This document has been reviewed by
Pantex Operations Security
and determined to contain **NO** information
deemed as
Classified or Official Use Only.

Pantex Plant
Environmental Restoration Program

RELEASE OF INFORMATION TO THE PUBLIC
DOCUMENTED REVIEW PROCESS
(Ref. WI 02.02.04.06.01)

Document Title Groundwater Monitoring Network Optimization Date: 4-15-08

Document Author Martin Amos x6458 Type of Doc Public Notice

Document Due Date 4-18-08 at 12pm Blanket Release Expires n/a

This review must be completed prior to release of information, in any form, to public domain.

Activity (Review) Mail Drop	Responsible Officer/Reviewer	Release Decision	Reviewer Signature	Date
Division Concurrence	Division Manager or Designee	Release Approved Yes ☑ No ☐	[signature]	4/15/08
Classification Review 12-5 CLS Office	Classification Office	Yes ☑ No ☐	[signature]	4-16-08
UCNI Review 12-5 CLS Office		Yes ☑ No ☐		
ECI Review 12-5 ECC Office	Export Control Compliance Office	Yes ☑ No ☐	[signature]	4-16-08
Critical Tech. Review 12-5 ECC Office		Yes ☑ No ☐		
OPSEC/OUO Review 12-5 OPSEC	OPSEC	Yes ☑ No ☐	[signature]	04-15-08
Legal 12-72 Legal	Legal	Yes ☑ No ☐	[signature]	04/16/08
Work is within Scope of M&O Contract		Yes ☑ No ☐		
Final Approval for Release 12-36 NNSA S&S	NNSA/PXSO	Yes ☑ No ☐	[signature]	4/16/2008

After all signatures are obtained, forward copy via email or plant mail to the Classification Officer and OSTI Transmittal Officer

Comments: For pick-up, please contact Kelly Collins [redacted]. 6968 or Marlon S[redacted] ext. 4058

08-422

RELEASE OF SENSITIVE UNCLASSIFIED INFORMATION DOCUMENTED REVIEW PROCESS

(Ref. WI 02.02.04.06.01)

Index Number PX-2209
Page Number 1 of 1
Issue Number 011
RIDS Number 4978

Document Title Optimization of Monitoring Well Placement For Potential RDX Breakthrough Detection in the Ogallala Aquifer   Date 5-6-08

Document Author Jeff Stovall x6342   Type of Doc Technical Report

Document Audience: TCEQ, EPA, and public
(Who is this document being released to or presented to)

Date Required: 5-9-08   Blanket Release Expires NA

This review must be completed prior to release of information, in any form, to public domain.

Activity (Review) Mail Drop	Responsible Officer/Reviewer	Release Decision	Reviewer Signature	Date
Division Concurrence	Division Manager or Designee	Release Approved Yes ☑ No ☐	AT Biggs for DCH	5/6/08
Classification Review 12-5 CLS Office	Classification Office	Yes ☑ No ☐	Don Derben	5-6-08
UCNI Review 12-5 CLS Office	Classification Office	Yes ☑ No ☐		
ECI Review 12-5 ECC Office	Export Control Compliance Office	Yes ☑ No ☐	Don Derben	5-6-08
Critical Tech. Review 12-5 ECC Office	Export Control Compliance Office	Yes ☑ No ☐		
OPSEC/OUO Review 12-5 OPSEC	OPSEC	Yes ☑ No ☐	George Weathers	05-06-08
Legal 12-72 Legal	Legal	Yes ☑ No ☐	David Cook	05/07/08
Work is within Scope of M&O Contract	Legal	Yes ☑ No ☐		
Final Approval for Release 12-36 NNSA S&S	NNSA/PXSO	Yes ☑ No ☐	J Kelly	5-7-2008
Office of Scientific Technical Information (OSTI).	Applied Technology	Forward copy of PX-2209 and information to be released to OSTI, Bldg 11-2		

After all signatures are obtained, forward copy of the PX-2209 and the document via e-mail (pdf file) to the Classification Office.

Comments: For pickup, please contact Kelly Collins x6968 or Marlon Smith x4058

G-3262

Groundwater Monitoring Network Optimization

Perched Groundwater Unit, Pantex Plant

Prepared for:

B & W Pantex L.L.C.
Pantex Plant
P.O. Box 30020
Amarillo, Texas 79120

February 12, 2008

GSI Environmental Inc.
2211 Norfolk, Suite 1000, Houston, Texas 77098-4054

Table of Contents

Figures

Appendices

ABBREVIATIONS

2ADNT	2-Amino, 4,6-dinitrotoluene
24DNT	2,4-Dinitrotoluene
26DNT	2,6-Dinitrotoluene
4ADNT	4-Amino, 2,6-dinitrotoluene
AEC	Atomic Energy Commission
AOC	Area of Concern
AR	Area Ratio
ARARs	Applicable or Relevant and Appropriate Requirements
BGS	Below Ground Surface
BRA	Baseline Risk Assessment
CES	Cost Effective Sampling
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	Constituent of Concern
COPC	Constituent of Potential Concern
COV	Coefficient of Variation
CR	Concentration Ratio
CSM	Conceptual Site Model
EDD	Electronic Data Deliverable
ESD	Explanation of Significant Difference
FGZ	Fine Grained Zone
GIS	Geographic Information System
HE	High Explosive
HHRA	Human Health Risk Assessment

HMX	High melting explosive (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
HSCB	Hypothetical Statistical Compliance Boundary
ICM	Interim Corrective Measures
LTM	Long-Term Monitoring
LTMO	Long-Term Monitoring Optimization
MAROS	Monitoring and Remediation Optimization Software
MCES	Modified Cost Effective Sampling
MCL	Maximum Contaminant Level
MK	Mann-Kendall Trend
MSC	Medium Specific Concentration
MSL	Mean Sea Level
NAPL	Non-Aqueous Phase Liquid
NPL	National Priorities List
O&M	Operation and Maintenance
OU	Operable Unit
PDWS	Primary Drinking Water Standard
PGPTS	Perched Groundwater Pump and Treat System
PLSF	Preliminary Location Sampling Frequency
POC	Point of Compliance
POE	Point of Exposure
PRG	Preliminary Remediation Goal
PRP	Potentially-Responsible Party
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act

RDX	Research Department Explosive (Hexahydro-1,3,5-trinitro-1,3,5-triazine)
RI	Remedial Investigation
ROD	Record of Decision
RRR	Risk Reduction Rules
RRS	Risk Reduction Standards
SF	Slope Factor
SWMU	Solid Waste Management Unit
TCE	Trichloroethene
TCEQ	Texas Commission on Environmental Quality
TNT	Trinitrotoluene
TTU	Texas Tech University
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WMG	Waste Management Group

GROUNDWATER MONITORING NETWORK OPTIMIZATION
PANTEX PLANT

EXECUTIVE SUMMARY

The following report reviews and provides recommendations for improving the efficacy of the groundwater monitoring network for perched groundwater underlying the Pantex Plant, near Amarillo, Texas in Carson County. The Pantex Plant consists of several historic manufacturing, storage and disposal locations associated with maintaining the United States' nuclear arsenal. As a result of historic waste management practices, perched groundwater underlying the facility is affected by various constituents associated with munitions production and equipment maintenance.

The current groundwater monitoring network has been evaluated using a formal qualitative approach as well as using statistical tools found in the Monitoring and Remediation Optimization System software (MAROS). Recommendations are made for groundwater sampling frequency and location based on current hydrogeologic conditions and articulated long-term monitoring (LTM) goals for the system. The recommendations presented below are based on a technical review, balancing both the statistical results with goals of the monitoring system and anticipated site management decisions. Final decisions on the locations and frequency of groundwater sampling will be made by B&W Pantex, DOE and regulators. The following report evaluates the monitoring system for perched groundwater using analytical and hydrogeologic data from sampling events conducted between January 2000 and May 2007.

Site Groundwater Monitoring Goals and Objectives

Goals for long-term protection of human health and the environment at Pantex have been articulated in the Corrective Measure Study/Feasibility Study (CMS/FS, BWXT, 2007b) as Remedial Action Objectives (RAO). Remedial actions for perched groundwater have been proposed that fulfill the following objectives:

- Reduce exposure risk posed by impacted perched groundwater through contact prevention;
- Achieve cleanup goals for constituents of concern (COCs) at points of exposure (POE) in the perched groundwater (at property boundaries and/or areas sensitive to vertical migration);
- Prevent growth of perched groundwater COC plumes;
- Prevent constituents of potential concern (COPCs) from exceeding regulatory screening levels (MCLs/MSCs) in the Ogallala Aquifer.

Long-term groundwater monitoring of the perched unit is an essential component of confirming that the RAOs are met. The perched groundwater monitoring network at Pantex must address a number of monitoring objectives.

- A primary goal for the network is to define and delineate groundwater exceeding applicable regulatory standards. Monitoring data from the site network are used to support institutional controls by identifying and delineating areas of affected groundwater.

- A second goal for the network is to monitor changes in the plumes over time including changes in concentrations at source areas and tails.
- A third goal of the monitoring network is to evaluate the efficacy of the chosen remedy or remedies to control and reduce concentrations of constituents. One aspect of this objective is to document natural attenuation of chemical constituents.
- The network will also provide sufficient data to optimize remediation systems.
- The final goal of the network is to provide early warning for potential impacts to the Ogallala Aquifer.

Project Goals and Objectives

The goal of the long-term monitoring optimization (LTMO) process is to review the current groundwater monitoring program and provide recommendations for improving the efficiency and accuracy of the network in supporting site monitoring objectives discussed above. Specifically, the LTMO process provides information on the site characterization, stability of the plume, sufficiency and redundancy of monitoring locations and the appropriate frequency of network sampling. Tasks involved in the LTMO process include:

- Evaluate well locations and screened intervals within the context of the hydrogeologic regime to determine if the site is well characterized;
- Evaluate overall plume stability through trend and moment analysis;
- Evaluate individual well concentration trends over time for target chemicals of potential concern (COPCs);
- Develop sampling location recommendations based on an analysis of spatial uncertainty;
- Develop sampling frequency recommendations based on qualitative and quantitative statistical analysis results;
- Evaluate individual well analytical data for statistical sufficiency and identify locations that have achieved clean-up goals.

The end product of the LTMO process at the Pantex Plant is a recommendation for specific sampling locations and frequencies that best address site monitoring goals and objectives listed above.

Results

Perched groundwater was divided into three sectors for analysis. Investigation wells were grouped into networks based on the direction of groundwater flow, source areas and major constituents associated with each sector. The Southeast Sector monitoring network consists of wells in perched groundwater extending south from Playa 1 and east and south of Zones 11 and 12. The Southwest Sector monitoring network includes and extends west and south of Zone 11. Investigation wells south of Zone 12 were included in both the Southwest and Southeast Sector spatial analyses to account for possible variability in groundwater flow. The North Sector includes groundwater north of Zones 11 and 12 in the vicinity of Playa 1. Statistical and qualitative evaluations of Pantex Plant perched groundwater analytical data have been conducted with results summarized below:

Southeast Sector

- Priority constituents in the Southeast Sector include RDX and 4-amino,2,6-dinitrotoluene (4ADNT). Groundwater affected by other COPCs is within the extent of groundwater affected by RDX. Hexavalent chromium (Cr(VI)) affects perched groundwater in the area between the Southeast and Southwest Sectors and was considered in the analysis of both monitoring networks.
- Several downgradient monitoring locations indicate increasing concentration trends for RDX and 4ADNT.
- Estimates of total dissolved mass over time indicate that the mass of RDX is stable within the plume. Estimates of dissolved mass of 4ADNT over time show more variability and may exhibit a weakly increasing trend consistent with degradation of the TNT parent compound.
- Estimates for the center of mass for the RDX and 4ADNT plumes indicate some expansion downgradient consistent with decreasing trends in the source and groundwater extraction areas and increasing concentration trends downgradient.
- Data provided by monitoring locations along the eastern boundary of the DOE property in conjunction with data from the Southeast Sector extraction wells may provide redundant information.
- Areas of concentration uncertainty exist within the plume south of Zone 12 near PTX06-1036 and the eastern edge of the plume in the area where the perched unit pinches out.
- Because of increasing concentration trends, and possible expansion of the plume, frequent (semiannual) monitoring of Southeast Sector wells is indicated.

Southwest Sector

- Priority constituents in the Southwest Sector include trichloroethene (TCE) and perchlorate. Groundwater affected by high explosives (HE) exists under the industrial area of Zone 11, but is not as widespread as that of the Southeast Sector.
- Over 50% of wells in the Southwest Sector monitor groundwater with low to no detections of COPCs, resulting in non-detect or no trend results for individual wells in the Sector. Increasing concentration trends for perchlorate are found at one location south of Zone 11 (PTX06-1012), while increasing TCE trends are found at two locations in the same area.
- Estimates for plume-wide total dissolved mass of perchlorate and TCE show no trends; however, estimates of the center or mass for the TCE plume over time are moving downgradient. Increasing distance between the source and center of mass for TCE is consistent with increasing trends in the downgradient region of this plume.
- Redundant locations were identified on the western edge of the plume in areas with very low concentrations of site COPCs.
- One area of concentration uncertainty was found in the region of PTX06-1012.
- Rates of concentration change are low over much of the Sector, consistent with a recommendation for reduced sampling frequency. The area between wells 1114-MW4 and PTX06-1012 was identified as an area of more rapid concentration change.

North Sector

- The only COC identified for the North Sector is RDX.
- The majority of monitoring locations in the North Sector are not affected by constituents above regulatory screening levels.
- Statistical trend evaluation results indicate many non-detect locations or wells showing intermittent detections (no trend). Concentration trends for RDX in the North Sector show decreasing trends just south of Playa 1. An increasing RDX trend was found at PTX06-1050 indicating possible spread of the plume to the northwest of the main perched groundwater unit.
- Due to the limited number of monitoring locations, moment analysis was not conducted for the North Sector.
- No wells in the North Sector were identified as redundant.
- One area of higher concentration uncertainty was found west of PTX06-1050.
- Rates of concentration change in the North Sector support a dramatic reduction in sampling frequency for many locations.

Recommendations

The following general recommendations are made based on the findings summarized above and those described in Section 3 below. General recommendations for monitoring are based on a combination of statistical results of analyses for priority COCs and a consideration of qualitative issues such as hydrogeology, potential receptors and monitoring goals. Detailed recommendations are presented in Section 4 and summarized on Table 16 and Figure 8.

The recommended network increases data collection effort in some areas to provide a dataset that fulfills statistical requirements for evaluating the effect of the remedies discussed in the CMS/FS (BWXT, 2007b). The recommended network reduces monitoring effort and cost in some areas, but recommends the addition of new wells in areas where further characterization would support site monitoring goals.

Southeast Sector

- The final recommended network for the Southeast Sector includes 29 investigation well locations, with approximately 51 groundwater samples collected annually. Data from 48 active extraction wells should be evaluated along with data from the investigation wells to characterize the Sector.
- Semiannual monitoring is recommended for 20 of 31 wells in the Southeast Sector. Seven wells in the source area or in areas of stable concentration trends are recommended for annual sampling. Three wells are intermittently or permanently dry and should be monitored for saturation, annually.
- Southeast Sector well PTX06-1014 is recommended for elimination from the routine monitoring program.
- Two new locations are recommended for the Southeast Sector. One new location is recommended for the area between PTX06-1036 and PTX06-1052. The other new location is recommended for the area east of PTX06-1039. New wells are recommended for semiannual sampling until a statistically significant dataset has been collected.

Southwest Sector

- The final recommended network for the Southwest Sector includes 22 monitoring locations, with an average of 27.5 groundwater samples analyzed annually.
- Six existing locations were found to provide redundant information and are recommended for elimination from routine monitoring in the Southwest Sector: PTX06-1006, PTX06-1087, PTX07-1P02, PTX07-1P03, PTX07-1Q02, and PTX10-1008 (Wells identified as redundant may be sampled to reduce uncertainty in some locations).
- Overall, four new groundwater monitoring locations are recommended for the Southwest Sector. Two new wells are recommended for the southern area of the perched unit to delineate constituents in the Southwest Sector. Two new locations south of PTX08-1005 are recommended to decrease spatial uncertainty in the area of the TCE/perchlorate plume near Zone 11.
- Semiannual sampling is recommended for four current wells (1114-MW4, PTX06-1012, PTX08-1005, and PTX08-1006) and for the four proposed new locations. Annual sampling is recommended at 9 locations, and biennial sampling is recommended for five perimeter wells.

North Sector

- The final recommendation for the North Sector monitoring network is to include a total of 21 investigation wells, with an average of 18 samples collected annually.
- No wells are recommended for elimination from the North Sector networks. However, many locations are recommended for dramatically reduced sampling frequency. If low to non-detect conditions persist in isolated perched groundwater in the future, some of these wells may be eliminated.
- One new monitoring location is recommended to delineate the RDX plume in the North Sector. The new monitoring location is recommended for an area downgradient of PTX06-1050 at the edge of the saturated unit.

Additional Recommendations

- Groundwater monitoring data as well as well construction and location information should continue to be managed in a site-wide relational database.
- Capture zone analysis for the perched groundwater extraction system in the Southeast Sector is recommended and should continue to be presented annually, as required by Compliance Plan No. 50284.
- Reevaluate the network in 5 years after any additional remedies have been implemented and a statistically significant dataset has been collected.

1.0 INTRODUCTION

The Pantex Plant in Carson County, Texas is an active facility owned by the United States Department of Energy/National Nuclear Security Administration (DOE/NNSA). The primary mission of the plant is to assemble, disassemble and evaluate nuclear weapons from the US stockpile, to develop, fabricate and test explosives and explosive components and provide secure storage for material from the above activities. The Pantex Plant is permitted as a hazardous waste facility under the Resource Conservation and Recovery Act (RCRA) and is a National Priorities Listed (NPL) site administered under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, Superfund).

The site is located approximately 17 miles northeast of Amarillo, Texas in Carson County in US Environmental Protection Agency (EPA) Region VI. The plant covers over 10,000 acres with additional property consisting of a 1,000 acre tract at Pantex Lake and over 5,000 acres owned by Texas Tech University (TTU) as a buffer around the site. Industrial operations occur on approximately 2,000 acres. Constituents associated with site manufacturing and testing activities currently affect soil and groundwater at the facility. Investigation and remediation activities have been on-going since the 1980s.

Groundwater monitoring plays a critical role in long-term environmental restoration of the Pantex Plant Site. The purpose of the following evaluation is to review the current groundwater monitoring network and provide recommendations for improving the efficiency and accuracy of the network for supporting site management decisions.

At the Pantex Plant, groundwater monitoring goals define why data are collected and how data from the site will be used. The groundwater monitoring network at Pantex must address the following monitoring objectives.

- *Define and delineate groundwater exceeding applicable regulatory standards.* Monitoring data from the site network are used to support institutional controls by identifying and delineating areas of affected groundwater.
- *Monitor changes in the plumes over time including changes in concentrations at source areas and tails.*
- *Evaluate the efficacy of the chosen remedy or remedies to control and reduce concentrations of constituents.* One aspect of this objective is to document natural attenuation of chemical constituents.
- *Provide sufficient data to optimize remedial systems.*
- *Provide early warning for potential impacts to the Ogallala formation or off-site receptors.*
- *Comply with regulatory requirements.*

In order to recommend an optimized network that addresses the stated monitoring objectives, spatial and analytical data from the site were analyzed using a series of quantitative and qualitative tools.
Tasks performed during Long-Term Monitoring Optimization (LTMO) process include:

- Evaluate well locations and screened intervals within the context of the hydrogeologic regime to determine if the site is well characterized;
- Evaluate overall plume stability through trend and moment analysis;
- Evaluate individual well concentration trends over time for target constituents of concern (COPCs);
- Develop sampling location recommendations based on an analysis of spatial uncertainty;
- Develop sampling frequency recommendations based on both qualitative and quantitative statistical analysis results;
- Evaluate individual well analytical data for statistical sufficiency and identify locations that have achieved clean-up goals.

A discussion of site background and regulatory context for the Pantex Plant Site is provided in Section 1 below. Section 2 details the analytical and statistical approach taken during the LTMO evaluation. A detailed discussion of results is provided in Section 3. Summary conclusions and recommendations are presented in Section 4.0.

1.1 Site Background and Regulatory History

The Pantex Plant site is located in the Texas Panhandle, in a historically agricultural area. Plant operations began in 1942 under the Army Ordnance Corps, manufacturing conventional munitions and high explosives (HE) such as trinitrotoluene (TNT). The Plant was briefly deactivated at the end of the World War II, and the property sold to TTU. In 1951, the site was reclaimed for use by the Atomic Energy Commission (AEC) to produce both nuclear weapons and HE compounds. Radioactive materials have not been manufactured at the facility but components containing radioactive materials are managed at the site. Compounds such as TNT, High Melting Explosive (HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) and Research Department Explosive (RDX, Hexahydro-1,3,5-trinitro-1,3,5-triazine) have been manufactured and used at the site.

Supervision of the site was eventually transferred to the DOE and NNSA. The Pantex Plant is currently managed as a government-owned, contractor-operated facility, overseen by DOE/NNSA and operated by Babcock & Wilcox Technical Services Pantex, LLC (B&W Pantex, formerly BWXT Pantex). As the prime contractor, B&W Pantex also directs environmental activities including investigation and remediation of areas impacted by past waste management practices.

In the late 1980's, environmental investigation and restoration activities began at DOE facilities across the country. Under the authority of the 1984 RCRA Hazardous and Solid Waste Amendments, the EPA conducted a *RCRA Facility Assessment* of the Pantex Plant in 1988. EPA identified Solid Waste Management Units (SWMUs) and Areas of Concern (AOC) containing environmental media possibly subject to interim corrective measures (ICMs). The RCRA Facility Investigation (RFI) identified operational areas at the site and groupings of corrective action units in common watersheds termed waste management groups (WMGs). Conceptual Site Models

(CSMs) were developed to describe the location and movement of constituents for each WMG.

In 1991 EPA, in cooperation with the Texas Commission on Environmental Quality (TCEQ) (formerly Texas Natural Resource Conservation Commission [TNRCC]), issued a Hazardous Waste permit to the Pantex Plant. In the same year, the Pantex Plant was proposed for the NPL for chemical constituents in both soil and groundwater. The Pantex Plant was formally listed in 1994, and a Memorandum of Agreement (MOA) between TCEQ and EPA established TCEQ as lead agency for oversight of remediation of chemical releases.

Since 1994, on-going interim investigation, remediation and corrective action measures have been conducted, and an integrated approach to address both CERCLA and RCRA requirements has been developed. A Record of Decision (ROD) for the Pantex Plant has not been issued. ICMs to date have been implemented as non-time critical removal actions under CERCLA for perched groundwater. Specific remedies in place include extensive groundwater extraction wells in the perched unit (perched groundwater pump and treat system [PGPTS]).

Environmental regulatory oversight of the Pantex Plant is, therefore, exercised under RCRA and CERCLA as well as other applicable Texas state regulations. All non-radiological environmental restoration activities at the Pantex Plant are conducted under the State of Texas Risk Reduction Rules (RRR) (30 TAC §335 Subchapter S, 1993). TCEQ defines three Risk Reduction Standards (RRS) for closure of affected sites. In 2005, EPA and TCEQ completed technical reviews of investigations for SWMUs at Pantex, and identified the appropriate RRS to be applied to the majority of Plant SWMUs. Most areas of perched groundwater evaluated in the following report will be covered under RRS 3. RRS 3 allows for COPCs to remain in place as long as the risk posed by those COPCs is not greater than the target risk values provided in the regulations. Cleanup goals under RRS 3 also allow the use of long-term site controls such as institutional and engineering controls to attain regulatory compliance. The long-term groundwater monitoring network for the perched unit is, therefore, an important component of compliance under RRS 3.

Under RRS 3, cleanup values known as Media Specific Concentrations (MSCs) can be derived using site-specific information detailed in the various BRA and Baseline Human Health Risk Assessment (BHHRA) Reports (BWXT, 2006). MSCs for the Pantex Plant are listed in the CMS/FS (BWXT, 2007) and have been used as the screening levels to evaluate the groundwater monitoring network.

RCRA Facility Investigations (RFIs) have been conducted for corrective action units at Pantex and have defined sources and the extent of impacts for several corrective action units. The Baseline Risk Assessments (BRA) for areas anticipated to be managed under RRS 3 have also been completed. A Corrective Measures Study/Feasibility Study (CMS/FS) (BWXT, 2007b), including evaluation of remedial options for the Site, was issued in September, 2007. Remedial actions for perched groundwater are anticipated to include continuation of the groundwater extraction system (PGPTS) and other ICMs already in place, as well as addition of new vertical extraction wells in the east/southeast and in the vicinity of Playa 1. Targeted *in situ* redox manipulation and enhanced bioremediation are proposed for the southeast fringe of perched groundwater. Natural attenuation processes will be a component of any remedial action chosen. Long-term groundwater monitoring will be required to confirm progress toward remedial goals.

1.2 Geology and Hydrogeology

The Pantex Plant lies on the High Plains portion of the Great Plains Physiographic Province in the Texas Panhandle. The area, known as the Llano Estacado is a broad, flat, plateau with topographic elevation across the site ranging between 3,501 feet above mean sea level (ft amsl) to 3,595 ft amsl. The average topographic slope across the Plant area is approximately 0.006 feet, and Plant surface water tends to drain to the on-site playas.

The uppermost hydrostratigraphic unit (HSU) at the Pantex Plant is the Blackwater Draw (BWD). The BWD extends up to 90 ft below ground surface (bgs) at the site, and is largely unsaturated. The unit consists of silts and sands and an approximately 20-foot thick lower unit composed of silty sand and caliche. The playas are depressions in the BWD.

The Ogallala Formation underlies the Blackwater Draw and is composed of coarse-grained fluvial sequences including channel sands and gravels overlain by finer overbank deposits. The Ogallala Formation in Texas is the southernmost extension of a major water-bearing unit that extends north to Nebraska and is exploited for municipal water supplies as well as crop irrigation and industrial water supplies. The Ogallala Aquifer is the principal municipal water supply for the city of Amarillo, which operates a municipal well field north of the Pantex Plant. The Ogallala Aquifer provides potable and industrial water for the Pantex Plant as well as agricultural water for the TTU property to the south.

A Caliche Caprock layer generally defines the top of the Ogallala Formation, but is not continuous across the entire Pantex Plant. The Caprock consists of a hard, dense and finely crystalline caliche. In the Pantex area, the Ogallala Formation consists of upper and lower permeable units separated by a Fine Grained Zone (FGZ). The FGZ consists of low-permeability silts and clays and varies in thickness from over 150 ft to less than 10 ft. The FGZ slopes down toward the southeast corner of the Pantex Plant. The upper unit of the Ogallala formation contains discontinuous areas of perched groundwater underlain by the FGZ. The Ogallala Aquifer resides in the lower permeable unit beneath the FGZ.

Underlying the Ogallala Formation are the lower permeability Dockum Group and Permian Quartermaster Formation, where the Dockum Group is not present.

1.2.1 Playas

The Texas Panhandle region is characterized by a number of topographic depressions or playas (playa lakes) that drain larger land areas but do not connect with other surface drainage outlets. Historically, playa lakes provide limited recharge of perched groundwater in the area of the Pantex Plant, in response to irregular, moderate precipitation events. The playas hold water temporarily, and because of the soil, hydrology and vegetation, they are frequently classified as (non-jurisdictional) wetlands. Three playas are present in the vicinity of industrial operations at the Pantex Plant and received the majority of surface runoff from the property, as well as, permitted discharges of treated effluent from the waste water treatment facility. Along with drainage ditches, the playas have served as groundwater recharge areas for perched groundwater underlying the Plant. With elimination of industrial discharges, discontinuation of routine discharges from the wastewater treatment facility, and the implementation of institutional controls, efforts are on-going to reduce recharge to the perched groundwater through these routes.

Playa 1 is north of Zone 12, and served as a receiving pond for treated and untreated waste water originating from the Zone 12 industrial area for many years. Most industrial discharges to plant ditches were discontinued in the 1980s and the remainder, including steam condensate discharges, were eliminated by 1999. Currently, occasional permitted discharges enter Playa 1 along with storm water runoff. Playa 2 is west/northwest of Zone 11, and Playa 3 is part of the Burning Ground WMG. Playas 2 and 3 receive only surface water runoff. A large playa basin associated with the Pantex Lake property lies 2.5 miles north of the main facility and Playa 4 is located on TTU property to the south.

1.2.2 Perched Groundwater

Perched groundwater is encountered at various locations across the Texas Panhandle in the upper permeable unit of the Ogallala Formation. At the Pantex Plant, groundwater from recharge areas, in particular playa lakes, tends to mound on top of the low permeability FGZ. The FGZ separates perched groundwater from the lower Ogallala aquifer.

Perched groundwater is found in three main areas under the Pantex Plant. The largest area of perched groundwater lies beneath Playa 1 and extends beneath Zones 11 and 12, pinching out on the TTU property to the south and off-site to the east (see Figure 1). Groundwater in this unit is associated with recharge from Playas 1, 2 and 4 and drainage ditches associated with Zones 11 and 12. Isolated areas of perched groundwater also occur under the Burning Ground (near Playa 3) and in the northeast corner of the Pantex Plant (near Pratt Playa). While groundwater in the perched units meets the technical definition of a potential drinking water source, no water supply wells are drilled into the unit for either drinking water or industrial water supply on-site and all public drinking water supply wells in the vicinity are drilled into the Ogallala Aquifer, with the exception of one perched groundwater well on offsite property north of the northeast corner of Pantex near Pratt Playa. The perched groundwater does not discharge to surface water bodies and hydraulic connection with the Ogallala is limited by the FGZ.

The extent and chemistry of the largest perched groundwater unit has been influenced by historic waste and water management practices associated with industrial activity at the plant. From the early 1950s to the 1980's portions of the main perched groundwater were impacted by constituents of potential concern (COPCs) and artificially high recharge originating from plant industrial processes. Because of mounding in the vicinity of Playa 1 and the topography of the FGZ, groundwater flow in the main perched unit tends to be radial, with the surface sloping to the southeast, south and east of Zone 12, and sloping to the southwest, west of Zone 11. Groundwater north of Playa 1 tends to flow to the north (see Figure 1 for potentiometric surface data). Radial flow within the main perched unit is the reason why the monitoring network was divided into sectors for the LTMO analysis (see Sectors identified on Figure 2 and described under Section 2.1.1).

Saturated thickness of perched groundwater varies across the unit with a high of approximately 70 feet beneath Playa 1 to 0 feet at the extreme edges of the unit. Depth to groundwater varies from about 215 feet near Playa 1 to approximately 280 feet at the south of the main perched unit under TTU property. Beneath the perched groundwater, the FGZ consists of low permeability silts and clays ranging from a few feet in thickness to more than 100 feet below Playa 1. The FGZ tends to isolate perched water from deeper strata; however, the FGZ becomes more course and permeable in areas to the south and east of the main Plant.

1.2.3 Ogallala Formation

The Ogallala Aquifer is encountered at depths of 400 to 500 feet bgs beneath the Pantex Plant with the water table sloping from southwest to northeast locally under the influence of the municipal well field. The saturated thickness of the Ogallala varies from less than 30 feet to over 400 feet. Removal of water from the Ogallala aquifer for municipal, industrial and large-scale agricultural uses has reduced the saturated thickness in many areas of the aquifer.

Based on monitoring data, the Ogallala Aquifer has not been impacted by releases from the Pantex Plant above conservative screening levels (see Figure 2 for current Ogallala monitoring well locations). The Ogallala Aquifer was considered as part of a potential exposure scenario during the Baseline Human Health Risk Assessment (Baseline HHRA). While the Ogallala does not currently pose an exposure risk to receptors, modeling results indicate that the Ogallala may be impacted by COPCs present in the perched groundwater at some time in the future. For this reason, groundwater in the Ogallala will be monitored for possible impacts in the future. The monitoring network for the Ogallala was not evaluated for this report, but is being evaluated elsewhere, using appropriate tools.

2.0 ANALYTICAL APPROACH

Evaluation of the groundwater monitoring network for the Pantex Plant consisted of both quantitative and qualitative methods. A quantitative statistical evaluation of the site was conducted using tools in the MAROS software. The qualitative evaluation reviewed hydrogeologic conditions, well construction and placement. Both quantitative statistical and qualitative evaluations were combined using a 'lines of evidence' approach to recommend a final groundwater monitoring strategy to support site monitoring objectives.

2.1 MAROS Method

The MAROS 2.2 software was used to evaluate the LTM network at the Pantex Plant. MAROS is a collection of tools in one software package that is used in an explanatory, non-linear but linked fashion to statistically evaluate groundwater monitoring programs. The tool includes models, statistics, heuristic rules, and empirical relationships to assist in optimizing a groundwater monitoring network system. Results generated from the software tool can be used to develop lines of evidence, which, in combination with professional judgment, can be used to inform regulatory decisions for safe and economical long-term monitoring of groundwater plumes. A summary description of each tool used in the analysis is provided in Appendix A of this report. For a detailed description of the structure of the software and further utilities, refer to the MAROS 2.2 User Manual (AFCEE, 2003) or Aziz, et al. (2003).

In MAROS 2.2, two levels of analysis are used for optimizing long-term monitoring plans: 1) an overview statistical evaluation with interpretive trend analysis based on temporal trend analysis resulting in plume stability information; and 2) a more detailed statistical optimization based on spatial and temporal redundancy reduction methods (see Appendix A or the MAROS Users Manual (AFCEE, 2003)).

2.1.1 Well Groups

Perched groundwater underlying the Pantex Plant is encountered in areas associated with natural and anthropogenic recharge from playa lakes and drainage ditches. Perched groundwater is not continuous across the site, and groundwater flow within the largest perched unit is radial from a mound underlying Playa 1 (see Figure 1). Because of the spatial heterogeneity in aquifer characteristics, perched unit investigation wells (monitoring wells) at the Pantex Plant were separated into analysis groups by sector in order to perform the MAROS analysis. Investigation wells were grouped according to predominant groundwater flow direction, sources and major constituents of concern (COCs).

Because MAROS is designed to evaluate two-dimensional monitoring networks, well depths and screened intervals were reviewed to determine if the well groups should be chosen based on depth. Perched groundwater in the upper Ogallala formation has a maximum saturated thickness of approximately 70 ft., with an average saturated thickness close to 20 ft (B&W Pantex well database). Median screen lengths for wells are approximately 25 feet. The unit is fairly homogeneous (with little to no channelization or fractures). Perched groundwater wells were considered to be screened at approximately the same depth, so well groups were not separated based on vertical heterogeneity in the aquifer. Well groups used in this report are defined for the purpose of the LTMO analysis and do not correspond with other classifications for site modeling.

Spatial sectors defined for the analysis are summarized in the table below and illustrated on Figure 2. The 75 investigation wells used in the core analysis are listed in Table 1, by sector. Data from extraction wells in the Southeast Sector were included to provide spatial information and concentration trends in this area. Data from each sector were evaluated separately for priority COCs, plume stability, spatial sufficiency, well redundancy, monitoring frequency and, where appropriate, data sufficiency. Some individual wells were included in more than one zone, with the final monitoring recommendation for the well based on the most conservative results for that well.

MAROS Analysis Group Name	Comment
Southeast Sector	The Southeast Sector monitoring network consists of wells in perched groundwater extending south from Playa 1 and east and south of Zones 11 and 12. Both onsite and offsite wells are included in one analysis group. The Southeast Zone network includes 31 groundwater monitoring wells. Data from 48 groundwater extraction wells were included in the analysis in order to provide better spatial coverage of the area. The Southeast Sector is a priority monitoring area due to the magnitude of COC concentrations and possible thinning of the FGZ in this area.
Southwest Sector	The Southwest Sector monitoring network includes and extends west and south of Zone 11. (No groundwater quality data were available for Zone 9 wells (FPOP)). Investigation wells south of Zone 12 were included in both the Southwest and Southeast Sector spatial analyses to account for possible variability in groundwater flow.
North Sector	Groundwater north of Zones 11 and 12 and Playa 1 is discontinuous and less impacted than the Southeast and Southwest Sectors. Wells in this Sector were analyzed for individual trends, but large scale spatial analysis was not appropriate for this Sector. The North Sector includes wells at Pantex Lake.

2.1.2 COC Choice

The varying groundwater flow directions, complex sources and commingled plumes cause widespread spatial heterogeneity in constituent concentrations at the Pantex Plant. In order to better evaluate the importance of each well in the network, each monitoring location was evaluated individually for priority constituents of concern (COCs). To identify priority COCs for individual sampling locations, the maximum concentration found for a constituent at each well between 2000 and 2007 was divided by the corresponding MSC or relevant regulatory screening level. The COC concentrations that exceeded the screening level by the highest ratio were identified as priority COCs for the individual well. The COC with the highest concentration relative to the screening level ratio for each investigation well is identified in Table 1 along with the ratio. Other Priority COCs (those with screening level ratios over 1) determined for each monitoring location are also listed in Table 1.

The COC most often identified as a priority at individual wells was RDX. For locations where the Risk Ratio is below 1, no constituents are detected above MSCs and no plume exists in that location. The dataset was not examined for statistical outliers, and, at some locations, a single detection of a compound caused the compound to be designated the priority for that well. Boron is frequently detected at Pantex area wells, but boron concentrations do not routinely exceed the RRS 2 screening level of 3.3 mg/L (see Table 1).

MAROS includes a short module that provides recommendations on prioritizing COCs on a plume-wide basis. Prioritization is based on *toxicity*, *prevalence*, and *mobility* of the compound. The toxicity ranking is calculated by examining a representative concentration (i.e. mean, median, etc.) for each compound for the entire plume. The representative concentration is then compared to the screening level (MSC) for that compound. COCs are ranked according to the extent the representative concentration exceeds the screening level. Ranking according to prevalence is performed by counting the number of wells in the network where concentrations are above screening levels and by identifying the number of wells where the compound is detected. COCs with the greatest detection frequency and the largest percentage of wells above screening levels are prioritized. Constituents found over screening levels are ranked for mobility based on Kd (sorption partition coefficient). The MAROS ranking was performed for each Sector network at Pantex.

2.1.3 Plume Stability

Within MAROS, historical analytical data are analyzed to develop a conclusion about plume stability. If a plume is found to be stable, in many cases, the number of locations and monitoring frequency can be reduced without loss of information. Plume stability results are assessed from time-series concentration data with the application of two types of statistical tools: individual well concentration trend analyses and plume-wide moment analysis.

Individual well concentrations are evaluated using both Mann-Kendall and Linear Regression trend tools. The Mann-Kendall nonparametric evaluation is considered one of the best methods to evaluate concentration trends as it does not assume the data fit a particular distribution (Gilbert, 1987). Individual well concentration trends were calculated for priority COPCs for the time period 2000 to 2007. Individual well Mann-Kendall trends were also used in the sampling frequency analysis, where trends determined for the 2004 to 2007 interval were compared with trends calculated using the entire dataset for each well. During the final 'lines of evidence' evaluation, individual well concentration trends are considered along with summary statistics such as percent detection and historic maximum concentration to recommend sampling frequencies for wells in the network.

Moment analysis algorithms in MAROS are simple approximations of complex calculations and are meant to estimate the total dissolved mass (zeroth moment), center of mass (first moment) and spread of mass (second moment) in the plume and the trend for each of these estimates over time. Trends in the total dissolved mass can indicate effective removal processes (decreasing trends) or plume stability. The zeroth moment is not intended to be an accurate calculation of total mass in the plumes at the Pantex Plant. The estimate of mass is based on a uniform saturated thickness or rough approximations of saturated thickness and porosity at each monitoring location, and perched groundwater underlying the Pantex Plant varies between roughly 0-70 feet in saturated thickness. The zeroth moment is a tool to determine if mass tends to increase or decrease within the extent of the monitoring network over time. So, only the trends for the zeroth moments are reported.

Trends for the first moment indicate the relative amount of mass upgradient vs. downgradient and the change in the distance of the center of mass from the source over time. Trends in the second moment indicate the relative distribution of mass between the center of the plume and the edge.

2.1.4 Well Redundancy and Sufficiency

Spatial analysis modules in MAROS recommend elimination of sampling locations that have little impact on the historical characterization of a contaminant plume while identifying areas in the plume where additional data are needed. For details on the redundancy and sufficiency analyses, see Appendix A or the MAROS Users Manual (AFCEE, 2003).

Sample locations are evaluated in MAROS for their importance in providing information to define concentrations within the groundwater plume. Wells identified as providing information redundant with surrounding wells are recommended for elimination from the program. (Note: elimination from the program does not necessarily mean plugging and abandoning the well. See Section 2.3 below.)

Well sufficiency is evaluated in MAROS using the same spatial analysis as that for redundancy. Areas identified as having unacceptably high or unexplained levels of concentration uncertainty are recommended for additional monitoring locations.

The well redundancy and sufficiency analysis uses the Delaunay method and is designed to select the minimum number of sampling locations based on the spatial analysis of the relative importance of each sampling location in the monitoring network. The importance of each sampling location is assessed by calculating a slope factor (SF) and concentration and area ratios (CR and AR respectively). Sampling locations with a high SF provide unique information and are retained in the network. Locations with low SF are considered for removal. Areas defined by many wells with high SF may be candidates for new well locations.

Monitoring networks at the Pantex Plant were defined for constituents based on source areas and continuous areas of perched groundwater with similar groundwater flow direction. SF's were calculated for all wells in the Southeast and Southwest Sectors of the Pantex Plant and the results were used to determine the importance of each well in the network for defining the extent of concentrations for the primary COCs in these areas. Monitoring locations in the North Sector have limited hydrologic connection, either by virtue of discontinuous groundwater, very low concentrations or because of variable flow directions. For this reason, spatial analysis in the North Sector provides limited information, and network recommendations are based on individual well trends and qualitative information.

The results from the Delaunay method and the method for determining new sampling locations are derived solely from the spatial configuration of the monitoring network and the spatial pattern of the contaminant plume based on a two-dimensional assumption. No parameters such as the hydrogeologic conditions are considered in the analysis. Therefore, qualitative information, professional judgment and regulatory considerations must be used to inform final decisions.

2.1.5 Sampling Frequency

MAROS uses a Modified Cost Effective Sampling (MCES) method to optimize sampling frequency for each location based on the magnitude, direction, and uncertainty of its concentration trends. The MCES method was developed on the basis of the Cost Effective Sampling (CES) method developed by Ridley et al. (1995). The MCES method estimates a conservative lowest-frequency sampling schedule for a given groundwater monitoring location that still provides needed information for regulatory and remedial decision-making.

MAROS has recommended a preliminary location sampling frequency (PLSF) for each monitoring location for perched groundwater at the Pantex Plant based on a combination of recent and long-term trends and the magnitude and rate of concentration change. The PLSF has been reviewed qualitatively and a final optimal sampling frequency has been recommended consistent with monitoring objectives and regulatory requirements.

<u>*2.1.6 Data Sufficiency*</u>

The MAROS Data Sufficiency module employs simple statistical methods to evaluate whether analytical data are adequate both in quantity and in quality to confirm the achievement of regulatory clean-up goals. Statistical tests for the MAROS module were taken from the USEPA *Methods for Evaluating the Attainment of Cleanup Standards Volume 2: Groundwater* statistical guidance document (USEPA, 1992). The statistical methods are designed to evaluate plumes where the majority of analytical results have dropped below screening levels. As perched water at the Pantex Plant is still in the remedial choice stage of regulation, this statistical package was not employed during the analysis of the network in the Southeast and Southwest Sectors. The analysis was performed for North Sector locations with significant percentages of non-detect results.

2.2 Data Input, Consolidation and Site Assumptions

Groundwater analytical data from the Pantex Plant area were supplied by B&W Pantex from the site database (BWXT, 2007a), supplemented with information from historic site reports and the CMS/FS (BWXT, 2007b). Groundwater monitoring locations included in the evaluation are listed in Table 1, with additional details provided on extraction wells in Appendix B Table B.1.

Chemical analytical data collected between January 2000 and July 2007 and well information data were organized in a database, from which summary statistics were calculated. In all, 75 investigation well locations in the perched unit were considered in the network evaluation for the Pantex Plant.

In order to provide reasonable consistency in statistical comparisons, analyses have been limited to certain time-frames. Individual well trend evaluations were performed for data collected between January 2000 and July 2007. The data represent a 7 year record for many wells, and provide an indication of long-term trends in site constituent concentrations. Some monitoring locations have been added to the network between 2000 and 2005 or sampled infrequently. Where possible, statistical trends have been calculated for recently-installed locations using their full data record.

For sample locations with more than 40 sample events (n>40), data were consolidated quarterly. That is, for locations with more than one sample result for one calendar quarter (3 month period), the average concentration was used in the statistical analysis. Duplicate samples were also averaged to develop one result for each COPC for each time-interval.

To ensure a consistent number and identity of wells for the moment analysis, site data were consolidated annually for the analysis. An average concentration for each well for each year was calculated by the software. Estimates of total dissolved mass, center of mass and spread of mass were calculated for each year 2000 – 2007 based on the average concentration at each monitoring point. Trends for each of the moments are based on the Mann-Kendall evaluation of each moment calculated for each year 2000 – 2007.

For the spatial analysis (well redundancy and sufficiency) and for the sample frequency analysis, recent data collected between July 2005 and July 2007 were used. This interval provides at least seven quarters of data for most locations under relatively consistent operation of the ICMs.

2.3 Qualitative Evaluation

Multiple factors should be considered in developing recommendations for monitoring at sites undergoing long-term groundwater restoration. The LTMO process for the Pantex Plant includes developing a 'lines of evidence' approach, combining statistical analyses with qualitative review to recommend an improved monitoring network. Results from the statistical analyses in combination with a qualitative review were used to determine continuation or cessation of monitoring at each well location, addition of new locations, and proposed frequency of monitoring for those locations retained in the network.

The primary consideration in developing any monitoring network is to ensure that information, collected efficiently, supports site management decisions. Site information needs are reflected in the monitoring objectives for the network. For this reason, any proposed changes to the network are reviewed to be consistent with and supportive of the stated monitoring objectives. The qualitative review process starts with evaluating each monitoring location for the role it plays supporting site monitoring objectives. For example, a location may provide vertical or horizontal delineation of the plume or may provide information on decay rates in the source area. Each well in the perched groundwater network was evaluated for its contribution to site monitoring objectives.

A recommendation to eliminate chemical analytical monitoring at a particular location based on the data reviewed does not necessarily constitute a recommendation to physically abandon the well. A change in site conditions might warrant resumption of monitoring at some time in the future. In some cases, stakeholders may pursue a comprehensive monitoring event for all historic wells every five to ten years to provide a broad view of plume changes over time.

In general, continuation of water level or hydrogeologic measurements at all site wells is recommended. Data on hydraulic gradients and potentiometric surfaces are often relatively inexpensive to collect and can be used to support model development and resource planning.

Qualitative evaluation for sampling frequency recommendations includes looking at factors such as the rate of change of concentrations, the groundwater flow velocity, and the type and frequency of decisions that must be made about the site. Additionally, consideration is given to the concentration at a particular location relative to the regulatory screening level, the length of the monitoring history and the location relative to potential receptors.

3.0 RESULTS

3.1 Southeast Perched Groundwater Sector

Data from 31 monitoring wells at various depths were included in the network analysis for the Southeast Sector along with data from 48 extraction wells (see Figure 3). Investigation well locations are listed in Table 1 with the size of the dataset for each well, and major COCs detected. Extraction well information is listed in Appendix B Table 1. Data from a total of 79 monitoring locations were considered in the analysis of the Southeast Sector.

Perched groundwater in the Southeast Sector has been subjected to extensive site characterization efforts, as well as a comprehensive modeling effort (BWXT, 2006; BWXT, 2007). The source areas for the Southeast Sector have been identified as Zones 11 and 12 and the ditch running alongside these industrial units draining to Playa 1. Groundwater flow is to the east/southeast from the source areas. The highest concentrations of COCs are located south and east of the DOE property boundary (see Figure 3), with lower concentrations at the historic source.

Based on results from site characterization efforts, affected groundwater in the Southeast Sector extends to the point where the saturation ends. Figure 3 indicates the location of wells drilled to the depth of perched water to the southern and eastern extents that were found to be dry. Delineation of affected groundwater in this Sector is defined by wells that provide data on the extent of saturation. Perched water does not release to surface water and its hydraulic connectivity with the Ogallala is limited by the presence of the FGZ; therefore, affected groundwater in this area is largely delineated.

3.1.1 COC Choice

Priority constituents for each individual well in the Southeast Sector are indicated on Table 1. A sector-wide evaluation of priority COCs was performed in the MAROS software and the results are indicated in the Table 3 MAROS COC Assessment for the Southeast Sector.

Based on toxicity and prevalence metrics, the two primary COCs for the Southeast Sector are RDX and 4ADNT. The median RDX concentration in the Southeast Sector network is approximately two orders of magnitude above the MSC. RDX concentrations exceed the MSC at 69 of 79 locations evaluated while 4ADNT exceeds at 63 of 79 locations. Table 3 provides details of how the COCs were ranked by toxicity, prevalence and mobility in the Southeast Sector. While other constituents were considered (Cr(VI), TNT, 2ADNT, 24DNT, TCE) in the analyses, the monitoring network was optimized specifically to address management of the RDX and 4ADNT affected groundwater. Plumes of TCE and TNT are entirely contained within the greater RDX affected groundwater. Groundwater affected by Cr(VI) exists to the south of Zones 11 and 12 and is also considered in the analysis of the Southwest Sector.

The results of the MAROS COC Assessment are shown on Table 3, but are specific to the monitoring network evaluation and are not meant to supplant the BRA's, which use different metrics to evaluate risk.

3.1.2 Plume Stability

3.1.2.1 Concentration Trends

Individual well concentration trends for the two priority COCs using the Mann-Kendall method (2000 to 2007) are summarized in the table below with detailed results shown in Table 4 and illustrated on Figures 3 and 4. Detailed Mann-Kendall reports for major COCs for each well in the network are located in Appendix B.

COC	Total Wells	Pantex Plant Southeast Perched Groundwater Mann-Kendall Trend Results by Number of Wells				
		Nondetect	Decreasing or Probably Decreasing	Stable	Increasing or Probably Increasing	No Trend or Insufficient Data
RDX	79	1 (1%)	38 (48%)	12 (15%)	19 (24%)	9 (11%)
4ADNT	79	5 (6%)	32 (41%)	15 (19%)	15 (19%)	12 (15%)
2ADNT	79	10 (12%)	35 (44%)	10 (12%)	9 (11%)	15 (19%)
TNT	79	21 (26%)	21 (26%)	7 (9%)	14 (18%)	16 (20%)

For the major HE COCs, the majority of locations evaluated for RDX and 4ADNT show decreasing (D or PD) to stable (S) Mann-Kendall trend results. Other COCs, such as TNT and 2ADNT show higher percentages of wells with no detections. No Trend (NT) statistical results are found at locations with high variance in the data or a limited number of detections of COCs.

Roughly 20% of wells monitor groundwater with increasing concentration trends. Increasing concentration trends are found in areas of the plume downgradient from extraction wells and in areas where the saturated thickness drops off. Areas with increasing concentration trends occur on the perimeter of the plume, as constituents from historic sources are transported to the terminus of the groundwater unit. Extraction wells in the center of the plume have largely decreasing concentration trends.

In the Southeast Sector Cr(VI) is less prevalent than the HE compounds with the plume limited to an area south of Zone 12. Interpretation of trend results for Cr(VI) is complicated by the change in analytical detection limits within the dataset. Well locations PTX06-1012, PTX06-1035 and PTX06-1036 show historic non-detect results between 2000 and 2005. Analytical detection limits were reduced in August 2005, resulting in detectable results in subsequent analyses. Locations with higher concentrations of Cr(VI) show decreasing trends (PTX06-1010, PTX08-1008, and PTX06-1052) indicating a shrinking plume in this area.

3.1.2.2 Moments

Moment analysis was used to estimate the dissolved mass (zeroth moment), center of mass (first moment) and distribution of mass (second moment) for the plumes and the trends for these metrics over time. In order to ensure a consistent number and identity of wells for each moment estimate, an annual average concentration for each well was calculated. For the Southeast Sector, data from both investigation and extraction wells were used to estimate the moments. Moments were calculated using both a uniform saturated thickness (30 ft) and variable saturated thickness using estimates of saturated thickness from the database. The number of wells in the sampling program each year for RDX (including extraction wells) range between 68 locations in 2007 to 76 in 2005.

Mann-Kendall trends of moments were evaluated for annually consolidated data 2000-2007. Trends for estimates of the zeroth, first and second moments for both RDX and 4ADNT for the Southeast Sector are shown in the table below, and first moments for RDX and 4ADNT are illustrated on Figure 4. MAROS reports for zeroth, first and second moments for other COPCs are located in Appendix B. Moment results were the same for both uniform and variable saturated thickness assumptions, except where noted.

Moment Type	Constituent	
	RDX Trend	4ADNT Trend
Zeroth (Total Dissolved Mass)	Stable	Probably Increasing*
First (Center of Mass)	Increasing	Probably Increasing
Second (Spread of Mass)	Increasing/Stable	No Trend/ No Trend

*Result for uniform saturated thickness. Variable thickness resulted in No Trend.

Statistical results indicate that the total dissolved mass of RDX in the plume has been stable between 2000 and 2007. The zeroth moment for 4ADNT shows a probably increasing trend using uniform saturated thickness and No Trend when specific saturated thicknesses are used. These results indicate a possible weakly increasing trend, indicating that dissolved mass of 4ADNT within the network may be increasing due to degradation of the parent compound (TNT). Zeroth moments for 2ADNT are stable while TNT results indicated probably decreasing mass (consistent with possible transformation processes).

First moments, or the distance of the center of mass from the source, are statistically increasing over time for RDX and probably increasing for 4ADNT. However, the change in the center of mass is not significant, given the scale of the plume in this area (see Figure 4). Increasing first moments are often seen when source concentrations decrease, leaving relatively more of the total mass in the tail region. For RDX and 4ADNT, individual well concentration trends are decreasing at the source and in the center of the plume (under the influence of the extraction wells) and some peripheral areas show increasing concentrations. As a result, the center of mass for the priority constituents is shifting slightly to the east over time. First moments for TNT and 2ADNT show no trend.

Second moments are a measure of the distribution of mass about the center of mass in the plume. Second moments in the direction of groundwater flow (X direction) for RDX, TNT and 2,4DNT indicate that the mass in the center of the plume is decreasing relative to the mass on the edges of the plume (increasing second moment). An increasing second moment is consistent with the removal of mass from the center of the plume by the PGPTS. Second moments for 4ADNT show no trend, indicating no significant change in the distribution of mass within the plume.

Considering the overall results of the moment analysis, the plumes in the Southeast Sector are largely stable, with little change in total mass and distribution of mass, largely decreasing concentrations in the source and center of the plume. Slowly changing conditions are consistent with a reduced frequency of monitoring.

3.1.3 Redundancy and Sufficiency

The spatial redundancy analysis was performed for the network using RDX and 4ADNT as the priority COCs. (Note: Spatial analyses were also performed for TNT, 2ADNT and Cr(VI) and were considered as supporting information for final network recommendations).

Data collected between the 3rd quarter 2005 and 2007 were used in the spatial optimization. Summary results for the redundancy analysis are presented on Table 5 and include average SF (the estimate of uncertainty surrounding the well) and the MAROS recommendation for retention or elimination of the well from the network for each perched unit investigation well for RDX and 4ADNT. The preliminary MAROS recommendations were reviewed and a final recommendation for inclusion in the network is indicated. Extraction wells were included in the analysis, but were not considered for removal from the monitoring network.

Although several investigation well locations were identified by the software as candidates for removal for individual compounds, no single well was identified as redundant for all COCs analyzed. Based on a qualitative review of the network and associated regulatory requirements, all wells, but one, were recommended for retention in the monitoring network for the immediate future. Location PTX06-1014 was recommended for elimination from routine monitoring as it has very low SFs for all COCs examined. PTX06-1014 is redundant with PTX06-1042, PTX06-1030 and PTX06-1102.

Monitoring wells along the DOE property in the vicinity of the extraction wells have low SF due to the density of data generated in this area. The lack of concentration uncertainty in this area is indicated on Figure 5 by several ‘S’ (small uncertainty) indicators in the Delaunay triangles formed between the property line wells and the extraction wells. Very low SFs were calculated for locations along the eastern border of the DOE property for RDX and 4ADNT. While these wells (PTX06-1038, PTX06-1039A, PTX06-1014, PTX06-1015, etc.) tend to provide some redundant information, they are retained in the network due to the detection of increasing concentration trends and the absence of monitoring locations to the east. Well redundancy along the DOE property line should be reevaluated in 5 years after collection of additional data. If low SFs are calculated after additional data collection efforts, the wells should be considered for removal from the routine monitoring network.

Well sufficiency for the network is evaluated using calculated SFs as measures of concentration uncertainty. MAROS uses the Delaunay triangulation and SF calculations to identify areas with high concentration uncertainties, but new wells are added only in locations where uncertainty is unexplained by site characteristics. The Southeast Sector network has a number of characteristics that contribute to concentration uncertainty. Source areas along the west include a line source (the ditch) and other sources that are spatially as well as temporally discontinuous. Radial groundwater flow and the drying of the unit on the edges also contribute to higher calculated uncertainties.

Results of the well sufficiency analysis for RDX are shown on Figure 5. Figure 5 shows the polygons created by the triangulation method and indicates areas of high uncertainty with an “L” or an “E” in the center of the triangle. For the Southeast Sector network, areas of high concentration uncertainty for RDX exist in the source area, largely as a result of the heterogeneity of the source and radial groundwater flow. No new wells are recommended for the source area as concentration uncertainty is explained by flow conditions.

Another area of spatial uncertainty exists south of the source in the area between PTX06-1052 and PTX06-1036. Sampling results for PTX06-1052 show no detections of RDX, 4ADNT or TNT. However, monitoring locations around PTX06-1052 show consistent detections of site HEs. Concentration uncertainty in the area may be exacerbated by dry and intermittently dry wells (PTX06-1037 and 1045) on the southern border of the unit. Conversely, for Cr(VI), the area around PTX06-1052 represents some of the highest concentrations (with decreasing trends) found in the perched unit, while adjacent well PTX06-1053 monitors groundwater with no detections of Cr(VI) Results of the sufficiency analysis indicate a new well in the vicinity of PTX06-1052, PTX06-1053 and PTX06-1036 may be beneficial for characterizing concentrations of RDX, Cr(VI), TNT and 4ADNT in the area.

Better characterization of the area south of Zone 12 will provide information on COC migration patterns from possible sources west of the Southeast Sector. Additional information in this area will improve delineation of Cr(VI) affected groundwater and provide data on continued attenuation of Cr(VI). Temporal trend results for Cr(VI) south of Zone 12 will provide better information when more samples are collected using the new analytical detection limits, especially for wells with relatively low concentrations such as PTX06-1036, PTX06-1012 and PTX06-1035.

A second new monitoring location is recommended for the saturated area east of the line of monitoring wells on the eastern DOE property boundary. Results of TNT and 24DNT sufficiency analyses indicate the Delaunay triangle east of PTX06-1041 between PTX06-1030 and PTX06-1069 has high concentration uncertainty (TNT SF=0.8, 24DNT SF=0.6 at PTX06-1041). Higher concentration uncertainties are often found in areas bounded by wells with low or intermittent detections of COCs (PTX06-1069) and areas of higher concentrations (PTX06-1041) separated by large distances. A new well would help delineate the extent and trend of concentrations on the eastern edge of the perched unit. Currently, wells in this area show increasing concentration trends for RDX and 4ADNT, but due to consistent detections, this area does not exhibit high statistical concentration uncertainties for these compounds.

3.1.4 Sampling Frequency

Table 6 summarizes the results of the MAROS preliminary sampling frequency analysis. Recent (2005-2007) and overall rates (2000-2007) of concentration change for RDX and 4ADNT were determined along with the recent and overall Mann-Kendall trends. The software recommends a preliminary sampling frequency based on review of recent and overall rates and trends. Detailed results of the analysis are shown on Table 6 with final sampling recommendations from a 'lines of evidence approach' listed on Table 7 and Table 16. The sampling frequency suggested by the software (MAROS Recommended Frequency) was compared against the current frequency and site monitoring goals. A final recommended frequency was determined based on both MAROS generated recommendations and site-specific qualitative analyses.

Groundwater monitoring to date at the Pantex Plant has focused on characterizing the nature and extent of affected groundwater. For this reason, the sampling intervals for investigation wells have not been consistent. Many locations are currently sampled once annually, and, therefore, do not have sufficient data (4 samples) to evaluate a recent trend 2005- 2007. In some cases, wells have been installed recently (PTX06-1095A), and do not have a statistically significant dataset. For locations with a limited recent dataset, MAROS often recommends conservative (more frequent) sampling frequency. For wells with a longer sampling record (sampling prior to 2000), and low rates of concentration change, a reduced sampling frequency is appropriate. The MAROS preliminary sampling frequency recommendation for the network varies from quarterly to annual sampling for the Southeast Sector.

A total of 31 investigation wells were analyzed using the MCES method. Three wells in the Southeast Sector are listed as dry to intermittently dry in the site database (BWXT, 2007a). Dry wells are recommended for inclusion in the hydrogeologic monitoring program to monitor water levels at these locations. Of the remaining 28 locations, one well is recommended for exclusion from the program. Well PTX06-1014 was determined to be redundant with well PTX06-1042. Other wells identified as possibly redundant were recommended for inclusion in the monitoring network until the final remedy is established.

The majority of the remaining investigation wells (20) are recommended for semiannual sampling. Several wells recommended for semiannual sampling have increasing concentration trends for RDX and 4ADNT. Semiannual sampling is recommended to provide a statistically significant dataset to evaluate the efficacy of the remedy over the next few years. Wells near the source are recommended for annual sampling as concentrations are generally decreasing. The table below summarizes the current monitoring frequency for wells in the network and the sampling frequency recommended after the lines of evidence evaluation.

Monitoring Wells	Recommended Well Sampling Frequency		
	Sampling Frequency	Current Sampling Frequency	Sampling Frequency Recommendation
	Quarterly	0	0
	Semi-annual	16	22
	Annual	12	7
	Biennial	0	0
Total Samples (average per year)		**44**	**51**
Total Wells		**28**	**29**

The Sampling Frequency Recommendation includes 2 new locations to be sampled semiannually. The current sampling frequency is estimated from the sample dates in the site analytical database (BWXT Pantex, 2007). Three dry wells in the Southeast Sector are recommended for inspection and hydrogeologic monitoring at an annual frequency.

A summary of the final network recommendations for the Southeast Sector are shown on Table 7 and on Figure 8. Table 7 lists lines of evidence used in making each recommendation and a short description of the function of each well in achieving site monitoring goals. The combination of annual and semiannual frequencies will ensure temporal coverage to “define and enclose” the plume as well as providing a record of attenuation of high concentrations in the interior and edges of the sector. The final proposed network increases sampling effort in the near future, but will provide data for improved statistical analyses within the next 5 years.

3.2 Southwest Sector

Data from 29 investigation well locations were used in the analysis of the Southwest Sector. Wells located south of Zone 12 (PTX06-1036, PTX06-1052, PTX06-1053, PTX08-1008, PTX08-1009) were used in both Southeast and Southwest spatial analyses to account for the diverging groundwater flow directions. Source areas for the Southwest Sector include Zones 11 and 12; however, the area was not impacted by the drainage ditch from Zone 12 to Playa 1, to any great extent. Sources in the Southwest were more isolated, therefore; COC plumes in the Southwest Sector are not as extensive. The Southwest Sector is characterized by large areas of very low to non-detect results with isolated areas of higher concentrations. Areas above MSCs include TCE and perchlorate affected groundwater underlying Zone 11.

Individual plumes within the Southwest Sector perched unit are largely delineated by unaffected wells down and cross-gradient. Affected groundwater is well delineated to the north and west of the perched unit. Perimeter wells PTX07-1Q01 and PTX07-1Q02 north to PTX06-1085 and PTX06-1087 monitor groundwater below site MSCs. Perched groundwater south of PTX06-1035 on TTU may require more wells to provide delineation between areas of affected groundwater and the edge of the perched unit.

3.2.1 COC Choice

Priority constituents for each individual well in the Southwest Sector are indicated on Table 1. The analytical dataset includes some results that may be outliers, so not all priority constituents identified on Table 1 are detected consistently at the location indicated. Risk ratios below 1 indicate the groundwater is not affected above regulatory screening levels at the locations indicated. A sector-wide evaluation of priority COCs was performed in the MAROS software and the results are indicated on Table 8 MAROS COC Assessment for the Southwest Sector. Cr(VI) is identified as a priority COC for a limited number of wells in the Southwest Sector. The priority COCs for the design of the Southwest monitoring network are perchlorate, TCE, and 4ADNT.

3.2.2 Plume Stability

3.2.2.1 Concentration Trends

Individual well concentration trends for wells in the Southwest Sector are summarized on Table 9. Summary results are presented in the table below.

The percentage of monitoring locations with no detections for specific COCs is very high in the Southwest Sector, consistent with the observation that the plumes within this sector are isolated.

COC	Total Wells	Pantex Plant Southwest Perched Groundwater Mann-Kendall Trend Results by Number of Wells				
		Nondetect	Decreasing or Probably Decreasing	Stable	Increasing or Probably Increasing	No Trend or Insufficient Data
Perchlorate	29	15 (52%)	5 (17%)	3 (10%)	1 (3%)	5 (17%)
TCE	29	15 (52%)	1 (3%)	4 (14%)	2 (7%)	7 (24%)
4ADNT	29	17 (58%)	2 (7%)	2 (7%)	1 (3%)	7 (24%)

Mann-Kendall trend results for perchlorate are illustrated on Figure 6. Locations with the highest concentrations of perchlorate show strongly decreasing concentration trends (1114-MW4, PTX08-1005, and PTX08-1006) or stable trends (PTX06-1007). Locations within the plume with low to intermittent detections show No Trend results (datasets with intermittent non-detect results often have high coefficients of variation (COV)). One location, PTX06-1012, shows an increasing concentration trend for perchlorate and a probably increasing trend for TCE. PTX06-1012 is downgradient from Zone 11 and is not bounded to the south by other investigation wells.

TCE affected groundwater is encountered in roughly the same area as perchlorate affected groundwater (see Figure 6). Locations with detections of TCE indicate largely stable to no trend results. The only area of possibly increasing TCE concentrations is located between wells 1114-MW4 and PTX06-1012, where probably increasing trends indicate an area that may require more monitoring effort. Strongly decreasing trends were calculated at location PTX06-1052, at the interface between the Southeast and Southwest flow directions.

4ADNT affected groundwater is not widespread in the Southwest Sector, and is more closely associated with Zone 12. The 4ADNT plume is largely east or commingled with perchlorate and TCE affected groundwater. Locations monitoring the highest Cr(VI) concentrations (PTX08-1008, PTX06-1010 and PTX06-1052) show decreasing concentration trends. Locations monitoring the edge of the Cr(VI) plume show intermittent detections, and require a larger dataset to interpret trends in this area.

3.2.2.2 Moments

Mann-Kendall trends of moments were evaluated for annually consolidated data 2000-2007. Trends for estimates of the zeroth, first and second moments for TCE and perchlorate for the Southwest Sector are shown in the table below. Detailed MAROS reports for zeroth, first and second moments are located in Appendix B.

Moment Type	**Constituent**	
	TCE Trend	**Perchlorate Trend**
Zeroth (Total Dissolved Mass)	No Trend	Stable
First (Center of Mass)	Increasing	No Trend
Second (Spread of Mass)	Stable/Increasing	No Trend/Increasing

Total mass estimates of TCE and perchlorate are not changing rapidly within the current network. Moment results for 4ADNT and RDX indicate stable mass estimates for these COCs. For perchlorate, the distribution of mass within the plume is not changing rapidly. There is some evidence of dilution of mass in the center of the plume for both TCE and perchlorate (increasing second moments). First moment estimates for TCE are increasing, indicating that the plume may still be expanding in the direction of groundwater flow. This result is consistent with increasing trends at location PTX06-1012.

3.2.3 Redundancy and Sufficiency

Summary results for the redundancy analysis for the Southwest Sector are presented on Table 10 and include average SF (the estimate of uncertainty surrounding the well) for each perched unit investigation well for perchlorate and TCE. Locations with SF approaching 0 are often recommended for elimination from routine monitoring, while locations with high SF provide unique information in the immediate spatial region and are retained. In the Southwest Sector, many wells monitoring unaffected groundwater have higher SF's, due to the distance between these locations and locations on the edge of the plumes. Non-detect or intermittent detections are an example of conditions that result in statistical concentration uncertainty that can be explained by site data (in this case, censored data). Some wells with high SF have been recommended for elimination from routine monitoring based on qualitative issues as the software can identify non-detect wells as having higher concentration uncertainty.

Location PTX06-1006 is recommended for exclusion from routine monitoring as it is redundant with PTX06-1011. Perimeter locations PTX06-1087, PTX07-1P02, PTX07-1P03, PTX07-1Q02 and PTX10-1008 that monitoring unaffected groundwater are recommended for elimination from the monitoring network as well.

The well sufficiency analysis identified the area south of Zone 11 between wells PTX08-1006, PTX06-1012, PTX06-1053 and PTX06-1008 as having high concentration uncertainty. Location PTX06-1012 shows increasing concentration trends for perchlorate and TCE, and no downgradient wells currently exist to define the extent of the trend. A new monitoring location is recommended for the area south of PTX06-1012. One to two new monitoring locations are recommended for the area between PTX06-1012 and PTX08-1005 to account for uncertainty in groundwater flow directions in this area. A new location has been recommended to delineate groundwater near the DOE property boundary south of Zone 10. Groundwater south of Zone 10 is anticipated to be unaffected by COPCs above MSCs, with the new well functioning as a point of compliance (POC) well for the Southwest Sector.

3.2.4 Sampling Frequency

Detailed results of the sampling frequency analysis for the Southwest Sector are shown on Table 11 with final recommendations listed on Table 12. Table 12 lists the lines of evidence used in making sampling recommendations and a brief description of the function of the well in the network. Locations included in both the Southeast and Southwest spatial analyses were recommended for sampling at the more conservative frequency of the two analyses.

Sampling frequencies for 24 wells in the Southwest Sector were determined. The current sampling frequency for this sector is largely annual, with seven locations not sampled in the recent time-frame (2005-2007). Currently, 17 wells are sampled routinely in this sector.

Based on results of the redundancy and sufficiency analyses, six locations are recommended for formal elimination from the network while four new locations in perched groundwater are recommended. The proposed new locations are recommended for semiannual sampling until 4-6 sample results are collected to provide statistical trend information. The final proposed network is illustrated on Figure 8 and summarized in the table below. New wells are included under the sampling frequency recommendation (Total Wells below) as well as locations that have not been sampled frequently in the recent time period.

Based on results of the temporal analysis, four current locations are recommended for semiannual sampling. Wells monitoring groundwater with high or increasing concentrations of TCE and perchlorate, such as 1114-MW4 and PTX08-1005 are recommended for semiannual sampling to capture changes in concentrations in this area. Wells monitoring groundwater with stable trends or infrequent detections are recommended for annual sampling. Perimeter or POC wells are recommended for biennial sampling. The final proposed network increases sampling effort in the near future, but will provide for a statistically significant dataset within 5 years.

Monitoring Wells	Recommended Well Sampling Frequency		
	Sampling Frequency	**Current Sampling Frequency**	**Sampling Frequency Recommendation**
	Quarterly	0	0
	Semi-annual	2	8
	Annual	14	9
	Biennial	1	5
Total Samples (average per year)		**18.5**	**27.5**
Total Wells		**17**	**22**

The Sampling Frequency Recommendation includes 4 new locations to be sampled semiannually. The current sampling frequency is estimated from the sample dates in the site analytical database (BWXT Pantex, 2007a).

3.3 North Sector

3.3.1 COC Choice

Priority constituents for each individual well in the North Sector are indicated on Table 1. Eighteen locations were considered in the North Sector analysis. Two locations at the Pantex Lake property were not analyzed as perched groundwater in this area is not affected by COCs associated with site activities. As with the Southwest Sector, many locations do not exceed MSCs (risk ratios below 1) and the primary COC may not be detected routinely at a location.

A sector-wide evaluation of priority COCs was performed in the MAROS software. The only COC identified as a priority sector-wide was RDX. Other constituents are present in perched groundwater at low levels or over limited spatial extents. Isolated areas of perched groundwater are found underlying the Burning Grounds and in the far northeast area of the property. Perched groundwater in these areas is characterized by fairly low detections of site COPCs and limited opportunity for mobility.

The North Sector includes the area of the main perched groundwater unit north of Playa 1. Perched groundwater in this area is affected by waste water drained to Playa 1 from industrial operations in Zone 12. A groundwater mound located just to the north of Playa 1 (see Figure1) causes radial flow in the North Sector. The RDX and 4ADNT plumes that extend south from Playa 1 were evaluated under section 3.1 above. Analyses of the North Sector included the area between Playa 1 and the extent of the perched unit and the area around SWMU 68b.

3.3.2 Plume Stability

3.3.2.1 Concentration Trends

Selected individual well concentration trends for wells in the North Sector for various COPCs are listed on Table 13 and illustrated on Figure 7. The majority of locations do not have detections of COPCs above MSCs. The only area of groundwater routinely affected above MSCs is the RDX plume north of Playa 1. A summary of Mann-Kendall trend results for the North Sector is shown below. No locations in the North Sector show decreasing trends for RDX (while several locations in the northern Southeast and Southwest Sectors show decreasing trends). One location, PXT06-1050 shows an increasing trend, with average concentrations above the MSC. Well PTX06-1114 has been installed upgradient of PTX06-1050 to define trends in the area, but the location has insufficient data to evaluate a trend at this time. No wells are currently located downgradient of PTX06-1050.

COC	Total Wells	Pantex Plant Southwest Perched Groundwater Mann-Kendall Trend Results by Number of Wells				
		Nondetect	Decreasing or Probably Decreasing	Stable	Increasing or Probably Increasing	No Trend or Insufficient Data
RDX	18	9 (50%)	0	3 (17%)	1 (5%)	5 (28%)

3.3.2.2 Moments

The moment analysis was not conducted for the North Sector as fewer than six wells were present in any individual network monitoring a common source area and groundwater flow direction. Outside of the main perched groundwater unit, COCs are not detected above MSCs on a consistent basis. Plume stability for affected groundwater in the North Sector was determined by evaluating delineation and individual well concentration trends.

3.3.3 Redundancy and Sufficiency

As with the moment analyses, network spatial redundancy and sufficiency analyses require greater than six monitoring locations with detections to evaluate stability within a network. For the North Sector, redundancy and sufficiency were evaluated using qualitative methods.

The area north of Playa 1 is the only area in the North Sector where groundwater consistently exceeds MSCs. RDX concentrations appear to be increasing downgradient of Playa 1 in the area of PTX06-1050. Addition of a well downgradient (west) of PTX06-1050 is recommended to define the extent and trend of RDX in the area. Wells in the main perched unit north of Playa 1 should be sampled semiannually until a sufficient dataset has been collected to evaluate dissolved RDX in the area.

3.3.4 Sampling Frequency

Detailed results of the sampling frequency analysis for the North Sector are shown on Table 14. Final recommendations are listed on Table 15, along with lines of evidence used to support the recommendation and a description of the function of each well in the network. Only data for the overall rate of change and overall concentration trends are shown on Table 14 as there were an insufficient number of sampling events to evaluate recent rates of change and trends (2005 – 2007). Analytical results from many locations show no detections or only intermittent detections of site COPCs.

Final sampling frequency recommendations are summarized in the table below. Due to the limited extent of affected groundwater, a reduction in monitoring effort over the majority of the North Sector is recommended.

Monitoring Wells	Recommended Well Sampling Frequency		
	Sampling Frequency	Current Sampling Frequency	Sampling Frequency Recommendation
	Quarterly	0	0
	Semi-annual	10	5
	Annual	6	4
	Biennial	4	5
	5 year interval	4	7
Total Samples (average per year)		**29**	**18**
Total Wells		**20**	**21**

The Sampling Frequency Recommendation includes 1 new location to be sampled semiannually. The current sampling frequency is estimated from the sample dates in the site analytical database (BWXT Pantex, 2007).

For wells located in the northeast corner of the DOE property boundary, a combination of biennial and 5-year sampling intervals was recommended. The perched groundwater in this area is isolated from the main perched groundwater unit, and is in an area where the FGZ is thick. COPCs are not detected above screening levels with regularity. A five-year sampling interval will provide data to demonstrate compliance with regulatory requirements over the long-term. A five-year sampling interval is also suggested for PTX07-1R03, located in an isolated area of perched groundwater.

Semiannual monitoring is recommended for wells monitoring RDX affected groundwater in the main perched unit (PTX06-1114, PTX06-1050, PTX07-1O01 and PTX07-1O02) and for the proposed new location. Annual monitoring is suggested for wells defining the outer edge of the plumes.

The final recommended sampling frequencies for all Pantex Plant sampling locations is provided on Table 16.

3.3.5 Data Sufficiency

Data sufficiency analysis is appropriate for sampling locations very close to meeting cleanup objectives. Several locations in the North Sector monitor groundwater with very few to no detections of COPCs. Data sufficiency analysis determines if and when a sufficient number of samples have been collected from a location to confirm that the groundwater is statistically below the cleanup goal and if the site has attained cleanup (USEPA, 1992). A Student's T-Test with power analysis and Sequential T-Test were performed on North Sector data. Results from these statistical tests are shown on Table 15. The Students T-test and power analysis identifies if groundwater locations statistically below the MSC with 80% power. The Sequential T-Test, a more rigorous analysis, identifies locations that have 'attained' cleanup, those where continued monitoring would provide a statistically significant dataset, and those locations far from achieving the cleanup goal.

Well locations where data meet the statistical standard of 'clean' can be used as POC or delineation points for regulatory purposes, or their monitoring frequency can be dramatically reduced without loss of information to support management decisions.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The primary goal of developing an optimized monitoring strategy at the Pantex Plant is to create a dataset that fully supports site management decisions and risk reduction goals while minimizing time and expense associated with collecting and interpreting analytical data. A summary of the final recommended monitoring network is presented on Table 16 and illustrated on Figure 8. The recommended network increases data collection effort in some areas to provide a dataset that fulfills statistical requirements for evaluating the effect of the remedies discussed in the CMS/FS (BWXT, 2007b). The recommended network reduces monitoring effort and cost in some areas, but recommends the addition of new wells in areas where further characterization would support site monitoring goals.

Tasks identified in Section 1 were performed for the current network. A summary of general results for each task is presented below:

- *Evaluate well locations and screened intervals within the context of the hydrogeologic regime to determine if the site is well characterized.*

  Result: Part of the network optimization process is to identify possible gaps in site characterization that may require additional sampling locations or site investigation. Based on well locations, screened intervals and hydrogeologic characteristics, affected groundwater in perched units is well characterized and delineated, in most areas. In some areas, the extent of affected groundwater is defined by the extent of perched groundwater, with perimeter wells dry. Areas that may benefit from additional delineation have been identified in the Southwest Sector southwest of Zone 11, in the North Sector northwest of Playa 1 and in the far eastern area of perched groundwater. Areas recommended for additional delineation are all near the perimeter of the perched unit where saturated thickness decreases. Recommendations for new delineation locations are based on both qualitative and quantitative statistical evaluations.

  Source areas have been well investigated and conceptual site models have been developed for all areas of affected groundwater (BWXT, 2007b). The majority of wells in the network have a sufficiently large dataset to perform statistical calculations.

  Recommendation: Monitoring network optimization is appropriate for the site at this time; however, further network evaluation may be beneficial after the final remedies are instituted (including installation of new extraction and *in situ* redox manipulation systems). Network recommendations presented in this report focus on collecting information over the next five years to support future assessment of remedy efficacy and delineation of affected groundwater. The monitoring network should be reevaluated after five years to determine if the system can be further optimized.

Areas of perched groundwater that are recommended for additional delineation include the area east of the DOE property in the vicinity of well PTX06-1040. The perched groundwater pinches out in this area, so delineation may be a function of confirming the limit of saturation.

Two new groundwater delineation locations are recommended for the area south/southwest of the main perched unit in the Southwest Sector to delineate constituents in this area.

An additional delineation well is also recommended for the area north and west of Playa 1 to characterize the RDX plume west of PTX06-1050.

- *Evaluate overall plume stability through trend and moment analysis. Evaluate individual well concentration trends over time for target chemicals of potential concern (COPCs);*

Result: The groundwater plumes in the Southeast Sector are largely stable under the influence of the extraction system and limited by the extent of saturation in the perched unit. Statistically increasing concentration trends are found for RDX and 4ADNT at downgradient locations in the Southeast Sector; however, the magnitude of increase is low compared with the overall concentrations at these locations.

An evaluation of moments in the Southeast Sector shows that total dissolved mass estimates are stable for RDX, and variable to possibly increasing for 4ADNT. Center of mass estimates for RDX and 4ADNT are statistically increasing (moving downgradient) slightly, consistent with increasing individual well trends at downgradient locations and decreasing concentration trends in the source and extraction well areas. The movement of the center of mass downgradient is not significant compared to the overall scale of the plume. Estimates of the distribution of mass about the center of mass (second moments) for RDX indicate some redistribution of mass from the center to the edge of the plume in the direction of groundwater flow. Overall results of the stability analysis indicate the plumes are largely stable with slow increases in the proportion of constituent mass in groundwater on the edges of the plume.

The primary plumes in the Southwest Sector include TCE and perchlorate affected groundwater near Zone 11 and HE plumes near Zone 12. Individual well trends for perchlorate are largely decreasing with the exception of an increasing trend found at downgradient location PTX06-1012. Moments for perchlorate show no trend to stable trends within the current network, indicating a fairly stable plume.

Individual well trends for TCE in the Southeast Sector are largely stable or show no trend. However, concentrations at wells 1114-MW4 and PTX06-1012 show probably increasing trends. Increasing trends at some downgradient locations are reflected in an increasing trend for the center of mass over time. Lines of evidence indicate some expansion of Zone 11 affected groundwater in the southerly direction.

The majority of monitoring locations in the North Sector are not affected by constituents above MSCs and statistical evaluation results indicate many locations where groundwater shows no detections or intermittent detections (no trend). Concentration trends for RDX in the North Sector show decreasing trends just south of Playa 1. An increasing RDX trend was found at PTX06-1050 indicating possible spread of the plume to the northwest of the main perched groundwater unit. Due to the limited number of monitoring locations, moment analysis was not conducted for the North Sector.

Recommendation: Monitoring frequency can be reduced for plumes where groundwater concentrations are not changing rapidly and where plumes are stable. Areas where reduced monitoring effort is appropriate have been identified in the North and Southwest Sectors (see Table 16 for final recommendations).

Concentrations are still changing in the Southeast, although the plume has been stabilized by installation of the PGPTS. The recommendation is to continue to collect data in Southeast Sector during the installation and early implementation of proposed remedies to provide a sufficient dataset to demonstrate the efficacy of future remedies.

- *Develop sampling location recommendations based on an analysis of spatial uncertainty;*

Result: Well redundancy analysis for the Southeast Sector indicates that wells installed along the DOE property boundary may provide redundant information when analyzed alongside data from the PGPTS. However, as these wells are the monitoring locations farthest downgradient to the east and monitor the property boundary, most are recommended for inclusion in the monitoring program until installation of additional remedy systems are completed. One investigation well in this area was recommended for elimination from routine monitoring.

Spatial uncertainty analysis for the Southeast Sector indicated high concentration uncertainty in the area south of Zone 12 and in the area east of the DOE property. High concentration uncertainty was found for RDX, Cr(VI) and 4ADNT for the southern location and for TNT and 2ADNT in the eastern area. Two new wells are recommended. Similarly, delineation of concentrations south of Zone 12 and east of PTX06-1053 would benefit from addition of a well to monitor possible transport of COCs through the area. The Southeast Sector will most likely be the focus of additional remedial activities, and providing data from the area immediately west of proposed remedial operations will support assessment of remedial effectiveness in this area (see Figure 8 for proposed new well locations).

For the Southwest Sector, wells monitoring unaffected groundwater on the western edge of the plume were found to provide redundant information based on a qualitative review and are formally recommended for removal from the routine monitoring program. Statistical redundancy was found in the area of PTX06-1006, near Zone 12. The spatial sufficiency analysis for the Southwest Sector identified an area of unexplained concentration uncertainty in the vicinity of PTX06-1012, and three new monitoring locations are recommended for this area.

Rather than recommending wells for elimination in the North Sector, delineation or POC wells were identified for reduced sampling frequency.

Recommendation: For the Southeast Sector well PTX06-1014 was determined to be redundant with well PTX06-1042, and is recommended for elimination from the routine monitoring program.

Two new locations are recommended for the Southeast Sector. One new location is recommended for the area between PTX06-1036 and PTX06-1052. Another new location is recommended for the area east of PTX06-1039A.

Six locations were found to provide redundant information and are recommended for elimination from routine monitoring in the Southwest Sector: PTX06-1006, PTX06-1087, PTX07-1P02, PTX07-1P03, PTX07-1Q02, and PTX10-1008.

Overall, four new groundwater monitoring locations are recommended for the Southwest Sector. Two new wells are recommended to delineate affected groundwater in the southern area of the perched unit. The wells are outside the current network southwest of PTX06-1012 and southwest of PTX06-1035. Two new locations south of PTX08-1005 are recommended to decrease spatial uncertainty in the area of the TCE/perchlorate plume near Zone 11 between PTX08-1005 and PTX06-1012.

No wells are recommended for elimination from the North Sector networks. However, many locations are recommended for dramatically reduced sampling frequency. If low to non-detect conditions persist in isolated perched units in the future, some of these wells may be eliminated.

One new monitoring location is recommended to delineate the RDX plume in the North Sector. The new monitoring location is recommended for an area downgradient (west) of PTX06-1050 at the edge of the saturated unit.

- *Develop sampling frequency recommendations based on both qualitative and quantitative statistical analysis results;*

Result: Preliminary sampling frequency recommendations generated by MAROS for RDX in the Southeast Sector included many recommendations for quarterly sampling due to the small number of recent sampling events during the past two years and due to increasing concentration trends at sampling locations. Sampling frequency recommendations for 4ADNT affected wells were less frequent. After a qualitative review of the network, a semiannual sampling frequency was recommended for most monitoring locations in the Southeast Sector. The qualitative review considered that additional historic data were available for many of the locations and that the perched groundwater unit is largely isolated from most exposure pathways, poses a limited risk and is covered by institutional controls to prevent contact with human or ecological receptors.

Locations in the Southeast Sector source area and in the northern area are recommended for annual sampling based on low rates of concentration change and decreasing concentration trends.

Many monitoring locations in the Southwest and North Sectors were recommended for reduced sampling frequency due to the number of non-detect results and the very low rate of change of concentrations in this sector.

Recommendation: Recommendations for sampling frequency were made based on the rate of concentration change, the magnitude and direction of concentration change and the need to acquire a statistically significant dataset over the next five years. Sampling frequency recommendations are summarized on Table 16 and Figure 8.

Southeast Sector investigation wells were recommended for a largely semiannual to annual sampling frequency. Of the 31 locations evaluated, 20 are recommended for semiannual sampling. Annual sampling frequency is appropriate for source area locations with decreasing trends and locations within the plume with low rates of concentration change.

Monitoring locations in the Southwest Sector that serve to delineate the extent of perched groundwater (outer edge wells) are recommended for biennial sampling. Interior monitoring locations that may characterize historic source areas or areas north of the source are recommended for annual sampling. Semiannual sampling is recommended for locations monitoring the perchlorate and TCE plume near Zone 11 and for recommended new locations.

In the North Sector, semiannual sampling is recommended for wells monitoring RDX affected groundwater in the main perched unit (PTX06-1114, PTX06-1050, PTX07-1O01 and PTX07-1O02) and for the proposed new location. Annual monitoring is suggested for wells defining the outer edge of the plumes.

Dramatically reduced monitoring is recommended for isolated perched groundwater near property boundaries in the North Sector. Biennial sampling is recommended for wells PTX01-1002, PTX04-1002, PTX06-1081, PTX07-1O06 and PTX-BEG3, while 5 year intervals are recommended for PTX04-1001, PTX06-1071, PTX06-1080, PTX06-1082, PTX06-1083, PTX07-1R03 and PTX08-1010.

- *Evaluate individual well analytical data for statistical sufficiency and identify locations that have achieved clean-up goals (North Sector only).*

.

Result: Data sufficiency was evaluated for North Sector investigation wells for RDX (other COPCs were statistically below MSCs). 15 locations in the North Sector had sufficient data to perform the analysis and of those, 10 monitor groundwater statistically below the MSC for RDX (7.7 ug/L) with 80% statistical power. Nine of the 10 wells below MSCs had sufficient data to demonstrate that groundwater was not affected by RDX using the Sequential T-Test. Wells with sufficient data to demonstrated "attainment" of groundwater regulatory standards can be considered as POC locations or can be considered for reduced sampling frequency.

Recommendation: Results from the data sufficiency analysis were used as one 'line of evidence' to reduce sampling frequency for several North Sector groundwater monitoring locations (see Table 15).

Additional Recommendations

- Groundwater monitoring data as well as well construction and location information should continue to be managed in a site-wide relational database.
- Capture zone analysis for the PGPTS extraction system in the Southeast Sector is recommended and should continue to be presented annually, as required by Compliance Plan No. 50284.
- Additional monitoring locations for the Ogallala Aquifer are recommended to ensure vertical delineation of the perched groundwater plume and to provide early warning if affected groundwater migrates through the FGZ.
- Reevaluate the network in 5 years after any additional remedies have been implemented and a statistically significant dataset has been collected.

5.0 CITED REFERENCES

AFCEE. (2003). Monitoring and Remediation Optimization System (MAROS) 2.2 Software Users Guide. Air Force Center for Environmental Excellence. http://www.gsi-net.com/software/MAROS_V2_1Manual.pdf

AFCEE. (1997). Air Force Center for Environmental Excellence, AFCEE Long-Term Monitoring Optimization Guide, http://www.afcee.brooks.af.mil.

Aziz, J. A., C. J. Newell, M. Ling, H. S. Rifai and J. R. Gonzales (2003). "MAROS: A Decision Support System for Optimizing Monitoring Plans." Ground Water **41**(3): 355-367.

BWXT Pantex/SAIC, 2006. *Baseline Human Health Risk Assessment Report for Zones 10, 11, and 12, Fire Training Area, Ditches and Playas, Independent Sites and Groundwater for the U.S. Department of Energy/National Nuclear Security Administration, Pantex Plant, Amarillo, Texas.* BWXT Pantex L.L.C., Texas, December 2006.

BWXT Pantex, 2007a. Pantex Plant groundwater database. Accessed September, 2007.

BWXT Pantex/ SAIC, 2007b. *Corrective Measures Study/ Feasibility Study Modeling Report, Department of Energy/National Nuclear Security Administration, Pantex Plant, Amarillo, Texas, Volume 1.* BWXT Pantex L.L.C., Texas September, 2007.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. New York. Van Norstrand Reinhold.

Ridley, M.N., Johnson, V. M and Tuckfield, R. C.(1995). Cost-Effective Sampling of Ground Water Monitoring Wells. HAZMACON. San Jose, California.

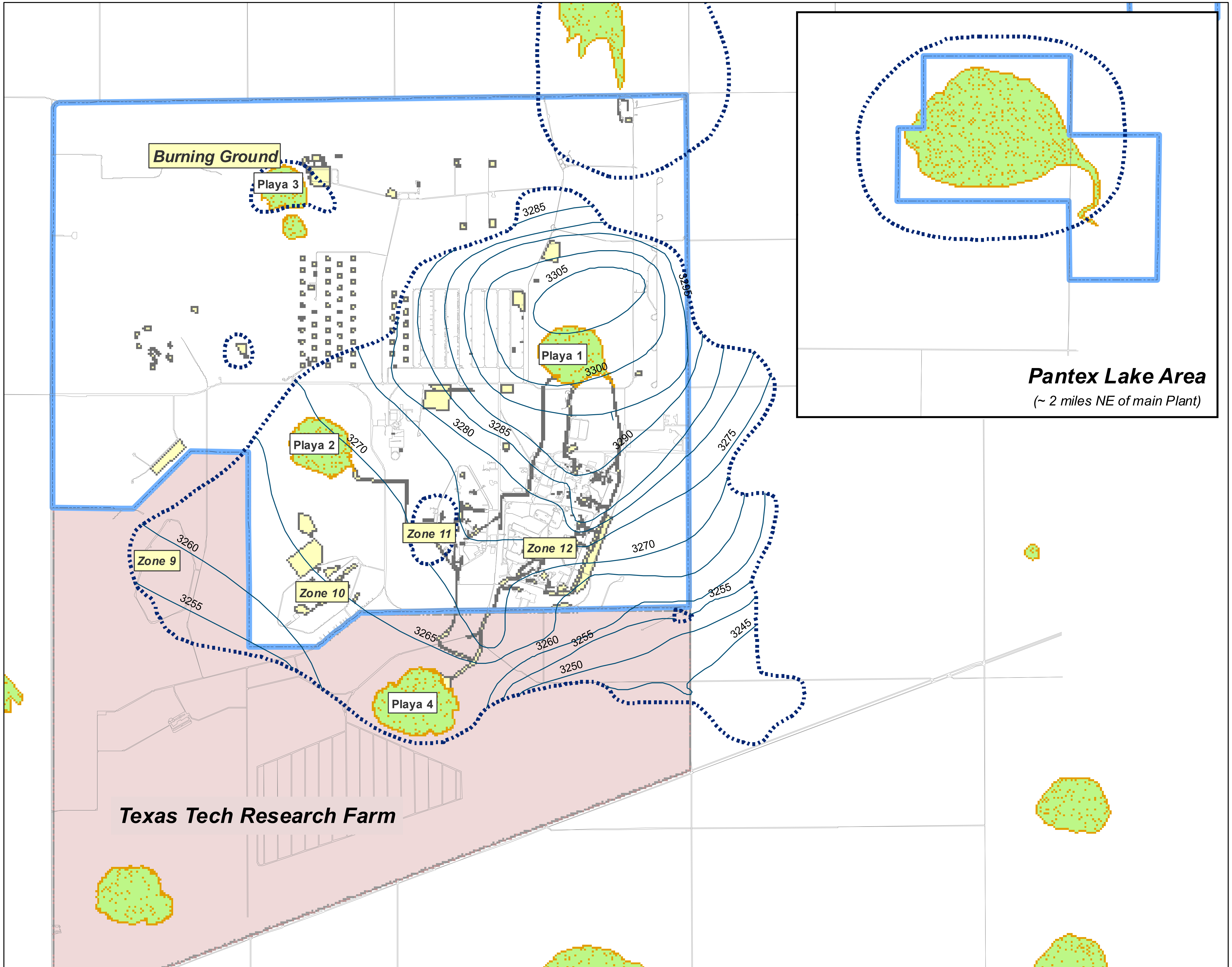
USEPA. 1992. *Methods for Evaluating the Attainment of Cleanup Standards Volume 2: Ground Water*. U.S. Environmental Protection Agency.

.

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

FIGURES



N

LEGEND

- Water Table Elevation 2006 Perched Groundwater
- Extent of Perched Water
- Pantex Roads
- USDOE Property
- Playa Lakes
- SWMU
- Texas Tech University Property

Notes:

1. Geographic data from BWXT Pantex September 2007.
2. Perched groundwater extent and groundwater elevations from 2006 data BWXT Pantex.
3. The Pantex Lake area is approximately 2 miles northeast of the main Plant.
4. Groundwater elevations for main plant indicated in ft. amsl.

Scale (ft)

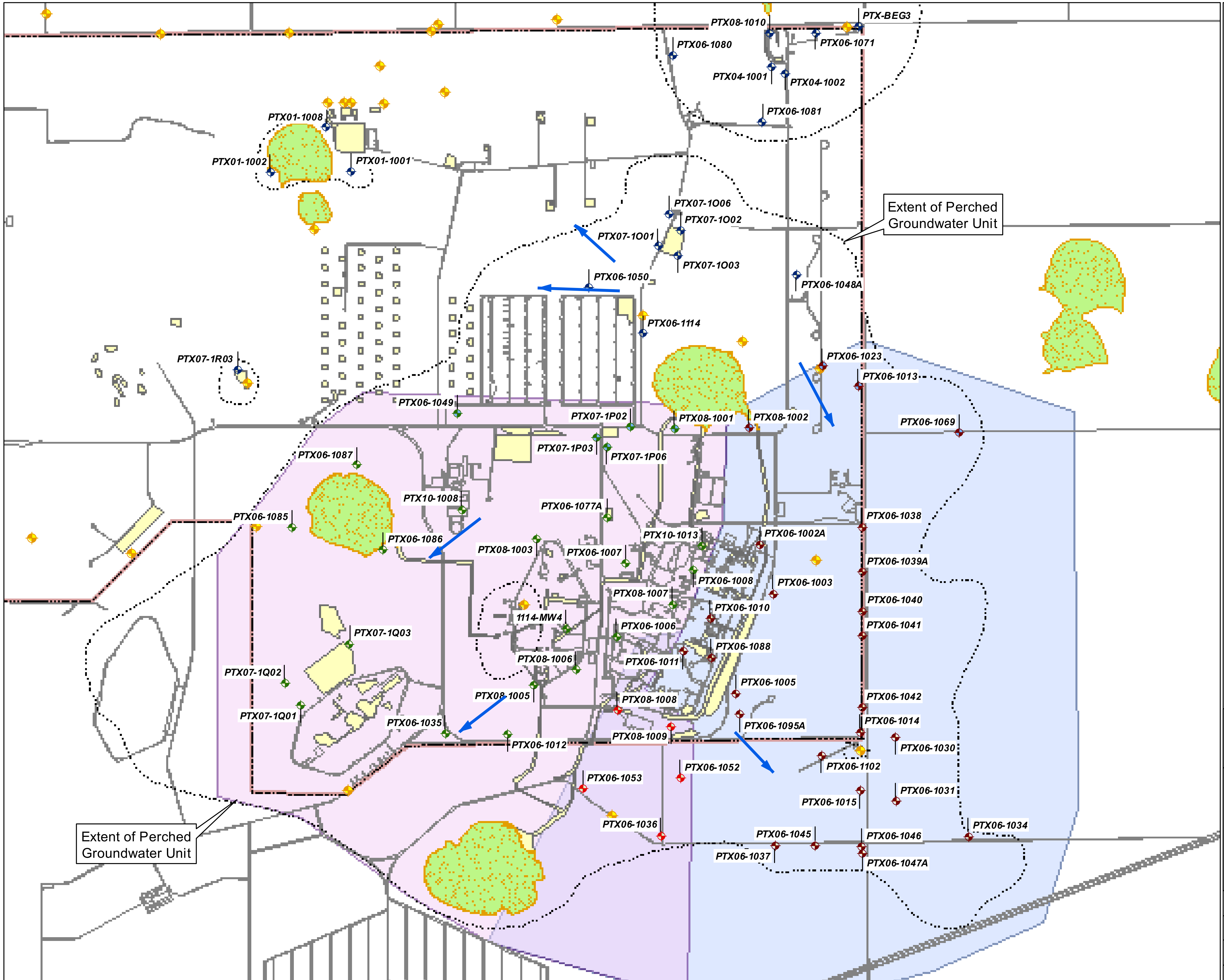
0 1,750 3,500

GSI ENVIRONMENTAL

PANTEX PLANT VICINITY

Carson County, Trxas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		FIGURE 1



N

LEGEND

Investigation Well Groups

- North Area
- North/Southeast Areas
- North/Southwest Areas
- Southeast Area
- Southwest Area
- Southeast/Southwest Areas
- Ogallala Wells (Current)

- Extent of Perched Water
- USDOE Property
- Playa Lakes
- SWMU
- Southwest Sector
- Southeast Sector
- Approximate Groundwater Flow Direction

Notes:

1. Only investigation well locations are indicated. Well ID's for perched groundwater wells are shown.
2. Approximate groundwater flow directions from 2006 potentiometric measurements.

Scale (ft)

0 1,250 2,500

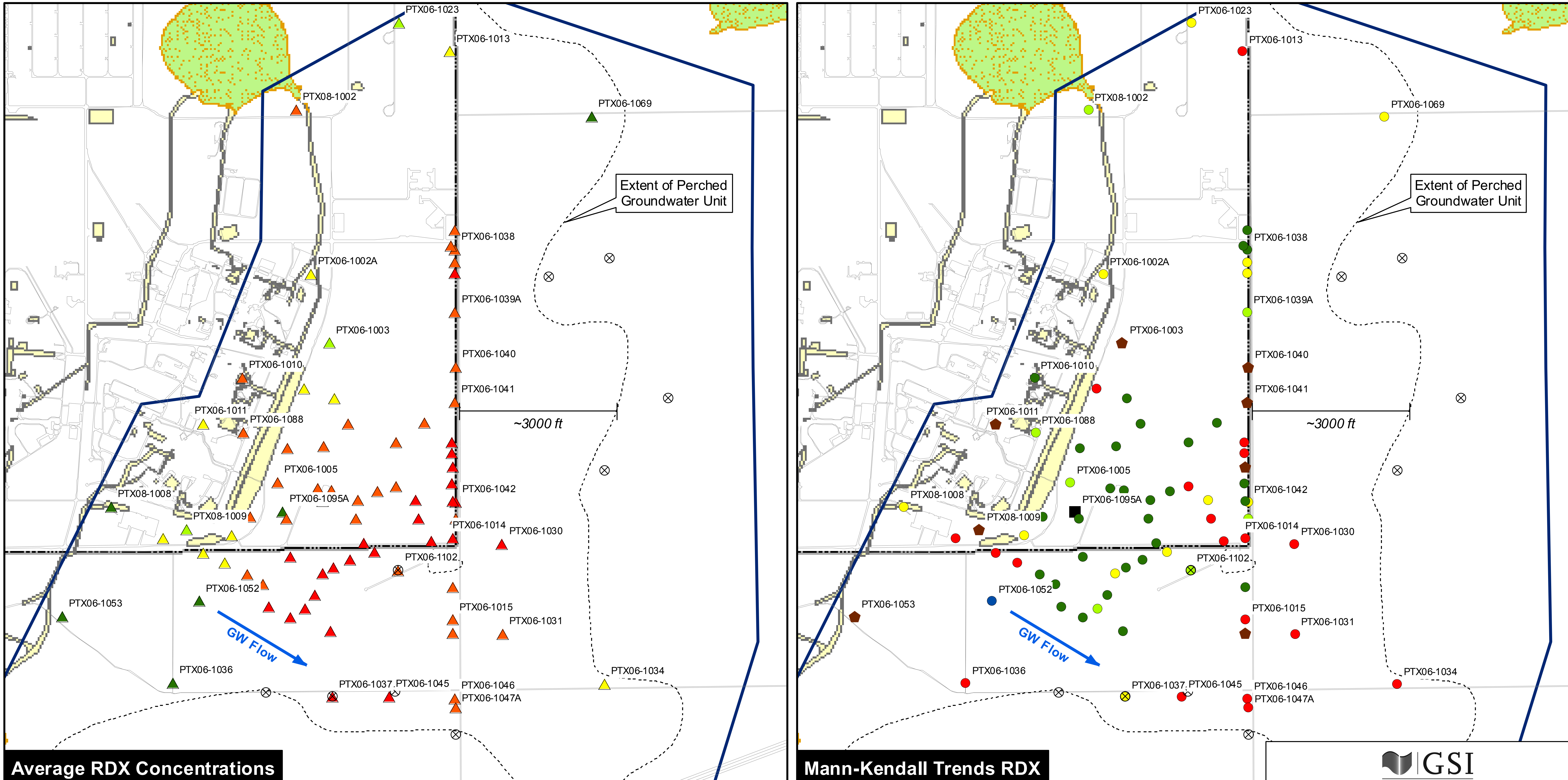
GSI ENVIRONMENTAL

PANTEX PERCHED GROUNDWATER

Investigation Well Locations

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		**FIGURE 2**



LEGEND

Average RDX Concentration [mg/L]

- ND - 0.001
- 0.001 - 0.007
- 0.007 - 0.05
- 0.05 - 1.0
- > 1.0

Mann-Kendall Trend RDX

- Decreasing
- Probably Decreasing
- Stable
- Probably Increasing
- Increasing
- Non Detect (2000-2007)
- No Trend
- Insufficient Data
- Dry Wells

RRS 2 RDX = 0.0077 mg/L

Notes:

1. Average RDX concentrations calculated using lowest detection limit substituted for ND values. Data 2000-2007.
2. Mann-Kendall trends were determined for RDX 2000-2007.
3. Investigation wells are labeled with their well ID. Extraction wells are not labeled.
4. See Pantex Vicinity legend for description of site features.

N

Scale (ft)

0 900 1,800

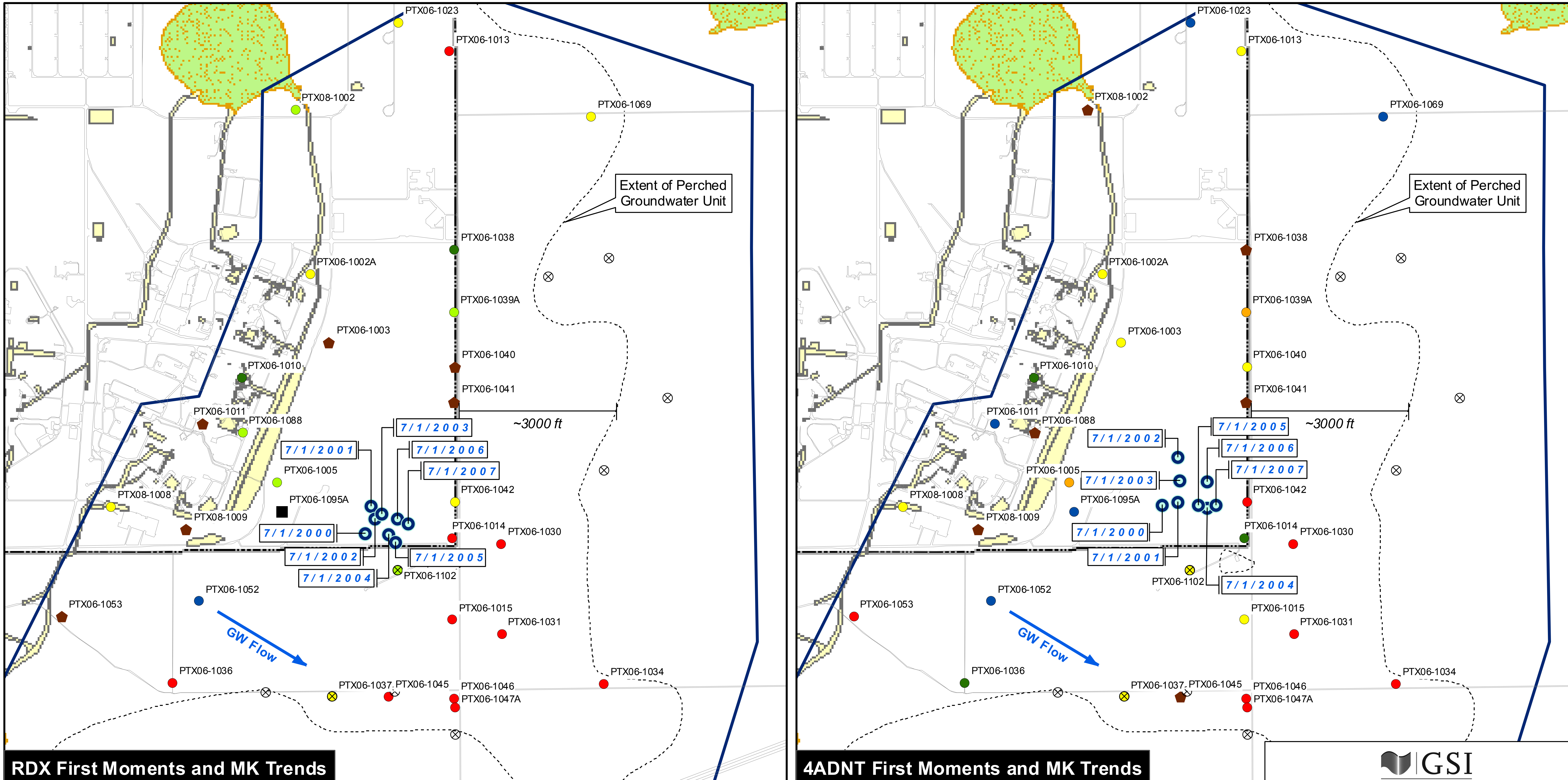
GSI ENVIRONMENTAL

PANTEX SOUTHEAST SECTOR PERCHED GROUNDWATER

RDX Average Concentrations and Mann-Kendall Trends

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		FIGURE 3



LEGEND

- Dry Wells Perched Unit
- First Moments (Center of Mass)

Mann-Kendall Trend

- Decreasing
- Probably Decreasing
- Stable
- Probably Increasing
- Increasing
- Non Detect (2000-2007)
- No Trend
- Insufficient Data

MSC RDX = 0.0077 mg/L; 4ADNT = 0.0012mg/L

Notes:

1. First Moments indicate the center of mass estimated based on annually consolidated analytical data from the well network. The effective date of the First Moment estimate is shown.
2. Mann-Kendall trends were determined for RDX and 4ADNT 2000-2007.
3. Only results for investigation wells are shown.

N

Scale (ft)

0 900 1,800

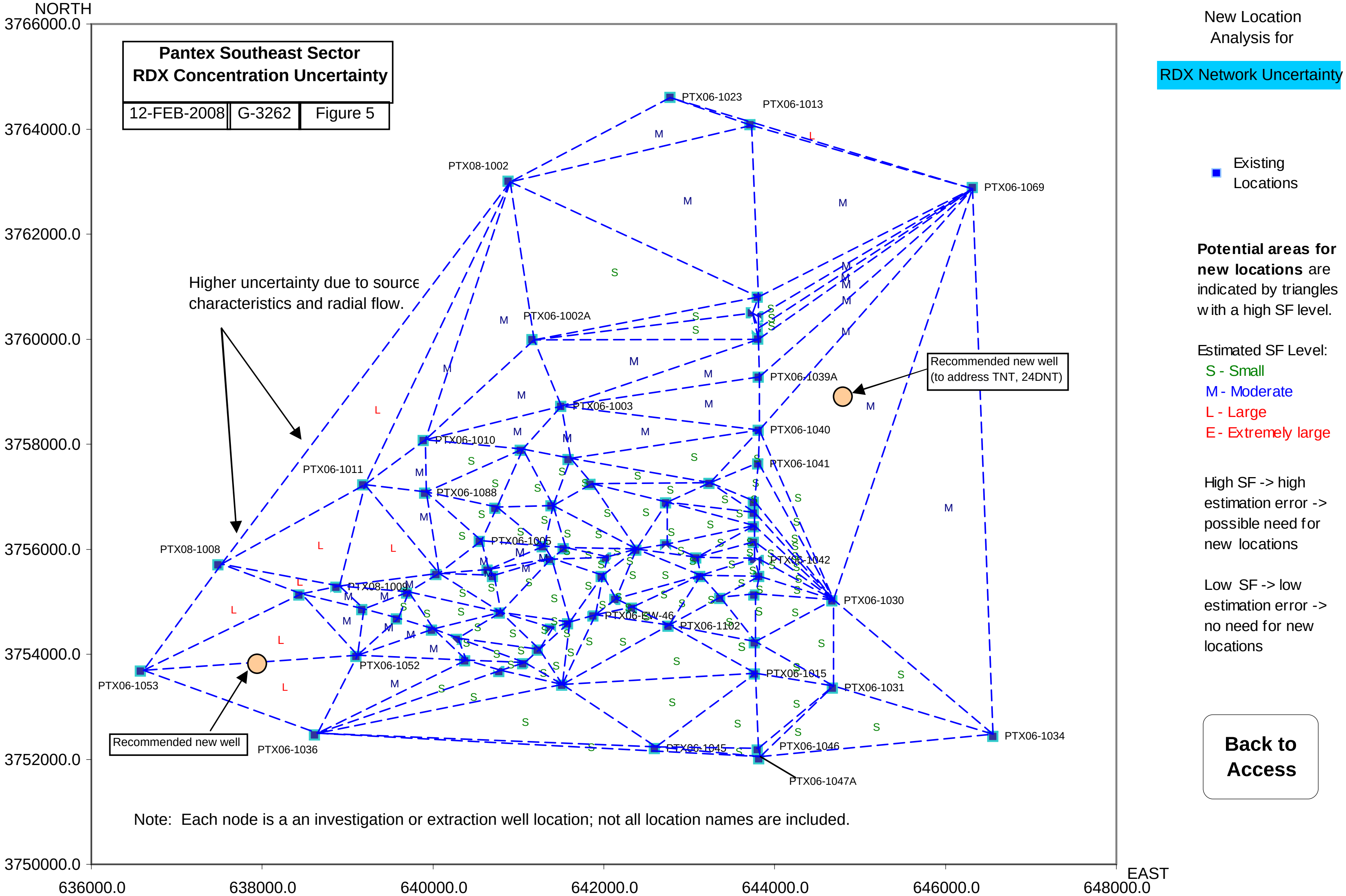
GSI ENVIRONMENTAL

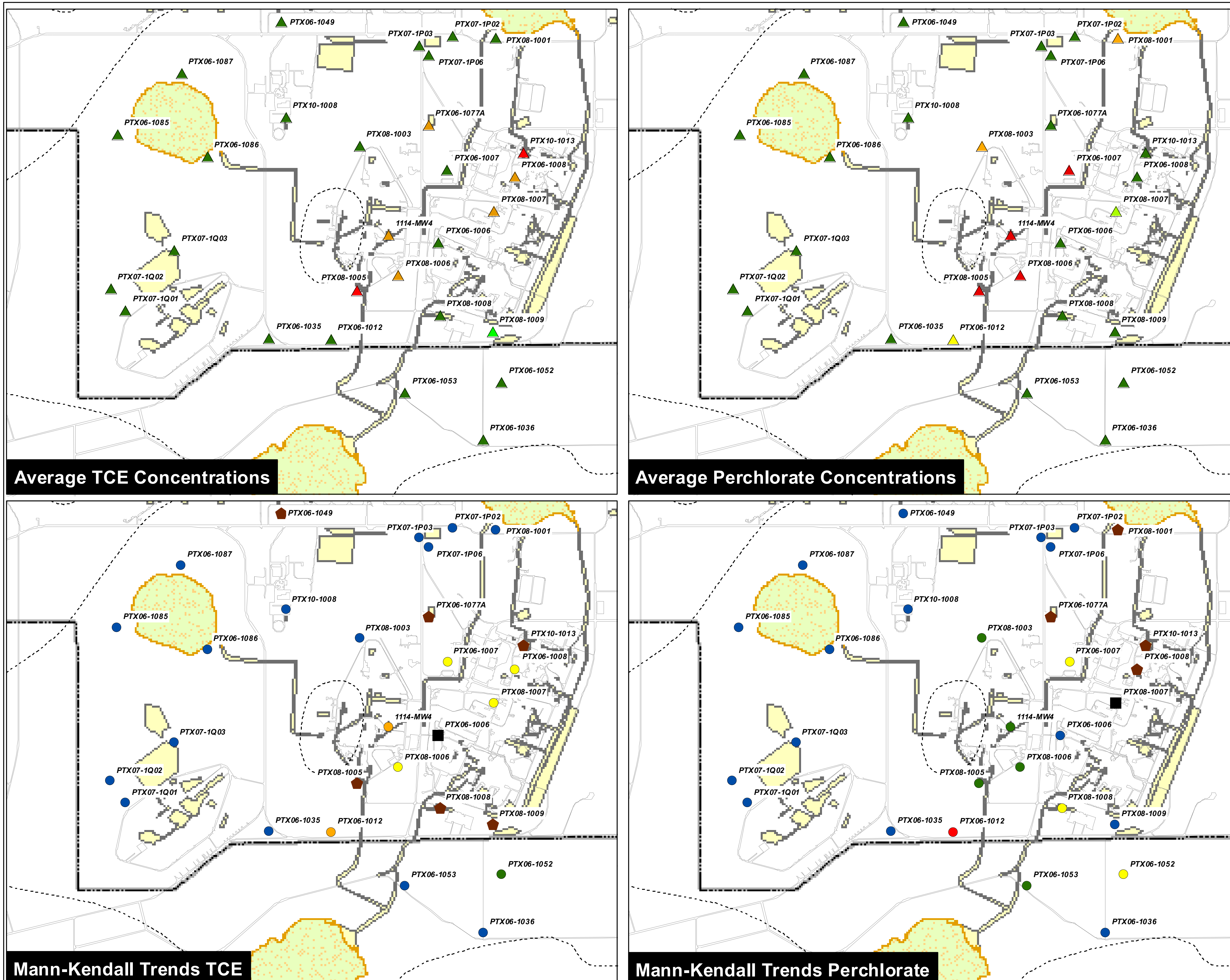
PANTEX SOUTHEAST PERCHED

RDX and 4ADNT First Moments and Mann-Kendall Trends

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		**FIGURE 4**


Pantex Southeast Sector
RDX Concentration Uncertainty
12-FEB-2008
G-3262
Figure 5
NORTH
EAST
3766000.0
3764000.0
3762000.0
3760000.0
3758000.0
3756000.0
3754000.0
3752000.0
3750000.0
636000.0
638000.0
640000.0
642000.0
644000.0
646000.0
648000.0
Higher uncertainty due to source characteristics and radial flow.
Recommended new well (to address TNT, 24DNT)
Recommended new well
PTX06-1023
PTX06-1013
PTX08-1002
PTX06-1069
PTX06-1002A
PTX06-1039A
PTX06-1003
PTX06-1040
PTX06-1010
PTX06-1041
PTX06-1011
PTX06-1088
PTX06-1005
PTX08-1008
PTX06-1042
PTX08-1009
PTX06-1030
PTX06-EW-46
PTX06-1102
PTX06-1052
PTX06-1053
PTX06-1015
PTX06-1031
PTX06-1036
PTX06-1045
PTX06-1046
PTX06-1034
PTX06-1047A
Note: Each node is a an investigation or extraction well location; not all location names are included.
New Location Analysis for
RDX Network Uncertainty
Existing Locations
Potential areas for new locations are indicated by triangles with a high SF level.
Estimated SF Level:
S - Small
M - Moderate
L - Large
E - Extremely large
High SF -> high estimation error -> possible need for new locations
Low SF -> low estimation error -> no need for new locations
Back to Access



N

LEGEND

Average Concentrations [mg/L]

	TCE	Perchlorate
▲ (dark green)	ND - 0.001	ND - 0.005
▲ (light green)	0.001 - 0.004	0.005 - 0.01
▲ (yellow)	0.004 - 0.005	0.01 - 0.026
▲ (orange)	0.005 - 0.015	0.026 - 0.1
▲ (red)	> 0.015	> 0.1

MSC TCE = 0.005 mg/L; Perchlorate = 0.026 mg/L

Mann-Kendall Trends

- Decreasing
- Probably Decreasing
- Stable
- Probably Increasing
- Increasing
- Non Detect (2000-2007)
- No Trend
- Insufficient Data

Notes:

1. Mann-Kendall trends were determined for TCE and perchlorate 2000-2007.
2. Only results for investigation wells are shown.
3. Average concentrations calculated using lowest detection limit substituted for ND values.

Scale (ft)

0 1,400 2,800

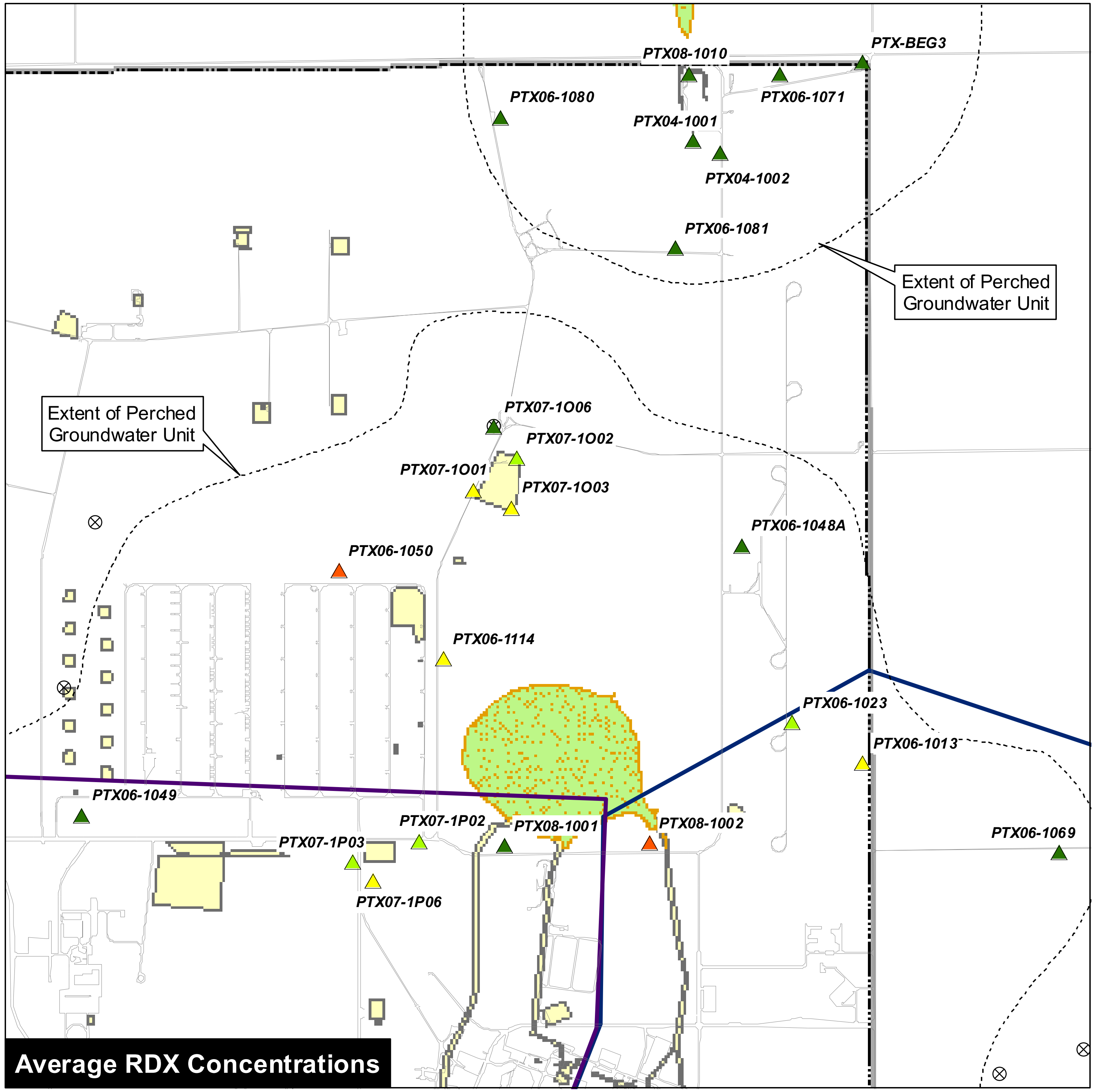
GSI ENVIRONMENTAL

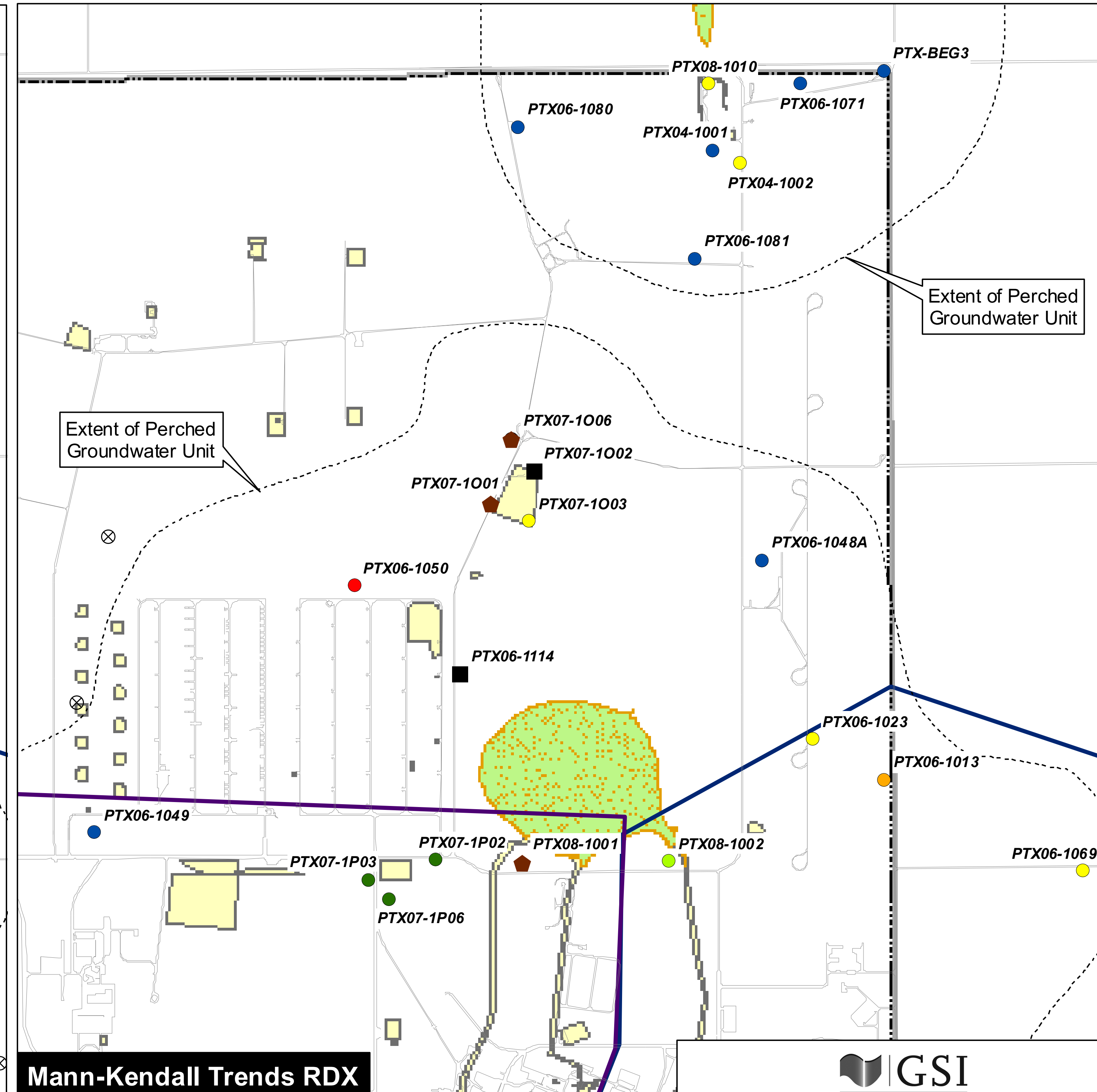
PANTEX SOUTHWEST SECTOR

TCE And Perchlorate Average Concentrations and Mann-Kendall Trends

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		FIGURE 6





LEGEND

Average RDX Concentration [mg/L]

- ND - 0.001
- 0.001 - 0.007
- 0.007 - 0.05
- 0.05 - 1.0
- > 1.0

Mann-Kendall Trend RDX

- Decreasing
- Probably Decreasing
- Stable
- Probably Increasing
- Increasing
- Non Detect (2000-2007)
- No Trend
- Insufficient Data

RRS 2 RDX = 0.0077 mg/L

Notes:

1. Average RDX concentrations calculated using lowest detection limit substituted for ND values. Data 2000-2007.
2. Mann Kendall trends were determined for RDX 2000-2007.
3. RDX is not detected in the area of the Burning Ground, Playa 3 and Pantex Lake.

N

Scale (ft)

0 900 1,800

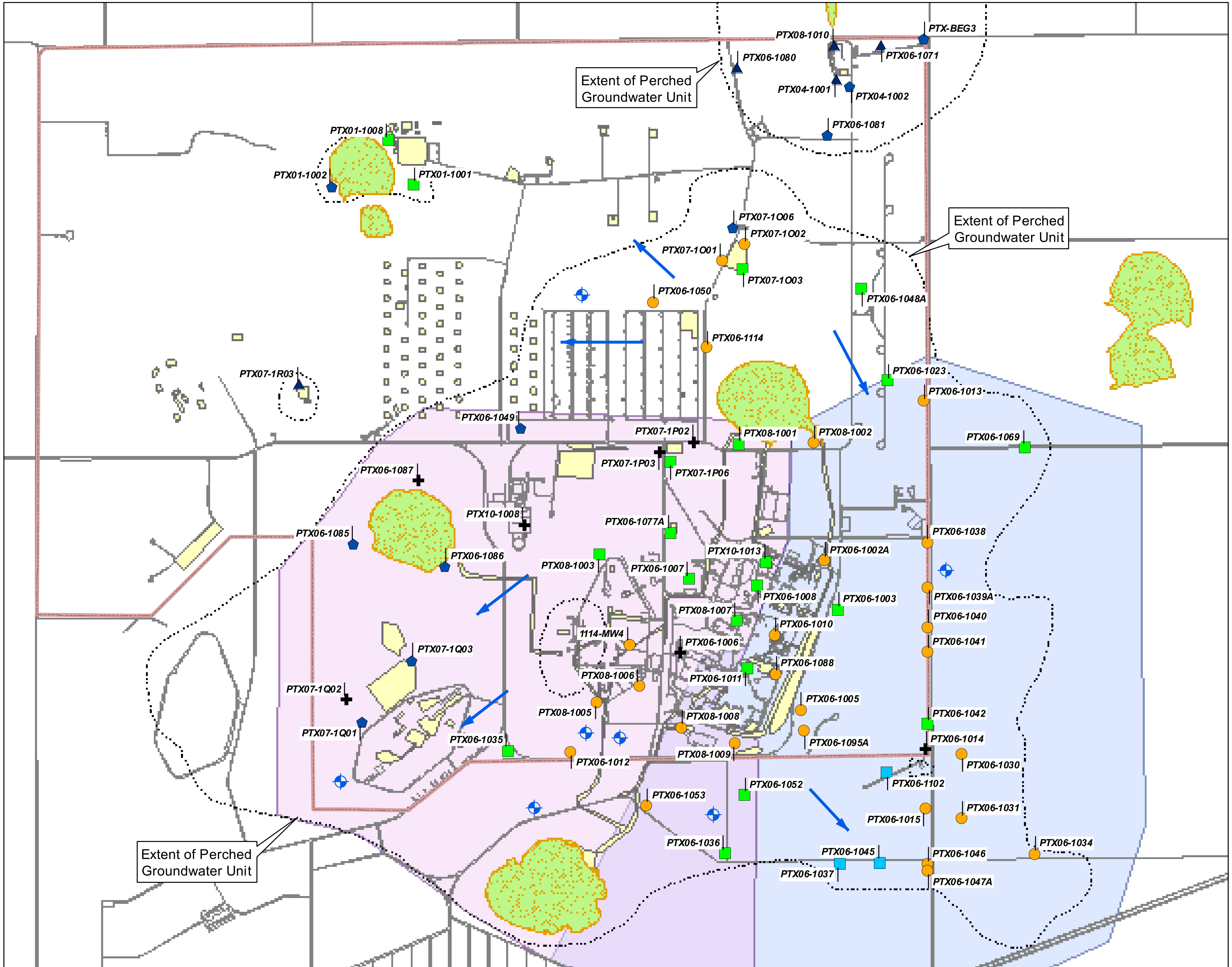
GSI ENVIRONMENTAL

PANTEX NORTH SECTOR PERCHED GROUNDWATER

RDX Average Concentrations and Mann-Kendall Trends

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		**FIGURE 7**



LEGEND

Recommended Sampling Frequency

- Semiannual
- Annual
- Annual HG
- Biennial
- Every 5 years
- Eliminate from routine monitoring
- Perched Proposed New Location

- Extent of Perched Water
- USDOE Property
- Playa Lakes
- SWMU
- Southwest Sector
- Southeast Sector
- Approximate Groundwater Flow Direction

Scale (ft)

0 1,250 2,500

GSI ENVIRONMENTAL

PANTEX PERCHED GROUNDWATER RECOMMENDED MONITORING NETWORK

Pantex Plant
Carson County, Texas

GIS Job No.	G-3262	Issued:	12-FEB-2008
Drawn By:	CDM	Revised:	----
Chk'd By:	MV	Map ID:	----
Appv'd By:	MV		**FIGURE 8**

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

TABLES

TABLE 1
PANTEX PLANT INVESTIGATION WELLS: PERCHED GROUNDWATER

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Earliest Sample Date	Most Recent Sample Date	Number of Samples (2000-2007)	Primary COC at Well	Risk Ratio	Monitoring Constituents					
						RDX	Cr (VI)	Perchlorate	Boron	TCE	4ADNT
Southeast Sector											
PTX06-1002A	7/26/2000	5/7/2007	7	RDX	6.23E+00	X				X	
PTX06-1003	5/1/2000	10/25/2006	7	RDX	2.05E+00				X		
PTX06-1005	1/26/2000	5/7/2007	8	RDX	1.74E+02	X	X			X	X
PTX06-1010	5/8/2000	5/17/2007	8	Cr (VI)	1.17E+02	X	X			X	
PTX06-1011	10/23/2000	5/17/2007	7	RDX	6.52E+00	X				X	
PTX06-1013*	11/20/2000	5/2/2007	11	RDX	1.49E+00	X					
PTX06-1014	11/30/2000	1/15/2007	14	RDX	2.31E+02	X			X		X
PTX06-1015	4/25/2000	2/15/2007	13	RDX	8.95E+01	X					X
PTX06-1023*	4/24/2000	1/17/2007	12	RDX	6.97E-01						
PTX06-1030	2/7/2000	2/12/2007	15	RDX	2.70E+02	X			X		X
PTX06-1031	2/7/2000	2/12/2007	15	RDX	8.71E+01	X					X
PTX06-1034	2/10/2000	2/12/2007	13	RDX	1.01E+01	X					X
PTX06-1036	3/20/2001	2/14/2007	13	4ADNT	9.17E-01						
PTX06-1037**	1/25/2000	5/17/2005	5	RDX	3.64E+02	X	X		X		X
PTX06-1038	1/31/2000	1/15/2007	14	RDX	1.79E+02	X					X
PTX06-1039A	1/31/2000	5/7/2007	11	RDX	1.77E+02	X			X		X
PTX06-1040	1/31/2000	1/15/2007	14	RDX	1.64E+02	X			X		X
PTX06-1041	1/24/2000	11/1/2006	12	RDX	1.69E+02	X			X		X
PTX06-1042	1/24/2000	1/15/2007	16	RDX	3.44E+02	X			X		X
PTX06-1045**	9/12/2000	10/23/2006	12	RDX	2.75E+02	X					X
PTX06-1046	1/5/2000	2/7/2007	17	RDX	1.24E+02	X					X
PTX06-1047A	3/20/2000	5/2/2007	14	RDX	5.84E+01	X					X
PTX06-1052	3/17/2000	2/14/2007	15	Cr (VI)	7.00E+01		X				
PTX06-1053	3/17/2000	2/14/2007	17	4ADNT	5.25E+00						X
PTX06-1069*	10/30/2001	7/26/2006	11	TNT	1.17E-01						
PTX06-1088	6/11/2003	5/17/2007	8	RDX	5.42E+01	X	X			X	X
PTX06-1095A	2/22/2007	5/8/2007	3	BORON	1.20E-01				X		
PTX06-1102**	6/1/2000	10/23/2006	10	RDX	1.57E+02	X					X
PTX08-1002*	2/1/2000	10/25/2006	7	RDX	3.60E+01	X			X		
PTX08-1008	2/1/2000	1/17/2007	11	Cr (VI)	1.40E+02		X				
PTX08-1009*	2/22/2001	5/22/2007	7	RDX	3.87E+00		X				
Southwest Sector											
1114-MW4	4/22/2002	5/21/2007	3	PERCHLORATE	1.29E+01			X		X	
PTX06-1006	7/27/2000	7/31/2003	3	Cr (VI)	1.00E-01						
PTX06-1007	4/17/2001	4/29/2003	3	4ADNT	1.23E+01			X			X
PTX06-1008	2/1/2000	10/27/2004	4	TCE	5.76E+00		X			X	
PTX06-1012	10/23/2000	1/30/2007	12	PERCHLORATE	1.68E+00			X			
PTX06-1035	4/19/2001	1/30/2007	10	4ADNT	1.92E+00						X
PTX06-1077A	2/20/2002	8/7/2006	4	TCE	3.04E+00					X	
PTX06-1085	5/27/2003	2/26/2004	4	BORON	7.56E-03						
PTX06-1086	5/27/2003	5/16/2007	8	RDX	2.44E+00	X					
PTX06-1087	5/27/2003	2/26/2004	4	BORON	8.86E-03						
PTX07-1Q01	4/16/2001	11/2/2006	5	26DNT	1.17E-01						
PTX07-1Q02	5/3/2001	11/2/2006	5	Cr (VI)	1.00E-01						
PTX07-1Q03	4/16/2001	5/16/2007	7	RDX	3.44E+00	X					
PTX08-1003	10/19/2000	11/2/2006	6	PERCHLORATE	1.47E+00			X			
PTX08-1005	4/25/2000	10/26/2006	6	TCE	2.52E+01					X	
PTX08-1006	4/25/2000	5/21/2007	8	4ADNT	3.87E+01	X		X		X	X
PTX08-1007	10/23/2000	7/30/2003	2	TCE	3.20E+00			X		X	
PTX10-1008	10/30/2001	10/26/2004	6	BORON	1.49E-02						
PTX10-1013	7/31/2000	10/26/2006	6	TCE	2.32E+01					X	
PTX06-1049*	3/16/2000	5/14/2007	11	TCE	3.08E-01						
PTX07-1P02*	1/23/2001	5/8/2007	6	RDX	5.45E-01		X				
PTX07-1P03*	4/19/2000	7/31/2003	4	RDX	9.61E-01						
PTX07-1P06*	3/15/2000	10/25/2006	10	RDX	1.42E+01	X					
PTX08-1001*	4/19/2001	5/8/2007	7	PERCHLORATE	2.71E+00		X	X			X

See Notes End of Table

TABLE 1
PANTEX PLANT INVESTIGATION WELLS: PERCHED GROUNDWATER

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Earliest Sample Date	Most Recent Sample Date	Number of Samples (2000-2007)	Primary COC at Well	Risk Ratio	Monitoring Constituents					
						RDX	Cr (VI)	Perchlorate	Boron	TCE	4ADNT
North Sector											
PTX01-1001	2/8/2000	5/14/2007	27	PERCHLORATE	5.62E+00			X			
PTX01-1002	4/17/2000	5/16/2007	26	PERCHLORATE	2.15E-01						
PTX01-1008**	8/1/2000	2/21/2007	13	TCE	1.46E+00						
PTX04-1001	1/26/2000	10/27/2003	6	TCE	4.00E-01						
PTX04-1002	1/22/2001	1/29/2007	12	26DNT	6.03E-01		X				
PTX06-1048A	3/16/2000	1/17/2007	15	TCE	8.20E-01						
PTX06-1050	3/20/2000	10/24/2006	10	RDX	7.09E+01	X			X		
PTX06-1071	8/20/2001	10/28/2004	8	Cr(VI)	1.16E-01						
PTX06-1080	8/9/2005	1/31/2007	12			No COPCs from site activities					
PTX06-1081	7/18/2002	1/31/2007	12	26DNT	3.65E-01						
PTX06-1114	2/22/2007	5/21/2007	2	RDX	4.10E+00	X					
PTX07-1O01	4/24/2000	10/24/2006	6	RDX	6.83E+00	X					
PTX07-1O02	4/18/2001	10/24/2006	3	RDX	1.23E+00						
PTX07-1O03	4/18/2001	5/14/2007	7	RDX	5.01E+00	X					
PTX07-1O06**	9/7/2000	10/28/2004	10	26DNT	2.40E-01						
PTX07-1R03**	5/29/2001	11/2/2006	8	Cr(VI)	1.90E-01						
PTX08-1010	8/9/2005	1/31/2007	15			No COCs above analytical detection limits					
PTX-BEG3	3/22/2001	1/29/2007	13	4ADNT	3.17E-01						
PTX06-1082	5/15/2003	11/1/2006	7			No COPCs from site activities					
PTX06-1083	5/15/2003	11/1/2006	7			No COPCs from site activities					

Notes:

1. Wells listed are investigation wells in current monitoring program. Extraction wells used in the analysis are listed in Appendix B.
   * = Well included in more than one Sector for spatial analysis.
   ** = Wells that are dry or intermittently dry, as indicated in database (BWXT, 2007a).
2. Data from B&W Pantex Plant database received September, 2007 (BWXT, 2007a).
3. Sampling dates for wells range from January 2000 (earliest sample dates) to July, 2007 (most recent sample dates). Data before 2000 may be available for some locations, but were not used in the analysis.
4. The priority chemical of concern (COC) at each well is the constituent detected at the highest level normalized by the MSC or appropriate RRS. The ratio is the maximum concentration of the COC divided by the screening level concentration. Values below 1 indicate no groundwater affected above MSC.
5. Number of samples is the number of individual sample dates in the database, results from duplicate samples from the same date are averaged and counted as one sample.
6. Monitoring constituents are those where the average concentration 2000-2007 is above the MSC.
7. RDX = Hexahydro, 1,3,5-trinitro, 1,3,5-triazine; TCE = trichloroethene, 4ADNT = 4-Amino, 2,6-dinitrotoluene; Cr(VI) = Hexavalent Chromium. 26DNT = 2,6-dinitrotoluene.

GSI ENVIRONMENTAL

TABLE 2
AQUIFER INPUT PARAMETERS

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Parameter	Units	Southeast	Southwest	North
Current Plume Length	ft	7000	6000	Various
Maximum Plume Length	ft	7000	6000	Various
Plume Width	ft	6400	6000	Various
Seepage Velocity (ft/yr)*	ft/yr	140	62	70
Distance to Receptors	ft	8000	10000	8000
Groundwater Fluctuations	--	No	No	No
Source Treatment	--	Pump and treat		
Plume Type	--	Explosives, VOCs		
NAPL Present		No	No	No
Number of investigation wells	--	31	29	29
Parameter		**Value**		
Groundwater flow direction		S/SE	S/SW	Various (45)
Porosity	--	0.25	0.25	0.25
Source Location near Well	--	PTX06-1010	PTX08-1006	Playa 1 (various)
Source X-Coordinate	ft	639886.625	636400.4375	639580.323
Source Y-Coordinate	ft	3758067	3756761.75	3764100.313
Coordinate System		NAD 83 SP Texas North FT		
Average Saturated Thickness Perched Zone	ft	30		
Priority Constituents		**MSC**	**Basis**	**Sectors Affected**
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	ug/L	7.7	GW-Res_c	All
4-Amino-2,6-Dinitrotoluene (4ADNT)	ug/L	1.2	GW-Res_{NCAdj}	All
2-Amino-4,6-Dinitrotoluene (2ADNT)	ug/L	1.2	GW-Res_{NCAdj}	Southeast
2,4,6-Trinitrotoluene (TNT)	ug/L	3.6	GW-Res_{NCAdj}	Southeast
2,4-Dinitrotoluene (24DNT)	ug/L	1	PQL	Southeast
Chromium (VI)	ug/L	100	MCL	Southeast
Perchlorate	ug/L	26	GW-Res_{NC}	Southwest
Trichloroethene	ug/L	5	MCL	Southwest

Notes:
1. Aquifer data from CMS/FS (BWXT, 2007a).
2. Priority COCs defined by prevalence, toxicity and mobility.
3. Saturated thickness represents an estimated average for the perched unit, which ranges from 0 to 70 ft in saturated thickness.
4. * = a range of transmissivites are present in the aquifer, and groundwater velocity is estimated for each sector.
5. MSC = Medium Specific Concentration, from CMS/FS (BWXT, 2007b).
   GW-Resc = TCEQ Standard No. 2 Groundwater MSC for Residential Use; NC = Noncarcinogenic; C = Carcinogenic;
   Adj = Value adjusted for a cumulative hazard index of 1; PQL = Practical Quantitation Limit; MCL = USEPA Maximum Contaminant Level.

MAROS COC Assessment

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Toxicity:

Contaminant of Concern	Representative Concentration (mg/L)	PRG (mg/L)	Percent Above PRG
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIA	7.7E-01	7.7E-03	9948.3%
4-AMINO-2,6-DINITROTOLUENE	7.5E-03	1.2E-03	524.2%
CHROMIUM, HEXAVALENT	5.8E-01	1.0E-01	480.9%
2-AMINO-4,6-DINITROTOLUENE	6.9E-03	1.2E-03	474.7%
2,4-DINITROTOLUENE	5.6E-03	1.0E-03	458.0%
2,4,6-TRINITROTOLUENE	9.7E-03	3.6E-03	170.2%
2,6-DINITROTOLUENE	1.7E-03	1.0E-03	66.0%
TRICHLOROETHYLENE (TCE)	6.8E-03	5.0E-03	35.6%
1,4-DIOXANE (P-DIOXANE)	8.1E-03	7.7E-03	4.8%

Note: Top COCs by toxicity were determined by examining a representative concentration for each compound over the entire site. The compound representative concentrations are then compared with the chosen PRG for that compound, with the percentage exceedance from the PRG determining the compound's toxicity. All compounds above exceed the PRG.

Prevalence:

Contaminant of Concern	Class	Total Wells	Total Exceedances	Percent Exceedances	Total detects
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE	ORG	79	69	87.3%	78
4-AMINO-2,6-DINITROTOLUENE	ORG	79	63	79.7%	74
2-AMINO-4,6-DINITROTOLUENE	ORG	79	55	69.6%	69
2,4-DINITROTOLUENE	ORG	79	51	64.6%	59
2,4,6-TRINITROTOLUENE	ORG	79	32	40.5%	58
CHROMIUM, HEXAVALENT	MET	55	16	29.1%	53
2,6-DINITROTOLUENE	ORG	78	20	25.6%	34
TRICHLOROETHYLENE (TCE)	ORG	79	19	24.1%	66
1,4-DIOXANE (P-DIOXANE)	ORG	34	0	0.0%	7

Note: Top COCs by prevalence were determined by examining a representative concentration for each well location at the site. The total exceedances (values above the chosen PRGs) are compared to the total number of wells to determine the prevalence of the compound.

Mobility:

Contaminant of Concern	Kd
1,4-DIOXANE (P-DIOXANE)	0.000479
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZI	0.00741
4-AMINO-2,6-DINITROTOLUENE	0.0985
2-AMINO-4,6-DINITROTOLUENE	0.0985
2,4,6-TRINITROTOLUENE	0.0985
2,6-DINITROTOLUENE	0.15
2,4-DINITROTOLUENE	0.15
TRICHLOROETHYLENE (TCE)	0.297
CHROMIUM, HEXAVALENT	14

TABLE 3 COC Assessment Southeast Sector

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Note: Top COCs by mobility were determined by examining each detected compound in the dataset and comparing their mobilities (Koc's for organics, assume foc = 0.001, and Kd's for metals).

Contaminants of Concern (COC's)

HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

2,4-DINITROTOLUENE

2-AMINO-4,6-DINITROTOLUENE

2,4,6-TRINITROTOLUENE

2,6-DINITROTOLUENE

TABLE 4
INVESTIGATION WELL TREND SUMMARY RESULTS SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

WellName	Number of Samples (2000 - 2007)	Number of Detects	Percent Detection	Maximum Concentration [ug/L]	Maximum Above MSC?	Average Concentration [ug/L]	Average Above MSC?	Mann-Kendall Trend	Linear Regression Trend	Overall Trend Result
RDX Southeast Sector										
PTX06-1002A	7	7	100%	**48**	Yes	**39.9**	Yes	S	S	S
PTX06-1003	7	6	86%	**16**	Yes	3.0	No	NT	NT	NT
PTX06-1005	8	8	100%	**1,340**	Yes	**581**	Yes	PD	PD	PD
PTX06-1010	8	6	75%	**673**	Yes	**181**	Yes	D	D	D
PTX06-1011	7	2	29%	**50**	Yes	7.3	No	NT	NT	NT
PTX06-1013	11	11	100%	**12**	Yes	**8.4**	Yes	I	I	I
PTX06-1014	14	14	100%	**1,780**	Yes	**1210**	Yes	I	I	I
PTX06-1015	13	13	100%	**689**	Yes	**366**	Yes	I	I	I
PTX06-1023	12	12	100%	5	No	3.9	No	S	S	S
PTX06-1030	15	15	100%	**2,080**	Yes	**1340**	Yes	I	I	I
PTX06-1031	15	15	100%	**671**	Yes	**331.0**	Yes	I	I	I
PTX06-1034	13	7	54%	**78**	Yes	**11.5**	Yes	I	I	I
PTX06-1036	13	6	46%	2	No	0.6	No	I	I	I
PTX06-1037	5	5	100%	**2,800**	Yes	**1860**	Yes	S	PD	S
PTX06-1038	14	14	100%	**1,380**	Yes	**795**	Yes	D	D	D
PTX06-1039A	11	11	100%	**1,360**	Yes	**702**	Yes	PD	D	D
PTX06-1040	14	14	100%	**1,260**	Yes	**874**	Yes	NT	NT	NT
PTX06-1041	12	12	100%	**1,300**	Yes	**885**	Yes	NT	D	S
PTX06-1042	16	16	100%	**2,650**	Yes	**1020**	Yes	S	PD	S
PTX06-1045	12	12	100%	**2,120**	Yes	**1160**	Yes	I	I	I
PTX06-1046	17	17	100%	**952**	Yes	**692**	Yes	I	I	I
PTX06-1047A	14	5	36%	**450**	Yes	**66**	Yes	I	I	I
PTX06-1052	15	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1053	17	2	12%	7	No	0.5	No	NT	PI	PI
PTX06-1069	11	1	9%	0.1	No	0.1	No	S	S	ND*
PTX06-1088	8	8	100%	**417**	Yes	**319**	Yes	PD	S	S
PTX06-1095A	3	1	33%	0.6	No	0.3	No	N/A	N/A	N/A
PTX06-1102	10	10	100%	**1,210**	Yes	**288**	Yes	PD	D	D
PTX08-1002	7	7	100%	**277**	Yes	**132**	Yes	PD	D	D
PTX08-1008	11	2	18%	0.1	No	0.1	No	S	PD	S
PTX08-1009	7	4	57%	**30**	Yes	2.6	No	NT	NT	NT
4ADNT Southeast Sector										
PTX06-1002A	7	6	86%	1	No	0.619	No	S	NT	S
PTX06-1003	7	2	29%	0.31	No	0.13	No	S	PD	S
PTX06-1005	8	5	63%	**7.5**	Yes	**2.37**	Yes	PI	NT	PI
PTX06-1010	8	3	38%	**3.7**	Yes	1.1	No	D	D	D
PTX06-1011	7	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1013	11	1	9%	0.094	No	0.0995	No	S	I	ND*
PTX06-1014	13	12	92%	**32.9**	Yes	**8.94**	Yes	D	S	PD
PTX06-1015	13	13	100%	**22.3**	Yes	**14.7**	Yes	S	D	PD
PTX06-1023	12	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1030	13	12	92%	**10.1**	Yes	**5**	Yes	I	PI	PI
PTX06-1031	14	14	100%	**4.7**	Yes	**2.66**	Yes	I	I	I
PTX06-1034	15	14	93%	**3.9**	Yes	**1.81**	Yes	I	I	I
PTX06-1036	13	10	77%	1.1	No	0.387	No	D	D	D
PTX06-1037	5	5	100%	**22**	Yes	**18.1**	Yes	S	S	S
PTX06-1038	14	12	86%	**32.9**	Yes	**13.3**	Yes	NT	NT	NT
PTX06-1039A	11	9	82%	**21.1**	Yes	**8.47**	Yes	PI	NT	PI
PTX06-1040	14	14	100%	**29.2**	Yes	**17.8**	Yes	S	S	S
PTX06-1041	12	12	100%	**28.4**	Yes	**18.2**	Yes	NT	NT	NT
PTX06-1042	16	11	69%	**10.1**	Yes	**3.32**	Yes	I	I	I
PTX06-1045	11	7	64%	**12.9**	Yes	**4.7**	Yes	NT	NT	NT
PTX06-1046	17	11	65%	**15.8**	Yes	**5.16**	Yes	I	I	I
PTX06-1047A	14	5	36%	**9.3**	Yes	**1.86**	Yes	I	I	I
PTX06-1052	15	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1053	17	13	76%	**6.3**	Yes	**1.64**	Yes	I	I	I
PTX06-1069	11	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1088	8	6	75%	**4.6**	Yes	**1.98**	Yes	NT	PI	PI
PTX06-1095A	3	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1102	9	7	78%	**8.51**	Yes	**3.35**	Yes	S	NT	S
PTX08-1002	7	4	57%	**2.8**	Yes	0.636	No	NT	NT	NT
PTX08-1008	11	9	82%	**1.8**	Yes	0.531	No	S	S	S
PTX08-1009	7	3	43%	**3.02**	Yes	0.771	No	NT	I	PI

Notes

1. Trends were evaluated for data collected between January 2000 and May 2007.
2. Number of Samples is the number of samples for the compound at this location during 2000 - 2007.
   Number of Detects is the number of samples where the compound was detected at this location.
3. The maximum concentration for the COC is the maximum analytical result analyzed between 2000 and 2007. Results above MSCs are indicated in **Bold**.
4. MSCs = Medium Specific Concentration from Corrective Measure Study. RDX = 7.7 ug/L; 4ADNT = 1.2 ug/L.
5. Maximum and average concentrations for wells with no detections are representative of the detection limits for the analyses.
6. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend;
   NT = No Trend; ND = well has all non-detect results for COC; ND* = one detection for compound, may be unaffected.
7. Mann-Kendall trend results are illustrated on Figure 3.

TABLE 5
WELL REDUNDANCY ANALYSIS SUMMARY RESULTS SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	RDX Average Slope Factor	Preliminary Statistical Result	4ADNT Average Slope Factor	Preliminary Statistical Result	Recommendation After Qualitative Review
PTX06-1002A	0.31	Retain	0.34	Retain	Retain
PTX06-1003	0.88	Retain	1.00	Retain	Retain
PTX06-1005	*0.20*	Retain	*0.19*	Retain	Retain
PTX06-1010	0.39	Retain	1.00	Retain	Retain
PTX06-1011	0.64	Retain	1.00	Retain	Retain
PTX06-1013	0.59	Retain	1.00	Retain	Retain
PTX06-1014	*0.04*	Retain	*0.09*	**Eliminate**	**Eliminate**
PTX06-1015	*0.05*	Retain	*0.14*	**Eliminate**	Retain, Consider future elimination
PTX06-1023	0.45	Retain	1.00	Retain	Retain
PTX06-1030	*0.07*	Retain	*0.13*	**Eliminate**	Retain
PTX06-1031	*0.03*	Retain	0.25	Retain	Retain
PTX06-1034	0.32	Retain	*0.14*	Retain	Retain
PTX06-1036	0.51	Retain	0.72	Retain	Retain
PTX06-1037	N/A	Retain	N/A	Retain	Retain
PTX06-1038	*0.04*	Retain	*0.05*	**Eliminate**	Retain, Consider future elimination
PTX06-1039A	*0.00*	**Eliminate**	*0.11*	Retain	Retain, Consider future elimination
PTX06-1040	*0.09*	Retain	0.28	Retain	Retain
PTX06-1041	*0.06*	Retain	0.20	Retain	Retain
PTX06-1042	*0.04*	Retain	*0.09*	**Eliminate**	Retain, Consider future elimination
PTX06-1045	*0.12*	Retain	*0.12*	Retain	Retain
PTX06-1046	*0.09*	Retain	*0.15*	Retain	Retain
PTX06-1047A	*0.12*	Retain	*0.08*	Retain	Retain
PTX06-1052	1.00	Retain	1.00	Retain	Retain
PTX06-1053	0.66	Retain	0.82	Retain	Retain
PTX06-1069	1.00	Retain	1.00	Retain	Retain
PTX06-1088	0.30	Retain	0.51	Retain	Retain
PTX06-1095A	1.00	Retain	1.00	Retain	Retain
PTX06-1102	0.41	Retain	N/A	Retain	Retain
PTX08-1002	0.27	Retain	0.49	Retain	Retain
PTX08-1008	1.00	Retain	0.49	Retain	Retain
PTX08-1009	0.92	Retain	0.33	Retain	Retain

Notes:
1. Slope Factor (SF) is the difference between the actual concentration and the concentration estimated from nearby wells normalized by the actual concentration. Slope factors close to 1 show the concentrations cannot be estimated from the adjacent wells, and the well is important in the network.
2. Slope factors were calculated using data collected between July 2005 and May 2007.
3. Well locations with slope factors below 0.3 and area ratios below 0.8 were considered for elimination.
4. N/A = Locations with insufficient data between 2005 - 2007 to calculate a slope factor.
5. Locations identified for future elimination should be reviewed, and possibly removed from the program after 5 years of data collection.

TABLE 6
SAMPLING FREQUENCY ANALYSIS RESULTS SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Recent Concentration Rate of Change [mg/yr]	Recent MK Trend (2005-2007)	Sampling Frequency Based on Recent Data (2005-2007)	Overall Concentration Rate of Change [mg/yr]	Overall MK Trend (2000 - 2007)	Sampling Frequency Based on Overall Data (2000 - 2007)	MAROS Recommended Sampling Frequency	Current Sampling Frequency
RDX Southeast Sector								
PTX06-1002A	--	N/A	--	-9.85E-07	S	Quarterly	Quarterly	Annual
PTX06-1003	--	N/A	--	-3.56E-06	NT	Annual	Annual	Annual
PTX06-1005	--	N/A	--	-4.16E-04	PD	Quarterly	Quarterly	Annual
PTX06-1010	--	N/A	--	-2.26E-04	D	Quarterly	Quarterly	Annual
PTX06-1011	--	N/A	--	8.34E-06	NT	Quarterly	Quarterly	Annual
PTX06-1013	--	N/A	--	1.32E-06	I	Quarterly	Quarterly	Annual
PTX06-1014	3.06E-04	S	Quarterly	2.30E-04	I	Quarterly	Quarterly	Semiannual
PTX06-1015	-3.23E-04	S	Annual	2.39E-04	I	Quarterly	Quarterly	Semiannual
PTX06-1023	-4.84E-06	S	Annual	-3.68E-07	S	Annual	Annual	Semiannual
PTX06-1030	-2.47E-04	S	Annual	2.89E-04	I	Quarterly	Quarterly	Semiannual
PTX06-1031	1.03E-04	S	Quarterly	2.63E-04	I	Quarterly	Quarterly	Semiannual
PTX06-1034	-9.48E-05	S	Annual	1.45E-05	I	Semiannual	Semiannual	Semiannual
PTX06-1036	-4.28E-07	S	Annual	9.17E-07	I	Annual	Biennial	Semiannual
PTX06-1037*	--	N/A	--	--	S	--	--	Dry
PTX06-1038	2.44E-04	NT	Quarterly	-1.13E-04	D	Annual	Quarterly	Semiannual
PTX06-1039A	--	N/A		-1.51E-04	PD	Quarterly	Quarterly	Annual
PTX06-1040	-2.06E-04	S	Annual	4.17E-05	NT	Quarterly	Quarterly	Semiannual
PTX06-1041	--	N/A		-2.93E-06	NT	Quarterly	Quarterly	Annual
PTX06-1042	-5.64E-04	S	Annual	-1.83E-04	S	Annual	Annual	Semiannual
PTX06-1045*	--	N/A		4.56E-04	I	Quarterly	Quarterly	Annual
PTX06-1046	5.74E-05	NT	Quarterly	1.70E-04	I	Quarterly	Quarterly	Semiannual
PTX06-1047A	--	N/A	--	1.46E-04	I	Quarterly	Quarterly	Annual
PTX06-1052	--	ND	Annual	-3.62E-39	ND	Annual	Biennial	Semiannual
PTX06-1053	-1.10E-05	NT	Annual	5.65E-07	NT	Annual	Annual	Semiannual
PTX06-1069	--	N/A	--	-5.04E-09	S	Annual	Annual	Semiannual
PTX06-1088	--	N/A	--	-4.63E-05	PD	Quarterly	Quarterly	Annual
PTX06-1095A	--	N/A	--	--	N/A	--	Annual	New Location
PTX06-1102*	--	N/A	--	-1.86E-04	PD	Quarterly	Quarterly	Biennial
PTX08-1002	--	N/A	--	-5.81E-05	PD	Quarterly	Quarterly	Annual
PTX08-1008	--	S	Annual	-6.51E-09	S	Annual	Biennial	Semiannual
PTX08-1009	--	N/A	--	2.06E-06	NT	Quarterly	Quarterly	Annual

See Notes End of Table

TABLE 6
SAMPLING FREQUENCY ANALYSIS RESULTS SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Recent Concentration Rate of Change [mg/yr]	Recent MK Trend (2005-2007)	Sampling Frequency Based on Recent Data (2005-2007)	Overall Concentration Rate of Change [mg/yr]	Overall MK Trend (2000 - 2007)	Sampling Frequency Based on Overall Data (2000 - 2007)	MAROS Recommended Sampling Frequency	Current Sampling Frequency
4ADNT Southeast Sector								
PTX06-1002A	--	N/A	--	5.68E-08	S	Semiannual	Semiannual	Annual
PTX06-1003	--	N/A	--	-4.91E-08	S	Annual	Annual	Annual
PTX06-1005	--	N/A	--	1.18E-06	PI	Quarterly	Quarterly	Annual
PTX06-1010	--	N/A	--	-1.43E-06	D	Annual	Annual	Annual
PTX06-1011	--	N/A	--	0.00E+00	S	Annual	Annual	Annual
PTX06-1013	--	N/A	--	1.36E-10	S	Annual	Annual	Annual
PTX06-1014	-9.81E-06	S	Annual	-3.31E-06	D	Annual	Annual	Semiannual
PTX06-1015	-6.14E-06	S	Annual	-3.77E-07	S	Annual	Annual	Semiannual
PTX06-1023	0.00E+00	S	Annual	0.00E+00	S	Annual	Biennial	Semiannual
PTX06-1030	1.18E-05	I	Quarterly	2.53E-06	I	Semiannual	Quarterly	Semiannual
PTX06-1031	-9.84E-07	S	Annual	7.25E-07	I	Annual	Annual	Semiannual
PTX06-1034	-5.49E-07	S	Annual	1.58E-06	I	Annual	Annual	Semiannual
PTX06-1036	-8.09E-09	S	Annual	-3.82E-07	D	Annual	Biennial	Semiannual
PTX06-1037*	--	N/A	--	--	N/A	--	--	Dry
PTX06-1038	1.09E-05	NT	Quarterly	2.76E-06	NT	Semiannual	Quarterly	Semiannual
PTX06-1039A	--	N/A	--	3.82E-06	PI	Quarterly	Quarterly	Annual
PTX06-1040	2.79E-06	NT	Semiannual	-1.38E-06	S	Annual	Semiannual	Semiannual
PTX06-1041	--	N/A	--	7.15E-08	NT	Quarterly	Quarterly	Annual
PTX06-1042	-3.42E-06	S	Annual	2.39E-06	I	Semiannual	Semiannual	Semiannual
PTX06-1045*	--	N/A	--	3.34E-06	NT	Quarterly	Quarterly	Annual
PTX06-1046	1.22E-05	NT	Quarterly	3.22E-06	I	Semiannual	Quarterly	Semiannual
PTX06-1047A	--	N/A	--	3.55E-06	I	Quarterly	Quarterly	Annual
PTX06-1052	0.00E+00	S	Annual	-3.62E-39	S	Annual	Biennial	Semiannual
PTX06-1053	-6.32E-06	D	Annual	1.63E-06	I	Annual	Annual	Semiannual
PTX06-1069	--	N/A	--	-4.26E-39	S	Annual	Annual	Semiannual
PTX06-1088	--	N/A	--	3.08E-06	NT	Quarterly	Quarterly	Annual
PTX06-1095A	--	N/A	--	0.00E+00	N/A	Annual	Annual	New Location
PTX06-1102*	--	--	--	--	--	--	--	Biennial
PTX08-1002	--	N/A	--	-1.22E-07	NT	Annual	Annual	Annual
PTX08-1008	-7.85E-07	D	Annual	1.43E-08	S	Annual	Biennial	Semiannual
PTX08-1009	--	N/A	--	1.12E-06	NT	Quarterly	Quarterly	Annual

Notes:

1. 'Recent' concentration rate of change and MK trends are calculated from data collected 2005 - 2007.
2. MK = Mann Kendall Trend; D = Decreasing, PD = Probably Decreasing, S = Stable, NT = No Trend, PI = Probably Increasing, I = Increasing, ND = Non-detect, N/A = insufficient data, less than 4 sample events for time interval indicated.
3. Overall rate of change and MK trend are for the full data set (2000-2007) for each well.
4. MAROS Recommended Sampling Frequency is the sampling frequency from MAROS based on both recent and overall trends.
5. Current sampling frequency is the approximate sampling frequency currently implemented.
6. The final recommended sampling frequency is listed on Table 7, and is based on a combination of qualitative and statistical evaluations.
7. * = Well is dry or intermittently dry. Dry wells should be evaluated periodically for saturation.

GSI ENVIRONMENTAL

TABLE 7
FINAL RECOMMENDED MONITORING NETWORK SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	RDX			4ADNT			Sampling Recommendation	Rationale
	Percent Detection	Mann Kendall Trend	Average SF	Percent Detection	Mann Kendall Trend	Average SF		
Southeast Sector								
PTX06-1002A	100%	S	0.31	86%	S	0.34	Semiannual	Source monitoring for RDX
PTX06-1003	86%	NT	0.88	29%	S	1.00	Annual	Downgradient from source, spatially important to track reduction in concentrations.
PTX06-1005	100%	PD	0.20	63%	PI	0.19	Semiannual	Downgradient from source, spatially important to track reduction in concentrations.
PTX06-1010	75%	D	0.39	38%	D	1.00	Semiannual	Source area monitors decreasing trends
PTX06-1011	29%	NT	0.64	0%	ND	1.00	Annual	Monitors near TCE plume, near variable groundwater flow direction.
PTX06-1013	100%	I	0.59	9%	S	1.00	Semiannual	Monitors northern edge of Southeast Sector near Playa1.
PTX06-1014	100%	I	0.04	92%	D	0.09	***Eliminate***	Redundant with PTX06-1030, PTX06 1042.
PTX06-1015	100%	I	0.05	100%	S	0.14	Semiannual	Downgradient, center of plume, monitors movement of COCs toward edge of unit.
PTX06-1023	100%	S	0.45	0%	ND	1.00	Annual	Delineates northern most area of Southeast Sector near Playa 1.
PTX06-1030	100%	I	0.07	92%	I	0.13	Semiannual	Easternmost well, monitors edge of plume before unit pinches out.
PTX06-1031	100%	I	0.03	100%	I	0.25	Semiannual	Easternmost well, monitors edge of plume before unit pinches out.
PTX06-1034	54%	I	0.32	93%	I	0.14	Semiannual	Easternmost well, monitors edge of plume before unit pinches out.
PTX06-1036	46%	I	0.51	77%	D	0.72	Annual	Delineates southern edge of plume, monitors movement of COCs from south of Zones 11 and 12 toward southern edge of perched unit.
PTX06-1037	100%	S	N/A	100%	S	N/A	Annual HG	Well possibly dry, perform hydrogeologic monitoring to confirm saturation status.
PTX06-1038	100%	D	0.04	86%	NT	0.05	Semiannual	Monitors decreasing trends along DOE property line, consider removing from program after 4 more sampling events.
PTX06-1039A	100%	PD	0.00	82%	PI	0.11	Semiannual	Monitors DOE property boundary, no wells east of this point, may be redundant, but more data required.
PTX06-1040	100%	NT	0.09	100%	S	0.28	Semiannual	Monitors high concentrations along DOE property line, no wells in saturated perched groundwater east of this point.
PTX06-1041	100%	NT	0.06	100%	NT	0.20	Semiannual	Monitors high concentrations along DOE property line, no wells in saturated perched groundwater east of this point.
PTX06-1042	100%	S	0.04	69%	I	0.09	Annual	Monitors high concentrations along DOE property line, no wells in saturated perched groundwater east of this point.

See Notes End of Table

TABLE 7
FINAL RECOMMENDED MONITORING NETWORK SOUTHEAST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	RDX Percent Detection	RDX Mann Kendall Trend	RDX Average SF	4ADNT Percent Detection	4ADNT Mann Kendall Trend	4ADNT Average SF	Sampling Recommendation	Rationale
Southeast Sector								
PTX06-1045	100%	I	0.12	64%	NT	0.12	Annual HG	Well possibly dry, perform hydrogeologic monitoring to confirm saturation status.
PTX06-1046	100%	I	0.09	65%	I	0.15	Semiannual	Monitors southern extent of perched unit, high and increasing concentrations of COCs.
PTX06-1047A	36%	I	0.12	36%	I	0.08	Semiannual	Monitors southern extent of perched unit, high and increasing concentrations of COCs.
PTX06-1052	0%	ND	1.00	0%	ND	1.00	Annual	Monitors unaffected groundwater south of source.
PTX06-1053	12%	NT	0.66	76%	I	0.82	Semiannual	Delineates 4ADNT plume to south, near groundwater flow divide, early warning for movement of COCs to south/southeastern extent of perched groundwater.
PTX06-1069	9%	S	1.00	0%	ND	1.00	Annual	Delineation of northern sector of perched groundwater.
PTX06-1088	100%	PD	0.30	75%	NT	0.51	Semiannual	Source area monitors decreasing trends, important for 1,3,5-trinitrobenzene.
PTX06-1095A	33%	N/A	1.00	0%	ND	1.00	Semiannual	Downgradient from source, spatially important to track reduction in concentrations.
PTX06-1102	100%	PD	0.41	78%	S	N/A	Annual HG	Well possibly dry, perform hydrogeologic monitoring to confirm saturation status.
PTX08-1002	100%	PD	0.27	57%	NT	0.49	Semiannual	Monitors decreasing source area near Playa 1
PTX08-1008	18%	S	1.00	82%	S	0.49	Semiannual	Chromium monitoring location
PTX08-1009	57%	NT	0.92	43%	NT	0.33	Semiannual	Chromium monitoring location

Notes:
1. HG = Well is either dry or intermittently dry; monitor well at indicated frequency for saturation.
2. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine result; NT = No Trend; ND = well has all non-detect results for COC indicated.
3. Mann-Kendall trends for 2000 - 2007 are shown.
4. SF = Slope Factor. SF close to 1 indicates well provides unique information in network. SF near 0 indicates well may be redundant.
5. Percent detection is the ratio of the number of detections to the number of samples for the compound indicated multiplied by 100.

MAROS COC Assessment

Project: Pantex SW **User Name:** MV

Location: Southwest Area **State:** Texas

Toxicity:

Contaminant of Concern	Representative Concentration (mg/L)	PRG (mg/L)	Percent Above PRG
CHROMIUM, HEXAVALENT	3.6E-01	1.0E-01	260.9%
4-AMINO-2,6-DINITROTOLUENE	2.0E-03	1.2E-03	67.7%
PERCHLORATE	3.4E-02	2.6E-02	31.9%
TRICHLOROETHYLENE (TCE)	6.1E-03	5.0E-03	21.4%

Note: Top COCs by toxicity were determined by examining a representative concentration for each compound over the entire site. The compound representative concentrations are then compared with the chosen PRG for that compound, with the percentage exceedance from the PRG determining the compound's toxicity. All compounds above exceed the PRG.

Prevalence:

Contaminant of Concern	Class	Total Wells	Total Exceedances	Percent Exceedances	Total detects
TRICHLOROETHYLENE (TCE)	ORG	29	7	24.1%	14
PERCHLORATE	INO	29	6	20.7%	14
4-AMINO-2,6-DINITROTOLUENE	ORG	29	4	13.8%	11
CHROMIUM, HEXAVALENT	MET	29	2	6.9%	23

Note: Top COCs by prevalence were determined by examining a representative concentration for each well location at the site. The total exceedances (values above the chosen PRGs) are compared to the total number of wells to determine the prevalence of the compound.

Mobility:

Contaminant of Concern	Kd
PERCHLORATE	
4-AMINO-2,6-DINITROTOLUENE	0.0985
TRICHLOROETHYLENE (TCE)	0.297
CHROMIUM, HEXAVALENT	14

Note: Top COCs by mobility were determined by examining each detected compound in the dataset and comparing their mobilities (Koc's for organics, assume foc = 0.001, and Kd's for metals).

Contaminants of Concern (COC's)

TRICHLOROETHYLENE (TCE)

PERCHLORATE

4-AMINO-2,6-DINITROTOLUENE

HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

CHROMIUM, HEXAVALENT

TABLE 9
INVESTIGATION WELL TREND SUMMARY RESULTS SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson, Texas

Well Name	Number of Samples (2000 - 2007)	Number of Detects	Percent Detection	Maximum Concentration [ug/L]	Maximum Above MSC?	Average Concentration [ug/L]	Average Above MSC?	Mann-Kendall Trend	Linear Regression Trend	Overall Trend Result
TCE Southwest Sector										
1114-MW4	6	6	100%	**14.7**	Yes	**8.97**	Yes	PI	I	PI
PTX06-1006	3	1	33%	0.5	No	0.5	No	N/A	N/A	N/A
PTX06-1007	6	5	83%	0.8	No	0.5	No	S	S	S
PTX06-1008	5	5	100%	**28.8**	Yes	**15.1**	Yes	S	S	S
PTX06-1012	12	4	33%	2.3	No	0.8	No	PI	I	PI
PTX06-1035	10	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX06-1036	13	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX06-1049	11	1	9%	1.5	No	0.6	No	NT	PI	ND*
PTX06-1052	15	7	47%	1.4	No	0.7	No	D	D	D
PTX06-1053	17	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX06-1077A	6	5	83%	**15.2**	Yes	**10.3**	Yes	NT	NT	NT
PTX06-1085	4	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX06-1086	8	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX06-1087	4	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1P02	7	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1P03	4	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1P06	10	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1Q01	5	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1Q02	5	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX07-1Q03	7	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX08-1001	7	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX08-1003	6	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX08-1005	6	6	100%	**126.0**	Yes	**57.1**	Yes	NT	NT	NT
PTX08-1006	8	8	100%	**8**	Yes	**5.3**	Yes	S	S	S
PTX08-1007	4	4	100%	**16.0**	Yes	**13.6**	Yes	S	S	S
PTX08-1008	11	3	27%	1	No	0.5	No	NT	PI	PI
PTX08-1009	8	6	75%	2.1	No	1.0	No	NT	NT	NT
PTX10-1008	6	0	0%	0.5	No	0.5	No	ND	ND	ND
PTX10-1013	7	7	100%	**116.0**	Yes	**46.5**	Yes	NT	PI	PI
Perchlorate Southwest Sector										
1114-MW4	5	5	100%	**336**	Yes	**236**	Yes	D	D	D
PTX06-1006	4	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1007	6	6	100%	**128**	Yes	**111**	Yes	S	S	S
PTX06-1008	4	1	25%	5.04	No	2.39	No	NT	NT	ND*
PTX06-1012	12	4	33%	**43.8**	Yes	12.6	No	I	I	I
PTX06-1035	10	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1036	12	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1049	9	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1052	14	1	7%	4.57	No	1.72	No	S	PD	ND*
PTX06-1053	16	4	25%	5.72	No	2.35	No	D	D	D
PTX06-1077A	4	2	50%	5.99	No	3.48	No	NT	PI	PI
PTX06-1085	4	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1086	8	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX06-1087	4	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1P02	7	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1P03	4	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1P06	9	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1Q01	5	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1Q02	5	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX07-1Q03	7	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX08-1001	7	7	100%	**70.5**	Yes	**61.1**	Yes	NT	PI	PI
PTX08-1003	7	7	100%	**38.3**	Yes	**31.2**	Yes	D	D	D
PTX08-1005	5	5	100%	**386**	Yes	**230**	Yes	D	D	D
PTX08-1006	9	9	100%	**408**	Yes	**178**	Yes	D	D	D
PTX08-1007	3	2	67%	12.3	No	7	No	N/A	N/A	N/A
PTX08-1008	12	1	8%	5.05	No	1.8	No	S	D	ND*
PTX08-1009	7	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX10-1008	6	0	0%	1.5	No	1.5	No	ND	ND	ND
PTX10-1013	7	2	29%	6.79	No	2.75	No	NT	NT	NT

See Notes End of Table

TABLE 9
INVESTIGATION WELL TREND SUMMARY RESULTS SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson, Texas

Well Name	Number of Samples (2000 - 2007)	Number of Detects	Percent Detection	Maximum Concentration [ug/L]	Maximum Above MSC?	Average Concentration [ug/L]	Average Above MSC?	Mann-Kendall Trend	Linear Regression Trend	Overall Trend Result
4ADNT Southwest Sector										
1114-MW4	3	1	33%	0.545	No	0.248	No	N/A	N/A	N/A
PTX06-1006	3	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1007	3	3	100%	**14.8**	Yes	**11.7**	Yes	N/A	N/A	N/A
PTX06-1008	4	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1012	12	1	8%	0.079	No	0.0977	No	NT	NT	ND*
PTX06-1035	10	8	80%	**48.5**	Yes	**5.65**	Yes	NT	NT	NT
PTX06-1036	13	10	77%	1.1	No	0.387	No	D	D	D
PTX06-1049	11	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1052	15	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1053	17	13	76%	**6.3**	Yes	**1.64**	Yes	I	I	I
PTX06-1077A	4	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1085	4	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1086	8	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX06-1087	4	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX07-1P02	6	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX07-1P03	4	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX07-1P06	10	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX07-1Q01	5	1	20%	0.072	No	0.1	No	S	S	ND*
PTX07-1Q02	5	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX07-1Q03	7	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX08-1001	7	1	14%	**2.4**	Yes	0.4	No	NT	PD	ND*
PTX08-1003	6	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX08-1005	6	6	100%	**2.3**	Yes	1.5	Yes	D	D	D
PTX08-1006	8	8	100%	**47.8**	Yes	**38.1**	Yes	NT	NT	NT
PTX08-1007	2	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX08-1008	11	9	82%	**1.8**	Yes	0.5	No	S	S	S
PTX08-1009	7	3	43%	**3.02**	Yes	0.8	No	NT	I	PI
PTX10-1008	6	0	0%	0.1	No	0.1	No	ND	ND	ND
PTX10-1013	6	0	0%	0.1	No	0.1	No	ND	ND	ND

Notes

1. Trends were evaluated for data collected between January 2000 and May 2007.
2. Number of Samples is the number of samples for the compound at this location.
   Number of Detects is the number of samples where the compound was detected at this location.
3. Maximum Result is the maximum concentration for the COC analyzed between 2000 and 2007. Results above MSCs are indicated in **Bold**.
4. Screening level from Corrective Measure Study. TCE = 5 ug/L; Perchlorate = 26 ug/L; 4ADNT = 1.2 ug/L.
5. Maximum and average concentrations for wells with no detections are representative of the detection limits for the analyses.
6. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend;
   NT = No Trend; ND = well has all non-detect results for COC, ND* = one detection for compound, may be unaffected.

GSI ENVIRONMENTAL

TABLE 10
WELL REDUNDANCY ANALYSIS SUMMARY RESULTS SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Perchlorate Average Slope Factor	Preliminary Statistical Result	TCE Average Slope Factor	Preliminary Statistical Result	Recommendation After Qualitative Review
1114-MW4	0.49	Retain	0.43	Retain	Retain
PTX06-1006	N/A		N/A		***Eliminate*** (redundant with PTX06-1011)
PTX06-1007	0.74	Retain	0.65	Retain	Retain
PTX06-1008	N/A		N/A		Retain (TCE)
PTX06-1012	0.89	Retain	0.39	Retain	Retain
PTX06-1035	0.83	Retain	0.33	Retain	Retain
PTX06-1036*	0.00	Retain	0.05	Retain	Retain (SE)
PTX06-1049	0.74	Retain	0.22	Retain	Retain
PTX06-1052*	0.00	Retain	0.17	Retain	Retain (SE)
PTX06-1053*	0.64	Retain	0.16	Retain	Retain (SE)
PTX06-1077A	N/A		0.56	Retain	Retain
PTX06-1085	N/A		N/A		Retain
PTX06-1086	0.79	Retain	0.41	Retain	Retain
PTX06-1087	N/A		N/A		***Eliminate***
PTX07-1P02	0.89	Retain	0.26	Retain	***Eliminate***
PTX07-1P03	N/A		N/A		***Eliminate***
PTX07-1P06	0.88	Retain	0.03	Retain	Retain
PTX07-1Q01	0.86	Retain	0.77	Retain	Retain
PTX07-1Q02	0.36	Retain	0.24	Retain	***Eliminate***
PTX07-1Q03	0.89	Retain	0.60	Retain	Retain
PTX08-1001	0.75	Retain	0.25	Retain	Retain
PTX08-1003	0.29	Retain	0.43	Retain	Retain
PTX08-1005	N/A	Retain	0.62	Retain	Retain
PTX08-1006	0.25	Retain	0.08	Eliminate	Retain (4ADNT)
PTX08-1007	N/A	Retain	N/A		Retain (TCE)
PTX08-1008*	0.74	Retain	0.18	Retain	Retain (SE)
PTX08-1009*	0.91	Retain	0.29	Retain	Retain (SE)
PTX10-1008	N/A		N/A		***Eliminate***
PTX10-1013	0.87	Retain	0.78	Retain	Retain

Notes:
1. Slope Factor (SF) is the difference between the actual concentration and the concentration estimated from nearby wells normalized by the actual concentration. Slope factors close to 1 show the concentrations cannot be estimated from the nearby wells, and the well is important in the network.
2. Slope factors were calculated using data collected between July 2005 and May 2007.
3. Well locations with slope factors below 0.3 and area ratios below 0.8 were considered for elimination. () = well retained for Southeast (SE) or for other COC indicated.
4. N/A = Locations with insufficient data between 2005 - 2007 to calculate a slope factor.
5. Wells recommended for elimination are not recommended for plugging and abandonment, but should be retained for hydrogeologic monitoring.
6. * = Well included in Southeast network, recommendation based on COCs from Southeast Sector.

GSI ENVIRONMENTAL

TABLE 11
SAMPLING FREQUENCY ANALYSIS RESULTS SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Recent Concentration Rate of Change [mg/yr]	Recent MK Trend (2005-2007)	Sampling Frequency Based on Recent Data (2005-2007)	Overall Concentration Rate of Change [mg/yr]	Overall MK Trend (2000 - 2007)	Sampling Frequency Based on Overall Data (2000 - 2007)	MAROS Recommended Sampling Frequency	Current Sampling Frequency
TCE Southwest Sector								
1114-MW4	6.52E-06	NT	Annual	5.62E-06	PI	Annual	Annual	Annual
PTX06-1006	--	N/A	--	--	N/A	--	N/A	Not Sampled
PTX06-1007	--	N/A	Annual	-7.70E-08	S	Annual	Annual	Annual
PTX06-1008	--	N/A	Semiannual	-3.60E-06	S	Semiannual	Semiannual	Annual (to 2004)
PTX06-1012	1.80E-06	PI	Annual	6.12E-07	PI	Annual	Biennial	Semiannual
PTX06-1035	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Semiannual
PTX06-1036	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Semiannual
PTX06-1049	2.85E-07	NT	Annual	1.49E-07	NT	Annual	Biennial	Annual
PTX06-1052	-6.16E-08	S	Annual	-2.97E-07	D	Annual	Biennial	Semiannual
PTX06-1053	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Semiannual
PTX06-1077A	--	N/A	Quarterly	4.61E-06	NT	Quarterly	Quarterly	Annual
PTX06-1085	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX06-1086	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX06-1087	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX07-1P02	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX07-1P03	--	ND	--	--	ND	--	N/A	Not Sampled
PTX07-1P06	--	ND	Annual	0.00E+00	ND	Annual	Annual	Annual
PTX07-1Q01	--	ND	Annual	0.00E+00	ND	Annual	Annual	Annual
PTX07-1Q02	--	ND	Annual	0.00E+00	ND	Annual	Annual	Biennial
PTX07-1Q03	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX08-1001	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX08-1003	--	ND	Annual	0.00E+00	ND	Annual	Annual	Annual
PTX08-1005	--	N/A	Quarterly	1.97E-05	NT	Quarterly	Quarterly	Annual
PTX08-1006	1.56E-07	S	Annual	-1.07E-06	S	Annual	Annual	Annual
PTX08-1007	--	N/A	--	--	N/A	--	N/A	Not Sampled
PTX08-1008	1.12E-07	NT	Annual	5.63E-08	NT	Annual	Biennial	Semiannual
PTX08-1009	1.05E-06	NT	Annual	1.90E-07	NT	Annual	Biennial	Annual
PTX10-1008	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX10-1013	--	N/A	Quarterly	2.53E-05	NT	Quarterly	Quarterly	Annual

See Notes End of Table

GSI ENVIRONMENTAL

TABLE 11
SAMPLING FREQUENCY ANALYSIS RESULTS SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Recent Concentration Rate of Change [mg/yr]	Recent MK Trend (2005-2007)	Sampling Frequency Based on Recent Data (2005-2007)	Overall Concentration Rate of Change [mg/yr]	Overall MK Trend (2000 - 2007)	Sampling Frequency Based on Overall Data (2000 - 2007)	MAROS Recommended Sampling Frequency	Current Sampling Frequency
Perchlorate Southwest Sector								
1114-MW4	-1.98E-04	D	Annual	-1.09E-04	D	Annual	Annual	Annual
PTX06-1006	--	ND	--	--	ND	--	--	Not Sampled
PTX06-1007	--	N/A	Quarterly	-5.84E-06	S	Quarterly	Quarterly	Annual
PTX06-1008	--	N/A	Annual	5.41E-07	NT	Annual	Annual	Annual (to 2004)
PTX06-1012	4.75E-05	PI	Annual	1.80E-05	I	Annual	Annual	Semiannual
PTX06-1035	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Semiannual
PTX06-1036	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Semiannual
PTX06-1049	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX06-1052	0.00E+00	S	Annual	-4.11E-07	S	Annual	Biennial	Semiannual
PTX06-1053	0.00E+00	S	Annual	-1.06E-06	D	Annual	Biennial	Semiannual
PTX06-1077A	--	N/A	--	--	N/A	--	--	Not Sampled
PTX06-1085	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX06-1086	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX06-1087	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX07-1P02	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX07-1P03	--	ND	--	--	ND	--	N/A	Not Sampled
PTX07-1P06	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Annual	Annual
PTX07-1Q01	--	ND	Annual	0.00E+00	ND	Annual	Annual	Annual
PTX07-1Q02	--	ND	Annual	0.00E+00	ND	Annual	Annual	Biennial
PTX07-1Q03	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX08-1001	4.63E-06	NT	Annual	1.12E-05	NT	Annual	Annual	Annual
PTX08-1003	--	N/A	Quarterly	-6.41E-06	D	Quarterly	Quarterly	Annual
PTX08-1005	--	N/A	--	--	N/A	--	--	Annual
PTX08-1006	1.79E-05	NT	Annual	-1.06E-04	D	Annual	Annual	Annual
PTX08-1007	--	ND	--	--	N/A	--	N/A	Not Sampled
PTX08-1008	0.00E+00	S	Annual	-7.34E-07	S	Annual	Biennial	Semiannual
PTX08-1009	0.00E+00	ND	Annual	0.00E+00	ND	Annual	Biennial	Annual
PTX10-1008	--	ND	Annual	0.00E+00	ND	Annual	Annual	Not Sampled
PTX10-1013	--	N/A	Annual	1.20E-06	NT	Annual	Annual	Annual

Notes:

1. 'Recent' concentration rate of change and MK trends are calculated from data collected 2005 - 2007.
2. MK = Mann Kendall Trend; D = Decreasing, PD = Probably Decreasing, S = Stable, NT = No Trend, PI = Probably Increasing, I = Increasing, ND = Non-detect, N/A = insufficient data, less than 4 sample events for time interval indicated.
3. Overall rate of change and MK trend are for the full data set (2000-2007) for each well.
4. MAROS Recommended Sampling Frequency is the sampling frequency from MAROS based on both recent and overall trends.
5. Current sampling frequency is the approximate sampling frequency currently implemented.
6. The final recommended sampling frequency is based on a combination of qualitative and statistical evaluations.
7. * = Well is dry or intermittently dry. Dry wells should be evaluated periodically for saturation.

TABLE 12
FINAL RECOMMENDED MONITORING NETWORK SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	TCE			Perchlorate			Sampling Recommendation	Rationale
	Percent Detection	Mann Kendall Trend	Average SF	Percent Detection	Mann Kendall Trend	Average SF		
Southwest Sector								
1114-MW4	100%	PI	0.43	100%	D	0.49	Semiannual	Monitors area of high TCE and Perchlorate, new well installation south of current location should require 2 yrs of semiannual monitoring, consider reducing to annual monitoring after 2 yrs.
PTX06-1006	33%	N/A	N/A	0%	ND	N/A	Eliminate	Largely non-detect, does not provide unique information.
PTX06-1007	83%	S	0.65	100%	S	0.74	Annual	Defines edge of perchlorate plume, stable trends.
PTX06-1008	100%	S	N/A	25%	NT	N/A	Annual	Defines western edge of TCE source; stable trends.
PTX06-1012	33%	PI	0.39	33%	I	0.89	Semiannual	Defines area of high concentrations for TCE and perchlorate, monitor semiannually after installation of new wells for approximately 3 years.
PTX06-1035	0%	ND	0.33	0%	ND	0.83	Annual	Delineates plume to non-detect at southern edge.
PTX06-1036*	0%	ND	0.05	0%	ND	0.00	Annual	Delineates southern edge of Southeast Sector, monitors movement of COCs from south of Zones 11 and 12 toward southern edge of perched unit.
PTX06-1049	9%	NT	0.22	0%	ND	0.74	Biennial	Monitors far northern edge of Southwestern Sector, delineates some COCs to non-detect.
PTX06-1052*	47%	D	0.17	7%	S	0.00	Annual	Non-detect well, south of source area.
PTX06-1053*	0%	ND	0.16	25%	D	0.64	Semiannual	Delineates 4ADNT plume to south, near groundwater flow divide, early warning for movement of COCs to south/southeastern extent of perched groundwater.
PTX06-1077A	83%	NT	0.56	50%	NT	N/A	Annual	Delineated edge of perchlorate and TCE plume to west.
PTX06-1085	0%	ND	N/A	0%	ND	N/A	Biennial	Delineates perched unit to the west of Playa 2, largely non-detect for all COCs.
PTX06-1086	0%	ND	0.41	0%	ND	0.79	Biennial	Delineates western edge of plume, largely non-detect, reduce monitoring frequency.
PTX06-1087	0%	ND	N/A	0%	ND	N/A	Eliminate	Redundant with other wells in this area, delineates plume, keep for hydrogeologic monitoring.

See notes end of table.

GSI ENVIRONMENTAL

TABLE 12
FINAL RECOMMENDED MONITORING NETWORK SOUTHWEST SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

	TCE			Perchlorate				
Well Name	Percent Detection	Mann Kendall Trend	Average SF	Percent Detection	Mann Kendall Trend	Average SF	Sampling Recommendation	Rationale
Southwest Sector								
PTX07-1P02	0%	ND	0.26	0%	ND	0.89	Eliminate	Monitors area around SWMU 68c, largely non-detect and redundant with other locations.
PTX07-1P03	0%	ND	N/A	0%	ND	N/A	Eliminate	Monitors area around SWMU 68c, largely non-detect and redundant with other locations.
PTX07-1P06	0%	ND	0.03	0%	ND	0.88	Annual	Monitors area around SWMU 68c for RDX.
PTX07-1Q01	0%	ND	0.77	0%	ND	0.86	Biennial	Delineates Southwest Sector to southwest, retain as delineation point at reduced sampling frequency.
PTX07-1Q02	0%	ND	0.24	0%	ND	0.36	Eliminate	Redundant with PTX07-1Q01.
PTX07-1Q03	0%	ND	0.60	0%	ND	0.89	Biennial	Monitors upgradient of SWMU 68d, largely non-detect reduce frequency of sampling.
PTX08-1001	0%	ND	0.25	100%	NT	0.75	Annual	Monitors northern edge of perchlorate plume.
PTX08-1003	0%	ND	0.43	100%	D	0.29	Annual	Monitors southern extent of perched unit, high and increasing concentrations of COCs.
PTX08-1005	100%	NT	0.62	100%	D	N/A	Semiannual	Defines area of high concentrations for TCE and perchlorate, monitor semiannually after installation of new wells for approximately 3 years.
PTX08-1006	100%	S	0.08	100%	D	0.25	Semiannual	Defines area of high concentrations for TCE and perchlorate, monitor semiannually after installation of new wells for approximately 3 years.
PTX08-1007	100%	S	N/A	67%	N/A	N/A	Annual	Delineates edge of TCE plume, largely stable trends.
PTX08-1008*	27%	NT	0.18	8%	S	0.74	Semiannual	Chromium monitoring location
PTX08-1009*	75%	NT	0.29	0%	ND	0.91	Semiannual	Chromium monitoring location
PTX10-1008	0%	ND	N/A	0%	ND	N/A	Eliminate	Investigated groundwater at AOC 6b; non-detect so eliminate from program.
PTX10-1013	100%	NT	0.78	29%	NT	0.87	Annual	Monitors decreasing source area near Playa 1

Notes:
1. HG = Well is either dry or intermittently dry; monitor well at indicated frequency for saturation.
2. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend; NT = No Trend; ND = well has all non-detect results for COC indicated.
3. Mann-Kendall trends for 2000 - 2007 are shown.
4. SF = Slope Factor. SF close to 1 indicates well provides unique information in network. SF near 0 indicates well may be redundant.

GSI ENVIRONMENTAL

TABLE 13
INVESTIGATION WELL TREND SUMMARY RESULTS NORTH SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

WellName	Number of Samples (2000 - 2007)	Number of Detects	Percent Detection	Maximum Concentration [ug/L]	Maximum Above MSC?	Average Concentration [ug/L]	Average Above MSC?	Mann-Kendall Trend	Linear Regression Trend	Overall Trend Result
RDX North Sector										
PTX04-1002	12	7	58%	0.4	No	0.2	No	S	S	S
PTX06-1013	10	10	100%	**12**	Yes	**8.4**	Yes	PI	I	PI
PTX06-1023	12	12	100%	5	No	3.9	No	S	S	S
PTX06-1050	10	10	100%	**546**	Yes	**281**	Yes	I	I	I
PTX06-1069	11	1	9%	0.2	No	0	No	S	S	ND*
PTX06-1114	2	1	50%	**32**	Yes	**15.9**	Yes	N/A	N/A	N/A
PTX07-1O01	6	6	100%	**53**	Yes	**42**	Yes	NT	NT	NT
PTX07-1O02	3	3	100%	**10**	Yes	7	No	N/A	N/A	N/A
PTX07-1O03	7	7	100%	**39**	Yes	**31**	Yes	S	PD	S
PTX07-1P02	6	5	83%	4	No	2	No	D	PD	D
PTX07-1P06	10	10	100%	**109**	Yes	**41**	Yes	D	D	D
PTX07-1R03	8	1	13%	0.2	No	0.1	No	NT	S	ND*
PTX08-1001	7	3	43%	0.9	No	0.3	No	NT	NT	NT
PTX08-1002	7	7	100%	**277**	Yes	**132**	Yes	PD	D	D
PTX08-1010	14	2	14%	0.3	No	0.1	No	S	S	S
4ADNT North Sector										
PTX01-1001	23	2	9%	0.20	No	0.11	No	NT	NT	NT
PTX06-1013	10	1	10%	0.09	No	0.10	No	NT	I	ND*
PTX06-1048A	15	5	33%	0.19	No	0.11	No	S	NT	S
PTX06-1050	10	8	80%	**4.6**	Yes	**2.26**	Yes	NT	NT	NT
PTX06-1114	2	2	100%	0.474	No	0.5	No	N/A	N/A	N/A
PTX07-1O01	6	5	83%	0.74	No	0.5	No	NT	NT	NT
PTX07-1O03	7	3	43%	0.1	No	0.1	No	NT	NT	NT
PTX08-1001	7	1	14%	**2.4**	Yes*	0.4	No	NT	PD	ND*
PTX08-1002	7	4	57%	**2.8**	Yes	0.6	No	NT	NT	NT
PTX-BEG3	13	11	85%	0.53	No	0.3	No	PI	NT	PI
Perchlorate North Sector										
PTX01-1001	24	16	67%	**146**	Yes	20.9	No	NT	NT	NT
PTX01-1002	24	2	8%	5.59	No	1.7	No	S	D	PD
PTX06-1048A	14	1	7%	4.93	No	1.76	No	S	S	ND*
TCE North Sector										
PTX01-1001	25	15	60%	**17**	Yes	4.3	No	PI	I	PI
PTX01-1008	14	7	50%	**7**	Yes	1.3	No	D	D	D
PTX04-1001	7	7	100%	**2**	Yes	1.5	No	S	S	S
PTX04-1002	14	13	93%	1.4	No	0.9	No	D	D	D
PTX06-1048A	15	14	93%	4.1	No	2.9	No	D	S	PD
PTX06-1081	12	10	83%	0.8	No	0.6	No	PI	NT	PI
PTX07-1O01	5	1	20%	0.4	No	0.5	No	S	PD	ND*
PTX07-1O02	4	4	100%	1.0	No	0.9	No	I	I	I
PTX07-1O06	9	5	56%	0.9	No	0.6	No	NT	NT	NT
PTX08-1010	14	2	14%	0.4	No	0.5	No	NT	I	PI

Notes
1. Only wells where the COC indicated was detected are shown. Trends were evaluated for data collected between January 2000 and May 2007.
2. Number of Samples is the number of samples for the compound at this location during 2000 - 2007.
   Number of Detects is the number of samples where the compound was detected at this location.
3. The maximum concentration for the COC is the maximum analytical result analyzed between 2000 and 2007. Results above MSCs are indicated in **Bold**.
4. MSCs = Medium Specific Concentration from Corrective Measure Study. RDX = 7.7 ug/L; 4ADNT = 1.2 ug/L; TCE = 5ug/L; Cr = 100 ug/L; Perchlorate = 26ug/L..
5. No exceedances of Cr(VI) were found in North Sector wells.
6. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend;
   NT = No Trend; ND = well has all non-detect results for COC; ND* = one detection for compound, may be unaffected.

GSI ENVIRONMENTAL

TABLE 14
SAMPLING FREQUENCY ANALYSIS RESULTS NORTH SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Priority Constituent at Location	Overall Concentration Rate of Change [mg/yr]	Overall MK Trend (2000 - 2007)	Sampling Frequency Based on Overall Data (2000 - 2007)	MAROS Recommended Sampling Frequency	Current Sampling Frequency
TCE Southwest Sector						
PTX01-1001	PERCHLORATE	-2.39E-06	NT	Annual	Biennial	Semiannual
PTX01-1002	PERCHLORATE	-2.53E-07	S	Annual	Biennial	Semiannual
PTX01-1008*	TCE	-1.51E-06	D	Annual	Biennial	Semiannual
PTX04-1001	TCE	--	S	--	--	Semiannual (to 2003)
PTX04-1002	26DNT	8.34E-08	NT	Annual	Annual	Semiannual
PTX06-1048A	TCE	-7.00E-07	D	Annual	Annual	Semiannual
PTX06-1050	RDX	7.74E-05	I	Quarterly	Quarterly	Semiannual
PTX06-1071	Cr(VI)	--	N/A	--	--	Not Sampled
PTX06-1080	1,4-DIOXANE	--	N/A	--	--	Semiannual
PTX06-1081	26DNT	5.72E-08	NT	Annual	Biennial	Semiannual
PTX06-1114	RDX	0.00E+00	N/A	Quarterly	Quarterly	Semiannual
PTX07-1O01	RDX	1.69E-06	NT	Quarterly	Quarterly	Annual
PTX07-1O02	RDX	0.00E+00	N/A	Quarterly	Quarterly	Annual
PTX07-1O03	RDX	-2.90E-06	S	Annual	Annual	Annual
PTX07-1O06*	26DNT	1.34E-08	NT	Annual	Annual	Semiannual (to 2004)
PTX07-1R03*	Cr(VI)	--	NT	--	--	Annual
PTX08-1010	1,4-DIOXANE	--	N/A	--	--	Semiannual
PTX-BEG3	4ADNT	-7.78E-08	S	Annual	Annual	Semiannual (to 2005)

Notes:
1. The priority chemical of concern (COC) at each well is the constituent detected at the highest level normalized by the MSC.
2. MK = Mann Kendall Trend; D = Decreasing, PD = Probably Decreasing, S = Stable, NT = No Trend, PI = Probably Increasing, I = Increasing, ND = Non-detect, N/A = insufficient data, less than 4 sample events for time interval indicated.
3. Recent data frequency is the estimated sample frequency based on the recent trend.
4. Overall rate of change and MK trend are for the full data set (2000-2007) for each well.
5. MAROS Recommended Sampling Frequency is the sampling frequency from MAROS based on both recent and overall trends.
6. Current sampling frequency is the approximate sampling frequency currently implemented.
7. The final recommended sampling frequency is based on a combination of qualitative and statistical evaluations.
8. * = Well is dry or intermittently dry. Dry wells should be evaluated periodically for saturation.

TABLE 15
FINAL RECOMMENDED MONITORING NETWORK PERCHED NORTH SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Priority COPC	Maximum Above MSC?	Percent Detection	Below MSC (Student's T-Test)	Attained Cleanup to MSC (Sequential T-Test)	MK Trend	Sampling Frequency Recommendation	Rationale
North Sector								
PTX01-1001	PERCHLORATE	Yes	67%	NO	Continue Sampling	NT	Annual	Monitors area around SWMU 28-36, isolated perched groundwater in area, low level detections of perchlorate; reduced sampling frequency until statistically significant dataset is attained..
PTX01-1002	PERCHLORATE	No	8%	YES	Attained	S	Biennial	Monitors area around SWMU 28-36, isolated perched groundwater in area, perchlorate statistically below MSCs. Retain for infrequent monitoring.
PTX01-1008	TCE	Yes	50%	YES	Continue Sampling	D	Annual	Monitors area around SWMU 28-36, isolated perched groundwater in area, low level detections of TCE.
PTX04-1001	TCE	No	100%	N/C	N/C	S	Every 5 years	Detections of TCE below MSCs. Monitors SWMU 140, NE corner of DOE property. Sample for EPA 5 year review to confirm groundwater unaffected.
PTX04-1002	2,6DNT	No	8%	YES	Continue Sampling	NT	Biennial	Detections of TCE and RDX below MSCs. Monitors SWMU 140, NE corner of DOE property, reduced sampling frequency until statistically significant dataset is attained.
PTX06-1048A	TCE	No	93%	YES	Continue Sampling	D	Annual	Low level detections of TCE; Delineates north/northeast of perched unit.
PTX06-1050	RDX	Yes	100%	NO	Not Attained	I	Semiannual	Monitors area northwest of Playa 1, area of highest concentration in North Sector.
PTX06-1071	Cr(VI)	No	12%	N/C	N/C	NT	Every 5 years	Only one detection for Cr(VI), non-detect for other COPCs, Monitors SWMU 140, NE corner of DOE property. Sample for EPA 5 year review to confirm groundwater unaffected.
PTX06-1080	None	No		N/C	N/C	ND	Every 5 years	No confirmed detections of COPCs, Monitors SWMU 140, NE corner of DOE property. Sample for EPA 5 year review to confirm groundwater unaffected.
PTX06-1081	2,6DNT	No	8%	YES	Continue Sampling	NT	Biennial	Only one detection of 26DNT, TCE detected below MSCs (but possibly increasing trend). Monitors SWMU 140, NE corner of DOE property. Sample to confirm TCE is not above MSCs.
PTX06-1114	RDX	Yes	50%	N/C	N/C	N/A	Semiannual	Monitors area between Playa 1 and PTX06-1050. Continue collecting data to evaluate RDX plume in this area.

See Notes End of Table

GSI ENVIRONMENTAL

TABLE 15
FINAL RECOMMENDED MONITORING NETWORK PERCHED NORTH SECTOR

LONG-TERM MONITORING OPTIMIZATION
PANTEX PLANT
Carson County, Texas

Well Name	Priority COPC	Maximum Above MSC?	Percent Detection	Below MSC (Student's T-Test)	Attained Cleanup to MSC (Sequential T-Test)	MK Trend	Sampling Frequency Recommendation	Rationale
North Sector								
PTX07-1O01	RDX	Yes	100%	NO	Not Attained	NT	Semiannual	Monitors SWMU 68b. Continue monitoring to characterize RDX plume in this area.
PTX07-1O02	RDX	Yes	100%	N/C	N/C	N/A	Semiannual	Monitors SWMU 68b. Continue monitoring to characterize RDX plume in this area.
PTX07-1O03	RDX	Yes	100%	NO	Not Attained	S	Annual	Monitors SWMU 68b. Continue monitoring to characterize RDX plume in this area.
PTX07-1O06	2,6DNT	No	20%	YES	Attained	NT	Biennial	Monitors SWMU 68b. Sporadic detections of COPCs below MSCs. Monitor to delineate RDX plume to south.
PTX07-1R03	Cr(VI)	No	50%	NO	Continue Sampling	PI	Every 5 years	Very low detections of Cr(VI), monitors SWMU 64, only well in vicinity
PTX08-1010	None	No		N/C	N/C		Every 5 years	Sporadic trace detections of COPCs, detections of HMX below MSCs, Monitors SWMU 140, NE corner of DOE property. Sample for EPA 5 year review to confirm groundwater unaffected.
PTX-BEG3	4ADNT	No	78%	YES	Continue Sampling	PI	Biennial	Detections of 4ADNT below MSCs near detection limits; Monitors SWMU 140, NE corner of DOE property. Retain to confirm groundwater below regulatory standards at property boundary.
PTX06-1082	None	No					Every 5 years	Monitor area to confirm no facility related COPCs are present.
PTX06-1083	None	No					Every 5 years	

Notes:
1. MSC = Medium Specific Concentration.
2. Student's T-test identifies groundwater statistically below MSC. N/C = Not calculated.
3. Sequential T-test identifies groundwater that has statistically achieved cleanup with high confidence. Attained = groundwater has attained cleanup; Continue Sampling = dataset does not achieve statistical significance; Not Attained = groundwater above limit.
4. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend; NT = No Trend; ND = well has all non-detect results for COC indicated; N/C not calculated.
5. Mann-Kendall trends for 2000 - 2007 are shown.

GSI ENVIRONMENTAL

TABLE 16
SUMMARY MONITORING NETWORK RECOMMENDATIONS PERCHED GROUNDWATER

LONG-TERM MONITORING OPTIMIZATION

PANTEX PLANT
Carson County, Texas

Investigation Wells Recommended for Semiannual Monitoring							
Southeast Sector	20	PTX06-1002A	PTX06-1005	PTX06-1010	PTX06-1013	PTX06-1015	PTX06-1030
		PTX06-1031	PTX06-1034	PTX06-1038	PTX06-1039A	PTX06-1040	PTX06-1041
		PTX06-1046	PTX06-1047A	PTX06-1053*	PTX06-1088	PTX06-1095A	PTX08-1002
		PTX08-1008*	PTX08-1009*				
Southwest Sector	4	1114-MW4	PTX06-1012	PTX08-1005	PTX08-1006		
North Sector	4	PTX06-1114	PTX06-1050	PTX07-1O01	PTX07-1O02		
Investigation Wells Recommended for Annual Monitoring							
Southeast Sector	7	PTX06-1003	PTX06-1011	PTX06-1023	PTX06-1036	PTX06-1042	PTX06-1052
		PTX06-1069					
Southwest Sector	9	PTX06-1007	PTX06-1008	PTX06-1035	PTX06-1077A	PTX07-1P06	PTX08-1001
		PTX08-1003	PTX08-1007	PTX10-1013			
North Sector	4	PTX01-1001	PTX01-1008	PTX06-1048A	PTX07-1O03		
Investigation Wells Recommended for Biennial or Greater Monitoring							
Southeast Sector	0	None					
Southwest Sector	5	PTX06-1049	PTX06-1085	PTX06-1086	PTX07-1Q01	PTX07-1Q03	
North Sector	12	PTX04-1001	PTX06-1071	PTX06-1080	PTX07-1R03	PTX08-1010	PTX06-1083
		PTX06-1082	PTX01-1002	PTX04-1002	PTX06-1081	PTX07-1O06	PTX-BEG3
New Investigation Wells Recommended							
Southeast	2						
Southwest Sector	4						
North Sector	1						
Investigation Wells Recommended for Hydrogeologic Monitoring (dry or redundant locations)							
Southeast	4	PTX06-1102	PTX06-1045	PTX06-1037	PTX06-1014		
Southwest Sector	6	PTX10-1008	PTX07-1Q02	PTX07-1P03	PTX07-1P02	PTX06-1087	PTX06-1006
North Sector	0	None					

Notes: Lines of evidence supporting monitoring recommendations for each well are shown on Tables 7,12, and 15.

** Indicates well used to characterize more than one Sector.*

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

APPENDIX A:

MAROS 2.2 Methodology

APPENDIX A
MARAOS 2.2 METHODOLOGY

Contents

MAROS METHODOLOGY

MAROS is a collection of tools in one software package that is used in an explanatory, non-linear but linked fashion. The tool includes models, statistics, heuristic rules, and empirical relationships to assist the user in optimizing a groundwater monitoring network system. The final optimized network maintains adequate delineation while providing information on plume dynamics over time. Results generated from the software tool can be used to develop lines of evidence, which, in combination with expert opinion, can be used to inform regulatory decisions for safe and economical long-term monitoring of groundwater plumes. For a detailed description of the structure of the software and further utilities, refer to the MAROS 2.2 Manual (AFCEE, 2003; http://www.gsi-net.com/software/MAROS_V2_1Manual.pdf) and Aziz et al., 2003.

1.0 MAROS Conceptual Model

In MAROS 2.2, two levels of analysis are used for optimizing long-term monitoring plans: 1) an overview statistical evaluation with interpretive trend analysis based on temporal trend analysis and plume stability information; and 2) a more detailed statistical optimization based on spatial and temporal redundancy reduction methods (see Figures A.1 and A.2 for further details). In general, the MAROS method applies to 2-D aquifers that have relatively simple site hydrogeology. However, for a multi-aquifer (3-D) system, the user has the option to apply the statistical analysis layer-by-layer.

The overview statistics or interpretive trend analysis assesses the general monitoring system category by considering individual well concentration trends, overall plume stability, hydrogeologic factors (e.g., seepage velocity, and current plume length), and the location of potential receptors (e.g., property boundaries or drinking water wells). The method relies on temporal trend analysis to assess plume stability, which is then used to determine the general monitoring system category. Since the monitoring system category is evaluated for both source and tail regions of the plume, the site wells are divided into two different zones: the source zone and the tail zone.

Source zone monitoring wells could include areas with non-aqueous phase liquids (NAPLs), contaminated vadose zone soils, and areas where aqueous-phase releases have been introduced into ground water. The source zone generally contains locations with historical high ground water concentrations of the COCs. The tail zone is usually the area downgradient of the contaminant source zone. Although this classification is a simplification of the plume conceptual model, this broadness makes the user aware on an individual well basis that the concentration trend results can have a different interpretation depending on the well location in and around the plume. The location and type of the individual wells allows further interpretation of the trend results, depending on what type of well is being analyzed (e.g., remediation well, leading plume edge well, or monitoring well). General recommendations for the monitoring network frequency and density are suggested based on heuristic rules applied to the source and tail trend results.

The detailed statistics level of analysis or sampling optimization consists of well redundancy and well sufficiency analyses using the Delaunay method, a sampling frequency analysis using the Modified Cost Effective Sampling (MCES) method and a data sufficiency analysis including statistical power analysis. The well redundancy analysis is designed to minimize monitoring locations and the Modified CES method is designed to minimize the frequency of sampling. The data sufficiency analysis uses simple statistical methods to assess the sampling record to determine if groundwater concentrations are statistically below target levels and if the current monitoring network and record is sufficient in terms of evaluating concentrations at downgradient locations.

2.0 Data Management

In MAROS, ground water monitoring data can be imported from simple database-format Microsoft® Excel spreadsheets, Microsoft Access tables, previously created MAROS database archive files, or entered manually. Monitoring data interpretation in MAROS is based on historical analytical data from a consistent set of wells over a series of sampling events. The analytical data is composed of the well name, coordinate location, constituent, result, detection limit and associated data qualifiers. Statistical validity of the concentration trend analysis requires constraints on the minimum data input of at least four wells (ASTM 1998) in which COCs have been detected. Individual sampling locations need to include data from at least six most-recent sampling events. To ensure a meaningful comparison of COC concentrations over time and space, both data quality and data quantity need to be considered. Prior to statistical analysis, the user can consolidate irregularly sampled data or smooth data that might result from seasonal fluctuations or a change in site conditions. Because MAROS is a terminal analytical tool designed for long-term planning, impacts of seasonal variation in the water unit are treated on a broad scale, as they relate to multi-year trends.

Imported ground water monitoring data and the site-specific information entered in Site Details can be archived and exported as MAROS archive files. These archive files can be appended as new monitoring data becomes available, resulting in a dynamic long-term monitoring database that reflects the changing conditions at the site (i.e. biodegradation, compliance attainment, completion of remediation phase, etc.). For wells with a limited monitoring history, addition of information as it becomes available can change the frequency or identity of wells in the network.

3.0 Site Details

Information needed for the MAROS analysis includes site-specific parameters such as seepage velocity and current plume length and width. Information on the location of potential receptors relative to the source and tail regions of the plume is entered at this point. Part of the trend analysis methodology applied in MAROS focuses on where the monitoring well is located, therefore the user needs to divide site wells into two different zones: the source zone or the tail zone. Although this classification is a simplification of the well function, this broadness makes the user aware on an individual well basis that the concentration trend results can have a different interpretation depending on the well location in and around the plume. It is up to the user to make further interpretation of the trend results, depending on what type of well is being analyzed (e.g., remediation well, leading plume edge well, or monitoring well). The Site Details section of MAROS contains a preliminary map of well locations to confirm well coordinates.

4.0 Constituent Selection

A database with multiple COCs can be entered into the MAROS software. MAROS allows the analysis of up to 5 COCs concurrently and users can pick COCs from a list of compounds existing in the monitoring data. MAROS runs separate optimizations for each compound. For sites with a single source, the suggested strategy is to choose one to three priority COCs for the optimization. If, for example, the site contains multiple chlorinated volatile organic compounds (VOCs), the standard sample chemical analysis will evaluate all VOCs, so the sample locations and frequency should based on the concentration trends of the most prevalent, toxic or mobile compounds. If different chemical classes are present, such as metals and chlorinated VOCs, choose and evaluate the priority constituent in each chemical class.

MAROS includes a short module that provides recommendations on prioritizing COCs based on toxicity, prevalence, and mobility of the compound. The toxicity ranking is determined by examining a representative concentration for each compound for the entire site. The representative concentration is then compared to the screening level (PRG or MCL) for that compound and the COCs are ranked according to the representative concentrations percent exceedence of the screening level. The evaluation of prevalence is performed by determining a representative concentration for each well location and evaluating the total exceedences (values above screening levels) compared to the total number of wells. Compounds found over screening levels are ranked for mobility based on Kd (sorption partition coefficient). The MAROS COC assessment provides the relative ranking of each COC, but the user must choose which COCs are included in the analysis.

5.0 Data Consolidation

Typically, raw data from long-term monitoring have been measured irregularly in time or contain many non-detects, trace level results, and duplicates. Therefore, before the data can be further analyzed, raw data are filtered, consolidated, transformed, and possibly smoothed to allow for a consistent dataset meeting the minimum data requirements for statistical analysis mentioned previously.

MAROS allows users to specify the period of interest in which data will be consolidated (i.e., monthly, bi-monthly, quarterly, semi-annual, yearly, or a biennial basis). In computing the representative value when consolidating, one of four statistics can be used: median, geometric mean, mean, and maximum. Non-detects can be transformed to one half the reporting or method detection limit (DL), the DL, or a fraction of the DL. Trace level results can be represented by their actual values, one half of the DL, the DL, or a fraction of their actual values. Duplicates are reduced in MAROS by one of three ways: assigning the average, maximum, or first value. The reduced data for each COC and each well can be viewed as a time series in a graphical form on a linear or semi-log plot generated by the software.

6.0 Overview Statistics: Plume Trend Analysis

Within the MAROS software there are historical data analyses that support a conclusion about plume stability (e.g., increasing plume, etc.) through statistical trend analysis of historical monitoring data. Plume stability results are assessed from time-series concentration data with the application of three statistical tools: Mann-Kendall Trend analysis, linear regression trend analysis and moment analysis. The two trend methods are used to estimate the concentration trend for each well and each COC based on a statistical trend analysis of concentrations versus time at each well. These trend analyses are then consolidated to give the user a general plume stability estimate and general monitoring frequency and density recommendations (see Figures A.1 through A.3 for further step-by-step details). Both qualitative and quantitative plume information can be gained by these evaluations of monitoring network historical data trends both spatially and temporally. The MAROS Overview Statistics are the foundation the user needs to make informed optimization decisions at the site. The Overview Statistics are designed to allow site personnel to develop a better understanding of the plume behavior over time and understand how the individual well concentration trends are spatially distributed within the plume. This step allows the user to gain information that will support a more informed decision to be made in the next level or detailed statistics optimization analysis.

6.1 Mann-Kendall Analysis

The Mann-Kendall test is a statistical procedure that is well suited for analyzing trends in data over time. The Mann-Kendall test can be viewed as a non-parametric test for zero slope of the first-order regression of time-ordered concentration data versus time. One advantage of the Mann-Kendall test is that it does not require any assumptions as to the statistical distribution of the data (e.g. normal, lognormal, etc.) and can be used with data sets which include irregular sampling intervals and missing data. The Mann-Kendall test is designed for analyzing a single groundwater constituent, multiple constituents are analyzed separately. The Mann-Kendall S statistic measures the trend in the data: positive values indicate an increase in concentrations over time and negative values indicate a decrease in concentrations over time. The strength of the trend is proportional to the magnitude of the Mann-Kendall statistic (i.e., a large value indicates a strong trend). The confidence in the trend is determined by consulting the S statistic and the sample size, n, in a Kendall probability table such as the one reported in Hollander and Wolfe (1973).

The concentration trend is determined for each well and each COC based on results of the S statistic, the confidence in the trend, and the Coefficient of Variation (COV). The decision matrix for this evaluation is shown in Table 3. A Mann-Kendall statistic that is greater than 0 combined with a confidence of greater than 95% is categorized as an Increasing trend while a Mann-Kendall statistic of less than 0 with a confidence between 90% and 95% is defined as a probably Increasing trend, and so on.

Depending on statistical indicators, the concentration trend is classified into six categories:

- Decreasing (D),
- Probably Decreasing (PD),
- Stable (S),
- No Trend (NT),
- Probably Increasing (PI)
- Increasing (I).

These trend estimates are then analyzed to identify the source and tail region overall stability category (see Figure 2 for further details).

6.2 Linear Regression Analysis

Linear Regression is a parametric statistical procedure that is typically used for analyzing trends in data over time. Using this type of analysis, a higher degree of scatter simply corresponds to a wider confidence interval about the average log-slope. Assuming the sign (i.e., positive or negative) of the estimated log-slope is correct, a level of confidence that the slope is not zero can be easily determined. Thus, despite a poor goodness of fit, the overall trend in the data may still be ascertained, where low levels of confidence correspond to "Stable" or "No Trend" conditions (depending on the degree of scatter) and higher levels of confidence indicate the stronger likelihood of a trend. The linear regression analysis is based on the first-order linear regression of the log-transformed concentration data versus time. The slope obtained from this log-transformed regression, the confidence level for this log-slope, and the COV of the untransformed data are used to determine the concentration trend. The decision matrix for this evaluation is shown in Table 4.

To estimate the confidence in the log-slope, the standard error of the log-slope is calculated. The coefficient of variation, defined as the standard deviation divided by the average, is used as a secondary measure of scatter to distinguish between "Stable" or "No Trend" conditions for negative slopes. The Linear Regression Analysis is designed for analyzing a single groundwater constituent; multiple constituents are analyzed separately, (up to five COCs simultaneously). For this evaluation, a decision matrix developed by Groundwater Services, Inc. is also used to determine the "Concentration Trend" category (plume stability) for each well.

Depending on statistical indicators, the concentration trend is classified into six categories:

- Decreasing (D),
- Probably Decreasing (PD),
- Stable (S),
- No Trend (NT),
- Probably Increasing (PI)
- Increasing (I).

The resulting confidence in the trend, together with the log-slope and the COV of the untransformed data, are used in the linear regression analysis decision matrix to determine the concentration trend. For example, a positive log-slope with a confidence of less than 90% is categorized as having No Trend whereas a negative log-slope is considered Stable if the COV is less than 1 and categorized as No Trend if the COV is greater than 1.

6.3 Overall Plume Analysis

General recommendations for the monitoring network frequency and density are suggested based on heuristic rules applied to the source and tail trend results.

Individual well trend results are consolidated and weighted by the MAROS according to user input, and the direction and strength of contaminant concentration trends in the source zone and tail zone for each COC are determined. Based on

i) the consolidated trend analysis,
ii) hydrogeologic factors (e.g., seepage velocity), and
iii) location of potential receptors (e.g., wells, discharge points, or property boundaries),

the software suggests a general optimization plan for the current monitoring system in order to efficiently but effectively monitor groundwater in the future. A flow chart utilizing the trend analysis results and other site-specific parameters to form a general sampling frequency and well density recommendation is outlined in Figure 2. For example, a generic plan for a shrinking petroleum hydrocarbon plume (BTEX) in a slow hydrogeologic environment (silt) with no nearby receptors would entail minimal, low frequency sampling of just a few indicators. On the other hand, the generic plan for a chlorinated solvent plume in a fast hydrogeologic environment that is expanding but has very erratic concentrations over time would entail more extensive, higher frequency sampling. The generic plan is based on a heuristically derived algorithm for assessing future sampling duration, location and density that takes into consideration plume stability. For a detailed description of the heuristic rules used in the MAROS software, refer to the MAROS 2.2Manual (AFCEE, 2003).

6.4 Moment Analysis

An analysis of moments can help resolve plume trends, where the zeroth moment shows change in dissolved mass vs. time, the first moment shows the center of mass location vs. time, and the second moment shows the spread of the plume vs. time. Moment calculations can predict how the plume will change in the future if further statistical analysis is applied to the moments to identify a trend (in this case, Mann Kendall Trend Analysis is applied). The trend analysis of moments can be summarized as:

- Zeroth Moment: An estimate of the total mass of the constituent for each sample event
- First Moment: An estimate of the center of mass for each sample event
- Second Moment: An estimate of the spread of the plume around the center of mass

The role of moment analysis in MAROS is to provide a relative estimate of plume stability and condition within the context of results from other MAROS modules. The Moment analysis algorithms in MAROS are simple approximations of complex calculations and are meant to estimate changes in total mass, center of mass and spread of mass for complex well networks. The Moment Analysis module is sensitive to the number and arrangement of wells in each sampling event, so, changes in the number and identity of wells during monitoring events, and the parameters chosen for data consolidation can cause changes in the estimated moments.

Plume stability may vary by constituent, therefore the MAROS Moment analysis can be used to evaluate multiple COCs simultaneously which can be used to provide a quick way of comparing individual plume parameters to determine the size and movement of constituents relative to one another. Moment analysis in the MAROS software can also be used to assist the user in evaluating the impact on plume delineation in future sampling events by removing identified “redundant” wells from a long-term monitoring program (this analysis was not performed as part of this study, for more details on this application of moment analysis refer to the MAROS Users Manual (AFCEE, 2003)).

The **zeroth moment** is the sum of concentrations for all monitoring wells and is a mass estimate. The zeroth moment calculation can show high variability over time, largely due to the fluctuating concentrations at the most contaminated wells as well as varying monitoring well network. Plume analysis and delineation based exclusively on concentration can exhibit fluctuating temporal and spatial values. The mass estimate is also sensitive to the extent of the site monitoring well network over time. The zeroth moment trend over time is determined by using the Mann-Kendall Trend Methodology. The zeroth Moment trend test allows the user to understand how the plume mass has changed over time. Results for the trend include: Increasing, probably Increasing, no trend, stable, probably decreasing, decreasing or not applicable (N/A) (Insufficient Data). When considering the results of the zeroth moment trend, the following factors should be considered which could effect the calculation and interpretation of the plume mass over time: 1) Change in the spatial distribution of the wells sampled historically 2) Different wells sampled within the well network over time (addition and subtraction of well within the network). 3) Adequate versus inadequate delineation of the plume over time

The **first moment** estimates the center of mass, coordinates (Xc and Yc) for each sample event and COC. The changing center of mass locations indicate the movement of the center of mass over time. Whereas, the distance from the original source location to the center of mass locations indicate the movement of the center of mass over time relative to the original source. Calculation of the first moment normalizes the spread by the concentration indicating the center of mass. The first moment trend of the distance to the center of mass over time shows movement of the plume in relation to the original source location over time. Analysis of the movement of mass should be viewed as it relates to 1) the original source location of contamination 2) the direction of groundwater flow and/or 3) source removal or remediation. Spatial and temporal trends in the center of mass can indicate spreading or shrinking or transient movement based on season variation in rainfall or other hydraulic considerations. No appreciable movement or a neutral trend in the center of mass would indicate plume stability. However, changes in the first moment over time do not necessarily completely characterize the changes in the concentration distribution (and the mass) over time. Therefore, in order to fully characterize the plume the First Moment trend should be compared to the zeroth moment trend (mass change over time).

The **second moment** indicates the spread of the contaminant about the center of mass (Sxx and Syy), or the distance of contamination from the center of mass for a particular COC and sample event. The Second Moment represents the spread of the plume over time in both the x and y directions. The Second Moment trend indicates the spread of the plume about the center of mass. Analysis of the spread of the plume should be viewed as it relates to the direction of groundwater flow. An Increasing trend in the second moment indicates an expanding plume, whereas a declining trend in the second moment indicates a shrinking plume. No appreciable movement or a neutral trend in the center of mass would indicate plume stability. The second moment provides a measure of the spread of the concentration distribution about the plume’s center of mass.

However, changes in the second moment over time do not necessarily completely characterize the changes in the concentration distribution (and the mass) over time. Therefore, in order to fully characterize the plume the Second Moment trend should be compared to the zeroth moment trend (mass change over time).

7.0 Detailed Statistics: Optimization Analysis

Although the overall plume analysis shows a general recommendation regarding sampling frequency reduction and a general sampling density, a more detailed analysis is also available with the MAROS 2.2 software in order to allow for further reductions on a well-by-well basis for frequency, well redundancy, well sufficiency and sampling sufficiency. The MAROS Detailed Statistics allows for a quantitative analysis for spatial and temporal optimization of the well network on a well-by-well basis. The results from the Overview Statistics should be considered along with the MAROS optimization recommendations gained from the Detailed Statistical Analysis described previously. The MAROS Detailed Statistics results should be reassessed in view of site knowledge and regulatory requirements as well as in consideration of the Overview Statistics (Figure 2).

The Detailed Statistics or Sampling Optimization MAROS modules can be used to determine the minimal number of sampling locations and the lowest frequency of sampling that can still meet the requirements of sampling spatially and temporally for an existing monitoring program. It also provides an analysis of the sufficiency of data for the monitoring program.

Sampling optimization in MAROS consists of four parts:

- Well redundancy analysis using the Delaunay method
- Well sufficiency analysis using the Delaunay method
- Sampling frequency determination using the Modified CES method
- Data sufficiency analysis using statistical power analysis.

The well redundancy analysis using the Delaunay method identifies and eliminates redundant locations from the monitoring network. The well sufficiency analysis can determine the areas where new sampling locations might be needed. The Modified CES method determines the optimal sampling frequency for a sampling location based on the direction, magnitude, and uncertainty in its concentration trend. The data sufficiency analysis examines the risk-based site cleanup status and power and expected sample size associated with the cleanup status evaluation.

7.1 Well Redundancy Analysis – Delaunay Method

The well redundancy analysis using the Delaunay method is designed to select the minimum number of sampling locations based on the spatial analysis of the relative importance of each sampling location in the monitoring network. The approach allows elimination of sampling locations that have little impact on the historical characterization of a contaminant plume. An extended method or wells sufficiency analysis, based on the Delaunay method, can also be used for recommending new sampling locations.

Details about the Delaunay method can be found in Appendix A.2 of the MAROS Manual (AFCEE, 2003).

Sampling Location determination uses the Delaunay triangulation method to determine the significance of the current sampling locations relative to the overall monitoring network. The Delaunay method calculates the network Area and Average concentration of the plume using data from multiple monitoring wells. A slope factor (SF) is calculated for each well to indicate the significance of this well in the system (i.e. how removing a well changes the average concentration.)

The Sampling Location optimization process is performed in a stepwise fashion. Step one involves assessing the significance of the well in the system, if a well has a small SF (little significance to the network), the well may be removed from the monitoring network. Step two involves evaluating the information loss of removing a well from the network. If one well has a small SF, it may or may not be eliminated depending on whether the information loss is significant. If the information loss is not significant, the well can be eliminated from the monitoring network and the process of optimization continues with fewer wells. However if the well information loss is significant then the optimization terminates. This sampling optimization process allows the user to assess "redundant" wells that will not incur significant information loss on a constituent-by-constituent basis for individual sampling events.

<u>7.2 Well Sufficiency Analysis – Delaunay Method</u>

The well sufficiency analysis, using the Delaunay method, is designed to recommend new sampling locations in areas *within* the existing monitoring network where there is a high level of uncertainty in contaminant concentration. Details about the well sufficiency analysis can be found in Appendix A.2 of the MAROS Manual (AFCEE, 2003).

In many cases, new sampling locations need to be added to the existing network to enhance the spatial plume characterization. If the MAROS algorithm calculates a high level of uncertainty in predicting the constituent concentration for a particular area, a new sampling location is recommended. The Slope Factor (SF) values obtained from the redundancy evaluation described above are used to calculate the concentration estimation error for each triangle area formed in the Delaunay triangulation. The estimated SF value for each area is then classified into four levels: Small, Moderate, Large, or Extremely large (S, M, L, E) because the larger the estimated SF value, the higher the estimation error at this area. Therefore, the triangular areas with the estimated SF value at the Extremely large or Large level can be candidate regions for new sampling locations.

The results from the Delaunay method and the method for determining new sampling locations are derived solely from the spatial configuration of the monitoring network and the spatial pattern of the contaminant plume. No parameters such as the hydrogeologic conditions are considered in the analysis. Therefore, professional judgment and regulatory considerations must be used to make final decisions.

<u>7.3 Sampling Frequency Determination - Modified CES Method</u>

The Modified CES method optimizes sampling frequency for each sampling location based on the magnitude, direction, and uncertainty of its concentration trend derived from its recent and historical monitoring records. The Modified Cost Effective Sampling (MCES) estimates a conservative lowest-frequency sampling schedule for a given groundwater monitoring location that still provides needed information for regulatory and remedial decision-making. The MCES method was developed on the basis of the Cost Effective Sampling (CES) method developed by Ridley et al (1995). Details about the MCES method can be found in Appendix A.9 of the MAROS Manual (AFCEE, 2003).

In order to estimate the least frequent sampling schedule for a monitoring location that still provides enough information for regulatory and remedial decision-making, MCES employs three steps to determine the sampling frequency. The first step involves analyzing frequency based on recent trends. A preliminary location sampling frequency (PLSF) is developed based on the rate of change of well concentrations calculated by linear regression along with the Mann-Kendall trend analysis of the most recent monitoring data (see Figure 3). The variability within the sequential sampling data is accounted for by the Mann-Kendall analysis. The rate of change vs. trend result matrix categorizes wells as requiring annual, semi-annual or quarterly sampling. The PLSF is then reevaluated and adjusted based on overall trends. If the long-term history of change is significantly greater than the recent trend, the frequency may be reduced by one level.

The final step in the analysis involves reducing frequency based on risk, site-specific conditions, regulatory requirements or other external issues. Since not all compounds in the target being assessed are equally harmful, frequency is reduced by one level if recent maximum concentration for a compound of high risk is less than 1/2 of the Maximum Concentration Limit (MCL). The result of applying this method is a suggested sampling frequency based on recent sampling data trends and overall sampling data trends and expert judgment.

The final sampling frequency determined from the MCES method can be Quarterly, Semiannual, Annual, or Biennial. Users can further reduce the sampling frequency to, for example, once every three years, if the trend estimated from Biennial data (i.e., data drawn once every two years from the original data) is the same as that estimated from the original data.

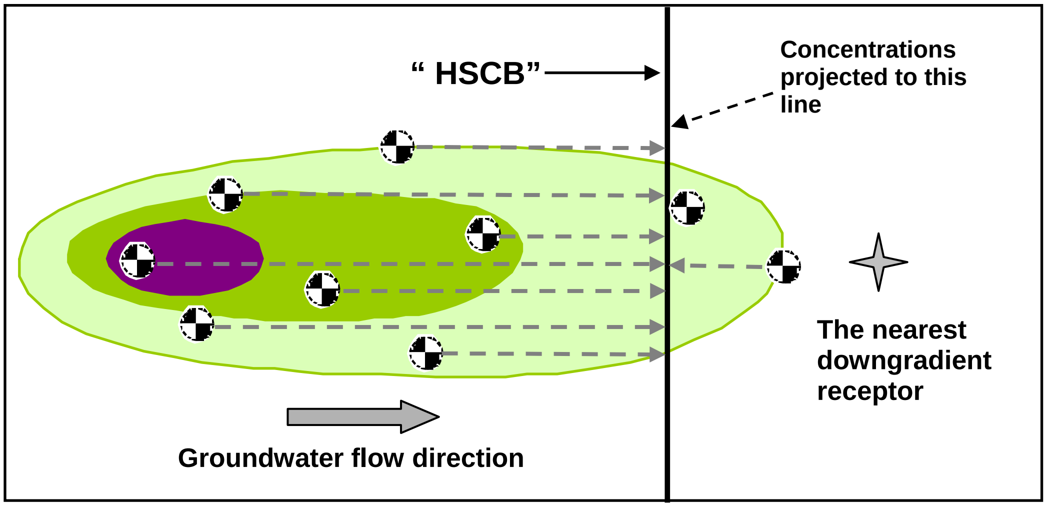
7.4 Data Sufficiency Analysis – Power Analysis

The MAROS Data Sufficiency module employs simple statistical methods to evaluate whether the collected data are adequate both in quantity and in quality for revealing changes in constituent concentrations. The first section of the module evaluates individual well concentrations to determine if they are statistically below a target screening level. The second section includes a simple calculation for estimating projected groundwater concentrations at a specified point downgradient of the plume. A statistical Power analysis is then applied to the projected concentrations to determine if the downgradient concentrations are statistically below the cleanup standard. If the number of projected concentrations is below the level to provide statistical significance, then the number of sample events required to statistically confirm concentrations below standards is estimated from the Power analysis.

Before testing the cleanup status for individual wells, the stability or trend of the contaminant plume should be evaluated. Only after the plume has reached stability or is reliably diminishing can we conduct a test to examine the cleanup status of wells. Applying the analysis to wells in an expanding plume may cause incorrect conclusions and is less meaningful.

Statistical power analysis is a technique for interpreting the results of statistical tests. The Power of a statistical test is a measure of the ability of the test to detect an effect given that the effect actually exists. The method provides additional information about a statistical test: 1) the power of the statistical test, i.e., the probability of finding a difference in the variable of interest when a difference truly exists; and 2) the expected sample size of a future sampling plan given the minimum detectable difference it is supposed to detect. For example, if the mean concentration is lower than the cleanup goal but a statistical test cannot prove this, the power and expected sample size can tell the reason and how many more samples are needed to result in a significant test. The additional samples can be obtained by a longer period of sampling or an increased sampling frequency. Details about the data sufficiency analysis can be found in Appendix A.6 of the MAROS Manual (AFCEE, 2003).

When applying the MAROS power analysis method, a hypothetical statistical compliance boundary (HSCB) is assigned to be a line perpendicular to the groundwater flow direction (see figure below). Monitoring well concentrations are projected onto the HSCB using the distance from each well to the compliance boundary along with a decay coefficient. The projected concentrations from each well and each sampling event are then used in the risk-based power analysis. Since there may be more than one sampling event selected by the user, the risk-based power analysis results are given on an event-by-event basis. This power analysis can then indicate if target are statistically achieved at the HSCB. For instance, at a site where the historical monitoring record is short with few wells, the HSCB would be distant; whereas, at a site with longer duration of sampling with many wells, the HSCB would be close. Ultimately, at a site the goal would be to have the HSCB coincide with or be within the actual compliance boundary (typically the site property line).



In order to perform a risk-based cleanup status evaluation for the whole site, a strategy was developed as follows.

- Estimate concentration versus distance decay coefficient from plume centerline wells.
- Extrapolate concentration versus distance for each well using this decay coefficient.
- Comparing the extrapolated concentrations with the compliance concentration using power analysis.

Results from this analysis can be *Attained* or *Not Attained*, providing a statistical interpretation of whether the cleanup goal has been met on the site-scale from the risk-based point of view. The results as a function of time can be used to evaluate if the monitoring system has enough power at each step in the sampling record to indicate certainty of compliance by the plume location and condition relative to the compliance boundary. For example, if results are *Not Attained* at early sampling events but are *Attained* in recent sampling events, it indicates that the recent sampling record provides a powerful enough result to indicate compliance of the plume relative to the location of the receptor or compliance boundary.

CITED REFERENCES

AFCEE 2003. Monitoring and Remediation Optimization System (MAROS) 2.1 Software Users Guide. Air Force Center for Environmental Excellence. http://www.gsi-net.com/software/MAROS_V2_1Manual.pdf

AFCEE. 1997. Air Force Center for Environmental Excellence, AFCEE Long-Term Monitoring Optimization Guide, http://www.afcee.brooks.af.mil.

Aziz, J. A., C. J. Newell, M. Ling, H. S. Rifai and J. R. Gonzales (2003). "MAROS: A Decision Support System for Optimizing Monitoring Plans." Ground Water **41**(3): 355-367.

Gilbert, R. O., 1987, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, NY, ISBN 0-442-23050-8.

Hollander, M. and Wolfe, D. A. (1973). Nonparametric Statistical Methods, Wiley, New York, NY.

Ridley, M.N. et al., 1995. Cost-Effective Sampling of Groundwater Monitoring Wells, the Regents of UC/LLNL, Lawrence Livermore National Laboratory.

U.S. Environmental Protection Agency, 1992. Methods for Evaluating the Attainment of Cleanup Standards Volume 2: Ground Water.

Weight, W. D. and J. L. Sonderegger (2001). Manual of Applied Field Hydrogeology. New York, NY, McGraw-Hill.

TABLE 1
Mann-Kendall Analysis Decision Matrix (Aziz, et. al., 2003)

Mann-Kendall Statistic	Confidence in the Trend	Concentration Trend
S > 0	> 95%	Increasing
S > 0	90 - 95%	Probably Increasing
S > 0	< 90%	No Trend
S ≤ 0	< 90% and COV ≥ 1	No Trend
S ≤ 0	< 90% and COV < 1	Stable
S < 0	90 - 95%	Probably Decreasing
S < 0	> 95%	Decreasing

TABLE 2
Linear Regression Analysis Decision Matrix (Aziz, et. al., 2003)

Confidence in the Trend	Log-slope	
	Positive	Negative
< 90%	No Trend	COV < 1 Stable COV > 1 No Trend
90 - 95%	Probably Increasing	Probably Decreasing
> 95%	Increasing	Decreasing

MAROS: Decision Support Tool

MAROS is a collection of tools in one software package that is used in an explanatory, non-linear fashion. The tool includes models, geostatistics, heuristic rules, and empirical relationships to assist the user in optimizing a groundwater monitoring network system while maintaining adequate delineation of the plume as well as knowledge of the plume state over time. Different users utilize the tool in different ways and interpret the results from a different viewpoint.

↓

Overview Statistics

What it is: Simple, qualitative and quantitative plume information can be gained through evaluation of monitoring network historical data trends both spatially and temporally. The MAROS Overview Statistics are the foundation the user needs to make informed optimization decisions at the site.

What it does: The Overview Statistics are designed to allow site personnel to develop a better understanding of the plume behavior over time and understand how the individual well concentration trends are spatially distributed within the plume. This step allows the user to gain information that will support a more informed decision to be made in the next level of optimization analysis.

What are the tools: Overview Statistics includes two analytical tools:

1) **Trend Analysis:** includes Mann-Kendall and Linear Regression statistics for individual wells and results in general heuristically-derived monitoring categories with a suggested sampling density and monitoring frequency.

2) **Moment Analysis:** includes dissolved mass estimation (0^{th} Moment), center of mass (1^{st} Moment), and plume spread (2^{nd} Moment) over time. Trends of these moments show the user another piece of information about the plume stability over time.

What is the product: A first-cut blueprint for a future long-term monitoring program that is intended to be a foundation for more detailed statistical analysis.

↓

Detailed Statistics

What it is: The MAROS Detailed Statistics allows for a quantitative analysis for spatial and temporal optimization of the well network on a well-by-well basis.

What it does: The results from the Overview Statistics should be considered along side the MAROS optimization recommendations gained from the Detailed Statistical Analysis. The MAROS Detailed Statistics results should be reassessed in view of site knowledge and regulatory requirements as well as the Overview Statistics.

What are the tools: Detailed Statistics includes four analytical tools:

1) **Sampling Frequency Optimization:** uses the Modified CES method to establish a recommended future sampling frequency.

2) **Well Redundancy Analysis:** uses the Delaunay Method to evaluate if any wells within the monitoring network are redundant and can be eliminated without any significant loss of plume information.

3) **Well Sufficiency Analysis:** uses the Delaunay Method to evaluate areas where new wells are recommended within the monitoring network due to high levels of concentration uncertainty.

4) **Data Sufficiency Analysis:** uses Power Analysis to assess if the historical monitoring data record has sufficient power to accurately reflect the location of the plume relative to the nearest receptor or compliance point.

What is the product: List of wells to remove from the monitoring program, locations where monitoring wells may need to be added, recommended frequency of sampling for each well, analysis if the overall system is statistically powerful to monitor the plume.

Figure 1. MAROS Decision Support Tool Flow Chart

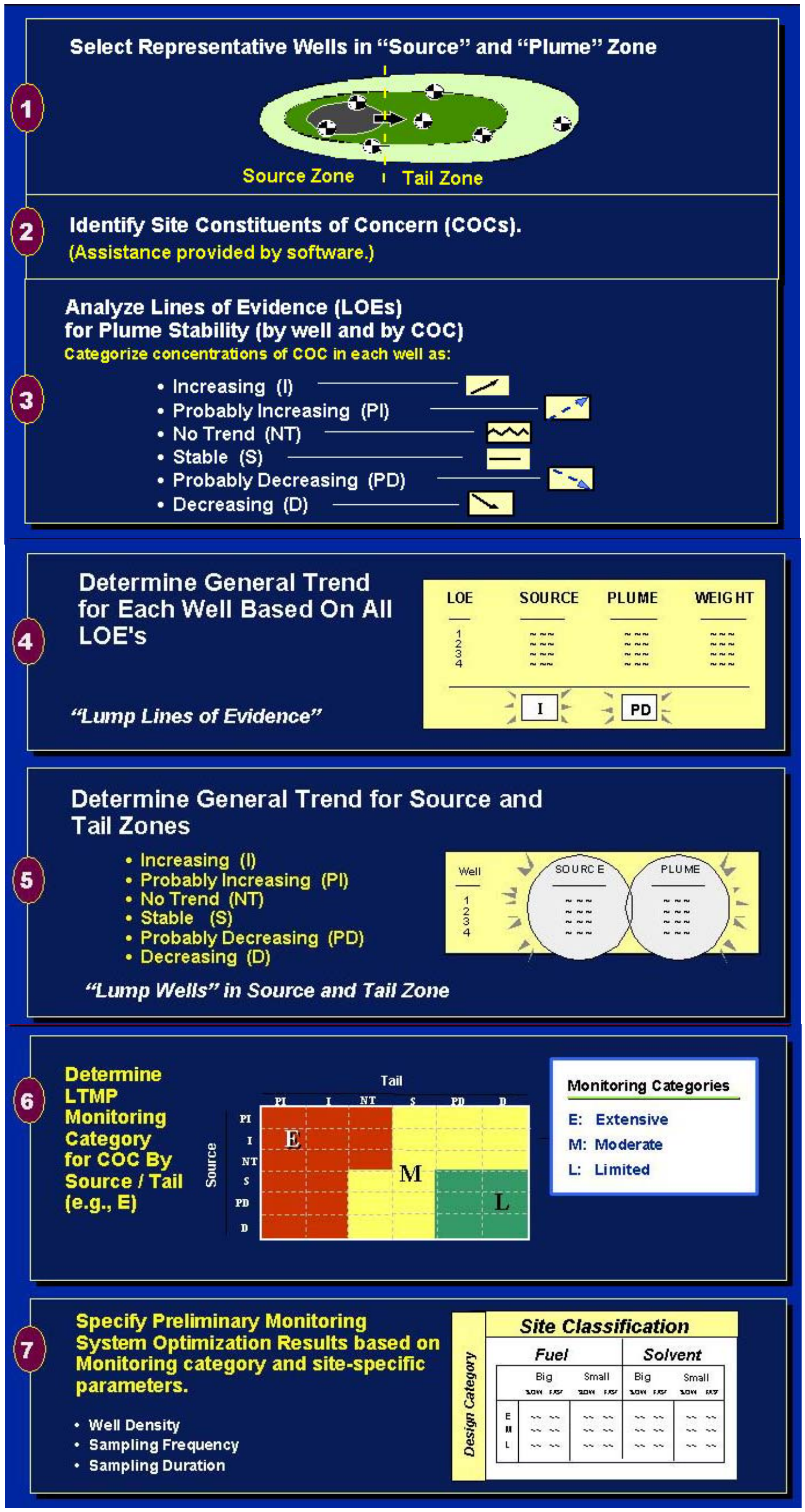


Figure 2:
MAROS Overview Statistics Trend Analysis Methodology

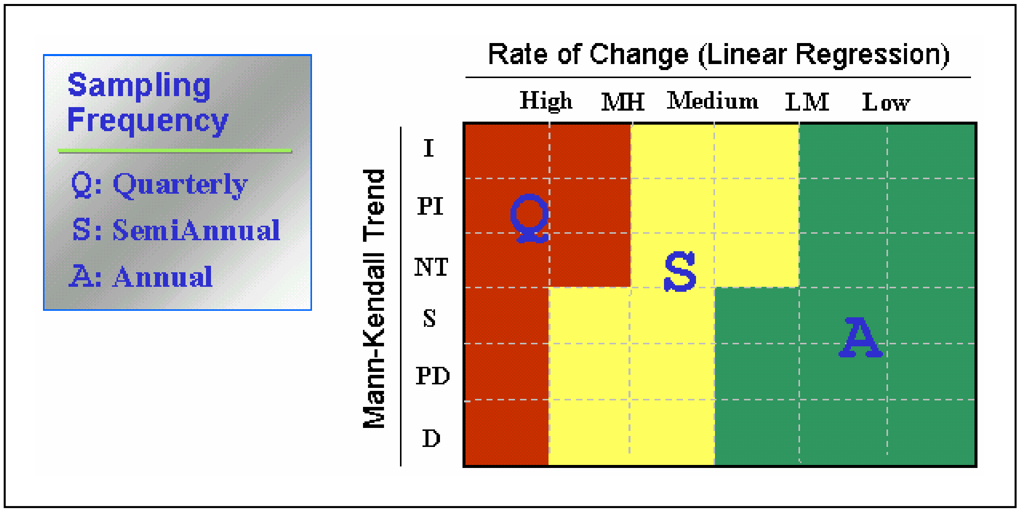


Figure 3. Decision Matrix for Determining Provisional Frequency (*Figure A.3.1 of the MAROS Manual (AFCEE 2003*)

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

APPENDIX B:

MAROS Supporting Information

Table B.1 Extraction Well Trend Summary Results RDX

TABLE B.1
EXTRACTION WELL TREND SUMMARY RESULTS RDX: 2000-2007

LONG-TERM MONITORING OPTIMIZATION
PANTEX FACILITY
Carson County, Texas

WellName	Number of Samples	Number of Detects	Percent Detection	Maximum Result [ug/L]	Max Result Above Standard?	Average Result [ug/L]	Average Result Above Standard?	Mann-Kendall Trend	Average Slope Factor
RDX Southeast Sector									
PTX06-EW-1	21	21	100%	1,600	Yes	926	Yes	D	0.08
PTX06-EW-10	22	19	86%	560	Yes	26	Yes	I	0.41
PTX06-EW-11	23	23	100%	1,300	Yes	794	Yes	D	0.07
PTX06-EW-12	22	22	100%	2,600	Yes	1,500	Yes	D	0.04
PTX06-EW-14	10	10	100%	1,360	Yes	674	Yes	NT	
PTX06-EW-15	25	25	100%	62	Yes	37	Yes	S	0.16
PTX06-EW-16	24	24	100%	2,300	Yes	1,510	Yes	S	0.14
PTX06-EW-17	23	23	100%	970	Yes	722	Yes	S	0.03
PTX06-EW-18	18	18	100%	1,100	Yes	536	Yes	D	0.02
PTX06-EW-19	23	23	100%	920	Yes	662	Yes	D	0.11
PTX06-EW-2	21	21	100%	1,040	Yes	733	Yes	D	0.02
PTX06-EW-20	23	23	100%	180	Yes	46	Yes	I	0.10
PTX06-EW-21	23	23	100%	110	Yes	40	Yes	D	0.48
PTX06-EW-22A	22	22	100%	910	Yes	154	Yes	D	0.08
PTX06-EW-23A	21	21	100%	1,400	Yes	772	Yes	D	0.04
PTX06-EW-24	22	22	100%	1,600	Yes	732	Yes	D	0.20
PTX06-EW-25	21	21	100%	840	Yes	271	Yes	D	0.09
PTX06-EW-26	23	23	100%	2,200	Yes	710	Yes	D	0.07
PTX06-EW-27	21	21	100%	2,500	Yes	1,060	Yes	I	0.02
PTX06-EW-28	20	20	100%	1,500	Yes	721	Yes	D	0.29
PTX06-EW-29	24	24	100%	1,800	Yes	580	Yes	D	0.26
PTX06-EW-3	23	23	100%	2,260	Yes	1,330	Yes	D	0.08
PTX06-EW-30	22	22	100%	1,600	Yes	798	Yes	D	0.04
PTX06-EW-31	22	22	100%	1,000	Yes	486	Yes	D	0.10
PTX06-EW-32	23	23	100%	1,400	Yes	672	Yes	D	0.03
PTX06-EW-33	22	22	100%	1,200	Yes	673	Yes	I	0.04
PTX06-EW-34	23	23	100%	1,800	Yes	1,200	Yes	S	0.01
PTX06-EW-35	22	22	100%	2,700	Yes	1,480	Yes	D	0.02
PTX06-EW-36	21	21	100%	2,600	Yes	1,130	Yes	D	0.11
PTX06-EW-37	21	21	100%	400	Yes	35	Yes	I	0.20
PTX06-EW-38C	22	22	100%	6,800	Yes	409	Yes	D	0.08
PTX06-EW-39	24	24	100%	1,300	Yes	611	Yes	D	0.05
PTX06-EW-4	25	25	100%	1,800	Yes	1,050	Yes	NT	0.01
PTX06-EW-40	22	22	100%	7,100	Yes	1,100	Yes	D	0.12
PTX06-EW-41	16	16	100%	15,000	Yes	1,730	Yes	D	0.07
PTX06-EW-42A	24	24	100%	8,100	Yes	1,340	Yes	PD	0.06
PTX06-EW-43	19	19	100%	5,500	Yes	2,420	Yes	D	0.05
PTX06-EW-44	24	24	100%	25,000	Yes	4,020	Yes	S	0.07
PTX06-EW-45	22	22	100%	4,900	Yes	3,320	Yes	D	0.06
PTX06-EW-46	24	24	100%	8,600	Yes	1,260	Yes	D	0.04
PTX06-EW-47	17	17	100%	1,900	Yes	1,250	Yes	D	0.02
PTX06-EW-48	22	22	100%	2,000	Yes	1,080	Yes	I	0.05
PTX06-EW-49	24	24	100%	10,000	Yes	1,380	Yes	S	0.04
PTX06-EW-5	18	18	100%	2,400	Yes	1,360	Yes	I	0.06
PTX06-EW-53	9	9	100%	1,400	Yes	923	Yes	PD	0.06
PTX06-EW-6	20	20	100%	5,920	Yes	2,540	Yes	D	0.03
PTX06-EW-7	25	25	100%	3,200	Yes	1,390	Yes	I	0.05
PTX06-EW-9	16	16	100%	290	Yes	32	Yes	I	0.22

Notes:
1. Extraction wells part of PGPTS in Southest Sector. Values for RDX 2000-2007.
2. Number of Samples is the number of samples analyzed for the compound at this location.
   Number of Detects is the number of samples where the compound has been detected at this location.
3. Maximum Result is the maximum concentration for the COC analyzed between 2000 and 2007.
4. Screening level from Corrective Measure Study. RDX = 7.7 ug/L.
6. D = Decreasing; PD = Probably Decreasing; S = Stable; PI = Probably Increasing; I = Increasing; N/A = Insufficient Data to determine trend;
   NT = No Trend; ND = well has all non-detect results for COC; ND* = Non-detect except for one trace value.
7. Mann-Kendall trend results are illustrated on Figure 3.

February 12, 2008

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

APPENDIX B:

Southeast Sector MAROS Reports

Mann-Kendall Reports

MAROS Moment Reports Southeast Sector
- Zeroth Moments
- First Moments
- Second Moments

MAROS Mann-Kendall Statistics Summary

Project: Pantex SE

User Name: MV

Location: SouthEast

State: Texas

Time Period: 1/15/2000 **to** 7/15/2007

Consolidation Period: No Time Consolidation

Consolidation Type: Geometric Mean

Duplicate Consolidation: Average

ND Values: Specified Detection Limit

J Flag Values : Actual Value

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2,4,6-TRINITROTOLUENE								
PTX06-1002A	T	7	0	0.00	0	43.7%	Yes	ND
PTX06-1003	S	7	6	0.86	-11	93.2%	No	PD
PTX06-1005	S	8	6	1.14	-9	83.2%	No	NT
PTX06-1010	S	6	2	1.91	-9	93.2%	No	PD
PTX06-1011	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1013	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1014	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1015	T	13	1	0.22	12	74.5%	No	NT
PTX06-1023	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1030	T	13	5	1.18	-30	96.2%	No	D
PTX06-1031	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1034	T	15	1	0.73	6	59.6%	No	NT
PTX06-1036	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1037	T	5	0	0.00	0	40.8%	Yes	ND
PTX06-1038	T	14	12	0.55	4	56.4%	No	NT
PTX06-1039A	T	11	6	1.52	23	95.7%	No	I
PTX06-1040	T	14	1	3.46	7	62.6%	No	NT
PTX06-1041	T	11	4	1.97	28	98.4%	No	I
PTX06-1042	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1045	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1046	T	16	0	0.00	0	48.2%	Yes	ND
PTX06-1047A	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-1052	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	0	0.00	0	48.4%	Yes	ND
PTX06-1069	T	11	1	0.42	-4	59.0%	No	S
PTX06-1088	S	8	8	0.51	-24	99.9%	No	D
PTX06-1095A	T	3	0	0.00	0	0.0%	Yes	ND
PTX06-1102	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-EW-1	T	21	21	0.73	-168	100.0%	No	D
PTX06-EW-10	T	20	1	3.53	13	65.0%	No	NT
PTX06-EW-11	T	21	3	1.14	-53	94.2%	No	PD
PTX06-EW-12	T	19	2	1.17	-35	88.1%	No	NT
PTX06-EW-14	T	8	1	1.57	-7	76.4%	No	NT
PTX06-EW-15	T	25	25	0.31	-113	99.6%	No	D
PTX06-EW-16	T	25	24	0.36	-95	98.7%	No	D
PTX06-EW-17	T	23	23	0.30	-88	99.0%	No	D
PTX06-EW-18	T	18	18	0.87	-104	100.0%	No	D
PTX06-EW-19	T	20	2	4.38	-37	87.7%	No	NT

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2,4,6-TRINITROTOLUENE								
PTX06-EW-2	T	21	21	0.14	-114	100.0%	No	D
PTX06-EW-20	T	23	23	0.66	19	68.1%	No	NT
PTX06-EW-21	T	23	23	0.47	-170	100.0%	No	D
PTX06-EW-22	T	22	22	0.43	-83	99.0%	No	D
PTX06-EW-23	T	22	22	0.25	-14	64.2%	No	S
PTX06-EW-24	T	21	21	0.27	-90	99.7%	No	D
PTX06-EW-25	T	21	21	0.63	-181	100.0%	No	D
PTX06-EW-26	T	23	23	0.57	59	93.7%	No	PI
PTX06-EW-27	T	17	0	0.00	0	48.4%	Yes	ND
PTX06-EW-28	T	20	20	0.33	-107	100.0%	No	D
PTX06-EW-29	T	23	22	0.49	-158	100.0%	No	D
PTX06-EW-3	T	23	23	0.49	-198	100.0%	No	D
PTX06-EW-30	T	20	2	0.91	31	83.3%	No	NT
PTX06-EW-31	T	19	8	1.45	111	100.0%	No	I
PTX06-EW-32	T	20	1	2.68	17	69.6%	No	NT
PTX06-EW-33	T	19	13	0.93	120	100.0%	No	I
PTX06-EW-34	T	20	18	0.53	119	100.0%	No	I
PTX06-EW-35	T	19	5	0.84	73	99.5%	No	I
PTX06-EW-36	T	19	18	0.57	-85	99.9%	No	D
PTX06-EW-37	T	21	3	3.91	-51	93.4%	No	PD
PTX06-EW-38	T	22	22	1.68	-187	100.0%	No	D
PTX06-EW-39	T	22	21	0.62	-20	70.2%	No	S
PTX06-EW-4	T	21	10	1.04	108	100.0%	No	I
PTX06-EW-40	T	20	20	0.33	-10	61.3%	No	S
PTX06-EW-41	T	16	15	1.64	21	81.3%	No	NT
PTX06-EW-42	T	21	17	1.16	123	100.0%	No	I
PTX06-EW-43	T	14	11	0.69	72	100.0%	No	I
PTX06-EW-44	T	20	20	0.39	145	100.0%	No	I
PTX06-EW-45	T	17	16	0.49	111	100.0%	No	I
PTX06-EW-46	T	20	10	1.06	91	99.9%	No	I
PTX06-EW-47	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-EW-48	T	19	4	2.52	62	98.5%	No	I
PTX06-EW-49	T	21	1	4.41	-20	71.5%	No	NT
PTX06-EW-5	T	16	4	3.71	24	84.7%	No	NT
PTX06-EW-53	T	9	0	0.00	0	46.0%	Yes	ND
PTX06-EW-6	T	17	2	1.66	-29	87.4%	No	NT
PTX06-EW-7	T	22	1	0.64	-21	71.1%	No	S
PTX06-EW-9	T	14	0	0.00	0	47.8%	Yes	ND
PTX08-1002	T	7	7	0.24	-9	88.1%	No	S
PTX08-1008	T	11	0	0.00	0	46.9%	Yes	ND
PTX08-1009	T	7	1	0.40	-2	55.7%	No	S
2,4-DINITROTOLUENE								
PTX06-1002A	T	7	0	0.00	0	43.7%	Yes	ND
PTX06-1003	S	7	3	0.98	1	50.0%	No	NT
PTX06-1005	S	8	4	1.32	-14	94.6%	No	PD
PTX06-1010	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1011	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1013	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1014	T	13	10	1.52	1	50.0%	No	NT

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2,4-DINITROTOLUENE								
PTX06-1015	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1023	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1030	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-1031	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-1034	T	15	2	0.36	9	65.1%	No	NT
PTX06-1036	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1037	T	6	0	0.00	0	42.3%	Yes	ND
PTX06-1038	T	14	11	1.15	-16	79.1%	No	NT
PTX06-1039A	T	11	9	0.69	18	90.5%	No	PI
PTX06-1040	T	13	2	0.71	19	86.1%	No	NT
PTX06-1041	T	12	11	0.71	36	99.3%	No	I
PTX06-1042	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1045	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1046	T	17	1	0.04	4	54.8%	No	NT
PTX06-1047A	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-1052	T	15	1	0.15	-4	55.8%	No	S
PTX06-1053	T	17	0	0.00	14	70.1%	Yes	ND
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1088	S	8	2	1.75	7	76.4%	No	NT
PTX06-1095A	T	3	0	0.00	0	0.0%	Yes	ND
PTX06-1102	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-EW-1	T	20	20	1.03	-135	100.0%	No	D
PTX06-EW-10	T	20	1	0.57	13	65.0%	No	NT
PTX06-EW-11	T	20	1	0.57	3	52.6%	No	NT
PTX06-EW-12	T	18	10	1.49	71	99.7%	No	I
PTX06-EW-14	T	7	0	0.00	0	43.7%	Yes	ND
PTX06-EW-15	T	25	23	0.54	-148	100.0%	No	D
PTX06-EW-16	T	24	24	1.04	-213	100.0%	No	D
PTX06-EW-17	T	23	23	1.13	-160	100.0%	No	D
PTX06-EW-18	T	16	14	1.08	-91	100.0%	No	D
PTX06-EW-19	T	18	13	2.36	69	99.6%	No	I
PTX06-EW-2	T	20	20	0.97	-139	100.0%	No	D
PTX06-EW-20	T	22	17	0.88	62	95.8%	No	I
PTX06-EW-21	T	23	22	0.86	-175	100.0%	No	D
PTX06-EW-22	T	21	20	1.17	-147	100.0%	No	D
PTX06-EW-23	T	21	21	1.13	-125	100.0%	No	D
PTX06-EW-24	T	20	20	0.62	-74	99.2%	No	D
PTX06-EW-25	T	20	20	1.21	-131	100.0%	No	D
PTX06-EW-26	T	21	20	1.21	-125	100.0%	No	D
PTX06-EW-27	T	17	15	0.98	2	51.6%	No	NT
PTX06-EW-28	T	20	19	1.02	-110	100.0%	No	D
PTX06-EW-29	T	22	19	1.51	-144	100.0%	No	D
PTX06-EW-3	T	22	22	1.35	-144	100.0%	No	D
PTX06-EW-30	T	18	7	0.64	42	93.9%	No	PI
PTX06-EW-31	T	18	17	0.78	-49	96.6%	No	D
PTX06-EW-32	T	19	5	3.23	-14	67.4%	No	NT
PTX06-EW-33	T	22	21	0.91	-88	99.4%	No	D
PTX06-EW-34	T	22	21	0.93	-130	100.0%	No	D
PTX06-EW-35	T	19	12	2.23	76	99.7%	No	I
PTX06-EW-36	T	19	18	1.55	-123	100.0%	No	D
PTX06-EW-37	T	21	2	4.03	-35	84.6%	No	NT

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2,4-DINITROTOLUENE								
PTX06-EW-38	T	22	21	3.00	-179	100.0%	No	D
PTX06-EW-39	T	21	16	1.84	-52	93.8%	No	PD
PTX06-EW-4	T	20	17	1.34	31	83.3%	No	NT
PTX06-EW-40	T	21	21	2.73	-163	100.0%	No	D
PTX06-EW-41	T	15	15	3.07	-63	99.9%	No	D
PTX06-EW-42	T	20	19	1.50	-113	100.0%	No	D
PTX06-EW-43	T	17	16	1.00	-44	96.2%	No	D
PTX06-EW-44	T	22	22	1.71	-150	100.0%	No	D
PTX06-EW-45	T	19	19	1.14	-125	100.0%	No	D
PTX06-EW-46	T	21	20	0.84	-106	99.9%	No	D
PTX06-EW-47	T	14	1	0.13	-7	62.6%	No	S
PTX06-EW-48	T	19	19	1.04	-46	94.2%	No	PD
PTX06-EW-49	T	21	2	4.50	-35	84.6%	No	NT
PTX06-EW-5	T	18	16	1.01	-84	100.0%	No	D
PTX06-EW-53	T	9	9	0.43	9	79.2%	No	NT
PTX06-EW-6	T	16	11	0.94	57	99.5%	No	I
PTX06-EW-7	T	22	19	1.56	37	84.3%	No	NT
PTX06-EW-9	T	14	1	0.91	11	70.5%	No	NT
PTX08-1002	T	7	6	0.47	-1	50.0%	No	S
PTX08-1008	T	11	0	0.00	0	46.9%	Yes	ND
PTX08-1009	T	7	0	0.00	0	43.7%	Yes	ND
2-AMINO-4,6-DINITROTOLUENE								
PTX06-1002A	T	7	0	0.00	0	43.7%	Yes	ND
PTX06-1003	S	7	2	0.17	-7	80.9%	No	S
PTX06-1005	S	8	4	1.06	6	72.6%	No	NT
PTX06-1010	S	7	4	1.17	-10	90.7%	No	PD
PTX06-1011	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1013	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1014	T	13	12	0.69	-56	100.0%	No	D
PTX06-1015	T	13	4	1.41	12	74.5%	No	NT
PTX06-1023	T	12	2	0.06	-15	82.8%	No	S
PTX06-1030	T	13	4	1.08	36	98.5%	No	I
PTX06-1031	T	14	6	1.38	-3	54.3%	No	NT
PTX06-1034	T	15	9	1.10	10	66.9%	No	NT
PTX06-1036	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1037	T	5	2	1.71	5	82.1%	No	NT
PTX06-1038	T	14	12	0.50	-10	68.6%	No	S
PTX06-1039A	T	11	10	0.46	21	94.0%	No	PI
PTX06-1040	T	14	8	1.13	46	99.4%	No	I
PTX06-1041	T	11	8	0.68	8	70.3%	No	NT
PTX06-1042	T	15	10	1.23	47	99.0%	No	I
PTX06-1045	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1046	T	16	1	0.26	7	60.5%	No	NT
PTX06-1047A	T	14	0	0.00	0	47.8%	Yes	ND
PTX06-1052	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	0	0.00	0	48.4%	Yes	ND
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1088	S	8	7	0.46	6	72.6%	No	NT
PTX06-1095A	T	3	0	0.00	0	0.0%	Yes	ND

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2-AMINO-4,6-DINITROTOLUENE								
PTX06-1102	T	8	3	1.77	-6	72.6%	No	NT
PTX06-EW-1	T	20	20	0.38	-90	99.8%	No	D
PTX06-EW-10	T	20	1	3.33	13	65.0%	No	NT
PTX06-EW-11	T	20	19	0.55	81	99.6%	No	I
PTX06-EW-12	T	22	22	0.50	118	100.0%	No	I
PTX06-EW-14	T	7	1	1.76	-6	76.4%	No	NT
PTX06-EW-15	T	21	11	0.52	-37	86.0%	No	S
PTX06-EW-16	T	25	25	0.36	-186	100.0%	No	D
PTX06-EW-17	T	23	23	0.27	-144	100.0%	No	D
PTX06-EW-18	T	18	18	0.39	-107	100.0%	No	D
PTX06-EW-19	T	23	23	0.25	-56	92.6%	No	PD
PTX06-EW-2	T	20	20	0.38	-143	100.0%	No	D
PTX06-EW-20	T	20	11	0.86	64	98.0%	No	I
PTX06-EW-21	T	23	21	0.70	-177	100.0%	No	D
PTX06-EW-22	T	22	22	1.59	-82	99.0%	No	D
PTX06-EW-23	T	22	22	0.22	-94	99.7%	No	D
PTX06-EW-24	T	21	21	0.38	-36	85.3%	No	S
PTX06-EW-25	T	20	20	0.51	-99	100.0%	No	D
PTX06-EW-26	T	23	23	0.36	-7	56.2%	No	S
PTX06-EW-27	T	21	21	0.40	-10	60.6%	No	S
PTX06-EW-28	T	20	20	0.44	-48	93.6%	No	PD
PTX06-EW-29	T	23	22	0.85	-188	100.0%	No	D
PTX06-EW-3	T	23	23	0.58	-159	100.0%	No	D
PTX06-EW-30	T	23	23	0.28	26	74.4%	No	NT
PTX06-EW-31	T	22	22	0.38	-161	100.0%	No	D
PTX06-EW-32	T	23	23	0.42	-98	99.6%	No	D
PTX06-EW-33	T	22	22	0.41	-55	93.6%	No	PD
PTX06-EW-34	T	23	23	0.45	-144	100.0%	No	D
PTX06-EW-35	T	20	19	0.52	-84	99.7%	No	D
PTX06-EW-36	T	21	20	0.58	-113	100.0%	No	D
PTX06-EW-37	T	21	1	2.05	-18	69.4%	No	NT
PTX06-EW-38	T	22	22	1.88	-55	93.6%	No	PD
PTX06-EW-39	T	24	24	0.75	-100	99.4%	No	D
PTX06-EW-4	T	25	25	0.26	-3	51.9%	No	S
PTX06-EW-40	T	22	22	1.32	-138	100.0%	No	D
PTX06-EW-41	T	16	16	1.96	-41	96.5%	No	D
PTX06-EW-42	T	23	23	3.05	-202	100.0%	No	D
PTX06-EW-43	T	19	19	0.75	-84	99.9%	No	D
PTX06-EW-44	T	23	23	1.85	-133	100.0%	No	D
PTX06-EW-45	T	22	22	0.34	-55	93.6%	No	PD
PTX06-EW-46	T	24	24	0.97	-124	99.9%	No	D
PTX06-EW-47	T	16	16	0.39	39	95.7%	No	I
PTX06-EW-48	T	22	22	0.39	-144	100.0%	No	D
PTX06-EW-49	T	21	18	3.26	151	100.0%	No	I
PTX06-EW-5	T	19	19	0.42	-97	100.0%	No	D
PTX06-EW-53	T	9	9	0.29	-18	96.2%	No	D
PTX06-EW-6	T	20	20	0.47	-66	98.3%	No	D
PTX06-EW-7	T	25	25	0.42	-106	99.3%	No	D
PTX06-EW-9	T	14	1	2.40	11	70.5%	No	NT
PTX08-1002	T	7	4	1.05	0	43.7%	No	NT
PTX08-1008	T	11	1	0.42	-6	64.8%	No	S

Project: Pantex SE

User Name: MV

Location: SouthEast

State: Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2-AMINO-4,6-DINITROTOLUENE								
PTX08-1009	T	7	1	0.78	-2	55.7%	No	S
4-AMINO-2,6-DINITROTOLUENE								
PTX06-1002A	T	7	6	0.45	0	43.7%	No	S
PTX06-1003	S	7	2	0.61	-5	71.9%	No	S
PTX06-1005	S	8	5	1.11	13	92.9%	No	PI
PTX06-1010	S	8	3	1.41	-16	96.9%	No	D
PTX06-1011	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1013	T	11	1	0.02	0	46.9%	No	S
PTX06-1014	T	13	12	0.65	-29	95.6%	No	D
PTX06-1015	T	13	13	0.34	-8	66.2%	No	S
PTX06-1023	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1030	T	13	12	0.68	33	97.5%	No	I
PTX06-1031	T	14	14	0.37	37	97.6%	No	I
PTX06-1034	T	15	14	0.80	73	100.0%	No	I
PTX06-1036	T	13	10	0.85	-43	99.6%	No	D
PTX06-1037	T	5	5	0.19	-4	75.8%	No	S
PTX06-1038	T	14	12	0.59	22	87.2%	No	NT
PTX06-1039A	T	11	9	0.74	18	90.5%	No	PI
PTX06-1040	T	14	14	0.31	-3	54.3%	No	S
PTX06-1041	T	12	12	0.32	10	72.7%	No	NT
PTX06-1042	T	16	11	0.90	60	99.7%	No	I
PTX06-1045	T	11	7	1.22	5	61.9%	No	NT
PTX06-1046	T	17	11	0.99	44	96.2%	No	I
PTX06-1047A	T	14	5	1.83	35	96.9%	No	I
PTX06-1052	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	13	1.15	96	100.0%	No	I
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1088	S	8	6	0.96	10	86.2%	No	NT
PTX06-1095A	T	3	0	0.00	0	0.0%	Yes	ND
PTX06-1102	T	9	7	0.95	-1	50.0%	No	S
PTX06-EW-1	T	19	18	0.50	-43	92.8%	No	PD
PTX06-EW-10	T	20	12	2.76	109	100.0%	No	I
PTX06-EW-11	T	24	23	0.29	29	75.4%	No	NT
PTX06-EW-12	T	22	21	0.43	10	59.9%	No	NT
PTX06-EW-14	T	11	10	0.51	-6	64.8%	No	S
PTX06-EW-15	T	25	23	0.63	-127	99.9%	No	D
PTX06-EW-16	T	25	24	0.39	-61	91.9%	No	PD
PTX06-EW-17	T	23	22	0.39	-83	98.5%	No	D
PTX06-EW-18	T	18	17	0.41	-34	89.3%	No	S
PTX06-EW-19	T	23	22	0.33	-61	94.3%	No	PD
PTX06-EW-2	T	19	14	0.66	-47	94.6%	No	PD
PTX06-EW-20	T	21	9	0.92	14	65.1%	No	NT
PTX06-EW-21	T	22	7	3.16	-62	95.8%	No	D
PTX06-EW-22	T	21	12	2.33	-16	67.3%	No	NT
PTX06-EW-23	T	21	21	0.28	-45	90.7%	No	PD
PTX06-EW-24	T	19	16	0.54	89	99.9%	No	I
PTX06-EW-25	T	18	8	0.78	-24	80.6%	No	S
PTX06-EW-26	T	23	23	0.58	-105	99.7%	No	D
PTX06-EW-27	T	21	21	0.41	100	99.9%	No	I

Project: Pantex SE

User Name: MV

Location: SouthEast

State: Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
4-AMINO-2,6-DINITROTOLUENE								
PTX06-EW-28	T	19	19	0.31	-30	84.3%	No	S
PTX06-EW-29	T	23	20	0.70	-171	100.0%	No	D
PTX06-EW-3	T	22	21	0.44	-116	100.0%	No	D
PTX06-EW-30	T	23	23	0.52	-63	94.9%	No	PD
PTX06-EW-31	T	22	22	0.55	-97	99.7%	No	D
PTX06-EW-32	T	23	23	0.32	-155	100.0%	No	D
PTX06-EW-33	T	22	22	0.32	-32	80.7%	No	S
PTX06-EW-34	T	23	23	0.66	-140	100.0%	No	D
PTX06-EW-35	T	22	21	0.58	105	99.9%	No	I
PTX06-EW-36	T	20	20	0.39	-18	70.7%	No	S
PTX06-EW-37	T	21	21	0.69	-112	100.0%	No	D
PTX06-EW-38	T	22	21	0.50	-116	100.0%	No	D
PTX06-EW-39	T	24	24	0.63	-182	100.0%	No	D
PTX06-EW-4	T	25	24	0.45	139	100.0%	No	I
PTX06-EW-40	T	22	21	0.43	-137	100.0%	No	D
PTX06-EW-41	T	16	15	0.75	-35	93.6%	No	PD
PTX06-EW-42	T	23	23	3.59	1	50.0%	No	NT
PTX06-EW-43	T	18	18	0.43	-45	95.2%	No	D
PTX06-EW-44	T	23	23	1.46	-42	85.9%	No	NT
PTX06-EW-45	T	21	21	0.27	-49	92.6%	No	PD
PTX06-EW-46	T	24	24	2.22	-76	96.9%	No	D
PTX06-EW-47	T	17	17	0.28	-35	91.8%	No	PD
PTX06-EW-48	T	22	22	0.52	-100	99.8%	No	D
PTX06-EW-49	T	23	23	1.60	-144	100.0%	No	D
PTX06-EW-5	T	19	18	0.56	-60	98.1%	No	D
PTX06-EW-53	T	9	9	0.35	-3	58.0%	No	S
PTX06-EW-6	T	20	19	0.81	-86	99.8%	No	D
PTX06-EW-7	T	25	24	0.35	104	99.2%	No	I
PTX06-EW-9	T	16	15	0.41	-39	95.7%	No	D
PTX08-1002	T	7	4	1.53	4	66.7%	No	NT
PTX08-1008	T	11	9	0.87	-8	70.3%	No	S
PTX08-1009	T	7	3	1.54	7	80.9%	No	NT
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
PTX06-1002A	T	7	7	0.14	-5	71.9%	No	S
PTX06-1003	S	7	6	1.93	-7	80.9%	No	NT
PTX06-1005	S	8	8	0.84	-14	94.6%	No	PD
PTX06-1010	S	8	6	1.25	-15	95.8%	No	D
PTX06-1011	S	7	2	2.59	1	50.0%	No	NT
PTX06-1013	T	11	11	0.19	23	95.7%	No	I
PTX06-1014	T	14	14	0.26	35	96.9%	No	I
PTX06-1015	T	13	13	0.65	60	100.0%	No	I
PTX06-1023	T	12	12	0.23	-10	72.7%	No	S
PTX06-1030	T	15	15	0.26	47	99.0%	No	I
PTX06-1031	T	15	15	0.66	97	100.0%	No	I
PTX06-1034	T	13	7	1.87	55	100.0%	No	I
PTX06-1036	T	13	6	1.17	43	99.6%	No	I
PTX06-1037	T	5	5	0.36	-6	88.3%	No	S
PTX06-1038	T	14	14	0.20	-35	96.9%	No	D
PTX06-1039A	T	11	11	0.31	-21	94.0%	No	PD

Project: Pantex SE **User Name:** MV

Location: SouthEast **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
PTX06-1040	T	14	14	0.15	9	66.6%	No	NT
PTX06-1041	T	12	12	0.24	2	52.7%	No	NT
PTX06-1042	T	16	16	0.39	-18	77.5%	No	S
PTX06-1045	T	12	12	0.34	38	99.6%	No	I
PTX06-1046	T	17	17	0.22	88	100.0%	No	I
PTX06-1047A	T	14	5	2.31	37	97.6%	No	I
PTX06-1052	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	2	3.15	23	81.5%	No	NT
PTX06-1069	T	11	1	0.14	-4	59.0%	No	S
PTX06-1088	S	8	8	0.15	-14	94.6%	No	PD
PTX06-1095A	T	3	1	0.00	0	0.0%	No	N/A
PTX06-1102	T	10	10	1.14	-16	90.7%	No	PD
PTX06-EW-1	T	21	21	0.37	-65	97.4%	No	D
PTX06-EW-10	T	22	19	4.55	87	99.3%	No	I
PTX06-EW-11	T	23	23	0.31	-202	100.0%	No	D
PTX06-EW-12	T	22	22	0.34	-94	99.7%	No	D
PTX06-EW-14	T	10	10	0.52	3	56.9%	No	NT
PTX06-EW-15	T	25	25	0.33	-43	83.5%	No	S
PTX06-EW-16	T	24	24	0.35	-40	83.1%	No	S
PTX06-EW-17	T	23	23	0.26	-16	65.3%	No	S
PTX06-EW-18	T	18	18	0.49	-78	99.9%	No	D
PTX06-EW-19	T	23	23	0.23	-120	100.0%	No	D
PTX06-EW-2	T	21	21	0.20	-85	99.5%	No	D
PTX06-EW-20	T	23	23	1.06	101	99.6%	No	I
PTX06-EW-21	T	23	23	0.72	-211	100.0%	No	D
PTX06-EW-22	T	22	22	1.18	-120	100.0%	No	D
PTX06-EW-23	T	21	21	0.27	-83	99.4%	No	D
PTX06-EW-24	T	22	22	0.45	-136	100.0%	No	D
PTX06-EW-25	T	21	21	0.88	-166	100.0%	No	D
PTX06-EW-26	T	23	23	0.63	-104	99.7%	No	D
PTX06-EW-27	T	21	21	0.41	111	100.0%	No	I
PTX06-EW-28	T	20	20	0.47	-120	100.0%	No	D
PTX06-EW-29	T	24	24	0.69	-203	100.0%	No	D
PTX06-EW-3	T	23	23	0.38	-181	100.0%	No	D
PTX06-EW-30	T	22	22	0.35	-92	99.6%	No	D
PTX06-EW-31	T	22	22	0.47	-159	100.0%	No	D
PTX06-EW-32	T	23	23	0.38	-123	100.0%	No	D
PTX06-EW-33	T	22	22	0.48	155	100.0%	No	I
PTX06-EW-34	T	23	23	0.31	-38	83.4%	No	S
PTX06-EW-35	T	22	22	0.41	-94	99.7%	No	D
PTX06-EW-36	T	21	21	0.56	-97	99.9%	No	D
PTX06-EW-37	T	21	21	2.42	100	99.9%	No	I
PTX06-EW-38	T	22	22	1.95	-142	100.0%	No	D
PTX06-EW-39	T	24	24	0.60	-79	97.4%	No	D
PTX06-EW-4	T	25	25	0.33	30	74.9%	No	NT
PTX06-EW-40	T	22	22	0.67	-143	100.0%	No	D
PTX06-EW-41	T	16	16	1.13	-47	98.2%	No	D
PTX06-EW-42	T	24	24	1.14	-57	91.7%	No	PD
PTX06-EW-43	T	19	19	0.54	-53	96.6%	No	D
PTX06-EW-44	T	24	24	0.65	-50	88.7%	No	S
PTX06-EW-45	T	22	22	0.22	-120	100.0%	No	D

Project: Pantex SE

User Name: MV

Location: SouthEast

State: Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
PTX06-EW-46	T	24	24	0.70	-100	99.4%	No	D
PTX06-EW-47	T	17	17	0.31	-75	99.9%	No	D
PTX06-EW-48	T	22	22	0.39	117	100.0%	No	I
PTX06-EW-49	T	24	24	0.63	-8	56.8%	No	S
PTX06-EW-5	T	18	18	0.24	78	99.9%	No	I
PTX06-EW-53	T	9	9	0.23	-16	94.0%	No	PD
PTX06-EW-6	T	20	20	0.64	-130	100.0%	No	D
PTX06-EW-7	T	25	25	0.32	127	99.9%	No	I
PTX06-EW-9	T	16	16	2.19	72	100.0%	No	I
PTX08-1002	T	7	7	0.70	-11	93.2%	No	PD
PTX08-1008	T	11	2	0.09	-15	85.9%	No	S
PTX08-1009	T	7	4	2.10	-8	84.5%	No	NT

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A)-
Due to insufficient Data (< 4 sampling events); Source/Tail (S/T)

The Number of Samples and Number of Detects shown above are post-consolidation values.

MAROS Zeroth Moment Analysis

Project: Pantex SE Sector

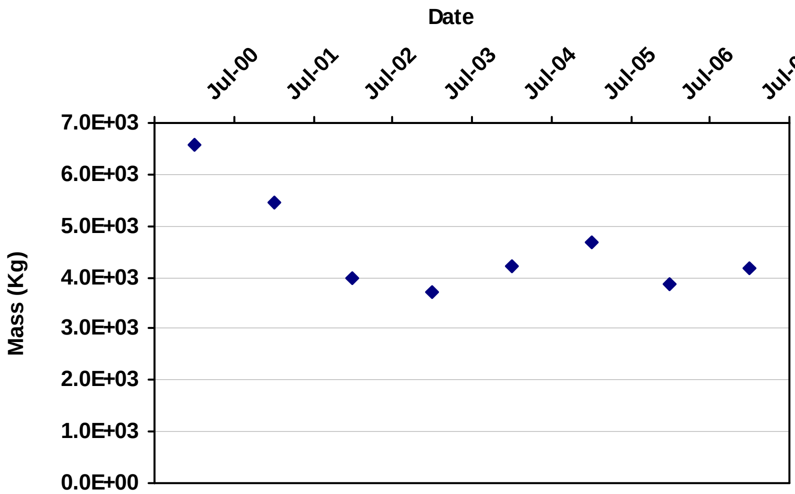
User Name: MV

Location: SouthEast

State: Texas

COC: HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 30 ft

Mann Kendall S Statistic:

-10

Confidence in Trend:

86.2%

Coefficient of Variation:

0.21

Zeroth Moment Trend:

S

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	6.6E+03	72
7/1/2001	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	5.5E+03	74
7/1/2002	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	4.0E+03	75
7/1/2003	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	3.7E+03	75
7/1/2004	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	4.2E+03	73
7/1/2005	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	4.7E+03	76
7/1/2006	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	3.9E+03	75
7/1/2007	HEXAHYDRO-1,3,5-TRINITRO-1,3,5-T	4.2E+03	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

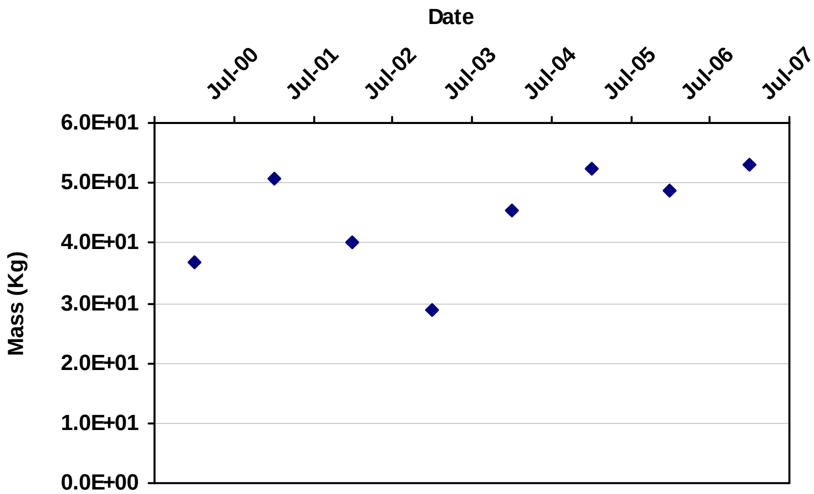
MAROS Zeroth Moment Analysis

Project: Pantex SE 4ADNT **User Name:** MV

Location: Southeast **State:** Texas

COC: 4-AMINO-2,6-DINITROTOLUENE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 30 ft

Mann Kendall S Statistic:

14

Confidence in Trend:

94.6%

Coefficient of Variation:

0.19

Zeroth Moment Trend:

PI

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	4-AMINO-2,6-DINITROTOLUENE	3.7E+01	68
7/1/2001	4-AMINO-2,6-DINITROTOLUENE	5.1E+01	68
7/1/2002	4-AMINO-2,6-DINITROTOLUENE	4.0E+01	75
7/1/2003	4-AMINO-2,6-DINITROTOLUENE	2.9E+01	75
7/1/2004	4-AMINO-2,6-DINITROTOLUENE	4.5E+01	74
7/1/2005	4-AMINO-2,6-DINITROTOLUENE	5.2E+01	76
7/1/2006	4-AMINO-2,6-DINITROTOLUENE	4.9E+01	73
7/1/2007	4-AMINO-2,6-DINITROTOLUENE	5.3E+01	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS Zeroth Moment Analysis

Project: Pantex SE Sector

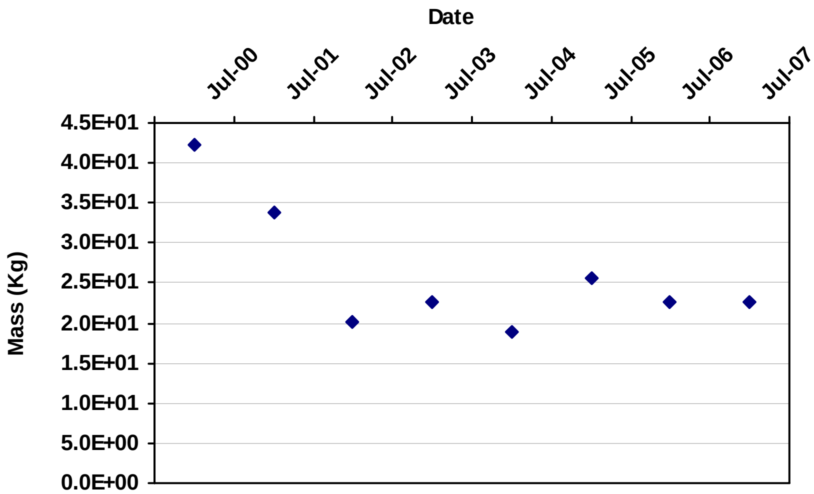
User Name: MV

Location: SouthEast

State: Texas

COC: 2-AMINO-4,6-DINITROTOLUENE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 30 ft

Mann Kendall S Statistic:

-10

Confidence in Trend:

86.2%

Coefficient of Variation:

0.30

Zeroth Moment Trend:

S

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	2-AMINO-4,6-DINITROTOLUENE	4.2E+01	71
7/1/2001	2-AMINO-4,6-DINITROTOLUENE	3.4E+01	68
7/1/2002	2-AMINO-4,6-DINITROTOLUENE	2.0E+01	74
7/1/2003	2-AMINO-4,6-DINITROTOLUENE	2.3E+01	75
7/1/2004	2-AMINO-4,6-DINITROTOLUENE	1.9E+01	74
7/1/2005	2-AMINO-4,6-DINITROTOLUENE	2.6E+01	76
7/1/2006	2-AMINO-4,6-DINITROTOLUENE	2.3E+01	75
7/1/2007	2-AMINO-4,6-DINITROTOLUENE	2.3E+01	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS Zeroth Moment Analysis

Project: Pantex SE Sector

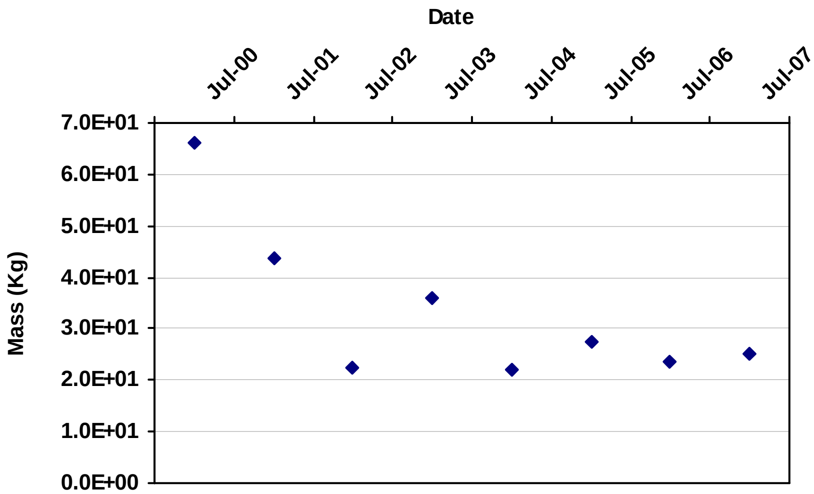
User Name: MV

Location: SouthEast

State: Texas

COC: 2,4,6-TRINITROTOLUENE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 30 ft

Mann Kendall S Statistic:

-12

Confidence in Trend:

91.1%

Coefficient of Variation:

0.46

Zeroth Moment Trend:

PD

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	2,4,6-TRINITROTOLUENE	6.6E+01	58
7/1/2001	2,4,6-TRINITROTOLUENE	4.4E+01	46
7/1/2002	2,4,6-TRINITROTOLUENE	2.3E+01	74
7/1/2003	2,4,6-TRINITROTOLUENE	3.6E+01	75
7/1/2004	2,4,6-TRINITROTOLUENE	2.2E+01	74
7/1/2005	2,4,6-TRINITROTOLUENE	2.8E+01	76
7/1/2006	2,4,6-TRINITROTOLUENE	2.3E+01	75
7/1/2007	2,4,6-TRINITROTOLUENE	2.5E+01	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS Zeroth Moment Analysis

Project: Pantex SE Sector

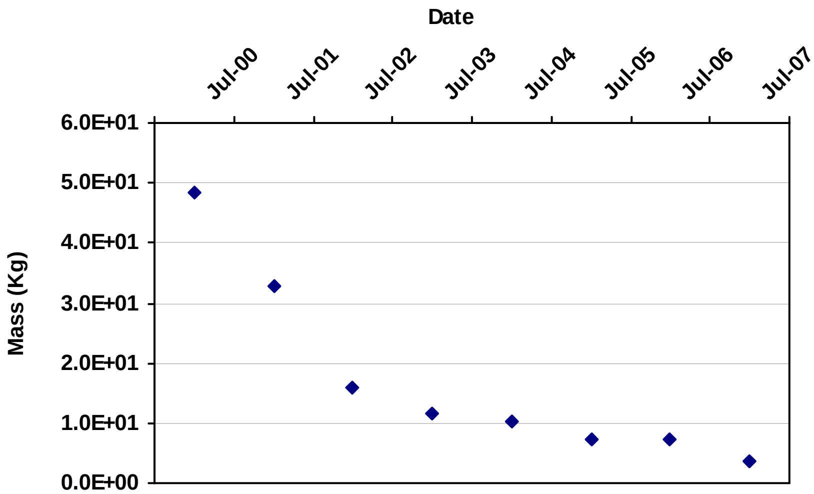
User Name: MV

Location: SouthEast

State: Texas

COC: 2,4-DINITROTOLUENE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 30 ft

Mann Kendall S Statistic:

-28

Confidence in Trend:

100.0%

Coefficient of Variation:

0.90

Zeroth Moment Trend:

D

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	2,4-DINITROTOLUENE	4.8E+01	61
7/1/2001	2,4-DINITROTOLUENE	3.3E+01	60
7/1/2002	2,4-DINITROTOLUENE	1.6E+01	75
7/1/2003	2,4-DINITROTOLUENE	1.2E+01	75
7/1/2004	2,4-DINITROTOLUENE	1.0E+01	74
7/1/2005	2,4-DINITROTOLUENE	7.2E+00	76
7/1/2006	2,4-DINITROTOLUENE	7.1E+00	75
7/1/2007	2,4-DINITROTOLUENE	3.7E+00	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS First Moment Analysis

Project: Pantex SE Sector

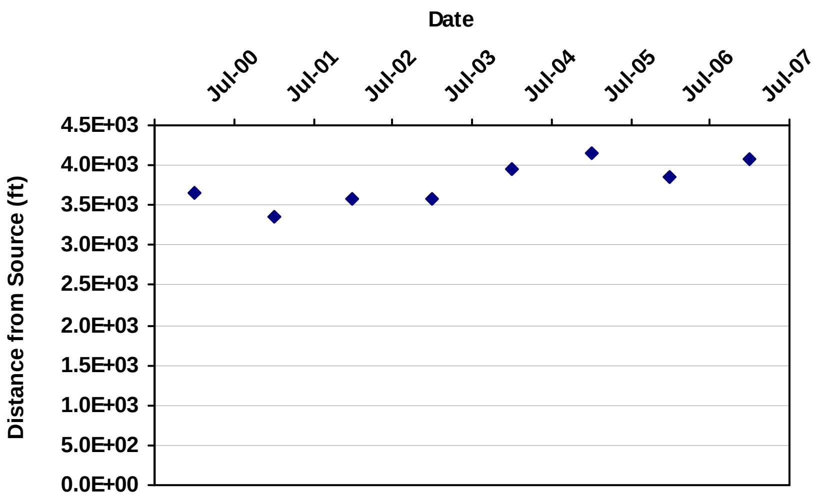
User Name: MV

Location: SouthEast

State: Texas

COC: HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

Distance from Source to Center of Mass



Mann Kendall S Statistic: 16

Confidence in Trend: 96.9%

Coefficient of Variation: 0.07

First Moment Trend: I

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	HEXAHYDRO-1,3,5-TRINITRO	642,159	3,755,213	3,648	72
7/1/2001	HEXAHYDRO-1,3,5-TRINITRO	642,270	3,755,709	3,352	74
7/1/2002	HEXAHYDRO-1,3,5-TRINITRO	642,347	3,755,474	3,575	75
7/1/2003	HEXAHYDRO-1,3,5-TRINITRO	642,462	3,755,563	3,592	75
7/1/2004	HEXAHYDRO-1,3,5-TRINITRO	642,602	3,755,185	3,959	73
7/1/2005	HEXAHYDRO-1,3,5-TRINITRO	642,726	3,755,051	4,143	76
7/1/2006	HEXAHYDRO-1,3,5-TRINITRO	642,751	3,755,476	3,862	75
7/1/2007	HEXAHYDRO-1,3,5-TRINITRO	642,962	3,755,385	4,080	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

MAROS First Moment Analysis

Project: Pantex SE 4ADNT

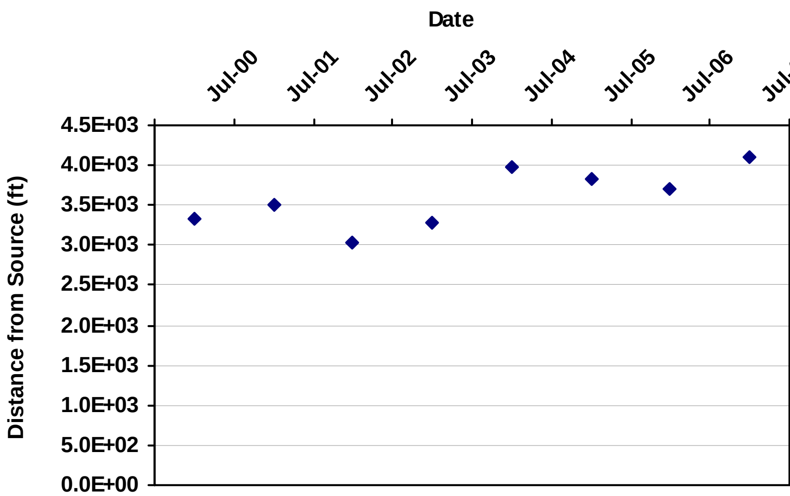
User Name: MV

Location: Southeast

State: Texas

COC: 4-AMINO-2,6-DINITROTOLUENE

Distance from Source to Center of Mass



Mann Kendall S Statistic: 14

Confidence in Trend: 94.6%

Coefficient of Variation: 0.10

First Moment Trend: PI

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	4-AMINO-2,6-DINITROTOLUE	642,251	3,755,727	3,327	68
7/1/2001	4-AMINO-2,6-DINITROTOLUE	642,537	3,755,791	3,493	68
7/1/2002	4-AMINO-2,6-DINITROTOLUE	642,537	3,756,604	3,027	75
7/1/2003	4-AMINO-2,6-DINITROTOLUE	642,578	3,756,182	3,285	75
7/1/2004	4-AMINO-2,6-DINITROTOLUE	643,070	3,755,680	3,979	74
7/1/2005	4-AMINO-2,6-DINITROTOLUE	642,920	3,755,726	3,831	76
7/1/2006	4-AMINO-2,6-DINITROTOLUE	643,074	3,756,165	3,712	73
7/1/2007	4-AMINO-2,6-DINITROTOLUE	643,250	3,755,727	4,097	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

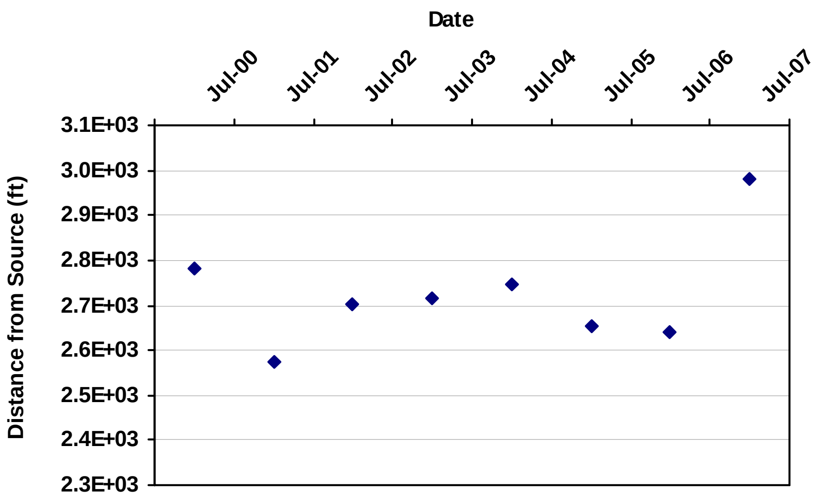
MAROS First Moment Analysis

Project: Pantex SE Sector | **User Name:** MV

Location: SouthEast | **State:** Texas

COC: 2-AMINO-4,6-DINITROTOLUENE

Distance from Source to Center of Mass



Mann Kendall S Statistic: 2

Confidence in Trend: 54.8%

Coefficient of Variation: 0.05

First Moment Trend: NT

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	2-AMINO-4,6-DINITROTOLUE	641,928	3,756,175	2,783	71
7/1/2001	2-AMINO-4,6-DINITROTOLUE	642,076	3,756,716	2,572	68
7/1/2002	2-AMINO-4,6-DINITROTOLUE	642,123	3,756,552	2,701	74
7/1/2003	2-AMINO-4,6-DINITROTOLUE	642,339	3,756,903	2,714	75
7/1/2004	2-AMINO-4,6-DINITROTOLUE	642,406	3,756,970	2,747	74
7/1/2005	2-AMINO-4,6-DINITROTOLUE	642,414	3,757,263	2,652	76
7/1/2006	2-AMINO-4,6-DINITROTOLUE	642,460	3,757,468	2,641	75
7/1/2007	2-AMINO-4,6-DINITROTOLUE	642,434	3,756,517	2,982	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

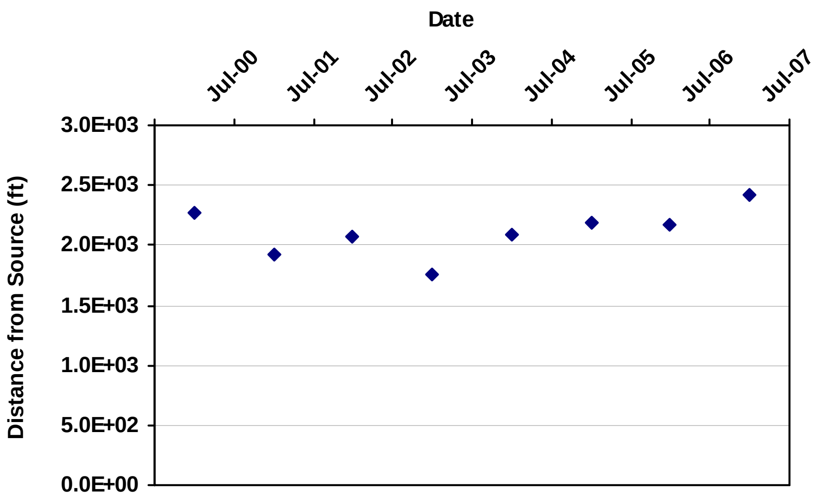
MAROS First Moment Analysis

Project: Pantex SE Sector **User Name:** MV

Location: SouthEast **State:** Texas

COC: 2,4,6-TRINITROTOLUENE

Distance from Source to Center of Mass



Mann Kendall S Statistic: 10

Confidence in Trend: 86.2%

Coefficient of Variation: 0.10

First Moment Trend: NT

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	2,4,6-TRINITROTOLUENE	641,619	3,756,608	2,264	58
7/1/2001	2,4,6-TRINITROTOLUENE	641,636	3,757,256	1,928	46
7/1/2002	2,4,6-TRINITROTOLUENE	641,598	3,756,904	2,069	74
7/1/2003	2,4,6-TRINITROTOLUENE	641,506	3,757,403	1,750	75
7/1/2004	2,4,6-TRINITROTOLUENE	641,473	3,756,697	2,096	74
7/1/2005	2,4,6-TRINITROTOLUENE	641,783	3,756,986	2,182	76
7/1/2006	2,4,6-TRINITROTOLUENE	641,887	3,757,209	2,176	75
7/1/2007	2,4,6-TRINITROTOLUENE	641,861	3,756,676	2,415	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

MAROS First Moment Analysis

Project: Pantex SE Sector

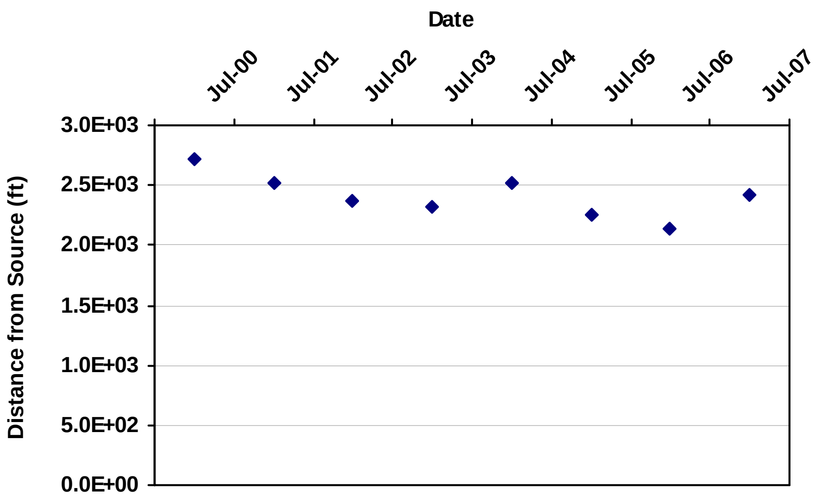
User Name: MV

Location: SouthEast

State: Texas

COC: 2,4-DINITROTOLUENE

Distance from Source to Center of Mass



Mann Kendall S Statistic:

-16

Confidence in Trend:

96.9%

Coefficient of Variation:

0.07

First Moment Trend:

D

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	2,4-DINITROTOLUENE	641,558	3,755,913	2,726	61
7/1/2001	2,4-DINITROTOLUENE	641,475	3,756,119	2,513	60
7/1/2002	2,4-DINITROTOLUENE	641,641	3,756,462	2,377	75
7/1/2003	2,4-DINITROTOLUENE	642,023	3,757,168	2,317	75
7/1/2004	2,4-DINITROTOLUENE	642,333	3,757,491	2,513	74
7/1/2005	2,4-DINITROTOLUENE	642,100	3,757,609	2,259	76
7/1/2006	2,4-DINITROTOLUENE	642,015	3,757,844	2,140	75
7/1/2007	2,4-DINITROTOLUENE	641,934	3,756,772	2,422	68

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

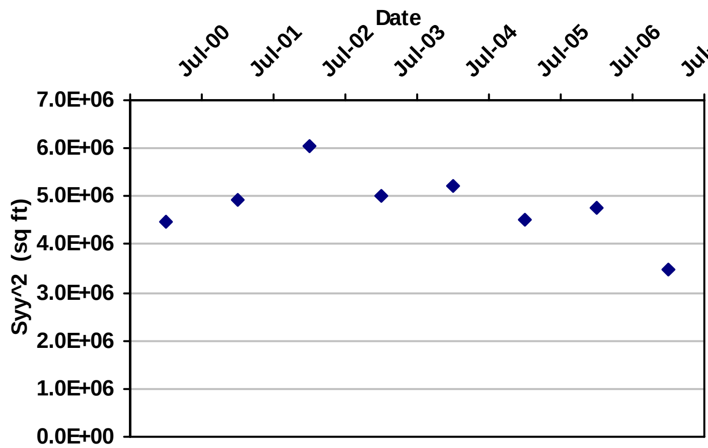
MAROS Second Moment Analysis

Project: Pantex SE Sector **User Name:** MV

Location: SouthEast **State:** Texas

COC: HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE

Change in Plume Spread Over Time

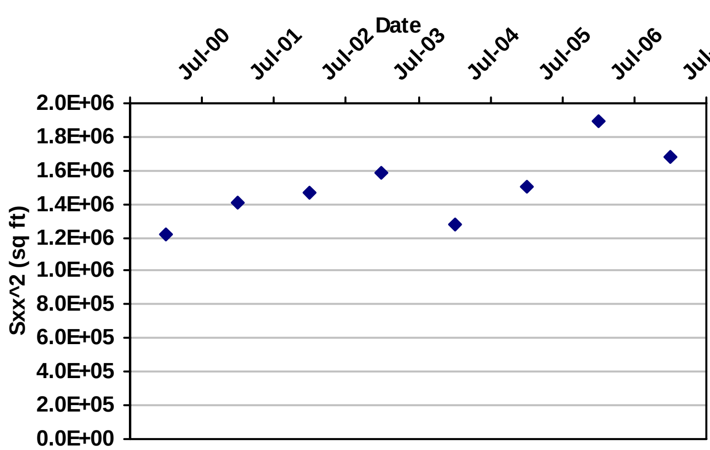


Mann Kendall S Statistic: -6

Confidence in Trend: 72.6%

Coefficient of Variation: 0.15

Second Moment Trend: S



Mann Kendall S Statistic: 18

Confidence in Trend: 98.4%

Coefficient of Variation: 0.14

Second Moment Trend: I

Data Table:

Effective Date	Constituent	Sigma XX (sq ft)	Sigma YY (sq ft)	Number of Wells
7/1/2000	HEXAHYDRO-1,3,5-TRINITRO	1,214,949	4,460,930	72
7/1/2001	HEXAHYDRO-1,3,5-TRINITRO	1,404,749	4,939,131	74
7/1/2002	HEXAHYDRO-1,3,5-TRINITRO	1,471,765	6,057,858	75
7/1/2003	HEXAHYDRO-1,3,5-TRINITRO	1,580,992	4,991,454	75
7/1/2004	HEXAHYDRO-1,3,5-TRINITRO	1,280,090	5,203,529	73
7/1/2005	HEXAHYDRO-1,3,5-TRINITRO	1,497,309	4,513,285	76
7/1/2006	HEXAHYDRO-1,3,5-TRINITRO	1,892,321	4,762,973	75
7/1/2007	HEXAHYDRO-1,3,5-TRINITRO	1,680,100	3,486,567	68

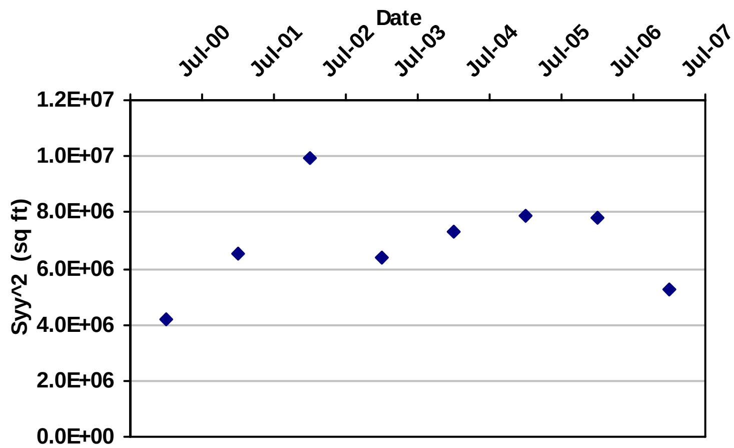
MAROS Second Moment Analysis

Project: Pantex SE 4ADNT **User Name:** MV

Location: Southeast **State:** Texas

COC: 4-AMINO-2,6-DINITROTOLUENE

Change in Plume Spread Over Time

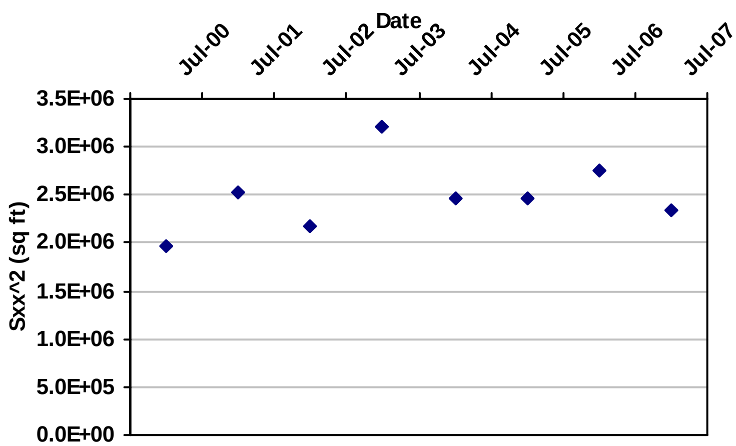


Mann Kendall S Statistic: 4

Confidence in Trend: 64.0%

Coefficient of Variation: 0.25

Second Moment Trend: NT



Mann Kendall S Statistic: 4

Confidence in Trend: 64.0%

Coefficient of Variation: 0.15

Second Moment Trend: NT

Data Table:

Effective Date	Constituent	Sigma XX (sq ft)	Sigma YY (sq ft)	Number of Wells
7/1/2000	4-AMINO-2,6-DINITROTOLUE	1,968,575	4,185,079	68
7/1/2001	4-AMINO-2,6-DINITROTOLUE	2,533,682	6,533,223	68
7/1/2002	4-AMINO-2,6-DINITROTOLUE	2,168,864	9,937,686	75
7/1/2003	4-AMINO-2,6-DINITROTOLUE	3,207,589	6,400,940	75
7/1/2004	4-AMINO-2,6-DINITROTOLUE	2,466,528	7,298,288	74
7/1/2005	4-AMINO-2,6-DINITROTOLUE	2,454,444	7,895,568	76
7/1/2006	4-AMINO-2,6-DINITROTOLUE	2,744,309	7,786,041	73
7/1/2007	4-AMINO-2,6-DINITROTOLUE	2,335,936	5,270,230	68

February 12, 2008

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

APPENDIX B:

Southwest Sector MAROS Reports

MAROS Mann-Kendall Statistics Summary

Project: Pantex SW

User Name: MV

Location: Southwest Area

State: Texas

Time Period: 1/15/2000 **to** 4/15/2007

Consolidation Period: No Time Consolidation

Consolidation Type: Geometric Mean

Duplicate Consolidation: Average

ND Values: Specified Detection Limit

J Flag Values : Actual Value

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
4-AMINO-2,6-DINITROTOLUENE								
1114-MW4	S	3	1	0.00	0	0.0%	No	N/A
PTX06-1006	T	3	0	0.00	0	0.0%	Yes	ND
PTX06-1007	S	3	3	0.00	0	0.0%	No	N/A
PTX06-1008	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1012	T	12	1	0.08	5	60.6%	No	NT
PTX06-1035	T	10	8	2.67	-8	72.9%	No	NT
PTX06-1036	T	13	10	0.85	-43	99.6%	No	D
PTX06-1049	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1052	S	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	13	1.15	96	100.0%	No	I
PTX06-1077A	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1085	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1086	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1087	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P02	T	6	0	0.00	0	42.3%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	10	0	0.00	0	46.4%	Yes	ND
PTX07-1Q01	T	5	1	0.13	-2	59.2%	No	S
PTX07-1Q02	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q03	T	7	0	0.00	0	43.7%	Yes	ND
PTX08-1001	T	7	1	2.03	-6	76.4%	No	NT
PTX08-1003	T	6	0	0.00	0	42.3%	Yes	ND
PTX08-1005	S	6	6	0.47	-13	99.2%	No	D
PTX08-1006	S	8	8	0.25	4	64.0%	No	NT
PTX08-1007	T	2	0	0.00	0	0.0%	Yes	ND
PTX08-1008	S	11	9	0.87	-8	70.3%	No	S
PTX08-1009	S	7	3	1.54	7	80.9%	No	NT
PTX10-1008	T	6	0	0.00	0	42.3%	Yes	ND
PTX10-1013	S	6	0	0.00	0	42.3%	Yes	ND
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
1114-MW4	S	3	0	0.00	0	0.0%	Yes	ND
PTX06-1006	T	3	0	0.00	0	0.0%	Yes	ND
PTX06-1007	S	3	2	0.00	0	0.0%	No	N/A
PTX06-1008	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1012	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1035	T	10	0	0.00	0	46.4%	Yes	ND
PTX06-1036	T	13	6	1.17	43	99.6%	No	I

Project: Pantex SW

User Name: MV

Location: Southwest Area

State: Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
PTX06-1049	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1052	S	15	0	0.00	0	48.0%	Yes	ND
PTX06-1053	T	17	2	3.15	23	81.5%	No	NT
PTX06-1077A	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1085	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1086	T	8	1	2.61	5	68.3%	No	NT
PTX06-1087	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P02	T	6	5	0.79	-13	99.2%	No	D
PTX07-1P03	T	4	4	0.20	-6	95.8%	No	D
PTX07-1P06	S	10	10	0.84	-33	99.9%	No	D
PTX07-1Q01	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q02	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q03	T	7	1	2.51	4	66.7%	No	NT
PTX08-1001	T	7	3	0.99	1	50.0%	No	NT
PTX08-1003	T	6	0	0.00	0	42.3%	Yes	ND
PTX08-1005	S	6	6	0.99	-13	99.2%	No	D
PTX08-1006	S	8	8	0.77	26	100.0%	No	I
PTX08-1007	T	2	2	0.00	0	0.0%	No	N/A
PTX08-1008	S	11	2	0.09	-15	85.9%	No	S
PTX08-1009	S	7	4	2.10	-8	84.5%	No	NT
PTX10-1008	T	6	1	0.00	-1	50.0%	No	S
PTX10-1013	S	6	4	1.48	-4	70.3%	No	NT
PERCHLORATE								
1114-MW4	S	5	5	0.38	-8	95.8%	No	D
PTX06-1006	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1007	S	6	6	0.09	-5	76.5%	No	S
PTX06-1008	T	4	1	0.74	1	50.0%	No	NT
PTX06-1012	T	12	4	1.46	32	98.4%	No	I
PTX06-1035	T	10	0	0.00	0	46.4%	Yes	ND
PTX06-1036	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1049	T	9	0	0.00	0	46.0%	Yes	ND
PTX06-1052	S	14	1	0.48	-13	74.1%	No	S
PTX06-1053	T	16	4	0.66	-38	95.2%	No	D
PTX06-1077A	T	4	2	0.67	5	89.6%	No	NT
PTX06-1085	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1086	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1087	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P02	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	9	0	0.00	0	46.0%	Yes	ND
PTX07-1Q01	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q02	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q03	T	7	0	0.00	0	43.7%	Yes	ND
PTX08-1001	T	7	7	0.23	9	88.1%	No	NT
PTX08-1003	T	7	7	0.18	-17	99.5%	No	D
PTX08-1005	S	5	5	0.60	-10	99.2%	No	D
PTX08-1006	S	9	9	0.65	-22	98.8%	No	D
PTX08-1007	T	3	2	0.00	0	0.0%	No	N/A
PTX08-1008	S	12	1	0.57	-11	74.9%	No	S

Project: Pantex SW **User Name:** MV

Location: Southwest Area **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
PERCHLORATE								
PTX08-1009	S	7	0	0.00	0	43.7%	Yes	ND
PTX10-1008	T	6	0	0.00	0	42.3%	Yes	ND
PTX10-1013	S	7	2	0.80	5	71.9%	No	NT
TRICHLOROETHYLENE (TCE)								
1114-MW4	S	6	6	0.50	9	93.2%	No	PI
PTX06-1006	T	3	1	0.00	0	0.0%	No	N/A
PTX06-1007	S	6	5	0.26	-8	89.8%	No	S
PTX06-1008	T	5	5	0.64	-2	59.2%	No	S
PTX06-1012	T	12	4	0.79	22	92.4%	No	PI
PTX06-1035	T	10	0	0.00	0	46.4%	Yes	ND
PTX06-1036	T	13	0	0.00	0	47.6%	Yes	ND
PTX06-1049	T	11	1	0.53	8	70.3%	No	NT
PTX06-1052	S	15	7	0.52	-46	98.8%	No	D
PTX06-1053	T	17	0	0.00	0	48.4%	Yes	ND
PTX06-1077A	T	6	5	0.59	7	86.4%	No	NT
PTX06-1085	T	4	0	0.00	0	37.5%	Yes	ND
PTX06-1086	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1087	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P02	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	10	0	0.00	0	46.4%	Yes	ND
PTX07-1Q01	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q02	T	5	0	0.00	0	40.8%	Yes	ND
PTX07-1Q03	T	7	0	0.00	0	43.7%	Yes	ND
PTX08-1001	T	7	0	0.00	0	43.7%	Yes	ND
PTX08-1003	T	6	0	0.00	0	42.3%	Yes	ND
PTX08-1005	S	6	6	0.62	7	86.4%	No	NT
PTX08-1006	S	8	8	0.41	-4	64.0%	No	S
PTX08-1007	T	4	4	0.13	-2	62.5%	No	S
PTX08-1008	S	11	3	0.17	5	61.9%	No	NT
PTX08-1009	S	8	6	0.52	1	50.0%	No	NT
PTX10-1008	T	6	0	0.00	0	42.3%	Yes	ND
PTX10-1013	S	7	7	0.67	7	80.9%	No	NT

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A)- Due to insufficient Data (< 4 sampling events); Source/Tail (S/T)

The Number of Samples and Number of Detects shown above are post-consolidation values.

MAROS Zeroth Moment Analysis

Project: Pantex SW

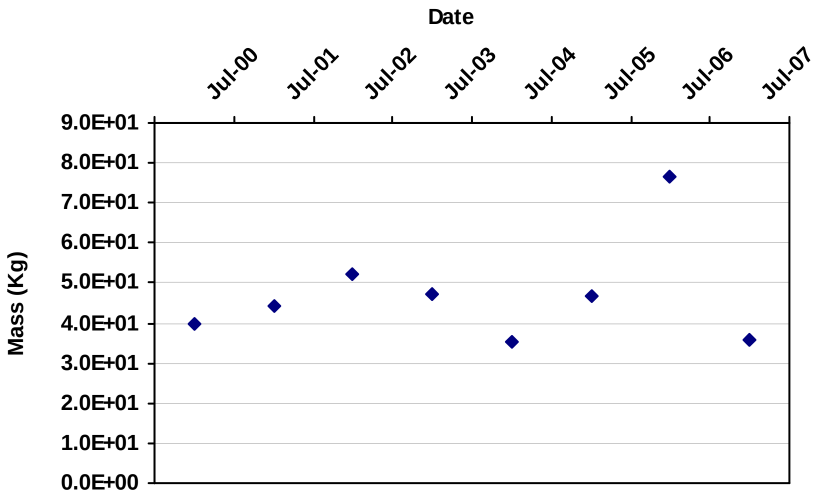
User Name: MV

Location: Southwest Area

State: Texas

COC: TRICHLOROETHYLENE (TCE)

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 50 ft

Mann Kendall S Statistic:

2

Confidence in Trend:

54.8%

Coefficient of Variation:

0.28

Zeroth Moment Trend:

NT

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	TRICHLOROETHYLENE (TCE)	4.0E+01	13
7/1/2001	TRICHLOROETHYLENE (TCE)	4.4E+01	24
7/1/2002	TRICHLOROETHYLENE (TCE)	5.2E+01	26
7/1/2003	TRICHLOROETHYLENE (TCE)	4.7E+01	29
7/1/2004	TRICHLOROETHYLENE (TCE)	3.6E+01	21
7/1/2005	TRICHLOROETHYLENE (TCE)	4.7E+01	22
7/1/2006	TRICHLOROETHYLENE (TCE)	7.7E+01	22
7/1/2007	TRICHLOROETHYLENE (TCE)	3.6E+01	14

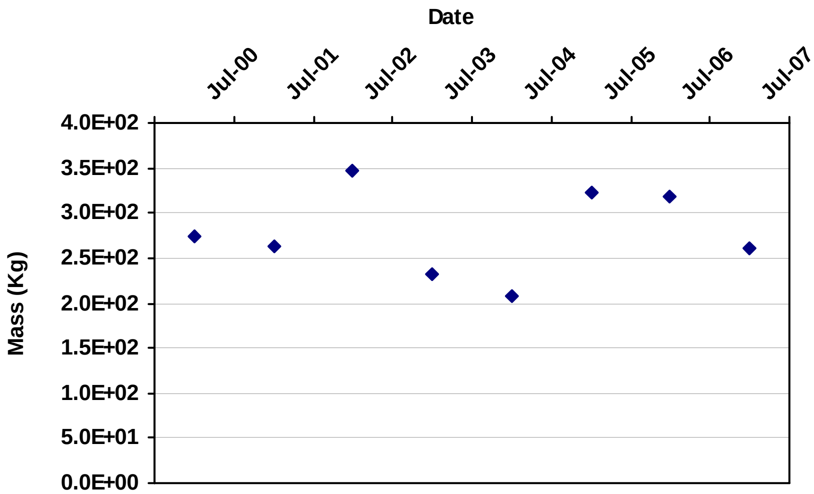
Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS Zeroth Moment Analysis

Project: Pantex SW
User Name: MV
Location: Southwest Area
State: Texas

COC: PERCHLORATE

Change in Dissolved Mass Over Time



Porosity: 0.25

Saturated Thickness:

Uniform: 50 ft

Mann Kendall S Statistic:

-4

Confidence in Trend:

64.0%

Coefficient of Variation:

0.17

Zeroth Moment Trend:

S

Data Table:

Effective Date	Constituent	Estimated Mass (Kg)	Number of Wells
7/1/2000	PERCHLORATE	2.7E+02	13
7/1/2001	PERCHLORATE	2.6E+02	24
7/1/2002	PERCHLORATE	3.5E+02	26
7/1/2003	PERCHLORATE	2.3E+02	28
7/1/2004	PERCHLORATE	2.1E+02	21
7/1/2005	PERCHLORATE	3.2E+02	20
7/1/2006	PERCHLORATE	3.2E+02	20
7/1/2007	PERCHLORATE	2.6E+02	14

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect. Moments are not calculated for sample events with less than 6 wells.

MAROS First Moment Analysis

Project: Pantex SW

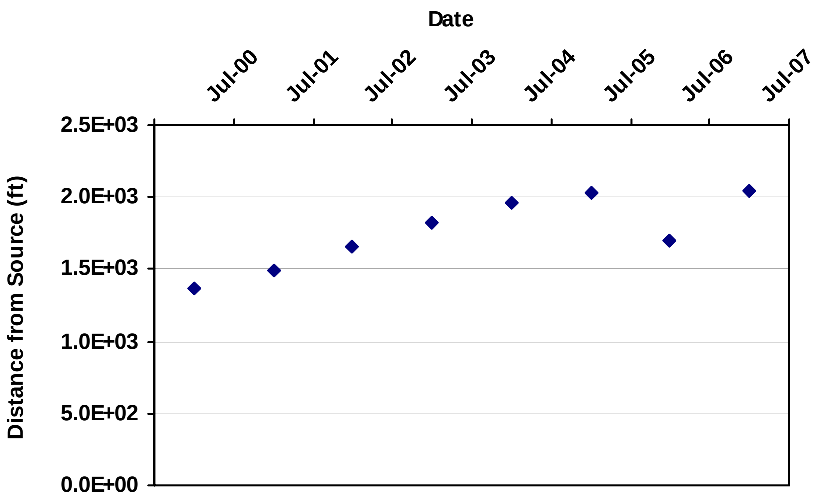
User Name: MV

Location: Southwest Area

State: Texas

COC: TRICHLOROETHYLENE (TCE)

Distance from Source to Center of Mass



Mann Kendall S Statistic: 22

Confidence in Trend: 99.8%

Coefficient of Variation: 0.14

First Moment Trend: I

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	TRICHLOROETHYLENE (TCE)	636,899	3,758,041	1,373	13
7/1/2001	TRICHLOROETHYLENE (TCE)	635,809	3,758,125	1,486	24
7/1/2002	TRICHLOROETHYLENE (TCE)	636,115	3,758,390	1,653	26
7/1/2003	TRICHLOROETHYLENE (TCE)	635,217	3,758,149	1,823	29
7/1/2004	TRICHLOROETHYLENE (TCE)	636,064	3,758,701	1,968	21
7/1/2005	TRICHLOROETHYLENE (TCE)	636,179	3,758,781	2,031	22
7/1/2006	TRICHLOROETHYLENE (TCE)	635,987	3,758,410	1,700	22
7/1/2007	TRICHLOROETHYLENE (TCE)	635,672	3,758,672	2,044	14

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

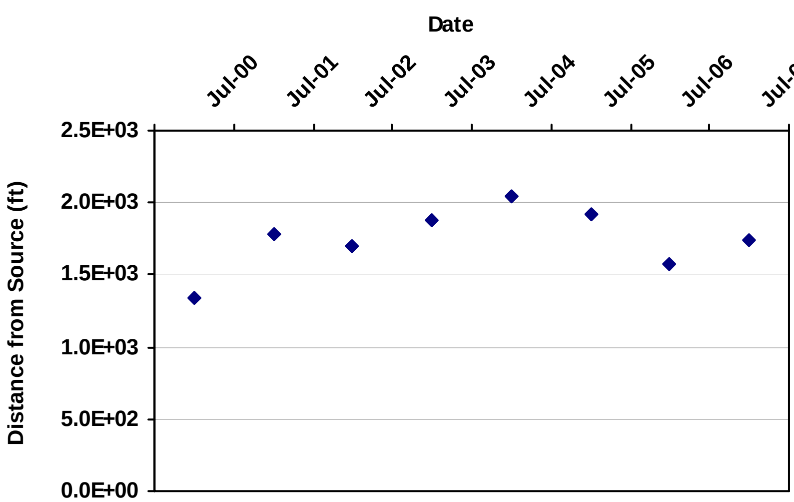
MAROS First Moment Analysis

Project: Pantex SW **User Name:** MV

Location: Southwest Area **State:** Texas

COC: PERCHLORATE

Distance from Source to Center of Mass



Mann Kendall S Statistic: 6

Confidence in Trend: 72.6%

Coefficient of Variation: 0.12

First Moment Trend: NT

Data Table:

Effective Date	Constituent	Xc (ft)	Yc (ft)	Distance from Source (ft)	Number of Wells
7/1/2000	PERCHLORATE	636,108	3,758,072	1,342	13
7/1/2001	PERCHLORATE	635,515	3,758,300	1,775	24
7/1/2002	PERCHLORATE	635,862	3,758,369	1,695	26
7/1/2003	PERCHLORATE	635,733	3,758,525	1,885	28
7/1/2004	PERCHLORATE	635,763	3,758,705	2,045	21
7/1/2005	PERCHLORATE	635,970	3,758,630	1,917	20
7/1/2006	PERCHLORATE	635,873	3,758,252	1,580	20
7/1/2007	PERCHLORATE	636,279	3,758,496	1,738	14

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events). Moments are not calculated for sample events with less than 6 wells.

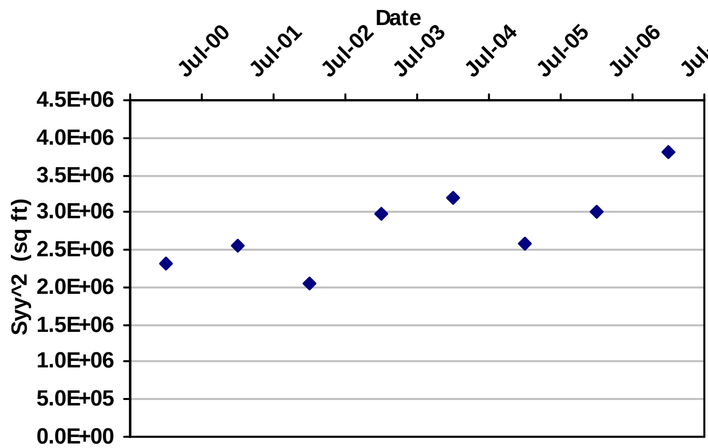
MAROS Second Moment Analysis

Project: Pantex SW **User Name:** MV

Location: Southwest Area **State:** Texas

COC: PERCHLORATE

Change in Plume Spread Over Time

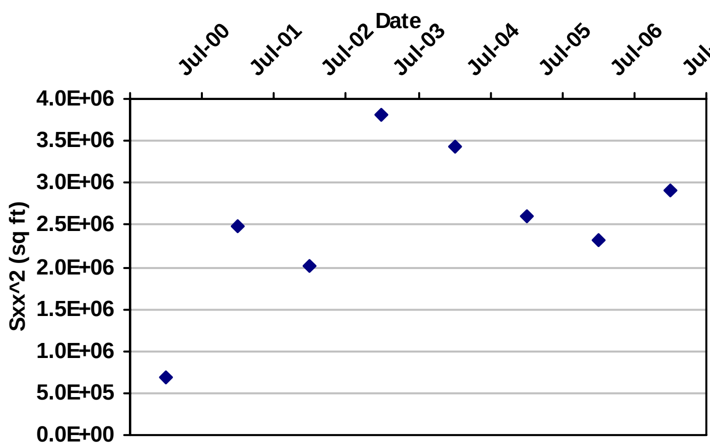


Mann Kendall S Statistic: 18

Confidence in Trend: 98.4%

Coefficient of Variation: 0.20

Second Moment Trend: I



Mann Kendall S Statistic: 8

Confidence in Trend: 80.1%

Coefficient of Variation: 0.38

Second Moment Trend: NT

Data Table:

Effective Date	Constituent	Sigma XX (sq ft)	Sigma YY (sq ft)	Number of Wells
7/1/2000	PERCHLORATE	674,631	2,319,199	13
7/1/2001	PERCHLORATE	2,492,690	2,548,386	24
7/1/2002	PERCHLORATE	2,018,251	2,041,502	26
7/1/2003	PERCHLORATE	3,808,129	2,974,789	28
7/1/2004	PERCHLORATE	3,435,859	3,198,986	21
7/1/2005	PERCHLORATE	2,604,765	2,578,513	20
7/1/2006	PERCHLORATE	2,328,383	2,996,988	20
7/1/2007	PERCHLORATE	2,903,960	3,820,155	14

GROUNDWATER MONITORING NETWORK OPTIMIZATION
Pantex Plant

Carson County, Texas

APPENDIX B:

North Sector MAROS Reports

MAROS Mann-Kendall Statistics Summary

Project: Pantex North | **User Name:** MV

Location: North/Playa 1 | **State:** Texas

Time Period: 1/15/2000 **to** 4/15/2007
Consolidation Period: No Time Consolidation
Consolidation Type: Geometric Mean
Duplicate Consolidation: Average
ND Values: Specified Detection Limit
J Flag Values : Actual Value

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
2,6-DINITROTOLUENE								
PTX01-1001	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1002	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1008	T	13	0	0.00	0	47.6%	Yes	ND
PTX04-1001	T	5	0	0.00	0	40.8%	Yes	ND
PTX04-1002	T	12	1	1.02	9	70.4%	No	NT
PTX06-1013	T	10	2	0.77	7	70.0%	No	NT
PTX06-1023	T	12	1	0.01	-5	60.6%	No	S
PTX06-1048A	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1049	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1050	S	10	0	0.00	5	63.6%	Yes	ND
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1071	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1080	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1081	T	12	1	0.63	9	70.4%	No	NT
PTX06-1114	T	2	0	0.00	0	0.0%	Yes	ND
PTX07-1O01	S	6	0	0.00	0	42.3%	Yes	ND
PTX07-1O02	T	3	0	0.00	0	0.0%	Yes	ND
PTX07-1O03	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1O06	T	10	2	0.40	7	70.0%	No	NT
PTX07-1P02	T	6	0	0.00	0	42.3%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	10	1	0.40	9	75.8%	No	NT
PTX07-1R03	T	8	0	0.00	0	45.2%	Yes	ND
PTX08-1001	T	6	0	0.00	0	42.3%	Yes	ND
PTX08-1002	S	7	0	0.00	0	43.7%	Yes	ND
PTX08-1010	T	14	0	0.00	0	47.8%	Yes	ND
PTX-BEG3	T	13	0	0.00	0	47.6%	Yes	ND
4-AMINO-2,6-DINITROTOLUENE								
PTX01-1001	T	23	2	0.23	21	69.9%	No	NT
PTX01-1002	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1008	T	13	0	0.00	0	47.6%	Yes	ND
PTX04-1001	T	6	0	0.00	0	42.3%	Yes	ND
PTX04-1002	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1013	T	10	1	0.02	1	50.0%	No	NT
PTX06-1023	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1048A	T	15	5	0.25	0	48.0%	No	S
PTX06-1049	T	11	0	0.00	0	46.9%	Yes	ND

Project: Pantex North

User Name: MV

Location: North/Playa 1

State: Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
4-AMINO-2,6-DINITROTOLUENE								
PTX06-1050	S	10	8	0.68	14	87.3%	No	NT
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1071	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1080	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1081	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1114	T	2	2	0.00	0	0.0%	No	N/A
PTX07-1O01	S	6	5	0.55	1	50.0%	No	NT
PTX07-1O02	T	3	0	0.00	0	0.0%	Yes	ND
PTX07-1O03	T	7	3	0.31	1	50.0%	No	NT
PTX07-1O06	T	10	0	0.00	0	46.4%	Yes	ND
PTX07-1P02	T	6	0	0.00	0	42.3%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	10	0	0.00	0	46.4%	Yes	ND
PTX07-1R03	T	8	0	0.00	0	45.2%	Yes	ND
PTX08-1001	T	7	1	2.03	-6	76.4%	No	NT
PTX08-1002	S	7	4	1.53	4	66.7%	No	NT
PTX08-1010	T	14	0	0.00	0	47.8%	Yes	ND
PTX-BEG3	T	13	11	0.44	25	92.7%	No	PI
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE								
PTX01-1001	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1002	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1008	T	13	0	0.00	0	47.6%	Yes	ND
PTX04-1001	T	6	0	0.00	0	42.3%	Yes	ND
PTX04-1002	T	12	7	0.58	-2	52.7%	No	S
PTX06-1013	T	10	10	0.19	19	94.6%	No	PI
PTX06-1023	T	12	12	0.23	-10	72.7%	No	S
PTX06-1048A	T	15	0	0.00	0	48.0%	Yes	ND
PTX06-1049	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1050	S	10	10	0.38	29	99.5%	No	I
PTX06-1069	T	11	1	0.14	-4	59.0%	No	S
PTX06-1071	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1080	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1081	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1114	T	2	1	0.00	0	0.0%	No	N/A
PTX07-1O01	S	6	6	0.24	1	50.0%	No	NT
PTX07-1O02	T	3	3	0.00	0	0.0%	No	N/A
PTX07-1O03	T	7	7	0.13	-9	88.1%	No	S
PTX07-1O06	T	10	2	1.04	9	75.8%	No	NT
PTX07-1P02	T	6	5	0.79	-13	99.2%	No	D
PTX07-1P03	T	4	4	0.20	-6	95.8%	No	D
PTX07-1P06	S	10	10	0.84	-33	99.9%	No	D
PTX07-1R03	T	8	1	0.17	1	50.0%	No	NT
PTX08-1001	T	7	3	0.99	1	50.0%	No	NT
PTX08-1002	S	7	7	0.70	-11	93.2%	No	PD
PTX08-1010	T	14	2	0.50	-3	54.3%	No	S
PTX-BEG3	T	13	0	0.00	0	47.6%	Yes	ND
PERCHLORATE								
PTX01-1001	T	24	16	1.63	16	64.4%	No	NT

Project: Pantex North **User Name:** MV

Location: North/Playa 1 **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
PERCHLORATE								
PTX01-1002	T	24	2	0.40	-25	72.2%	No	S
PTX01-1008	T	13	0	0.00	0	47.6%	Yes	ND
PTX04-1001	T	6	0	0.00	0	42.3%	Yes	ND
PTX04-1002	T	16	0	0.00	0	48.2%	Yes	ND
PTX06-1013	T	9	0	0.00	0	46.0%	Yes	ND
PTX06-1023	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1048A	T	13	1	0.54	-12	74.5%	No	S
PTX06-1049	T	9	0	0.00	0	46.0%	Yes	ND
PTX06-1050	S	7	0	0.00	0	43.7%	Yes	ND
PTX06-1069	T	11	0	0.00	0	46.9%	Yes	ND
PTX06-1071	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1080	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1081	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1114	T	2	0	0.00	0	0.0%	Yes	ND
PTX07-1O01	S	6	0	0.00	0	42.3%	Yes	ND
PTX07-1O02	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1O03	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1O06	T	9	0	0.00	0	46.0%	Yes	ND
PTX07-1P02	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	9	0	0.00	0	46.0%	Yes	ND
PTX07-1R03	T	8	0	0.00	0	45.2%	Yes	ND
PTX08-1001	T	7	7	0.23	9	88.1%	No	NT
PTX08-1002	S	10	0	0.00	0	46.4%	Yes	ND
PTX08-1010	T	14	0	0.00	0	47.8%	Yes	ND
PTX-BEG3	T	12	0	0.00	0	47.3%	Yes	ND
TRICHLOROETHYLENE (TCE)								
PTX01-1001	T	25	15	1.10	65	93.2%	No	PI
PTX01-1002	T	25	0	0.00	0	49.1%	Yes	ND
PTX01-1008	T	14	7	1.46	-43	99.0%	No	D
PTX04-1001	T	7	7	0.26	-2	55.7%	No	S
PTX04-1002	T	14	13	0.38	-67	100.0%	No	D
PTX06-1013	T	10	0	0.00	0	46.4%	Yes	ND
PTX06-1023	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1048A	T	15	14	0.43	-55	99.7%	No	D
PTX06-1049	T	11	1	0.53	8	70.3%	No	NT
PTX06-1050	S	10	0	0.00	0	46.4%	Yes	ND
PTX06-1069	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1071	T	8	0	0.00	0	45.2%	Yes	ND
PTX06-1080	T	12	0	0.00	0	47.3%	Yes	ND
PTX06-1081	T	12	10	0.17	21	91.3%	No	PI
PTX06-1114	T	2	0	0.00	0	0.0%	Yes	ND
PTX07-1O01	S	5	1	0.10	-4	75.8%	No	S
PTX07-1O02	T	4	4	0.11	6	95.8%	No	I
PTX07-1O03	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1O06	T	9	5	0.28	4	61.9%	No	NT
PTX07-1P02	T	7	0	0.00	0	43.7%	Yes	ND
PTX07-1P03	T	4	0	0.00	0	37.5%	Yes	ND
PTX07-1P06	S	10	0	0.00	0	46.4%	Yes	ND

Project: Pantex North **User Name:** MV

Location: North/Playa 1 **State:** Texas

Well	Source/ Tail	Number of Samples	Number of Detects	Coefficient of Variation	Mann-Kendall Statistic	Confidence in Trend	All Samples "ND" ?	Concentration Trend
TRICHLOROETHYLENE (TCE)								
PTX07-1R03	T	8	0	0.00	0	45.2%	Yes	ND
PTX08-1001	T	7	0	0.00	0	43.7%	Yes	ND
PTX08-1002	S	6	0	0.00	0	42.3%	Yes	ND
PTX08-1010	T	14	2	0.15	23	88.3%	No	NT
PTX-BEG3	T	13	0	0.00	0	47.6%	Yes	ND

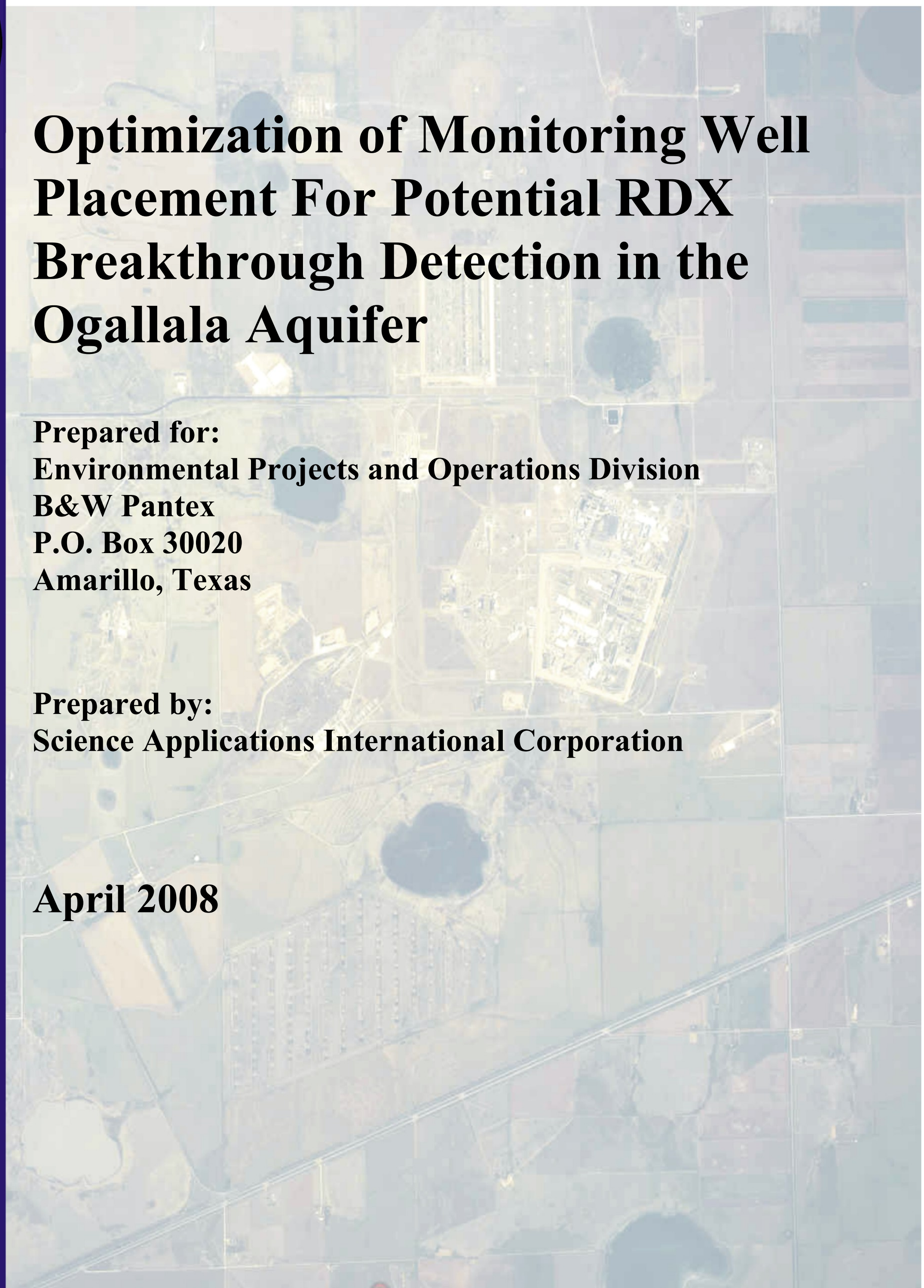
Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A)- Due to insufficient Data (< 4 sampling events); Source/Tail (S/T)

The Number of Samples and Number of Detects shown above are post-consolidation values.

U.S. Department of Energy/ National Nuclear Security Administration

P A N T E X

P L A N T



Optimization of Monitoring Well Placement For Potential RDX Breakthrough Detection in the Ogallala Aquifer

Prepared for:
Environmental Projects and Operations Division
B&W Pantex
P.O. Box 30020
Amarillo, Texas

Prepared by:
Science Applications International Corporation

April 2008

From Science to Solutions

Optimization of Monitoring Well Placement for Breakthrough Detection in the Ogallala Aquifer

Environmental Projects and Operations Division
B&W Pantex
P.O. Box 30020
Amarillo, TX 79120

Prepared By:

Science Applications International Corporation
8866 Commons Blvd., Suite 201
Twinsburg, OH 44087

April 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMNS AND ABBREVIATIONS

2-D	two-dimensional
3-D	three-dimensional
ArgusONE	Argus Open Numerical Environments
bgs	below ground surface
B&W Pantex	Babcock & Wilcox Technical Services Pantex, LLC
CMS/FS	Corrective Measures Study/Feasibility Study
DOE	Department of Energy
FGZ	fine-grained zone
ft/d	feet per day
ft/ft	feet horizontally/feet vertically
GAM	Groundwater Availability Model
GSLIB	Geostatistical Software Library
GUI	graphical user interface
meters	meter
ppb	parts per billion
ppm	parts per million
PTC	Princeton Transport Code
TTU	Texas Tech University
TWDB	Texas Water Development Board

EXECUTIVE SUMMARY

The Babcock and Wilcox Technical Services Pantex, LLC (B&W Pantex) Environmental Projects and Operations Division is assessing the need for additional monitoring wells to be installed at several locations around the Pantex Plant for early detection of potential groundwater impacts to the Ogallala Aquifer. This effort focuses on the area east of the Plant, where modeling predicted contaminants might migrate beneath the perched groundwater from discharges south of the Plant (BWXT Pantex/SAIC, 2007). The objective of this effort is to identify best locations for up to three new Ogallala Aquifer monitoring wells, using the PlumeFinder technology, and incorporating the results of previous modeling. Due to its widespread occurrence in perched groundwater and relatively high mobility, RDX (a high explosive) was modeled to determine the best locations for the wells. Although source strength and location are not directly measured, insight can be gleaned from the corrective measures study / feasibility study (CMS/FS) (BWXT Pantex/SAIC, 2007) modeling efforts.

The Ogallala Aquifer beneath the impacted perched groundwater is not accessible for investigation, because of the concern that drilling through the perched groundwater may create pathways allowing the spread of contamination. As a result, irreducible uncertainty stemming from a lack of field data is present in the area of interest. The uncertainty specifically pertains to the hydraulic conductivity, potentiometric surface, and the elevation of the redbeds marking the base of the aquifer.

Modeling is combined with optimal estimation techniques to address this uncertainty. Specifically, geostatistical representations of the Ogallala Aquifer hydraulic conductivity fields are coupled with flow and transport simulations to determine the areas of greatest uncertainty in potential RDX plume location. This approach, known as the “PlumeFinder,” is technology which integrates groundwater flow and transport simulation, geostatistical simulation, Monte Carlo simulation, and Kalman filter analysis to optimize monitoring well locations. In the analysis presented here, plume location (plume fringe) is defined as the 1 ppb isopleth contour for RDX and investigated over a 50-year simulation period. The areas of greatest uncertainty in the 1 ppb isopleth location then become candidates for new well locations, which in turn reduce the uncertainty in plume delineation by the maximum amount possible. To locate the leading edge of the RDX plume, both the retardation of RDX and potential biodegradation were ignored. This results in a conservative estimate (shortest travel time) to the fringe of the eastern perched groundwater while identifying the best location for early detection monitoring well placement. The actual travel time for RDX to migrate within the Ogallala Aquifer, if it occurs, is expected to be longer than simulated in this analysis.

The following procedure is used to implement the PlumeFinder technology:

- Gather available information on the groundwater flow and transport properties of the aquifer.
- Gather available information on the current chemistry of the aquifer.
- Use a preliminary groundwater flow and transport model to characterize the movement of groundwater and dissolved contaminants in the aquifer.
- Apply the PlumeFinder technology to baseline the maximum measure of uncertainty from a suspected source area based on the knowledge of the groundwater flow and contaminant transport properties.
- Apply the PlumeFinder technology to assess the maximum measure of uncertainty from a suspected source area based on the knowledge of the groundwater flow and contaminant transport

properties and the existing monitoring well network. This step quantifies the value of the existing monitoring well network as compared to no monitoring wells.

- Use the PlumeFinder technology to generate the next best monitoring well location to gather subsurface information given what is currently known. Constrain the possible locations of future monitoring wells to locations outside the area of impacted perched groundwater.
- Assess the value in the proposed monitoring well with respect to the reduction in the uncertainty in the extent of contamination.
- Update the PlumeFinder observation database with the expected concentration at the new monitoring well location, and repeat the analysis (for up to three wells in the current analysis) to select the next best location for plume fringe location.

The PlumeFinder technology currently requires Princeton Transport Code (PTC) to be used as the numerical code for the flow and transport model. Consequently, to conduct this analysis, a two-dimensional (2-D) model of the Ogallala Aquifer was developed using PTC. This PTC Ogallala Aquifer model was developed by integrating historical information, previous modeling efforts, geostatistical codes, and current field data. Previous models developed for this area include the Pantex BIOF&T3D model and the Pantex Ogallala Aquifer model, both documented in BWXT/SAIC 2007. The latter was a local refinement of the Northern Ogallala Groundwater Availability Model (GAM) (Dutton, Reedy, and Mace, 2001; Dutton 2004). The domain of interest for the PTC model was selected to be an area of approximately 9 square miles (12,000 feet by 24,000 feet) including the southeastern portion of Pantex Plant and areas south and east.

Only sporadic, non-trending, and very low-level (parts per billion [ppb]) detections of RDX have been observed in Ogallala Aquifer monitoring wells. However, RDX detections in the parts per million (ppm) range are routinely observed in perched groundwater above the Ogallala Aquifer. Groundwater simulations show RDX may impact the Ogallala Aquifer in the future (BWXT/SAIC 2007), and the proposed monitoring wells are in response to this potential issue.

Delineation of potential future plumes can be improved by adding three new monitoring wells at locations determined using the PlumeFinder technology in combination with previous modeling results. Installation of new wells, in concert with the existing Ogallala Aquifer monitoring wells, increases the certainty of early plume detection. A new well located using PlumeFinder reduces the maximum measure of uncertainty of plume delineation beyond the fringe of the perched aquifer by 72 %. Two additional wells beyond the eastern extent of perched groundwater provide early detection of potential contamination originating along the fringe of perched groundwater. Since the majority of the projected plume is beneath the perched aquifer, most of the uncertainty in its extent resides there. If the total uncertainty reduction is computed (within and beyond the perched groundwater extent) then the reduction in uncertainty achieved with the addition of a new well located by PlumeFinder is only 16%. This demonstrates the contribution of irreducible uncertainty which results from employing safe investigative practices by imposing the constraint that no wells be drilled through the perched groundwater to investigate a hypothetical plume.

The following specific recommendations are provided upon installation of the additional monitoring wells:

- Assess the groundwater flow field by collecting a complete set of potentiometric surface data to reduce uncertainty in current groundwater flow directions.
- Update the conceptual site model as appropriate (e.g. base of Ogallala Aquifer, lithology, and hydraulic properties).

- Collect analytical data, test for the occurrence of RDX in the Ogallala Aquifer, and assess trends or patterns; compare this with existing information on the sporadic detection of RDX in the Ogallala Aquifer.
- Collect monitored natural attenuation parameters to assess natural degradation rates for RDX with time.
- Compare to previous water table maps, chemical information and expected degradation rates from the CMS/FS. If information is similar (i.e. quasi-stable) then continue long-term monitoring; if not then update the preliminary groundwater model and revise PlumeFinder results to ensure well locations remain adequate for early RDX detection.

1.0 INTRODUCTION

1.1 BACKGROUND

In 2002, Pantex Plant initiated a comprehensive site investigation and groundwater modeling program to evaluate the extent and potential movement of groundwater and contaminants beneath the Plant. RDX, a high explosive, is one of the most ubiquitous contaminants detected in soils and perched groundwater beneath Pantex Plant. The perched groundwater occurs above the fine-grained zone (FGZ), a series of fining-upward sequences capped by clay layers several feet thick. Near the southern and eastern extent of perched groundwater, site investigation data noted a decrease in clay content and higher permeability of the upper surface of the FGZ. Consistent with the field observations, modeling results showed the potential for low-level RDX impacts to the Ogallala Aquifer in these areas. Due to the concern of spreading RDX contamination by drilling through contaminated perched groundwater and into the Ogallala Aquifer, numerical models were developed to estimate the rate and direction of potential RDX migration.

The detection monitoring capabilities of the existing Ogallala Aquifer monitoring well network can be improved by the installation of additional wells in appropriate locations. To determine the best locations to enhance the detection monitoring network, Pantex Plant requires a tool that links a groundwater flow and transport model and geostatistical techniques to optimize placement of new wells south and east of the Plant. As part of this task, SAIC developed a model to encompass the southeastern and eastern portions of the site and offsite areas, and incorporated an optimization tool to determine the best monitoring well placement.

1.2 OBJECTIVE AND TASK DEFINITION

The objective of this effort is to identify best locations for up to three new Ogallala Aquifer monitoring wells using the PlumeFinder technology and incorporating predictions from previous modeling efforts such as the Baseline Human Health Risk Assessment (BWXT Pantex/SAIC, 2006) and CMS/FS (BWXT Pantex/SAIC, 2007). Two potential source areas, one to the south of Pantex Plant and another distributed along the eastern extent of perched groundwater saturation, are evaluated because they are the most likely areas for contaminant breakthrough from the overlying and impacted perched groundwater. These areas were selected based upon site investigation data and prior modeling. The potential source to the south represents the most likely area of breakthrough based upon the current understanding of site conditions and the modeling predictions presented in the CMS/FS. The potential source along the eastern extent of perched groundwater represents the next most likely area of contaminant breakthrough, again, based upon the current understanding of site conditions. Based upon site investigation data, the confining unit underlying perched groundwater is more transmissive along the fringe of perched groundwater than within its interior. So the fringe of perched groundwater is considered a likely area for contamination to migrate to the Ogallala Aquifer. In addition, a constraint is imposed in this analysis that proposed wells not be drilled through perched groundwater.

The best locations are determined by completing a combination of a PlumeFinder assessment of RDX migration from the potential areas of impact to the Ogallala Aquifer and evaluations of well location using results from the CMS/FS modeling.

The outcomes of this task include determining the effectiveness of the current Ogallala Aquifer monitoring well network in the southeastern and eastern Plant areas and recommending placement of three additional monitoring wells. To accomplish these objectives, existing information and modeling results are reviewed to assess where RDX may potentially be migrating to the Ogallala Aquifer. The information required to predict a plume includes:

- Groundwater flow directions and rates, measured and simulated
- Source strength and timing, simulated
- Regulatory / risk-based criteria for plume detection
- Reactions (such as biological) that act to reduce the plume size, measured and simulated

The source locations under consideration are estimated to be in the locations where the FGZ becomes more permeable and groundwater transitions from predominantly horizontal to vertical flow. In this region, vertical flow occurs from the perched groundwater through the FGZ to the underlying unsaturated Ogallala Formation and Ogallala Aquifer. Although source strength and location are not well-defined via direct measurement, knowledge exists from previous site investigations and modeling efforts. The hydrogeologic conditions in the Ogallala Aquifer are also uncertain, specifically the hydraulic conductivity beneath the perched groundwater and the pumping rates from nearby irrigation wells. To address the uncertainty, geostatistical representations of the aquifer hydraulic conductivity are coupled with flow and transport simulations, and the simulation results are used to assess the areas of greatest uncertainty in potential RDX plume fringe location. These areas then became candidates for new well locations that reduce the uncertainty of the groundwater plume fringe location by the maximum amount possible.

1.3 DOCUMENT OUTLINE

Section 1 provides an introduction to the effort and work to be accomplished. Section 2 provides an overview of the methodology and modeling approach employed, including a summary of concepts and tools used in this analysis. Section 3 provides detailed information about the model developed and results of the simulations and associated optimization. Section 4 presents the report summary and conclusions. Finally, Section 5 provides a list of references used in this study.

2.0 METHODOLOGY

2.1 APPROACH

The overall approach to determine the best locations for new wells to enhance the detection monitoring network includes:

1. Develop an understanding of flow and transport conditions in the Ogallala Aquifer beneath the perched groundwater from physical consistency with observed conditions elsewhere.

2. Use the Plume Finder Technology to optimize the early warning detection well network.

The first step was largely completed through recent work at Pantex Plant in support of other Environmental Restoration Program objectives. An extensive hydrogeologic investigation has been completed, and the data collected was used to develop a conceptual model for the site. The results of flow and transport models developed from this framework enhance the understanding of the hydrogeology and provide physically-based estimates of aquifer conditions and properties beneath the perched groundwater. The second step uses the best optimization tools currently available to directly incorporate the results of previous work into the design of the well network. These optimization tools are further described in this chapter.

2.2 OPTIMIZATION

Optimization tools are used to guide decisions that are defensible by integrating physics-based simulation models, models based on measured data and observations, and direct incorporation of uncertainty through geostatistics. Simulation models provide a mathematical statement of current and expected future conditions in the subsurface based on the physics of groundwater flow and contaminant transport, but these models are limited by the amount of data available to calibrate the models. By combining the physics and data models, optimization tools provide optimal estimates based on knowledge gained from both the physical simulator and the data. The information content from the different models and associated uncertainty with each is fused through the use of signal processing or formal optimization algorithms. For this project, the uncertainty in predicted plume fringe location is quantified, and the optimum monitoring well locations provide the maximum reduction in this uncertainty.

Optimization tools are extremely useful when limited data are available. For example, this occurs beneath the perched groundwater where investigations have been limited because of the potential for cross contamination to the Ogallala Aquifer as a result of drilling through the FGZ. In this case, optimization tools quantify the uncertainty of a monitoring well network and help determine if our understanding of the subsurface is supported by available data.

2.3 PLUMEFINDER

The PlumeFinder is an optimization tool that identifies the optimal locations (i.e., those locations that reduce the uncertainty in contaminant plume location the most) for new monitoring wells. PlumeFinder works by identifying (before sampling) the next sampling location in 2-D (two-dimensional) or 3-D (three-dimensional) space that, when sampled, minimizes the uncertainty of the plume boundary location after the sample has been taken. Sampling activity is prioritized because a new sampling location is proposed only if it provides the maximum amount of information when solving the plume location challenge. Output from the PlumeFinder evaluation consists of a rank-ordered list of sample locations for new monitoring wells that minimize the uncertainty in delineating the plume boundary. The PlumeFinder optimization software is based on well-accepted mathematical and statistical concepts and was developed under the direction of Dr. George Pinder at the Research Center for Groundwater Remediation Design at the University of Vermont, USA (McGrath and Pinder, 1996). It has been extended by Larry Deschaine as part of his PhD work at the Chalmers University of Technology, Sweden.

The PlumeFinder works by modeling the information content provided by new sampling locations and quantifies the "maximum measure of uncertainty" in the plume boundary. The procedure is as follows:

1. Build a preliminary flow and transport model for the site. This initial model need not be perfect and does not need rigorous site knowledge to be effective.
2. Generate PlumeFinder statistics.
    a. Geostatistics are used to generate 500 aquifer realizations from observed variations of hydraulic conductivity in the aquifer.
    b. Each aquifer realization is simulated (for a period of 50 years in the current analysis) with the model to create a modeled plume in the aquifer.
    c. Kalman filtering is used to combine the modeled plume realizations with observed data and estimate the uncertainty in plume delineation.
    d. A rank-ordered list of monitoring well locations is created based on their maximum measures of uncertainty.
3. Collect data and add to observation database.
    a. For existing monitoring wells, measured concentration and, if available, hydraulic conductivity, data are included. If measured concentrations are non-detect, a value of one-half the detection limit is assumed.
    b. For future monitoring wells, concentration data is assumed using a value of one-half the plume fringe threshold.
4. Impose the additional constraints; in this case a constraint is imposed that the well not be placed within the extent of perched groundwater.
5. Quantify the confidence in the knowledge of the plume location from the existing Ogallala Aquifer monitoring wells and proposed new monitoring well.

For the transport modeling used in the PlumeFinder analysis presented here a unit source was used, the plume fringe was defined as 1/1000 of the unit source, and RDX concentrations at proposed new monitoring well locations were set at ½ of the plume fringe value (1 part per billion [ppb]). Modeling of the recommended alternative in the CMS/FS (BWXT Pantex/SAIC, 2007) indicated a maximum predicted RDX concentration of 4 ug/l in the Ogallala Aquifer. With the RDX contaminant plume fringe defined as the 0.774 ug/l isocontour, the maximum ratio of plume fringe concentration to potential source in the Ogallala Aquifer is approximately 1/5. No measurements of RDX in the Ogallala Aquifer have been made in the predicted area of breakthrough. Perched groundwater concentrations above this area are on the order of 1 to 4 parts per million (ppm). Therefore, a source to strength ratio of 1000:1 was applied and no retardation or biodecay was applied during the 50-year transport simulation. While conservative, this methodology identified the most likely area of plume migration and the uncertainty with this migration beyond the extent of perched groundwater. The region of uncertainty in a focused area beyond the perched groundwater became the location for the first monitoring well.

2.4 MODELING

Numerous challenges exist in developing a modeling approach for this problem. Historical data describing the timing and volume of wastewater releases to the ditches are limited, so the transport of compounds through the upper unsaturated zone to perched groundwater is not well understood. Limited direct observation data are available to determine the timing and mass flux of releases from perched groundwater to the Ogallala Aquifer, including specific flow and transport mechanisms and rates, hydraulic conductivity, and natural attenuation processes in the Ogallala Aquifer. In addition, current and historical withdrawals from the irrigation and water supply wells local to the site are not known with great certainty because the flows are not typically measured at the wellhead nor are detailed operational records kept. These uncertainties are well documented in the Pantex CMS/FS Modeling Report (BWXT/SAIC 2007). In spite of these uncertainties, a method for determining for the best locations for monitoring the potential breakthrough of RDX plumes is needed. The PlumeFinder optimization tool is helpful in developing superior investigation strategies for plume delineation when compared to standard Monte Carlo simulation techniques which merely provide upper and lower bounds on confidence. PlumeFinder uses Monte Carlo and Latin Hypercube techniques and assesses the noise in the concentration signal, compares it on a nodal and model-wide basis to the value of the concentrations samples, and uses Kalman filtering to fuse this information and arrive at the optimal estimate of the plume location.

To implement the PlumeFinder optimization tool, information was obtained and assessed from four primary sources:

- The *Groundwater RCRA Facility Investigation Report* (Stoller, 2004)
- Analytical data available for monitoring wells proximate to the area of interest (from the Pantex Integrated Environmental Database)
- The site-wide BIOF&T3D groundwater flow and contaminant transport model (BWXT/SAIC, 2007)
- The Pantex MODFLOW-SURFACT Ogallala Aquifer model (BWXT/SAIC 2007), which was a local refinement of the Northern Ogallala GAM (Dutton, Reedy, and Mace, 2001; Dutton 2004)

The following tools were used to facilitate this approach:

- Argus Open Numerical Environments (ArgusONE) Modeling Environment – model independent graphical user interface
- Princeton Transport Code (PTC) – finite element flow and transport code
- GSLIB – Geostatistical Software Library
- PlumeFinder – tool that integrates all of the above through optimization algorithms

The PlumeFinder technology currently requires the Princeton Transport Code (PTC) for numerical flow and transport because PlumeFinder includes links to PTC within the ArgusONE modeling environment. Therefore, a 2-D model of the Ogallala Aquifer was first developed using PTC. The PTC Ogallala Aquifer model was developed by integrating historical information, previous modeling efforts, geostatistical codes (GSLIB), and current field data. Previous models developed for this area include the Pantex CMS/FS BIOF&T3D model (BWXT/SAIC 2007) and the Pantex Ogallala Aquifer model (BWXT/SAIC 2007).

The domain of interest includes areas south and east of Pantex (along the fringe of perched groundwater saturation) where (1) investigation data indicate the FGZ becomes more permeable, and therefore introduce likely points of breakthrough to the underlying Ogallala Aquifer and (2) previous modeling results predicted low level impacts to the Ogallala Aquifer.

A transport simulation time of 50 years was selected for the evaluation to support development of the early detection monitoring network.

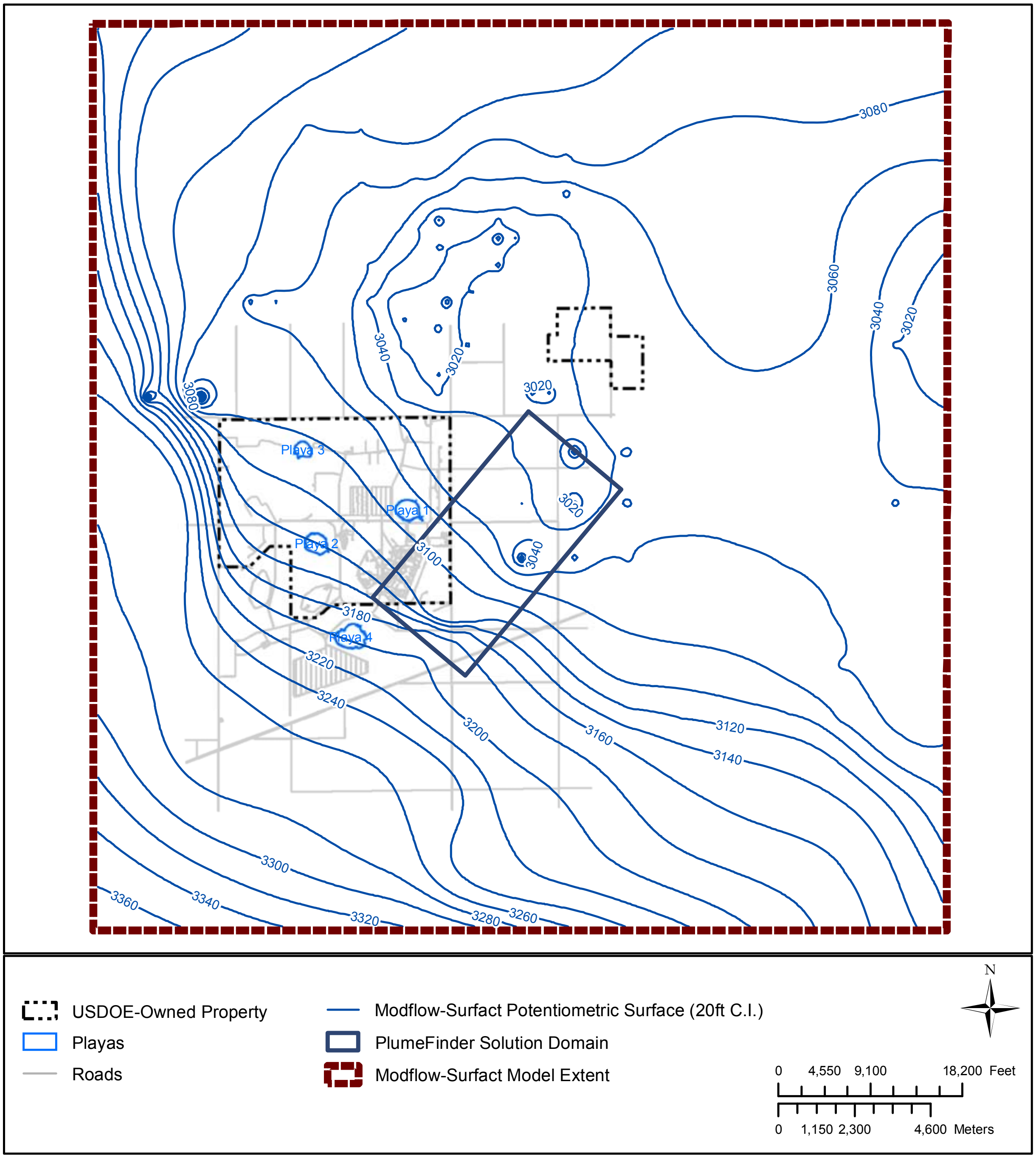


Figure 2-1. MODFLOW-SURFACT and PTC/PlumeFinder Model Domains

PlumeFinder differs from standard groundwater flow and transport modeling because in addition to flow and transport, the "information content" is modeled and the worth of new monitoring well data is computed (McGrath & Pinder, 1996). This contrasts the typical approach which simply computes the expected residual mass of RDX. The following example illustrates the PlumeFinder concept.

Given all the unknowns in the above problem statement, if one were to give this problem to 500 different analysts, one could reasonably expect 500 different answers if conventional modeling techniques were used. Each analyst would be free to choose their own interpretation of required information such as historical pumping rates and locations, hydraulic conductivity, and transport process and attenuation parameters. There would be a finite probability that any of the 500 analysts could be correct, but there would be no way to tell which analyst provided the best results using conventional modeling techniques. This is both disconcerting and untenable for decision makers.

Using the PlumeFinder technology, hundreds of different aquifers can be simulated – each with the same probability of being correct. The results from all these simulations are combined, and the areas that have the most uncertainty in the plume concentration are chosen as the best areas to investigate. This approach provides a scientifically-based decision that considers the unknowns.

2.5 MODEL CODE AND GRAPHICAL USER INTERFACE

The PlumeFinder technology includes links to the PTC (Pinder, George, F. 1997) numerical flow and transport code. PTC is a 3-D, finite element, saturated flow and single component transport model. PTC has been used for over 20 years, and has been used at major Superfund sites. The PTC model can be accessed through the ArgusONE graphical user interface (GUI) that allows for visualization of models through plug-in extensions. These tools are the interface for the PlumeFinder technology.

PTC is a very robust, accurate, and fast numerical flow and transport solver. This robustness and solution speed is critically important when conducting PlumeFinder integrated modeling and statistical investigations, because 1,500 separate aquifer realizations and subsequent flow and transport simulations are needed to solve the particular optimization challenge presented here. Future modeling needs are also considered satisfied by PTC and the ArgusONE GUI because the possibility of plume migration management exists.

The GSLIB (Deutsch and Journel, 1992) was selected for generating aquifer realizations based on observed variations in hydraulic conductivity data. GSLIB is the industry-standard for geostatistical analysis and the source code is publicly available.

3.0 ANALYSIS AND RESULTS

3.1 MODEL DEVELOPMENT

A summary of the hydrogeology and current studies of the Ogallala Aquifer are included in the sections below.

3.1.1 Hydrogeology

Pantex is situated on the High Plains of the Texas Panhandle. One of the major aquifer systems, the Ogallala Aquifer has more water being pumped from it than any other aquifer in Texas. The Ogallala Formation in which the Aquifer is seated consists of alluvial sands, silt, clay, gravel, and several caliche horizons. An unconfined aquifer in the sands and gravels of the lower Ogallala is the principal source of groundwater in the High Plains region, and is a primary source of potable water for Pantex and the City of Amarillo. In the vicinity of Pantex, this aquifer lies approximately 107 to 130 meters (350 to 425 feet) below ground surface (bgs). The base of the Ogallala is an irregular surface that represents the pre-Ogallala topography, which was influenced by the dissolution of underlying Permian salts and erosion. Consequently, the depth to the base of the Ogallala Formation varies across the Plant from approximately 122 meters (400 feet) below the southwest corner of the Plant to nearly 244m (800 feet) below the northeast corner of the facility. The thickness of the Ogallala Formation in the vicinity of Pantex ranges from approximately 99 to 220 meters (325 to 725 feet), increasing from southwest to northeast. Figure 3-1 shows the water table of the Ogallala Aquifer near Pantex as measured in December 2007.

Regionally, the Ogallala Aquifer water table slopes from northwest to southeast, generally following the regional topographic surface. In the vicinity of Pantex, however, the water table slopes from southwest to northeast, as shown in Figure 3-1, in response to extensive pumping from the City of Amarillo Carson County well field north of Pantex. Figure 3-1 also indicates an area of no saturation in the aquifer on the eastern side of the Texas Tech University (TTU) property. As water levels in the aquifer continue to decline, this area of no saturation will expand.

Groundwater in the Ogallala Aquifer is recharged from downward percolation of water, either from the surface of the High Plains or from the overlying perched groundwater zones. The distribution of recharge is poorly known, with estimates ranging from less than 0.01 inches per year to several feet per year. Higher recharge rates occur where the Ogallala Formation occurs at the surface and where surface water runoff is focused, such as beneath drainage ditches and playas. Lower rates occur for uplands (areas between the ditches and playas). A good summary of the recharge rates is presented in the Subsurface Modeling Report (BWXT/SAIC 2004 and 2007). For this effort, recharge rates were specified based on the MODFLOW-SURFACT model of the Ogallala Aquifer presented in the CMS/FS (BWXT/SAIC 2007).

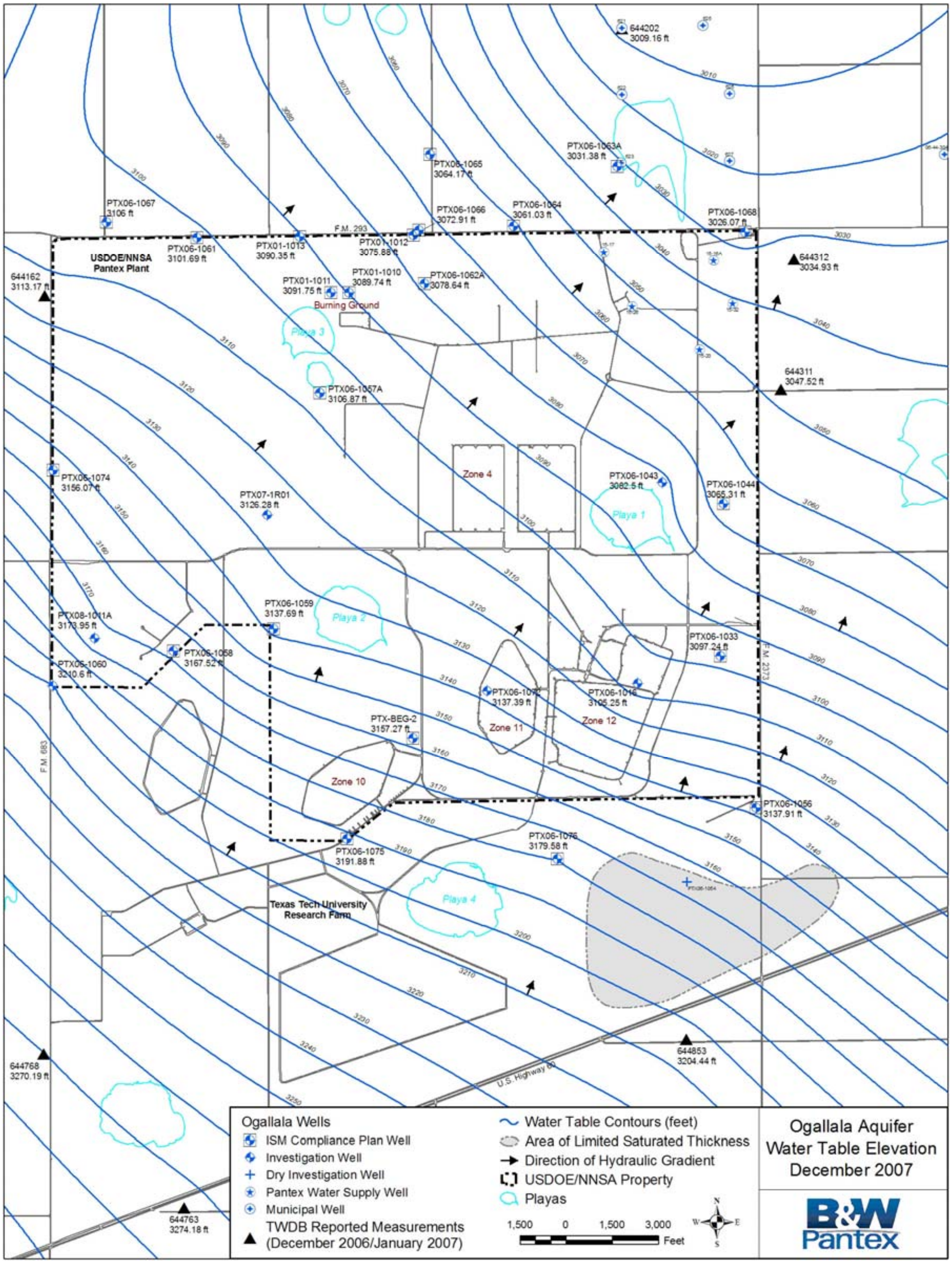


Figure 3-1. Ogallala Aquifer Water Table, December 2007

Few site-specific measurements of hydraulic conductivity have been completed in the Ogallala Aquifer at Pantex. As a result, information from regional studies has been used to supplement the site-specific hydraulic conductivity data. Of particular interest in the Bureau of Economic Geology study (Dutton, Reedy, and Mace, 2001) were the tests compiled from Mullican (1997) and from the groundwater database maintained by the Texas Water Development Board (TWDB). Mullican (1997) obtained information on 70 aquifer tests which included high-quality specific-capacity tests. Mullican (1997) were also able to cull data from an additional 1,271 specific-capacity tests in the TWDB groundwater database. To estimate transmissivity and hydraulic conductivity from specific capacity, they used an analytical technique developed by Theis (1963). Hydraulic conductivity was determined by dividing transmissivity by the saturated thickness exposed to the well bore.

Based on results from the data compilation and specific-capacity analysis, the hydraulic conductivity for the Ogallala Aquifer was found to be log-normally distributed (Figure 3-2) with a geometric mean of approximately 14.8 feet per day (ft/d) and a standard deviation that spans from 5 to 44 ft/d. The upper range of the standard deviation (i.e., 44 ft/d) is three times the geometric mean of approximately 14.8 ft/d, indicating variability in hydraulic conductivity. Because of this variability, uncertainty in hydraulic conductivity was evaluated using geostatistical methods to develop 500 equally plausible representations of the Ogallala Aquifer within the Ogallala Aquifer flow model.

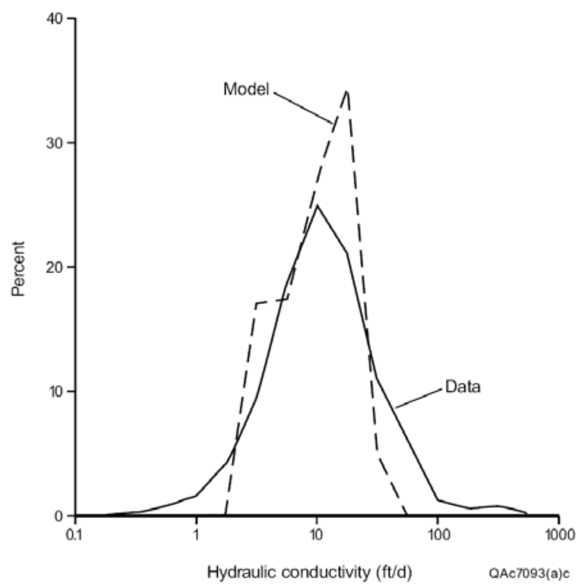


Figure 3-2. Bureau of Economic Geology Finding of Lognormal Distribution for Hydraulic Conductivity in the Ogallala Aquifer (after Dutton et al, 2000).

The greatest source of uncertainty in assessing transport is the uncertainty in hydraulic conductivity (Smith and Schwartz, 1981). To illustrate that hydraulic conductivity is the most sensitive parameter for determining plume location, the sensitivity of average groundwater velocity to gradient, porosity, and hydraulic conductivity is evaluated (within the range of values expected at the Plant). Considering Darcy's Law (v=ki/n; where v = velocity, k = hydraulic conductivity, i = hydraulic gradient, and n = porosity), sensitivity to changes in the gradient or porosity changes within the range of measured values at the Plant are relatively small compared to sensitivity to the anticipated range in hydraulic conductivity.

For example, the gradient ranges from 0.003 feet horizontally/feet vertically (ft/ft) beyond the northeast corner of the Plant to 0.012 ft/ft in the vicinity of Zone 12 in the 2007 water table shown in Figure 3-1. The porosity, n, has been measured in a number of samples collected at the Plant and ranges from approximately 29% to 42% based on samples collected from above the water table (SAIC, 2000). Specific yield values can be used to estimate porosity (although they typically underestimate porosity slightly). Specific yield values from 41 test holes scattered throughout the region averaged about 16% (SAIC, 2000). Porosity values published in the literature range from 25% to 35% for the sandy-gravelly sediments (Fetter, 1988) that comprise the Ogallala Aquifer.

Using a constant hydraulic conductivity of 5 ft/d for illustrative purposes, the increase in velocity for the gradient change is by a factor of 4.0 and the decrease in velocity for the porosity change is by a factor of .381. Velocities shown below are in ft/d:

Gradient Change (using the lower end of the porosity range)

$v = 5(.003)/.16$	$v = 5(.0012)/.16$
$v = .094$	$v = .375$

Porosity Change (using the mid-point of the gradient range)

$v = 5(.0075)/.16$	$v = 5(.0075)/.42$
$v = .234$	$v = .089$

The change in velocity from varying hydraulic conductivity by the upper and lower end of the standard deviation range, we see an increase in velocity by a factor of 8.8.

Hydraulic Conductivity Change (using the lower end of the porosity range and the mid-point of the gradient range)

$v = 5(.0075)/.16$	$v = 44(.0075)/.16$
$v = .150$	$v = 1.320$

This example illustrates that the greatest variation is from the hydraulic conductivity field and hence, why it is chosen as the parameter to capture using geostatistics in the PlumeFinder analysis. This example also corresponds with the results by Smith and Schwartz, (1981) that the greatest source of uncertainty is hydraulic conductivity. The remaining transport parameters are as follows:

- Retardation factor: none specified. Retardation refers to the relative velocity of the center of the transport plume to the advective groundwater flow. Neglecting retardation permits the advective portion of the simulated RDX plume to migrate with the same velocity as the groundwater.
- Dispersivity: Dx=50 ft, Dy=5 ft and Dz = 5 ft. Dispersivity refers to the process of the plume spreading in all directions from its centerline. The dispersivity parameters are taken directly from the model reported in the Corrective Measures Study/Feasibility Study (CMS/FS). Smaller values will produce a narrower, focused plume and larger values will produce wider, more disperse plumes with lower peaks values.
- Molecular diffusion: none specified. The process of molecular diffusion (Brownian motion) describes how a concentration of a chemical such as RDX would diffuse from areas of higher concentrations to areas of lower concentrations. This is a slow process, and the dispersion due to the movement outweighs this effect for the Ogallala Aquifer flow system. A non-zero value would results in a practically negligible addition to the dispersive plume front.

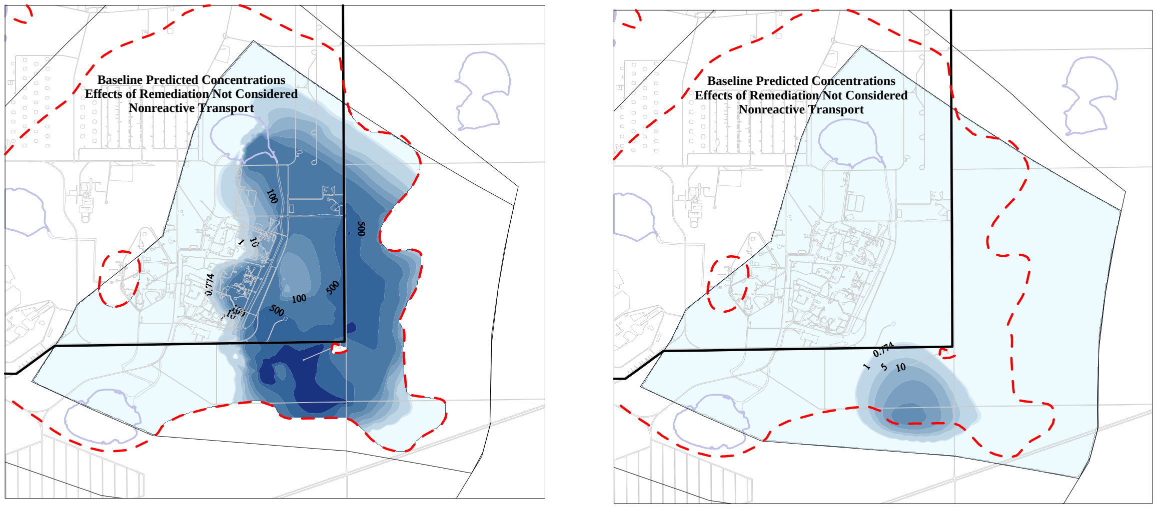
- Biological decay: none specified. The biological decay processes destroy contaminants such as RDX. Neglecting biodegradation allows the simulated RDX to migrate the furthest.
- Porosity: 0.25%. Porosity is the open area of the soils where the water flows. All other parameters being equal and given a fixed flux, higher values of porosity produce slower plume migration and lower values result in faster plume migrations.
- Source strength: constant unit source. In the southeastern portion of the Plant where RDX is projected to migrate from the perched groundwater to the Ogallala Aquifer at detectable concentrations based on CMS/FS modeling a continuous constant unit source is specified. Since the flux through the source area is realization-specific, each simulated aquifer will generate a unique source flux. A second hypothetical source along the eastern fringe of the perched extent is not directly simulated in the PlumeFinder analysis but is evaluated separately.
- Base hydraulic conductivity: specified from the CMS/FS MODFLOW-SURFACT Ogallala Aquifer model (BWXT/SAIC 2007b). This is the base conductivity field used for the geostatistical realizations. It is used directly only in the deterministic case, and varied geostatistically to generate 500 stochastic realizations of the Ogallala Aquifer. The base hydraulic conductivity is not used directly the PlumeFinder fringe calculations.

Finally, variograms from several studies (Clark, 1979; McCuen and Snyder, 1986) show that hydraulic conductivity in the Ogallala Aquifer is spatially correlated. Spatial correlation infers that points that are closer together are more similar to each other than points that are further apart. Fitting a spherical theoretical variogram (Dutton, Reedy, and Mace, 2001) to the experimental variogram resulted in a nugget of 0.12 $[\log(ft/d)]^2$, a sill of 0.22 $[\log(ft/d)]^2$, and a range of 140,000 feet. The range suggests that hydraulic conductivity is spatially correlated within 140,000 feet (26 miles) in the Ogallala Aquifer. The distance correlation is the range (length) beyond which a conductivity measurement no longer has value in predicting local conductivities.

3.1.2 Water Quality

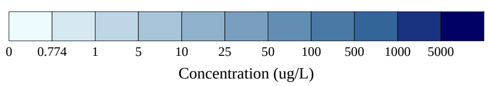
Past operational and waste handling procedures have resulted in contamination of the perched groundwater beneath the Plant. Groundwater quality in the Ogallala Aquifer is characterized by groundwater samples collected from monitoring wells installed in the aquifer. Although non-trending sporadic detections of constituents occur in the Ogallala Aquifer at low, non-actionable concentrations below regulatory screening levels, no constituents of concern have been identified in the Ogallala Aquifer based on the current monitoring network.

Modeling conducted as part of the Baseline Human Health Risk Assessment and CMS/FS indicates the potential for contaminants in perched groundwater, particularly RDX, to impact the Ogallala Aquifer in the future (BWXT/SAIC 2006 and BWXT/SAIC 2007). Figure 3-3, taken from the Baseline Human Health Risk Assessment Report, shows modeled concentrations of RDX in the perched groundwater and Ogallala Aquifer after 20 years of transport in the absence of corrective actions. The figure on the left shows that the highest concentrations of RDX in perched groundwater occur south of Pantex Plant beneath TTU property with high concentrations of RDX also found along the eastern boundary of Pantex. The figure on the right shows modeled impacts to the Ogallala Aquifer occur near the southern extent of perched groundwater, beneath the area containing the highest RDX concentrations in perched groundwater. This area was identified as the source area for the PlumeFinder modeling.



a) RDX predicted in Perched Groundwater at T=20 years

b) RDX predicted in the Ogallala Aquifer at T=20 years



RDX
RBSV = 0.774 ug/L
RRS2 Residential = 7.7 ug/L

Note: In accordance with 30 TAC §335.553(b)(2), these figures depict the results of baseline simulations of potential future conditions resulting from the release of contaminants in the absence of any actions to control or mitigate the release. Accompanying text in Appendix N must be used to fully interpret these modeling results.

Figure 3-3. Modeled RDX Concentrations in the Perched Groundwater and Ogallala Aquifer

A second potential source area along the eastern extent of perched groundwater is also considered, although it is not directly included as a source in the PlumeFinder analysis. No impacts exceeding risk based levels to the Ogallala Aquifer were predicted in this area, but the area is considered a potential source because of the high RDX concentrations in perched groundwater coupled with a slightly more permeable FGZ along the fringe of perched groundwater.

RDX is projected to migrate from the perched groundwater to the Ogallala Aquifer. Before entering the Ogallala Aquifer, the RDX must vertically traverse the unsaturated zone between the FGZ and the Ogallala Aquifer water table. In the southeast area this distance is much less than along the eastern extent of saturation. The FGZ is also simulated as slightly less permeable along the eastern extent in the CMS/FS models compared to the southern fringe of perched groundwater. Increased travel time simulated through a thicker unsaturated zone and slightly lower FGZ permeability mitigates predicted impacts to the Ogallala Aquifer hence less impact to the Ogallala Aquifer is expected along the eastern fringe of perched groundwater. However, given the lack of direct data in the Ogallala Aquifer in this area it is prudent to locate monitoring wells capable of detecting RDX migration here.

3.1.3 <u>Previous Models</u>

Few regional aquifers have been as extensively studied as the Ogallala Aquifer. Models of groundwater flow have been important tools for managing the groundwater resource and evaluating future changes in water level and saturated thickness. At least 15 numerical groundwater flow models have been developed for different parts of the aquifer. Most recently, studies were completed by the Bureau of Economic Geology at the University of Texas on withdrawal projections in the Ogallala Aquifer in the Panhandle Water Planning Area (Dutton, Reedy, and Mace, 2001; Dutton 2004). The studies predicted that by 2050, major areas of the aquifer will have less than 50 feet of remaining saturated thickness and parts of the aquifer in various counties in the Panhandle Water Planning Area may be dry.

Two recent site-specific models have been developed which include the Ogallala Aquifer in the area-of-interest for this study. The motivation for developing these models was to support decision-making that protects the Ogallala and Amarillo well field. Specifically, these are the Pantex CMS/FS BIOF&T3D model and the Pantex MODFLOW-SURFACT Ogallala Aquifer model (BWXT/SAIC 2007).

Ideally, the CMS/FS BIOF&T3D model (BWXT/SAIC 2007) would be integrated with PlumeFinder technology to optimize the proposed well locations. However, execution of one simulation with this model requires approximately 7 to 20 days using computers available in 2007. As part of this study, over 1,500 final simulations were completed during the PlumeFinder analysis. This includes computing flow and transport over a 50-year period, using different – though equally plausible – aquifer conductivity realizations. Years of computational time would be required using the fully 3-D, variable saturated, coupled transient flow and transport model with all the site complexity.

Use of the CMS/FS BIOF&T3D model in a PlumeFinder analysis presented a significant computational hurdle. Therefore, the MODFLOW-SURFACT Ogallala Aquifer model was used to set up a PTC flow and transport model, and then this PTC flow and transport model was applied to the PlumeFinder analysis.

3.1.4 PlumeFinder / Princeton Transport Code (PTC) Model

The first step in the PlumeFinder analysis was to develop the PTC Ogallala Aquifer groundwater flow and transport model from the MODFLOW-SURFACT Ogallala Aquifer model (BWXT/SAIC 2007). The MODFLOW-SURFACT model contains the most recent updates of aquifer properties (including bottom elevation of the Ogallala Aquifer, the hydraulic conductivity and water table information) in the area of interest local to the Plant. It acceptably simulates flow under both steady-state conditions (using reduced pumping rates as described in BWXT/SAIC 2007) and transient conditions. The steady state version was selected for conversion to PTC for computational efficiency. The CMS/FS modeling conducted with the BIOF&T3D model included comparisons of RDX transport results using a declining, transient water table and a steady-state water table for the Ogallala Aquifer. The simulations produced nearly identical results, so the use of the steady-state model is not expected to significantly affect the outcome of the PlumeFinder analysis.

The MODFLOW-SURFACT Ogallala Aquifer steady-state model was used as-is in developing the PTC Ogallala Aquifer model, with the two minor refinements to include a finer grid and modify of two wells. In the final steady-state Ogallala Aquifer model, each model grid cell was 844.8 feet (257.5 meters) wide in the east-west direction and 897.6 feet (273.6 meters) wide in the north-south direction. In the transient Ogallala Aquifer model that was used for predicting future flow conditions, a finer grid cell size was used: 211.2 feet (64.4 meters) in the east-west direction and 224.4 feet (68.4 meters) in the north-south direction. The latter grid resolution was needed to assist in subsequent contaminant transport calculations in PTC, so the withdrawal rates from the steady-state Ogallala Aquifer model were substituted into the finer transient Ogallala Aquifer model grid to obtain the steady-state head solution in the more finely discretized model. During this process, two wells were modified with respect to those included in the final steady-state model. First, one Pantex production was excluded; this well was active c.1994 (i.e., consistent with the time period represented by the steady-state model) but is not active today. Second, one irrigation well that was inadvertently omitted from the final steady-state model was added. This irrigation well lies north of the Amarillo well field, and has insignificant impact on this or previous analyses.

To focus the PlumeFinder calculations, simulations were conducted with the steady-state Ogallala Aquifer model to guide the selection of the PTC model extent. Two unit sources were included. One was an areal source placed in the potential areas of RDX breakthrough to the Ogallala Aquifer predicted by the BIOF&T3D model (BWXT/SAIC 2007) and another was a distributed line source along the eastern fringe of perched groundwater. Transport parameters for RDX were specified consistent with those used in the BIOF&T3D model, with the following notable exceptions:

- Biodegradation is assumed not to occur.
- Retardation is assumed not to occur.
- The source strength in the Ogallala Aquifer is assumed 1000 times greater than the plume fringe (1 ppb) for RDX.

The assumptions are more conservative (result in larger predicted plume extent) than those included (biodegradation & retardation) or simulated (peak concentrations of RDX in the Ogallala Aquifer) from the CMS. For instance, a biodecay rate of 25 years and a retardation factor of approximately 1.7 were assumed in the CMS. This conservatism ensures the PTC model extent is sufficiently large to encompass all realizations produced for the PlumeFinder evaluation. Transport was simulated until the plume produced by both simulated source areas reached steady-state. The source areas and the resulting steady-state plume are depicted in Figure 3-4.

Withdrawals from the Amarillo production wells (generally north and northeast of Pantex) and the local area irrigation wells create cones of depression in the Ogallala Aquifer water table (Figure 3-4) that provide an outer bound for contaminant migration. Consequently, the PTC model domain was specified to extend just beyond this depression, as shown in Figure 3-4. The PTC model domain is substantially smaller than the MODFLOW-SURFACT model domain. This smaller model domain permits the 500 PTC models (i.e. the individual realizations generated after geostatistically varying the hydraulic conductivity) to be executed in about 5 minutes, or less than 1 second per run. The PTC model and the PlumeFinder solution domain cover approximately 9 square miles (12,000 feet by 24,000 feet) including the southeastern portion of the Plant area and the likely points of breakthrough to the south and east.

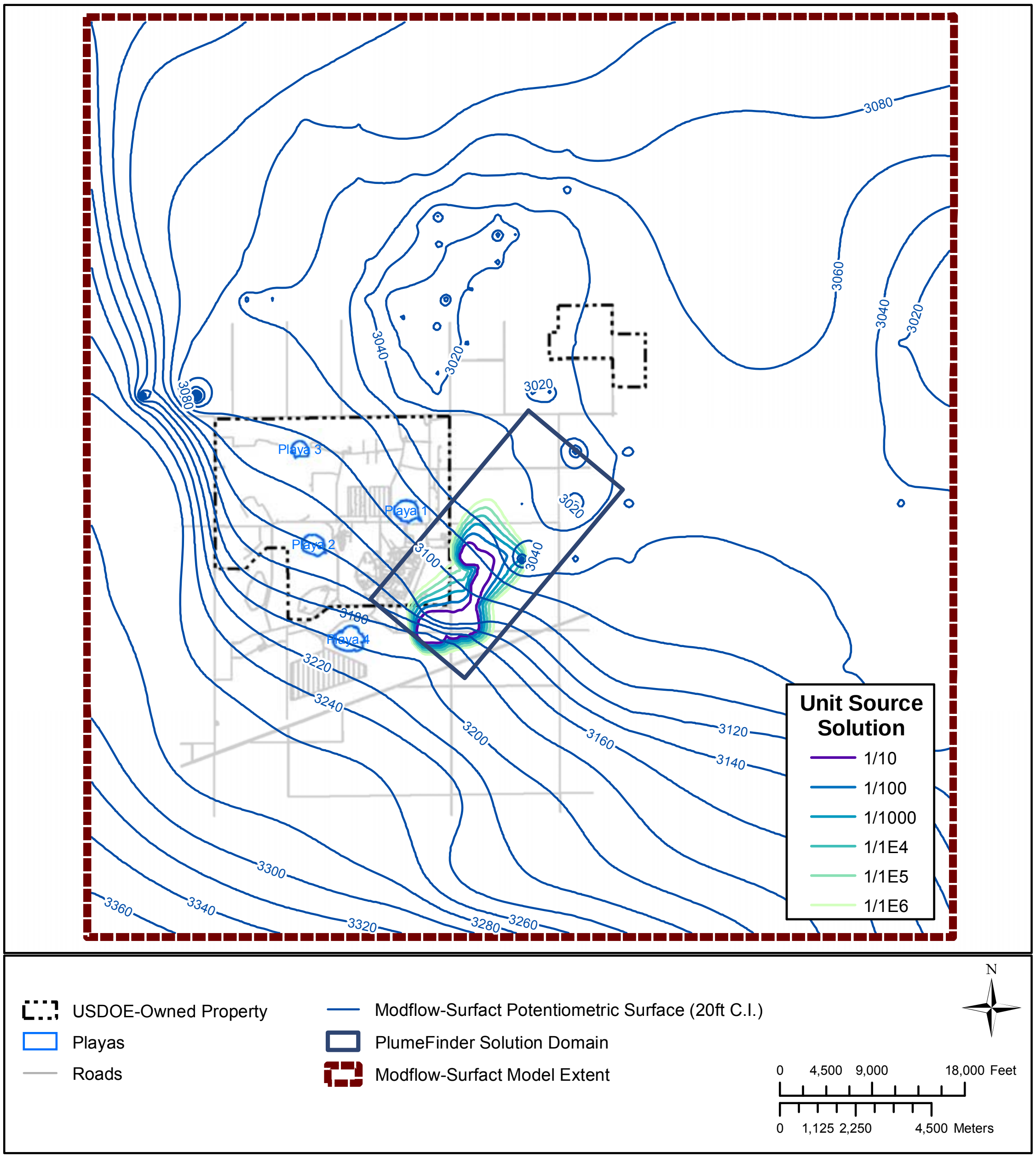


Figure 3-4. Model Domains and Steady-State Plume

Simulations were also conducted with the MODFLOW-SURFACT model to assess the sensitivity of contaminant transport to the pumping rate of irrigation wells immediately east of Pantex Plant, nearest the areas of potential breakthrough. Future pumping rates at the wells are unknown; therefore, the wells impart uncertainty on the transport directions in the area of interest. Transport and particle tracking were conducted to assess the sensitivity of results to the pumping rate of the well closest to the potential breakthrough areas. Three sensitivity simulations were conducted with pumping rate reductions of 50%, 75%, and 87.5% for this well. Predicted steady-state heads, steady-state transport results, and particle tracking results for the rate used in the steady-state model are presented in Figure 3-5a. Similar items are presented in Figure 3-5b for a 75% reduction in pumping rate for this well.

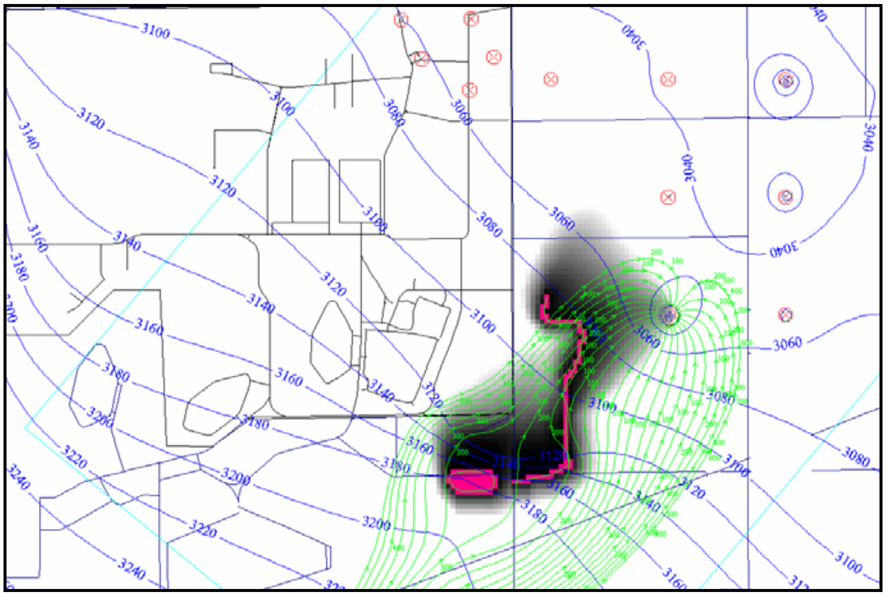


Figure 3-5a. Unchanged Flow Rate at Pumping Well

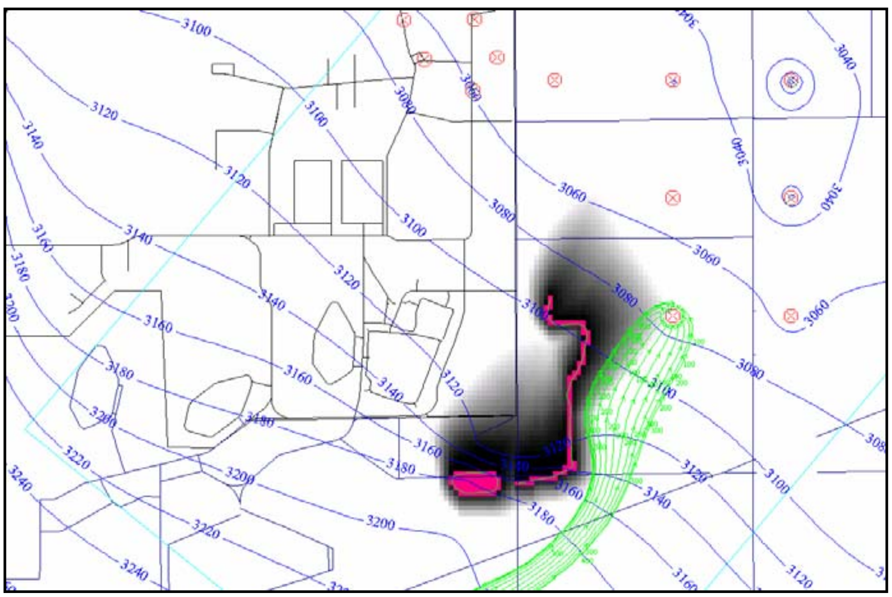


Figure 3-5b. Reduced Flow Rate at Pumping Well

Figure 3-5. Capture Zone and Transport Sensitivity Results

Comparing the two figures, a diminished capture zone for the well can be seen from the particle tracking comparison. However, impacts on the overall extent of the steady-state plume are not dramatic. Based on this comparison, the decision was made to represent all pumping wells with constant head boundary conditions in the PTC model rather than specify a constant flow rate in each. The constant head boundary condition allows the PTC model to calculate a variable flow rate at each well so that a constant water level is maintained in the cell. Note that much of the RDX release may be captured by a single pumping well. This is plausible but other alternatives cannot be discounted since there is a high degree of uncertainty due to the lack of direct field measurements in this area. Installation of the monitoring wells proposed from this analysis would add direct field measurements for this region and reduce the uncertainty.

After establishing the PTC model domain, aquifer properties including hydraulic conductivity, recharge, aquifer top and bottom elevations, and porosity were transferred directly from the MODFLOW-SURFACT model to the PTC model via the ArgusONE numerical modeling GUI. South of the southeast edge of Pantex, a dry area in the Ogallala Aquifer has been observed at one monitoring well. The area is simulated in the MODFLOW-SURFACT model as a partially saturated area, using the value of recharge as the flow in the cell to avoid the dry cell condition. In some areas, the aquifer thickness was less than one foot. Initial testing of the PTC model revealed that realizations with some classes of hydraulic conductivity fields caused the PTC model to fail due to stability limitations in areas with minimal saturated thickness. In these problematic iterations the water table "fell" below the aquifer bottom, causing the hydraulic conductivity in the numerical matrix to go negative and the solver to crash. To prevent these model convergence issues, a confined aquifer configuration was used in the PTC model, and the simulated aquifer thickness was held constant at its initial conditions. This solved the thin aquifer condition and allowed the saturated flow model to be used without requiring a computationally intensive variably saturated flow model or removing the thinner portions of the model domain out of the model. (Removing areas with minimal aquifer thickness was not preferred because the potential RDX source is in these areas.)

The heads from the drawdown of the pumping wells in the steady-state MODFLOW-SURFACT model were transferred into the PTC model and specified as constant head boundary conditions, with specified head values based on the steady-state flow solution. The PTC model boundaries were specified using constant head boundary conditions, again with head values based on the steady-state flow solution. Steady-state flow was then simulated in the PTC model and compared to the MODFLOW-SURFACT model, as seen in Figure 3-6. The comparison shows only minor differences in simulated heads between the two models in the areas of the well fields and at the boundaries with somewhat greater differences underneath the southeastern breakthrough area. The differences can be attributed directly to the combination of both different grid sizes used to solve the model domain, specifically in the area of the wells, and the simplification to apply the approximation of a constant aquifer thickness. The results for the final set of 500 realizations (hydraulic conductivity, head, and concentration) are provided on the attached compact disc.

Figure 3-7 shows the source used in the PTC model and applied to the associated PlumeFinder modeling. This source is placed in the potential area of RDX breakthrough to the Ogallala Aquifer predicted by the BIOF&T3D model (BWXT/SAIC 2007). A unit source strength of 1 ppm was assumed, and the fate and transport solution was calculated with a duration of 50 years. The Plume fringe was defined as the 1 ppb isocontour, and thus the ratio of source concentration to fringe concentration was 1000:1. Neither biodegradation nor retardation was included as a transport process. As a result, the conservative assumptions increased the predicted RDX migration along the likely pathway of the plume and identified the area where RDX from the southern source (breakthrough area) would first migrate beyond the perched groundwater extent.

This PTC model mesh used in the PlumeFinder is shown in Figure 3-8. The dense node arrangement associated with the source ensures accuracy in this critically important region of the model domain and limits numerical dispersion of the transport solution.

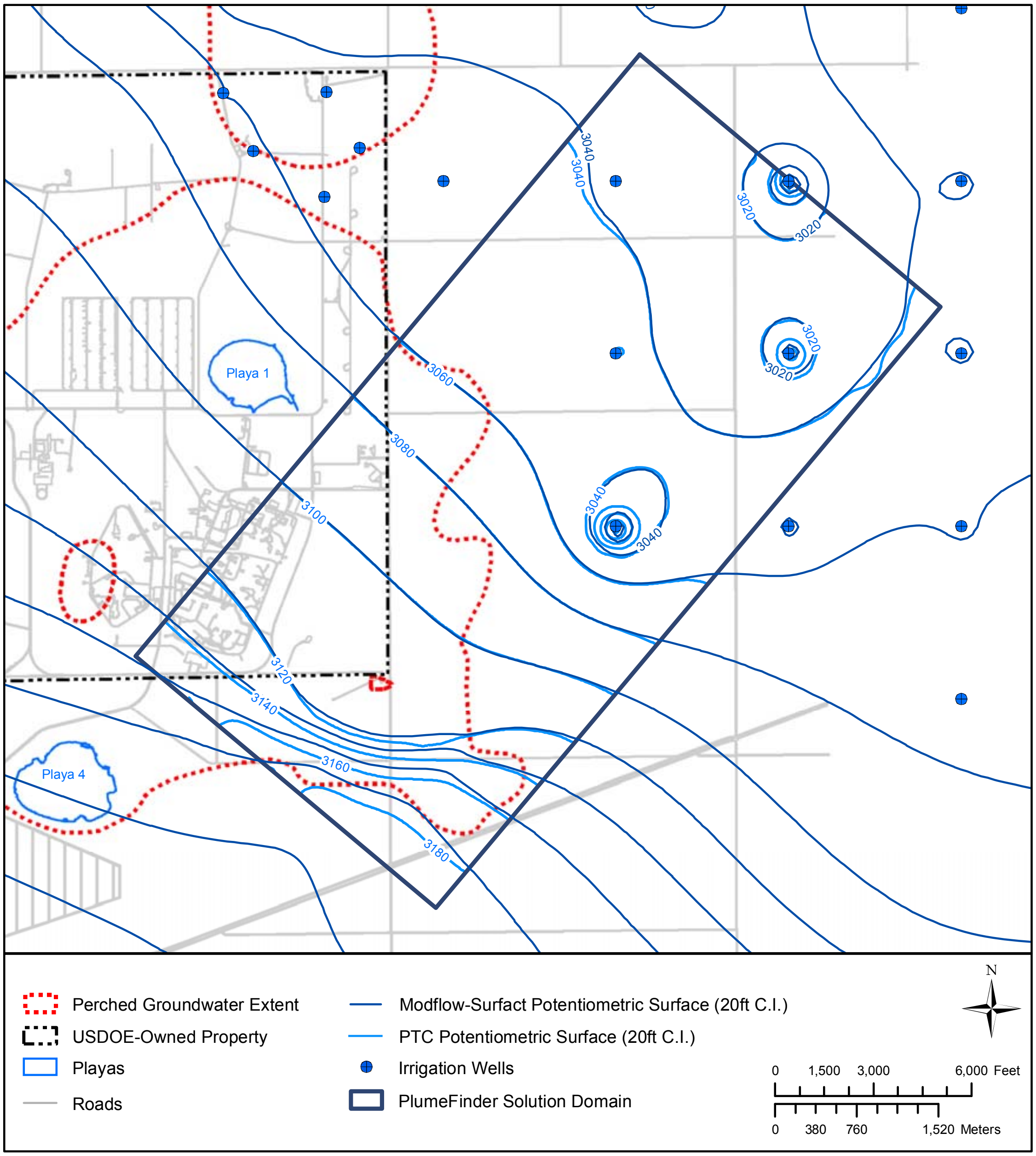


Figure 3-6. Potentiometric Surfaces Defined in PTC Model and Modflow-Surface Model

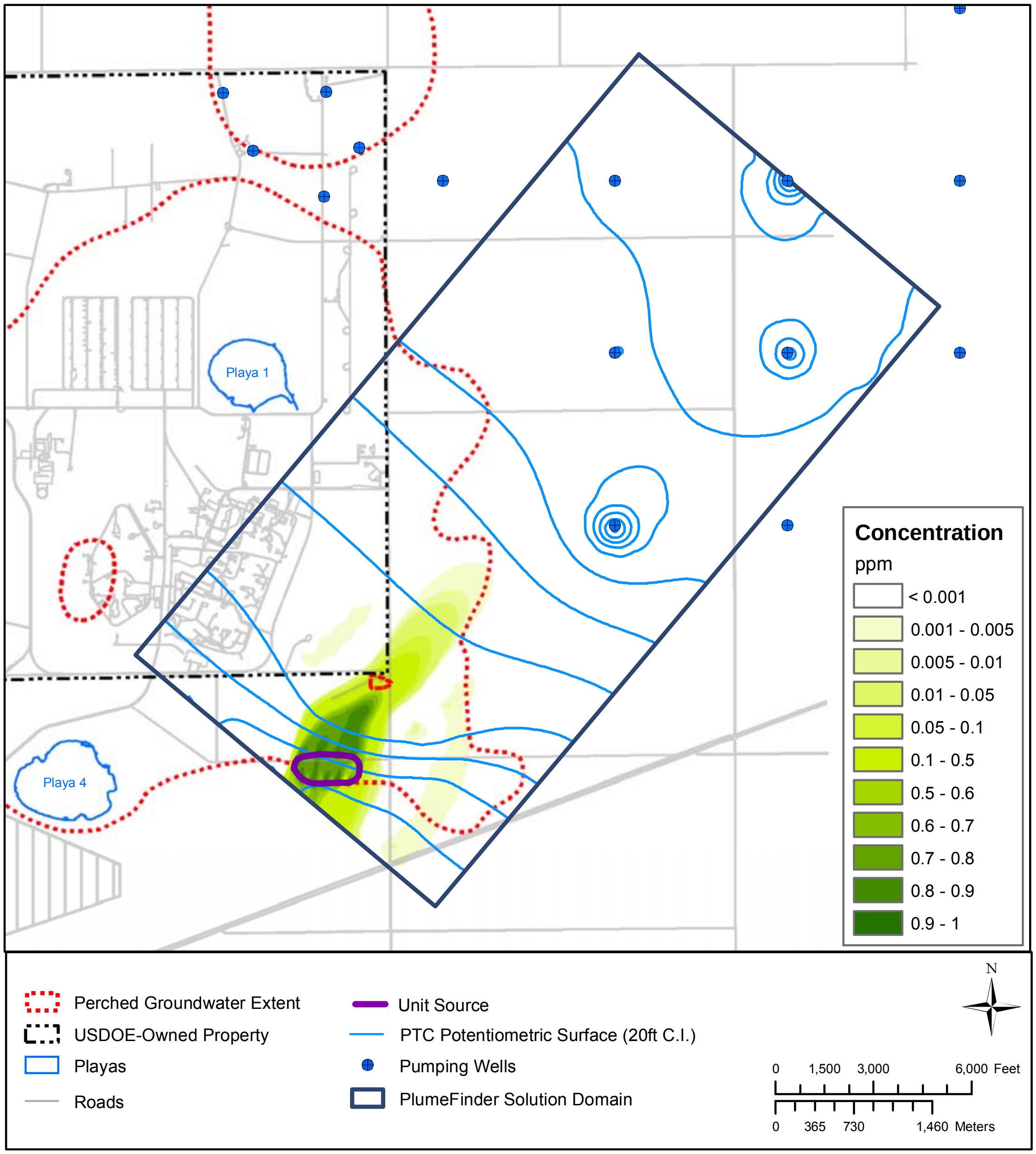


Figure 3-7. Contaminant Source and 50 year Deterministic Transport Plume in PTC Model

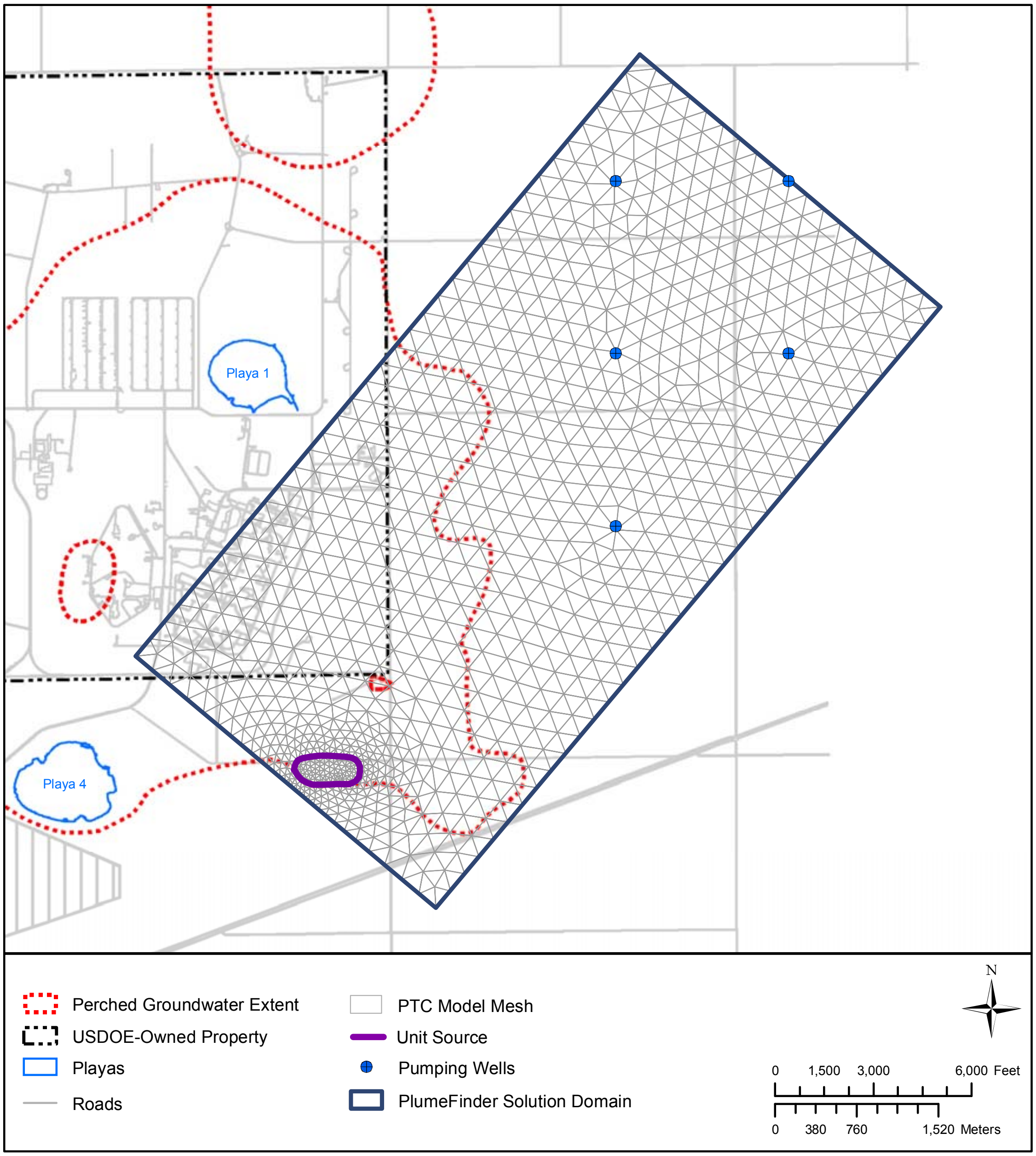


Figure 3-8. PlumeFinder Computational Mesh in PTC Model

3.1.5 Additional Considerations

Hydraulic conductivity: Hydraulic conductivity is assumed to be locally isotropic; that is, the same in the x and y directions within each element. However, because of uncertainty associated with the hydraulic conductivity and the limited amount of available test data, geostatistics were used to create 500 likely aquifers and the combined results analyzed to provide recommended locations for new monitoring wells. The variogram for the entire Ogallala Aquifer was used as discussed above. The extent the variogram may differ from local conditions is unknown. The variogram provides the best available information from which to base the hydraulic conductivity realizations.

Groundwater flow direction: With the exception of a few monitoring wells, the actual flow patterns beneath the perched groundwater are unknown from direct measurement. The inferred flow directions represent the best estimate from measurements recorded in the Ogallala Aquifer monitoring wells.

Potential Source Locations to the Ogallala Aquifer: The potential source of RDX to the Ogallala Aquifer is inferred. RDX has not been directly measured at any consistent value at any location in the Ogallala Aquifer. RDX is consistently detected in the perched groundwater at values in the mg/l range. The assumed sources used in the PlumeFinder analysis and accompanying qualitative assessment are the best estimates of where RDX could migrate into the Ogallala Aquifer, based upon both site investigation data and previous modeling results.

Fifty-year monitoring design period: Fifty years was chosen as a period from which to evaluate the plume fringe uncertainty. Uncertainty grows over time. Sporadic and unreplicated detections of RDX complicate the analysis, as it is uncertain whether or not a plume fringe exists in these monitoring locations. Only three Ogallala Aquifer monitoring wells within the PTC model extent still contain groundwater from which to make assessments.

Irrigation wells (pumping wells): The stochastic analysis of the plume fringe location also addresses the uncertainty associated with the pumping rates of irrigation and water supply wells. Simulations conducted with the MODFLOW-SURFACT Ogallala Aquifer model indicate that flow in the Ogallala Aquifer (and therefore contaminant transport) directions are sensitive to the pumping rates of wells east of Pantex near the areas of potential breakthrough. Future pumping rates at the wells are unknown, and the wells are not under Pantex control. These wells therefore impart substantial uncertainty on the transport directions in the area of interest. Because well pumping rates are allowed to vary with the different aquifer realizations, this uncertainty is somewhat addressed in the PlumeFinder analysis.

One last consideration is that the analysis presented here does not incorporate degradation or biological decay of RDX in the transport calculations. Degradation rates, usually expressed in terms of a first-order kinetic reaction rate, for RDX are well documented in the literature but have not been measured in the Ogallala Aquifer. Because biological reactions are redox-zone specific, the biochemistry is important in assessing the transport of material in the subsurface and will therefore be important in early detection of a plume fringe. As described in the *CMS/FS Modeling Report* (BWXT/SAIC 2007), the degradation rate of RDX is an irreducible uncertainty that can only be addressed over time as information on the redox zones and degradation rates in the Ogallala Aquifer groundwater.

A principled groundwater flow and transport model helps overcome data limitations through accurate representation of the underlying physics. However, a deterministic solution may not capture the variety of possibilities that exist to effectively manage potential migration of RDX. The PlumeFinder technology incorporates the major elements of the uncertainty, and provides a mechanism to support management decisions following a systematic and proven approach. Below are the results of the analysis.

3.2 PLUMEFINDER ANALYSIS AND RESULTS

The objective of this analysis is to identify best locations for up to three new Ogallala Aquifer monitoring wells using the PlumeFinder technology and incorporating predictions from previous modeling efforts. PlumeFinder optimally locates wells to better delineate the boundary of a contaminant plume. As noted earlier, PlumeFinder integrates the PTC model, the model GUI (Argus ONE), and geostatistical software into a computer system for guiding the investigation of contaminated aquifers. As discussed in the previous section, PlumeFinder is based on the idea that the best means of delineating a contaminant plume boundary is to place wells in such a manner as to minimize the uncertainty of the boundary location.

The threshold level that defines the RDX plume boundary is 1/1000th of the assumed unit source strength of 1 mg/l. This assumed unit source and plume fringe threshold are conservative. The recommended alternative in the CMS/FS (BWXT Pantex/SAIC, 2007) indicated a maximum predicted RDX concentration of 4 ug/l in the Ogallala Aquifer and a plume fringe defined by the 0.774 ug/l isocontour. An approximately 1/5 ratio produces an area of plume fringe uncertainty much smaller than if a lesser ratio of 1:1000 is used. Despite conservative assumptions in the PlumeFinder analysis, the likelihood that RDX will migrate from the source area to a point beyond the extent of perched groundwater in the east is low in this 50-year design period.

The GSLIB code was used to geostatistically vary the hydraulic conductivity field and generate multiple realizations of the Ogallala Aquifer. The hydraulic conductivity variogram from the Northern Ogallala GAM (Dutton, et al., 2001) was used as input into the model. Because pumping wells are simulated as constant head boundaries, the flow into them varied depending on the geostatistical representation of the aquifer hydraulic conductivity. The analysis consisted of generating 500 aquifer realizations, executing flow and transport simulations for each, and repeating this for each PlumeFinder investigation scenario. Three scenarios were evaluated: no wells, the existing monitoring well network, and one optimally located monitoring well. This resulted in 500 separate flow and transport simulations for each scenario, totaling 1500 simulations. The mathematics underlying PlumeFinder, specifically the Kalman filtering aspect, are explained in Appendix A. The flow and transport mathematics are provided in the PTC textbook and manuals (Pinder, 1997 & 2002). The applied geostatistics are described in the Geostatistical Software Library and User's Guide (Deutsch and Journel, 1992).

3.2.1 Baseline Uncertainty (No Monitoring Wells)

As a first step, the PlumeFinder investigation was executed without monitoring well information to provide a baseline for evaluating the existing well network. The results of the base case can be seen in Figure 3-9. In this figure, darker colors depict greater uncertainty and lighter colors depict higher confidence. The best location to place a well is in the area of maximum uncertainty outside the perched groundwater extent. The value for uncertainty (shown in the legend of Figure 3-9) is a measure of the uncertainty in the value of the RDX concentration in the groundwater when compared to the plume fringe value. The volume underneath the measure of uncertainty value has been normalized to 100%.

- Uncertainty beneath the Perched Groundwater – Most of the plume migration and uncertainty associated with fringe location occurs beneath the perched groundwater, an area for the most part precluded from investigation in the Ogallala Aquifer for reasons of cross-contamination concerns.

- Uncertainty beyond the Extent of Perched Groundwater – Two areas of plume fringe uncertainty occur beyond the extent of perched groundwater saturation, one to the south of the Plant, and one to the east.

- In the area to the south observations show the Ogallala Aquifer to be dry in at least some locations. Investigations in this area are prudent, and B&W Pantex is already planning on further investigations to characterize the Ogallala in this area.
- The area to the east represents the most likely location where RDX could migrate from beneath the perched groundwater extent. The PlumeFinder technology is used to identify the best monitoring well location in this area to the east of perched groundwater saturation.

3.2.2 Uncertainty in Current Monitoring Well Network

Figure 3-10 shows the results when the information for the existing three Ogallala Aquifer wells (within the PTC model domain) is added. An assumed concentration of half the plume fringe value (1 ppb) was specified at the three existing well locations. By inspection, information is most lacking in the southeast near the extent of perching groundwater. This finding is consistent with the known uncertainties in the conceptual site model. This analysis shows that the current monitoring well network in the Ogallala Aquifer only reduced the uncertainty in the plume fringe location by 8%.

The reduction in uncertainty is low for several reasons. First and foremost, to avoid the potential for cross contamination, there are only a limited number of monitoring wells (three) installed downgradient of the source area. All are installed through localized areas within the current extent of the perched groundwater where the FGZ projected above the perched groundwater table. PTX06-1033 is outside the area impacted by the source assumed here and has no effect on reducing uncertainty. PTX06-1032 is in an area of low uncertainty with respect to plume delineation and accounts for a minor reduction in uncertainty. PTX06-1056 is directly downgradient of the source area and accounts for nearly all the reduction in uncertainty from the existing Ogallala Aquifer monitoring well network. PTX06-1054, south of the source area, contains insufficient water for sampling and was therefore not included in the PlumeFinder analysis. There are no existing monitoring wells east of the perched groundwater extent capable of characterizing the Ogallala Aquifer near a potential secondary source in that area.

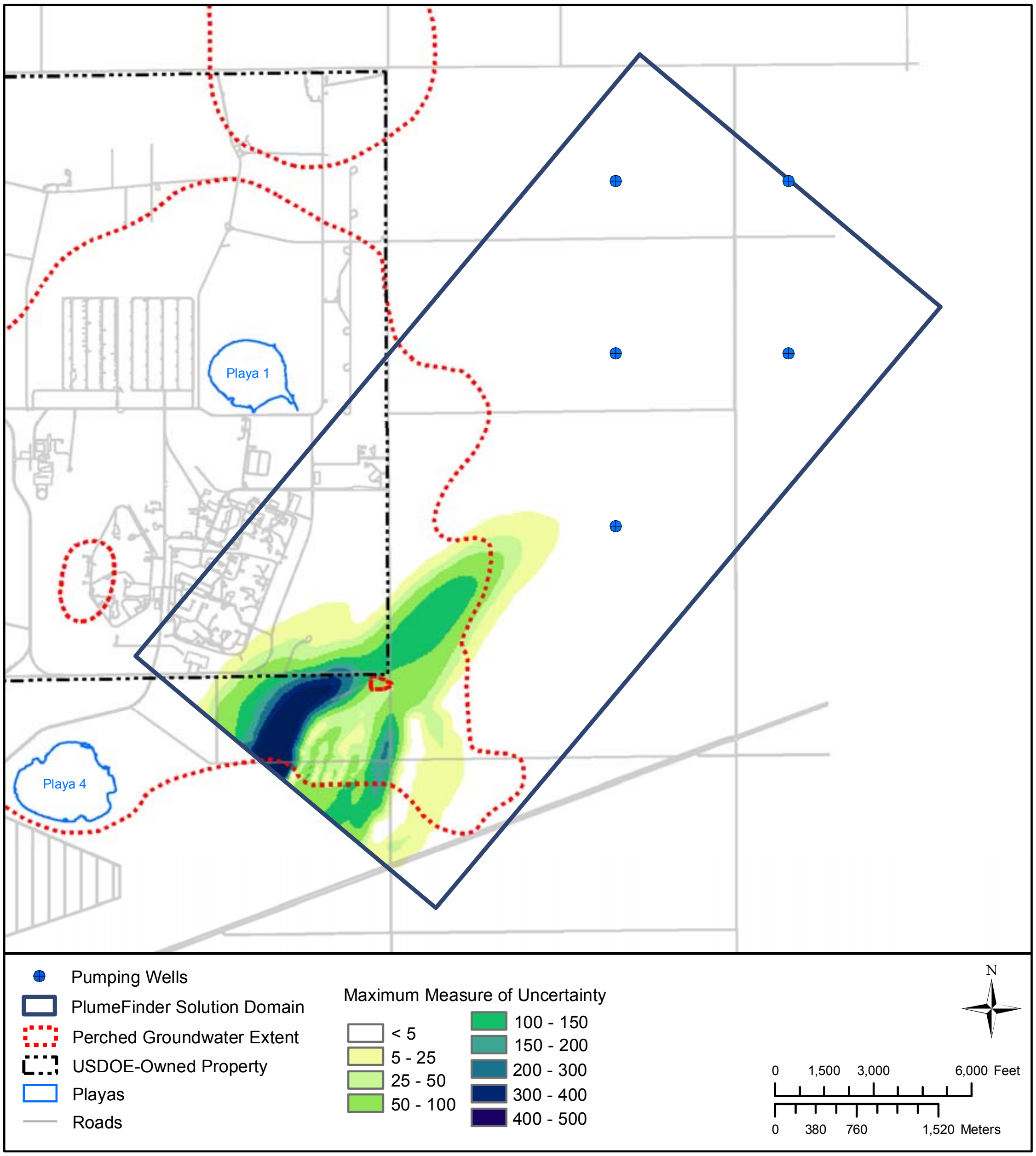


Figure 3-9. PlumeFinder Rendering of Baseline Uncertainty

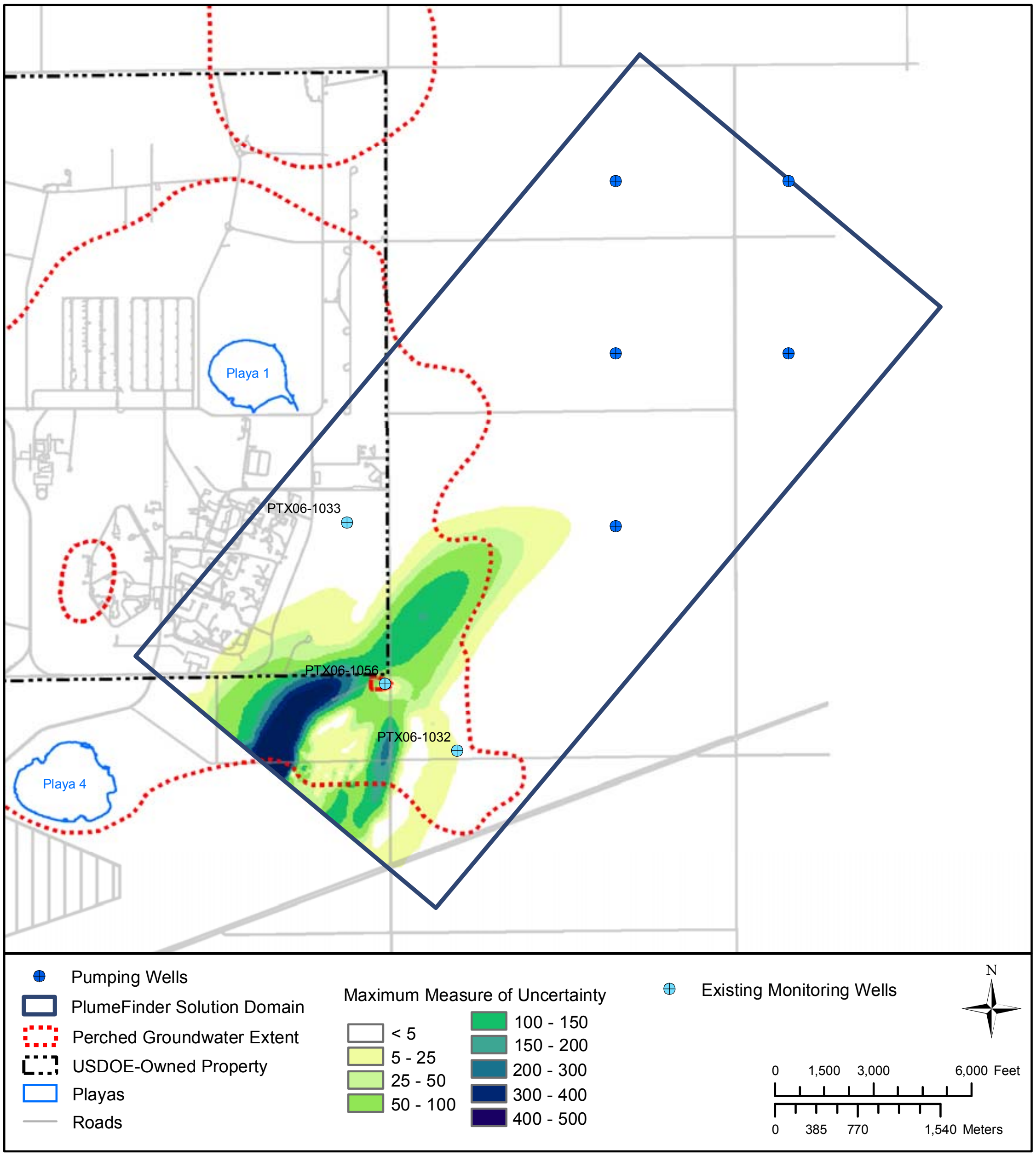


Figure 3-10. PlumeFinder Rendering of Uncertainty with Existing Pantex Monitoring Wells

3.2.3 Uncertainty with Proposed New Monitoring Wells

A proposed new well is added in the optimal location (i.e., at the location of the maximum value of uncertainty from Figure 3-10) that is to the east of the perched groundwater extent. This location can be seen in Figure 3-11. Assuming the new well detects the plume fringe, Figure 3-11 shows its projected effectiveness in decreasing the uncertainty in plume delineation if installed. This represents a 72% reduction in the volumetric uncertainty beyond the extent of perching from the current case (which assumed the Pantex monitoring well network). Overall, the total uncertainty reduction is 16% when considering the entire volume (below perched, south of Plant, and east of Plant).

The majority of the remaining uncertainty exists beneath perched groundwater and constitutes irreducible uncertainty due to the constraint that wells not be drilled through areas of perched groundwater containing RDX. As such, it is more desirable to place two additional wells slightly downgradient of the extent of perched groundwater rather than to drill through the perched groundwater to install monitoring wells. The locations of these well are shown on Figure 3-12. They are placed based on insight from the CMS/FS and associated BIOF&T3D modeling. They are not placed by the PlumeFinder analysis. The purpose of these two wells is early warning detection of RDX from the eastern portion of the perched groundwater, as opposed to farther field plume detection from the potential RDX source area beneath perched groundwater. They are located as preliminary investigation wells to gather subsurface information in these areas. PF-2 is where the extent of perched groundwater extends the least when compared to the surrounding area to assess the potential for downward migration (see Figure 3-3a) , and PF-3 is at the point where there is a decreasing area of RDX in the perched groundwater (also Figure 3-3a). These placements are motivated by an understanding of the physics of the 3-D flow and transport system. They are not positioned simply by placing them between potential receptors, for example. Installation of these wells will provide key observation data to better understand the flow and transport properties in this area and to assist in making informed decisions regarding potential RDX migration.

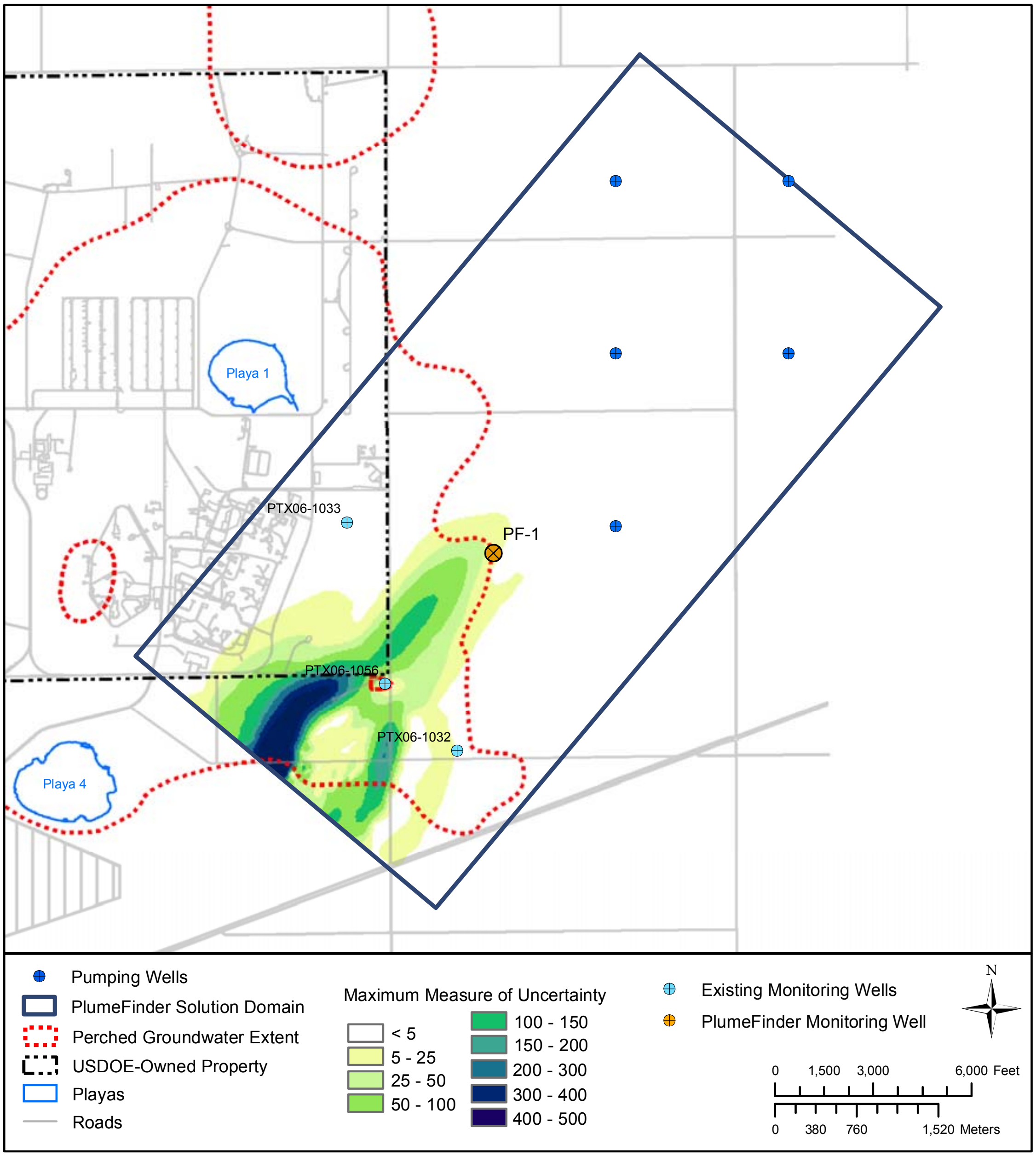


Figure 3-11. PlumeFinder Rendering of Uncertainty with First New Well Installed

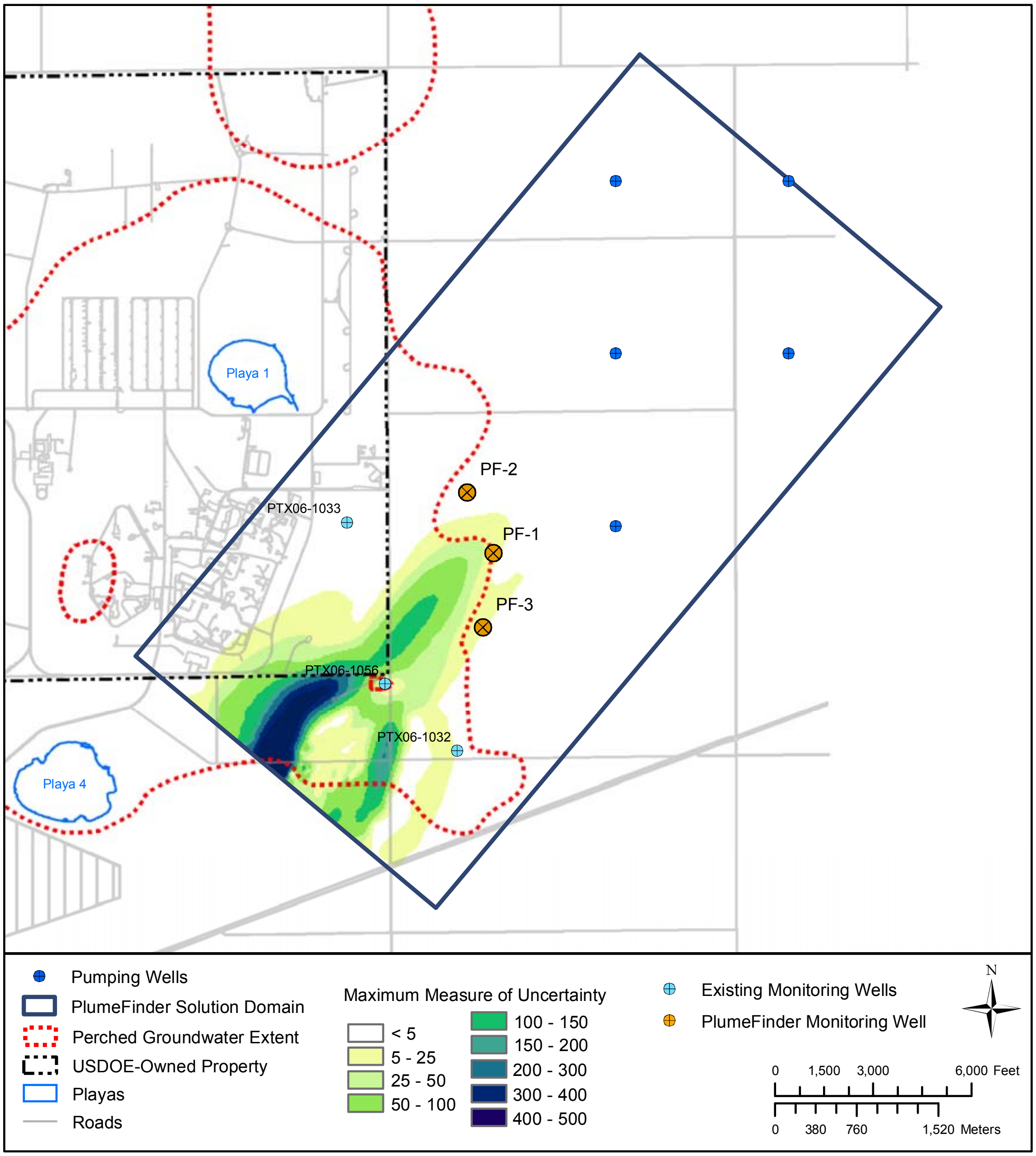


Figure 3-12. PlumeFinder Rendering of Uncertainty with Second and Third New Wells Installed

3.2.4 Summary of PlumeFinder Results

The first monitoring well, PF-1, details the effect of uncertainty from a potential RDX source area in the southeastern portion of the Plant derived from contamination in the overlying perched groundwater. Proposed wells PF-2 and PF-3 additionally help to provide early warning detection at the fringe of perched groundwater, and are based on professional judgment since the reduction in uncertainty computed from the PlumeFinder analysis indicated minimal value beyond the one monitoring well for reducing uncertainty from the potential source in the southeast. These three locations are based on the optimization performed with PlumeFinder combined with understanding the 3-D flow and transport physics to provide early warning detection for RDX derived from vertical flow near the extent of perched groundwater. Important points to consider are:

1) The fluxes from the perched groundwater vary with location and over time as the perched groundwater slowly drains into the Ogallala Aquifer.

2) Remediation is underway which is designed to minimize the risk that RDX enters the Ogallala Aquifer.

3) Placement of groundwater monitoring wells directly adjacent to the perceived extent of perched groundwater might cause a failure to identify RDX migrating to the Ogallala Aquifer due to the lack of direct observations in this area.

4) Placement of monitoring wells too far from the perched groundwater extent reduces their usefulness as an early warning system.

5) Currently, there are no Ogallala Aquifer monitoring wells east of the perched groundwater extent (second source); and therefore, there is no way to determine if the Ogallala Aquifer has been impacted in this area. Modeling results from the risk assessment and CMS/FS indicate only very low (ppb range) potential impacts in this area.

Hence, the proposed monitoring well network provides a balance of these complexities and the one well (PF-1) is optimal for detecting plume fringes from a potential source in the southeast area within a 50-year time period. The other two wells, PF-2 and PF-3, are good locations to assess migration of RDX along the eastern fringe of perched groundwater. For the monitoring well network to be workable, the well screens must be long enough to account for the documented and projected decline in the Ogallala Aquifer water table.

Note that in this analysis precise knowledge of the flow and transport system is not necessary, but is very helpful in making good decisions about well placement. The PlumeFinder assesses the ability of a monitoring location to provide information valuable to determining where the plume fringe resides. The conclusions for the PlumeFinder analysis for RDX in the Ogallala Aquifer are as follows:

- The existing monitoring network was established by installing monitoring wells through the FGZ. Although this was done using safe installation criteria, the existing network has limited value for RDX detection beneath the perched groundwater. It demonstrates the amount of irreducible uncertainty to safely investigate beneath the perched groundwater.

- Better delineation of the plume fringe can be achieved by adding three new wells outside the eastern extent of perched groundwater. The wells, however, do little to reduce the uncertainty in RDX plume fringe delineation beneath the perched groundwater.

- A periodic review of the flow directions and a regular sampling regimen, including both target and monitored natural attenuation parameters, is warranted.

- This analysis can be updated pending installation of the three proposed wells, collection of water table data, hydraulic conductivity, and RDX concentrations, if warranted.

4.0 SUMMARY

4.1 RESULTS OF WELL PLACEMENT OPTIMIZATION

A significant benefit in understanding the potential plume migration, as well as plume fringe delineation, can be gained by this analysis. Adding three new monitoring wells provides for a solid increase in understanding the groundwater flow and transport in this eastern area – an area currently devoid of Ogallala Aquifer monitoring wells. It also shows the irreducible uncertainty in knowledge of plume migration beneath the perched groundwater when safe investigation practices limit the amount of available data. The locations for three new monitoring wells are shown in Figure 4-1. PF-1 has been established using the PlumeFinder technology while PF-2 and PF-3 are recommended based on previous modeling efforts and site investigation data. With the high cost of monitoring well installation and sampling in the Ogallala Aquifer, it is prudent to collect additional subsurface characterization data before more new wells are installed beyond the three recommended. Additional valuable information includes verifying the presence or absence of RDX in the aquifer, determining the flow direction variation with time, and determining natural attenuation parameters over time and distance. This data will reduce the uncertainty in the information used to locate additional wells, if needed. A summary of the volume under the measure of uncertainty for RDX is presented in Table 4-1. The corresponding percentage reduction in far field plume fringe uncertainty from the current conditions is shown in parenthesis.

The reduction in uncertainty shown in Table 4-1 indicates that the first proposed monitoring well network has been well designed and reduces the uncertainty in plume location beyond the extent of perched groundwater for RDX by 72%. This translates into a total reduction of uncertainty for the entire plume (to the south and beneath the perched groundwater) of only 16%. Increasing the uncertainty reduction more would require drilling through the perched aquifer, which is not recommended. Hence, this 16% improvement also represents the irreducible uncertainty in understanding the flow and transport system. The installation of the second and third wells is for early warning detection of RDX originating along the eastern fringe of perched groundwater.

- PF-1: This is a dual-purpose monitoring well. This location resolves the greatest portion of uncertainty from the southeastern perched groundwater area and provides early warning detection for RDX emanating from the eastern fringe.

- PF-2 and PF-3: These serve as early detection wells for RDX emanating from the eastern fringe, and are derived from the physics-based understanding of 3-D flow and transport and the conceptual site understanding.

4-1. PlumeFinder RDX Results Summary

PlumeFinder Simulation	Overall Measure of Uncertainty Residual (reduction)
Baseline (No Wells Installed)	100%
Current Conditions (Existing Well Network)	92% (8% reduction)
Add One New Well (improvement from current conditions)	84% (16% reduction)
Add One New Well (improvement from current conditions east of perched groundwater)	28% (72% reduction)

The results of this analysis are significant because they document the baseline condition, quantify the value of the existing well network, and provide insight for optimally refining the well monitoring network. Adequate knowledge of the plume location is important to conducting good site investigations and making good plume management decisions. The PlumeFinder technology used in this study quantifies the plume fringe location even when data is limited and uncertain, so informed decisions can be made to ensure that long term monitoring or remediation activities are optimally located. The PlumeFinder technology applied here provides one new well location recommendation to produce the maximum reduction in plume uncertainty using proven mathematical and geostatistical principles. It also shows and quantifies the residual uncertainty beneath the perched groundwater. Above all, plume management needs to be done in a cost-effective manner with a focus on collecting information with demonstrated value to decision-makers. An improvement in the Ogallala Aquifer monitoring system can be made and the corresponding management risk associated with the decision to commit funds to implement additional wells for that purpose is clarified and quantified as a result of using the PlumeFinder technology.

4.2 RECOMMENDATIONS

The reduction in uncertainty from this analysis is relatively low when compared with other studies, and is driven by the inaccessibility of the areas of highest uncertainty beneath the perched groundwater. Therefore, the following recommendations supplement this analysis:

- A periodic evaluation of flow directions and regular sampling of chemical parameters, including both target and monitored natural attenuation parameters, is needed. The groundwater flow field should be assessed by careful examination of potentiometric data and water chemistry in this area.

- Following installation of the three new Ogallala Aquifer monitoring wells, data gleaned from the new wells should be compared with historical Ogallala Aquifer water table and chemical information, and an assessment of natural attenuation should be performed.

- The new field data should be compared with the current model assumptions, and any updates / refinements implemented, as merited.

- Future new well locations, if warranted, should be assessed using the PlumeFinder technology.

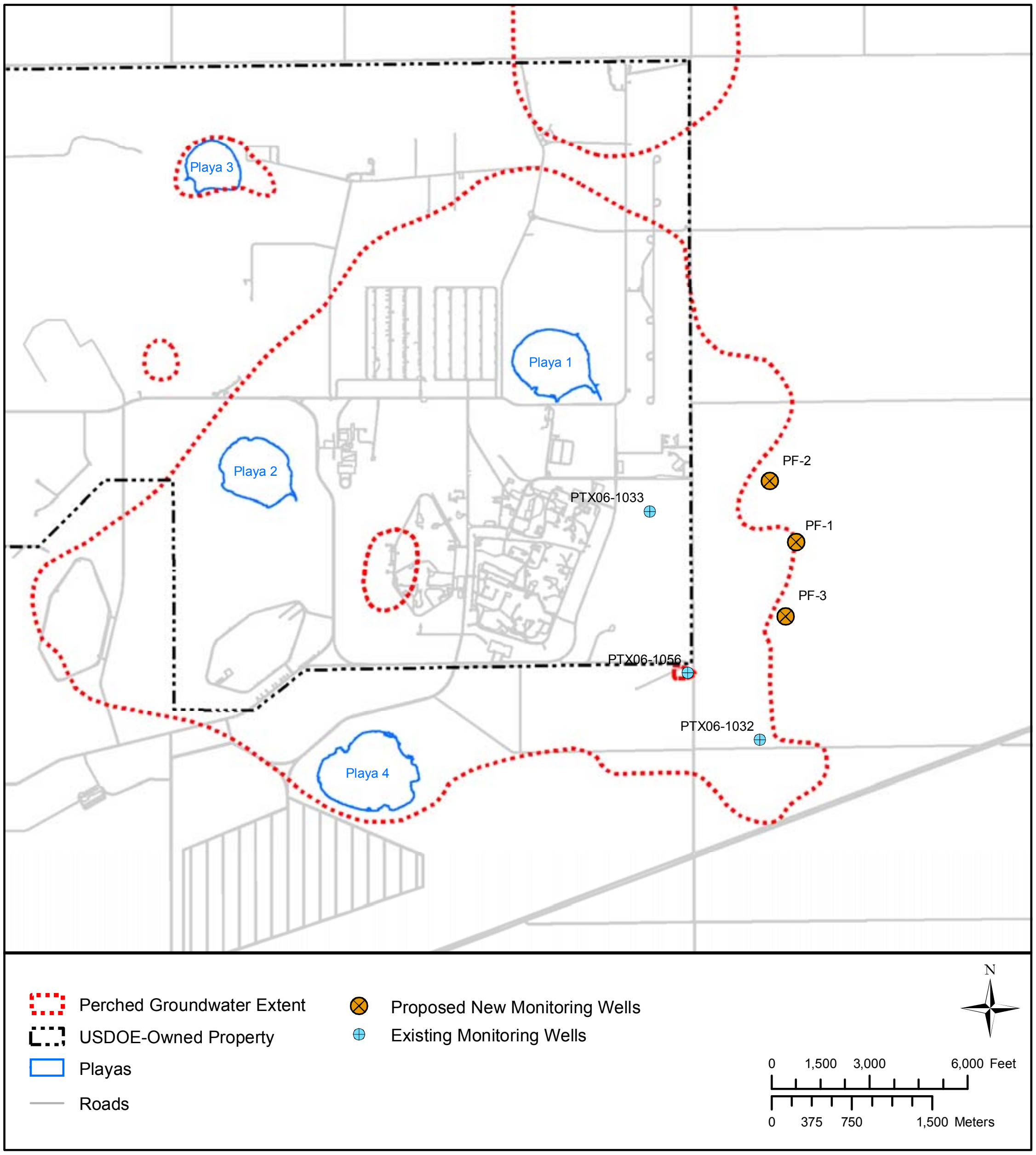


Figure 4-1. Proposed New Well Locations based on PlumeFinder Results

5.0 REFERENCES

Battelle, 1997. *Three-Dimensional (3-D) Site-Wide Groundwater Flow and Contaminant Transport Model for U.S. Department of Energy*.

BWXT Pantex/SAIC, 2004. *Subsurface Modeling Report for USDOE/NNSA Pantex Plant.*

BWXT Pantex/SAIC, 2006. *Baseline Human Health Risk Assessment Report for USDOE/NNSA Pantex Plant.*

BWXT Pantex/SAIC, 2007. *Corrective Measures Study/Feasibility Study Modeling Report for USDOE/NNSA Pantex Plant.*

Clark, Isobel, 1979. *Practical Geostatistics*. London, Applied Science Publishers, Limited.

Deschaine, L. M., 2004. "Mathematical Simulation and Optimization of Subsurface Environmental Contamination Events." PhD Dissertation, Chalmers University of Technology, Goteborg, Sweden (unpublished) pages 101 thru 110. Available upon request.

Deutsch and Journel, 1992. *Geostatistical Software Library and User's Guide*. Oxford University Press.

Dutton, Reedy, and Mace, 2001. *Saturated Thickness in the Ogallala Aquifer Panhandle Water Planning Area - Simulation of 2000 through 2050 Withdrawal Projections*. Bureau of Economic Geology, University of Texas at Austin. December 2001.

Dutton, 2004. *Adjustments to Parameters to Improve the Calibration of the Og-n Model of the Ogallala Aquifer, Panhandle Water Planning Area*. Bureau of Economic Geology, University of Texas at Austin. June 2004.

Fetter, C. W., *Applied Hydrogeology, Second Edition.* Macmillan Publishing Company, New York, 592p.

HydroGeoLogic, 1996. MODFLOW-SURFACT, Software (Version 2.2) Documentation, Hydrogeologic, Inc. Herndon, Virginia.

Isaaks and Srivastava, 1989. *Applied Geostatistics*. Oxford University Press.

McCuen, R.H., and Snyder, W.M., 1986. *Hydrologic Modeling: Statistical Methods and Applications*. Englewood Cliffs, New Jersey, Prentice Hall.

McGrath, W. A., and Pinder, G. F., (1996) "Sampling Network Design for Delineating Groundwater Contaminant Plumes,". In *Proceedings: Computational Methods in Water Resources*, pp 185-192, Cancun, Mexico.

Mullican, W.F., Johns, N.D., and Fryar, A.E., 1997. *Playas and Recharge of the Ogallala Aquifer on the Southern High Plains of Texas - An Examination Using Numerical Techniques*. The University of Texas at Austin, Bureau of Economic Geology. Report of Investigations No 242.

National Research Council, 2000. *Natural Attenuation for Groundwater Remediation.* National Research Council, National Academy Press, 2000 pages 156-163. ISBN 0-309-06932-7.

Pinder, George, F. 1997. *Princeton Transport Code: A three-dimensional finite Element Flop and Transport Simulator*, RCGRD, University of Vermont, VT.

Pinder, 2002 *Groundwater Modeling Using Geographic Information Systems*, John Wiley & Sons, 224 pages.

Resources and Systems International, Inc., 2006. *BIOF&T3D Technical Documentation and User Guide*.

SAIC, 2000. *Update to Conceptual Model for Groundwater Flow at Pantex Plant*, Letter Report, October 2000.

Stoller, 2004. *Pantex Plant Final RCRA Facility Investigation Report, Groundwater, USDOE Pantex Plant*, S.M. Stoller Corporation, Colorado, March.

Smith, L. and Schwartz, F.W., 1981. *Mass Transport and Role of Hydraulic Conductivity Data in Predictions*, Water Resources Research 17(5), 1463-1479.

Suarez, M. P., and Rifai, H. S., "Biodegradation Rates for Fuel Hydrocarbons and Chlorinated Solvents in Groundwater," *Bioremediation Journal* 3(4):337-362, 1999.

Theis, C.V., 1963. "Estimating the Transmissivity of a Water-Table Aquifer from the Specific Capacity of a Well." U.S. Geological Survey Water-Supply Paper.

Appendix A

Kalman Filtering used in the PlumeFinder Analysis

TABLE OF CONTENTS

LIST OF EQUATIONS

1.0 OPTIMAL ESTIMATION VIA KALMAN FILTERING

The goal of optimal estimation is to be able to develop an estimate of the subsurface conditions with respect to flow and transport. This estimate then becomes the state of the system for optimization and decision-making under uncertainty. As discussed in the report, the costs associated in collecting information content about the subsurface results in only sparse knowledge available for analysis. To estimate how the subsurface conditions may vary, geostatistics are used to generate representative realizations. These realizations are used as inputs to the computational fluid dynamic models. This results in a distribution of subsurface conditions, as opposed to a single valued estimate. We now have a quandary: we have predictions of the subsurface condition from models, and we also have data from field surveys. While the role of information theory in this problem is conceptually enlightening, the most important part of this problem is solving the input/output representation of a linear or non-linear system. This generates a probability distribution function for the unknown (e.g., concentration of contaminate in groundwater), and the associated entropy reveals a certain measure of the uncertainty of it. This type of problem falls into the general field of optimum filtering and the stochastic signal extraction from noisy data.

Common parameter estimation in the geo-sciences groundwater modeling community consist primarily of: Bayesian estimators, cokriging estimators, geostatistical inverse methods, Kalman filtering, least squares methods, maximum likelihood methods, and pilot point techniques. McLaughlin and Townley (1996) showed that all these methods are special cases of the Gaussian maximum a posteriori estimator. Additionally, it is shown that using equivalent assumptions, the Kalman filter is equivalent to the least squares estimate, maximum likelihood estimate and the maximum a posteriori estimate. See for example: *Applied Optimal Estimation* (Gelb 1974), *Optimal Estimation with an Introduction to Stochastic Control Theory* (Lewis 1986), *Optimal Control and Estimation* (Stengel 1994). A nice overview of the extended Kalman filter is found in *Stochastic Methods in Subsurface Contaminant Hydrology* (Govindaraju 2002).

The first references found using Kalman filtering in groundwater investigations appeared in 1990s. Techniques have been developed to integrate the information content from both the predictive models and the observed measurements. The technique used in this work was integrating the computational fluid dynamic model (PTC) with a Kalman filter, as it has been demonstrated to provide the best unbiased estimate of the subsurface conditions integrating the uncertainty in the simulator and field data.

2.0 EXTENDED KALMAN FILTERING

The extended Kalman filter is a method to combine the information from samples that are available at discreet time and space with the predictions of a subsurface simulator to provide the minimum error estimate of subsurface conditions.

For extended Kalman filtering to be effective, a stochastic representation of the aquifer is necessary. Stochastic aquifer realizations were conducted using the GSLIB geostatistical package. This approach used the GAMS variogram to generate 500 aquifer realizations; the set of these realizations is called the ensemble. The concept here being that the deterministic representation is difficult to be precisely accurate, so one is always dealing in stochastic nature and uncertainty when developing predictions of subsurface behavior, specifically of the Ogallala Aquifer beneath the Pantex Plant.

The filter used in the analysis is comprised of essentially two parts:

1. The propagation component that specifies how the conditional moments (i.e., hydraulic head, contaminant distribution, flow velocity fields) evolve between times information is available (via sensor measurements). This component performs what a subsurface flow and transport simulator typically perform in conventional groundwater flow and transport projects.

2. The updating component incorporates the new information and specifies how the propagated moments are modified. This component performs the activity typical of a parameter estimation algorithm

The key benefit that the Kalman filter performed is the formal way to integrate the information from the physical PTC simulator and the monitoring well field data. But rather than do these separately, the Kalman filter updates both the mean and the covariance of the model state and associated parameters. Because the conditional statistics are used as the uncertainty measure— as opposed to the spatial variability—the assumption of ergodicity is not required. Ergodicity refers to a stationary random function and its ability to tend towards the stationary mean of its cdf. This concept is used widely in geostatistical analysis. This is an important point. At the scales that are of interest in most flow and transport studies, the conditional hydrobiogeochemical moments are most likely non-stationary and, hence, nonergodic. It should be noted that the updated estimates need not be mass conservative, but the best representation of the mass available given the uncertainty of the information available about the system and its performance.

The Kalman filter is a recursive algorithm. It is a convenient way to fuse the predictions between a subsurface simulator and field data. It estimates the state variables in a linear system by optimally combining the information content of the model and data, incorporating uncertainty. In linear systems, the Kalman filter estimate is the true conditional mean —the truly optimal (minimum variance) estimate. The Kalman filter must be extended to handle non-linear systems, such as most groundwater flow and transport challenges. Linearizing the state equation around the latest parameter estimates to approximate the conditional mean does this. Essentially, this formulation is like a series of linear batch filters. Practice has shown that even with this reduced dimensionality and linearization, the extended Kalman filter will provide an estimate that is close enough to the conditional mean and mode.

To explain this concept, the mathematical explanation that follows is essentially taken from *Stochastic Methods in Subsurface Contaminant Hydrology* (Govindaraju 2002), with insight added to help bring out the value of this approach. The state and parameter equations for a flow and transport simulator were presented above. Here, we focus on the equations of the Kalman filter and the state-parameter moment update equations:

Equation 1. Kalman Filter

$$K(x,t) = P_{xx}(x,x',t)H^T(x',t)[H(x,t)P_{xx}(x,x',t)H^T(x',t) + R(x,x',t)]^{-1}$$

K (x, t) is the Kalman gain matrix. This matrix provides the weighting between the expected values from the simulations and the measured values at the sensor locations.

P_{xx} (x, x’, t) is a first order approximation of the conditional covariance between two variables and two locations, denoted as x and x’ at time t. Conditioning makes the stochastic analyses more site specific for the Pantex Plant / Ogallala Aquifer flow and transport system. The variables are properties typically measured in the field such as hydraulic head, conductivity, chemical concentrations, and the like. The Pantex heads and concentrations were measured in the monitoring wells, and the conductivity information from the local and GAMS modeling studies. The conditional mean of the variable's random field is the minimum variance unbiased estimate of the actual site-specific distribution. The conditional variance measures the uncertainty of this estimate. The conditional covariance relates to the behavior between different variables.

H (x', t) is an operator in space and time. It specifies the relationship between the augmented state vector and the measurements made in the field. The augmented state vector contains the stochastic simulator – the heads, velocities, concentrations, and the uncertain parameters such as conductivities, retardation, biochemical degradation, source strength. The assumptions of these are provided in the main body of the report.

R (x, x', t) is the measurement covariance matrix covariance between two variables and two locations, denoted as x and x' at time t.

The second key equation relates how the augmented state vector [X (x, t)], the vector that contains the stochastic simulator – the heads, velocities, concentrations, and the uncertain parameters (such as conductivities, retardation, biochemical degradation, source strength, etc.) is updated after a measurement is made. Since we are placing a hypothetical monitoring well, we have no direct measurement. We assume it will detect a value of half the plume fringe value, but that neither hydraulic conductivity nor heads are known. This minimizes the possibility biasing the results based on estimates from the regional Ogallala model. After actual monitoring well installation, the concentration, water levels and hydraulic conductivity should be measured.

Equation 2. Augmented State Vector Update

$$\hat{X}^{+}(x,t) = \hat{X}^{-}(x,t) + K(x,t)[Z(x,t) - H(x,t)\hat{X}^{-}(x,t)]$$

$\hat{X}(x,t)$ is the first-order approximation of the conditional mean, given all measurements. The (-) sign indicates the estimate before the new measurement information is given, and the (+) indicates the estimate after the new information is analyzed.

Z (x, t) is the measurement vector. It is equal to H (x, t) X (x, t) + V (x, t). H and X are defined above, and V (x, t) is a measurement error vector, with zero mean, Gaussian white noise. It relates to the fact that when a measurement is made, the uncertainty about the value of the measurement at that point in time is reduced to zero plus the measurement error.

The third key equation relates how the first order approximation of the conditional covariance between two variables and two locations, denoted as x and x' at time t [P_{xx} (x, x', t)] is updated after a measurement is made:

Equation 3. Conditional Covariance Update

$$P_{xx}^{+}(x,x',t) = P_{xx}^{-}(x,x',t) - K(x,t)H(x,t)P_{xx}^{-}(x,x',t)$$

The Kalman filter performs as follows:

- Equation 1 defines the Kalman filter.

- Equation 2 states that the best linear unbiased estimate (minimum variance) of the augmented state vector [$\hat{X}^{+}(x,t)$] is a linear combination of the model prediction [$\hat{X}^{-}(x,t)$] and the field measurement [Z (x, t)]. This is how the predictive model information and field measurements are used in concert to provide the best estimate of the subsurface conditions. In general, subsurface simulators are coded to conserve mass. By adding the information content of the field data, the mass conservation is not guaranteed. This is, however, the best estimate of the subsurface conditions when the information is imperfect. It has a correction for the field data reliability, for if the measurements are unreliable, the measurement covariance matrix [R (x, x', t)] will be large. Because this term appears as an inverse in the Kalman gain matrix, K (x, t) will be small. Because K (x, t) weighs the observations, the best estimate will be close to the model estimate. If the measurements are of high accuracy, then this equation ensures that the estimate is consistent with the observed field data. This functionality allows for optimization of allowable measurement error: do you collect a lot of data with low fidelity? A few highly accurate data points or some combination of both is an optimal investigation design question. For this investigation, only formal monitoring wells are considered.

- Equation 3 is the heart of the optimal sampling design approach. The first order approximation [P_{xx} (x, x', t)] of the updated conditional covariance between two variables and two locations, denoted as x and x' at time t, does not depend on any new observations. Note that all the terms rely on knowledge we currently have – denoted by (-), as opposed to (+). This equation is linearized around the most recently updated estimate of X (x, t), the augmented state vector – which depends on measurements to date but not the future. This provides insight to how the Kalman filter will behave and its accuracy before any new samples are taken. Because this equation is the difference between two positive definite matrices, the difference most also be positive definite. This says that the value of adding information (taking samples) is quantifiable, and the updated covariance matrix will always be less than or equal to the forecast covariance matrix. Of course, if the measurement covariance matrix [R (x, x', t)] goes to infinity, the second term of this equation will go to zero. This means that the samples have no value, which is consistent with why the matrix goes to infinity (unreliable samples).

These important attributes of the Kalman filter provided great value in finding the best location for a monitoring well in the Ogallala Aquifer just slightly beyond the eastern extent of perched groundwater at Pantex Plant.

3.0 REFERENCES

Gelb, A., 1974. *Applied Optimal Estimation.* Cambridge, Massachusetts, MIT Press., 16th printing, 374 pages.

Govindaraju, R.S., 2002. *Stochastic Methods in Subsurface Contaminant Hydrology.* ASCE Press.

Lewis, R., 1986; *Optimal Estimation with an Introduction to Stochastic Control Theory*, Wiley Inter-Science, 376 pages.

McLaughlin, D.B. and Townley, L.R. 1996. A Reassessment of the Groundwater Inverse Problem, Water Resources Research 32 (5), pp. 1131–1161.

Stengel, R., 1994. *Optimal Control and Estimation*: New York, Dover Publications, 638 pages.