PANTEX QUARTERLY PROGRESS REPORT

Remedial Action Progress

1st Quarter 2016

In support of Hazardous Waste Permit #50284 and

Pantex Plant Interagency Agreement

June 2016

Pantex Plant

FM 2373 and U.S. Highway 60

P.O. Box 30030

Amarillo, TX 79120

CERTIFICATION STATEMENT

1st Quarter 2016 Remedial Action Progress Report
Pantex Plant, June 2016

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

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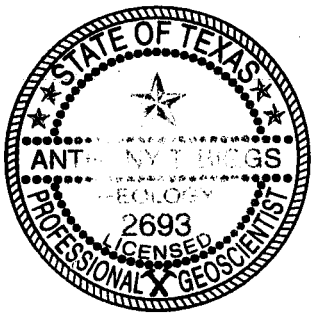
Quarterly Progress Report
1st Quarter 2016
in Support of Hazardous Waste Permit #50284
and Pantex Plant Interagency Agreement
for the Pantex Plant, Amarillo, Texas
June 2016

Prepared by
Consolidated Nuclear Security, LLC
Management and Operating Contractor
for the
Pantex Plant and Y-12 National Security Complex
under Contract No. DE-NA0001942
with the
U.S. Department of Energy
National Nuclear Security Administration

In accordance with 30 TAC §335.553 (g), this report has been prepared and sealed by an appropriately qualified licensed professional engineer or licensed professional geoscientist.



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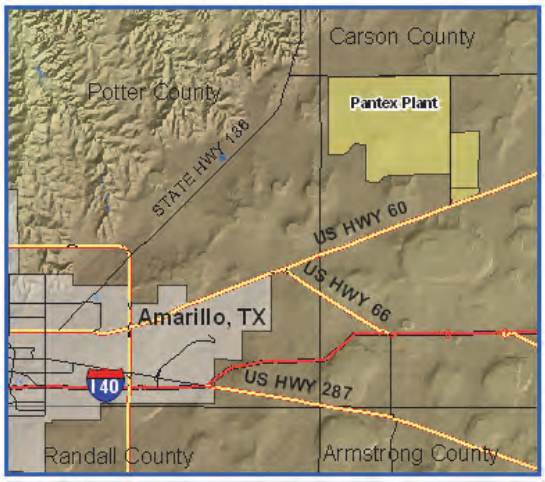
List of Acronyms

µg/L	micrograms per liter
CatOX	catalytic oxidation
COC	contaminant of concern
Cr(VI)	hexavalent chromium
CSIA	compound-specific isotope analysis
DCE	dichloroethene
DHC	*Dehalococcoides* spp.
DNT	dinitrotoluene
DNX	hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine
DO	dissolved oxygen
FGZ	fine-grained zone
GAC	granular activated carbon
GWPS	groundwater protection standard
HE	high explosive
HW-50284	Hazardous Waste Permit #50284
IAG	Interagency Agreement
ISPM	in situ performance monitoring
ISB	in situ bioremediation
lb	pound
LiDAR	light detection and ranging
mg/kg	milligrams per kilogram
Mgal	million gallons
MNX	hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine
mV	millivolts
NAPL	non-aqueous phase liquid
ORP	oxidation-reduction potential
P1PTS	Playa 1 Pump and Treat System
PID	photoionization detector
PQL	practical quantitation limit
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
SAP	sampling and analysis plan
SEPTS	Southeast Pump and Treat System
SVE	soil vapor extraction
SWMU	Solid Waste Management Units
TCE	trichloroethene
TNX	hexahydro-1,3,5-trinitroso-1,3,5-triazine
TOC	total organic carbon
TZM	treatment zone monitoring
VFA	volatile fatty acid
VOC	volatile organic compound
WWTF	wastewater treatment facility

INTRODUCTION

The Pantex Plant, located in the Texas Panhandle 17 miles northeast of Amarillo, has implemented a response action to remediate perched groundwater and soils. Two types of systems have been installed for the groundwater response action: pump and treat systems in two areas and in situ bioremediation (ISB) systems in two areas. A soil vapor extraction (SVE) system has been installed to remediate volatile organic compounds (VOCs) in soils at the Burning Ground area. This quarterly report addresses progress achieved through implementation of the Remedial Actions for 1st quarter 2016.



This report provides an intermediate data summary for response action systems throughout the year. More intensive data reporting is included in the annual progress reports. The quarterly progress reports address three of the five evaluations included in the annual progress reports: response action effectiveness, uncertainty management, and early detection. The reports provide required information from Hazardous Waste Permit #50284 (HW-50284) CP Table VII and the Pantex Interagency Agreement (IAG).

Maps of the plumes, remedial action systems, sampling locations, and system wells are provided in Appendix A. Graphs of operation and flow rates for the pump and treat systems are provided in Appendix B. Graphs of important parameters for the ISB treatment zone and downgradient wells are provided in Appendix C.

RESPONSE ACTION EFFECTIVENESS

This quarterly progress report focuses on specific criteria for the pump and treat systems, ISB systems, and a small-scale SVE system. System operation, mass removal, and evaluation of effluent in reference to established operational goals are reported for the pump and treat systems. For the ISB systems, this report evaluates geochemical conditions and availability of food source in the treatment zone and reduction of contaminants of concern (COCs) in downgradient performance monitoring wells to evaluate whether the treatment zone is working effectively. System operation, mass removal, and effluent photoionization detector (PID) readings are evaluated for the SVE system.

PUMP AND TREAT SYSTEMS

The Remedial Action at the Pantex Plant includes two pump and treat systems: Southeast Pump and Treat System (SEPTS) and Playa 1 Pump and Treat System (P1PTS). The pump and treat systems are designed to extract water and remove contaminant mass from the water before the

effluent is beneficially used by the wastewater treatment facility (WWTF) and irrigation system, for general Plant needs, or for amendment injections at the ISB systems. The systems were also designed to remove water from the perched aquifer to reduce saturated thickness. This reduction in saturated thickness reduces migration of contaminants both vertically and horizontally so that natural breakdown processes can occur over time. Reducing migration provides protection for the underlying High Plains Aquifer (also known as and referred to herein as the Ogallala Aquifer). The SEPTS has the capability to inject the treated water back into the perched aquifer when beneficial use is not possible. Operational priorities for the pump and treat systems emphasize beneficial use of water.

SEPTS operation exceeded goals during 1st quarter (see operational graphs in Appendix B). P1PTS was operated intermittently to avoid early granular activated carbon (GAC) change-out prior to shut down for a planned GAC vessel replacement. The system was shut down beginning February for the vessel replacement and to begin the tie-in for PTX06-EW-81. The throughput was low throughout the quarter at P1PTS and during January at SEPTS. P1PTS throughput was primarily affected by the loss of two wells during the quarter. Pantex is troubleshooting the problem and working toward getting the wells operational; PTX06-EW-81 will be available for use after upgrades are complete. SEPTS throughput was affected by loss of wells in January. Overall, the primary goal of beneficial use was met while continuing to operate the systems.

Pump and Treat System
4th Quarter Operation

Playa 1 Pump and Treat System (P1PTS)	
Days Operated	35
% Operation Time	35%
Volume Water Treated (Mgal)	7.4
HE Mass Removal (lbs)	3.7
Beneficial Use of Water	100%

Southeast Pump and Treat System (SEPTS)	
Days Operated	91
% Operation Time	99%
Volume Water Treated (Mgal)	33.1
HE Mass Removal (lbs)	161.4
Chromium Mass Removal (lbs)	18.6
Beneficial Use of Water	100%

Value below operational goals

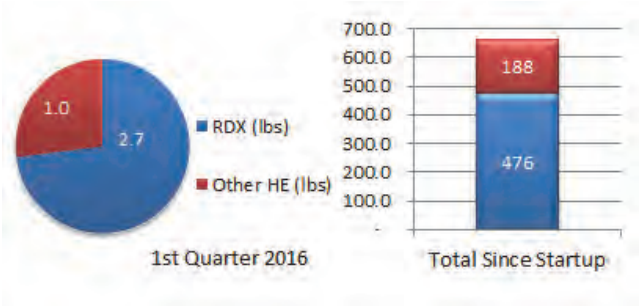


Figure 1. P1PTS Mass Removal

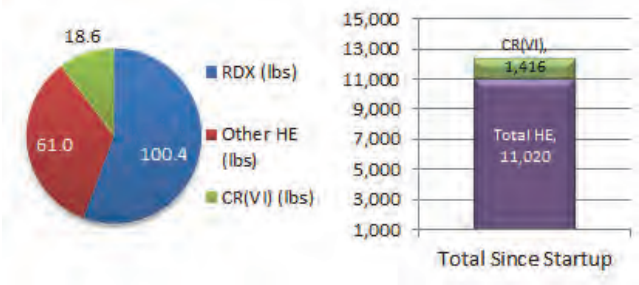


Figure 2. SEPTS Mass Removal

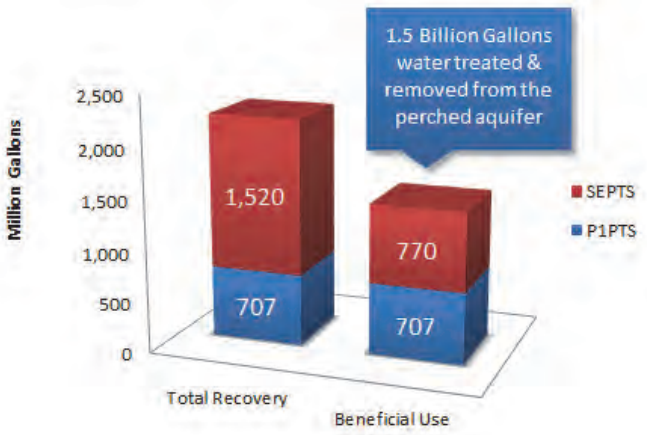


Figure 3. System Recovery and Use

The P1PTS removes primarily RDX and the SEPTS removes primarily RDX and hexavalent chromium [Cr(VI)]. Figures 1 and 2 provide mass removal information for RDX and other high explosives (HEs) for 1st quarter, as well as totals since startup of the system. Concentrations near Playa 1 are much lower due to the source declining; therefore, mass removal is much lower at this system. The primary goal of the P1PTS is water removal to decrease saturated thickness, with mass removal as a secondary goal.

The total recovery and treatment from both systems since startup has been calculated at over 2.2 billion gallons. Because the SEPTS was originally designed to inject treated water, all of the treated water prior to 2005 was injected. However, a significant volume of treated water has been used beneficially since 2005, with a total of about 1.5 billion gallons extracted and treated from the perched aquifer since startup of the irrigation system. The recovery and beneficial use totals are presented in Figure 3. Evaluation of effluent data from both systems indicate all COCs were treated to levels below the groundwater protection standards (GWPS).

ISB Systems

Two ISB systems (Zone 11 ISB and Southeast ISB) were installed at Pantex. The systems are designed with closely spaced wells to set up a treatment zone in areas of the perched groundwater where pump and treat may not be as effective, or where the area is sensitive to vertical migration of COCs to the Ogallala Aquifer. Amendment is injected into these systems to establish treatment zones where COCs are degraded. Monitoring wells were installed downgradient of the treatment zone to monitor whether the system is effectively degrading the COCs (see maps in Appendix A). The primary COCs at the Zone 11 ISB are trichloroethene (TCE) and perchlorate. The primary COCs at the Southeast ISB are RDX and hexavalent chromium.

For the treatment zone wells, this report evaluates whether the conditions are present to degrade the COCs in each area, and evaluates the presence of a continued food source for the microbial reduction of COCs (see Table 1). Downgradient monitoring wells are evaluated to determine if the ISB systems are effective in degrading the COCs and any breakdown products of the COCs. Graphs of data from sampled treatment zone wells and downgradient in situ performance monitoring (ISPM) wells are included in Appendix C.

Zone 11 ISB

Installation of the Zone 11 ISB Remedial Action was completed in 2009, and an expansion was completed in early 2015. Seven injection events have been completed at the current system, with

the first complete injection event occurring in the expansion zone in 2015. Because of the substantial saturated thickness of the perched aquifer in that area, the requirement for deep reducing conditions to treat TCE completely, and a high groundwater velocity, Pantex has planned for yearly injections at this system. Pantex completed the seventh injection event in November 2015, so 1st quarter 2016 results reflect post-injection conditions. The seventh injection event included bioaugmentation of the western side of the Zone 11 ISB where reducing conditions have been established.

Table 1. ISB System Performance

	Treatment Zone Wells		Downgradient Performance Monitoring Wells		
System	**Reducing Conditions**	**Food Source Available**	**Primary COCs Reduced?**	**COCs < GWPS?**	**Degradation Products of COCs Reduced?**
Zone 11 ISB	Very Mild to Strong	Yes	Yes	Perchlorate in 4 of 6 wells TCE in 5 of 6 wells	No[1]
Southeast ISB	Very Mild to Strong	Yes	Yes	RDX in 2 of 3 wells Cr(VI) in 3 of 3 wells[2]	Yes

Mild conditions = oxidation-reduction potential (ORP) of 0 to -50 millivolts (mV)
Strong conditions = ORP < -100 mV and sulfate and nitrate reduced indicating conditions are present for methanogenesis.
[1] Cis-1,2-dichloroethene concentrations remain high in two downgradient wells while vinyl chloride concentrations (final breakdown compound) remain at low concentrations or not detected. Pantex bioaugmented the original wells on the west side of the system during the seventh injection event in 2015. DHC counts indicate that the bioaugmentation was successful, but counts were too low for complete reductive dechlorination to occur. Analytical, CSIA, and DHC reductase data support this understanding as no indication of complete reduction has been observed thus far.
[2]Pantex has been sampling four downgradient wells at this system. However, one of the wells (PTX06-1123) could not be sampled this quarter because the well did not have enough water to sample. This well had demonstrated complete treatment since October 2012.

The system has a well-established treatment zone in the original portion of the system where injection has occurred since 2009. The expansion area was injected in 2015. All sampling in the expansion area occurs at treatment zone monitoring wells that are located between the injection wells. Data indicate that the injection has affected oxidation-reduction potential (ORP) and dissolved oxygen (DO), but further injections will be necessary to achieve the deep reducing conditions needed to treat TCE. Because the expansion area is not demonstrating treatment yet, only data from the original portion of the system are reviewed here to evaluate the continued treatment of TCE and perchlorate.

Data indicate good reducing conditions for perchlorate at the original portion of the Zone 11 ISB. Reducing conditions were milder than expected in some of the wells that were bioaugmented in 2015. However, methane concentrations were high in all but two treatment zone wells this quarter, indicating deep reducing conditions conducive to TCE breakdown in most areas. TCE continues to be reduced to 1,2-dichloroethene (DCE), but further reduction is not indicated by the analytical

data. The reducing conditions indicate that growth and survival of the *Dehalococcoides* spp. (DHC) could be affected in some areas of the ISB due to elevated DO and mild ORP. Food source is adequate for continued reducing conditions at the sampled injection wells. Analytical results for the treatment zone monitoring wells and PTX06-ISB075 replacement well indicate the food source is much lower in the areas between injection wells.

The original portion of the Zone 11 ISB has been effective at treating perchlorate and partially treating TCE. Perchlorate was not detected in the wells sampled in the treatment zone this quarter. In three non-injected monitoring wells in the original portion of the treatment zone (PTX06-1169, PTX06-1170, and PTX06-ISB075 replacement well), *cis*-1,2- DCE exceeded the GWPS; TCE concentrations were also above the GWPS in two of these wells. Vinyl chloride continues to be non-detect in the treatment zone. TCE was detected below the GWPS in one other injected treatment zone well. Results do not currently indicate a strong influence from the DHC bioaugmentation event, as TCE is not completely reduced, *cis*-1,2-DCE continues to remain high, and vinyl chloride is not detected. To evaluate the effectiveness of the bioaugmentation, Pantex conducted sampling in February and March 2016 for DHC counts, presence of TCE and vinyl chloride reductase genes, and compound specific isotope analysis (CSIA). The results of the sampling are detailed in Appendix D. DHC was detected, indicating that the bioaugmentation was at least partially successful. The DHC counts were below target counts needed for complete reductive dechlorination to occur. Additionally, all reductase gene data and CSIA data are consistent with the analytical data, indicating that no reduction beyond *cis*-1,2-DCE is occurring at this time.

Pantex has also continued to evaluate trends in declining injection flow rates and issues that may affect the growth and survival of the DHC. Based on data from PTX06-ISB081 that suggests that pausing injection at a well may help with clearing the biofouling, Pantex is pausing injection at two ISB wells on the perchlorate side to determine if the wells can be injected at the next injection event. The perchlorate side only requires very mild reducing conditions to achieve reduction, so this approach should allow continued reduction of perchlorate. Pantex will also reduce the amount of lactate used during injection in an attempt to reduce biofouling and potential drops in pH that could affect the DHC. These changes are discussed in detail in the 2015 Annual Progress Report.

Pantex evaluates performance at six downgradient monitoring wells for the original portion of the Zone 11 ISB. Four of these wells have demonstrated perchlorate below detection limits. Two of the wells (PTX06-1148 and 1150) farther downgradient have been slower to respond due to expected longer travel times. One of the two wells demonstrated continued decreasing perchlorate, while the other measurement was consistent with the previous quarter's measurement. TCE concentrations are demonstrating a decreasing trend, with concentrations greatly decreased but remaining above the GWPS in one of the two wells that are primarily affected by TCE.

Pantex began rehabilitation of wells in March 2016 in preparation for the 2016 injection. To avoid loss of reducing conditions that could affect the DHC, Pantex will inject with anaerobic makeup water mixed with amendment. Injection is expected to be complete in June 2016. Pantex will collect more samples in late 2016 to continue to evaluate the effectiveness of the bioaugmentation.

SOUTHEAST ISB

The Southeast ISB was installed in 2007. Five injection events have been completed at this system. Pantex has scheduled the Southeast ISB for injections approximately every 18 months to avoid depletion of food source and possible loss of reducing conditions. The last injection was completed in April 2015.

Evaluation of data in treatment zone wells indicates adequate reducing conditions for the treatment of RDX and hexavalent chromium in most wells. Data indicate very mild reducing conditions in PTX06-ISB024, a first row well. Data indicate that food source is available for the continued reduction of COCs. Evaluation of COC data indicates no detection of HEs and chromium detected below background. Two wells did not have enough water to sample.

Four downgradient wells have been historically sampled at this system. Two of the closest downgradient monitoring wells for the Southeast ISB demonstrate that reduction of RDX, HE degradation products, and hexavalent chromium has occurred, resulting in concentrations below the GWPS, with most not detected. PTX06-1123 had demonstrated concentrations below the GWPS; however, this well could not be sampled this quarter due to insufficient water. PTX06-1153 continues to exhibit RDX concentrations above 200 ug/L and variable hexavalent chromium concentrations, with the most recent three results below the GWPS. Pantex continues to monitor this well and other new wells installed nearby to determine if treated water is slow to reach it or if this well may not be hydraulically connected to the Southeast ISB. During 2016, Pantex plans to install passive flux meters at specific well locations to determine the mass and water flux into the Southeast ISB. PTX06-1153 will be included in that study. Results will be available later in 2016.

Some of the injection and performance monitoring wells are indicating variable water conditions at the Southeast ISB. Two Southeast ISB performance monitoring wells (one upgradient, one farther downgradient) remain dry and cannot be sampled. PTX06-1123 could not be sampled this quarter. The inability to sample these wells is expected to continue due to effects from injection and upgradient pump and treat operations that are decreasing the saturated thickness across the area.

Pantex plans to inject this system after completion of the injection of the Zone 11 ISB in 2016. The injection event for the Southeast ISB is expected to be complete by the end of September 2016.

BURNING GROUND SVE

The Burning Ground SVE system began operation in 2002 as a large-scale catalytic oxidizer (CatOX) system. Due to a large reduction in VOC concentrations, a small CatOX system has been operating at the Burning Ground SVE system since April 2012. This small-scale system focuses on treating residual non-aqueous phase liquid (NAPL) and soil gas at a single extraction well, SVE-S-20, near the source area.

The system was intermittently operated during 1st quarter 2016. The system was shut down for minor repairs and for alarms; however, the system operated over 99% of the quarter, with 2,178 hours of operation.

Mass removal calculated for 1st quarter for VOCs contributing more than 1% of the total VOC concentration and since startup is presented in Figure 4. The system removed about 57 lbs of VOCs during 1st quarter and has removed over 18,200 lbs of VOCs since startup. System destruction efficiency was at least 99%, based on PID data.

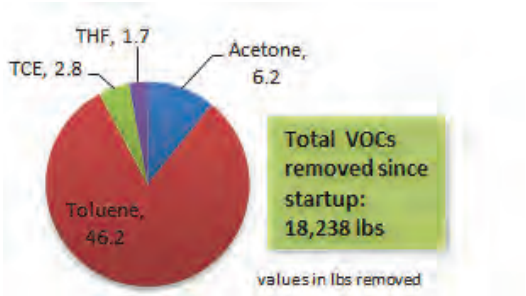


Figure 4. Burning Ground SVE Mass Removal

Uncertainty Management and Early Detection

Uncertainty management and early detection wells are evaluated to determine if there are unexpected conditions in areas where previous groundwater contamination has not been detected or confirmed (Ogallala and perched), or in previous plume locations where concentrations have fallen below GWPS, background, and the practical quantitation limit (PQL) (e.g., perched wells at the Burning Ground and Old Sewage Treatment Plant areas). Indicator COCs are evaluated at the uncertainty management/early detection wells in the quarterly report. A map depicting the wells evaluated is included in Appendix A.

Review of the uncertainty management/early detection data collected during 1st quarter indicates unexpected conditions continuing at one Ogallala Aquifer well (PTX06-1056). Data indicate continued detections of the HE 4-amino-2,6-dinitrotoluene (DNT) and the VOC 1,2-dichloroethane. No detections exceeded GWPS in the Ogallala Aquifer uncertainty management/early detection wells sampled during 1st quarter.

PTX06-1056 continues to demonstrate detections of 4-amino-2,6-DNT, a breakdown product of the HE 2,4-trinitrotoluene (TNT), with the concentrations first exceeding the PQL in August 2015. As agreed with regulatory agencies and in accordance with the Pantex Contingency Plan, Pantex collected three monthly samples at PTX06-1056 to evaluate the change in concentration for 4-amino-2,6-DNT. The monthly samples were collected from November to January. Samples collected in November and December were included in the 4th Quarter 2015 Progress Report. The three samples indicated that 4-amino-2,6-DNT was detected slightly above the PQL in one sample and slightly below the PQL in two samples, with no clear indication of an increasing trend. As agreed with regulatory agencies, Pantex will continue with quarterly sampling to evaluate trends in these detections.

Pantex has proactively evaluated potential sources for the contamination. A nearby perched well that was drilled deeply into the fine-grained zone (FGZ) was plugged to address that potential source. Pantex will also complete a cement bond log on PTX06-1056 to determine if the annular

Summary of Ogallala Detections, 1st Quarter 2016

Well ID	Sample Date	Analyte	Measured Value (µg/L or pCi/L)	PQL (µg/L)
PTX06-1056	1/19/2016	1,2-Dichloroethane	0.41	1
PTX06-1056	1/19/2016	4-Amino-2,6-Dinitrotoluene	0.261	0.27

seal is competent. Pantex has also contracted for outside review of PTX06-1056 and area data to determine further steps for source determination.

No perched uncertainty management/early detection data were collected during 1st quarter.

Schedule Update

Pantex has provided a detailed schedule of upcoming work in the 2015 Annual Progress Report. Completed work and ongoing and upcoming work to be started or completed by the date of publication of this report are provided here.

Pantex completed the following items prior to publication of this report:

- Design and connection of PTX06-EW-81A began in June 2015 and was completed in June 2016.
- Upgrade of P1PTS components began in June 2015 and was completed in May 2016.
- DHC and CSIA sampling began in February 2016 and was completed by the end of March 2016. Results are included in this report.

Pantex continues to progress toward completion of the following items:

- Pantex is in the process of contracting for long-term maintenance of landfills to address holes/voids, lack of vegetation, and erosion of landfill covers as needed. Contracting will commence in June 2016. Work is expected to be completed annually, as needed, for filling holes/voids and seeding.
- Pantex is addressing erosion of Landfill 3 slopes in specific areas noted in the 2014 and 2015 inspections by contracting for a design to prevent erosion in those areas. The contracting was complete in April 2016 and the design is scheduled for completion in August 2016.
- Rehabilitation efforts at the Zone 11 ISB began in March 2016, with injection starting in April 2016. Injection is scheduled for completion in July 2016.

- Rehabilitation efforts began at the Southeast ISB in August 2016, with injection activities scheduled to begin in September 2016.
- Contracting for design of the SEPTS extension began in June 2016, with the design scheduled for completion in September 2016.

Upcoming work includes the following:

- Pantex is preparing to contract for replacement of the Solid Waste Management Unit (SWMU) 2 and SWMU 5/5 ditch liner. Inspection of the liner during 2nd quarter 2015 indicated that the liner had multiple tears and the edges are no longer anchored in some areas. Due to the age of the liner and the expected lifetime of 10 years, Pantex will replace the liner. Contracting will commence in 2016 and work is expected to start in August 2016.
- Pantex plans to install eight wells this summer. Pantex will install five injection wells to extend the SEPTS treatment east of FM2373. PTX06-1071 has failed, and will be replaced prior to the five-year sampling event. A new well will be installed between PTX06-1133A and PTX06-1158 at the southeast lobe to determine extent in that area. A new well will also be installed north of the Zone 11 ISB expansion well PTX06-1180, to further define extent of the TCE plume on the western side of Zone 11.
- Pantex plans to install closure turf on the Burning Ground landfills to provide long-term prevention of erosion and infiltration. Contracting will begin in July 2016, with completion of the covers expected by December 2016.
- Pantex plans to conduct the light detection and ranging (LiDAR) study for the five-year review of the landfill covers. The contracting will begin this summer, with the data collection expected to be completed by November 2016.

Conclusions and Recommendations for Change

The Remedial Actions continue to operate and meet short-term expectations for cleanup of the perched groundwater in areas under influence of the remediation systems. The pump and treat systems continue to remove COC mass and water from the perched aquifer, thus decreasing head that is driving vertical and lateral movement of perched groundwater.

The ISB systems continue to demonstrate that treatment downgradient of the systems has been generally effective, and many COC concentrations have been greatly reduced or now meet the GWPS at the Southeast ISB. One downgradient well (PTX06-1153) for the Southeast ISB is not responding as well as others. Pantex continues to evaluate conditions in that area to determine if the well is impacted by water from the western end of the Southeast ISB or if it is not hydraulically connected to that system. As discussed above, passive flux meters will be deployed this summer to evaluate water and mass flux into specific wells at the Southeast ISB. That information will be provided later in 2016. Monitoring will continue at PTX06-1153 as described in the sampling and

analysis plan (SAP), as the quarterly samples will provide adequate information for this well. Further recommendations will be made based on the evaluation of data over time.

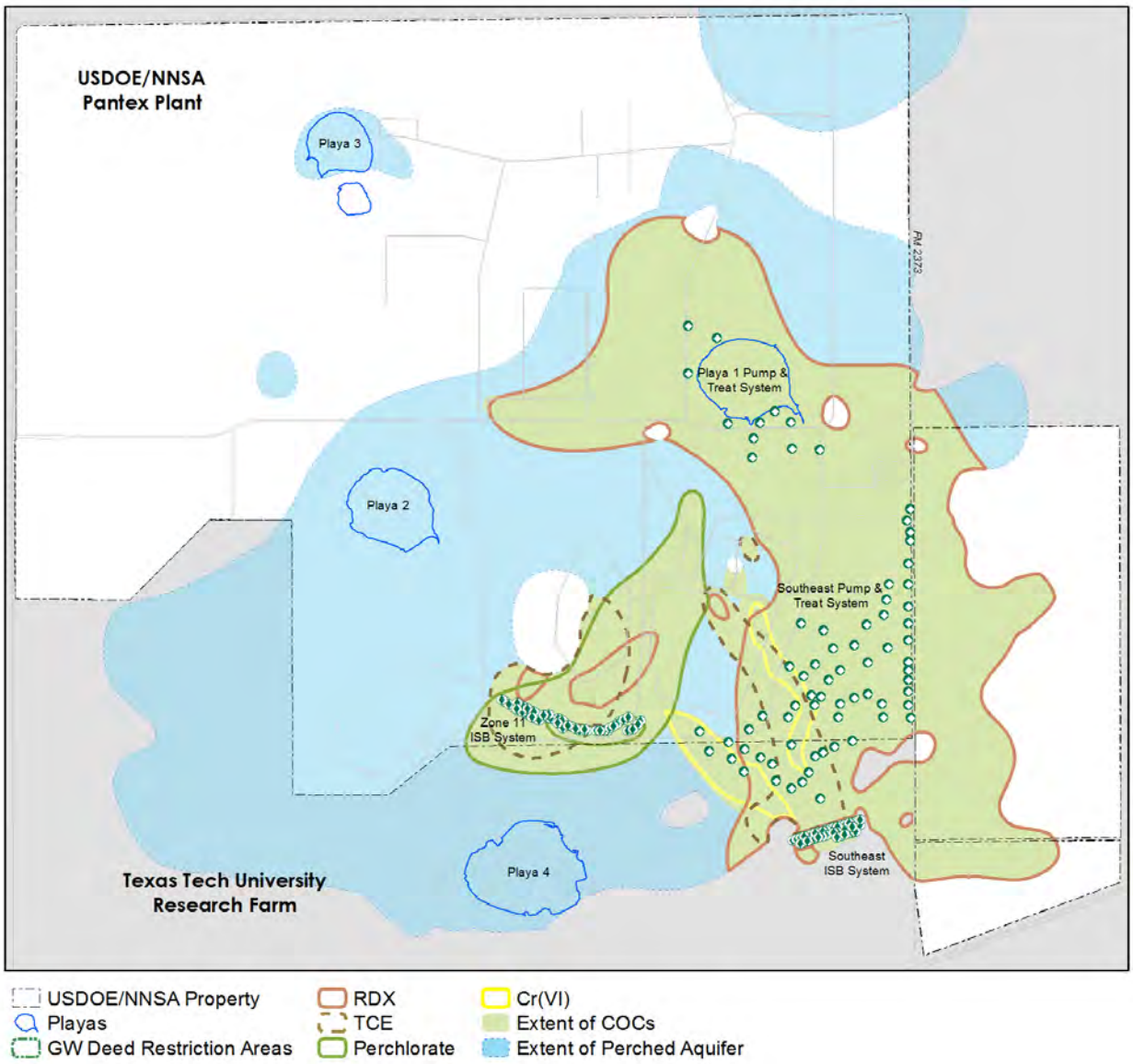
Downgradient wells at the Zone 11 ISB are generally demonstrating treatment. Four of the six downgradient ISPM wells exhibit perchlorate concentrations below the GWPS, and perchlorate concentrations are continuing to decline in the other two wells. TCE concentrations since the start of the Remedial Action continue to indicate a decreasing trend near the GWPS in downgradient ISPM wells PTX06-1012 and PTX06-1155. Elevated c*is*-1,2-DCE and the lack of vinyl chloride at wells inside and downgradient of the treatment zone continue to suggest that complete dechlorination of TCE is not occurring. The current system completed injection and bioaugmention with DHC in November 2015. Data collected to evaluate the effectiveness of the bioaugmentation demonstrates that DHC are present, but counts are not high enough for complete reductive dechlorination to occur. Pantex will collect samples again later this year to continue to evaluate the effectiveness of the bioaugmentation.

The SVE system continues to treat soil gas and residual NAPL in the SEP/CBP area of the Burning Ground, thereby mitigating vertical movement of VOCs to groundwater. Pantex has continued to have problems with completing rebound tests, so progress toward a path to closure for this system will continue after evaluating other options.

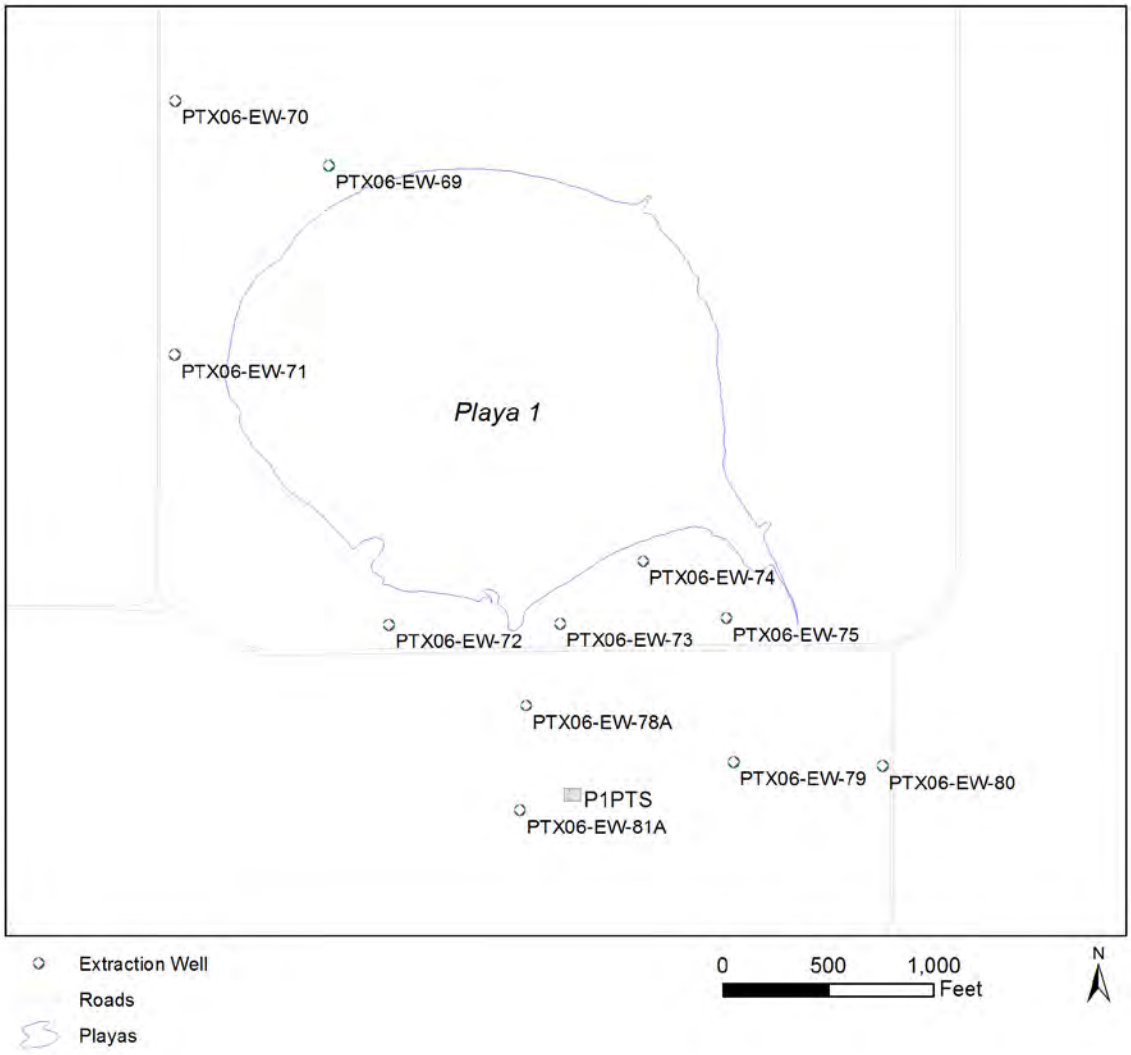
The groundwater remedies are considered to be protective for the short-term, as untreated perched groundwater use is controlled to prevent human contact and monitoring data continue to indicate that the Remedial Actions remain protective of the Ogallala Aquifer. Although detections of 4-amino-2,6-DNT and 1,2-dichloroethane below the GWPS have occurred in one Ogallala well, Pantex is actively following the Groundwater Contingency Plan. Pantex has also proactively conducted work to determine possible causes of the detections. Pantex has addressed one potential source by plugging a nearby perched well that was drilled deeply into the FGZ. Pantex will also complete a cement bond log on PTX06-1056 in 2016 to determine if the annular seal is competent. Additionally, Pantex has contracted for an outside review to determine further steps for source determination. Pantex continues to monitor this Ogallala well quarterly to determine if a trend emerges.

Pantex continues to evaluate options for the southeast lobe of perched groundwater east of FM 2373. As recommended in the 2015 Annual Progress Report, Pantex plans to extend the SEPTS operation to that area to address the continued plume movement to the south.

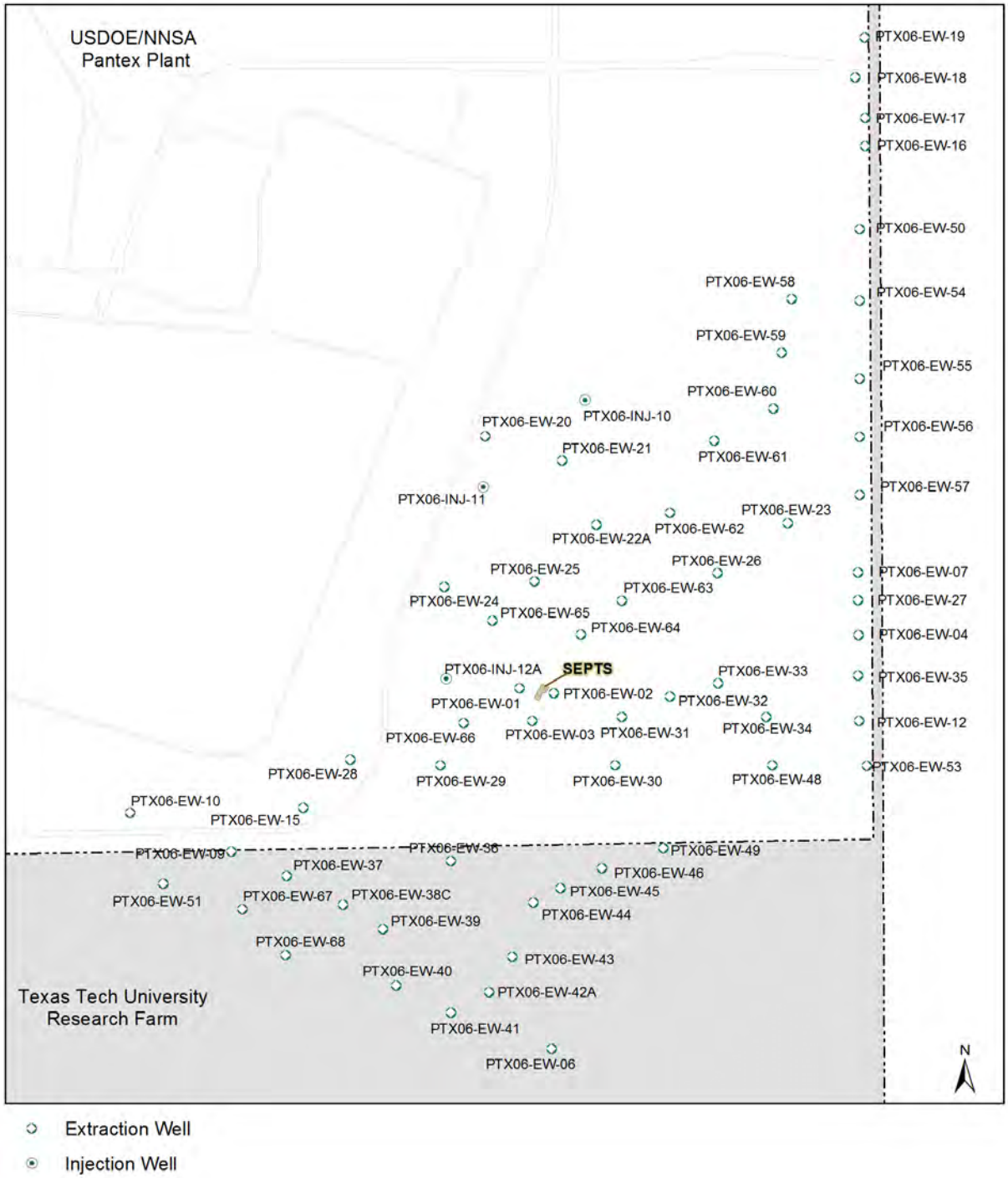
Appendix A
Maps



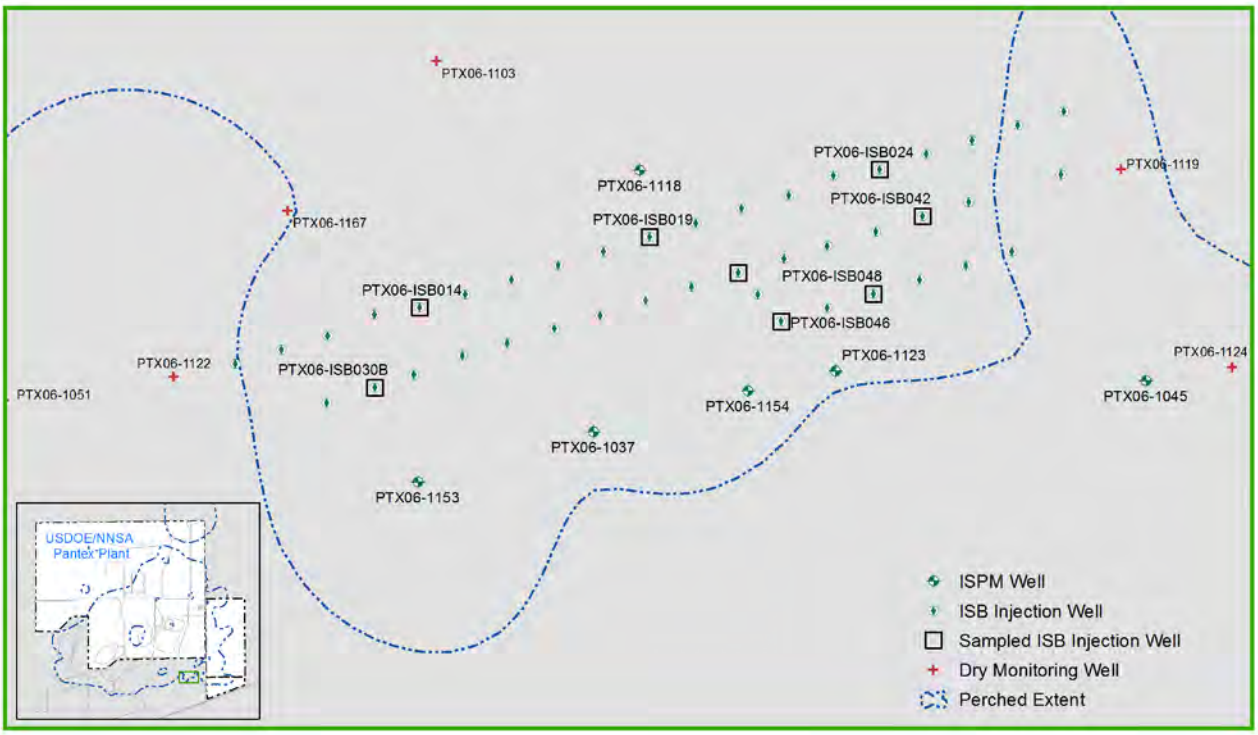
Extent of Perched Groundwater and Contaminant Plumes



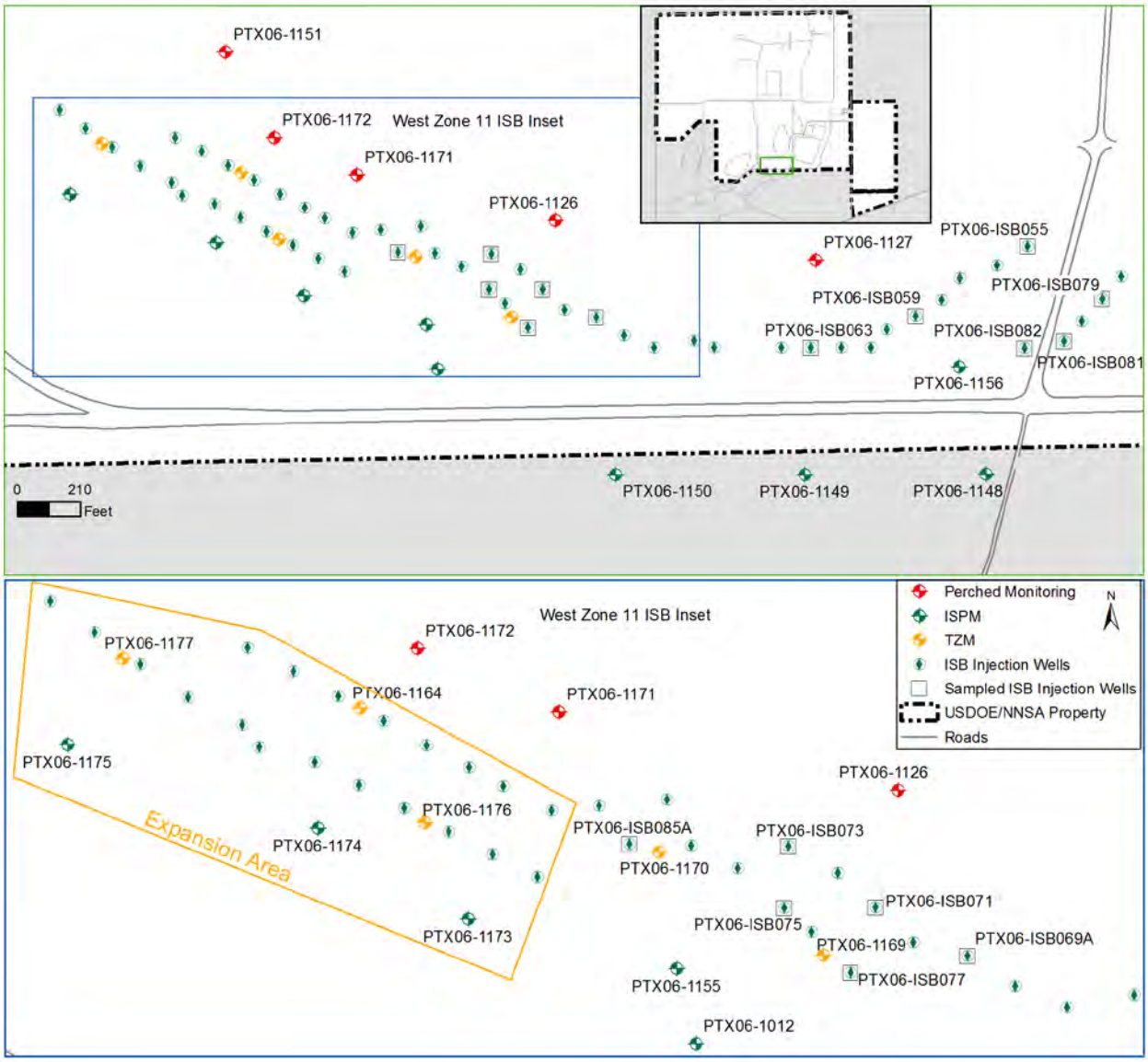
Playa 1 Pump and Treat System Wells



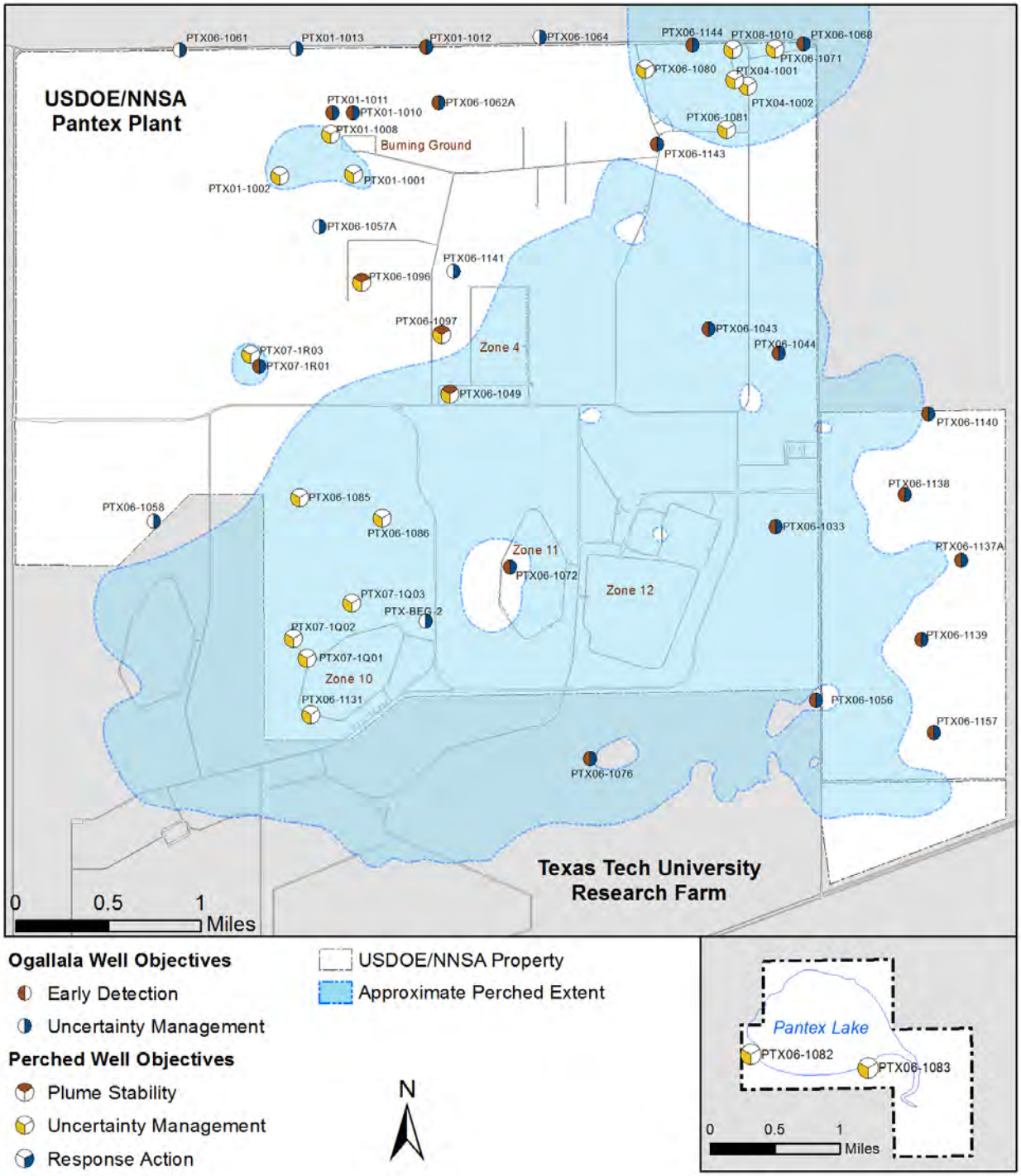
Southeast Pump and Treat System Wells



Southeast ISB Wells and Sampling Locations



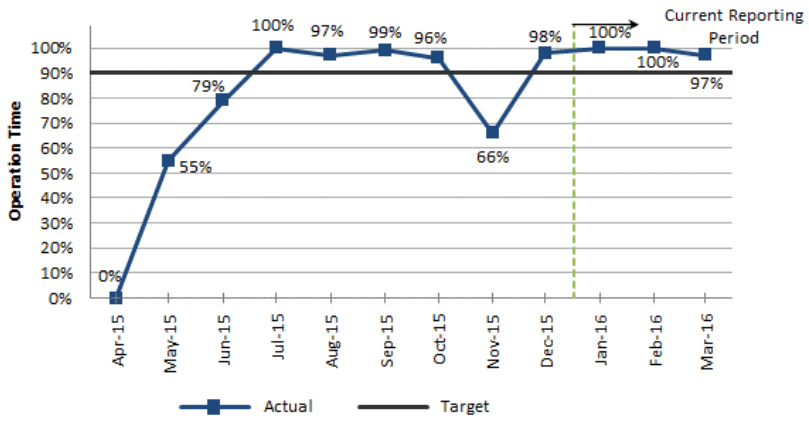
Zone 11 ISB Wells and Sampling Locations



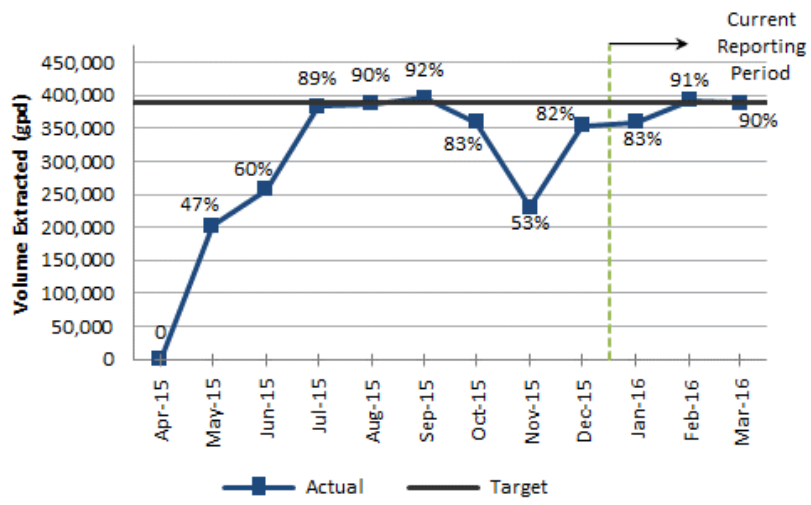
Uncertainty Management and Early Detection Wells Evaluated in the Quarterly Progress Report

Appendix B
Pump and Treat Systems Graphs

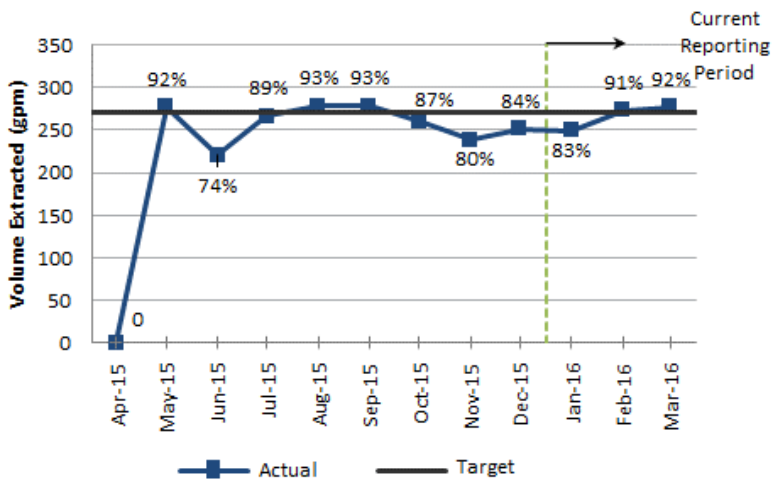
Southeast Pump and Treat Graphs



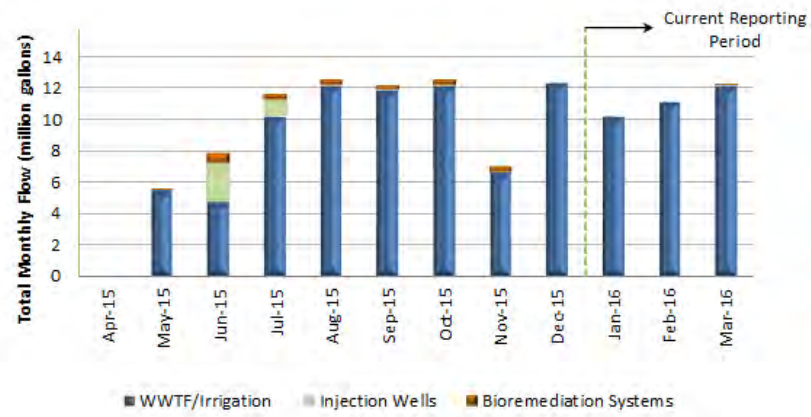
SEPTS Operation Time vs Target



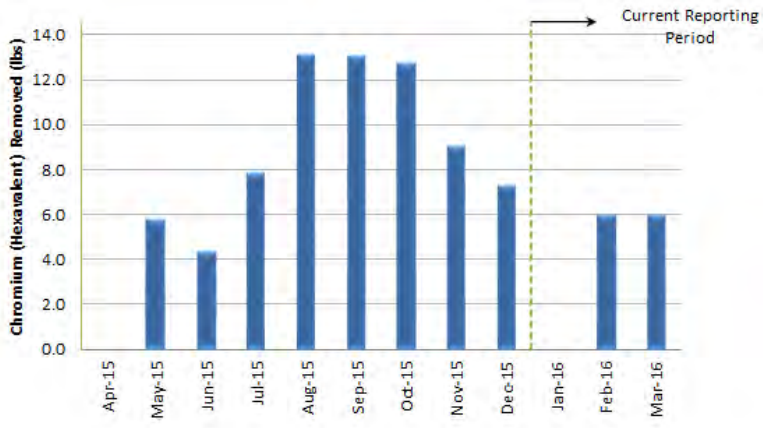
SEPTS GPD and % Capacity



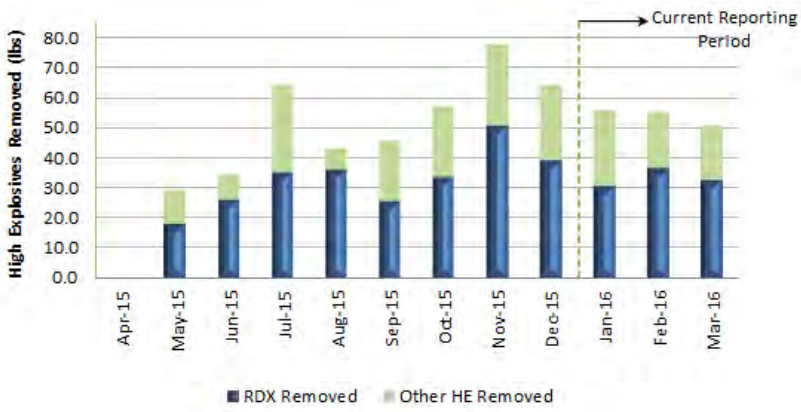
SEPTS Average GPM and % Capacity



SEPTS Monthly Total Flow

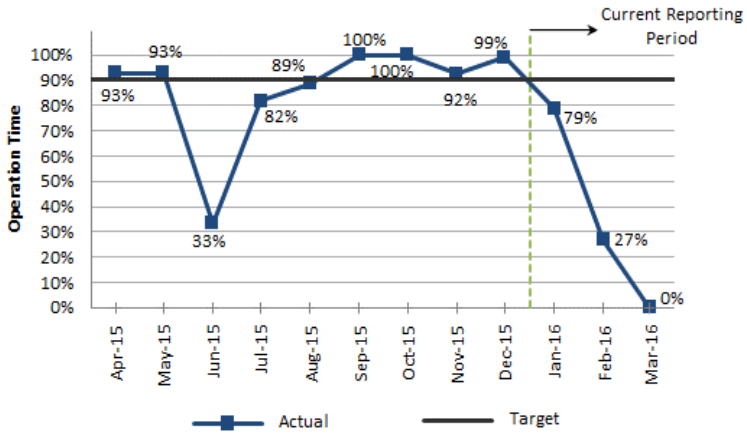


SEPTS Chromium Mass Removal by Month

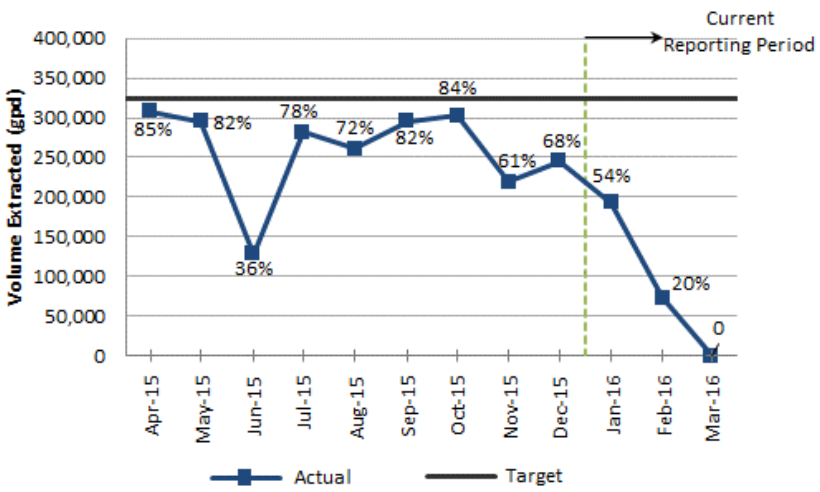


SEPTS HE Mass Removal by Month

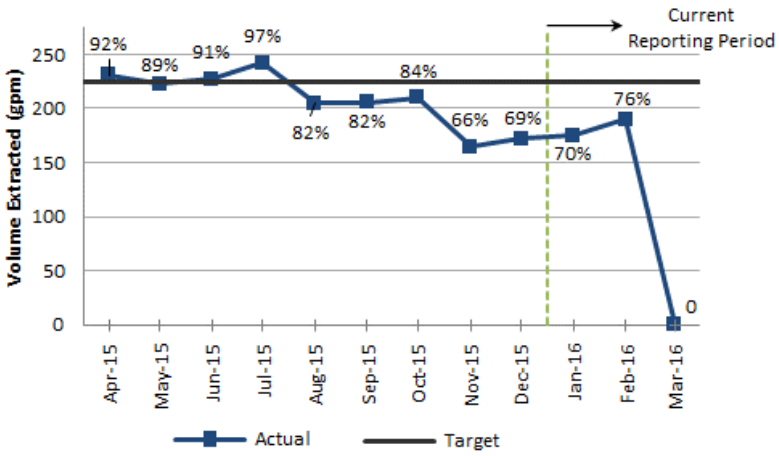
Playa 1 Pump and Treat Graphs



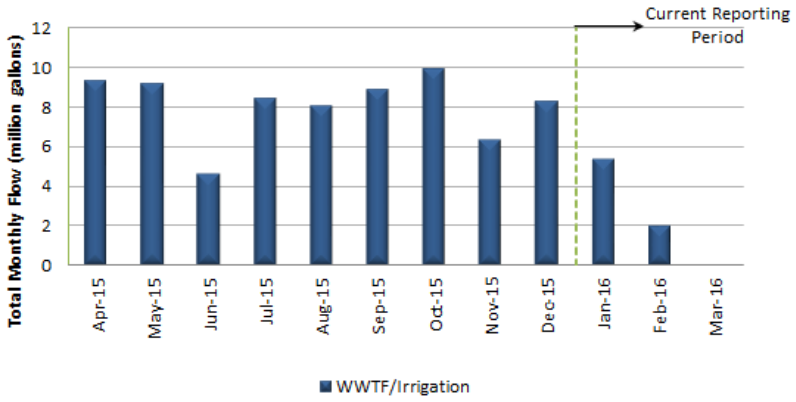
P1PTS Operational Time Vs Target



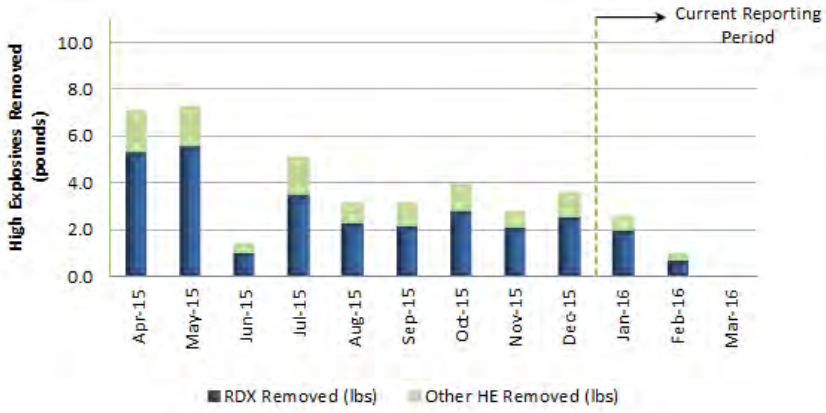
P1PTS Average GPD and % Capacity



P1PTS Average GPM and % Capacity



P1PTS Monthly System Total Flow



P1PTS HE Mass Removal by Month

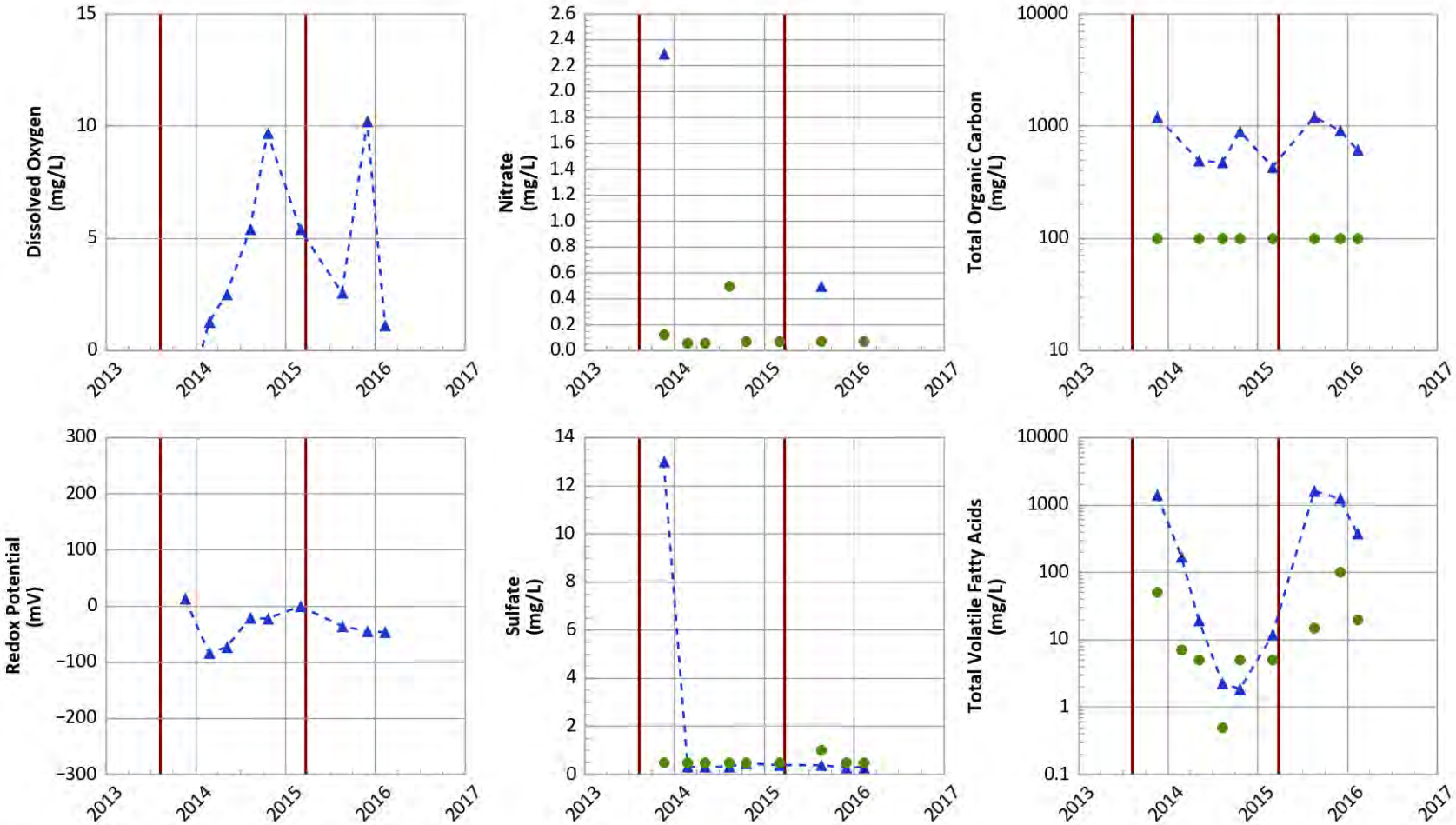
Appendix B Glossary

Operation Time	Operation time represents the percentage of the total number of hours the system was actually operated vs. the total possible hours the system could have operated on a monthly basis.
GPM Extraction	The gallons per minute (GPM) extraction rate represents the extraction rate from the well field while the system was operating. This is a measurement of the well field's capability to support the overall system throughput goals. Low well field rates can occur due to inoperable wells or decline in saturated thickness that makes extraction difficult.
GPD Extraction	The gallons per day (GPD) extraction rate represents the system's ability to meet overall throughput goals, considering the well field extraction rate and the system's operational rate. This rate is affected by the ability to extract water from the well field and the system downtime.
Total Monthly Flow	Total monthly flow is the total volume of extracted water measured at the influent point of the pump and treat system. Individual well measurements and flow rates are provided in the annual progress report.

Appendix C
ISB Graphs

Southeast ISB Graphs

PTX06-ISB014 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

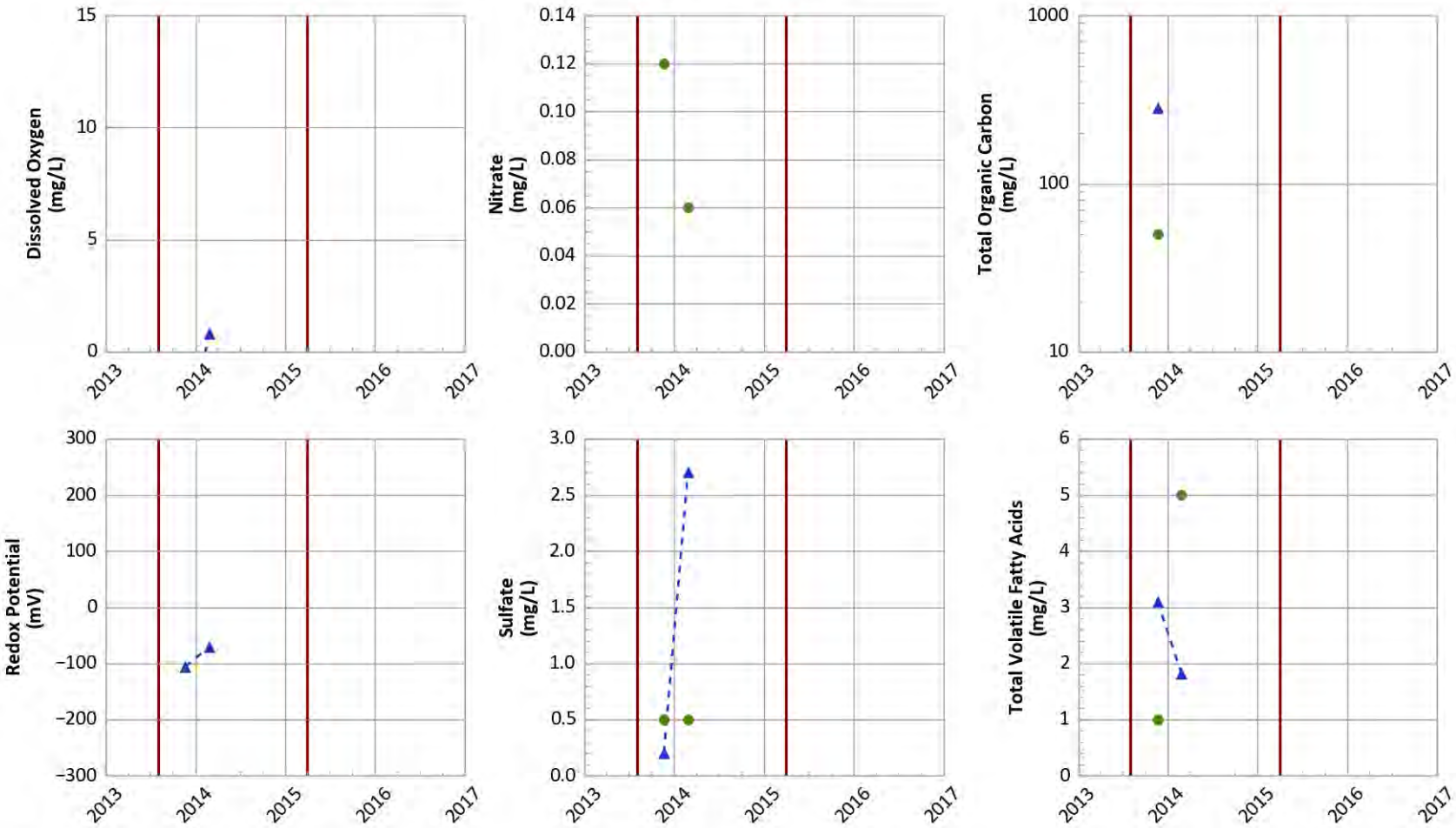


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB019 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

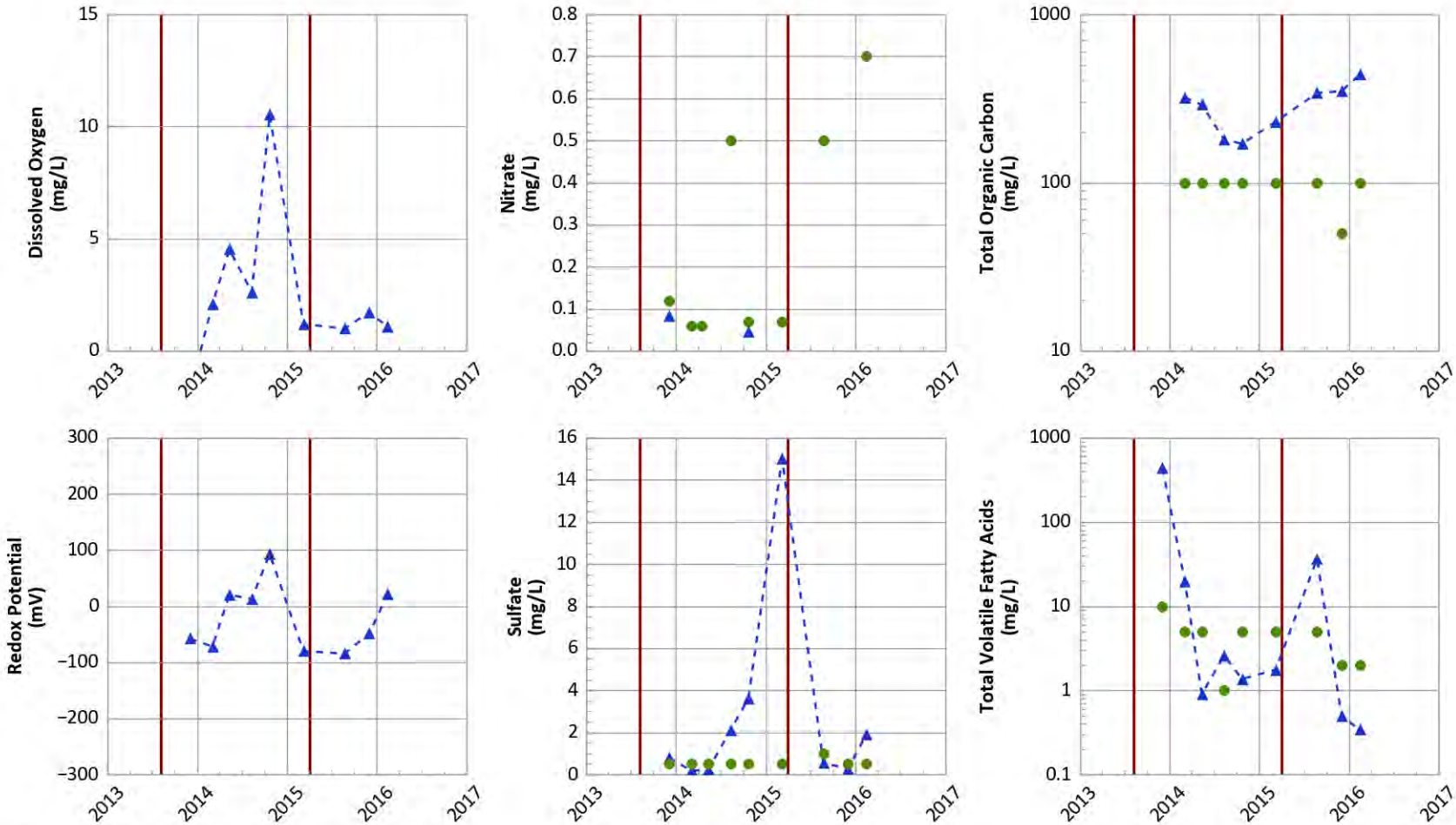


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB024 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

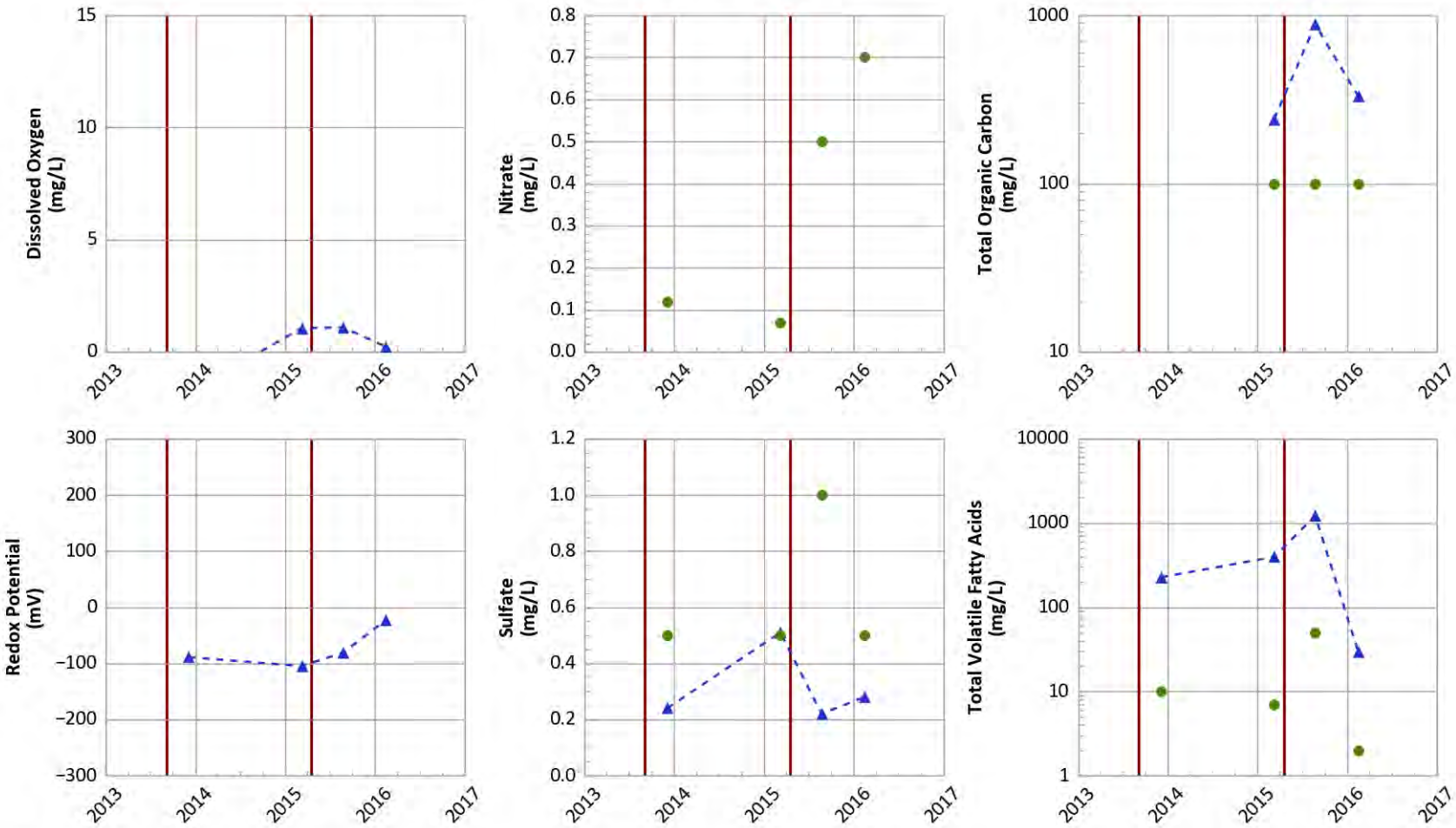


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB030B Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

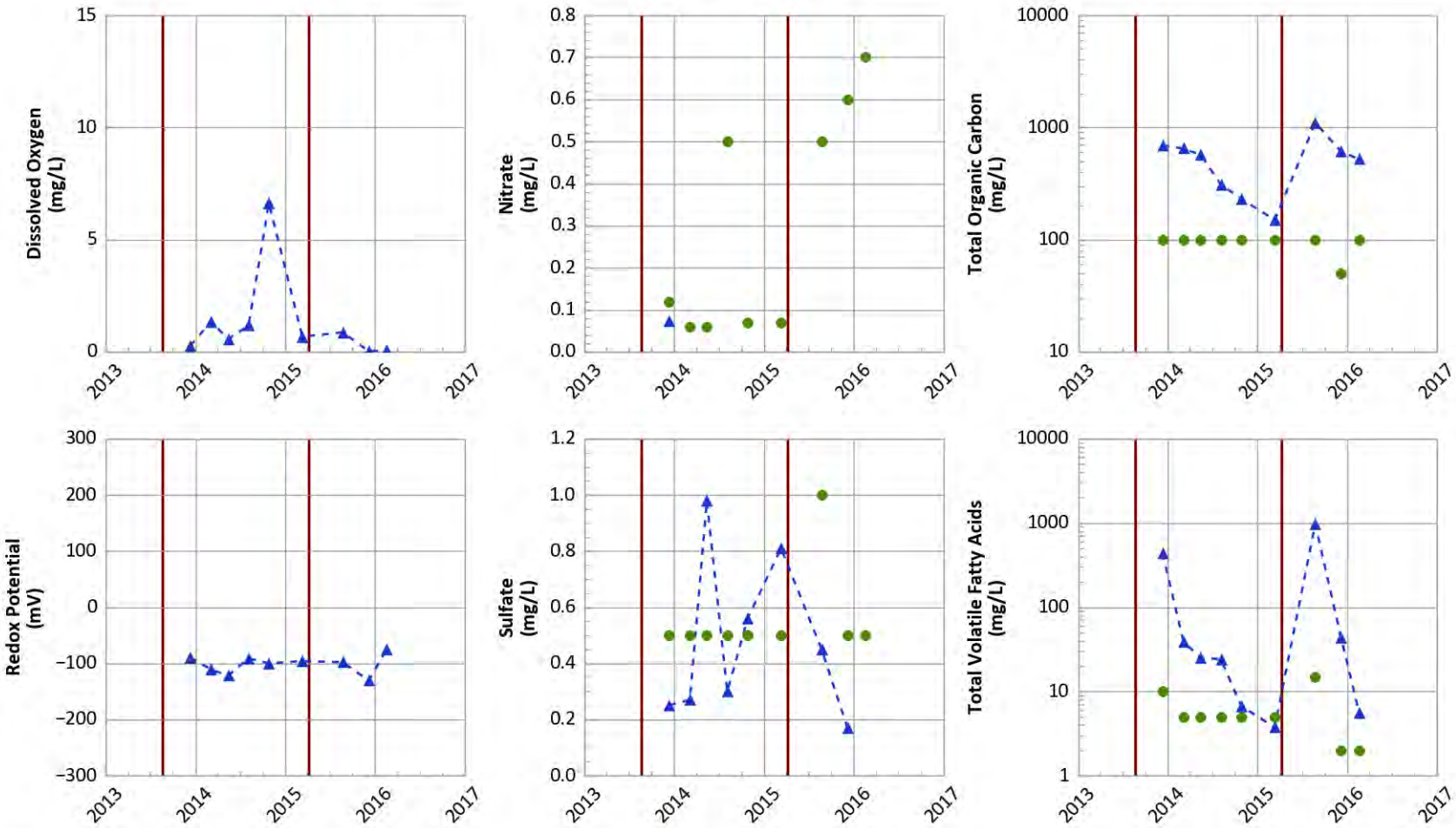


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB038 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

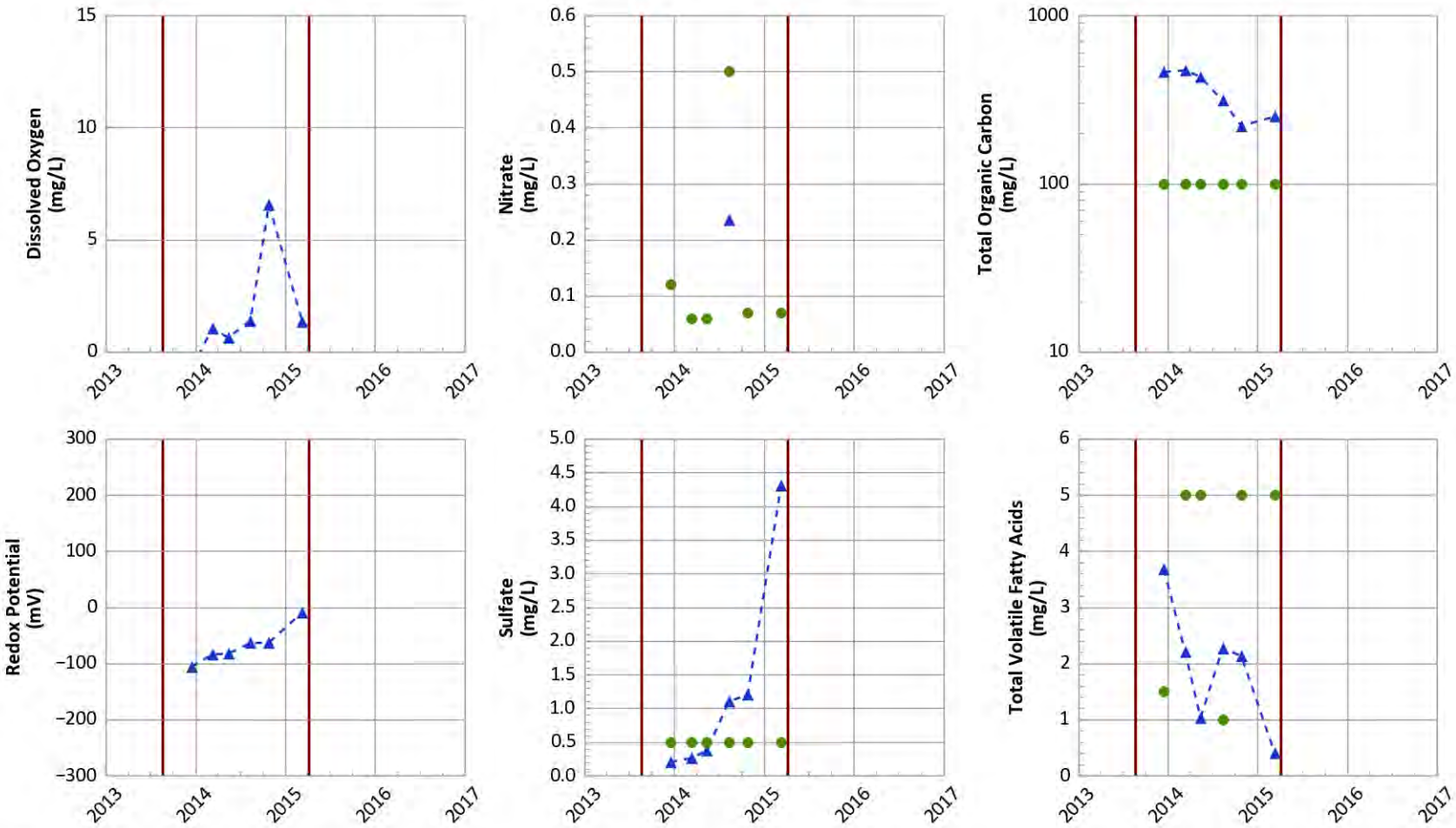


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB042 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

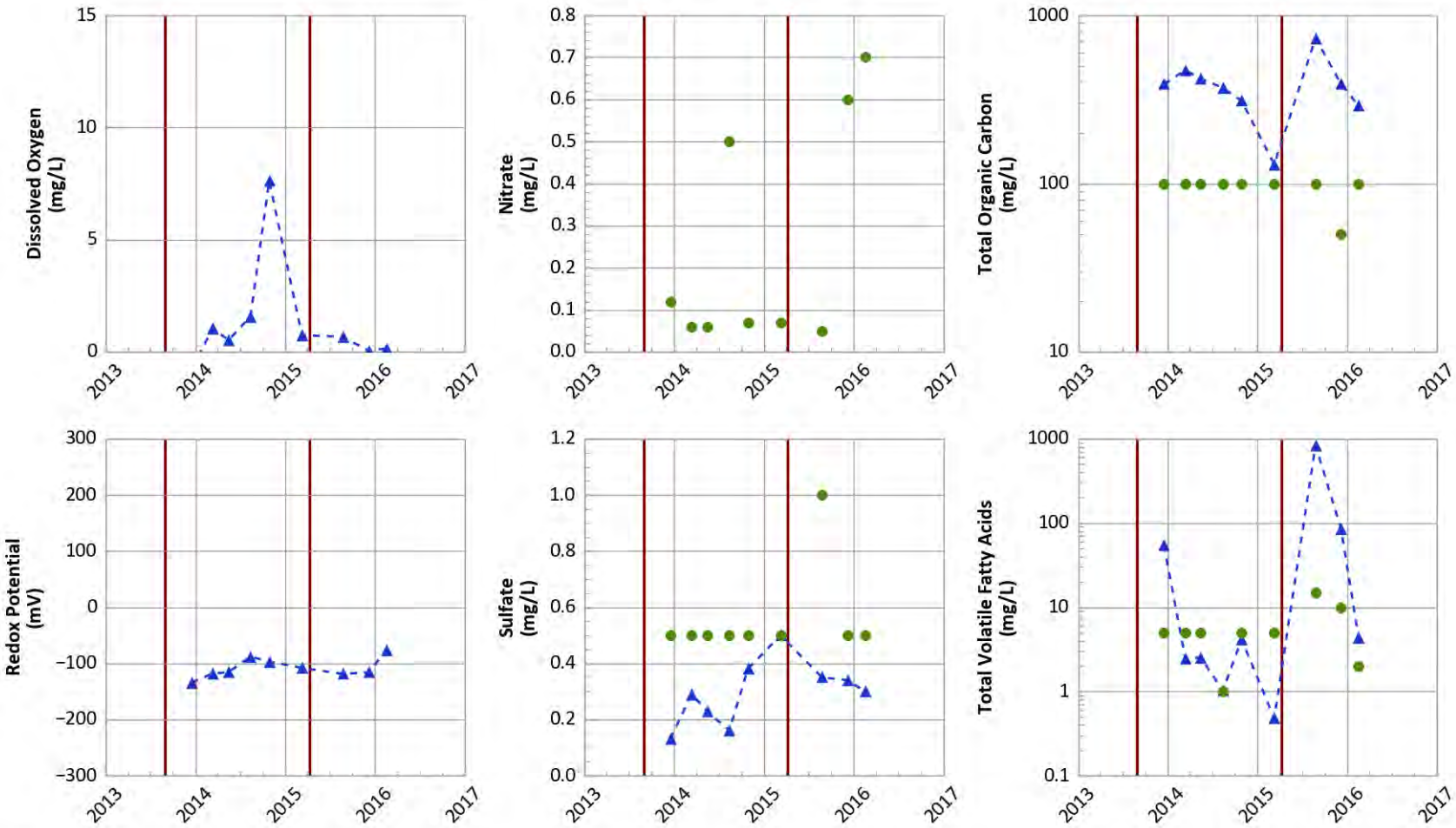


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB046 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

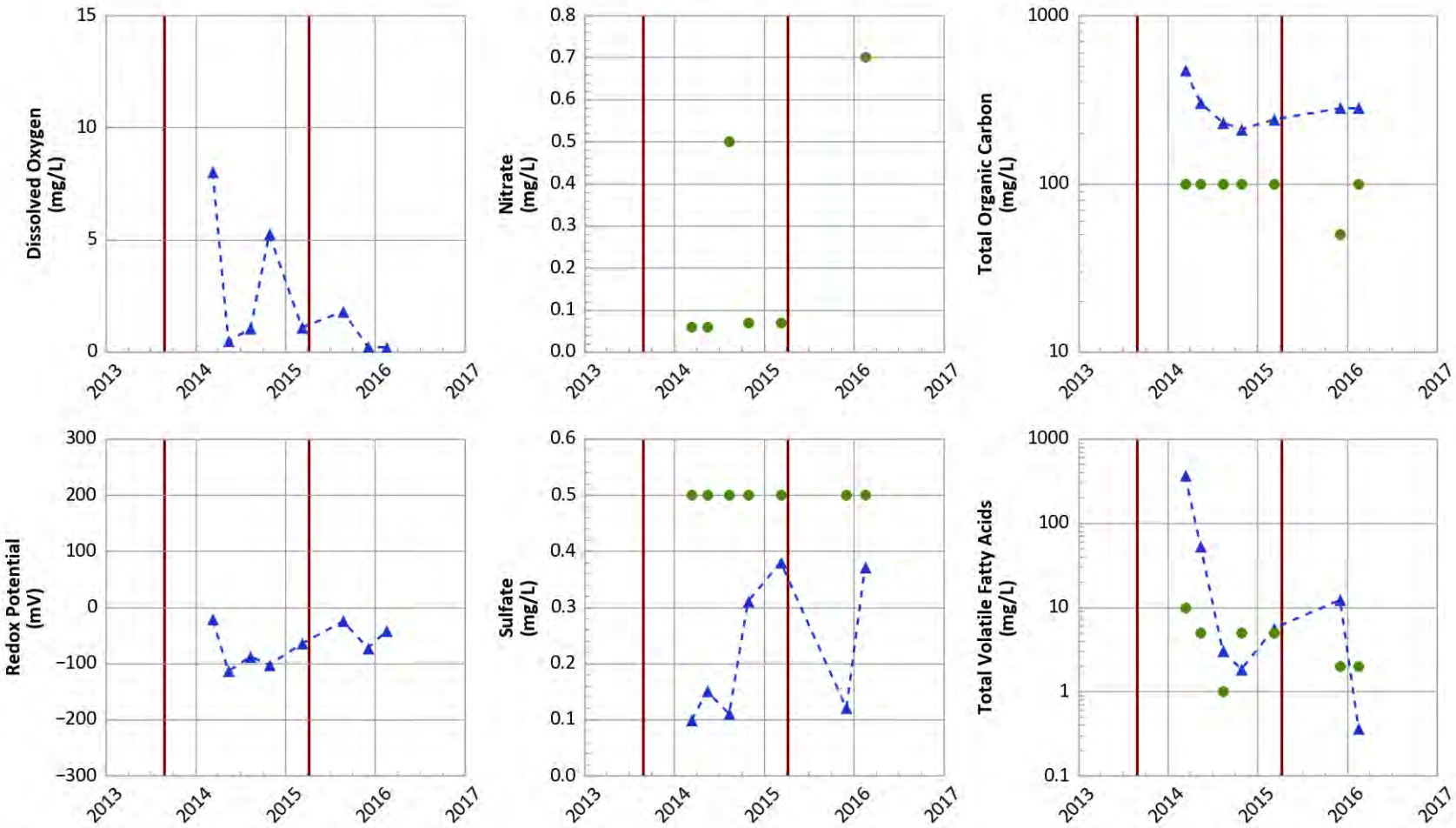


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB048 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

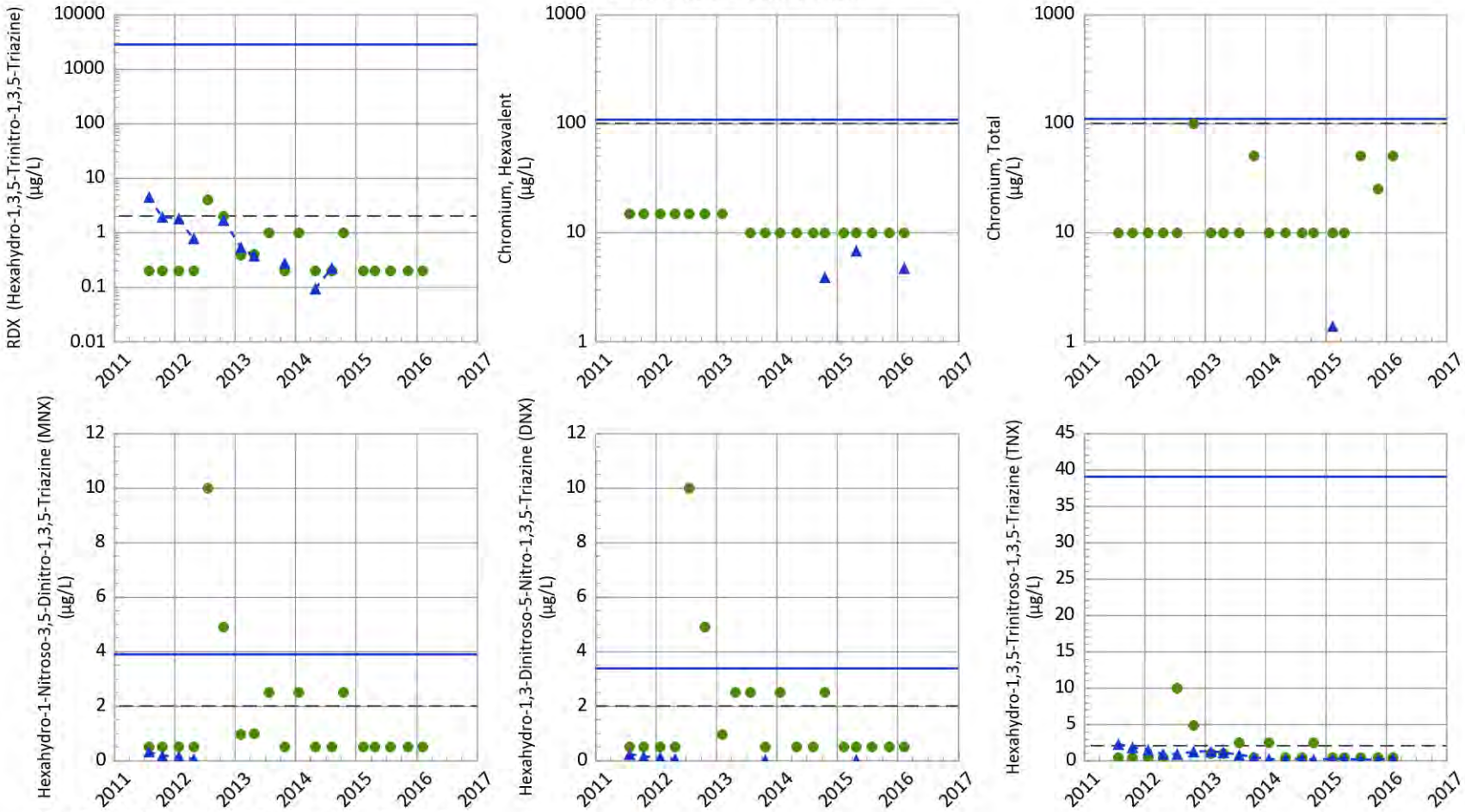


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1037 Downgradient Performance Indicators
Southeast In Situ Bioremediation System
USDOE/NNSA Pantex Plant



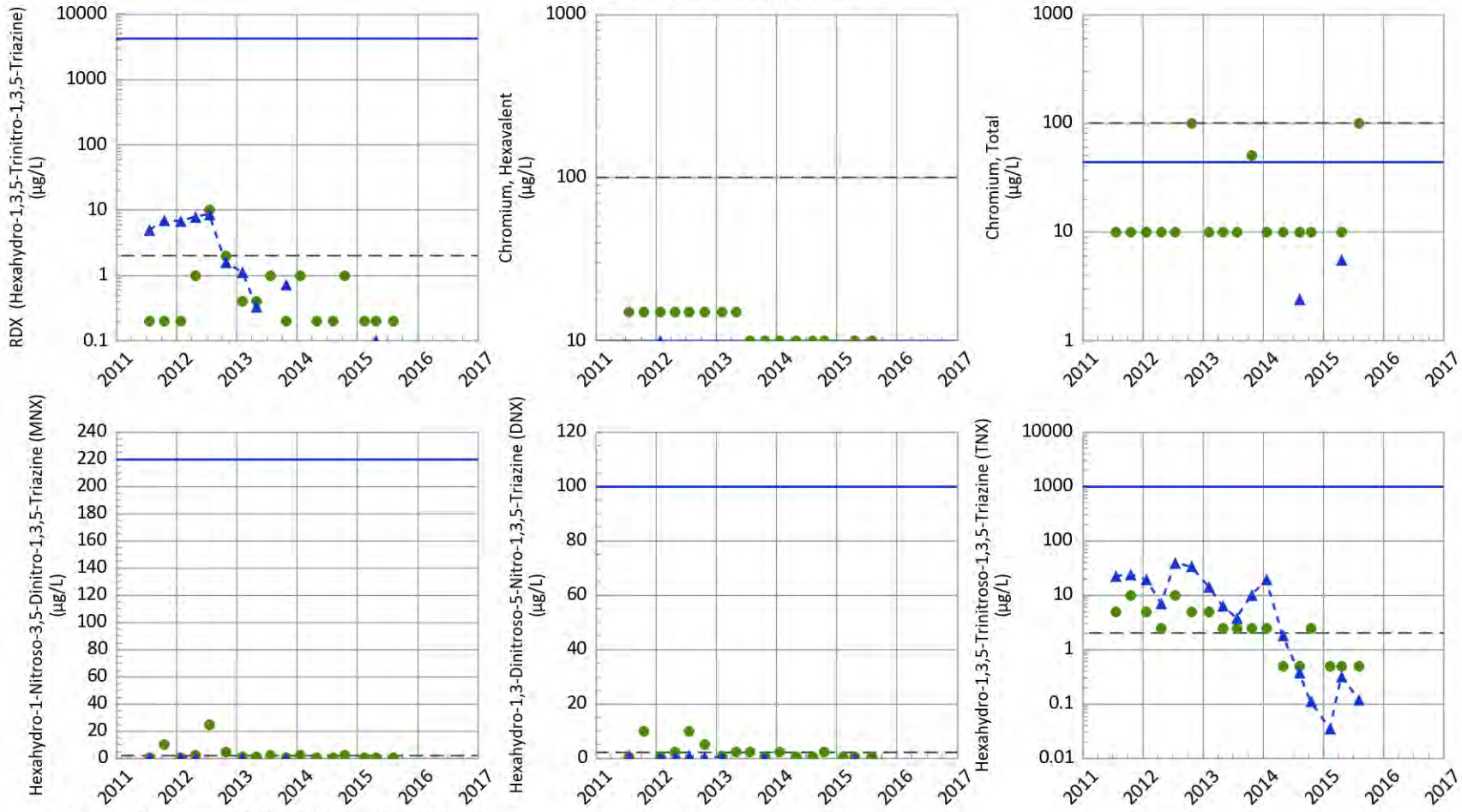
Most Recent Measured COC Concentrations (Feb 08, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
RDX	Non-Detect	2.0
MNX	Non-Detect	2.0
CR-6	4.75	100.0
DNX	Non-Detect	2.0
CR	Non-Detect	100.0
TNX	0.23	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1123 Downgradient Performance Indicators
Southeast In Situ Bioremediation System
USDOE/NNSA Pantex Plant



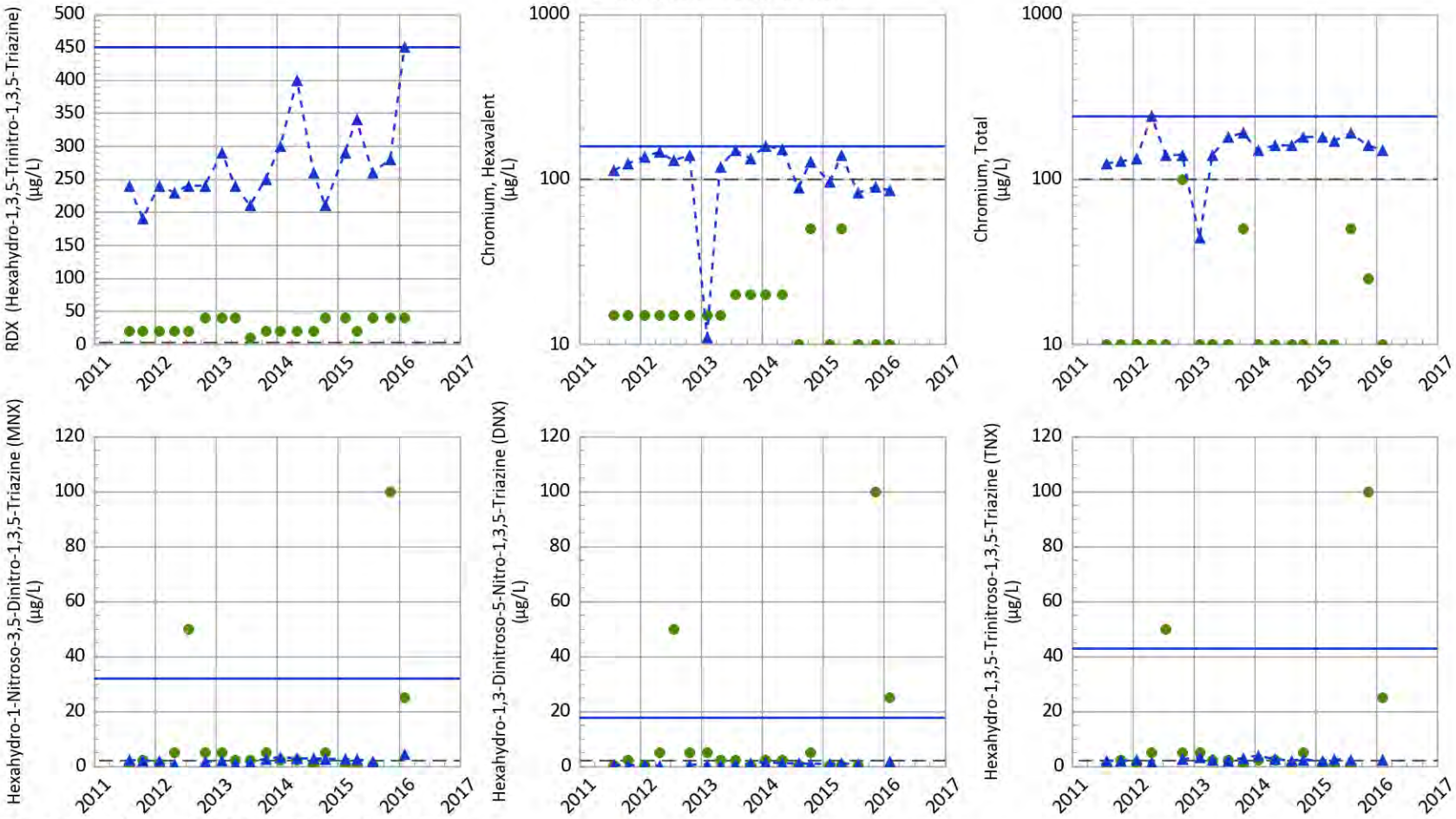
Most Recent Measured COC Concentrations (Aug 05, 2015)

COC	Concentration (µg/L)	GWPS (µg/L)
RDX	Non-Detect	2.0
MNX	Non-Detect	2.0
CR-6	Non-Detect	100.0
DNX	Non-Detect	2.0
CR	Non-Detect	100.0
TNX	0.12	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1153 Downgradient Performance Indicators
Southeast In Situ Bioremediation System
USDOE/NNSA Pantex Plant



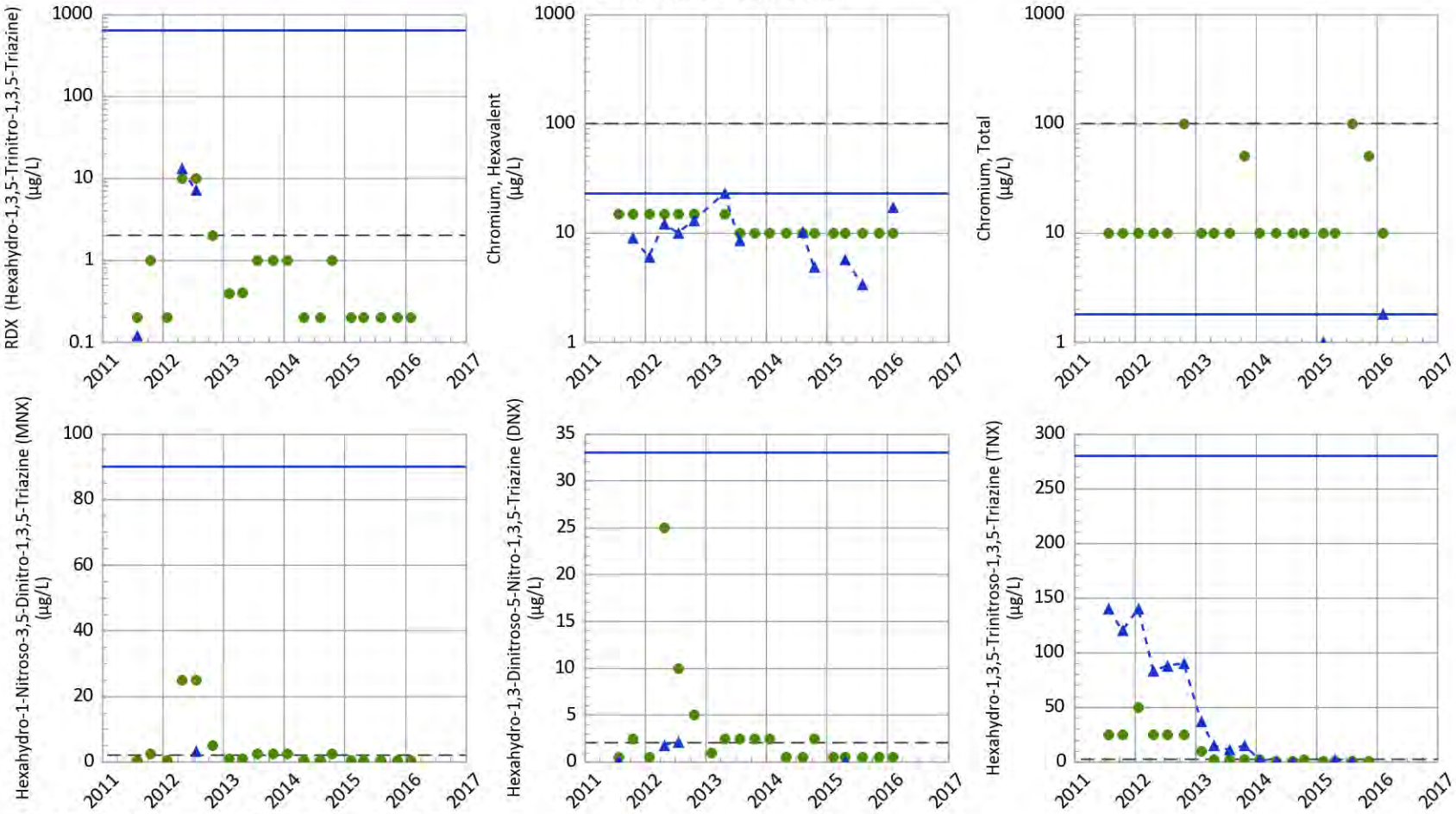
Most Recent Measured COC Concentrations (Feb 03, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
RDX	450.0	2.0
MNX	4.6	2.0
CR-6	85.5	100.0
DNX	1.8	2.0
CR	150.0	100.0
TNX	2.5	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1154 Downgradient Performance Indicators
Southeast In Situ Bioremediation System
USDOE/NNSA Pantex Plant



Most Recent Measured COC Concentrations (Aug 05, 2015)

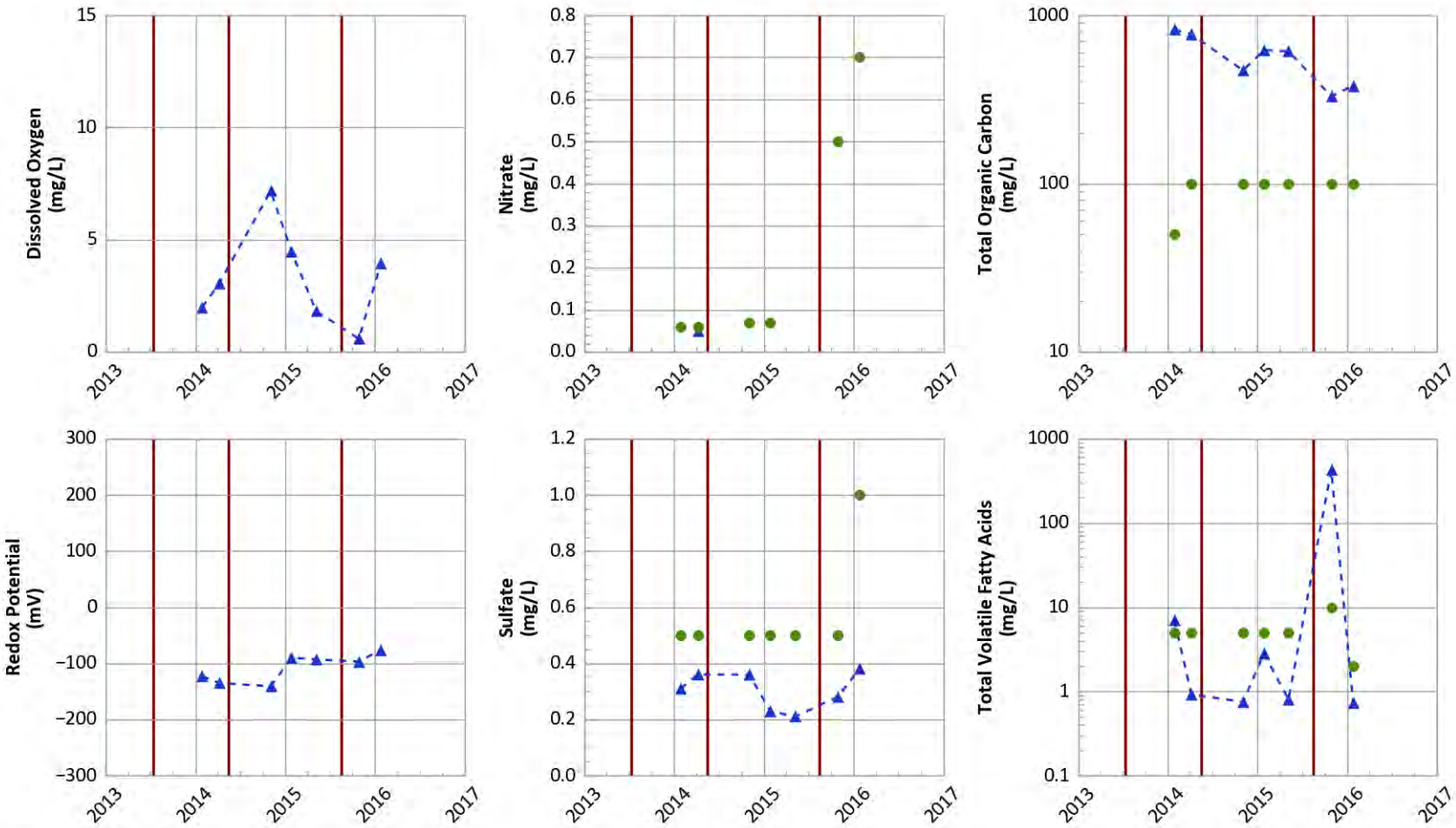
COC	Concentration (µg/L)	GWPS (µg/L)
RDX	Non-Detect	2.0
MNX	Non-Detect	2.0
CR-6	17.0	100.0
DNX	Non-Detect	2.0
CR	1.8	100.0
TNX	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

Zone 11 ISB Graphs

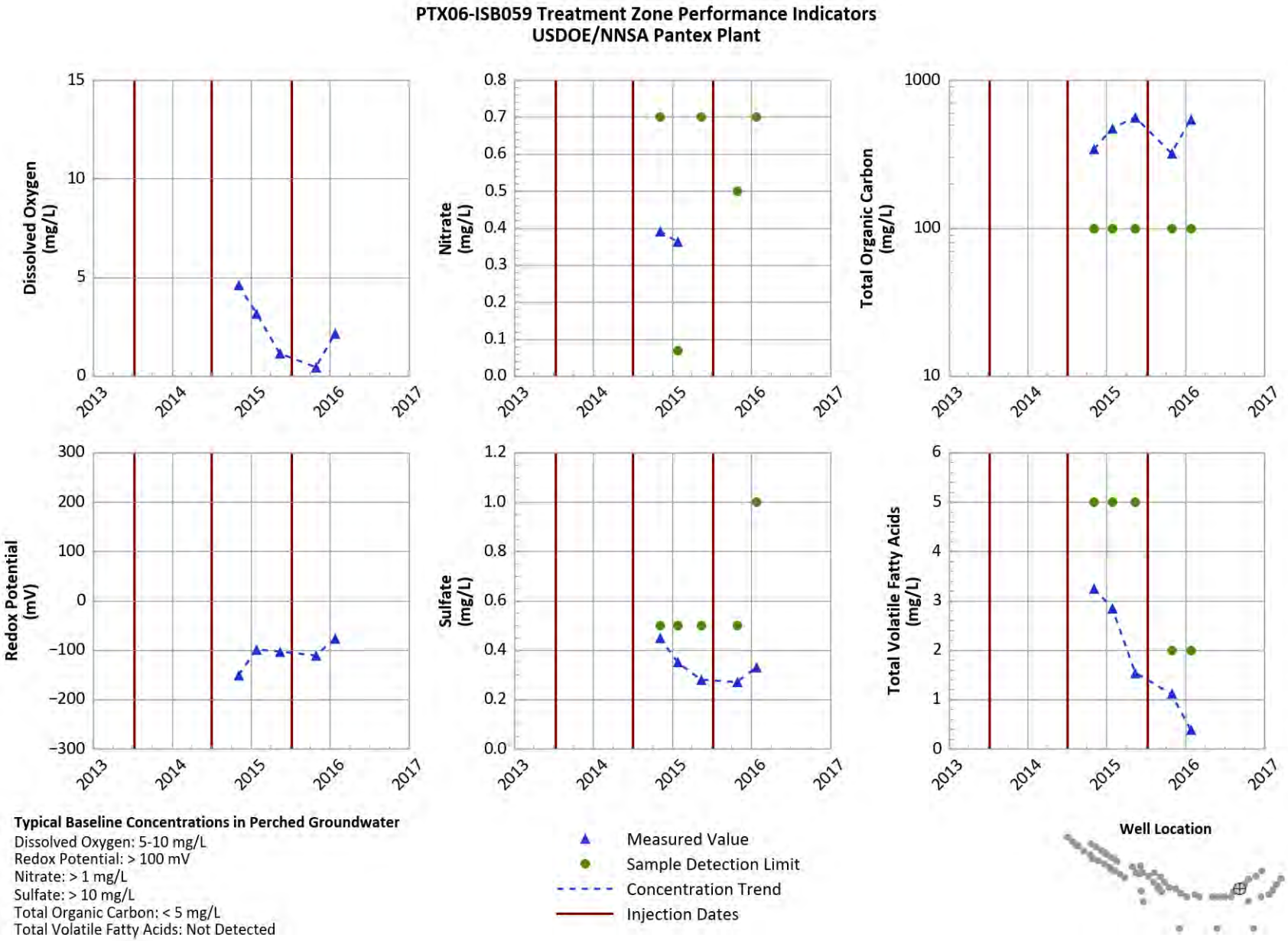
PTX06-ISB055 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant



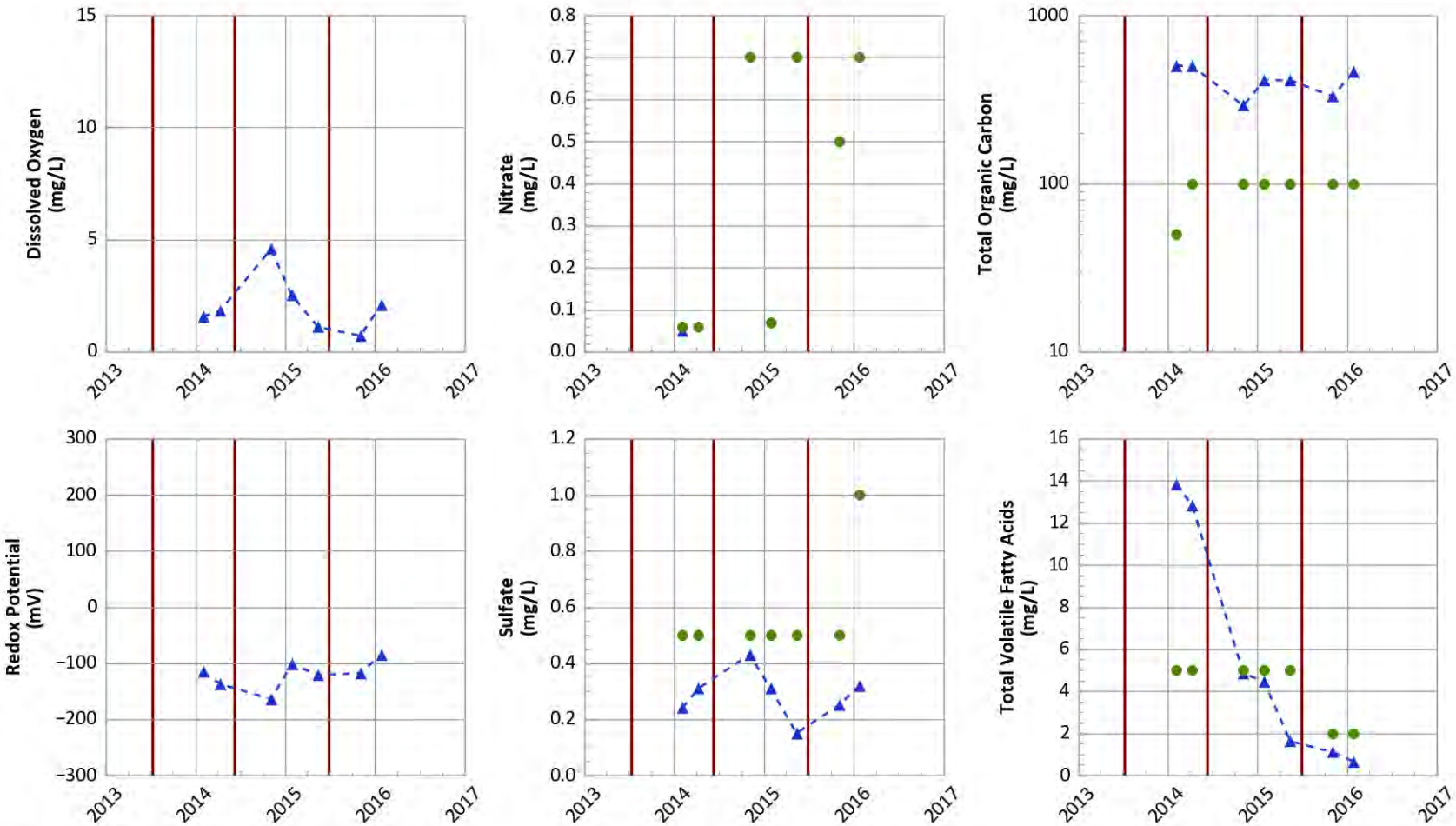
Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location


PTX06-ISB059 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant
Dissolved Oxygen (mg/L)
Nitrate (mg/L)
Total Organic Carbon (mg/L)
Redox Potential (mV)
Sulfate (mg/L)
Total Volatile Fatty Acids (mg/L)
2013
2014
2015
2016
2017
Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected
Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates
Well Location

PTX06-ISB063 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

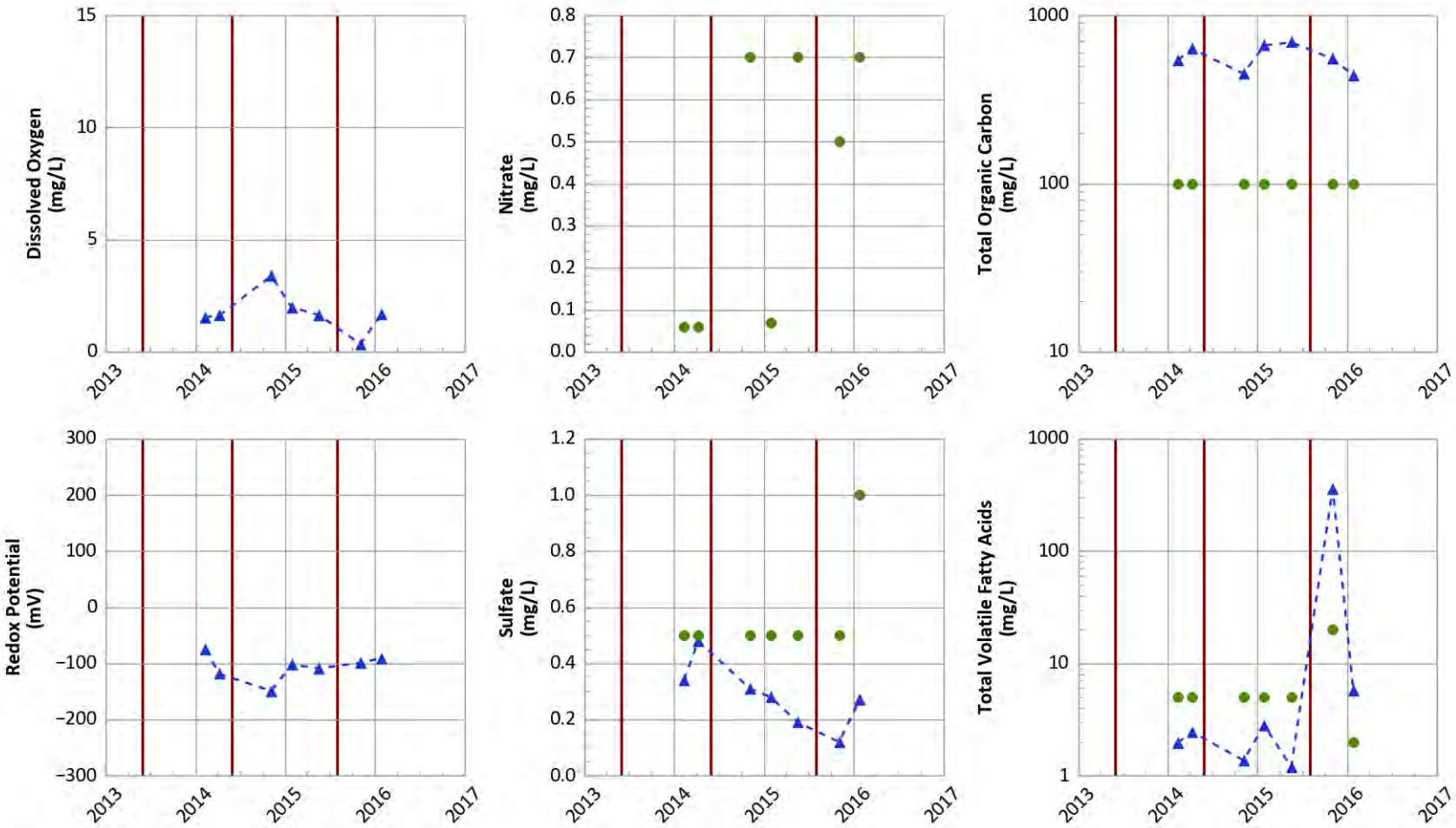


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB069A Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

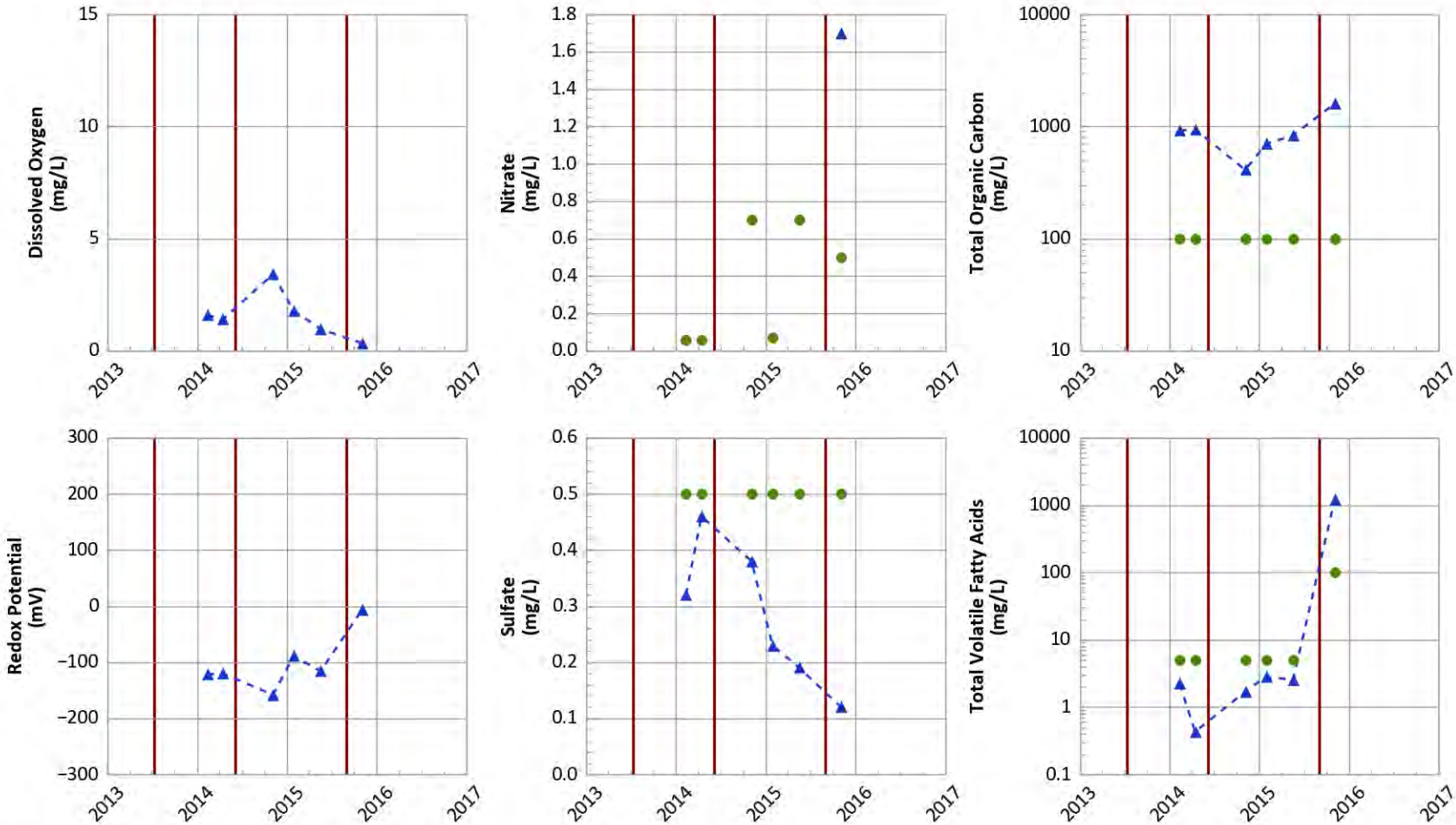


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB071 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

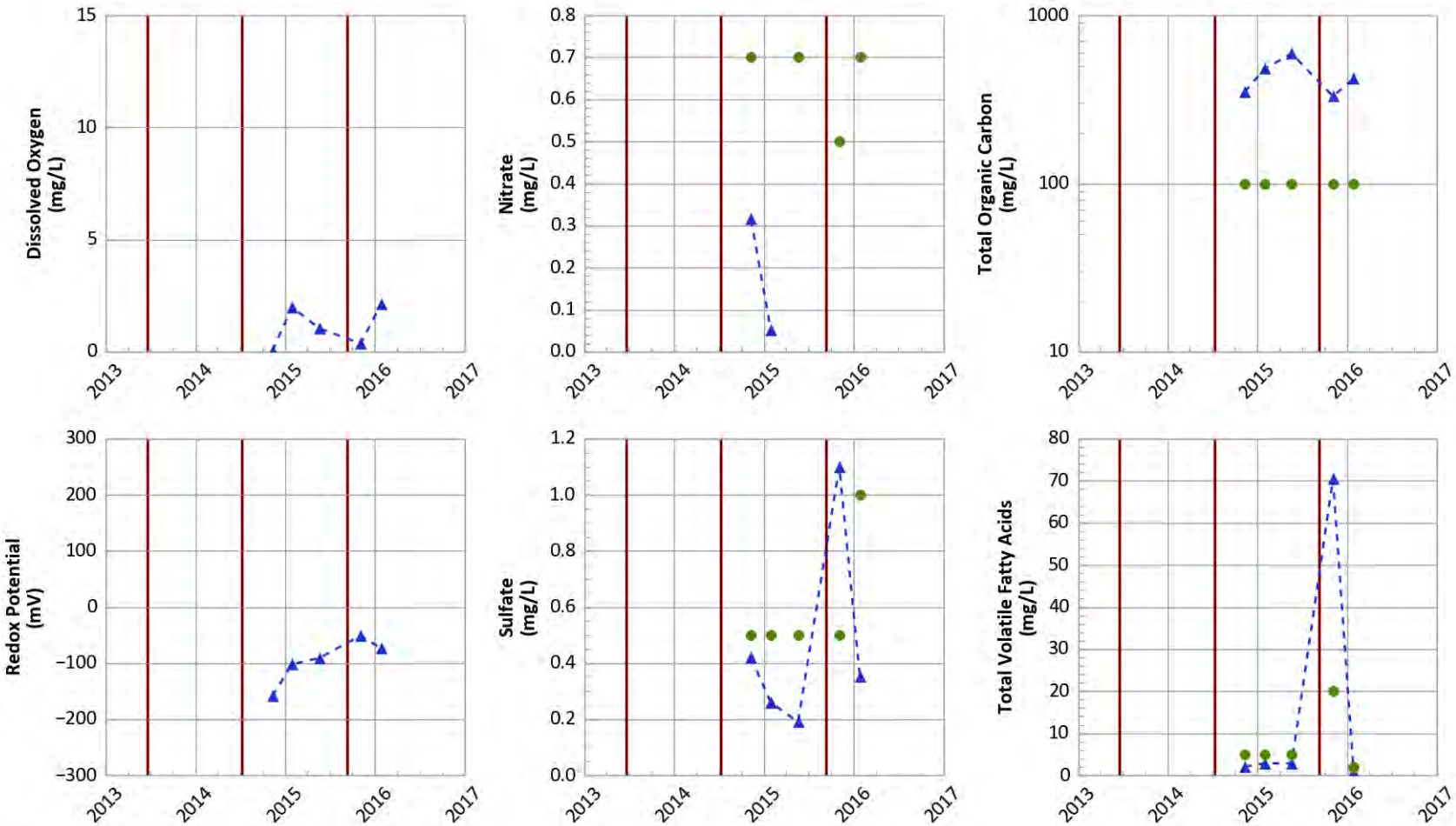


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB073 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

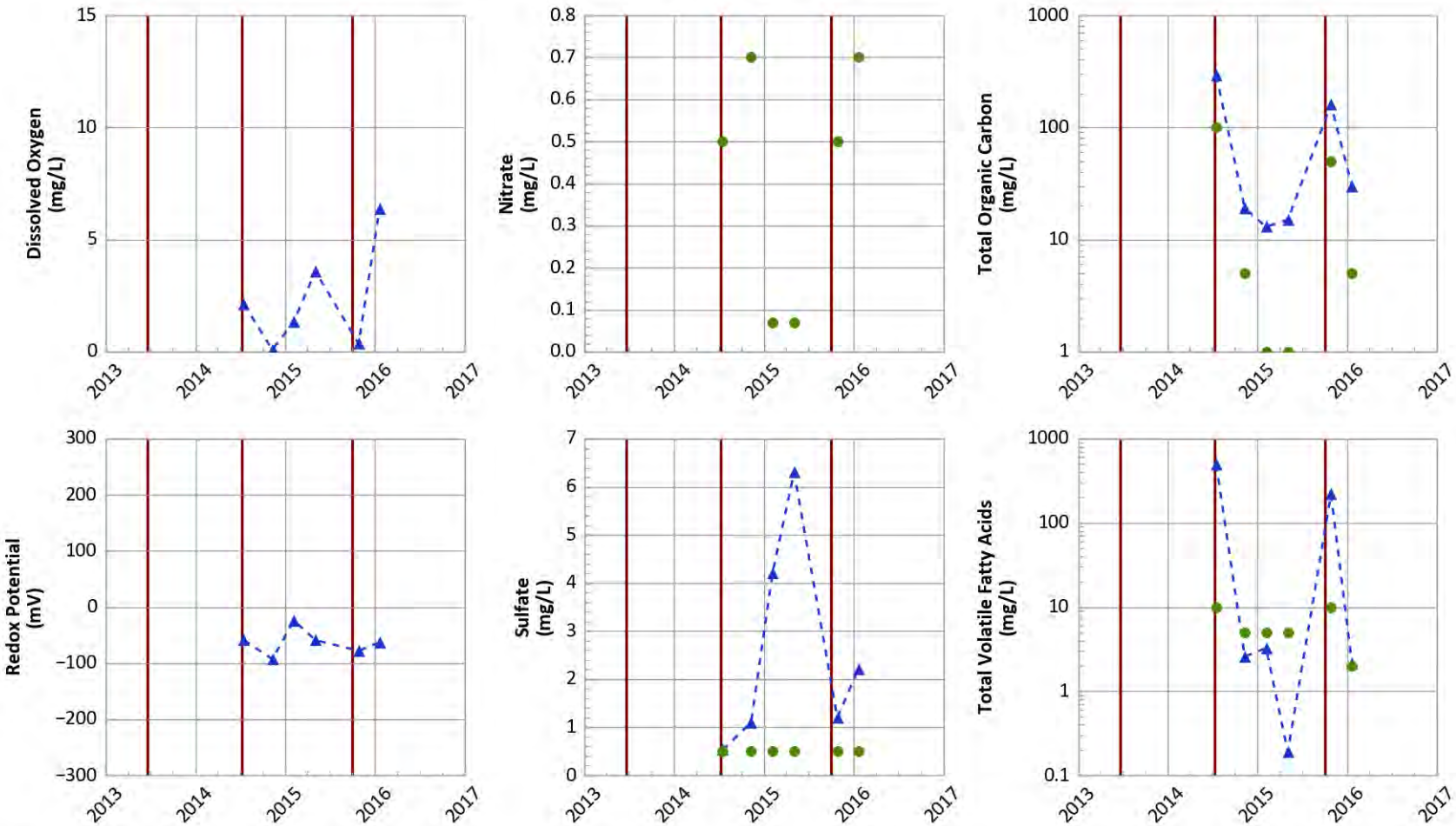


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB075 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

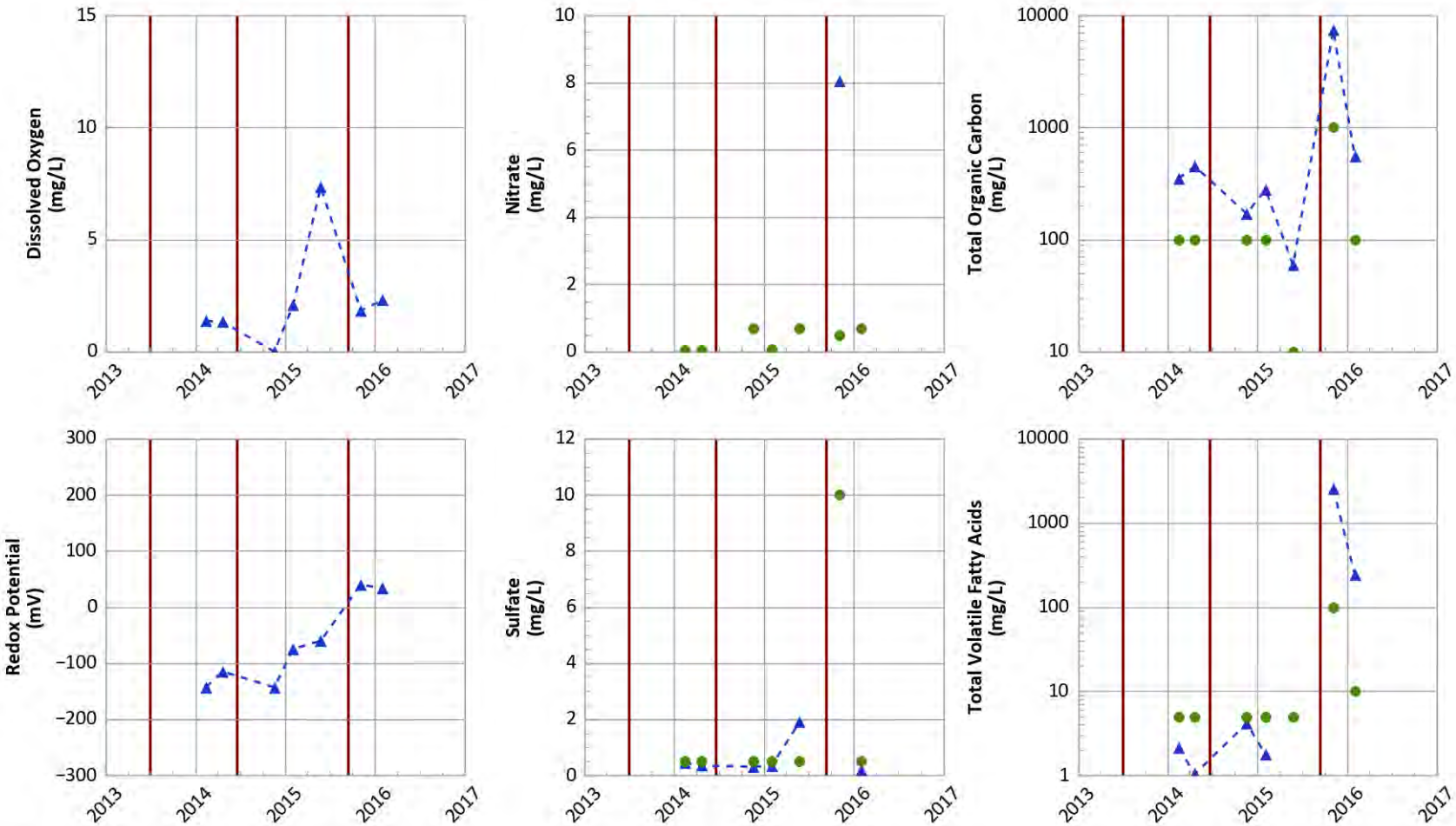


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB077 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

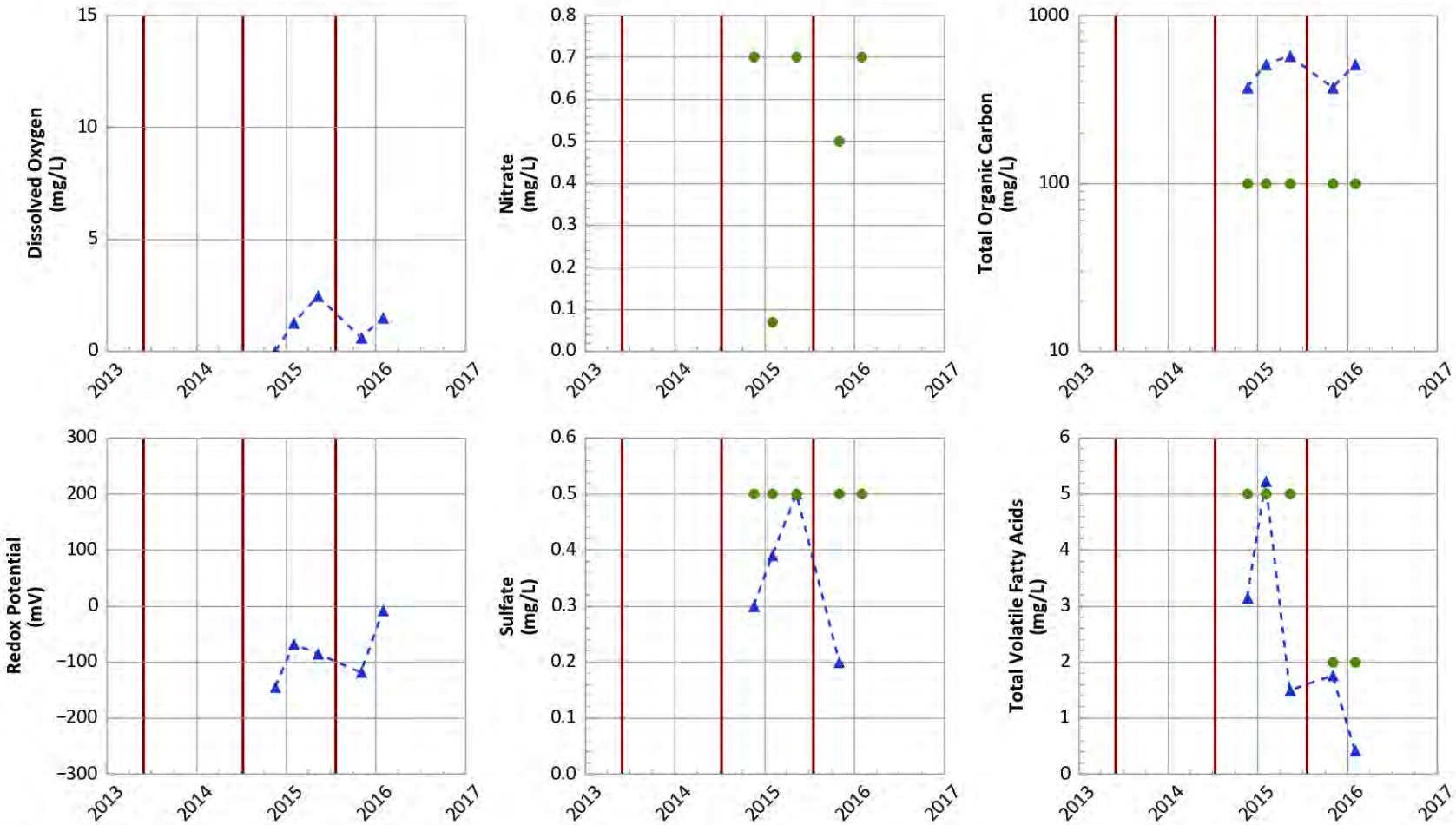


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB081 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

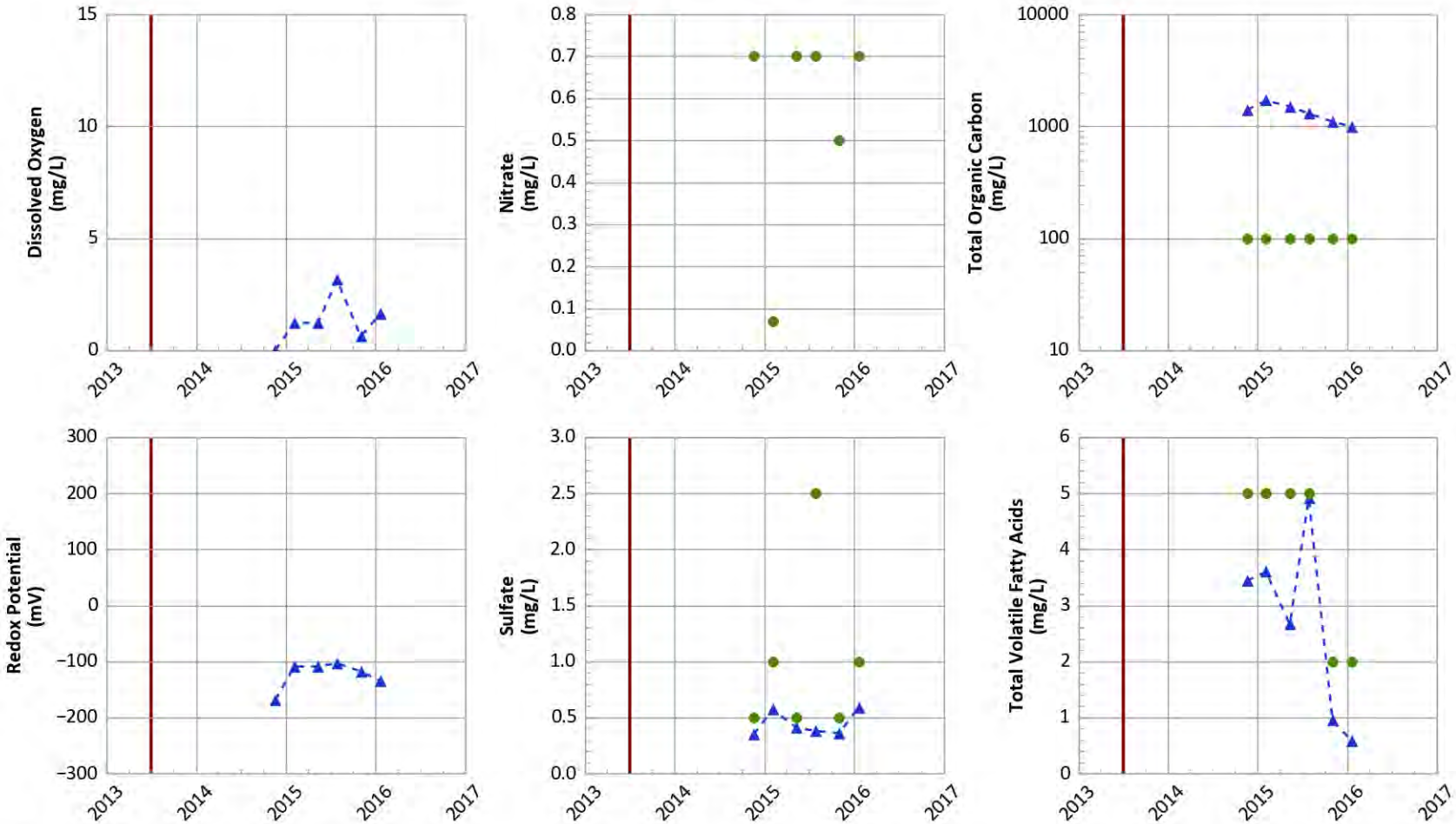


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-ISB082 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

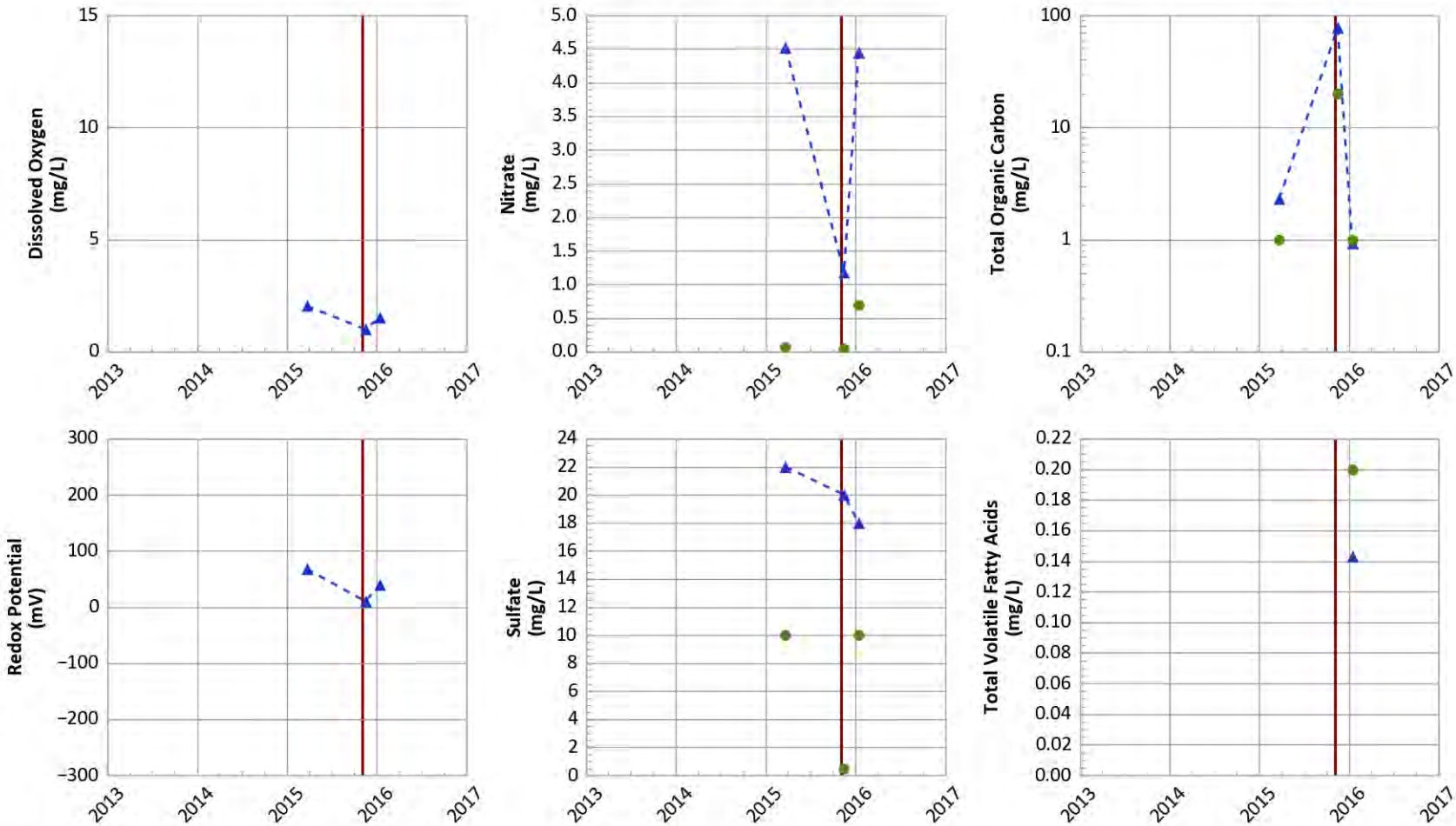


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1164 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

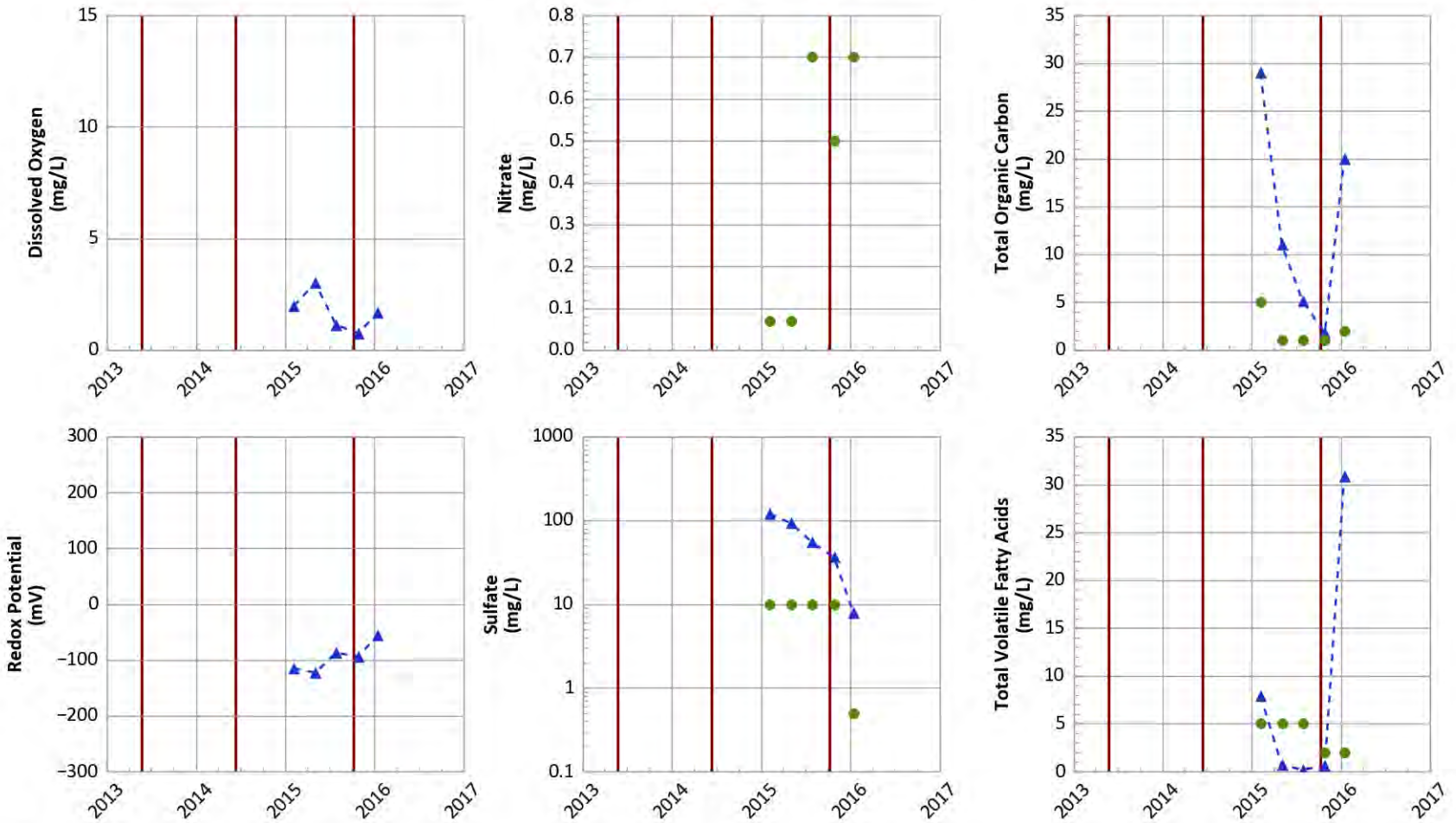


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1170 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

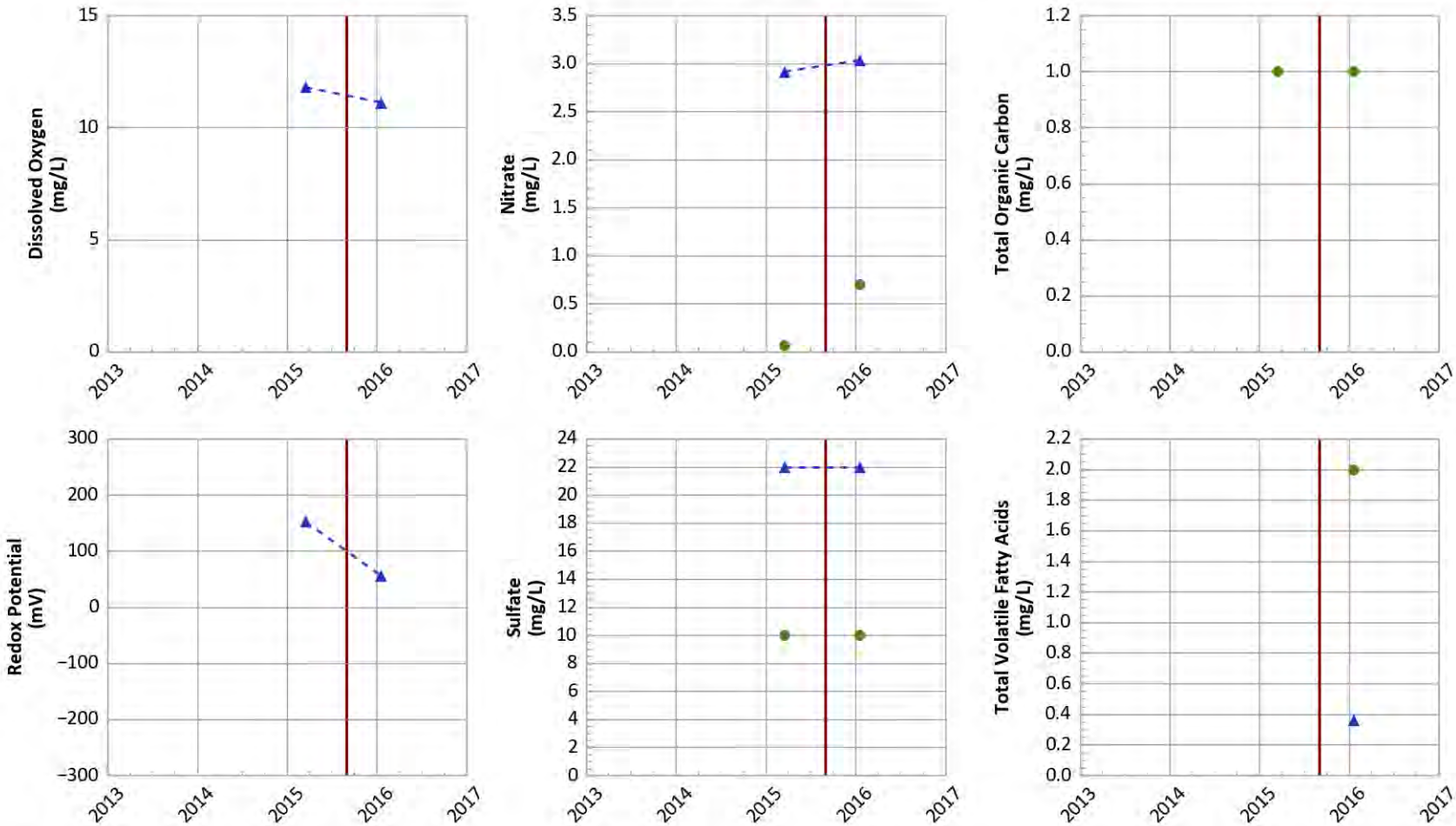


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1176 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

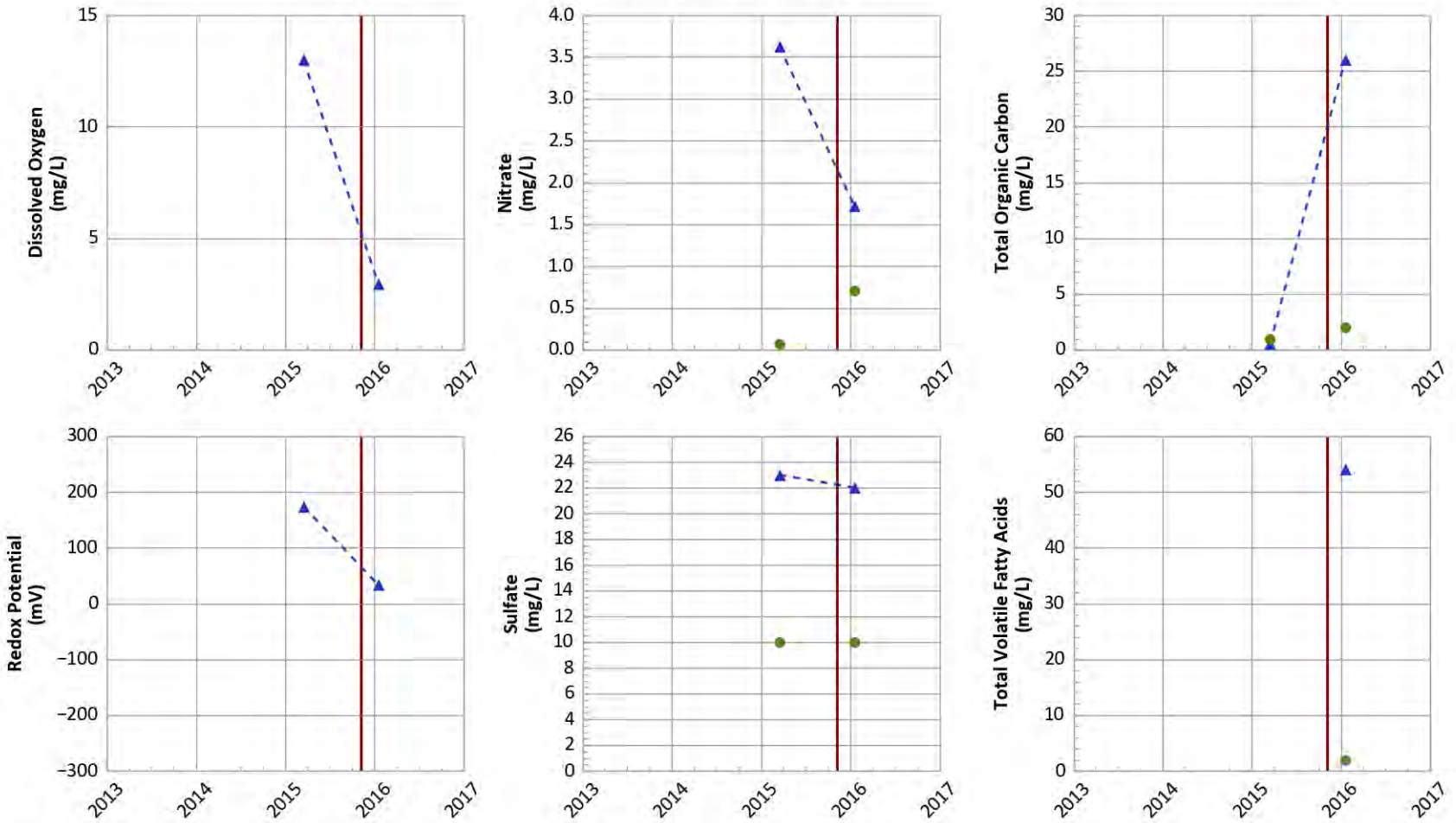


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1177 Treatment Zone Performance Indicators
USDOE/NNSA Pantex Plant

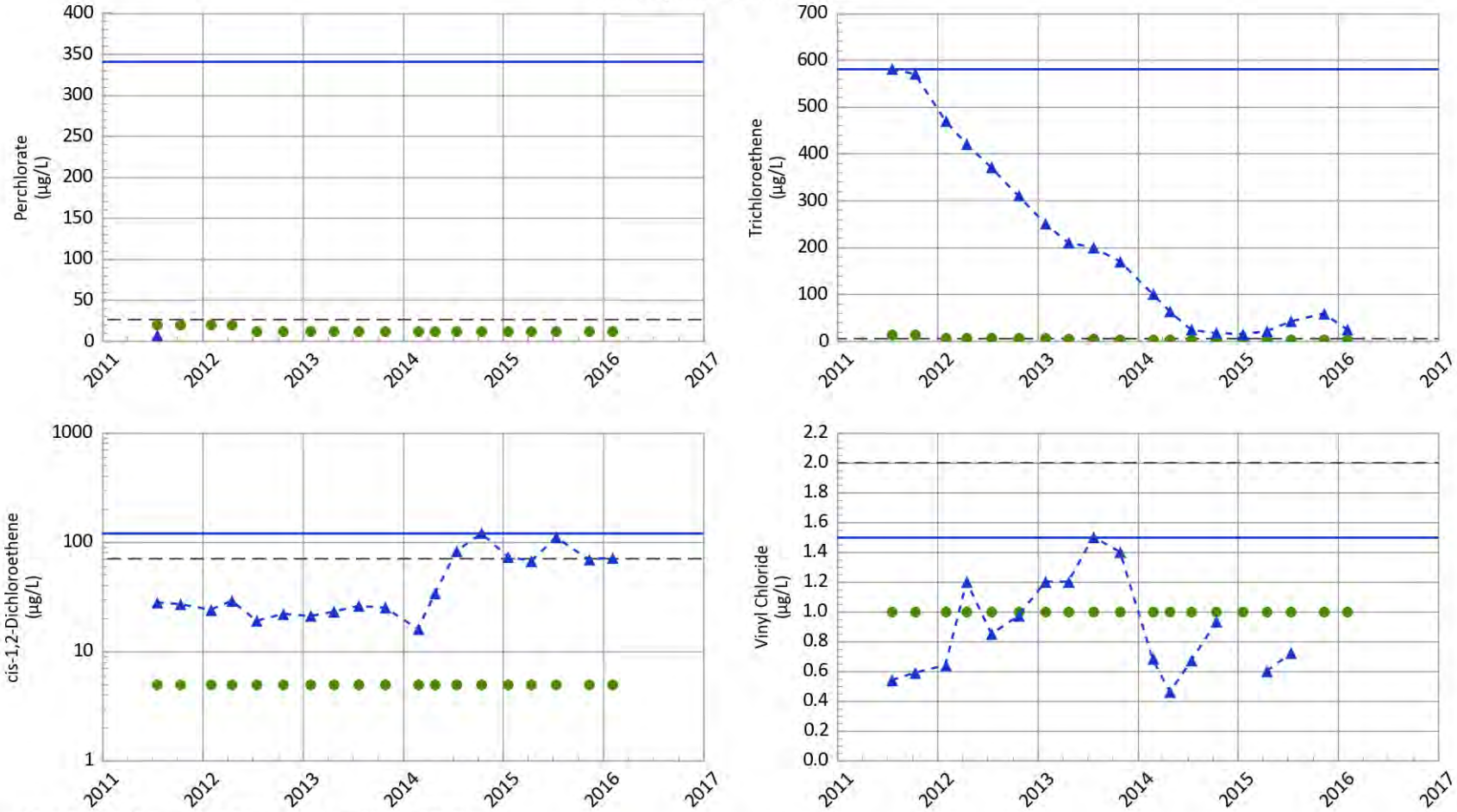


Typical Baseline Concentrations in Perched Groundwater
Dissolved Oxygen: 5-10 mg/L
Redox Potential: > 100 mV
Nitrate: > 1 mg/L
Sulfate: > 10 mg/L
Total Organic Carbon: < 5 mg/L
Total Volatile Fatty Acids: Not Detected

Measured Value
Sample Detection Limit
Concentration Trend
Injection Dates

Well Location

PTX06-1012 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



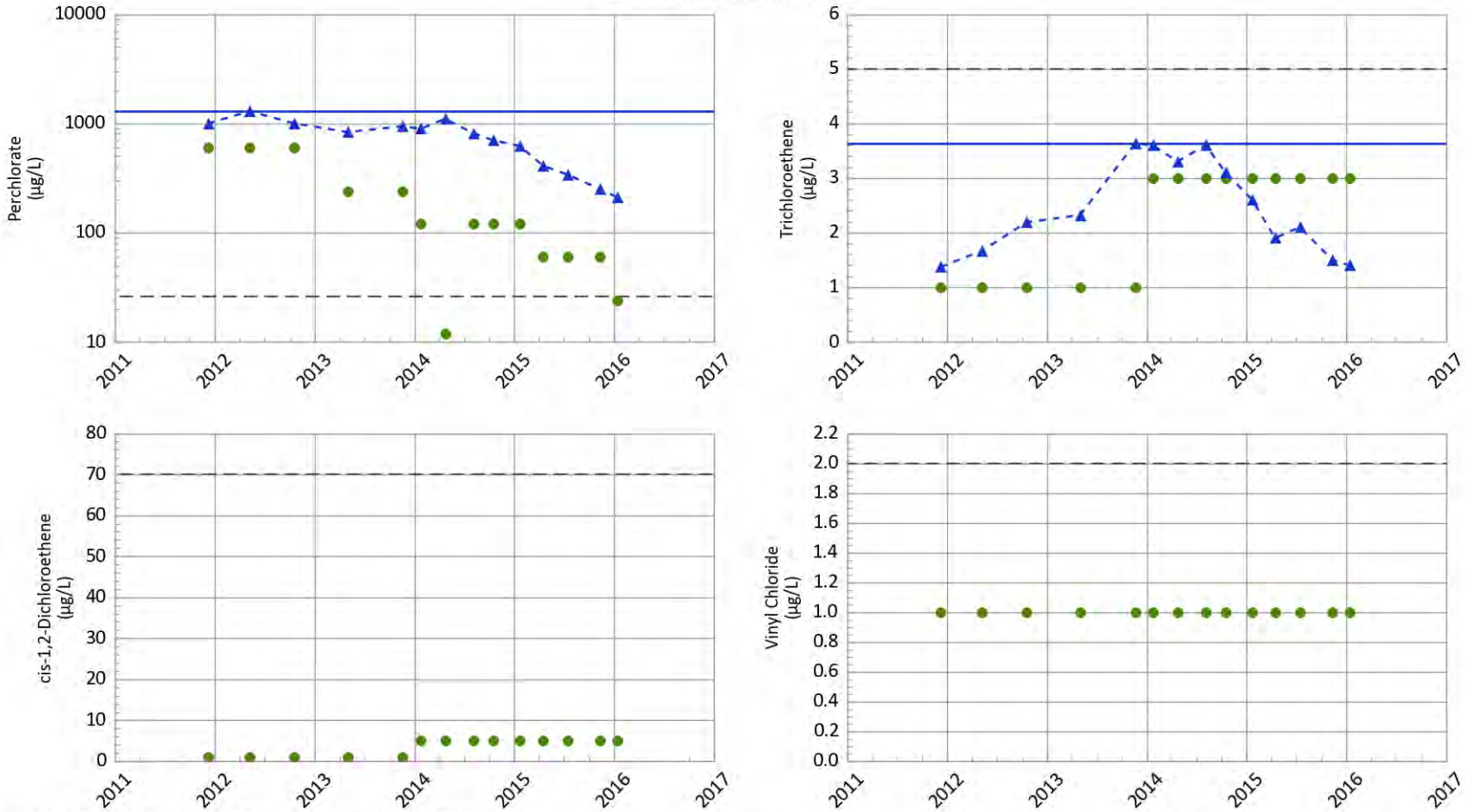
Most Recent Measured COC Concentrations (Jul 13, 2015)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	Non-Detect	26.0
DCE12C	72.0	70.0
TCE	25.0	5.0
VC	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1148 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



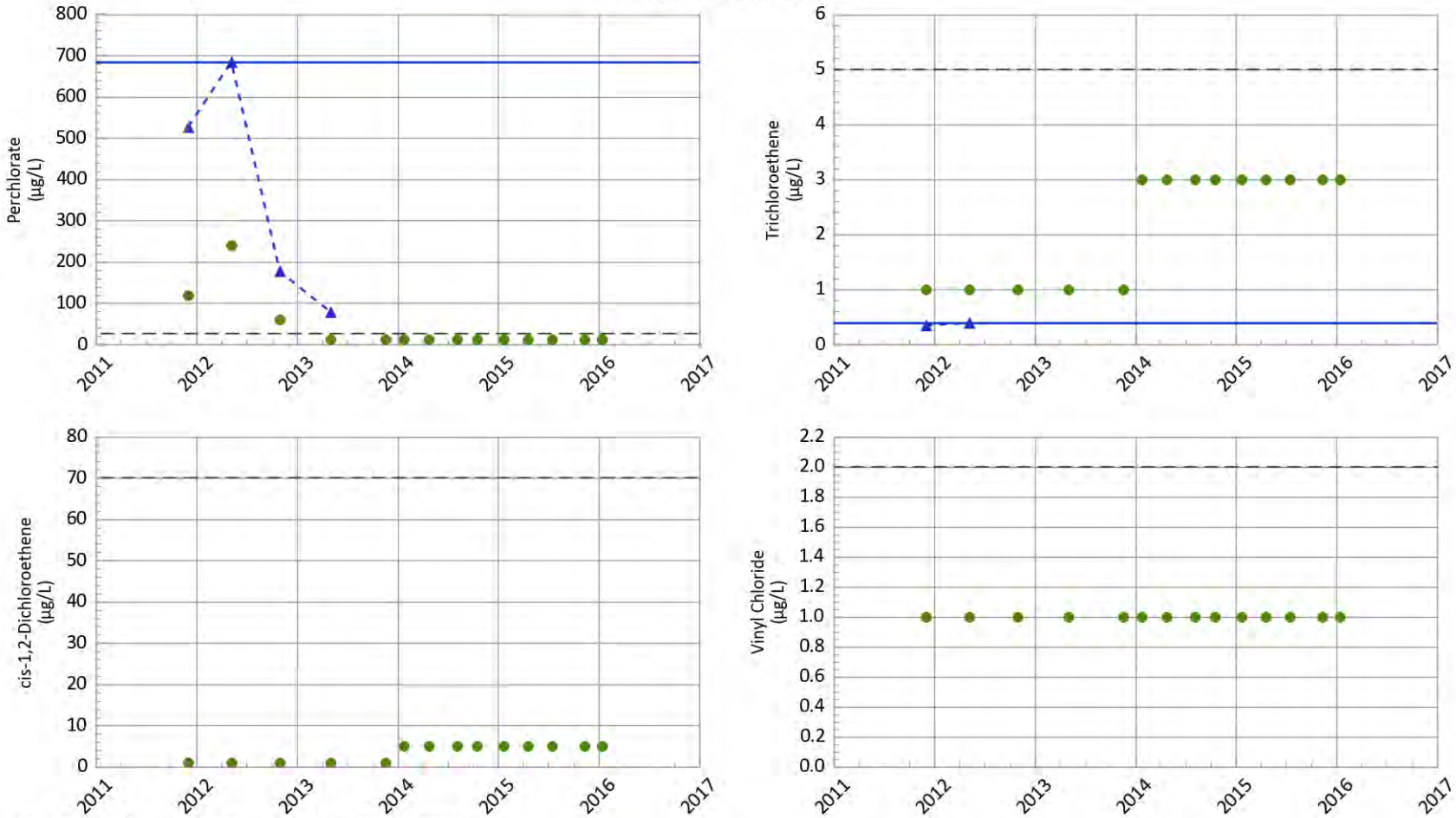
Most Recent Measured COC Concentrations (Jan 13, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	210.0	26.0
DCE12C	Non-Detect	70.0
TCE	1.4	5.0
VC	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1149 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



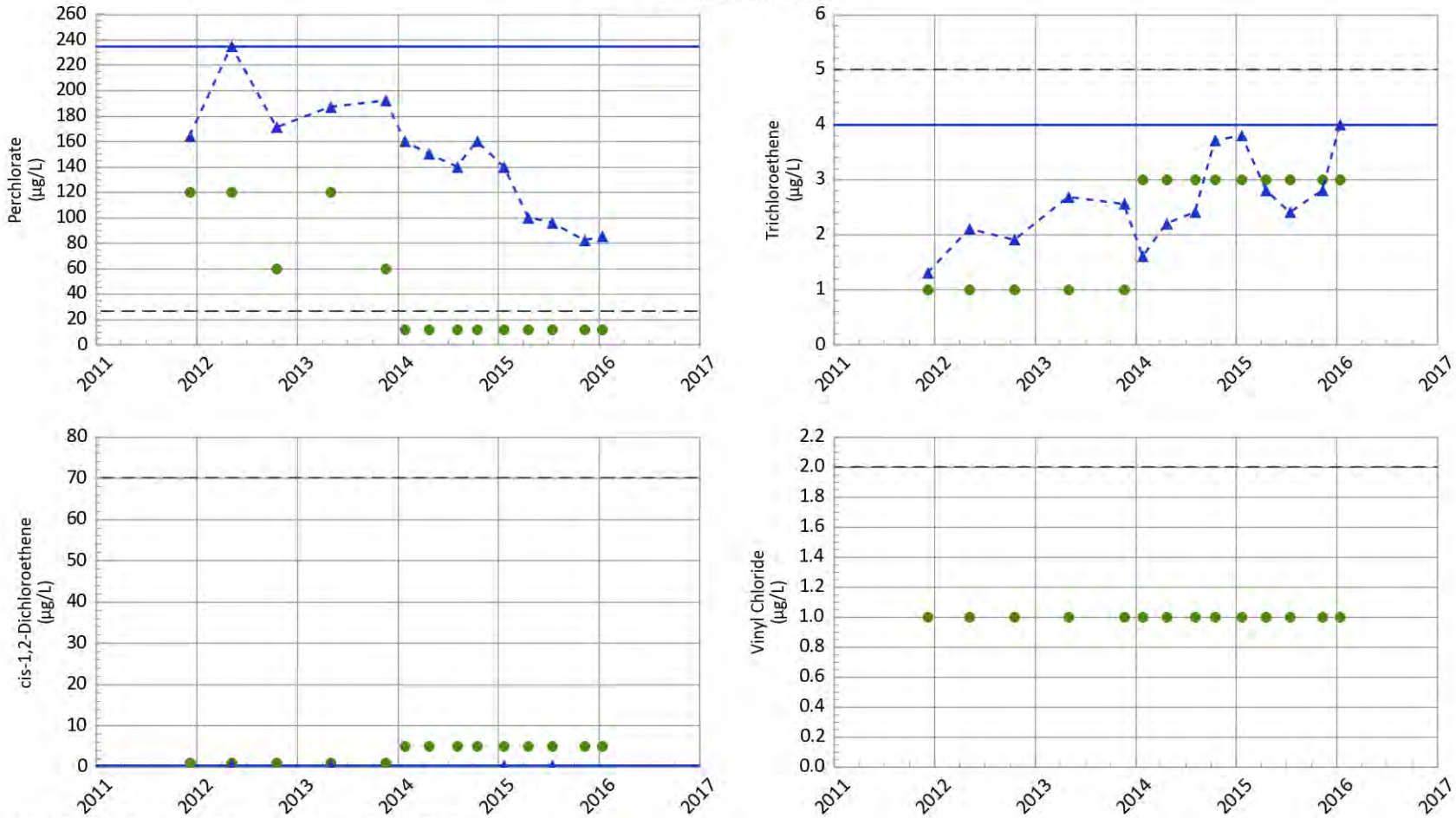
Most Recent Measured COC Concentrations (Jan 13, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	Non-Detect	26.0
DCE12C	Non-Detect	70.0
TCE	Non-Detect	5.0
VC	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1150 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



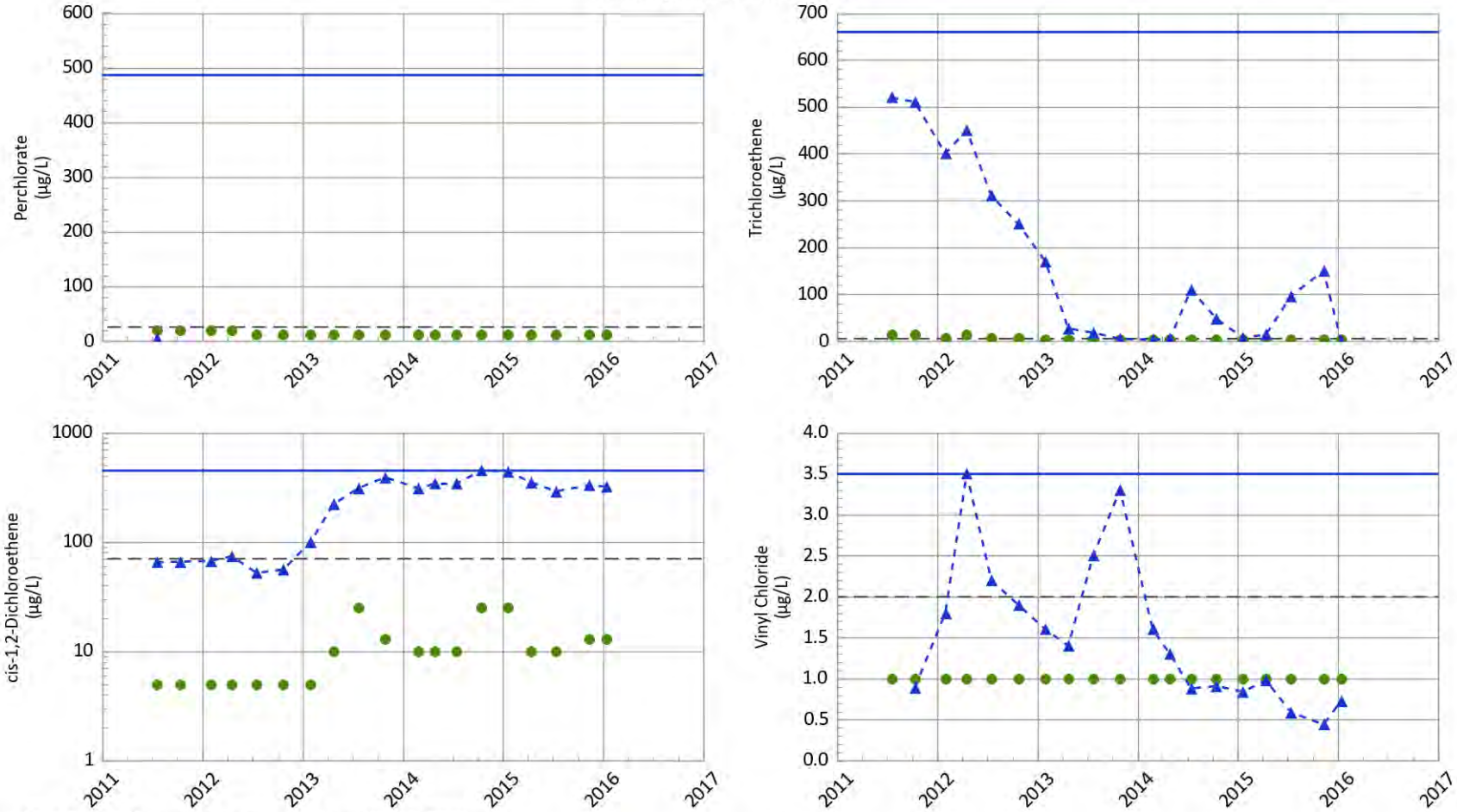
Most Recent Measured COC Concentrations (Jan 13, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	85.0	26.0
DCE12C	Non-Detect	70.0
TCE	4.0	5.0
VC	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1155 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



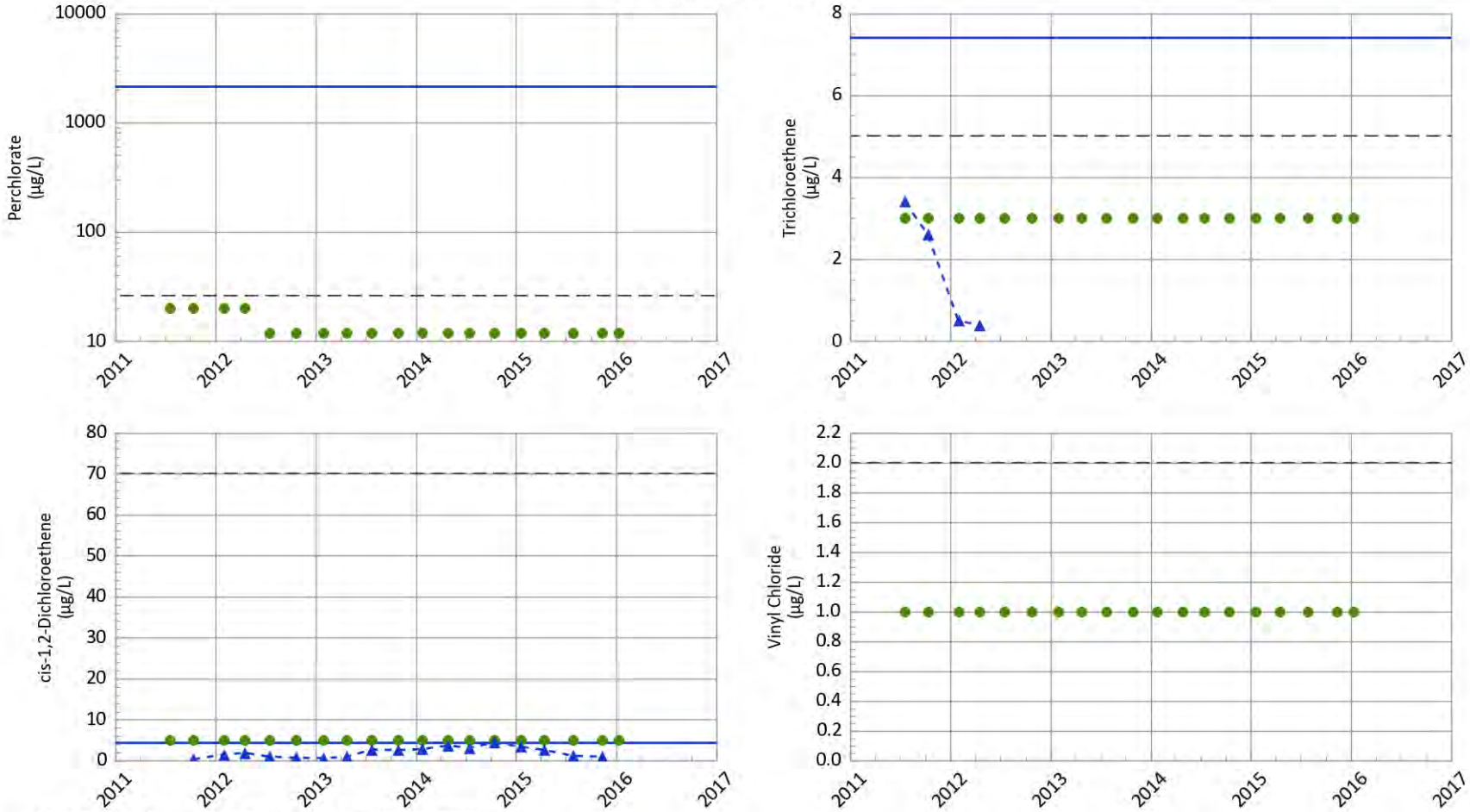
Most Recent Measured COC Concentrations (Jan 12, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	Non-Detect	26.0
DCE12C	320.0	70.0
TCE	0.8	5.0
VC	0.73	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

PTX06-1156 Downgradient Performance Indicators
Zone 11 In Situ Bioremediation System
USDOE/NNSA Pantex Plant



Most Recent Measured COC Concentrations (Jan 11, 2016)

COC	Concentration (µg/L)	GWPS (µg/L)
PERC	Non-Detect	26.0
DCE12C	Non-Detect	70.0
TCE	Non-Detect	5.0
VC	Non-Detect	2.0

- Measured Value
- Sample Detection Limit
- Concentration Trend
- Maximum Concentration
- Groundwater Protection Standard

Well Location

Appendix D
Bioaugmentation Sampling Results

Bioaugmentation Sampling Results

To determine the effectiveness of the bioaugmentation, Pantex has planned a series of sampling events. The first sampling event occurred in February and March 2016. Evaluation of the effectiveness of the bioaugmentation consists of evaluating the following lines of evidence:

- Counts of *Dehalococcoides* spp. (DHC) to determine if counts are high enough for reductive dechlorination to occur. Samples were analyzed using a quantitative polymerase chain reaction (qPCR) technique. Information from Lu et al. (2006) indicate that reductive dechlorination should occur with DHC counts of 1E+04 cells per milliliter (cells/mL) or higher. Reductive dechlorination can occur at milder counts (between 1E+01 and 1E+04 cells/mL) if reducing conditions are strong.

- Counts of TCE reductase gene. The tceA gene encodes the enzyme responsible for reductive dechlorination of TCE to *cis*-1,2-dichloroethene (DCE) in some strains of DHC. While the presence of this gene is not always required, it does provide an additional line of evidence for reductive dechlorination of TCE.

- Counts of vinyl chloride reductase gene. The vcrA gen encodes the vinyl chloride reductase enzyme responsible for reductive dechlorination of cis-DCE and vinyl chloride to ethene by DHC. Presence of the vcrA gene indicates the potential for reductive dechlorination of DCE and/or vinyl chloride to ethene.

- Compound specific isotope analysis (CSIA). This analysis evaluates the fractionation of heavy to lighter carbon isotopes for TCE, *cis*-1,2-DCE, and vinyl chloride. The lighter isotopes are first used by bacteria, affecting the ratio of light to heavy isotopes. Pantex collected baseline data in 2013 at upgradient and downgradient wells outside the influence of the in situ bioremediation (ISB) to which to compare data. While this analysis does not definitively prove that DHC is degrading the chemicals, it does demonstrate whether degradation is occurring for each chemical. Since Pantex could only demonstrate degradation of TCE prior to bioaugmentation, current CSIA data should reflect degradation of vinyl chloride if the DHC are actively degrading TCE to ethene.

- Results of geochemical data to evaluate the reducing conditions at the wells. These data are presented in the main report and will be discussed qualitatively here. Important parameters such as dissolved oxygen (DO), oxidation-reduction potential (ORP), nitrate, sulfate, methane, and ethene concentrations are considered to determine if reducing conditions may be impacting the DHC.

These lines of evidence will be used over time to determine the overall effectiveness. This evaluation draws conclusions from the first sampling event following the bioaugmentation. Further sampling will be required to determine the overall effectiveness of the bioaugmentation, as the DHC are expected to grow with time.

Seven wells in the treatment zone were targeted for sampling in 2016 at the Zone 11 ISB treatment zone (see Appendix A for Zone 11 ISB map). Sampling was conducted twice to evaluate different methods of collection. The first event involved the use of micropurge methods normally used for sampling at the wells. Water samples were collected and sent to Microbial Insights for analysis. One of the wells, PTX06-ISB071, could not be sampled using micropurge methods due to a thick plug of amendment/biomass at the top of the well. Portable sampling equipment clogged up and could not be cleared up, even with multiple attempts at sampling. The second sampling event involved the use of Bio-Traps®, which are passive sampling devices that provide surface area for microbial growth. The traps were deployed in the same wells for 30 days, removed, and shipped to Microbial Insights for analysis. PTX06-ISB071 was sampled using the Bio-Trap® sampler, as the use of weights to suspend the trap in the well allowed the weights and Bio-Trap® to sink through the mass at the top of the well.

qPCR Results

Results from the qPCR sampling are presented in Table 1.

Table 1

Well	Sample Date	Sample Matrix	DHC (cells/mL)	*tce*A (cells/mL)	*vcr*A (cells/mL)
PTX06-1170	2/22/2016	Water	2.54E+01	2.90E+00	4.00E-01 J
PTX06-ISB075	2/22/2016	Water	2.90E+00	ND	ND
PTX06-ISB069A	2/24/2016	Water	8.53E+01	9.700E+00 J	ND
PTX06-ISB073	2/24/2016	Water	2.75E+01	5.600E+00 J	ND
PTX06-ISB077	2/24/2016	Water	6.20E+00 J	ND	ND
PTX06-1169	2/24/2016	Water	4.40E+00	ND	ND
PTX06-ISB071		Water	NS	NS	NS
PTX06-1170	3/28/2016	Bio-trap	ND	ND	ND
PTX06-ISB075	3/28/2016	Bio-trap	3.63E+01	ND	ND
PTX06-ISB069A	3/28/2016	Bio-trap	8.10E+01	ND	ND
PTX06-ISB073	3/28/2016	Bio-trap	1.17E+01 J	ND	ND
PTX06-ISB077	3/28/2016	Bio-trap	1.26E+02	ND	5.50E+00 J
PTX06-1169	3/28/2016	Bio-trap	ND	ND	ND
PTX06-ISB071	3/28/2016	Bio-trap	3.36E+02	ND	ND

NS=Not sampled
ND=Not detected
J=Estimated concentration between the quantitation and minimum detection limits

As discussed above, a concentration of 1E+04 cells/mL provides the best results for reductive dechlorination of TCE to ethane (Lu et al., 2006). This count was the target for the culture as injected in 2015. Table 1 indicates that DHC was detected during this sampling event, indicating some degree of success. Samples collected prior to bioaugmentation indicated that DHC were not present in upgradient wells, in one sampled treatment zone well, or in downgradient wells. However, current DHC counts were low and counts for the TCE and vinyl chloride reductase gene do not indicate that reductive dechlorination is occurring yet.

Microbial Insights reviewed the qPCR data, as well as field and analytical data collected in these wells and the following conclusions were drawn:

- DHC counts were significantly below the threshold proposed by Lu et al. (2006) as generally useful rates of biological reductive dechlorination. In the Bio-Trap® samples, two wells, PTX06-1170 and PTX06-1169, indicated no detectable levels of DHC.

- Very low levels of the TCE *tceA* reductase gene and the vinyl chloride *vcrA* reductase gene were detected in the groundwater samples. These results suggest there is a low potential for reductive dechlorination of TCE to ethene.

- Field measurements and analytical data indicate poor conditions for reductive dechlorination in most wells. DO, ORP, sulfate, and methane concentrations were variable, but indicate mild reducing conditions in most of the sampled wells in the bioaugmentation area.

CSIA Results

Water samples collected in February 2016 were also analyzed for CSIA. CSIA evaluates the changes in isotopic ratios to evaluate the type of concentration changes that are occurring. Physical processes such as dilution, diffusion, and volatilization do not change the isotopic ratios in compounds to the same extent as chemical or biochemical processes such as degradation. For volatile organic compounds (VOCs) in groundwater, this means that degradation of a compound is the major cause of significant changes in isotopic ratios (ITRC, 2011).

The basic principle behind using CSIA for determining degradation of TCE is that, during biodegradation, the microbes preferentially consume lighter isotopes before heavier ones. So, if a compound is being degraded, the ratio of heavy isotopes to light isotopes increases; this process is also called fractionation. In the case of degradation of TCE in the Zone 11 ISB treatment zone, the TCE molecules with the lighter carbon isotopes (^{12}C) will be degraded before the TCE molecules with heavier carbon isotopes (^{13}C), resulting in a heavier (less negative) ratio of $^{13}C/^{12}C$. The complicating factor in this case is that there are potentially multiple degradation reactions occurring simultaneously, as depicted in Figure 1, and both cis-1,2-dichloroethane and vinyl chloride are being both created and consumed if complete dechlorination is occurring. However, two key points should be considered when evaluating the data:

- If a daughter product does not degrade, it still gets heavier (less negative isotopic ratio of carbon δ^{13C}) as the parent gets heavier.
- The undegraded daughter product can get no heavier than the original, undegraded parent product.

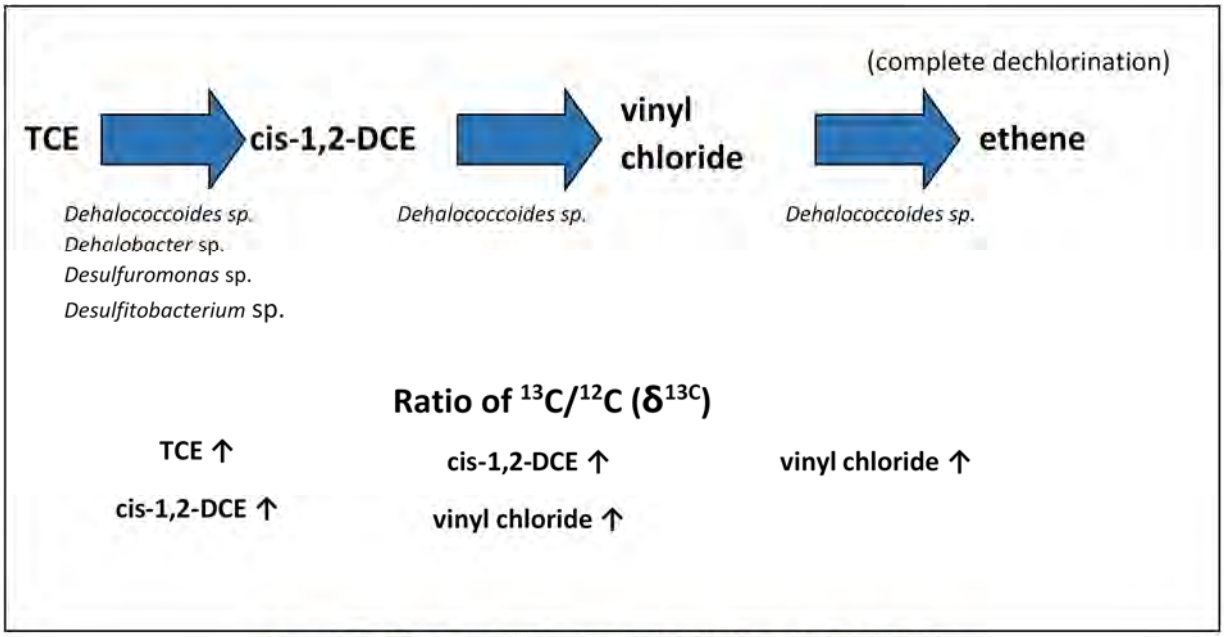


Figure 1. TCE Degradation and Its Effect on Isotopic Ratios

These two key points are illustrated in Figure 2, which compares typical graphs of isotopic ratios of parent and daughter products over time when daughter products are degrading and with no daughter product degradation.

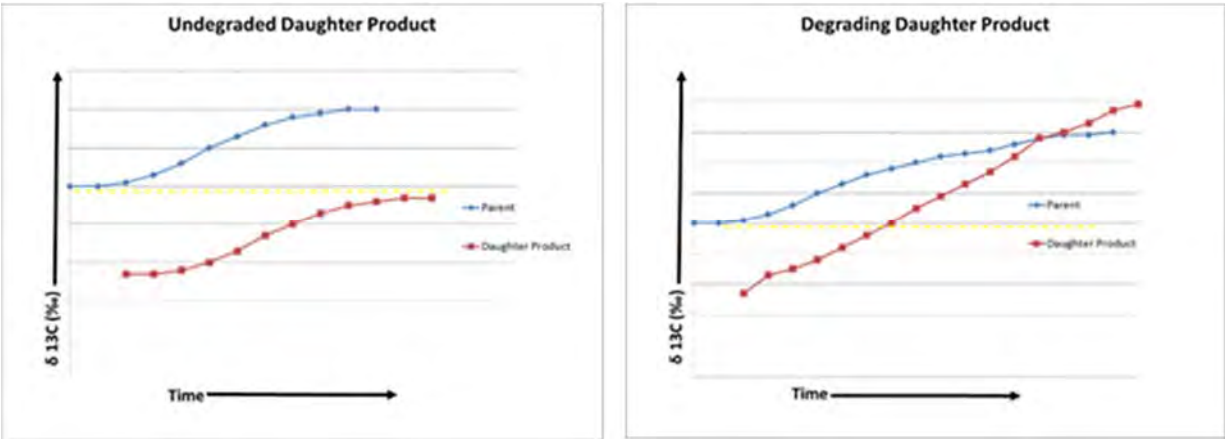


Figure 2. Comparison of Daughter Product Formation and Degradation

Table 2 summarizes the CSIA data collected from wells in February 2016. Baseline data were collected at upgradient wells in 2014 and indicated no significant degradation in those wells. These results also represent baseline results to which treatment zone wells can be compared. Additionally, the line of wells from PTX06-1126 to the PTX06-ISB075 replacement well to downgradient well PTX06-1155 represents a general groundwater flow path through the ISB treatment zone. Data were collected at those wells prior to bioaugmentation, but provided limited information regarding degradation in the treatment zone. Table 2 only provides the baseline upgradient well data, as no new downgradient well data were collected and continuing changes in the treatment zone could affect the downgradient data. The data indicated that some degradation was occurring for cis-1,2-DCE at PTX06-ISB075, but TCE was not detected. This indicated some degree of degradation at that well prior to bioaugmentation.

Table 2. CSIA Results, Zone 11 ISB

Well	Sample Date	Ratio of $^{13}C/^{12}C$ ($\delta^{13}C$), ‰		
		TCE	Cis-DCE	Vinyl Chloride
PTX06-1126	Upgradient Baseline	-27.67	-27.75	ND
Expansion Area Wells - Baseline				
PTX06-1164	2/24/2016	-27.44	-27.6	ND
PTX06-1176	2/24/2016	-27.40	-27.28	ND
PTX06-1177	2/24/2016	-28.29	-28.59	ND
Bioaugmentation Wells				
PTX06-1169	2/22/2016	-19.17	-22.36	ND
PTX06-1170	2/22/2016	-25.55	-27.83	ND
PTX06-ISB069A	2/22/2016	ND	-19.16	ND
PTX06-ISB073	2/24/2016	ND	-16.58	ND
PTX06-ISB075	2/24/2016	-21.63	-26.12	ND
PTX06-ISB077	2/24/2016	-16.24	-17.23	ND

ND=Not detected

CSIA data were collected in wells that are regularly sampled in the bioaugmentation area of the Zone 11 ISB. Additionally, baseline CSIA data were collected in the expansion zone, where only one amendment injection has occurred and no bioaugmentation has occurred. The CSIA data are summarized in Table 2. The following key conclusions can be drawn from the CSIA data:

- TCE fractionation downgradient of PTX06-1126 has become less negative (heavier), indicating treatment. The change in values can be seen in the original part of the

system, where bioaugmentation occurred. The fractionation at wells in the expansion zone is similar to the upgradient well PTX06-1126, indicating no degradation. Data collected prior to bioaugmentation were inconclusive (not detected) with regard to degradation in one treatment zone well, so a change in fractionation cannot be compared.

- Cis-1,2-DCE isotopic ratios were variable, but there is indication of treatment at most of the wells in the original treatment zone where bioaugmentation occurred. Two non-injected wells that are located between injection wells (PTX06-1169 and PTX06-ISB075 replacement well) demonstrate values closer to baseline, indicating that treatment is weak in those areas. Data are only available for PTX06-ISB075 prior to bioaugmentation, and those results were slightly better than the current results (cis-1,2-DCE ratio of -24.41). PTX06-1170, another monitor well between injection wells, does not demonstrate a significant difference from baseline conditions at the upgradient well PTX06-1126.
- Vinyl chloride isotopic ratios are non-detect, as this chemical was not detected in any current samples. The vinyl chloride ratios collected prior to bioaugmentation did not indicate that degradation was occurring.

Conclusions

The qPCR and CSIA data discussed above, combined with the recent dataset from the Zone 11 ISB area, indicate that complete dechlorination is not likely occurring at this time due to low counts of DHC and mild reducing conditions in many areas of the Zone 11 ISB where bioaugmentation has occurred.

Pantex took many steps during the bioaugmentation process to potentially increase the survival of the DHC, including injection with anaerobic makeup water mixed with amendment during the entire injection event, injection of the DHC under very specific conditions for DO, ORP, and pH, injection of the DHC using nitrogen gas, and injection of DHC below the water level in the wells. Pantex has a deep water table, and the effects of pressure/shear forces on the survival of the DHC under these injection conditions was unknown. To continue to potentially increase the survivability of the DHC, Pantex plans to use anaerobic makeup water with the amendment during the 2016 injection to maintain deep reducing conditions for the DHC that were previously injected. Pantex plans to sample for DHC, reductase genes, and CSIA again late in 2016. Results of that sampling will be provided in the appropriate quarterly and annual report.

References

Interstate Technology & Regulatory Council (ITRC). 2011. Compound Specific Isotope Analysis EMD Team Fact Sheet. November 2011. Available at <http://www.itrcweb.org/documents/team_emd/CSIA_Fact_Sheet.pdf>.

Lu, X., J.T. Wilson, and DH. Kampbell. 2006. Relationship between *Dehalococcoides* DNA in ground water and rates of reductive dechlorination at field scale. *Water Research* 40:3131-3140.