Strategies, aimed to reduce the degradation of water quality and to predict future changes in surface waters due to natural and anthropogenic forcing, critically rely on the ability to track water quality changes through time and to accurately quantify the distribution of water sediment attributes (e.g., organic carbon, contaminant). Geostatistical methods provide a means to produce reliable estimates of these attributes along with their associated uncertainties by utilizing the sparse but essential available measurements of water quality attributes (e.g., dissolved oxygen). The three components of this dissertation focus on the development of geostatistical data fusion methods that make optimal use of the available monitoring data in three locations: the Passaic River, Lake Erie, and Chesapeake Bay.

The first component of this dissertation focuses on the Passaic River sediment and presents a method for accurately estimating the spatial distribution of the total organic carbon using a dataset with non-uniform resolutions. Estimating the spatial distribution of water sediment attributes at a uniform spatial resolution is often required for site characterizations and the design of appropriate risk-based remediation alternatives. However, the distribution of sediment attribute is typically obtained from sediment core sections where data are typically reported as averages from non-uniform sections. The geostatistical downscaling method developed is shown to resolve this non-uniform resolution problem by explicitly accounting for the relationship between the coarse and non-uniform resolution measurements and the fine and uniform resolution distribution. In addition to examining water sediments, an exploration of the degradation of water quality in time and space is also of great importance. For example, hypoxia (low dissolved oxygen) has been observed in Lake Erie and Chesapeake Bay since the early 1900s, leading to negative impacts such as ecosystem habitat degradation, altered migration patterns, and decreased fishery production. The other two components of this dissertation show the interannual hypoxic extent in these two systems by combining spatially explicit auxiliary data (e.g., data representing spatial trends) with in situ dissolved oxygen measurements. Additionally, this research further evaluates the significance of nutrients and weather patterns on hypoxia in Chesapeake Bay since mid-1980s.