

Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

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The Monitoring and Remediation Optimization System (MAROS) software developed by the Air Force Center for Environmental Excellence (AFCEE) was used to evaluate the sampling frequency of monitoring wells in the Topock Groundwater Monitoring Program (GMP) network. This memorandum summarizes the results of the evaluation and provides recommendations for revised sampling frequencies.

MAROS Description

MAROS is a modular set of tools that uses simple statistical and heuristic methods to evaluate appropriate sampling frequencies for wells in long-term groundwater monitoring programs. The capabilities of MAROS include plume trend analysis, detailed characterization of sample frequency, well redundancy, well sufficiency, and data sufficiency. MAROS is designed for single plumes, two-dimensional analysis, and evaluation only within the existing well network.

Application of MAROS to the Topock GMP Data Set

Sampling frequency analysis for hexavalent chromium [Cr(VI)] was the primary focus of the Topock groundwater monitoring program evaluation. Sampling frequency analysis relies primarily on evaluating data trends, particularly rate of change, at individual wells. MAROS requires at least four data points to calculate a trend at a well, but a trend based on only four data points may be erroneous. A minimum of six data points is recommended.

MAROS is designed to be used at sites where a static set of wells has been sampled at a regular frequency over a long period. Addition of new wells to the monitoring network during the period of interest often causes MAROS to reach an erroneous conclusion that the plume is migrating and results in excessive sampling frequency recommendations. At a site such as Topock, where new wells have been added each year, it is best to evaluate data from groups of wells for which data are available over the entire time period of interest.

Because Topock wells are sampled at various frequencies and MAROS provides the most meaningful results when all of the site wells are sampled during the same event, the GMP data set was reduced to reflect quarterly sampling intervals. To obtain the most conservative data set, the maximum concentration detected at the well during the quarter was used in the analysis of wells sampled more than once during a given quarter.

The program was run for a 2-year period and included data from April 1, 2004 through March 31, 2006, for all of the routinely-sampled monitoring wells. The 2-year data set is considered to be the most representative of current conditions at the site, while including most of the wells at the site. As more quarterly data becomes available, MAROS analysis can be performed on the more recent wells which have fewer than 6 quarters of data available.

Because MAROS performs a two-dimensional analysis, the data set was broken up by monitoring wells in the upper depth interval (UA), the middle depth interval (MA), and the lower depth interval (LA). Separate runs were made for each depth interval. The wells in the Alluvial Aquifer have been separated into three depth intervals to present groundwater quality and groundwater level data. The depth intervals are based on grouping the monitoring wells screened at common elevations and do not represent distinct hydrostratigraphic units or separate aquifer zones. The Alluvial Aquifer is considered to be hydraulically undivided. The contaminant used for the trend analysis was Cr(VI).

MAROS Inputs

In addition to analytical data, MAROS uses some hydrogeologic data. These data are used to evaluate plume movement. One value for each parameter is identified per depth interval. The values selected are shown on Table 1. The contaminant source was assumed to be approximately at the location of monitoring well MW-10. Wells included in the analysis must be assigned to one of two categories: source well or tail well. At least one source well must be selected for each layer. In each layer, the well(s) nearest the source area well (MW-10) were assigned to the source category. Source wells included: MW-09 and MW-10 in UA, MW-20-100 in MA, and MW-38D and MW-24B in LA. Although it is approximately 1,800 feet downgradient of the assumed contaminant source (near MW-10), MW-20-100 was selected as the source area well for the MA because it is the closest downgradient well to MW-10 for which a sufficient data set is available (it has a regular sampling frequency), and it has the highest Cr(VI) concentrations of the MA dataset.

TABLE 1
MAROS Input Parameters for Each Depth Interval
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Parameter	UA	MA	LA	Input Source
Seepage velocity (ft/yr)	127	152	142	Average from groundwater model
Generalized groundwater flow direction	East	East	East	Average from groundwater model
Saturated thickness (ft)	30	30	70	Average from groundwater model
Effective Porosity (%)	18	18	18	Average from groundwater model
Porosity (%)	30	30	30	C.W. Fetter, <i>Applied Hydrogeology</i> , 1994; and site specific sediment samples
50 ppb plume width (ft)	2920	2850	2540	1 st Quarter 2006 Monitoring

TABLE 1
MAROS Input Parameters for Each Depth Interval
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Parameter	UA	MA	LA	Input Source
				Event Plume Map
50 ppb plume length (ft)	1460	1420	2080	1 st Quarter 2006 Monitoring Event Plume Map
Maximum plume length (ft)	1460	1420	2080	1 st Quarter 2006 Monitoring Event Plume Map
Distance from source to nearest downgradient receptor (ft) [Colorado River]	2080	2080	2080	1 st Quarter 2006 Monitoring Event Plume Map
Distance from source to nearest downgradient property line (ft)) [Colorado River]	2080	2080	2080	1 st Quarter 2006 Monitoring Event Plume Map
Distance from plume tail to nearest downgradient receptor (ft)) [Colorado River]	460	350	60	1 st Quarter 2006 Monitoring Event Plume Map
Distance from plume tail to nearest downgradient property line (ft)) [Colorado River]	460	350	60	1 st Quarter 2006 Monitoring Event Plume Map

Data Sets Used

As previously described, separate runs were performed for wells with at least 2 years of data for each depth interval. Table 2 lists the wells that were included in each layer. Wells which were not included because they have less than 2 years of data are listed in Table 9.

TABLE 2
Wells Included in MAROS Evaluation, by Depth Interval
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

UA Wells	MA Wells	LA Wells
MW-35-060	MW-34-055	MW-28-090
MW-36-020	MW-36-050	MW-31-135
MW-36-040	MW-36-070	MW-34-080
MW-38S	MW-37S	MW-35-135
MW-39-040	MW-39-050	MW-36-090
MW-40S	MW-39-060	MW-36-100
MW-32-020	MW-39-070	MW-37D

TABLE 2
 Wells Included in MAROS Evaluation, by Depth Interval
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

UA Wells	MA Wells	LA Wells
MW-32-035	MW-30-050	MW-38D
MW-33-040	MW-33-090	MW-39-080
MW-09	MW-20-100	MW-39-100
MW-10	Park Moabi	MW-40D
MW-11		MW-20-130
MW-12		MW-24B
MW-13		
MW-14		
MW-15		
MW-16		
MW-17		
MW-18		
MW-19		
MW-20-070		
MW-21		
MW-22		
MW-24A		
MW-25		
MW-26		
MW-27-020		
MW-28-025		
MW-29		
MW-30-030		
MW-31-060		

Data were consolidated into quarterly events, selecting the maximum Cr(VI) concentration detected during each period at each well. As recommended by MAROS authors, non-detects (NDs) were set to the lowest detection limit (0.0002 milligrams per liter [mg/L]). When the actual detection limit was used, false increasing and decreasing trends were interpreted by the program, as ND values varied depending on the detection limit.

Description of MAROS Analyses Performed

Sampling Frequency Optimization

Sampling frequency analysis determines the sampling interval for each sampling location using the Modified Cost Effective Sampling (CES) method. CES is a methodology developed to estimate the lowest-frequency sampling schedule for a given monitoring well, while still providing stakeholders the needed information for regulatory and remedial decision-making. The CES method evaluates the frequency of well sampling based on statistics describing the trend, variability, and magnitude of contaminant concentrations. Contaminant rate of change at a well is evaluated relative to the cleanup goal or maximum contaminant level (MCL). The California MCL for total chromium (0.05 mg/L) was used in this evaluation. The central premise of the CES method is that sampling frequency should be based on the rate of change of constituents at the well rather than well location within the plume. The sampling frequency method MAROS employs is based on the CES method, with some modifications to integrate with the overall MAROS approach.

MAROS Results for Upper Depth Interval (UA) Wells

Table 4 lists all of the UA monitoring wells included in the analysis, the current sampling frequency for each well, and the MAROS-recommended sampling frequency. MAROS recommends biennial sampling for the majority of the UA wells.

TABLE 4
UA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-35-060	Quarterly	Annual
MW-36-020	Quarterly	Biennial
MW-36-040	Quarterly	Biennial
MW-38S	Semiannual	Annual
MW-39-040	Quarterly	Biennial
MW-40S	Quarterly	Biennial
MW-32-020	Quarterly	Biennial
MW-32-035	Quarterly	Biennial
MW-33-040	Quarterly	Biennial
MW-09	Semiannual	Annual
MW-10	Semiannual	Quarterly
MW-11	Semiannual	Annual
MW-12	Quarterly	Annual

TABLE 4
 UA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-13	Quarterly	Biennial
MW-14	Quarterly	Annual
MW-15	Semiannual	Biennial
MW-16	Semiannual	Biennial
MW-17	Semiannual	Biennial
MW-18	Semiannual	Annual
MW-19	Quarterly	Quarterly
MW-20-070	Quarterly	Annual
MW-21	Quarterly	Biennial
MW-22	Quarterly	Biennial
MW-24A	Semiannual	Quarterly
MW-25	Quarterly	Annual
MW-26	Quarterly	Annual
MW-27-020	Quarterly	Biennial
MW-28-025	Quarterly	Biennial
MW-29	Quarterly	Biennial
MW-30-030	Quarterly	Biennial
MW-31-060	Quarterly	Annual

MAROS Results for Middle Depth Interval (MA) Wells

Table 6 lists all of the MA monitoring wells included in the analysis, the current sampling frequency for each well, and the MAROS-recommended sampling frequency. MAROS recommends annual or biennial sampling for the majority of the MA wells.

TABLE 6
 MA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-34-055	Quarterly	Biennial
MW-36-050	Quarterly	Biennial

TABLE 6
 MA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-36-070	Monthly	Biennial
MW-37S	Quarterly	Biennial
MW-39-050	Quarterly	Annual
MW-39-060	Quarterly	Annual
MW-39-070	Monthly	Annual
MW-30-050	Quarterly	Annual
MW-33-090	Quarterly	Biennial
MW-20-100	Quarterly	Quarterly
Park Moabi	Quarterly	Biennial

MAROS Results for Lower Depth Interval (LA) Wells

Table 8 lists all of the LA monitoring wells included in the analysis, the current sampling frequency for each well, and the MAROS-recommended sampling frequency. MAROS recommends annual sampling for the majority of the LA wells.

TABLE 8
 LA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-28-090	Monthly	Biennial
MW-31-135	Quarterly	Annual
MW-34-080	Monthly	Biennial
MW-35-135	Quarterly	Annual
MW-36-090	Monthly	Annual
MW-36-100	Monthly	Annual
MW-37D	Quarterly	Quarterly
MW-38D	Semiannual	Annual
MW-39-080	Monthly	Annual
MW-39-100	Monthly	Annual
MW-40D	Quarterly	Annual

TABLE 8
LA MAROS-recommended Sampling Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Current Sampling Frequency	MAROS Sampling Frequency
MW-20-130	Quarterly	Quarterly
MW-24B	Semiannual	Quarterly

Long-term Monitoring Recommendations

The MAROS software recommended a reduced sampling frequency for most of the routinely-sampled monitoring wells at Topock. Annual or biennial sampling was recommended for most of the monitoring wells. Table 9 is a summary of the current sampling frequencies for the Topock GMP and interim measures observation and compliance wells. The table includes a summary of the MAROS-recommended sampling frequency for each monitoring well included in the MAROS evaluation.

TABLE 9
Recommended Topock Groundwater Monitoring Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Well Type	Current Sampling Frequency	MAROS Recommended Frequency
UA			
MW-09	GMP	Semiannual	Annual
MW-10	GMP	Semiannual	Quarterly
MW-11	GMP	Semiannual	Annual
MW-12	GMP	Quarterly	Annual
MW-13	GMP	Quarterly	Biennial
MW-14	GMP	Quarterly	Annual
MW-15	GMP	Semiannual	Biennial
MW-16	GMP	Semiannual	Biennial
MW-17	GMP	Semiannual	Biennial
MW-18	GMP	Semiannual	Annual
MW-19	GMP	Quarterly	Quarterly
MW-20-070	GMP	Quarterly	Annual
MW-21	GMP	Quarterly	Biennial
MW-22	GMP	Quarterly	Biennial

TABLE 9
 Recommended Topock Groundwater Monitoring Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Well Type	Current Sampling Frequency	MAROS Recommended Frequency
MW-24A	GMP	Semiannual	Quarterly
MW-25	GMP	Quarterly	Annual
MW-26	GMP	Quarterly	Annual
MW-27-020	GMP	Quarterly	Biennial
MW-28-025	GMP	Quarterly	Biennial
MW-29	GMP	Quarterly	Biennial
MW-30-030	GMP	Quarterly	Biennial
MW-31-060	GMP	Quarterly	Annual
MW-32-020	GMP	Quarterly	Biennial
MW-32-035	GMP	Quarterly	Biennial
MW-33-040	GMP	Quarterly	Biennial
MW-35-060	GMP	Quarterly	Annual
MW-36-020	GMP	Quarterly	Biennial
MW-36-040	GMP	Quarterly	Biennial
MW-38S	GMP	Semiannual	Annual
MW-39-040	GMP	Quarterly	Biennial
MW-40S	GMP	Quarterly	Biennial
MW-41S	GMP	Quarterly	NA
MW-42-030	GMP	Quarterly	NA
MW-43-025	GMP	Quarterly	NA
MW-47-055	GMP	Quarterly *	NA
OW-01S	IM No. 3 Observation Well	Quarterly	NA
OW-02S	IM No. 3 Observation Well	Quarterly	NA
OW-03S	IM No. 3 Observation Well	Semiannual	NA
OW-05S	IM No. 3 Observation Well	Quarterly	NA
MA			
CW-01M	IM No. 3 Compliance Well	Semiannual	NA
CW-02M	IM No. 3 Compliance Well	Semiannual	NA
CW-03M	IM No. 3 Compliance Well	Semiannual	NA
CW-04M	IM No. 3 Compliance Well	Semiannual	NA

TABLE 9
 Recommended Topock Groundwater Monitoring Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Well Type	Current Sampling Frequency	MAROS Recommended Frequency
MW-20-100	GMP	Quarterly	Quarterly
MW-27-060	GMP	Quarterly	NA
MW-30-050	GMP	Quarterly	Annual
MW-33-090	GMP	Quarterly	Biennial
MW-34-055	GMP	Quarterly	Biennial
MW-36-050	GMP	Quarterly	Biennial
MW-36-070	GMP	Monthly	Biennial
MW-37S	GMP	Quarterly	Biennial
MW-39-050	GMP	Quarterly	Annual
MW-39-060	GMP	Quarterly	Annual
MW-39-070	GMP	Monthly	Annual
MW-41M	GMP	Quarterly	NA
MW-42-055	GMP	Quarterly	NA
MW-42-065	GMP	Quarterly	NA
MW-44-070	GMP	Quarterly *	NA
MW-50-095	GMP	Quarterly *	NA
MW-51	GMP	Quarterly *	NA
OW-01M	IM No. 3 Observation Well	Quarterly	NA
OW-02M	IM No. 3 Observation Well	Quarterly	NA
OW-03M	IM No. 3 Observation Well	Semiannual	NA
OW-05M	IM No. 3 Observation Well	Quarterly	NA
PGE-06	Water Supply Well	Biennially	NA
Park Moabi	Water Supply Well	Quarterly	Biennial
LA			
CW-01D	IM No. 3 Compliance Well	Semiannual	NA
CW-02D	IM No. 3 Compliance Well	Semiannual	NA
CW-03D	IM No. 3 Compliance Well	Semiannual	NA
CW-04D	IM No. 3 Compliance Well	Semiannual	NA
MW-20-130	GMP	Quarterly	Quarterly
MW-24B	GMP	Semiannual	Quarterly

TABLE 9
 Recommended Topock Groundwater Monitoring Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Well Type	Current Sampling Frequency	MAROS Recommended Frequency
MW-27-085	GMP	Monthly	NA
MW-28-090	GMP	Monthly	Biennial
MW-31-135	GMP	Quarterly	Annual
MW-33-150	GMP	Monthly	NA
MW-33-210	GMP	Monthly	NA
MW-34-080	GMP	Monthly	Biennial
MW-34-100	GMP	Biweekly	NA
MW-35-135	GMP	Quarterly	Annual
MW-36-090	GMP	Monthly	Annual
MW-36-100	GMP	Monthly	Annual
MW-37D	GMP	Quarterly	Quarterly
MW-38D	GMP	Semiannual	Annual
MW-39-080	GMP	Monthly	Annual
MW-39-100	GMP	Monthly	Annual
MW-40D	GMP	Quarterly	Annual
MW-41D	GMP	Quarterly	NA
MW-43-075	GMP	Quarterly *	NA
MW-43-090	GMP	Quarterly *	NA
MW-44-115	GMP	Biweekly *	NA
MW-44-125	GMP	Biweekly *	NA
MW-45-095a	GMP	Not Sampled	NA
MW-45-095b	GMP	Not Sampled	NA
MW-46-175	GMP	Biweekly *	NA
MW-46-205	GMP	Monthly *	NA
MW-47-115	GMP	Quarterly *	NA
MW-49-135	GMP	Quarterly *	NA
MW-49-275	GMP	Quarterly *	NA
MW-49-365	GMP	Quarterly *	NA
MW-50-200	GMP	Quarterly *	NA
OW-01D	IM No. 3 Observation Well	Quarterly	NA

TABLE 9
 Recommended Topock Groundwater Monitoring Frequency
Evaluation of Sampling Frequencies of Topock GMP Monitoring Wells

Well	Well Type	Current Sampling Frequency	MAROS Recommended Frequency
OW-02D	IM No. 3 Observation Well	Quarterly	NA
OW-03D	IM No. 3 Observation Well	Semiannual	NA
OW-05D	IM No. 3 Observation Well	Quarterly	NA
TW-4	GMP	Quarterly *	NA
TW-5	GMP	Quarterly *	NA

NA = Not applicable, insufficient number of samples for high degree of confidence in MAROS analysis results

* = Interim sampling frequency