Drainage network is an important geomorphologic and hydrologic feature which significantly controls runoff generation. Drainage network is composed of unchannelized valleys and channels. In this dissertation, the hydrologic controls on the drainage networks extracted from high resolution Digital Elevation Models (DEMs) based on Light Detection and Ranging (LiDAR) are investigated. A method for automatic extraction of valley and channel networks from high-resolution DEMs is presented. This method utilizes both positive (i.e., convergent topography) and negative (i.e., divergent topography) curvature to delineate the valley network. Valley extracted from DEMs may be wet (flowing) or dry at any given time depending on the hydrologic conditions. The temporal dynamics of flowing streams are vitally important for understanding hydrologic processes including surface water and groundwater interaction and hydrograph recession. A systematic method is developed to map wet channel networks by integrating elevation and signal intensity of ground returns. The signal intensity thresholds for identifying wet pixels are extracted from frequency distributions of intensity return within the convergent topography extent using a Gaussian mixture model. Moreover, the concept of edge in digital image processing, defined based on the intensity gradient, is utilized to enhance detection of small wet channels. Several studies in the past focused on the relationship between drainage density (i.e., drainage length divided by drainage area) and long-term climate and reported a U"shape relationship. In this dissertation, this relationship is revisited and the effect of drainage area on drainage density is investigated. The branching angles, i.e., the angle between two adjoining channels, in drainage networks are important features related to the network topology and contain valuable information about the forming mechanisms of the landscape. Based on channel networks extracted from 1 m DEMs of 120 catchments with minimal human impacts across the United States, we show that the junction angles have two distinct modes.