Chapter 2. Regional Landscapes and the Hydrologic Cycle

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Introduction

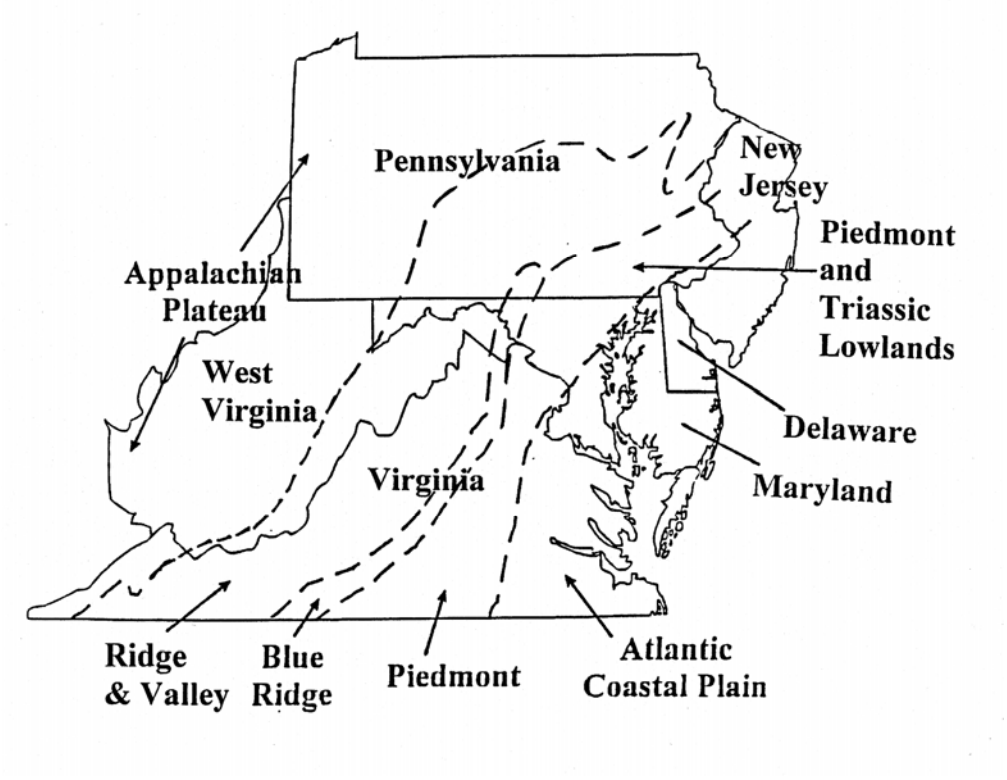
The relative risk of nutrient movement to groundwater and surface waters in any soil landscape is strongly controlled by the nature of the underlying parent material. Differing parent materials weather into varied landforms and associated soil types. These are then affected by management practices, resulting in different infiltration and runoff rates. These differences in local soil hydrologic character directly influence field level runoff behavior and the degree to which percolating leaching waters are filtered through reactive subsoils before they reach groundwater discharge points.

Soils and landscapes of the Mid-Atlantic region

Physiographic provinces

The surface soil landscape of the Mid-Atlantic region is dominated by its underlying geology that in turn controls regional landforms. The Mid-Atlantic possesses five unique physiographic provinces (Figure 2.1) related to the underlying geologic formations and associated landforms. Going from east to west, these provinces are the Atlantic Coastal Plain, the Piedmont, the Blue Ridge, the Ridge and Valley, and finally, the Appalachian Plateau. Soils vary considerably from province to province, as do their related nutrient management concerns. Basic soil/parent material relationships and how they interact with important watershed and nutrient management issues are discussed below.

Figure 2.1. Physiographic provinces of the Mid-Atlantic region.



Atlantic Coastal Plain

The *Atlantic Coastal Plain* Province extends from the Eastern shore to its western boundary with the Piedmont at the Fall Zone. Baltimore, Richmond, and several other major cities are located on the Fall Line of rivers that occurs within the broader Fall Zone. The Coastal Plain is composed almost entirely of unconsolidated fluvio-marine sediments that are predominantly sandy in original texture. Significant deposits of finer textured silts and clays are found interbedded in the sediments along with occasional marl (shell/lime) and peat deposits. The Coastal Plain supports some of the Mid-Atlantic region's most intensive combined row crop/animal agriculture production systems, particularly on the Delmarva Peninsula and in Southside Virginia.

In general, the soils of the Coastal Plain are younger and sandier to the east and older and higher in clay to the west. The lower Coastal Plain landscapes to the east tend to be quite broad and undissected when compared to the higher landscapes associated with the Upper Coastal Plain. Many soils in the Lower Coastal Plain are quite wet and have been drained for agricultural production. These soils and those lying immediately adjacent to the waters of the Chesapeake Bay are environmentally sensitive and demand careful nutrient management.

Many Coastal Plain soils are also very sandy in texture and therefore have high leaching potentials. However, many of these sandy surface soils are

underlain by clay-enriched subsoils that can scavenge and hold nutrient cations. Moderate to steep slopes are encountered to some extent in the Middle and Upper Coastal Plain, particularly in areas adjacent to active streams.

Piedmont

The *Piedmont* Province is underlain by igneous and metamorphic rocks weathered for long periods into soft weathered rock, or *saprolite* that comprise the soil's parent material. In general, the soils are deep, have high clay content, and are commonly severely eroded.

The Piedmont landscape is a randomly dissected plain with a gentle slope from the base of the Blue Ridge to the Fall Zone. Large, flat areas are uncommon in the Piedmont, and most agricultural fields are located in the moderately sloping summit and shoulder positions of the local landscape. The local geology of the Piedmont can be quite complex, and shallow, rocky soils are often intermixed with less management-sensitive soils. Soil wetness is generally a problem only in areas immediately adjacent to streams, although upland wetlands do occur in the Piedmont, particularly in flatter summit areas underlain by high clay soils.

The Piedmont also contains a number of imbedded Triassic Basins that can be quite large. These basins contain soils formed in sediments or from sedimentary rock that resemble the soils of the Coastal Plain or the Appalachian Plateau.

Blue Ridge

The *Blue Ridge* Province occurs in a narrow strip associated with the Blue Ridge Front of the Appalachian Mountains and is underlain by complex metamorphic and igneous intrusive rocks. Most of the Blue Ridge is steep and rocky and not suited to agricultural production. The soils in these areas are typically shallow to bedrock. However, localized areas of the province are moderately rolling and highly resemble the Piedmont in their basic soil landscape characteristics. In these areas, forage and row-crop-based animal production systems are common and frequently intensive.

Ridge and Valley

The *Ridge and Valley* Province is underlain by folded and faulted rocks of sedimentary origin. The ridges are dominantly supported by harder, iron- and silica-rich rocks such as sandstones and are covered with shallow, rocky soils on steep slopes and deep loamy soils in coves. The valleys are generally underlain by limestones and carbonate-rich shales that have weathered into deep productive soils with silty surface layers and clayey subsoils. These limestone valleys, particularly from the Shenandoah River north through central Pennsylvania, support some of the most intensive row-crop and animal production agriculture in the Mid-Atlantic region.

Karst terrain and its associated sinkholes commonly occur throughout this province over the purer limestone parent materials. Karst areas require intensive nutrient management. Many soils in this province are also shallow over fractured rock and are, therefore, environmentally sensitive. The landscape over the limestones is typically moderately rolling, but excessively steep sideslopes and rock outcrops are also common.

Much of this valley landscape is overlain by river terrace deposits that are usually productive, but may contain significant amounts of cobblestones that can limit tillage. Poorly drained soils are typically confined to areas next to streams. Many soils of the Ridge and Valley Province are shallow to fractured rock, particularly those that have formed over shales and purer carbonates.

Appalachian Plateau

The *Appalachian Plateau* Province is a deeply dissected region underlain by flat-lying sedimentary rocks that are dominantly sandstones, siltstones, and shales. Thin coal seams are also common. The vast majority of this province is steeply sloping and covered with forest, although rolling uplands on the Plateau are farmed to a significant extent in western Pennsylvania and in some localized areas further south. Agriculture production activities are intensive in some areas, but most of the land in this province is used for non-agricultural uses. The soils are generally coarse textured and frequently shallow to rock. Much of this province in northwestern Pennsylvania has been covered by a mantle of till resulting from glaciation. The portions of this province to the south were not affected by glaciation.

Exceptions

Soils with contrasting characteristics to those described above may be found in any of the Mid-Atlantic physiographic provinces. For example, major river systems, such as the James and Susquehanna, cut through the provinces from west to east and have a unique set of floodplain and terrace soils associated with their historic paths. Very productive soils associated with relict river terraces are commonly found tens of miles away from current stream channels, particularly in the limestone valleys.

Many of the soils of the glaciated northwestern part of the Mid-Atlantic, which were formed in till and outwash, are considerably different from the soils formed in residual saprolite (weathered rock) further south. In areas such as the Ridge and Valley Province, the soil's parent material can change drastically over a distance of several feet, with associated changes in both soil properties and appropriate land use.

Detailed information on soils, geology, and land-use interactions is available from soil survey reports for most counties in the Mid-Atlantic region (http://soils.usda.gov/), and the reader is encouraged to consult this information before any significant project or planning process is undertaken.

The hydrologic cycle and soil-water balances

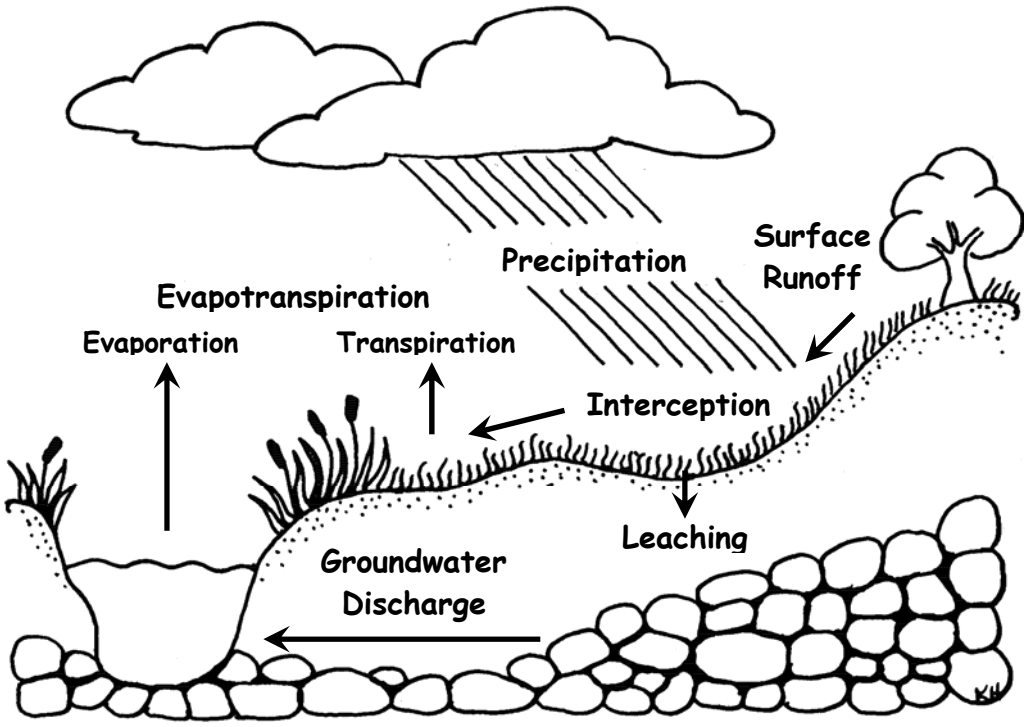
Introduction

A basic understanding of the hydrologic cycle (illustrated in Figure 2.2) is necessary to understand nutrient loss mechanisms and to develop management strategies to reduce nutrient losses to groundwater and surface water. The primary components of the hydrologic cycle most important to nutrient transport in groundwater and surface water are:

- precipitation
- evapotranspiration (evaporation + transpiration)
- surface runoff, interception, and leaching
- discharge of groundwater into streams (base flow)

Nutrients move into the groundwater system via leaching and to surface water via runoff or groundwater discharge. Any contaminants dissolved in surface runoff, such as NO_3^-, can contribute to surface water contamination. In addition, seepage of groundwater into surface water often occurs in stream beds and tidal portions of the Chesapeake Bay system.

Figure 2.2. The hydrologic cycle.



Precipitation

Long-term *precipitation* averages range from 35 inches to over 50 inches annually in different areas of the Chesapeake Bay watershed. Although timing and amounts of precipitation will vary in each individual year, these deviations from the average cannot be reliably predicted in advance.

Evapo-transpiration

Evapotranspiration is the sum of surface *evaporation* of moisture plus the removal of soil moisture by the *transpiration* of living vegetation. It accounts for about 20 inches to 35 inches of the total precipitation in the Chesapeake Bay watershed, and is highest when growing season air temperatures are highest, as long as the soil is fully vegetated. The removal of soil water by evapotranspiration decreases and net leaching increases when air temperatures drop below 40° F, or when an actively growing crop is removed.

Long-term average rainfall by month does not vary significantly throughout the year in the Mid-Atlantic region. Evapotranspiration, however, is much higher during the late spring, summer, and early fall because water use by crops is much higher during this period.

Surface runoff, interception, and leaching

Precipitation that falls onto the soil surface in excess of the infiltration rate will *run off* to lower portions of the landscape or to surface streams. In vegetated areas, 5% to 40% of this precipitation is *intercepted* by the leaves of plants depending on the intensity of rainfall and the morphology of the canopy. Water that infiltrates the soil is largely removed by evapotranspiration during the growing season. Remaining soil water, particularly that held in large macropores, is subject to *leaching* below the rooting zone and may eventually reach groundwater. During leaching, soluble nutrients such as NO_3^- percolate through the soil with water because they are not readily bound to soil surfaces. The relative amounts of surface runoff, interception and leaching from an area are influenced by storm intensity, storm duration, slope, soil type, type of vegetation, and amount of residue.

Water losses to the atmosphere due to evapotranspiration during most of the active growing season will exceed rainfall contribution to soil moisture. Consequently, the risk of leaching or runoff of water is much lower during the summer than during the winter. During periods of low evapotranspiration, significant leaching and runoff can occur.

Discharge of groundwater into streams (base flow)

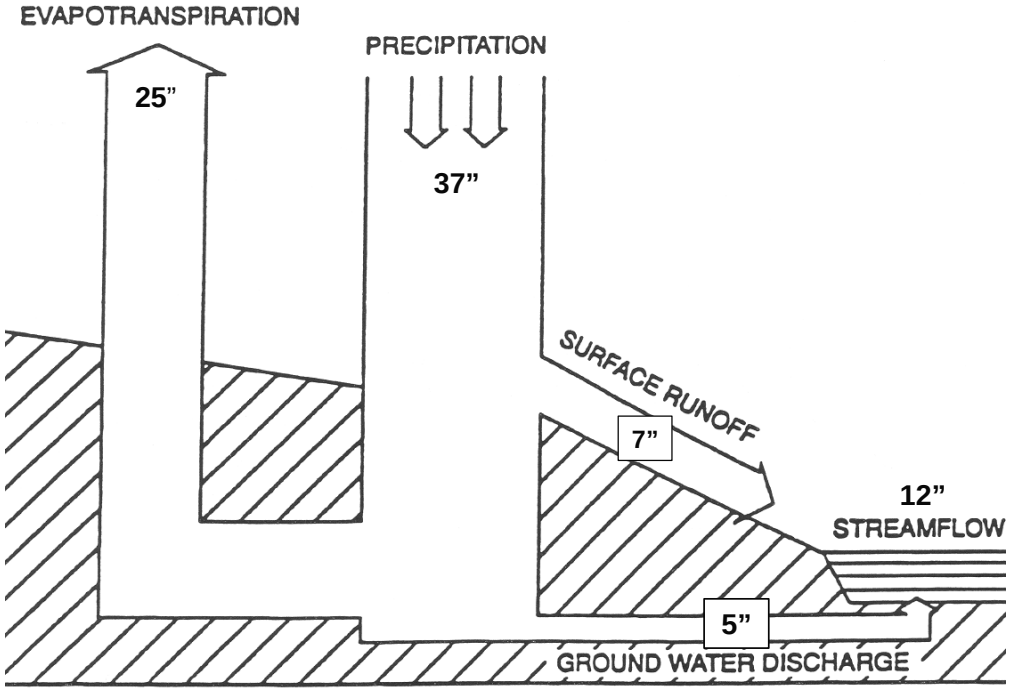
Groundwater that infiltrates upland soils and then discharges into local streams is also termed *base flow*. The base flow in the specific Ridge and Valley Province watershed represented by Figure 2.3 accounts for about 5 inches per acre of watershed area, while direct surface flow accounts for 7 inches per acre annually. Surface flow contribution to stream water occurs

during and after rainfall events or snow melt and is, therefore, highly variable over time. In contrast, base flow is generally a continuous contributor to stream flow throughout the year. During dry periods, base flow is the primary contributor to stream flow, which vividly demonstrates the interconnection of groundwater and surface waters.

In the Piedmont Province, surface runoff of water is a larger contributor than base flow to surface water flow because of the topography and geology of the area.

In the Atlantic Coastal Plain Province, base flow and subsurface seepage of groundwater contribute more than surface runoff to surface water bodies. In some areas of the Coastal Plain, groundwater discharge may account for as much as 80% of total annual contributions to surface water due to the permeable soils and shallow groundwater that are characteristic of this physiographic province. Groundwater in the Coastal Plain Province typically moves in a downwardly arcing path from uplands towards discharge points at a rate of several inches to as much as 2 feet per day.

Figure 2.3. General water budget, Upper South Fork of the Shenandoah River (adapted from Virginia Division of Conservation and Recreation, 1993.)



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