Decision Support Software for Designing Monitoring Plans

Julia Aziz[1], Charles Newell[2], Hanadi Rifai[3], Ming Ling[4], and Jim Gonzales[5]

Abstract: The Monitoring and Remediation Optimization System (MAROS) software has been developed by the Tech Transfer Division of the Air Force Center for Environmental Excellence (AFCEE) to provide site managers a strategy for formulating appropriate long-term groundwater monitoring programs that can be implemented at lower costs. The MAROS software optimizes a site-specific monitoring program that is currently tracking the occurrence of contaminant migration in groundwater. MAROS is a decision support tool based on statistical methods applied to site-specific data that account for relevant current and historical site data as well as hydrogeologic factors (e.g. seepage velocity) and the location of potential receptors (e.g., wells, discharge points, or property boundaries). Based on this site-specific information the software suggests an optimization plan for the current monitoring system in order to efficiently achieve the termination of the monitoring program. For example, plumes that appear to be decreasing in extent, based on adequate monitoring data over several years, are analyzed statistically to determine the strength and reliability of the trend. If it can be demonstrated statistically through primary lines of evidence (i.e. Mann-Kendall Analysis and/or Linear Regression Analysis) and/or secondary lines of evidence (modeling or empirical) that the plume is shrinking with a high degree of confidence, then future monitoring can either be suspended or reduced in scope.

MAROS allows the option to apply heuristically-derived rules based on trend analysis results and site information or to utilize more rigorous statistical methods (i.e. Delaunay Triangulation and/or Cost Effective Sampling) in determining the minimum number of wells, sampling frequency, and well density suggested for future compliance monitoring at the site. These preliminary monitoring optimization results provide a basis for which to make more cost effective, scientifically based future long-term monitoring decisions. As the monitoring program proceeds, more recent sampling results can be added to historical data to assess the progress of the current monitoring strategy. The optimization process can be reviewed and updated periodically using the MAROS guidance recommendations. MAROS addresses a variety of groundwater contaminant plumes (e.g., fuels, solvents, metals) and is designed to be "evergreen" so that long-term monitoring plans can be modified as the plume changes over time (e.g., reducing monitoring efforts when a plume changes from stable to shrinking). The software and manual are now being distributed free over the internet (www.gsi-net.com).

Introduction. Long-term monitoring of affected groundwater is a significant cost driver for groundwater-related environmental restoration activities. For example, a commonly-used rule of thumb is that the cost of collecting a single groundwater sample, analyzing the results, and reporting the data is $1000 per well. If this is multiplied by thousands of sites with a number of wells for each site and long monitoring periods, the potential cost liability is billions of dollars.

[1] Environmental Engineer, Groundwater Services, Inc., Houston, Texas, 77098, USA, , Ph (713) 522-6300, Fx (713) 522-8010, jjaziz@gsi-net.com

[2] Vice President, Groundwater Services, Inc., Houston, Texas, 77098, USA, cjnewell@gsi-net.com

[3] Associate Professor, Dept. of Civil and Environmental Engineering, University of Houston, Texas, 77098, USA, Ph. (713) 743 4271, rifai@uh.edu

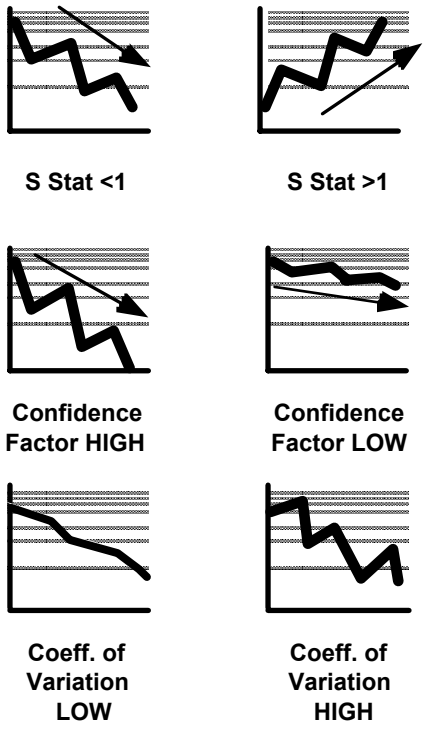
[4] Graduate Student, Dept. of Civil and Environ. Eng., University of Houston, Houston, TX, 77098, USA

[5] Air Force Center for Environmental Excellence, Brooks AFB, Texas, USA, Ph. (210) 536-4324, James.gonzales@hqafcee.brooks.af.mil

The table below summarizes the "calculus of long-term monitoring" and shows what cost drivers the MAROS software tool addresses.

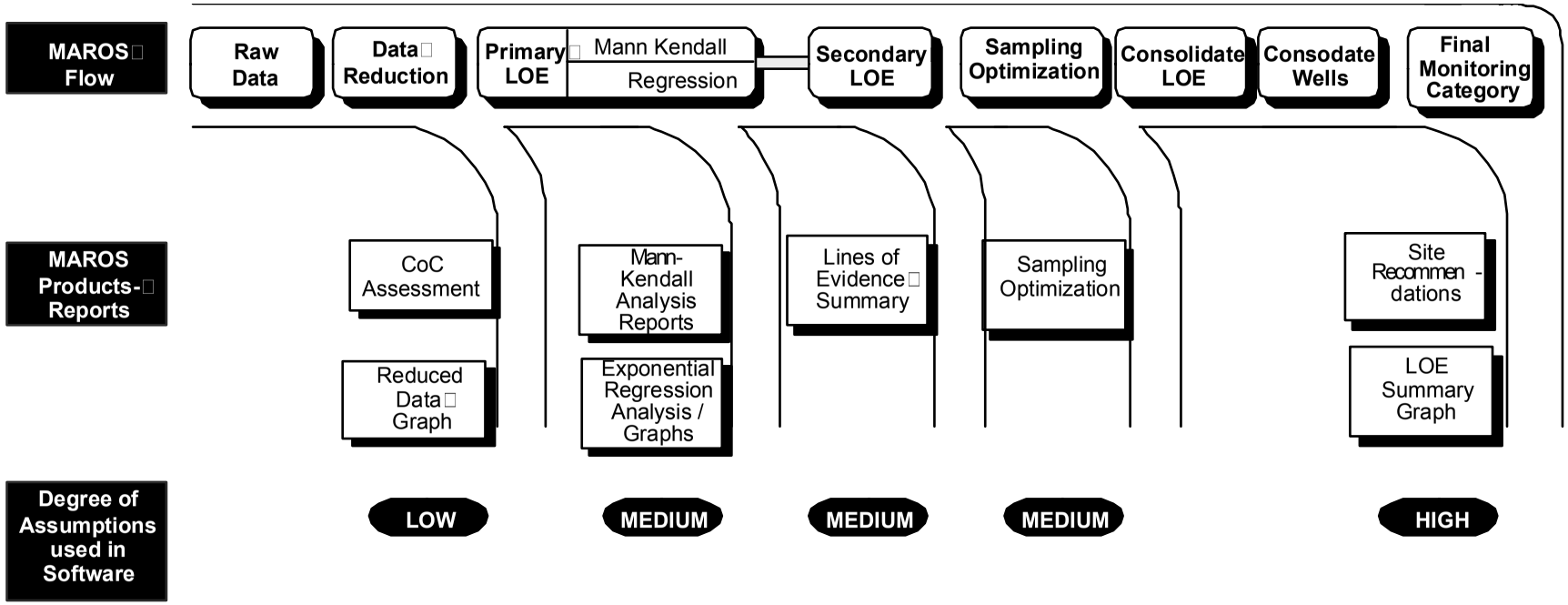
	TOTAL LONG TERM MONITORING COST DRIVER			
	Number of Sites	Cost Per Well	Number of Wells	Sampling Freq. and Duration
Potential for Cost Reductions?	*NO*	***YES***	***YES***	***YES***
Potential for Cost Reductions Addressed by This Tool?	*NO*	*NO*	***YES***	***YES***

MAROS Software Details: One of the most important concepts incorporated into the MAROS system is that knowledge of plume trends (increasing, stable, or shrinking) is extremely important for designing a reliable and cost-effective long-term monitoring system. MAROS uses both non-parametric (Mann-Kendall) and parametric (linear regression) techniques to define plume trends.



For example, the MAROS system uses a combination of the Mann-Kendall S statistic (based on the relative ranking of the plume data over time), a calculated confidence level, and the coefficient of variance to categorize the plume into one of six classes (increasing, probably increasing, stable, probably decreasing, decreasing, or no trend). The graphic on the right is a conceptual representation of the three types of information, where the S statistic shows the direction of the trend, the confidence factor shows how strong the trend is, and the coefficient of variation indicates how much scatter there is in the data. A similar approach is used for linear regression, except the slope of the regression line is used in place of the Mann-Kendall S statistic. Overall stable, decreasing, or probably decreasing plumes will require less intensive monitoring than increasing, probably increasing, or no trend plumes.

Other features of MAROS are tools to import and "cleanup" monitoring data (i.e., handle non-detects, duplicates, and lump data in quarters, years, etc.); tools for entering other types of knowledge (such as information regarding plume stability from modeling studies); and methods to evaluate each individual monitoring well to determine if it contributes important information about the plume or whether it is redundant ("sampling optimization"). Figure 1 shows a "road map" of the MAROS architecture. New features that will be available in the next version of MAROS now being developed (version 2.0) are: power analysis to develop a relationship between sampling frequency, number of stations, and the minimum difference in the monitored variable that can be detected can be established; moment analysis to give another perspective on trends; and a more detailed graphical interface. Currently Version 1 of MAROS is being distributed free over the internet (www.gsi-net.com). Version 2.0 will be available in Fall 2001.



LOE: Line of Evidence

Figure 1 MONITORING AND REMEDIATION OPTIMIZATION SYSTEM (MAROS) PROGRAM FLOW
(Tech Transfer Division, Air Force Center for Environmental Excellence (AFCEE)