Sediment Distribution and Characteristics

Sediments at the bottom of ponds are a source or sink for nutrients in relation to the water column, contribute to turbidity during storm events, serve as the growth medium for aquatic plants and nesting sites for fish, and provide the necessary habitat needed to sustain a wide variety of invertebrates. Sediment characteristics described here for ponds in the Brandywine watershed are based primarily on a MS Thesis by West Chester University student Andrew Brainard.

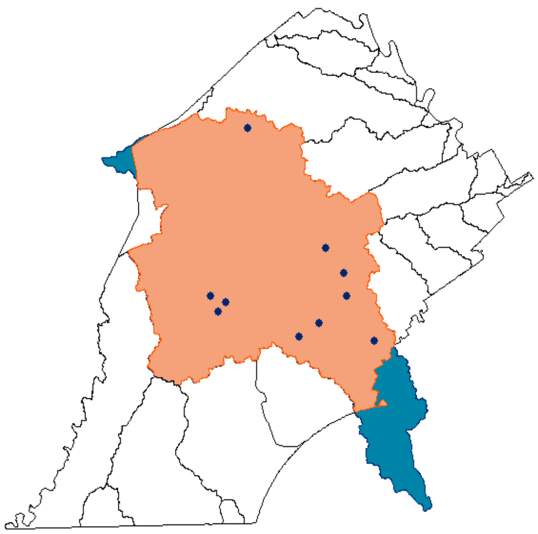

Fig. 1. Outline of Chester County, with the Brandywine Creek watershed shown in orange and the locations of 10 farm ponds indicated as blue circles.

Sediment characteristics were evaluated in 10 ponds within the Brandywine Creek watershed, in Central Chester County during summer 2009 (Fig. 1). The ponds varied in size from 0.04 ha to 0.56 ha, and from 0.7 m to 1.2 m in mean depth. All were constructed during the 20th century, and varied in age from 21 to 60 years.

Ten sediment cores were obtained at regularly spaced intervals from each pond using a hand-held corer (Fig. 2) deployed from the stern of a small pram. The sediments were analyzed for sediment volume, dry bulk density (dry mass/volume), particle size distribution (percent sand) and percent organic matter.
Sediments in deeper portions of the ponds, further from shore, were characteristically finer-grained

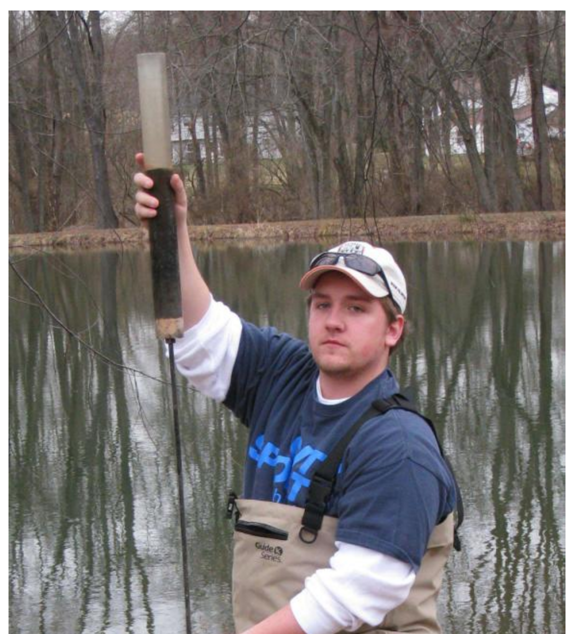

Fig. 2 Andrew Brainard, with core tube and plunger used to extract pond sediments.

(reduced sand), had greater organic content, and lower dry bulk density (Fig. 3). In effect, heavier sand grains were typically deposited near their point of entry into the pond, whereas finer particles were carried by water currents into deeper water.

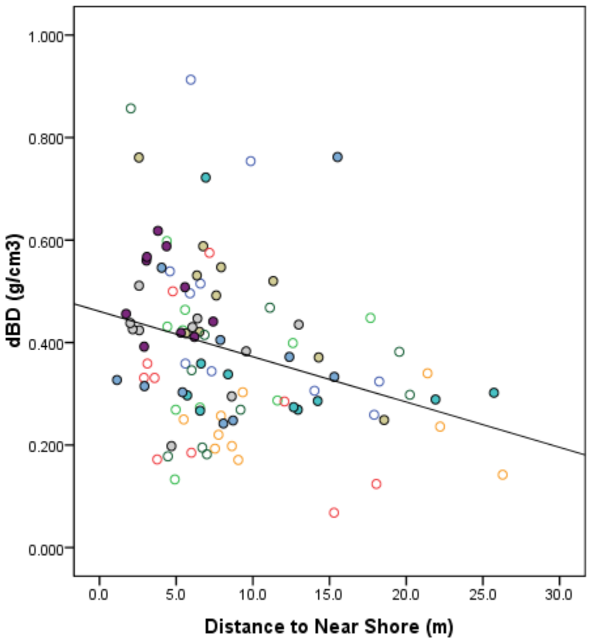

Fig. 3. Dry bulk density declined with increasing distance from shore, although the strength of the relationship varied among ponds (indicated by symbols in the figure).

These patterns have important implications for ponds and their owners. First, organisms that either live in or on the sediments depend strongly on particle size and organic content, with sandier, near-shore sediments often providing better growing conditions for some plants and more organic and nutrient-rich sediments in deeper water providing more suitable habitat for others. Second, dry bulk density and particle size distribution can be used to determine the extent to which sediment inputs are retained within the pond, and thus the rate of in-filling.

Sediment Nutrients

The sediments contain inorganic particles, organic "detritus" (the remains of algae, zooplankton, etc.), live benthic algae, a host of bacteria, very small invertebrates termed the meiobenthos, and larger macroinvertebrates. The sediments also contain much higher quantities of nutrients than are found in the water column; some of these are bound in solid phase organic molecules, while a portion is present in inorganic form in the interstitial water.

Contrary to expectations, reducing external phosphorus inputs from the watersheds of P-limited shallow ponds frequently has little immediate impact on pond water quality (Perrow et al., 1994; Moss et al., 1996; Nixdorf and Deneke, 1997).   This occurs because of the large reserves of phosphorus remaining in the sediments. Phosphorus in the sediments can be resupplied to the water column both by upward diffusion of dissolved PO_4^{3-} under anoxic conditions and by resuspension of particulate phosphorus by storms or human activity. Increases in total P in the water column during July in most of the study ponds likely occurred because of increased PO_4^{3-} release from the sediments as the bottom waters became more anoxic. Even if external sources of P are reduced, recycling of P from the sediments (unless dredged) may thus maintain high levels of phosphorus in the water column for many years until sediment concentrations are depleted

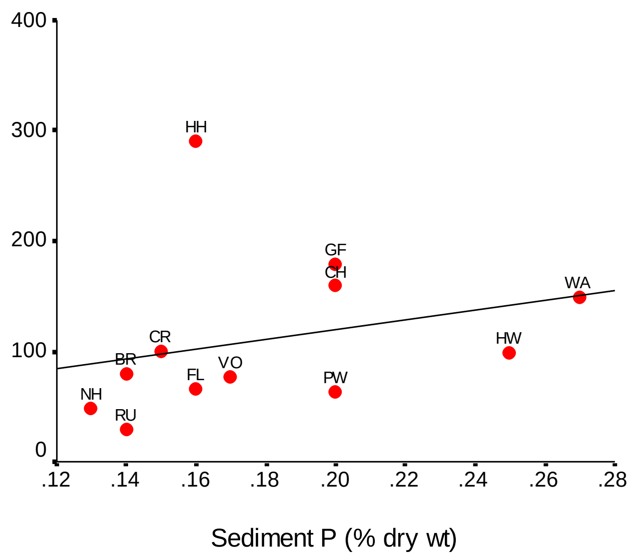

Fig. 4. Sediment P content vs. total phosphorus in the water column during July. The sediments may serve as a "sink" for phosphorus as organic particles settle, but also release phosphorus to the overlying water, especially when oxygen concentrations are very low.

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Results presented here are based on data collected for 13 Chester County ponds in 2002. Cores of the top 0.5 cm of the sediments were obtained from each pond during visits in July. The relationship between particulate phosphorus in the surface sediments to total phosphorus in the water column is shown in Figure 4. Sediment P was typically slightly greater in ponds with higher concentrations of P in the water column. A positive correlation between sediment P and water column P is expected because not only does sediment-associated phosphorus reenter the water column (directly via resuspension and indirectly via remineralization and diffusion), but particulate phosphorus within the water column (e.g., as phytoplankton) sinks to the sediments.

In effect, nutrients in particles that settle to the sediments are in fact frequently exchanged with the water column, are the chief nutrient source for rooted plants, and are a reservoir of nutrients for plants and algae in the water column. Homeowners concerned with pond management must thus consider the large supply of nutrients residing in the sediments as well as nutrients entering from the watershed.

Sediment Accumulation Rates

Ponds serve as "collection points" in the landscape for sediments derived from soil erosion. Although the in-filling of lakes and reservoirs has received considerable attention, few studies have been directed at sediment burial rates in small ponds, despite the fact that ponds greatly outnumber larger water-bodies in most regions and are frequently built explicitly for sediment retention (but see Renwick et al. 2005; Downing et al. 2008; Downing 2010).

Fig. 5. Metal probe used to determine current, and original, water depth at regularly spaced locations within each pond.

The 10 ponds evaluated during summer 2009 all had known construction dates; 5 ponds had stream inflows, and 5 had no stream inputs. A metal probe (Fig. 5) was used to determine the current water depth, then inverted and pushed to the original pond bottom to measure the original water depth) at 32 to 44 GPS-indexed locations. The measurements for each pond were then integrated to compute the amount of sediment that had accumulated since the time of original pond construction. Bathymetric maps were also created to show the depth contours of the original and current pond basin (Fig. 6).

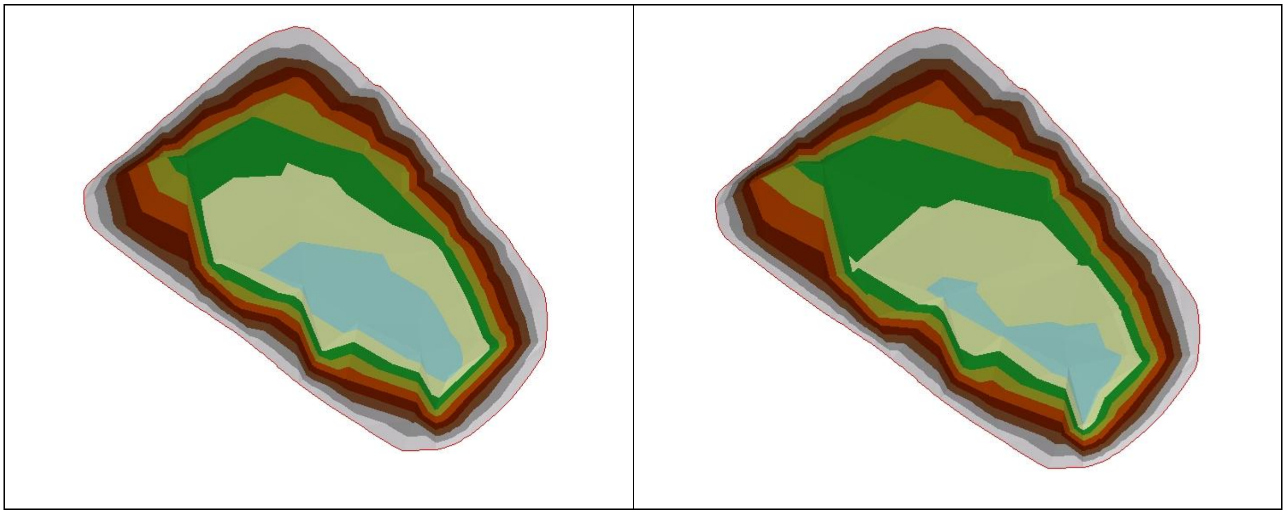


Fig. 6. Original (L) and current (R) depth contours of one of the 10 ponds sampled for sediment characteristics and accumulation rates.

Annual rates of sediment burial, expressed per unit of pond area, declined with increasing pond size (Fig. 7). This means that owners of small ponds can expect their ponds to fill in more rapidly and require dredging or other management earlier or more often than owners of larger ponds. As shown in the figure, ponds receiving stream inputs also accumulated sediments more rapidly than ponds without inflows. Stated differently, ponds with inflows derive much of their sediment from material conveyed by the streams, particularly during storms.

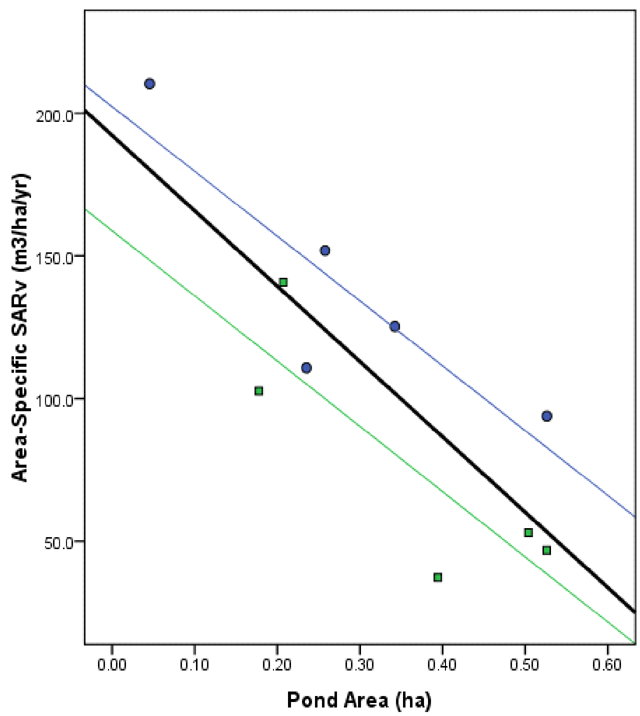


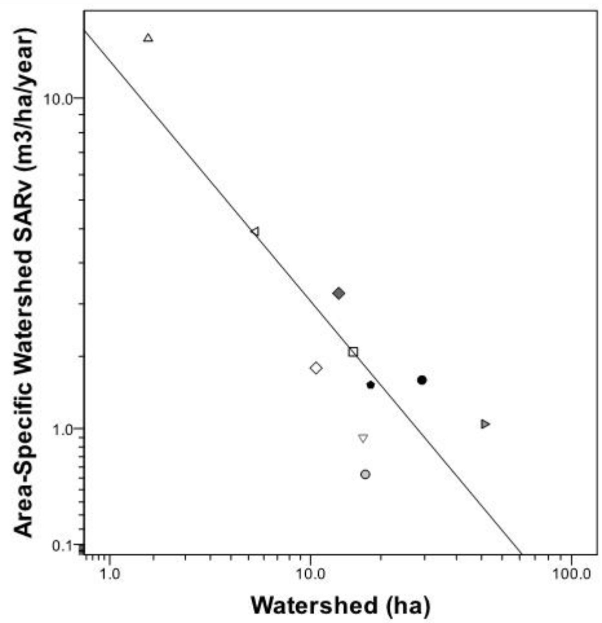
Fig. 7. Per unit pond area-specific annual sediment accumulation rates (based on sediment volume), related to pond area in ponds with stream inflows (blue circles and line) vs. without inflows (green squares and line).

The watersheds from which the ponds largely derived their sediments (a portion of the material is produced by algae and plants within the pond) may be determined by examining the “high ground” surrounding the pond. Size, land use and slope are particularly important watershed features. For example, the pond shown in Figure 8 has a relatively small watershed relative to its own size. Much of that watershed consists of meadow (and therefore experiences less erosion than would have been the case with cornfields, for example). The influent stream transports sediments relatively quickly (compare to transport by overland runoff) to the downstream pond shown, but receives a measure of protection in being surrounded on both sides by riparian trees.

Fig. 8. Watershed features of a pond in the Brandywine drainage, Chester County.

In general, ponds with larger watersheds experience greater quantities of sediment in-filling (as well as nutrient runoff). However, rates of sediment burial, when expressed per unit watershed area as in Figure 9, typically decline as watershed area increases. This occurs because a portion of the sediment that is eroded from soils more distant from the pond are intercepted by swales or other low-lying areas. indicate that as watershed area increases, each hectare of watershed area contributes less to the pond.

Fig. 9. Per unit watershed area-specific annual sediment accumulation rates (based on sediment volume), related to pond area in ponds with stream inflows



In effect, ponds can have very different "life-spans" according to their size, the land area that drains to them, and the presence or absence of a stream connection; sediment removal to extend the life of a pond is more frequent in smaller ponds with stream inflows, and is an important consideration for landowners, managers and conservation organizations. As ponds age, they become shallower and typically support more rooted plants, which in term help to trap sediments by slowing down water movement. Although bank erosion during pond construction may initially contribute substantially to sediment burial, stabilization of the shoreline by natural vegetation can help considerably to reduce subsequent in-filling. An example of the oldest pond among those studied, with a well-developed and diverse assemblage of aquatic and riparian plants, is shown in Figure 10.

Fig. 10. A well established pond in the northern portion of the Brandywine watershed, with a diversity of plants that (with the exception of the pink water lilies) naturally colonized the shoreline and deeper water. The additional protection provided by the riparian vegetation has done much to increase the pond's longevity.