Base flow recession curve during a dry period is a distinct hydrologic signature of a watershed. The base flow recession analysis for both streamflow and spring flow has been extensively studied in the literature. Studies have shown that the recession behaviors during the early stage and the late stage are different in many watersheds. However, research on the transition from early stage to late stage is limited and the hydrologic control on the transition is not completely understood.

In this dissertation, a novel cumulative regression analysis method is developed to identify the transition flow objectively for individual recession events in the well-studied Panola Mountain Research Watershed in Georgia, USA. The streamflow at the watershed outlet is identified when the streamflow at the perennial stream head approaches zero, i.e., flowing streams contract to perennial streams. The identified transition flows are then compared with observed flows when the flowing stream contracts to the perennial stream head. As evidenced by a correlation coefficient of 0.90, these two characteristics of streamflow are found to be highly correlated, suggesting a fundamental linkage between the transition of base flow recession from early to late stages and the drying up of ephemeral streams. At the early stage, the contraction of ephemeral streams mostly controls the recession behavior. At the late stage, perennial streams dominate the flowing streams and groundwater hydraulics governs the recession behavior.

The ephemeral stream densities vary from arid regions to humid regions. Therefore, the characteristics of transition flow across the climate gradients are also tested in 40 watersheds. It is found that climate, which is represented by climate aridity index, is the dominant controlling factor on transition flows from early to late recession stages. Transition flows and long-term average base flows are highly correlated with a correlation coefficient of 0.82. Long-term average base flow and the transition flow of recession are base flow characteristics at two temporal scales, i.e., the long-term scale and the event scale during a recession period. This is a signature of the co-evolution of climate, vegetation, soil, and topography at the watershed scale.

The characteristics of early and late recession are applied for quantifying human impacts on streamflow in agricultural watersheds with extensive groundwater pumping for irrigation. A recession model is developed to incorporate the impacts of human activities (such as groundwater pumping) and climate variability (such as evapotranspiration) on base flow recession. Groundwater pumping is estimated based on the change of observed base flow recession in watersheds in the High Plains Aquifer. The estimated groundwater pumping rate is found consistent compared with the observed data of groundwater uses for irrigation.

Besides streamflow recession analysis, this dissertation also presents a novel spring recession model for Silver Springs in Florida by incorporating groundwater head, spring pool altitude, and net recharge into the existing Torricelli model. The results show that the effective springshed area has continuously declined since 1988. The net recharge has declined since the 1970s with a significant drop in 2002. Subsequent to 2002, the net recharge increased modestly but not to the levels prior to the 1990s. The decreases in effective springshed area and net recharge caused by changes in hydroclimatic conditions including rainfall and temperature, along with groundwater withdrawals, contribute to the declined spring flow.