Application of Expanded GTS Algorithm to Air Force Plant 6

Kirk M. Cameron, Ph.D.
MacStat Consulting, Ltd.
10330 Mill Creek Ct., Colorado Springs, CO 80908
Phone: (719) 532-0453, Email: kcmacstat@qwest.net

Introduction

For the past few years, the Air Force Center for Environmental Excellence (AFCEE) has been developing strategies for optimizing its sampling and analysis efforts at sites where it must conduct long-term monitoring (LTM) of ground-water. The basic goal of these optimization efforts is to ensure that adequate and sufficient amounts of data are retained to enable good regulatory and remedial decisions, while at the same time not wasting valuable resources. In many cases, some of the sampling information that is now being collected is partially redundant or is being used inefficiently. Optimization strategies aim to minimize this waste of resources while maximizing the usefulness of the sampling data that is retained.

One of these optimization efforts is a strategy known as the Geostatistical Temporal-Spatial (GTS) algorithm (Cameron & Hunter, 2002). GTS has been developed in conjunction with AFCEE and applied at sites in Massachusetts, and is being further refined and tested at Air Force sites in California, New Hampshire, and Maine. The GTS algorithm is designed to provide a decision-logic framework that looks at two areas of optimization: redundancy in sampling frequencies and redundancy in sampling locations. Geostatistical and trend identification methods are used to assess the degree of statistical information contained in the existing well network and to suggest how that network might be improved.

Components of the GTS algorithm are also quite useful for related purposes. Some of these applications include 1) the optimization of treatment systems, for instance examining the sampling frequencies of influent and effluent streams to pump-and-treat remedial operations; 2) characterization and mapping of sites; 3) identifying changes in contaminant patterns over time; 4) subsurface mapping of bedrock or other geologic strata; 5) estimating hydrogeologic parameters needed for geophysical or fate-transport models; 6) determination of optimal locations for new sampling or drilling.

Methods

An expanded version of the GTS algorithm is also being applied to Air Force Plant 6 in Georgia. The long-term monitoring and remediation program at Plant 6 provides several challenges to sampling and network optimization. These challenges include fractured geology, less than adequate spatial coverage by existing wells, and highly statistically skewed contaminant plumes. To address these issues, the GTS optimization algorithm is being modified and improved to provide greater flexibility and applicability to challenging environments.

The spatial portion of GTS has been improved in the following ways. 1) Better spatial modeling: GTS now uses locally-weighted smoothers to estimate variograms, variogram outliers are identified and appropriately handled, automated routines have been written to search for anisotropies and to plot variogram surfaces, and variograms are also estimated using robust statistics to ensure that key features of the spatial correlation function are identified and properly modeled. 2) Use of alternate spatial interpolators: GTS has added estimation of site maps via probability kriging and locally-weighted quadratic regression, both techniques designed to produce more accurate concentration maps and to allow for estimation of confidence surfaces and maps of misclassification probabilities. 3) Comparisons of different approaches for picking potentially optimal spatial networks: GTS can now compare the optimality results derived from using either global kriging weights, declustering weights, or genetic algorithms to identify candidate optimal spatial networks.

On the temporal side, locally-weighted regression (Loader, 1999) has been added to allow estimation of complex trends in the determination of optimal sampling frequencies at individual wells and to develop confidence bands around these trends. It is also being used to provide smoother estimates of multi-well temporal variograms for use in identifying optimal uniform site-wide or unit-wide sampling frequencies.

Discussion

All of these changes are designed to improve the accuracy of map estimation and trend identification. Without accurate estimates of maps and trends, the adequacy or fitness of potentially optimal monitoring and remedial networks cannot be correctly assessed. GTS uses four specific measures to assess the fitness of any proposed well network. These include 1) the net change in global variance under different possible well networks, 2) the net portion of the site that becomes inestimable as the network is re-configured, 3) the fraction of the site where the net change in local variance exceeds a threshold, and 4) the portion where the net change in mapped concentration levels exceeds a threshold. All of these measures provide important clues as to the adequacy of any proposed optimization and also provide a rational means of justifying a specific optimization plan.

Since the application of GTS to Plant 6 is ongoing, the final results of the effort are not yet available. However, some preliminary results of applying the modified GTS to data from Plant 6 are presented.

References

Cameron, K. & Hunter, P. (2002) Using spatial models and kriging techniques to optimize long-term ground-water monitoring networks: a case study. **Environmetrics**, 13, 629-656.

Loader, C. (1999) **Local Regression and Likelihood**. New York: Springer-Verlag.