Additional thoughts on water and forests – T.Kyker-Snowman – DCR DWSP – 9/15/09

The **water supply protection provided by forest cover** functions at every scale, from the individual tree, to a forest stand (by definition, relatively homogeneous in composition and structure), and most importantly, on the landscape scale of a relatively more diverse forested watershed.

An **individual tree** serves to capture and slow precipitation, processes pollutants through both mechanical trapping and biochemical processing, and buffers against local soil saturation through passive interception and evaporation and active transpiration (collectively, 'evapotranspiration'). When rain falls on an individual tree, a significant portion of that rain is intercepted by leaves, branches, and/or the trunk of the tree (when the rain falls as snow, an even greater proportion is intercepted, especially by evergreens). An individual rain drop may be held until it is evaporated (approximately 10-15% of rainfall), it may simply run down the trunk of the tree to the ground (~5%), or it may drop to the forest floor directly (often after coalescing with other raindrops), or simply fall through gaps in the vegetation. While trees serve to break the fall of raindrops, these drops can regain terminal velocity within about 30 feet, so that a groundcover of plants and young trees and/or layers of accumulated organic materials are necessary to limit the erosive power of rain on the soils beneath a maturing forest.

While many factors determine evapotranspiration rates, a mature, open-grown deciduous tree is estimated to have in excess of 200,000 leaves, which, on a summer day, can transpire as much as 900 gallons of water. The evapotranspiration associated with an individual tree limits the frequency with which the soils it occupies become saturated, thereby maintaining infiltration and limiting overland flow of water and the associated transport of nutrients and sediments. In addition, trees directly process pollutants in a variety of beneficial ways. Some airborne pollutants are simply trapped on the surfaces of the tree, removing them from the ambient air and temporarily stalling their entry to the water system. Biochemical reduction of pollutants by plants (the basis of "bioremediation") is a varied and complex combination of processes that includes: improved degradation by soil microorganisms through rhizosphere enhancement (primarily nutrient additions); the uptake, translocation, and volatilization of unmetabolized compounds; and the uptake and metabolism or storage of other compounds. So long as pollutant levels are not toxic to the trees, these processes continuously clean the water that moves through the forest.

In addition to these direct influences on water quality, individual trees also: anchor soil; produce soil macropores as roots penetrate and die, increasing infiltration capacity and reducing overland flow; capture and utilize inorganic nutrients in the soil for growth and metabolism; provide shade that regulates decomposition processes and the temperature of streams; deliver organic materials (leaves, twigs) to the forest floor, thus reducing erosion; and produce seed that enhances the forest's ability to recover from disturbances.

A **forest stand** protects water supplies through the multiplication of the effects of individual trees and understory plants, but also provides collective effects that go beyond those of individual plants. When an individual tree in a stand matures and begins to decline, it also begins to lose its ability to affect water quality. Leaf area, transpiration, root penetration, growth and nutrient uptake, shade, and eventually seed production all decline. This process may result from simple stem exclusion, through which an initial stand of perhaps a million seedlings per acre is reduced by competition to a mature forest of 100-200 trees. Or it may result from a large array of defoliators, fungi, or viruses, or from injuries following wind or ice storms. Regardless of the cause, the influence of a forest stand is that the living, thriving trees surrounding a tree in decline will utilize the resources made available by the dying tree, including sunlight, water, and nutrients, and the result for water quality is uninterrupted protection. When a disturbance suddenly damages or kills mature trees, the protection provided by the stand relies upon regeneration to replace the functions of these trees, rather than upon surrounding, vigorous trees.

Stand types (roughly homogeneous combinations of species and age classes) produce categorically similar effects on water quantity. Evergreen conifer stands generally reduce water yield to levels below that produced by deciduous trees on similar sites, primarily because evergreens continue transpiring throughout the year and because they intercept a higher percentage of snowfall, a portion of which either evaporates or directly sublimates. Stand age affects water quality, also in roughly predictable ways. Young, established stands of any species mix are accumulating biomass more rapidly than older, maturing stands, and therefore assimilating available nutrients more aggressively due to higher biotic demand for these nutrients. As expected, this demand is highest during the growing season, which is reflected in the seasonal patterns of nutrient flux. As decomposition and respiration rates begin to balance or exceed the rate of primary production, the capacity for nutrient assimilation by older stands begins to decline. Although nutrients are still held tightly by older stands, outside additions (e.g., atmospheric transport of nitrous oxides) can overwhelm this assimilation capacity of these forests and result in leaching and hydrologic losses, and long-standing accumulations of organics can lead to higher losses of organic forms of nutrients to adjacent waters.

At the landscape scale, the forested watershed accumulates the effects of individual trees and forest stands to provide highly resilient protection for drinking water supplies. Even when intense land use practices such as 19th century clearing and agriculture have pushed the resulting forest toward homogeneity, the range of seed sources, topographic positions, water regimes, aspects, soil types, and bedrock composition conspire to maintain a diversity of stand types. The mix of types across the watershed at any given time produces a predictable yield, a predictable volume of water delivered to the reservoir or river system, while the inherent diversity in species composition provides the watershed forest with a level of redundancy in maintaining itself that rivals the most responsibly engineered water treatment plant. The diverse structure in this living green filter, like diversity in an investment portfolio, yields more consistent performance through the vagaries of climate fluctuations, wind, snow, and ice, rainfall intensity, and damaging native and alien pests than a forest (or an artificial filter) built to a single design. The range in structural and species composition across the forested watershed represents built-in multiple barriers, providing a forest biofilter that functions 24 hours a day on free solar energy to provide unrivaled protection for drinking water supplies.