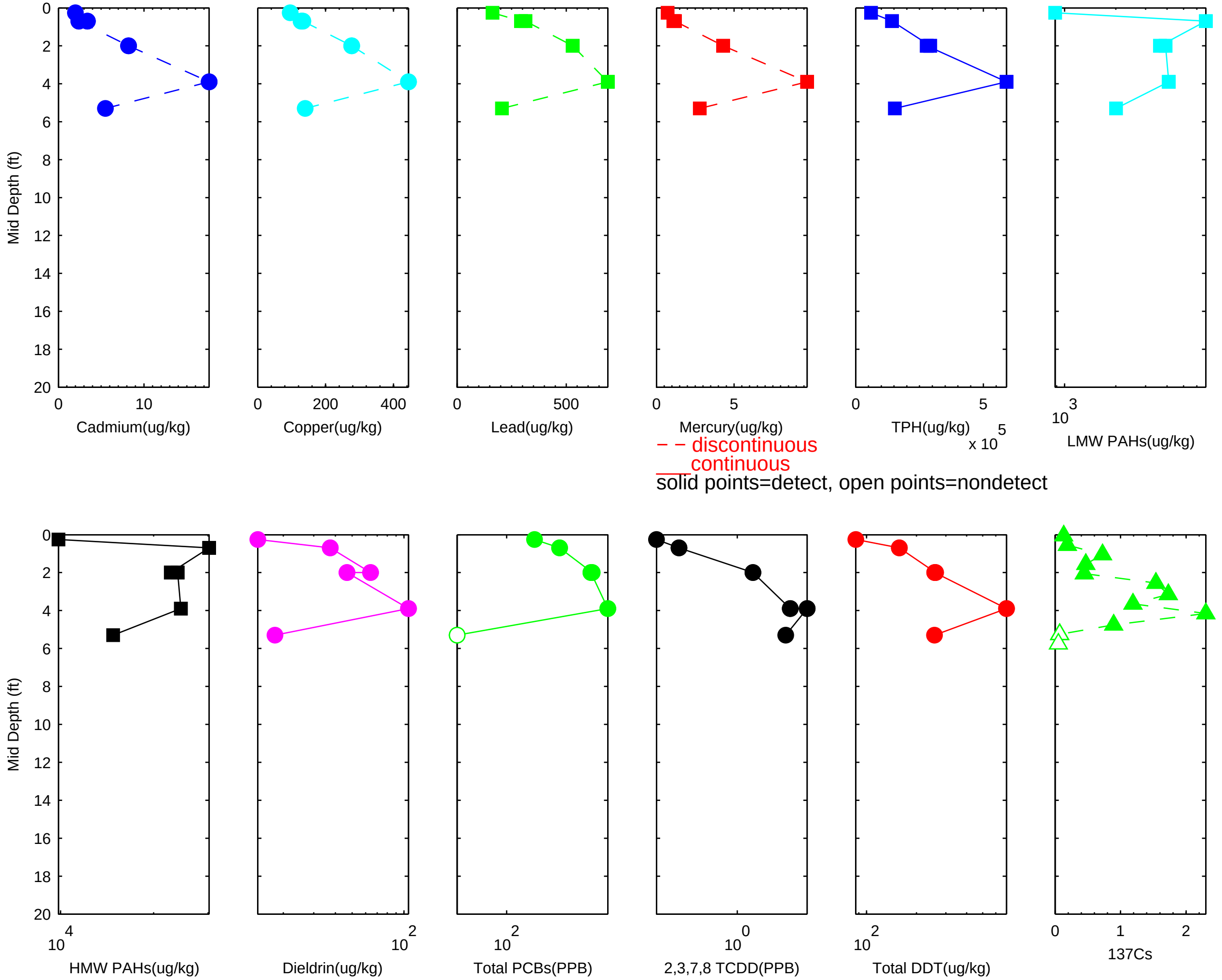


Sample ID: 271 River Mile 6.28 PASSAIC 1995 RI Sampling Program



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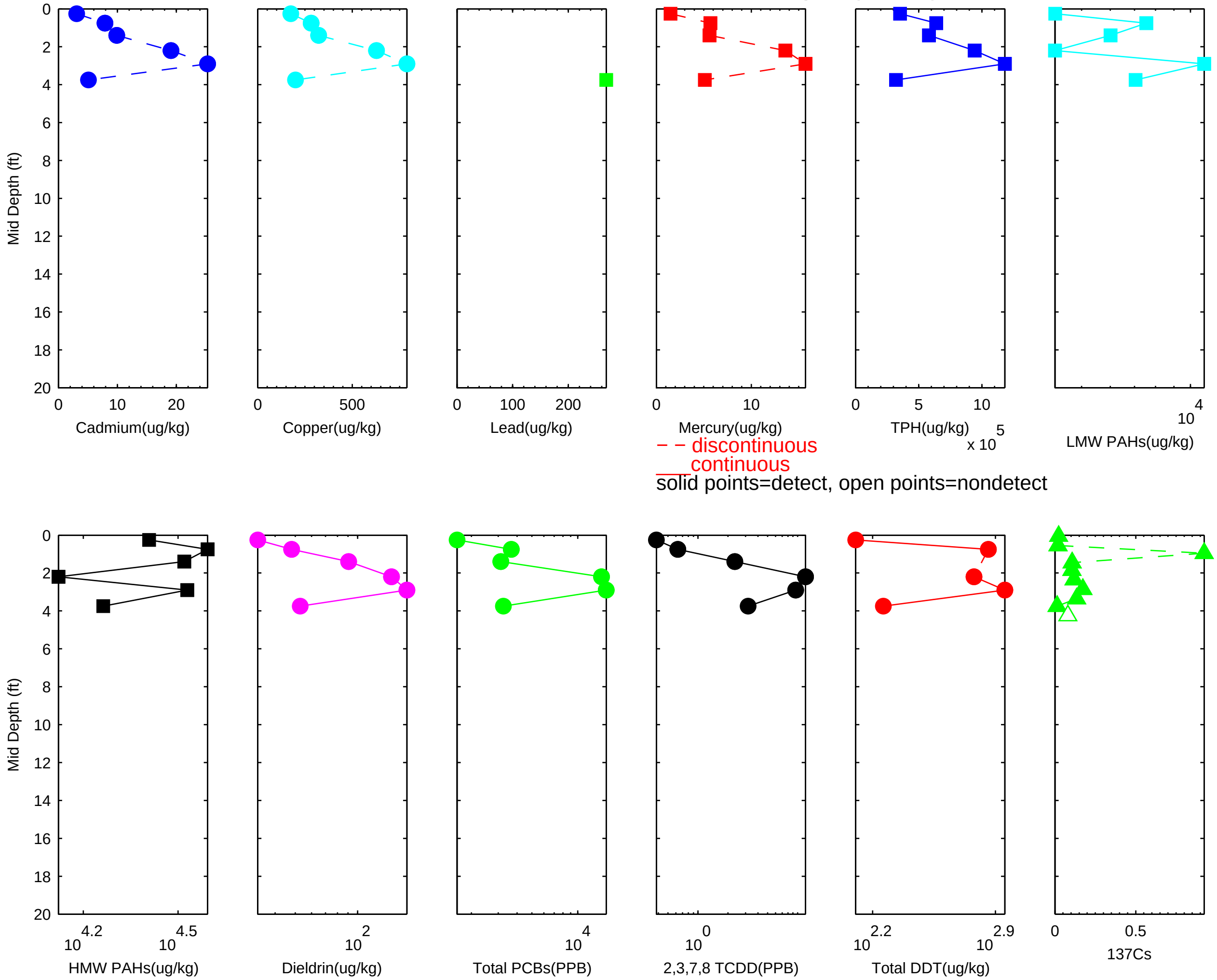
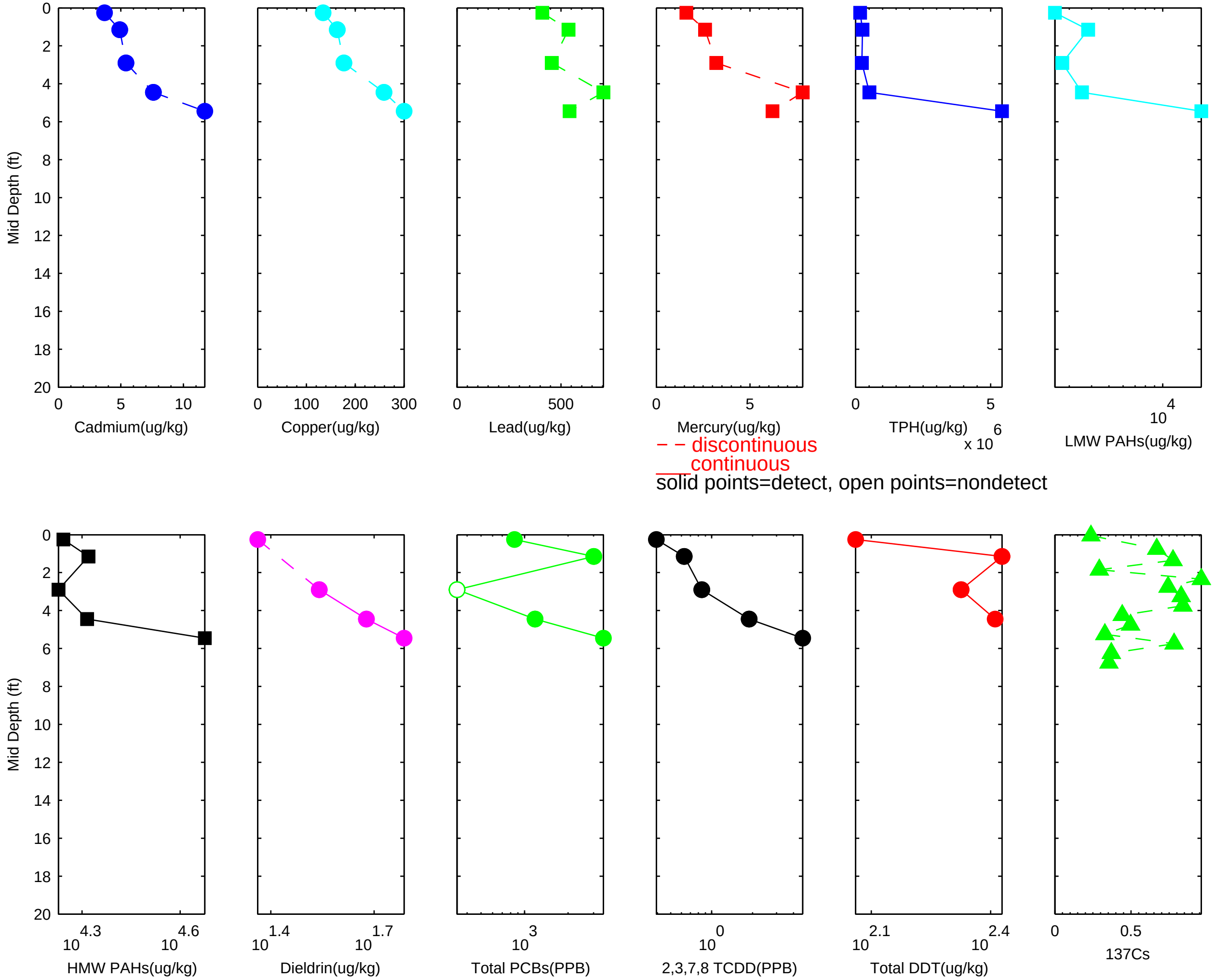


Sample ID: 269 River Mile 5.96 PASSAIC 1995 RI Sampling Program



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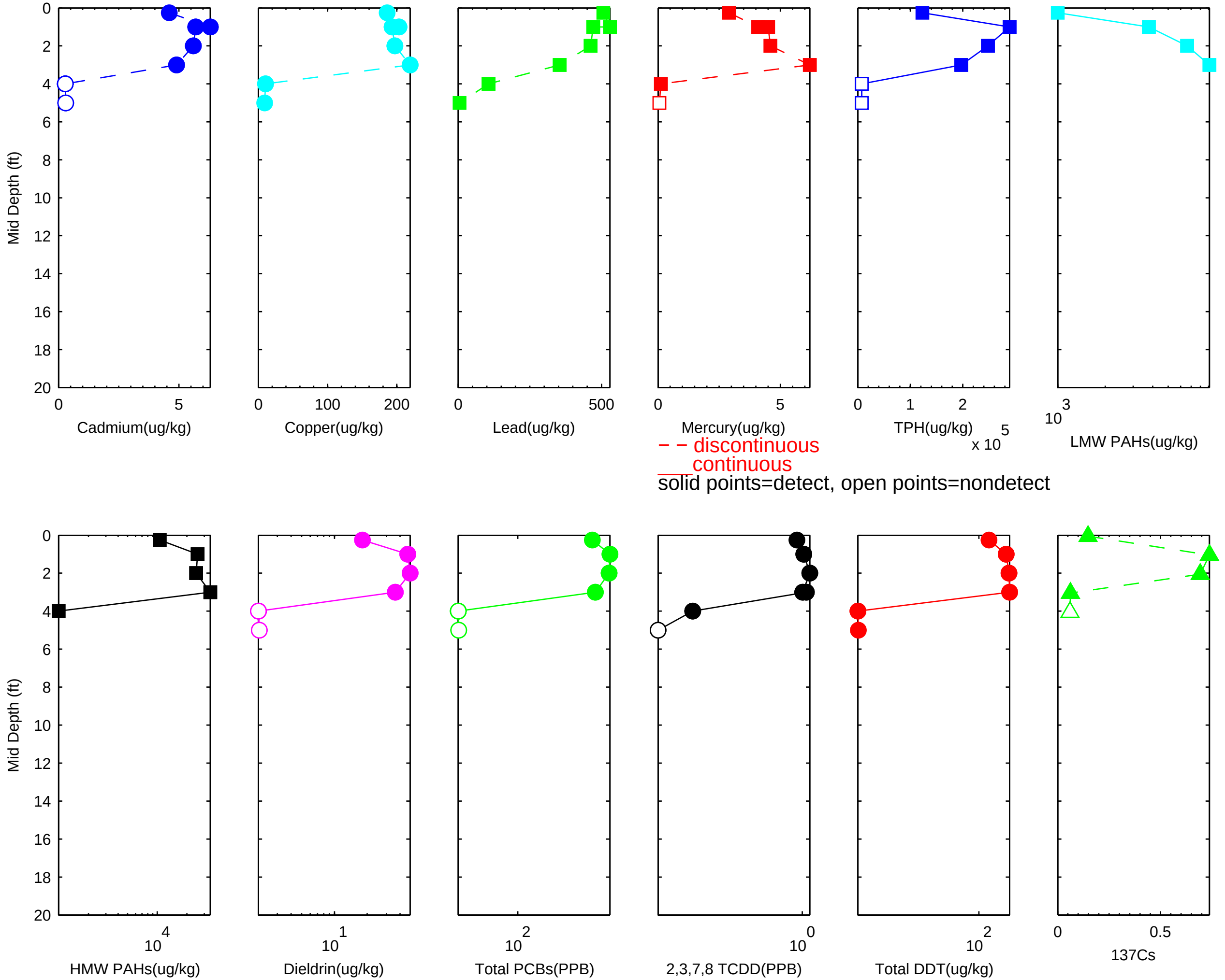

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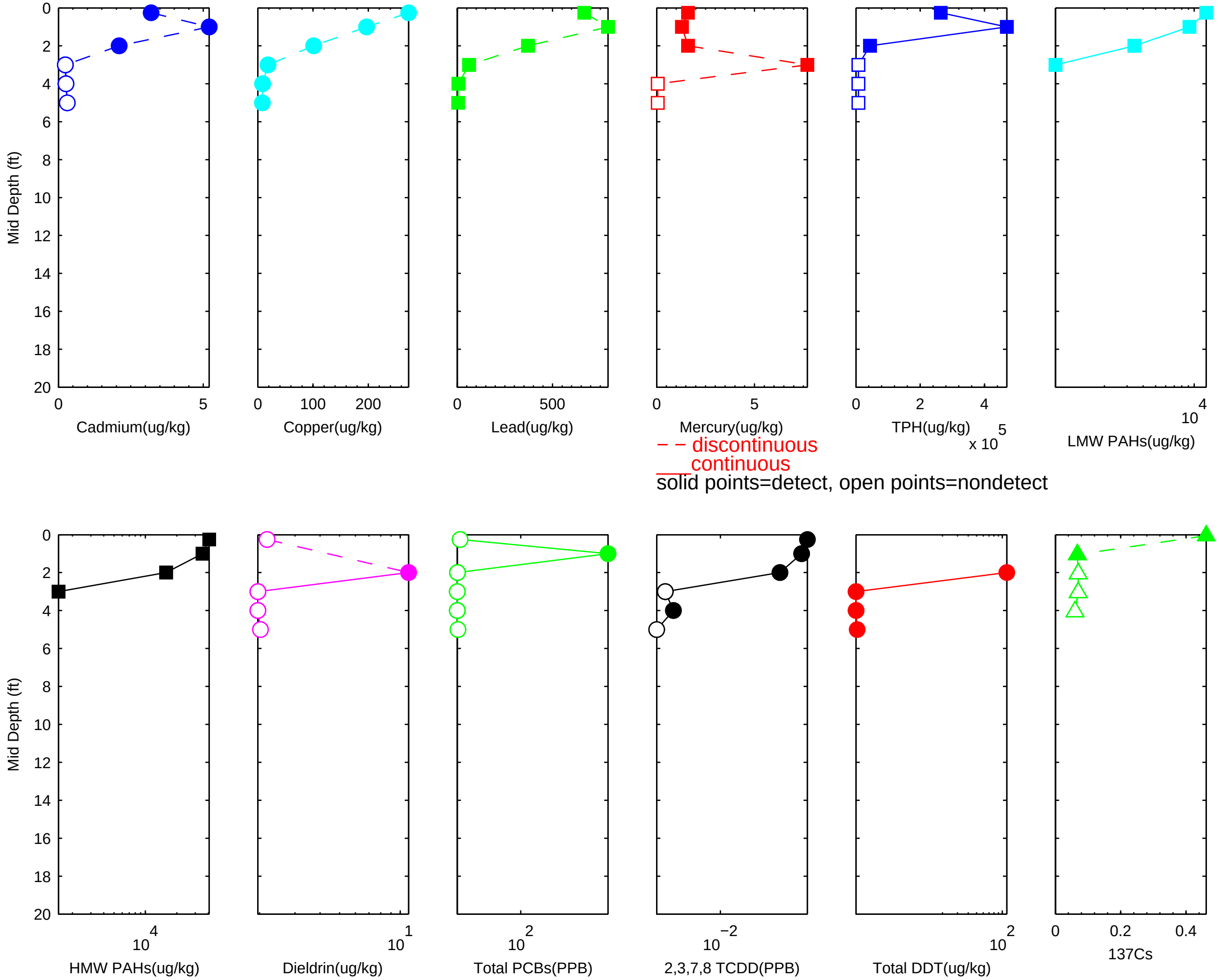

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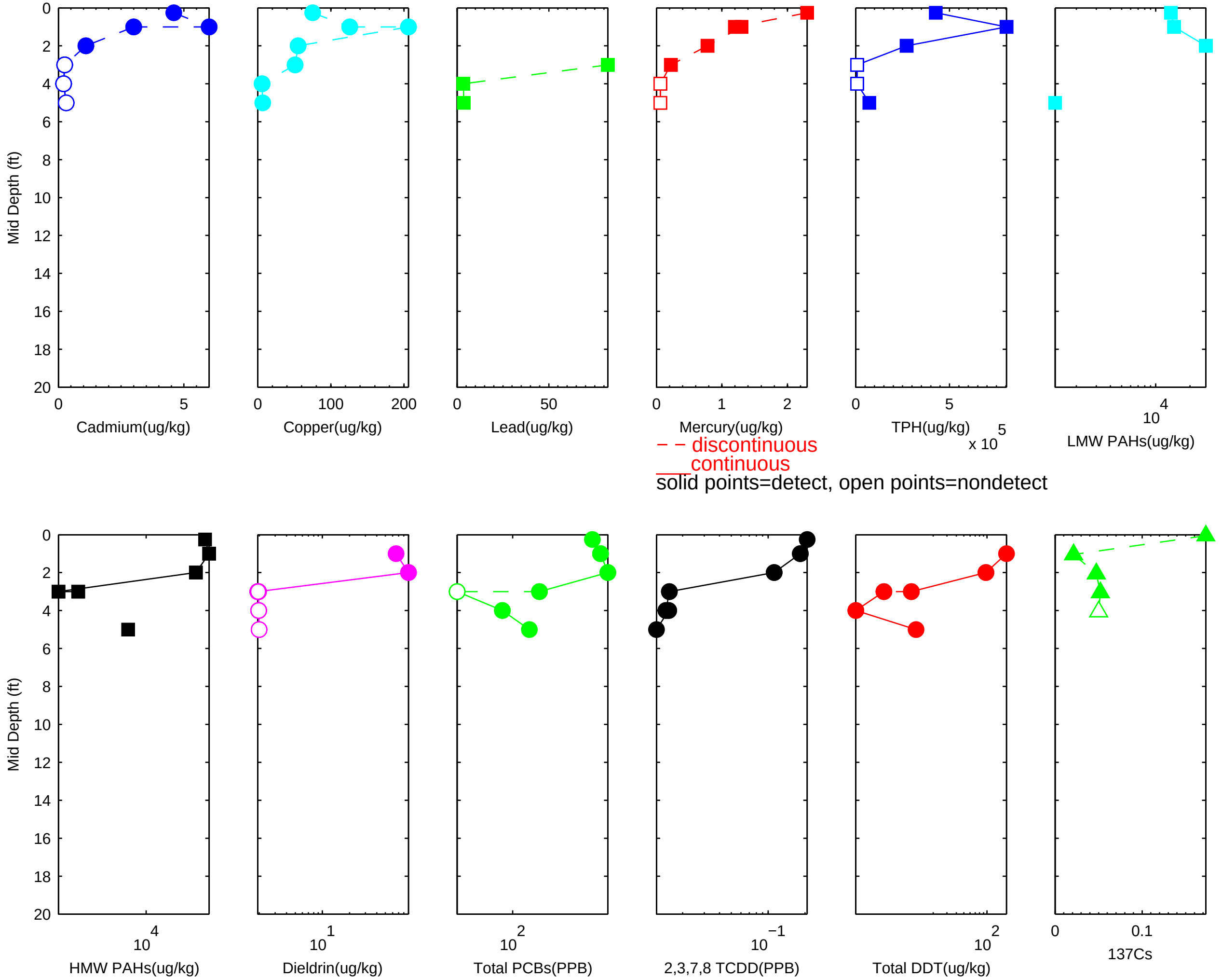

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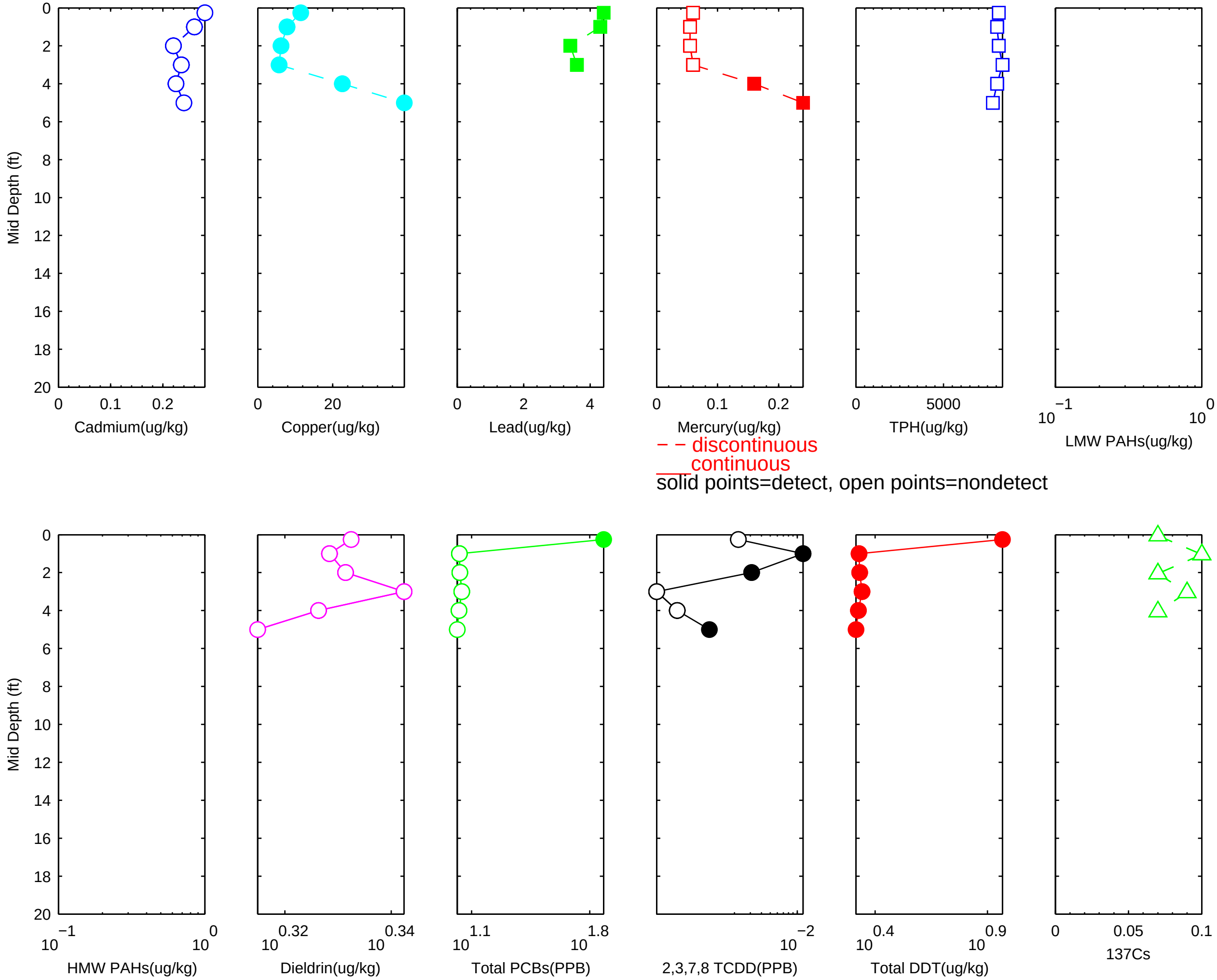

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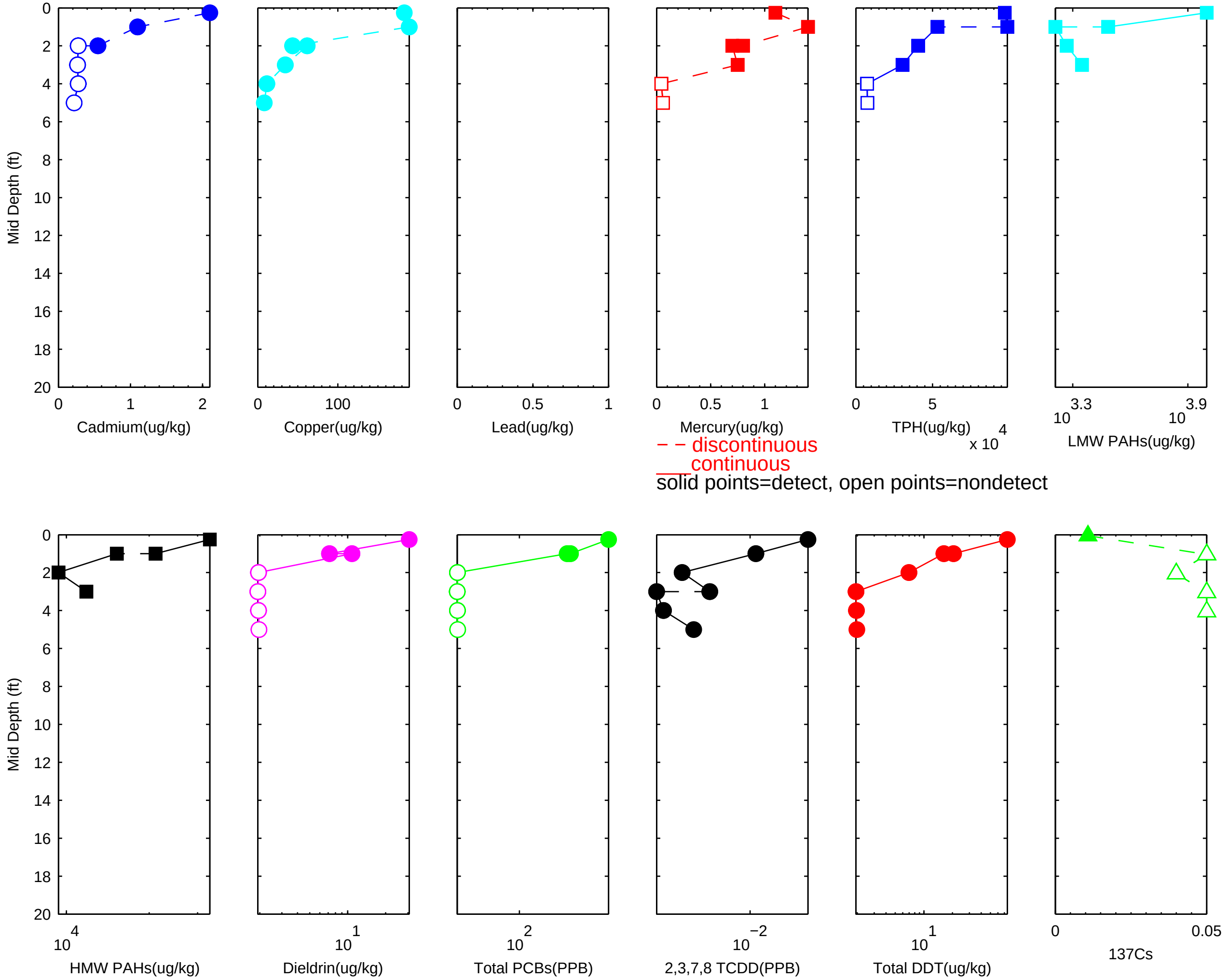

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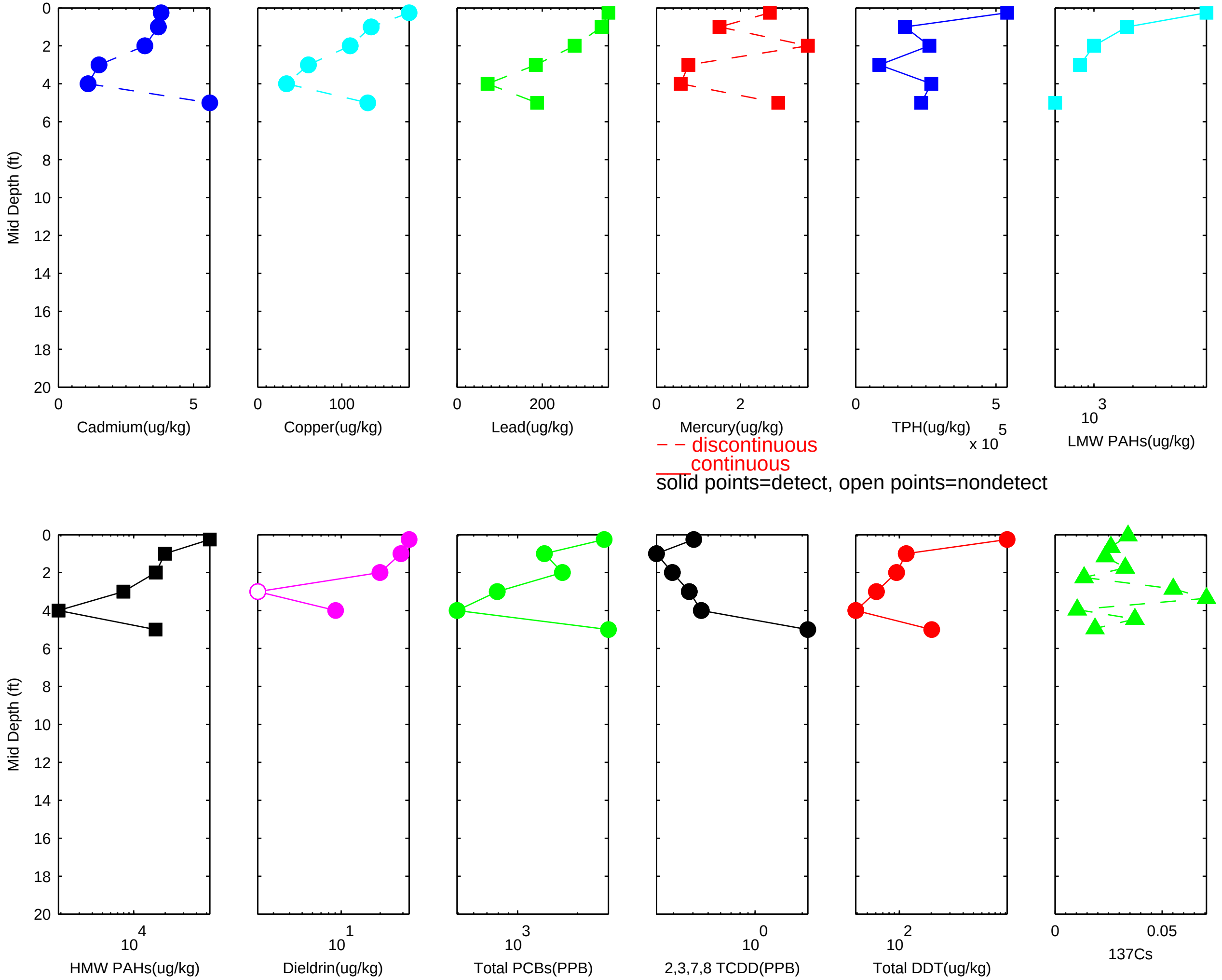

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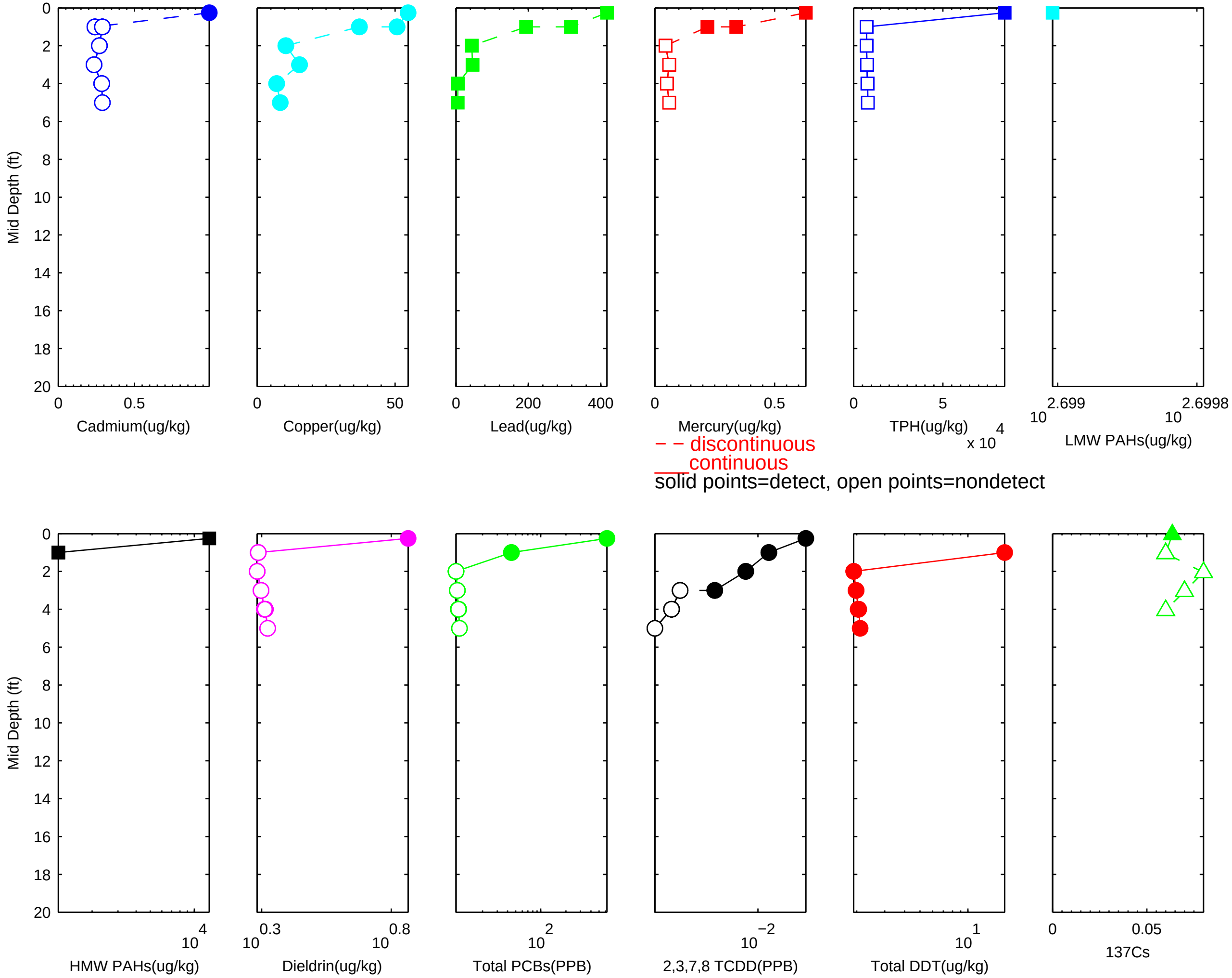

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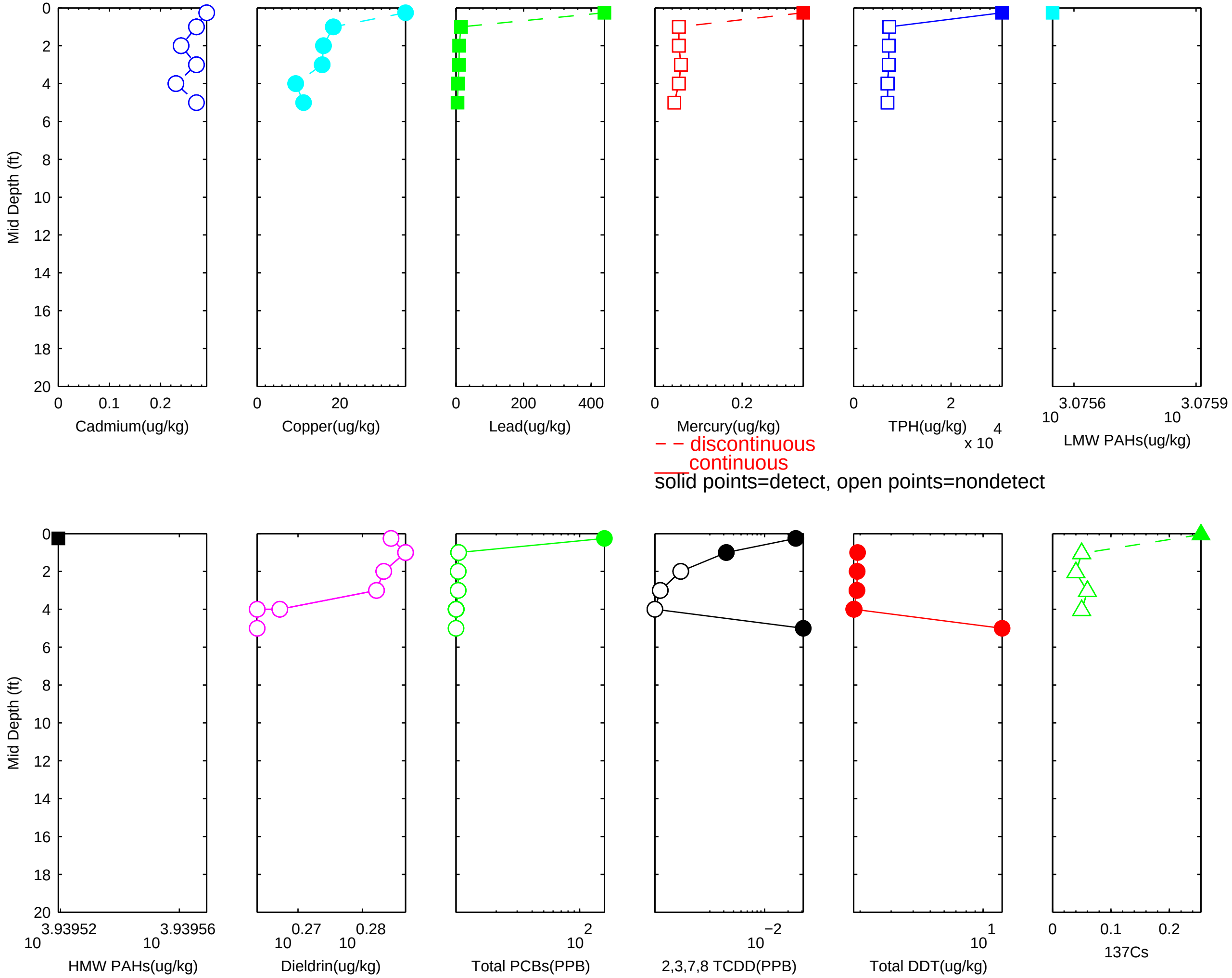

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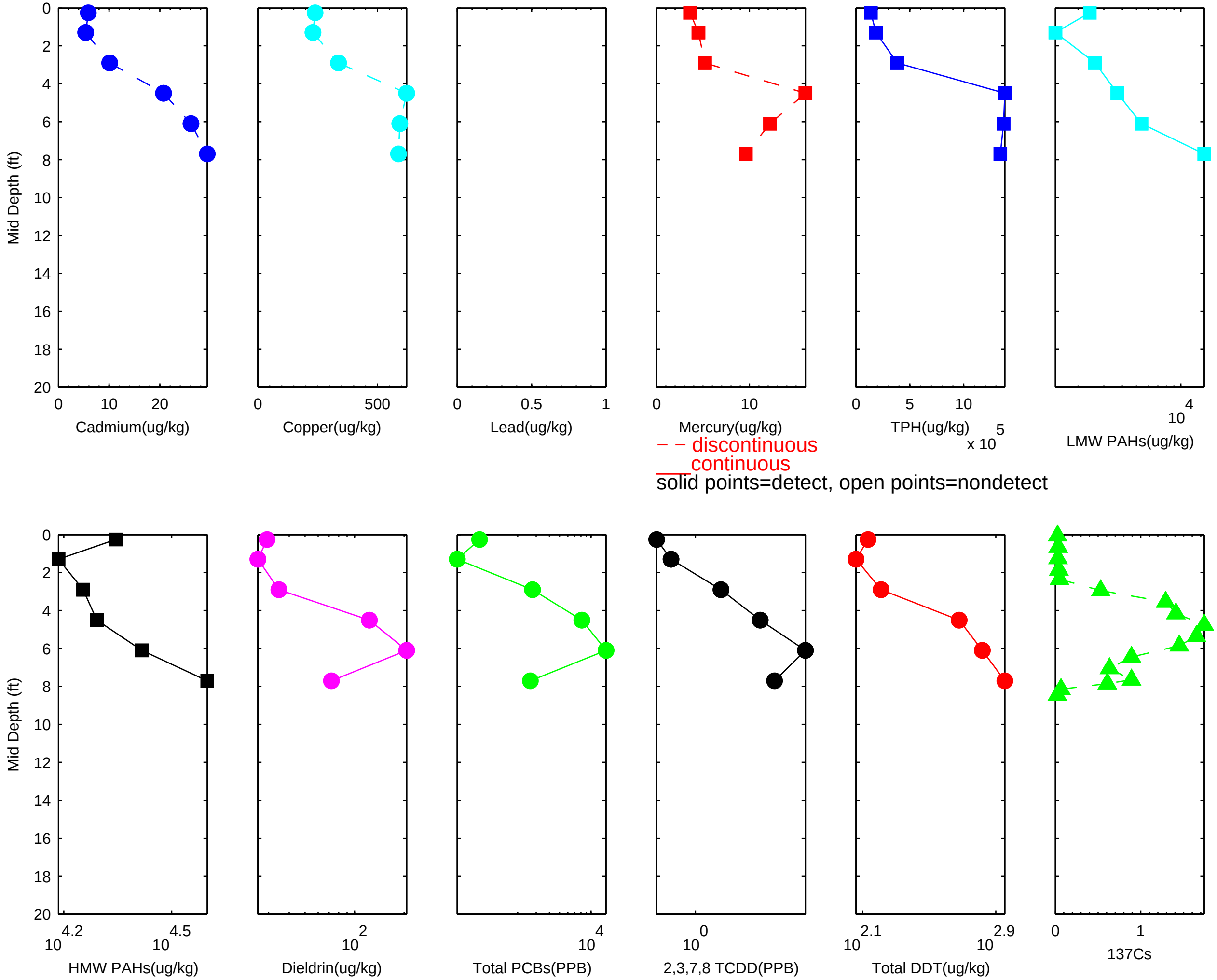

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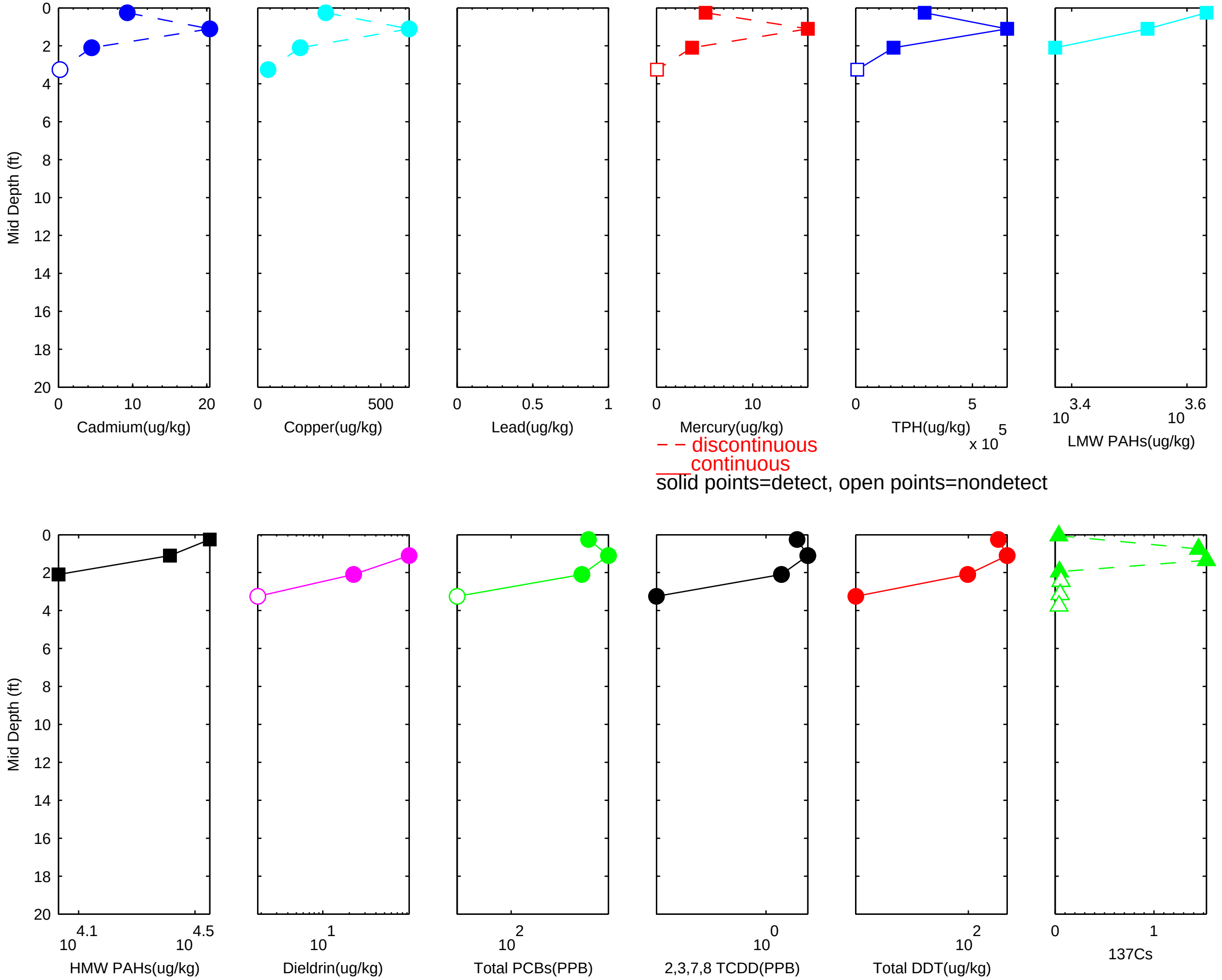

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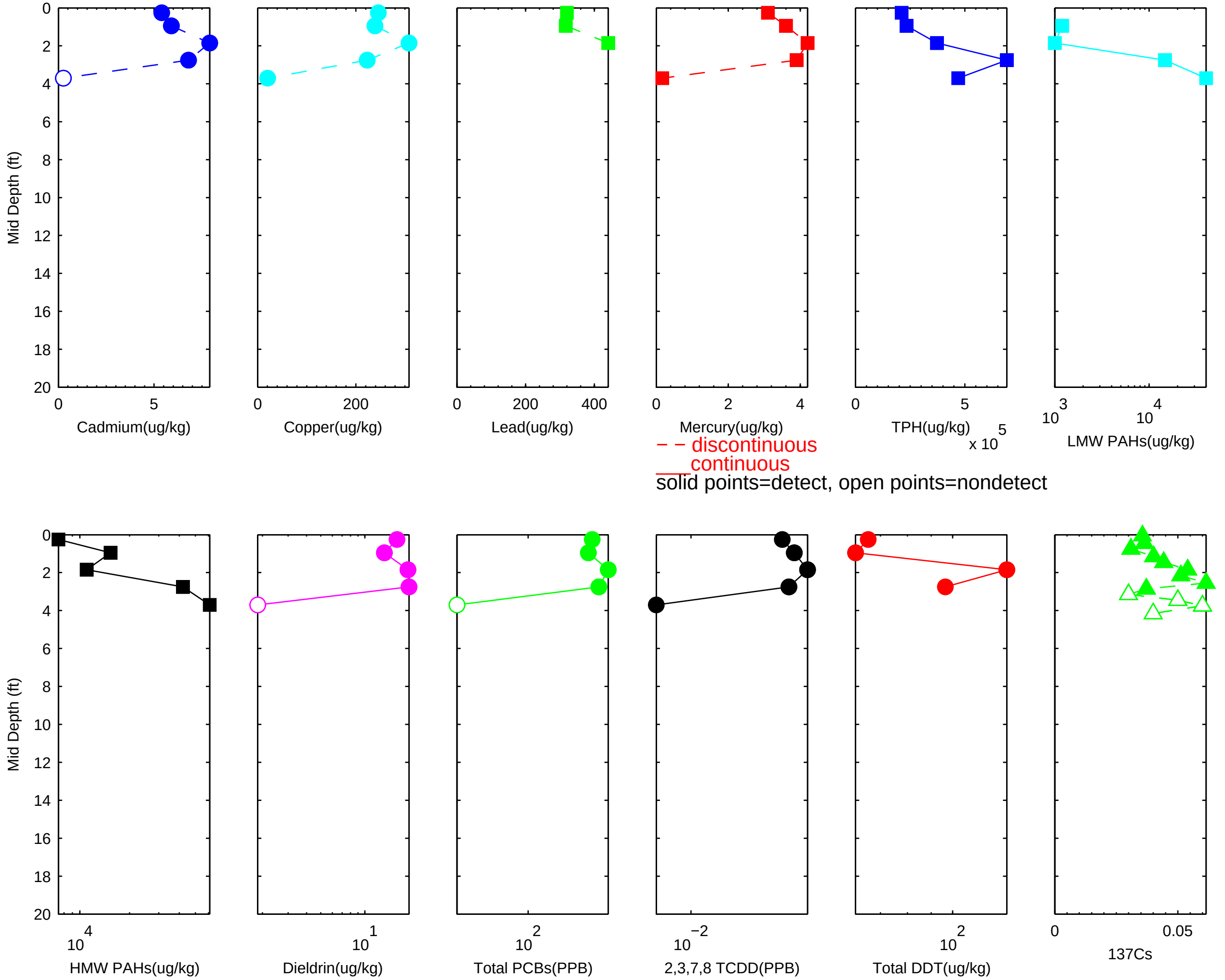

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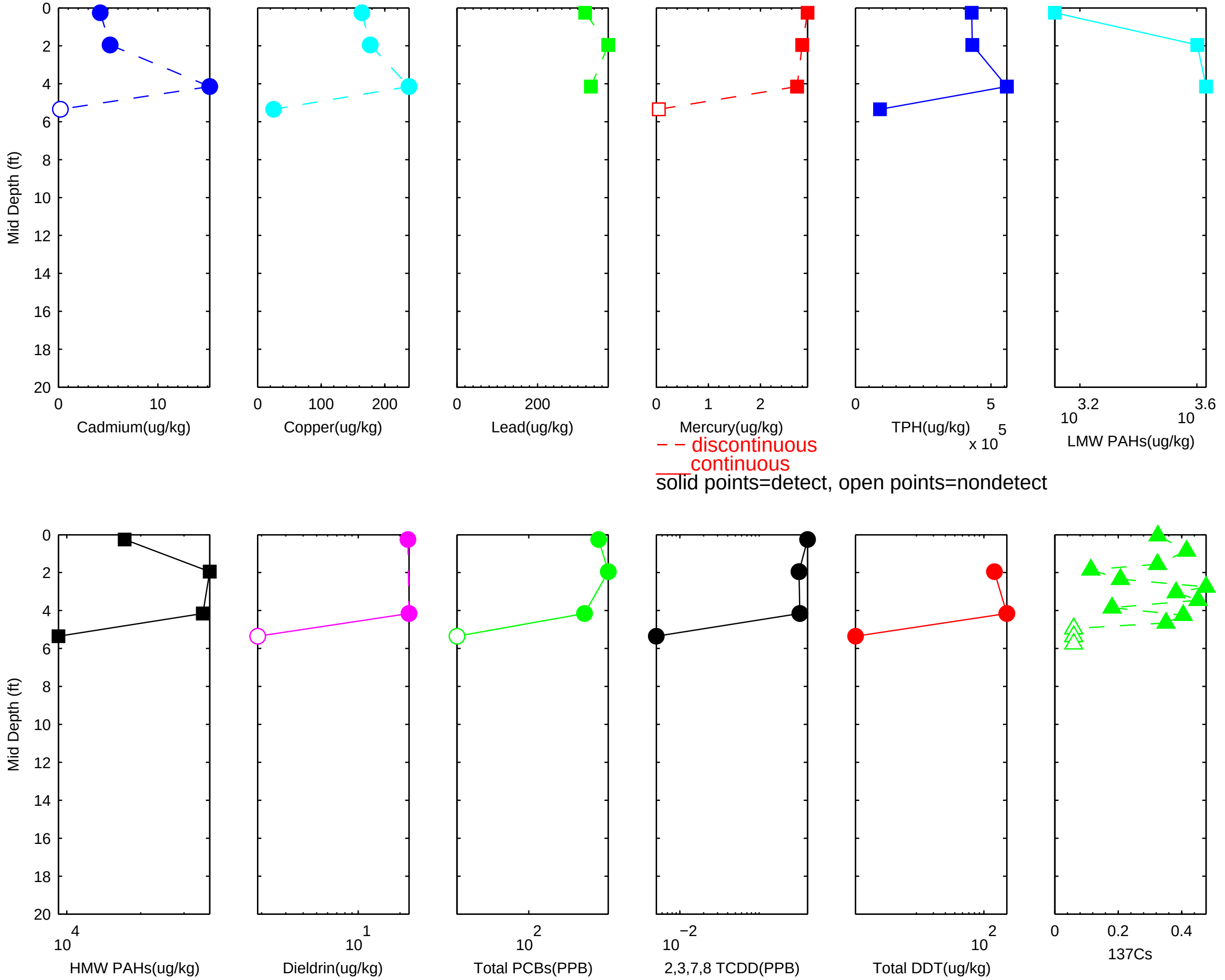

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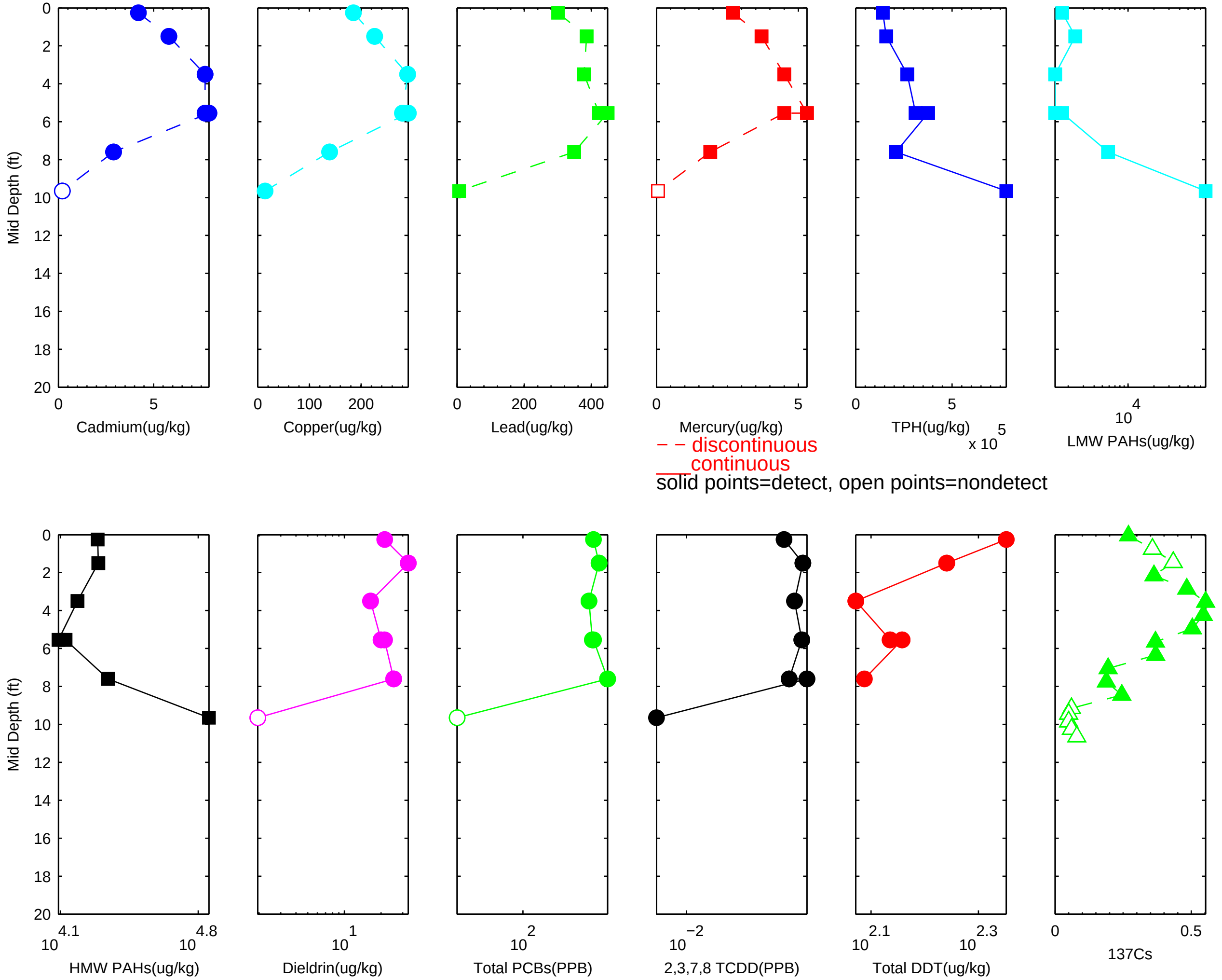

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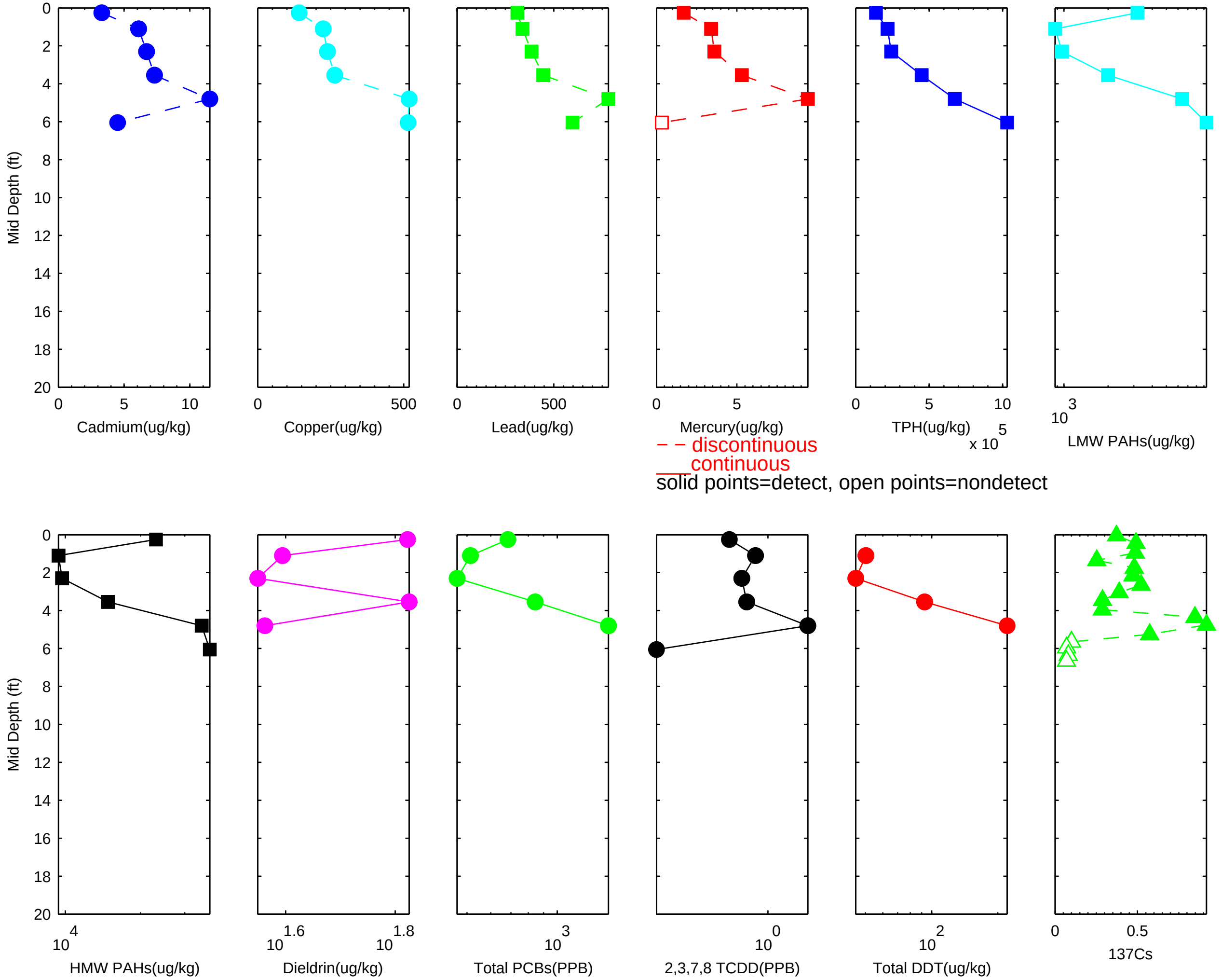

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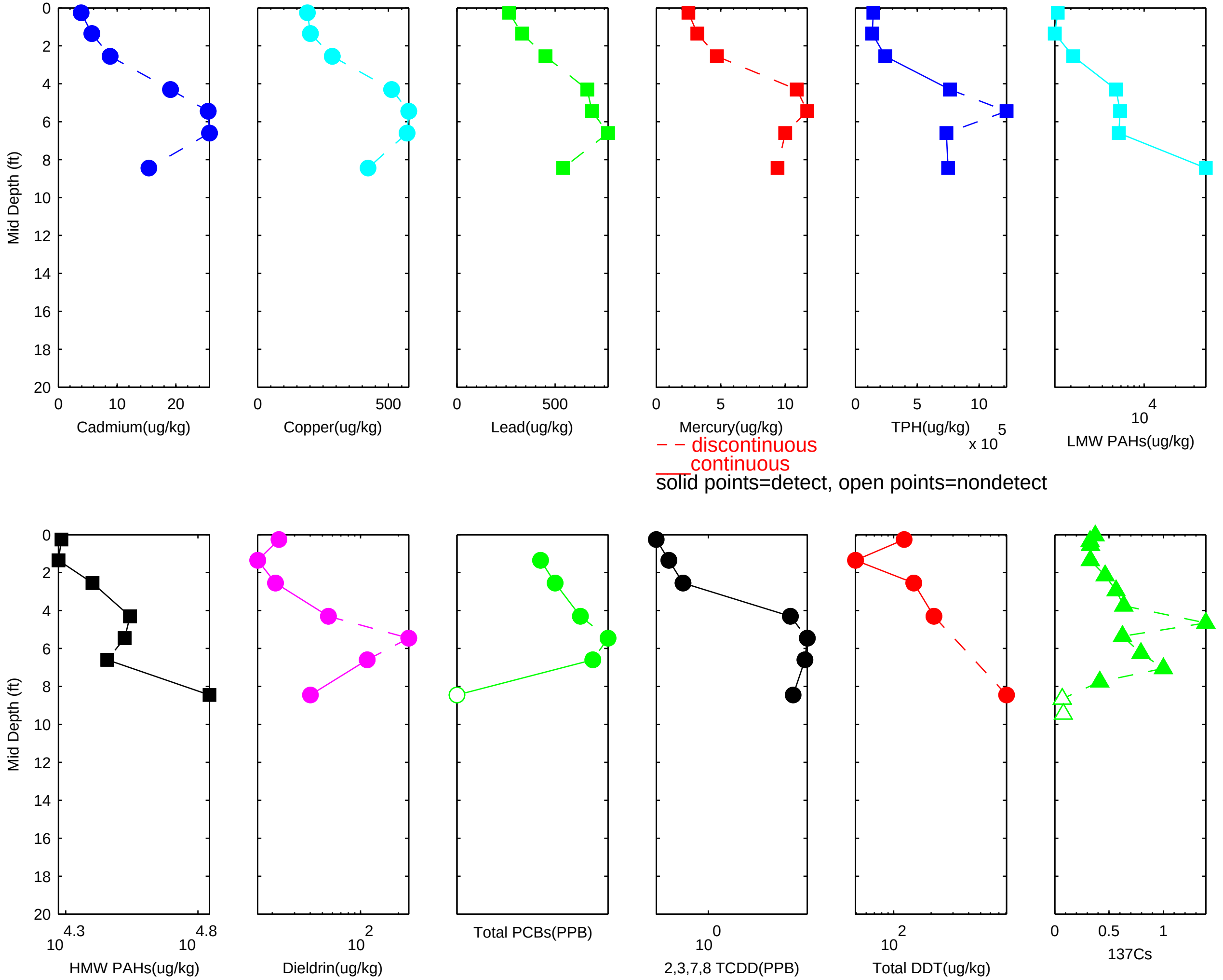

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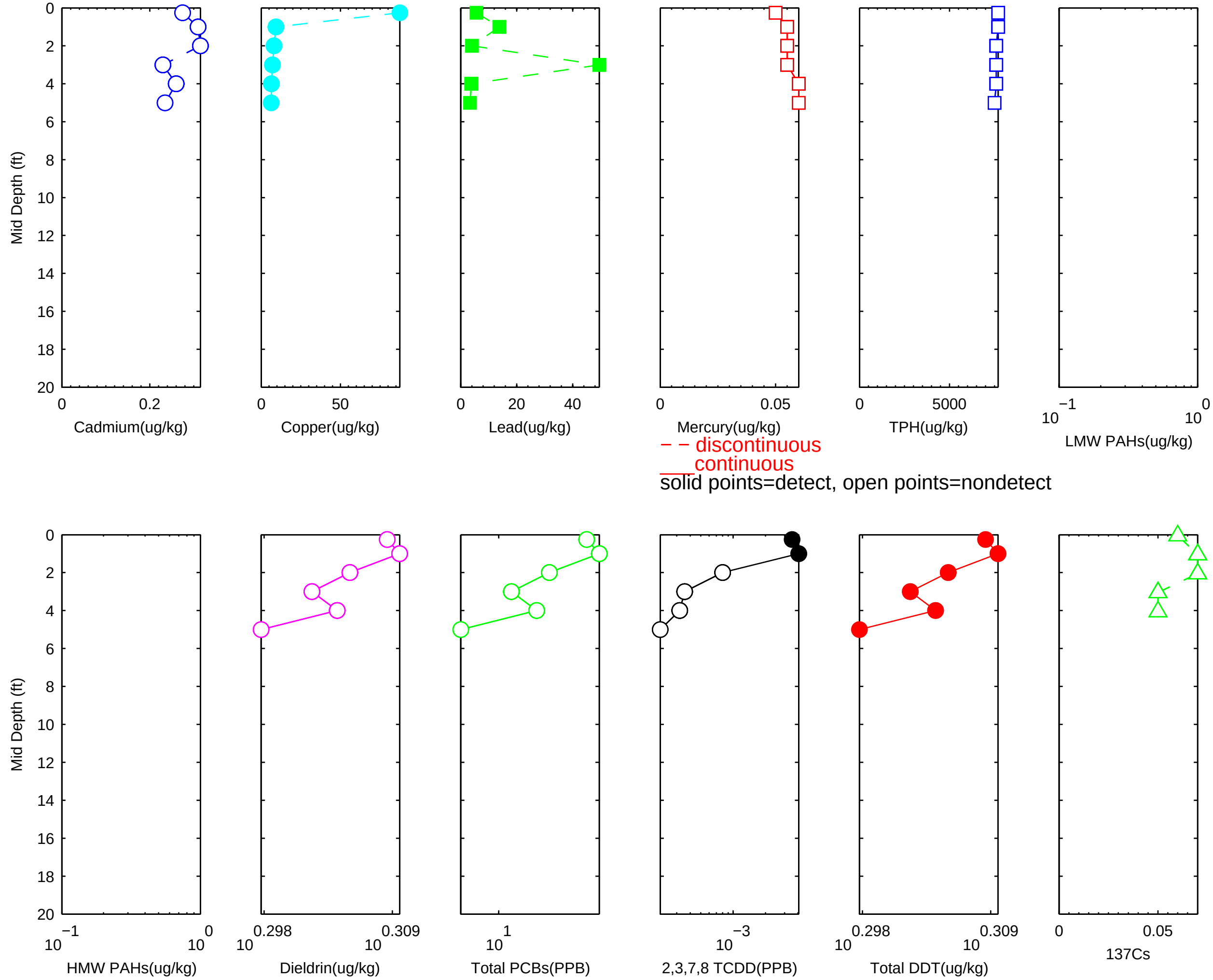

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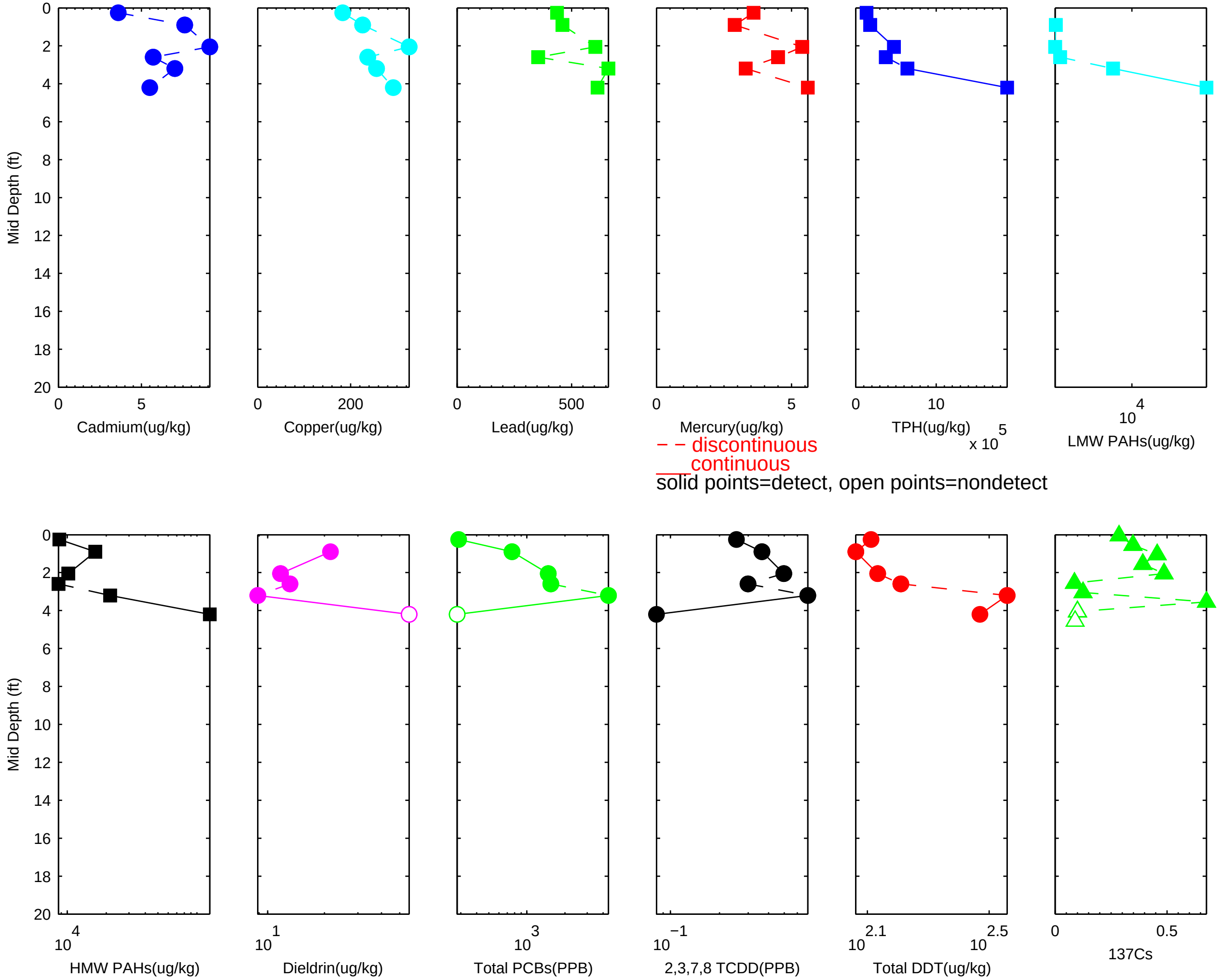

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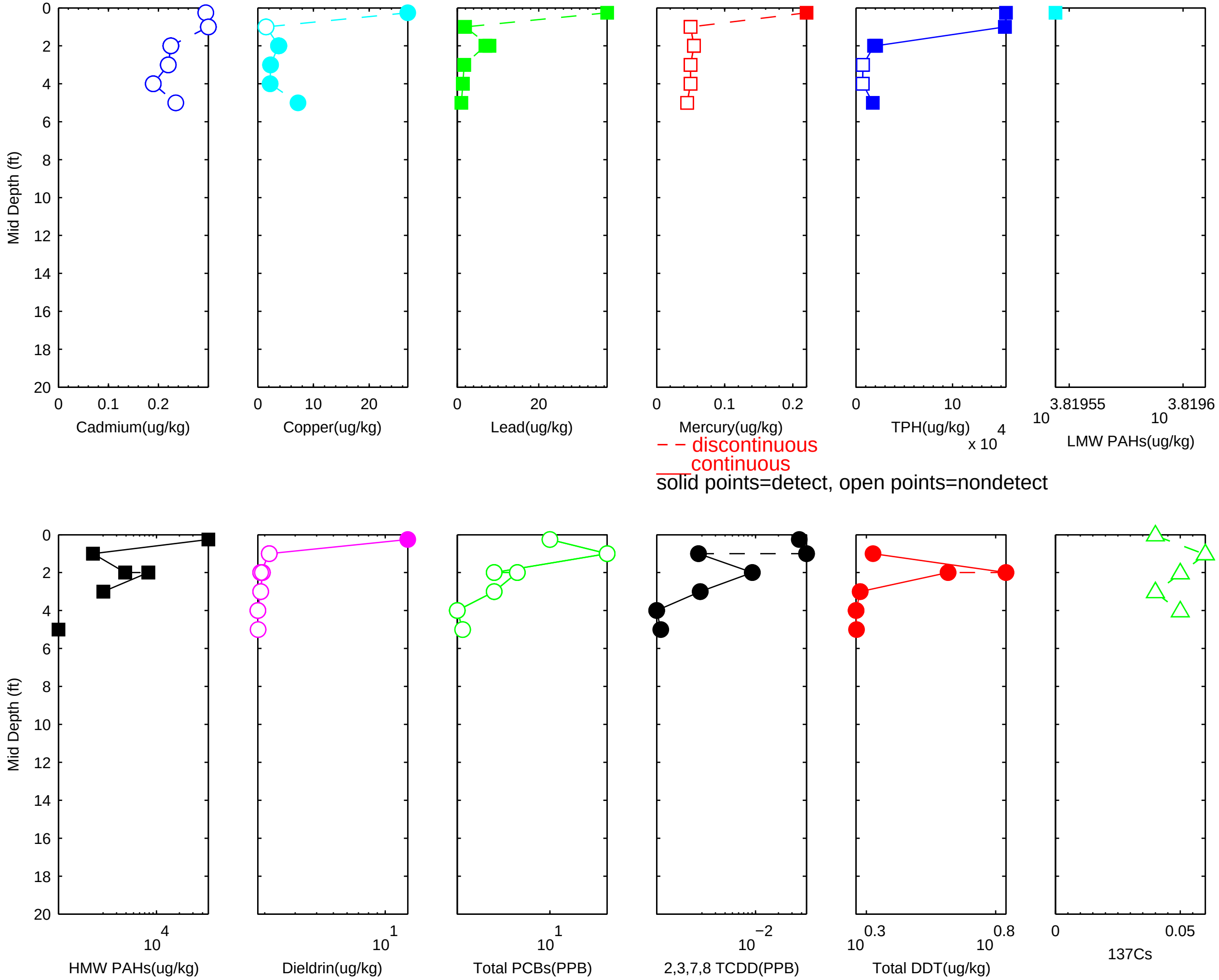

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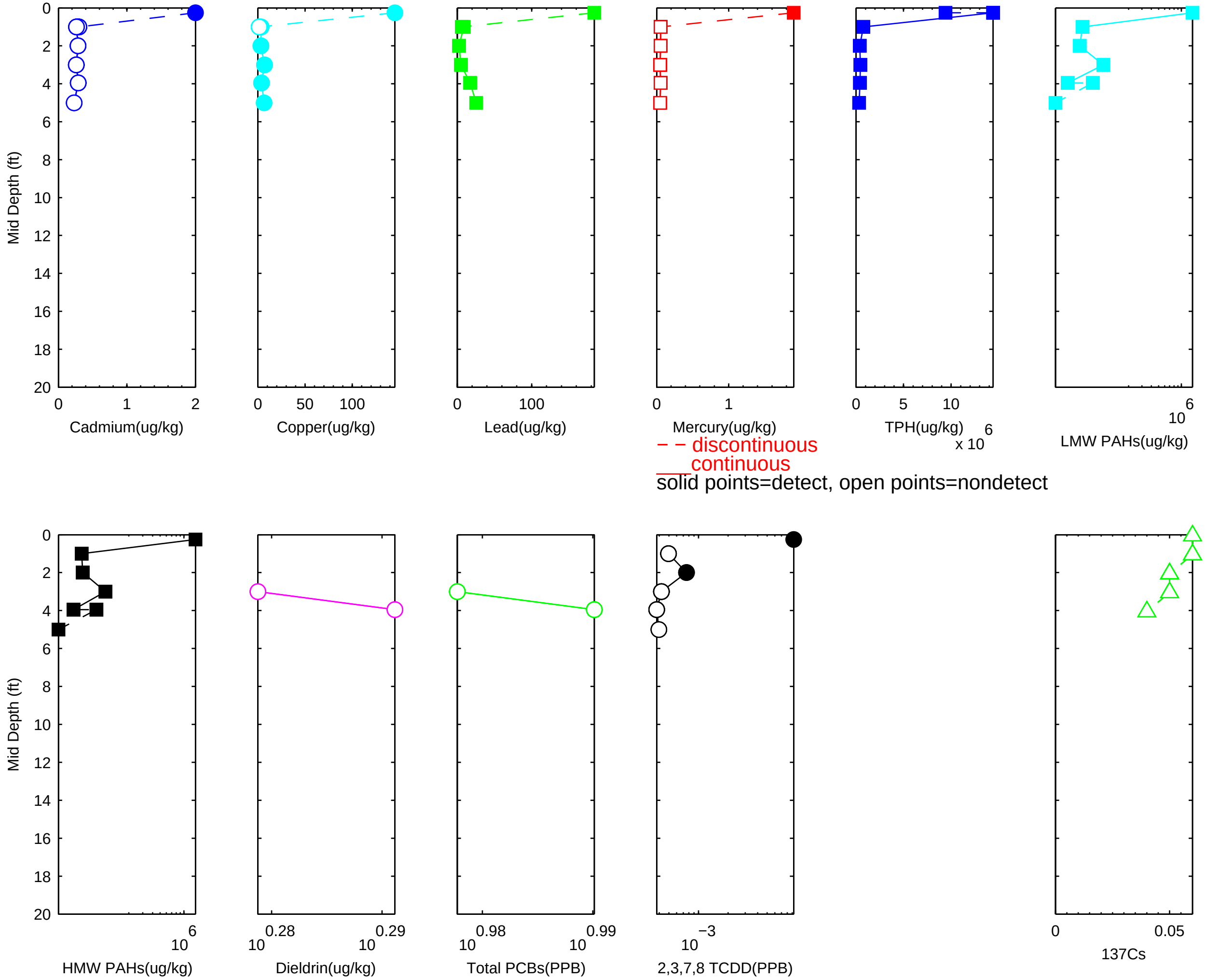

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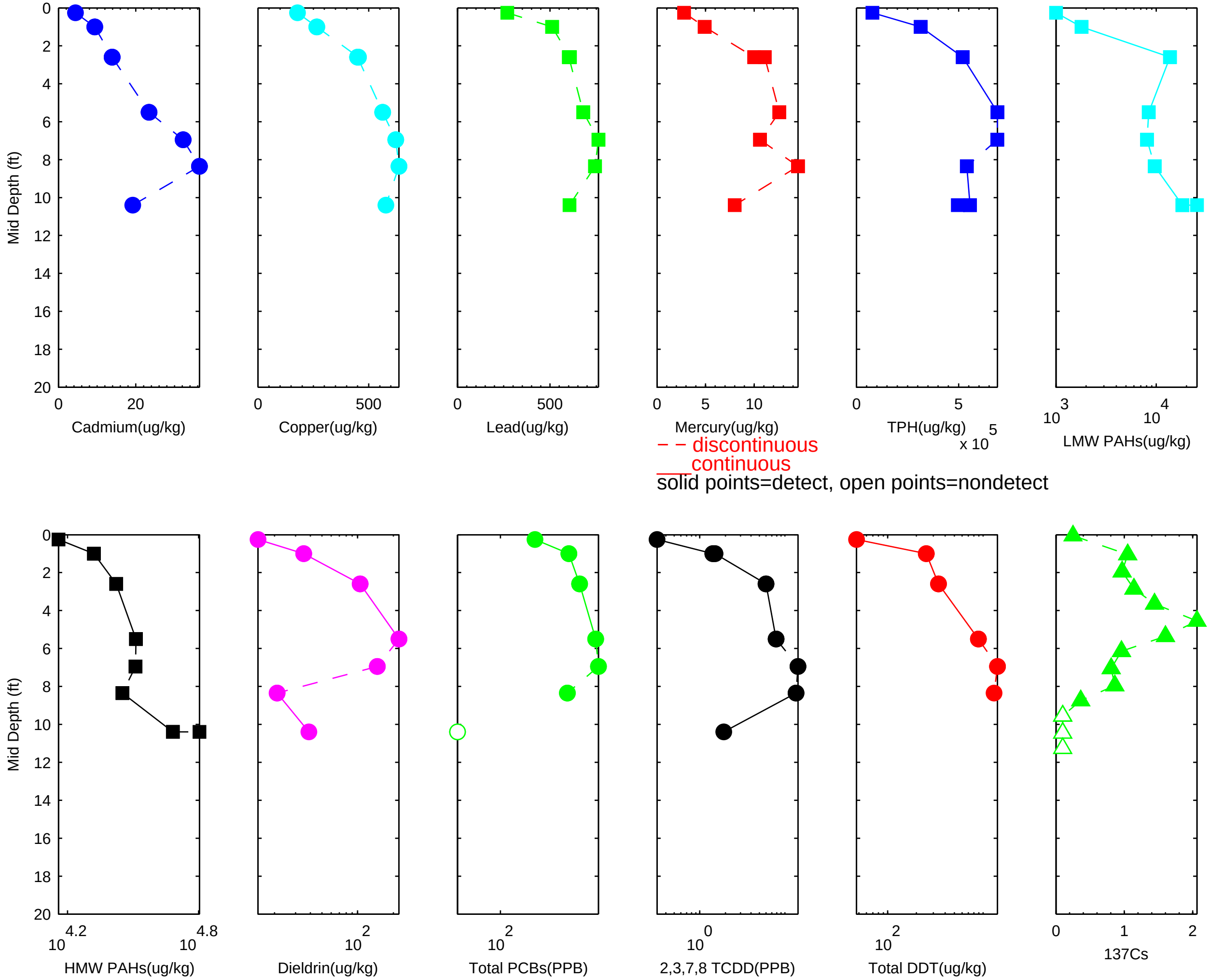

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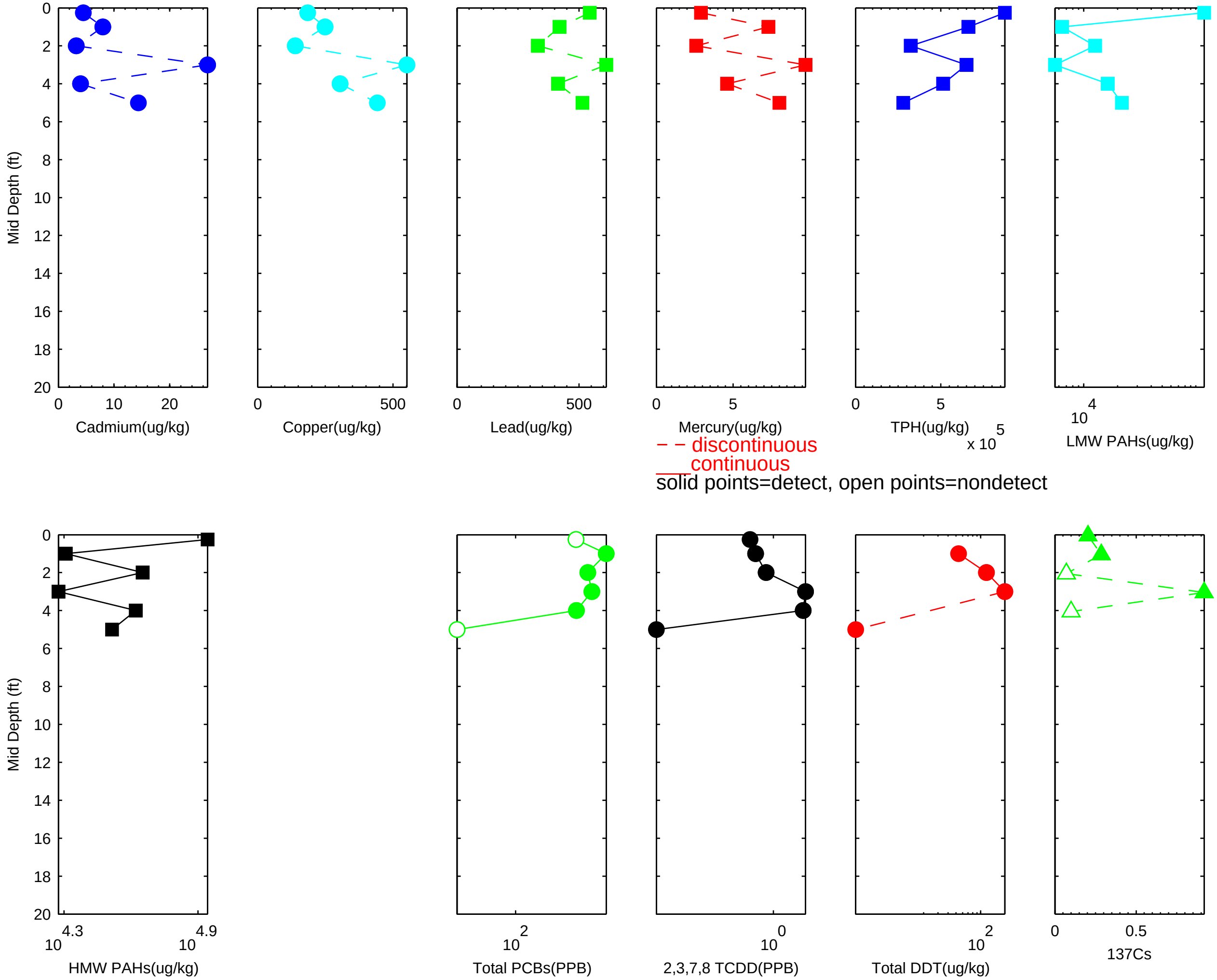

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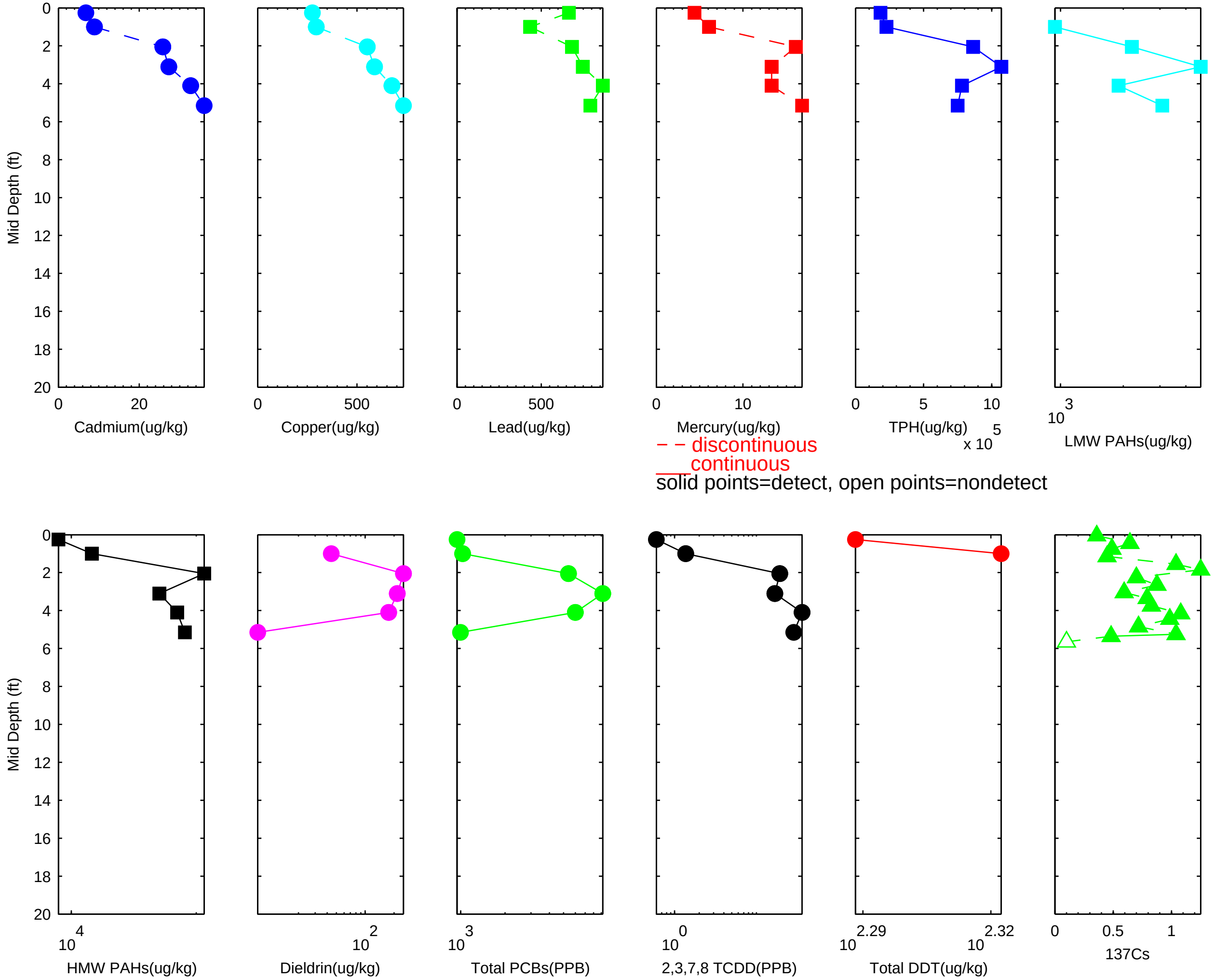

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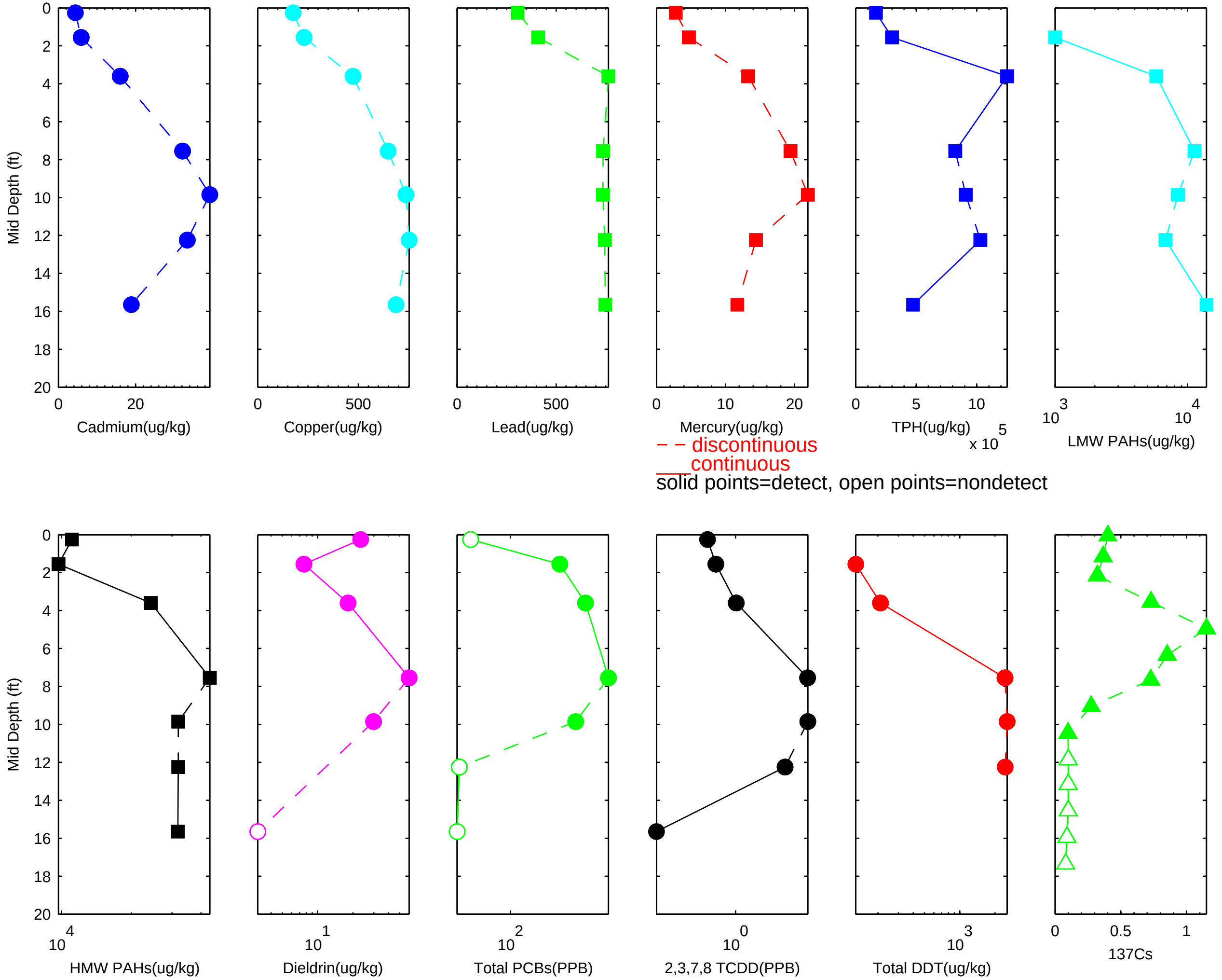

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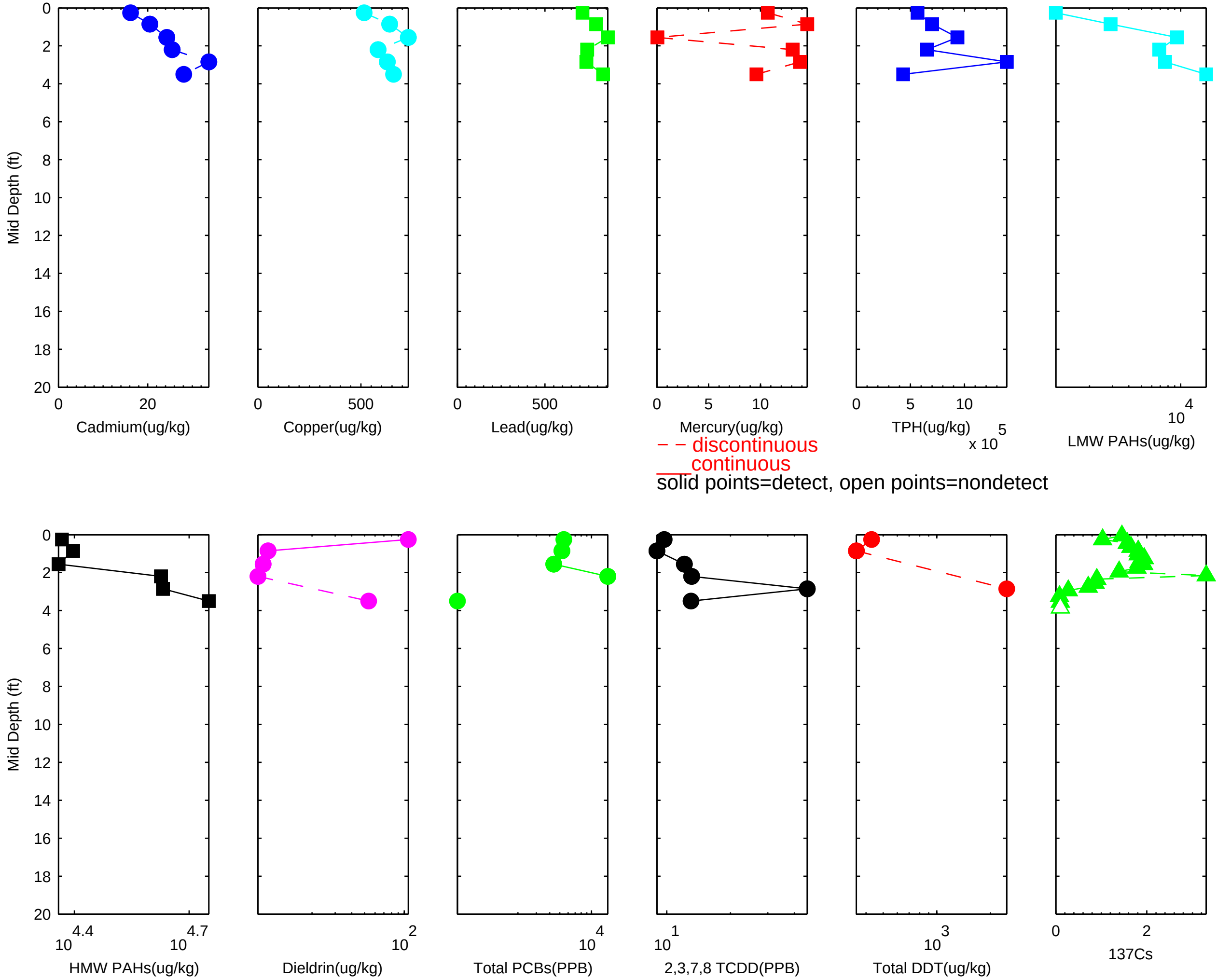

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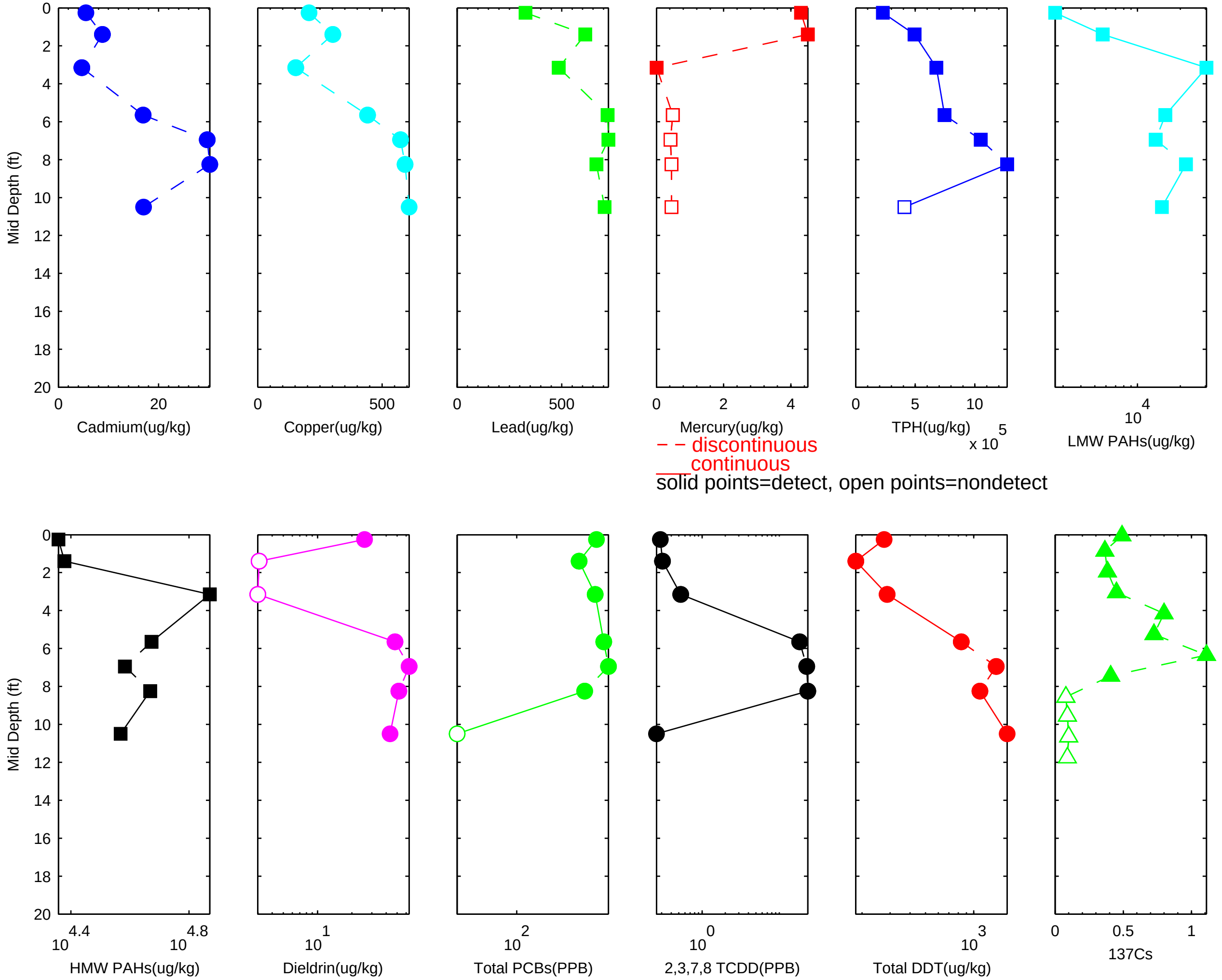

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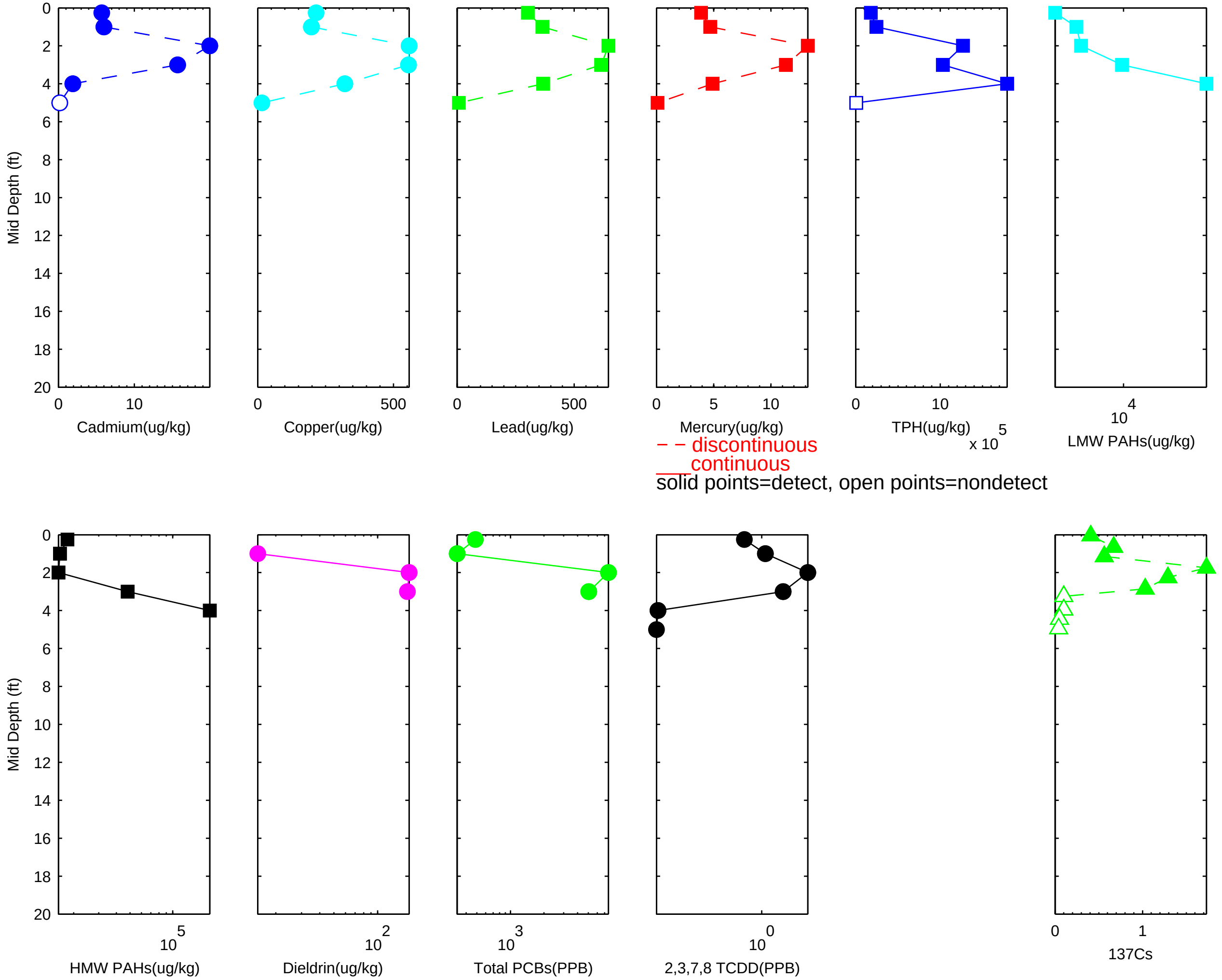

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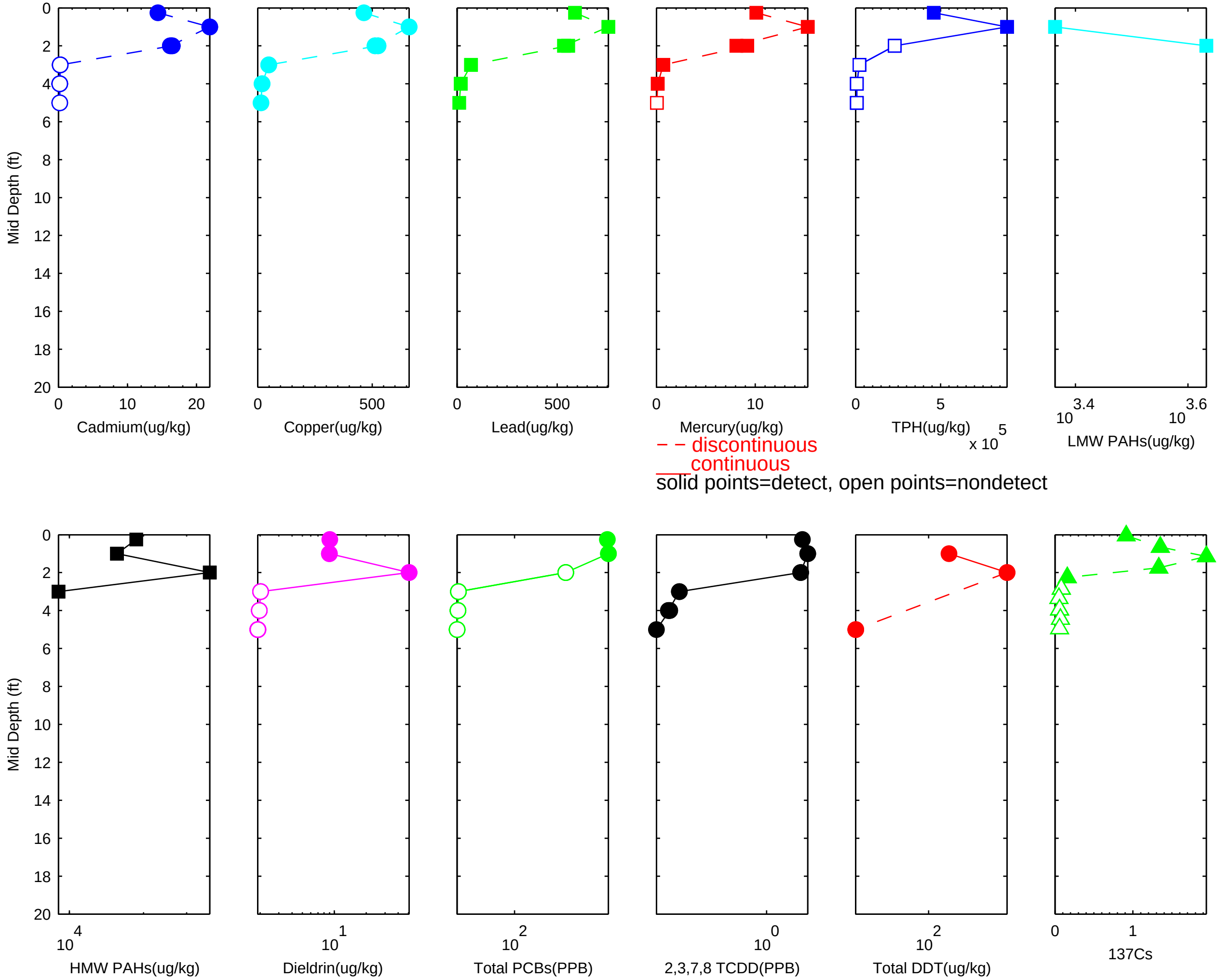

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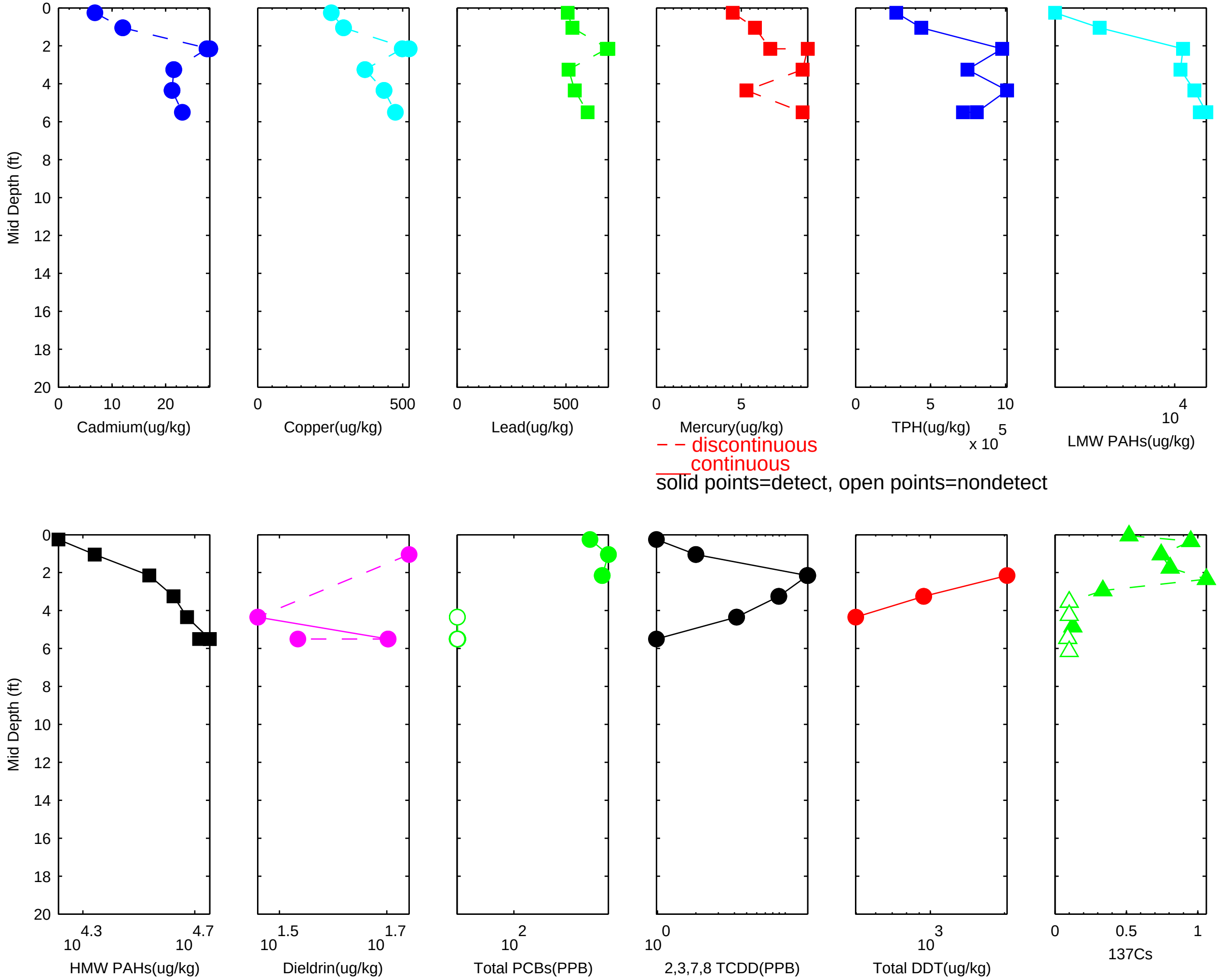

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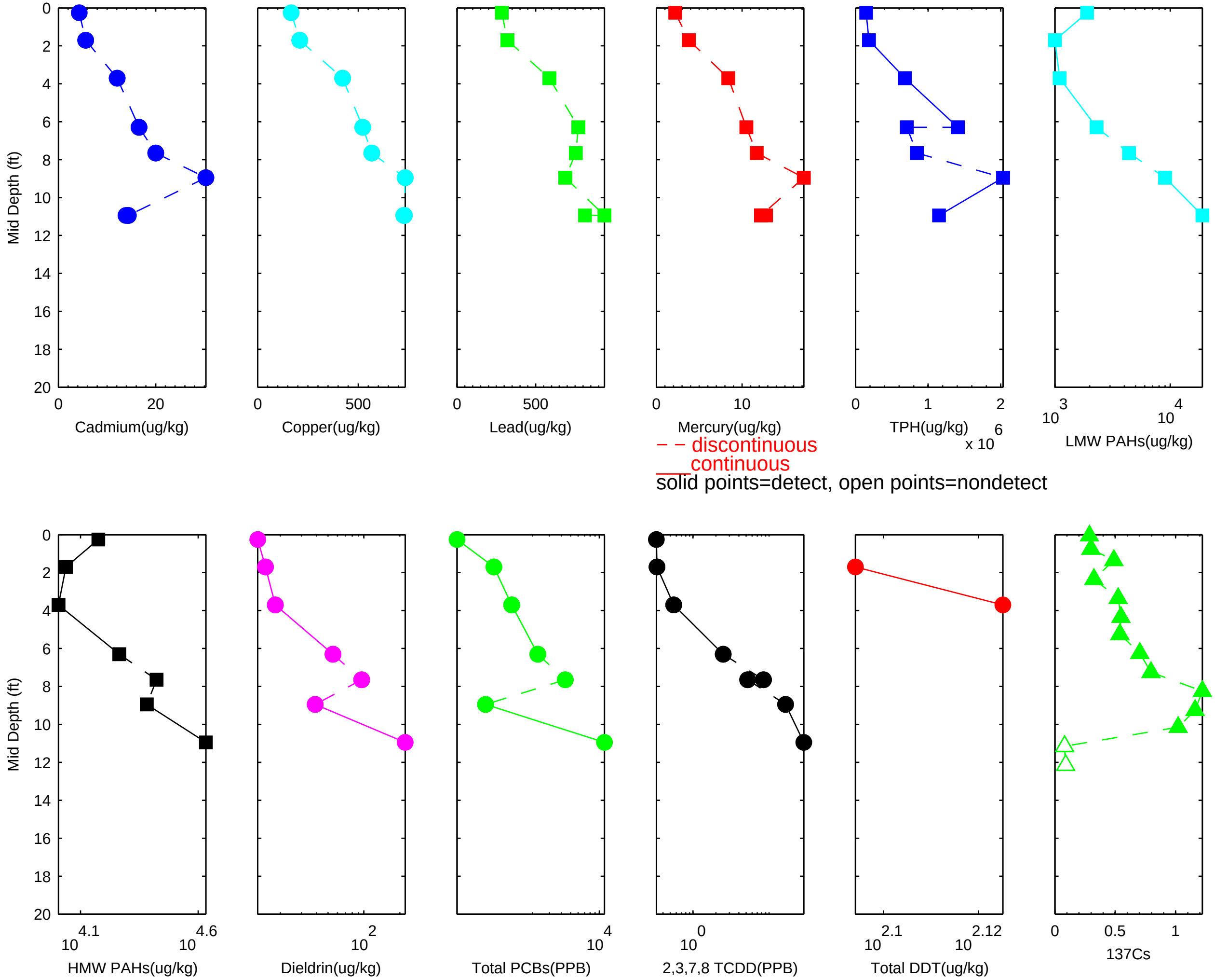

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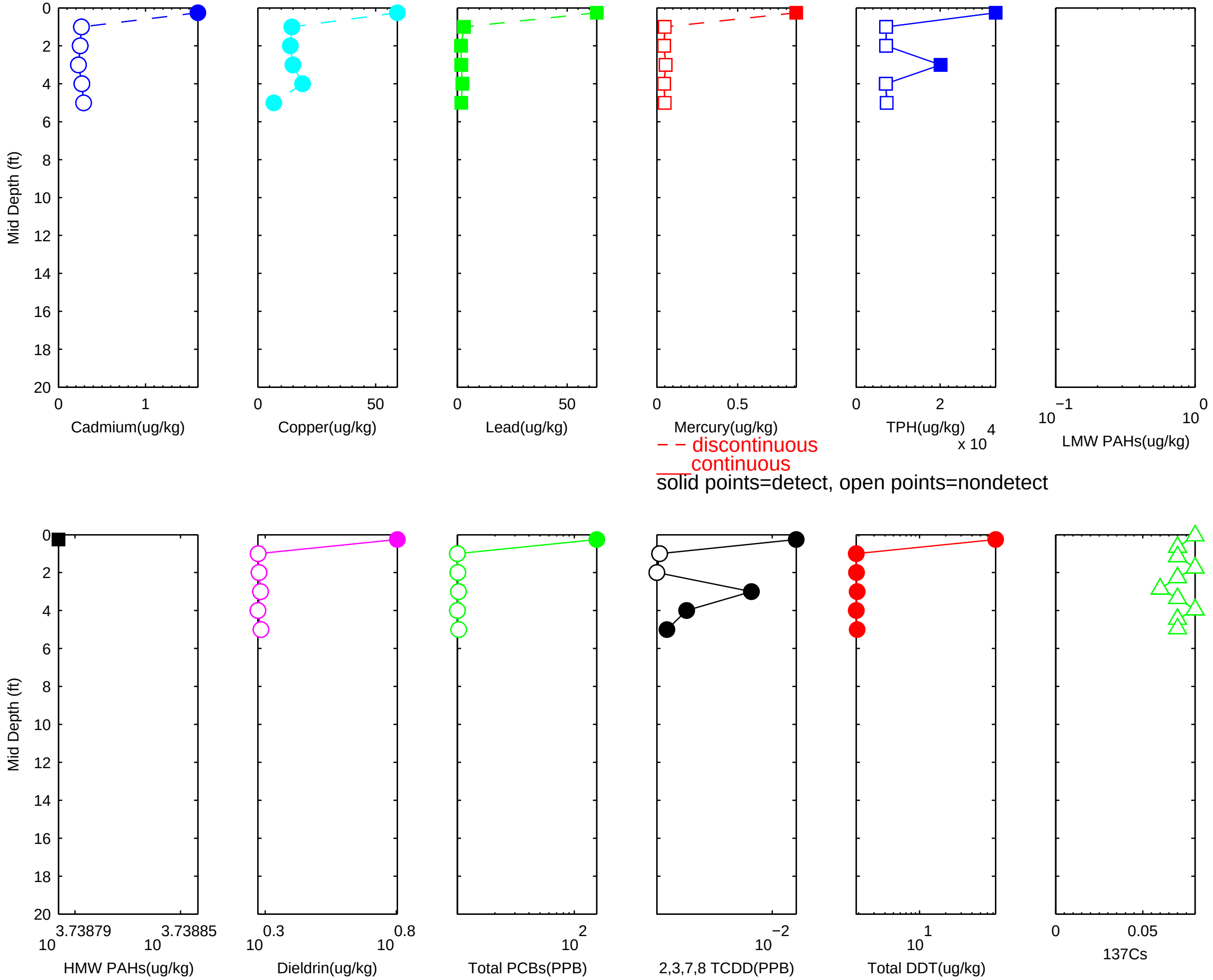

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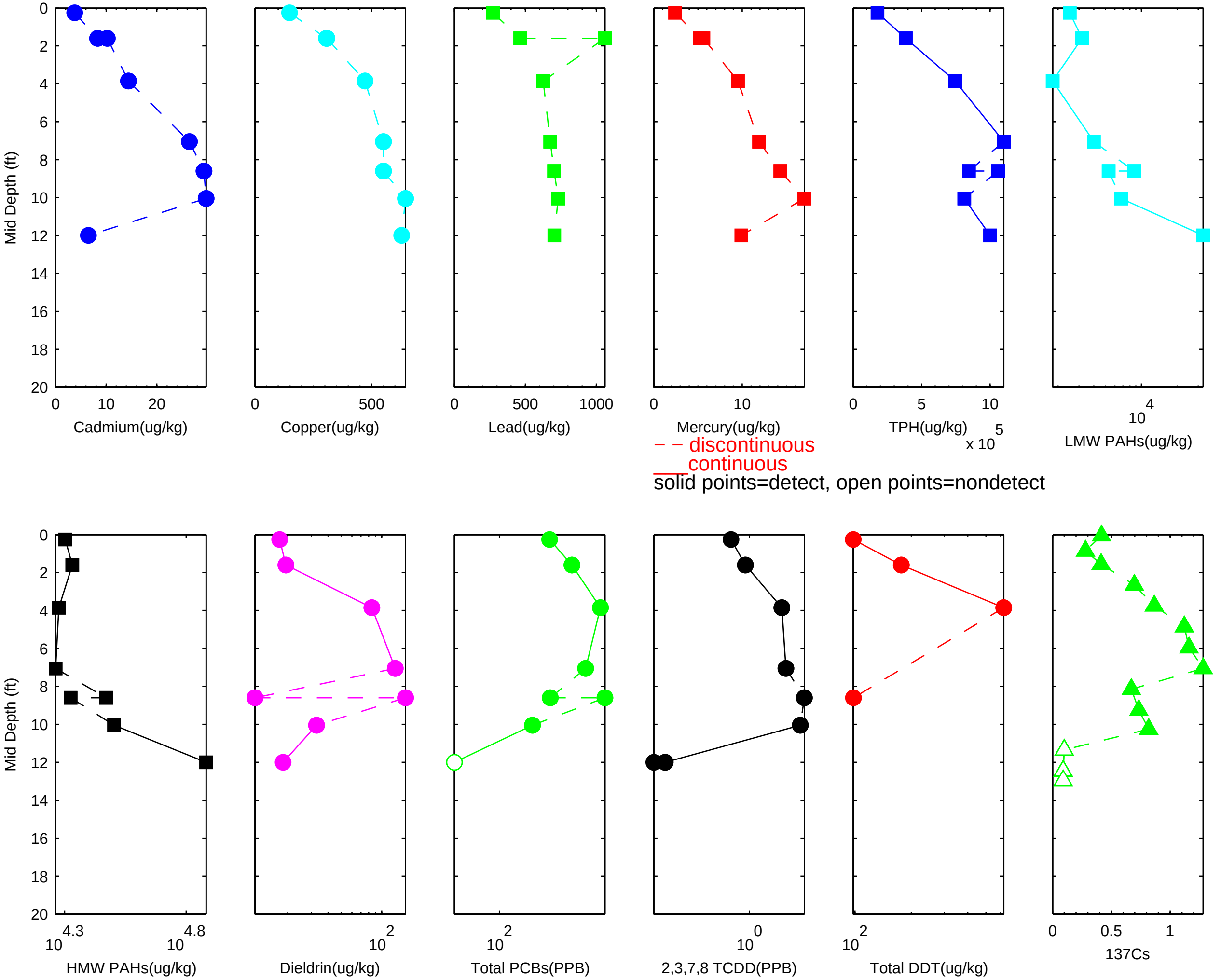

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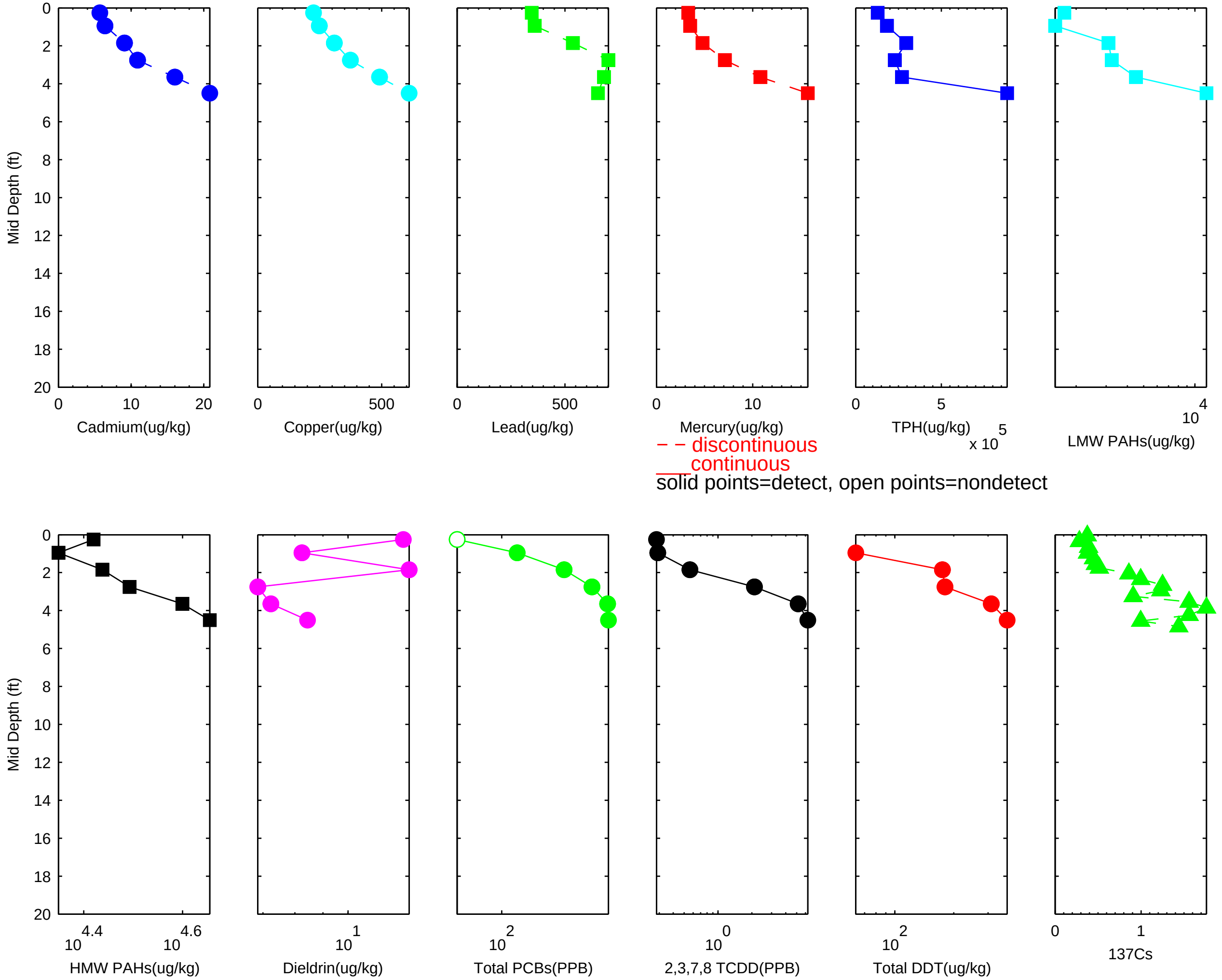
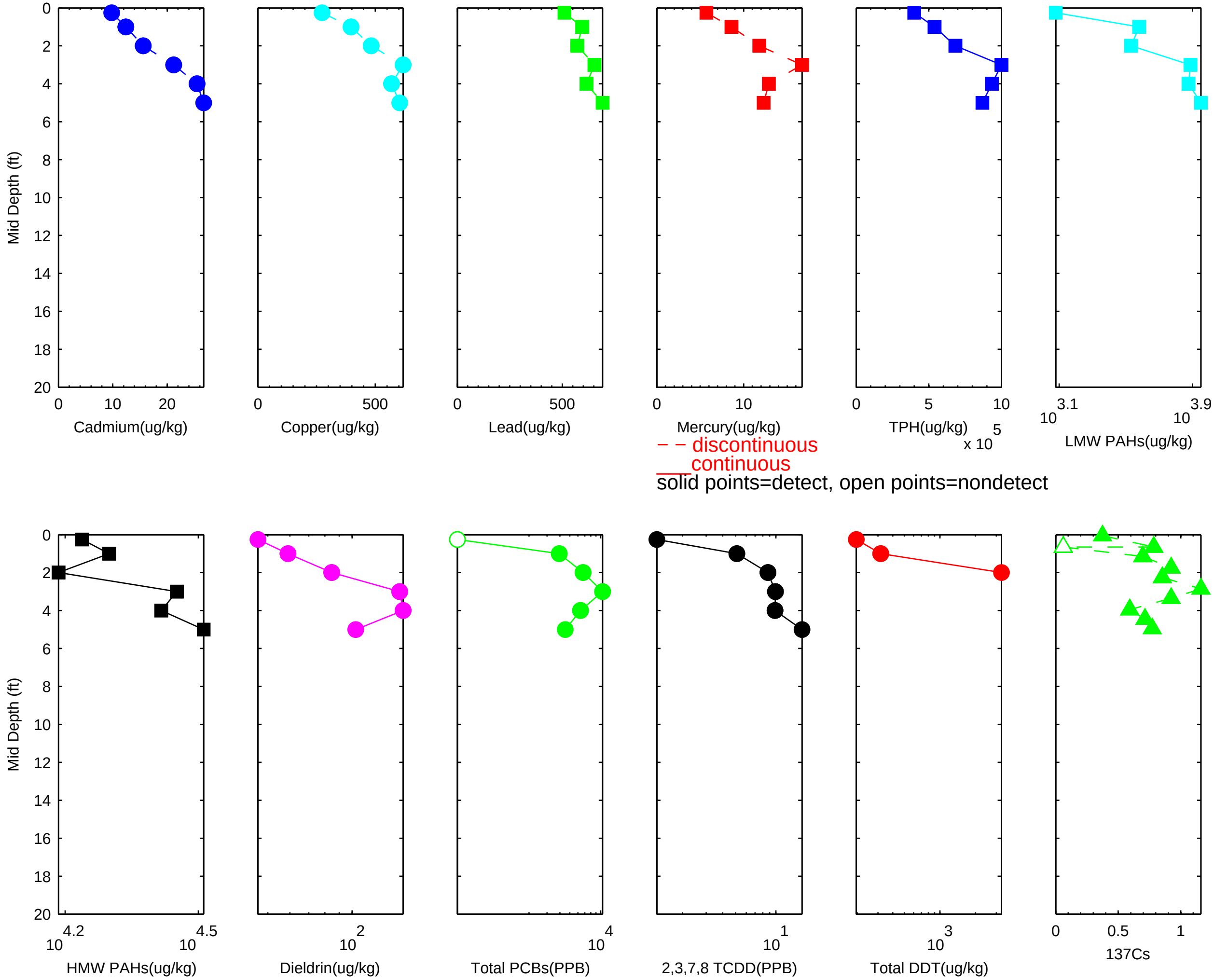


Sample ID: 227 River Mile 2.86 PASSAIC 1995 RI Sampling Program



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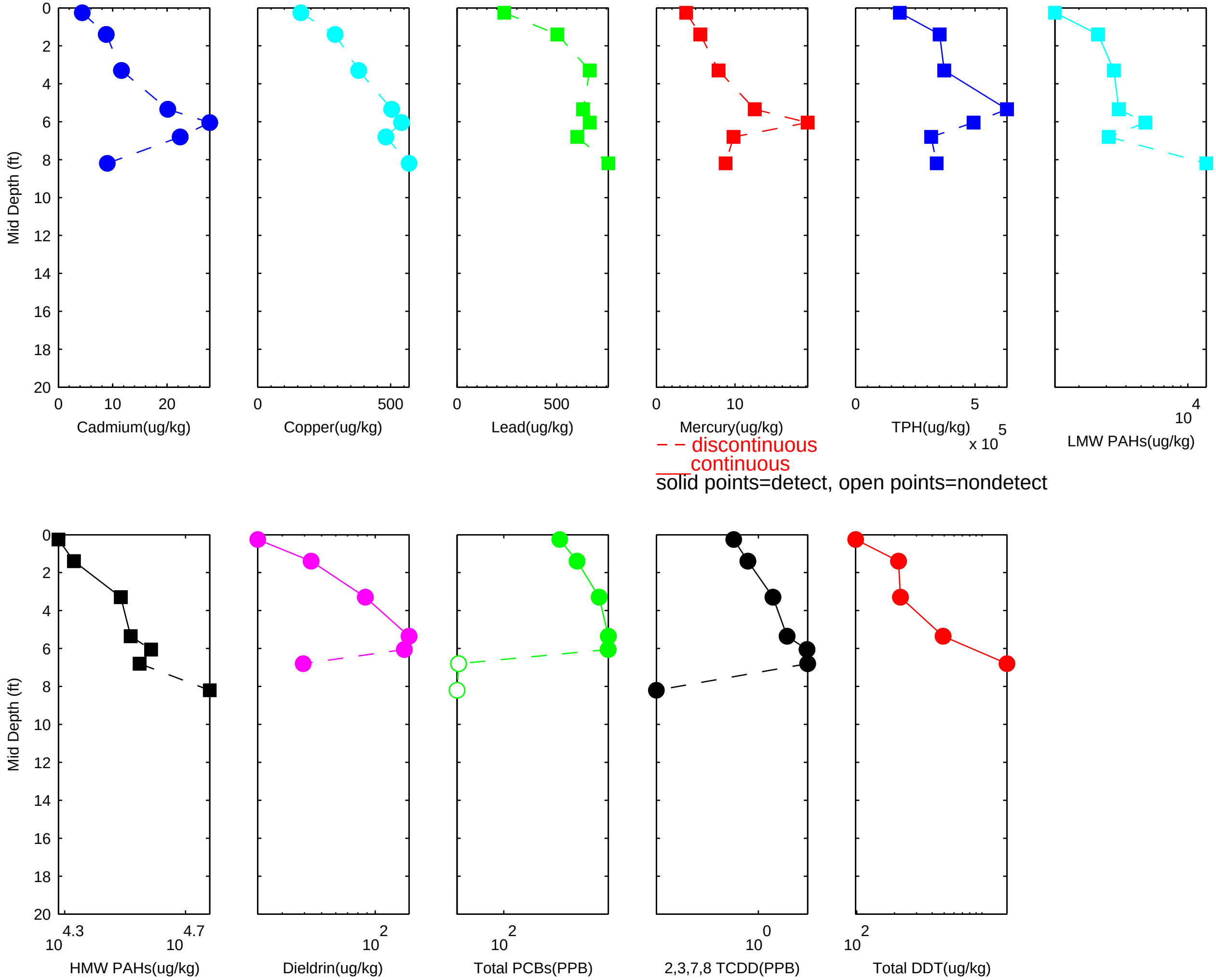

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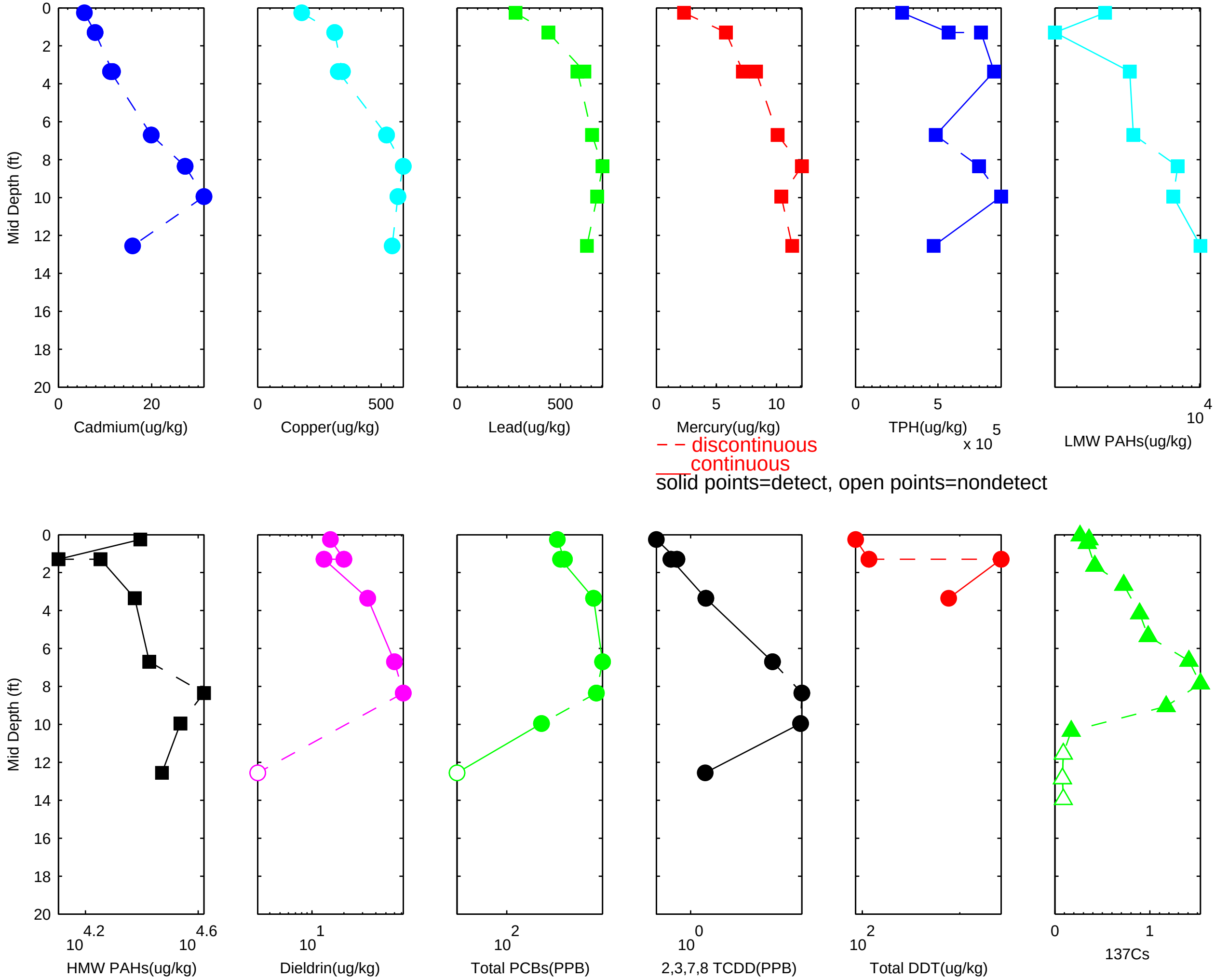
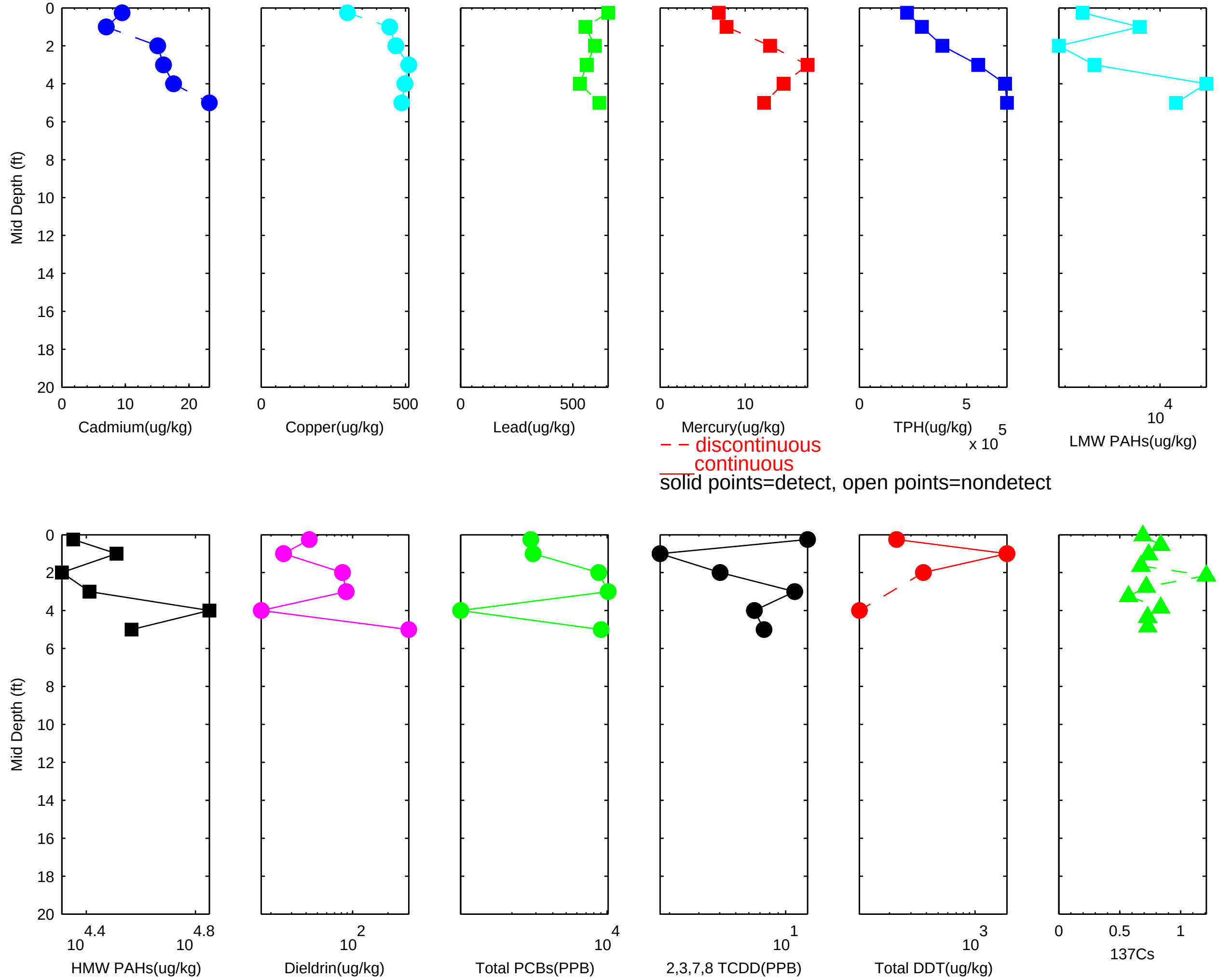


– – discontinuous
___ continuous
solid points=detect, open points=nondetect

Sample ID: 224 River Mile 2.63 PASSAIC 1995 RI Sampling Program



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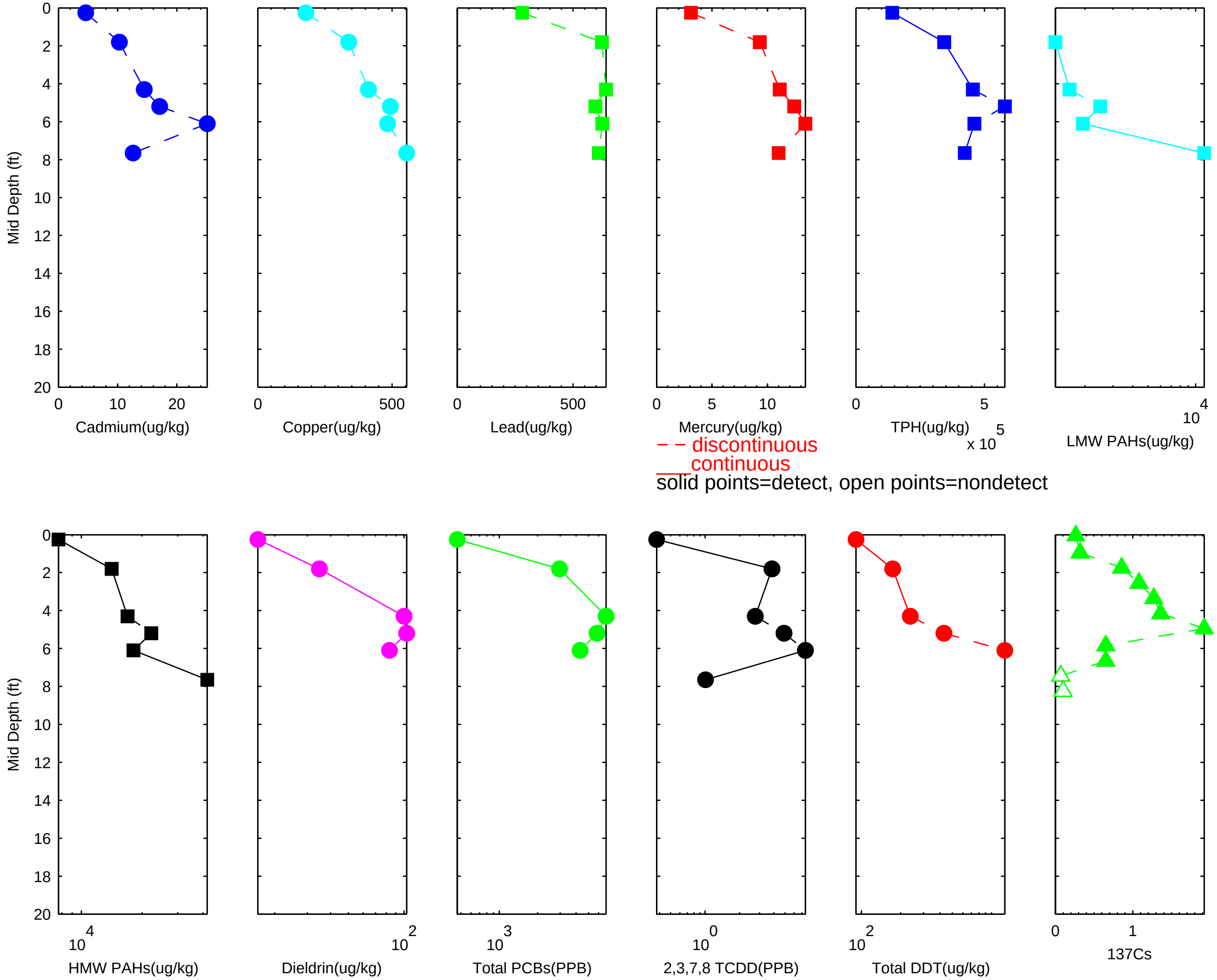

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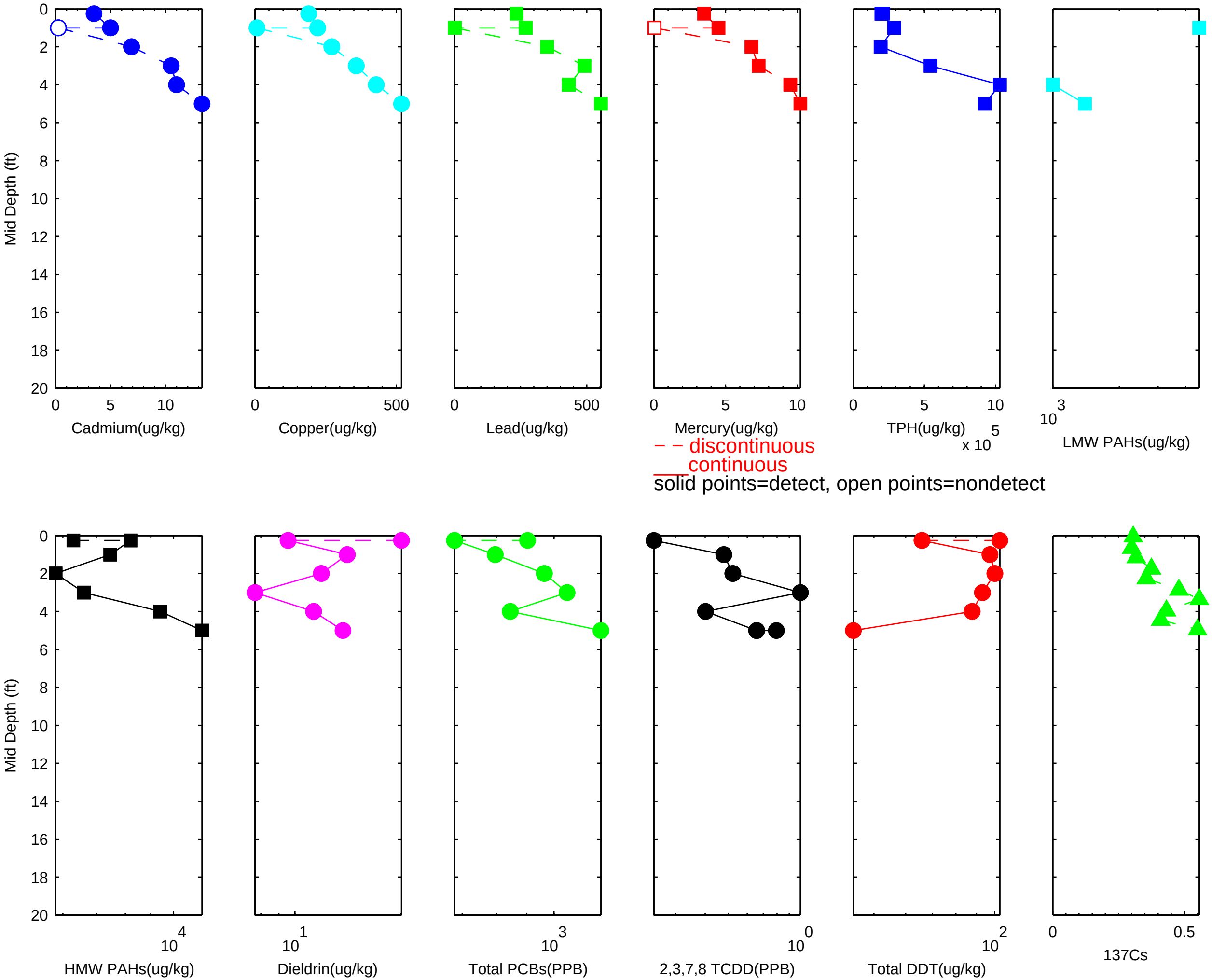

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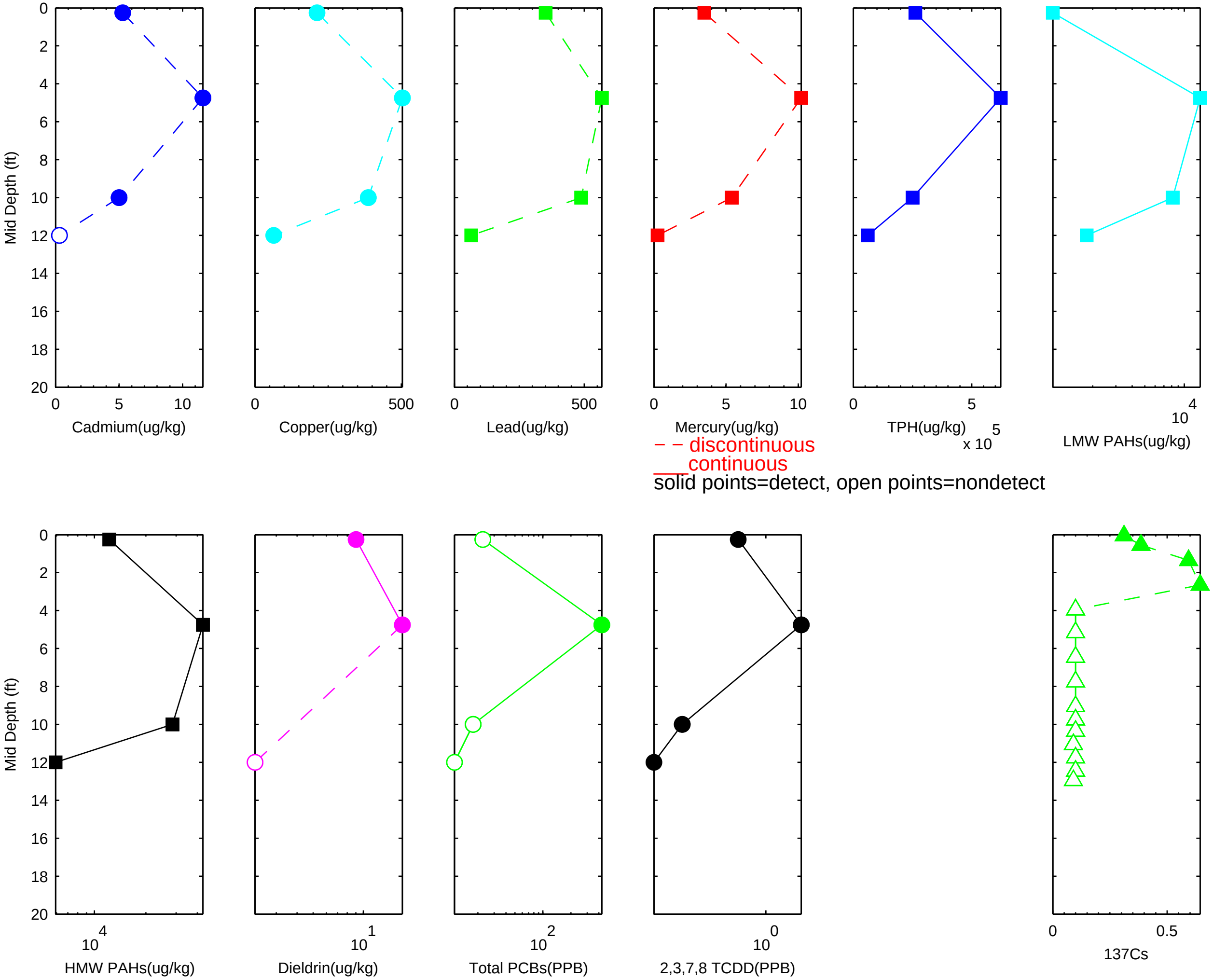

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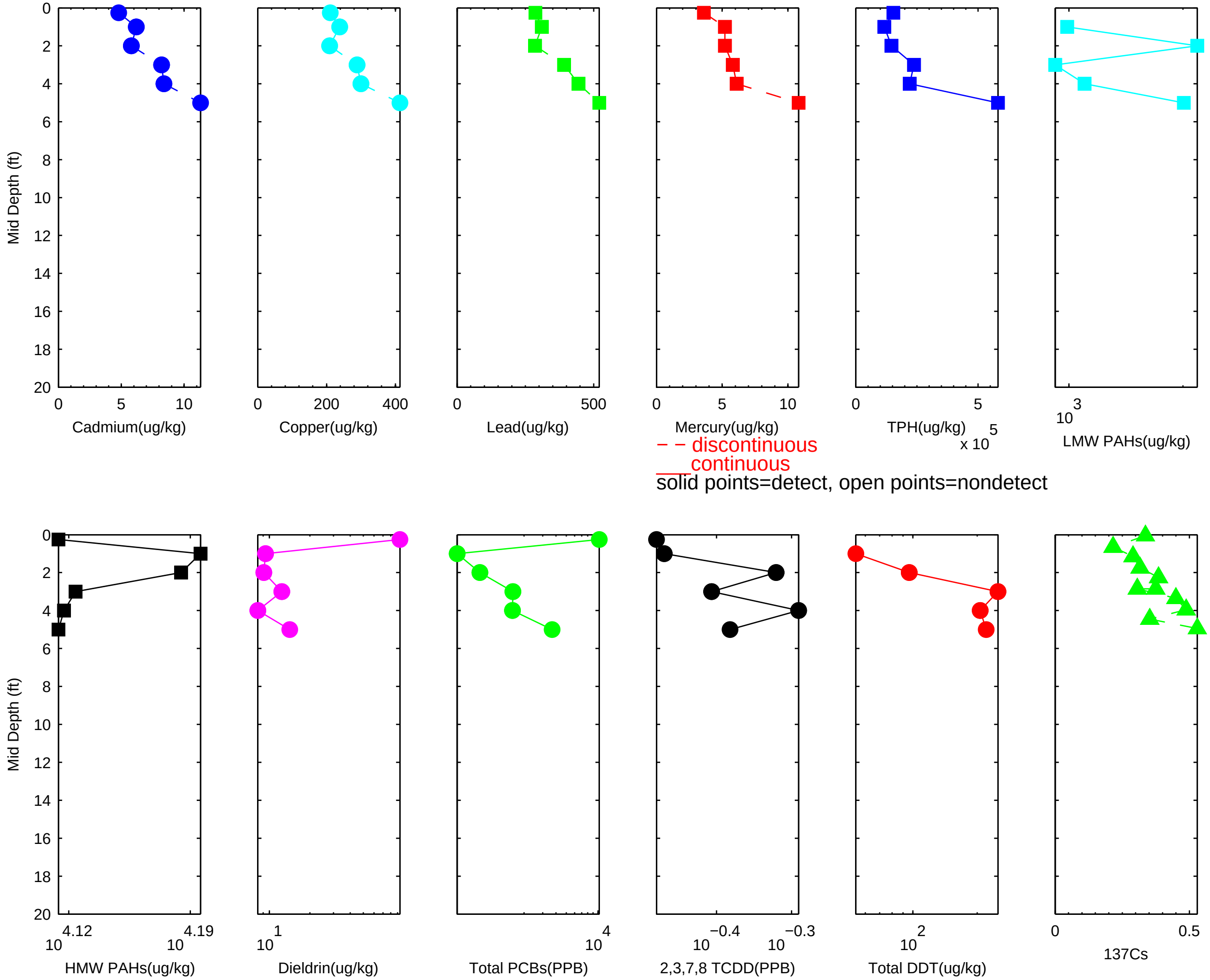

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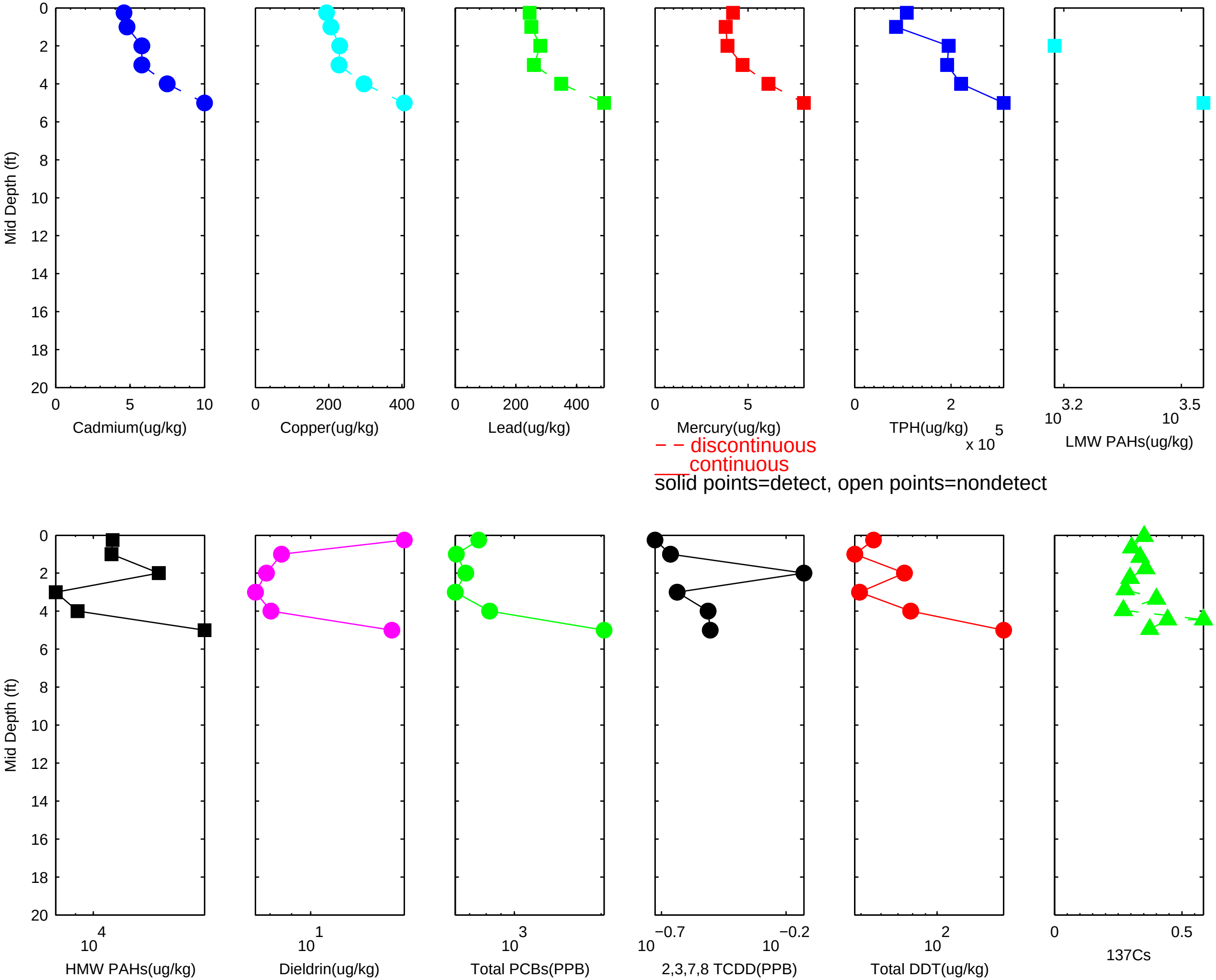

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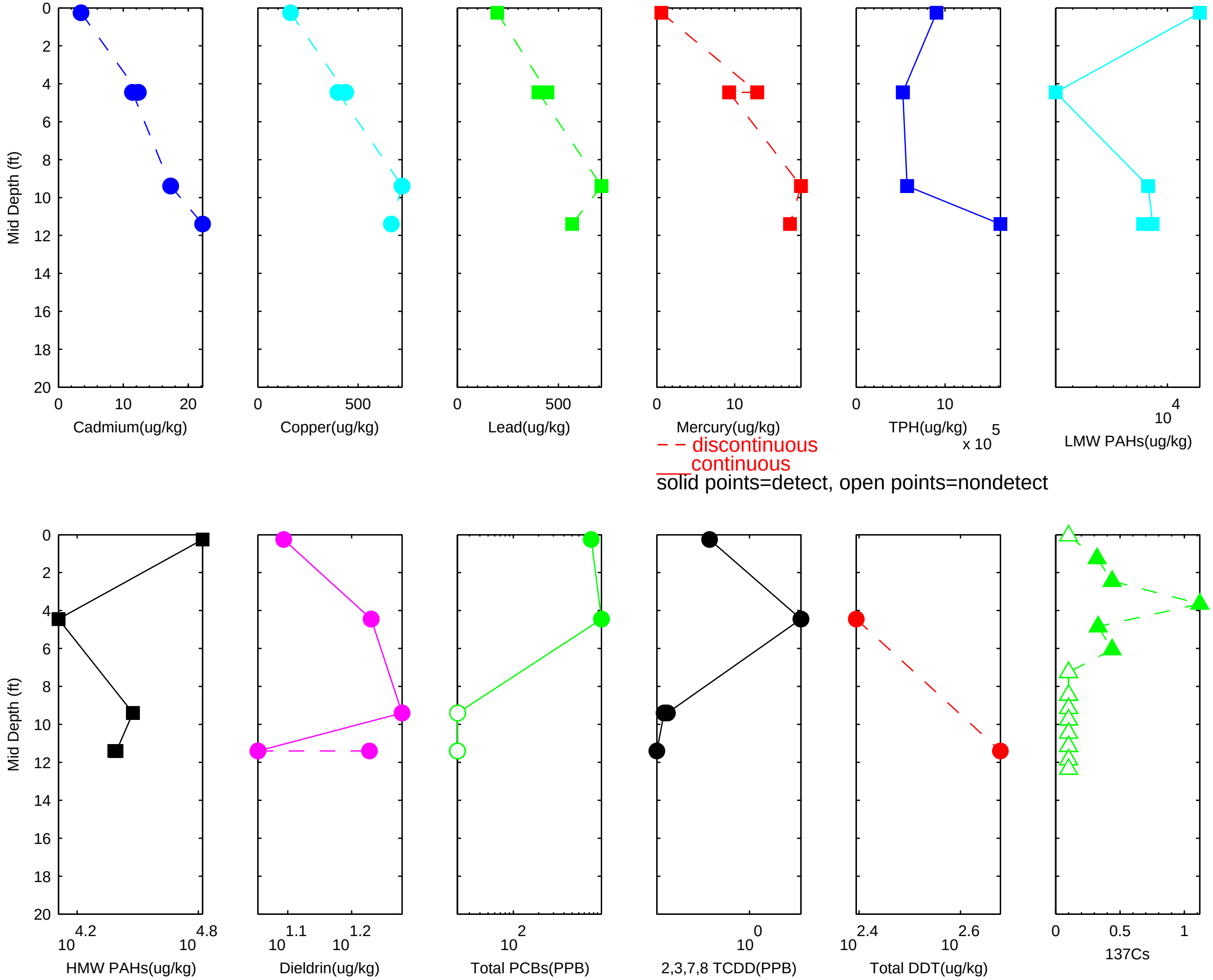

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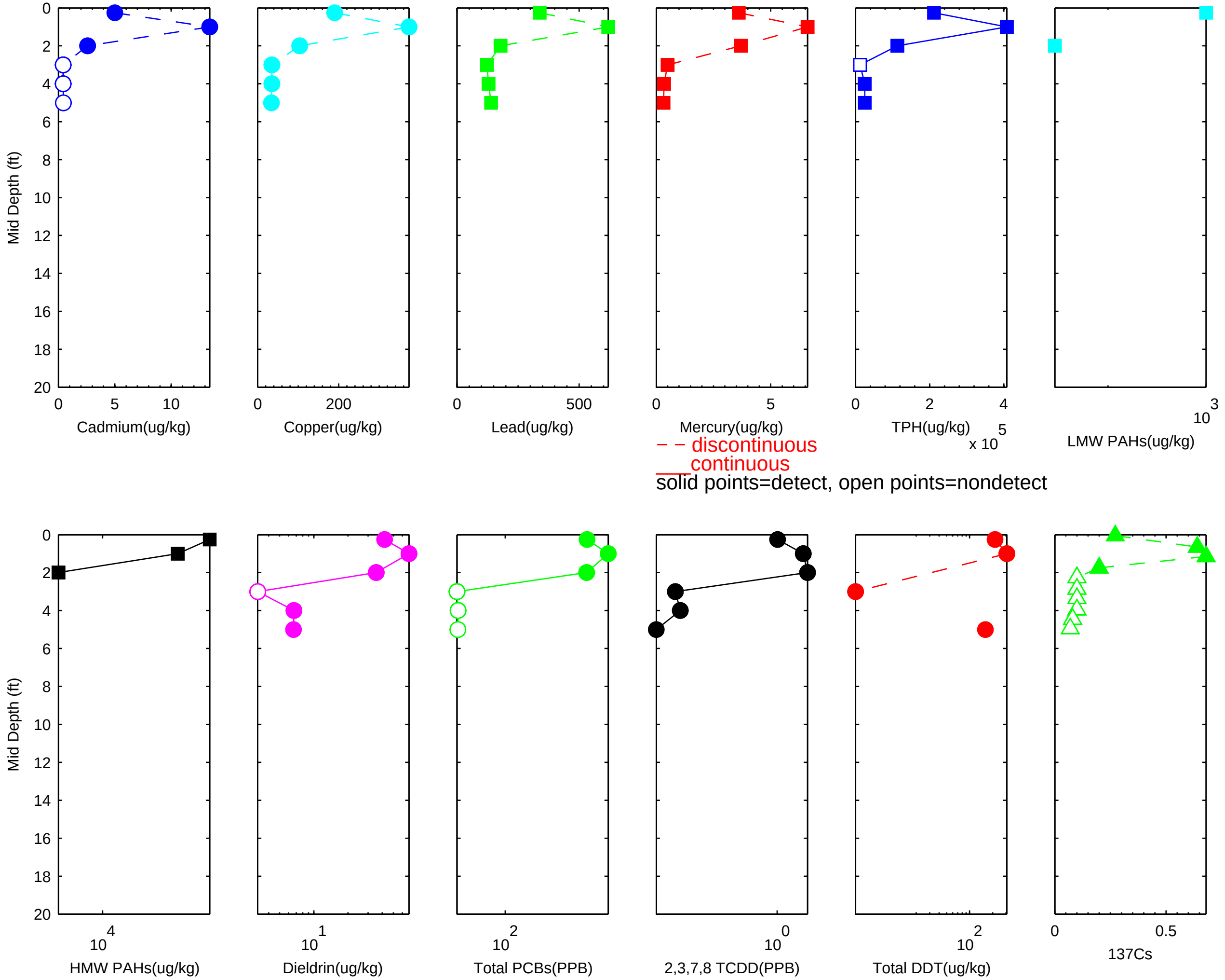

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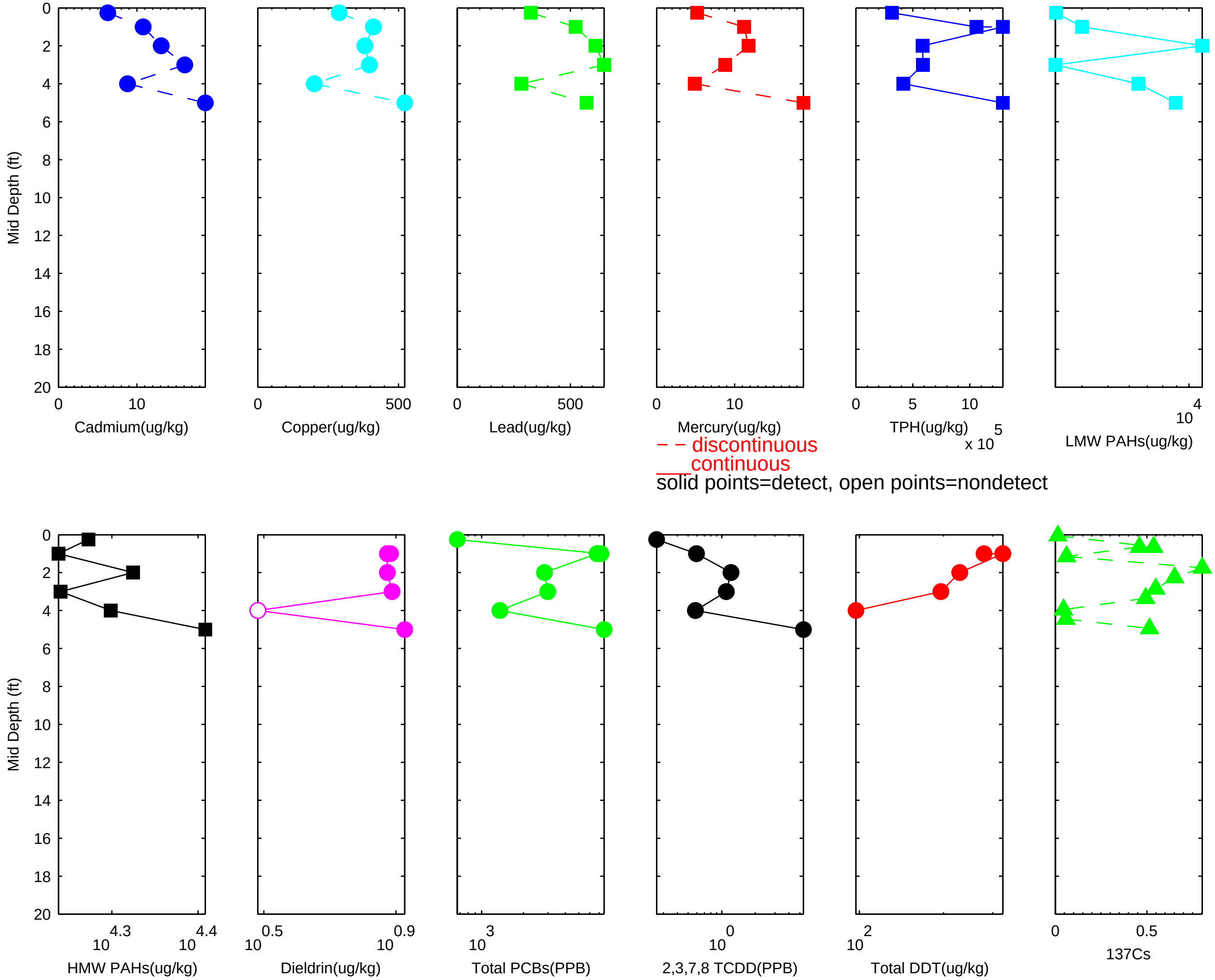

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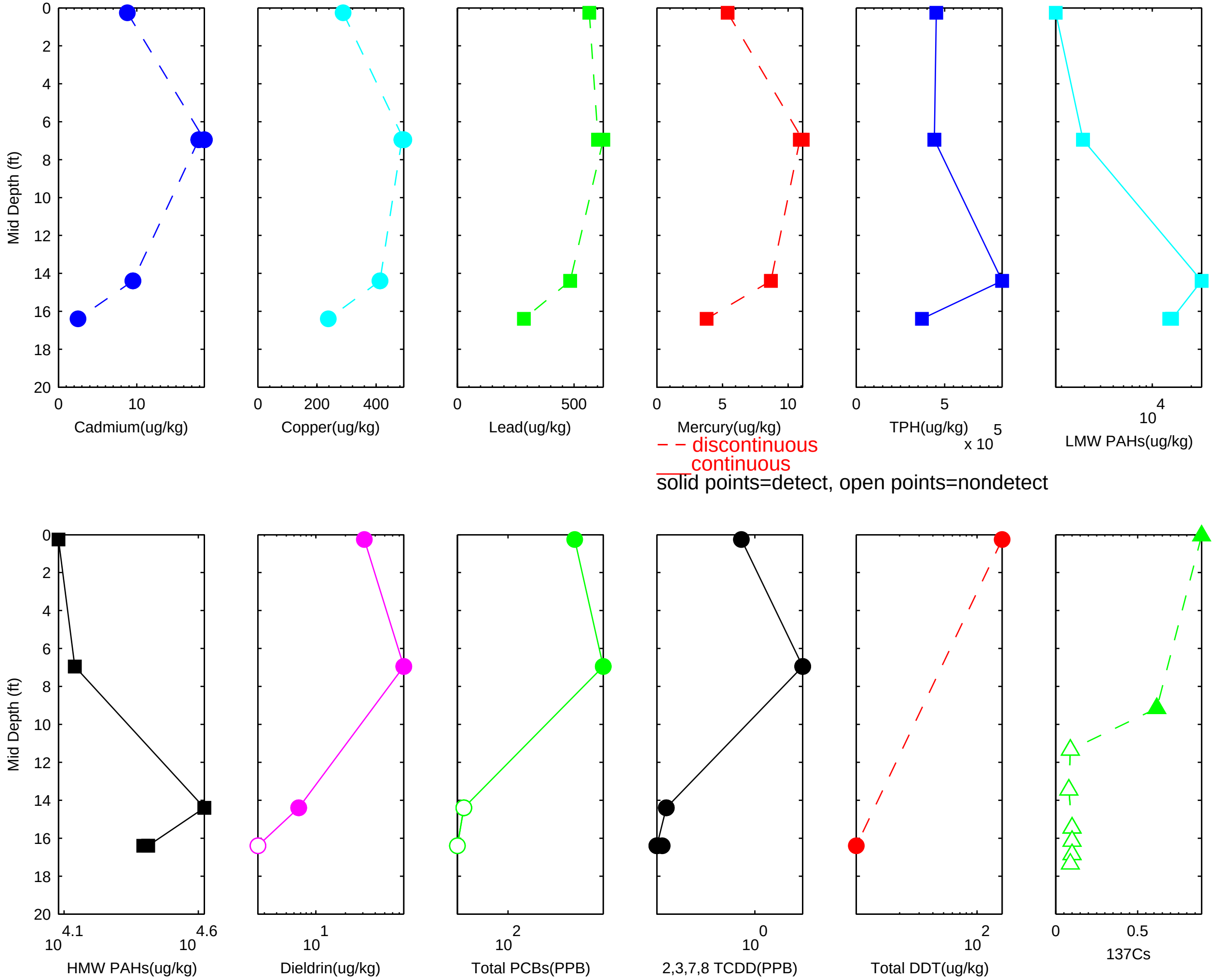

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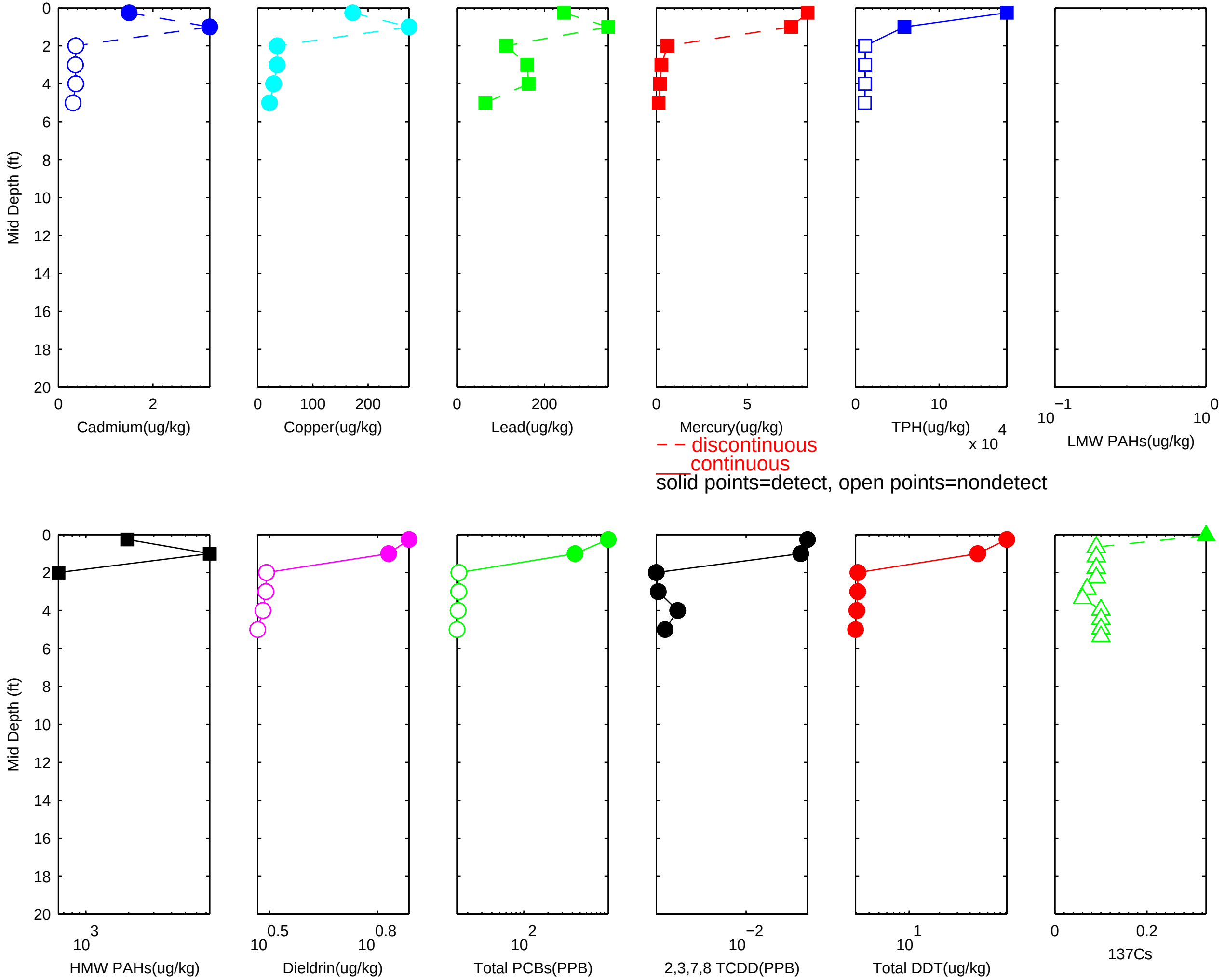

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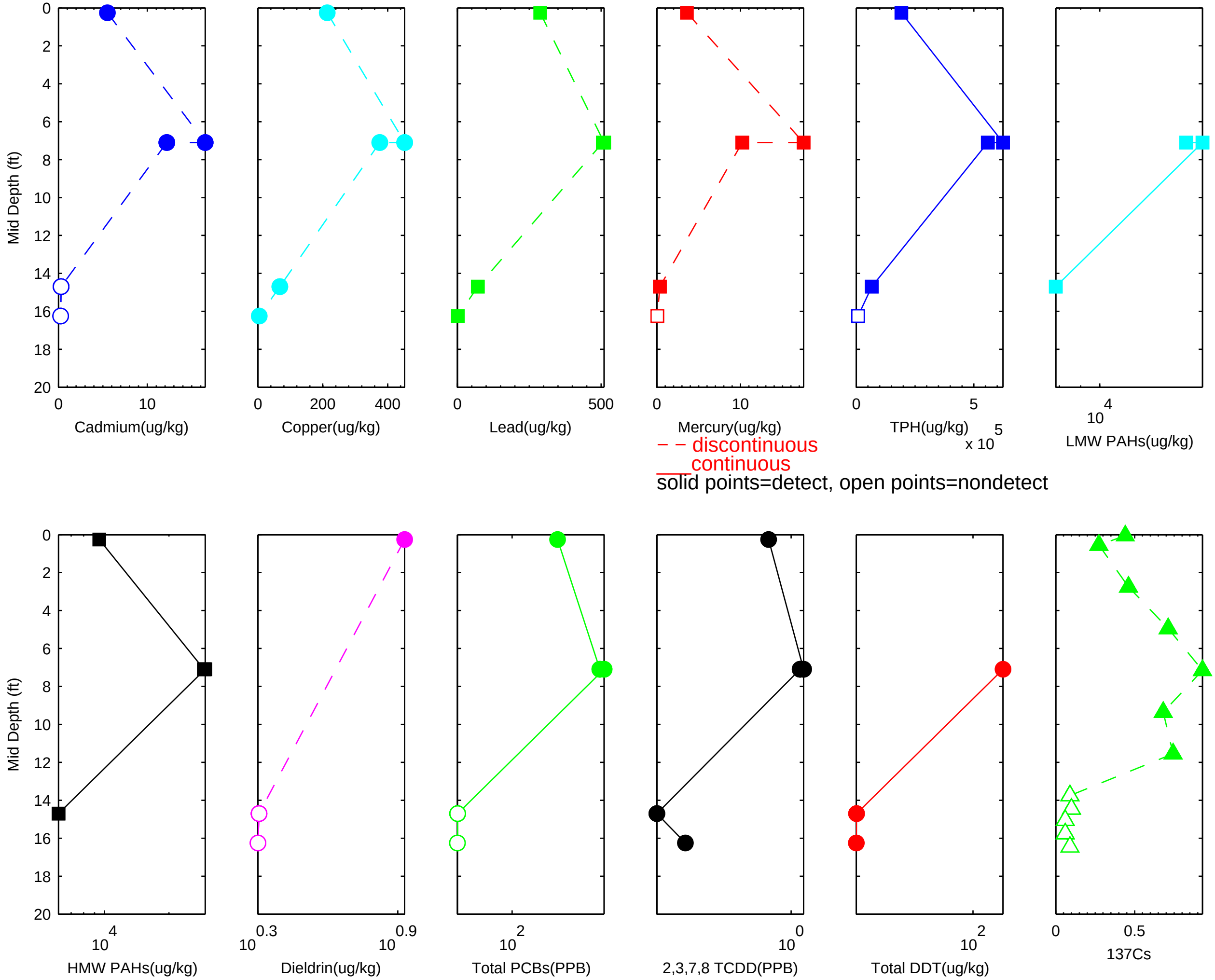

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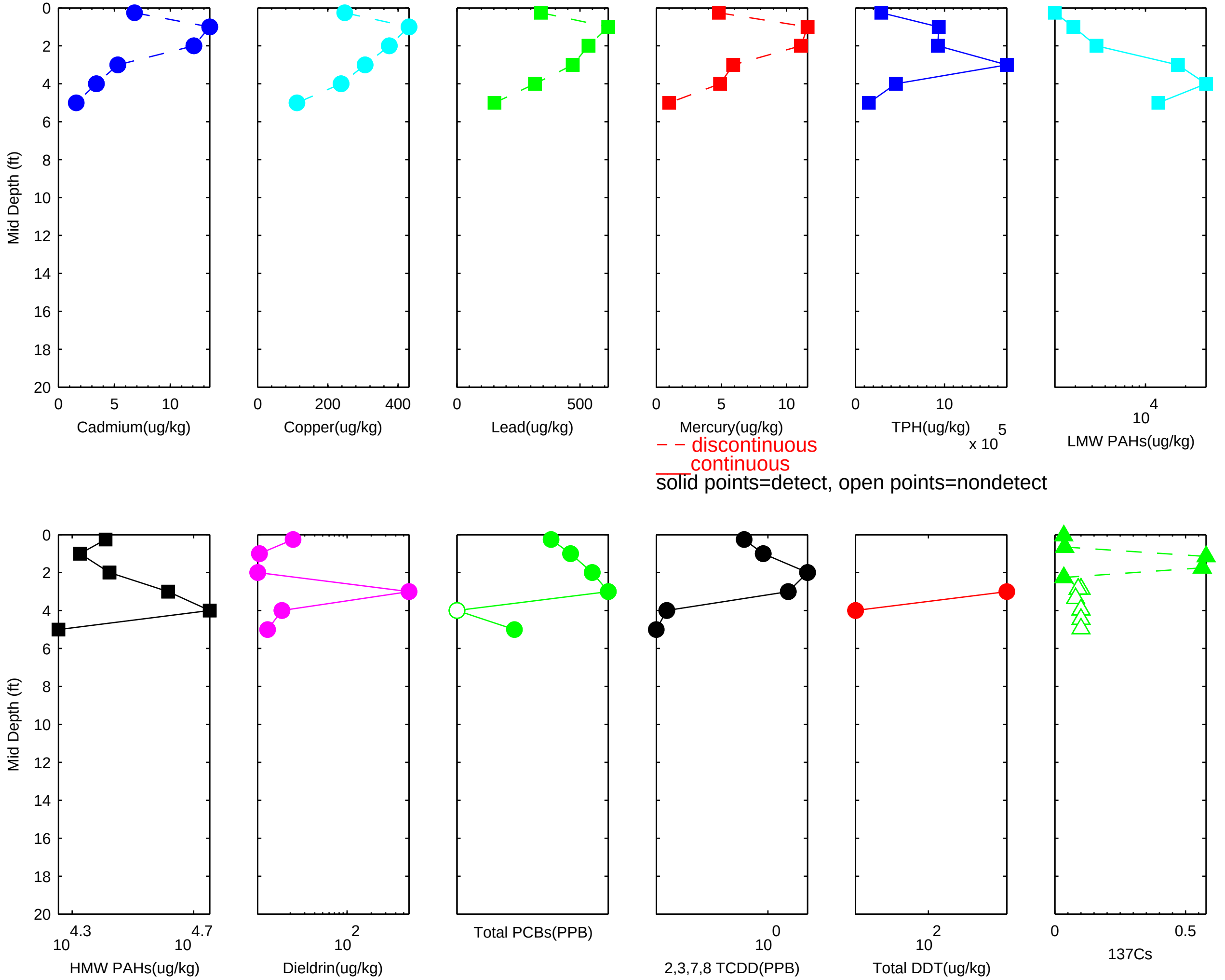

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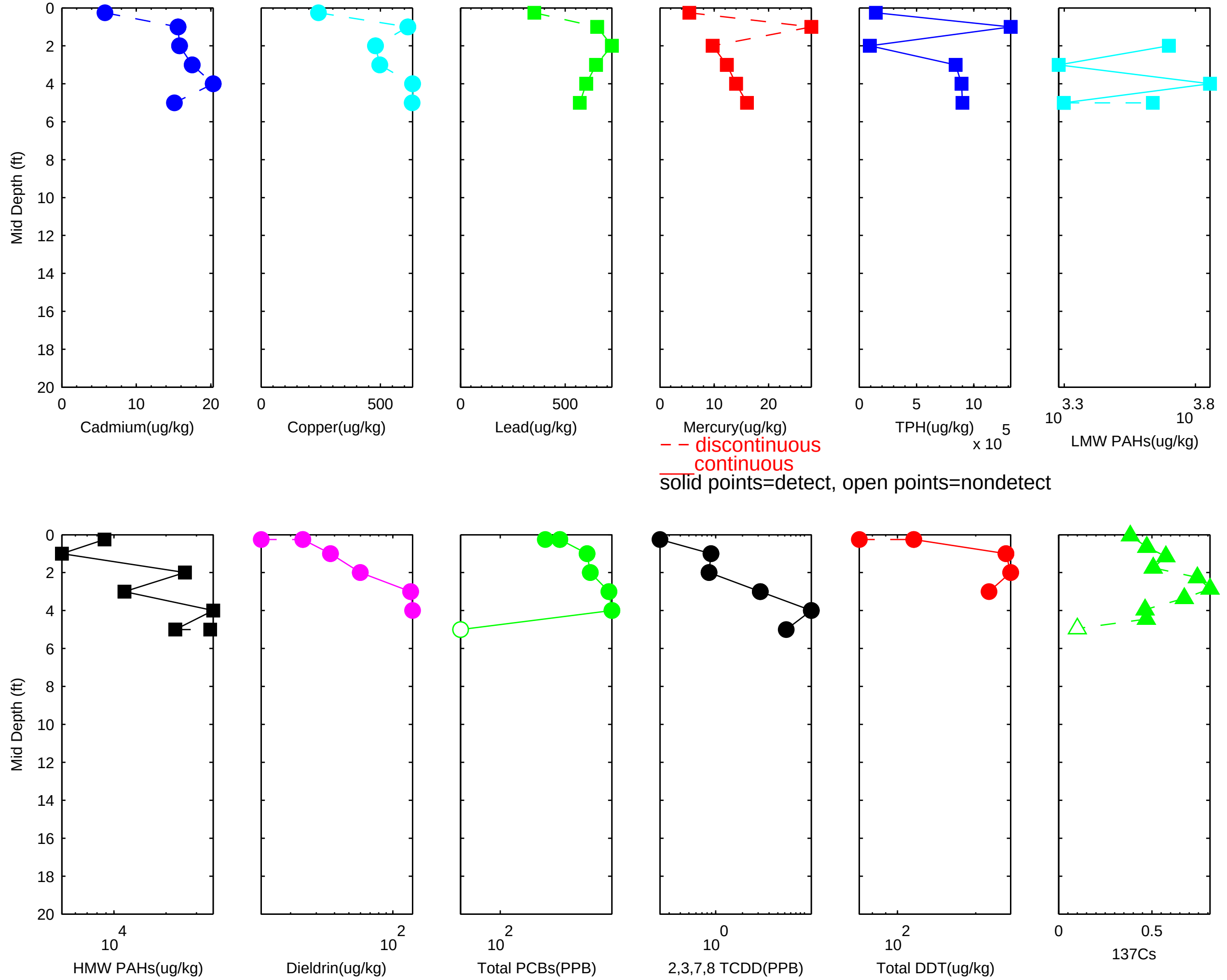

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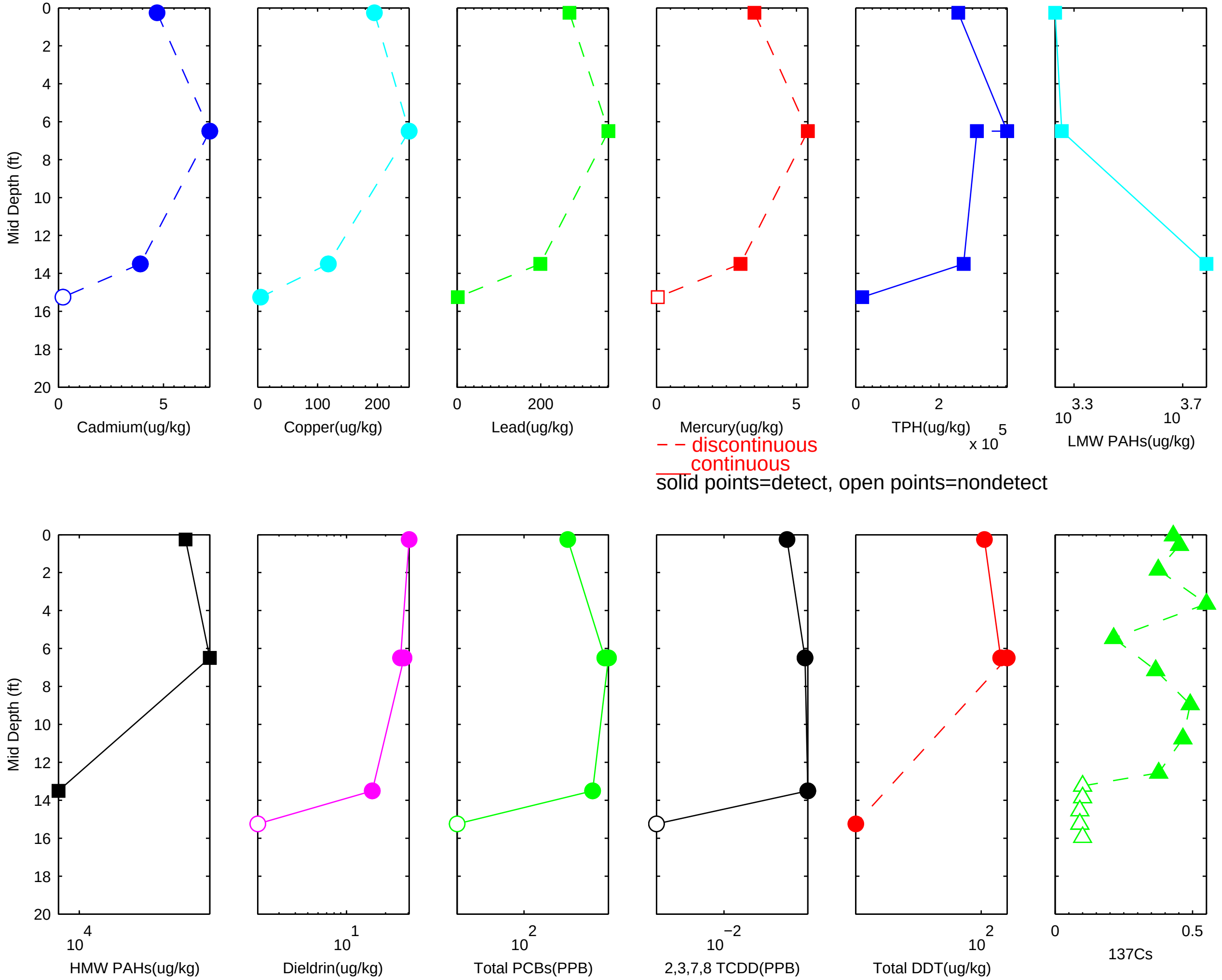

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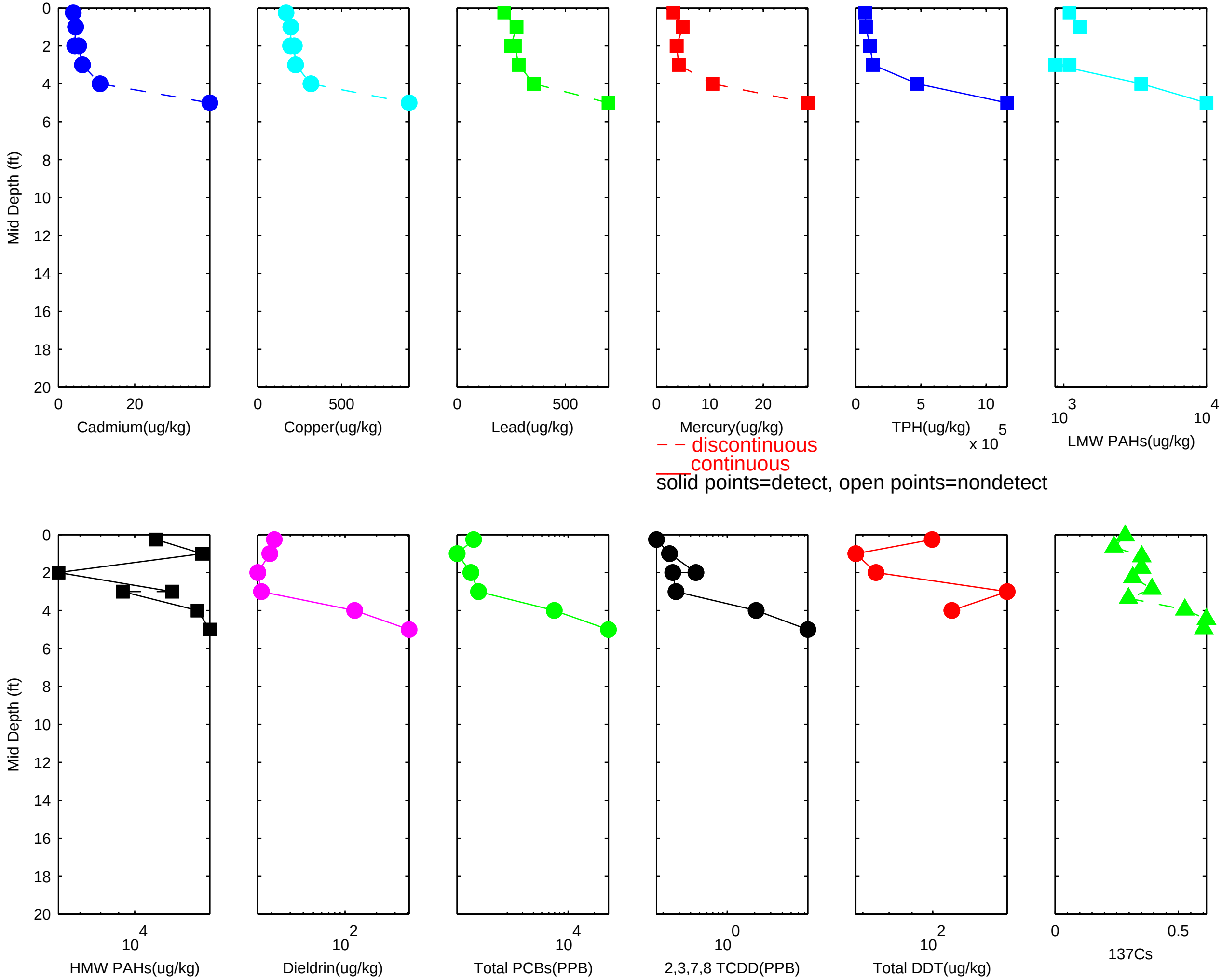

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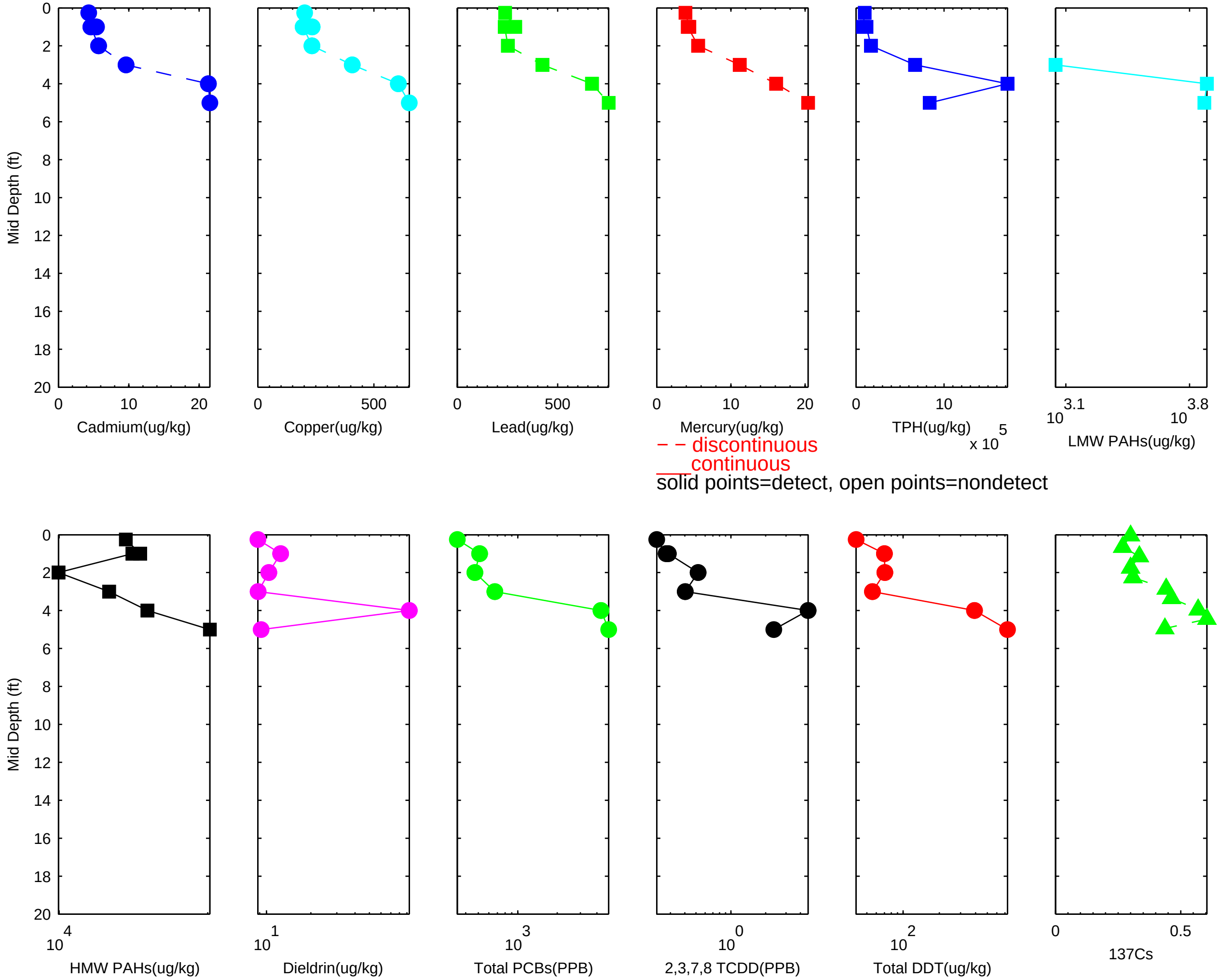

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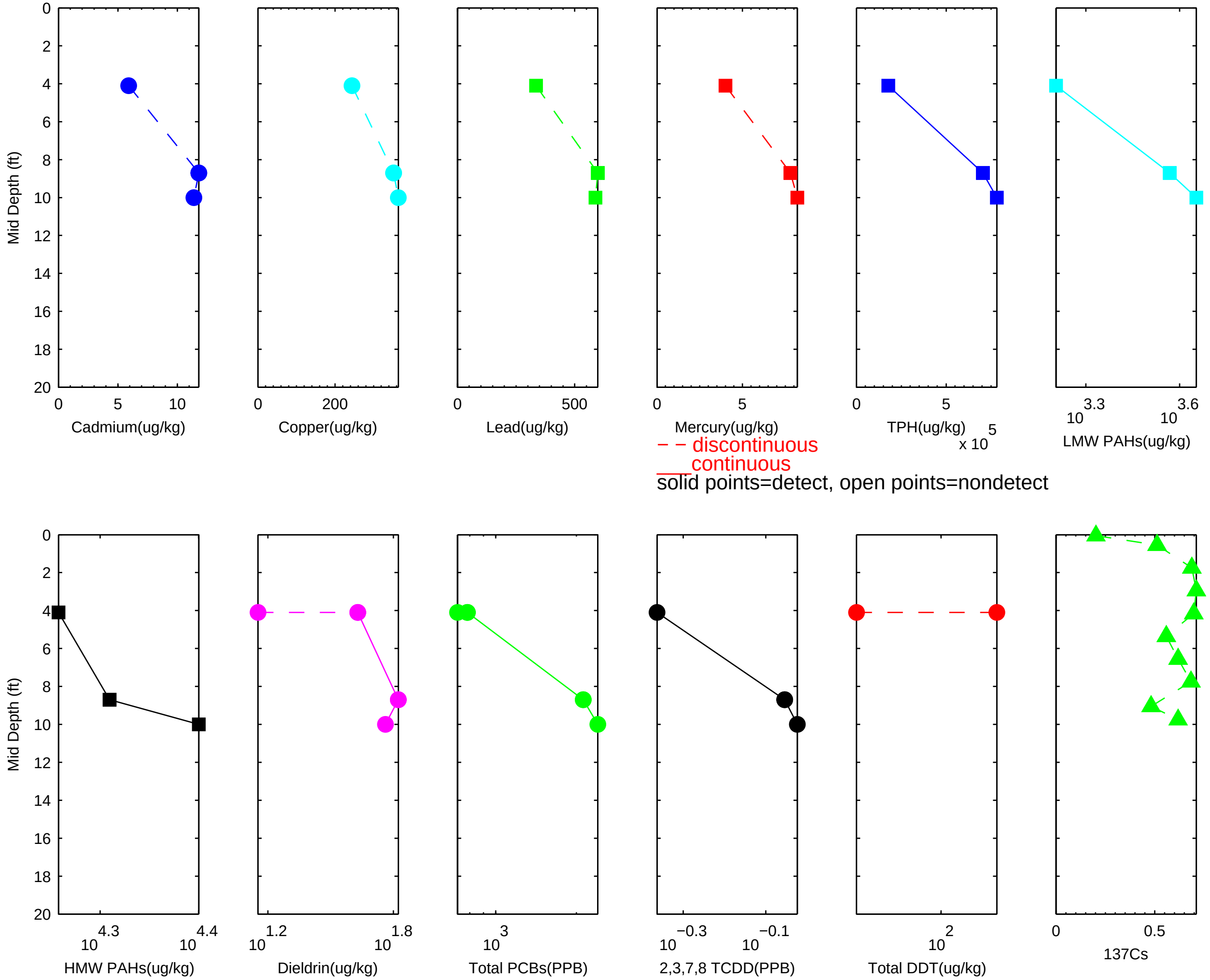

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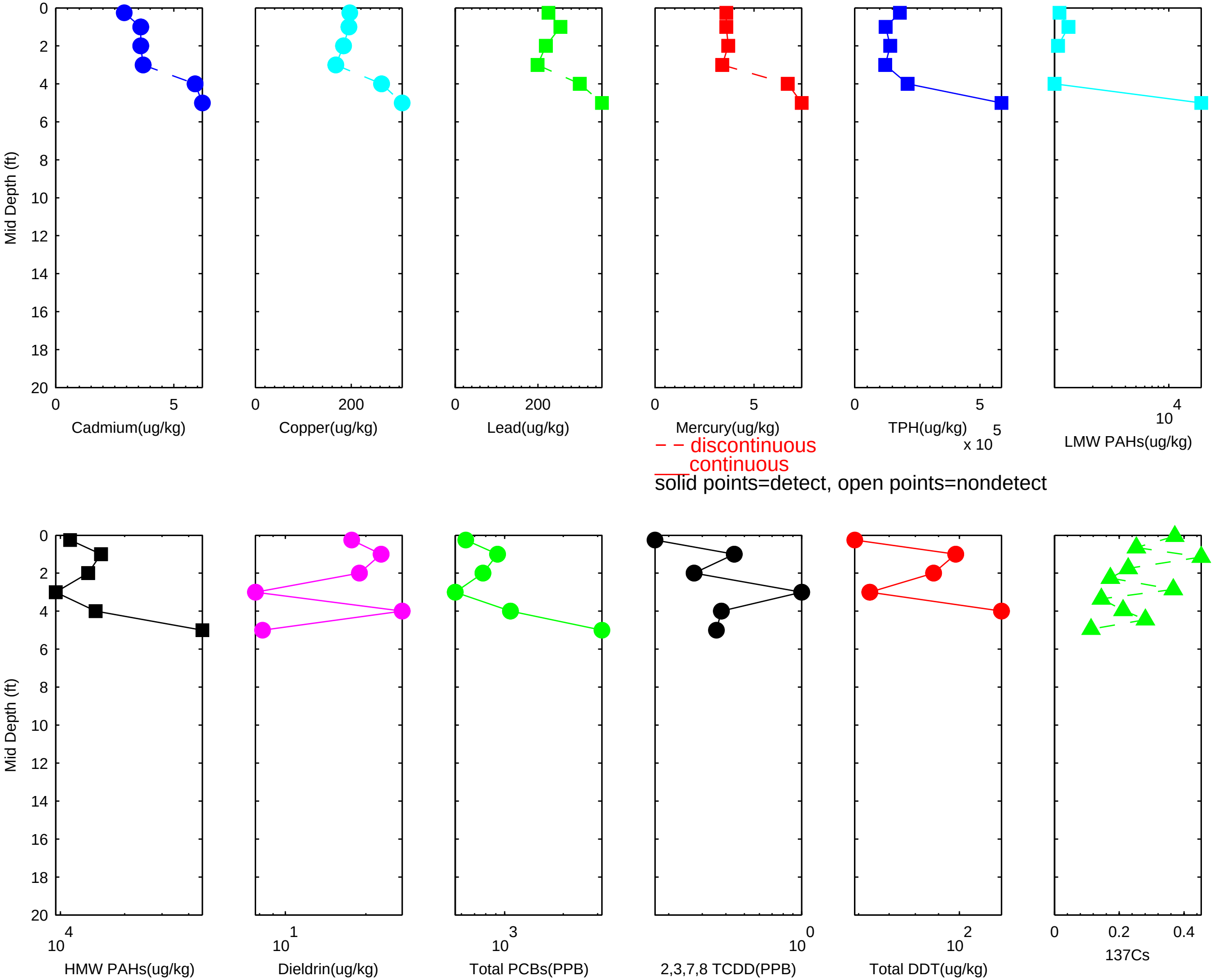
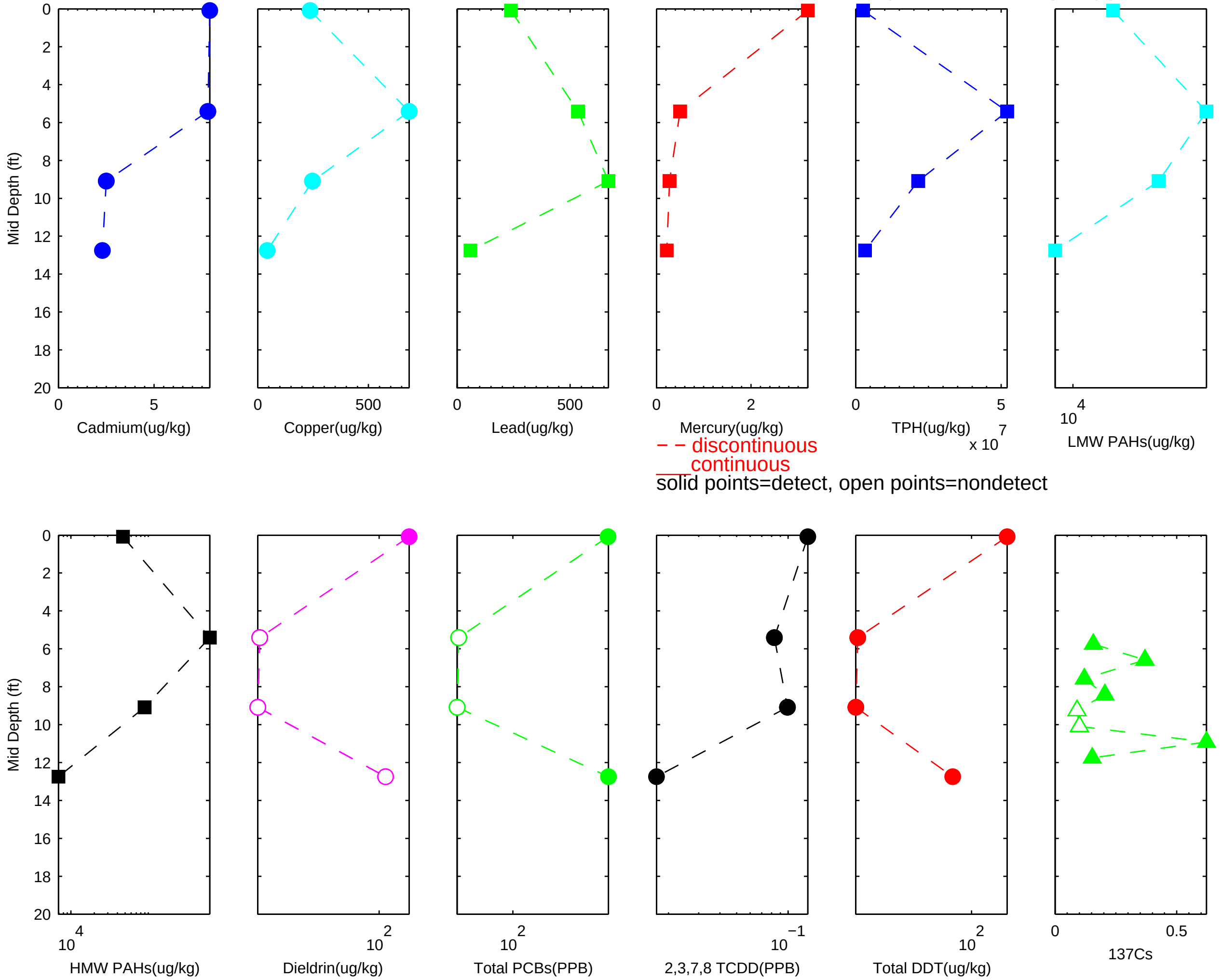
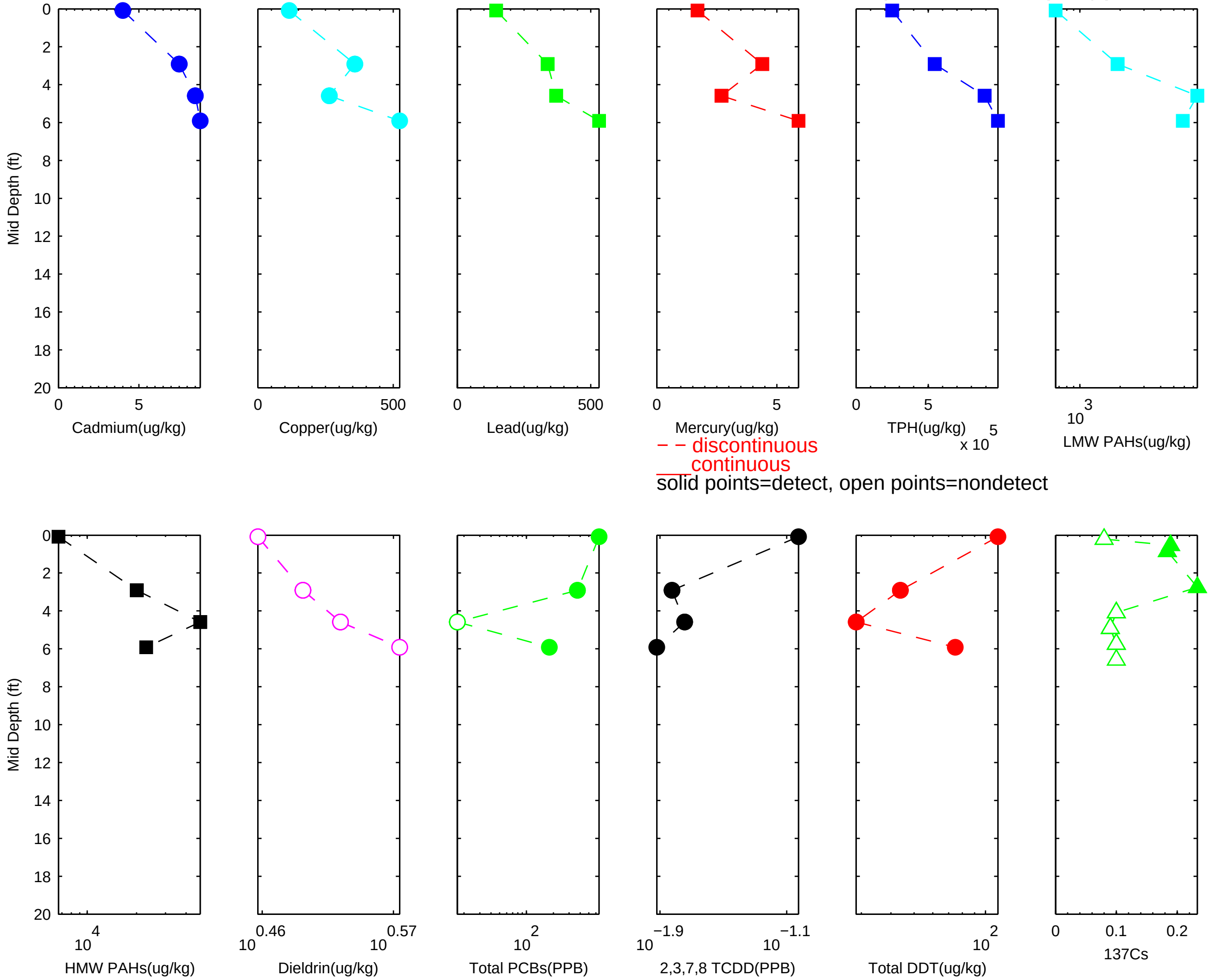


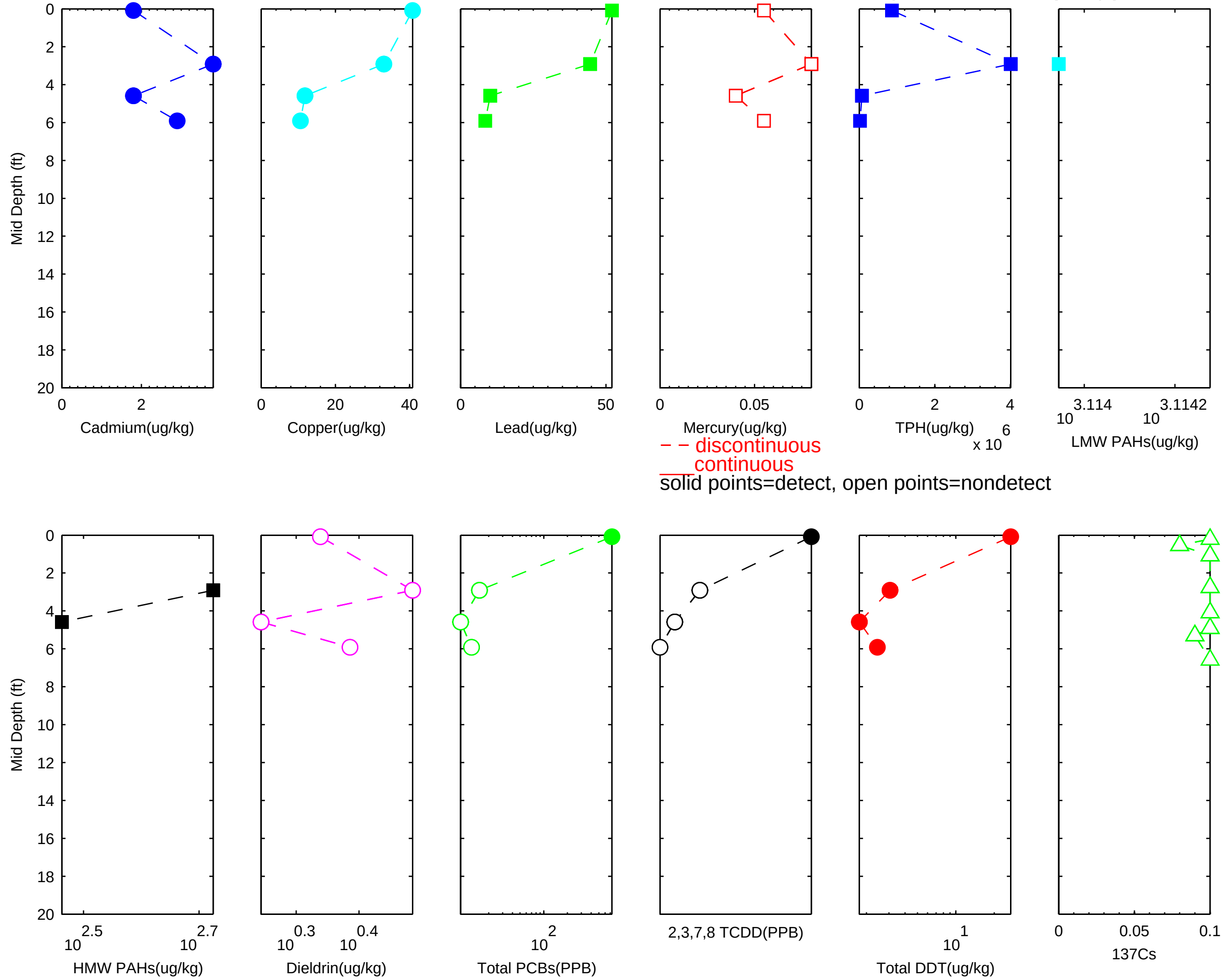
Sample ID: 100 River Mile 1.13PASSAIC 1993 Core Sediment Investigation − 02 (July)



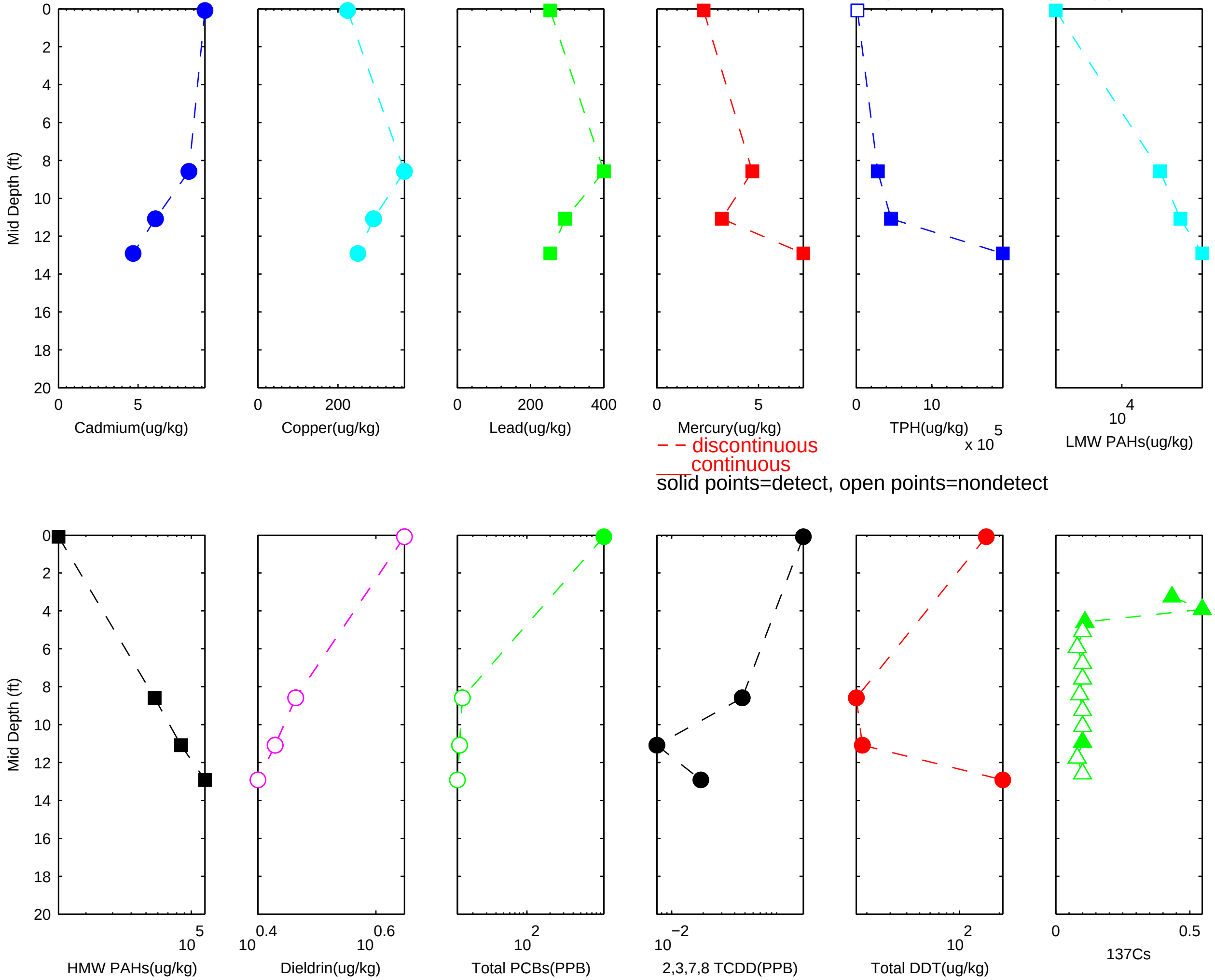
Sample ID: 99A River Mile 0.64PASSAIC 1993 Core Sediment Investigation − 02 (July)



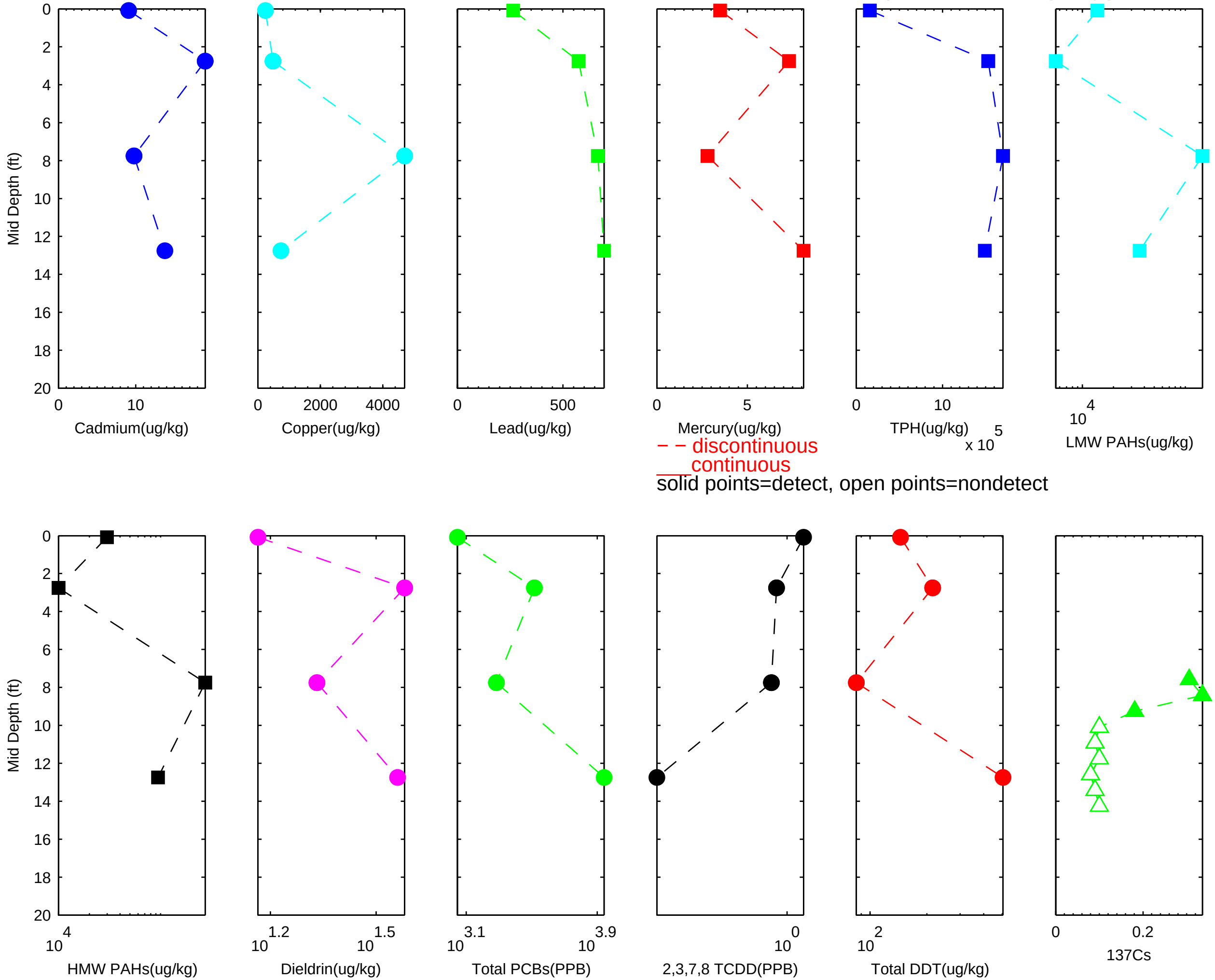
Sample ID: 98A River Mile 0.54PASSAIC 1993 Core Sediment Investigation − 02 (July)



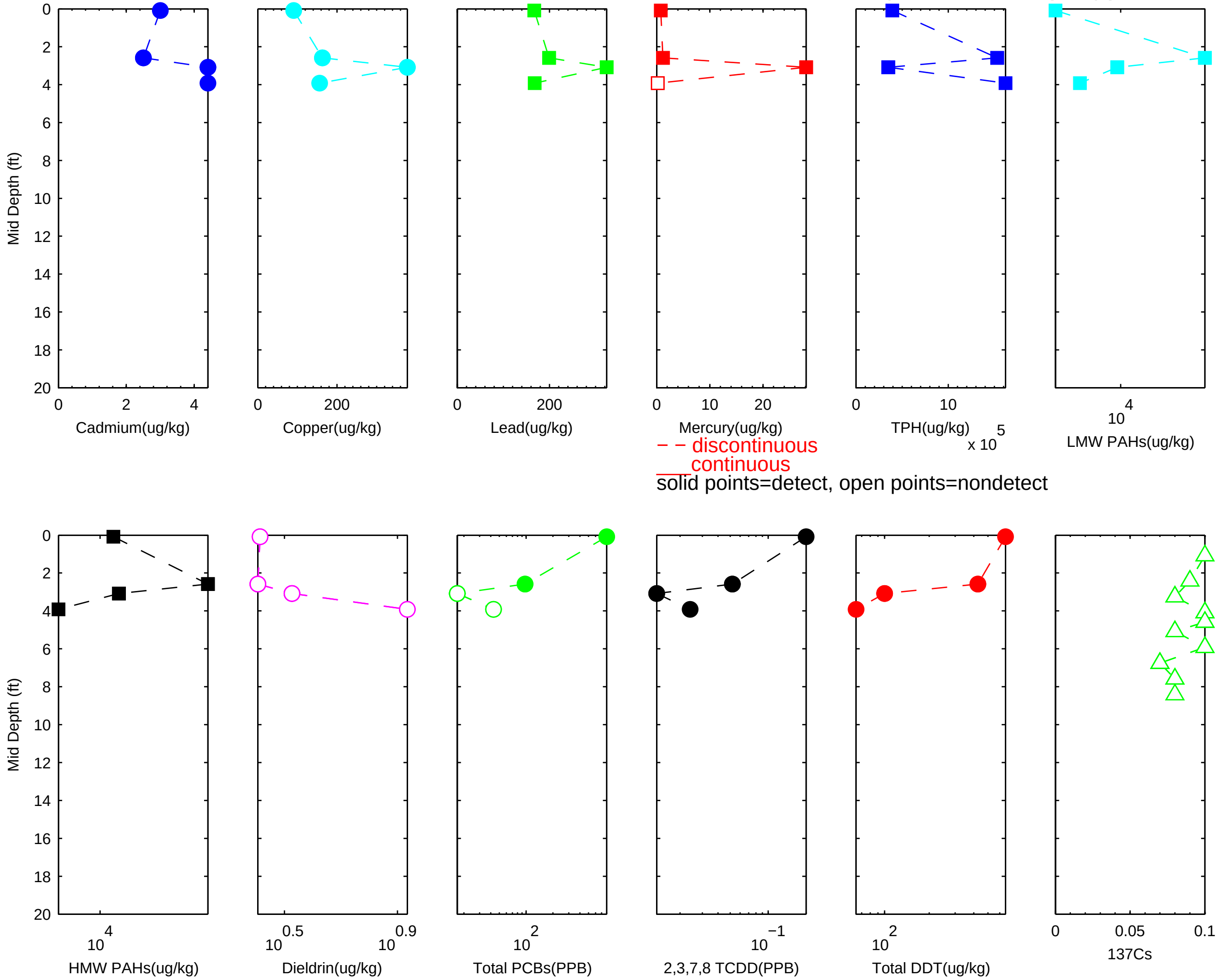
Sample ID: 97B River Mile 1.51PASSAIC 1993 Core Sediment Investigation − 02 (July)



Sample ID: 96A River Mile 1.1 PASSAIC 1993 Core Sediment Investigation − 02 (July)



Sample ID: 95A River Mile 2.3 PASSAIC 1993 Core Sediment Investigation − 02 (July)



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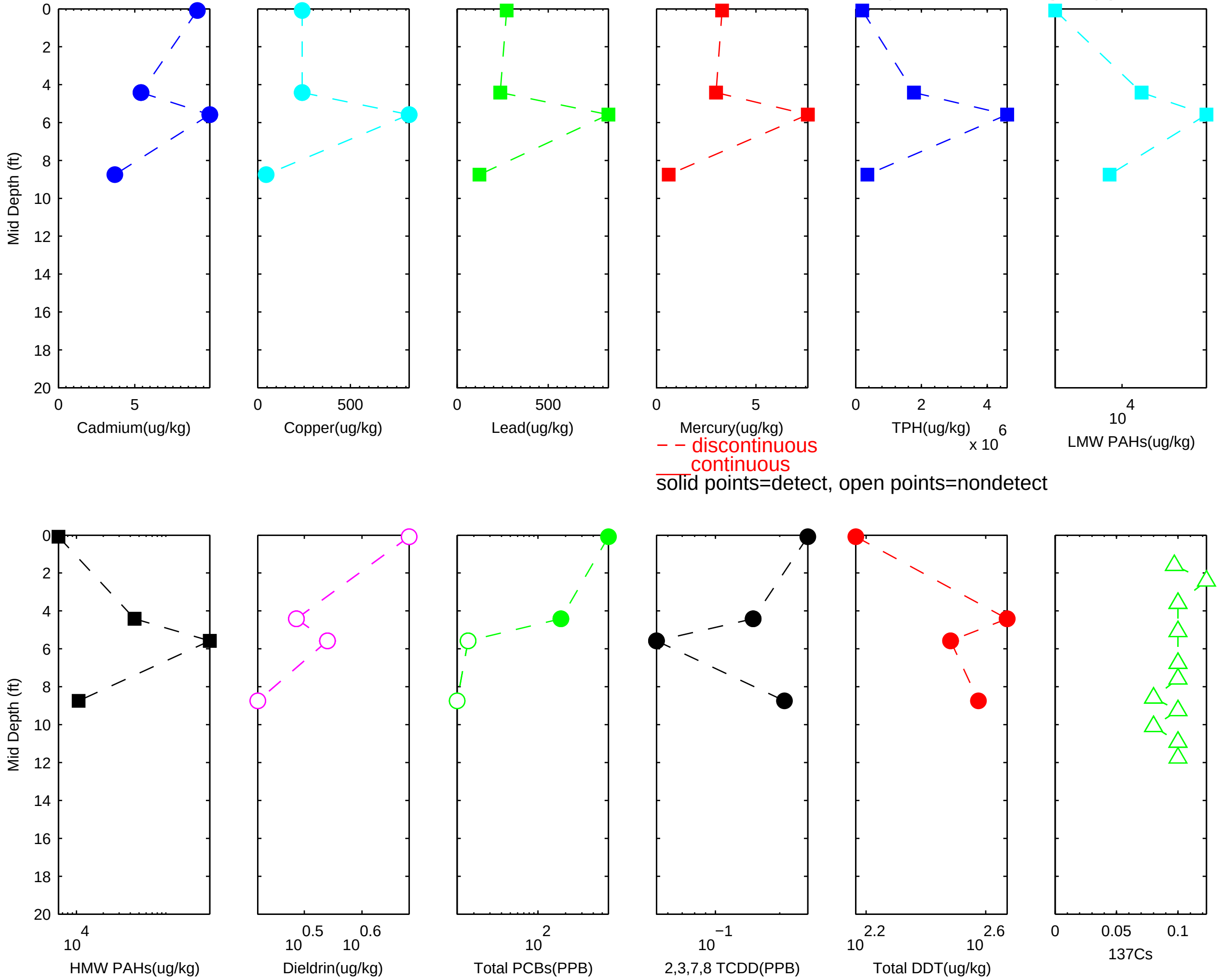

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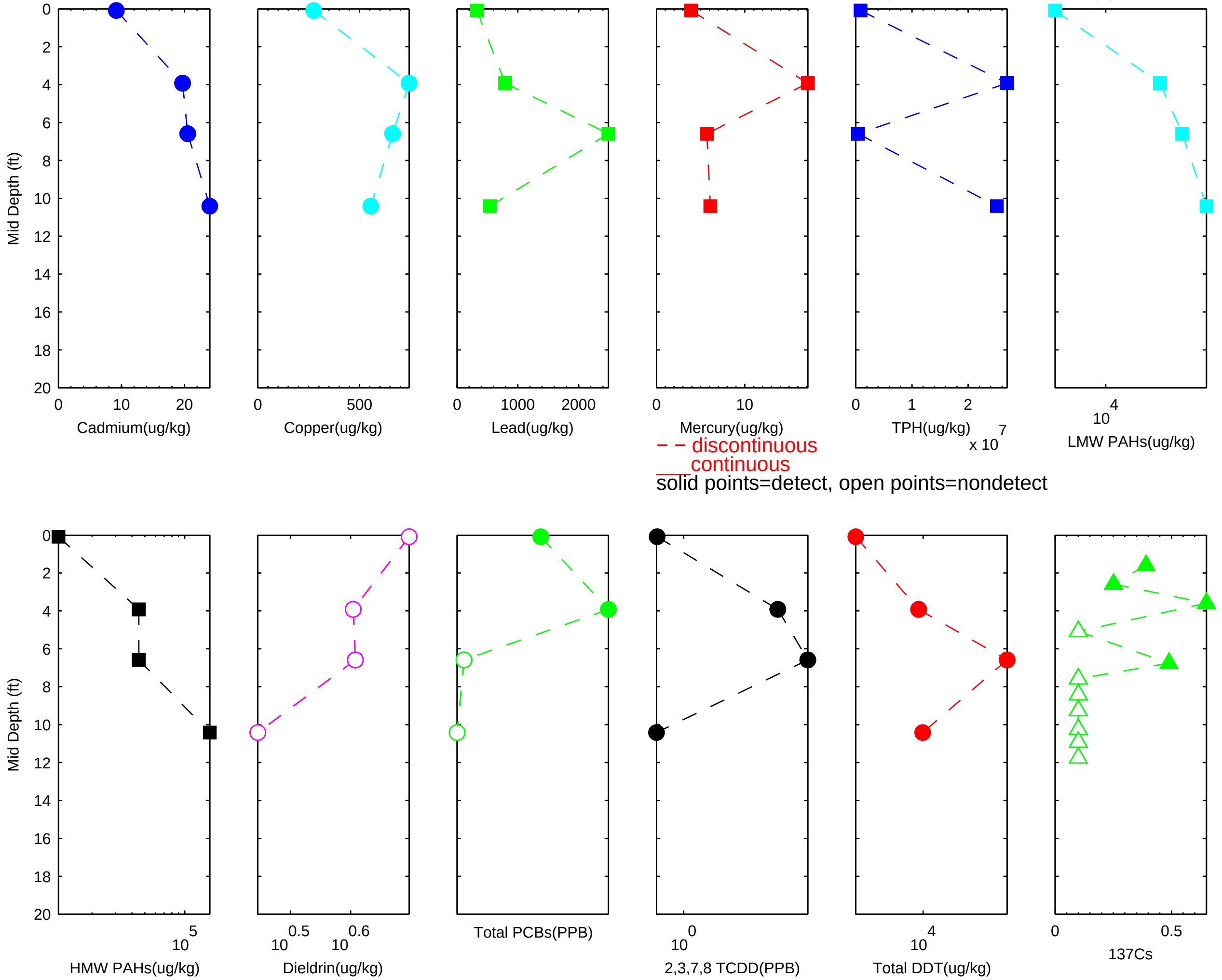

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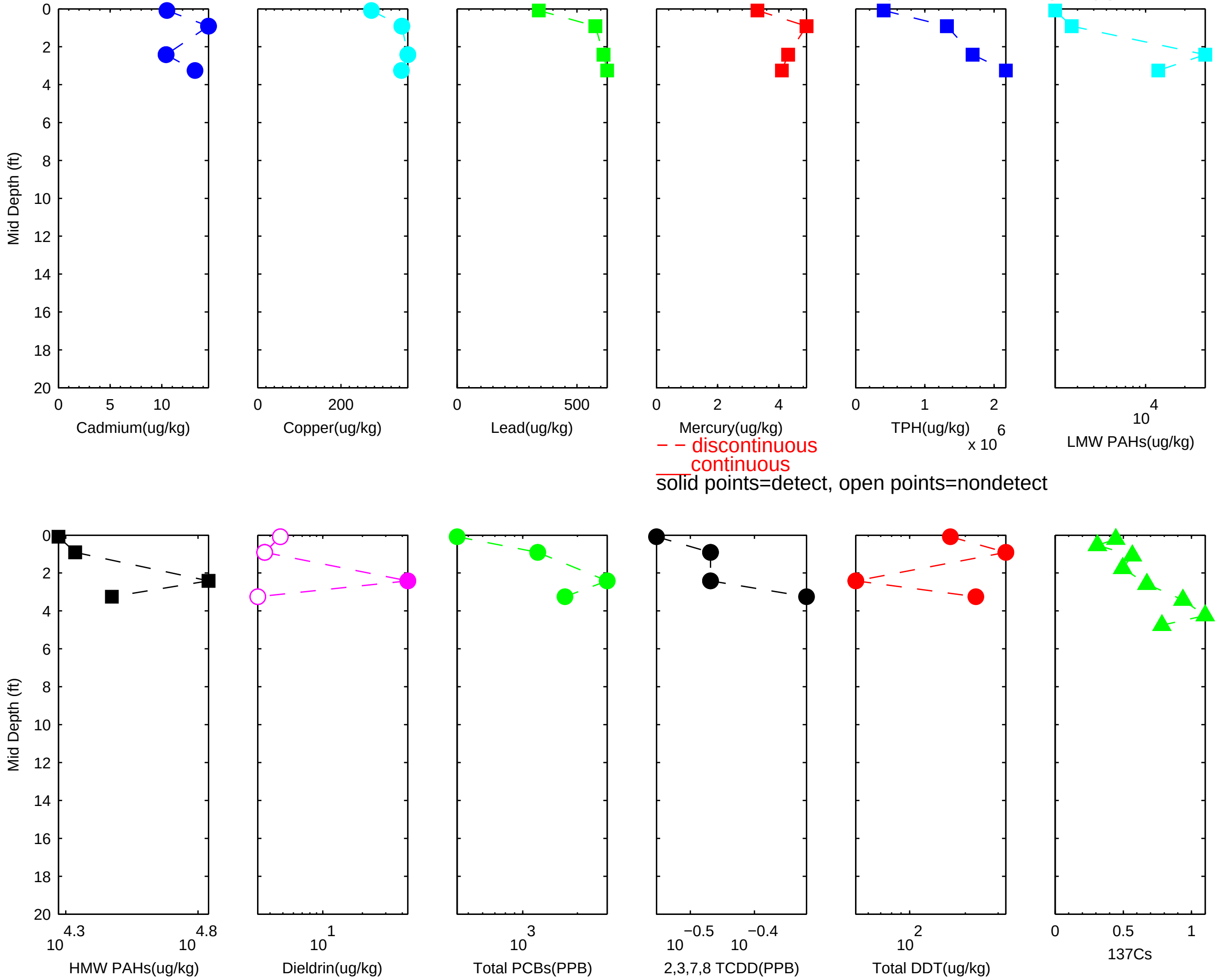

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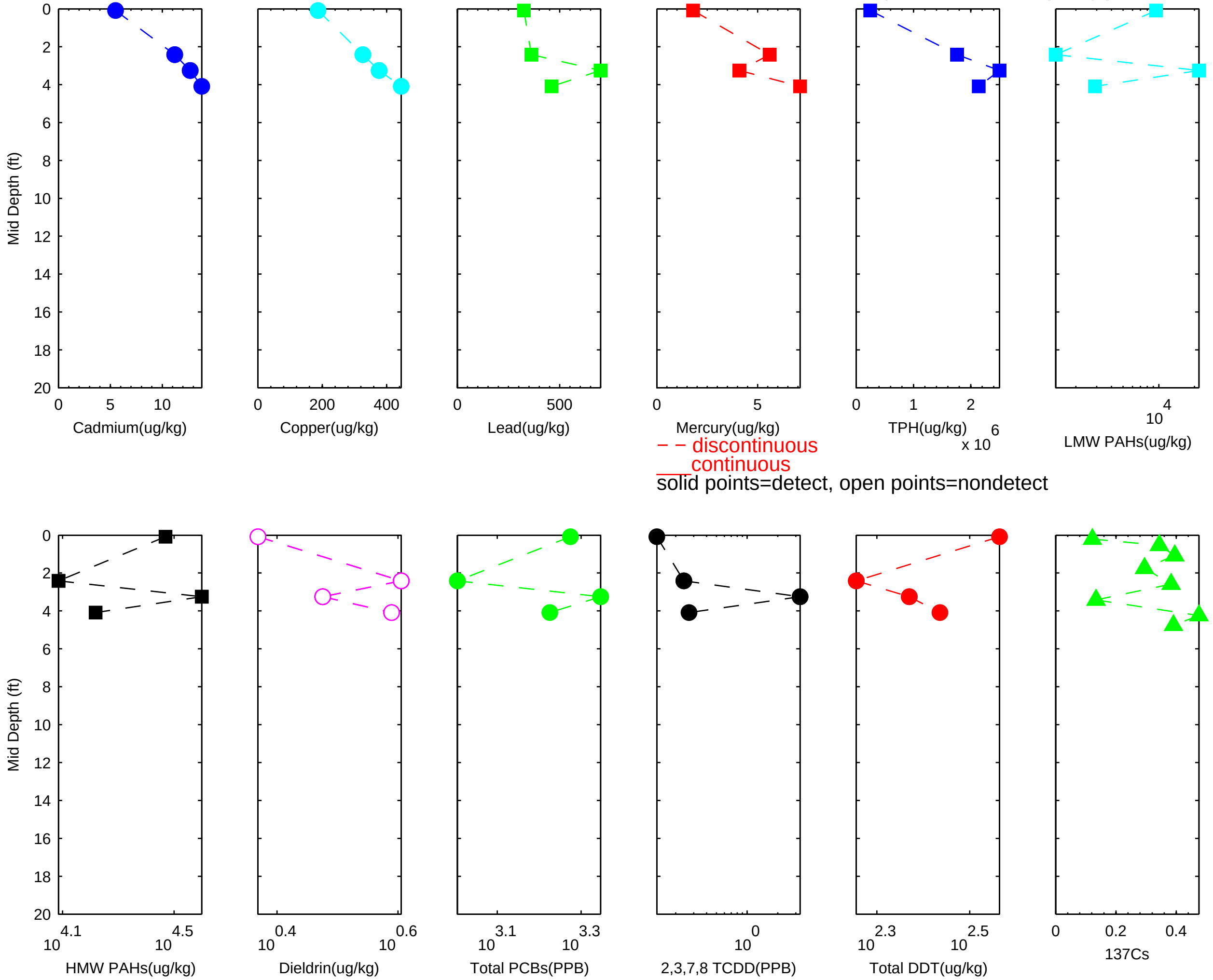
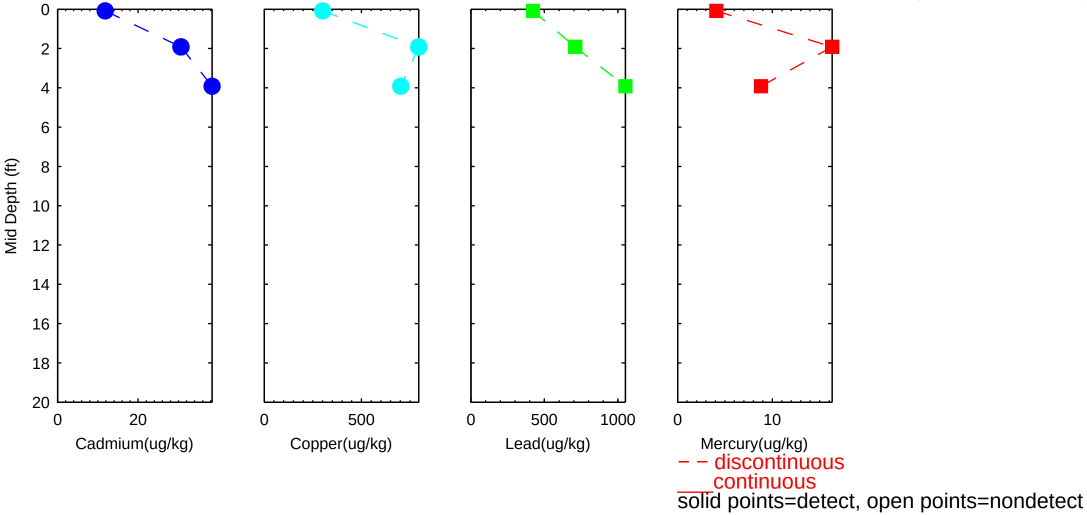
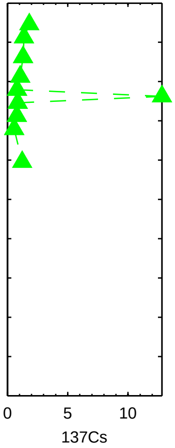
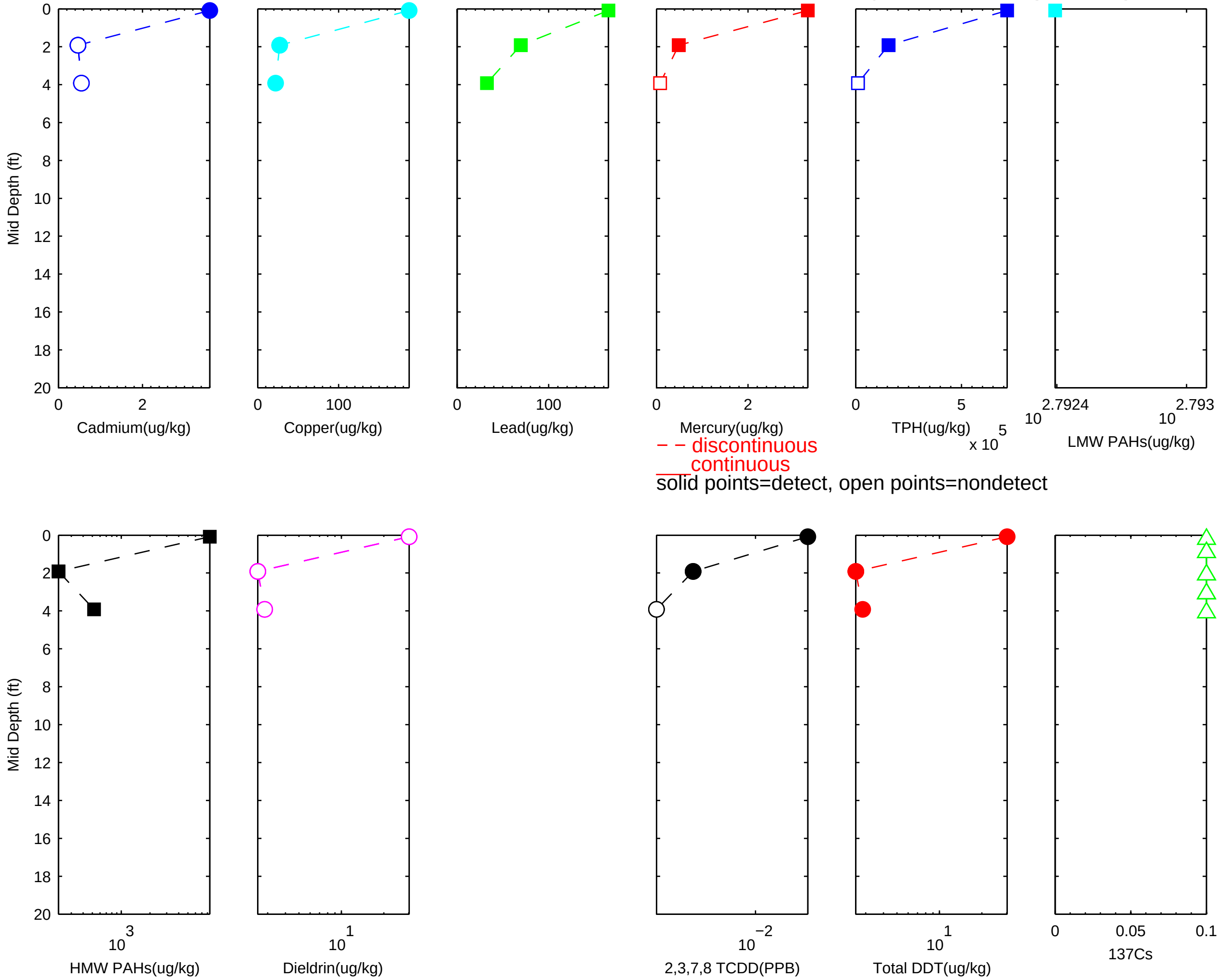


Sample ID: 90A River Mile 6.94PASSAIC 1993 Core Sediment Investigation − 02 (July)

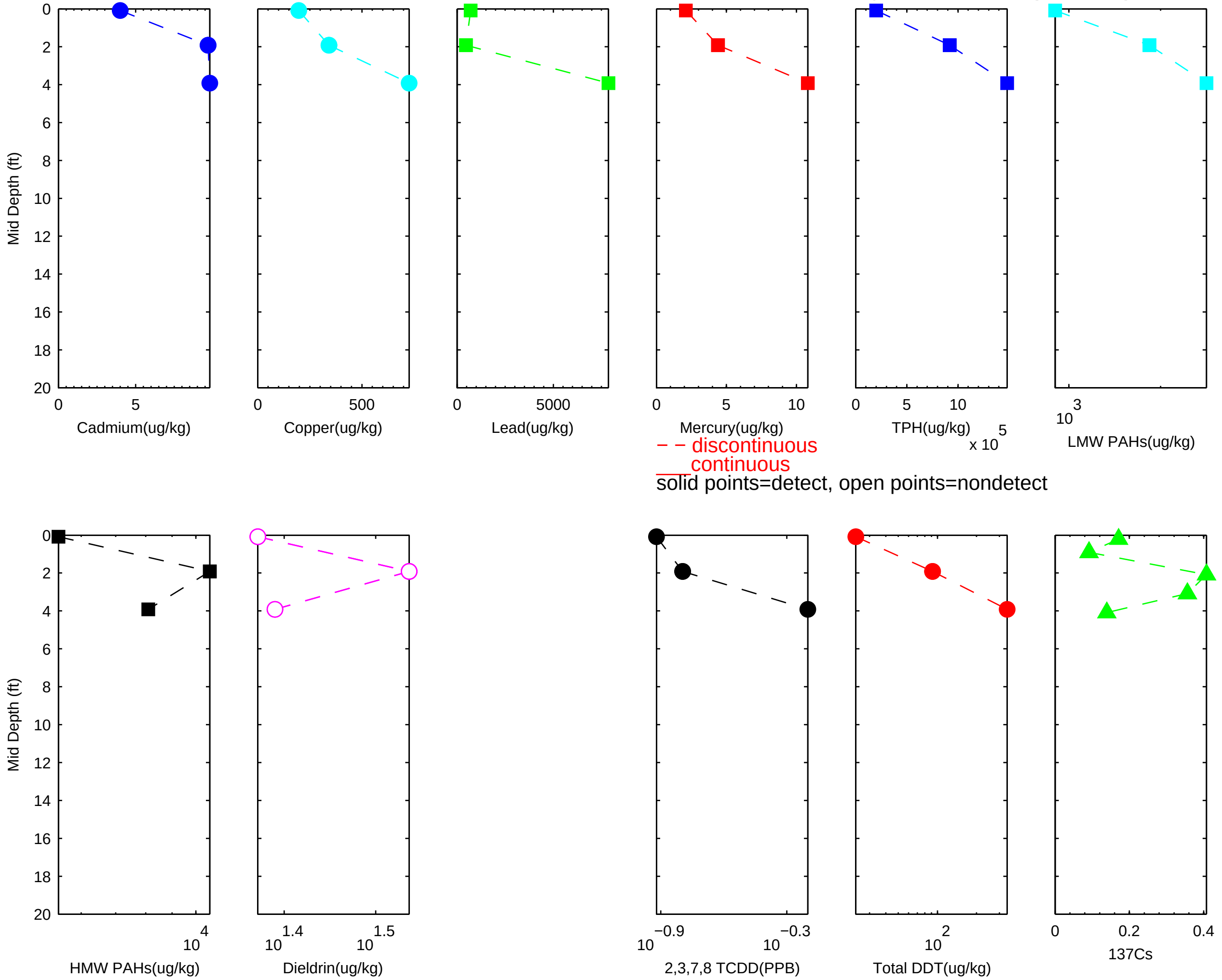




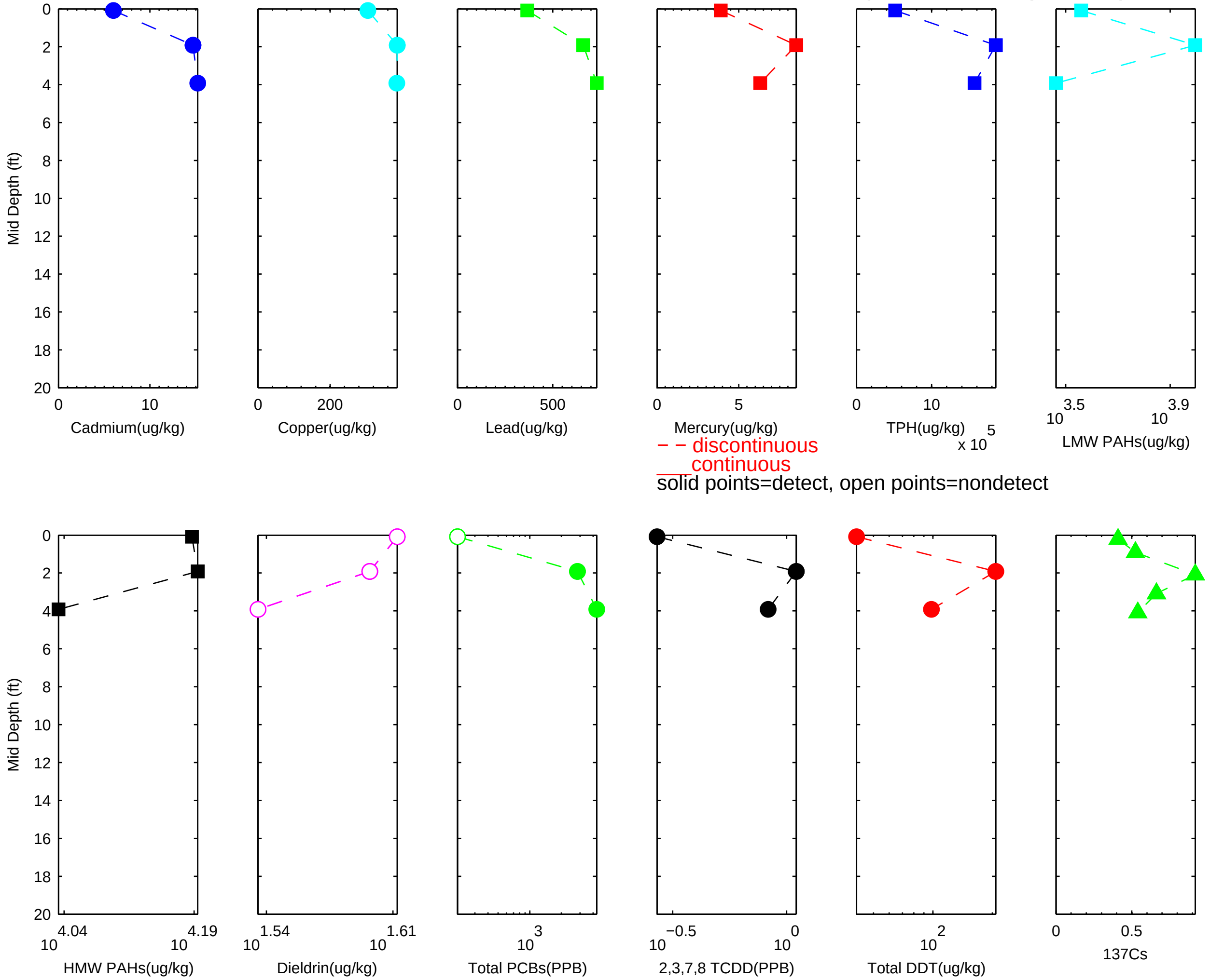
Sample ID: 82A River Mile 0.34PASSAIC 1993 Core Sediment Investigation − 01 (March)



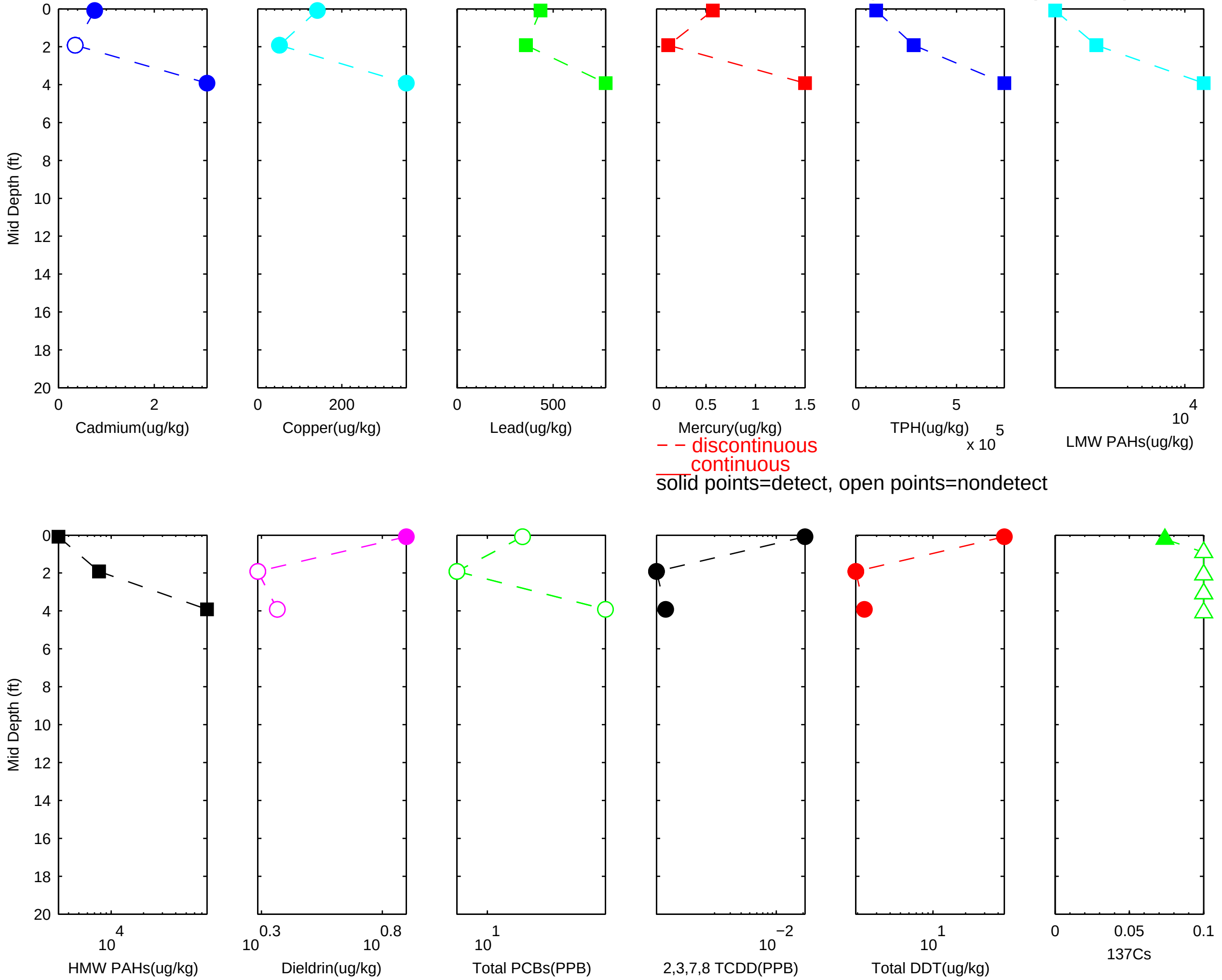
Sample ID: 81A River Mile 0.31 PASSAIC 1993 Core Sediment Investigation − 01 (March)



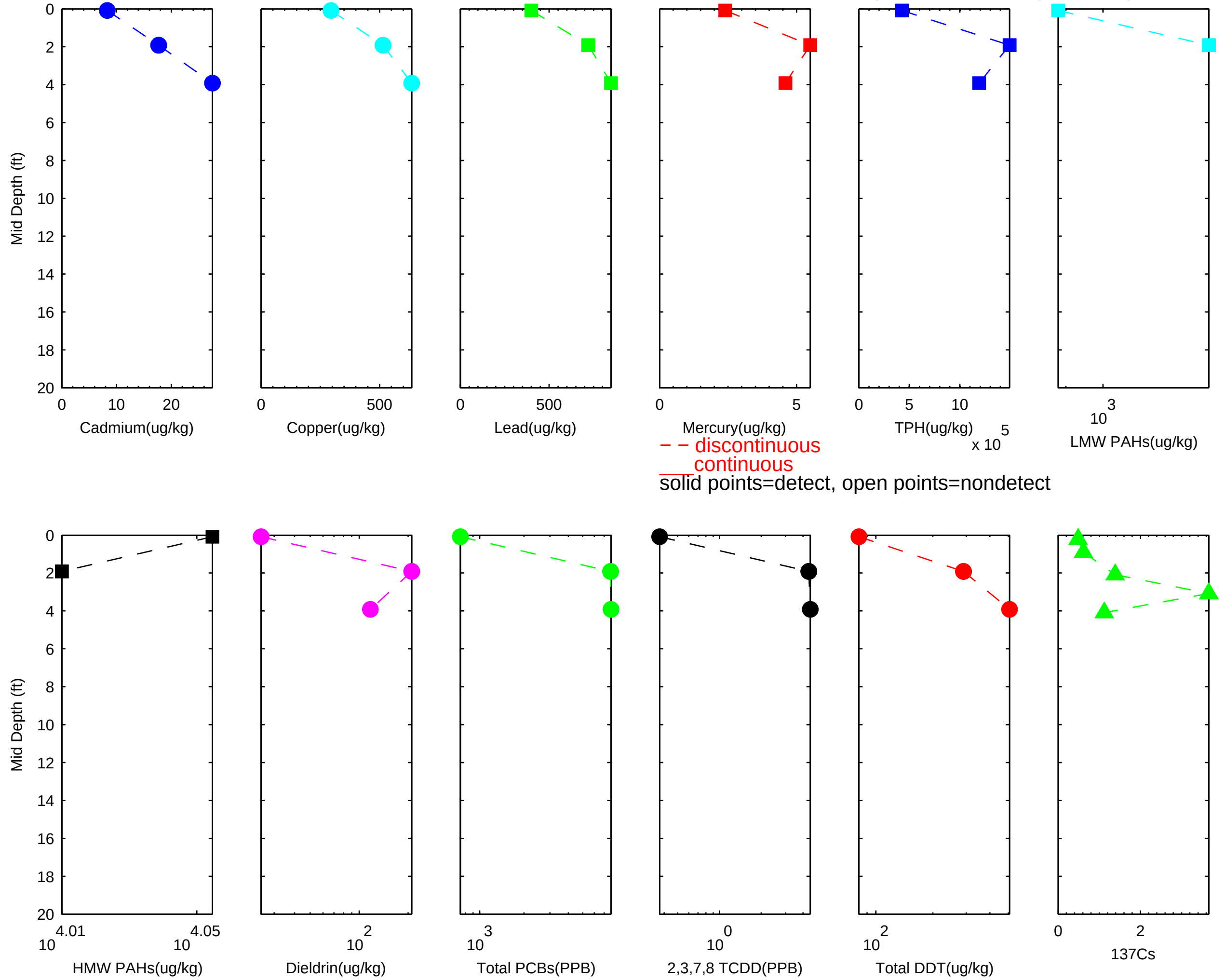
Sample ID: 77A River Mile 2.14 PASSAIC 1993 Core Sediment Investigation − 01 (March)



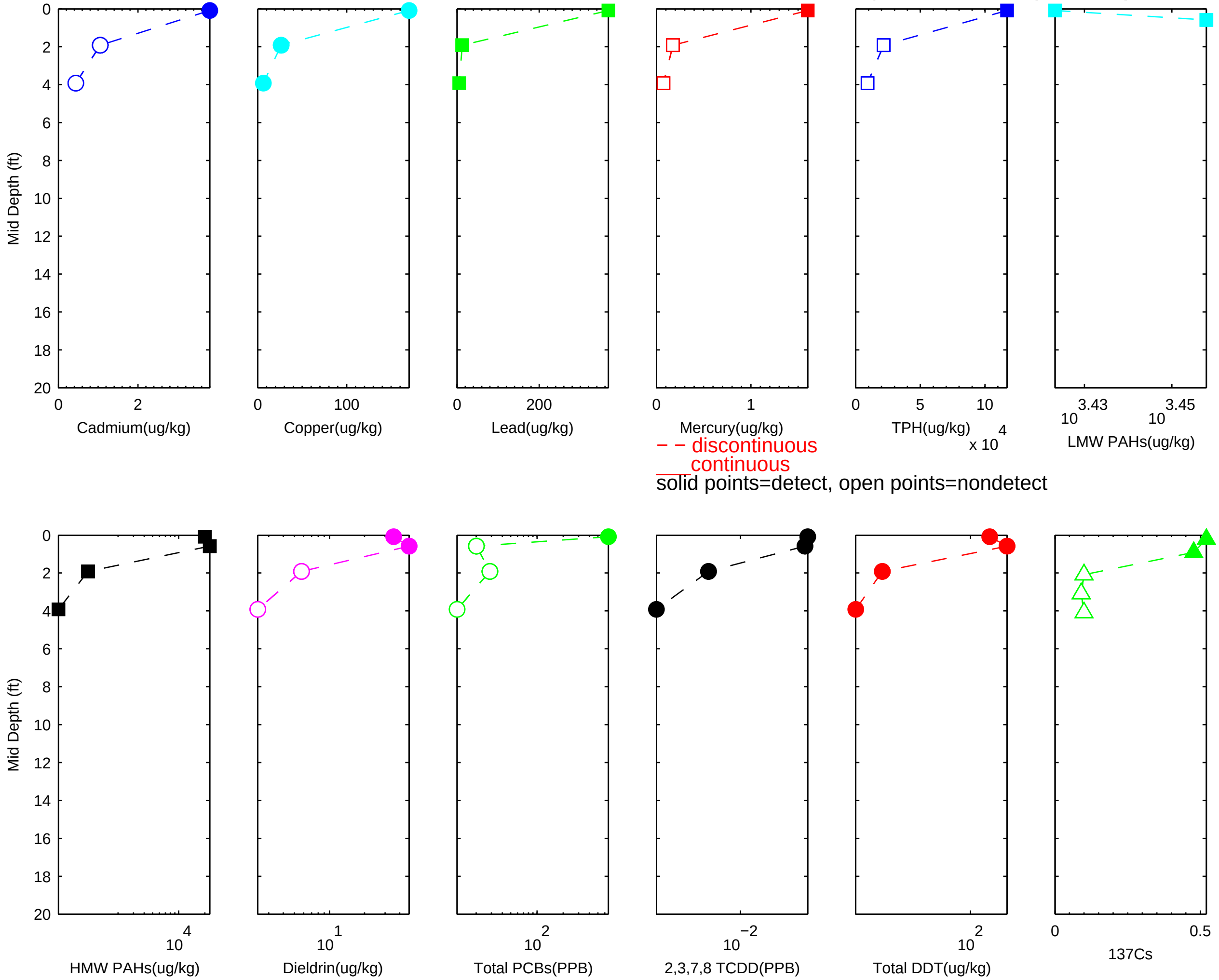
Sample ID: 76A River Mile 6.92 PASSAIC 1993 Core Sediment Investigation − 01 (March)



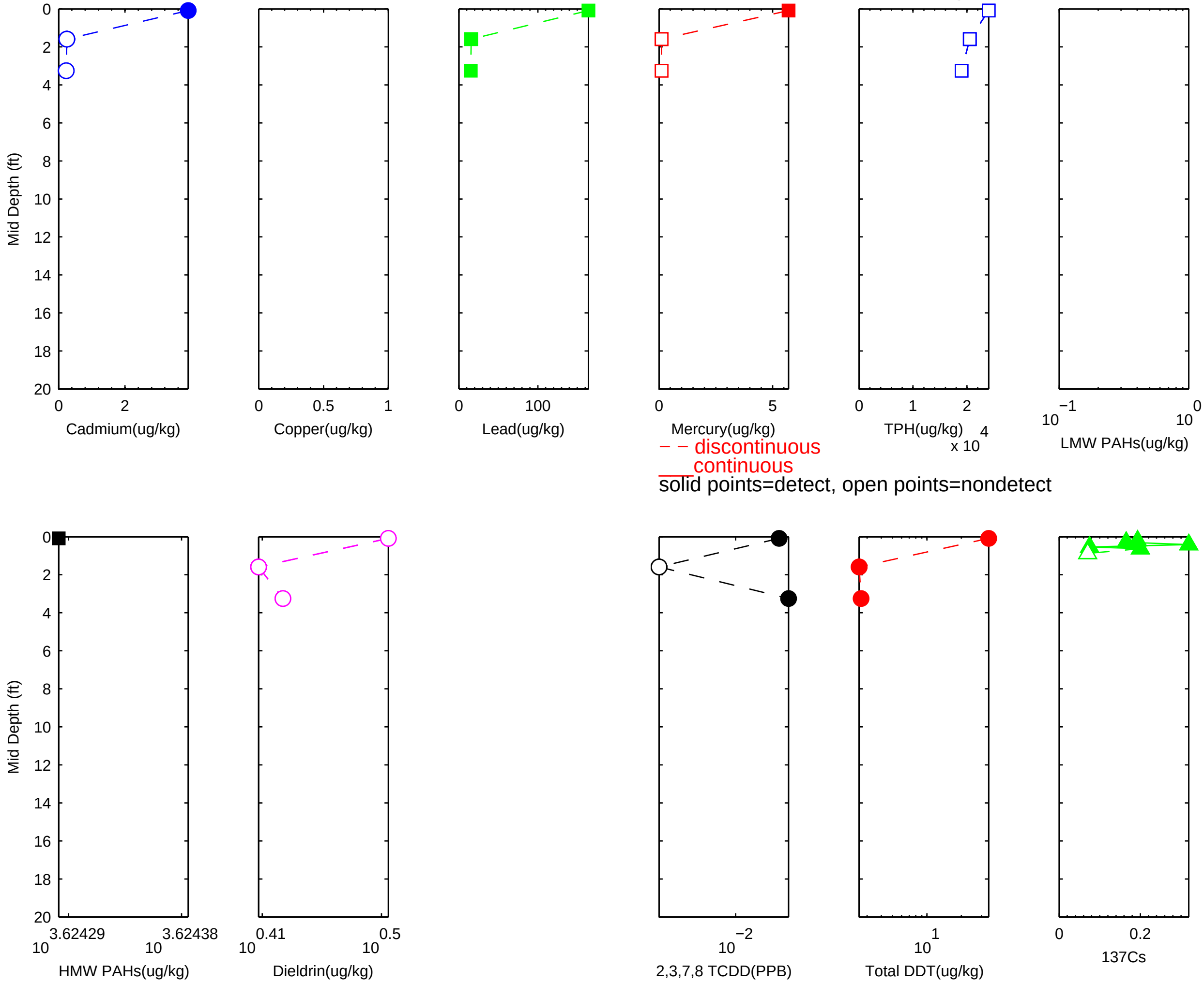
Sample ID: 75A River Mile 6.94PASSAIC 1993 Core Sediment Investigation − 01 (March)



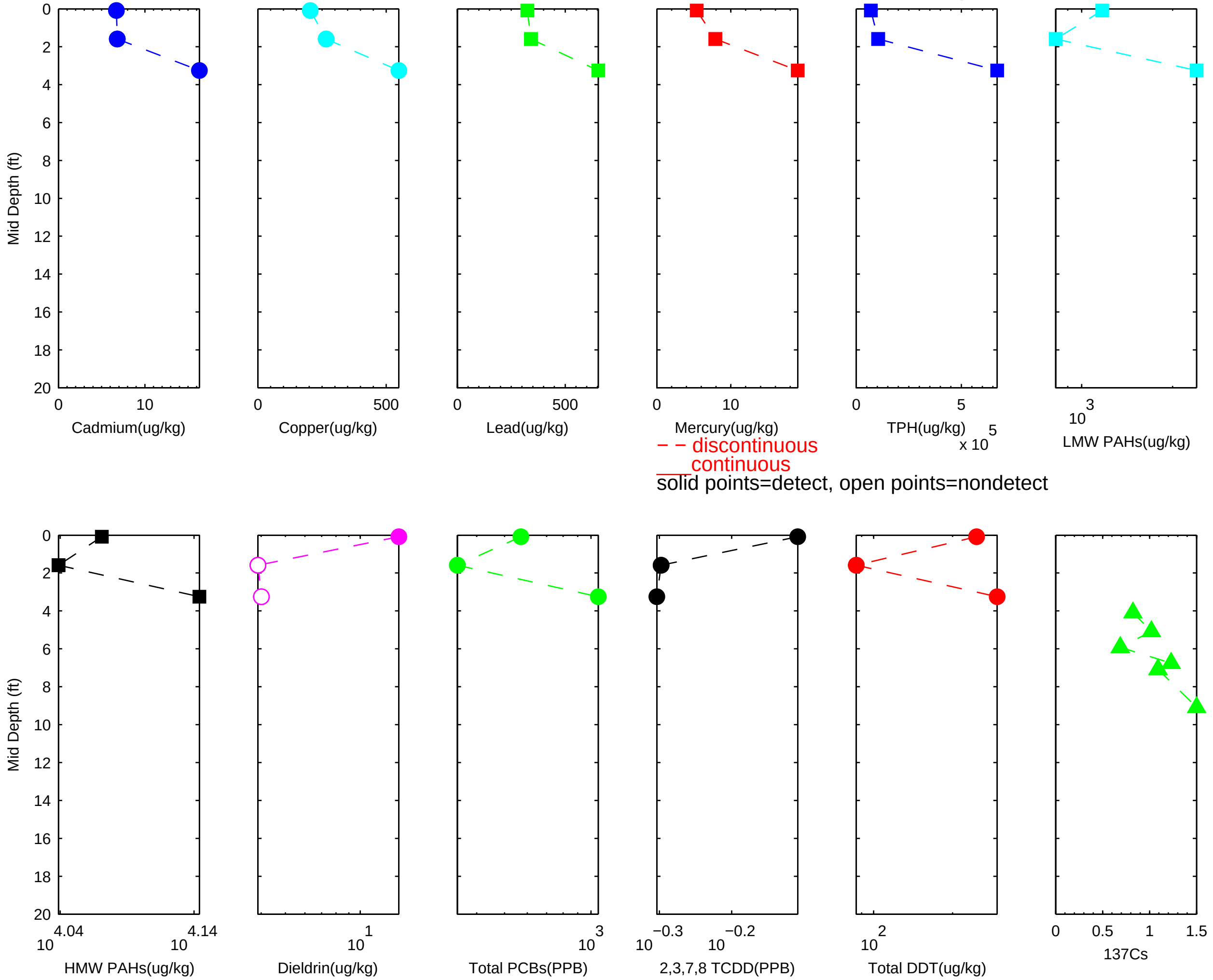
Sample ID: 74A River Mile 11.16PASSAIC 1993 Core Sediment Investigation − 01 (March)



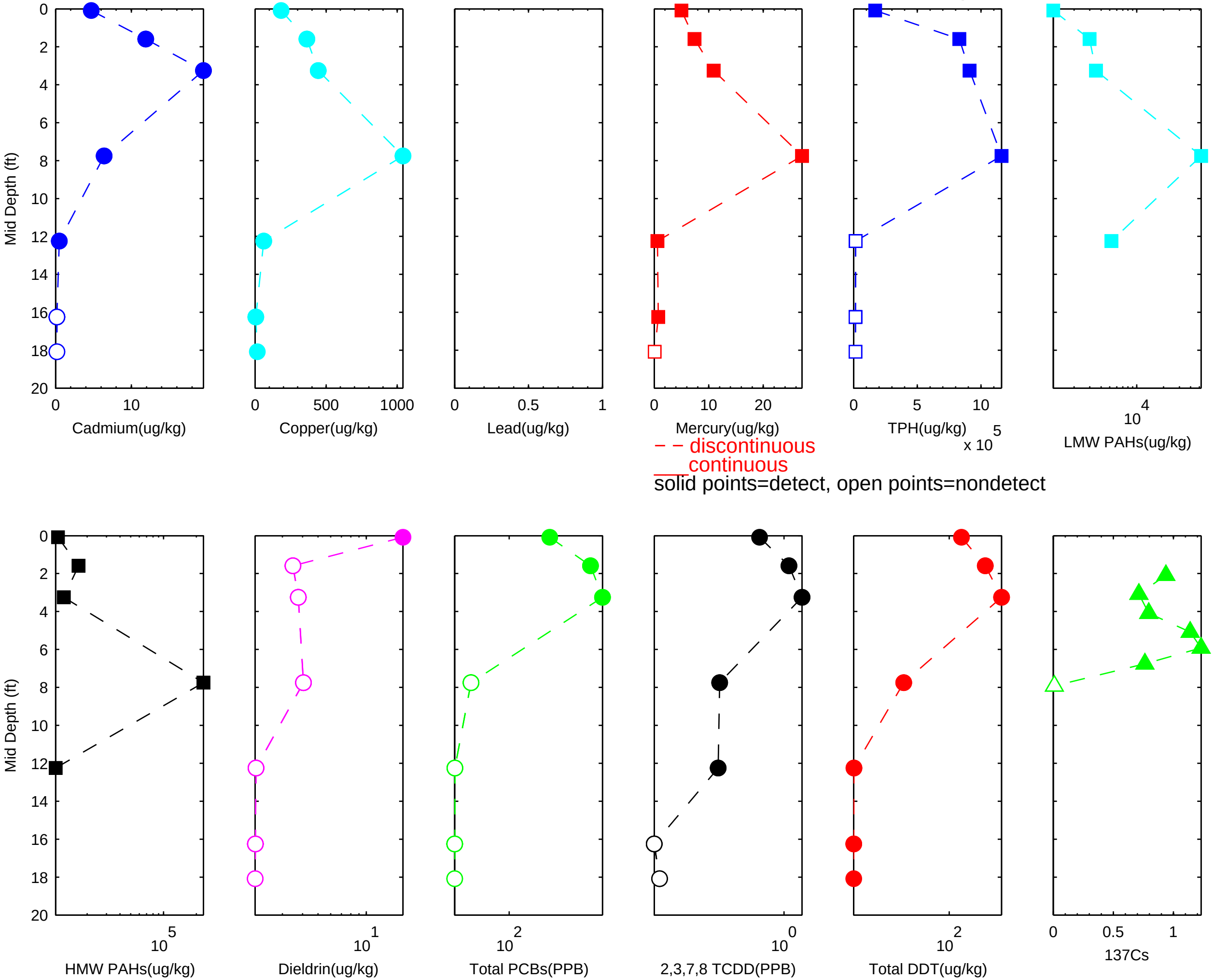
Sample ID: 26A River Mile 0.21   PASSAIC 1991 Core Sediment Investigation



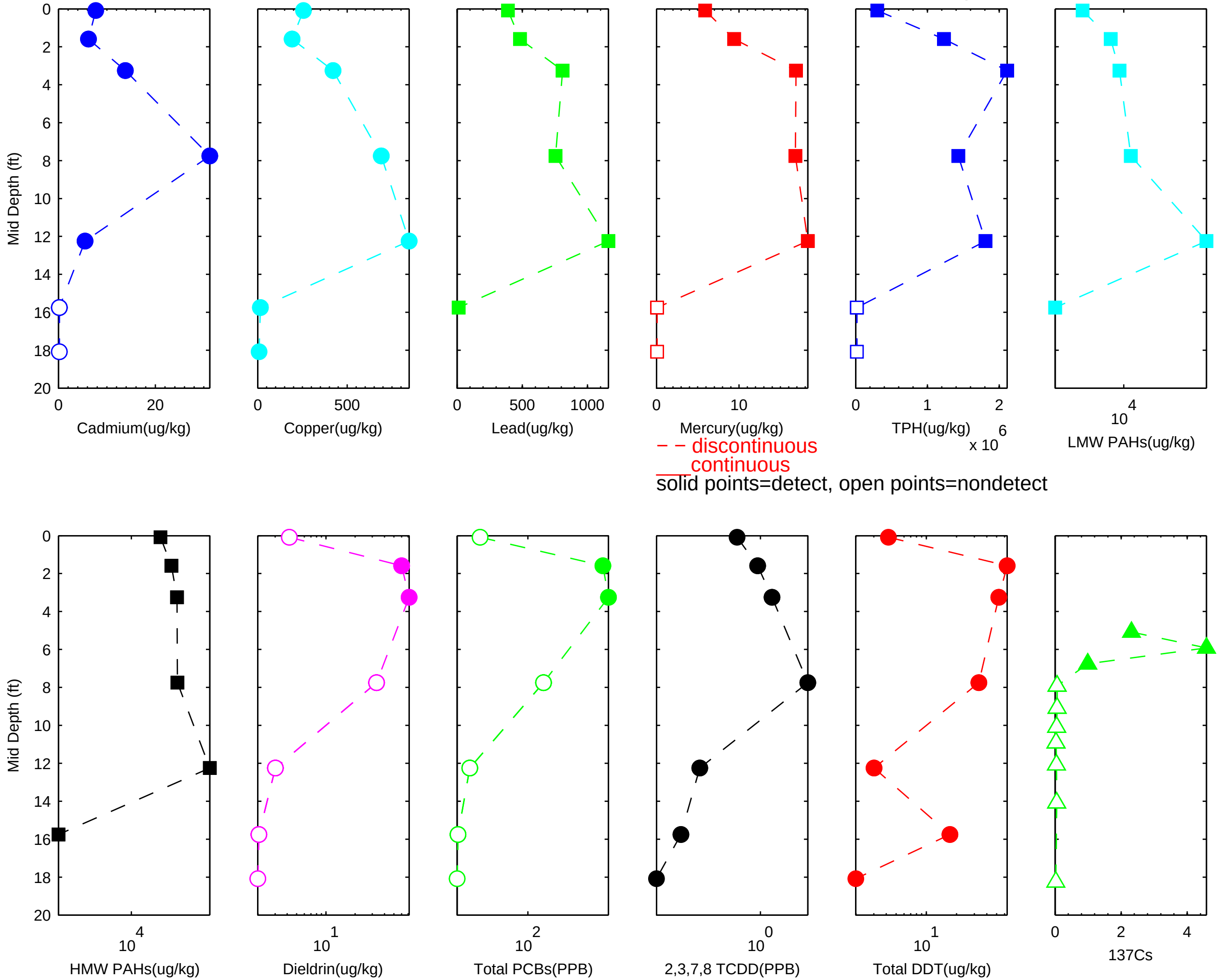
Sample ID: 23A River Mile 2.02   PASSAIC 1991 Core Sediment Investigation



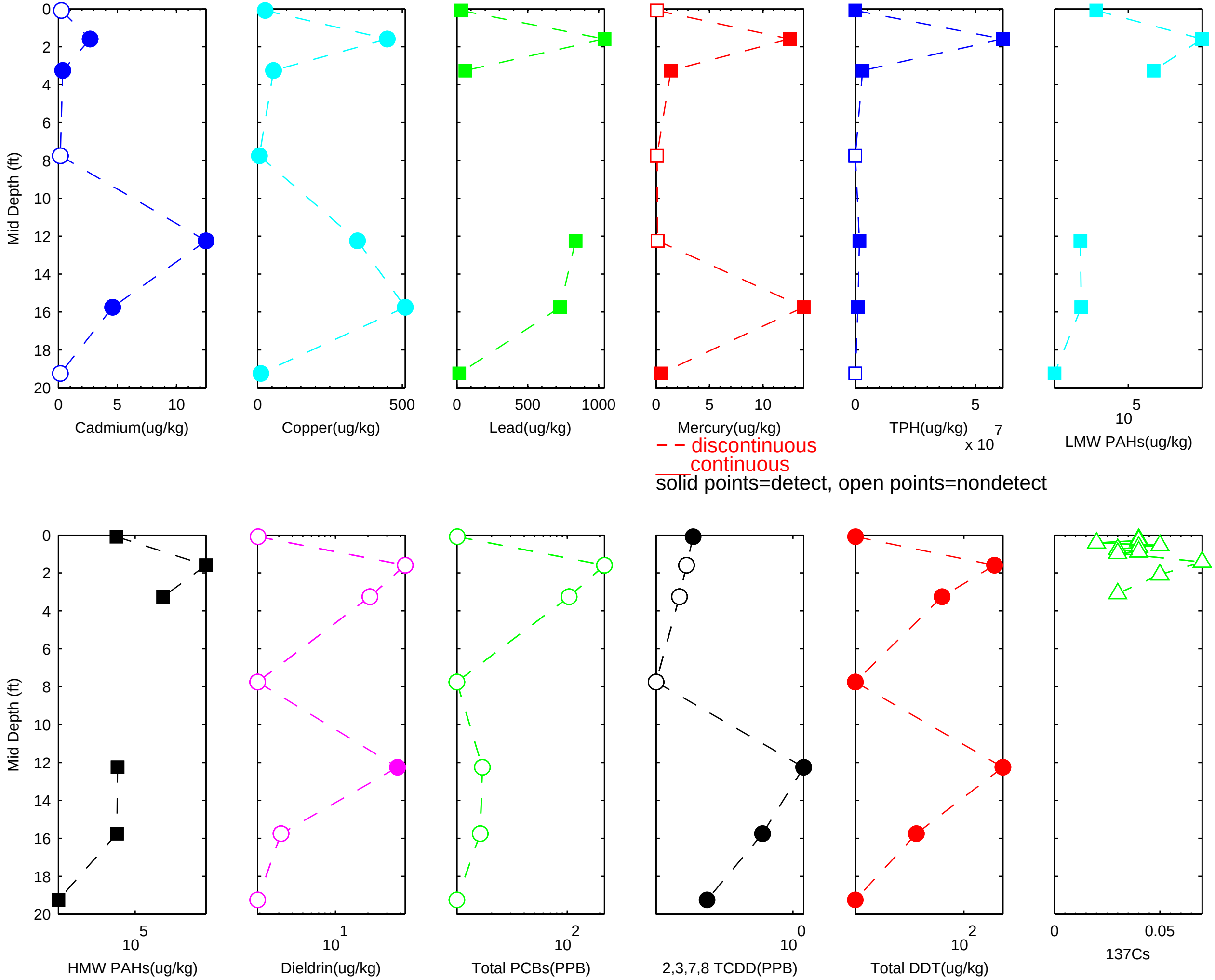
Sample ID: 22A River Mile 2.39   PASSAIC 1991 Core Sediment Investigation



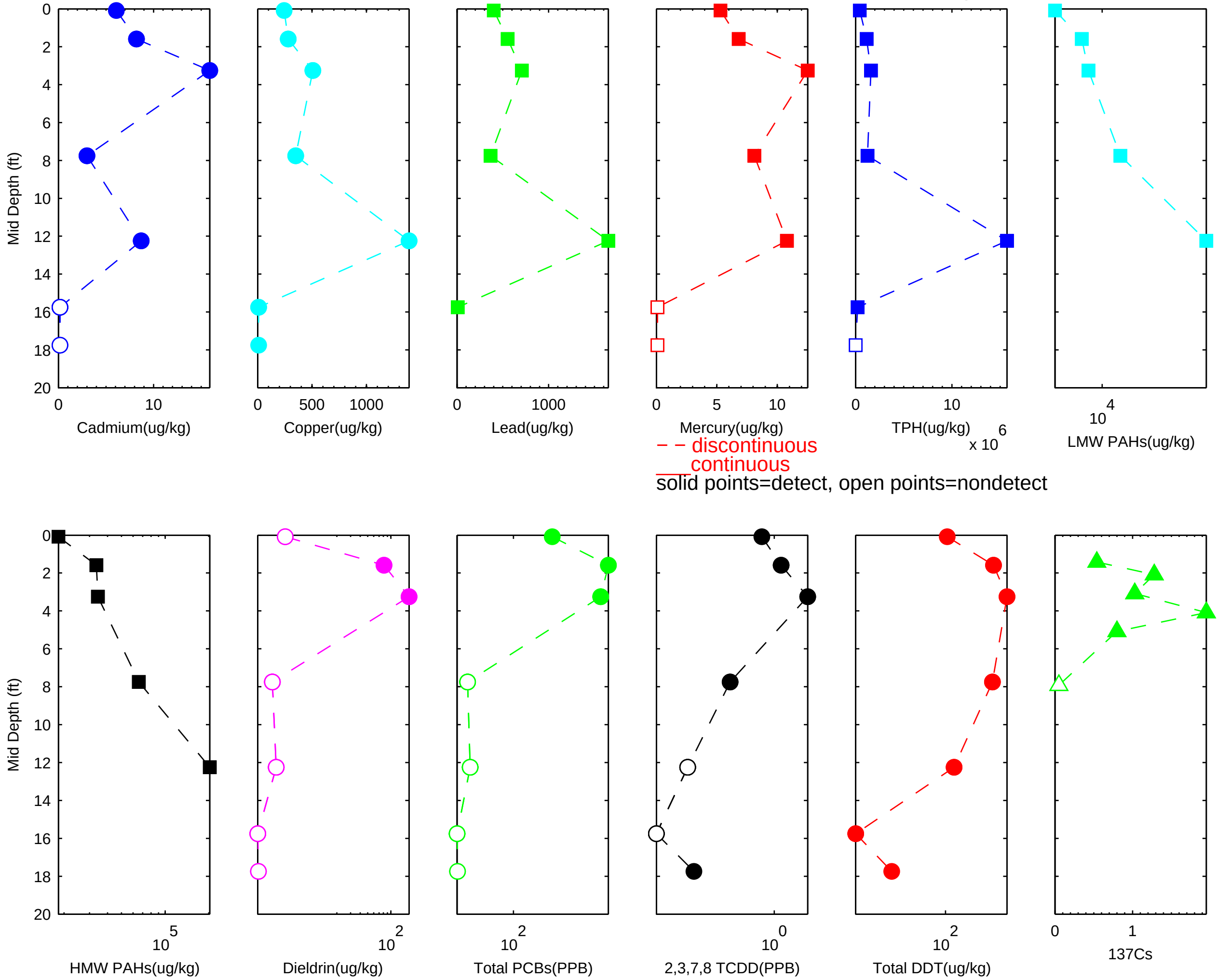
Sample ID: 21A River Mile 3.01   PASSAIC 1991 Core Sediment Investigation



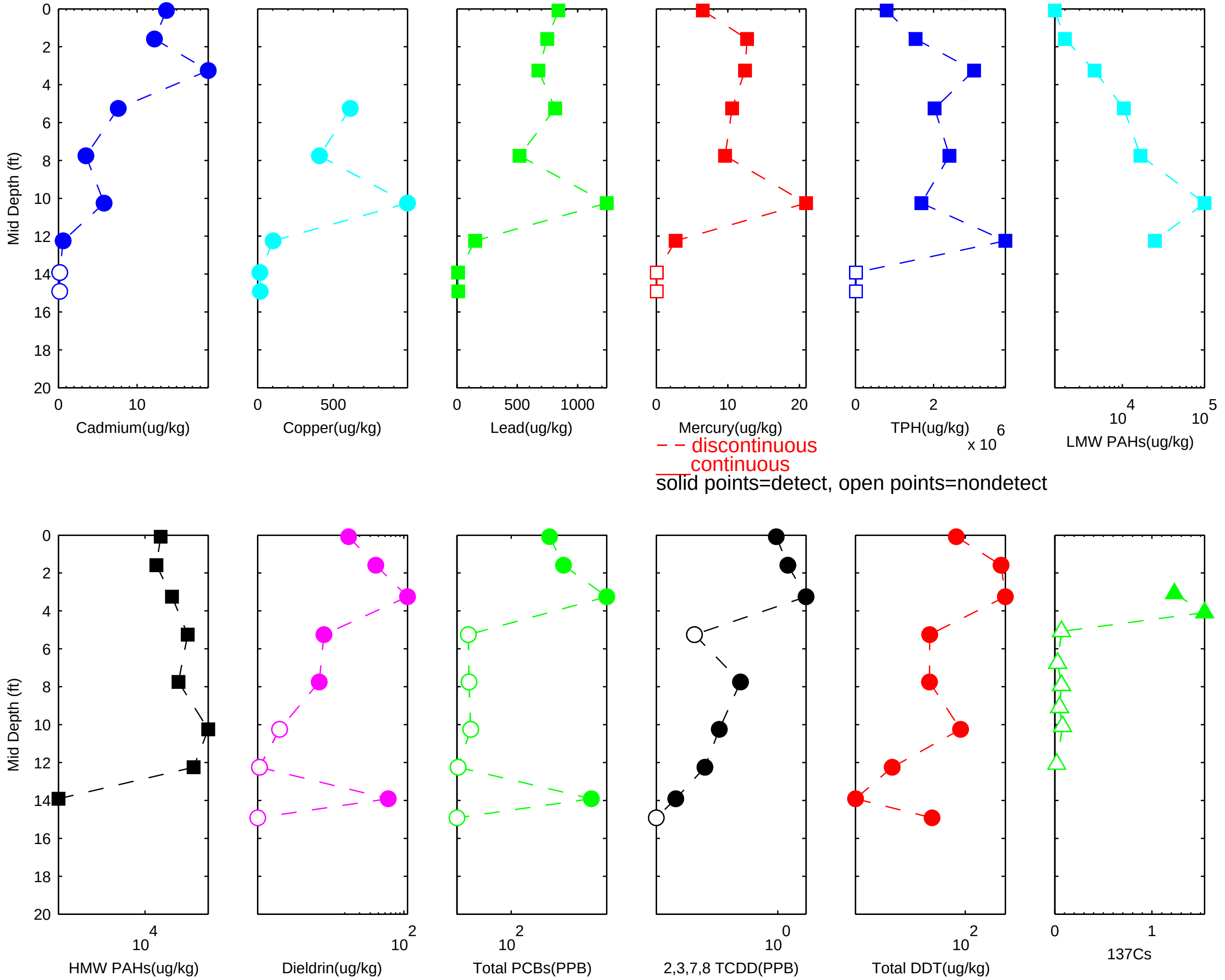
Sample ID: 20A River Mile 3.05 PASSAIC 1991 Core Sediment Investigation



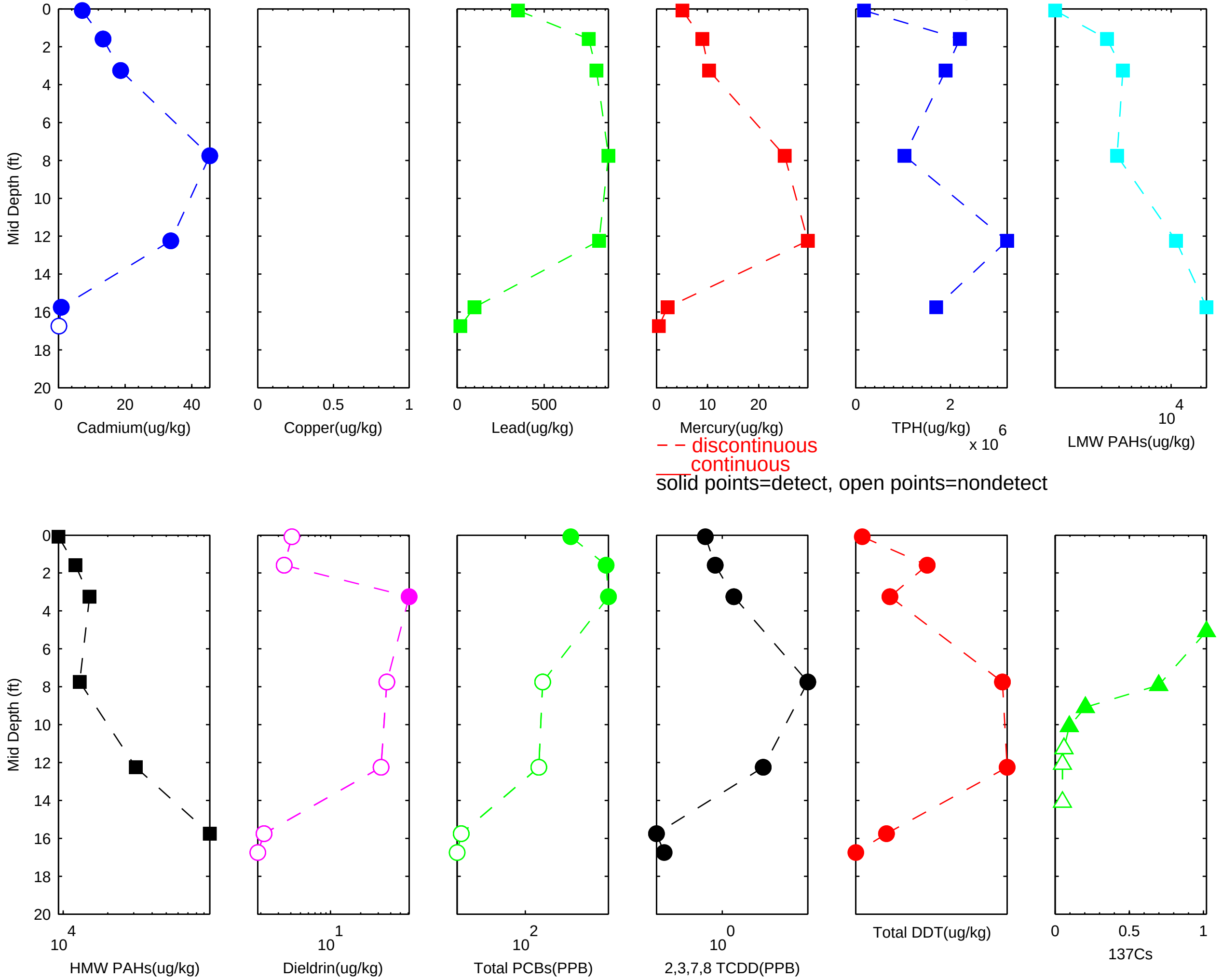
Sample ID: 19A River Mile 3.09   PASSAIC 1991 Core Sediment Investigation



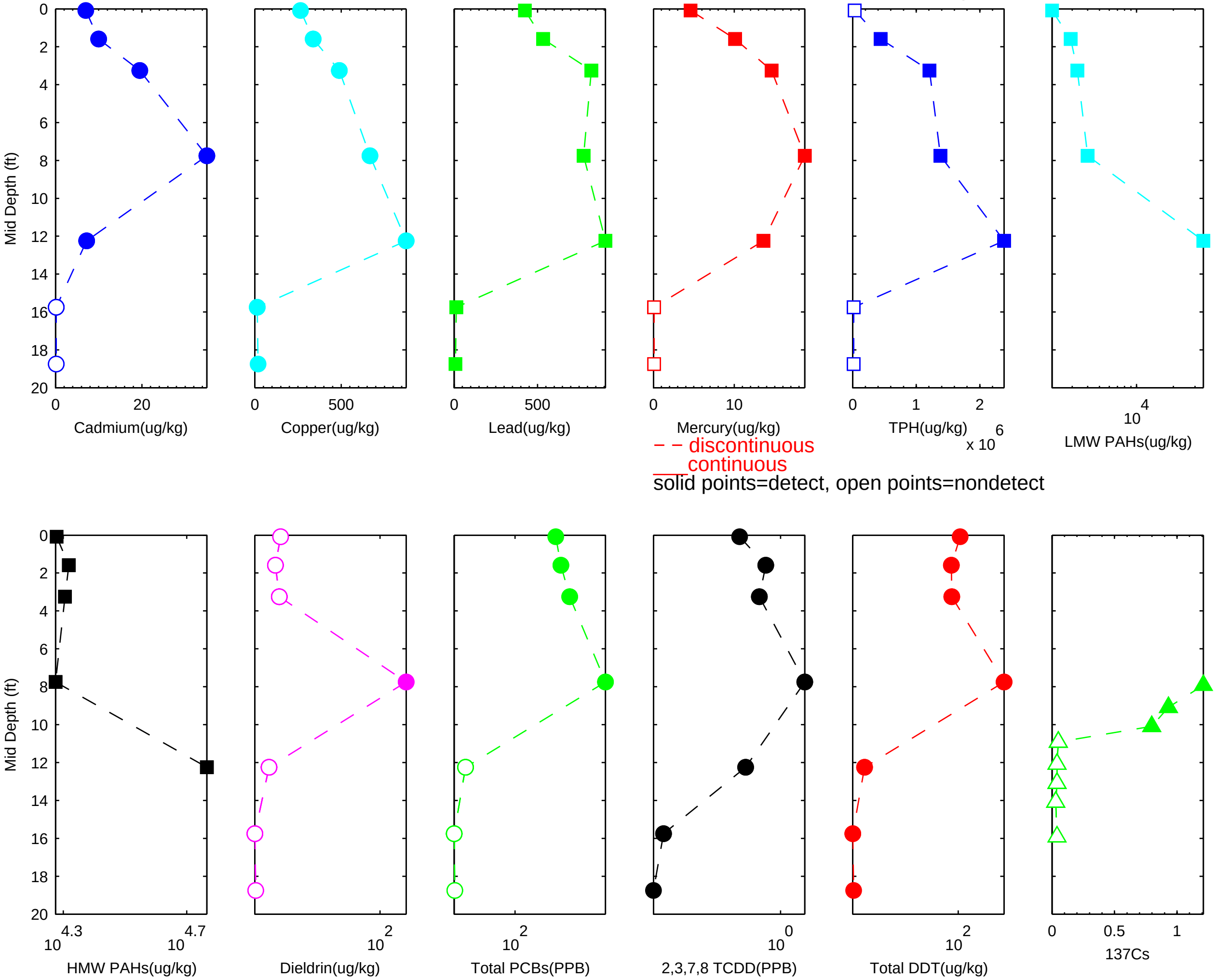
Sample ID: 18A River Mile 3.14   PASSAIC 1991 Core Sediment Investigation



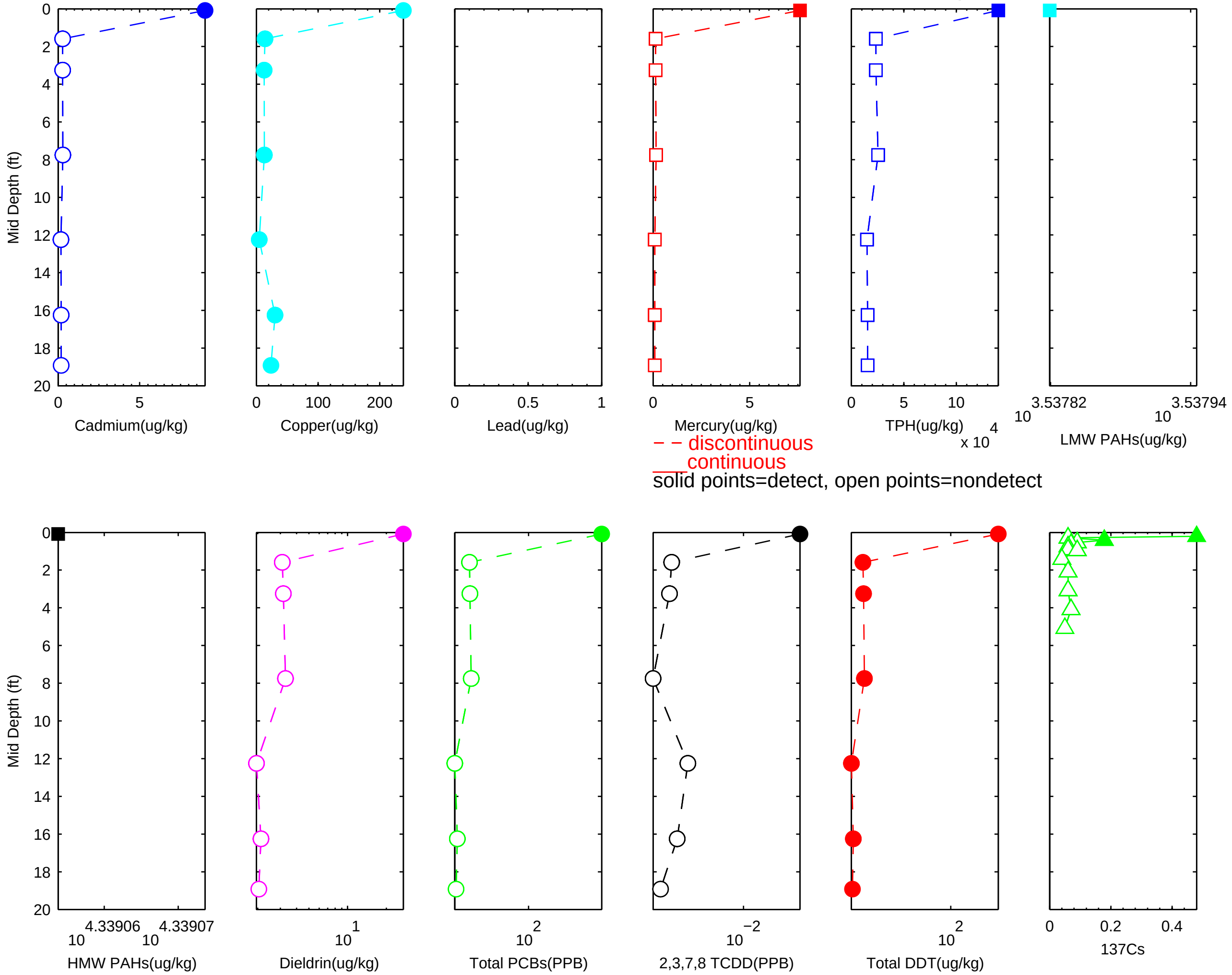
Sample ID: 17A River Mile 3.25 PASSAIC 1991 Core Sediment Investigation



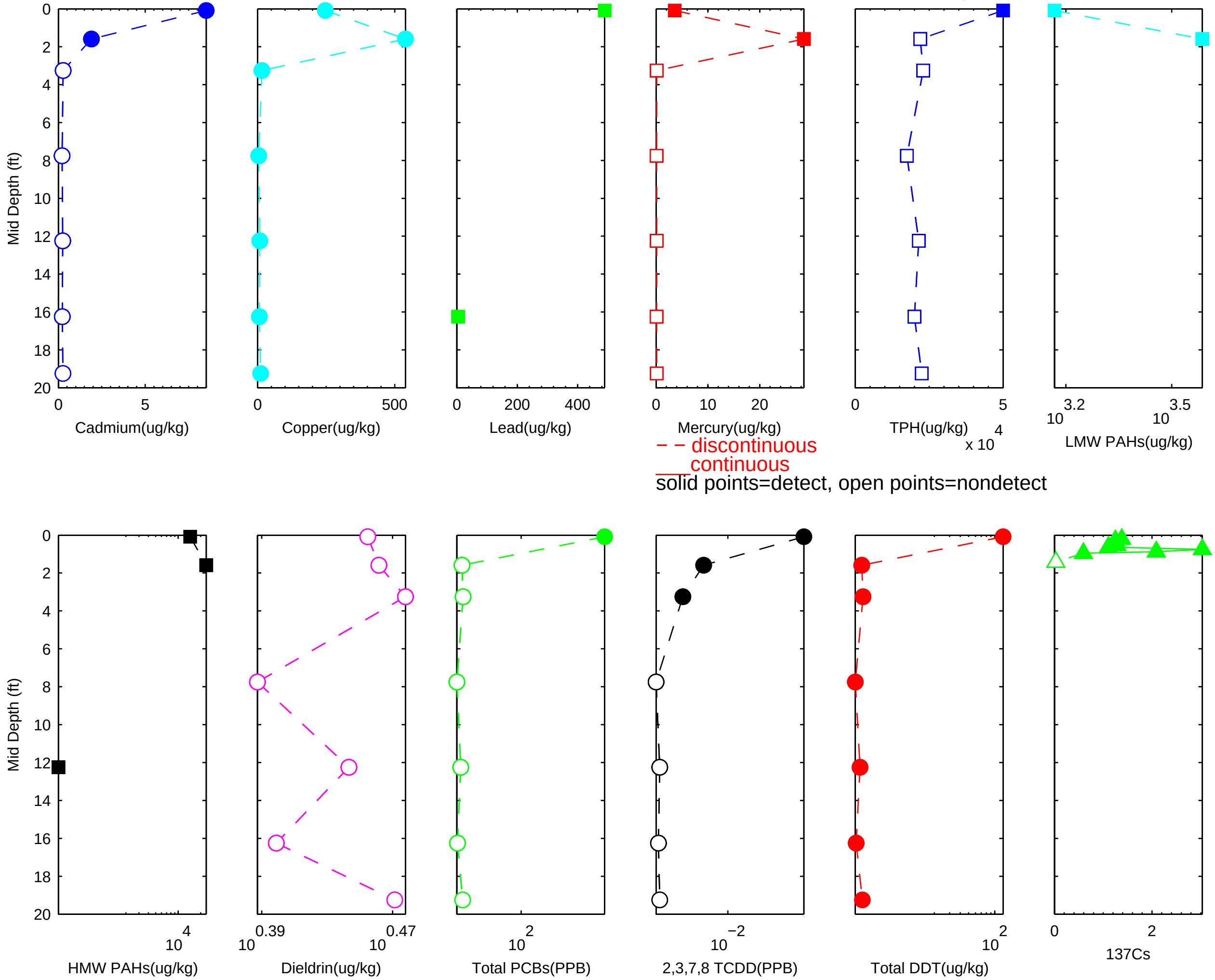
Sample ID: 16A River Mile 3.36 PASSAIC 1991 Core Sediment Investigation



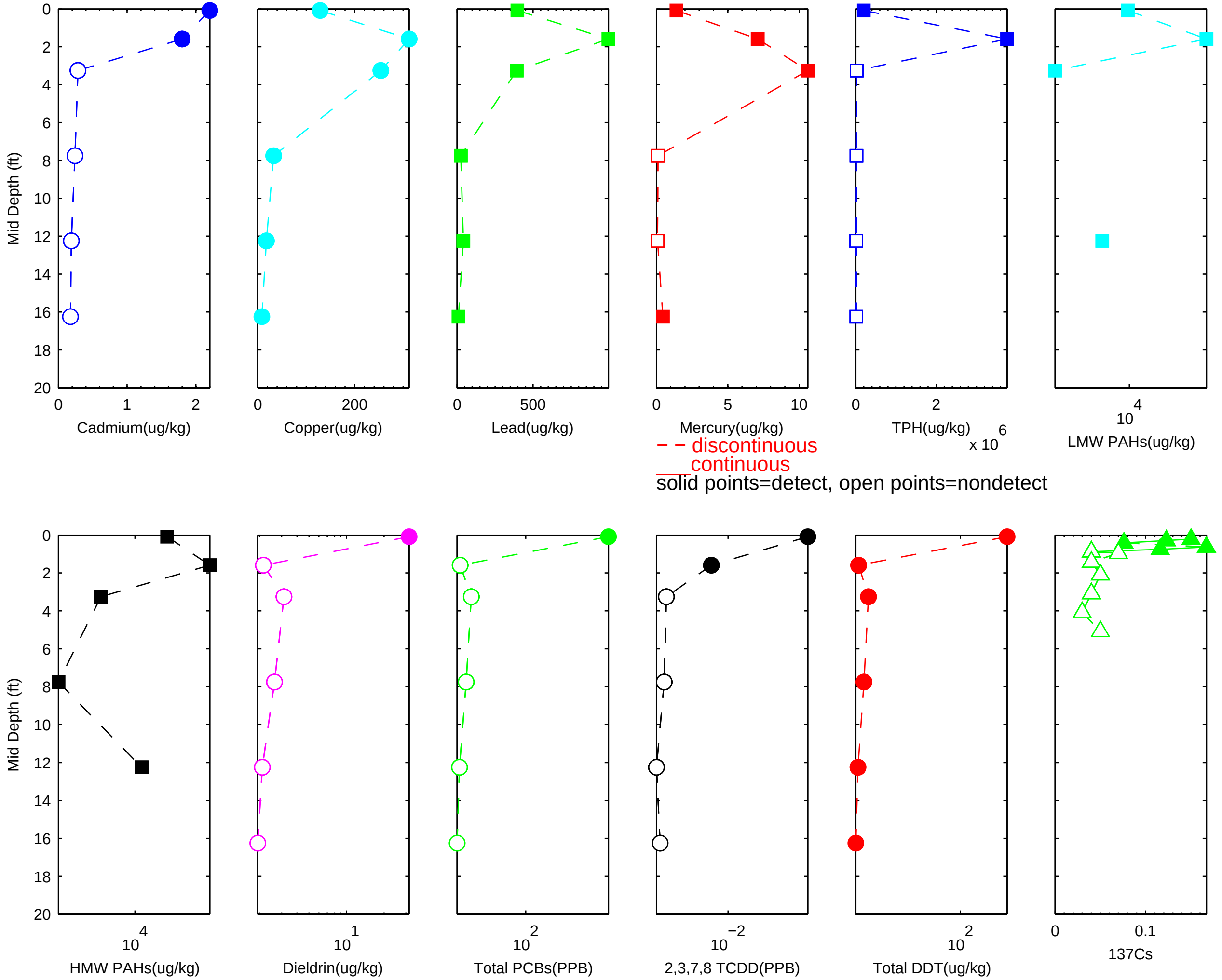
Sample ID: 15A River Mile 3.55   PASSAIC 1991 Core Sediment Investigation



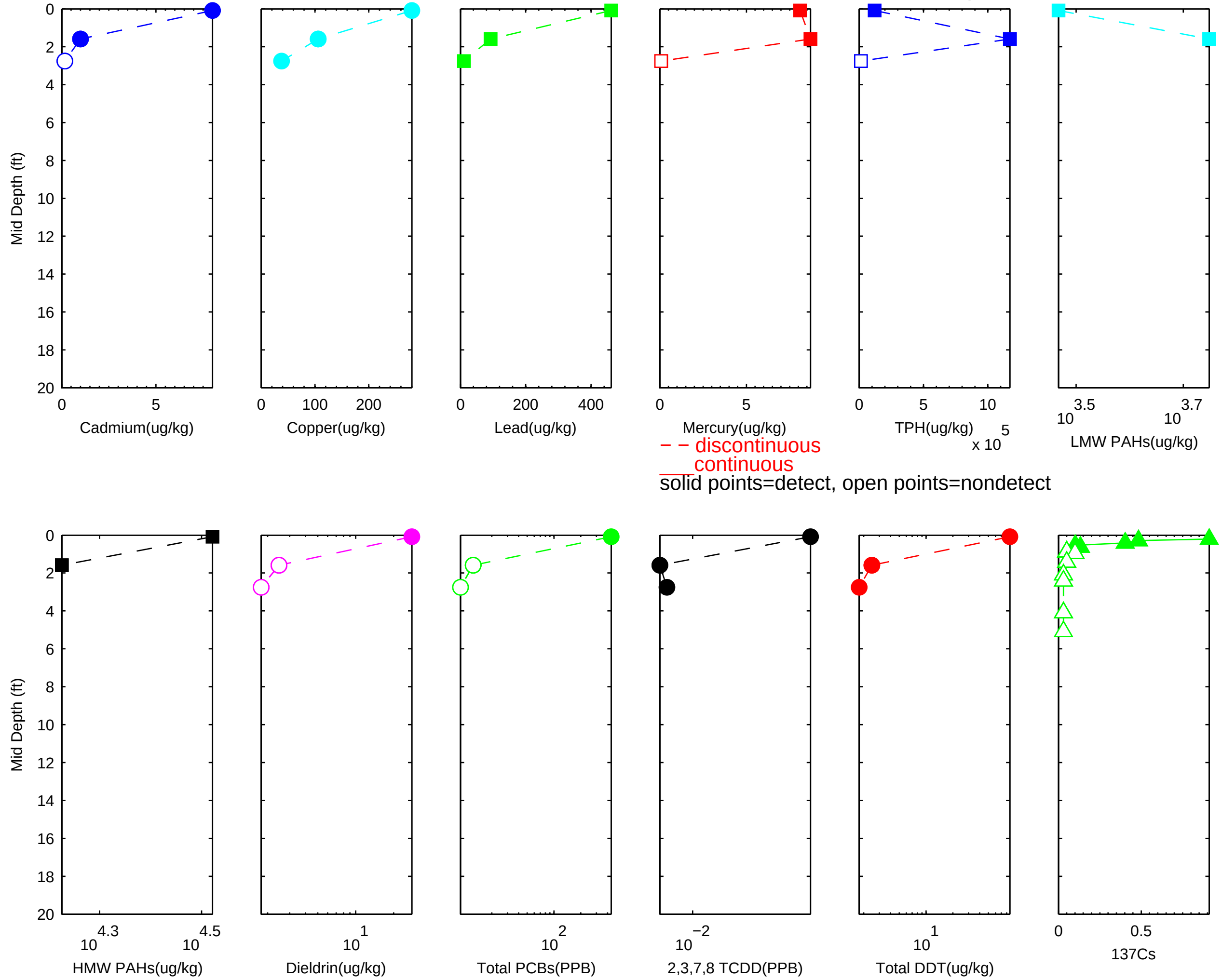
Sample ID: 14A River Mile 4.2   PASSAIC 1991 Core Sediment Investigation



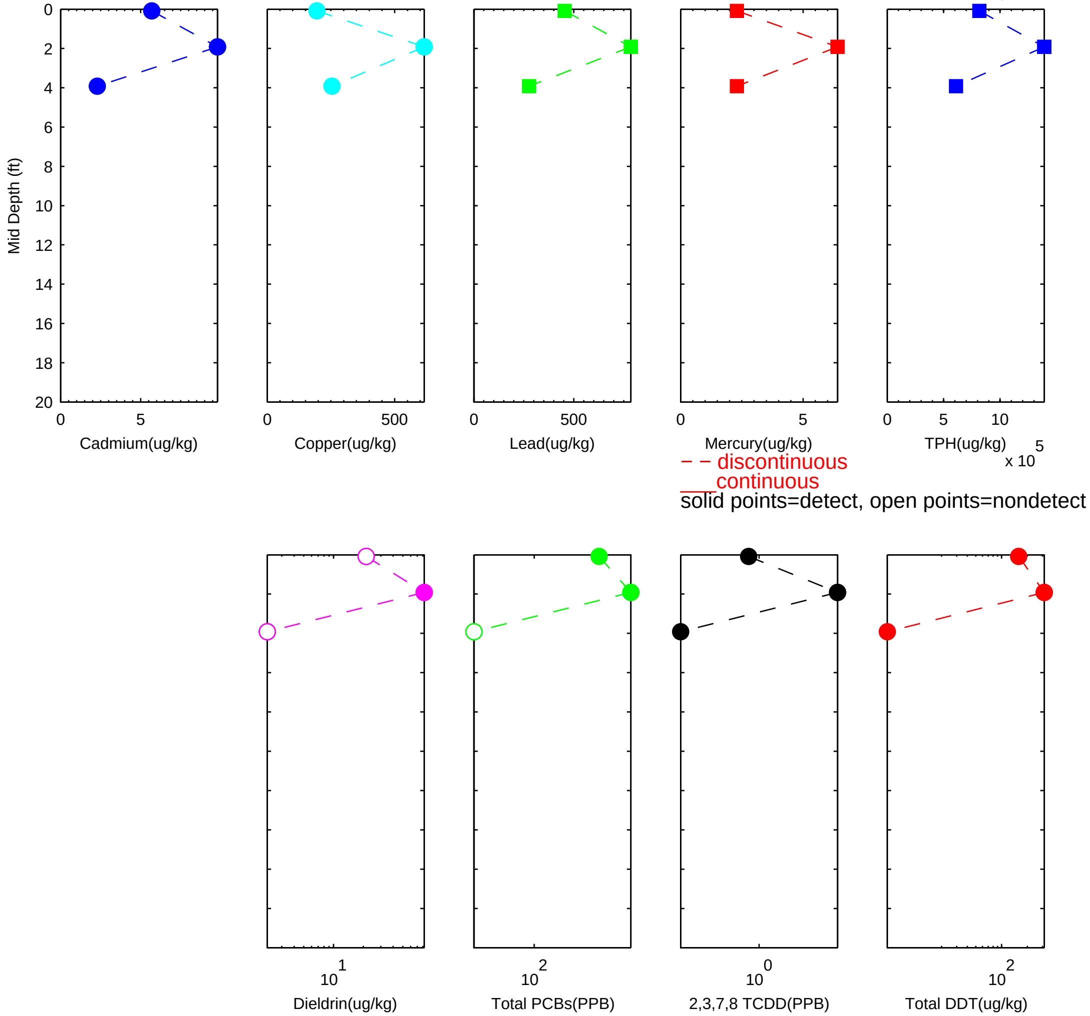
Sample ID: 13A River Mile 3.97   PASSAIC 1991 Core Sediment Investigation



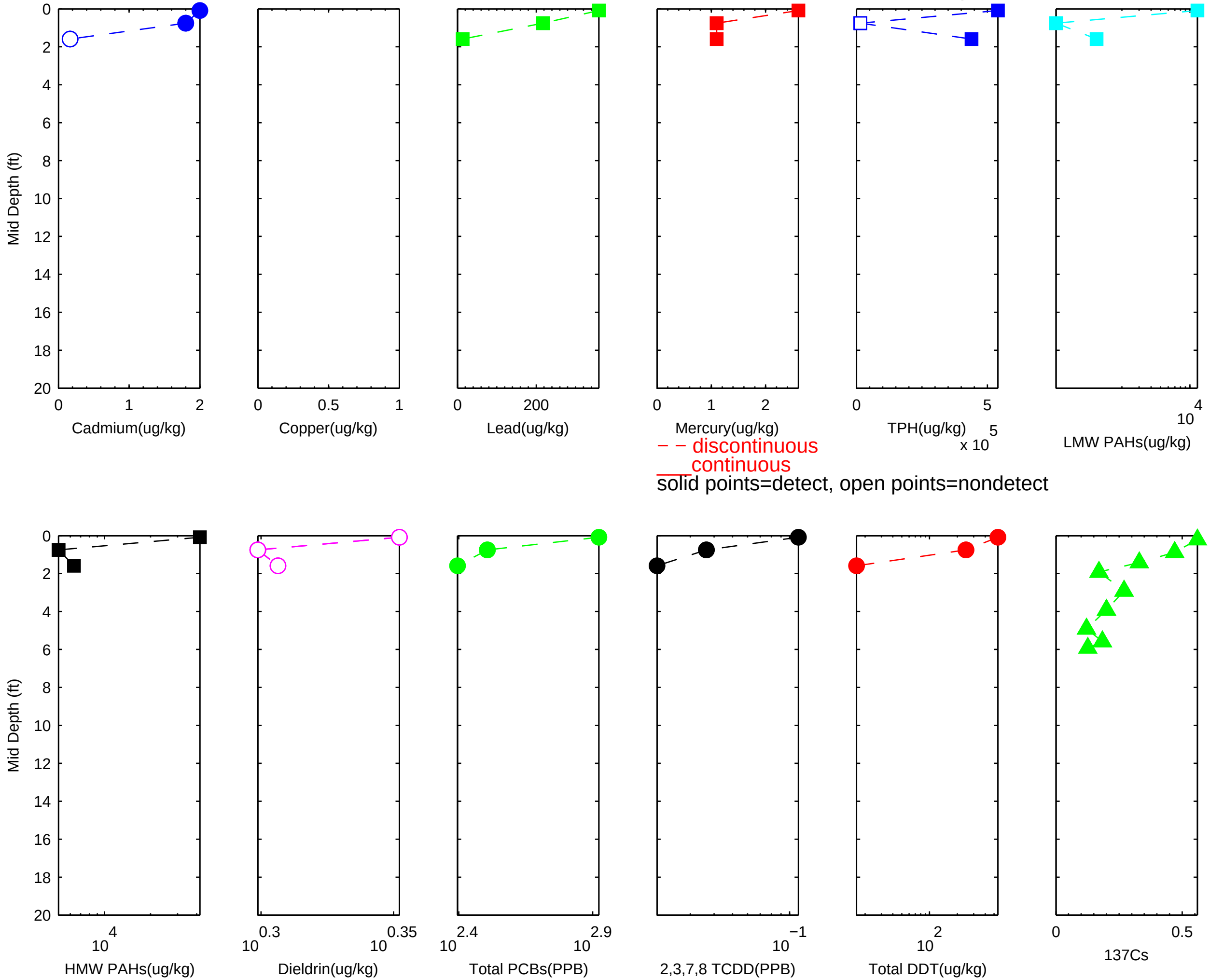
Sample ID: 12A River Mile 4.87   PASSAIC 1991 Core Sediment Investigation



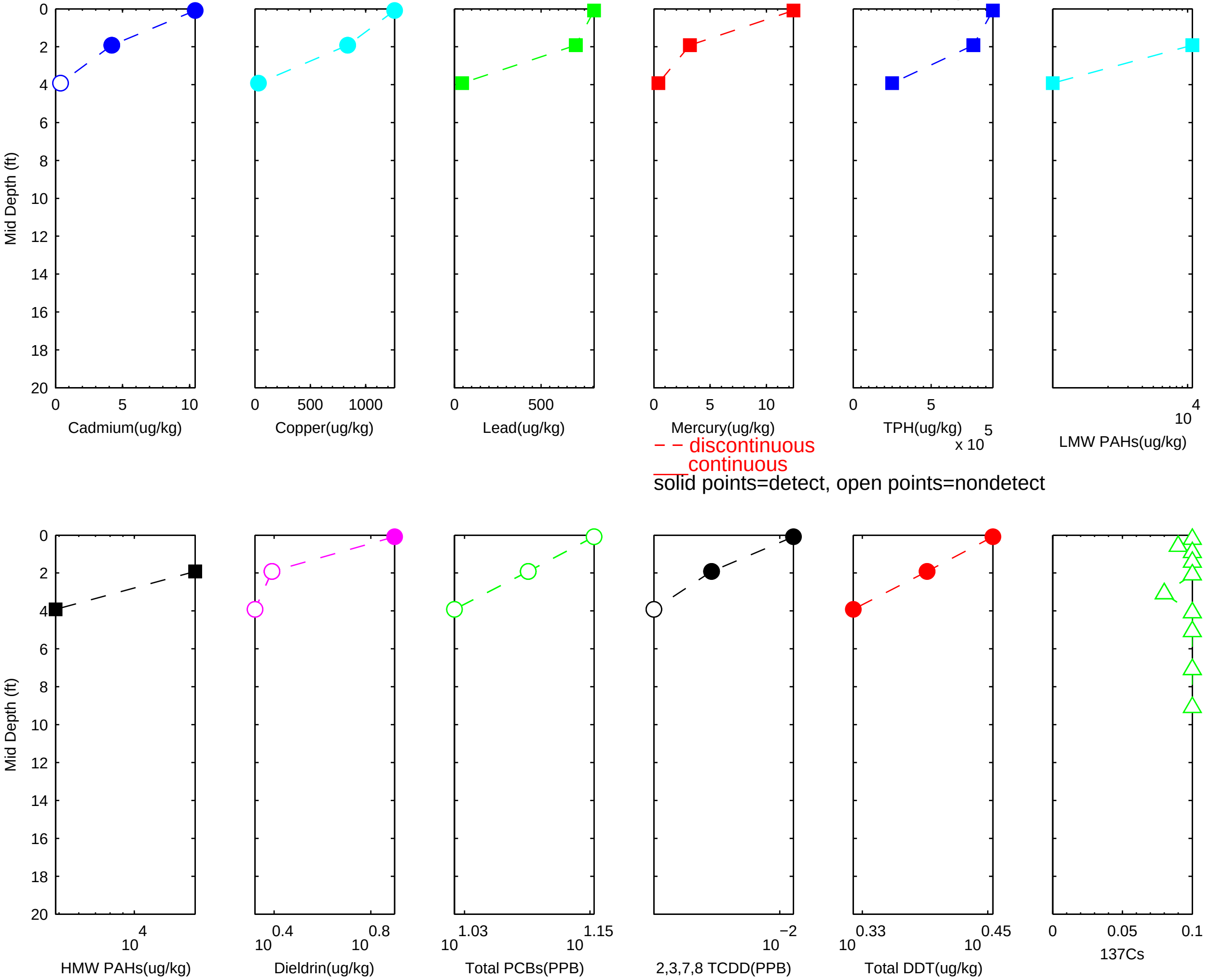
Sample ID: 10A River Mile 6.91   PASSAIC 1991 Core Sediment Investigation



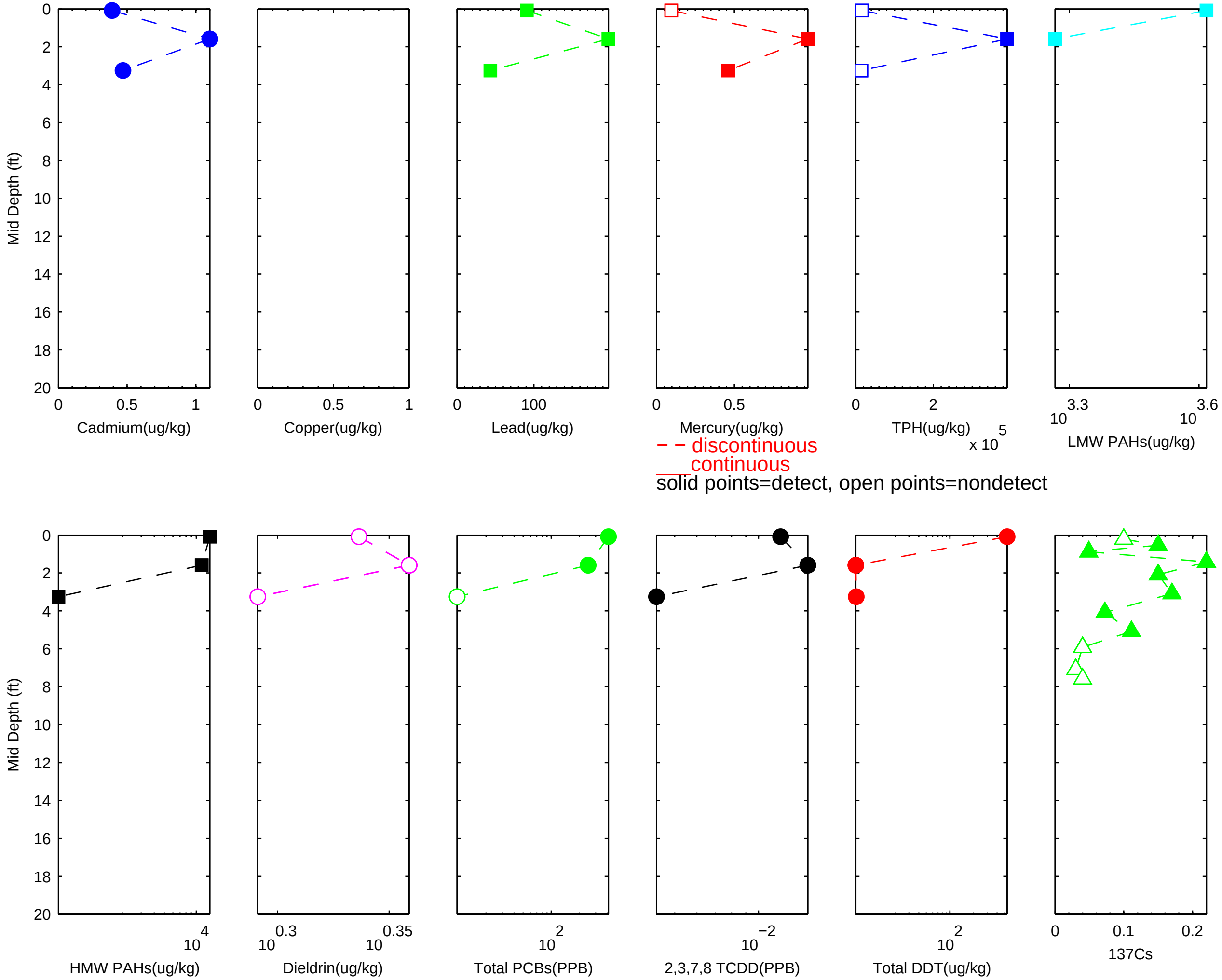
Sample ID: 09A River Mile 7.98 PASSAIC 1991 Core Sediment Investigation



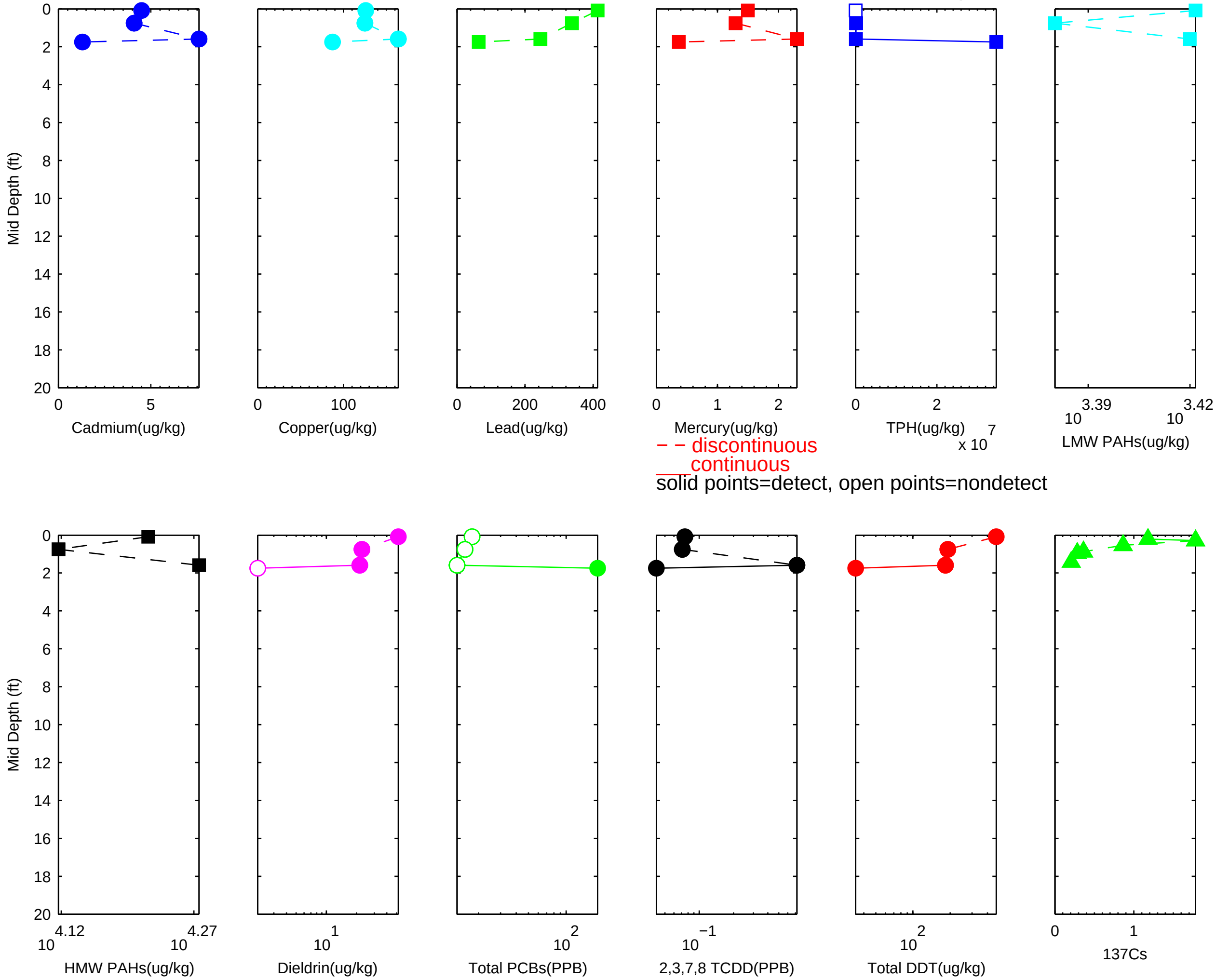
Sample ID: 08A River Mile 8.91   PASSAIC 1991 Core Sediment Investigation



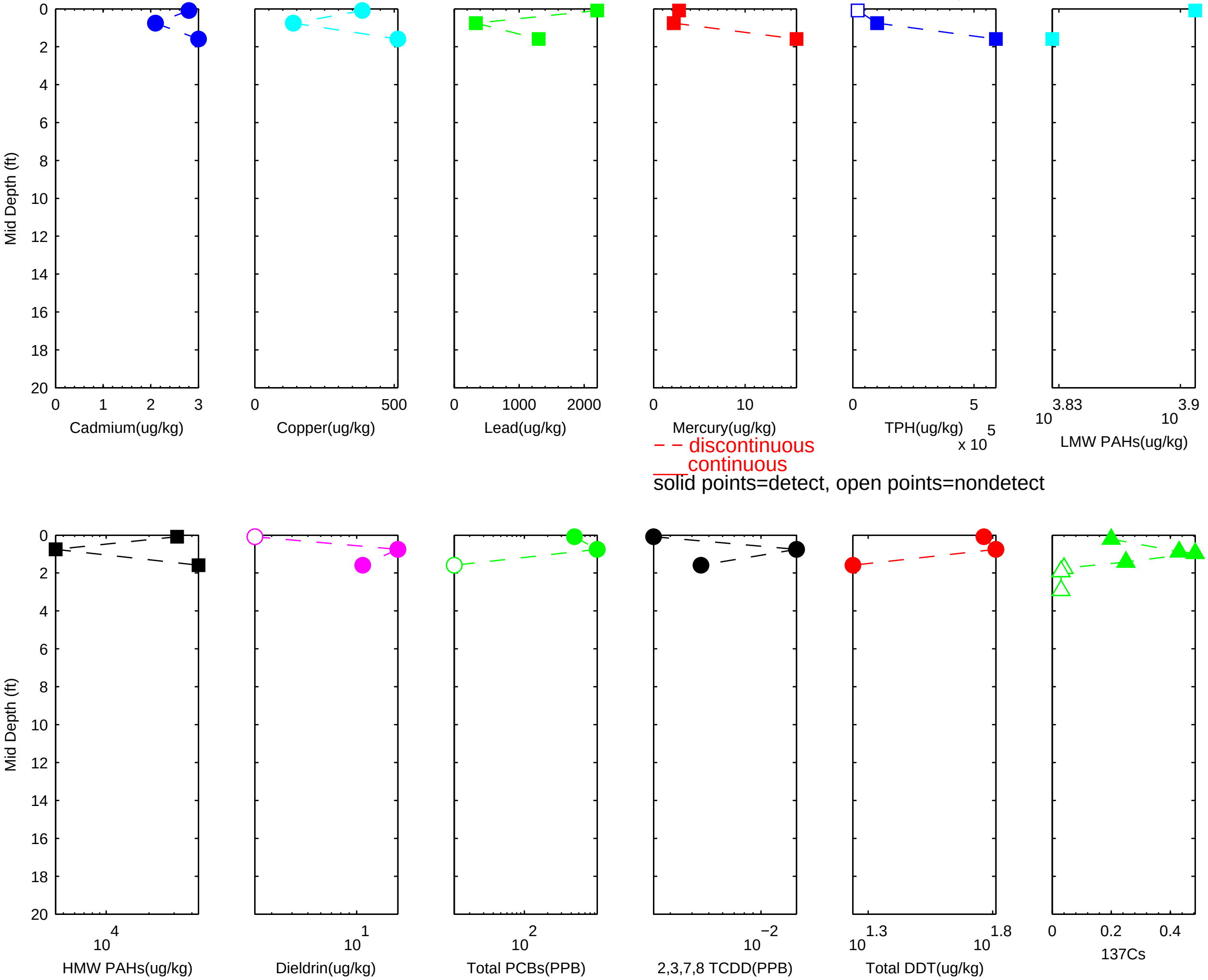
Sample ID: 06A River Mile 11.21 PASSAIC 1991 Core Sediment Investigation



Sample ID: 05B River Mile 11.19 PASSAIC 1991 Core Sediment Investigation



Sample ID: 02A River Mile 16.95   PASSAIC 1991 Core Sediment Investigation

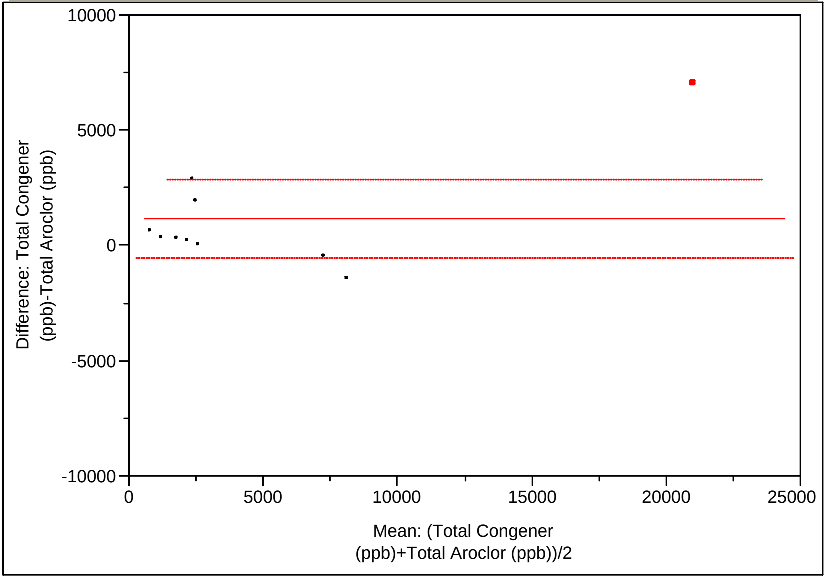


Attachment B

Statistical Analysis Relating Total PCB Concentrations by Aroclor and PCB Congener Methods

Matched Pairs 2008 Low Resolution Core Comparison: Aroclor vs Congener

Difference: Total Congener (ppb)-Total Aroclor (ppb)



Total Congener (ppb)	5521.3	t-Ratio	1.53572
Total Aroclor (ppb)	4366.4	DF	9
Mean Difference	1154.9	Prob > |t|	0.1590
Std Error	752.025	Prob > t	0.0795
Upper95%	2856.1	Prob < t	0.9205
Lower95%	-546.3		
N	10		
Correlation	0.95881		

Wilcoxon Sign-Rank

	Total Congener (ppb)-Total Aroclor (ppb)
Test Statistic	15.500
Prob > |z|	0.131
Prob > z	0.065
Prob < z	0.935