Geostatistical Analysis

Geostatistical methods are a collection of tools that permit optimized sampling design and interpolation of environmental attributes for mapping, as well as time series analysis. Geostatistical interpolation methods range from deterministic (i.e., predictions without quantified uncertainty) to probabilistic (i.e., predictions based on a probability distribution), and can serve a variety of data quality objectives, decision-making needs, and uncertainty quantification levels. Geostatistical methods differ from conventional interpolation methods by quantifying and using the actual spatial behavior of a variable of interest to make more accurate prediction of that variable. These methods are superior to other mapping methods for applications that require a high degree of confidence in the results, such as:

- **Mapping for remedial decision making,**
- **Uncertainty quantification (e.g., confidence intervals)**
- **Integration of data from various sources**
- **Phased sampling design**
- **Identifying and accounting for factors controlling spatial variation**

Geostatistical methods are used in a wide variety of applications that require spatial analysis and predictions, often in conjunction with geographic information systems (GIS). Geostatistical models can be integrated into physical models of contaminant transport and fate to optimize predictions of the physical or geostatistical model, or to estimate uncertainty through simulation.

LimnoTech offers extensive experience in the theory and development of geostatistical models for riverine systems, soil and groundwater.

LimnoTech has a national reputation for the development and application of models and other tools to address complex scientific and environmental engineering issues and to aid in the selection and design of management alternatives, especially as they relate to remedial decision-making, risk assessment and water quality issues. To enhance our capabilities in this area, we also employ geostatistical modeling methods to support these types of environmental assessments.

LimnoTech has successfully used geostatistics in projects to evaluate groundwater/surface water interactions, to characterize contaminated sites, to delineate the extent of sediment contamination, and to guide remedial investigations and design remedies in contaminated sediments.

Geostatistical Consultation of Contaminated Sediment Extent in the Passaic River, NJ. The lower Passaic River has been designated a Superfund site because of elevated concentrations of dioxins, furans and other co-contaminants in its sediments. LimnoTech developed a probabilistic geostatistical model of 2,3,7,8-TCDD for the lower six miles of the Passaic River, to assist in an evaluation of remedial alternatives, providing a basis for estimating contaminated depths, volumes, areas and associated estimates of remedial costs. LimnoTech also developed a conceptual model of erodibility zones within the lower six miles of the River. This was accomplished by constructing overlays of available indicators of erodibility, and using a lines-of-evidence approach to identify erosion potential. Lines of evidence included information about navigational dredging, bathymetry, radionuclide-based sedimentation rates, surface sediment grain types, surficial contaminant concentrations, sediment core depths, and shear stress predictions. The probabilistic kriging model yielded predictions at a series of confidence levels, allowing the client to explore and optimize remedial strategies and their impact on predicted remedial volumes and costs, along with the uncertainties therein.

Support to Preremedial Design, Fox River and Green Bay, WI. This project involved analytical support to the Fox River remedial design team, including geostatistical dredge prism determination, hydrodynamic evaluations of cap stability, and long-term post-remedial monitoring. Probabilistic geostatistical methods were used to characterize the depth of PCB contamination to support remedial design (dredging and capping). Several innovative geostatistical approaches were used to satisfy project requirements, such as prediction of contamination depth at various levels of confidence, accurate representation of areas with zero depth of contamination, accurate representation of dredging and flow pattern-related discontinuities in sediment depth, and optimization of the dredge prism based on predicted false positive/false negative rates and other statistical performance measures. Methods included a geostatistical interpolation model that follows flow paths, and integrated submodels for different reaches/channels based on the spatial distribution of historic dredging activities in the river, and probabilistic estimation to determine the most appropriate confidence level for dredging cutline design. LimnoTech's optimized probabilistic model has proved to be a powerful basis of design for Fox River remediation. Results are being used by the remediation engineering team to finalize dredge depths and capping areas under the selected remedial alternative.

LimnoTech has successfully used geostatistics in numerous, diverse projects to guide remedial investigations and produce design remedies.

Hydraulic Modeling to Support Capacity Assessment and Development of Sewer System Master Plan for Washington, D.C. LimnoTech applied the commercial MOUSE model to simulate stormwater inflow and infiltration in combined and separate sewer system areas of Washington, D.C., to predict routing of flow through the City's collection system, and to identify capacity-constrained areas. Geostatistical methods were used to predict groundwater elevations and the possible interaction of groundwater with the sewer system. The analysis was based on well data with greatly varying spatial coverage over the area of study. To allow groundwater level prediction in unsampled areas and overall reduction in prediction uncertainty, high-resolution topographic elevation was integrated into the probabilistic geostatistical model. The MOUSE model is being used to evaluate the effectiveness of various control alternatives on a system-wide basis.

Characterization of the Tittabawassee River and Floodplain to Support Remedial Investigation Activities. The Tittabawassee River has been the focus of several investigations directed toward gaining an understanding of the distribution of contaminants in river water, sediments, fish, and in floodplain soils. Under the first phase of this project, LimnoTech summarized previous studies and helped the client develop a preliminary conceptual model of the site. LimnoTech is expanding the understanding of the system by developing hydraulic models of the river and floodplain; performing a field study to characterize the distribution of in-river sediments and the redistribution of dioxins/furans during flooding events in the floodplain; monitoring flow and solids in the river and solids and dioxins/furans in the floodplain; and developing a geospatial model of dioxins/furans in the floodplain. The geospatial model of dioxin/furan concentrations in the floodplain integrates flow modeling, geostatistical interpolation and multiple regression, using information on influencing factors and floodplain geomorphology. The first phase included a geostatistically based sampling design for the river and the floodplain based on previously available data, and a pilot study targeting representative areas of the river-floodplain system. The geostatistical prediction model will incorporate flow direction, stratification based on the difference in dioxin/furan concentrations in disturbed/undisturbed areas and geomorphologic depositional units, and will integrate these relationships with other factors determined to be statistically significant factors influencing concentrations. Results will support future remedial decision-making.

Field Investigation and Numerical Modeling of Sediment Transport and Stability in the Hackensack River, NJ. LimnoTech investigated chromium contamination and sediment stability for remedial decision-making. LimnoTech has developed a numerical model for Hackensack River hydrodynamics in the vicinity of its mouth at Newark Bay as well as a three-dimensional geostatistical model of chromium concentrations at the study area. The geostatistical model integrates information about the stratification of different sediment types and their association with differing levels of contamination for a robust prediction of horizontal and vertical contamination extent. These results are combined with statistical evaluations of monitoring data of tidal fluctuations, tidal velocities, bathymetric evaluations, geochronologic studies of sediments, and in-situ erosion rate studies to assist in remedial alternative evaluation and selection site.